

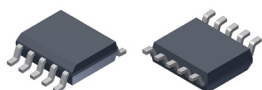
## Three Phase Sensorless Sinusoidal Fan Driver

### FEATURES AND BENEFITS

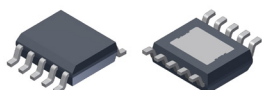
- Standby mode
- Sensorless operation
- Low-noise sinusoidal modulation
- Quiet startup
- Low  $R_{DS(on)}$  power MOSFETs
- Minimal external components
- PWM speed input
- FG speed output
- Lock detection
- Soft start
- Short-circuit protection (OCP)
- Overcurrent limit (OCL)

### PACKAGES:

10-lead SSOP (suffix LN)



10-lead eSOIC with exposed thermal pad (suffix LK)



*Not to scale*

### DESCRIPTION

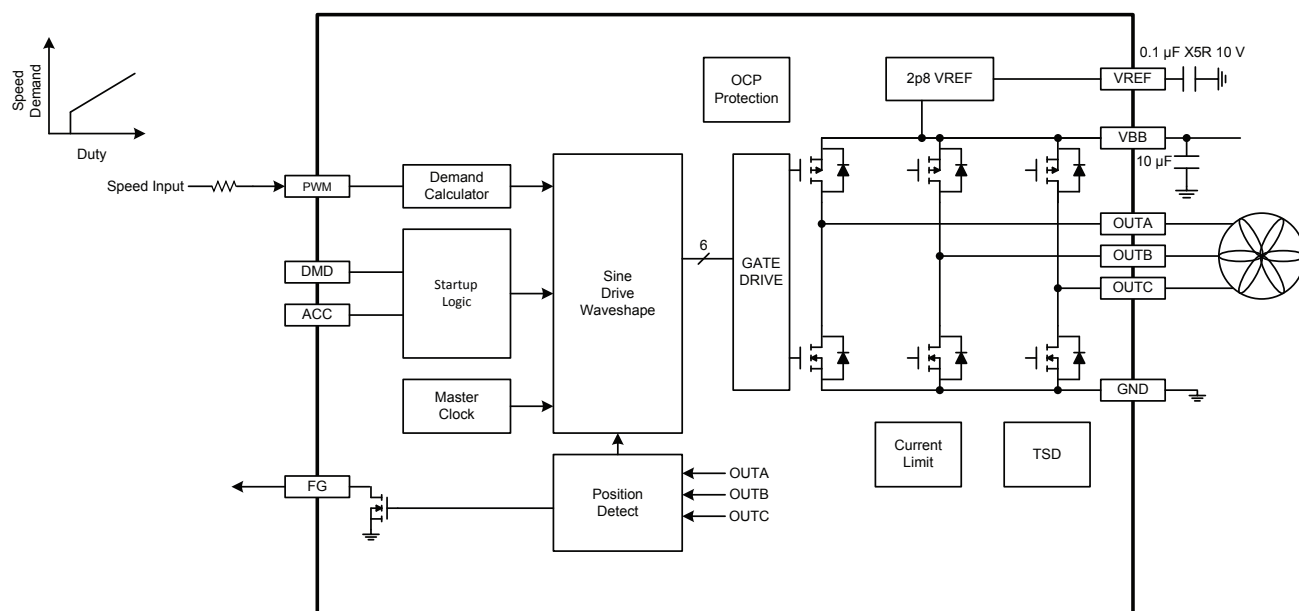
The A5936 three phase motor driver incorporates sinusoidal drive to minimize vibration for fan applications.

A sinusoidal voltage profile is applied to the windings of the motor at startup to quickly and quietly start up and gradually ramp up the motor to desired speed.

The motor speed is controlled by applying a duty cycle command to the PWM input. The PWM input is allowed to operate over a wide frequency range.

The A5936 is available in a 10-lead SSOP (suffix LN), and a 10-lead eSOIC with exposed power pad (suffix LK). The packages are lead (Pb) free, with 100% matte-tin leadframe plating.

### TYPICAL APPLICATION



## SELECTION GUIDE

| Part Number  | Ambient Temperature Range | Packing                      | Package                                |
|--------------|---------------------------|------------------------------|----------------------------------------|
| A5936GLKTR-T | −40°C to 105°C            | 3000 pieces per 13-inch reel | 10-lead eSOIC with exposed thermal pad |
| A5936GLNTR-T | −40°C to 105°C            | 3000 pieces per 13-inch reel | 10-lead SSOP                           |



