

## LM2695 High Voltage (30V, 1.25A) Step Down Switching Regulator

Check for Samples: [LM2695](#)

### FEATURES

- Integrated 33V, N-Channel Buck Switch
- Integrated Start-Up Regulator
- Input Voltage Range: 8V to 30V
- No Loop Compensation Required
- Ultra-Fast Transient Response
- Operating Frequency Remains Constant with Load Current and Input Voltage
- Maximum Duty Cycle Limited During Start-Up
- Adjustable Output Voltage
- Valley Current Limit At 1.25A
- Precision Internal Reference
- Low Bias Current
- Highly Efficient Operation
- Thermal Shutdown

### TYPICAL APPLICATIONS

- High Efficiency Point-Of-Load (POL) Regulator
- Non-Isolated Telecommunication Buck Regulator
- Secondary High Voltage Post Regulator

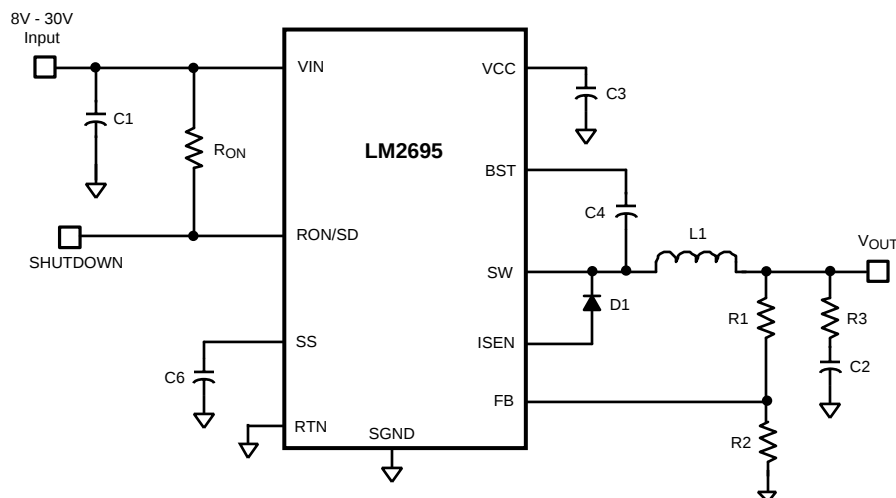
### DESCRIPTION

The LM2695 Step Down Switching Regulator features all of the functions needed to implement a low cost, efficient, buck bias regulator capable of supplying 1.25A to the load. This buck regulator contains a 33V N-Channel Buck Switch, and is available in the thermally enhanced WSON-10 and HTSSOP-14 packages. The hysteretic regulation scheme requires no loop compensation, results in fast load transient response, and simplifies circuit implementation. The operating frequency remains constant with line and load variations due to the inverse relationship between the input voltage and the on-time. The current limit detection is set at 1.25A. Additional features include: VCC under-voltage lockout, thermal shutdown, gate drive under-voltage lockout, and maximum duty cycle limiter.

### PACKAGE

- 10-Pin WSON (4 mm x 4 mm)
- 14-Pin HTSSOP
- Exposed Thermal Pad For Improved Heat Dissipation

### Basic Step Down Regulator



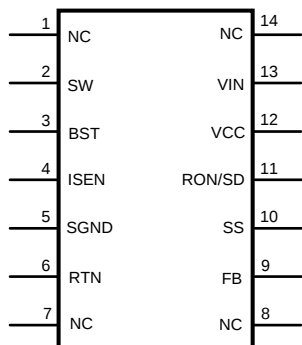
Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

All trademarks are the property of their respective owners.

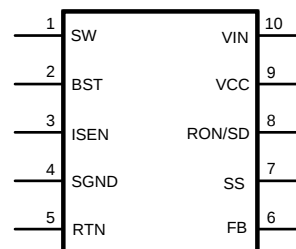
PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of the Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

Copyright © 2006–2013, Texas Instruments Incorporated

## Connection Diagram



**Figure 1. 14-Lead HTSSOP (Top View)**  
See PWP0014A Package



**Figure 2. 10-Lead WSON (Top View)**  
See DPR0010A Package

### PIN DESCRIPTIONS

| Pin Number |           | Name        | Description                              | Application Information                                                                                                                                                |
|------------|-----------|-------------|------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| WSON-10    | HTSSOP-14 |             |                                          |                                                                                                                                                                        |
| 1          | 2         | SW          | Switching Node                           | Internally connected to the buck switch source. Connect to the inductor, free-wheeling diode, and bootstrap capacitor.                                                 |
| 2          | 3         | BST         | Boost pin for bootstrap capacitor        | Connect a 0.022 $\mu$ F capacitor from SW to this pin. The capacitor is charged from $V_{CC}$ via an internal diode during each off-time.                              |
| 3          | 4         | $I_{SEN}$   | Current sense                            | The re-circulating current flows through the internal sense resistor, and out of this pin to the free-wheeling diode. Current limit is nominally set at 1.25A.         |
| 4          | 5         | $S_{GND}$   | Sense Ground                             | Re-circulating current flows into this pin to the current sense resistor.                                                                                              |
| 5          | 6         | RTN         | Circuit Ground                           | Ground for all internal circuitry other than the current limit detection.                                                                                              |
| 6          | 9         | FB          | Feedback input from the regulated output | Internally connected to the regulation and over-voltage comparators. The regulation level is 2.5V.                                                                     |
| 7          | 10        | SS          | Softstart                                | An internal 12.3 $\mu$ A current source charges an external capacitor to 2.5V, providing the softstart function.                                                       |
| 8          | 11        | $R_{ON/SD}$ | On-time control and shutdown             | An external resistor from $V_{IN}$ to this pin sets the buck switch on-time. Grounding this pin shuts down the regulator.                                              |
| 9          | 12        | $V_{CC}$    | Output from the startup regulator        | Nominally regulates at 7.0V. An external voltage (8V-14V) can be applied to this pin to reduce internal dissipation. An internal diode connects $V_{CC}$ to $V_{IN}$ . |
| 10         | 13        | $V_{IN}$    | Input supply voltage                     | Nominal input range is 8.0V to 30V.                                                                                                                                    |
|            | 1,7,8,14  | NC          | No connection.                           | No internal connection.                                                                                                                                                |
|            |           | EP          | Exposed Pad                              | Exposed metal pad on the underside of the device. It is recommended to connect this pad to the PC board ground plane 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)(3)</sup>

|                           |                  |
|---------------------------|------------------|
| VIN to RTN                | 33V              |
| BST to RTN                | 47V              |
| SW to RTN (Steady State)  | -1.5V            |
| ESD Rating <sup>(4)</sup> | Human Body Model |
| BST to VCC                | 33V              |
| VIN to SW                 | 33V              |
| BST to SW                 | 14V              |
| VCC to RTN                | 14V              |
| SGND to RTN               | -0.3V to +0.3V   |
| Current out of ISEN       | See Text         |
| SS to RTN                 | -0.3V to 4V      |
| All Other Inputs to RTN   | -0.3 to 7V       |
| Storage Temperature Range | -65°C to +150°C  |
| Junction Temperature      | 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) For detailed information on soldering plastic WSON-10 packages, refer to the Packaging Data Book available from TI.
- (3) If Military/Aerospace specified devices are required, please contact the TI Sales Office/Distributors for availability and specifications.
- (4) The human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin.

