

## 50 V Code-Free FOC BLDC Motor Controller

### FEATURES AND BENEFITS

- Code-free sensorless field-oriented control (FOC)
- Proprietary non-reverse fast startup
- Soft-On Soft-Off (SOSO) for quiet operation
- Analog / PWM / Clock mode speed control
- Closed-loop speed control
- Configurable current limit
- Windmill startup operation
- Lock detection
- Short-circuit protection (OCP)
- Brake and direction inputs

### APPLICATIONS

- Ceiling fans
- Pedestal fans
- Bathroom exhaust fans
- Home appliance fans and pumps



### DESCRIPTION

The AMT49406 is a 3-phase, sensorless, brushless DC (BLDC) motor driver (gate driver) which can operate from 5.5 to 50 V.

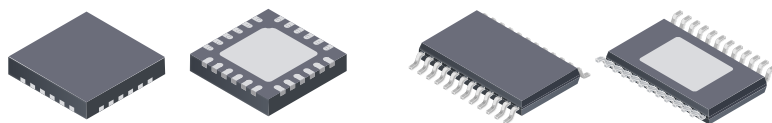
A field-oriented control (FOC) algorithm is fully integrated to achieve the best efficiency and acoustic noise performance. The device optimizes the motor startup performance in a stationary condition, a windmill condition, and even in a reverse windmill condition.

Motor speed is controlled through analog, PWM, or CLOCK input. Closed-loop speed control is optional, and RPM-to-clock frequency ratio is programmable.

A simple I<sup>2</sup>C interface is provided for setting motor-rated voltage, rated current, rated speed, resistance, and startup profiles.

The AMT49406 is available in a 24-contact 4 mm × 4 mm QFN with exposed thermal pad (suffix ES) and a 24-lead TSSOP with exposed thermal pad (suffix LP). These packages are lead (Pb) free, with 100% matte-tin leadframe plating.

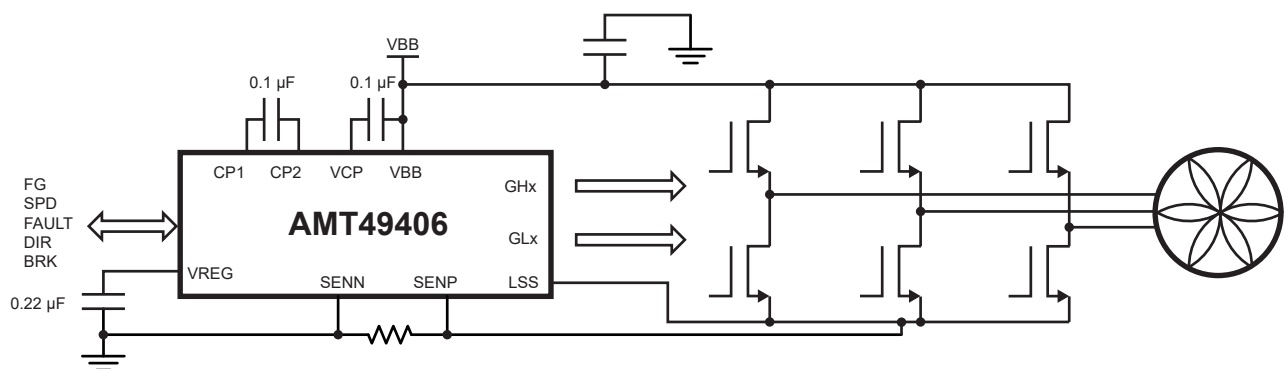
### PACKAGES



24-contact QFN  
with exposed thermal pad  
4 mm × 4 mm × 0.75 mm  
(ES package)

24-lead TSSOP  
with exposed thermal pad  
(LP package)

*Not to scale*



**Figure 1: Typical Application**

## SELECTION GUIDE

| Part Number   | Ambient Temperature Range ( $T_A$ ) (°C) | Packaging                               | Packing                      |
|---------------|------------------------------------------|-----------------------------------------|------------------------------|
| AMT49406GESSR | –40 to 105                               | 24-contact QFN with exposed thermal pad | 6000 pieces per 13-inch reel |
| AMT49406GLPTR | –40 to 105                               | 24-lead TSSOP with exposed thermal pad  | 4000 pieces per 13-inch reel |



## ABSOLUTE MAXIMUM RATINGS

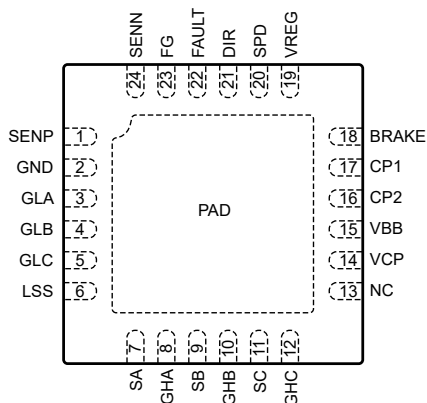
| Characteristic              | Symbol               | Notes            | Rating                           | Unit |
|-----------------------------|----------------------|------------------|----------------------------------|------|
| Supply Voltage              | $V_{BB}$             |                  | 50                               | V    |
| Logic Input Voltage Range   | $V_{IN}$             | SPD, BRAKE, DIR  | –0.3 to 6                        | V    |
| Logic Output                | $V_O$                | FG ( $I < 5$ mA) | 6                                | V    |
| LSS                         | $V_{LSS}$            | DC               | $\pm 500$                        | mV   |
|                             |                      | $t_W < 500$ ns   | $\pm 4$                          | V    |
| VREG                        | $V_{REG}$            |                  | 0 to 4                           | V    |
| SENN, SENP                  | $V_{SENN}, V_{SENP}$ | DC               | $\pm 500$                        | mV   |
|                             |                      | $t_W < 500$ ns   | $\pm 4$                          | V    |
| Output Voltage              | $V_{OUT}$            | SA, SB, SC       | –2 to $V_{BB} + 2$               | V    |
| GHx                         | $V_{GHx}$            |                  | $V_{Sx} - 0.3$ to $V_{CP} + 0.3$ | V    |
| GLx                         | $V_{GLx}$            |                  | $V_{LSS} - 0.3$ to 8.5           | V    |
| VCP                         | $V_{CP}$             |                  | $V_{BB} - 0.3$ to $V_{BB} + 8$   | V    |
| CP1                         | $V_{CP1}$            |                  | –0.3 to $V_{BB} + 0.3$           | V    |
| CP2                         | $V_{CP2}$            |                  | $V_{BB} - 0.3$ to $V_{CP} + 0.3$ | V    |
| Junction Temperature        | $T_J$                |                  | 150                              | °C   |
| Storage Temperature Range   | $T_{stg}$            |                  | –55 to 150                       | °C   |
| Operating Temperature Range | $T_A$                | Range G          | –40 to 105                       | °C   |

## THERMAL CHARACTERISTICS

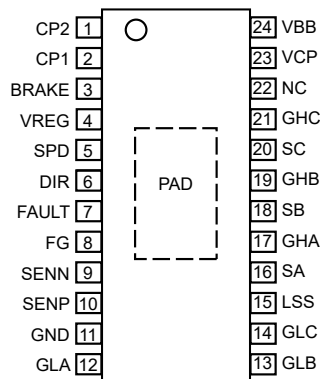
| Characteristic             | Symbol          | Test Conditions*                                                      | Value | Unit |
|----------------------------|-----------------|-----------------------------------------------------------------------|-------|------|
| Package Thermal Resistance | $R_{\theta JA}$ | 24-contact QFN (package ES), on 2-sided PCB 1-in. <sup>2</sup> copper | 45    | °C/W |
|                            |                 | 24-lead TSSOP (package LP), on 2-sided PCB 1-in. <sup>2</sup> copper  | 36    | °C/W |

\*Additional thermal information available on the Allegro website.