## ABSOLUTE MAXIMUM RATINGS

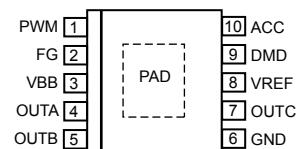
| Characteristic               | Symbol       | Notes               | Value             | Unit |
|------------------------------|--------------|---------------------|-------------------|------|
| Supply Voltage               | $V_{BB}$     | $t_w < 10$ ms       | 20                | V    |
|                              |              |                     | 18                | V    |
| Logic Input Voltage Range    | $V_{IN}$     | PWM, DMD            | −0.3 to 6         | V    |
| Logic Output                 | $V_O$        | FG                  | $V_{BB}$          | V    |
| Analog Input Range           | $V_{IN}$     | ACC                 | −0.3 to $V_{REF}$ | V    |
| Output Current               | $I_{OUT}$    |                     | $I_{OCL}$         | A    |
| Output Voltage               | $V_{OUT}$    | OUTA, OUTB, OUTC    | $V_{BB} + 1$      | V    |
| Operating Temperature Range  | $T_A$        | G temperature range | −40 to 105        | °C   |
| Maximum Junction Temperature | $T_{J(max)}$ |                     | 150               | °C   |
| Storage Temperature          | $T_{stg}$    |                     | −55 to 150        | °C   |

## THERMAL CHARACTERISTICS

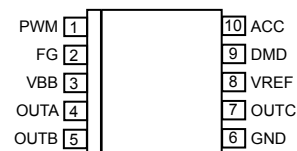
| Characteristic             | Symbol          | Package | Test Conditions                            | Value | Unit |
|----------------------------|-----------------|---------|--------------------------------------------|-------|------|
| Package Thermal Resistance | $R_{\theta JA}$ | LK      | 2-sided PCB with 1 in. <sup>2</sup> copper | 35    | °C/W |
|                            |                 | LN      | 2-sided PCB with 1 in. <sup>2</sup> copper | 100   | °C/W |

## Terminal List Table

| Name | Pin Number |     | Function                   |
|------|------------|-----|----------------------------|
|      | LN         | LK  |                            |
| PWM  | 1          | 1   | Logic input – speed demand |
| FG   | 2          | 2   | Output signal              |
| VBB  | 3          | 3   | Input supply               |
| OUTA | 4          | 4   | Motor terminal             |
| OUTB | 5          | 5   | Motor terminal             |
| GND  | 6          | 6   | Ground                     |
| OUTC | 7          | 7   | Motor terminal             |
| VREF | 8          | 8   | Reference voltage output   |
| DMD  | 9          | 9   | Logic input                |
| ACC  | 10         | 10  | Analog input               |
| PAD  | –          | PAD | Thermal pad                |



Package LK Pinouts



Package LN Pinouts

**ELECTRICAL CHARACTERISTICS:** Valid at  $T_A = 25^\circ\text{C}$ ,  $V_{BB} = 5$  to  $16\text{ V}$ , unless otherwise specified

| Characteristic                                | Symbol          | Test Conditions                                                     | Min. | Typ. | Max. | Unit             |
|-----------------------------------------------|-----------------|---------------------------------------------------------------------|------|------|------|------------------|
| VBB Supply Current                            | $I_{BB}$        | Active Mode (PWM duty < DC_ON)                                      | –    | 7.5  | 10   | mA               |
|                                               | $I_{BBS}$       | Standby Mode                                                        | –    | <1   | 10   | $\mu\text{A}$    |
| VREF Output Voltage                           | $V_{REF}$       | $I = 0$ to $5\text{ mA}$                                            | 2.85 | 2.9  | 2.95 | V                |
| Logic Input Low Level                         | $V_{IL}$        |                                                                     | 0.8  | –    | –    | V                |
| Logic Input High Level                        | $V_{IH}$        |                                                                     | –    | –    | 2    | V                |
| Logic Input Hysteresis                        | $V_{HYS}$       |                                                                     | 200  | 300  | 600  | mV               |
| Input Current (DMD, PWM, ACC)                 | $I_{IN}$        |                                                                     | –10  | <1   | 10   | $\mu\text{A}$    |
| Output Saturation Voltage (FG)                | $V_{SAT}$       | $I = 5\text{ mA}$                                                   | –    | –    | 0.3  | V                |
| Output Leakage (FG)                           | $I_{FG}$        | $V = 16\text{ V}$ , PWM = Low                                       | –    | –    | 5    | $\mu\text{A}$    |
| <b>POWER DRIVER</b>                           |                 |                                                                     |      |      |      |                  |
| Total Driver On-Resistance<br>(Sink + Source) | $R_{DS(on)}$    | $I = 1\text{ A}$ , $T_J = 25^\circ\text{C}$ , $V_{BB} = 8\text{ V}$ | –    | 1    | 1.25 | $\Omega$         |
|                                               |                 | Source driver                                                       | –    | 650  | –    | m $\Omega$       |
|                                               |                 | Sink driver                                                         | –    | 350  | –    | m $\Omega$       |
|                                               |                 | $I = 1\text{ A}$ , $T_J = 25^\circ\text{C}$ , $V_{BB} = 4\text{ V}$ | –    | –    | 2    | $\Omega$         |
| Motor PWM Frequency                           | $f_{PWMOUT}$    |                                                                     | 23.4 | 24.4 | 25.4 | kHz              |
| PWM Duty Cycle Range                          | $f_{PWMIN}$     |                                                                     | 0.1  | –    | 100  | kHz              |
| Duty Cycle On Threshold                       | DC_ON           |                                                                     | –    | 10   | –    | %                |
| Duty Cycle Off Threshold                      | DC_OFF          |                                                                     | –    | 7.4  | –    | %                |
| ACC Accuracy                                  | $V_{ACC}$       | Relative to Parameter Table Target                                  | –40  | –    | 40   | mV               |
| <b>PROTECTION</b>                             |                 |                                                                     |      |      |      |                  |
| Lock Protection                               | $t_{OFF}$       |                                                                     | 4.8  | 5    | 5.2  | s                |
| VBB Undervoltage Lockout (UVLO)               | $V_{BBUVLO}$    | $V_{BB}$ rising                                                     | –    | 4.7  | 4.9  | V                |
|                                               |                 | $V_{BB}$ falling                                                    | –    | 3.85 | 3.95 | V                |
| VBB UVLO Hysteresis                           | $V_{BBUVLOHYS}$ |                                                                     | –    | 850  | –    | mV               |
| Overcurrent Limit                             | $I_{OCL}$       |                                                                     | 1.5  | 2    | 3    | A                |
| Thermal Shutdown Temperature                  | $T_{JTSD}$      | Temperature increasing                                              | 150  | 165  | 180  | $^\circ\text{C}$ |
| Thermal Shutdown Hysteresis                   | $\Delta T_J$    | Recovery = $T_{JTSD} - \Delta T_J$                                  | –    | 35   | –    | $^\circ\text{C}$ |

