



# THE DATASHEET OF LM25005MH/NOPB

## LM25005 42V, 2.5A Step-Down Switching Regulator

Check for Samples: [LM25005](#)

### FEATURES

- Integrated 42V, 160mΩ N-Channel MOSFET
- Ultra-Wide Input Voltage Range from 7V to 42V
- Internal Bias Regulator
- Adjustable Output Voltage from 1.225V
- 1.5% Feedback Reference Accuracy
- Current Mode Control with Emulated Inductor Current Ramp
- Single Resistor Oscillator Frequency Setting
- Oscillator Synchronization Input
- Programmable Soft-Start
- Shutdown / Standby Input
- Wide Bandwidth Error Amplifier
- Thermal Shutdown

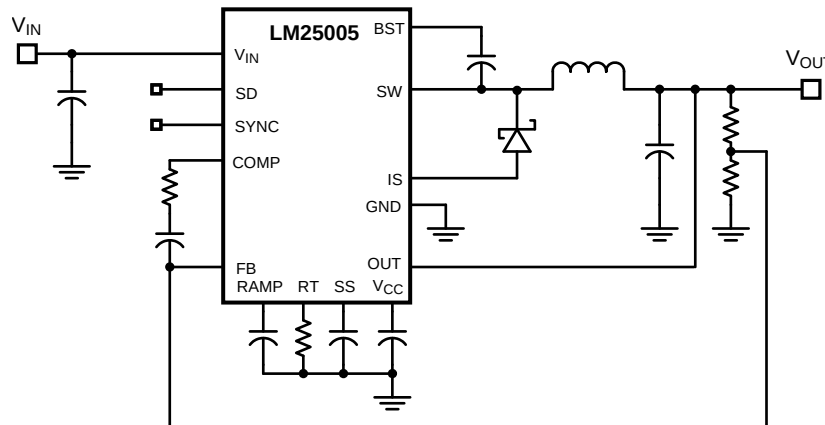
### DESCRIPTION

The LM25005 switching regulator features all of the functions necessary to implement an efficient, high voltage buck regulator using a minimum of external components. This easy to use regulator includes a 42V, 160mΩ, N-channel MOSFET, with an output current capability of 2.5 Amps. The regulator control method is based upon current mode control utilizing an emulated current ramp. Current mode control provides inherent line voltage feed-forward, cycle-by-cycle current limiting and ease of loop compensation. The use of an emulated control ramp reduces noise sensitivity of the pulse-width modulation circuit, allowing reliable control of very small duty cycles necessary in high input voltage applications. The operating frequency is programmable from 50kHz to 500kHz. An oscillator synchronization pin allows multiple LM25005 regulators to self-synchronize or to be synchronized to an external clock. Additional protection features include: current limit, thermal shutdown and remote shutdown capability. The device is available in a power enhanced HTSSOP package featuring an exposed die attach pad to aid thermal dissipation.

### Package

- HTSSOP (Exposed Pad)

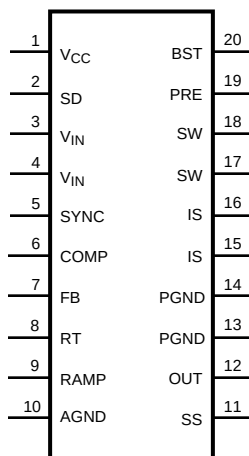
### Simplified Application Schematic



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.

## Connection Diagram



**Figure 1. Top View  
20-Lead HTSSOP**

### PIN DESCRIPTIONS

| Pin(S) | Name | Description                                | Application Information                                                                                                                                                                                                                                                                                                                                                                                                                              |
|--------|------|--------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1      | VCC  | Output of the bias regulator               | Vcc tracks Vin up to 9V. Beyond 9V, Vcc is regulated to 7 Volts. A 0.1uF to 1uF ceramic decoupling capacitor is required. An external voltage (7.5V – 14V) can be applied to this pin to reduce internal power dissipation.                                                                                                                                                                                                                          |
| 2      | SD   | Shutdown or UVLO input                     | If the SD pin voltage is below 0.7V the regulator will be in a low power state. If the SD pin voltage is between 0.7V and 1.225V the regulator will be in standby mode. If the SD pin voltage is above 1.225V the regulator will be operational. An external voltage divider can be used to set a line undervoltage shutdown threshold. If the SD pin is left open circuit, a 5μA pull-up current source configures the regulator fully operational. |
| 3, 4   | Vin  | Input supply voltage                       | Nominal operating range: 7V to 42V                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 5      | SYNC | Oscillator synchronization input or output | The internal oscillator can be synchronized to an external clock with an external pull-down device. Multiple LM25005 devices can be synchronized together by connection of their SYNC pins.                                                                                                                                                                                                                                                          |
| 6      | COMP | Output of the internal error amplifier     | The loop compensation network should be connected between this pin and the FB pin.                                                                                                                                                                                                                                                                                                                                                                   |
| 7      | FB   | Feedback signal from the regulated output  | This pin is connected to the inverting input of the internal error amplifier. The regulation threshold is 1.225V.                                                                                                                                                                                                                                                                                                                                    |
| 8      | RT   | Internal oscillator frequency set input    | The internal oscillator is set with a single resistor, connected between this pin and the AGND pin. The recommended frequency range is 50KHz to 500KHz.                                                                                                                                                                                                                                                                                              |
| 9      | RAMP | Ramp control signal                        | An external capacitor connected between this pin and the AGND pin sets the ramp slope used for current mode control. Recommended capacitor range 50pF to 2000pF.                                                                                                                                                                                                                                                                                     |
| 10     | AGND | Analog ground                              | Internal reference for the regulator control functions                                                                                                                                                                                                                                                                                                                                                                                               |
| 11     | SS   | Soft-start                                 | An external capacitor and an internal 10μA current source set the time constant for the rise of the error amp reference. The SS pin is held low during standby, Vcc UVLO and thermal shutdown.                                                                                                                                                                                                                                                       |
| 12     | OUT  | Output voltage connection                  | Connect directly to the regulated output voltage.                                                                                                                                                                                                                                                                                                                                                                                                    |
| 13, 14 | PGND | Power ground                               | Low side reference for the PRE switch and the IS sense resistor.                                                                                                                                                                                                                                                                                                                                                                                     |

### PIN DESCRIPTIONS (continued)

| Pin(S) | Name | Description                                   | Application Information                                                                                                                                                                                                                                                                                                                  |
|--------|------|-----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 15, 16 | IS   | Current sense                                 | Current measurement connection for the re-circulating diode. An internal sense resistor and a sample/hold circuit sense the diode current near the conclusion of the off-time. This current measurement provides the DC level of the emulated current ramp.                                                                              |
| 17, 18 | SW   | Switching node                                | The source terminal of the internal buck switch. The SW pin should be connected to the external Schottky diode and to the buck inductor.                                                                                                                                                                                                 |
| 19     | PRE  | Pre-charge assist for the bootstrap capacitor | This open drain output can be connected to SW pin to aid charging the bootstrap capacitor during very light load conditions or in applications where the output may be pre-charged before the LM25005 is enabled. An internal pre-charge MOSFET is turned on for 250ns each cycle just prior to the on-time interval of the buck switch. |
| 20     | BST  | Boost input for bootstrap capacitor           | An external capacitor is required between the BST and the SW pins. A 0.022µF ceramic capacitor is recommended. The capacitor is charged from V <sub>CC</sub> via an internal diode during the off-time of the buck switch.                                                                                                               |
| NA     | EP   | Exposed Pad                                   | Exposed metal pad on the underside of the device. It is recommended to connect this pad to the PWB ground plane, in order to aid in heat dissipation.                                                                                                                                                                                    |



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<sup>(1)(2)</sup>

|                           |                            |
|---------------------------|----------------------------|
| V <sub>IN</sub> to GND    | 45V                        |
| BST to GND                | 60V                        |
| PRE to GND                | 45V                        |
| SW to GND (Steady State)  | -1.5V                      |
| BST to V <sub>CC</sub>    | 45V                        |
| V <sub>CC</sub> to GND    | 14V                        |
| BST to SW                 | 14V                        |
| OUT to GND                | Limited to V <sub>in</sub> |
| SD, SYNC, SS, FB to GND   | 7V                         |
| ESD Rating <sup>(3)</sup> | Human Body Model           |
| Storage Temperature Range | -65°C to +150°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 ensured specifications and test conditions, see the [Electrical Characteristics](#).
- (2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/Distributors for availability and specifications.
- (3) The human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin.

### Operating Ratings<sup>(1)</sup>

|                                |                  |
|--------------------------------|------------------|
| V <sub>IN</sub>                | 7V to 42V        |
| Operation 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 ensured 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**.  $V_{IN} = 24\text{V}$ ,  $R_T = 32.4\text{k}\Omega$  unless otherwise stated.<sup>(1)</sup>

