

Active Clamp Voltage Mode PWM Controller

Check for Samples: [LM5025](#)

FEATURES

- Internal Start-up Bias Regulator
- 3A Compound Main Gate Driver
- Programmable Line Under-Voltage Lockout (UVLO) with Adjustable Hysteresis
- Voltage Mode Control with Feed-Forward
- Adjustable Dual Mode Over-Current Protection
- Programmable Overlap or Deadtime between the Main and Active Clamp Outputs
- Volt x Second Clamp
- Programmable Soft-start
- Leading Edge Blanking
- Single Resistor Programmable Oscillator
- Oscillator UP / DOWN Sync Capability
- Precision 5V Reference
- Thermal Shutdown

PACKAGES

- TSSOP-16
- WSON-16 (5x5 mm) Thermally Enhanced

DESCRIPTION

The LM5025 PWM controller contains all of the features necessary to implement power converters utilizing the Active Clamp / Reset technique. The device can be configured to control either a P-Channel clamp switch or an N-Channel clamp switch. With the active clamp technique, higher efficiencies and greater power densities can be realized compared to conventional catch winding or RDC clamp / reset techniques. Two control outputs are provided, the main power switch control (OUT_A) and the active clamp switch control (OUT_B). The active clamp output can be configured for either a specified overlap time (for P-Channel switch applications) or a specified deadtime (for N-Channel applications). The two internal compound gate drivers parallel both MOS and Bipolar devices, providing superior gate drive characteristics. This controller is designed for high-speed operation including an oscillator frequency range up to 1MHz and total PWM and current sense propagation delays less than 100ns. The LM5025 includes a high-voltage start-up regulator that operates over a wide input range of 13V to 90V. Additional features include: Line Under Voltage Lockout (UVLO), softstart, oscillator UP/DOWN sync capability, precision reference and thermal shutdown.

Typical Application Circuit

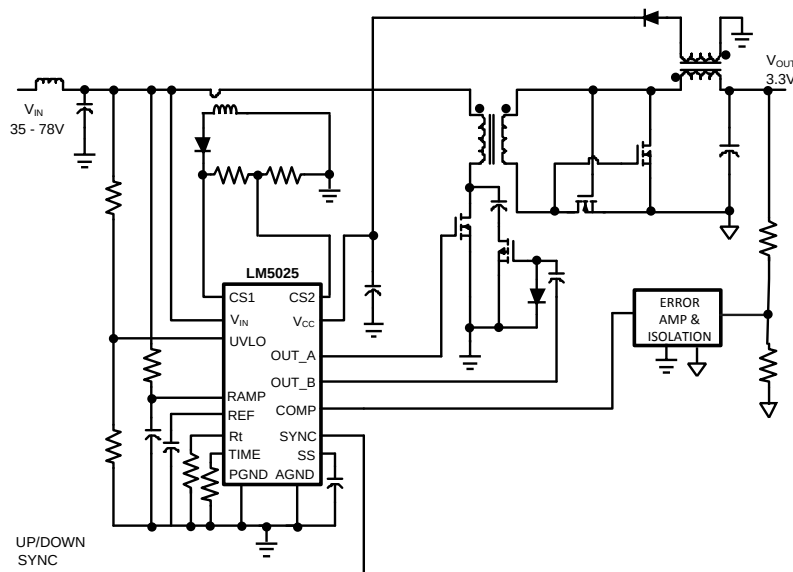


Figure 1. Simplified Active Clamp Forward Power Converter



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.

All trademarks are the property of their respective owners.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of the Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

Copyright © 2003–2013, Texas Instruments Incorporated

Connection Diagram

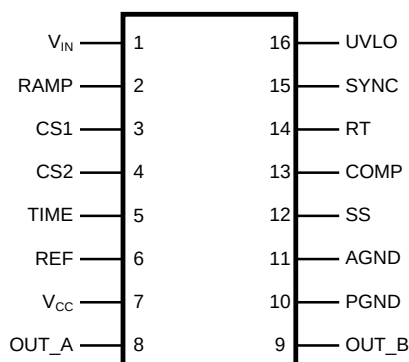


Figure 2. 16-Lead TSSOP, WSON

Table 1. Pin Descriptions

PIN	NAME	DESCRIPTION	APPLICATION INFORMATION
1	V _{IN}	Source Input Voltage	Input to start-up regulator. Input range 13V to 90V, with transient capability to 100V.
2	RAMP	Modulator ramp signal	An external RC circuit from Vin sets the ramp slope. This pin is discharged at the conclusion of every cycle by an internal FET, initiated by either the internal clock or the V*Sec Clamp comparator.
3	CS1	Current sense input for cycle-by-cycle limiting	If CS1 exceeds 0.25V the outputs will go into Cycle-by-Cycle current limit. CS1 is held low for 50ns after OUT_A switches high providing leading edge blanking.
4	CS2	Current sense input for soft restart	If CS2 exceeds 0.25V the outputs will be disabled and a softstart commenced. The soft-start capacitor will be fully discharged and then released with a pull-up current of 1μA. After the first output pulse (when SS =1V), the SS charge current will revert back to 20μA. CS2 is held low for 50ns after OUT_A switches high, providing leading edge blanking.
5	TIME	Output overlap/Deadtime control	An external resistor (R _{SET}) sets either the overlap time or dead time for the active clamp output. An R _{SET} resistor connected between TIME and GND produces in-phase OUT_A and OUT_B pulses with overlap. An R _{SET} resistor connected between TIME and REF produces out-of-phase OUT_A and OUT_B pulses with deadtime.
6	REF	Precision 5 volt reference output	Maximum output current: 10mA Locally decouple with a 0.1μF capacitor. Reference stays low until the line UVLO and the V _{CC} UV comparators are satisfied.
7	V _{CC}	Output from the internal high voltage start-up regulator. The V _{CC} voltage is regulated to 7.6V.	If an auxiliary winding raises the voltage on this pin above the regulation setpoint, the internal start-up regulator will shutdown, reducing the IC power dissipation.
8	OUT_A	Main output driver	Output of the main switch PWM output gate driver. Output capability of 3A peak sink current.
9	OUT_B	Active Clamp output driver	Output of the Active Clamp switch gate driver. Capable of 1.25A peak sink current..
10	PGND	Power ground	Connect directly to analog ground.
11	AGND	Analog ground	Connect directly to power ground. For the WSON package option the exposed pad is electrically connected to AGND.
12	SS	Soft-start control	An external capacitor and an internal 20μA current source set the softstart ramp. The SS current source is reduced to 1uA initially following a CS2 over-current event or an over temperature event.
13	COMP	Input to the Pulse Width Modulator	An internal 5KΩ resistor pull-up is provided on this pin. The external opto-coupler sinks current from COMP to control the PWM duty cycle.
14	RT	Oscillator timing resistor pin	An external resistor connected from RT to ground sets the internal oscillator frequency.

Table 1. Pin Descriptions (continued)

PIN	NAME	DESCRIPTION	APPLICATION INFORMATION
15	SYNC	Oscillator UP/DOWN synchronization input	The internal oscillator can be synchronized to an external clock with a frequency 20% lower than the internal oscillator's free running frequency. There is no constraint on the maximum sync frequency.
16	UVLO	Line Under-Voltage shutdown	An external voltage divider from the power source sets the shutdown comparator levels. The comparator threshold is 2.5V. Hysteresis is set by an internal current source (20μA) that is switched on or off as the UVLO pin potential crosses the 2.5V threshold.