Note 1: Specified limits are tested at a single temperature and assured across the operating temperature range by design and characterization.

## FUNCTIONAL DESCRIPTION

The A5936 targets fan applications to meet the objectives of low audible noise, minimal vibration, and high efficiency. Allegro's proprietary control algorithm results in a sinusoidal current waveform that adapts to a variety of motor characteristics to dynamically optimize efficiency across a wide range of speeds.

The speed of the fan can be controlled by voltage mode (control of power supply amplitude) or variable duty cycle PWM input. Use of the PWM input allows overall system cost savings by eliminating the requirement of an external variable power supply. Operation down to 4 V can be achieved to allow the IC to fit into legacy systems with voltage mode operation.

The PWM input is measured and converted to a 9-bit number.

This 9-bit "demand" is applied to a PWM generator block to create the modulation profile. The modulation profile is applied to the three motor outputs, with 120-degree phase relationship, to create the sinusoidal current waveform as shown in Figure 1.

A BEMF detection "window" is opened on phase A modulation profile to measure the rotor position so as to define the modulation timing. The control system maintains the window to a small level to minimize the disturbance and approximate the ideal sinusoidal current waveform as much as possible.

Protection features include lock detection with restart, overcurrent limit, motor output short circuit, supply undervoltage monitor, and thermal shutdown.

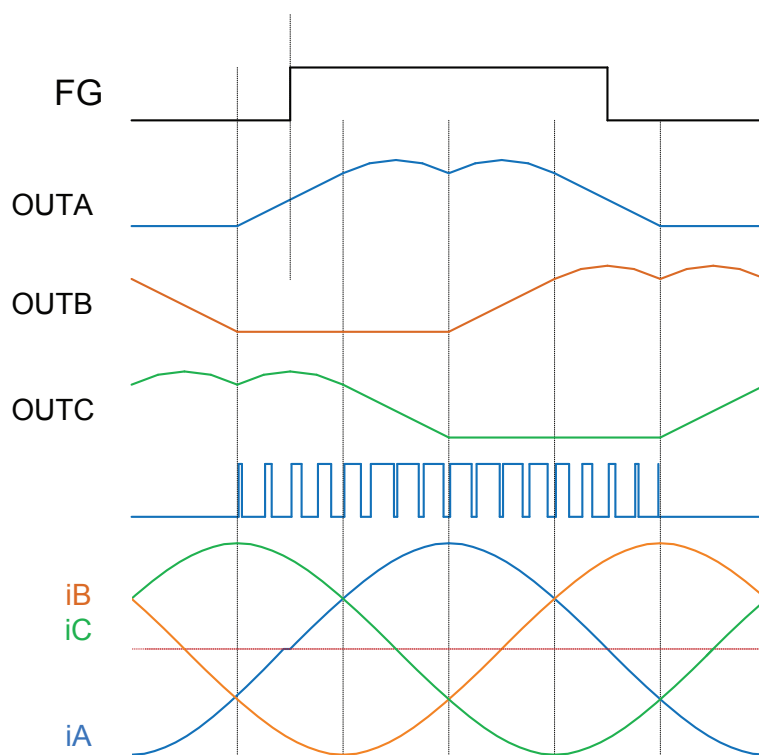


Figure 1: Sinusoidal PWM

**Lock Detect.** Speed is monitored to determine if rotor is locked. If a lock condition is detected, the IC will be disabled for  $t_{OFF}$  before an auto-restart is attempted.

