

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

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 guaranteed overlap time (for P-Channel switch applications) or a guaranteed 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.

Packages

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



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Typical Application Circuit

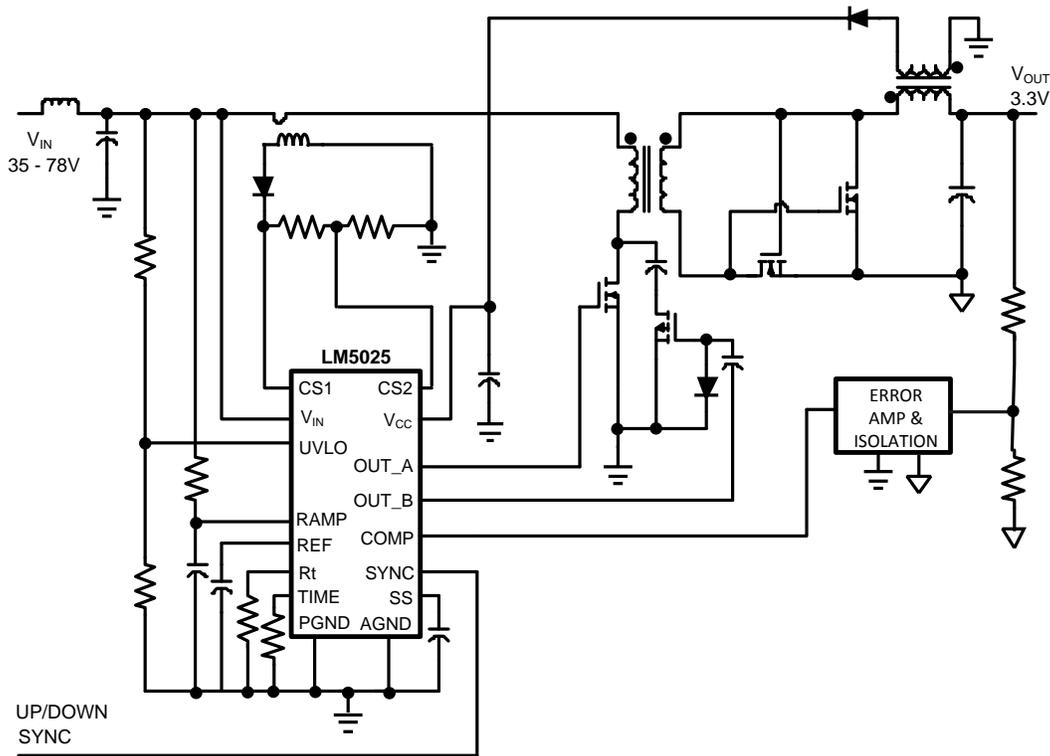


Figure 1. Simplified Active Clamp Forward Power Converter

Connection Diagram

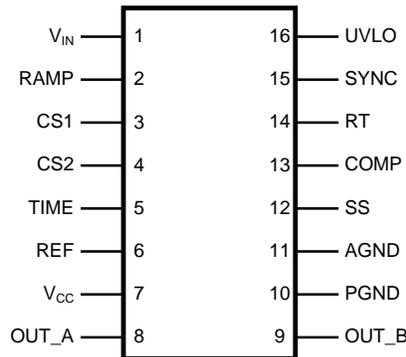


Figure 2. 16-Lead TSSOP, WSON

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 V _{in} 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.

Table 1. Pin Descriptions (continued)

PIN	NAME	DESCRIPTION	APPLICATION INFORMATION
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 1 μ A. After the first output pulse (when SS =1V), the SS charge current will revert back to 20 μ A. 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 0.1 μ F 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 20 μ A current source set the softstart ramp. The SS current source is reduced to 1 μ A initially following a CS2 over-current event or an over temperature event.
13	COMP	Input to the Pulse Width Modulator	An internal 5K Ω 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.
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 (20 μ A) that is switched on or off as the UVLO pin potential crosses the 2.5V threshold.

