TPL7407LA 30-V 7-Channel Low Side Driver

1 Features

- 600-mA Rated Drain Current (Per Channel)
- CMOS Pin-to-Pin Improvement of 7-channel Darlington Array (For example: ULN2003A)
- Power Efficient (Very low V_{OL})
  - Less Than 4 Times Lower V_{OL} at 100 mA Than Darlington Array
- Very Low Output Leakage < 10 nA Per Channel
- Extended Ambient Temperature Range: T_A = –40°C to +125°C
- High-Voltage Outputs 30 V
- Compatible with 1.8-V to 5-V Microcontroller and Logic Interface
- Internal Free-wheeling Diodes for Inductive Kick-back Protection
- Input Pull-down Resistors Allows Tri-stating the Input Driver
- Input RC-Snubber to Eliminate Spurious Operation in Noisy Environment
- Inductive Load Driver Applications
- ESD Protection Exceeds JESD 22
  - 2-kV HBM, 500-V CDM

2 Applications

- Inductive Loads
  - Relays
  - Unipolar Stepper & Brushed DC Motors
  - Solenoids & Valves
- LEDs
- Logic Level Shifting
- Gate & IGBT Drive

3 Description

The TPL7407LA is a high-voltage, high-current NMOS transistor array. This device consists of seven NMOS transistors that feature high-voltage outputs with common-cathode clamp diodes for switching inductive loads. The maximum drain-current rating of a single NMOS channel is 600 mA. New regulation and drive circuitry added to give maximum drive strength across all GPIO ranges (1.8 V–5 V).The transistors can be paralleled for higher current capability.

The TPL7407LA's key benefit is its improved power efficiency and lower leakage than a Bipolar Darlington Implementation. With the lower V_{OL} the user is dissipating less than half the power than traditional relay drivers with currents less than 250 mA per channel.

Device Information[1]

PART NUMBER	PACKAGE (PINS)	BODY SIZE (NOM)
TPL7407LAPW	TSSOP (16)	5.00 mm × 4.40 mm

(1) For all available packages, see the orderable addendum at the end of the datasheet.

Simple Application Schematic

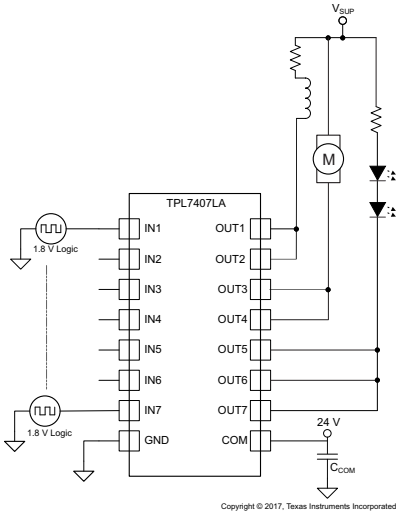


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4 Revision History

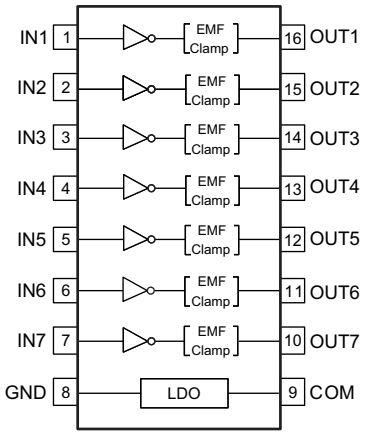
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

DATE	REVISION	NOTES
May 2017	*	Initial release.

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5 Pin Configuration and Functions

PW Package
16-Pin TSSOP
Top View



Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
COM	9	—	Supply pin that must be tied to 6.5 V or higher for proper operation (see the *Power Supply Recommendations* section for more information)
GND	8	—	Ground pin
IN(X)	1	I	GPIO inputs that drives the outputs "low" (or sink current) when driven "high"
	2		
	3		
	4		
	5		
	6		
	7		
OUT(X)	10	O	Driver output that sinks currents after input is driven "high"
	11		
	12		
	13		
	14		
	15		
	16		

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6 Specifications

6.1 Absolute Maximum Ratings

at 25°C free-air temperature (unless otherwise noted) (1)

		MIN	MAX	UNIT
V_{OUT}	Pins OUT1-OUT7 to GND voltage	–0.3	32	V
V_{OK}	Output clamp diode reverse voltage (2)	–0.3	32	V
V_{COM}	COM pin voltage (2)	–0.3	32	V
V_{IN}	Pins IN1-IN7 to GND voltage (2)	–0.3	30	V
I_{DS}	Continuous drain current per channel (3) (4)		600	mA
I_{OK}	Output clamp current		500	mA
I_{GND}	Total continuous GND-pin current		–2	A
T_J	Operating virtual junction temperature	–40	150	°C
T_{stg}	Storage temperature	–65	150	°C

(1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to the GND/substrate pin, unless otherwise noted.
(3) Maximum power dissipation is a function of $T_J(max)$, θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(max) – T_A)/\theta_{JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
(4) The package thermal impedance is calculated in accordance with JESD 51-7.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 (1)	±2000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101 (2)	±500	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process. Manufacturing with less than 500-V HBM is possible with the necessary precautions.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process. Manufacturing with less than 250-V CDM is possible with the necessary precautions.

