

Three-Phase Sensorless Fan Driver IC

FEATURES AND BENEFITS

- AEC-Q100 qualified (K version)
- Closed-loop speed control
- Speed curve configuration via EEPROM
- I²C serial port
- Sinusoidal modulation for reduced audible noise and low vibration
- Sensorless (no Hall sensors required)
- Low $R_{DS(ON)}$ power MOSFETs—3 A capability
- Minimal external components
- PWM speed input
- FG speed output
- RD rotor lock output
- Lock detection
- Soft start
- Standby mode
- Shorted load protection

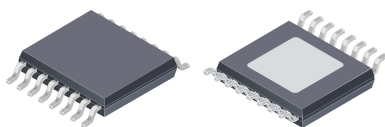
DESCRIPTION

The A5931 three-phase motor driver IC incorporates sensorless sinusoidal drive to minimize vibration for high speed server fans. Sensorless control eliminates the requirement for Hall sensors for server fan applications.

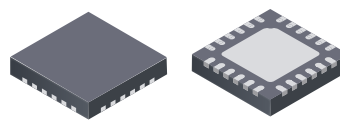
A flexible closed-loop speed control system is integrated into the IC. EEPROM is used to tailor the common functions of the fan speed curve to a specific application. This eliminates the requirement for a microprocessor-based system and minimizes programming requirements.

The A5931 is available in a 24-contact 4 mm × 4 mm QFN with exposed thermal pad (suffix ES), and a 16-lead TSSOP with exposed thermal pad (suffix LP). These packages are lead (Pb) free, with 100% matte-tin leadframe plating.

PACKAGES:



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



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

Not to scale

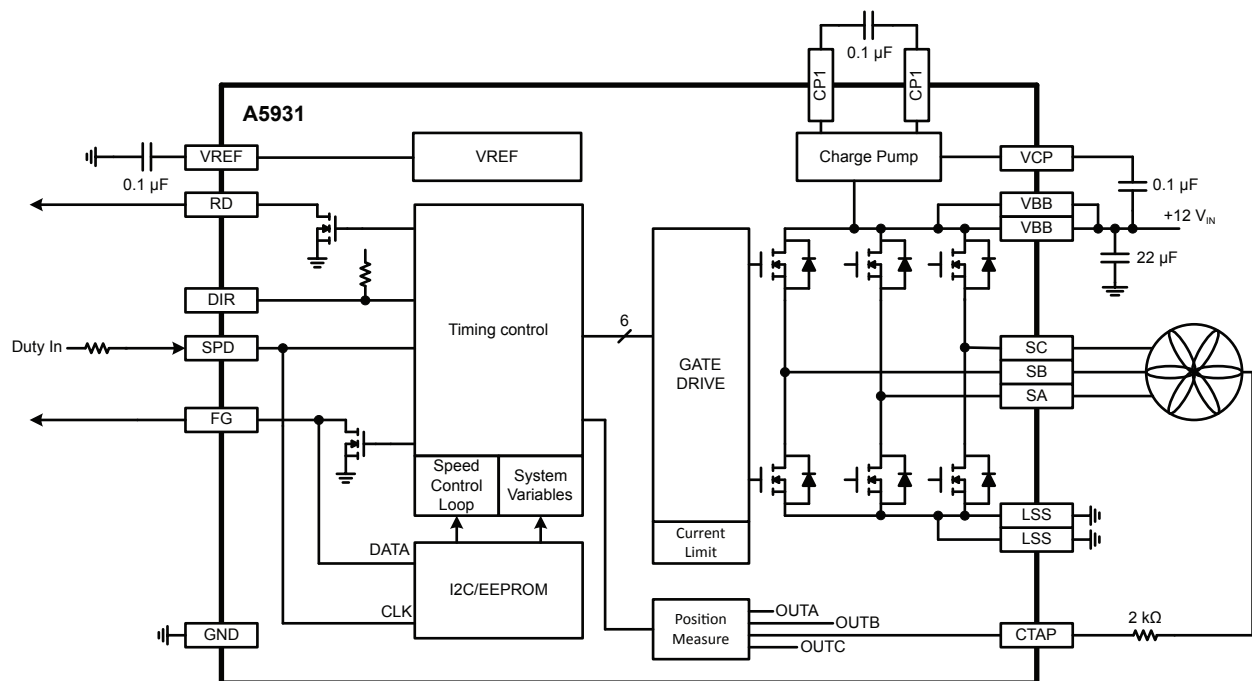


Figure 1: Typical Application

SPECIFICATIONS

SELECTION GUIDE

| Part Number | Operating Temperature Range (T_A) (°C) | Packaging | Packing |
|--------------|--|---|------------------------------|
| A5931GESTR-T | –40 to 105 | 24-contact QFN with exposed thermal pad | 1500 pieces per 7-inch reel |
| A5931GLPTR-T | –40 to 105 | 16-lead TSSOP with exposed thermal pad | 4000 pieces per 13-inch reel |
| A5931KLPTR-T | –40 to 125 | 16-lead TSSOP with exposed thermal pad | 4000 pieces per 13-inch reel |



ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Notes | Rating | Unit |
|-----------------------------|-----------|---------------|--------------------|------|
| Supply Voltage | V_{BB} | DC | 18 | V |
| | | $t_w < 10$ ms | 20 | V |
| Logic Input Voltage Range | V_{IN} | SPD, DIR | –0.3 to 6 | V |
| Logic Output | V_O | FG, RD | V_{BB} | V |
| Output Current | I_{OUT} | | internally limited | A |
| Output Voltage | V_{OUT} | | $V_{BB} + 1$ | 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 |
| | | Range K | –40 to 125 | °C |

RECOMMENDED OPERATIONAL RANGE

| Characteristic | Symbol | Notes | Min. | Typ. | Max. | Unit |
|---------------------------|-----------|---|------|------|------|------|
| Supply Voltage | V_{BB} | DC | 5 | 12 | 16 | V |
| Logic Input Voltage Range | V_{IN} | PWM | –0.3 | – | 6 | V |
| Motor Current | I_{OUT} | Motor phase current – sinusoidal running mode | – | – | 3000 | mA |

THERMAL CHARACTERISTICS

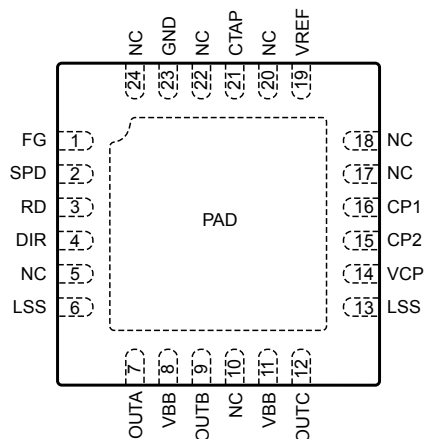
| Characteristic | Symbol | Test Conditions* | Value | Unit |
|----------------------------|-----------------|---|-------|------|
| Package Thermal Resistance | $R_{\theta JA}$ | 24-contact QFN (package ES), on 2-sided PCB 1-in. ² copper | 45 | °C/W |
| | | 16-lead TSSOP (package LP), on 2-sided PCB 1-in. ² copper | 35 | °C/W |

*Additional thermal information available on the Allegro website.

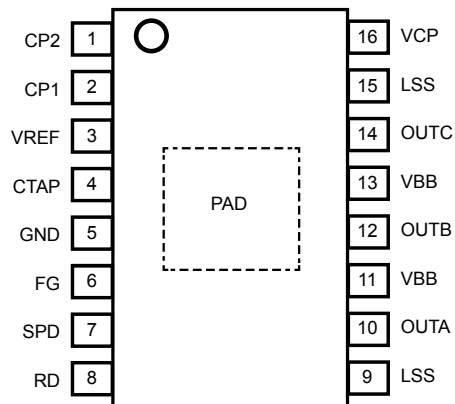
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PINOUT DIAGRAMS AND TERMINAL LIST TABLE



ES Package Pinouts



LP Package Pinouts

Terminal List Table

| Terminal Number | | Name | Function |
|-----------------|------------|------|--|
| ES Package | LP Package | | |
| 1 | 6 | FG | Output signal |
| 2 | 7 | SPD | Logic input – speed demand |
| 3 | 8 | RD | Logic output signal |
| 4 | – | DIR | Logic input |
| 5 | – | NC | No connect |
| 6 | 9 | LSS | Low-side source connection |
| 7 | 10 | OUTA | Motor terminal |
| 8 | 11 | VBB | Input supply |
| 9 | 12 | OUTB | Motor terminal |
| 10 | – | NC | No connect |
| 11 | 13 | VBB | Input supply |
| 12 | 14 | OUTC | Motor terminal |
| 13 | 15 | LSS | Low-side source connection |
| 14 | 16 | VCP | Charge pump capacitor |
| 15 | 1 | CP2 | Charge pump capacitor |
| 16 | 2 | CP1 | Charge pump capacitor |
| 17 | – | NC | No connect |
| 18 | – | NC | No connect |
| 19 | 3 | VREF | Reference voltage output |
| 20 | – | NC | No connect |
| 21 | 4 | CTAP | Motor terminal |
| 22 | – | NC | No connect |
| 23 | 5 | GND | Ground |
| 24 | – | NC | No connect |
| – | – | PAD | Exposed pad for enhanced thermal dissipation |