Block Diagram

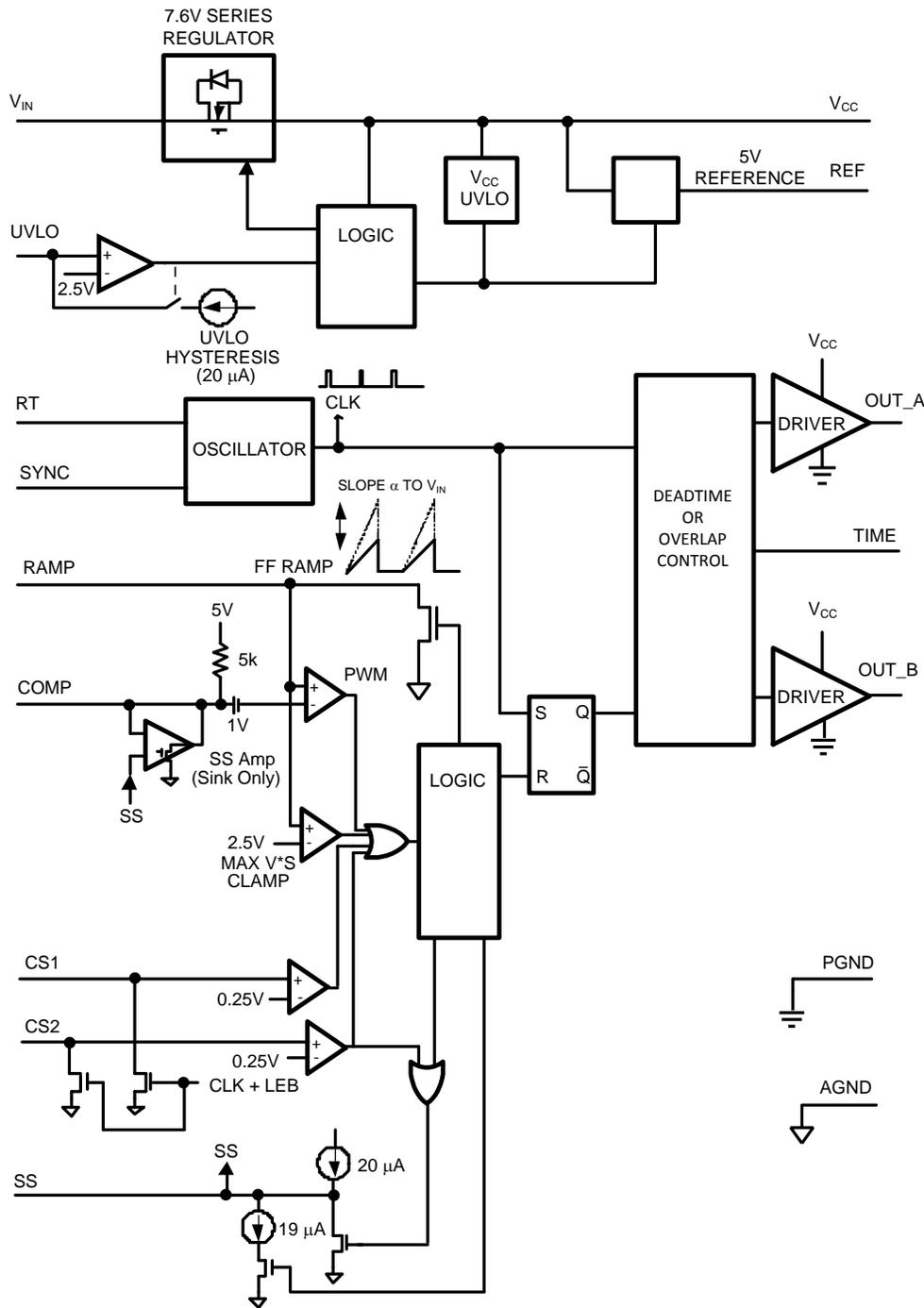


Figure 3. Simplified Block Diagram



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 National Semiconductor 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 guaranteed 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 guaranteed specifications and test conditions, see the Electrical Characteristics.