| Symbol                        | Parameter                          | Conditions                                     | Min         | Typ   | Max         | Units         |
|-------------------------------|------------------------------------|------------------------------------------------|-------------|-------|-------------|---------------|
| <b>STARTUP REGULATOR</b>      |                                    |                                                |             |       |             |               |
| VccReg                        | Vcc Regulator Output               |                                                | <b>6.85</b> | 7.15  | <b>7.45</b> | V             |
|                               | Vcc LDO Mode turn-off              |                                                |             | 9     |             | V             |
|                               | Vcc Current Limit                  | $V_{cc} = 0\text{V}$                           |             | 20    |             | mA            |
| <b>VCC SUPPLY</b>             |                                    |                                                |             |       |             |               |
|                               | Vcc UVLO Threshold                 | (Vcc increasing)                               | <b>5.95</b> | 6.35  | <b>6.75</b> | V             |
|                               | Vcc Undervoltage Hysteresis        |                                                |             | 1     |             | V             |
|                               | Bias Current (lin)                 | $FB = 1.3\text{V}$                             |             | 3     | <b>4.5</b>  | mA            |
|                               | Shutdown Current (lin)             | $SD = 0\text{V}$                               |             | 50    | <b>85</b>   | $\mu\text{A}$ |
| <b>SHUTDOWN THRESHOLDS</b>    |                                    |                                                |             |       |             |               |
|                               | Shutdown Threshold                 | (SD Increasing)                                | <b>0.5</b>  | 0.7   | <b>0.9</b>  | V             |
|                               | Shutdown Hysteresis                |                                                |             | 0.1   |             | V             |
|                               | Standby Threshold                  | (Standby Increasing)                           | <b>1.18</b> | 1.225 | <b>1.27</b> | V             |
|                               | Standby Hysteresis                 |                                                |             | 0.1   |             | V             |
|                               | SD Pull-up Current Source          |                                                |             | 5     |             | $\mu\text{A}$ |
| <b>SWITCH CHARACTERISTICS</b> |                                    |                                                |             |       |             |               |
|                               | Buck Switch $R_{ds(on)}$           |                                                |             | 160   | <b>320</b>  | m $\Omega$    |
|                               | BOOST UVLO                         |                                                |             | 3.8   |             | V             |
|                               | BOOST UVLO Hysteresis              |                                                |             | 0.56  |             | V             |
|                               | Pre-charge Switch $R_{ds(on)}$     |                                                |             | 75    |             | $\Omega$      |
|                               | Pre-charge Switch on-time          |                                                |             | 275   |             | ns            |
| <b>CURRENT LIMIT</b>          |                                    |                                                |             |       |             |               |
|                               | Cycle by Cycle Current Limit       | $RAMP = 0\text{V}$                             | <b>3</b>    | 3.5   | <b>4.25</b> | A             |
|                               | Cycle by Cycle Current Limit Delay | $RAMP = 2.5\text{V}$                           |             | 100   |             | ns            |
| <b>SOFT-START</b>             |                                    |                                                |             |       |             |               |
|                               | SS Current Source                  |                                                | <b>7</b>    | 10    | <b>14</b>   | $\mu\text{A}$ |
| <b>OSCILLATOR</b>             |                                    |                                                |             |       |             |               |
|                               | Frequency1                         |                                                | <b>180</b>  | 200   | <b>220</b>  | KHz           |
|                               | Frequency2                         | $R_T = 11\text{k}\Omega$                       | <b>425</b>  | 485   | <b>525</b>  | KHz           |
|                               | SYNC Source Impedance              |                                                |             | 10    |             | k $\Omega$    |
|                               | SYNC Sink Impedance                |                                                |             | 160   |             | $\Omega$      |
|                               | SYNC Threshold (falling)           |                                                |             | 1.4   |             | V             |
|                               | Upper SYNC Frequency               |                                                |             |       | <b>550</b>  | KHz           |
|                               | SYNC Pulse Width Minimum           |                                                | <b>15</b>   |       |             | ns            |
| <b>RAMP GENERATOR</b>         |                                    |                                                |             |       |             |               |
|                               | Ramp Current 1                     | $V_{in} = 36\text{V}$ , $V_{out} = 10\text{V}$ | <b>136</b>  | 160   | <b>184</b>  | $\mu\text{A}$ |
|                               | Ramp Current 2                     | $V_{in} = 10\text{V}$ , $V_{out} = 10\text{V}$ | <b>18</b>   | 25    | <b>32</b>   | $\mu\text{A}$ |
| <b>PWM COMPARATOR</b>         |                                    |                                                |             |       |             |               |
|                               | Forced Off-time                    |                                                |             | 500   |             | ns            |
|                               | Min On-time                        |                                                |             | 80    |             | ns            |
|                               | COMP to PWM Comparator Offset      |                                                |             | 0.7   |             | V             |

(1) Min and Max limits are 100% production tested at  $25^\circ\text{C}$ . Limits over the operating temperature range are ensured through correlation using Statistical Quality Control (SQC) methods. Limits are used to calculate Average Outgoing Quality Level (AOQL).

## 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**.  $V_{IN} = 24\text{V}$ ,  $R_T = 32.4\text{k}\Omega$  unless otherwise stated.<sup>(1)</sup>

| Symbol                    | Parameter                   | Conditions             | Min          | Typ   | Max          | Units              |
|---------------------------|-----------------------------|------------------------|--------------|-------|--------------|--------------------|
| <b>ERROR AMPLIFIER</b>    |                             |                        |              |       |              |                    |
|                           | Feedback Voltage            | $V_{fb} = \text{COMP}$ | <b>1.207</b> | 1.225 | <b>1.243</b> | V                  |
|                           | FB Bias Current             |                        |              | 10    |              | nA                 |
|                           | DC Gain                     |                        |              | 70    |              | dB                 |
|                           | COMP Sink / Source Current  |                        | <b>3</b>     |       |              | mA                 |
|                           | Unity Gain Bandwidth        |                        |              | 3     |              | MHz                |
| <b>THERMAL SHUTDOWN</b>   |                             |                        |              |       |              |                    |
| $T_{sd}$                  | Thermal Shutdown Threshold  |                        |              | 165   |              | $^\circ\text{C}$   |
|                           | Thermal Shutdown Hysteresis |                        |              | 25    |              | $^\circ\text{C}$   |
| <b>THERMAL RESISTANCE</b> |                             |                        |              |       |              |                    |
| $\theta_{JC}$             | Junction to Case            |                        |              | 4     |              | $^\circ\text{C/W}$ |
| $\theta_{JA}$             | Junction to Ambient         |                        |              | 40    |              | $^\circ\text{C/W}$ |

## Typical Performance Characteristics

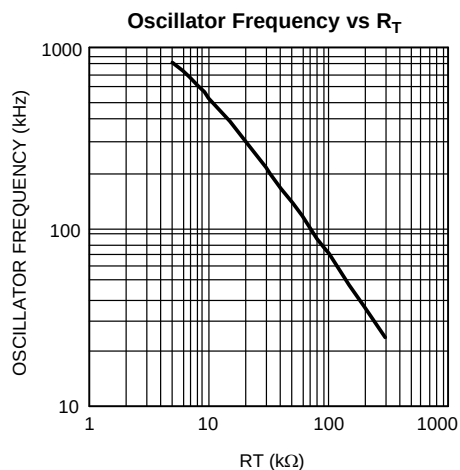


Figure 2.

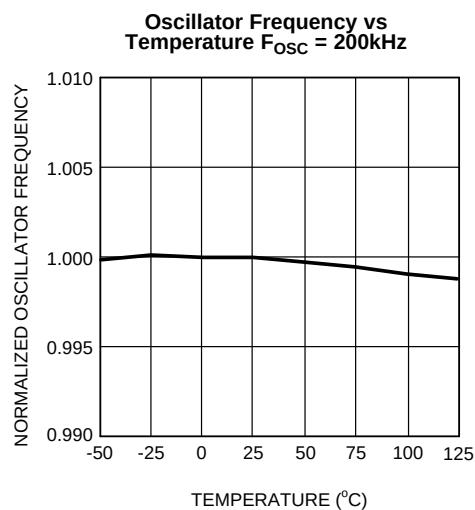


Figure 3.

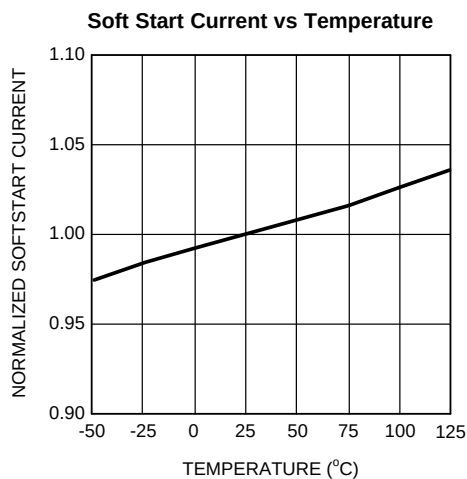


Figure 4.

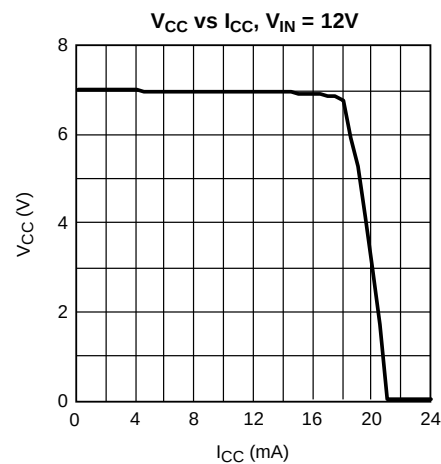


Figure 5.

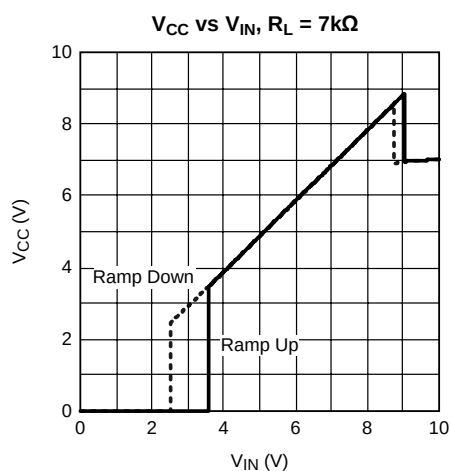


Figure 6.

