

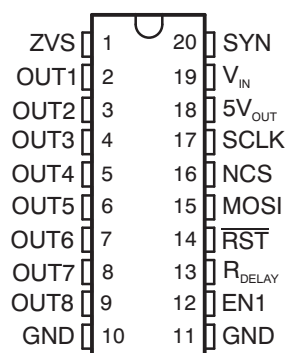
FEATURES

- Eight Low-Side Drivers With Internal Clamp for Inductive Loads and Current Limiting for Self Protection
 - Seven Outputs Rated at 150 mA and Controlled Through Serial Interface
 - One Output Rated at 150 mA and Controlled Through Serial Interface and Dedicated Enable Pin
- 5-V \pm 5% Regulated Power Supply With 200-mA Load Capability at V_{IN} Max of 18 V
- Internal Voltage Supervisory for Regulated Output
- Serial Communications for Control of Eight Low-Side Drivers
- Enable/Disable Input for OUT1
- 5-V or 3.3-V I/O Tolerant for Interface to Microcontroller
- Programmable Power-On Reset Delay Before \overline{RST} Asserted High, Once 5 V Is Within Specified Range (6 ms Typ)
- Programmable Deglitch Timer Before \overline{RST} Is Asserted Low (40 μ s Typ)
- Zero-Voltage Detection Signal With Built-In Filter of 20 μ s
- Thermal Shutdown for Self Protection

APPLICATIONS

- Electrical Appliances
 - Air Conditioning Units
 - Ranges
 - Dishwashers
 - Refrigerators
 - Microwaves
 - Washing Machines
- General-Purpose Interface Circuits, Allowing Microcontroller Interface to Relays, Electric Motors, LEDs, and Buzzers

N OR PWP PACKAGE
(TOP VIEW)



DESCRIPTION/ORDERING INFORMATION

The power supply provides regulated 5-V output to power the system microcontroller and drive eight low-side switches. The AC zero-detect circuitry is monitoring the crossover voltage of the mains AC supply. The resultant signal is a low-frequency clock output on the ZVS terminal, based on the AC-line cycle. This information allows the microcontroller to reduce in-rush current by powering loads on the AC-line peak voltage.

A serial communications interface controls the eight low-side outputs; each output has an internal snubber circuit to absorb the energy in the inductor at turn OFF. Alternatively, the system can use a fly-back diode to V_{IN} to help recirculate the energy in an inductive load at turn OFF.

ORDERING INFORMATION

T_A	PACKAGE		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 125°C	PDIP – N	Tube of 20	TPL9201N	TPL9201
	PowerPAD™ – PWP	Reel of 2000	TPL9201PWPR	IC9201
		Tube of 70	TPL9201PWP	



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

PowerPAD is a trademark of Texas Instruments.

TPL9201
8-CHANNEL RELAY DRIVER
WITH INTEGRATED 5-V LDO AND ZERO-VOLT DETECTION

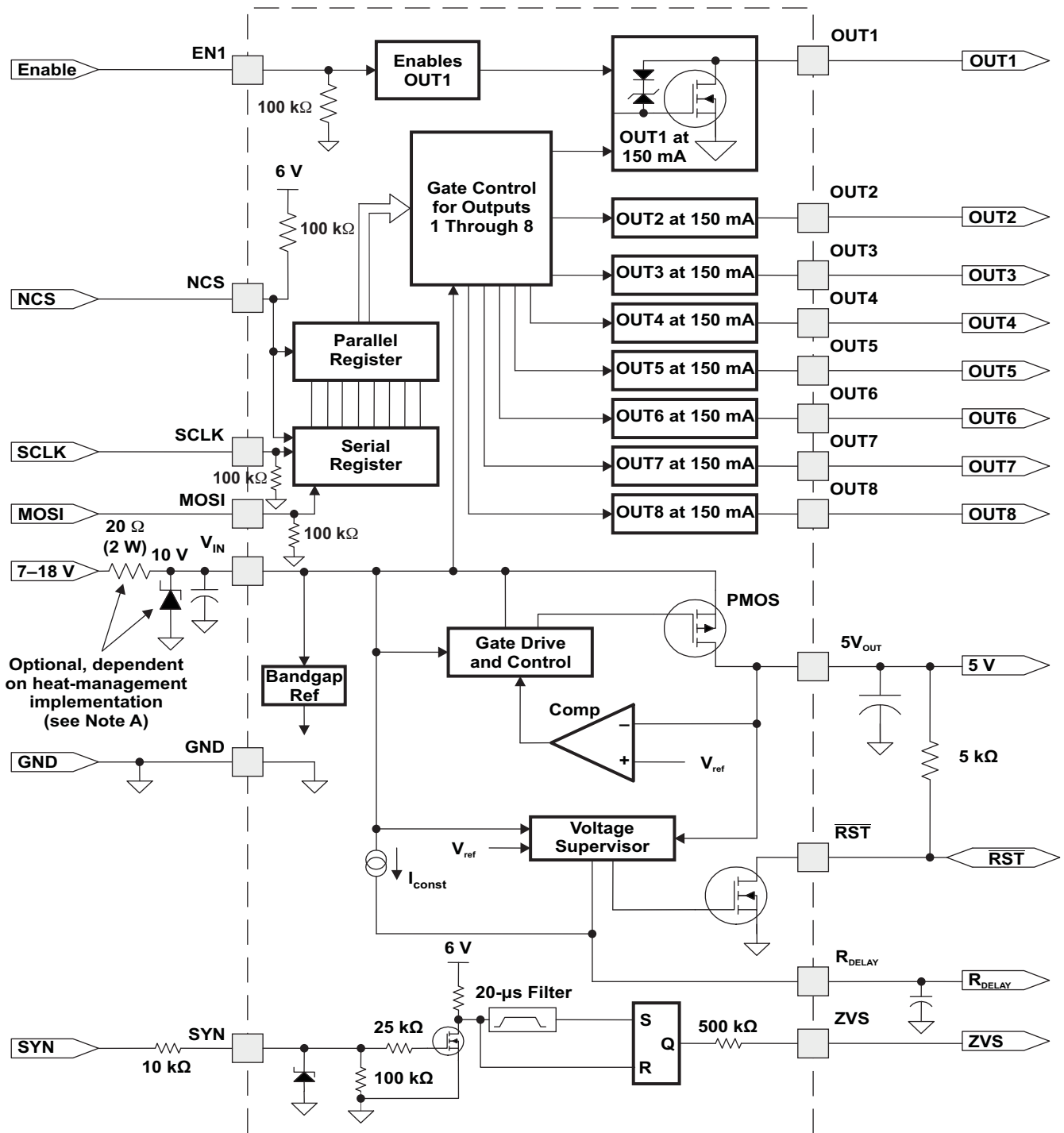
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PINOUT CONFIGURATION