## PINOUT DIAGRAMS AND TERMINAL LIST TABLE



ES Package Pinouts



LP Package Pinouts

Terminal List Table

| Terminal Number |            | Name  | Function                                     |
|-----------------|------------|-------|----------------------------------------------|
| ES Package      | LP Package |       |                                              |
| 16              | 1          | CP2   | Charge pump                                  |
| 17              | 2          | CP1   | Charge pump                                  |
| 18              | 3          | BRAKE | Logic input                                  |
| 19              | 4          | VREG  | 2.8 V regulator voltage                      |
| 20              | 5          | SPD   | PWM or clock mode speed control              |
| 21              | 6          | DIR   | Direction control                            |
| 22              | 7          | FAULT | Fault indicator output                       |
| 23              | 8          | FG    | Motor speed output                           |
| 24              | 9          | SENN  | Current sense negative terminal              |
| 1               | 10         | SENP  | Current sense positive terminal              |
| 2               | 11         | GND   | Ground                                       |
| 3               | 12         | GLA   | Low-side gate drive output                   |
| 4               | 13         | GLB   | Low-side gate drive output                   |
| 5               | 14         | GLC   | Low-side gate drive output                   |
| 6               | 15         | LSS   | Low-side source                              |
| 7               | 16         | SA    | Motor output                                 |
| 8               | 17         | GHA   | High-side gate drive output                  |
| 9               | 18         | SB    | Motor output                                 |
| 10              | 19         | GHB   | High-side gate drive output                  |
| 11              | 20         | SC    | Motor output                                 |
| 12              | 21         | GHC   | High-side gate drive output                  |
| 13              | 22         | NC    | No connect                                   |
| 14              | 23         | VCP   | Charge pump                                  |
| 15              | 24         | VBB   | Power supply                                 |
| PAD             | PAD        | PAD   | Exposed pad for enhanced thermal dissipation |

**ELECTRICAL CHARACTERISTICS** [1]: Valid over operating ambient temperature range and operating voltage range, unless noted otherwise

| Characteristics                      | Symbol              | Test Conditions                    | Min. | Typ. | Max. | Unit |
|--------------------------------------|---------------------|------------------------------------|------|------|------|------|
| <b>GENERAL</b>                       |                     |                                    |      |      |      |      |
| Supply Voltage Range                 | $V_{BB}$            | Driving                            | 5.5  | –    | 48   | V    |
|                                      |                     | Operating                          | 5.5  | –    | 50   | V    |
| VBB Supply Current                   | $I_{BB}$            | $I_{VREG} = 0$ mA                  | –    | 8    | 12   | mA   |
|                                      |                     | Standby mode                       | –    | 10   | 20   | μA   |
| Reference Voltage                    | $V_{REG}$           | $I_{OUT} = 10$ mA                  | 2.7  | 2.86 | 2.95 | V    |
| <b>GATE DRIVE</b>                    |                     |                                    |      |      |      |      |
| High Side Gate Drive Output          | $V_{GH}$            | $V_{BB} = 8$ V                     | 6.5  | 6.8  | –    | V    |
|                                      |                     | $V_{BB} = 24$ V                    | 6.5  | 6.8  | –    | V    |
| Low Side Gate Drive Output           | $V_{GL}$            | $V_{BB} = 8$ V                     | 6.5  | 7.3  | –    | V    |
|                                      |                     | $V_{BB} = 24$ V                    | 6.5  | 7.3  | –    | V    |
| Gate Drive Source Current            | $I_{SO}$            |                                    | –    | 55   | –    | mA   |
| Gate Drive Sink Current              | $I_{SI}$            |                                    | –    | 105  | –    | mA   |
| <b>MOTOR DRIVE</b>                   |                     |                                    |      |      |      |      |
| PWM Duty On Threshold                | $PWM_{ON}$          | Relative to target                 | –0.5 | –    | 0.5  | %    |
| PWM Duty Off Threshold               | $PWM_{OFF}$         | Relative to target                 | –0.5 | –    | 0.5  | %    |
| PWM Input Frequency Range            | $f_{PWM(MIN)}$      | PWM input frequency setting = 0    | 2.5  | –    | 100  | kHz  |
|                                      |                     | PWM input frequency setting = 1    | 80   | –    | 3200 | Hz   |
| Clock Input Frequency Range          | $f_{CLOCK}$         | CLOCK mode                         | 1    | –    | 2000 | Hz   |
| SPD Standby Threshold (Analog Enter) | $V_{SPD(TH\_ENT)}$  |                                    | 50   | 100  | 150  | mV   |
| SPD Standby Threshold (Analog Exit)  | $V_{SPD(TH\_EXIT)}$ |                                    | 0.4  | 0.75 | 1    | V    |
| SPD On Threshold                     | $V_{SPD(ON)}$       | ON/OFF setting = 10%               | 210  | 250  | 290  | mV   |
| SPD Max                              | $V_{SPD(MAX)}$      |                                    | –    | 2.5  | –    | V    |
| SPD ADC Resolution                   | $V_{SPDADC(RES)}$   |                                    | –    | 9.78 | –    | mV   |
| SPD ADC Accuracy                     | $V_{SPDADC(ACC)}$   | $V_{SPD} = 0.2$ to $2.5$ V         | –40  | –    | 40   | mV   |
| Speed Closed Loop Accuracy           | $f_{SPD(ACC)}$      | PWM mode or Analog mode            | –5   | –    | 5    | %    |
|                                      |                     | Clock mode                         | –0.1 | –    | 0.1  | rpm  |
| Dead Time                            | $t_{DT}$            | Code = 9                           | –    | 400  | –    | ns   |
| Motor PWM Frequency                  | $f_{PWM}$           | $T_A = 25^\circ\text{C}$           | 23.3 | 24.4 | 25.4 | kHz  |
| <b>PROTECTION</b>                    |                     |                                    |      |      |      |      |
| VBB UVLO                             | $V_{BB(UVLO)}$      | $V_{BB}$ rising                    | –    | 4.75 | 4.95 | V    |
| VBB UVLO Hysteresis                  | $V_{BB(HYS)}$       |                                    | 200  | 300  | 450  | mV   |
| Thermal Shutdown Temperature         | $T_{JTSD}$          | Temperature increasing             | –    | 165  | –    | °C   |
| Thermal Shutdown Hysteresis          | $\Delta T_J$        | Recovery = $T_{JTSD} - \Delta T_J$ | –    | 20   | –    | °C   |

Continued on next page...