Block Diagram

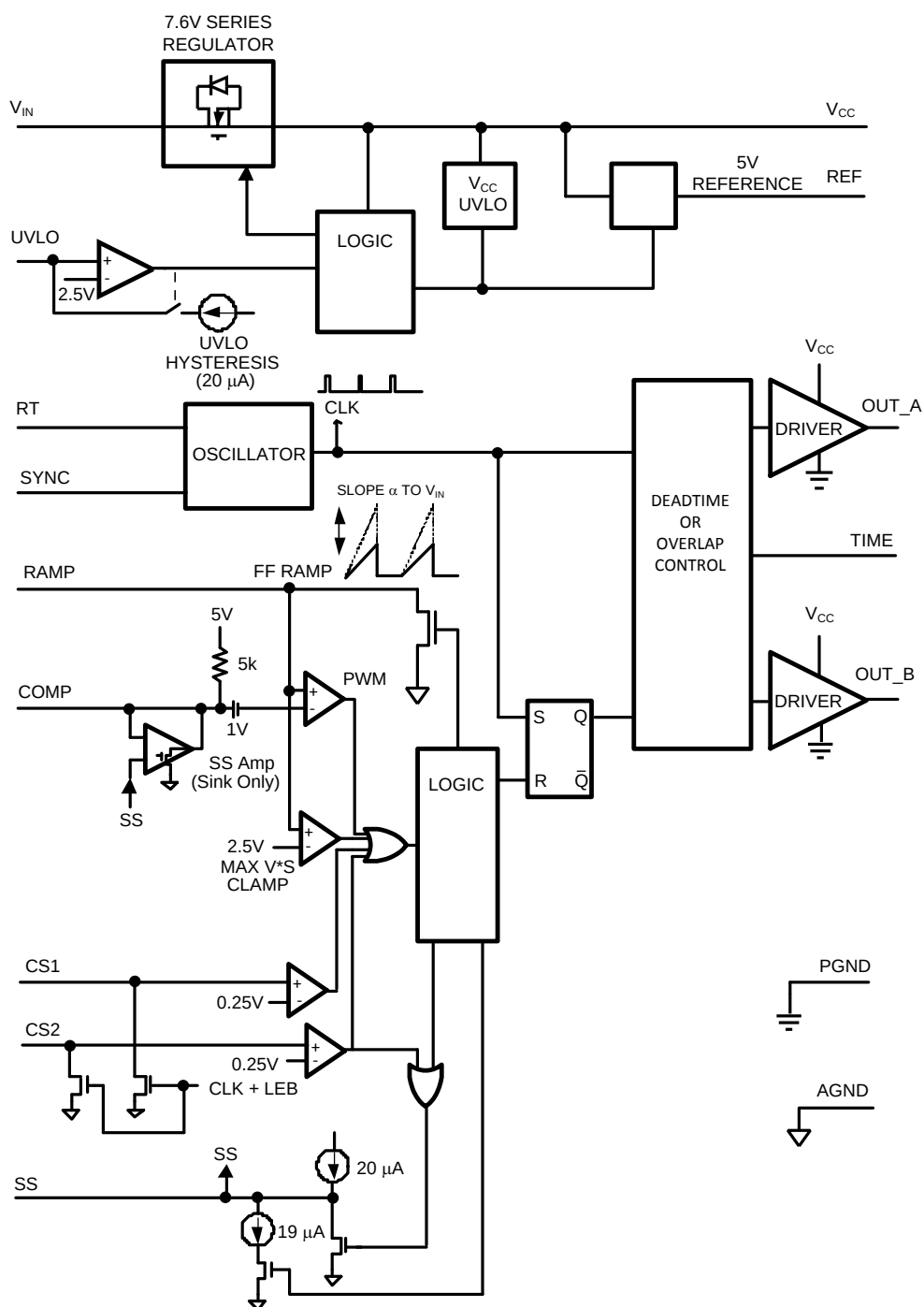


Figure 3. Simplified Block Diagram



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

Absolute Maximum Ratings⁽¹⁾⁽²⁾

V_{IN} to GND		-0.3V to 100V
V_{CC} to GND		-0.3V to 16V
CS1, CS2 to GND		-0.3 to 1.00V
All other inputs to GND		-0.3 to 7V
ESD Rating ⁽³⁾	Human Body Model	2kV
	Machine Model	200V
Storage Temperature Range		-55°C to 150°C
Junction Temperature		150°C

- (1) Military/Aerospace specified devices are required, please contact the TI Sales Office/ Distributors for availability and specifications.
(2) Absolute Maximum Ratings are limits beyond which damage to the device may occur. Operating Ratings are conditions under which operation of the device is intended to be functional. For specifications and test conditions, see the Electrical Characteristics.
(3) For detailed information on soldering plastic TSSOP and WSON packages, refer to the Packaging Data Book.

Operating Ratings⁽¹⁾

V_{IN} Voltage	13 to 90V
External Voltage Applied to V_{CC}	8 to 15V
Operating Junction Temperature	-40°C to +125°C

- (1) Absolute Maximum Ratings are limits beyond which damage to the device may occur. Operating Ratings are conditions under which operation of the device is intended to be functional. For specifications and test conditions, see the Electrical Characteristics.

Electrical Characteristics

Specifications with standard typeface are for $T_J = 25^\circ\text{C}$, and those with **boldface** type apply over full **Operating Junction Temperature range**. $V_{IN} = 48\text{V}$, $V_{CC} = 10\text{V}$, $R_T = 31.3\text{k}\Omega$, $R_{SET} = 27.4\text{k}\Omega$ unless otherwise stated ⁽¹⁾

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Startup Regulator						
V_{CC} Reg	V_{CC} Regulation	No Load	7.3	7.6	7.9	V
	V_{CC} Current Limit	⁽²⁾	20	25		mA
$I-V_{IN}$	Startup Regulator Leakage (external V_{CC} Supply)	$V_{IN} = 100\text{V}$		165	500	μA
	Shutdown Current (I_{in})	UVLO = 0V		350	450	μA
V_{CC} Supply						
	V_{CC} Under-voltage Lockout Voltage (positive going V_{CC})		V_{CC} Reg - 220mV	V_{CC} Reg - 120mV		V
	V_{CC} Under-voltage Hysteresis		1.0	1.5	2.0	V
	V_{CC} Supply Current (I_{CC})	$C_{gate} = 0$			4.2	mA
Reference Supply						
V_{REF}	Ref Voltage	$I_{REF} = 0\text{ mA}$	4.85	5	5.15	V
	Ref Voltage Regulation	$I_{REF} = 0\text{ to }10\text{mA}$		25	50	mV
	Ref Current Limit		10	20		mA
Current Limit						
CS1 Prop	CS1 Delay to Output	CS1 Step from 0 to 0.4V, Time to onset of OUT Transition (90%), $C_{gate} = 0$		40		ns
CS2 Prop	CS2 Delay to Output	CS2 Step from 0 to 0.4V, Time to onset of OUT Transition (90%), $C_{gate} = 0$		50		ns

- (1) All electrical characteristics having room temperature limits are tested during production with $T_A = T_J = 25^\circ\text{C}$. All hot and cold limits are specified by correlating the electrical characteristics to process and temperature variations and applying statistical process control.
(2) Device thermal limitations may limit usable range.