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

|                      |                  |
|----------------------|------------------|
| VIN                  | 8.0V to 30V      |
| 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 type are for  $T_J = 25^\circ\text{C}$  only; limits in **boldface** type apply over the full Operating Junction Temperature ( $T_J$ ) range. Minimum and Maximum limits are ensured through test, design, or statistical correlation. Typical values represent the most likely parametric norm at  $T_J = 25^\circ\text{C}$ , and are provided for reference purposes only. Unless otherwise stated the following conditions apply:  $V_{IN} = 24\text{V}$ ,  $R_{ON} = 200\text{k}\Omega^{(1)}$ .

| Symbol                                                  | Parameter                                | Conditions                                                        | Min          | Typ  | Max          | Units              |
|---------------------------------------------------------|------------------------------------------|-------------------------------------------------------------------|--------------|------|--------------|--------------------|
| <b>Start-Up Regulator, <math>V_{CC}</math></b>          |                                          |                                                                   |              |      |              |                    |
| $V_{CCReg}$                                             | $V_{CC}$ regulated output                |                                                                   | <b>6.6</b>   | 7    | <b>7.4</b>   | V                  |
|                                                         | $V_{IN}$ - $V_{CC}$ dropout voltage      | $I_{CC} = 0\text{ mA}$ ,<br>$V_{CC} = UVLO_{VCC} + 250\text{ mV}$ |              | 1.3  |              | V                  |
|                                                         | $V_{CC}$ output impedance                | $0\text{ mA} \leq I_{CC} \leq 5\text{ mA}$                        |              | 140  |              | $\Omega$           |
|                                                         | $V_{CC}$ current limit <sup>(2)</sup>    | $V_{CC} = 0\text{V}$                                              |              | 9.7  |              | mA                 |
| $UVLO_{VCC}$                                            | $V_{CC}$ under-voltage lockout threshold | $V_{CC}$ increasing                                               |              | 5.7  |              | V                  |
|                                                         | $UVLO_{VCC}$ hysteresis                  | $V_{CC}$ decreasing                                               |              | 150  |              | mV                 |
|                                                         | $UVLO_{VCC}$ filter delay                | 100 mV overdrive                                                  |              | 3    |              | $\mu\text{s}$      |
|                                                         | $I_{IN}$ operating current               | Non-switching, $FB = 3\text{V}$                                   |              | 0.5  | <b>0.8</b>   | mA                 |
|                                                         | $I_{IN}$ shutdown current                | $RON/SD = 0\text{V}$                                              |              | 95   | <b>200</b>   | $\mu\text{A}$      |
| <b>Switch Characteristics</b>                           |                                          |                                                                   |              |      |              |                    |
| $R_{ds(on)}$                                            | Buck Switch $R_{ds(on)}$                 | $I_{TEST} = 200\text{ mA}$                                        |              | 0.33 | <b>0.7</b>   | $\Omega$           |
| $UVLO_{GD}$                                             | Gate Drive $UVLO$                        | $V_{BST} - V_{SW}$ Increasing                                     | <b>3.0</b>   | 4.4  | <b>5.5</b>   | V                  |
|                                                         | $UVLO_{GD}$ hysteresis                   |                                                                   |              | 480  |              | mV                 |
| <b>Softstart Pin</b>                                    |                                          |                                                                   |              |      |              |                    |
|                                                         | Pull-up voltage                          |                                                                   |              | 2.5  |              | V                  |
|                                                         | Internal current source                  |                                                                   |              | 12.3 |              | $\mu\text{A}$      |
| <b>Current Limit</b>                                    |                                          |                                                                   |              |      |              |                    |
| $I_{LIM}$                                               | Threshold                                | Current out of ISEN                                               | <b>1</b>     | 1.25 | <b>1.5</b>   | A                  |
|                                                         | Resistance from ISEN to SGND             |                                                                   |              | 130  |              | m $\Omega$         |
|                                                         | Response time                            |                                                                   |              | 150  |              | ns                 |
| <b>On Timer</b>                                         |                                          |                                                                   |              |      |              |                    |
| $t_{ON} - 1$                                            | On-time                                  | $V_{IN} = 10\text{V}$ , $R_{ON} = 200\text{ k}\Omega$             | <b>2.1</b>   | 2.8  | <b>3.6</b>   | $\mu\text{s}$      |
| $t_{ON} - 2$                                            | On-time                                  | $V_{IN} = 30\text{V}$ , $R_{ON} = 200\text{ k}\Omega$             |              | 950  |              | ns                 |
|                                                         | Shutdown threshold                       | Voltage at $RON/SD$ rising                                        | <b>0.45</b>  | 0.8  | <b>1.2</b>   | V                  |
|                                                         | Threshold hysteresis                     | Voltage at $RON/SD$ falling                                       |              | 37   |              | mV                 |
| <b>Off Timer</b>                                        |                                          |                                                                   |              |      |              |                    |
| $t_{OFF}$                                               | Minimum Off-time                         |                                                                   |              | 250  |              | ns                 |
| <b>Regulation and Over-Voltage Comparators (FB Pin)</b> |                                          |                                                                   |              |      |              |                    |
| $V_{REF}$                                               | FB regulation threshold                  | SS pin = steady state                                             | <b>2.440</b> | 2.5  | <b>2.550</b> | V                  |
|                                                         | FB over-voltage threshold                |                                                                   |              | 2.9  |              | V                  |
|                                                         | FB bias current                          |                                                                   |              | 1    |              | nA                 |
| <b>Thermal Shutdown</b>                                 |                                          |                                                                   |              |      |              |                    |
| $T_{SD}$                                                | Thermal shutdown temperature             |                                                                   |              | 175  |              | $^\circ\text{C}$   |
|                                                         | Thermal shutdown hysteresis              |                                                                   |              | 20   |              | $^\circ\text{C}$   |
| <b>Thermal Resistance</b>                               |                                          |                                                                   |              |      |              |                    |
| $\theta_{JA}$                                           | Junction to Ambient<br>0 LFPM Air Flow   | Both Packages                                                     |              | 37   |              | $^\circ\text{C/W}$ |
| $\theta_{JC}$                                           | Junction to Case                         | Both Packages                                                     |              | 6.6  |              | $^\circ\text{C/W}$ |

(1) Typical specifications represent the most likely parametric norm at  $25^\circ\text{C}$  operation.