ELECTRICAL CHARACTERISTICS: Valid for $T_A = -40^{\circ}\text{C}$ to 105°C (G version) or $T_A = -40^{\circ}\text{C}$ to 125°C (K version), and $V_{BB} = 5$ to 16 V, unless noted otherwise

| Characteristics | Symbol | Test Conditions | Min. | Typ. | Max. | Unit |
|--|--------------|---|-------|------|------|--------------------|
| GENERAL | | | | | | |
| VBB Supply Current | I_{BB} | Active mode (PWM duty < DC_ON) | – | 8.5 | 13 | mA |
| | I_{BBS} | $V_{BB} = 12$ V, standby mode | – | – | 100 | μA |
| Reference Voltage | V_{REF} | $I = 0$ to 10 mA | 2.75 | 2.85 | 2.95 | V |
| POWER DRIVER | | | | | | |
| Total Driver On-Resistance (Sink + Source) [2] | $R_{DS(ON)}$ | $I_{OUT} = 1.5$ A, $T_J = 25^{\circ}\text{C}$, $V_{BB} = 12$ V, G Version | – | 210 | 250 | m Ω |
| | | $I_{OUT} = 1.5$ A, $T_J = 25^{\circ}\text{C}$, $V_{BB} = 12$ V, K Version | – | 225 | 265 | m Ω |
| | | $I_{OUT} = 1.5$ A, $T_J = 125^{\circ}\text{C}$, $V_{BB} = 12$ V, G Version | – | 300 | 360 | m Ω |
| | | $I_{OUT} = 1.5$ A, $T_J = 125^{\circ}\text{C}$, $V_{BB} = 12$ V, K Version | – | 320 | 380 | m Ω |
| | | Source Driver, $T_J = 25^{\circ}\text{C}$, G Version | – | 105 | – | m Ω |
| | | Sink Driver, $T_J = 25^{\circ}\text{C}$, G Version | – | 105 | – | m Ω |
| Motor PWM Frequency | f_{PWM} | | 23.4 | 24.4 | 25.4 | kHz |
| SPEED CONTROL | | | | | | |
| PWM Input Frequency Range | f_{PWIN} | | 6 [3] | – | 100 | kHz |
| Duty Cycle On Threshold | DC_ON | Relative to target | –0.5 | – | 0.5 | % |
| Duty Cycle Off Threshold | DC_OFF | Relative to target | –0.5 | – | 0.5 | % |
| Speed Setpoint | F_{SPD} | PWM mode | –5 | – | 5 | % |
| SPD Standby Threshold (Analog) | V_{SPDTH} | A5931KLPT-R only | – | 0.7 | 0.8 | V |
| SPD On Threshold | V_{SPDON} | DC_ON = 10%, A5931KLPT-R only | – | 300 | – | mV |
| SPD On Threshold | V_{SPDOFF} | DC_OFF = 8%, A5931KLPT-R only | – | 258 | – | mV |
| SPD ADC Resolution | V_{SPDLSB} | A5931KLPT-R only | – | 4.82 | – | mV |
| SPD ADC Code Offset | SPD_OFF | A5931KLPT-R only | – | 12 | – | LSB |
| SPD ADC Accuracy [4] | SPD_ACC | $V_{SPD} = 0.2$ to 2.5 V, relative to equation, A5931KLPT-R only | –20 | – | 20 | LSB |
| PROTECTION CIRCUITS | | | | | | |
| Lock Timing | t_{OFF} | Relative to target | –10 | – | 10 | % |
| VBB Undervoltage Threshold | V_{BBUVLO} | V_{BB} rising | – | 4.3 | 4.5 | V |
| VBB Undervoltage Hysteresis | V_{BBHYS} | | 160 | 300 | 480 | mV |
| Overcurrent Protection | I_{OCP} | | 4.2 | 6.5 | 8.5 | A |
| Thermal Shutdown Temperature | T_{JTSD} | Temperature increasing | 150 | 165 | 180 | $^{\circ}\text{C}$ |
| Thermal Shutdown Hysteresis | ΔT_J | Recovery = $T_{JTSD} - \Delta T_J$ | – | 20 | – | $^{\circ}\text{C}$ |

[1] Specified limits are tested at a single temperature and assured over temperature range by design and characterization.

[2] $R_{DS(ON)}$ difference due to bond wire material, copper (G version) versus gold (K version).

[3] Refer to description for SPD pin.

[4] SPD Analog mode is not tested for A5931GES-T or A5931GLP-T.

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ELECTRICAL CHARACTERISTICS (continued): Valid for $T_A = -40^{\circ}\text{C}$ to 105°C (G version) or $T_A = -40^{\circ}\text{C}$ to 125°C (K version), and $V_{BB} = 5$ to 16 V, unless noted otherwise

| Characteristics | Symbol | Test Conditions | Min. | Typ. | Max. | Unit |
|--|--------------|---|------|------|------|---------------|
| LOGIC/INPUT OUTPUT/I²C | | | | | | |
| 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 |
| Logic Input Current | I_{IN} | SPD | –10 | <1 | 10 | μA |
| | | DIR, $V_{IN} = 0$ V, 100 k Ω pull-up | – | 28 | – | μA |
| Output Saturation Voltage (FG, RD) | V_{SAT} | $I = 5$ mA | – | – | 0.3 | V |
| Output Leakage (FG, RD) | I_O | $V = 16$ V, switch OFF | – | – | 5 | μA |
| I²C TIMING | | | | | | |
| SCL Clock Frequency | f_{CLK} | | 3 | – | 400 | kHz |
| Bus Free-Time Between Stop/Start | t_{BUF} | | 1.3 | – | – | μs |
| Hold Time Start Condition | $t_{HD:STA}$ | | 0.6 | – | – | μs |
| Setup Time for Start Condition | $t_{SU:STA}$ | | 0.6 | – | – | μs |
| SCL Low Time | t_{LOW} | | 1.3 | – | – | μs |
| SCL High Time | t_{HIGH} | | 0.6 | – | – | μs |
| Data Setup Time | $t_{SU:DAT}$ | | 100 | – | – | ns |
| Data Hold Time | $t_{HD:DAT}$ | | 0 | – | 900 | ns |
| Setup Time for Stop Condition | $t_{SU:STO}$ | | 0.6 | – | – | ms |

[1] Specified limits are tested at a single temperature and assured over temperature range by design and characterization.

FUNCTIONAL DESCRIPTION

Basic Operation

The A5931 targets high-speed fan applications to meet the objectives of minimal vibration, high efficiency, and ability to customize the IC to the speed control specification.

In typical systems, an MCU is required to meet each application specification. The A5931 integrates the basic closed-loop speed control function, thus allowing elimination of the cost, PCB space, and programming requirements of a custom MCU.

For each specific application, the EEPROM settings can be created with the Allegro EVB and software. Contact Allegro sales to order the custom IC. (Minimum volume requirements will apply).

The speed of the fan is typically controlled by variable duty cycle PWM input. The duty cycle is measured and converted to a 9-bit number. This 9-bit “demand” is translated to a speed signal based on settings that are configured via EEPROM.

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

Standby mode can be achieved by holding SPD pin low for longer than the programmed lock off-time. In specific speed curve options, the motor will never turn off, if speed is set to run at a minimum value with 0% duty cycle applied. In this type of configuration, standby mode is not available.

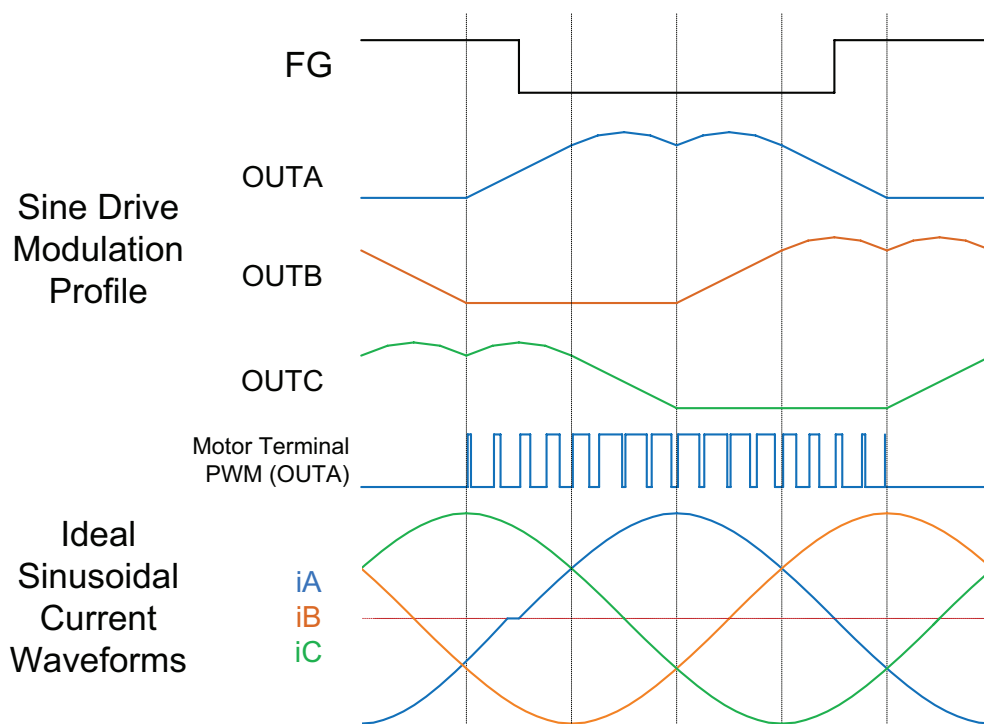


Figure 2: Sinusoidal Drive Sequence for DIR = HI

FG. Open-drain output, represents the speed of the motor for normal operation. Additionally, the FG pin serves as the data line, (SDA) for I²C communication.

