![Texas Instruments]

TPS63024
TPS630241, TPS630242

ZHCSDM2A – NOVEMBER 2014 – REVISED DECEMBER 2014

TPS63024x 高电流、高效单电感器降压-升压转换器

1 特性

- 支持降压和升压运行间自动和无缝转换的实际降压或升压运行
- 输入电压范围 2.3V 至 5.5V
- 1.5A 持续输出电流：$V_{IN} \geq 2.5V$，$V_{OUT} = 3.3V$
- 可调和固定输出电压
- 在降压或升压模式中效率高达 95%，而在 $V_{IN} = V_{OUT}$ 时，效率高达 97%
- 2.5MHz 典型开关频率
- 运行静态电流 35μA
- 集成软启动
- 省电模式
- 真正关断功能
- 输出电容器放电功能
- 过热保护和过流保护
- 宽电容值选择
- 小型 1.766mm x 2.086mm，20 引脚晶圆级芯片尺寸 (WCSP) 封装

2 应用范围

- 手机、智能电话
- 平板个人电脑
- 个人电脑和智能手机配件
- 负载点稳压
- 电池供电类 应用

3 说明

TPS63024 是一款高效、低静态电流降压-升压转换器，此转换器适用于输入电压会高于或低于输出的应用。在升压模式下，输出电流可高达 1.5A，而在降压模式下，输出电流可高达 3A。开关内的最大平均电流被限制在 3A（典型值）。TPS63024 根据输入电压在降压或升压模式之间自动切换，以便在整个输入电压范围内调节输出电压，从而确保两个模式间的无缝转换。此降压-升压转换器基于一个使用同步整流的固定频率、脉宽调制 (PWM) 控制器以获得最高效率。在低负载电流情况下，此转换器进入省电模式，以便在整个负载电流范围内保持高效率。有一个使用户能够在自动 PFM/PWM 模式运行和强制 PWM 运行之间进行选择的 PFM/PWM 引脚。在 PWM 模式期间，通常使用一个 2.5MHz 的固定频率。使用一个外部电阻分压器可对输出电压进行编程，或者在芯片上对输出电压进行内部固定。转换器可被禁用以最大限度地减少电池消耗。在关机期间，负载从电池上断开。此器件采用 20 引脚，1.766mm x 2.086 mm，WCSP 封装。
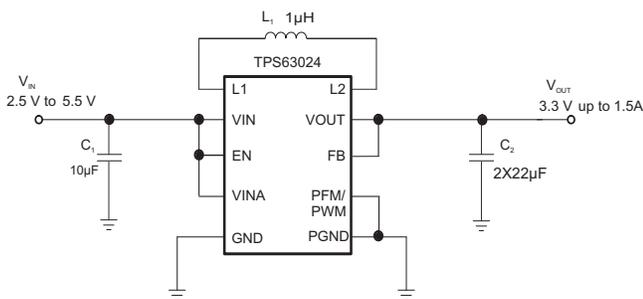
器件信息[1]

器件型号	封装	封装尺寸（标称值）
TPS63024	芯片尺寸球状引脚栅格阵列 (DSBGA) (20)	1.766mm x 2.086mm
TPS630241		
TPS630242		

(1) 如需了解所有可用封装，请参阅产品说明书末尾的可订购产品附录。

器件比较

器件编号	**VOUT**
TPS63024	可调节
TPS630241	2.9V
TPS630242	3.3 V

典型应用

效率与输出电流间的关系

目录

4 修订历史记录

注：之前版本的页码可能与当前版本有所不同。

Changes from Original (November 2014) to Revision A   **Page**

- Added Specifications, Detailed Description section, Application and Implementation section, Power Supply Recommendations section, Layout section, Device and Documentation Support section; and, changed status to Production Data. 4

5 Pin Configuration and Functions

WCSP
20-Pin
YFF (TOP VIEW)

E1	D1	C1	B1	A1
E2	D2	C2	B2	A2
E3	D3	C3	B3	A3
E4	D4	C4	B4	A4
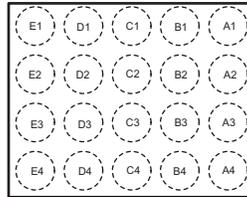
Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
VOUT	A1,A2,A3	PWR	Buck-boost converter output
FB	A4	IN	Voltage feedback of adjustable version, must be connected to VOUT for fixed output voltage versions
L2	B1,B2,B3	PWR	Connection for Inductor
PFM/PWM	B4	IN	set low for PFM mode, set high for forced PWM mode. It must not be left floating
PGND	C1,C2,C3	PWR	Power Ground
GND	C4	PWR	Analog Ground
L1	D1,D2,D3	PWR	Connection for Inductor
EN	D4	IN	Enable input. Set high to enable and low to disable. It must not be left floating.
VIN	E1,E2,E3	PWR	Supply voltage for power stage
VINA	E4	PWR	Supply voltage for control stage.

6 Specifications

6.1 Absolute Maximum Ratings[1]

over junction temperature range (unless otherwise noted)

		VALUE		UNIT
		MIN	MAX	
Voltage[2]	VIN, L1, EN, VINA, PFM/PWM	−0.3	7	V
	VOUT, FB	−0.3	4	V
	L2[3]	−0.3	4	V
	L2[4]	-0.3	5.5	V
Input current	Continuos average current into L1[5]		2.7	A
T_J	Operating junction temperature	−40	125	°C
T_{stg}	Storage temperature range	−65	150	

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to network ground pin.
(3) DC voltage rating.
(4) AC transient voltage rating.
(5) Maximum continuos average input current 3.5A, under those condition do not exceed 105°C for more than 25% operating time.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±2000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101[2]	±700	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions[1]

		MIN	TYP	MAX	UNIT
V_{IN}	Input Voltage Range	2.3		5.5	V
V_{OUT}	Output Voltage	2.5		3.6	V
L	Inductance [2]	0.5	1	1.3	µH
C_{out}	Output Capacitance[3]	16			µF
T_A	Operating ambient temperature	–40		85	°C
T_J	Operating virtual junction temperature	–40		125	°C

(1) Refer to the Application Information section for further information
(2) Effective inductance value at operating condition. The nominal value given matches a typical inductor to be chosen to meet the inductance required.
(3) Due to the dc bias effect of ceramic capacitors, the effective capacitance is lower then the nominal value when a voltage is applied. This is why the capacitance is specified to allow the selection of the nominal capacitor required with the dc bias effect for this type of capacitor. The nominal value given matches a typical capacitor to be chosen to meet the minimum capacitance required.

6.4 Thermal Information

	THERMAL METRIC[1]	TPS63024x YFF 20 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	53.8	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	0.5	
$R_{\theta JB}$	Junction-to-board thermal resistance	10.1	
ψ_{JT}	Junction-to-top characterization parameter	1.4	
ψ_{JB}	Junction-to-board characterization parameter	9.8	
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.