**ELECTRICAL CHARACTERISTICS** <sup>[1]</sup> (continued): Valid over operating ambient temperature range and operating voltage range, unless noted otherwise

| Characteristics                  | Symbol    | Test Conditions                | Min. | Typ. | Max. | Unit    |
|----------------------------------|-----------|--------------------------------|------|------|------|---------|
| <b>LOGIC, IO, I<sup>2</sup>C</b> |           |                                |      |      |      |         |
| Input Current                    | $I_{IN}$  | SPD, FG; $V_{IN} = 0$ to 5.5 V | -5   | 1    | 5    | $\mu A$ |
|                                  |           | BRK, DIR; $V_{IN} = 5$ V       | -    | 50   | -    | $\mu A$ |
| Logic Input, Low Level           | $V_{IL}$  |                                | 0    | -    | 0.8  | V       |
| Logic Input, High Level          | $V_{IH}$  |                                | 2    | -    | 5.5  | V       |
| Logic Input Hysteresis           | $V_{HYS}$ |                                | 200  | 300  | 600  | mV      |
| FG Output Leakage                | $I_{FG}$  | $V = 5.5$ V                    | -    | -    | 1    | $\mu A$ |

<sup>[1]</sup> Specified limits are tested at 25°C and 125°C and statistically assured over operating temperature range by design and characterization.

## FUNCTIONAL DESCRIPTION

The AMT49406 is a three-phase BLDC controller with integrated gate driver. It operates from 5.5 to 50 V and targets pedestal fan, ceiling fan, and ventilation fan applications.

The integrated field-oriented control (FOC) algorithm achieves the best efficiency and dynamic response and minimizes acoustic noise. Allegro's proprietary non-reverse startup algorithm improves startup performance. The motor will start up towards the target direction after power-up without reverse shaking or vibration. The Soft-On Soft-Off (SOSO) feature gradually increases the current to the motor at "on" command (windmill condition), and gradually reduces the current from the motor at the "off" command, further reducing the acoustic noise and operating the motor smoothly.

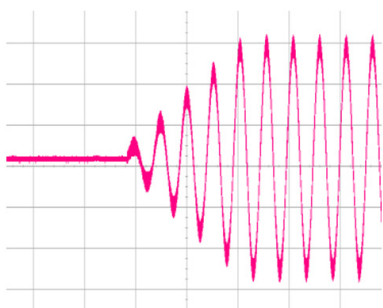


Figure 2: Current Waveform of Soft-On

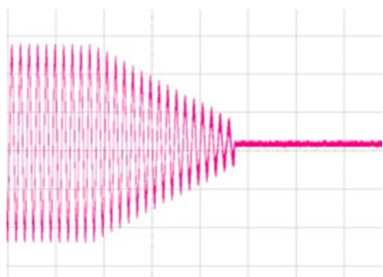


Figure 3: Current Waveform of Soft-Off

## Speed Control

Speed demand is provided via the SPD pin. Three speed control modes are selectable through the EEPROM. The AMT49406 also features a closed-loop speed function, which can be enabled or disabled via the EEPROM.

**PWM Mode:** The motor speed is controlled by the PWM duty cycle on the SPD pin, and higher duty cycle represents higher speed demand. If closed-loop speed is disabled, the output amplitude will be proportional to the PWM duty cycle. If closed-loop speed is enabled, the motor speed is proportional to the PWM duty cycle, and 100% duty represents the rated speed of the motor, which can be programmed in the EEPROM.

$$\text{close\_loop\_speed} = \text{rated\_speed} \times \text{duty\_input}$$

The SPD PWM frequency range is 80 Hz to 100 kHz. If it is higher than 2.8 kHz, set PWMfreq = 0; if it is lower than 2.8 kHz, set PWMfreq = 1.

**Analog Mode:** The motor speed is controlled by the analog voltage on the SPD pin, with higher voltage representing higher speed demand. If closed-loop speed is disabled, the output amplitude will be proportional to the analog voltage input. If closed-loop speed is enabled, the motor speed is as follows:

$$\text{closed\_loop\_speed} = \text{rated\_speed} \times \text{analog\_input} / \text{SPD}_{MAX}$$

**CLOCK Mode:** In the clock speed control mode, the closed-loop speed is always enabled. Higher frequency on the SPD pin will drive a higher motor speed as follows:

$$\text{close\_loop\_speed (rpm)} = \text{clock\_input} \times \text{speed\_ctrl\_ratio},$$

where the speed\_ctrl\_ratio can be programmed in the EEPROM.

For example, if the ratio is 4 and the clock input frequency is 60 Hz, then the motor will operate at 240 rpm. Note the number of motor pole pairs must be set properly in the programming application for the rated speed (rpm) setting to be accurate.

If the clock frequency commands a speed that is higher than twice the rated speed, the AMT49406 treats it as a clock input error and stops the motor.

For all three speed control modes with closed-loop speed enabled, if the demand speed is higher than the maximum speed, the system can run at a certain supply voltage and load condition, and the AMT49406 will just provide the maximum output voltage (if current limit is not triggered) or the maximum output current (if current limit is triggered).

The SPD pin is also used as SCL in the I<sup>2</sup>C mode.

## Motor Stop and Standby Mode

If the speed demand is less than the programmed threshold, the motor will stop.

| On/Off Setting | On Threshold | Off Threshold |
|----------------|--------------|---------------|
| 6%             | 7.8%         | 5.9%          |
| 10%            | 11.7%        | 9.8%          |
| 15%            | 14.9%        | 12.9%         |
| 20%            | 21.5%        | 19.6%         |

For example, consider 10% is set as the threshold. If PWM duty is less than 9.8% (in PWM mode), or the analog voltage is less than 250 mV (in Analog mode), or the CLOCK input frequency is less than 9.8% of the “rated\_speed” (in CLOCK mode), the IC will stop the motor and enter the “idle” mode.

In order to enter standby, two conditions must be met: 1) the motor must be stationary, and 2) PWM or CLOCK signal must remain logic low (in PWM and CLOCK mode) or the analog voltage remains less than  $V_{SPD(TH\_ENT)}$  (in Analog mode) for longer than one second.

A rising edge on PWM or CLOCK will wake the IC in PWM and CLOCK mode, and in Analog mode, the SPD voltage must be higher than  $V_{SPD(TH\_EXIT)}$  to wake up the IC.

Standby Mode will turn off all circuitry including the charge pump and VREG.

After powering on, the device will always be in the active mode before entering standby mode.

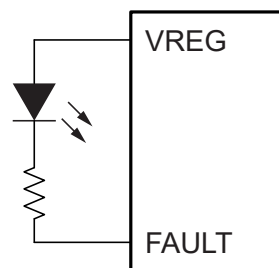
The standby mode can be disabled in the EEPROM.

**Direction Input:** Logic input to control motor direction. For logic high, the motor phases are ordered A→B→C. For logic low, the motor phases are ordered A→C→B. The AMT49406 supports changing the direction input while the motor is running. The direction can also be controlled through register.

**BRAKE:** Active-high signal turns on all low sides for braking function. The Brake function overrides speed control input. Care should be taken to avoid stress on the MOSFET when braking while the motor is running. With braking, the current will be limited only by  $V_{BEMF}/R_{MOTOR}$ . The AMT49406 includes an optional feature which holds off braking until the motor speed drops to a low enough (configurable) level so that the braking current will not damage the MOSFET.

**FAULT:** Open-drain output provides motor operation fault status. Default is high when there is no fault.

An LED and a serial resistor is recommended between the FAULT and VREG pins. The LED indicates fault information.