**Standby Mode.** Standby mode can be achieved by holding PWM pin low for longer than the Lock off-time. The IC powers up in standby mode. Standby mode is released after a short pulse ( $>1\ \mu s$ ) is applied to PWM pin. During standby mode,  $V_{REF}$  is powered down to allow minimum current draw.

**FG.** Open-drain output provides speed information to the system. For the default setting, FG changes state one period per electrical revolution of the motor (as shown in Figure 1).

**Current Limit.** Load current is monitored on the low-side MOSFET. If the current has reached  $I_{OCL}$ , the source drivers will turn off for the remaining time of the PWM cycle.

**ACC.** Startup setting selection (see Startup section).

**DMD.** Startup setting selection (see Startup section).

**PWM.** A duty cycle measurement circuit converts the applied duty to a demand value (9-bit resolution) to control speed of the fan. The motor drive will be enabled if duty is larger than  $DC\_ON$ . The PWM input is filtered to prevent spurious noise from turning on or off unexpectedly.

**Power Supply Modulation.** Speed can be controlled simply by varying the power supply voltage. Motor drive will be enabled and disabled at undervoltage rising and falling thresholds. To use this method of speed control, pullup PWM pin to VBB with 50 k $\Omega$  resistor.

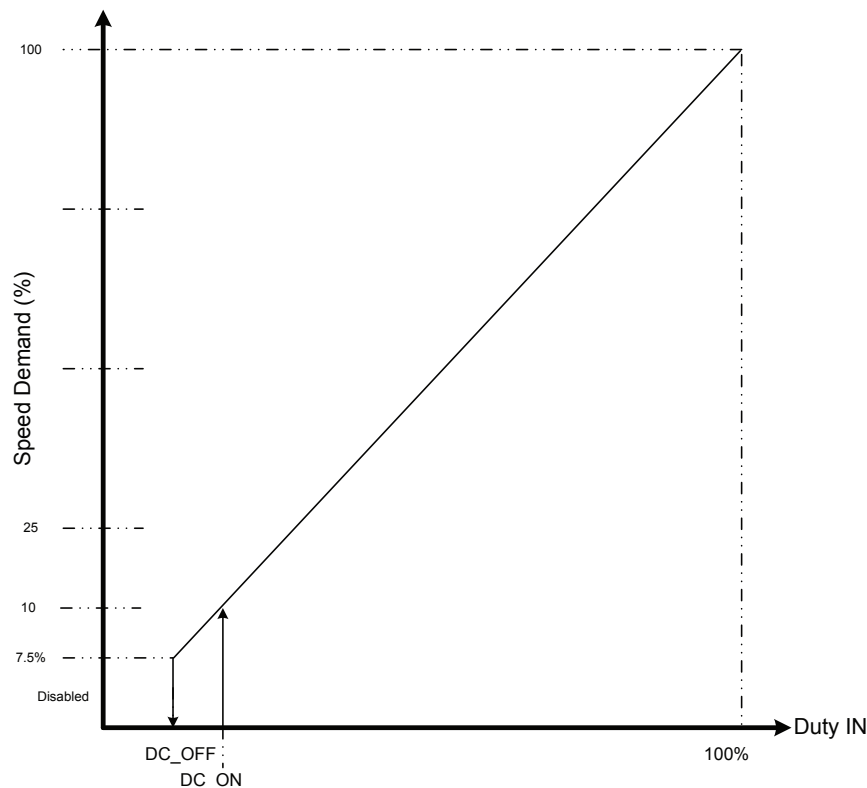
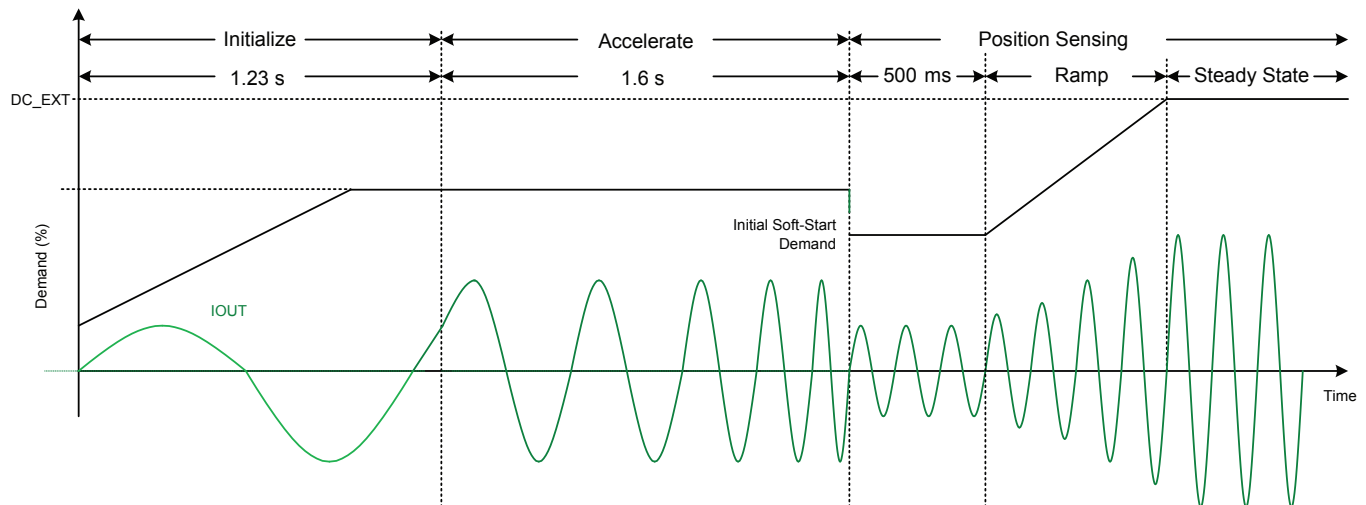