The FG output signal typically represents two periods per mechanical revolution. f_{FGOUT} may not be same as electrical frequency:

$$f_{ELEC} = f_{FGOUT} \times \text{NumberOfPolePairs} / 2$$

$$f_{FGOUT} = f_{ELEC} \times 2 / \text{NumberOfPolePairs}$$

$$RPM = 30 \times f_{FGOUT}$$

$$RPM = f_{ELEC} \times 60 / \text{NumberOfPolePairs}$$

RD. Open-drain output, logic high indicates a rotor fault condition as defined by EEPROM variables. RD function can be disabled via EEPROM. When function is disabled, RD pin goes high to indicate end of open-loop starting sequence.

SPD. Speed Demand input pin. Choice of analog voltage control or PWM duty control is determined by EEPROM selection.

Duty cycle control. The input Duty cycle signal is measured with logic circuit. The calculated output number is translated to a speed Demand signal with a resolution of 0.2%.

The maximum input PWM frequency is 100 kHz. To avoid interaction with the I²C circuitry, which share the FG and SPD inputs, the minimum PWM frequency may be limited based on the maximum frequency of the speed output pin FG.

$f_{PWM(min)}$ is the larger number of $2.5 \times f_{FGOUT(max)}$ or 100 Hz.

$f_{FGOUT(max)}$ is the maximum speed under all operating conditions.

Note: f_{FGOUT} (Hz) depends on selection of pole-pair in EEPROM, typically equals $RPM / 30$.

Analog control (A5931KLP only). Voltage applied will increase speed demand. An internal 9-bit A/D converter will translate the input to a speed demand.

$$\text{Code} = V_{IN(SP D)} / 4.82 \text{ mV} - 12 \text{ where code} = [0 \dots 511]$$

$$\text{Applied Duty (\%)} = \text{Code} / 511.$$

CTAP. This analog input is an optional connection for motor common (Wye motors). It is required to insert a 2 k Ω resistor in series with the pin. If not used, as in case of Delta wound motor, then pin must be left open circuit.

LOCK DETECT. A5931 will turn off for the programmed time (t_{OFF}) when the rotor is in a locked condition.

DIR (ES package only). Logic input to control direction of motor. Logic “1” moves the outputs in sequence A→B→C. To reverse direction, logic “0” will sequence A→C→B. If the DIR pin changes while motor is running, the motor coasts for the programmed time, t_{LOCK} . After t_{LOCK} timeout, a normal startup sequence occurs. If motor is still moving opposite of intended direction, resynchronization logic will stop the motor before standard startup sequence.

DIR is pulled up internally with 100 k Ω resistor. To avoid any concern with PCB noise, it is recommended to connect pin to GND or VREF externally.

OC. Overcurrent protection is intended to protect the IC from application conditions of shorted load, motor short to ground, and motor short to battery. The OCP protection monitors the drain-to-source voltage (VDS) across any source or sink driver when the output is turned on. The OCP level is approximately 6.5 A. If the OCP threshold is exceeded for 640 nanoseconds, all drivers are shut off. This fault mode can be reset by PWM ON/OFF or timeout of t_{LOCK} , depending on EEPROM bit OCPOPT.

Pin shorts to GND (low inductance) on PCB should be avoided. It is possible during startup that the applied duty can be set below the blank time of the OCP circuit. For this scenario, there can be multiple pulses of high current that may overstress the IC before the OCP shutdown can occur.

OCL. An optional overcurrent limit function can be set to four different levels via EEPROM. In general, current limit should be set to a value beyond the maximum expected run current. If current limit occurs during normal operation, audible noise or motor stalling could potentially be observed. The current limit circuit monitors the VDS of the sink-side MOSFET and turns off the source driver(s) for the remainder of the PWM cycle. Current limit needs to be enabled via EEPROM bit OCLD set low. If enabled, then OCL bits in the EEPROM control the level as follows:

Table 1: Overcurrent Limit

| Code | I _{OCL} (A) |
|------|----------------------|
| 00 | 3.2 |
| 01 | 2.6 |
| 10 | 1.8 |
| 11 | 1 |

SPEED CURVE PARAMETERS

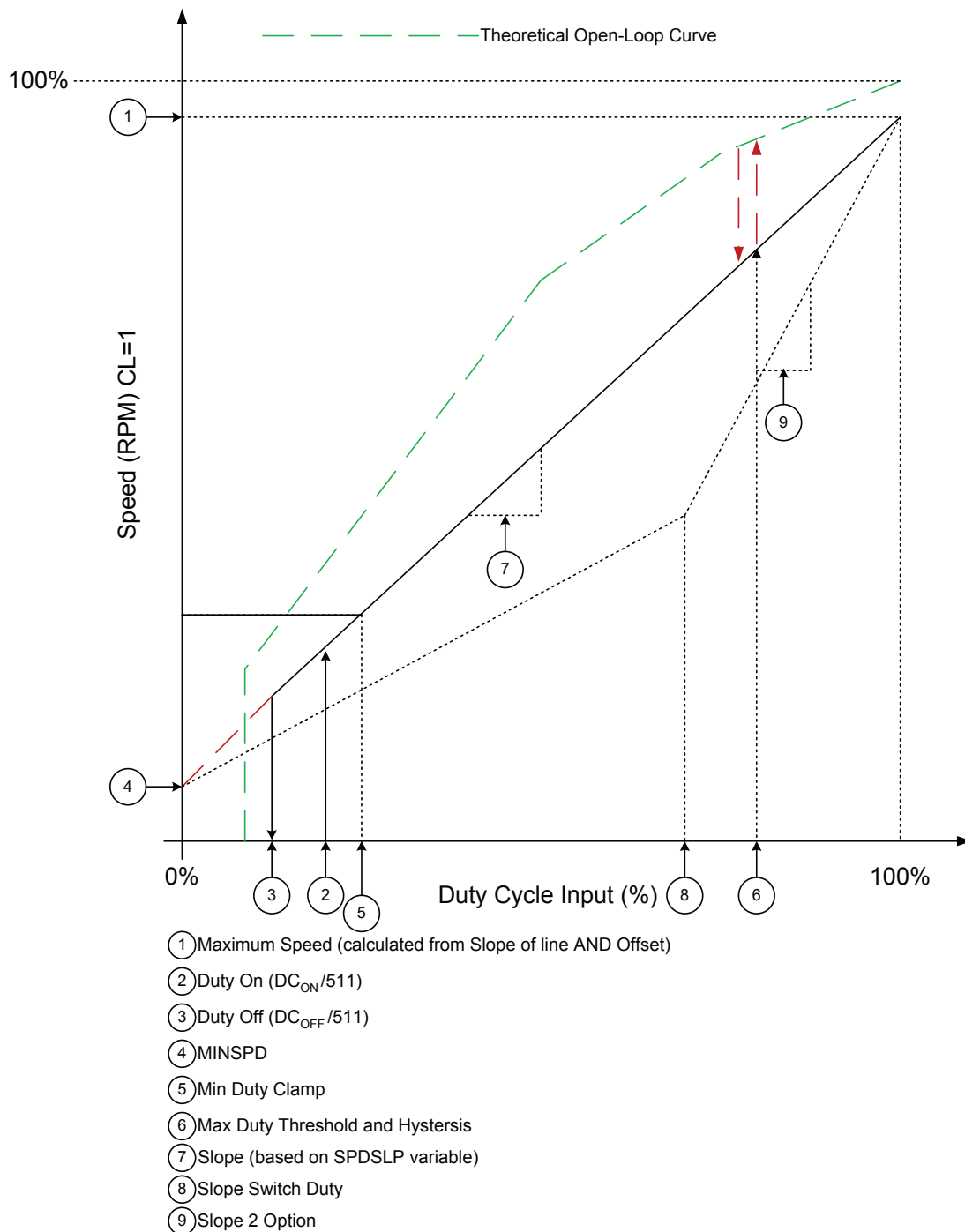


Figure 3: Speed Curve Parameters

Speed Curve Parameters (continued)

Refer to “Figure 3: Speed Curve Parameters” on page 9 for items below.

Minimum Speed Setpoint. The minimum speed is defined by the value stored in EEPROM variable MINSPD. The resolution is 1 rpm.

$$\text{MINSPD (rpm)} = 0.4095$$

Maximum Speed Setpoint. The A5931 calculates the maximum speed based on line equation $y = mx + B$. The maximum speed is defined as the speed with input duty = 100%.

The desired maximum speed is used to set the EEPROM variable SPDSLPI.

$$\text{SPDSLPI} = 64 \times (\text{Maximum Speed (rpm)} - \text{MINSPD}) / 511$$

Example: Max Speed = 25000, Min Speed = 3000.

$$\text{SPDSLPI} = 64 \times 22000 / 511 = 2755$$

where SPDSLPI = 0.8192

$$\text{Motor Speed (rpm)} = \text{Slope} \times \text{DutyIN} + \text{MINSPD}.$$

where Slope = $\text{SPDSLPI} \times 511 / 64$ and DutyIN expressed in %.

Duty In Enable Threshold. EEPROM variable DCON defines the input duty signal that enables the drive. DCON is an 8-bit number with resolution of 0.2%, which results in a maximum setting of 49.9%.

$$\text{Duty On (\%)} = 100 \times \text{DCON} / 511$$

If DCON is set to “0”, motor will turn on with 0% duty cycle input.