NO.	NAME	I/O	DESCRIPTION
1	ZVS	O	Zero-voltage synchronization
2	OUT1	O	Low-side output 1
3	OUT2	O	Low-side output 2
4	OUT3	O	Low-side output 3
5	OUT4	O	Low-side output 4
6	OUT5	O	Low-side output 5
7	OUT6	O	Low-side output 6
8	OUT7	O	Low-side output 7
9	OUT8	O	Low-side output 8
10 ⁽¹⁾	GND	I	Ground
11 ⁽¹⁾	GND	I	Ground
12	EN1	I	Enable/disable for OUT1
13	R _{DELAY}	O	Power-up reset delay
14 ⁽²⁾	$\overline{\text{RST}}$	I/O	Power-on reset output (open drain, active low)
15	MOSI	I	Serial data input
16	NCS	I	Chip select
17	SCLK	I	Serial clock for data synchronization
18	5V _{OUT}	O	Regulated output
19	V _{IN}	I	Unregulated input voltage source
20	SYN	I	AC zero detect input

- (1) Terminals 10 and 11 are fused internally in the lead frame for the 20-pin PDIP package.
(2) Terminal 14 can be used as an input or an output.

FUNCTIONAL BLOCK DIAGRAM



A. The resistor and Zener diode are required if there is insufficient thermal-management allocation.

TPL9201

8-CHANNEL RELAY DRIVER

WITH INTEGRATED 5-V LDO AND ZERO-VOLT DETECTION

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DETAILED DESCRIPTION

The 5-V regulator is powered from V_{IN} , and the regulated output is within $5\text{ V} \pm 5\%$ over the operating conditions. The open-drain power-on reset ($\overline{\text{RST}}$) pin remains low until the regulator exceeds the set threshold, and the timer value set by the capacitor on the reset delay (R_{DELAY}) pin expires. If both of these conditions are satisfied, $\overline{\text{RST}}$ is asserted high. This signifies to the microcontroller that serial communications can be initiated to the TPL9201.

The serial communications is an 8-bit format, with data transfer synchronized using a serial clock from the microcontroller. A single register controls all the outputs (one bit per output). The default value is zero (OFF). If an output requires pulse width modulation (PWM) function, the register must be updated at a rate faster than the desired PWM frequency. OUT1 can be controlled by serial input from the microcontroller or with the dedicated enable (EN1) pin. If EN1 is pulled low or left open, the serial input through the shift register controls OUT1. If EN1 is pulled high, OUT1 always is turned on, and the serial input for OUT1 is ignored.

The SYN input translates the image of the mains voltage through the secondary of the transformer. The SYN input has a resistor to protect from high currents into the IC. The zero-voltage synchronization output translates the AC-line cycle frequency into a low-frequency clock, which can be used for a timing reference and to help power loads on the AC-line peak voltage (to reduce in-rush currents).

If $\overline{\text{RST}}$ is asserted, all outputs are turned OFF internally, and the input register is reset to all zeroes. The microcontroller must write to the register to turn the outputs ON again.

Absolute Maximum Ratings⁽¹⁾

		MIN	MAX	UNIT
$V_{I(\text{unreg})}$	Unregulated input voltage ⁽²⁾⁽³⁾	V_{IN}	24	V
		SYN	24	
$V_{I(\text{logic})}$	Logic input voltage ⁽²⁾⁽³⁾	EN1, MOSI, SCLK, and NCS	7	V
		\overline{RST} and R_{DELAY}	7	
V_O	Low-side output voltage		16.5	V
I_{LIMIT}	Output current limit ⁽⁴⁾	OUTn = ON and shorted to V_{IN} with low impedance		350 mA
θ_{JA}	Thermal impedance, junction to ambient ⁽⁵⁾	N package		69 °C/W
		PWP package		33
θ_{JC}	Thermal impedance, junction to case ⁽⁵⁾	N package		54 °C/W
		PWP package		20
θ_{JP}	Thermal impedance, junction to thermal pad ⁽⁵⁾	PWP package		1.4 °C/W
P_D	Continuous power dissipation ⁽⁶⁾	N package		1.8 W
		PWP package		3.7
ESD	Electrostatic discharge ⁽⁷⁾		2	kV
T_A	Operating ambient temperature range	–40	125	°C
T_{stg}	Storage temperature range	–65	125	°C
T_{lead}	Lead temperature	Soldering, 10 s		260 °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 GND.
- (3) Absolute negative voltage on these pins must not go below –0.5 V.
- (4) Not more than one output should be shorted at a time, and duration of the short circuit should not exceed 1 ms.
- (5) The thermal data is based on using 1-oz copper trace with JEDEC 51-5 test board for PWP and JEDEC 51-7 test board for N.
- (6) The data is based on ambient temperature of 25°C max.
- (7) The Human-Body Model is a 100-pF capacitor discharged through a 1.5-k Ω resistor into each pin.