6.3 Recommended Operating Conditions

Over operating temperature range

		MIN	MAX	UNIT
V_{OUT}	OUT1 – OUT7 pin voltage for recommended operation	0	30	V
V_{COM}	COM pin voltage range for full output drive	6.5	30	V
V_{IL}	IN1- IN7 input low voltage ("Off" high impedance output)		0.9	V
V_{IH}	IN1- IN7 input high voltage ("Full Drive" low impedance output)	1.5		V
T_A	Operating free-air temperature	–40	125	°C
I_{DS}	Continuous drain current	0	500	mA

6.4 Thermal Information

THERMAL METRIC (1)		TPL7407LA TSSOP (PW) 16 PINS	UNIT
θ_{JA}	Junction-to-ambient thermal resistance	113.1	°C/W
θ_{JCtop}	Junction-to-case (top) thermal resistance	46.5	°C/W
θ_{JB}	Junction-to-board thermal resistance	58.6	°C/W
ψ_{JT}	Junction-to-top characterization parameter	7	°C/W
ψ_{JB}	Junction-to-board characterization parameter	58	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

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6.5 Electrical Characteristics

T_J= –40°C to +125°C; Typical Values at T_A= 25°C (1)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{OL} (V_{DS})	OUT1- OUT7 low-level output voltage	V_{IN} ≥ 1.5 V	I_D = 100 mA		210	450	mV
			I_D = 200 mA		430	900	
V_{IL}	IN1- IN7 low-level input voltage	I_D = 5 µA				0.9	V
V_{IH}	IN1- IN7 high-level input voltage	I_D = 100 mA		1.5			V
$I_{OUT(OFF)}$ (I_{DS_OFF})	OUT1- OUT7 OFF-state leakage current	V_{OUT} = 24V, V_{IN} ≤ 0.9V			10	500	nA
V_F	Clamp forward voltage	I_F = 200 mA				1.4	V
$I_{IN(off)}$	IN1- IN7 Off-state input current	V_{INX} = 0 V	V_{OUT} = 40 V			500	nA
$I_{IN(ON)}$	IN1- IN7 ON state input current	V_{INX} = 1.5 V – 5 V				10	µA
I_{COM}	Static current flowing through COM pin	V_{COM} = 6.5 V – 40 V			17	30	µA

(1) During production testing, device is tested under short duration, therefore $T_A = T_J$.

6.6 Switching Characteristics

Typical Values at T_A= 25°C

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PLH}	Propagation delay time, low- to high-level output	V_{INX} ≥ 1.65 V, Vpull-up = 24 V, Rpull-up = 48 Ω		350		ns
t_{PHL}	Propagation delay time, high- to low-level output	V_{INX} ≥ 1.65 V, Vpull-up = 24 V, Rpull-up = 48 Ω		350		ns
C_i	Input capacitance	V_I = 0, f = 100 kHz		5		pF

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6.7 Typical Characteristics

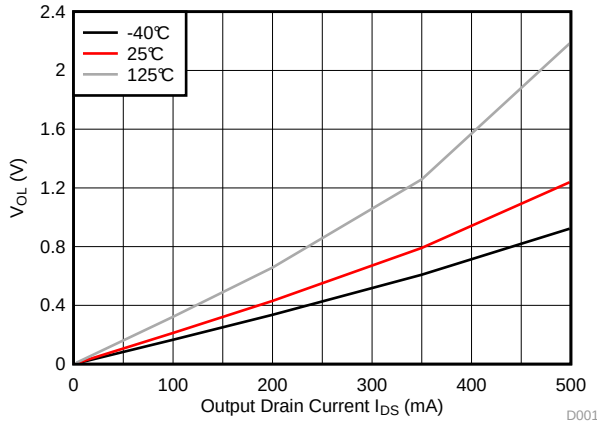


Figure 1. V_{OL} (V_{DS})