(2)  $V_{CC}$  provides self bias for the internal gate drive and control circuits. Device thermal limitations limit external loading

## Typical Performance Characteristics

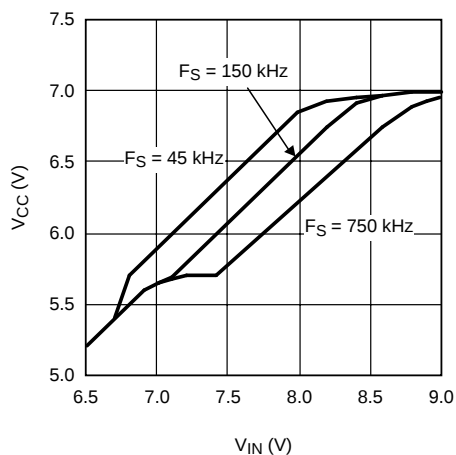


Figure 3.  $V_{CC}$  vs  $V_{IN}$

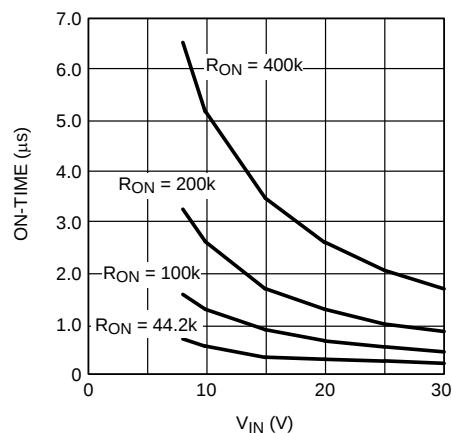
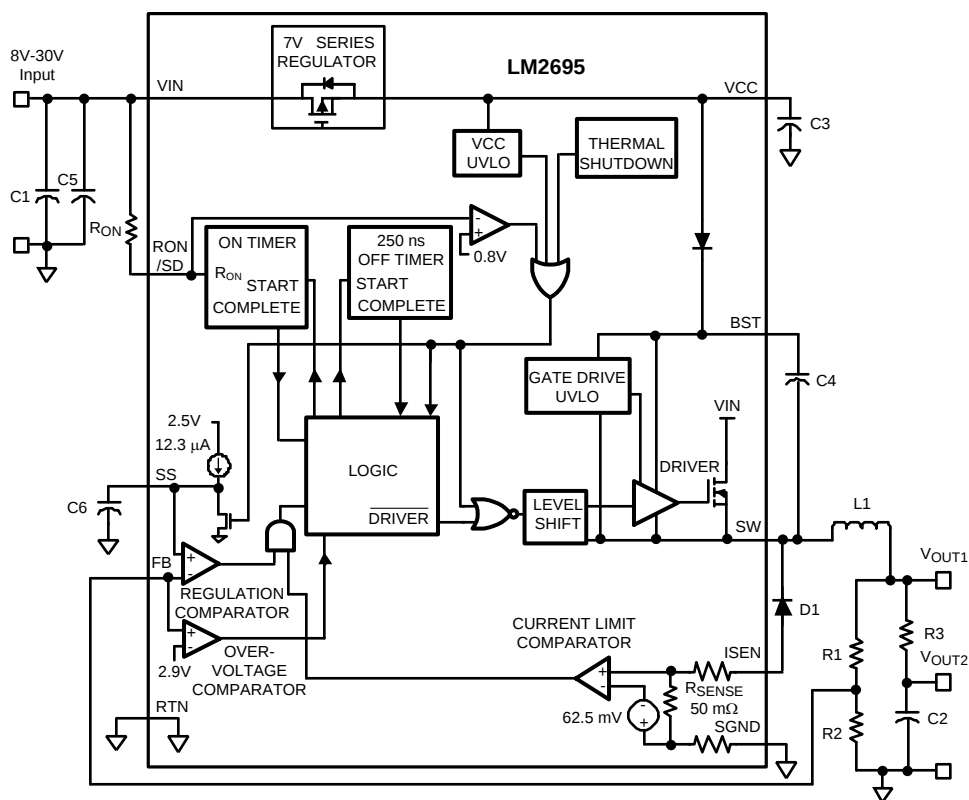


Figure 4. ON-Time vs  $V_{IN}$  and  $R_{ON}$

## Typical Application Circuit and Block Diagram



## Functional Description

The LM2695 Step Down Switching Regulator features all the functions needed to implement a low cost, efficient buck bias power converter capable of supplying 1.25A to the load. This high voltage regulator contains a 33V N-Channel buck switch, is easy to implement, and is available in the thermally enhanced WSON-10 and HTSSOP-14 packages. The regulator's operation is based on a hysteretic control scheme, and uses an on-time control which varies inversely with  $V_{IN}$ . This feature allows the operating frequency to remain relatively constant with load and input voltage variations. The hysteretic control requires no loop compensation resulting in very fast load transient response. The valley current limit detection circuit, internally set at 1.25A, holds the buck switch off until the high current level subsides. The functional block diagram is shown in [Typical Application Circuit and Block Diagram](#).

The LM2695 can be applied in numerous applications to efficiently regulate down higher voltages. Additional features include: Thermal shutdown,  $V_{CC}$  under-voltage lockout, gate drive under-voltage lockout, and maximum duty cycle limiter.

### Hysteretic Control Circuit Overview

The LM2695 buck DC-DC regulator employs a control scheme based on a comparator and a one-shot on-timer, with the output voltage feedback (FB) compared to an internal reference (2.5V). If the FB voltage is below the reference the buck switch is turned on for a time period determined by the input voltage and a programming resistor ( $R_{ON}$ ). Following the on-time the switch remains off for a minimum of 250 ns, and until the FB voltage falls below the reference. The buck switch then turns on for another on-time period. Typically, during start-up, or when the load current increases suddenly, the off-times are at the minimum of 250 ns. Once regulation is established, the off-times are longer.

When in regulation, the LM2695 operates in continuous conduction mode at heavy load currents and discontinuous conduction mode at light load currents. In continuous conduction mode current always flows through the inductor, never reaching zero during the off-time. In this mode the operating frequency remains relatively constant with load and line variations. The minimum load current for continuous conduction mode is one-half the inductor's ripple current amplitude. The operating frequency is approximately:

$$F_S = \frac{V_{OUT}}{1.3 \times 10^{-10} \times R_{ON}} \quad (1)$$

The buck switch duty cycle is equal to:

$$DC = \frac{t_{ON}}{t_{ON} + t_{OFF}} = \frac{V_{OUT}}{V_{IN}} \quad (2)$$

In discontinuous conduction mode current through the inductor ramps up from zero to a peak during the on-time, then ramps back to zero before the end of the off-time. The next on-time period starts when the voltage at FB falls below the reference - until then the inductor current remains zero, and the load current is supplied by the output capacitor (C2). In this mode the operating frequency is lower than in continuous conduction mode, and varies with load current. Conversion efficiency is maintained at light loads since the switching losses reduce with the reduction in load and frequency. The approximate discontinuous operating frequency can be calculated as follows:

$$F_S = \frac{V_{OUT}^2 \times L_1 \times 1.18 \times 10^{20}}{R_L \times (R_{ON})^2} \quad (3)$$

where

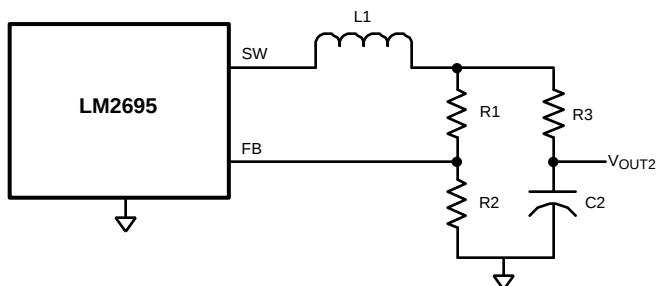
- $R_L$  = the load resistance

The output voltage is set by two external resistors ( $R_1$ ,  $R_2$ ). The regulated output voltage is calculated as follows:

$$V_{OUT} = 2.5 \times (R_1 + R_2) / R_2 \quad (4)$$

Output voltage regulation is based on ripple voltage at the feedback input, requiring a minimum amount of ESR for the output capacitor C2. The LM2695 requires a minimum of 25 mV of ripple voltage at the FB pin. In cases where the capacitor's ESR is insufficient additional series resistance may be required (R3 in [Typical Application Circuit and Block Diagram](#)).

For applications where lower output voltage ripple is required the output can be taken directly from a low ESR output capacitor as shown in [Figure 5](#). However, R3 slightly degrades the load regulation.



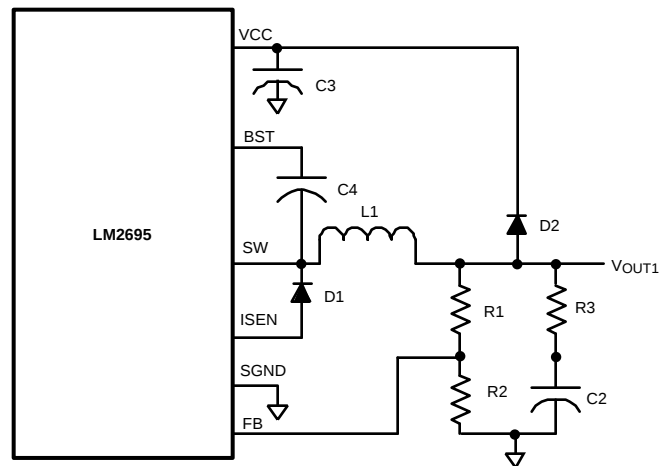
**Figure 5. Low Ripple Output Configuration**

## Start-Up Regulator, V<sub>CC</sub>

The start-up regulator is integral to the LM2695. The input pin (VIN) can be connected directly to line voltage up to 30V, with transient capability to 33V. The V<sub>CC</sub> output regulates at 7.0V, and is current limited at 9.7 mA. Upon power up, the regulator sources current into the external capacitor at VCC (C3). When the voltage on the VCC pin reaches the under-voltage lockout threshold of 5.7V, the buck switch is enabled and the Softstart pin is released to allow the Softstart capacitor (C6) to charge up.

The minimum input voltage is determined by the regulator's dropout voltage, the V<sub>CC</sub> UVLO falling threshold (≈5.5V), and the frequency. When V<sub>CC</sub> falls below the falling threshold the V<sub>CC</sub> UVLO activates to shut off the output. If V<sub>CC</sub> is externally loaded, the minimum input voltage increases since the output impedance at V<sub>CC</sub> is ≈140Ω.

To reduce power dissipation in the start-up regulator, an auxiliary voltage can be diode connected to the V<sub>CC</sub> pin. Setting the auxiliary voltage to between 8V and 14V shuts off the internal regulator, reducing internal power dissipation. The sum of the auxiliary voltage and the input voltage (V<sub>CC</sub> + V<sub>IN</sub>) cannot exceed 47V. Internally, a diode connects VCC to VIN. See [Figure 6](#).



**Figure 6. Self Biased Configuration**

## Regulation Comparator

The feedback voltage at FB is compared to the voltage at the Softstart pin (2.5V). In normal operation (the output voltage is regulated), an on-time period is initiated when the voltage at FB falls below 2.5V. The buck switch stays on for the programmed on-time, causing the FB voltage to rise above 2.5V. After the on-time period, the buck switch stays off until the FB voltage falls below 2.5V. Input bias current at the FB pin is less than 100 nA over temperature.

## Over-Voltage Comparator

The voltage at FB is compared to an internal 2.9V reference. If the voltage at FB rises above 2.9V the on-time pulse is immediately terminated. This condition can occur if the input voltage or the output load changes suddenly, or if the inductor (L1) saturates. The buck switch remains off until the voltage at FB falls below 2.5V.

## ON-Time Timer, and Shutdown

The on-time for the LM2695 is determined by the R<sub>ON</sub> resistor and the input voltage (V<sub>IN</sub>), and is calculated from:

$$t_{ON} = \frac{1.3 \times 10^{-10} \times R_{ON}}{V_{IN}} \quad (5)$$

See Figure 4. The inverse relationship with  $V_{IN}$  results in a nearly constant frequency as  $V_{IN}$  is varied. To set a specific continuous conduction mode switching frequency ( $F_S$ ), the  $R_{ON}$  resistor is determined from the following:

$$R_{ON} = \frac{V_{OUT}}{F_S \times 1.3 \times 10^{-10}} \quad (6)$$

In high frequency applications the minimum value for  $t_{ON}$  is limited by the maximum duty cycle required for regulation and the minimum off-time of (250 ns,  $\pm 15\%$ ). The minimum off-time limits the maximum duty cycle achievable with a low voltage at  $V_{IN}$ . The minimum allowed on-time to regulate the desired  $V_{OUT}$  at the minimum  $V_{IN}$  is determined from the following:

$$t_{ON(min)} = \frac{V_{OUT} \times 288 \text{ ns}}{(V_{IN(min)} - V_{OUT})} \quad (7)$$

The LM2695 can be remotely shut down by taking the  $R_{ON}/SD$  pin below 0.8V. See Figure 7. In this mode the SS pin is internally grounded, the on-timer is disabled, and bias currents are reduced. Releasing the  $R_{ON}/SD$  pin allows normal operation to resume. The voltage at the  $R_{ON}/SD$  pin is between 1.5V and 3.0V, depending on  $V_{IN}$  and the  $R_{ON}$  resistor.