Electrical Characteristics

Specifications with standard typeface are for T_J = 25°C, and those with **boldface** type apply over full **Operating Junction Temperature range**. V_{IN} = 48V, V_{CC} = 10V, RT = 31.3kΩ, R_{SET} = 27.4kΩ) 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} = 100V		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 mA	4.85	5	5.15	V
	Ref Voltage Regulation	I _{REF} = 0 to 10mA		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

- (1) All limits are guaranteed. All electrical characteristics having room temperature limits are tested during production with T_A = T_J = 25°C. All hot and cold limits are guaranteed 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
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
	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	$T_A = 25^\circ\text{C}$ $T_J = T_{low}$ 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
Output Timing Control						
	Overlap Time	$R_{SET} = 38\text{k}\Omega$ connected to GND, 50% to 50% transitions	75	105	135	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
	Deadtime	$R_{SET} = 29.5\text{ k}\Omega$ connected to REF, 50% to 50% transitions	75	105	135	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
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		$^\circ\text{C/W}$
		WSON Package		32		$^\circ\text{C/W}$

Typical Performance Characteristics

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

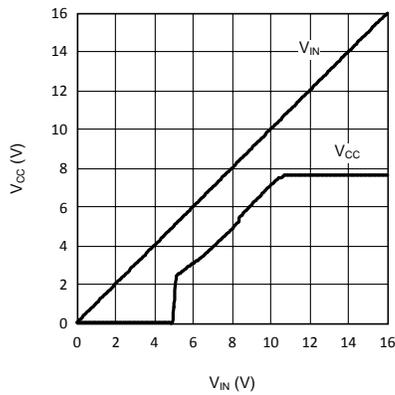


Figure 4.

V_{CC} vs I_{CC}

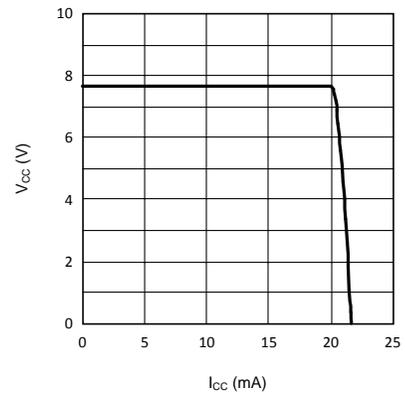


Figure 5.

V_{REF} vs I_{REF}

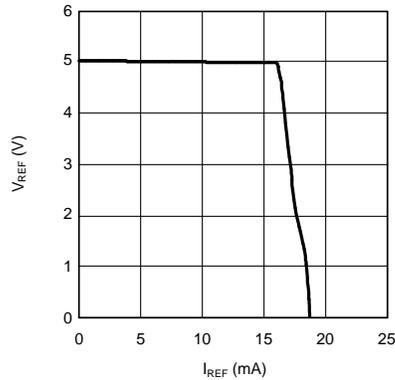


Figure 6.

Oscillator Frequency vs RT

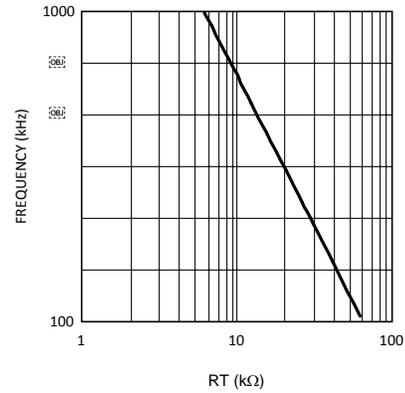


Figure 7.