**Figure 4: AMT49406 with LED and Serial Resistor**

| Fault Type        | FAULT Pin                                                                                                               | LED Pattern               |
|-------------------|-------------------------------------------------------------------------------------------------------------------------|---------------------------|
| Lock detected     | low                                                                                                                     | constant on               |
| OCP               | 0.67 seconds high<br>0.67 seconds low                                                                                   | slow flashing             |
| OTP               | 0.67 seconds low<br>0.17 seconds high<br>0.08 seconds low<br>0.17 seconds high<br>0.08 seconds low<br>0.17 seconds high | long-short-short flashing |
| system error      | 0.08 seconds low<br>0.08 seconds high<br>0.08 seconds low<br>1.09 seconds high                                          | double short flashing     |
| OVP               | 0.17 seconds high<br>0.17 seconds low                                                                                   | fast flashing             |
| zero speed demand | 0.25 seconds high<br>0.08 seconds low<br>0.34 seconds high<br>0.67 seconds low                                          | long-short flashing       |

**FG:** Open-drain output provides motor speed information to the system. The open-drain output can be pulled up to VREG or an external 3.3 or 5 V supply.

The FG pin is also used as SDA in I<sup>2</sup>C mode. The first I<sup>2</sup>C command can pass only when the FG is high (open drain off). After the first I<sup>2</sup>C command, the FG pin is no longer used for speed information, and the FG pin is dedicated as a data pin for the I<sup>2</sup>C interface.

FG is default high after power-on and exit from standby mode, and stays high for at least 9.8 ms. To ensure successful I<sup>2</sup>C communication, it is recommended to have the first I<sup>2</sup>C demand right after power-up or exit from standby mode within 9.8 ms.

**VREG:** Voltage reference (2.8 V) to power internal digital logic and analog circuitry. VREG can be used to power external circuitry with up to 10 mA bias current, if desired. A ceramic capacitor with 0.22  $\mu$ F or greater is required on the pin to stabilize the supply.

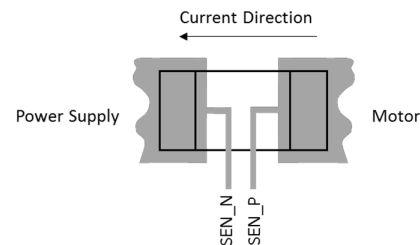
When VREG is loaded externally, the power consumption of the internal LDO is calculated by the equation:

$$P_{LDO} = (I_{LOAD} + I_{INTERNAL}) \times (V_{BB} - V_{REG}).$$

Ensure that the system has good power dissipation and the temperature is within the operating temperature range. The AMT49406 thermal shutdown function does not protect the LDO.

**Bus Current Sensing:** A single shunt-resistor connection between SENN and SENP is used to measure the bus current for the FOC algorithm and current limit. The resistor value is approximately tens of a milliohm, depends on the rated current of the system. The voltage difference between SENN and SENP should be less than 65 mV to prevent the signal saturation. For example, if the rated current is 4 A, it is recommend to use a 15 m $\Omega$  sensing resistor, so that 4 A  $\times$  15 m $\Omega$  is between 55 and 65 mV.

Use Kelvin sensing connection for the shunt resistor.



**Lock Detect:** A logic circuit monitors the motor position to determine if motor is running as expected. If a fault is detected, the motor drive will be disabled for the configurable  $t_{LOCK}$  time before an auto-restart is attempted. For additional information, refer to the configuration guide.

**Current Control:** The motor's rated current at rated speed and normal load must be programmed to the EEPROM for proper operation. The AMT49406 will limit the motor current (phase current peak value) to 1.3 times the programmed rated current during acceleration or increasing load, which protects the IC and the motor. The current profile during startup can also be programmed.

**Overcurrent Protection (short protection):** The  $V_{DS}$  voltages across each power MOSFET are monitored by the AMT49406. If a  $V_{DS}$  is higher than the threshold when that MOSFET enabled, an OCP fault is triggered and the IC will stop driving immediately.

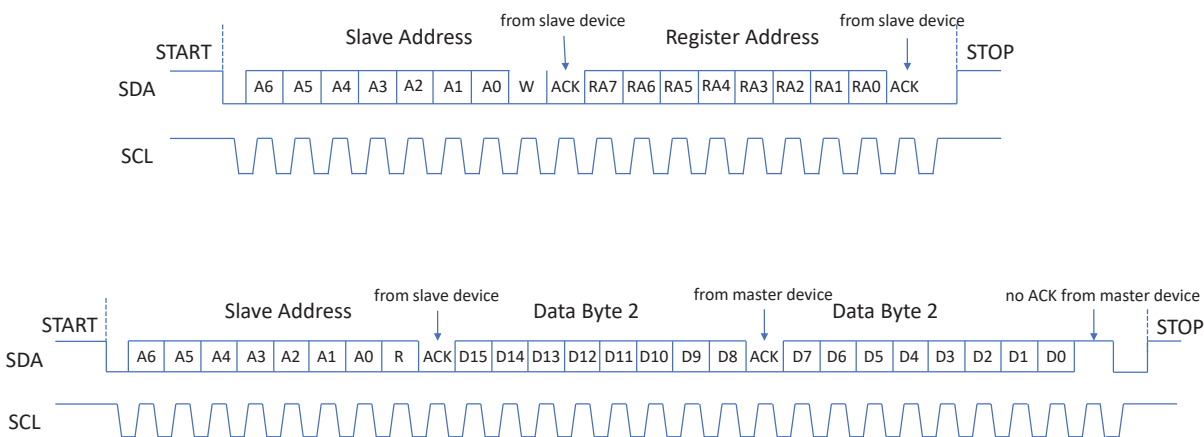
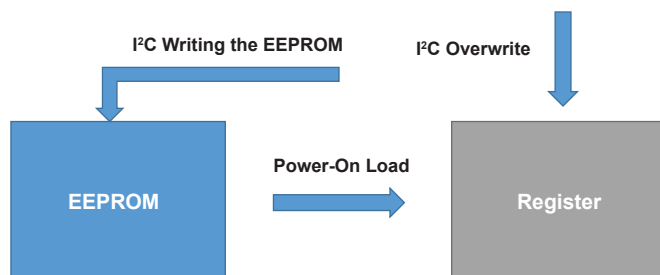
## I<sup>2</sup>C OPERATION AND EEPROM MAP

The I<sup>2</sup>C interface allows the user to program the register and parameters into EEPROM. The AMT49406 7-bit slave address is 0x55.

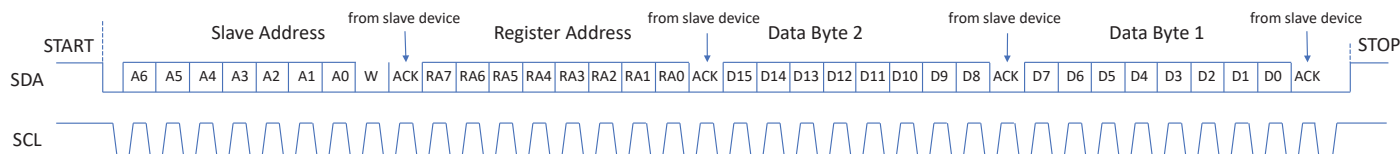
After power-on, the default values in EEPROM will be loaded into the registers, which determines motor system operation. I<sup>2</sup>C can overwrite those values and change the motor system operation on the fly.

I<sup>2</sup>C can also be used to program the EEPROM, which is normally done in the production line.

The figures below shows the I<sup>2</sup>C interface timing.