Dissipation Ratings

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 125^\circ\text{C}$ POWER RATING
N	1812 mW	14.5 mW/°C	362 mW
PWP	3787 mW	30.3 mW/°C	757 mW

Recommended Operating Conditions

		MIN	MAX	UNIT		
$V_{I(\text{unreg})}$	Unregulated input voltage	V_{IN}	7	18	V	
		SYN	0	18		
$V_{I(\text{logic})}$	Logic input voltage	EN1, MOSI, SCLK, NCS, \overline{RST} , and R_{DELAY}		0	5.25	V
T_A	Operating ambient temperature	–40	125	°C		

TPL9201

8-CHANNEL RELAY DRIVER

WITH INTEGRATED 5-V LDO AND ZERO-VOLT DETECTION

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Electrical Characteristics

$T_A = -40^\circ\text{C}$ to 125°C , $V_{IN} = 7\text{ V}$ to 18 V (unless otherwise stated)

PARAMETER	TEST CONDITIONS	MIN	TYP ⁽¹⁾	MAX	UNIT		
Supply Voltage and Current							
$V_{IN}^{(2)}$	Input voltage	7		18	V		
I_{VIN}	Input supply current	Enable = ON, OUT1–OUT8 = OFF		3	mA		
		Enable = ON, OUT1–OUT8 = ON		5			
Logic Inputs (MOSI, NCS, SCLK, and EN1)							
V_{IL}	Logic input low level	$I_{IL} = 100\ \mu\text{A}$		0.8	V		
V_{IH}	Logic input high level	$I_{IL} = 100\ \mu\text{A}$		2.4			
Reset ($\overline{\text{RST}}$)							
V_{OL}	Logic level output	$I_{OL} = 1.6\ \text{mA}$		0.4	V		
$V_{OH}^{(3)}$	Logic level output	5-k Ω pullup to V_{CC}		$V_{CC} - 0.8$	V		
V_H	Disabling reset threshold	5-V regulator ramps up		4.25	4.5	V	
V_L	Enabling reset threshold	5-V regulator ramps down		3.3	3.75	V	
V_{HYS}	Threshold hysteresis			0.12	0.5	V	
Reset Delay (R_{DELAY})							
I_{OUT}	Output current			18	28	48	μA
T_{DW}	Reset delay timer	$C = 47\ \text{nF}$		3	6		ms
T_{UP}	Reset capacitor to low level	$C = 47\ \text{nF}$		45			μs
Output (OUT1–OUT8)							
V_{OL}	Output ON	$I_{OUTn} = 150\ \text{mA}$		0.4	0.7		V
I_{OH}	Output leakage	$V_{OH} = \text{Max of } 16.5\ \text{V}$		2			μA
Regulator Output ($5V_{OUT}$)							
$5V_{OUT}$	Output supply	$I_{5V_{OUT}} = 5\ \text{mA}$ to $200\ \text{mA}$, $V_{IN} = 7\ \text{V}$ to $18\ \text{V}$, $C_{5V_{OUT}} = 1\ \mu\text{F}$		4.75	5	5.25	V
$I_{5V_{OUT}} \text{ limit}$	Output short-circuit current	$5V_{OUT} = 0\ \text{V}$		200			mA
Thermal Shutdown							
T_{SD}	Thermal shutdown			150			$^\circ\text{C}$
T_{HYS}	Hysteresis			20			$^\circ\text{C}$
Zero Voltage Synchronization (ZVS)							
V_{SYNTH}	Transition threshold			0.4	0.75	1.1	V
I_{SYN}	Input activating current	$R_{ZV} = 10\ \text{k}\Omega$, $V_{SYN} = 24\ \text{V}$		2			mA
t_D	Transition filtering time	Rising and falling		10	30	70	μs

(1) All typical values are at $T_A = 25^\circ\text{C}$.

(2) There are external high-frequency noise-suppression capacitors and filter capacitors on V_{IN} .

(3) V_{CC} is the pullup resistor voltage.

Output Control Register

MSB						LSB	
IN8	IN7	IN6	IN5	IN4	IN3	IN2	IN1
0	0	0	0	0	0	0	0

INn = 0: Output OFF

INn = 1: Output ON

To operate the output in PWM mode, the output control register must be updated at a rate twice the desired PWM frequency of the output. Maximum PWM frequency is 5 kHz. The register is updated every 100 μs.

ENABLE TRUTH TABLE

EN1	SERIAL INPUT FOR OUT1	OUT1
Open	H	On
Open	L	Off
L	H	On
L	L	Off
H	H	On
H	L	On

Serial Communications Interface

The serial communications is an 8-bit format, with data transfer synchronized using a serial clock from the microcontroller (see Figure 1). A single register controls all the outputs. The signal gives the instruction to control the output of TPL9201.

The NCS signal enables the SCLK and MOSI data when it is low. After NCS is set low for T_1 , synchronization clock and data begin to transmit and, after the 8-bit data has been transmitted, NCS is set high again to disable SCLK and MOSI and transfer the serial data to the control register. SCLK must be held low when NCS is in the high state.