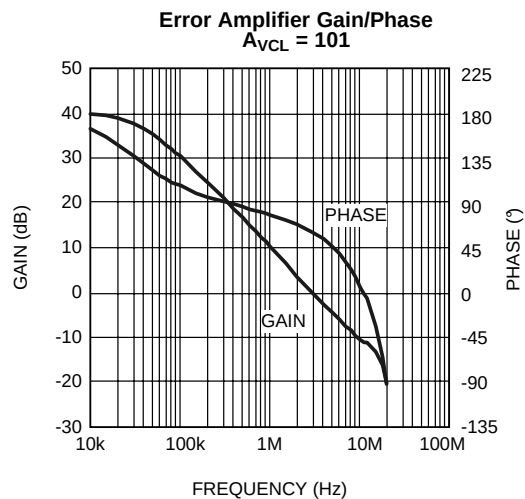
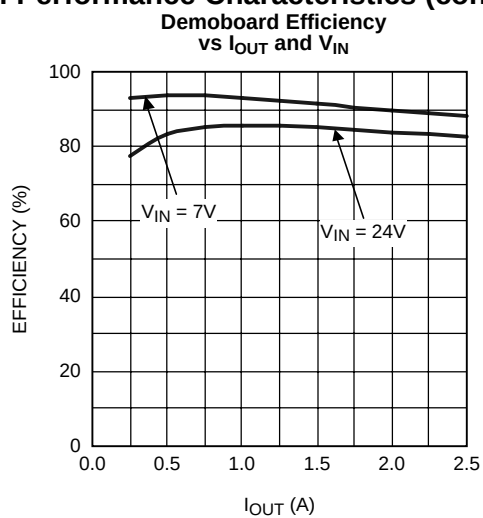


Figure 7.

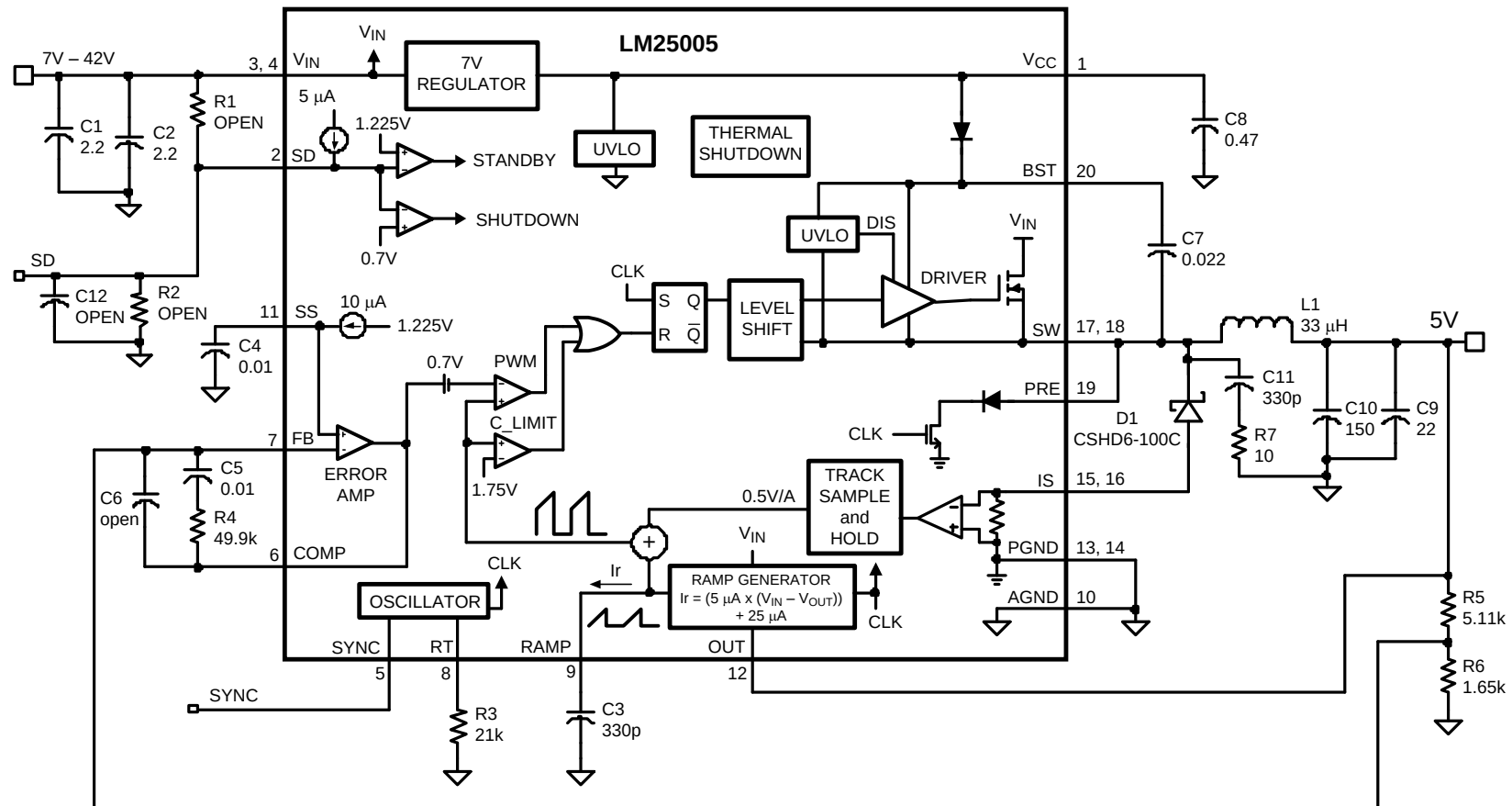
## Typical Performance Characteristics (continued)



**Figure 8.**



## Typical Application Circuit and Block Diagram



## Detailed Operating Description

The LM25005 switching regulator features all of the functions necessary to implement an efficient high voltage buck regulator using a minimum of external components. This easy to use regulator integrates a 42V N-Channel buck switch with an output current capability of 2.5 Amps. The regulator control method is based on current mode control utilizing an emulated current ramp. Peak current mode control provides inherent line voltage feed-forward, cycle-by-cycle current limiting, and ease of loop compensation. The use of an emulated control ramp reduces noise sensitivity of the pulse-width modulation circuit, allowing reliable processing of very small duty cycles necessary in high input voltage applications. The operating frequency is user programmable from 50kHz to 500kHz. An oscillator synchronization pin allows multiple LM25005 regulators to self synchronize or be synchronized to an external clock. The output voltage can be set as low as 1.225V. Fault protection features include, current limiting, thermal shutdown and remote shutdown capability. The device is available in the HTSSOP package featuring an exposed pad to aid thermal dissipation.

The functional block diagram and typical application of the LM25005 are shown in the [Typical Application Circuit and Block Diagram](#). The LM25005 can be applied in numerous applications to efficiently step-down a high, unregulated input voltage. The device is well suited for telecom, industrial and automotive power bus voltage ranges.

### High Voltage Start-Up Regulator

The LM25005 contains a dual-mode internal high voltage startup regulator that provides the Vcc bias supply for the PWM controller and boot-strap MOSFET gate driver. The input pin (Vin) can be connected directly to the input voltage, as high as 42 Volts. For input voltages below 9V, a low dropout switch connects Vcc directly to Vin. In this supply range, Vcc is approximately equal to Vin. For Vin voltage greater than 9V, the low dropout switch is disabled and the Vcc regulator is enabled to maintain Vcc at approximately 7V. The wide operating range of 7V to 42V is achieved through the use of this dual mode regulator.

The output of the Vcc regulator is current limited to 20mA. Upon power up, the regulator sources current into the capacitor connected to the Vcc pin. When the voltage at the Vcc pin exceeds the Vcc UVLO threshold of 6.3V and the SD pin is greater than 1.225V, the output switch is enabled and a soft-start sequence begins. The output switch remains enabled until Vcc falls below 5.3V or the SD pin falls below 1.125V.

An auxiliary supply voltage can be applied to the Vcc pin to reduce the IC power dissipation. If the auxiliary voltage is greater than 7.3V, the internal regulator will essentially shut off, reducing the IC power dissipation. The Vcc regulator series pass transistor includes a diode between Vcc and Vin that should not be forward biased in normal operation. Therefore the auxiliary Vcc voltage should never exceed the Vin voltage.

In high voltage applications extra care should be taken to ensure the Vin pin does not exceed the absolute maximum voltage rating of 45V. During line or load transients, voltage ringing on the Vin line that exceeds the [Absolute Maximum Ratings](#) can damage the IC. Both careful PC board layout and the use of quality bypass capacitors located close to the Vin and GND pins are essential.

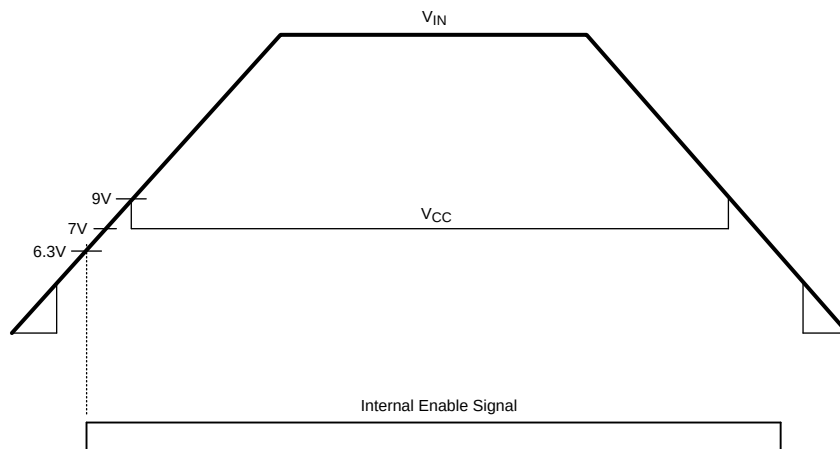


Figure 9. Vin and Vcc Sequencing

## Shutdown / Standby

The LM25005 contains a dual level Shutdown (SD) circuit. When the SD pin voltage is below 0.7V, the regulator is in a low current shutdown mode. When the SD pin voltage is greater than 0.7V but less than 1.225V, the regulator is in standby mode. In standby mode the Vcc regulator is active but the output switch is disabled. When the SD pin voltage exceeds 1.225V, the output switch is enabled and normal operation begins. An internal 5µA pull-up current source configures the regulator to be fully operational if the SD pin is left open.

An external set-point voltage divider from Vin to GND can be used to set the operational input range of the regulator. The divider must be designed such that the voltage at the SD pin will be greater than 1.225V when Vin is in the desired operating range. The internal 5µA pull-up current source must be included in calculations of the external set-point divider. Hysteresis of 0.1V is included for both the shutdown and standby thresholds. The voltage at the SD pin should never exceed 8V. When using an external set-point divider, it may be necessary to clamp the SD pin to limit its voltage at high input voltage conditions.