**Figure 5: Read Command**



**Figure 6: Write Command**

## Register and EEPROM Map

Each register bit is associated with one EEPROM bit. The register address is the associated EEPROM bit address plus 64. For example, the rated speed is in EEPROM address 8, bit[10:0]; the associated register address is 72, bit[10:0].

In the following table, the bits shaded in gray should be kept at their default values. Changing these values may cause malfunction or damage to the part. If programming the EEPROM with

a custom programmer, it is recommended to use the AMT49406 application to determine the appropriate settings, save the settings file, and use the file contents to program to the EEPROM. The application's settings file contains one line for each EEPROM address, containing addresses 8 through 22 (15 lines/addresses).

Registers not shown in the table are not for users to access. Changing the value in undocumented registers may cause malfunction or damage to the part.

**Table 1: Register and EEPROM Map**

| Address |       | AMT49406 Register Map                                                                                                                                    |                      |                  |                      |
|---------|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|------------------|----------------------|
| 0       |       | Allegro internal information. No associated register for these EEPROM data                                                                               |                      |                  |                      |
| 1       |       |                                                                                                                                                          |                      |                  |                      |
| 2       |       |                                                                                                                                                          |                      |                  |                      |
| 3       |       |                                                                                                                                                          |                      |                  |                      |
| 4       |       |                                                                                                                                                          |                      |                  |                      |
| 5       |       |                                                                                                                                                          |                      |                  |                      |
| 6       |       | User-flexible code. No associated register for these EEPROM data. Provided to user. For example, tracking number of product, product revision info, etc. |                      |                  |                      |
| 7       |       |                                                                                                                                                          |                      |                  |                      |
| 8 / 72  | 3:0   | Rated_speed [3:0]                                                                                                                                        |                      |                  |                      |
|         | 7:4   | Rated_speed [7:4]                                                                                                                                        |                      |                  |                      |
|         | 11:8  | speed_close_loop                                                                                                                                         | Rated speed [10:8]   |                  |                      |
|         | 15:12 | PWMin_range                                                                                                                                              | Direction            | Accelerate_range | Clock_PWM            |
| 9 / 73  | 3:0   | Acceleration [3:0]                                                                                                                                       |                      |                  |                      |
|         | 7:4   | Acceleration [7:4]                                                                                                                                       |                      |                  |                      |
|         | 11:8  | Motor_Resistance [3:0]                                                                                                                                   |                      |                  |                      |
|         | 15:12 | Motor_Resistance [7:4]                                                                                                                                   |                      |                  |                      |
| 10 / 74 | 3:0   | Rated Current [3:0]                                                                                                                                      |                      |                  |                      |
|         | 7:4   | Rated Current [7:4]                                                                                                                                      |                      |                  |                      |
|         | 11:8  | SPD mode                                                                                                                                                 | Rated Current [10:8] |                  |                      |
|         | 15:12 | Startup_Current [2:0]                                                                                                                                    |                      |                  |                      |
| 11 / 75 | 3:0   | Open_Drive                                                                                                                                               |                      |                  |                      |
|         | 7:4   | Power_Ctl_En                                                                                                                                             |                      |                  | open_ph_protect      |
|         | 11:8  | Startup_mode [1:0]                                                                                                                                       |                      |                  |                      |
|         | 15:12 |                                                                                                                                                          |                      |                  |                      |
| 12 / 76 | 3:0   | PID_P [3:0]                                                                                                                                              |                      |                  |                      |
|         | 7:4   | PID_P [7:4]                                                                                                                                              |                      |                  |                      |
|         | 11:8  | Motor_Inductance [3:0]                                                                                                                                   |                      |                  |                      |
|         | 15:12 | Open_Window                                                                                                                                              |                      | over_Speed_Lock  | Motor_Inductance [4] |

Continued on next page...

**Table 1: Register and EEPROM Map (continued)**

| Address |       | AMT49406 Register Map      |                |                                 |            |
|---------|-------|----------------------------|----------------|---------------------------------|------------|
| 13 / 77 | 3:0   | PID_I [3:0]                |                |                                 |            |
|         | 7:4   | PID_I [7:4]                |                |                                 |            |
|         | 11:8  |                            |                |                                 |            |
|         | 15:12 |                            | delay_start    |                                 |            |
| 14 / 78 | 3:0   |                            |                |                                 |            |
|         | 7:4   |                            |                |                                 |            |
|         | 11:8  |                            |                |                                 |            |
|         | 15:12 |                            |                |                                 |            |
| 15 / 79 | 3:0   | Angle_Error_Lock (startup) |                |                                 |            |
|         | 7:4   | soft_on                    | soft_off       |                                 |            |
|         | 11:8  | Deadtime_setting [3:0]     |                |                                 |            |
|         | 15:12 | Safe_Brake_thrd [1:0]      |                |                                 |            |
| 16 / 80 | 3:0   | OCP_reset_mode             | OCP_Enable     |                                 |            |
|         | 7:4   | First_cycle_speed [1:0]    |                |                                 |            |
|         | 11:8  | Decelerate_buffer [1:0]    |                | Accelerate_buffer [1:0]         |            |
|         | 15:12 |                            |                | BEMF_Lock_filter [1:0]          |            |
| 17 / 81 | 8:0   | Speed_demand [8:0]         |                |                                 |            |
|         | 9     | i2c_speed_mode             |                |                                 |            |
|         | 15:10 |                            |                |                                 |            |
| 18 / 82 | 3:0   |                            |                |                                 |            |
|         | 7:4   |                            |                |                                 |            |
|         | 11:8  | IPD_Current_Thr [3:0]      |                |                                 |            |
|         | 15:12 |                            |                | IPD_Current_Thr [5:4]           |            |
| 19 / 83 | 7:0   |                            |                |                                 |            |
|         | 15:8  |                            |                |                                 |            |
| 20 / 84 | 7:0   | Rated_Voltage              |                |                                 |            |
|         | 15:8  | Sense_Resistor             |                |                                 |            |
| 21 / 85 | 3:0   |                            |                |                                 |            |
|         | 7:4   | slight_mv_demand [2:0]     |                |                                 |            |
|         | 11:8  |                            |                | speed_input_off_threshold [1:0] |            |
|         | 15:12 | standby_dis                |                |                                 |            |
| 22 / 86 | 3:0   | speed close loop parameter |                |                                 |            |
|         | 7:4   | Restart_attempt            |                | speed close loop parameter      |            |
|         | 11:8  | Lock_restart_set           | vibration_lock |                                 | Brake_mode |
|         | 15:12 |                            |                |                                 |            |

