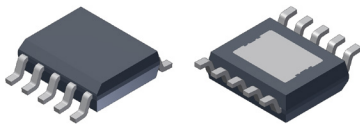# Integrated Sensorless FOC BLDC Driver

FEATURES AND BENEFITS

- Coding-free sensorless field-oriented control (FOC)
- Standby mode current less than 10 µA
- Quiet and quick startup
- Only two external components for minimal application circuit
- PWM speed input, FG speed output
- Lock detection
- Soft-on soft-off (SOSO)
- Optional closed-loop speed control
- Configurable current limit
- Windmill and reverse windmill operation
- Lock detection
- Short-circuit protection (OCP)

EFFICIENCY WITH EASE
QUIETMOTION

PACKAGE:

10-lead SOIC
with exposed thermal pad
(LK package)

Not to scale

DESCRIPTION

The AMT49400 is an advanced 3-phase, sensorless, brushless DC (BLDC) motor driver with integrated power MOSFETs.

A minimal application circuit can be achieved with only two external components due to device's high level of integration, which includes control algorithm, analog circuit, and power stage.

A field-oriented control (FOC) algorithm is fully integrated to achieve the best efficiency and acoustic noise performance. EEPROM programmability is included to optimize motor startup performance.

The motor speed is controlled by applying a duty cycle command to the PWM input. A simple I^{2}C interface is provided for setting motor-rated voltage, rated current, rated speed, resistance, and startup profiles. The I^{2}C interface is also used for on/off control, speed control, and speed readback.

The AMT49400 is available in a 10-lead SOIC with exposed pad, (suffix LK).

APPLICATIONS

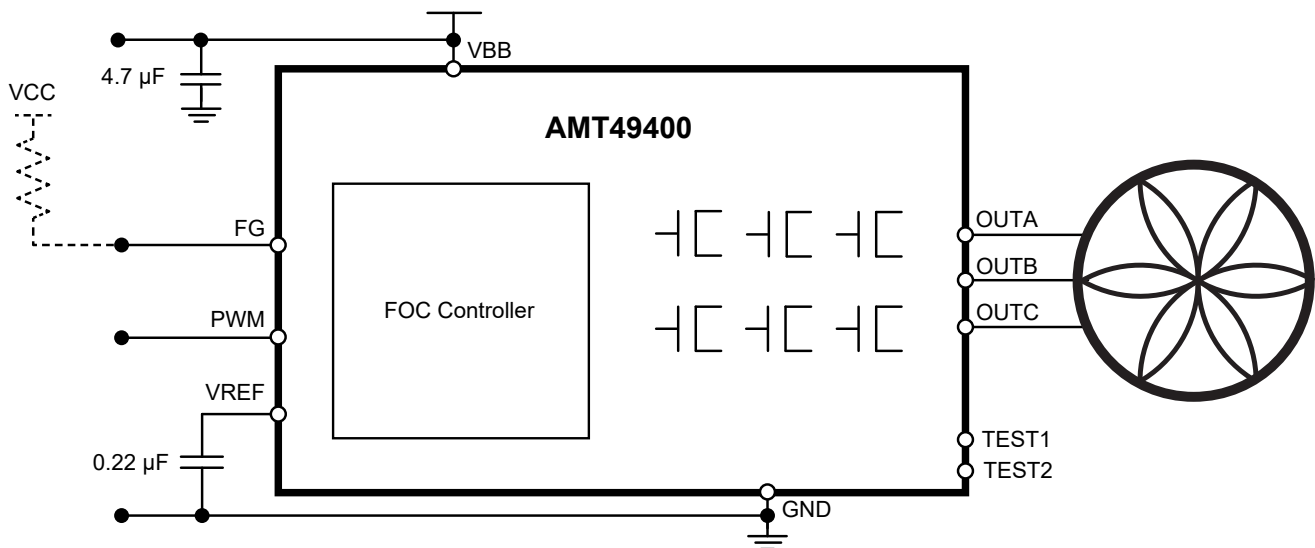- Computer fans
- Exhaust fans
- Home appliance fans and pumps