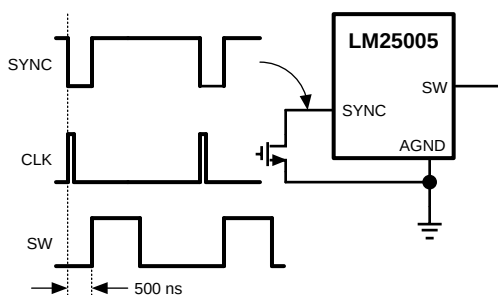
The SD pin can also be used to implement various remote enable / disable functions. Pulling the UVLO pin below the 0.7V threshold totally disables the controller. If the SD pin voltage is above 1.225V the regulator will be operational.

## Oscillator and Sync Capability

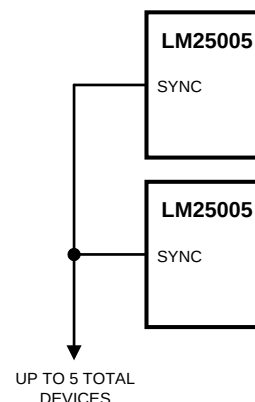
The LM25005 oscillator frequency is set by a single external resistor connected between the RT pin and the AGND pin. The R<sub>T</sub> resistor should be located very close to the device and connected directly to the pins of the IC (RT and AGND). To set a desired oscillator frequency (F), the necessary value for the R<sub>T</sub> resistor can be calculated from the following equation:

$$R_T = \frac{\frac{1}{F} - 580 \times 10^{-9}}{135 \times 10^{-12}} \quad (1)$$

The SYNC pin can be used to synchronize the internal oscillator to an external clock. The external clock must be of **higher frequency** than the free-running frequency set by the R<sub>T</sub> resistor. A clock circuit with an open drain output is the recommended interface from the external clock to the SYNC pin. The clock pulse duration should be greater than 15 ns.



**Figure 10. Sync from External Clock**



**Figure 11. Sync from Multiple Devices**

Multiple LM25005 and/or LM5005 devices can be synchronized together simply by connecting the SYNC pins together. In this configuration all of the devices will be synchronized to the highest frequency device. The diagram in [Figure 12](#) illustrates the SYNC input/output features of the LM25005. The internal oscillator circuit drives the SYNC pin with a strong pull-down / weak pull-up inverter. When the SYNC pin is pulled low either by the internal oscillator or an external clock, the ramp cycle of the oscillator is terminated and a new oscillator cycle begins. Thus, if the SYNC pins of several LM25005 IC's are connected together, the IC with the highest internal clock frequency will pull the connected SYNC pins low first and terminate the oscillator ramp cycles of the other IC's. The LM25005 or LM5005 with the highest programmed clock frequency will serve as the master and control the switching frequency of the all the devices with lower oscillator frequency.

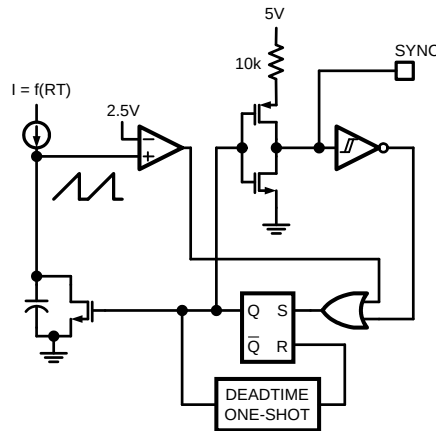


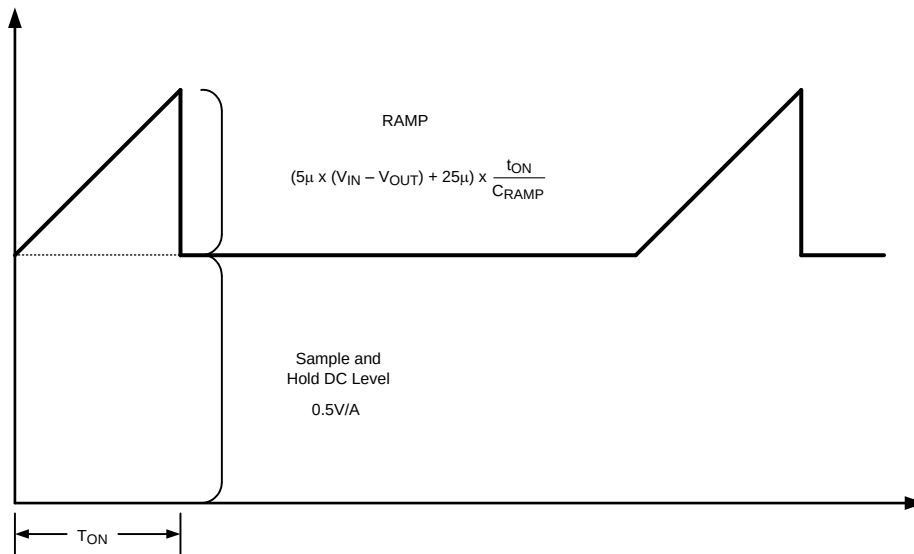
Figure 12. Simplified Oscillator Block Diagram and SYNC I/O Circuit

### Error Amplifier and PWM Comparator

The internal high gain error amplifier generates an error signal proportional to the difference between the regulated output voltage and an internal precision reference (1.225V). The output of the error amplifier is connected to the COMP pin allowing the user to provide loop compensation components, generally a type II network, as illustrated in [Typical Application Circuit and Block Diagram](#). This network creates a pole at DC, a zero and a noise reducing high frequency pole. The PWM comparator compares the emulated current sense signal from the RAMP generator to the error amplifier output voltage at the COMP pin.

### RAMP Generator

The ramp signal used in the pulse width modulator for current mode control is typically derived directly from the buck switch current. This switch current corresponds to the positive slope portion of the output inductor current. Using this signal for the PWM ramp simplifies the control loop transfer function to a single pole response and provides inherent input voltage feed-forward compensation. The disadvantage of using the buck switch current signal for PWM control is the large leading edge spike due to circuit parasitics that must be filtered or blanked. Also, the current measurement may introduce significant propagation delays. The filtering, blanking time and propagation delay limit the minimum achievable pulsewidth. In applications where the input voltage may be relatively large in comparison to the output voltage, controlling small pulsewidths and duty cycles is necessary for regulation. The LM25005 utilizes a unique ramp generator, which does not actually measure the buck switch current but rather reconstructs the signal. Reconstructing or emulating the inductor current provides a ramp signal to the PWM comparator that is free of leading edge spikes and measurement or filtering delays. The current reconstruction is comprised of two elements; a sample & hold DC level and an emulated current ramp.



**Figure 13. Composition of Current Sense Signal**

The Sample and Hold DC level illustrated in Figure 13, is derived from a measurement of the re-circulating Schottky diode anode current. The re-circulating diode anode should be connected to the IS pin. The diode current flows through an internal current sense resistor between the IS and PGND pins. The voltage level across the sense resistor is sampled and held just prior to the onset of the next conduction interval of the buck switch. The diode current sensing and sample & hold provide the dc level of the reconstructed current signal. The positive slope inductor current ramp is emulated by an external capacitor connected from the RAMP pin to AGND and an internal voltage controlled current source. The ramp current source that emulates the inductor current is a function of the  $V_{in}$  and  $V_{out}$  voltages per the following equation:

$$I_{RAMP} = (5\mu \times (V_{in} - V_{out})) + 25\mu A \quad (2)$$

Proper selection of the RAMP capacitor depends upon the selected value of the output inductor. The value of  $C_{RAMP}$  can be selected from:  $C_{RAMP} = L \times 10^{-5}$ , where  $L$  is the value of the output inductor in Henrys. With this value, the scale factor of the emulated current ramp will be approximately equal to the scale factor of the dc level sample and hold (  $0.5 \text{ V} / \text{A}$  ). The  $C_{RAMP}$  capacitor should be located very close to the device and connected directly to the pins of the IC (RAMP and AGND).

For duty cycles greater than 50%, peak current mode control circuits are subject to sub-harmonic oscillation. Sub-harmonic oscillation is normally characterized by observing alternating wide and narrow pulses at the switch node. Adding a fixed slope voltage ramp (slope compensation) to the current sense signal prevents this oscillation. The  $25\mu A$  of offset current provided from the emulated current source adds some fixed slope to the ramp signal. In some high output voltage, high duty cycle applications, additional slope may be required. In these applications, a pull-up resistor may be added between the  $V_{CC}$  and RAMP pins to increase the ramp slope compensation.

For  $V_{OUT} > 7.5V$ :

Calculate optimal slope current,  $I_{OS} = V_{OUT} \times 5\mu A/V$ .

For example, at  $V_{OUT} = 10V$ ,  $I_{OS} = 50\mu A$ .

Install a resistor from the RAMP pin to  $V_{CC}$ :

$$R_{RAMP} = V_{CC} / (I_{OS} - 25\mu A)$$

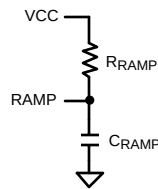


Figure 14.  $R_{RAMP}$  to  $V_{CC}$  for  $V_{OUT} > 7.5V$

## Current Limit

The LM25005 contains a unique current monitoring scheme for control and over-current protection. When set correctly, the emulated current sense signal provides a signal which is proportional to the buck switch current with a scale factor of  $0.5 \text{ V} / \text{A}$ . The emulated ramp signal is applied to the current limit comparator. If the emulated ramp signal exceeds 1.75V (3.5A) the present current cycle is terminated (cycle-by-cycle current limiting). In applications with small output inductance and high input voltage the switch current may overshoot due to the propagation delay of the current limit comparator. If an overshoot should occur, the diode current sampling circuit will detect the excess inductor current during the off-time of the buck switch. If the Sample and Hold DC Level exceeds the 1.75V current limit threshold, the buck switch will be disabled and skip pulses until the diode current sampling circuit detects the inductor current has decayed below the current limit threshold. This approach prevents current runaway conditions due to propagation delays or inductor saturation since the inductor current is forced to decay following any current overshoot.