**Table 2: Register and EEPROM Map Notes**

| Parameter                 | Address    | Notes                                                                                                                                                                                      |
|---------------------------|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Rated_Voltage             | 20 [7:0]   | Rated Voltage (V) = Rated_voltage_register_value / 5                                                                                                                                       |
| Rated_Speed               | 8 [10:0]   | Rated Speed (Hz) = Rated_speed_register_value × 0.530                                                                                                                                      |
| Motor_Resistance          | 9 [15:8]   | Motor Resistance ( $\Omega$ ) = Motor_resistance_register_value / [ (Rated_voltage_register_value × 4.096) / (Sense_resistor_register_value / 125) / (Rated_voltage_register_value / 10) ] |
| Rated_Current             | 10 [10:0]  | Rated Current (mA) = Rated_current_register_value / (Sense_resistor_register_value / 125)                                                                                                  |
| Startup_Current           | 10 [15:13] | 0: NA. else Startup Current = Rated Current × 1/8 × (startup_current_register_value + 1)                                                                                                   |
| Acceleration              | 9 [7:0]    | Acceleration (Hz/s) = Acceleration_register_value × k if range = 0 then k = 0.05, else k = 3.2                                                                                             |
| Accelerate_range          | 8 [13]     |                                                                                                                                                                                            |
| speed_close_loop          | 8 [11]     | 1: closed loop. 0: open loop.                                                                                                                                                              |
| Direction                 | 8 [14]     | 1: A→B→C. 0: A→C→B.                                                                                                                                                                        |
| SPD mode                  | 10 [11]    | 1: analog 0: digital (PWM or Clock).                                                                                                                                                       |
| Clock_PWM                 | 8 [12]     | 1: clock mode. 0: PWM mode.                                                                                                                                                                |
| PWMin_range               | 8 [15]     | 1: ≤ 2.8 kHz 0: > 2.8 kHz.                                                                                                                                                                 |
| clock_speed_ratio         | 22 [5:0]   | Ratio (rpm/Hz) = clock_speed_ratio_value × 0.25. clock_speed_ratio maximum value is 42.                                                                                                    |
| Speed_input_off_threshold | 21 [9:8]   | 00: 10%. 01: 6%<br>10: 15%. 11: 20%                                                                                                                                                        |
| Startup_mode              | 11 [11:10] | 00: 6 pulse mode. 01: 2 pulse mode.<br>10: slight-move mode. 11: align & go.                                                                                                               |
| IPD_current_thrd          | 18 [13:8]  | IPD current threshold (A) = IPD_current_thrd_value × 0.086                                                                                                                                 |
| Slight_mv_demand          | 21 [7:5]   | Amplitude demand in slight move mode (%) = value × 3.2 + 2.4                                                                                                                               |
| PID_P                     | 12 [7:0]   | Position observer loop P gain.                                                                                                                                                             |
| PID_I                     | 13 [7:0]   | Position observer loop I gain.                                                                                                                                                             |
| Motor_Inductance          | 12 [12:8]  | Refer to the configuration guide.                                                                                                                                                          |
| Sense_Resistor            | 20 [15:8]  | Sense resistor value (m $\Omega$ ) = sense_resistor_value / 3.7                                                                                                                            |
| Open_drive                | 11 [3]     | Refer to the configuration guild.                                                                                                                                                          |
| Power_Ctrl_En             | 11 [7]     | 1: enable the current limit.                                                                                                                                                               |
| Open_window               | 12 [15]    | 1: open window for inductance tuning. 0: normal                                                                                                                                            |
| delay_start               | 13[14]     | 1: delayed start. 0: start right after windmill checking.                                                                                                                                  |
| Soft_off                  | 15 [6]     | Refer to the functional description.                                                                                                                                                       |
| Soft_on                   | 15 [7]     | Refer to the functional description.                                                                                                                                                       |
| First_Cycle_Speed         | 16 [7:6]   | 00: 0.55 Hz. 01: 1.1 Hz. 10: 2.2 Hz. 11: 4.4 Hz                                                                                                                                            |
| Accelerate_buffer         | 16 [9:8]   | Refer to the configuration guide.                                                                                                                                                          |
| Decelerate_buffer         | 16 [11:10] | Refer to the configuration guide.                                                                                                                                                          |
| Deadtime_setting          | 15[11:8]   | (n + 1) × 40 ns.                                                                                                                                                                           |
| Standby_mode              | 21 [15]    | 0: enable. 1: disable.                                                                                                                                                                     |
| Brake_mode                | 22 [8]     | 0: brake when safe. 1: 100% uncontrolled                                                                                                                                                   |
| Safe_brake_thrd           | 15 [15:14] | 00: 1× rated current. 01: 2×. 10: 4×. 11: 8×.                                                                                                                                              |
| OCP_reset_mode            | 16 [3]     | 0: upon motor restart. 1: after 5 seconds.                                                                                                                                                 |

Continued on next page...

Table 2: Register and EEPROM Map Notes (continued)

| Parameter        | Address     | Notes                                                                                     |
|------------------|-------------|-------------------------------------------------------------------------------------------|
| OCP_Enable       | 16 [2:0]    | 100: 480 ns filter. 111: OCP disabled.                                                    |
| Angle_Error_Lock | 15 [3:2]    | Lock detect during startup.<br>00: disabled. 01: 5 degrees. 10: 9 degrees. 11: 13 degrees |
| BEMF_lock_filter | 16 [13:12]  | Refer to the configuration guide.                                                         |
| Open_ph_protect  | 11 [4]      | Refer to the configuration guide.                                                         |
| Vibration_lock   | 22 [10]     | Refer to the configuration guide.                                                         |
| Over_speed_lock  | 12 [13]     | Refer to the configuration guide.                                                         |
| Restart_attempt  | 22 [7:6]    | 00: Always. 01: 3 times. 10: 5 times. 11: 10 times.                                       |
| Lock_restart_set | 22 [11]     | 0: 5 seconds. 1: 10 seconds.                                                              |
| i2c_spd_mode     | 17 [9]      | 0: controlled by SPD pin. 1: controlled by register value in 17 [8:0].                    |
| i2c_spd_demand   | 17 [8:0]    | 0~511 represents 0~100%                                                                   |
| <b>READBACK</b>  |             |                                                                                           |
| Motor speed      | 120         | Motor Speed (Hz) = register_value × 0.530 Hz                                              |
| Bus current      | 121         | Bus current (mA) = register_value / (Sense_resistor_register_value / 125)                 |
| Q-axis current   | 122         | Q-axis current (mA) = register_value / (Sense_resistor_register_value / 125)              |
| V <sub>BB</sub>  | 123         | V <sub>BB</sub> (V) = register_value / 5                                                  |
| Temperature      | 124         | Temperature (°C) = register_value – 53                                                    |
| Control demand   | 125         | 0~511 represents 0~100%                                                                   |
| Control command  | 126         | 0~511 represents 0~100%                                                                   |
| Operation state  | 127 [15:12] |                                                                                           |

Note: Refer to application note and user interface for additional detail.

## Programming EEPROM

The AMT49406 contains 24 words of EEPROM, each of 16 bit length. The EEPROM is controlled with the following I<sup>2</sup>C registers.

### EEPROM Control – Register 161: Used to control programming of EEPROM

| Bit  | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3  | 2  | 1  | 0  |
|------|----|----|----|----|----|----|---|---|---|---|---|---|----|----|----|----|
| Name | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | RD | WR | ER | EN |

| Bit  | Name | Description                                                                                                              |
|------|------|--------------------------------------------------------------------------------------------------------------------------|
| 0    | EN   | Set EEPROM voltage required for Writing or Erasing.                                                                      |
| 1    | ER   | Sets Mode to Erase.                                                                                                      |
| 2    | WR   | Sets Mode to Write.                                                                                                      |
| 3    | RD   | Sets Mode to Read. Note this bit is not needed to read the EEPROM when using the method described on the following page. |
| 15:4 | n/a  | Do not use; always set to zero (0) during programming process.                                                           |

### EEPROM Address – Register 162: Used to set the EEPROM address to be altered

| Bit  | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4         | 3 | 2 | 1 | 0 |
|------|----|----|----|----|----|----|---|---|---|---|---|-----------|---|---|---|---|
| Name | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | eeADDRESS |   |   |   |   |

| Bit  | Name      | Description                                                                         |
|------|-----------|-------------------------------------------------------------------------------------|
| 0:4  | eeADDRESS | Used to specify the EEPROM address to be erased or written. There are 24 addresses. |
| 15:5 | n/a       | Do not use; always set to zero (0) during programming process.                      |

### EEPROM Data\_In – Register 163: Used to set the EEPROM new data to be programmed

| Bit  | 15       | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|------|----------|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| Name | eeDATAin |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |

| Bit  | Name     | Description                                                                                                        |
|------|----------|--------------------------------------------------------------------------------------------------------------------|
| 15:0 | eeDATAin | Used to specify the new EEPROM data to be changed. This must be set to 0 when erasing the current EEPROM contents. |

## EEPROM Commands

To change the contents of a memory location, the word must be first erased. The EEPROM programming process (writing or erasing) takes about 15 ms per word.