Figure 1: Typical Application

AMT49400

Integrated Sensorless FOC BLDC Driver

SELECTION GUIDE

Part Number	Ambient Temperature Range (T_A) (°C)	Packaging	Packing
AMT49400GLKATR	–40 to 105	10-lead SOIC with exposed thermal pad	3000 pieces per 13-inch reel

ABSOLUTE MAXIMUM RATINGS

Characteristic	Symbol	Notes	Rating	Unit
Supply Voltage	V_{BB}	t_w < 10 ms	–0.3 to 20	V
			–0.3 to 18	V
Logic Input Voltage Range	V_{IN}	PWM	–0.3 to 6	V
		PWM (pull-up resistor > 50 kΩ)	V_{BB}	V
Logic Output – FG	V_O	FG	18	V
Output Current	I_{OUT}		2	A
Output Voltage	V_{OUT}		GND – 1 to V_{BB} + 1	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	$R_{\theta JA}$	10-lead SOIC (package LK), on 2-sided PCB 1-in.^{2} copper	40	°C/W

*Additional thermal information available on the Allegro website.

PINOUT DIAGRAM AND TERMINAL LIST
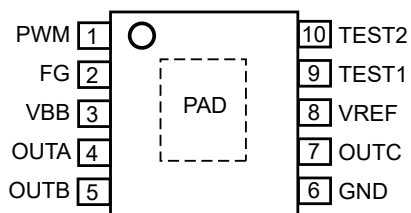
LK-10 Package Pinouts

Terminal List Table

Terminal Number	Name	Function
1	PWM	Logic input – speed demand
2	FG	Output signal
3	VBB	Input supply
4	OUTA	Motor terminal
5	OUTB	Motor terminal
6	GND	Ground
7	OUTC	Motor terminal
8	VREF	Reference voltage output
9	TEST1	Test use only
10	TEST2	Test use only
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
GENERAL						
Supply Voltage Range	V_{BB}		4	–	16	V
VBB Supply Current	I_{BB}	I_{VREF} = 0 mA	–	4	5	mA
		Standby mode	–	<1	10	µA
Reference Voltage	V_{REF}	I_{OUT} = 0 to 5 mA	2.7	2.8	2.95	V
LOGIC IOs						
Logic Input – Low Level	V_{IL}		–	–	0.8	V
Logic Input – High Level	V_{IH}		2	–	–	V
Logic Input Hysteresis	V_{HYS}		140	300	600	mV
Output Leakage (FG)	I_{O_FG}	V_{FG} = 18 V	–	–	5	µA
POWER DRIVER						
Total Driver On-Resistance (Sink + Source)	$R_{DS(on)}$	I = 1 A, T_J = 25°C, V_{BB} = 12 V	–	1000	1150	mΩ
		Source Driver	–	750	–	mΩ
		Sink Driver	–	250	–	mΩ
Motor PWM Frequency	f_{PWMOUT}	T_J = 25°C	23.3	24.4	25.5	kHz
		Over temperature	22.8	24.4	26.0	kHz
CONTROL CIRCUITRY						
PWM Duty On Threshold	DC_{ON}	Relative to Target (guaranteed by scan chain)	–0.5	–	0.5	%
PWM Duty Off Threshold	DC_{OFF}	Relative to Target (guaranteed by scan chain)	–0.5	–	0.5	%
PWM Input Frequency Range	f_{PWM}	PWM input frequency setting = 0	2.5	–	100	kHz
		PWM input frequency setting = 1	80	–	3200	Hz
PROTECTION						
Short to VBB			–	2.6	–	A
Short to GND			–	3	–	A
VBB UVLO Rising	$V_{BB(UVLO,r)}$	V_{BB} rising	–	3.85	4	V
VBB UVLO Falling	$V_{BB(UVLO,f)}$	V_{BB} falling	3.4	–	–	V
VBB UVLO Hysteresis	$V_{BB(UVLO,hys)}$		160	300	600	mV
Current Limit	I_{OCL}	Rated current 1.5 A	–5	–	5	%
Thermal Shutdown Temperature	T_{JTSD}	Temperature increasing	–	165	–	°C
Thermal Shutdown Hysteresis	ΔT_J	Recovery = $T_{JTSD} - \Delta T_J$	–	20	–	°C