6.5 Electrical Characteristics

V_{IN}=2.3V to 5.5V, T_J= −40°C to 125°C, typical values are at T_A=25°C (unless otherwise noted)

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
SUPPLY							
V_{IN}	Input voltage range			2.3		5.5	V
V_{IN_Min}	Minimum input voltage to turn on into full load		R_{LOAD}= 2.2Ω		2.7		V
I_Q	Quiescent current	V_{IN}	I_{OUT}=0mA, EN=V_{IN}=3.6V, V_{OUT}=3.3V T_J=-40°C to 85°C, not switching		35	70	µA
		V_{OUT}				12	µA
I_{sd}	Shutdown current		EN=low, T_J=-40°C to 85°C		0.1	2	µA
UVLO	Under voltage lockout threshold		V_{IN} falling	1.6	1.7	2	V
	Under voltage lockout hysteresis				70		mV
	Thermal shutdown		Temperature rising		140		°C
LOGIC SIGNALS EN, PFM/PWM							
V_{IH}	High level input voltage		V_{IN}=2.3V to 5.5V	1.2			V
V_{IL}	Low level input voltage		V_{IN}=2.3V to 5.5V			0.4	V
I_{lkg}	Input leakage current		PFM/PWM, EN=GND or V_{IN}		0.01	0.2	µA
OUTPUT							
V_{OUT}	Output Voltage range			2.5		3.6	V
V_{FB}	Feedback regulation voltage		TPS63024		0.8		V
V_{FB}	Feedback voltage accuracy		PWM mode, TPS63024	-1%		1%	
V_{FB}	Feedback voltage accuracy [1]		PFM mode, TPS63024	-1%	1.3%	+3%	
V_{OUT}	Output voltage accuracy		PWM mode, TPS630241	2.871	2.9	2.929	V
V_{OUT}	Output voltage accuracy[1]		PFM mode, TPS630241	2.871	2.938	2.987	V
V_{OUT}	Output voltage accuracy		PWM mode, TPS630242	3.267	3.3	3.333	V
V_{OUT}	Output voltage accuracy[1]		PFM mode, TPS630242	3.267	3.343	3.399	V
$I_{PWM/PFM}$	Output current to enter PFM mode		V_{IN} =3V; V_{OUT} = 3.3V		350		mA
I_{FB}	Feedback input bias current		V_{FB} = 0.8V		10	100	nA
$R_{DS\_Buck(on)}$	High side FET on-resistance		V_{IN}=3.0V, V_{OUT}=3.3V		35		mΩ
	Low side FET on-resistance		V_{IN}=3.0V, V_{OUT}=3.3V		50		mΩ
$R_{DS\_Boost(on)}$	High side FET on-resistance		V_{IN}=3.0V, V_{OUT}=3.3V		25		mΩ
	Low side FET on-resistance		V_{IN}=3.0V, V_{OUT}=3.3V		50		mΩ
I_{IN}	Average input current limit [2]		V_{IN}=3.0V, V_{OUT}=3.3V T_J= 25°C to 125°C	2.12	3	3.54	A
f_s	Switching Frequency				2.5		MHz
R_{ON_DISC}	Discharge ON-Resistance		EN=low		120		Ω
	Line regulation		V_{IN}=2.8V to 5.5V, I_{OUT}=1.5A		7.4		mV/V
	Load regulation		V_{IN}=3.6V,I_{OUT}=0A to 1.5A		2.5		mV/A

(1) Conditions: L=1 µH, C_{OUT}= 2 × 22µF.
(2) For variation of this parameter with Input voltage and temperature see *Figure 8*. To calculate minimum output current in a specific working point see *Figure 8* and *Equation 1* trough *Equation 4*.

6.6 Timing Requirements

V_{IN}= 2.3V to 5.5V, T_J= –40°C to 125°C, typical values are at T_A= 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OUTPUT						
t_{SS}	Softstart time	EN=low to high, Buck mode V_{IN}=3.6V, V_{OUT}=3.3V, I_{OUT}=1.5A		450		µs
		EN=low to high, Boost mode V_{IN}=2.8V, V_{OUT}=3.3V, I_{OUT}=1.5A		700		µs
t_d	Start up delay	Time from when EN=high to when device starts switching		100		µs

6.7 Typical Characteristics
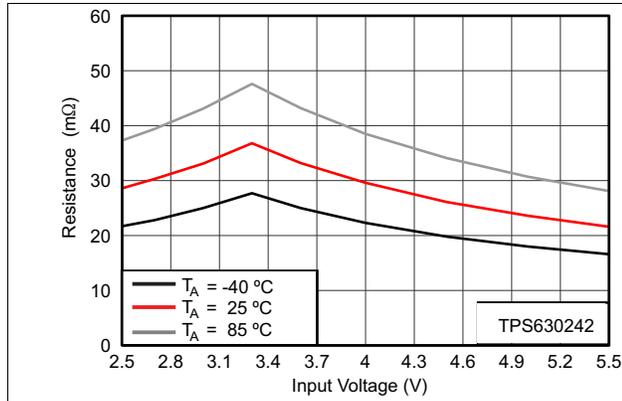
Figure 1. High Side FET On-Resistance vs VIN
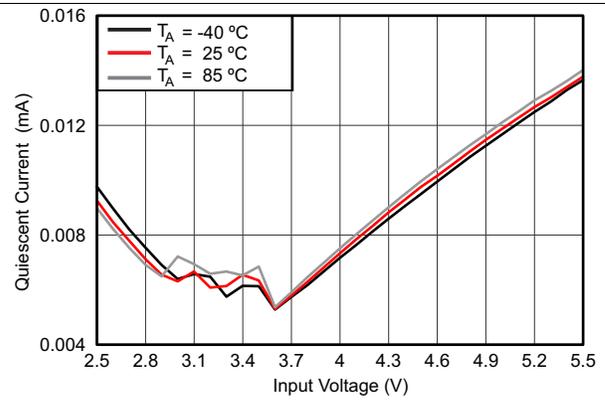
Figure 2. Quiescent Current vs Input Voltage

7 Detailed Description

7.1 Overview

The TPS63024x use 4 internal N-channel MOSFETs to maintain synchronous power conversion at all possible operating conditions. This enables the device to keep high efficiency over the complete input voltage and output power range. To regulate the output voltage at all possible input voltage conditions, the device automatically switches from buck operation to boost operation and back as required by the configuration. It always uses one active switch, one rectifying switch, one switch is held on, and one switch held off. Therefore, it operates as a buck converter when the input voltage is higher than the output voltage, and as a boost converter when the input voltage is lower than the output voltage. There is no mode of operation in which all 4 switches are switching at the same time. Keeping one switch on and one switch off eliminates their switching losses. The RMS current through the switches and the inductor is kept at a minimum, to minimize switching and conduction losses. Controlling the switches this way allows the converter to always keep higher efficiency.