Electrical Characteristics (continued)

Specifications with standard typeface are for $T_J = 25^\circ\text{C}$, and those with **boldface** type apply over full **Operating Junction Temperature range**. $V_{IN} = 48\text{V}$, $V_{CC} = 10\text{V}$, $R_T = 31.3\text{k}\Omega$, $R_{SET} = 27.4\text{k}\Omega$ unless otherwise stated ⁽¹⁾

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
	Cycle by Cycle Threshold Voltage (CS1)		0.22	0.25	0.28	V
	Cycle Skip Threshold Voltage (CS2)	Resets SS capacitor; auto restart	0.22	0.25	0.28	V
	Leading Edge Blanking Time			50		ns
	CS Sink Impedance (clocked)	$I_{CS} = 10\text{mA}$		30	50	Ω
Soft-Start						
	Soft-start Current Source Normal		17	22	27	μA
	Soft-start Current Source following a CS2 event		0.5	1	1.5	μA
Oscillator						
	Frequency1	$T_A = 25^\circ\text{C}$ $T_J = T_{low} \text{ to } T_{high}$	180 175	200	220 225	kHz
	Frequency2	$R_T = 10.4\text{k}\Omega$	500	580	660	kHz
	Sync threshold			2		V
	Min Sync Pulse Width				100	ns
	Sync Frequency Range		160			kHz
PWM Comparator						
	Delay to Output	COMP step 5V to 0V, Time to onset of OUT_A transition low		40		ns
	Duty Cycle Range		0		80	%
	COMP to PWM Offset		0.7	1	1.3	V
	COMP Open Circuit Voltage		4.3		5.9	V
	COMP Short Circuit Current	COMP = 0V	0.6	1	1.4	mA
Volt x Second Clamp						
	Ramp Clamp Level	Delta RAMP measured from onset of OUT_A to Ramp peak, COMP = 5V	2.4	2.5	2.6	V
UVLO Shutdown						
	Undervoltage Shutdown Threshold		2.44	2.5	2.56	V
	Undervoltage Shutdown Hysteresis		16	20	24	μA
Output Section						
	OUT_A High Saturation	MOS Device at $I_{out} = -10\text{mA}$		5	10	Ω
	OUTPUT_A Peak Current Sink	Bipolar Device at $V_{CC}/2$		3		A
	OUT_A Low Saturation	MOS Device at $I_{out} = 10\text{mA}$		6	9	Ω
	OUTPUT_A Rise Time	$C_{gate} = 2.2\text{nF}$		20		ns
	OUTPUT_A Fall Time	$C_{gate} = 2.2\text{nF}$		15		ns
	OUT_B High Saturation	MOS Device at $I_{out} = -10\text{mA}$		10	20	Ω
	OUTPUT_B Peak Current Sink	Bipolar Device at $V_{CC}/2$		1		A
	OUT_B Low Saturation	MOS Device at $I_{out} = 10\text{mA}$		12	18	Ω
	OUTPUT_B Rise Time	$C_{gate} = 1\text{nF}$		20		ns
	OUTPUT_B Fall Time	$C_{gate} = 1\text{nF}$		15		ns

Electrical Characteristics (continued)

Specifications with standard typeface are for $T_J = 25^{\circ}\text{C}$, and those with **boldface** type apply over full **Operating Junction Temperature range**. $V_{IN} = 48\text{V}$, $V_{CC} = 10\text{V}$, $R_T = 31.3\text{k}\Omega$, $R_{SET} = 27.4\text{k}\Omega$ unless otherwise stated ⁽¹⁾

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Output Timing Control						
	Overlap Time	$R_{SET} = 38\text{ k}\Omega$ connected to GND, 50% to 50% transitions	75	105	135	ns
	Deadtime	$R_{SET} = 29.5\text{ k}\Omega$ connected to REF, 50% to 50% transitions	75	105	135	ns
Thermal Shutdown						
T_{SD}	Thermal Shutdown Threshold			165		$^{\circ}\text{C}$
	Thermal Shutdown Hysteresis			25		$^{\circ}\text{C}$
Thermal Resistance						
θ_{JA}	Junction to Ambient	TSSOP Package		125		$^{\circ}\text{C/W}$
		WSOP Package		32		$^{\circ}\text{C/W}$

Typical Performance Characteristics

V_{CC} Regulator Start-up Characteristics, V_{CC} vs V_{IN}

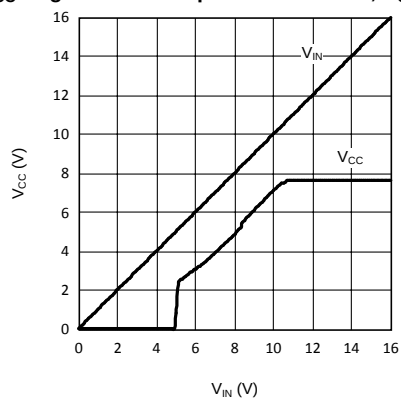


Figure 4.

V_{CC} vs I_{CC}

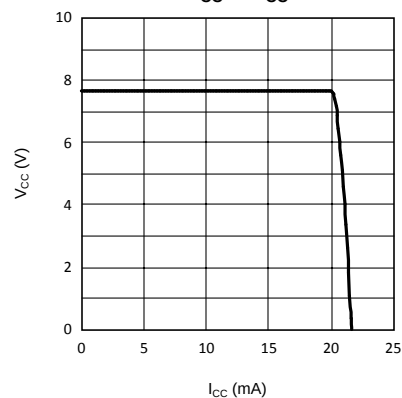


Figure 5.

V_{REF} vs I_{REF}

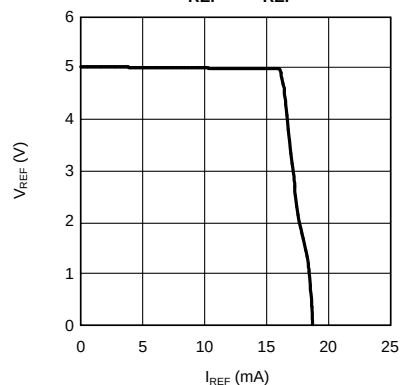


Figure 6.

Oscillator Frequency vs RT

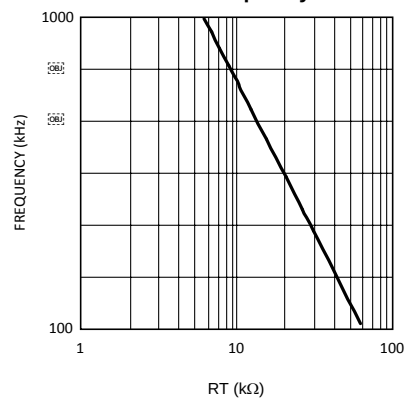


Figure 7.

Overlap Time vs R_{SET}

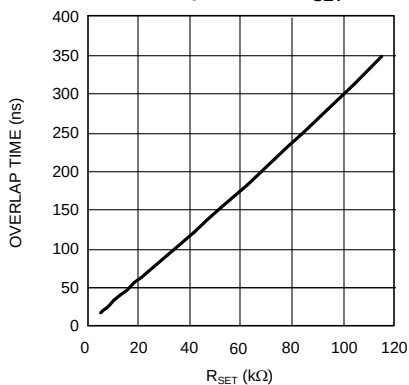


Figure 8.