Overlap Time vs R_{SET}

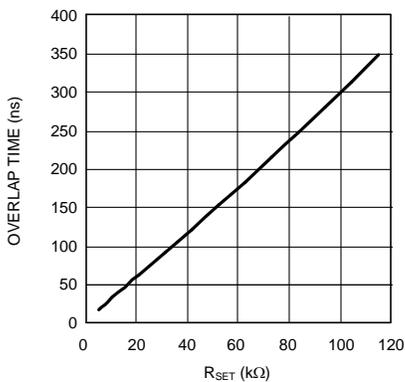


Figure 8.

Overlap Time vs Temperature
R_{SET} = 38K

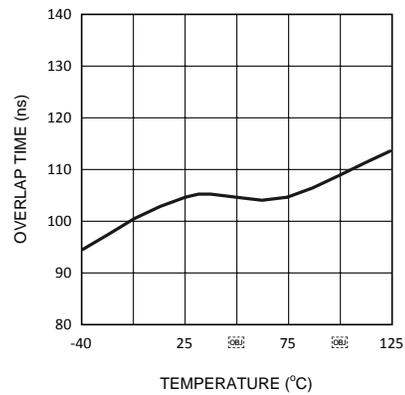


Figure 9.

Typical Performance Characteristics (continued)

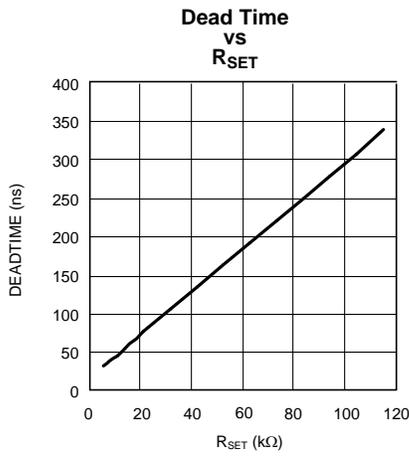


Figure 10.

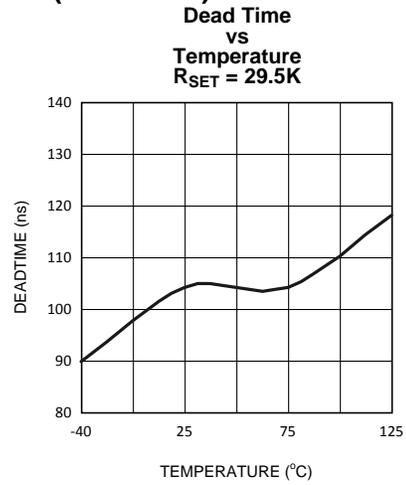


Figure 11.

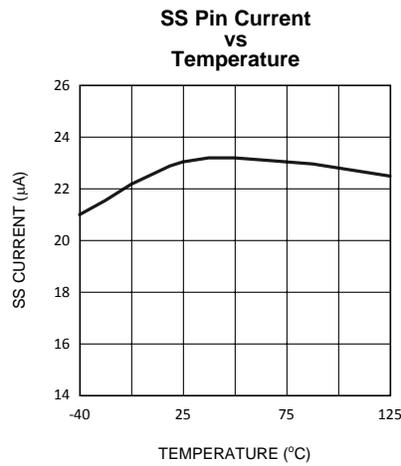


Figure 12.

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 guaranteed overlap time (for P-Channel switch applications) or a guaranteed 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 $k\Omega$, Time in ns