Each word must be written individually. The example below is shown in the following format:

I<sup>2</sup>C Write/Read, I2C\_register\_address [data] // comment

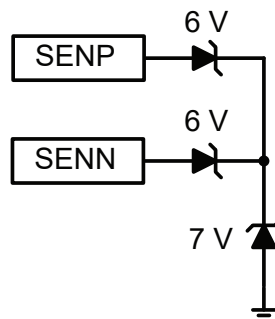
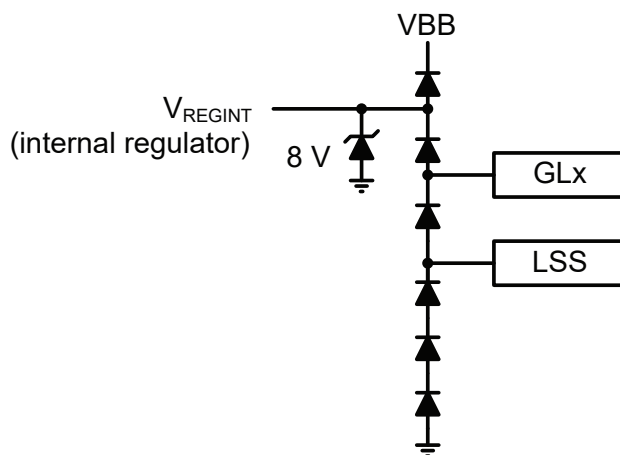
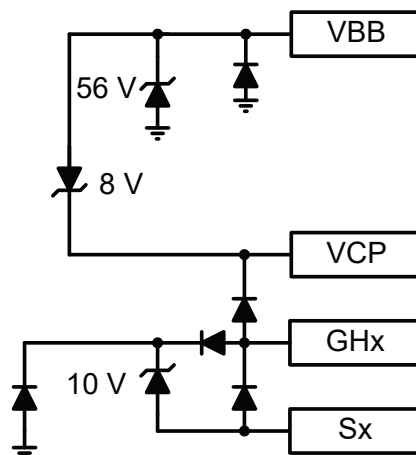
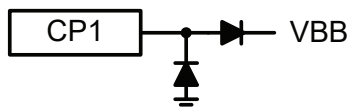
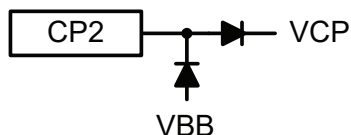
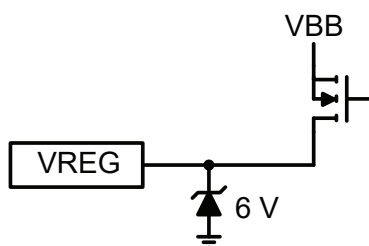
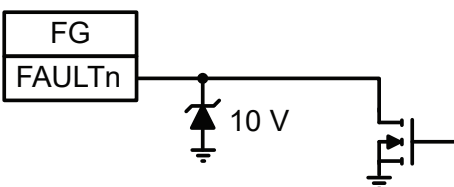
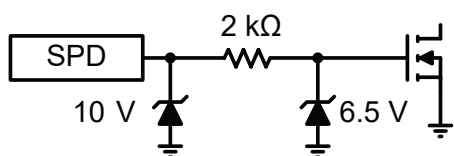
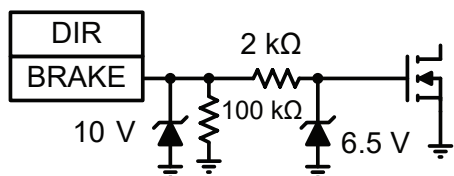
Example #1: Write 261 (0x000105) to EEPROM address 7

1. Erase the existing data.
  - A. I<sup>2</sup>C Write, 162 [7] // set which EEPROM address to erase.
  - B. I<sup>2</sup>C Write, 163 [0] // set Data\_In = 0x000000.
  - C. I<sup>2</sup>C Write, 161 [3] // set control to erase and set voltage high.
  - D. Wait 15 ms // requires 15 ms high-voltage pulse to erase.
2. Write the new data.
  - A. I<sup>2</sup>C Write, 162 [7] // set which EEPROM address to write.
  - B. I<sup>2</sup>C Write, 163 [261] // set Data\_In = 261 (0x000105).
  - C. I<sup>2</sup>C Write, 161 [5] // set control to write and set voltage high.
  - D. Wait 15 ms // requires 15 ms high-voltage pulse to write.

Example #2: Read EEPROM address 7 to confirm the data was properly programmed.