**Overlap Time vs Temperature
R_{SET} = 38K**

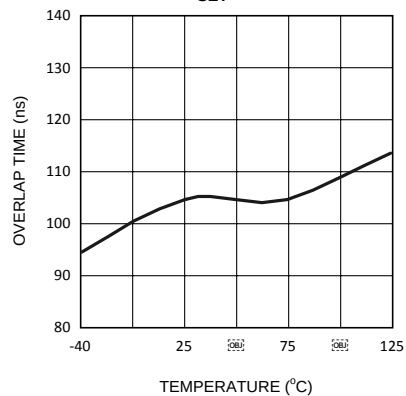


Figure 9.

Typical Performance Characteristics (continued)

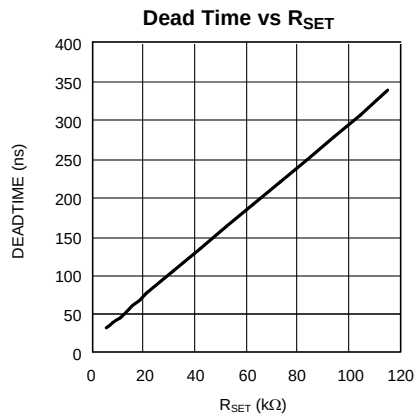


Figure 10.

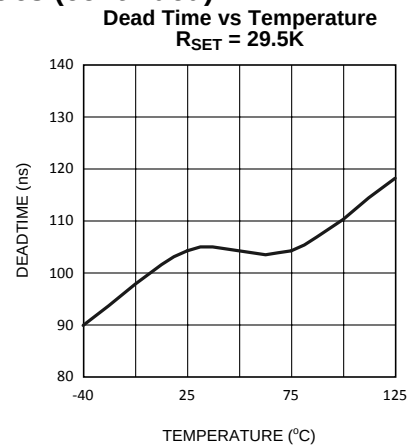


Figure 11.

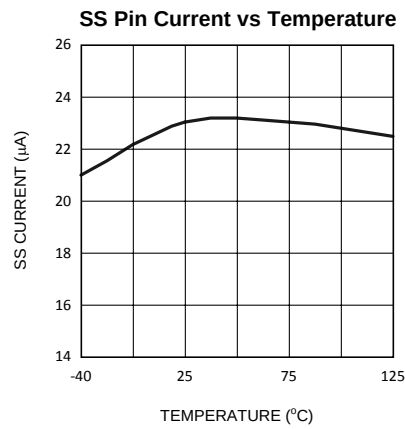


Figure 12.

DETAILED OPERATING DESCRIPTION

The LM5025 PWM controller contains all of the features necessary to implement power converters utilizing the Active Clamp Reset technique. The device can be configured to control either a P-Channel clamp switch or an N-Channel clamp switch. With the active clamp technique higher efficiencies and greater power densities can be realized compared to conventional catch winding or RDC clamp / reset techniques. Two control outputs are provided, the main power switch control (OUT_A) and the active clamp switch control (OUT_B). The active clamp output can be configured for either a specified overlap time (for P-Channel switch applications) or a specified dead time (for N-Channel applications). The two internal compound gate drivers parallel both MOS and Bipolar devices, providing superior gate drive characteristics. This controller is designed for high-speed operation including an oscillator frequency range up to 1MHz and total PWM and current sense propagation delays less than 100ns. The LM5025 includes a high-voltage start-up regulator that operates over a wide input range of 13V to 90V. Additional features include: Line Under Voltage Lockout (UVLO), softstart, oscillator UP/DOWN sync capability, precision reference and thermal shutdown.

High Voltage Start-Up Regulator

The LM5025 contains an internal high voltage start-up regulator that allows the input pin (V_{IN}) to be connected directly to the line voltage. The regulator output is internally current limited to 20mA. When power is applied, the regulator is enabled and sources current into an external capacitor connected to the V_{CC} pin. The recommended capacitance range for the V_{CC} regulator is 0.1 μ F to 100 μ F. When the voltage on the V_{CC} pin reaches the regulation point of 7.6V and the internal voltage reference (REF) reaches its regulation point of 5V, the controller outputs are enabled. The outputs will remain enabled until V_{CC} falls below 6.2V or the line Under Voltage Lock Out detector indicates that V_{IN} is out of range. In typical applications, an auxiliary transformer winding is connected through a diode to the V_{CC} pin. This winding must raise the V_{CC} voltage above 8V to shut off the internal start-up regulator. Powering V_{CC} from an auxiliary winding improves efficiency while reducing the controller power dissipation.

The external V_{CC} capacitor must be sized such that the capacitor and V_{CC} self-bias will maintain a V_{CC} voltage greater than 6.2V during the initial start-up. During a fault mode when the converter auxiliary winding is inactive, external current draw on the V_{CC} line should be limited so the power dissipated in the start-up regulator does not exceed the maximum power dissipation of the controller.

An external start-up regulator or other bias rail can be used instead of the internal start-up regulator by connecting the V_{CC} and the V_{IN} pins together and feeding the external bias voltage into the two pins.

Line Under-Voltage Detector

The LM5025 contains a line Under Voltage Lock Out (UVLO) circuit. An external set-point voltage divider from V_{in} to GND, sets the operational range of the converter. The divider must be designed such that the voltage at the UVLO pin will be greater than 2.5V when V_{in} is in the desired operating range. If the undervoltage threshold is not met, all functions of the controller are disabled and the controller remains in a low power standby state. UVLO hysteresis is accomplished with an internal 20 μ A current source that is switched on or off into the impedance of the set-point divider. When the UVLO threshold is exceeded, the current source is activated to instantly raise the voltage at the UVLO pin. When the UVLO pin voltage falls below the 2.5V threshold, the current source is turned off causing the voltage at the UVLO pin to fall. The UVLO pin can also be used to implement a remote enable / disable function. Pulling the UVLO pin below the 2.5V threshold disables the converter.

PWM Outputs

The relative phase of the main (OUT_A) and active clamp outputs (OUT_B) can be configured for the specific application. For active clamp configurations utilizing a ground referenced P-Channel clamp switch, the two outputs should be in phase with the active clamp output overlapping the main output. For active clamp configurations utilizing a high side N-Channel switch, the active clamp output should be out of phase with main output and there should be a dead time between the two gate drive pulses. A distinguishing feature of the LM5025 is the ability to accurately configure either dead time (both off) or overlap time (both on) of the gate driver outputs. The overlap / deadtime magnitude is controlled by the resistor value connected to the TIME pin of the controller. The opposite end of the resistor can be connected to either REF for deadtime control or GND for overlap control. The internal configuration detector senses the connection and configures the phase relationship of the main and active clamp outputs. The magnitude of the overlap/dead time can be calculated as follows:

$$\text{Overlap Time (ns)} = 2.8 \times R_{\text{SET}} - 1.2$$

$$\text{Dead Time (ns)} = 2.9 \times R_{\text{SET}} + 20$$

R_{SET} in k Ω , Time in ns

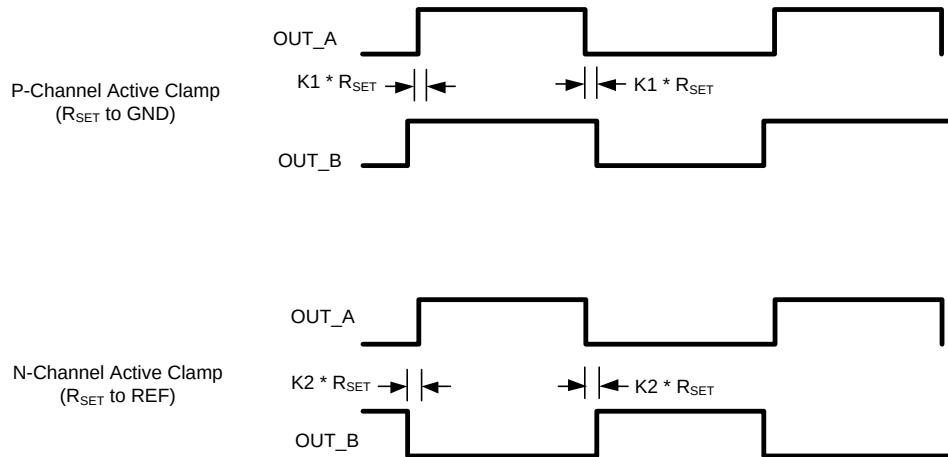


Figure 13. PWM Outputs

Compound Gate Drivers

The LM5025 contains two unique compound gate drivers, which parallel both MOS and Bipolar devices to provide high drive current throughout the entire switching event. The Bipolar device provides most of the drive current capability and provides a relatively constant sink current which is ideal for driving large power MOSFETs. As the switching event nears conclusion and the Bipolar device saturates, the internal MOS device continues to provide a low impedance to complete the switching event.