Figure 2: PWM Speed Input Characteristic

## Quiet Startup Operation



**Figure 3: Applied Demand (Modulated Voltage) and Resultant ( $I_{OUT}$ ) Typical Wave During Startup**

A5936 achieves quiet startup with the following sequence:

1. The Demand value is selected by combination of logic level on DMD voltage applied to pin ACC.
2. Slowly ramp PWM duty from low value to a chosen Open-Loop Demand level by applying one cycle of sine drive at frequency of 812 mHz.
3. Ramp up frequency of open-loop sinusoidal modulation for 1.6 s. The acceleration value is selected by voltage applied to pin ACC.
4. Switch to position measurement mode, and apply an initial soft-start demand level of 51% of the level applied during acceleration stage.
5. Hold the PWM duty at same level for 500 ms. This short delay helps the motor synchronize.
6. Ramp up duty to final value:
  - A. Time to ramp to final value depends on initial demand ( $V_{INIT}$ ),  $V_{BB}$ , and applied input duty ( $DC\_EXT$ ).
  - B. The ramp rate is 15 ms/count for duty < 25% and 7.5 ms/count for duty cycles > 25%

Example:

$$V_{BB} = 12 \text{ V}, V_{INIT} = 6 \text{ V}, DC\_EXT = 80\%$$

$$\text{Initial Soft-Start Demand} = [(V_{INIT}/V_{BB}) \times 51\%] =$$

$$25.5\% \rightarrow \text{Counts} = 511 \times 25.5\% = 130$$

$$DC\_EXT = 80\% \rightarrow \text{Counts} = 511 \times 80\% = 409$$

$$T\_RAMP = (409 - 130) \times 7.5 \text{ ms/count} \rightarrow 2 \text{ s}$$

A5936

Three Phase Sensorless Sinusoidal Fan Driver

Startup Adjustment

Various permutations of startup parameters are chosen via lookup table with A/D conversion.

Sixteen choices of startup parameters are selected by applying voltage at pin ACC.

Choose resistor divider ratio from the table below. The circuit compensates for minor variation of  $V_{REF}$ . It is recommended to select  $R1+R2$  in range 10 to 200 k $\Omega$ . ACC must be connected to a voltage between  $V_{REF}$  and GND and should not be be left open circuit.

The parameters are loaded at power-on. When testing,  $V_{BB}$  must be powercycled to check new values.

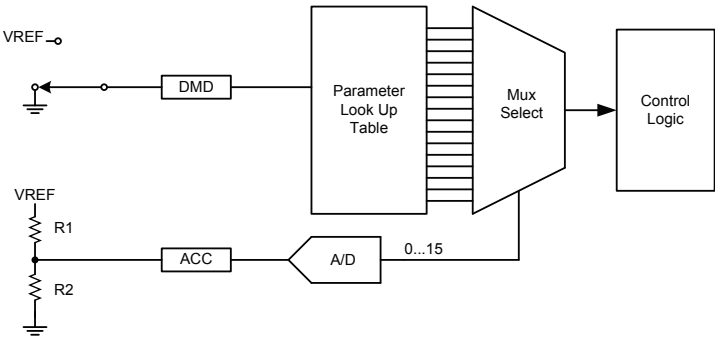


Figure 4

| ACC       | Resistor Ratio<br>(R2/R1+R2) | Code | Standard Values (k $\Omega$ )<br>R1 | Standard Values (k $\Omega$ )<br>R2 | Acceleration<br>(Hz/s) | $V_{INIT}$ (V)<br>During Open Loop<br>(DMD = HI) | $V_{INIT}$ (V)<br>During Open Loop<br>(DMD = LO) | Max. Electrical<br>Frequency<br>(Hz) |
|-----------|------------------------------|------|-------------------------------------|-------------------------------------|------------------------|--------------------------------------------------|--------------------------------------------------|--------------------------------------|
| GND       | n/a                          | 0    | n/a                                 | n/a                                 | 3.1                    | 6                                                | 3                                                | 500                                  |
| 0.322     | 0.112                        | 1    | 90.9                                | 11.5                                | 5.1                    | 6                                                | 3                                                | 500                                  |
| 0.644     | 0.223                        | 2    | 34.8                                | 10                                  | 7                      | 6                                                | 3                                                | 500                                  |
| 0.966     | 0.335                        | 3    | 102                                 | 51.1                                | 9                      | 6                                                | 3                                                | 500                                  |
| 1.288     | 0.446                        | 4    | 9.09                                | 11.5                                | 10.9                   | 6                                                | 3                                                | 500                                  |
| 1.610     | 0.558                        | 5    | 9.09                                | 11.5                                | 14.8                   | 6                                                | 3                                                | 500                                  |
| 1.932     | 0.669                        | 6    | 11.5                                | 23.2                                | 18.8                   | 6                                                | 3                                                | 500                                  |
| 2.254     | 0.781                        | 7    | 2.8                                 | 10                                  | 26.6                   | 6                                                | 3                                                | 500                                  |
| $V_{REF}$ | n/a                          | 8    | n/a                                 | n/a                                 | 26.6                   | 2                                                | 1                                                | 1000                                 |