The device provides a seamless transition from buck to boost or from boost to buck operation.
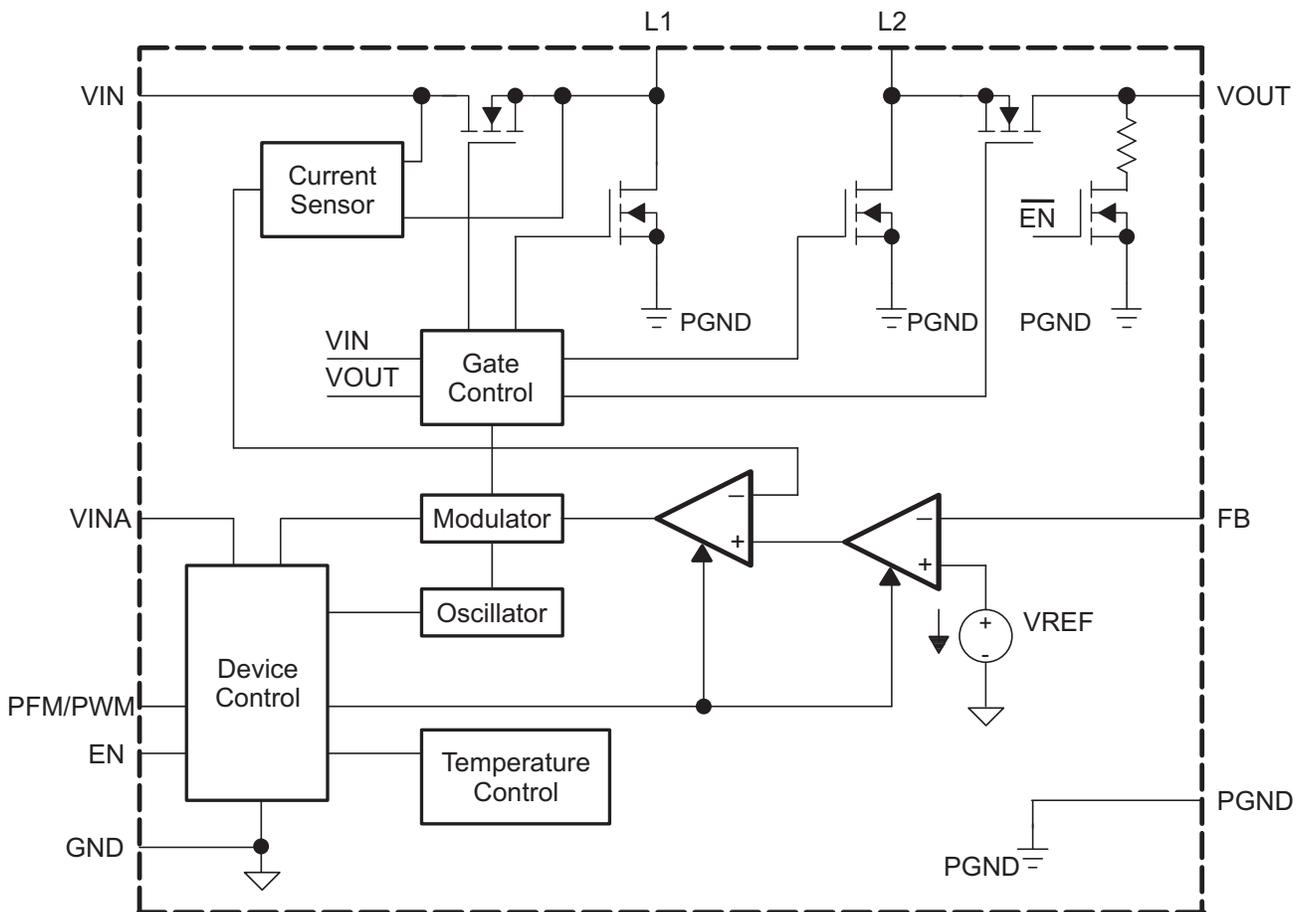
7.2 Functional Block Diagram

Figure 3. Functional Block Diagram (Adjustable Output Voltage)

Functional Block Diagram (continued)

Figure 4. Functional Block Diagram (Fixed Output Voltage)

7.3 Feature Description

7.3.1 Undervoltage Lockout (UVLO)

To avoid mis-operation of the device at low input voltages, an undervoltage lockout is included. UVLO shuts down the device at input voltages lower than typically 1.7V with a 70 mV hysteresis.

7.3.2 Output Discharge Function

When the device is disabled by pulling enable low and the supply voltage is still applied, the internal transistor use to discharge the output capacitor is turned on, and the output capacitor is discharged until UVLO is reached. This means, if there is no supply voltage applied the output discharge function is also disabled. The transistor which is responsible of the discharge function, when turned on, operates like an equivalent 120Ω resistor, ensuring typically less than 10ms discharge time for 20uF output capacitance and a 3.3V output.

7.3.3 Thermal Shutdown

The device goes into thermal shutdown once the junction temperature exceeds typically 140°C.

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Feature Description (continued)

7.3.4 Softstart

To minimize inrush current and output voltage overshoot during start up, the device has a Softstart. At turn on, the input current raises monotonically until the output voltage reaches regulation. During Softstart, the input current follows the current ramp charging the internal Softstart capacitor. The device smoothly ramps up the input current bringing the output voltage to its regulated value even if a large capacitor is connected at the output.

The Softstart time is measured as the time from when the EN pin is asserted to when the output voltage has reached 90% of its nominal value. There is typically a 100µs delay time from when the EN pin is asserted to when the device starts the switching activity. The Softstart time depends on the load current, the input voltage, and the output capacitor. The Softstart time in boost mode is longer then the time in buck mode. The total typical Softstart time is 1ms.

The inductor current is able to increase and always assure a soft start unless a real short circuit is applied at the output.

7.3.5 Short Circuit Protection

The TPS63024x provides short circuit protection to protect itself and the application. When the output voltage does not increase above 1.2V, the device assumes a short circuit at the output and limits the input current to 3A.