## Soft-Start

The soft-start feature allows the regulator to gradually reach the initial steady state operating point, thus reducing start-up stresses and surges. The internal soft-start current source, set to  $10\mu\text{A}$ , gradually increases the voltage of an external soft-start capacitor connected to the SS pin. The soft-start capacitor voltage is connected to the reference input of the error amplifier. Various sequencing and tracking schemes can be implemented using external circuits that limit or clamp the voltage level of the SS pin.

In the event a fault is detected (over-temperature,  $V_{CC}$  UVLO, SD) the soft-start capacitor will be discharged. When the fault condition is no longer present a new soft-start sequence will commence.

## Boost Pin

The LM25005 integrates an N-Channel buck switch and associated floating high voltage level shift / gate driver. This gate driver circuit works in conjunction with an internal diode and an external bootstrap capacitor. A  $0.022\mu\text{F}$  ceramic capacitor, connected with short traces between the BST pin and SW pin, is recommended. During the off-time of the buck switch, the SW pin voltage is approximately - 0.5V and the bootstrap capacitor is charged from  $V_{CC}$  through the internal bootstrap diode. When operating with a high PWM duty cycle, the buck switch will be forced off each cycle for 500ns to ensure that the bootstrap capacitor is recharged.

Under very light load conditions or when the output voltage is pre-charged, the SW voltage will not remain low during the off-time of the buck switch. If the inductor current falls to zero and the SW pin rises, the bootstrap capacitor will not receive sufficient voltage to operate the buck switch gate driver. For these applications, the PRE pin can be connected to the SW pin to pre-charge the bootstrap capacitor. The internal pre-charge MOSFET and diode connected between the PRE pin and PGND turns on each cycle for 250ns just prior to the onset of a new switching cycle. If the SW pin is at a normal negative voltage level (continuous conduction mode), then no current will flow through the pre-charge MOSFET/diode.

## 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 degrees Celsius, the controller is forced into a low power reset state, disabling the output driver and the bias regulator. This feature is provided to prevent catastrophic failures from accidental device overheating.

## APPLICATION INFORMATION

### EXTERNAL COMPONENTS

The procedure for calculating the external components is illustrated with the following design example. The Bill of Materials for this design is listed in [5V, 2.5A Demo Board Bill of Materials](#). The circuit shown in [Typical Application Circuit and Block Diagram](#) is configured for the following specifications:

- $V_{OUT} = 5V$
- $V_{IN} = 7V$  to  $42V$
- $F_s = 300\text{ KHz}$
- Minimum load current (for CCM) =  $250\text{ mA}$
- Maximum load current =  $2.5A$

### R<sub>T</sub> (R<sub>T</sub>)

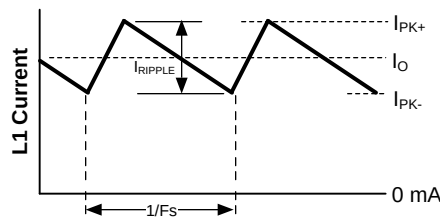
$R_T$  sets the oscillator switching frequency. Generally, higher frequency applications are smaller but have higher losses. Operation at  $300\text{KHz}$  was selected for this example as a reasonable compromise for both small size and high efficiency. The value of  $R_T$  for  $300\text{KHz}$  switching frequency can be calculated as follows:

$$R_T = \frac{[(1 / 300 \times 10^3) - 580 \times 10^{-9}]}{135 \times 10^{-12}} \quad (3)$$

The nearest standard value of  $21\text{ k}\Omega$  was chosen for  $R_T$ .

### L1

The inductor value is determined based on the operating frequency, load current, ripple current, and the minimum and maximum input voltage ( $V_{IN(min)}$ ,  $V_{IN(max)}$ ).



**Figure 15. Inductor Current Waveform**

To keep the circuit in continuous conduction mode (CCM), the maximum ripple current  $I_{RIPPLE}$  should be less than twice the minimum load current, or  $0.5\text{ A-p-p}$ . Using this value of ripple current, the value of inductor ( $L1$ ) is calculated using the following:

$$L1 = \frac{V_{OUT} \times (V_{IN(max)} - V_{OUT})}{I_{RIPPLE} \times F_s \times V_{IN(max)}} \quad (4)$$

$$L1 = \frac{5V \times (42V - 5V)}{0.5A \times 300\text{ kHz} \times 42V} = 29\text{ }\mu\text{H} \quad (5)$$

This procedure provides a guide to select the value of  $L1$ . The nearest standard value ( $33\text{ }\mu\text{H}$ ) will be used.  $L1$  must be rated for the peak current ( $I_{PK+}$ ) to prevent saturation. During normal loading conditions, the peak current occurs at maximum load current plus maximum ripple. During an overload condition the peak current is limited to  $3.5A$  nominal ( $4.25A$  maximum). The selected inductor (see [5V, 2.5A Demo Board Bill of Materials](#)) has a conservative  $6.2\text{ Amp}$  saturation current rating. For this manufacturer, the saturation rating is defined as the current necessary for the inductance to reduce by  $30\%$ , at  $20^\circ\text{C}$ .



### C3 (C<sub>RAMP</sub>)

With the inductor value selected, the value of C3 (C<sub>RAMP</sub>) necessary for the emulation ramp circuit is:

$$C_{RAMP} = L \times 10^{-5}$$

where

- L is in Henrys (With L1 selected for 33μH the recommended value for C3 is 330pF) (6)

### C9, C10

The output capacitors C9, and C10, smooth the inductor ripple current and provide a source of charge for transient loading conditions. For this design a 22μF ceramic capacitor and a 150μF SP organic capacitor were selected. The ceramic capacitor provides ultra low ESR to reduce the output ripple voltage and noise spikes, while the SP capacitor provides a large bulk capacitance in a small volume for transient loading conditions. An approximation for the output ripple voltage is:

$$\Delta V_{OUT} = \Delta I_L \times \left( ESR + \frac{1}{8 \times F_S \times C_{OUT}} \right) \quad (7)$$

### D1

A Schottky type re-circulating diode is required for all LM25005 applications. Ultra-fast diodes are not recommended and may result in damage to the IC due to reverse recovery current transients. The near ideal reverse recovery characteristics and low forward voltage drop are particularly important diode characteristics for high input voltage and low output voltage applications common to the LM25005. The reverse recovery characteristic determines how long the current surge lasts each cycle when the buck switch is turned on. The reverse recovery characteristics of Schottky diodes minimize the peak instantaneous power in the buck switch occurring during turn-on each cycle. The resulting switching losses of the buck switch are significantly reduced when using a Schottky diode. The reverse breakdown rating should be selected for the maximum V<sub>IN</sub>, plus some safety margin.

The forward voltage drop has a significant impact on the conversion efficiency, especially for applications with a low output voltage. "Rated" current for diodes vary widely from various manufactures. The worst case is to assume a short circuit load condition. In this case the diode will carry the output current almost continuously. For the LM25005 this current can be as high as 3.5A. Assuming a worst case 1V drop across the diode, the maximum diode power dissipation can be as high as 3.5W. For the reference design a 60V Schottky in a DPAK package was selected.

### C1, C2

The regulator supply voltage has a large source impedance at the switching frequency. Good quality input capacitors are necessary to limit the ripple voltage at the VIN pin while supplying most of the switch current during the on-time. When the buck switch turns on, the current into the VIN pin steps to the lower peak of the inductor current waveform, ramps up to the peak value, then drops to zero at turn-off. The average current into VIN during the on-time is the load current. The input capacitance should be selected for RMS current rating and minimum ripple voltage. A good approximation for the required ripple current rating necessary is I<sub>RMS</sub> > I<sub>OUT</sub> / 2.

Quality ceramic capacitors with a low ESR should be selected for the input filter. To allow for capacitor tolerances and voltage effects, two 2.2 μF, 100V ceramic capacitors will be used. If step input voltage transients are expected near the maximum rating of the LM25005, a careful evaluation of ringing and possible spikes at the device VIN pin should be completed. An additional damping network or input voltage clamp may be required in these cases.

### C8

The capacitor at the VCC pin provides noise filtering and stability for the V<sub>CC</sub> regulator. The recommended value of C8 should be no smaller than 0.1 μF, and should be a good quality, low ESR, ceramic capacitor. A value of 0.47 μF was selected for this design.



**C7**

The bootstrap capacitor between the BST and the SW pins supplies the gate current to charge the buck switch gate at turn-on. The recommended value of C7 is 0.022  $\mu$ F, and should be a good quality, low ESR, ceramic capacitor.

**C4**

The capacitor at the SS pin determines the soft-start time, i.e. the time for the reference voltage and the output voltage, to reach the final regulated value. The time is determined from:

$$t_{ss} = \frac{C4 \times 1.225V}{10 \mu A} \quad (8)$$

For this application, a C4 value of 0.01  $\mu$ F was chosen which corresponds to a soft-start time of 1 ms.

**R5, R6**

R5 and R6 set the output voltage level, the ratio of these resistors is calculated from:

$$R5/R6 = (V_{OUT} / 1.225V) - 1 \quad (9)$$

For a 5V output, the R5/R6 ratio calculates to 3.082. The resistors should be chosen from standard value resistors, a good starting point is selection in the range of 1.0 k $\Omega$  - 10 k $\Omega$ . Values of 5.11 k $\Omega$  for R5, and 1.65 k $\Omega$  for R6 were selected.

**R1, R2, C12**

A voltage divider can be connected to the SD pin to set a minimum operating voltage  $V_{IN(min)}$  for the regulator. If this feature is required, the easiest approach to select the divider resistor values is to select a value for R1 (between 10 k $\Omega$  and 100 k $\Omega$  recommended) then calculate R2 from:

$$R2 = 1.225 \times \left( \frac{R1}{V_{IN(min)} + (5 \times 10^{-6} \times R1) - 1.225} \right) \quad (10)$$

Capacitor C12 provides filtering for the divider. The voltage at the SD pin should never exceed 8V, when using an external set-point divider it may be necessary to clamp the SD pin at high input voltage conditions. The reference design utilizes the full range of the LM25005 (7V to 42V); therefore these components can be omitted. With the SD pin open circuit the LM25005 responds once the Vcc UVLO threshold is satisfied.