During turn-off at the Miller plateau region, typically around 2V - 3V, is where gate driver current capability is needed most. The resistive characteristics of all MOS gate drivers are adequate for turn-on since the supply to output voltage differential is fairly large at the Miller region. During turn-off however, the voltage differential is small and the current source characteristic of the Bipolar gate driver is beneficial to provide fast drive capability.

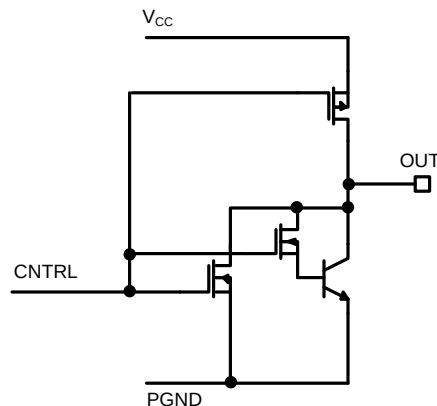


Figure 14. Compound Gate Drivers

PWM Comparator

The PWM comparator compares the ramp signal (RAMP) to the loop error signal (COMP). This comparator is optimized for speed in order to achieve minimum controllable duty cycles. The internal 5k Ω pull-up resistor, connected between the internal 5V reference and COMP, can be used as the pull-up for an optocoupler. The comparator polarity is such that 0V on the COMP pin will produce a zero duty cycle on both gate driver outputs.

Volt Second Clamp

The Volt x Second Clamp comparator compares the ramp signal (RAMP) to a fixed 2.5V reference. By proper selection of RFF and CFF, the maximum ON time of the main switch can be set to the desired duration. The ON time set by Volt x Second Clamp varies inversely with the line voltage because the RAMP capacitor is charged by a resistor connected to Vin while the threshold of the clamp is a fixed voltage (2.5V). An example will illustrate the use of the Volt x Second Clamp comparator to achieve a 50% duty cycle limit, at 200KHz, at a 48V line input: A 50% duty cycle at a 200KHz requires a 2.5μs of ON time. At 48V input the Volt x Second product is 120V x μs (48V x 2.5μs). To achieve this clamp level:

$$R_{FF} \times C_{FF} = V_{IN} \times T_{ON} / 2.5V \quad (1)$$

$$48 \times 2.5\mu / 2.5 = 48\mu \quad (2)$$

Select $C_{FF} = 470\text{pF}$. $R_{FF} = 102\text{k}\Omega$

The recommended capacitor value range for CFF is 100pF to 1000pF.

The C_{FF} ramp capacitor is discharged at the conclusion of every cycle by an internal discharge switch controlled by either the internal clock or by the V x S Clamp comparator, whichever event occurs first.

Current Limit

The LM5025 contains two modes of over-current protection. If the sense voltage at the CS1 input exceeds 0.25V the present power cycle is terminated (cycle-by-cycle current limit). If the sense voltage at the CS2 input exceeds 0.25V, the controller will terminate the present cycle, discharge the softstart capacitor and reduce the softstart current source to 1μA. The softstart (SS) capacitor is released after being fully discharged and slowly charges with a 1μA current source. When the voltage at the SS pin reaches approximately 1V, the PWM comparator will produce the first output pulse at OUT_A. After the first pulse occurs, the softstart current source will revert to the normal 20μA level. Fully discharging and then slowly charging the SS capacitor protects a continuously overloaded converter with a low duty cycle hiccup mode.

These two modes of over-current protection allow the user great flexibility to configure the system behavior in over-load conditions. If it is desired for the system to act as a current source during an over-load, then the CS1 cycle-by-cycle current limiting should be used. In this case the current sense signal should be applied to the CS1 input and the CS2 input should be grounded. If during an overload condition it is desired for the system to briefly shutdown, followed by softstart retry, then the CS2 hiccup current limiting mode should be used. In this case the current sense signal should be applied to the CS2 input and the CS1 input should be grounded. This shutdown / soft-start retry will repeat indefinitely while the over-load condition remains. The hiccup mode will greatly reduce the thermal stresses to the system during heavy overloads. The cycle-by-cycle mode will have higher system thermal dissipations during heavy overloads, but provides the advantage of continuous operation for short duration overload conditions.

In some systems it is possible utilize both modes concurrently, whereby slight overload conditions activate the CS1 cycle-by cycle mode while more severe overloading activates the CS2 hiccup mode. Operating both modes concurrently, requires that the slope of the inductor current be sufficient to reach the CS2 threshold before the CS1 function turns off the main output switch. This requires a high dv/dt at the current sense pin. The signal must be fast enough to reach the second level threshold before the first threshold detector (CS1) turns off the gate driver. Excessive filtering on the CS pin, an extremely low value current sense resistor or an inductor that does not saturate with excessive loading may prevent the second level threshold from ever being reached.

A small RC filter, located near the controller, is recommended for each of the CS pins. Each CS input has an internal FET which discharges the current sense filter capacitor at the conclusion of every cycle, to improve dynamic performance. This same FET remains on an additional 50ns at the start of each main switch cycle to attenuate the leading edge spike in the current sense signal.

The LM5025 CS comparators are very fast and may respond to short duration noise pulses. Layout considerations are critical for the current sense filter and sense resistor. The capacitor associated with the CS filter must be placed very close to the device and connected directly to the pins of the IC (CS and GND). If a current sense transformer is used, both leads of the transformer secondary should be routed to the filter network, which should be located close to the IC. If a sense resistor in the source of the main switch MOSFET is used for current sensing, a low inductance type of resistor is required. When designing with a current sense resistor, all of the noise sensitive low power ground connections should be connected together near the IC GND and a single connection should be made to the power ground (sense resistor ground point).