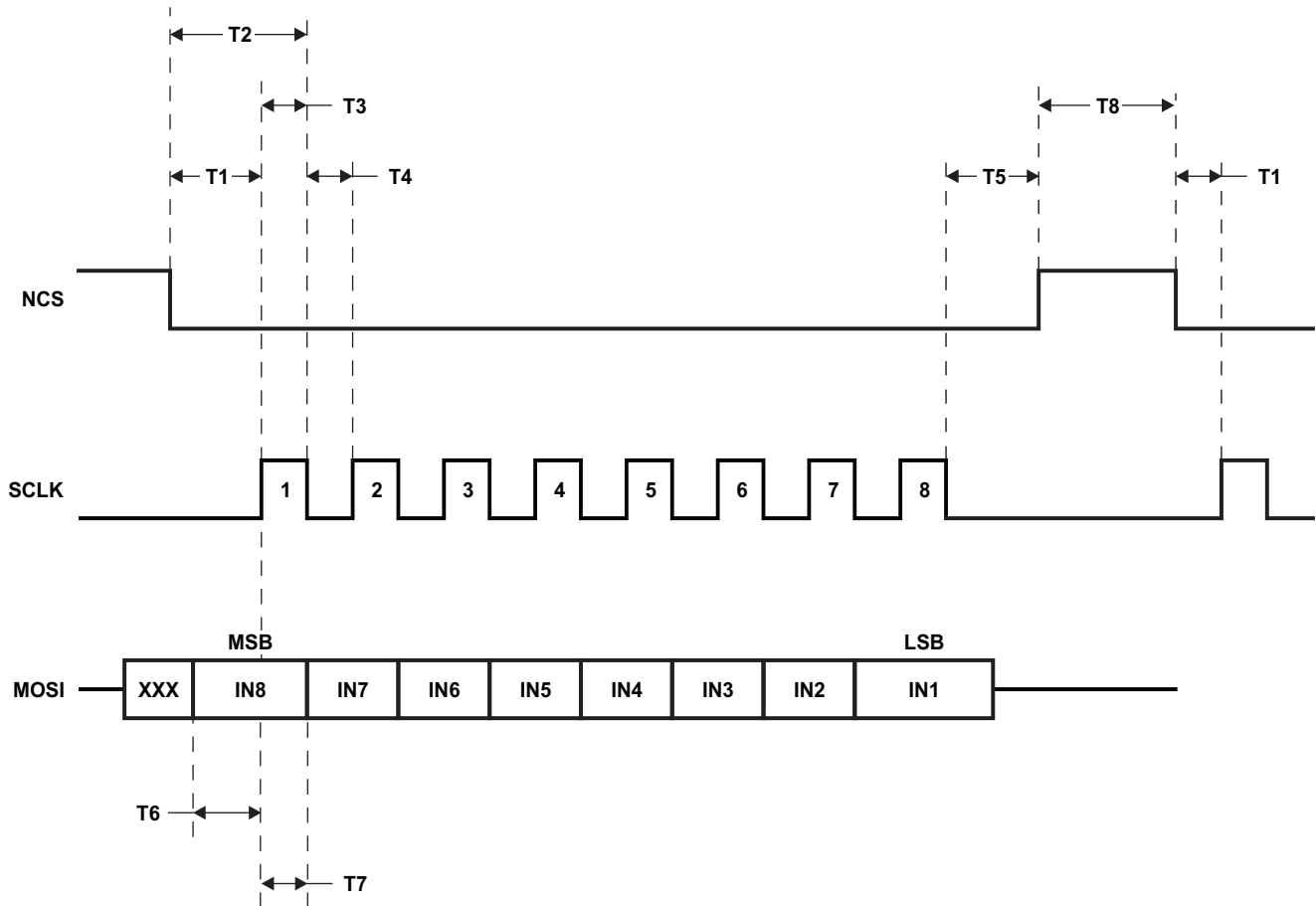


Figure 1. Serial Communications

Timing Requirements

$T_A = -40^\circ\text{C}$ to 125°C , $V_{IN} = 7\text{ V}$ to 18 V (unless otherwise stated)

PARAMETER		MIN	TYP	MAX	UNIT
f_{SPI}	SPI frequency		4		kHz
T1	Delay time, NCS falling edge to SCLK rising edge	10			ns
T2	Delay time, NCS falling edge to SCLK falling edge	80			ns
T3	Pulse duration, SCLK high	60			ns
T4	Pulse duration, SCLK low	60			ns
T5	Delay time, last SCLK falling edge to NCS rising edge	80			ns
T6	Setup time, MOSI valid before SCLK edge	10			ns
T7	Hold time, MOSI valid after SCLK edge	10			ns
T8	Time between two words for transmitting	170			ns

Reset Delay (R_{DELAY})

The R_{DELAY} output provides a constant current source to charge an external capacitor to approximately 6.5 V. The external capacitor is selected to provide a delay time, based on the current equation for a capacitor, $I = C(\Delta v/\Delta t)$ and a 28- μA typical output current.

Therefore, the user should select a 47-nF capacitor to provide a 6-ms delay at 3.55 V.