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

FUNCTIONAL DESCRIPTION

The AMT49400 is a three-phase BLDC controller with integrated MOSFETs. It operates from 4 to 16 V and targets computer fan, ventilation fan, and other fan or pump 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.
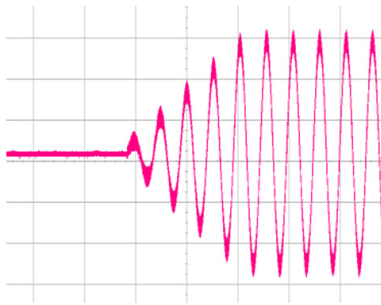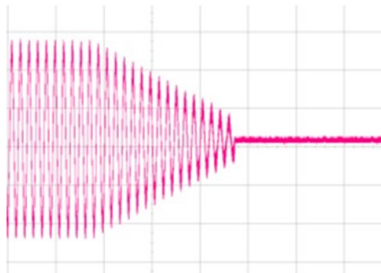

Figure 2: Current Waveform of Soft-On

Figure 3: Current Waveform of Soft-Off

Speed Control

Speed demand is provided via the PWM pin. The AMT49400 also features a closed-loop speed function, which can be enabled or disabled via the EEPROM.

The motor speed is controlled by the PWM duty cycle, 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.

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

The 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.

The PWM pin is also used as SCL in the I^{2}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%, the IC will stop the motor.

If the PWM signal remains logic low for longer than one second, and the motor is stationary, the AMT49400 will enter standby mode. A rising edge on PWM will wake the IC.

Standby Mode will turn off all circuitry including VREF.

FG: Open-drain output provides motor speed information to the system. The open drain output can be pulled up to V_{BB}, V_{REF}, or an external V_{CC} (<18 V).

The FG pin is also used as SDA in I2C mode. The first I2C command can pass only when the FG is high (open drain off). After the first I2C command, the FG pin is no longer used for speed information, and the FG pin is dedicated as a data pin for the I2C 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 I2C communication, it is recommended to have the first I2C demand right after power-up or exit from standby mode within 9.8 ms.

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

Lock Detect: A logic circuit monitors the motor position to determine if motor is running as expected. If a lock condition is detected, the motor drive will be disabled for 5 seconds before an auto-restart is attempted.

Current Control: The motor's rated current at rated speed and normal load must be programmed to the EEPROM for proper operation. The AMT49400 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 AMT49400 has a short circuit protection feature which prevents damage to the IC or motor. The three conditions, phase to GND, phase to VBB, and phase to phase will trigger the OCP event, and the AMT49400 will stop driving current to the motor immediately. The OCP can recover after a power cycle or PWM demand cycle. If the OCP restart mode (EEPROM setting) is "time", the OCP can recover after 5 seconds.

I²C OPERATION AND EEPROM MAP

The I²C interface allows the user to program the register and parameters into EEPROM. The AMT49400 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. I²C can overwrite those values and change the motor system operation on the fly.

I²C can also be used to program the EEPROM, which is normally done in the production line.