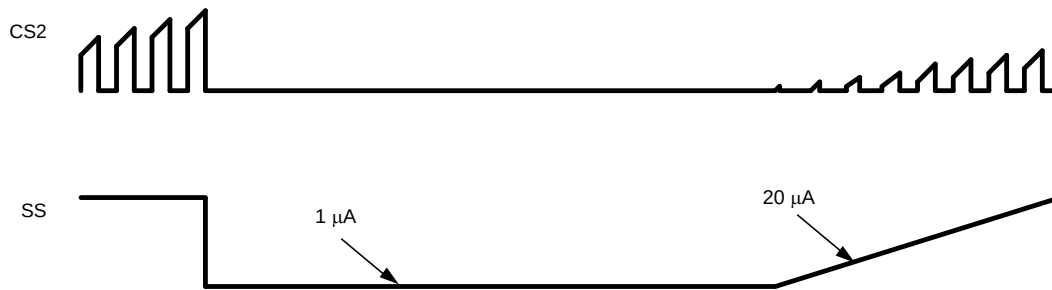


Figure 15. Current Limit

Oscillator and Sync Capability

The LM5025 oscillator is set by a single external resistor connected between the RT pin and GND. To set a desired oscillator frequency (F), the necessary RT resistor can be calculated from:

$$RT = (5725/F)^{1.026}$$

where

- F is in kHz
- RT in kΩ

(3)

The RT resistor should be located very close to the device and connected directly to the pins of the IC (RT and GND).

A unique feature of LM5025 is the ability to synchronize the oscillator to an external clock with a frequency that is either higher or lower than the frequency of the internal oscillator. The lower frequency sync frequency range is 80% of the free running internal oscillator frequency. There is no constraint on the maximum SYNC frequency. A minimum pulse width of 100ns is required for the synchronization clock. If the synchronization feature is not required, the SYNC pin should be connected to GND to prevent any abnormal interference. The internal oscillator can be completely disabled by connecting the RT pin to REF. Once disabled, the sync signal will act directly as the master clock for the controller. Both the frequency and the maximum duty cycle of the PWM controller can be controlled by the SYNC signal (within the limitations of the Volt x Second Clamp). The maximum duty cycle (D) will be (1-D) of the SYNC signal.

Feed-Forward Ramp

An external resistor (R_{FF}) and capacitor (C_{FF}) connected to V_{IN} and GND are required to create the PWM ramp signal. The slope of the signal at the RAMP pin will vary in proportion to the input line voltage. This varying slope provides line feedforward information necessary to improve line transient response with voltage mode control. The RAMP signal is compared to the error signal at the COMP pin by the pulse width modulator comparator to control the duty cycle of the main switch output. The Volt Second Clamp comparator also monitors the RAMP pin and if the ramp amplitude exceeds 2.5V the present cycle is terminated. The ramp signal is reset to GND at the end of each cycle by either the internal clock or the Volt Second comparator, whichever occurs first.

Soft-start

The softstart feature allows the power converter to gradually reach the initial steady state operating point, thus reducing start-up stresses and surges. At power on, a 20µA current is sourced out of the softstart pin (SS) into an external capacitor. The capacitor voltage will ramp up slowly and will limit the COMP pin voltage and therefore the PWM duty cycle. In the event of a fault as determined by V_{CC} undervoltage, line undervoltage (UVLO) or second level current limit, the output gate drivers are disabled and the softstart capacitor is fully discharged. When the fault condition is no longer present a softstart sequence will be initiated. Following a second level current limit detection (CS2), the softstart current source is reduced to 1µA until the first output pulse is generated by the PWM comparator. The current source returns to the nominal 20µA level after the first output pulse (~1V at the SS pin).

Thermal Protection

Internal Thermal Shutdown circuitry is provided to protect the integrated circuit in the event the maximum junction temperature is exceeded. When activated, typically at 165°C, the controller is forced into a low power standby state with the output drivers and the bias regulator disabled. The device will restart after the thermal hysteresis (typically 25°C). During a restart after thermal shutdown, the softstart capacitor will be fully discharged and then charged in the low current mode (1μA) similar to a second level current limit event. The thermal protection feature is provided to prevent catastrophic failures from accidental device overheating.

Application Circuit: Input 36-78V, Output 3.3V, 30A

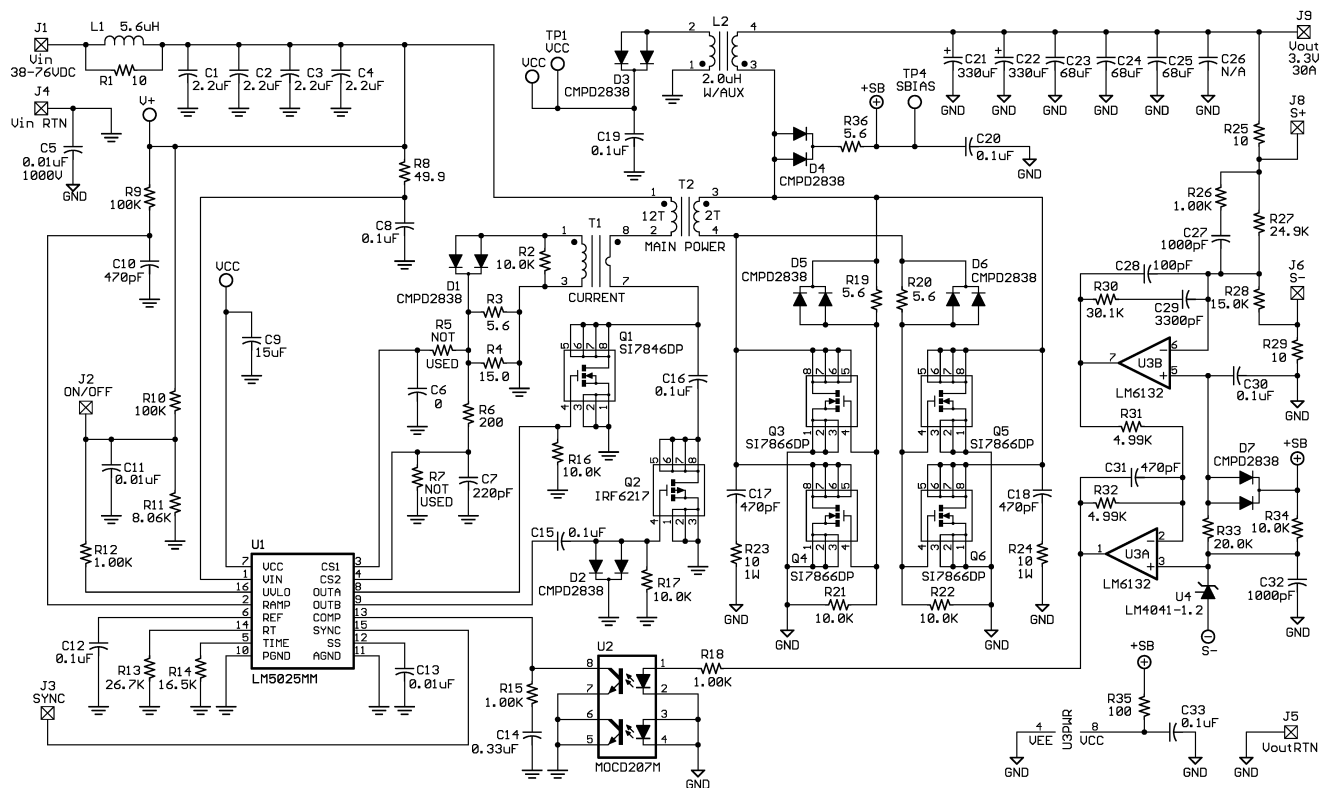


Figure 16. Application Circuit

REVISION HISTORY

Changes from Revision A (March 2013) to Revision B

Page

- Changed layout of National Data Sheet to TI format [14](#)

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
LM5025MTC/NOPB	ACTIVE	TSSOP	PW	16	92	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LM5025 MTC	Samples
LM5025MTCX	NRND	TSSOP	PW	16	2500	TBD	Call TI	Call TI	-40 to 125	LM5025 MTC	
LM5025MTCX/NOPB	ACTIVE	TSSOP	PW	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU CU SN	Level-1-260C-UNLIM	-40 to 125	LM5025 MTC	Samples
LM5025SD/NOPB	ACTIVE	WSO	NHQ	16	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	5025SD	Samples
LM5025SDX/NOPB	ACTIVE	WSO	NHQ	16	4500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	5025SD	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.