7.4 Device Functional Modes

7.4.1 Control Loop Description
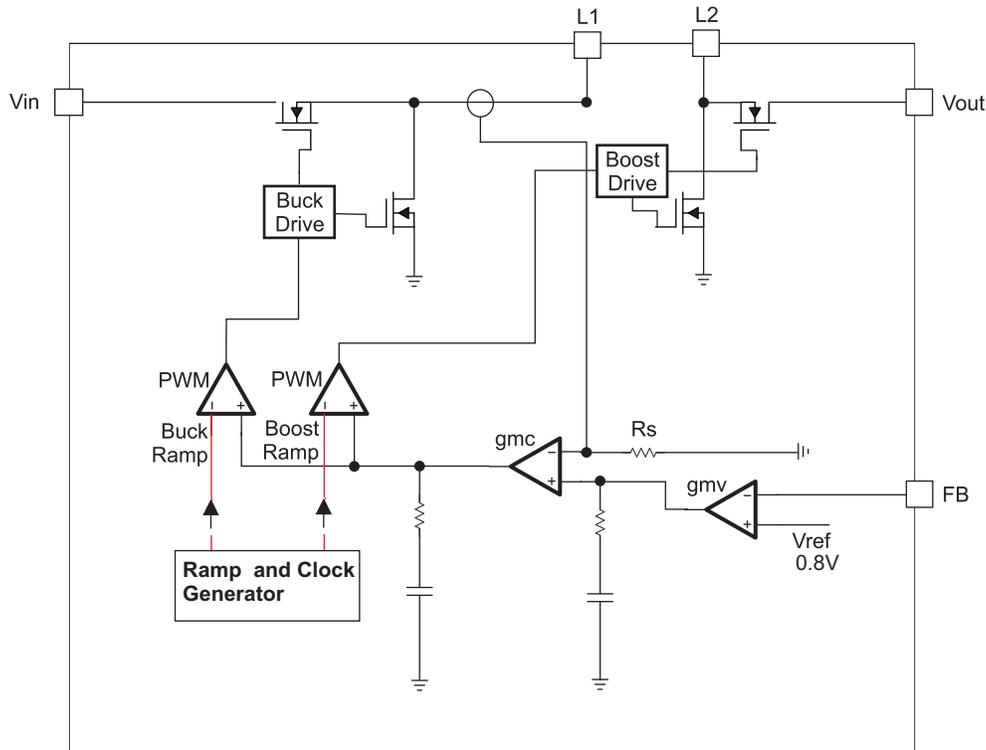
Figure 5. Average Current Mode Control

The controller circuit of the device is based on an average current mode topology. The average inductor current is regulated by a fast current regulator loop which is controlled by a voltage control loop. *Figure 5* shows the control loop.

The non inverting input of the transconductance amplifier, gmv, is assumed to be constant. The output of gmv defines the average inductor current. The inductor current is reconstructed by measuring the current through the high side buck MOSFET. This current corresponds exactly to the inductor current in boost mode. In buck mode the current is measured during the on time of the same MOSFET. During the off time, the current is reconstructed internally starting from the peak value at the end of the on time cycle. The average current and the feedback from the error amplifier gmv forms the correction signal gmc. This correction signal is compared to the buck and the boost sawtooth ramp giving the PWM signal. Depending on which of the two ramps the gmc output crosses either the Buck or the Boost stage is initiated. When the input voltage is close to the output voltage, one buck cycle is always followed by a boost cycle. In this condition, no more than three cycles in a row of the same mode are allowed. This control method in the buck-boost region ensures a robust control and the highest efficiency.

Device Functional Modes (continued)

7.4.2 Power Save Mode Operation
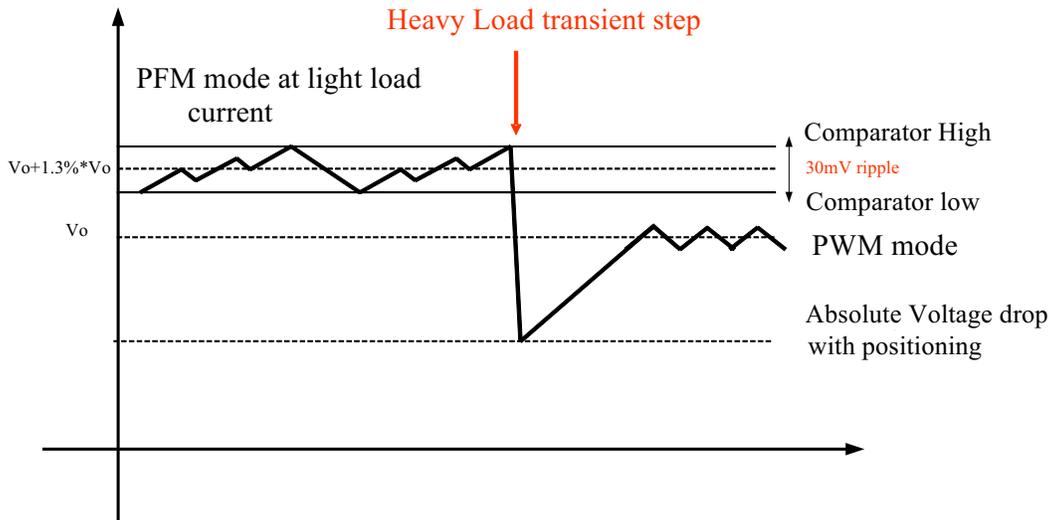
Figure 6. Power Save Mode Operation

Depending on the load current, in order to provide the best efficiency over the complete load range, the device works in PWM mode at load currents of approximately 350 mA or higher. At lighter loads, the device switches automatically into Power Save Mode to reduce power consumption and extend battery life. The PFM/PWM pin is used to select between the two different operation modes. To enable Power Save Mode, the PFM/PWM pin must be set low.

During Power Save Mode, the part operates with a reduced switching frequency and lowest supply current to maintain high efficiency. The output voltage is monitored with a comparator at every clock cycle by the thresholds comp low and comp high. When the device enters Power Save Mode, the converter stops operating and the output voltage drops. The slope of the output voltage depends on the load and the output capacitance. When the output voltage reaches the comp low threshold, at the next clock cycle the device ramps up the output voltage again, by starting operation. Operation can last for one or several pulses until the comp high threshold is reached. At the next clock cycle, if the load is still lower than about 350mA, the device switches off again and the same operation is repeated. Instead, if at the next clock cycle, the load is above 350mA, the device automatically switches to PWM mode.

In order to keep high efficiency in PFM mode, there is only one comparator active to keep the output voltage regulated. The AC ripple in this condition is increased, compared to the PWM mode. The amplitude of this voltage ripple in the worst case scenario is 50mV pk-pk, (typically 30mV pk-pk), with 20µF effective output capacitance. In order to avoid a critical voltage drop when switching from 0A to full load, the output voltage in PFM mode is typically 1.3% above the nominal value in PWM mode. This is called Dynamic Voltage Positioning and allows the converter to operate with a small output capacitor and still have a low absolute voltage drop during heavy load transients.

Power Save Mode is disabled by setting the PFM/PWM pin high.

Device Functional Modes (continued)

7.4.3 Current Limit

The current limit variation depends on the difference between the input and output voltage. The maximum current limit value is at the highest difference.

Given the curves provided in *Figure 8*, it is possible to calculate the output current reached in boost mode, using *Equation 1* and *Equation 2* and in buck mode using *Equation 3* and Equation 4.