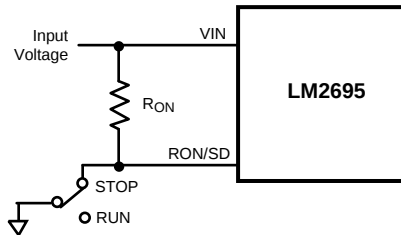


Figure 7. Shutdown Implementation

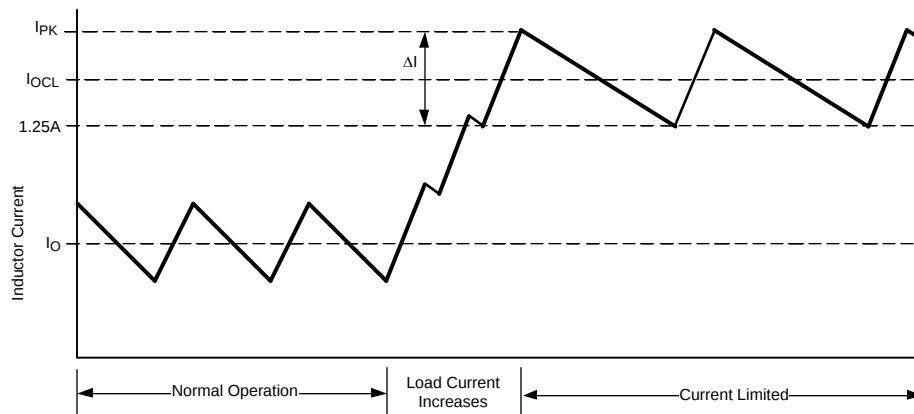
## Current Limit

Current limit detection occurs during the off-time by monitoring the recirculating current through the free-wheeling diode (D1). Referring to [Typical Application Circuit and Block Diagram](#), when the buck switch is turned off the inductor current flows through the load, into SGND, through the sense resistor, out of ISEN and through D1. If that current exceeds 1.25A the current limit comparator output switches to delay the start of the next on-time period if the voltage at FB is below 2.5V. The next on-time starts when the current out of ISEN is below 1.25A and the voltage at FB is below 2.5V. If the overload condition persists causing the inductor current to exceed 1.25A during each on-time, that is detected at the beginning of each off-time. The operating frequency is lower due to longer-than-normal off-times.

Figure 8 illustrates the inductor current waveform. During normal operation the load current is  $I_O$ , the average of the ripple waveform. When the load resistance decreases the current ratchets up until the lower peak reaches 1.25A. During the Current Limited portion of Figure 8, the current ramps down to 1.25A during each off-time, initiating the next on-time (assuming the voltage at FB is  $< 2.5V$ ). During each on-time the current ramps up an amount equal to:

$$\Delta I = (V_{IN} - V_{OUT}) \times t_{ON} / L1 \quad (8)$$

During this time the LM2695 is in a constant current mode, with an average load current ( $I_{OCL}$ ) equal to  $1.25A + \Delta I/2$ .



**Figure 8. Inductor Current - Current Limit Operation**

The current limit threshold can be increased by connecting an external resistor between SGND and ISEN. The external resistor will typically be less than 1Ω. The peak current out of SW and ISEN must not exceed 2A. The average current out of SW must be less than 1.5A.

### N - Channel Buck Switch and Driver

The LM2695 integrates an N-Channel buck switch and associated floating high voltage gate driver. The peak current allowed through the buck switch is 2A, and the maximum allowed average current is 1.5A. The gate driver circuit works in conjunction with an external bootstrap capacitor and an internal high voltage diode. A 0.022 μF capacitor (C4) connected between BST and SW provides the voltage to the driver during the on-time. During each off-time, the SW pin is at approximately -1V, and C4 charges from V<sub>CC</sub> through the internal diode. The minimum off-time of 250 ns ensures a minimum time each cycle to recharge the bootstrap capacitor.

### Softstart

The softstart feature allows the converter to gradually reach a steady state operating point, thereby reducing start-up stresses and current surges. Upon turn-on, after V<sub>CC</sub> reaches the under-voltage threshold, an internal 12.3 μA current source charges up the external capacitor at the SS pin to 2.5V. The ramping voltage at SS (and the non-inverting input of the regulation comparator) ramps up the output voltage in a controlled manner.

An internal switch grounds the SS pin if V<sub>CC</sub> is below the under-voltage lockout threshold, if a thermal shutdown occurs, or if the RON/SD pin is grounded.

### Thermal Shutdown

The LM2695 should be operated so the junction temperature does not exceed 125°C. If the junction temperature increases, an internal Thermal Shutdown circuit, which activates (typically) at 175°C, takes the controller to a low power reset state by disabling the buck switch and the on-timer, and grounding the Softstart pin. This feature helps prevent catastrophic failures from accidental device overheating. When the junction temperature reduces below 155°C (typical hysteresis = 20°C), the Softstart pin is released and normal operation resumes.

## APPLICATIONS INFORMATION

### EXTERNAL COMPONENTS

The following guidelines can be used to select the external components.

**R1 and R2:** The ratio of these resistors is calculated from:

$$R1/R2 = (V_{OUT}/2.5V) - 1 \quad (9)$$

R1 and R2 should be chosen from standard value resistors in the range of 1.0 kΩ - 10 kΩ which satisfy the above ratio.

**R<sub>ON</sub>:** The minimum value for R<sub>ON</sub> is calculated from:

$$R_{ON} \geq \frac{200 \text{ ns} \times V_{IN(MAX)}}{1.3 \times 10^{-10}} \quad (10)$$

Equation 1 can be used to select R<sub>ON</sub> if a specific frequency is desired as long as the above limitation is met.

**L1:** The main parameter affected by the inductor is the output current ripple amplitude (I<sub>OR</sub>). The limits for I<sub>OR</sub> must be determined at both the minimum and maximum nominal load currents.

a) If the maximum load current is less than the current limit threshold (1.25A), the minimum load current is used to determine the maximum allowable ripple. To maintain continuous conduction mode the lower peak should not reach 0 mA. For this case, the maximum ripple current is:

$$I_{OR(MAX1)} = 2 \times I_{O(min)} \quad (11)$$

The ripple calculated in Equation 11 is then used in the following equation:

$$L1 = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{I_{OR} \times F_S \times V_{IN}}$$

where

- V<sub>IN</sub> is the maximum input voltage
  - F<sub>S</sub> is determined from Equation 1
- (12)

This provides a minimum value for L1. The next larger standard value should be used, and L1 should be rated for the I<sub>PK</sub> current level.

b) If the maximum load current is greater than the current limit threshold (1.25A), the LM2695 ensures the lower peak reaches 1.25A each cycle, requiring that I<sub>OR</sub> be at least twice the difference. The upper peak, however, must not exceed 2A. For this case, the ripple limits are:

$$I_{OR(MAX2)} = 2 \times (2A - I_{O(max)}) \quad (13)$$

and

$$I_{OR(MIN1)} = 2 \times (I_{O(max)} - 1.25A) \quad (14)$$

The lesser of Equation 13 and Equation 14 is then used in Equation 12. If I<sub>OR(MAX2)</sub> is used, the maximum V<sub>IN</sub> is used in Equation 12. The next larger value should then be used for L1. If I<sub>OR(MIN1)</sub> is used, the minimum V<sub>IN</sub> is used in Equation 12. The next smaller value should then be used for L1. L1 must be rated for the peak value of the current waveform (I<sub>PK</sub> in Figure 8).