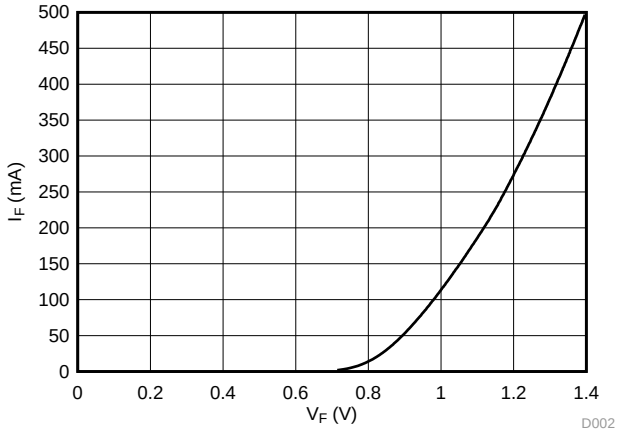


Figure 2. Flyback Diode Forward Voltage at 25°C

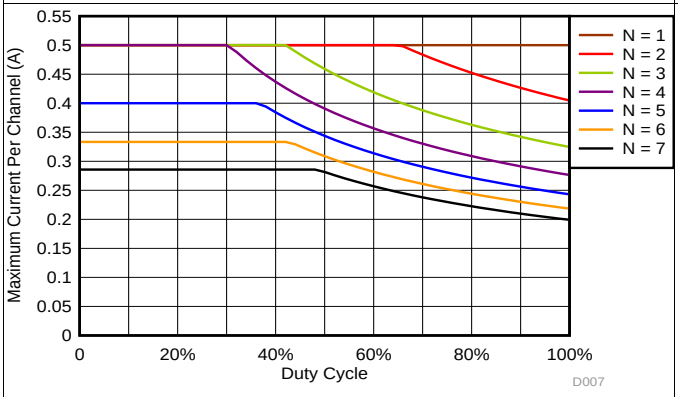


Figure 3. Maximum Collector Current vs Duty Cycle at 25°C

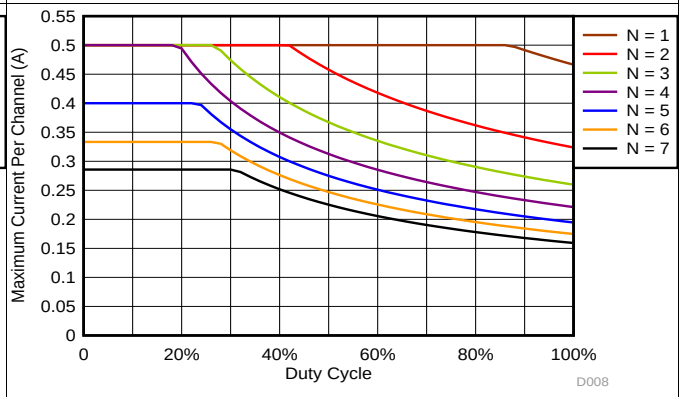


Figure 4. Maximum Collector Current vs Duty Cycle at 70°C

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7 Detailed Description

7.1 Overview

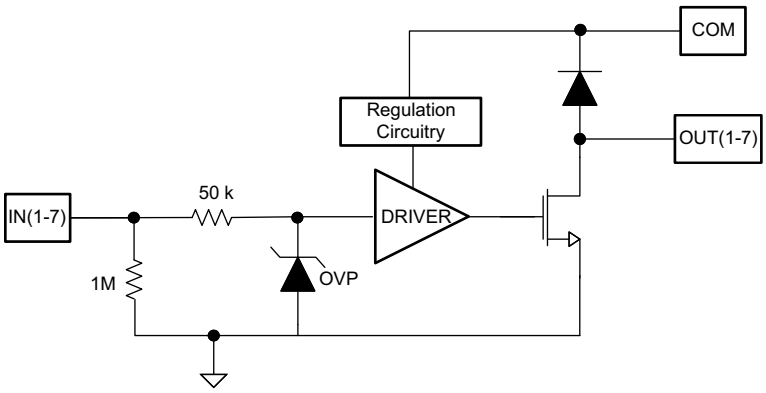
This device has proven ubiquity and versatility across a wide range of applications. This is due to its integration of 7 low side NMOS transistors that are capable of sinking up to 600 mA and wide GPIO range capability.

The TPL7407LA comprises seven high voltage, high current NMOS transistors tied to a common ground driven by internal level shifting and gate drive circuitry. The TPL7407LA offers solutions to many interface needs, including solenoids, relays, lamps, small motors, and LEDs. Applications requiring sink currents beyond the capability of a single output may be accommodated by paralleling the outputs.

The TPL7407LA also enables pin to pin replacement with legacy 7 channel darlington pair implementations.

This device can operate over a wide temperature range (–40°C to +125°C).

7.2 Functional Block Diagram



7.3 Feature Description

Each channel of the TPL7407LA consists of high power low side NMOS transistors driven by level shifting and gate driving circuitry. The gate drivers allow for high output current drive with a very low input voltage, meaning full operation with low GPIO voltages.

In order to enable floating inputs a 1-MΩ pull-down resistor exists on each channel. Another 50-kΩ resistor exists between the input and gate driving circuitry. This exists to limit the input current whenever there is an over voltage and the internal Zener clamps. It also interacts with the inherent capacitance of the gate driving circuitry to behave as an RC snubber to help prevent spurious switching in noisy environment.

In order to power the gate driving circuitry an LDO exists. See the *Power Supply Recommendations* section for further detail on this circuitry.

The diodes connected between the output and COM pin is used to suppress kick-back voltage from an inductive load that is excited when the NMOS drivers are turned off (stop sinking) and the stored energy in the coils causes a reverse current to flow into the coil supply.

7.4 Device Functional Modes

7.4.1 Inductive Load Drive

When the COM pin is tied to the coil supply voltage, the TPL7407LA is able to drive inductive loads and suppress the kick-back voltage via the internal free wheeling diodes.

7.4.2 Resistive Load Drive

When driving a resistive load, a pull-up resistor is needed in order for the TPL7407LA to sink current and for there to be a logic high level. The COM pin must be supplied ≥ 6.5 V for full functionality.

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Device Functional Modes (continued)

7.4.3 ON State Input Current

The current into the INx pins is defined in the electrical characteristics table for input voltages from 1.5 V to 5 V. At higher voltages, this leakage increases, and the input current can be estimated using the approximate clamp voltage for the OVP diode, 6.4 V. Equation 1 shows how to approximate input current for input voltages greater than 6.4 V:

$$I_{IN(ON)} = V_{IN} / 1M\Omega + (V_{IN} - 6.4V) / 50k\Omega \quad (1)$$

where

- V_{IN} is the input voltage
- 1 MΩ is the input pull-down resistance
- 50 kΩ is the input series resistance
- 6.8 V is the approximate clamp voltage for the OVP diode

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8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The TPL7407LA is typically used to drive a high voltage and/or current peripheral from an MCU or logic device that cannot tolerate these conditions. The following design is a common application of the TPL7407LA, driving inductive loads. This includes motors, solenoids & relays. Each load type can be modeled by what's seen in Figure 7.