Duty In Disable Threshold. EEPROM variable DCOFF defines the input duty signal that disables the drive. DCOFF is an 8-bit number with resolution of 0.2%, which results in a maximum setting of 49.9%.

$$\text{Duty Off(\%)} = \text{DCOFF} / 511$$

DCOFF should always be set to a lower number than DCON.

Duty Cycle Invert. To create mirror image of speed curve, set duty cycle invert bit to “1”.

Minimum Duty Clamp. Minimum speed can be clamped to a value to allow motor to run at defined low-level speed. This is achieved by ignoring the duty cycle input if below the programmed MINDTY level.

$$\text{Min Duty Clamp (\%)} = 100 \times \text{MINDTY} / 511$$

Therefore the minimum speed will be defined by:

$$\text{MinSpeedClamp(rpm)} = \text{Slope} \times \text{MinDutyClamp} + \text{MINSPD}$$

Setting MINDTY to 0 disables the function.

$$\text{MINDTY} = 0.255.$$

Maximum Duty Clamp. EEPROM variable DTYMAX defines a duty level at which the motor will change operation from closed-loop curve. The change of operation would depend on MAXDTYOPT setting. If MAXDTYOP = 0, open-loop operation will result. If MAXDTYOPT = 1, then operation will remain closed-loop; however, the speed will be clamped at the value calculated by DTYMAX level.

4 bits are used for this setting at resolution of 1.6% to cover the range 76.5% to 100%.

$$\text{Maximum Duty (\%)} = 100 \times (511 - \text{MAXDTY} \times 8) / 511$$

MAXDTY = 0.15; if MAXDTY = 0, then function is disabled.

Hysteresis is needed to prevent motor from going back and forth between open- and closed-loop mode.

$$\text{MAXDTYHYS} = 0.15.$$

$$\text{Hys(\%)} = (\text{MAXDTYHYS} + 1) \times 0.4$$

Dual Slope Option. Two different slopes can be selected by setting variable SLPSWDTY greater than 0.

$$\text{Slope2} = (\text{MAXSPEED} - \text{SLPSWRPM}) / (100\% - \text{SLPSWDTY})$$

$$\text{Slope1} = (\text{SLPSWRPM} - \text{MINSPEED}) / \text{SLPSWDTY}$$

RD FUNCTION

Rotor lock output RD can be used to indicate motor is not running as expected. A high level on RD will indicate a fault.

Refer to the following four timing diagrams and Table 2 for understanding of the RD function and flexibility to adjust parameters via EEPROM.

Table 2

| EEPROM Parameter | Range | Resolution | Comment |
|------------------|-------------|------------------|--|
| LOCKEVT | 0/1 | | 0 = RD triggered at lock event count of 2 1 = Use RDBLANK for lock events |
| RDHIGH (rpm) | 0 to 4080 | 16 rpm | If set to 0; RD function disabled |
| RDLOW (rpm) | 0 to 4080 | 16 rpm | Must be programmed lower than RD_high |
| RDDL | 0 to 15 | 1 second | |
| RDBLANK | 0.1 to 25.4 | 100 milliseconds | |
| TLOCK | 0.1 to 25.4 | 100 milliseconds | |

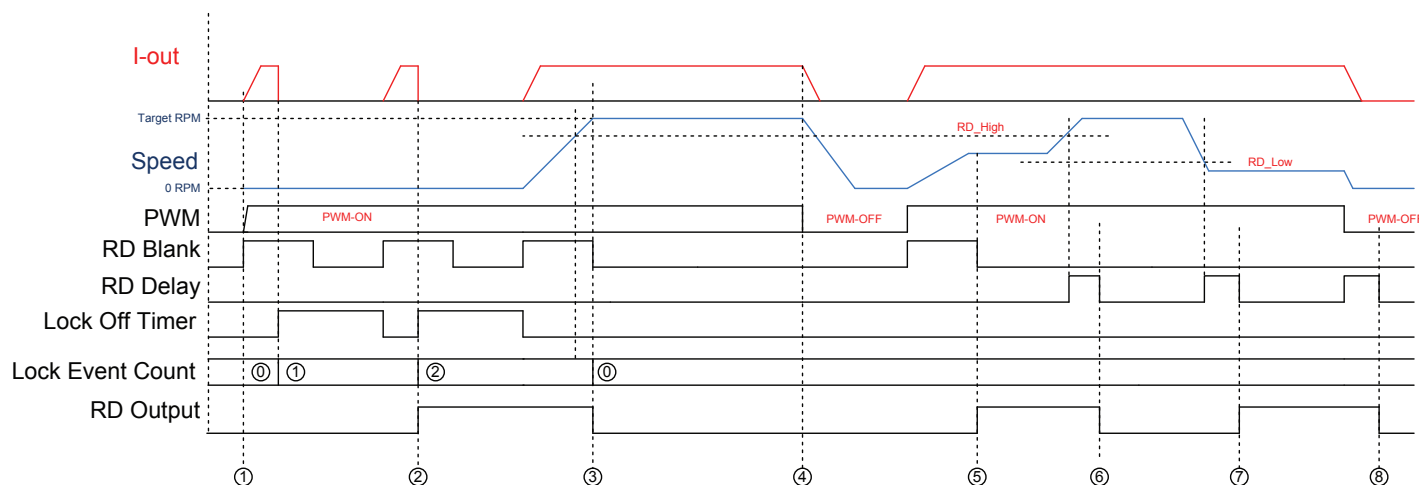


Figure 4: RD Timing Diagram (LOCKEVT = 0)

1. Power on with rotor locked condition
2. RD is high after 2nd lock event
3. RD resets low after RD Blank if Speed > RD_High;
Lock Event Count reset to zero
4. PWM off – RD is low since normal condition
5. RD is high after RD Blank if Speed < RD_High
6. RD is low if Speed > RD_High after RD Delay
7. RD is high if Speed < RD_Low after RD Delay
8. PWM off – RD goes low after RD Delay low since normal condition

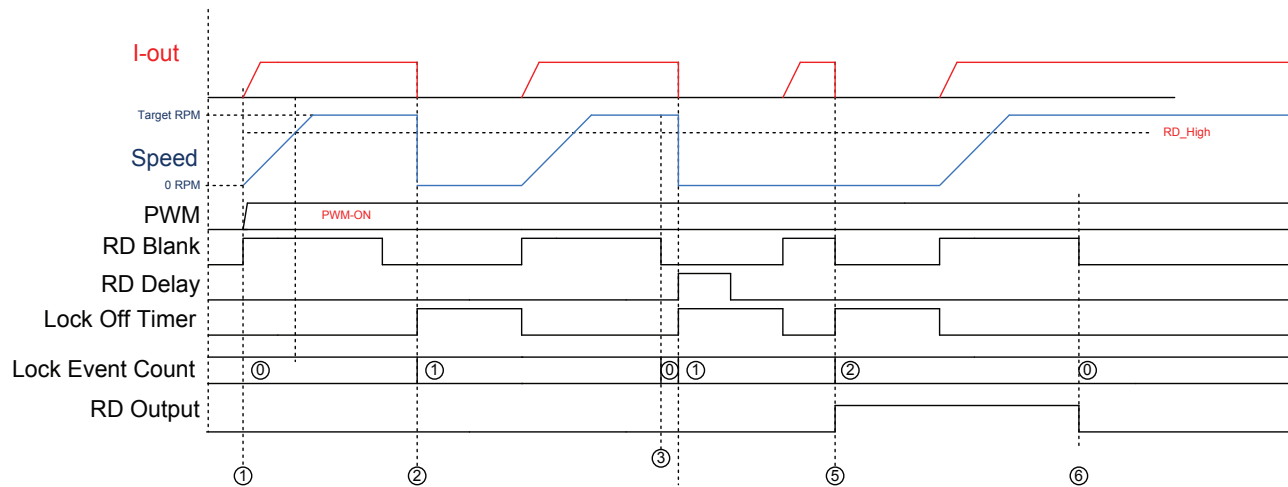


Figure 5: RD Timing Diagram (LOCKEVT = 0); lock condition while running

1. Power on with PWM normal startup
2. Rotor locked while running – Lock Event Counter is one
3. If Speed > RD_high after RD Blank, Lock Event count reset to zero
4. Rotor locked while running – Lock Event Counter is one
5. RD is high after 2nd lock event
6. RD reset to low after RD Blank if (Speed > RD_High); Lock Event Count reset to zero

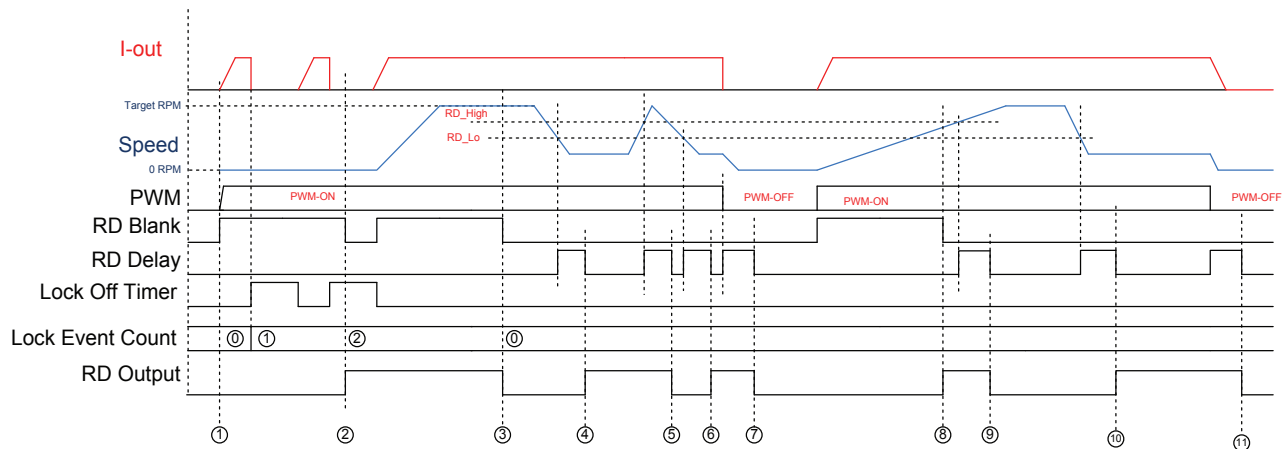


Figure 6: RD Timing Diagram (LOCKEVT = 1)