**C3:** The capacitor at the V<sub>CC</sub> output provides not only noise filtering and stability, but also prevents false triggering of the V<sub>CC</sub> UVLO at the buck switch on/off transitions. For this reason, C3 should be no smaller than 0.1 μF, and should be a good quality, low ESR, ceramic capacitor.

**C2, and R3:** Since the LM2695 requires a minimum of 25 mV<sub>p-p</sub> of ripple at the FB pin for proper operation, the required ripple at V<sub>OUT1</sub> is increased by R1 and R2. This necessary ripple is created by the inductor ripple current acting on C2's ESR + R3. The minimum ripple current is calculated using Equation 12, rearranged to solve for I<sub>OR</sub> at minimum V<sub>IN</sub>. The minimum ESR for C2 is then equal to:

$$ESR_{(min)} = \frac{25 \text{ mV} \times (R1 + R2)}{R2 \times I_{OR(min)}} \quad (15)$$

If the capacitor used for C2 does not have sufficient ESR, R3 is added in series as shown in [Typical Application Circuit and Block Diagram](#). Generally R3 is less than 1Ω. C2 should generally be no smaller than 3.3 μF, although that is dependent on the frequency and the allowable ripple amplitude at V<sub>OUT1</sub>. Experimentation is usually necessary to determine the minimum value for C2, as the nature of the load may require a larger value. A load which creates significant transients requires a larger value for C2 than a non-varying load.

**D1:** The important parameters are reverse recovery time and forward voltage. The reverse recovery time determines how long the reverse current surge lasts each time the buck switch is turned on. The forward voltage drop is significant in the event the output is short-circuited as it is mainly this diode's voltage (plus the voltage across the current limit sense resistor) which forces the inductor current to decrease during the off-time. For this reason, a higher voltage is better, although that affects efficiency. A reverse recovery time of ≈30 ns, and a forward voltage drop of ≈0.75V are preferred. The reverse leakage specification is important as that can significantly affect efficiency. D1's reverse voltage rating must be at least as great as the maximum V<sub>IN</sub>, and its current rating must equal or exceed I<sub>PK</sub> [Figure 8](#).

**C1 and C5:** C1's purpose is to supply most of the switch current during the on-time, and limit the voltage ripple at V<sub>IN</sub>, on the assumption that the voltage source feeding V<sub>IN</sub> has an output impedance greater than zero. If the source's dynamic impedance is high (effectively a current source), it supplies the average input current, but not the ripple current.

At maximum load current, when the buck switch turns on, the current into V<sub>IN</sub> suddenly increases to the lower peak of the inductor's ripple current, ramps up to the peak value, then drop to zero at turn-off. The average current during the on-time is the load current. For a worst case calculation, C1 must supply this average load current during the maximum on-time. C1 is calculated from:

$$C1 = \frac{I_O \times t_{ON}}{\Delta V}$$

where

- I<sub>O</sub> is the load current
  - t<sub>ON</sub> is the maximum on-time
  - ΔV is the allowable ripple voltage at V<sub>IN</sub>
- (16)

C5's purpose is to help avoid transients and ringing due to long lead inductance at V<sub>IN</sub>. A low ESR, 0.1 μF ceramic chip capacitor is recommended, located close to the LM2695.

**C4:** The recommended value for C4 is 0.022 μF. A high quality ceramic capacitor with low ESR is recommended as C4 supplies a surge current to charge the buck switch gate at turn-on. A low ESR also helps ensure a complete recharge during each off-time.

**C6:** The capacitor at the SS pin determines the softstart time, i.e. the time for the reference voltage at the regulation comparator, and the output voltage, to reach their final value. The time is determined from the following:

$$t_{SS} = \frac{C6 \times 2.5V}{12.3 \mu A}$$
(17)

## PC BOARD LAYOUT

The LM2695 regulation, over-voltage, and current limit comparators are very fast, and respond to short duration noise pulses. Layout considerations are therefore critical for optimum performance. The layout must be as neat and compact as possible, and all of the components must be as close as possible to their associated pins. The current loop formed by D1, L1, C2 and the SGND and ISEN pins should be as small as possible. The ground connection from C2 to C1 should be as short and direct as possible.

If it is expected that the internal dissipation of the LM2695 will produce excessive junction temperatures during normal operation, good use of the PC board's ground plane can help considerably to dissipate heat. The exposed pad on the bottom of the IC package can be soldered to a ground plane, and that plane should extend out from beneath the IC, and be connected to ground plane on the board's other side with several vias, to help dissipate the heat. The exposed pad is internally connected to the IC substrate. Additionally the use of wide PC board traces, where possible, can help conduct heat away from the IC. Judicious positioning of the PC board within the end product, along with the use of any available air flow (forced or natural convection) can help reduce the junction temperatures.

## REVISION HISTORY

| Changes from Original (April 2013) to Revision A           | Page               |
|------------------------------------------------------------|--------------------|
| • Changed layout of National Data Sheet to TI format ..... | <a href="#">13</a> |

## PACKAGING INFORMATION

| Orderable part number          | Status<br>(1) | Material type<br>(2) | Package   Pins    | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|--------------------------------|---------------|----------------------|-------------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">LM2695MH/NOPB</a>  | Active        | Production           | HTSSOP (PWP)   14 | 94   TUBE             | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 125   | L2695<br>MH         |
| LM2695MH/NOPB.A                | Active        | Production           | HTSSOP (PWP)   14 | 94   TUBE             | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 125   | L2695<br>MH         |
| LM2695MH/NOPB.B                | Active        | Production           | HTSSOP (PWP)   14 | 94   TUBE             | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 125   | L2695<br>MH         |
| <a href="#">LM2695SDX/NOPB</a> | Active        | Production           | WSON (DPR)   10   | 4500   LARGE T&R      | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 125   | L2695SD             |
| LM2695SDX/NOPB.A               | Active        | Production           | WSON (DPR)   10   | 4500   LARGE T&R      | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 125   | L2695SD             |
| LM2695SDX/NOPB.B               | Active        | Production           | WSON (DPR)   10   | 4500   LARGE T&R      | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 125   | L2695SD             |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

**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 |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LM2695SDX/NOPB | WSO          | DPR             | 10   | 4500 | 330.0              | 12.4               | 4.3     | 4.3     | 1.3     | 8.0     | 12.0   | Q1            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