Note: ACC Target voltages based on  $V_{REF}$  of 2.885 V

## APPLICATION INFORMATION

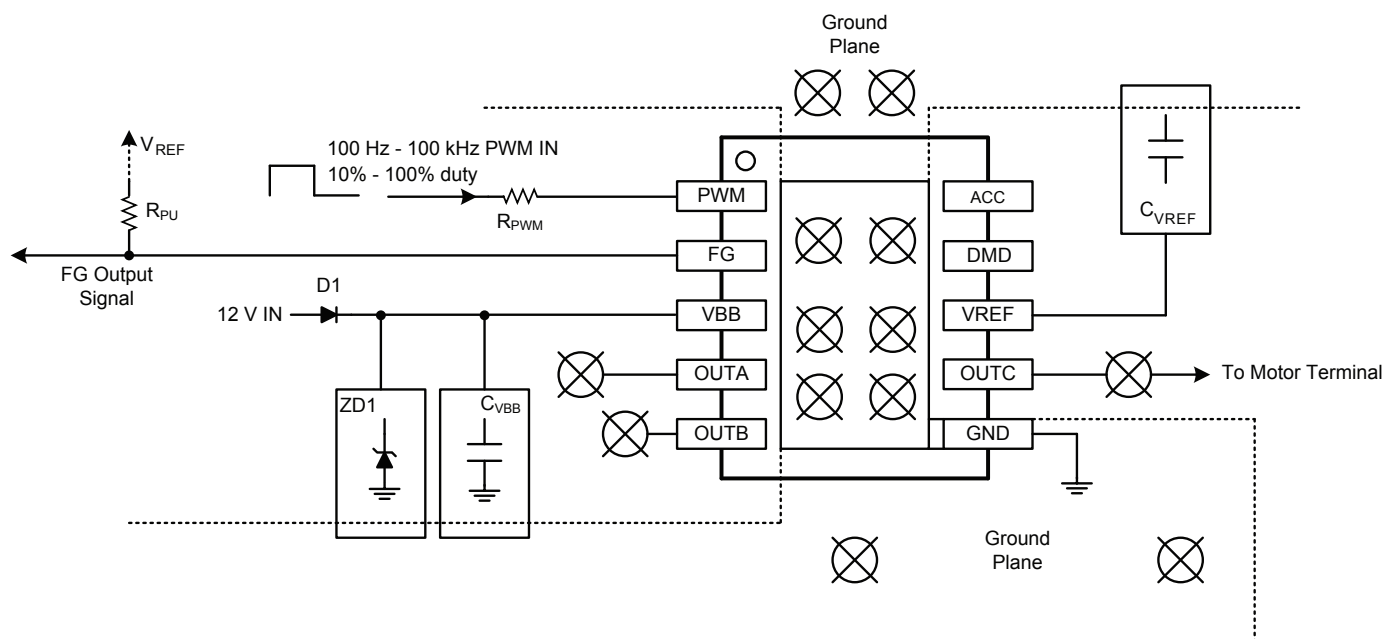


Figure 5: Typical Application Circuit

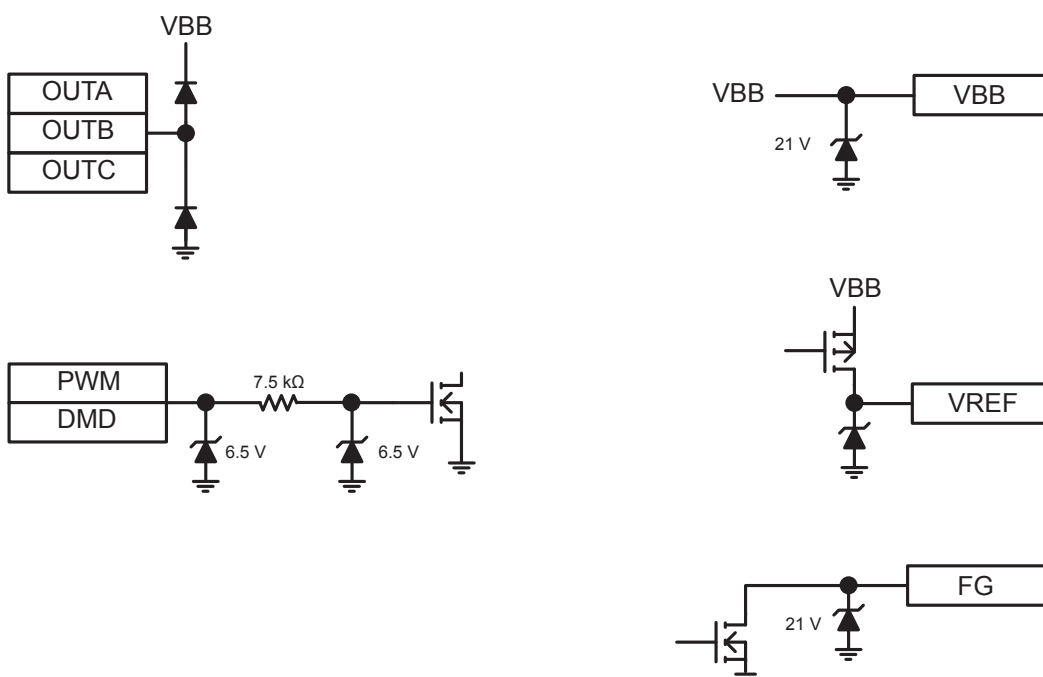
| Name              | Suggested Value        | Comment                                                                                                                                                                                                        |
|-------------------|------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| C <sub>VREF</sub> | 0.1 $\mu$ F, X5R, 10 V | Ceramic capacitor required                                                                                                                                                                                     |
| C <sub>VBB</sub>  | 4.7 to 47 $\mu$ F      | Power Supply Stabilization – Electrolytic or ceramic OK.                                                                                                                                                       |