1. Power on with rotor locked condition
2. RD is high after RD Blank if Speed < RD_High
3. RD resets low after RD Blank if Speed > RD_High
4. RD changes to high if Speed < RD_Low after RD Delay
5. RD changes to low if Speed > RD_High after RD Delay
6. RD changes to high if Speed < RD_Low after RD Delay
7. RD changes to low when PWM goes off after RD Delay
8. RD changes to high after RD Blank if Speed < RD_High even if Speed > RD_Low
9. RD changes to low if Speed > RD_High after RD Delay
10. RD changes to high if Speed < RD_Low after RD Delay
11. RD changes to low when PWM goes off after RD Delay

Note: RD Blank should be programmed longer than the time it takes to accelerate to the RD_High level.
Startup time + time to accelerate to RD_High.

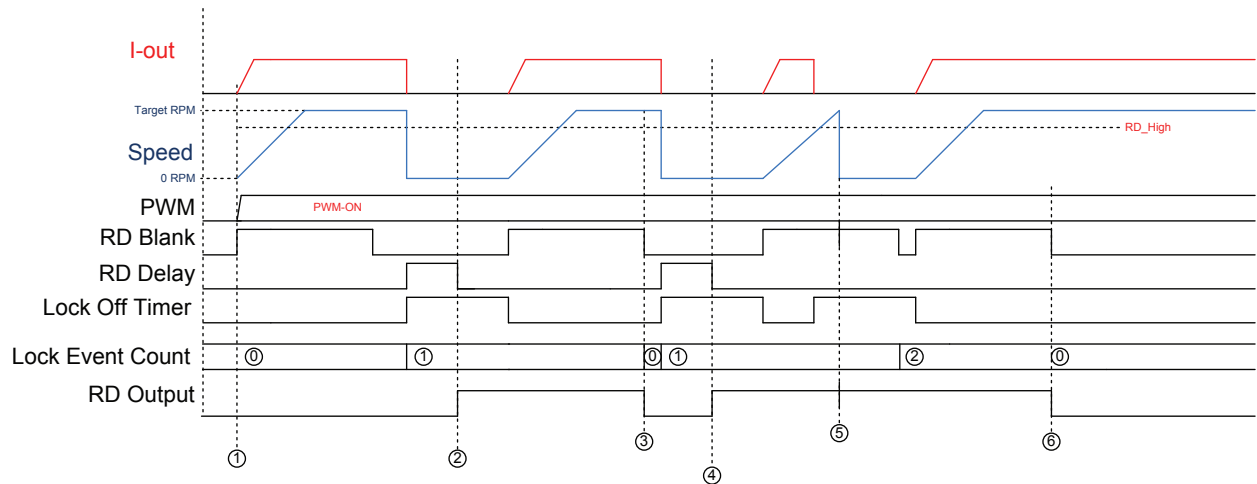


Figure 7: RD Timing Diagram (LOCKEVT = 1); lock condition while running

1. Power on with PWM normal startup
2. Rotor locked while running – RD changes to high after RD Delay if Speed < RD_Low
3. RD changes to low if Speed > RD_high after RD Blank
4. Rotor locked while running – RD changes to high after RD Delay if Speed < RD_Low
5. RD remains high, even if Speed is OK, since RD Blank has not timed out
6. RD reset to low after RD Blank if Speed > RD_High

EEPROM MAP

Table 3: EEPROM Map

| ADDR | Bits | Name | Description | Default Setting | Default Value (decimal) |
|------|-------|-----------|--|-----------------------|-------------------------|
| 0 | 15:0 | Dev1 | Device information for customer use | n/a | 0 |
| 1 | 11:0 | MINSPD | Range = 0 to 4095, LSB = 1 rpm | 2000 | 2000 |
| | 12 | DUTYINV | 0 = normal, 1 = invert | 0 | 0 |
| | 13 | MAXOFF | 0 = normal, 1 = max speed when duty < DC_Off | 0 | 0 |
| | 14 | MAXDTYOPT | 0 = run at open loop, 1 = run at MAXDTYCLP | 1 | 1 |
| | 15 | Unused | | | |
| 2 | 13:0 | SPDSL1P1 | Calculated slope of speed curve | set for 19909 rpm | 2243 |
| | 15:14 | Unused | | 0 | 0 |
| 3 | 7:0 | DCON | Range = 0 to 49.9%, LSB = 0.2% | 10% | 97 |
| | 15:8 | DCOFF | Range = 0 to 49.9%, LSB = 0.2% | 7.4% | 79 |
| 4 | 3:0 | MAXDTYCLP | Range = 100% to 76.5%, LSB = 1.6% | 0 | 0 |
| | 7:4 | MAXDTYHYS | Range = 0 to 5.9%, LSB = 0.4% | 0 | 0 |
| | 14:8 | MINDTYCLP | Range = 0 to 49.9%, LSB = 0.39% | 0 | 0 |
| | 15 | Unused | | | |
| 5 | 7:0 | STRDMD | Range = 0 to 16 V, LSB = 63 mV | 945 mV | 15 |
| | 15:8 | DMDPOST | Range = 0 to 100%, LSB = 0.39% | 100% | 255 |
| 6 | 7:0 | ALIGN | Range = 0 to 20.4 seconds, LSB = 80 ms | 480 ms | 6 |
| | 15:8 | ASLOPE | Range = 160 ms to 40 seconds | 511 ms | 80 |
| 7 | 7:0 | STRTF | Range = 0 to 20.4 seconds, LSB = 80 ms | 2 Hz | 32 |
| | 15:8 | ACCEL | Range = 0 to 99.6 Hz/s, LSB = 0.78 | 42 Hz/s | 107 |
| 8 | 7:0 | ACCELT | Range = 0 to 20.4 seconds, LSB = 80 ms | 480 ms | 6 |
| | 15:8 | RMOT | Phase to Phase Motor Resistance ^[1] | 1.3 | 13 |
| 9 | 3:0 | DMDRMPAL | Range = 3.8 to 63.8 ms/count, LSB = 3.8 | 23.8 ms/count | 5 |
| | 7:4 | DMDRMPAH | Range = 3.8 to 63.8 ms/count, LSB = 3.8 | 7.8 ms/count | 1 |
| | 11:8 | DMDRMPDL | Range = 3.8 to 63.8 ms/count, LSB = 3.8 | 15.8 ms/count | 3 |
| | 15:12 | DMDRMPDH | Range = 3.8 to 63.8 ms/count, LSB = 3.8 | 15.8 ms/count | 3 |
| 10 | 15:0 | Dev2 | Device information | n/a | n/a |
| 11 | 7:0 | MAXSPD | Maximum electrical frequency | 1061 Hz | 23 |
| | 15:8 | TLOCK | Range = 0 to 25.5 seconds | 5 seconds | 50 |
| 12 | 7:0 | RDLOW | Range = 0 to 4095, LSB = 16 rpm | 0 | 0 |
| | 15:8 | RDHIGH | Range = 0 to 4095, LSB = 16 rpm | 0 | 0 |
| 13 | 7:0 | RDBLANK | Range = 0 to 25.5 seconds, LSB = 100 ms | 0 | 0 |
| | 12:8 | RDDL | Range = 0 to 15 seconds, LSB = 1 second | 0 | 0 |
| 14 | 11:0 | PHASLP | Calculated slope for linear phase advance | set for 11°@20000 rpm | 367 |
| | 15:12 | SOWLIN | Window width with linear phase advance | 28° | 15 |

^[1] RMOT is for GUI use; it does not change operation of the IC

Continued on next page...