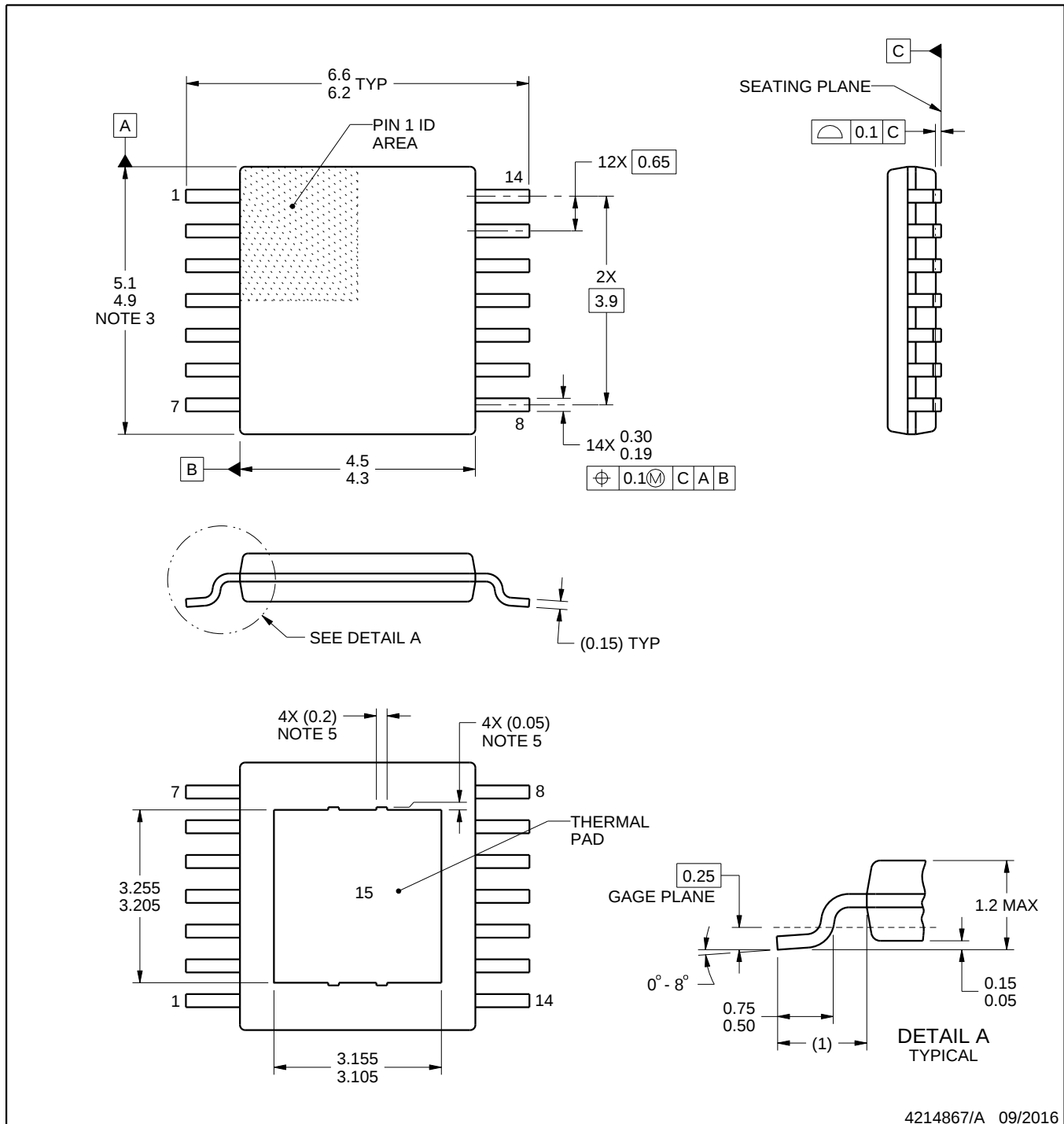
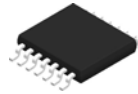
| Device         | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LM2695SDX/NOPB | WSON         | DPR             | 10   | 4500 | 367.0       | 367.0      | 35.0        |

## TUBE



\*All dimensions are nominal

| Device          | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|-----------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| LM2695MH/NOPB   | PWP          | HTSSOP       | 14   | 94  | 495    | 8      | 2514.6 | 4.06   |
| LM2695MH/NOPB.A | PWP          | HTSSOP       | 14   | 94  | 495    | 8      | 2514.6 | 4.06   |
| LM2695MH/NOPB.B | PWP          | HTSSOP       | 14   | 94  | 495    | 8      | 2514.6 | 4.06   |



4214867/A 09/2016

## NOTES:

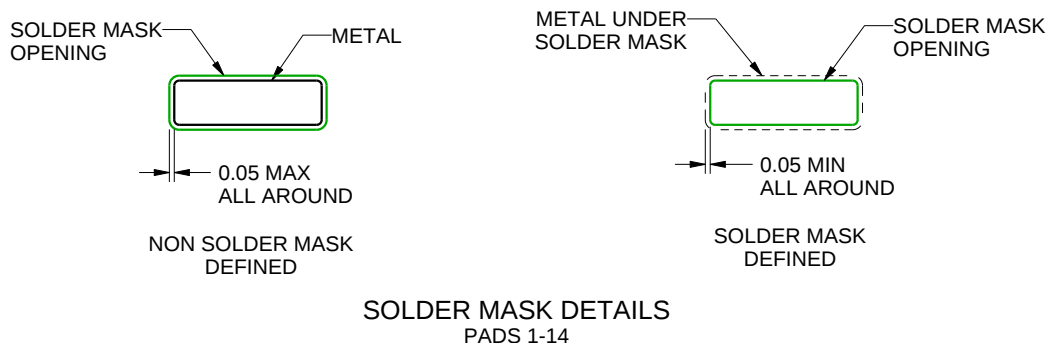
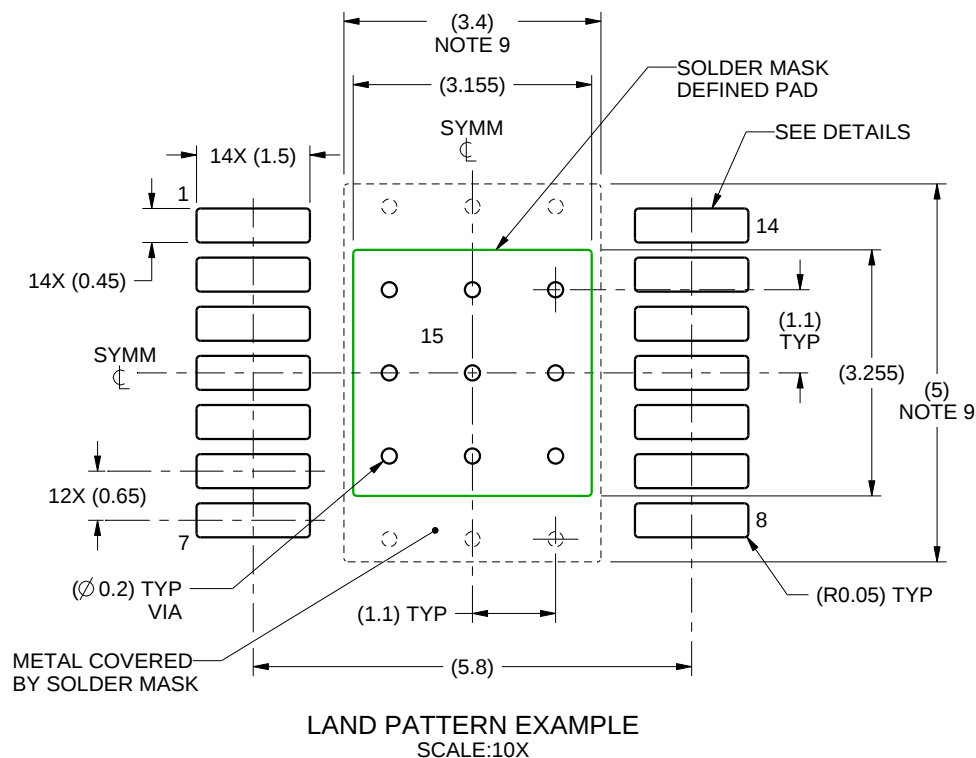
PowerPAD is a trademark of Texas Instruments.