| R <sub>FG</sub>   | 10 k $\Omega$          | Optional – pullup resistor for speed feedback                                                                                                                                                                  |
| D1                | Not Installed          | May be required to isolate motor from system or for reverse polarity protection                                                                                                                                |
| ZD1               | SMBJ14A                | Optional TVS to limit maximum V <sub>BB</sub> due to transients due to motor generation or power line. Suggested to clamp below 18 V (EX: Fairchild SMBJ14A). Typically required if blocking diode D1 is used. |
| R <sub>PWM</sub>  | 1 k $\Omega$           | Optional – If PWM wired to connector – R <sub>PWM</sub> will isolate IC pin from noise or overvoltage transients.                                                                                              |

## Layout Notes

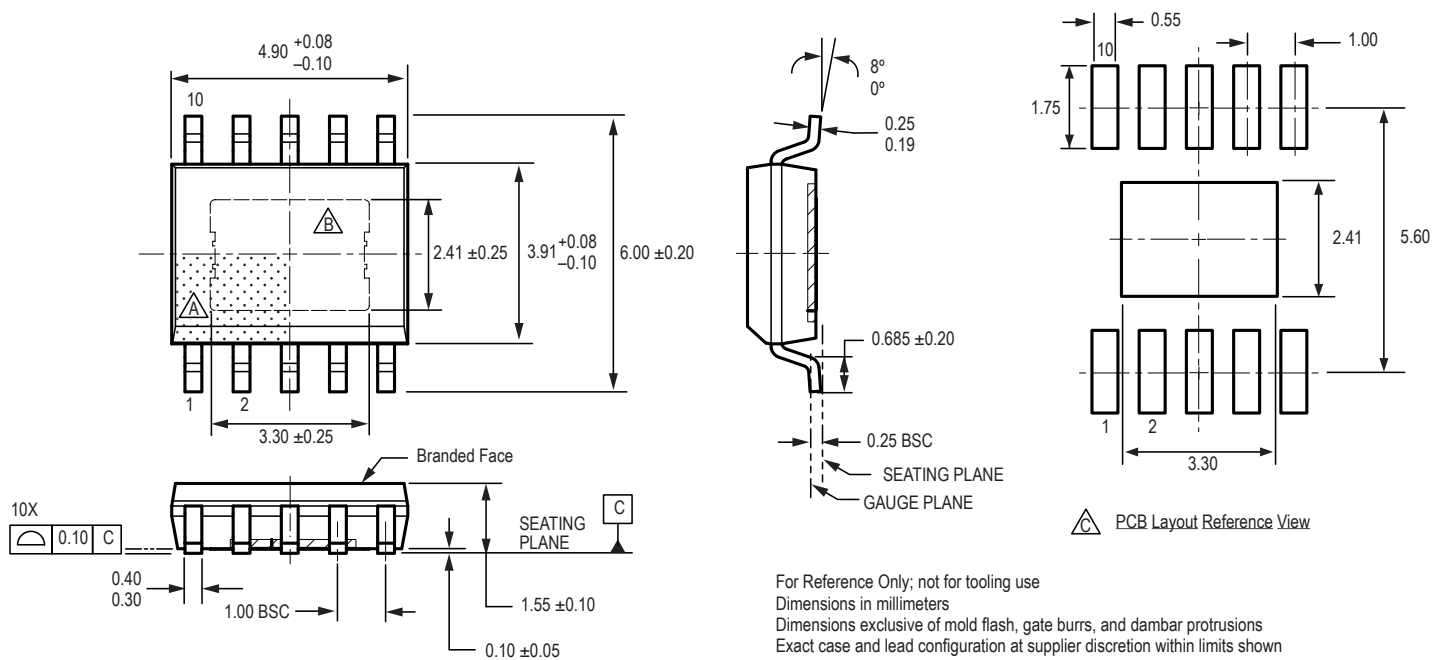
1. Add thermal vias to exposed pad area.
2. Add ground plane on top and bottom of PCB.
3. Place C<sub>VREF</sub> and C<sub>VBB</sub> as close as possible to IC, connected to GND plane.