8.1.1 Unipolar Stepper Motor Driver

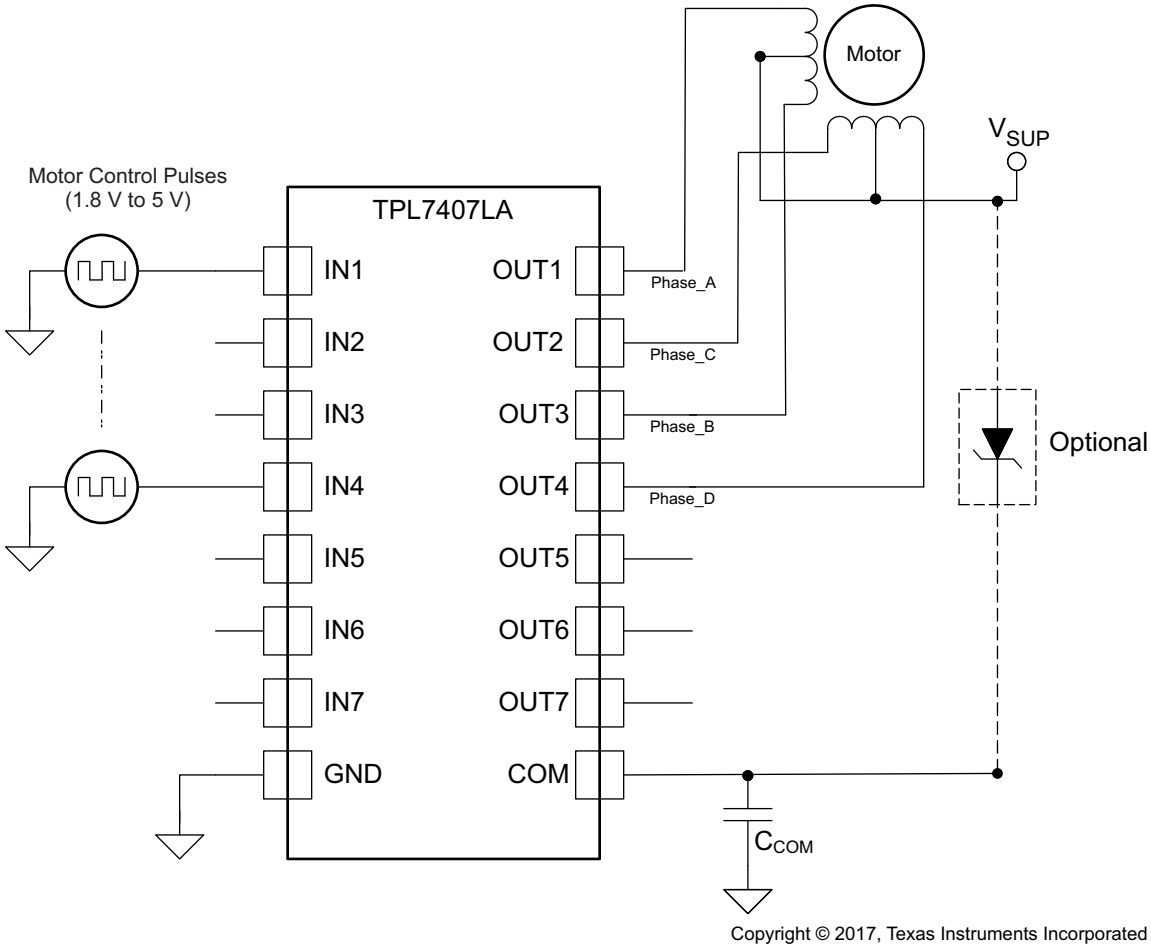


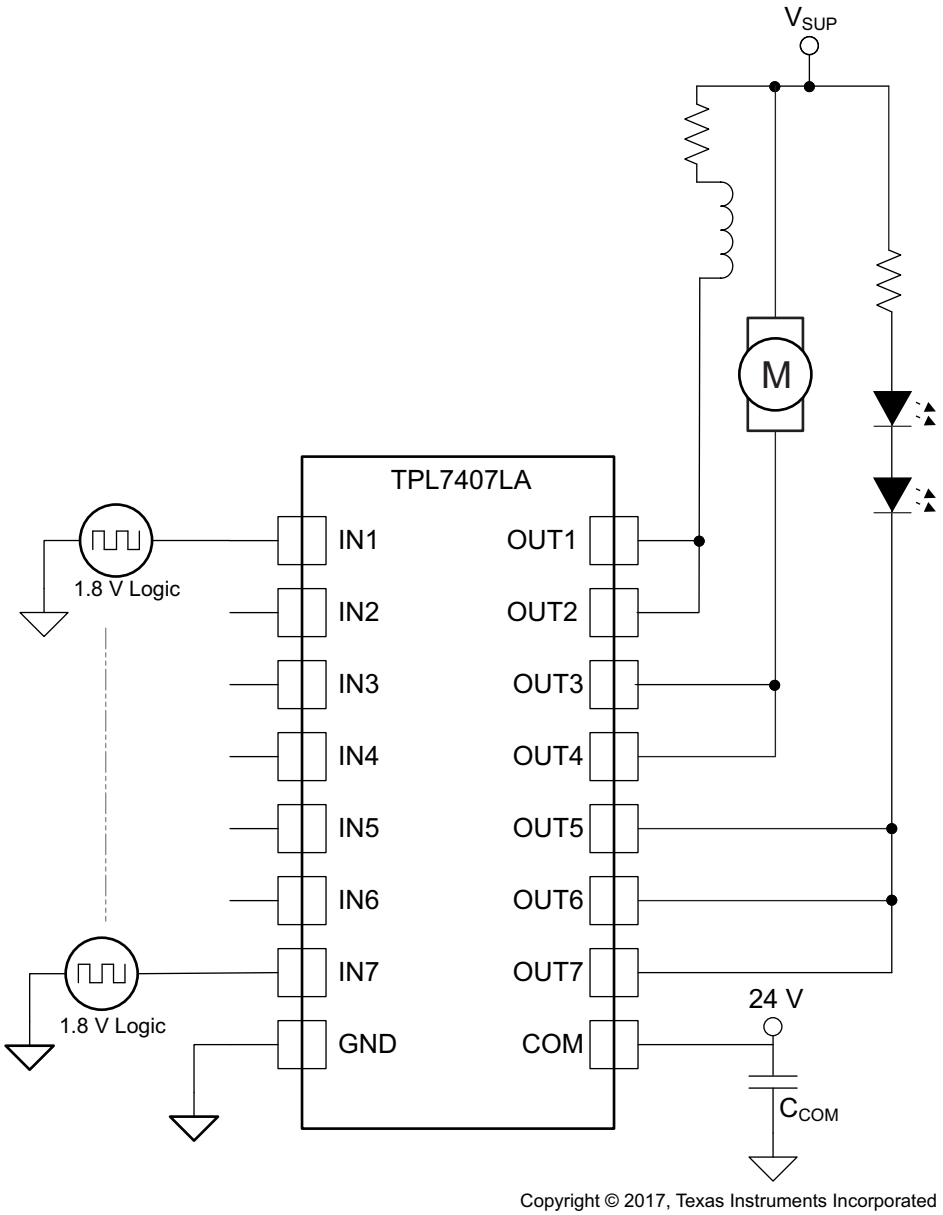
Figure 5. Stepper Motor Driver Schematic

Figure 5 shows an implementation of the TPL7407LA for driving a uniploar stepper motor. The unconnected input channels can be used for other functions. When an input pin is left open the internal 1-MΩ pull down resistor pulls the respective input pin to GND potential. For higher noise immunity use an external short across an unconnected input and GND pins. The COM pin must be tied to the supply of whichever inductive load is being driven for the driver to be protected by the free-wheeling diode.