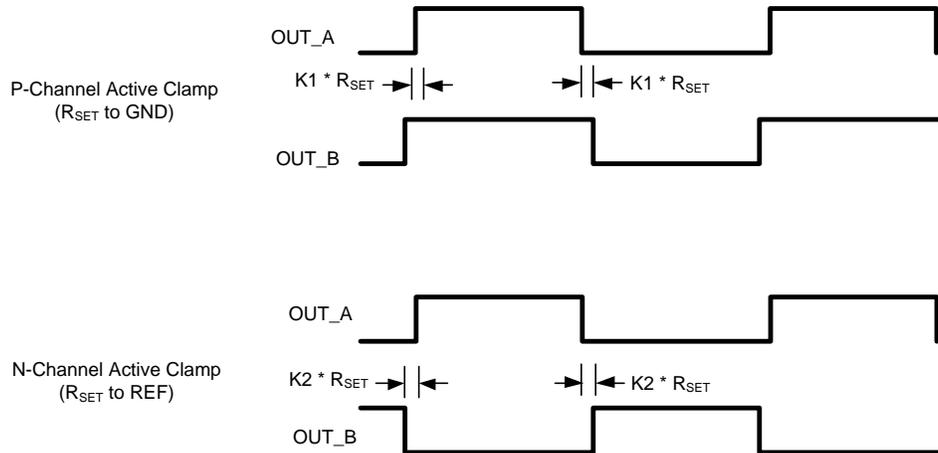


Figure 13. PWM Outputs

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.

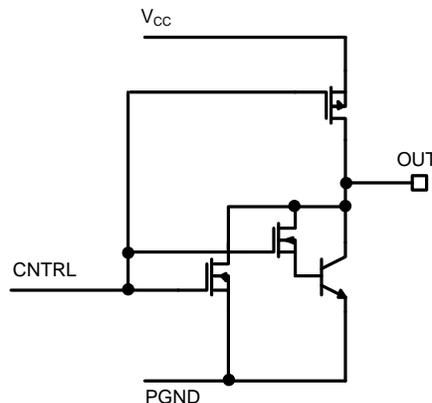


Figure 14. Compound Gate Drivers

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 over-loaded 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).

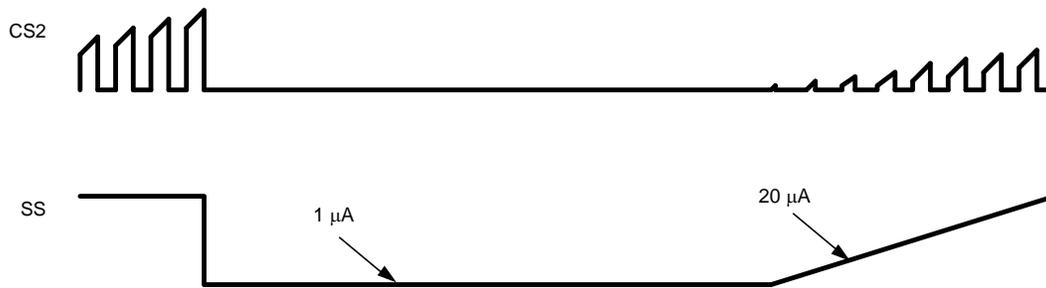


Figure 15. Current Limit

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:

$$RT = (5725/F)^{1.026} \quad (3)$$

where F is in kHz and RT in k Ω .

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, which ever 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 20 μ A 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 1 μ A until the first output pulse is generated by the PWM comparator. The current source returns to the nominal 20 μ A 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