Duty Cycle Boost $\qquad D = \dfrac{V_{OUT} - V_{IN}}{V_{OUT}}$

$\hspace{12cm}$ (1)

Output Current Boost $\quad I_{OUT} = \eta \ \times I_{IN} (1\text{-}D)$ $\hspace{6cm}$ (2)

Duty Cycle Buck $\qquad D = \dfrac{V_{OUT}}{V_{IN}}$

$\hspace{12cm}$ (3)

Output Current Buck $\quad I_{OUT} = (\ \eta \ \times I_{IN}) \ / \ D$

where

- η = Estimated converter efficiency (use the number from the efficiency curves or 0.90 as an assumption)
- I_{IN}= Minimum average input current (Figure 8) $\hspace{8cm}$ (4)

7.4.4 Supply and Ground

The TPS63024x provides two input pins (VIN and VINA) and two ground pins (PGND and GND).

The VIN pin supplies the input power, while the VINA pin provides voltage for the control circuits. A similar approach is used for the ground pins. GND and PGND are used to avoid ground shift problems due to the high currents in the switches. The reference for all control functions is the GND pin. The power switches are connected to PGND. Both grounds must be connected on the PCB at only one point, ideally, close to the GND pin.

7.4.5 Device Enable

The device starts operation when the EN pin is set high. The device enters shutdown mode when the EN pin is set low. In shutdown mode, the regulator stops switching, all internal control circuitry is switched off, and the load is disconnected from the input.

8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The TPS63024x are high efficiency, low quiescent current buck-boost converters suitable for application where the input voltage is higher, lower or equal to the output. Output currents can go as high as 1.5A in boost mode and as high as 3A in buck mode. The maximum average current in the switches is limited to a typical value of 3A.

8.2 Typical Application
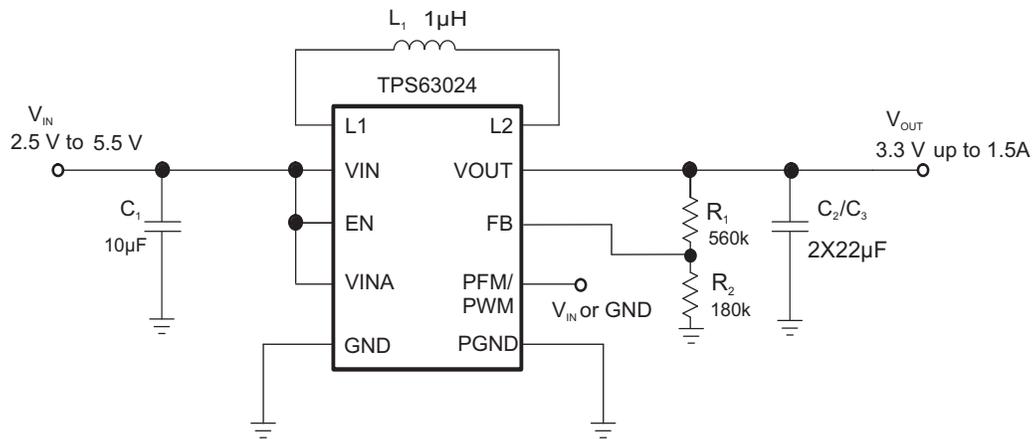
Figure 7. 3.3-V Adjustable Version

8.2.1 Design Requirements

The design guideline provides a component selection to operate the device within the recommended operating conditions.

Table 1 shows the list of components for the Application Characteristic Curves.

Table 1. Components for Application Characteristic Curves[1]

REFERENCE	DESCRIPTION	MANUFACTURER
	TPS63024	Texas Instruments
L1	1 µH, 8.75A, 13mΩ, SMD	XAL4020-102MEB, Coilcraft
C1	10 µF 6.3V, 0603, X5R ceramic	Standard
C2,C3	22 µF 6.3V, 0603, X5R ceramic	Standard
R1	560kΩ	Standard
R2	180kΩ	Standard

(1) See *Third-Party Products Discalimer*

8.2.2 Detailed Design Procedure

The first step is the selection of the output filter components. To simplify this process Table 2 outline possible inductor and capacitor value combinations.

8.2.2.1 Output Filter Design

Table 2. Matrix of Output Capacitor and Inductor Combinations

NOMINAL INDUCTOR VALUE [µH][1]	NOMINAL OUTPUT CAPACITOR VALUE [µF][2]				
	44	47	66	88	100
0.680			+	+	+
1.0	+[3]	+	+	+	+
1.5			+	+	+

(1) Inductor tolerance and current de-rating is anticipated. The effective inductance can vary by 20% and –30%.
(2) Capacitance tolerance and bias voltage de-rating is anticipated. The effective capacitance can vary by 20% and –50%.
(3) Typical application. Other check mark indicates recommended filter combinations

8.2.2.2 Inductor Selection

The inductor selection is affected by several parameter like inductor ripple current, output voltage ripple, transition point into Power Save Mode, and efficiency. See Table 3 for typical inductors.

Table 3. List of Recommended Inductors[1]

INDUCTOR VALUE	COMPONENT SUPPLIER	SIZE (LxWxH mm)	Isat/DCR
1 µH	Coilcraft XAL4020-102ME	4 X 4 X 2.10	4.5A/10mΩ
1 µH	Toko, DFE322512C	3.2 X 2.5 X 1.2	4.7A/34mΩ
1 µH	TDK, SPM4012	4.4 X 4.1 X 1.2	4.1A/38mΩ
1 µH	Wuerth, 74438334010	3 X 3 X 1.2	6.6A/42.10mΩ
0.6 µH	Coilcraft XFL4012-601ME	4 X 4 X 1.2	5A/17.40mΩ
0.68µH	Wuerth,744383340068	3 X 3 X 1.2	7.7A/36mΩ

(1) See Third-Party Products Desclaimer

For high efficiencies, the inductor should have a low dc resistance to minimize conduction losses. Especially at high-switching frequencies, the core material has a high impact on efficiency. When using small chip inductors, the efficiency is reduced mainly due to higher inductor core losses. This needs to be considered when selecting the appropriate inductor. The inductor value determines the inductor ripple current. The larger the inductor value, the smaller the inductor ripple current and the lower the conduction losses of the converter. Conversely, larger inductor values cause a slower load transient response. To avoid saturation of the inductor, the peak current for the inductor in steady state operation is calculated using Equation 6. Only the equation which defines the switch current in boost mode is shown, because this provides the highest value of current and represents the critical current value for selecting the right inductor.

$$\text{Duty Cycle Boost} \qquad D = \frac{V_{OUT} - V_{IN}}{V_{OUT}} \tag{5}$$

$$I_{PEAK} = \frac{Iout}{\eta \times (1 - D)} + \frac{Vin \times D}{2 \times f \times L}$$

where

- D = Duty Cycle in Boost mod
- f = Converter switching frequency (typical 2.5MHz)
- L = Inductor value
- η = Estimated converter efficiency (use the number from the efficiency curves or 0.90 as an assumption)
- **Note:** The calculation must be done for the minimum input voltage which is possible to have in boost mode (6)

Calculating the maximum inductor current using the actual operating conditions gives the minimum saturation current of the inductor needed. It's recommended to choose an inductor with a saturation current 20% higher than the value calculated using Equation 6. Possible inductors are listed in Table 3.