EEPROM MAP (continued)

| ADDR | Bits | Name | Description | Default Setting | Default Value (decimal) |
|------|-------|-----------|--|-----------------|-------------------------|
| 15 | 0 | PCDLY | Post-coast delay: 0 = 100 ms, 1 = 500 ms | 500 ms | 1 |
| | 1 | STBYDIS | Standby Mode: 0 = Enable, 1 = Disable | 0 | 0 |
| | 3:2 | PWMF | Motor PWM selection | 24 or 48 kHz | 2 |
| | 5:4 | BEMFFILT | Bemf Comparator filter | 4 μ s | 0 |
| | 6 | TCENB | Temperature compensation: 0 = Off, 1 = On | 0 | 0 |
| | 8:7 | WINDM | Windmill option | 0 | 0 |
| | 12:9 | SPDCLP | Minimum clamp is speed control mode | 4.6% | 2 |
| | 14:13 | OCL | Set overcurrent limit level | 0 | 0 |
| | 15 | OCLD | 1 = disable overcurrent limit | 0 | 0 |
| 16 | 0 | CL | Speed Control Mode: 0 = open loop, 1 = closed | enabled | 1 |
| | 1 | PHA | Running Mode: 0 = auto, 1 = linear phase advance | 0 | 0 |
| | 2 | LOCKEVT | RD function mode select | 0 | 0 |
| | 3 | SPDSEL | Speed control select: 0 = PWM duty, 1 = analog | 0 | 0 |
| | 6:4 | PP | Pole pair = PP + 1 | 2 pp | 1 |
| | 7 | NOCOAST | 1 = no coast, 0 = coast | 1 | 1 |
| | 8 | ALIGNMODE | 0 = align, 1 = one cycle | one cycle | 1 |
| | 10:9 | QCKSTRT | 0 = disable, 1 = enable | 0 | 0 |
| | 11 | FGSTRT | 0 = FG disabled during startup, 1 = FG enabled | 0 | 0 |
| | 13:12 | BEMFHYS | BEMF hysteresis level for startup | 40 mV | 1 |
| | 14 | SOWAUTO | Initial value of window | 21° | 1 |
| | 15 | OCPOPT | 0 = reset after TLOCK, 1 = after PWM on/off | TLOCK | 0 |
| 17 | 7:0 | KP | Closed loop | 16 | 16 |
| | 15:8 | KI | Closed loop | 2 | 2 |
| 18 | 7:0 | SLPSWDTY | Duty at which slope changes | 0 | 0 |
| | 15:8 | Unused | | | |
| 19 | 14:0 | SLPSWRPM | Range 0 to 16384, LSB = 1 rpm | 2000 rpm | 2000 |
| | 15 | Unused | | | |
| 20 | 13:0 | SPDSL2P2 | Calculated slope | 0 | 0 |
| | 15:14 | Unused | | | |
| 21 | 15:0 | Allegro | Allegro use only | n/a | |
| 22 | 15:0 | Dev3 | Device information | n/a | |
| 23 | 15:0 | Allegro | Allegro use only | n/a | |

SERIAL PORT CONTROL OPTION

Normally the IC is controlled by duty cycle input and uses the EEPROM data that is stored to create the speed curve profile. However, it is possible to use direct serial port control to avoid programming EEPROM.

When using direct control, the input duty cycle command is replaced by writing a 9-bit number to register 165.

Example:

REGADDR[data]: (in decimal)

165[511] → Duty = 100%

165[102] → Duty = 102 / 511 = 20%

Upon power up, the IC defaults to duty cycle input mode. To use serial port mode, the internal registers should be programmed before turning the part on. The sequence to use serial port mode is:

1. Drive FG and SPD pins low *
2. Power-up IC
3. Program registers for parameter setting that correspond to each of the EEPROM memory locations.
 - A. REGADDR = 64 + EEPROM ADDR.
 - B. Program register addresses 65 to 84 corresponding to EEPROM addresses 1 to 20.
 - C. It may be helpful to use the GUI text file to help define the hex data for each of the EEPROM addresses.
4. Write to register 165 to start motor

* Note: If SPD is not driven low before power up, motor will try to start immediately as the default high value will demand 100% on signal.

Serial Port

The A5931 uses standard fast mode I²C serial port format to program the EEPROM or to control the IC speed serially. The SPD pin functions as the clock (SCL) input, and the FG pin is the data line (SDA). No special sequence is needed to begin transferring data. If the motor is running, the FG may then pull the data line low while trying to initialize into serial port mode. Once an I²C command is sent, the SPD input is ignored, and the motor will turn off as if a PWM duty command of 0% was sent.

The A5931 7-bit slave address is 0x55.

I²C Timing Diagrams

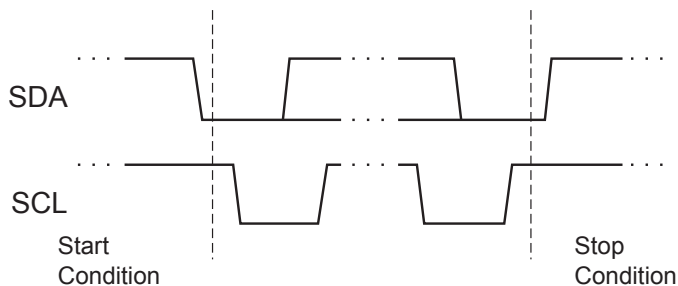


Figure 8: Start and Stop Conditions

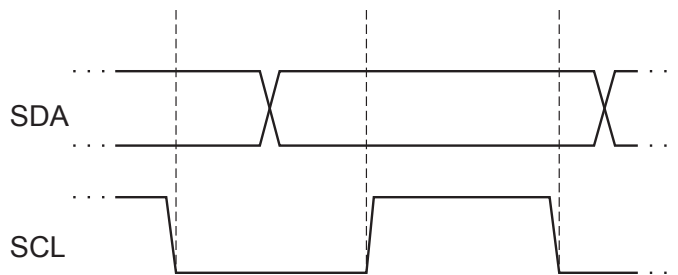


Figure 9: Clock and Data Bit Synchronization

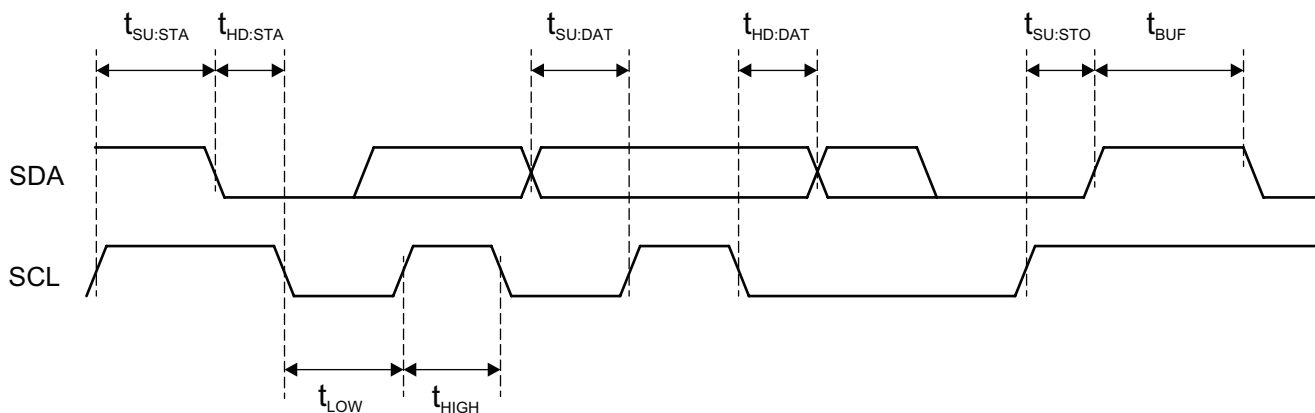


Figure 10: I²C-Compatible Timing Requirements

Write Command

1. Start Condition
2. 7-bit I²C Slave Address (Device ID) 1010101, R/W Bit = 0
3. Internal Register Address
4. 2 data bytes, MSB first
5. Stop Condition

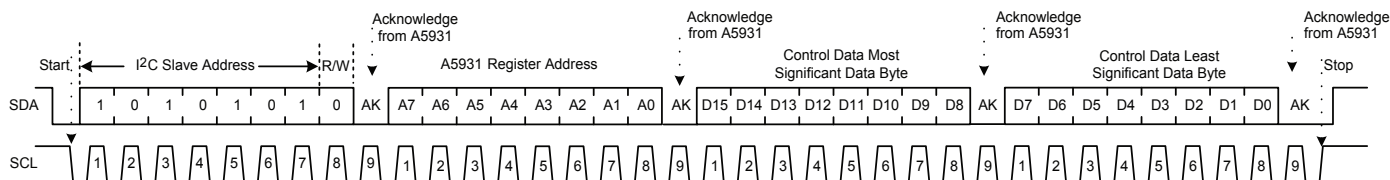


Figure 11: Write Command

Read Command

1. Start Condition
2. 7-bit I²C Slave Address (Device ID) 1010101, R/W Bit = 0
3. Internal Register Address to be read
4. Stop Condition
5. Start Condition
6. 7-bit I²C Slave Address (Device ID) 1010101, R/W Bit = 1
7. Read 2 data bytes
8. Stop Condition

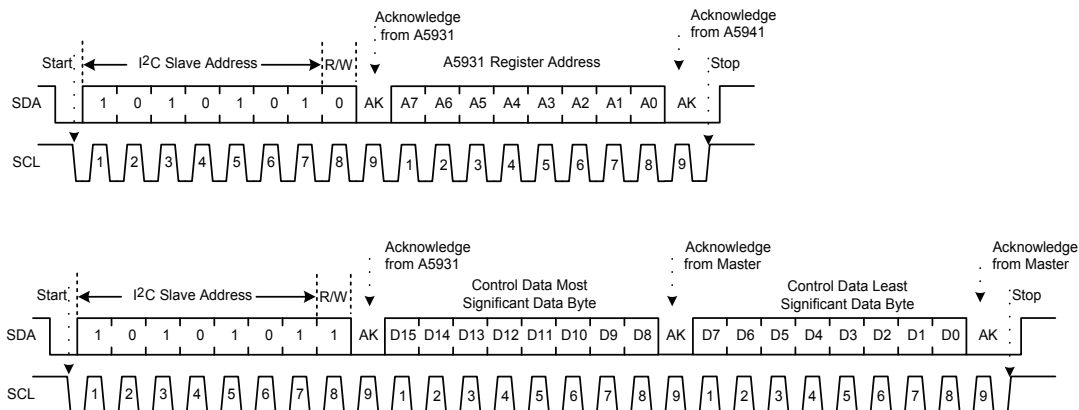


Figure 12: Read Command

Programming EEPROM

The A5931 contains 24 words of 16-bit length. The EEPROM is controlled with the following I²C registers. Refer to application note for EEPROM definition.