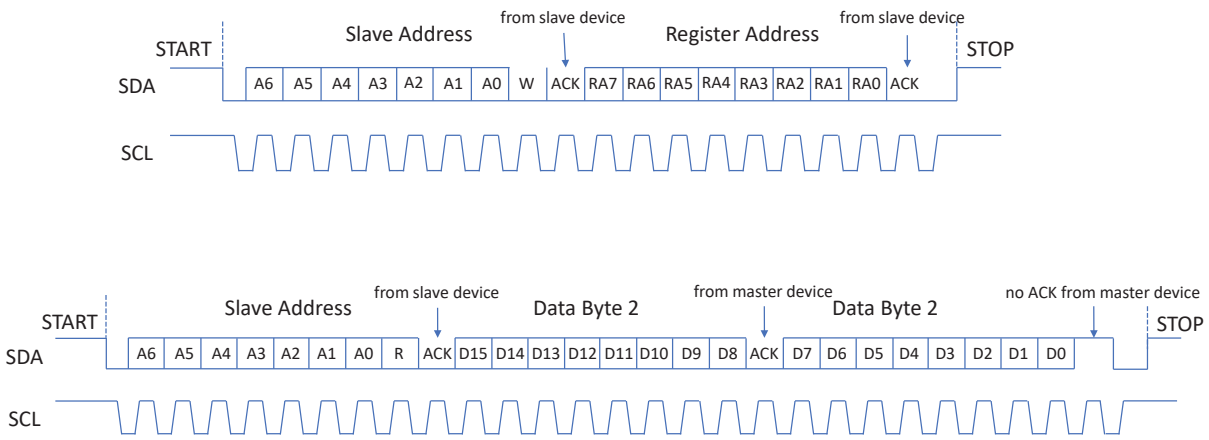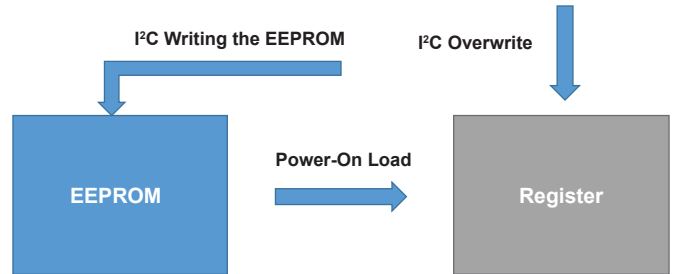The figures below shows the I²C interface timing.
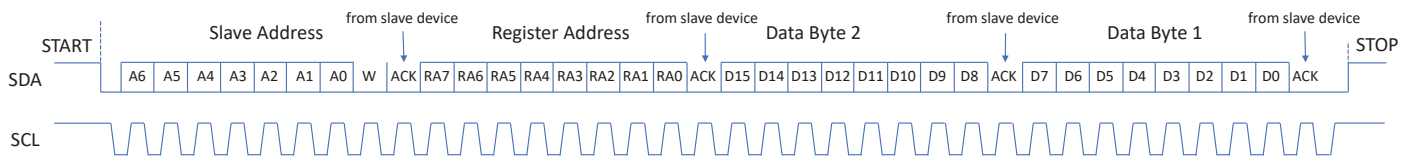

Figure 4: Read Command

Figure 5: 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 AMT49400 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	Bit	AMT49400 Register Map (MSB → LSB)
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_ABC | Accelerate_range | (reserved)
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	(reserved) | Rated Current [10:8]
	15:12	Startup_Current [2:0] | (reserved)
11 / 75	3:0	Open_Drive | (reserved)
	7:4	Power_Ctrl_En | (reserved)
	11:8	Startup_Mode [1:0] | (reserved)
	15:12	(reserved)
12 / 76	3:0	PID_P [3:0]
	7:4	PID_P [7:4]
	11:8	MotorInductance [3:0]
	15:12	(reserved) | MotorInductance [4]

Continued on next page...

Table 1: Register and EEPROM Map (continued)

Address	Bits	AMT49400 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	startup_angle_lock			
	7:4	soft_on	soft_off		
	11:8				
	15:12				
16 / 80	3:0	OCP_reset_mode			
	7:4	First_cycle_speed [1:0]			
	11:8	DeccBuffer [1:0]		AcceBuffer [1:0]	
	15:12			BEMF_Lock_Filter [1:0]	
17 / 81	8:0	Speed_demand [8:0]			
	9	i2c_speed_mode			
	15:10	FG_freq_option [2:0]		FG_output_opt [1:0]	
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				
21 / 85	3:0				
	7:4	slight_move_demand [2:0]			
	11:8			Low_duty_threshold [1:0]	
	15:12				
22 / 86	3:0	closed_loop_time_constant [3:0]			
	7:4			closed_loop_time_constant [5:4]	
	11:8				
	15:12				