8.2.2.3 *Capacitor Selection*

8.2.2.3.1 *Input Capacitor*

At least a 10μF input capacitor is recommended to improve line transient behavior of the regulator and EMI behavior of the total power supply circuit. An X5R or X7R ceramic capacitor placed as close as possible to the VIN and PGND pins of the IC is recommended. This capacitance can be increased without limit. If the input supply is located more than a few inches from the TPS63024x converter additional bulk capacitance may be required in addition to the ceramic bypass capacitors. An electrolytic or tantalum capacitor with a value of 47 μF is a typical choice.

8.2.2.3.2 *Output Capacitor*

For the output capacitor, use of a small ceramic capacitors placed as close as possible to the VOUT and PGND pins of the IC is recommended. The recommended nominal output capacitance value is 20 μF with a variance as outlined in *Table 2*.

There is also no upper limit for the output capacitance value. Larger capacitors causes lower output voltage ripple as well as lower output voltage drop during load transients.

8.2.2.4 *Setting The Output Voltage*

When the adjustable output voltage version TPS63024x is used, the output voltage is set by an external resistor divider. The resistor divider must be connected between VOUT, FB and GND. When the output voltage is regulated properly, the typical value of the voltage at the FB pin is 800mV. The current through the resistive divider should be about 10 times greater than the current into the FB pin. The typical current into the FB pin is 0.1μA, and the voltage across the resistor between FB and GND, R_2, is typically 800 mV. Based on these two values, the recommended value for R2 should be lower than 180kΩ, in order to set the divider current at 4μA or higher. It is recommended to keep the value for this resistor in the range of 180kΩ. From that, the value of the resistor connected between VOUT and FB, R1, depending on the needed output voltage (V_{OUT}), can be calculated using *Equation 7*:

$$ R1 = R2 \times \left(\frac{V_{OUT}}{V_{FB}} - 1 \right) $$

(7)

8.2.3 Application Curves

Figure 8. Minimum Average Input Current vs Input Voltage

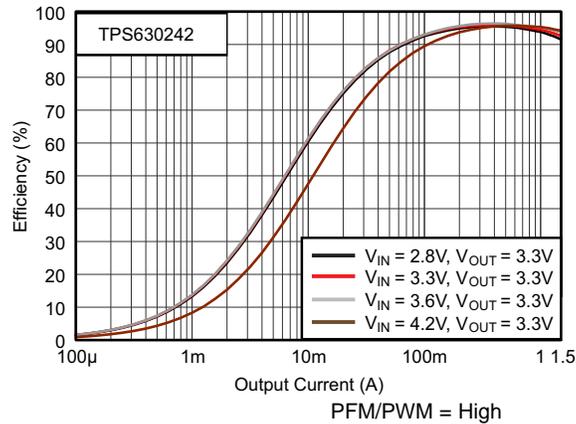**Figure 9. Efficiency vs Output Current**
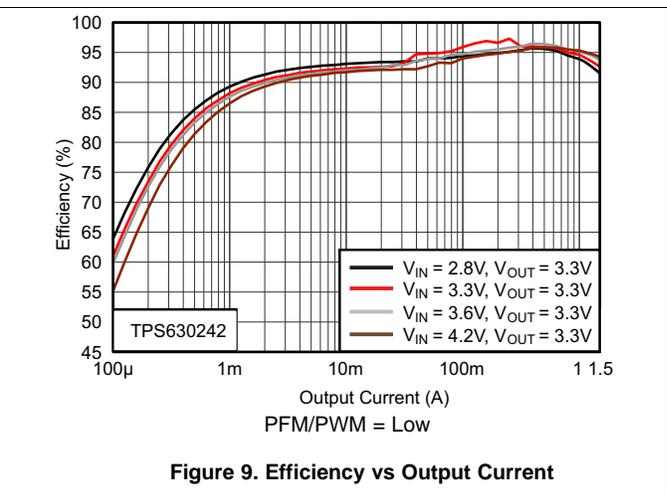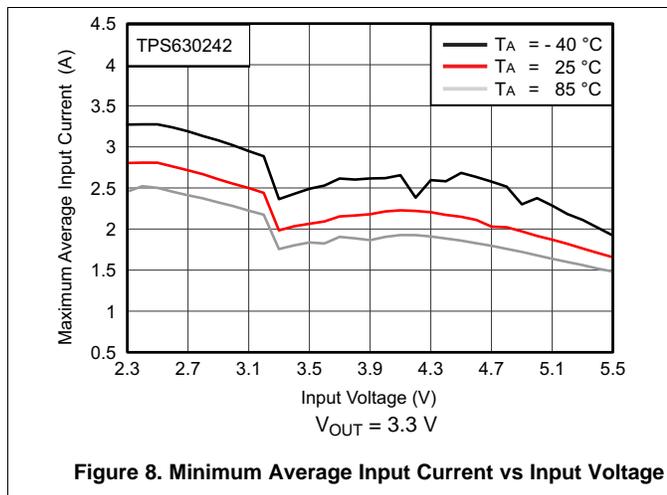
Figure 10. Efficiency vs Output Current
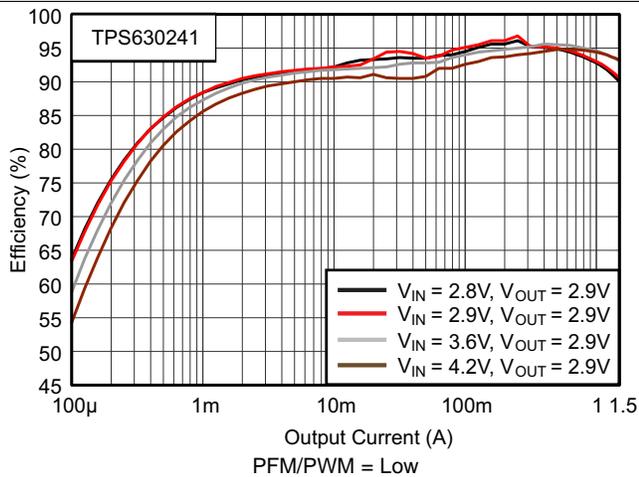