Table 4: EEPROM Control – Register 161 (Used to control programming of EEPROM)

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|---|---|---|---|---|---|----|----|----|----|
| 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 during programming process |

Table 5: EEPROM Address – Register 162 (Used to set the EEPROM address to be altered)

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

| Bit | Name | Description |
|------|-----------|---|
| 4:0 | eeADDRESS | Used to specify EEPROM address to be changed. |
| 15:5 | n/a | Do not use; always set to zero during programming process |

Table 6: EEPROM DataIn – Register 163 (Used to set the EEPROM new data to be programmed)

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

| Bit | Name | Description |
|------|----------|---|
| 15:0 | eeDATAIn | Used to specify the new EEPROM data to be changed |

Table 7: DataOUT – Register 164 (Used for read operations)

| | | | | | | | | | | | | | | | |
|-----------|----|-----------|----|---|----|---|---|---|---|---|---|---|---|---|---|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| eeDATAout | | | | | | | | | | | | | | | |
| Bit | | Name | | Description | | | | | | | | | | | |
| 15:0 | | eeDATAout | | Used to readback EEPROM data from address defined in register 162 | | | | | | | | | | | |

There are 3 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.

Each word must be written individually.

Example #1: Write EEPROM address 5 to 261 (0x0105)

1) Erase the word

- I²C Write REGADDR[Data] ; comment
- a. 162[5] ; set EEPROM address to erase
- b. 163[0] ; set 0000 as Data In
- c. 161[3] ; set control to Erase and trigger high-voltage pulse
- d. Wait 15 ms ; wait for pulse to end
- e. 161[0] ; clear voltage

2) Write the new data

- a. 162[5] ; set EEPROM address to write
- b. 163[261] ; set Data In = 261
- c. 161[5] ; set control to Write and trigger high-voltage pulse
- d. Wait 15 ms ; wait for pulse to end
- e. 161[5] ; clear voltage

Example #2: Read EEPROM address 5 to confirm correct data properly programmed

1) Read the word

- a. 5[I²C Read] ; read register 5; this will be the contents of EEPROM

APPLICATION INFORMATION

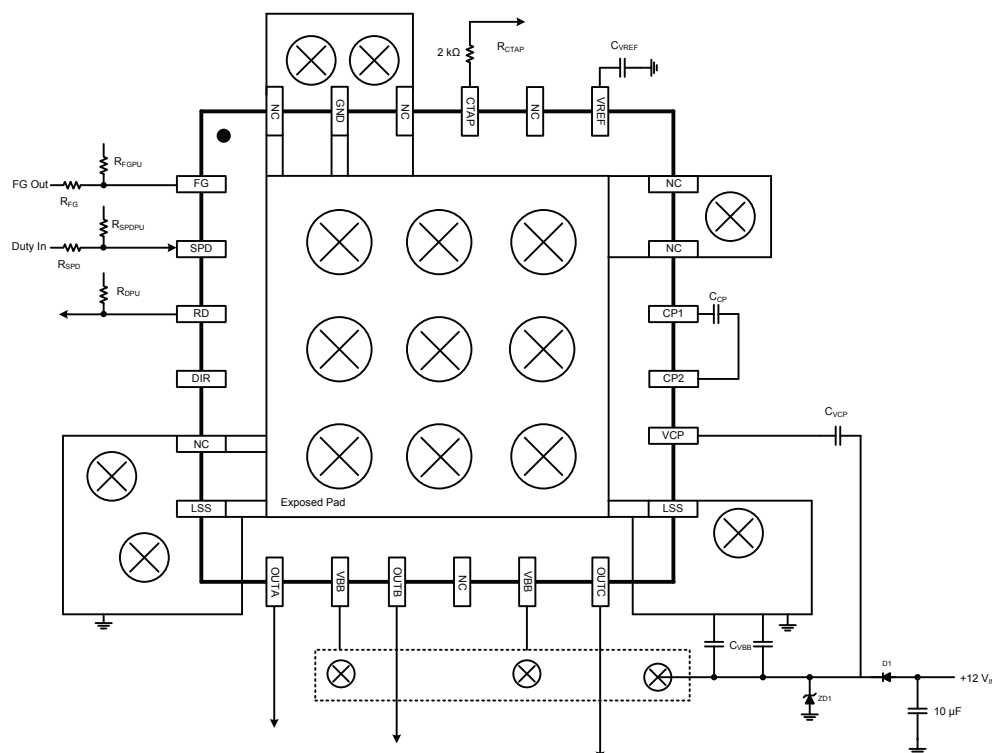


Figure 13: Typical Application Circuit

Table 8: Typical Application Components

| Name | Suggested Value | Comment |
|-------------|----------------------|--|
| C_{VREF} | 0.1 μ F/X5R/10 V | Ceramic capacitor required |
| C_{VBB} | 10 to 100 μ F | Power supply stabilization – electrolytic or ceramic OK. |
| C_{VCP} | 0.1 μ F | Ceramic capacitor required |
| C_{CP} | 0.1 μ F | Ceramic capacitor required |
| D1 | Not installed | May be required to isolate motor from system or for reverse polarity protection |
| ZD1 | SMBJ14A | TVS to limit max V_{BB} due to transients due to motor generation on power line. Suggested to clamp below 16 V. |
| R_{CTAP} | 2 k Ω | 2 k Ω series resistance; not required if pin left O/C |
| R_{FG} | 500 Ω | Optional – If FG wired to connector – R_{FG} will isolate IC pin from noise or overvoltage transients or protect from connector issues |
| R_{FGPU} | 10 k Ω | Open-drain pull-up resistor – required if using pin for I ² C |
| R_{SPD} | 500 Ω | Optional – If PWM wired to connector – R_{SPD} will isolate IC pin from noise or overvoltage transients or protect from connector issues |
| R_{SPDPU} | 10 k Ω | Open-drain pull-up resistor – required if using pin for I ² C |
| R_{RD} | 10 k Ω | Open-drain pull-up resistor – optional for RD function or test use |

Layout Notes:

1. Add thermal vias to exposed pad area.
2. Add ground plane on top and bottom of PCB.
3. Place C_{VREF} and C_{VBB} as close as possible to IC, connected to GND plane.

PIN DIAGRAMS

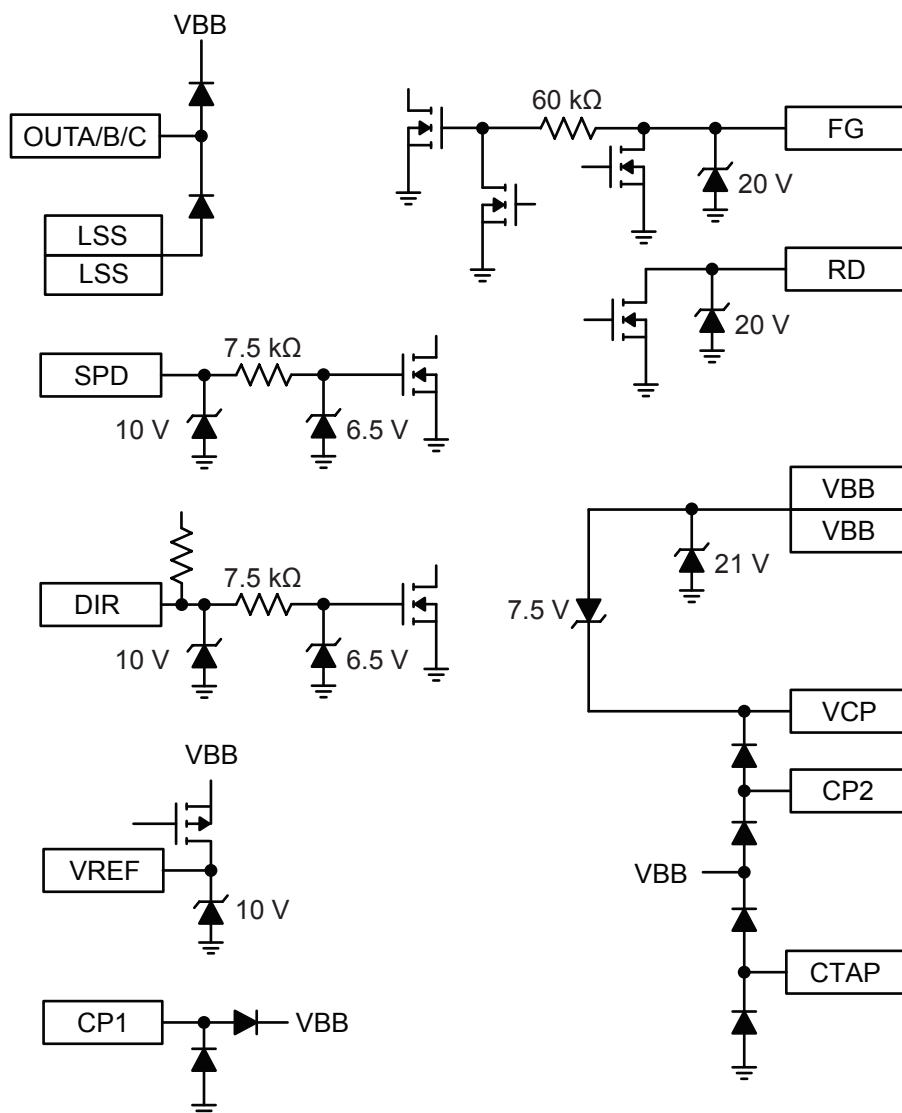


Figure 14: Pin Diagrams

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.