Table 2: Register and EEPROM Map Notes

Parameter	Address	Notes
Rated_Voltage	20 [7:0]	Rated Voltage (V) = Rated_voltage_register_value / 255 × 20 V
Rated_Speed	8 [10:0]	Rated Speed (Hz) = Rated_speed_register_value × 0.530
Rated_Current	10 [10:0]	Rated Current (mA) = Rated_current_register_value / 0.78
Motor_Resistance	9 [15:8]	Motor Resistance (Ω) = Motor_resistance_register_value / 8.3
Startup_Current	10 [15:11]	Startup Current = Rated Current × 1/8 × (startup_current_register_value + 1)
Acceleration	9 [7:0]	Acceleration (Hz/s) = Acceleration_register_value × k
Accelerate_range	8 [13]	if range = 0 then k = 0.05, else k = 3.2
First_cycle_speed	16 [7:6]	00: 0.55 Hz. 01: 1.1 Hz. 10: 2.2 Hz. 11: 4.4 Hz
PWMin_range	8 [15]	1: ≤ 2.8 kHz 0: > 2.8 kHz.
Low_duty_threshold	21 [9:8]	00: 10%. 01: 6%. 10: 15%. 11: 20%.
FG_freq_option	17 [15:13]	Refer to the application note.
FG_output_option	17 [12:11]	Refer to the application note.
speed_close_loop	8 [11]	1: closed loop. 0: open loop.
Direction	8 [14]	1: A→B→C. 0: A→C→B.
Startup_mode	11 [11:10]	01: 2 pulse mode. 10: slight-move mode. 11: align & go.
IPD_Current_Thr	18 [13:8]	IPD current threshold (A) = IPD_current_thrd_value × 0.04
Slight_move_demand	21 [7:5]	Amplitude demand in slight move mode (%) = value × 3.2 + 2.4
delay_start	13 [14]	Delay start by 100 ms.
closed_loop_time_constant	22 [5:0]	Refer to the application note.
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 application note.
Open_drive	11 [3]	Refer to the application note.
Power_Ctrl_En	11 [7]	Refer to the application note.
Open_window	11 [15]	1: open window for inductance tuning. 0: normal Refer to the application note.
Soft_off	15 [6]	Refer to the application note.
Soft_on	15 [7]	Refer to the application note.
Accelerate_buffer	16 [9:8]	Refer to the application note.
Decelerate_buffer	16 [11:10]	Refer to the application note.
OCP_reset_mode	16 [3]	0: upon motor restart. 1: after 5 seconds.
startup_angle_lock	15 [3:2]	Refer to the application note.
BEMF_lock_filter	16 [13:12]	Refer to the application note.
open_phase_protect	11 [4]	1: enable open phase protection. 0: disable.
Over_speed_lock	12 [13]	1: enable. 0: disable.
i2c_speed_mode	17 [9]	0: controlled by PWM pin. 1: controlled by register value in 17 [8:0].
i2c_speed_demand	17 [8:0]	0~511 represents 0~100%

Continued on next page...

Integrated Sensorless FOC BLDC Driver

Table 2: Register and EEPROM Map Notes (continued)

Parameter	Address	Notes
READBACK		
Motor speed	120	Motor Speed (Hz) = register_value × 0.530 Hz
Bus current	121	Bus current (mA) = register_value / 0.78 / temperature_compensation_factor. Refer to application note for more details.
Q-axis current	122	Q-axis current (mA) = register_value / 0.78
V_{BB}	123	V_{BB} (V) = register_value × 20 / 255
Temperature	124	Temperature (°C) = register_value – 73
Control demand	125	0~511 represents 0~100%
Control command	126	0~511 represents 0~100%

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

Programming EEPROM

The AMT49400 contains 24 words of EEPROM, each of 16 bit length. The EEPROM is controlled with the following I²C 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.
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 EEPROM address to be changed. There are 20 addresses. Do not change address 0 or 19 as these are factory-controlled.
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.

EEPROM Commands

There are three basic commands, Read, Erase, and Write. To change the contents of a memory location, the word must be first erased. The EEPROM programming process (writing or erasing) takes 10 ms per word.

Considering the oscillator frequency variation, after the erasing (or writing) command (sending 0x0003/5 to address 161), wait at least 15 ms before sending any I^{2}C command.