$$I = C(\Delta v/\Delta t)$$

$$28\ \mu\text{A} = C \times (3.55\ \text{V}/6\ \text{ms})$$

$$C = 47\ \text{nF}$$

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APPLICATION INFORMATION

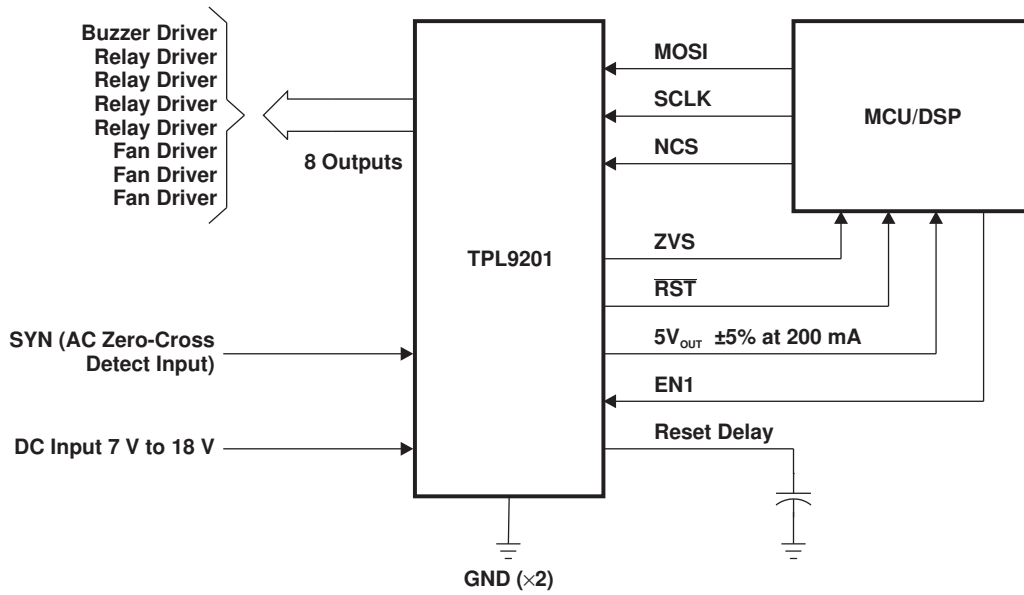


Figure 2. Typical Application

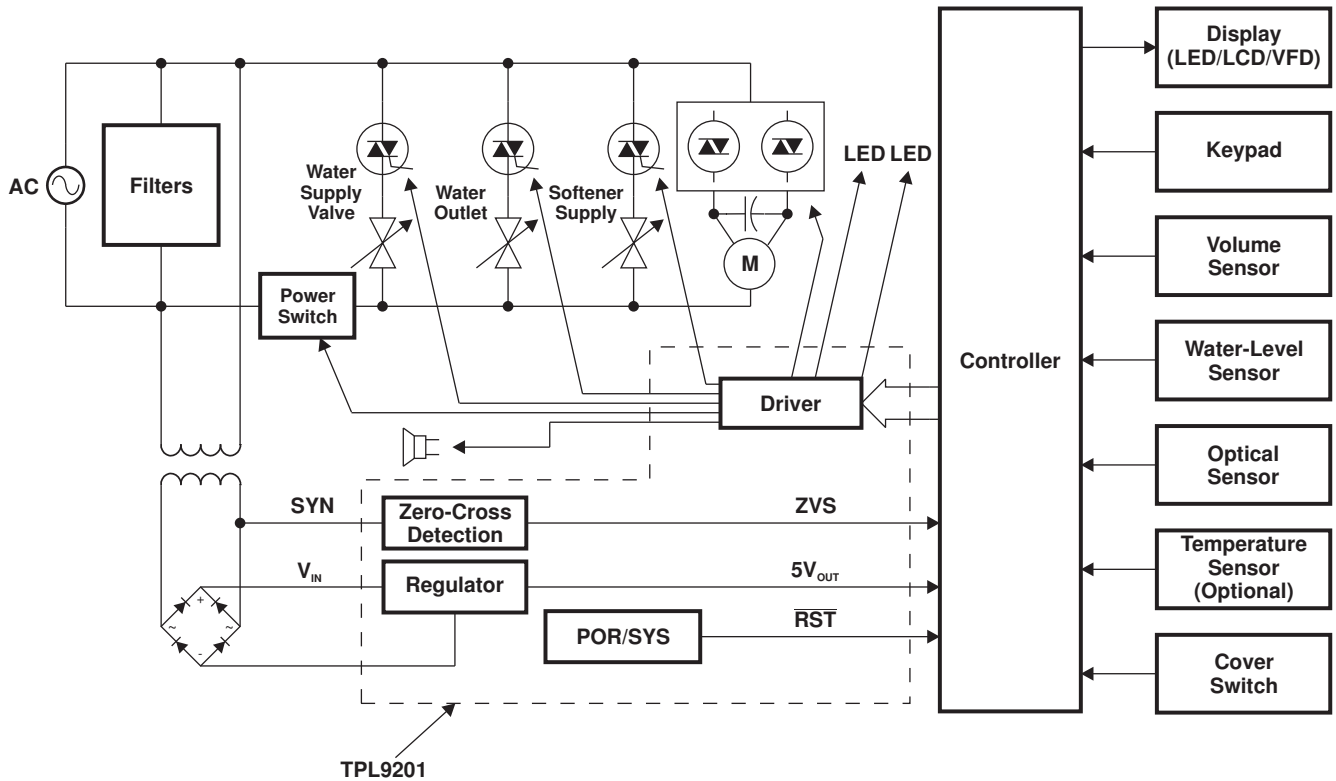


Figure 3. Washing-Machine Application

APPLICATION INFORMATION (continued)

PCB Layout

To maximize the efficiency of this package for application on a single-layer or multi-layer PCB, certain guidelines must be followed when laying out this part on the PCB.

The following information is to be used as a guideline only.

For further information, see the PowerPAD concept implementation document.

Application Using a Multilayer PCB

In a multilayer board application, the thermal vias are the primary method of heat transfer from the package thermal pad to the internal ground plane (see [Figure 4](#) and [Figure 5](#)).

The efficiency of this method depends on several factors: die area, number of thermal vias, thickness of copper, etc. (see the *PowerPAD™ Thermally Enhanced Package Technical Brief*, literature number [SLMA002](#)).

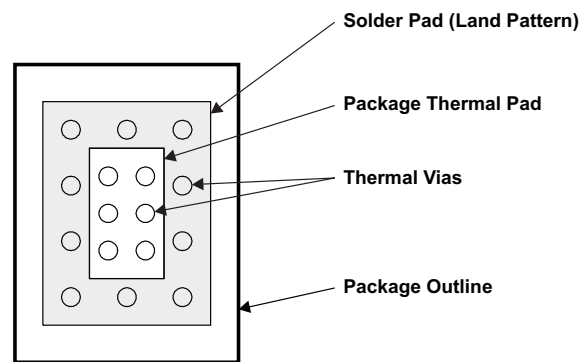


Figure 4. Package and PCB Land Configuration for a Multilayer PCB

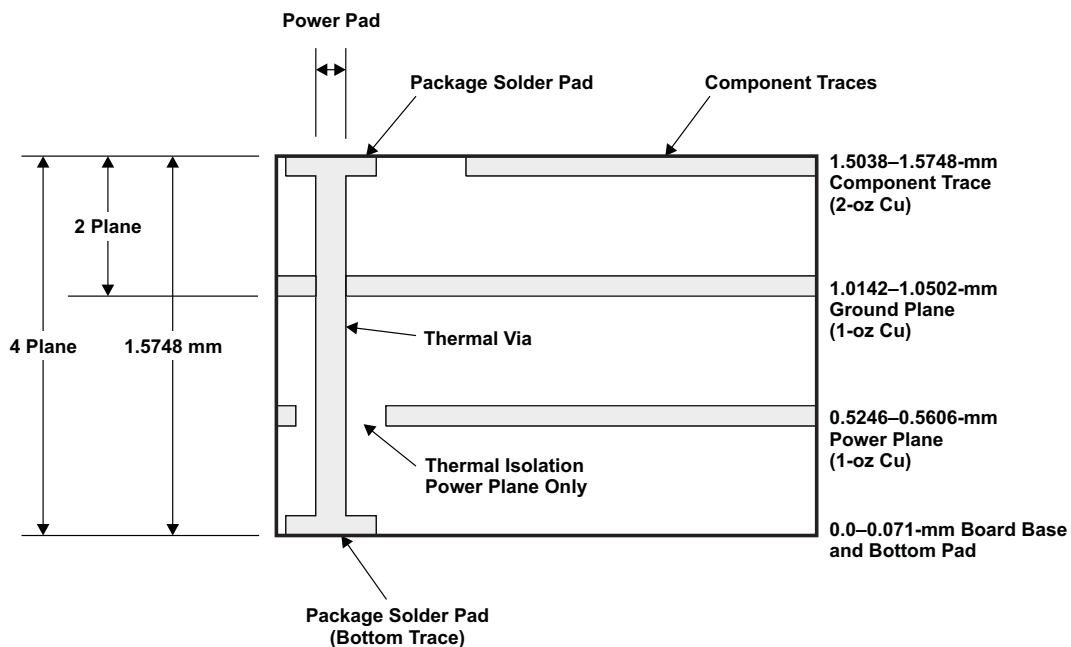


Figure 5. Multilayer Board (Side View)

APPLICATION INFORMATION (continued)

Application Using a Single-Layer PCB

In a single-layer board application, the thermal pad is attached to a heat spreader (copper area) by using the low thermal-impedance attachment method (solder paste or thermal-conductive epoxy). With either method, it is advisable to use as much copper trace area as possible to dissipate the heat.