**R7, C11**

A snubber network across the power diode reduces ringing and spikes at the switching node. Excessive ringing and spikes can cause erratic operation and couple spikes and noise to the output. In the limit, spikes beyond the rating of the LM25005 or the re-circulating diode can damage these devices. Selecting the values for the snubber is best accomplished through empirical methods. First, make sure the lead lengths for the snubber connections are very short. For the current levels typical for the LM25005 a resistor value between 5 and 20 Ohms is adequate. Increasing the value of the snubber capacitor results in more damping but higher losses. Select a minimum value of C11 that provides adequate damping of the SW pin waveform at high load.

## R4, C5, C6

These components configure the error amplifier gain characteristics to accomplish a stable overall loop gain. One advantage of current mode control is the ability to close the loop with only two feedback components, R4 and C5. The overall loop gain is the product of the modulator gain and the error amplifier gain. The DC modulator gain of the LM25005 is as follows:

$$\text{DC Gain}_{(\text{MOD})} = G_{m(\text{MOD})} \times R_{\text{LOAD}} = 2 \times R_{\text{LOAD}} \quad (11)$$

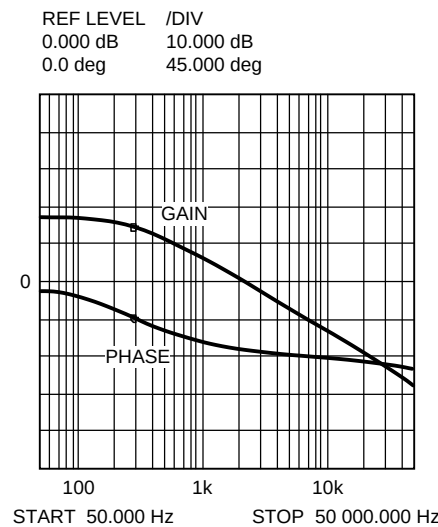
The dominant low frequency pole of the modulator is determined by the load resistance ( $R_{\text{LOAD}}$ ) and output capacitance ( $C_{\text{OUT}}$ ). The corner frequency of this pole is:

$$f_{p(\text{MOD})} = 1 / (2\pi R_{\text{LOAD}} C_{\text{OUT}}) \quad (12)$$

For  $R_{\text{LOAD}} = 5 \Omega$  and  $C_{\text{OUT}} = 177 \mu\text{F}$  then  $f_{p(\text{MOD})} = 180\text{Hz}$

$$\text{DC Gain}_{(\text{MOD})} = 2 \times 5 = 10 = 20 \text{ dB}$$

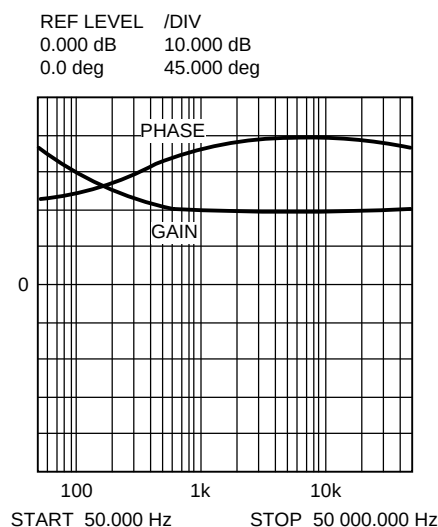
For the design example of [Typical Application Circuit and Block Diagram](#) the following modulator gain vs. frequency characteristic was measured as shown in [Figure 16](#).



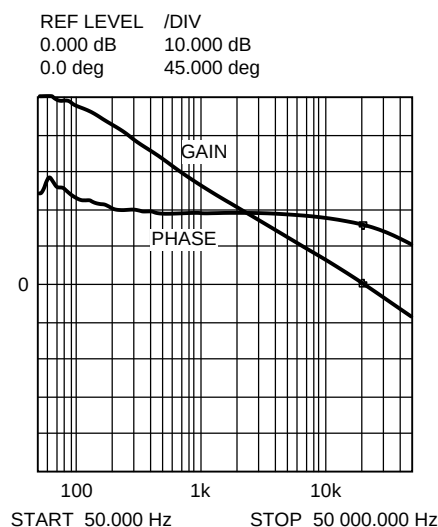
**Figure 16. Gain and Phase of Modulator**  
 **$R_{\text{LOAD}} = 5 \text{ Ohms}$  and  $C_{\text{OUT}} = 177 \mu\text{F}$**

Components R4 and C5 configure the error amplifier as a type II configuration which has a pole at DC and a zero at  $f_z = 1 / (2\pi R4 C5)$ . The error amplifier zero cancels the modulator pole leaving a single pole response at the crossover frequency of the loop gain. A single pole response at the crossover frequency yields a very stable loop with 90 degrees of phase margin.

For the design example, a target loop bandwidth (crossover frequency) of 20 kHz was selected. The compensation network zero ( $f_z$ ) should be selected at least an order of magnitude less than the target crossover frequency. This constrains the product of R4 and C5 for a desired compensation network zero  $1 / (2\pi R4 C5)$  to be less than 2kHz. Increasing R4 while proportionally decreasing C5, increases the error amp gain. Conversely, decreasing R4 while proportionally increasing C5, decreases the error amp gain. For the design example C5 was selected for 0.01 $\mu\text{F}$  and R4 was selected for 49.9 k $\Omega$ . These values configure the compensation network zero at 320 Hz. The error amp gain at frequencies greater than  $f_z$  is:  $R4 / R5$ , which is approximately 10 (20dB).

**Figure 17. Error Amplifier Gain and Phase**

The overall loop can be predicted as the sum (in dB) of the modulator gain and the error amp gain.

**Figure 18. Overall Loop Gain and Phase**

If a network analyzer is available, the modulator gain can be measured and the error amplifier gain can be configured for the desired loop transfer function. If a network analyzer is not available, the error amplifier compensation components can be designed with the guidelines given. Step load transient tests can be performed to verify acceptable performance. The step load goal is minimum overshoot with a damped response. C6 can be added to the compensation network to decrease noise susceptibility of the error amplifier. The value of C6 must be sufficiently small since the addition of this capacitor adds a pole in the error amplifier transfer function. This pole must be well beyond the loop crossover frequency. A good approximation of the location of the pole added by C6 is:  $f_{p2} = f_z \times C5 / C6$ .

## BIAS POWER DISSIPATION REDUCTION

Buck regulators operating with high input voltage can dissipate an appreciable amount of power for the bias of the IC. The  $V_{CC}$  regulator must step-down the input voltage  $V_{IN}$  to a nominal  $V_{CC}$  level of 7V. The large voltage drop across the  $V_{CC}$  regulator translates into a large power dissipation within the  $V_{CC}$  regulator. There are several techniques that can significantly reduce this bias regulator power dissipation. Figure 19 and Figure 20 depict two methods to bias the IC from the output voltage. In each case the internal  $V_{CC}$  regulator is used to initially bias the  $V_{CC}$  pin. After the output voltage is established, the  $V_{CC}$  pin potential is raised above the nominal 7V regulation level, which effectively disables the internal  $V_{CC}$  regulator. The voltage applied to the  $V_{CC}$  pin should never exceed 14V. The  $V_{CC}$  voltage should never be larger than the  $V_{IN}$  voltage.

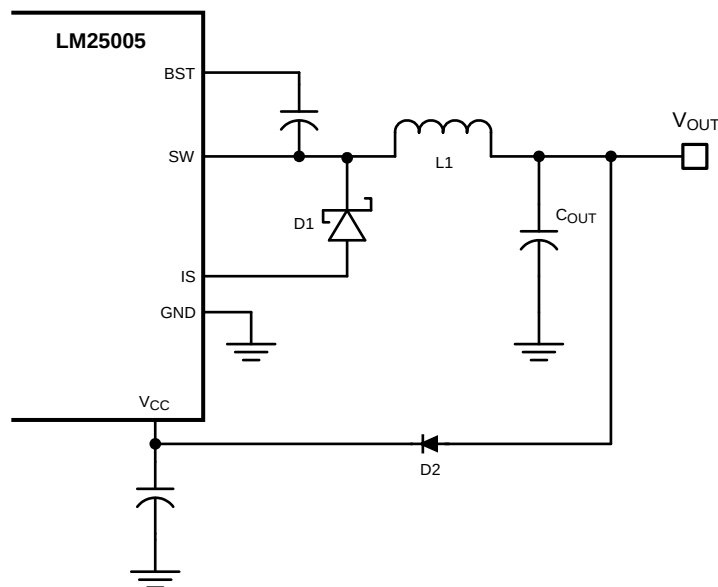


Figure 19.  $V_{CC}$  Bias from  $V_{OUT}$  for  $8V < V_{OUT} < 14V$

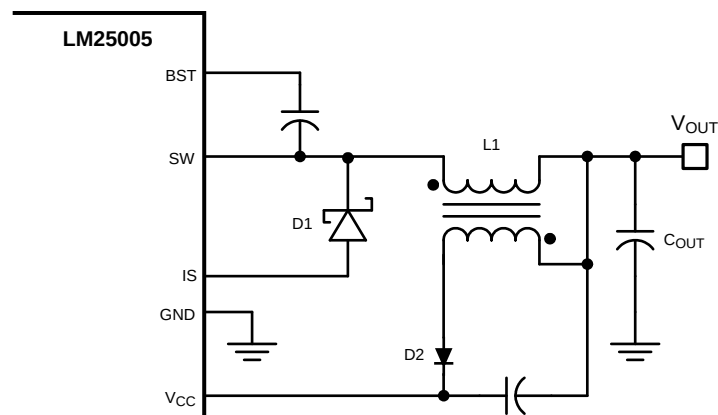


Figure 20.  $V_{CC}$  Bias with Additional Winding on the Output Inductor

## PCB LAYOUT AND THERMAL CONSIDERATIONS

The circuit in the [Typical Application Circuit and Block Diagram](#) serves as both a block diagram of the LM25005 and a typical application board schematic for the LM25005. In a buck regulator there are two loops where currents are switched very fast. The first loop starts from the input capacitors, to the regulator VIN pin, to the regulator SW pin, to the inductor then out to the load. The second loop starts from the output capacitor ground, to the regulator PGND pins, to the regulator IS pins, to the diode anode, to the inductor and then out to the load. Minimizing the loop area of these two loops reduces the stray inductance and minimizes noise and possible erratic operation. A ground plane in the PC board is recommended as a means to connect the input filter capacitors to the output filter capacitors and the PGND pins of the regulator. Connect all of the low power ground connections ( $C_{SS}$ ,  $R_T$ ,  $C_{RAMP}$ ) directly to the regulator AGND pin. Connect the AGND and PGND pins together through the topside copper area covering the entire underside of the device. Place several vias in this underside copper area to the ground plane.