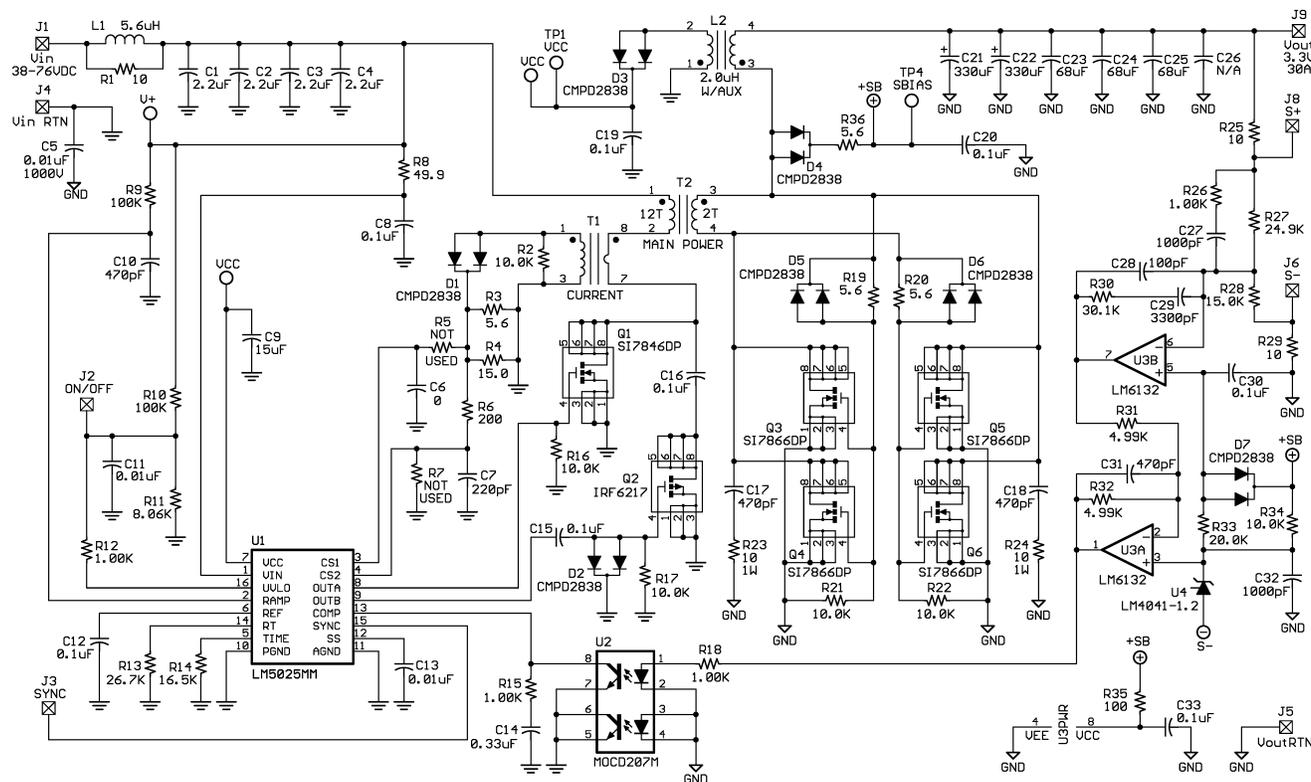


Figure 16. Application Circuit

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
LM5025MTC	ACTIVE	TSSOP	PW	16	92	TBD	Call TI	Call TI	-40 to 125	LM5025 MTC	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	ACTIVE	TSSOP	PW	16	2500	TBD	Call TI	Call TI	-40 to 125	LM5025 MTC	Samples
LM5025MTCX/NOPB	ACTIVE	TSSOP	PW	16	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LM5025 MTC	Samples
LM5025SD	ACTIVE	WSON	NHQ	16	1000	TBD	Call TI	Call TI	-40 to 125	5025SD	Samples
LM5025SD/NOPB	ACTIVE	WSON	NHQ	16	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	5025SD	Samples
LM5025SDX/NOPB	ACTIVE	WSON	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.

OBSOLETE: 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) Only one of markings shown within the brackets will appear on the physical device.

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TAPE AND REEL INFORMATION

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
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	WSON	NHQ	16	1000	178.0	12.4	5.3	5.3	1.3	8.0	12.0	Q1
LM5025SD/NOPB	WSON	NHQ	16	1000	178.0	12.4	5.3	5.3	1.3	8.0	12.0	Q1
LM5025SDX/NOPB	WSON	NHQ	16	4500	330.0	12.4	5.3	5.3	1.3	8.0	12.0	Q1