CAUTION:

If the attachment method is not implemented correctly, the functionality of the product cannot be assured. Power-dissipation capability is adversely affected if the device is incorrectly mounted onto the circuit board.

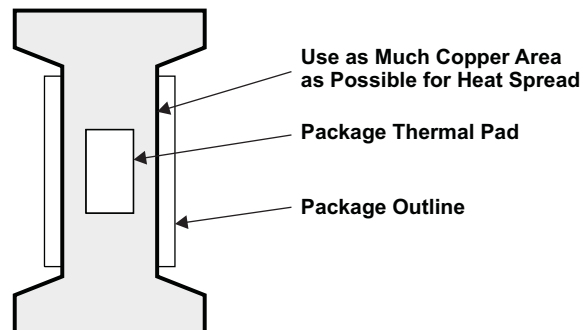


Figure 6. Layout Recommendations for a Single-Layer PCB

APPLICATION INFORMATION (continued)

Recommended Board Layout

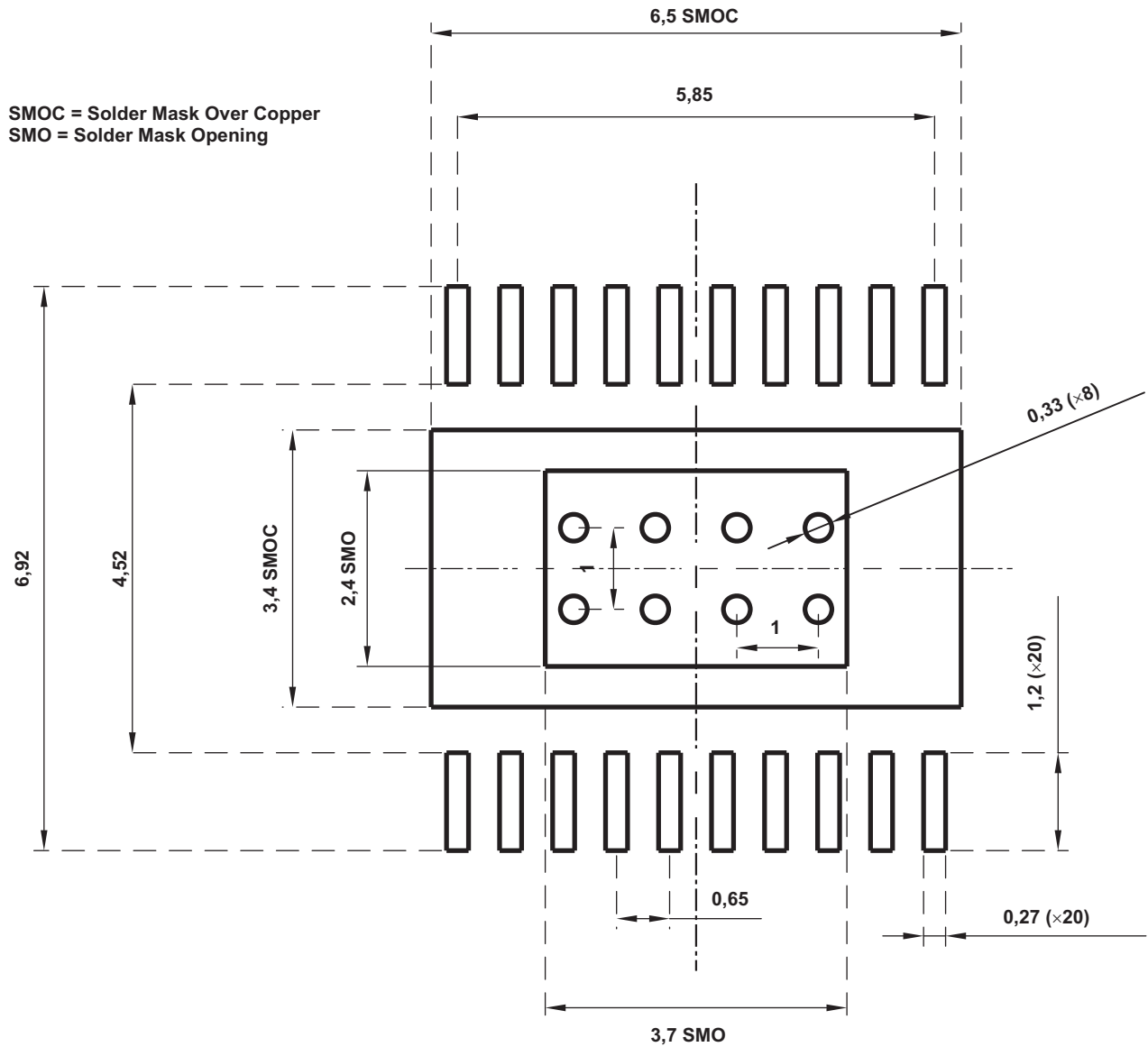


Figure 7. Recommended Board Layout for PWP

PACKAGING INFORMATION

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
TPL9201N	ACTIVE	PDIP	N	20	20	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TPL9201NE4	ACTIVE	PDIP	N	20	20	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TPL9201PWP	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1YEAR
TPL9201PWPG4	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1YEAR
TPL9201PWPR	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1YEAR
TPL9201PWPRG4	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1YEAR

⁽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.

OBSELETE: TI has discontinued the production of the device.