Application Information (continued)

For more information on this application, see the *Stepper Motor Driving With Peripheral Drivers (Driver ICs)* application report.

8.1.2 Multi-Purpose Sink Driver



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Figure 6. Multi-Purpose Sink Driver Schematic

When configured as per Figure 6, the TPL7407LA may be used as a multi-purpose driver. The output channels may be tied together to sink more current. The TPL7407LA can easily drive motors, relays & LEDs with little power dissipation. COM must be tied to highest load voltage, which may or may not be same as inductive load supply.

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8.2 Typical Application

A common application for the TPL7407LA is driving inductive loads such as relays, solenoids, and unipolar stepper motors.

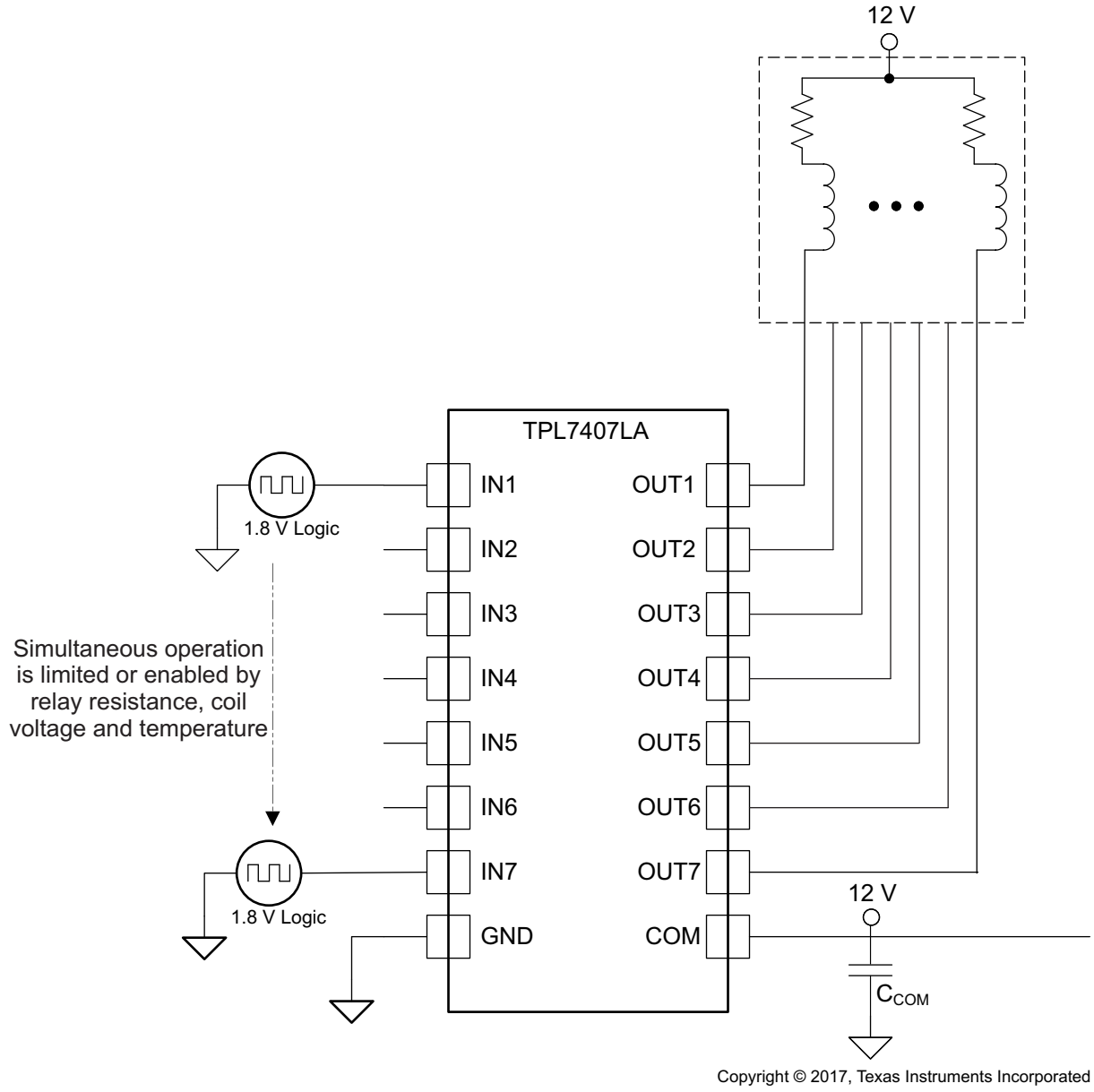


Figure 7. Inductive Load Driver Schematic

Typical Application (continued)

8.2.1 Design Requirements

For this design example, use the parameters listed in Table 1 as the input parameters.

Table 1. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
GPIO Voltage	1.8 V, 3.3 V or 5 V
Coil supply voltage	6.5 V to 30 V
Number of channels	7
Output current (R_{COIL})	20 mA to 300 mA per channel
C_{COM}	0.1 µF
Duty cycle	100%

8.2.2 Detailed Design Procedure

When using the TPL7407LA in a coil driving application, determine the following:

- Input Voltage Range
- Temperature Range
- Output & Drive Current
- Power Dissipation

8.2.2.1 TTL and other Logic Inputs

The TPL7407LA input interface is specified for standard 1.8 V through 5 V CMOS logic interface and can tolerate up to 30 V. At any input voltage the output drivers is going to be driven at its maximum when Vcom is greater than or equal to 6.5 V.

8.2.2.2 Input RC Snubber

The TPL7407LA features an input RC snubber that helps prevent spurious switching in noisy environments. Connect an external 1 kΩ to 5 kΩ resistor in series with the input to further enhance the TPL7407LA's noise tolerance.

8.2.2.3 High-Impedance Input Drivers

The TPL7407LA features a 1-MΩ input pull-down resistor. The presence of this resistor allows the input drivers to be tri-stated. When a high-impedance driver is connected to a channel input the TPL7407LA detects the channel input as a low level input and remains in the OFF position. The input RC snubber helps improve noise tolerance when input drivers are in the high-impedance state.