The two highest power dissipating components are the re-circulating diode and the LM25005 regulator IC. The easiest method to determine the power dissipated within the LM25005 is to measure the total conversion losses ( $P_{in} - P_{out}$ ) then subtract the power losses in the Schottky diode, output inductor and snubber resistor. An approximation for the Schottky diode loss is  $P = (1-D) \times I_{out} \times V_{fwd}$ . An approximation for the output inductor power is  $P = I_{OUT}^2 \times R \times 1.1$ , where R is the DC resistance of the inductor and the 1.1 factor is an approximation for the ac losses. If a snubber is used, the power loss can be estimated with an oscilloscope by observation of the resistor voltage drop at both turn-on and turn-off transitions. The regulator has an exposed thermal pad to aid power dissipation. Adding several vias under the device to the ground plane will greatly reduce the regulator junction temperature. Selecting a diode with an exposed pad will aid the power dissipation of the diode.

### 5V, 2.5A Demo Board Bill of Materials

| ITEM | PART NUMBER    | DESCRIPTION                  | VALUE        |
|------|----------------|------------------------------|--------------|
| C 1  | C4532X7R2A225M | CAPACITOR, CER, TDK          | 2.2μ, 100V   |
| C 2  | C4532X7R2A225M | CAPACITOR, CER, TDK          | 2.2μ, 100V   |
| C 3  | C0805C331G1GAC | CAPACITOR, CER, KEMET        | 330p, 100V   |
| C 4  | C2012X7R2A103K | CAPACITOR, CER, TDK          | 0.01μ, 100V  |
| C 5  | C2012X7R2A103K | CAPACITOR, CER, TDK          | 0.01μ, 100V  |
| C 6  | OPEN           | NOT USED                     |              |
| C 7  | C2012X7R2A223K | CAPACITOR, CER, TDK          | 0.022μ, 100V |
| C 8  | C2012X7R1C474M | CAPACITOR, CER, TDK          | 0.47μ, 16V   |
| C 9  | C3225X7R1C226M | CAPACITOR, CER, TDK          | 22μ, 16V     |
| C 10 | EEFHE0J151R    | CAPACITOR, SP, PANASONIC     | 150μ, 6.3V   |
| C 11 | C0805C331G1GAC | CAPACITOR, CER, KEMET        | 330p, 100V   |
| C 12 | OPEN           | NOT USED                     |              |
| D 1  | CSHD6-60C      | DIODE, 60V, CENTRAL          |              |
|      | 6CWQ10FN       | DIODE, 100V, IR (D1-ALT)     |              |
| L 1  | DR127-330      | INDUCTOR, COOPER             | 33μH         |
| R 1  | OPEN           | NOT USED                     |              |
| R 2  | OPEN           | NOT USED                     |              |
| R 3  | CRCW08052102F  | RESISTOR                     | 21K          |
| R 4  | CRCW08054992F  | RESISTOR                     | 49.9K        |
| R 5  | CRCW08055111F  | RESISTOR                     | 5.11K        |
| R 6  | CRCW08051651F  | RESISTOR                     | 1.65K        |
| R 7  | CRCW2512100J   | RESISTOR                     | 10, 1W       |
| U 1  | LM25005        | REGULATOR, TEXAS INSTRUMENTS |              |

## PCB Layout

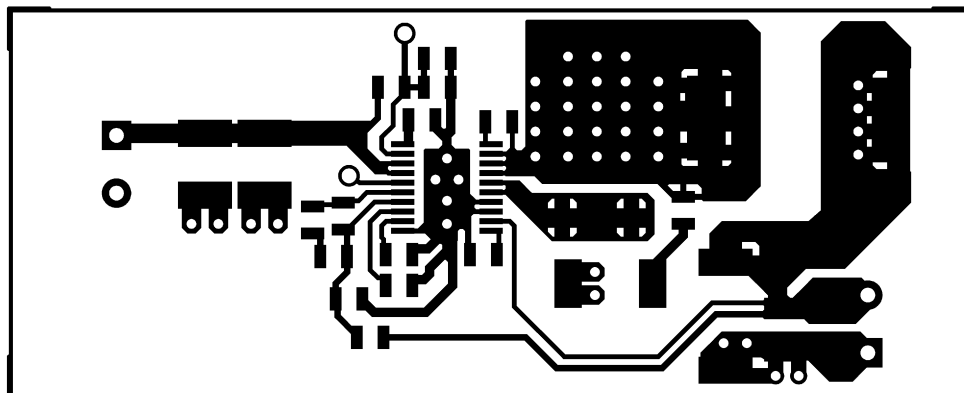


Figure 21. Component Side

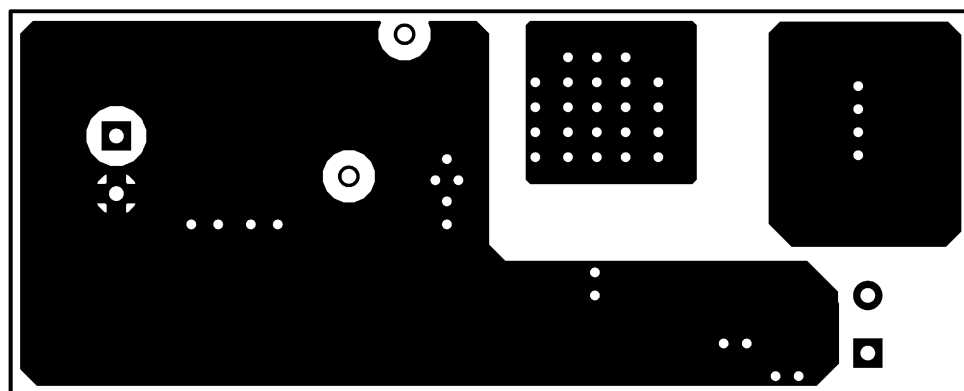


Figure 22. Solder Side

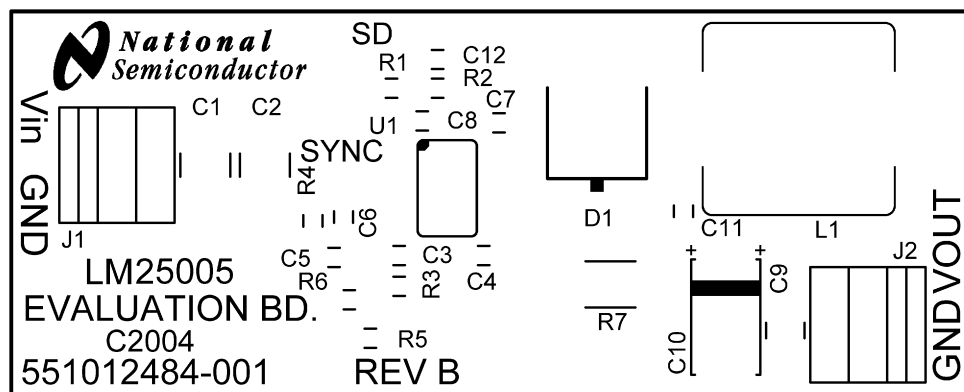


Figure 23. Silkscreen

## REVISION HISTORY

### Changes from Revision B (March 2013) to Revision C

### Page

- Changed layout of National Data Sheet to TI format ..... [20](#)

## PACKAGING INFORMATION

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| LM25005MH        | NRND          | HTSSOP       | PWP                | 20   | 73             | TBD                        | Call TI                 | Call TI              | -40 to 125   | LM25005<br>MH           |                         |
| LM25005MH/NOPB   | ACTIVE        | HTSSOP       | PWP                | 20   | 73             | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-1-260C-UNLIM   | -40 to 125   | LM25005<br>MH           | <a href="#">Samples</a> |
| LM25005MHX/NOPB  | ACTIVE        | HTSSOP       | PWP                | 20   | 2500           | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-1-260C-UNLIM   | -40 to 125   | LM25005<br>MH           | <a href="#">Samples</a> |

(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) 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.