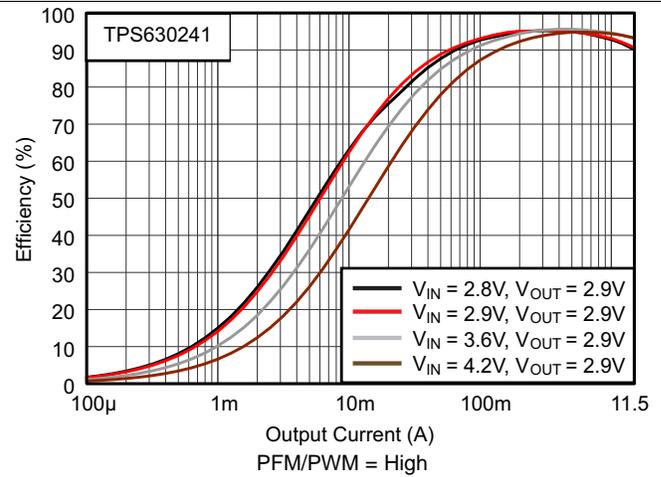**Figure 11. Efficiency vs Output Current**

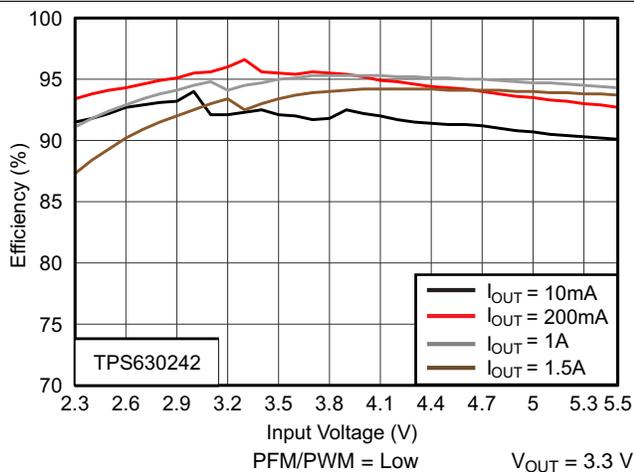**Figure 12. Efficiency vs Output Current**

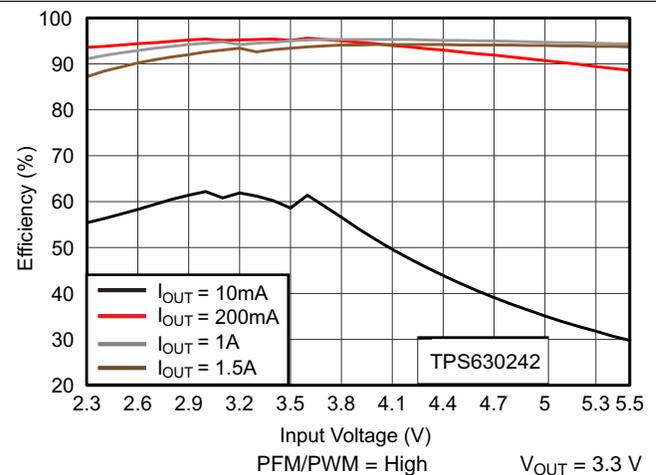**Figure 13. Efficiency vs Input Voltage**

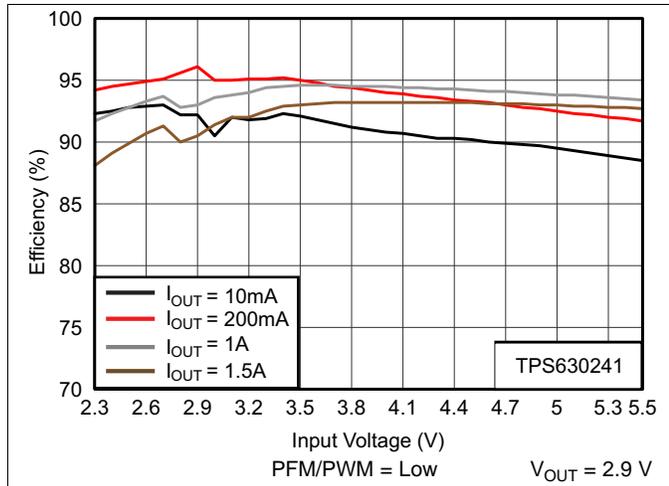**Figure 14. Efficiency vs Input Voltage**

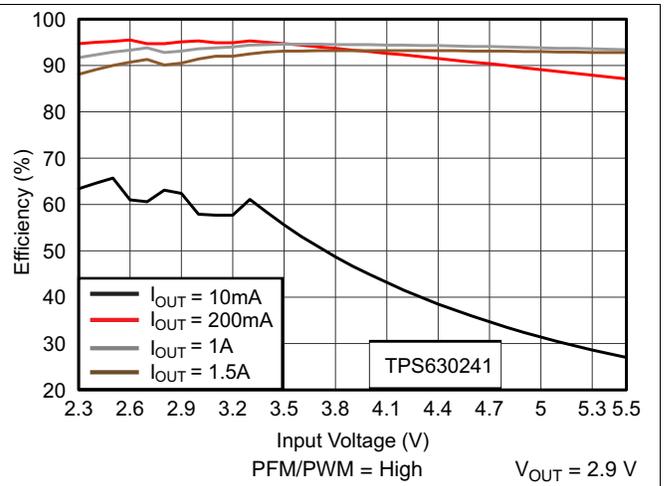**Figure 15. Efficiency vs Input Voltage**
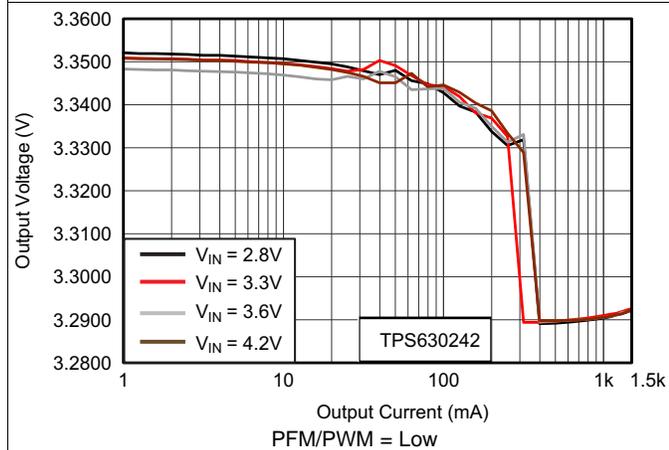