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.

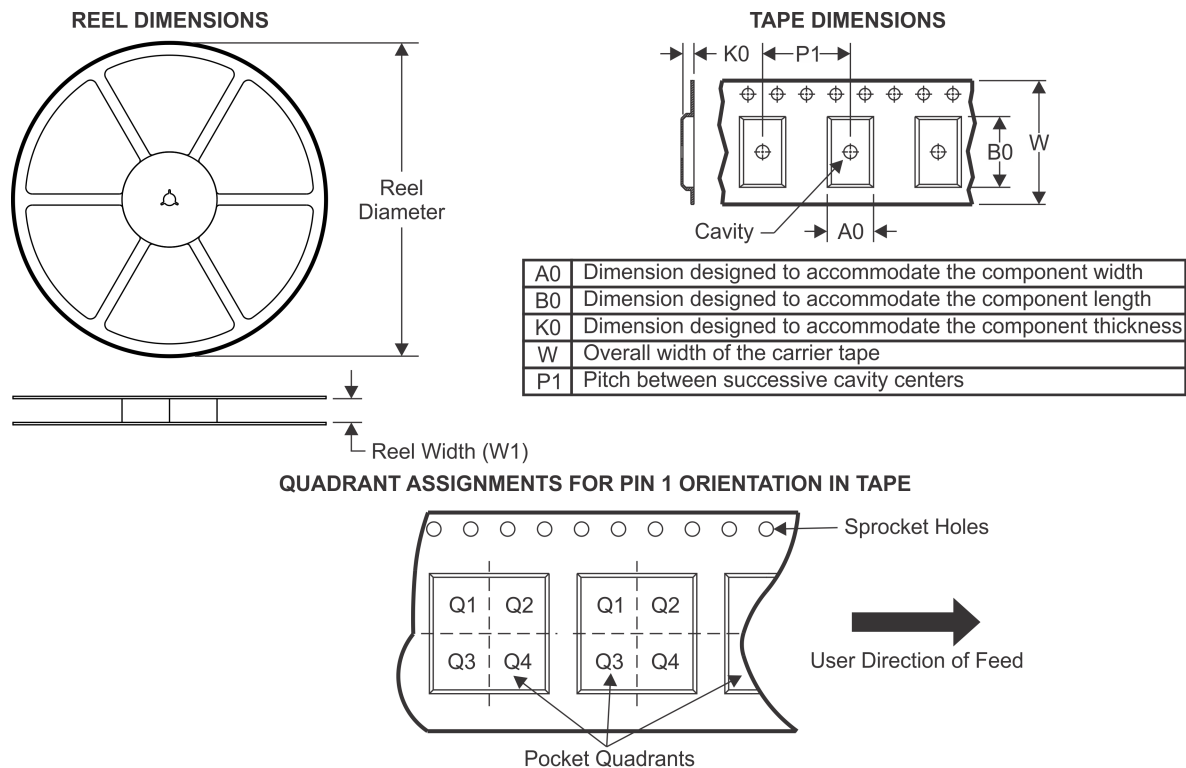
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(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.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

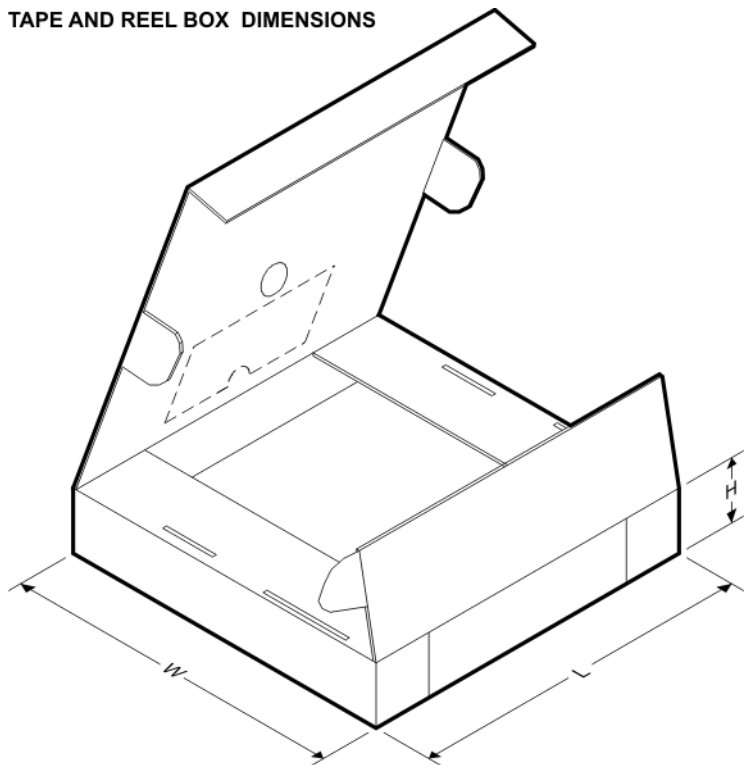
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION


*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
LM5025MTCX	TSSOP	PW	16	2500	330.0	12.4	6.95	8.3	1.6	8.0	12.0	Q1
LM5025MTCX/NOPB	TSSOP	PW	16	2500	330.0	12.4	6.95	8.3	1.6	8.0	12.0	Q1
LM5025SD/NOPB	WSO	NHQ	16	1000	178.0	12.4	5.3	5.3	1.3	8.0	12.0	Q1
LM5025SDX/NOPB	WSO	NHQ	16	4500	330.0	12.4	5.3	5.3	1.3	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS

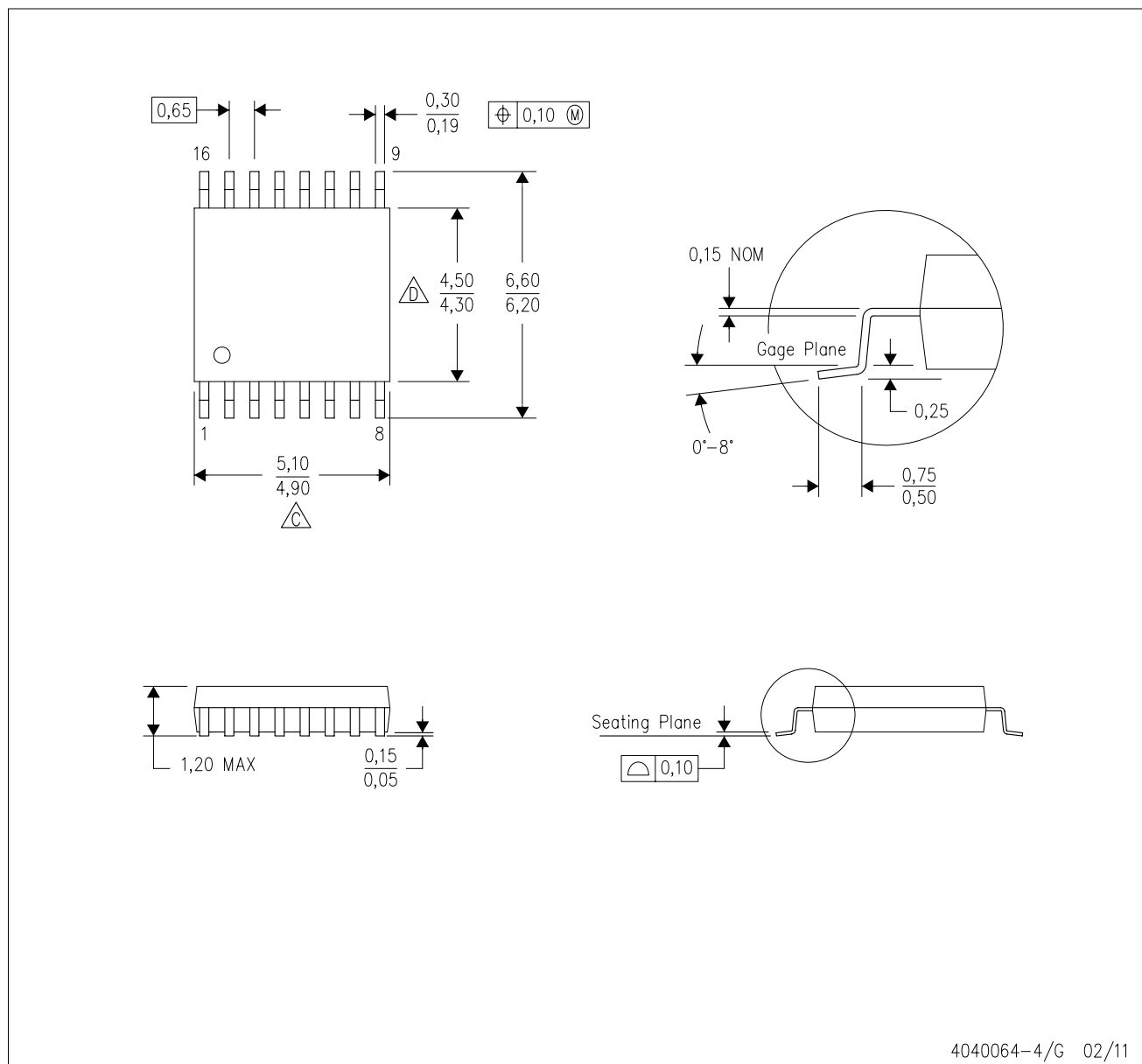


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM5025MTCX	TSSOP	PW	16	2500	367.0	367.0	35.0
LM5025MTCX/NOPB	TSSOP	PW	16	2500	367.0	367.0	35.0
LM5025SD/NOPB	WSO	NHQ	16	1000	210.0	185.0	35.0
LM5025SDX/NOPB	WSO	NHQ	16	4500	367.0	367.0	35.0

PW (R-PDSO-G16)

PLASTIC SMALL OUTLINE

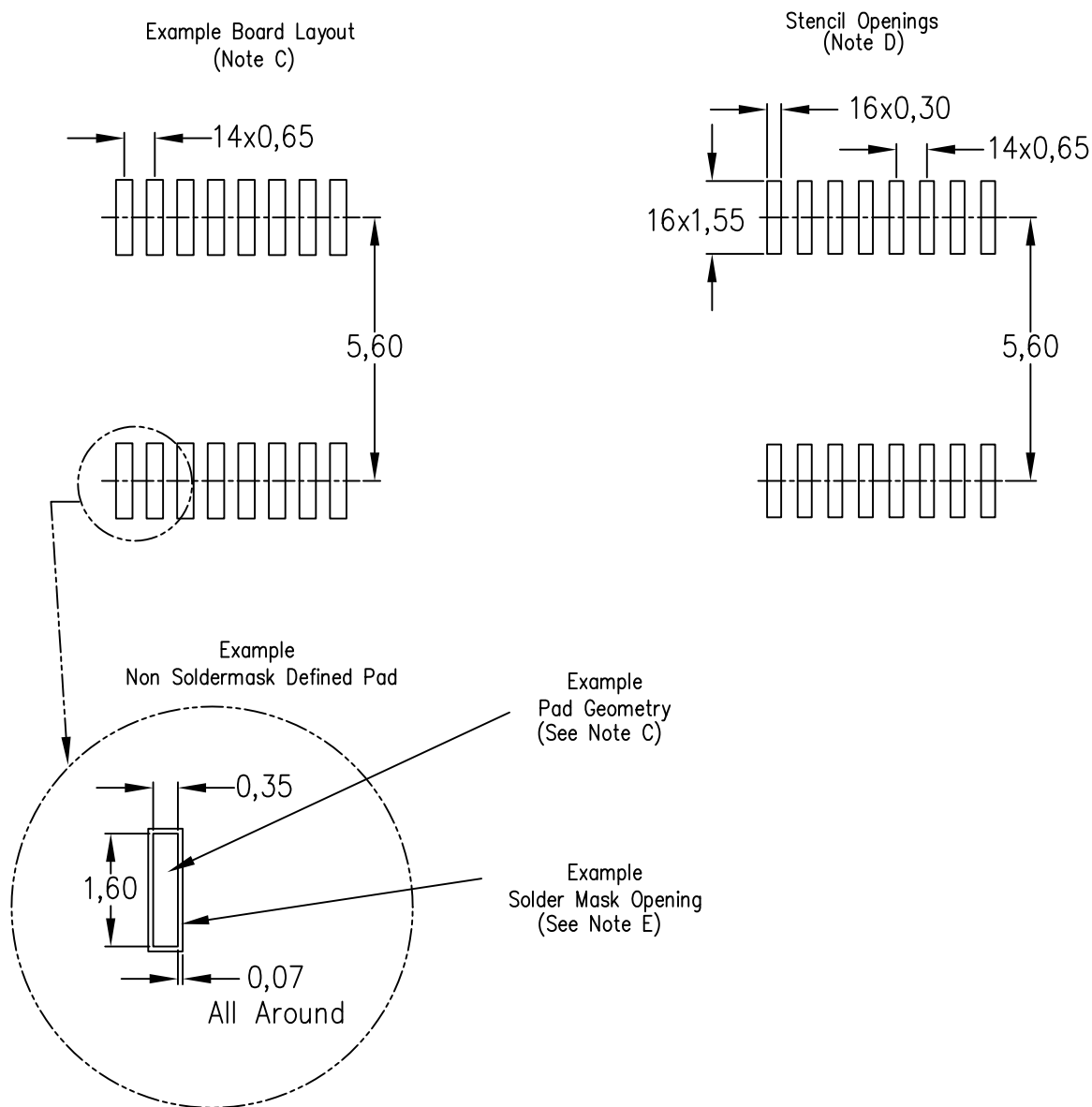


4040064-4/G 02/11

- 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



4211284-3/F 12/12

- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - Publication IPC-7351 is recommended for alternate designs.
 - 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.
 - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.



IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products

Audio	www.ti.com/audio
Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DLP® Products	www.dlp.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
OMAP Applications Processors	www.ti.com/omap
Wireless Connectivity	www.ti.com/wirelessconnectivity

Applications

Automotive and Transportation	www.ti.com/automotive
Communications and Telecom	www.ti.com/communications
Computers and Peripherals	www.ti.com/computers
Consumer Electronics	www.ti.com/consumer-apps
Energy and Lighting	www.ti.com/energy
Industrial	www.ti.com/industrial
Medical	www.ti.com/medical
Security	www.ti.com/security
Space, Avionics and Defense	www.ti.com/space-avionics-defense
Video and Imaging	www.ti.com/video

TI E2E Community

e2e.ti.com