⁽²⁾ Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

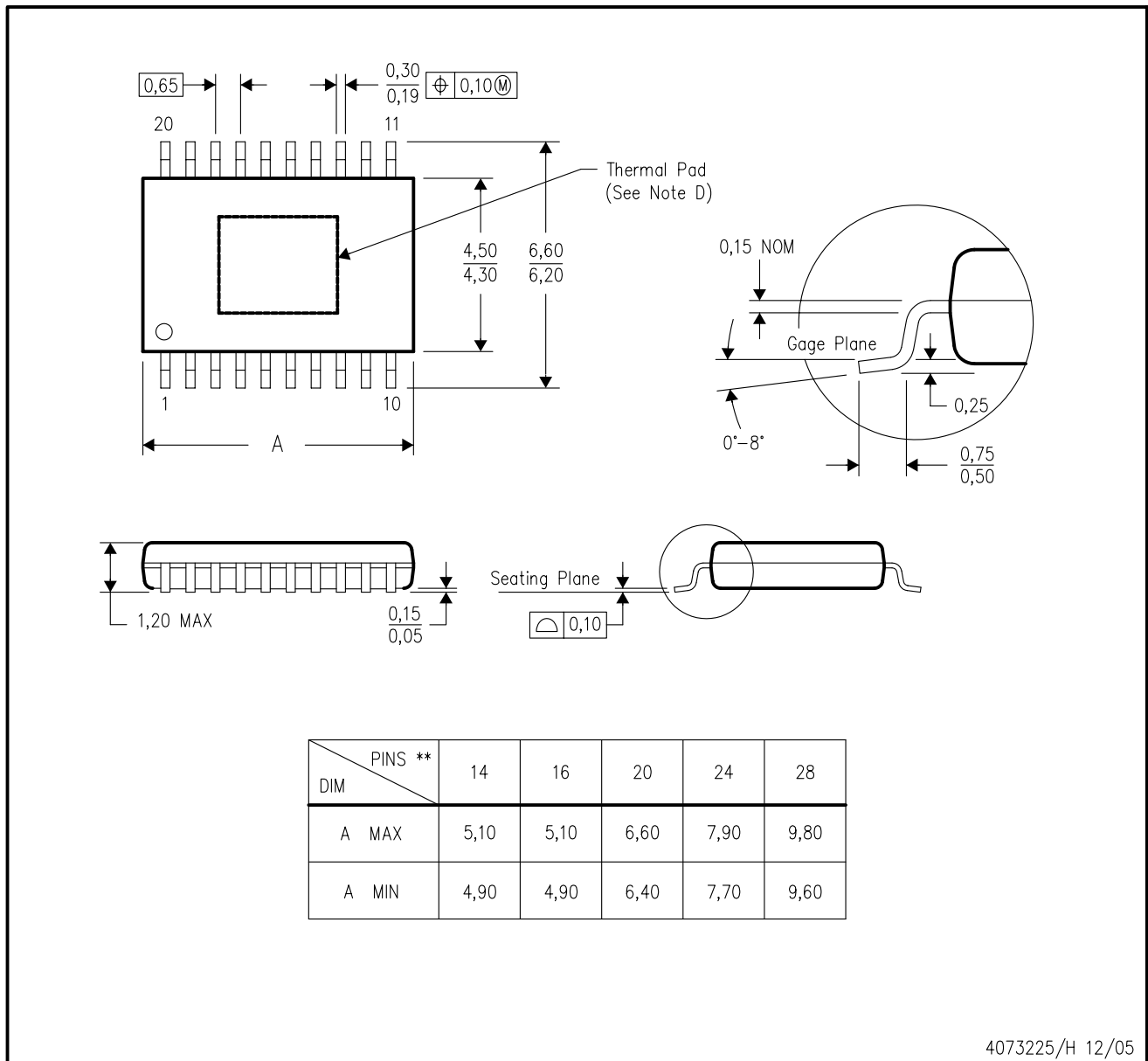
⁽³⁾ MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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PWP (R-PDSO-G**) 20 PIN SHOWN

PowerPAD™ PLASTIC SMALL-OUTLINE PACKAGE



4073225/H 12/05

- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Body dimensions do not include mold flash or protrusions. Mold flash and protrusion shall not exceed 0.15 per side.
 - D. This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at www.ti.com <<http://www.ti.com>>.
 - E. Falls within JEDEC MO-153

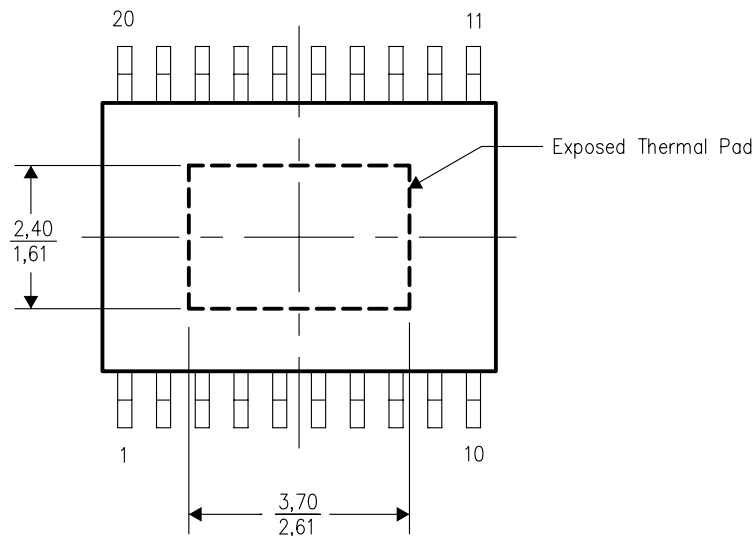
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THERMAL INFORMATION

This PowerPAD™ package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. When the thermal pad is soldered directly to the printed circuit board (PCB), the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to a ground plane or special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.