8.2.2.4 Drive Current

The coil current is determined by the coil voltage (V_{SUP}), coil resistance & output low voltage (V_{OL}) as shown in Equation 2.

$$I_{COIL} = (V_{SUP} - V_{OL})/R_{COIL} \quad (2)$$

8.2.2.5 Output Low Voltage

The output low voltage (V_{OL}) is drain to source (V_{DS}) voltage of the output NMOS transistors when the input is driven high and it is sinking current and can be determined by the *Specifications* section or Figure 1.

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8.2.3 Application Curve

Figure 8 was generated with TPL7407LA driving an OMRON G5NB relay -- V_{in} = 5 V; V_{sup} = 12 V & R_{COIL} = 2.8 kΩ

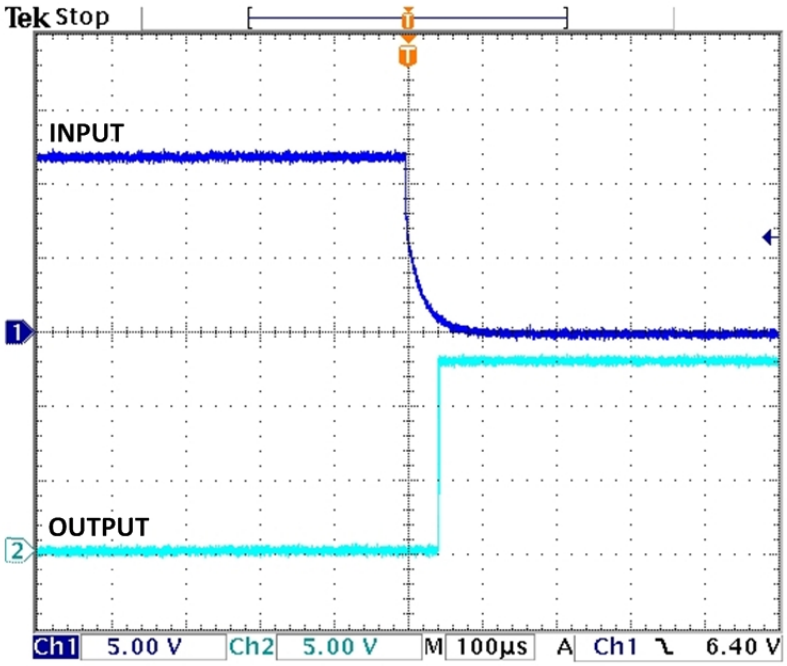


Figure 8. Output Response With De-Activation of Coil (Turnoff)

9 Power Supply Recommendations

The COM pin is the power supply pin of this device to power the gate drive circuitry. While a bypass capacitor on this pin is recommended for sensitive power supplies, it is not required for proper operation of the device. The COM pin supply ensures full drive potential with any GPIO above 1.5 V. The gate drive circuitry is based on low voltage CMOS transistors that can only handle a max gate voltage of 7 V. An integrated LDO reduces the COM voltage of 6.5 V to 30 V to a regulated voltage of 5.3 V. Though 6.5 V minimum is recommended for Vcom, the part still functions with a reduced COM voltage that has a reduced gate drive voltage and a resulting higher Rdson.

10 Layout

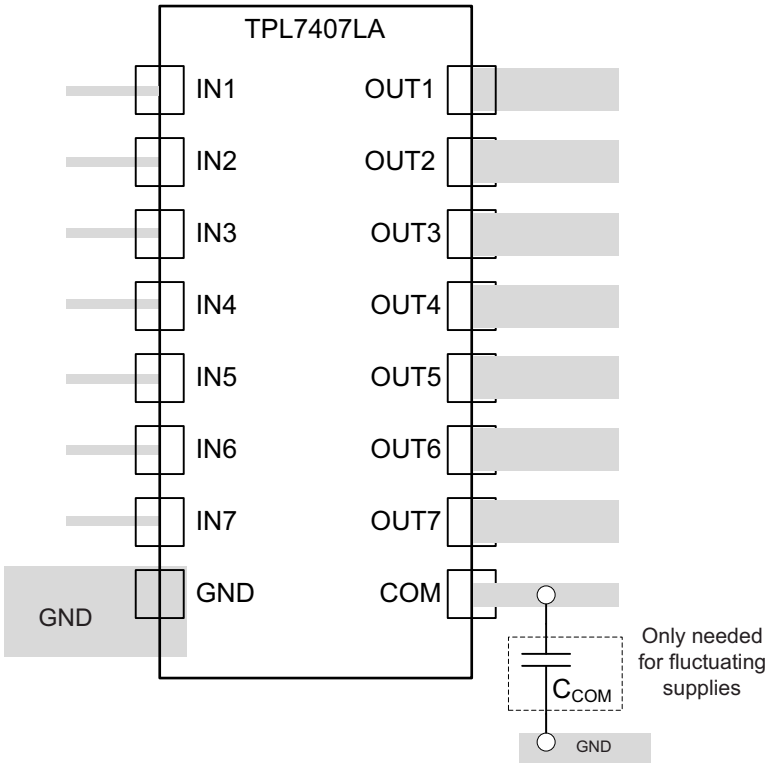
10.1 Layout Guidelines

Thin traces can be used on the input due to the low current logic that is typically used to drive the TPL7407LA. Care must be taken to separate the input channels as much as possible, as to eliminate cross-talk. Thick traces are recommended for the output, in order to drive whatever high currents that may be needed. Wire thickness can be determined by the trace material's current density and desired drive current.

Since all of the channels currents return to a common ground, it is best to size that trace width to be very wide. Some applications require up to 2 A.

Since the COM pin only draws up to 30 µA, thick traces are not necessary.

10.2 Layout Example



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Figure 9. Package Layout

10.3 Thermal Considerations

The number of coils driven is dependent on the coil current and on-chip power dissipation. The number of coils driven can be determined by Figure 3 or Figure 4.