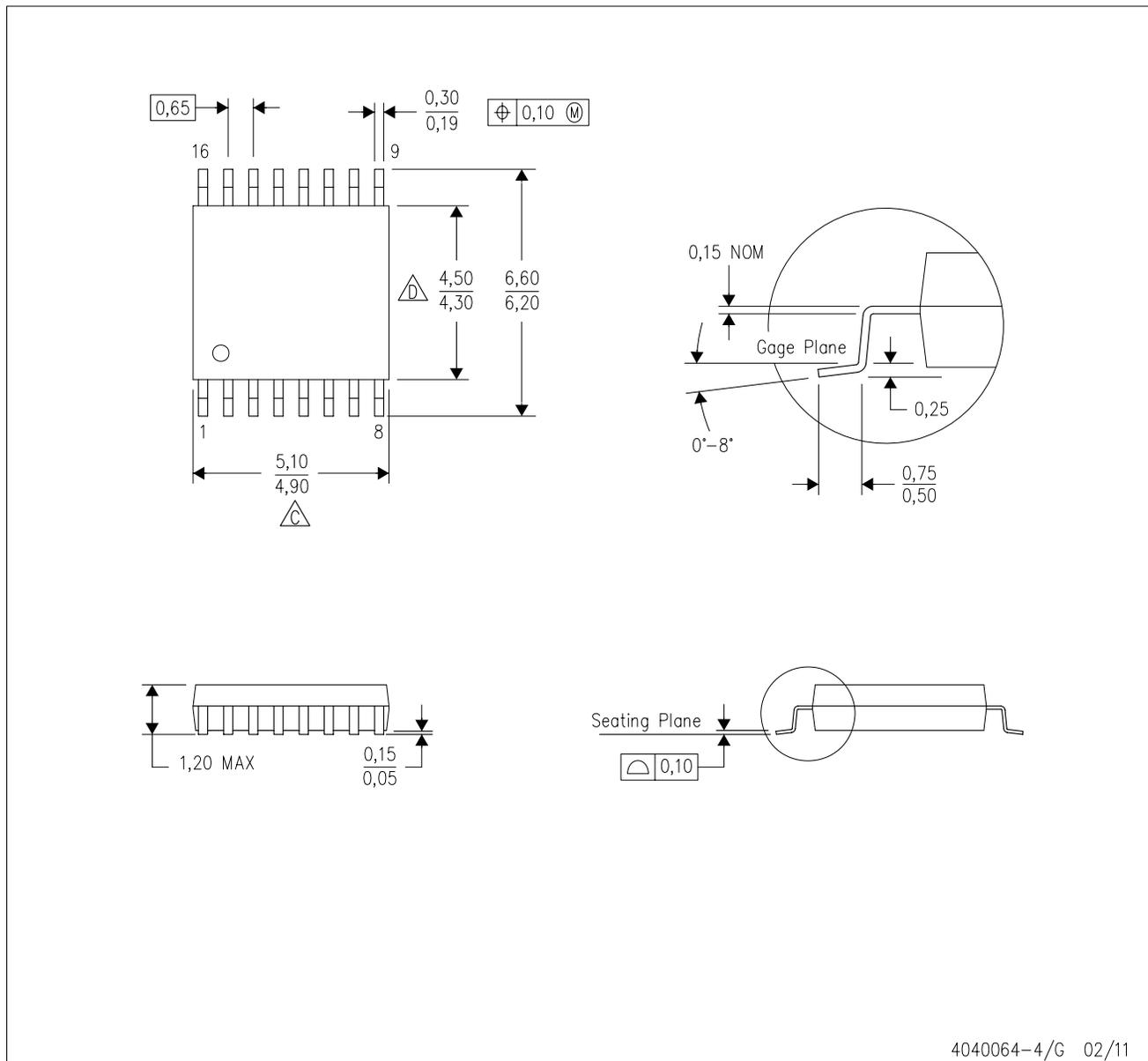
TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM5025MTCX	TSSOP	PW	16	2500	349.0	337.0	45.0
LM5025MTCX/NOPB	TSSOP	PW	16	2500	349.0	337.0	45.0
LM5025SD	WSON	NHQ	16	1000	203.0	190.0	41.0
LM5025SD/NOPB	WSON	NHQ	16	1000	203.0	190.0	41.0
LM5025SDX/NOPB	WSON	NHQ	16	4500	349.0	337.0	45.0

PW (R-PDSO-G16)