Each word must be written individually. The following examples are shown in the following format:

I2C_register_address [data]   ; comment

Example #1: Write EEPROM address 7 to 261 (hex = 0x0105)

1. Erase the existing data.

    A. 162 [7]   ; set EEPROM address to erase.
    B. 163 [0]   ; set Data_In = 0x0000.
    C. 161 [3]   ; set control to Erase and Voltage High.
    D. Wait 15 ms   ; requires 10 ms High Voltage Pulse to Write.

2. Write the new data.

    A. 162 [7]   ; set EEPROM address to write.
    B. 163 [261]   ; set Data_In = 261.
    C. 161 [5]   ; set control to Write and Set Voltage High.
    D. Wait 15 ms   ; requires 10 ms High Voltage Pulse to Write.

Example #2: Read address 7 to confirm correct data properly programmed.

1. Read the word.

    A. 7 [N/A for read]   ; read register 7; this will be contents of EEPROM.

PIN DIAGRAMS
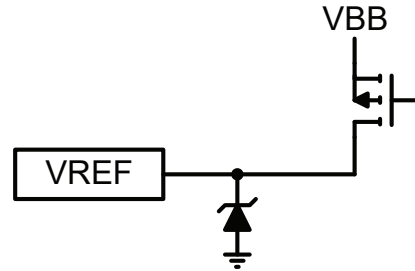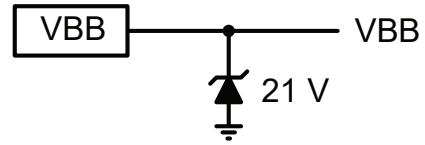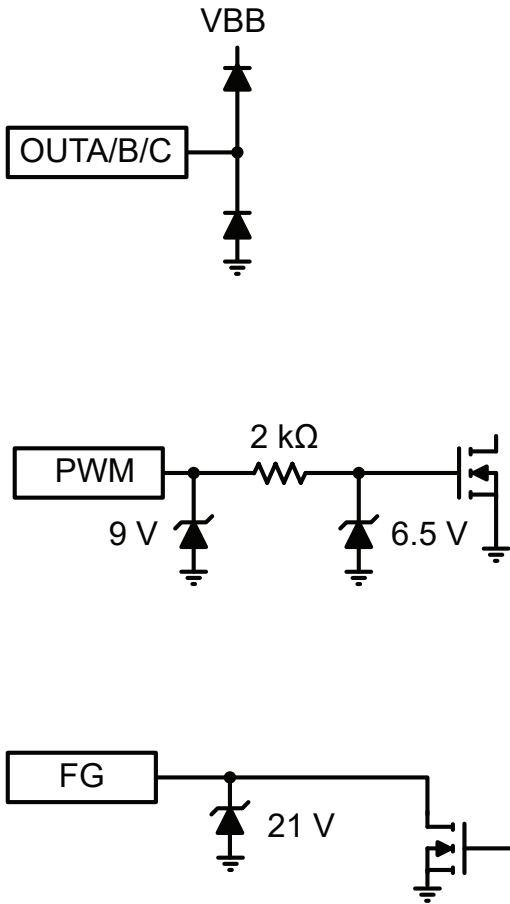
PACKAGE OUTLINE DRAWING