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Thermal Considerations (continued)

For a more accurate determination of number of coils possible, use Equation 3 to calculate TPL7407LA on-chip power dissipation P_D:

$$P_D = \sum_{i=1}^{N} V_{OLi} \times I_{Li}$$

where

- N is the number of channels active together
- V_{OLi} is the OUT_i pin voltage for the load current I_{Li}. This is the same as $V_{CE(SAT)}$ (3)

In order to guarantee reliability of TPL7407LA and the system, the on-chip power dissipation must be lower than or equal to the maximum allowable power dissipation ($P_{D(MAX)}$) dictated by below equation Equation 4.

$$PD_{(MAX)} = \left(T_{J(MAX)} - T_A\right) \Big/ \theta_{JA}$$

where

- $T_{J(MAX)}$ is the target maximum junction temperature
- T_A is the operating ambient temperature
- θ_{JA} is the package junction to ambient thermal resistance (4)

It is recommended to limit rhe TPL7407LA IC's die junction temperature to less than 125°C. The IC junction temperature is directly proportional to the on-chip power dissipation.

10.3.1 Improving Package Thermal Performance

θ_{JA} value depends on the PC board layout. An external heat sink and/or a cooling mechanism, like a cold air fan, can help reduce θ_{JA} and thus improve device thermal capabilities. Refer to TI's design support web page at www.ti.com/thermal for a general guidance on improving device thermal performance.

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11 Device and Documentation Support

11.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.2 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.3 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

11.4 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

11.5 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TPL7407LAPWR	ACTIVE	TSSOP	PW	16	2000	TBD	Call TI	Call TI	-40 to 125	TPL747LA	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

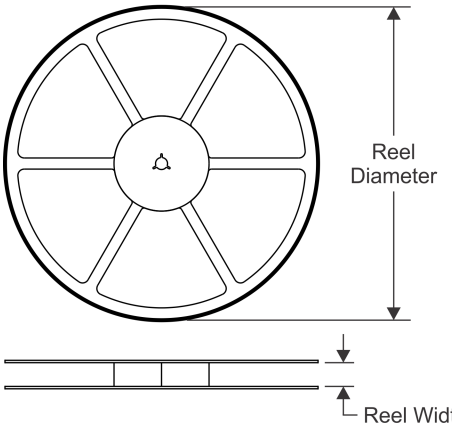
(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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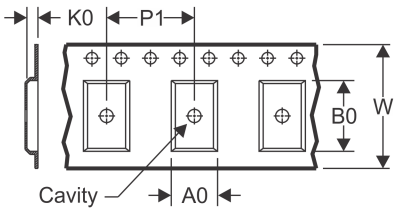
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TAPE AND REEL INFORMATION

REEL DIMENSIONS

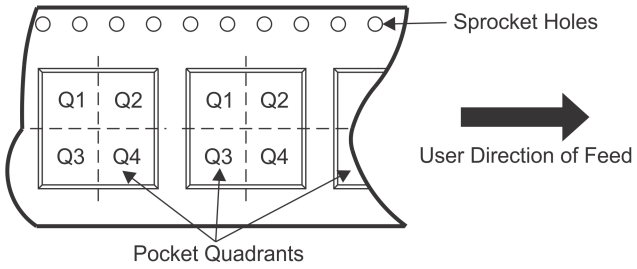


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

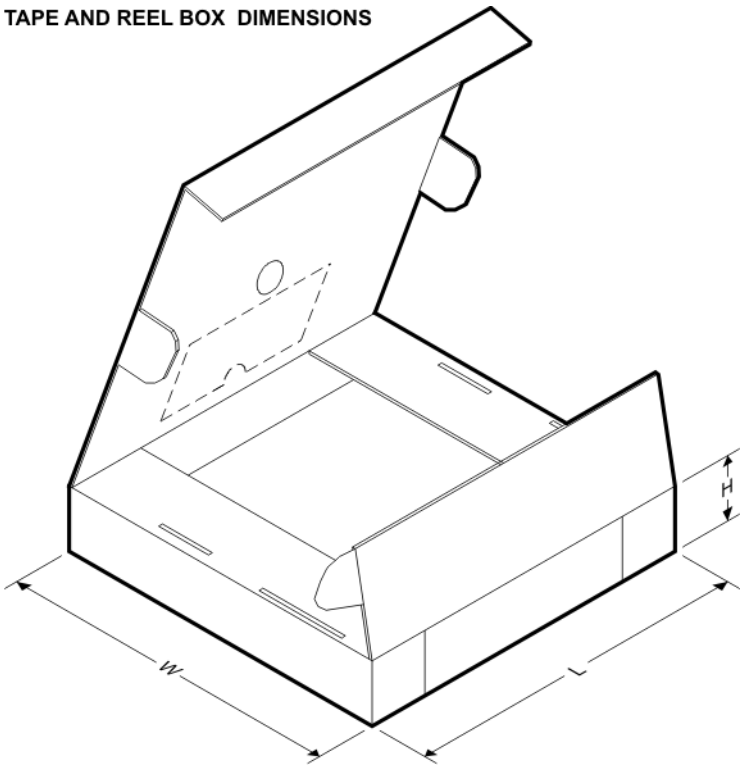
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPL7407LAPWR	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1