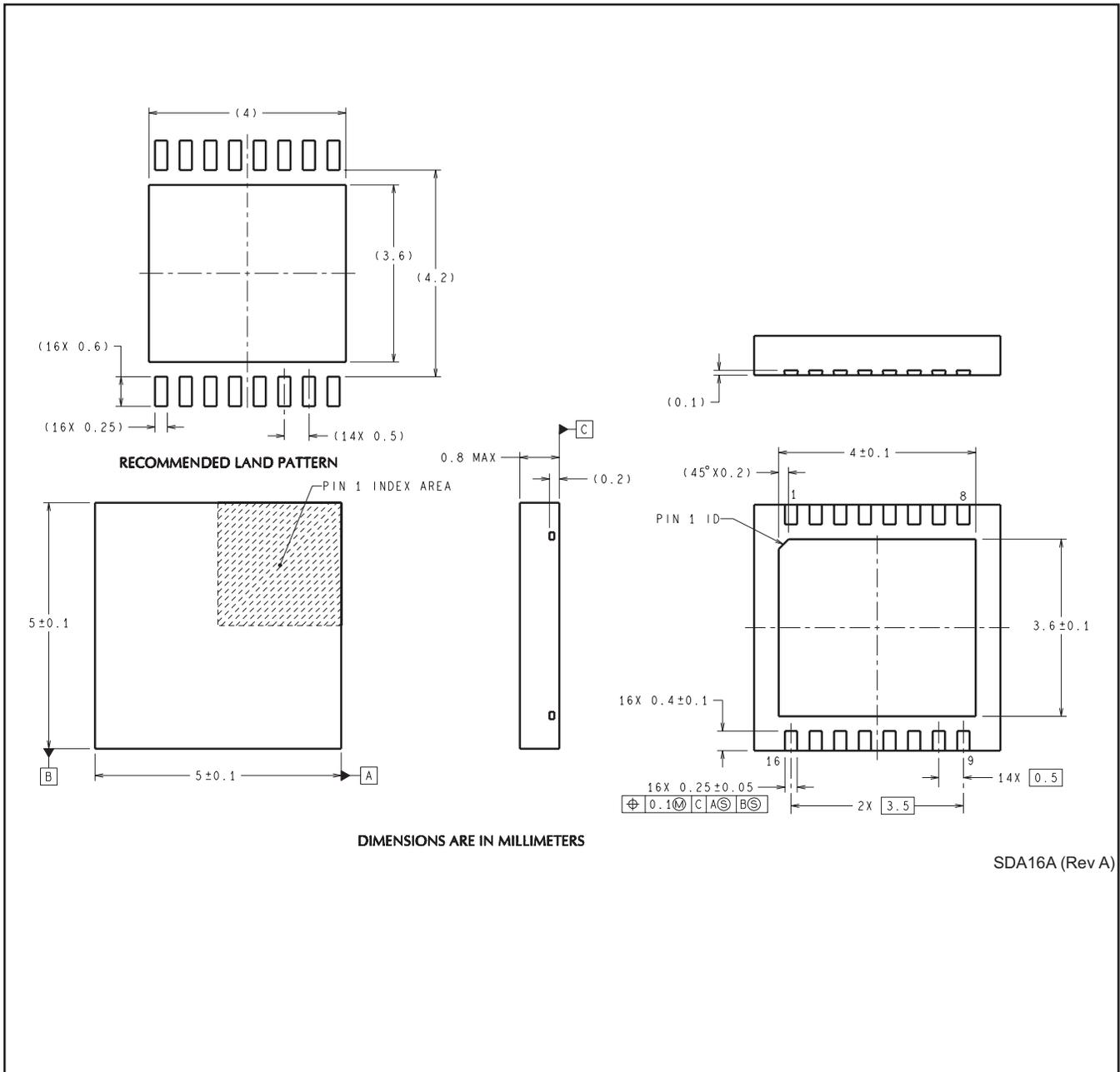
PLASTIC SMALL OUTLINE



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

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