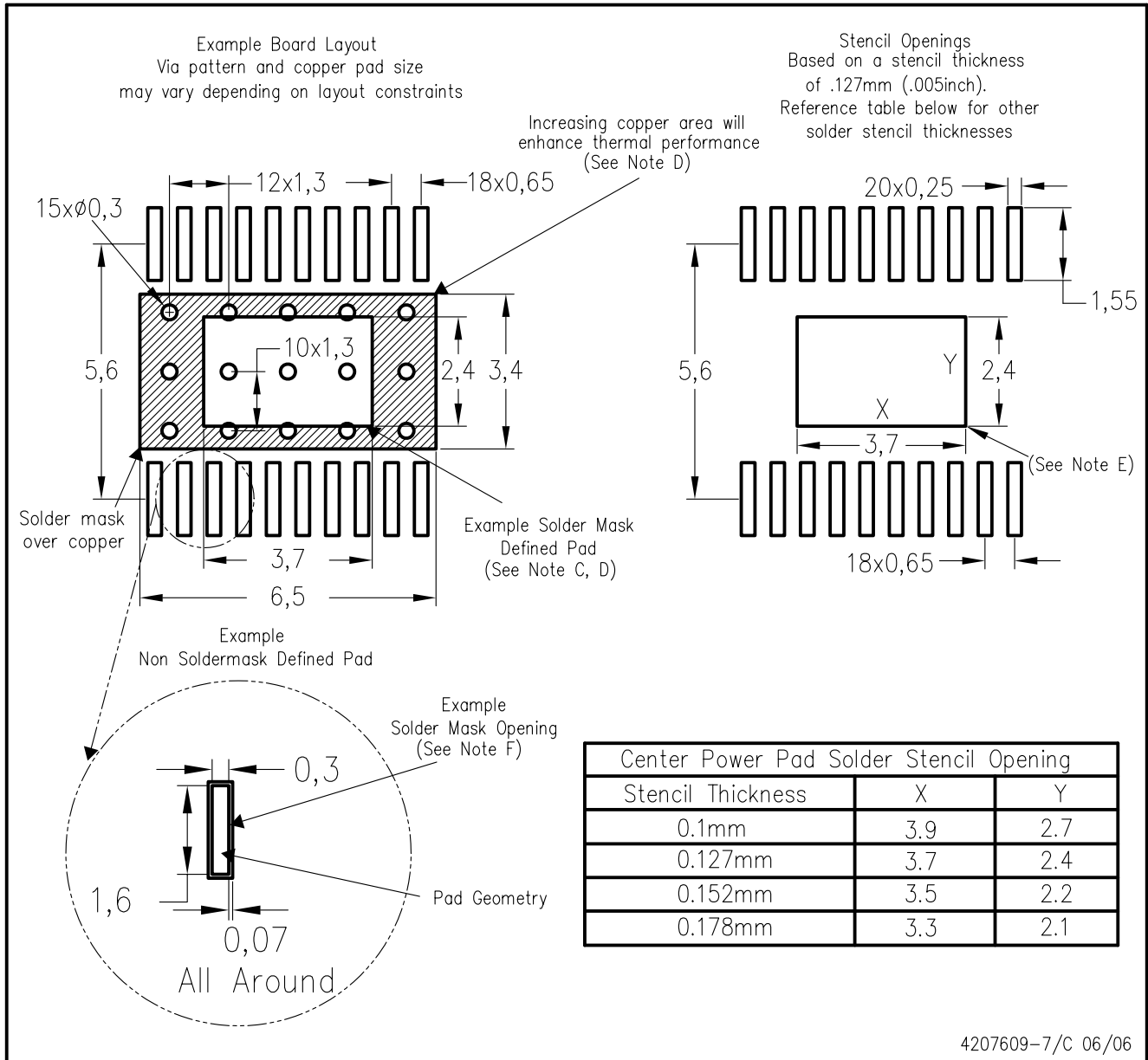


Top View

NOTE: All linear dimensions are in millimeters

Exposed Thermal Pad Dimensions

PWP (R-PDSO-G20) PowerPAD™



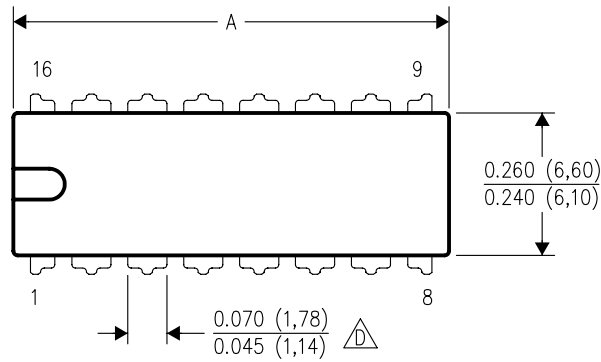
- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
 - D. This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002, SLMA004, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <<http://www.ti.com>>. Publication IPC-7351 is recommended for alternate designs.
 - E. 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. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.
 - F. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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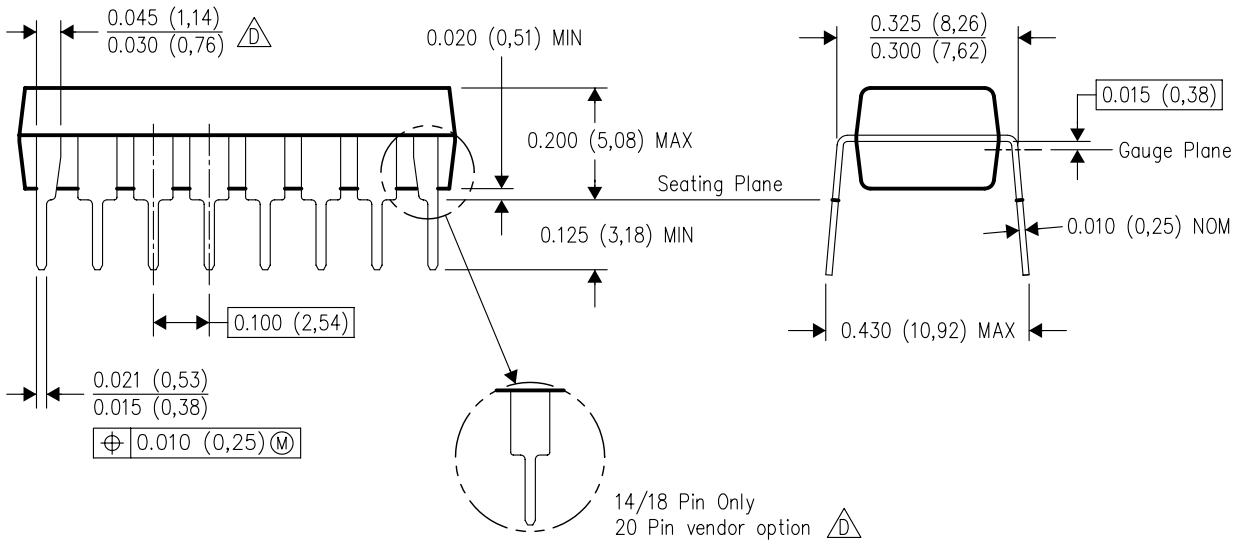
N (R-PDIP-T**)

PLASTIC DUAL-IN-LINE PACKAGE

16 PINS SHOWN



DIM	PINS **			
	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
MS-001 VARIATION	AA	BB	AC	AD



4040049/E 12/2002

- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - $\triangle C$ Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).
 - $\triangle D$ The 20 pin end lead shoulder width is a vendor option, either half or full width.

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