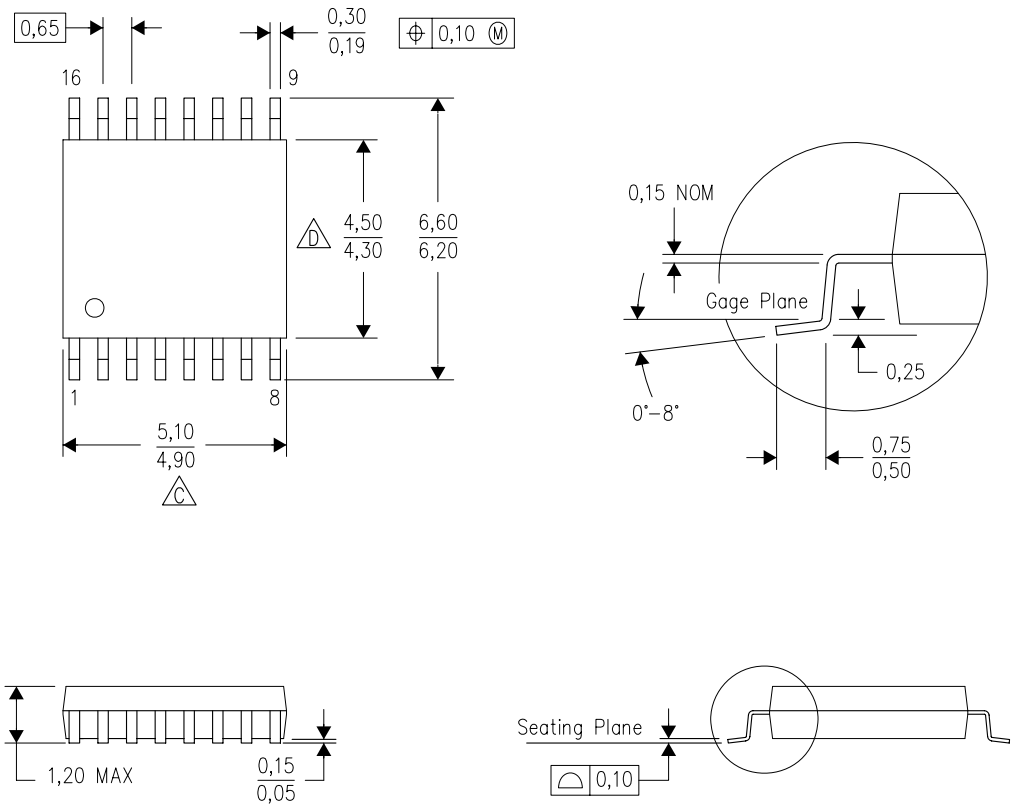
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPL7407LAPWR	TSSOP	PW	16	2000	364.0	364.0	27.0

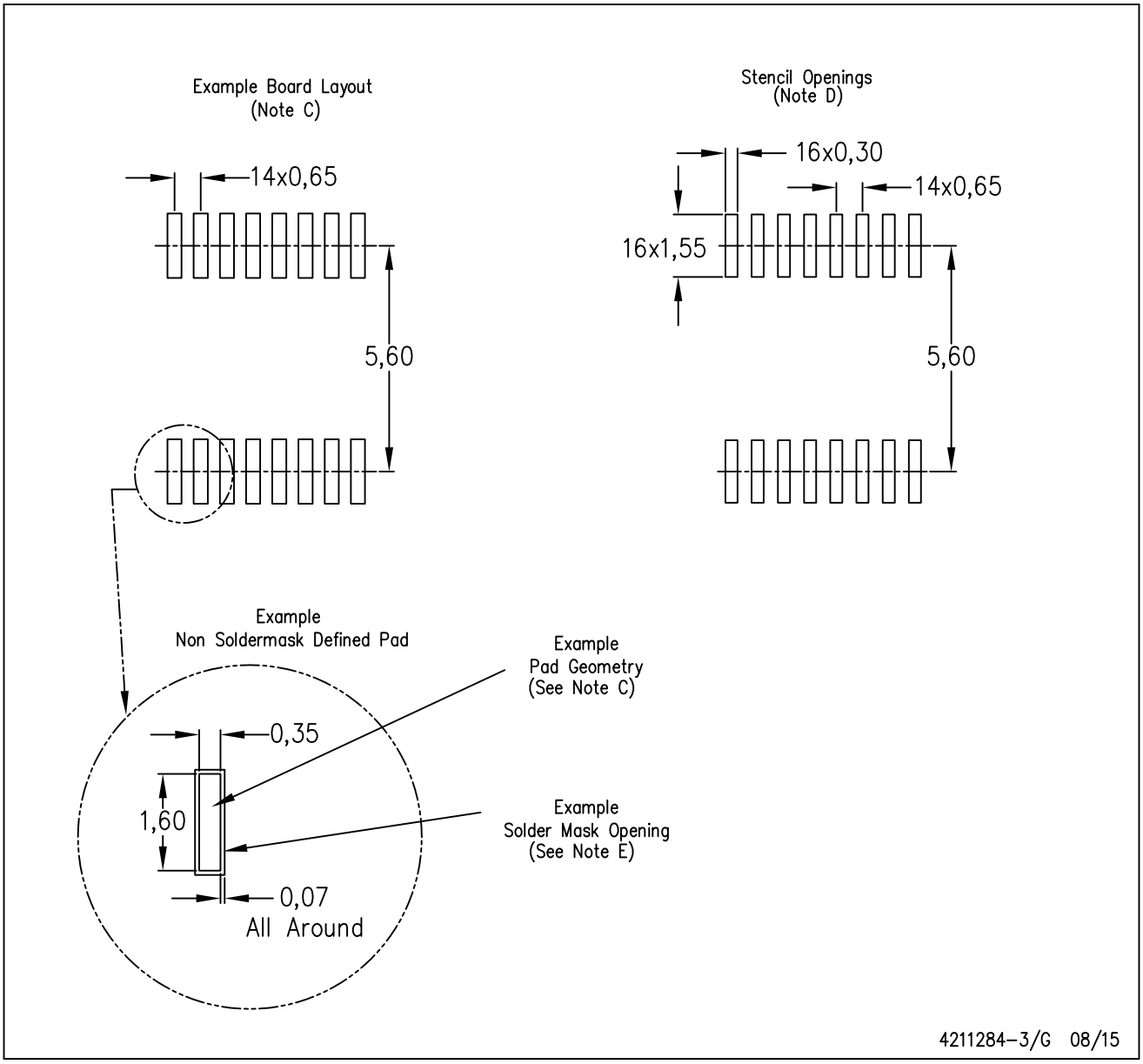
PW (R–PDSO–G16) PLASTIC SMALL OUTLINE



4040064–4/G 02/11

NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.
E. Falls within JEDEC MO–153

PW (R–PDSO–G16) PLASTIC SMALL OUTLINE



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC–7525 for other stencil recommendations.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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