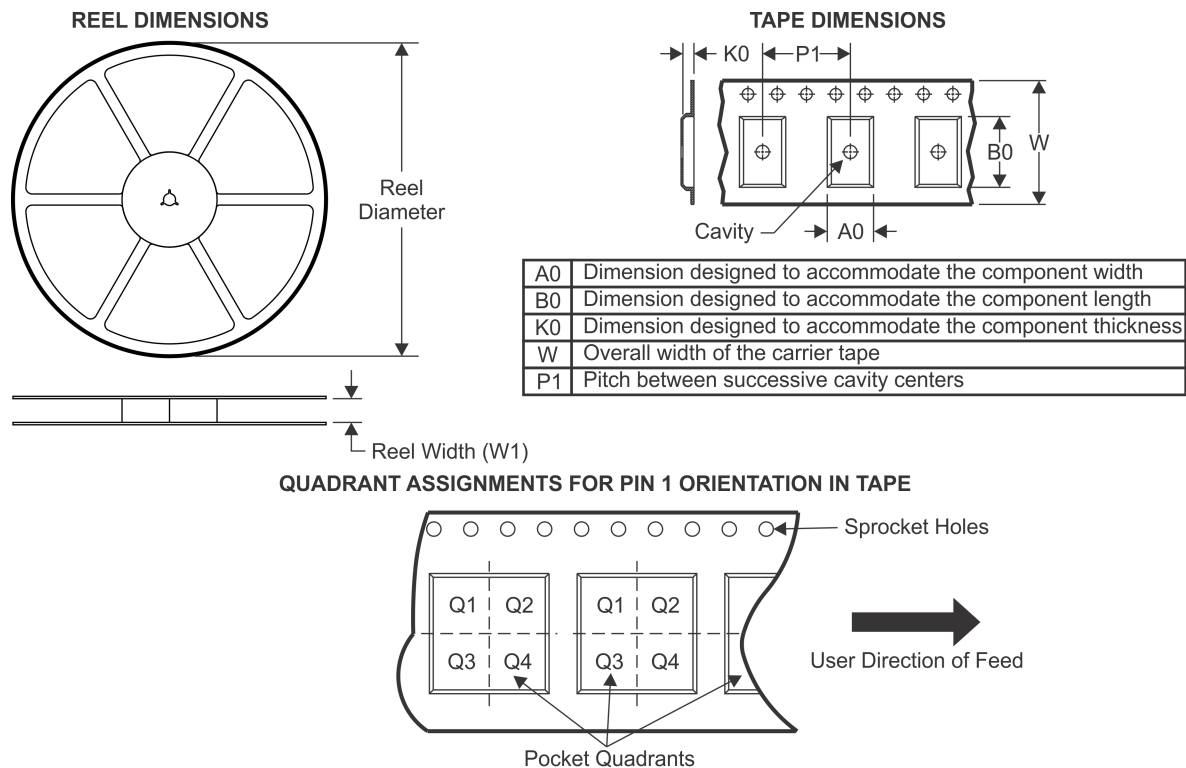
**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. 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.

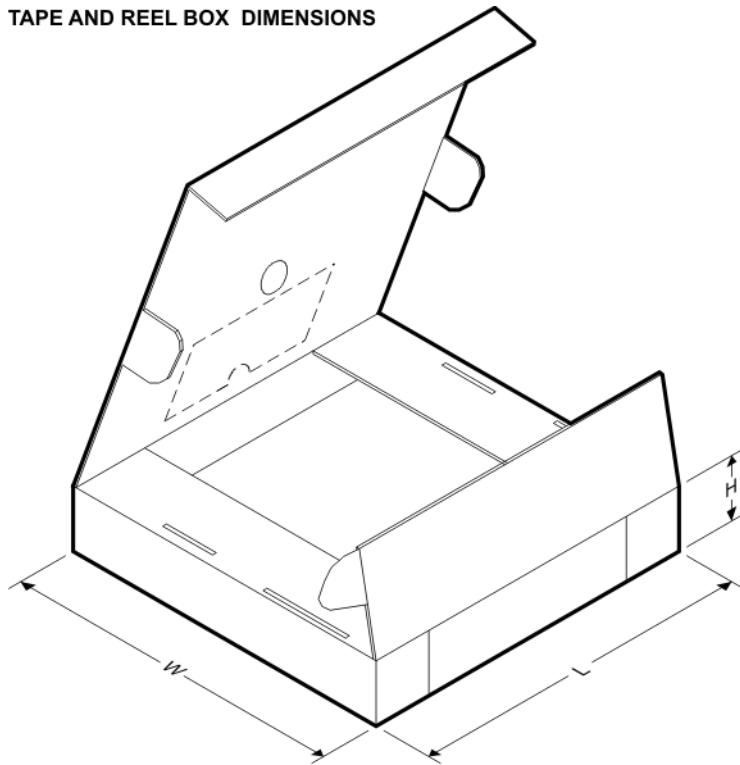
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**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 |
|-----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LM25005MHX/NOPB | HTSSOP       | PWP             | 20   | 2500 | 330.0              | 16.4               | 6.95    | 7.1     | 1.6     | 8.0     | 16.0   | Q1            |

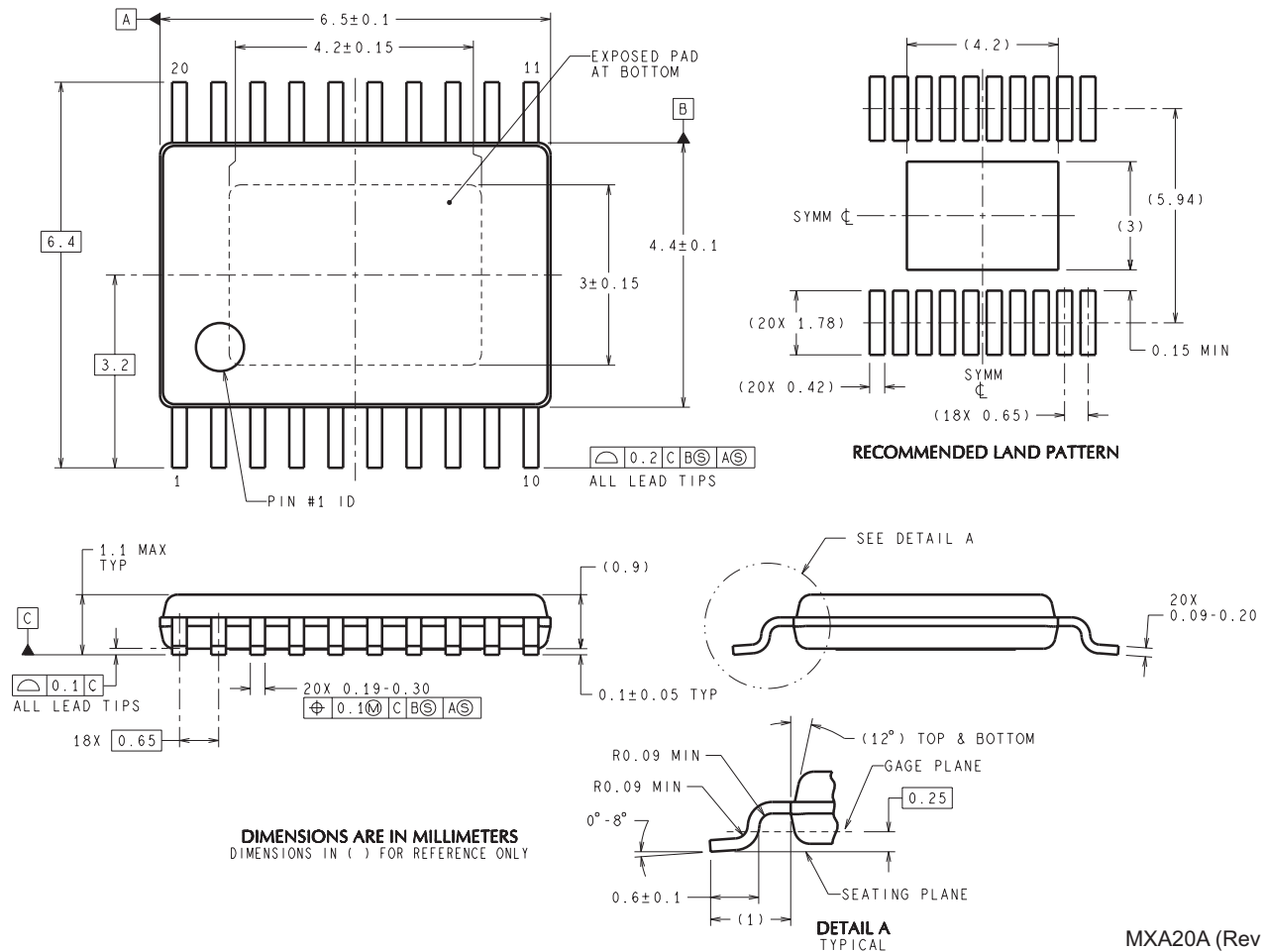
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device          | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LM25005MHX/NOPB | HTSSOP       | PWP             | 20   | 2500 | 367.0       | 367.0      | 35.0        |

PWP0020A



MXA20A (Rev C)

## 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                        | <a href="http://www.ti.com/audio">www.ti.com/audio</a>                               |
| Amplifiers                   | <a href="http://amplifier.ti.com">amplifier.ti.com</a>                               |
| Data Converters              | <a href="http://dataconverter.ti.com">dataconverter.ti.com</a>                       |
| DLP® Products                | <a href="http://www.dlp.com">www.dlp.com</a>                                         |
| DSP                          | <a href="http://dsp.ti.com">dsp.ti.com</a>                                           |
| Clocks and Timers            | <a href="http://www.ti.com/clocks">www.ti.com/clocks</a>                             |
| Interface                    | <a href="http://interface.ti.com">interface.ti.com</a>                               |
| Logic                        | <a href="http://logic.ti.com">logic.ti.com</a>                                       |
| Power Mgmt                   | <a href="http://power.ti.com">power.ti.com</a>                                       |
| Microcontrollers             | <a href="http://microcontroller.ti.com">microcontroller.ti.com</a>                   |
| RFID                         | <a href="http://www.ti-rfid.com">www.ti-rfid.com</a>                                 |
| OMAP Applications Processors | <a href="http://www.ti.com/omap">www.ti.com/omap</a>                                 |
| Wireless Connectivity        | <a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a> |

### Applications

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

### TI E2E Community

[e2e.ti.com](http://e2e.ti.com)

## Looking for pricing, stock, or lifecycle information?

Click below to explore more details on WIN SOURCE:

 [View LM25005MH/NOPB on WIN SOURCE](#)

 [Texas Instruments](#) Information

## Optimize Your Supply Chain with WIN SOURCE Solutions

-  Global Sourcing Solution
-  Obsolete Management
-  Cost Control Management
-  Shortage Management
-  Alternative Solution
-  Excess Inventory Management