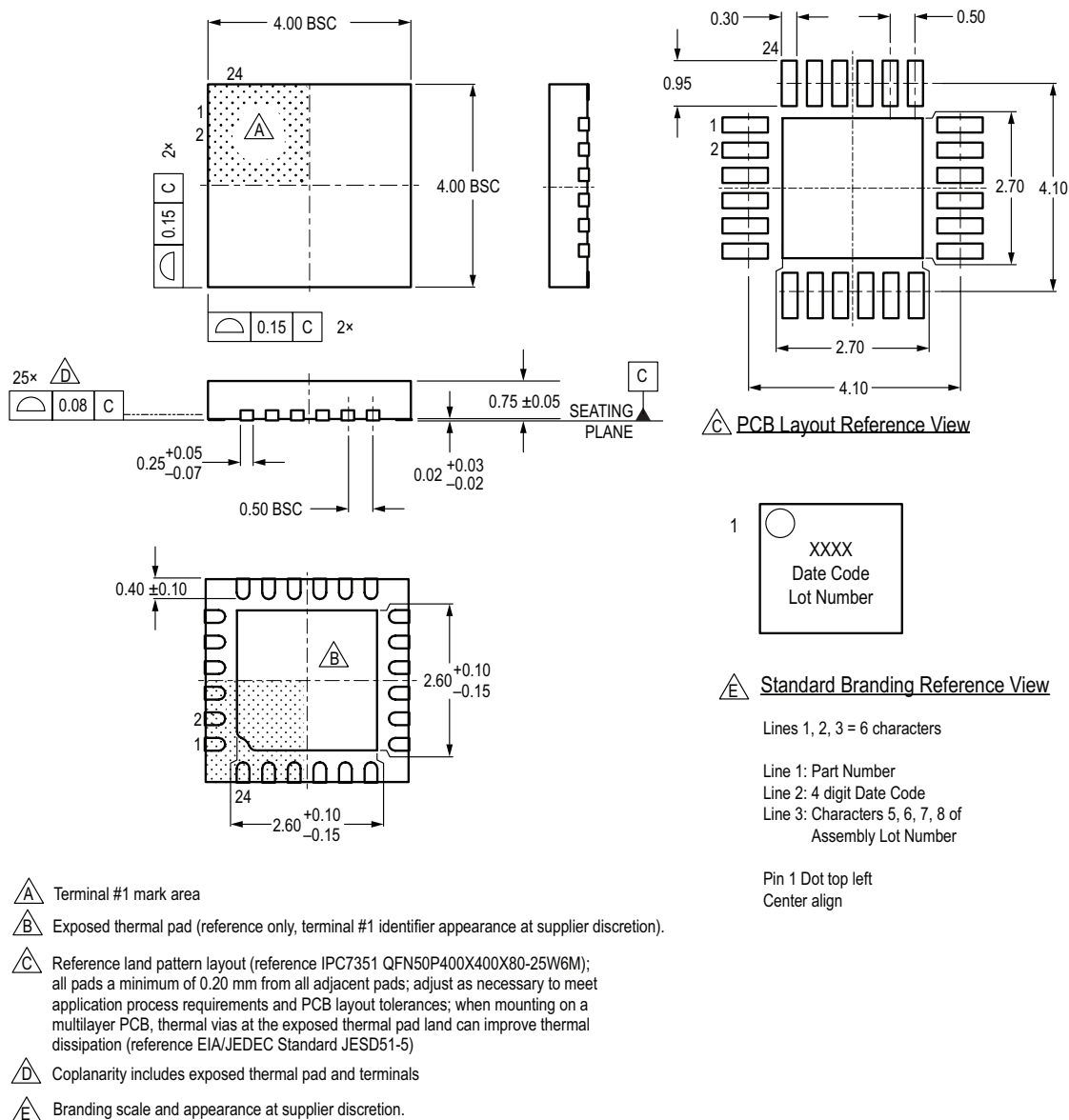


Figure 15: Package ES, 24-Contact QFN with Exposed Pad

For Reference Only – Not for Tooling Use

(Reference JEDEC MO-153 ABT; Allegro DWG-0000379, Rev. 3)

Dimensions in millimeters – NOT TO SCALE

Dimensions exclusive of mold flash, gate burrs, and dambar protrusions
Exact case and lead configuration at supplier discretion within limits shown

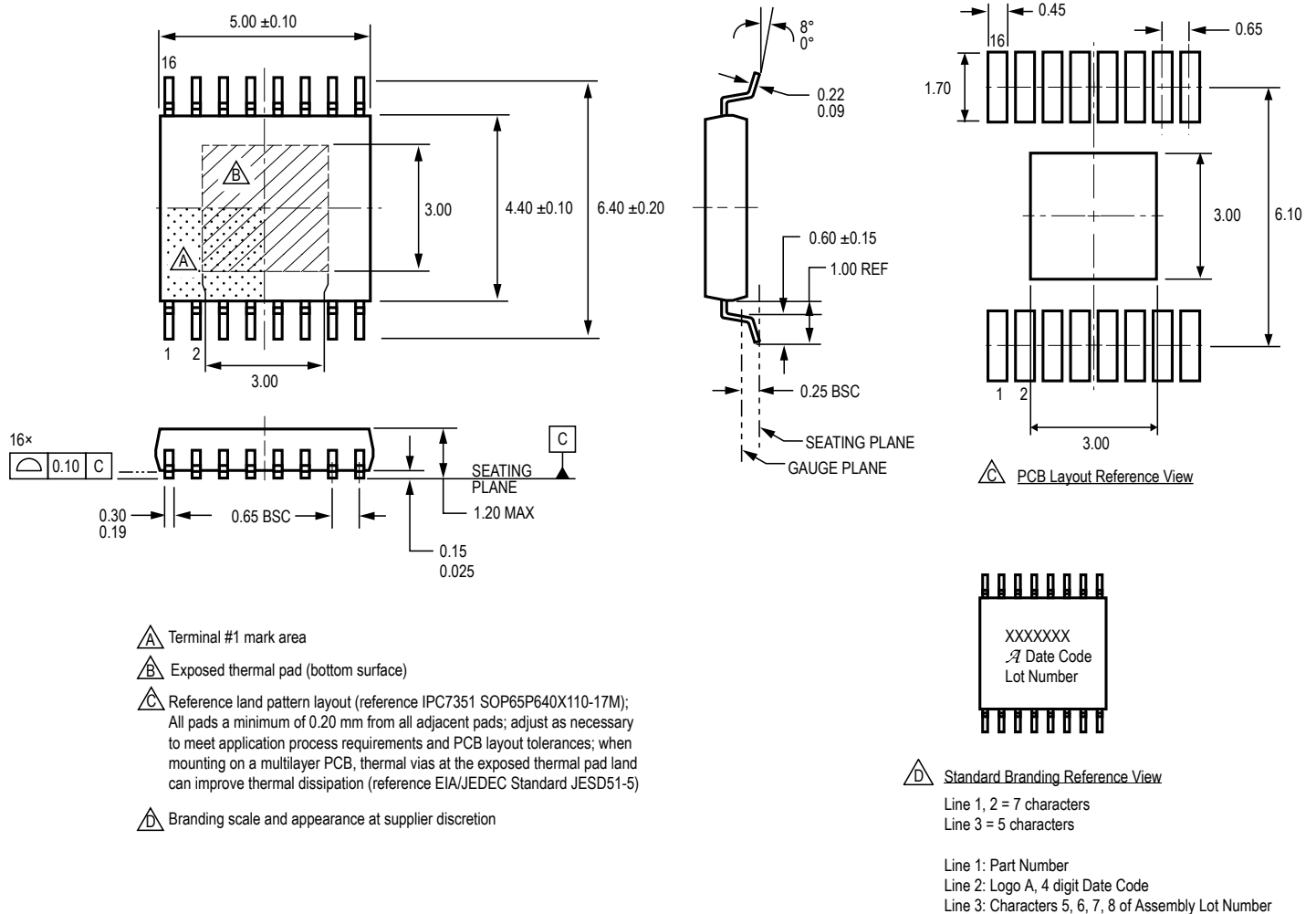


Figure 16: Package LP, 16-Lead TSSOP with Exposed Pad

Revision History

| Number | Date | Description |
|--------|--------------------|--|
| – | September 20, 2016 | Initial release |
| 1 | February 10, 2017 | Corrected Figure 1: Typical Application (page 1); added K temperature range option (page 2). |
| 2 | April 24, 2017 | Corrected Logic Input Low Level and Logic Input High Level (page 6). |
| 3 | May 10, 2017 | Updated Overcurrent Protection typical and maximum values (page 5), EEPROM map (page 16), and Table 5 (page 20). |
| 4 | June 14, 2017 | Updated Total Driver On-Resistance for K version (page 5). |
| 5 | September 28, 2018 | Minor editorial updates |
| 6 | October 29, 2018 | Updated PWM Duty Input min value (page 5), FG and SPD functional description sections (page 8) |
| 7 | November 15, 2018 | Updated PWM Input Frequency Range (page 5), SPD and DIR functional description sections (page 8) |
| 8 | July 25, 2019 | Minor editorial updates; initial release to web |
| 9 | November 29, 2021 | Updated Speed Control test conditions (page 5), Analog Control (page 8), and package drawings (pages 24-25) |

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