## PIN DIAGRAMS

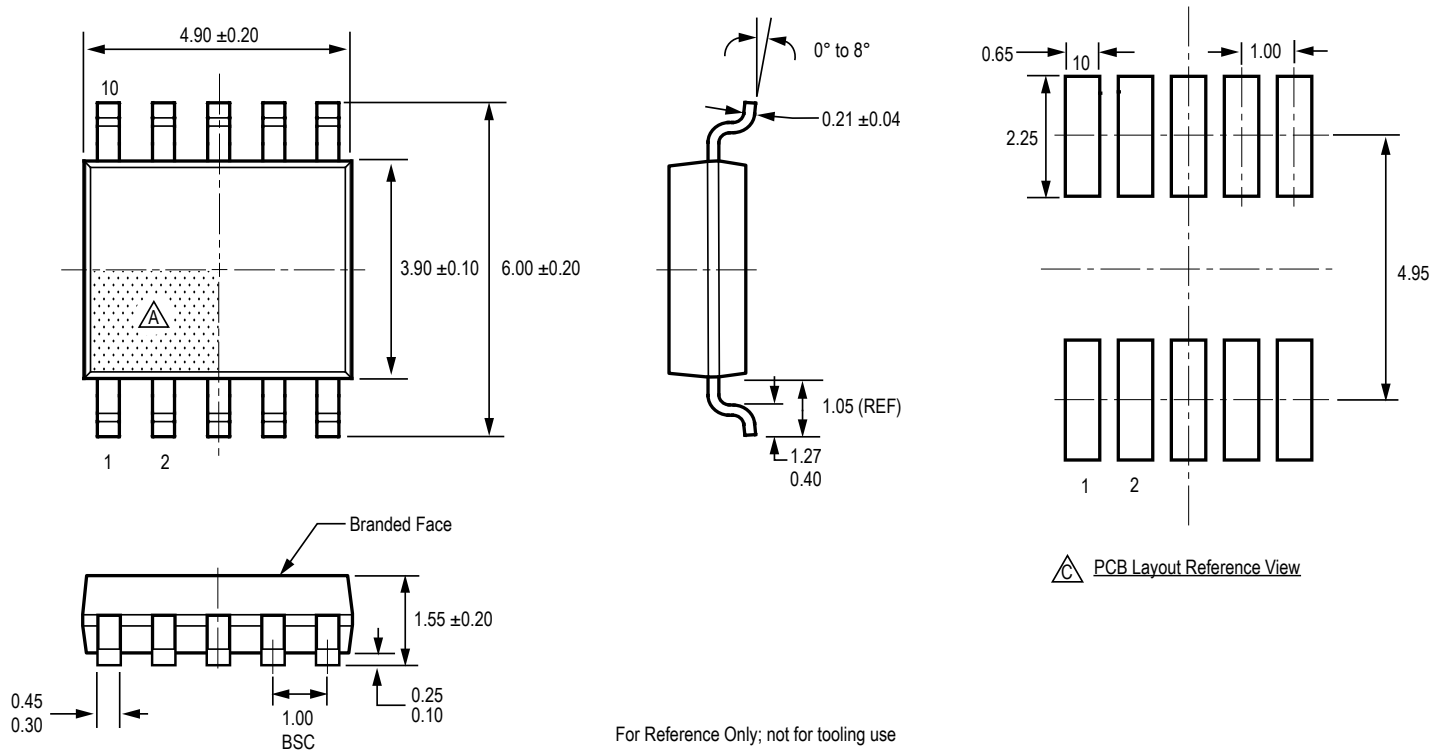


Package LK, 10-Lead eSOIC  
with Exposed Pad



- Terminal #1 mark area
- Exposed thermal pad (bottom surface)
- 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)

## Package LN, 10-Lead SSOP



**Revision History**

| Number | Date              | Description                |
|--------|-------------------|----------------------------|
| –      | February 13, 2017 | Initial release            |
| 1      | June 26, 2017     | Corrected typo in Figure 1 |
| 2      | July 5, 2018      | Minor editorial updates    |
| 3      | July 15, 2019     | Minor editorial updates    |

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