1. Read the word.
  - A. I<sup>2</sup>C Read, 7 // read I2C register 7; this will be contents of EEPROM address 7.

## PIN DIAGRAMS



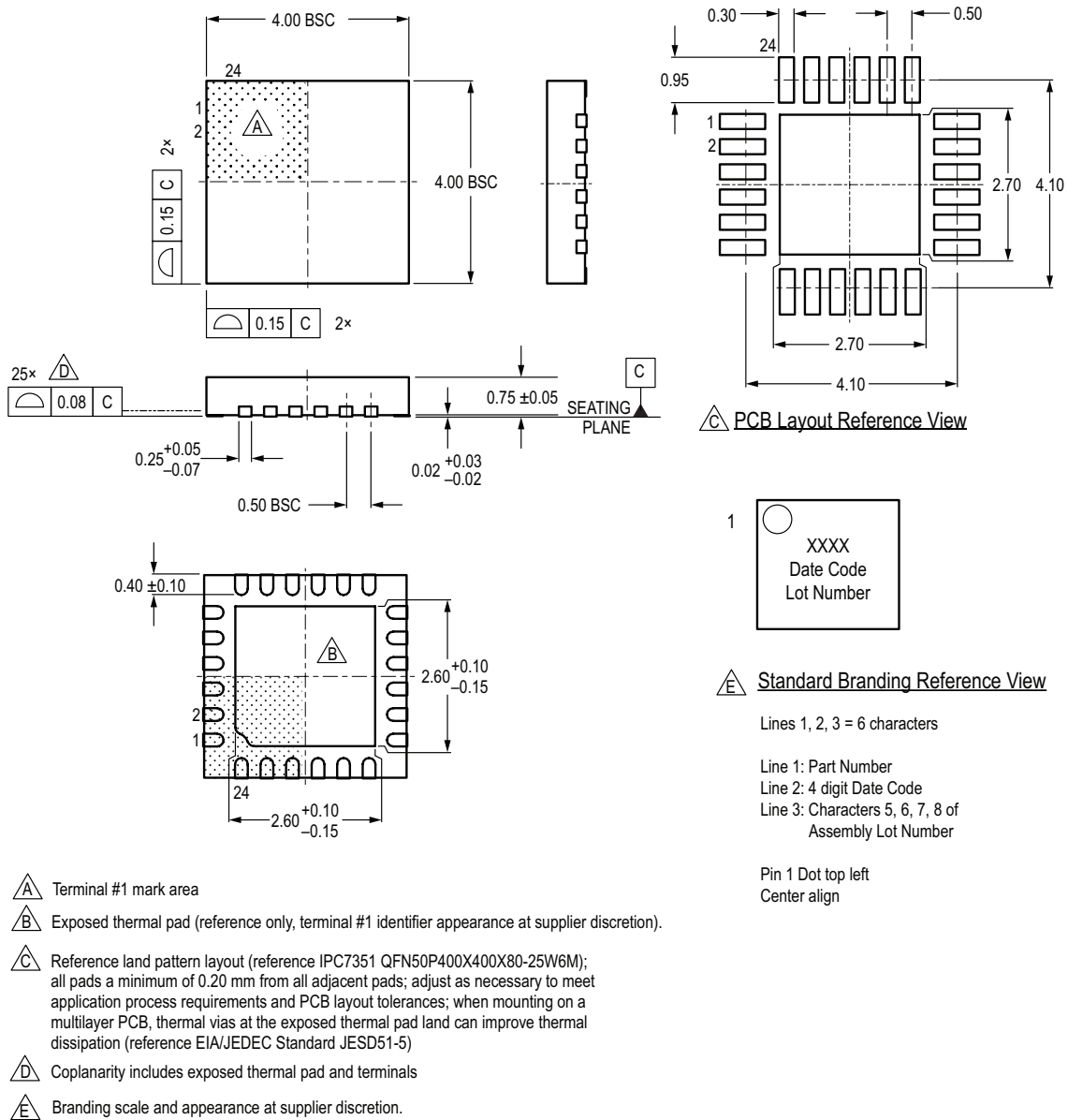
## PACKAGE OUTLINE DRAWING

### For Reference Only – Not for Tooling Use

(Reference Allegro DWG-0000222 Rev. 4 or JEDEC MO-220WGGD.)

Dimensions in millimeters – NOT TO SCALE.

Exact case and lead configuration at supplier discretion within limits shown.



**Figure 7: Package ES, 24-Contact QFN with Exposed Pad**

## For Reference Only – Not for Tooling Use

(Reference MO-153 ADT)

NOT TO SCALE

Dimensions in millimeters

Dimensions exclusive of mold flash, gate burrs, and dambar protrusions

Exact case and lead configuration at supplier discretion within limits shown

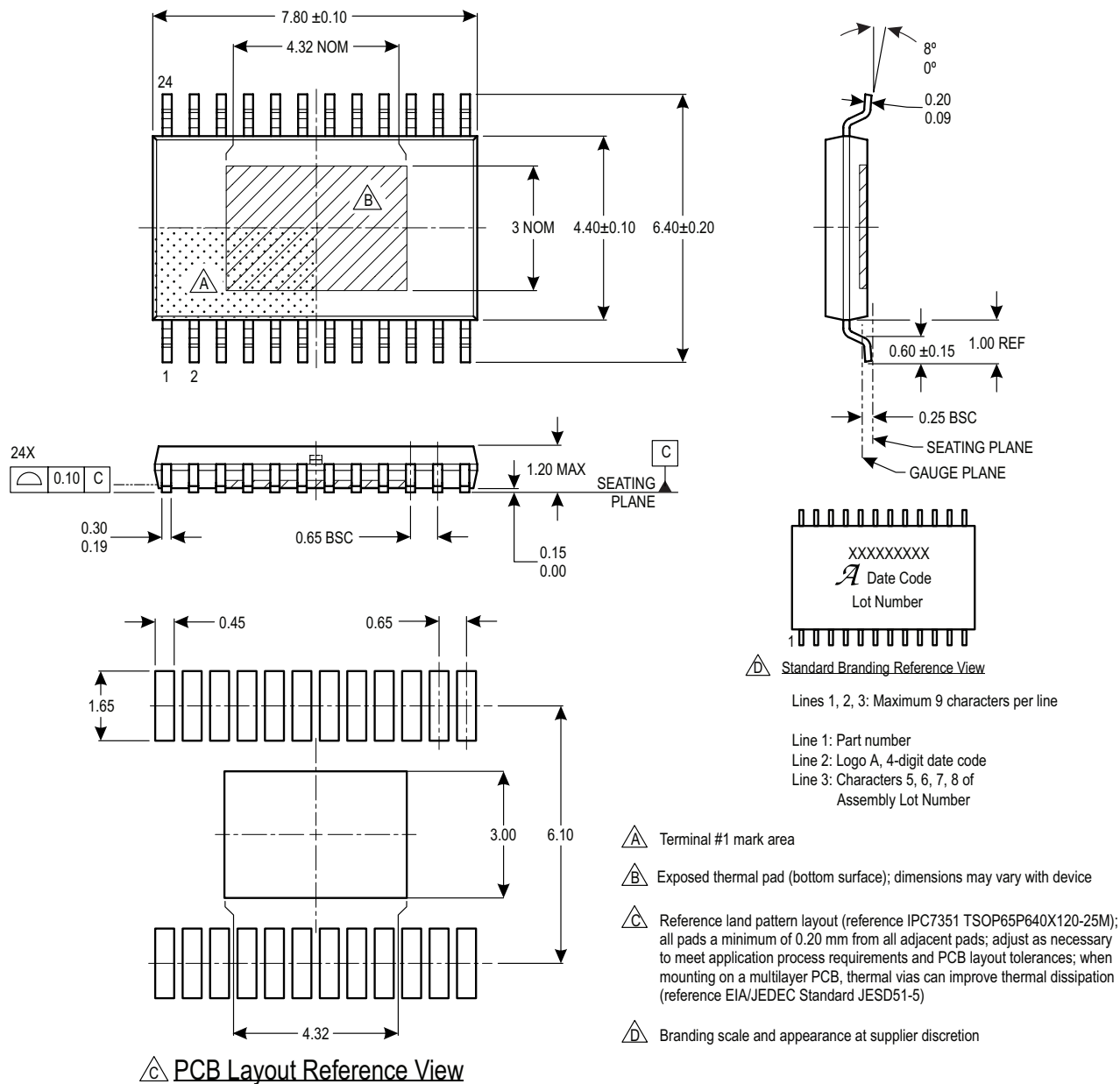


Figure 8: Package LP, 24-Lead TSSOP with Exposed Pad

**Revision History**

| Number | Date              | Description                                                                                                                                 |
|--------|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| –      | December 13, 2018 | Initial release                                                                                                                             |
| 1      | January 24, 2019  | Updated Motor PWM Frequency (page 4)                                                                                                        |
| 2      | June 2, 2020      | Corrected delay_start address (page 12) and minor editorial updates                                                                         |
| 3      | July 28, 2021     | Updated Programming EEPROM register descriptions (page 14); updated EEPROM Commands section (page 15); updated ES package drawing (page 17) |

Copyright 2021, Allegro MicroSystems.

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

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

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

Copies of this document are considered uncontrolled documents.

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

[www.allegromicro.com](http://www.allegromicro.com)