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. Reference JEDEC registration MO-153.
5. Features may differ and may not be present.

**PWP0014A**

## PowerPAD™ TSSOP - 1.2 mm max height

## PLASTIC SMALL OUTLINE



4214867/A 09/2016

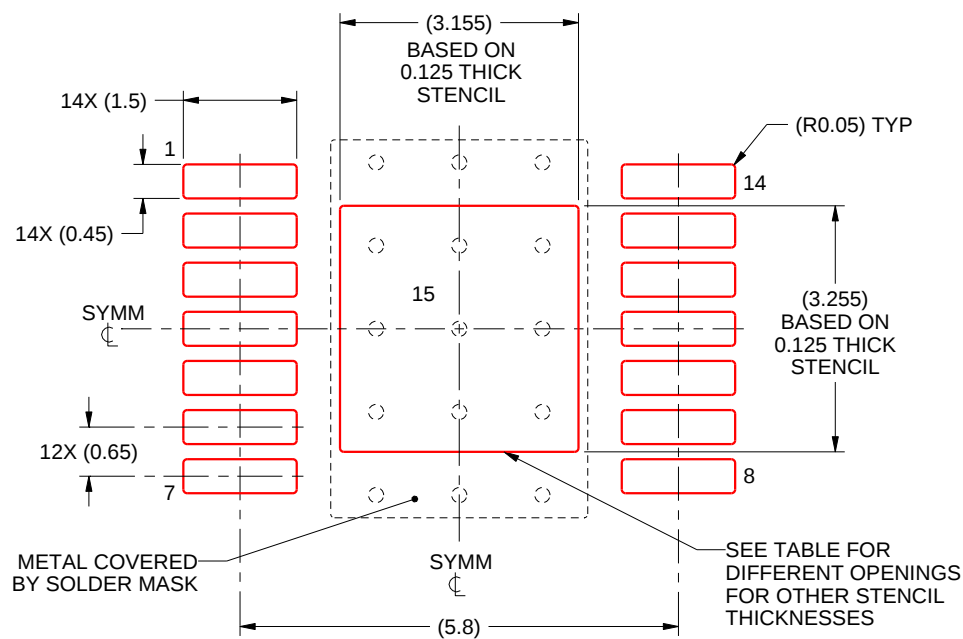
NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature numbers SLMA002 ([www.ti.com/lit/slma002](http://www.ti.com/lit/slma002)) and SLMA004 ([www.ti.com/lit/slma004](http://www.ti.com/lit/slma004)).
9. Size of metal pad may vary due to creepage requirement.

**PWP0014A**

## PowerPAD™ TSSOP - 1.2 mm max height

## PLASTIC SMALL OUTLINE



## SOLDER PASTE EXAMPLE

100% PRINTED SOLDER COVERAGE BY AREA  
SCALE:10X

| STENCIL THICKNESS | SOLDER STENCIL OPENING |
|-------------------|------------------------|
| 0.1               | 3.53 X 3.64            |
| 0.125             | 3.155 X 3.255 (SHOWN)  |
| 0.15              | 2.88 X 2.97            |
| 0.175             | 2.67 X 2.75            |

4214867/A 09/2016

NOTES: (continued)

10. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
11. Board assembly site may have different recommendations for stencil design.

## GENERIC PACKAGE VIEW

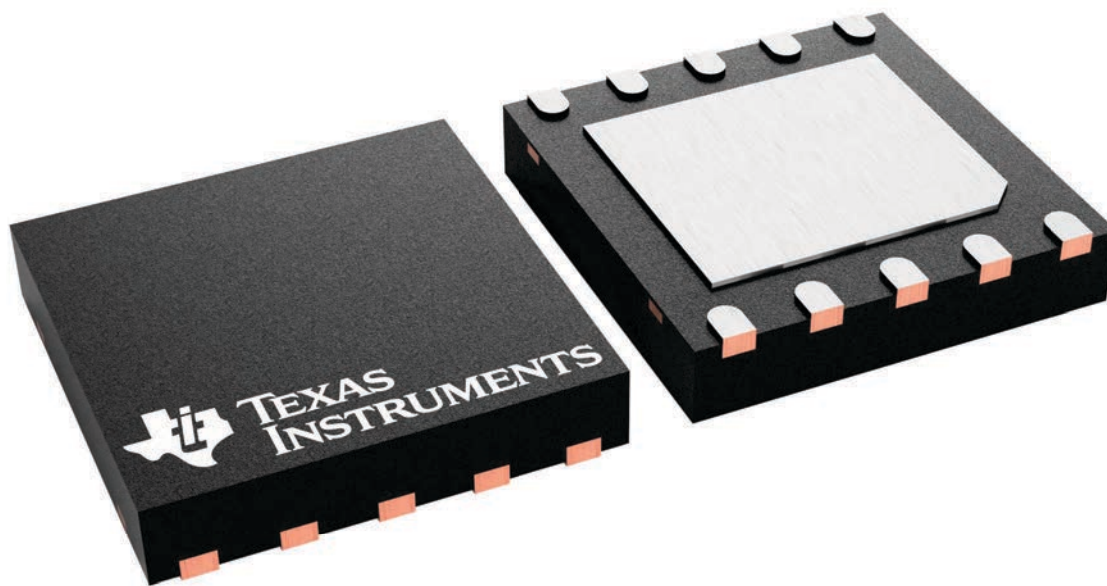
**DPR 10**

**WSON - 0.8 mm max height**

4 x 4, 0.8 mm pitch

PLASTIC SMALL OUTLINE - NO LEAD

This image is a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.



4232220/A

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2025, Texas Instruments Incorporated