For Reference Only – Not for Tooling Use

(Reference DWG-0000380, Rev. 1)
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
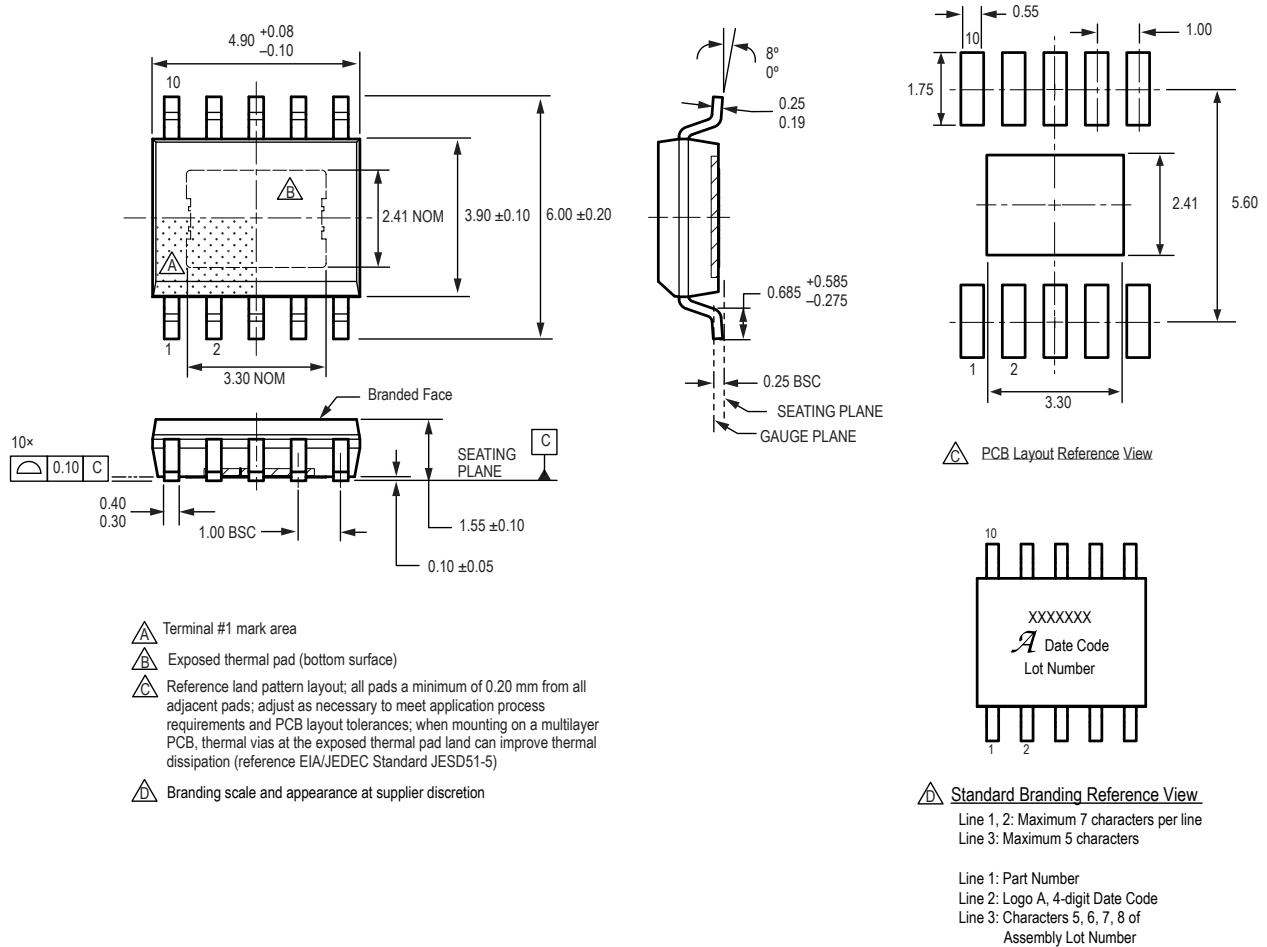
A Terminal #1 mark area

B Exposed thermal pad (bottom surface)

C Reference land pattern layout; all pads a minimum of 0.20 mm from all
adjacent pads; adjust as necessary to meet application process
requirements and PCB layout tolerances; when mounting on a multilayer
PCB, thermal vias at the exposed thermal pad land can improve thermal
dissipation (reference EIA/JEDEC Standard JESD51-5)

D Branding scale and appearance at supplier discretion

C PCB Layout Reference View

D Standard Branding Reference View

Line 1, 2: Maximum 7 characters per line
Line 3: Maximum 5 characters

Line 1: Part Number
Line 2: Logo A, 4-digit Date Code
Line 3: Characters 5, 6, 7, 8 of
Assembly Lot Number

Figure 6: Package LK, 10-Lead SOIC with Exposed Pad

Revision History

Number	Date	Description
–	March 22, 2019	Initial release
1	March 28, 2019	Corrected part number in selection guide (page 2)
2	June 10, 2019	Minor editorial updates

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

www.allegromicro.com