Figure 16. Efficiency vs Input Voltage

Figure 17. Output Voltage vs Output Current

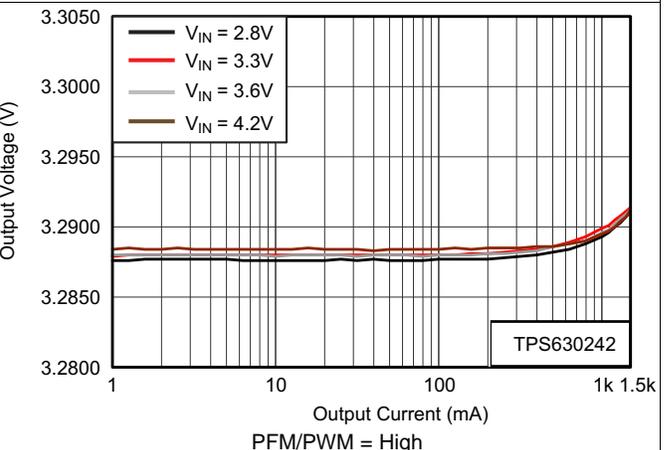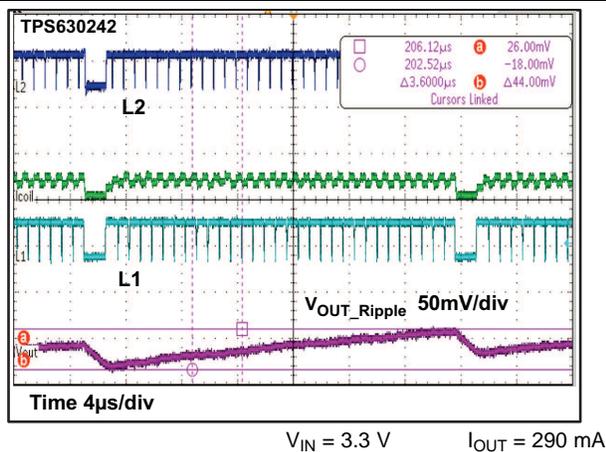**Figure 18. Output Voltage vs Output Current**

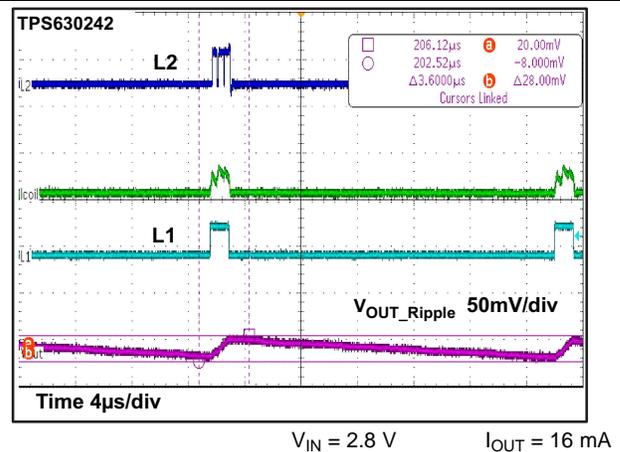**Figure 19. Output Voltage Ripple in Buck-Boost Mode and PFM to PWM Transition**

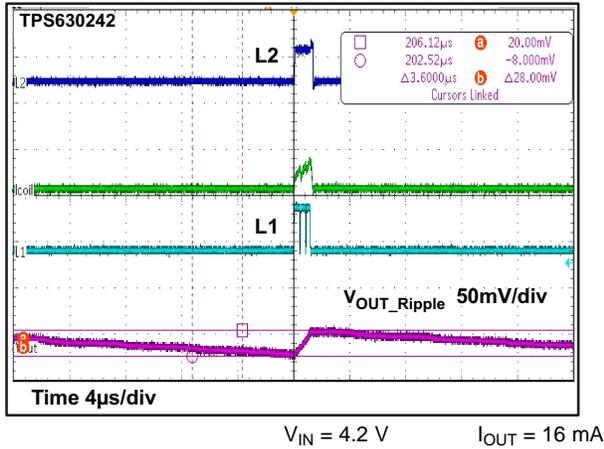**Figure 20. Output Voltage Ripple in Boost Mode and PFM Operation**

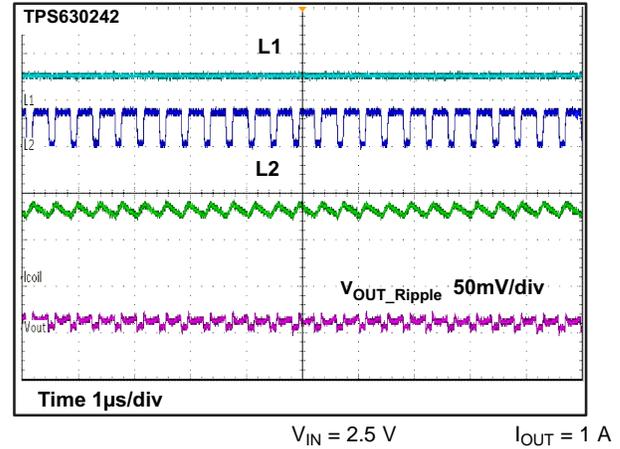**Figure 21. Output Voltage Ripple in Buck Mode and PFM Operation**

V_{IN} = 4.2 V I_{OUT} = 16 mA

Figure 22. Switching Waveforms in Boost Mode and PWM Operation

V_{IN} = 2.5 V I_{OUT} = 1 A
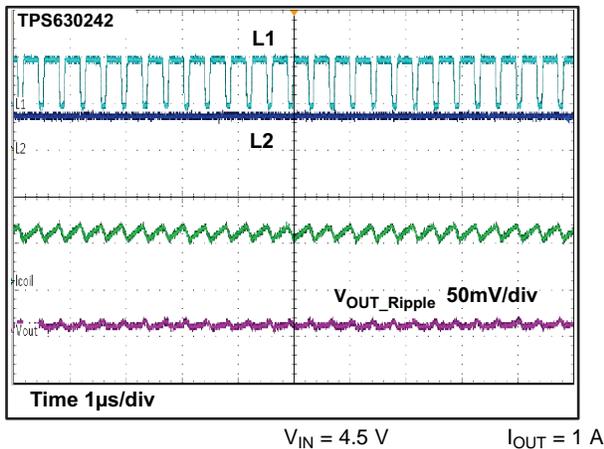
Figure 23. Switching Waveforms in Buck Mode and PWM Operation

V_{IN} = 4.5 V I_{OUT} = 1 A
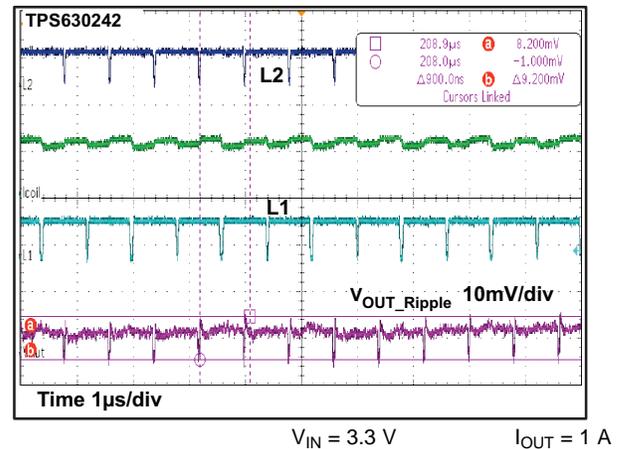
Figure 24. Switching Waveforms in Buck-Boost Mode and PWM Operation

V_{IN} = 3.3 V I_{OUT} = 1 A
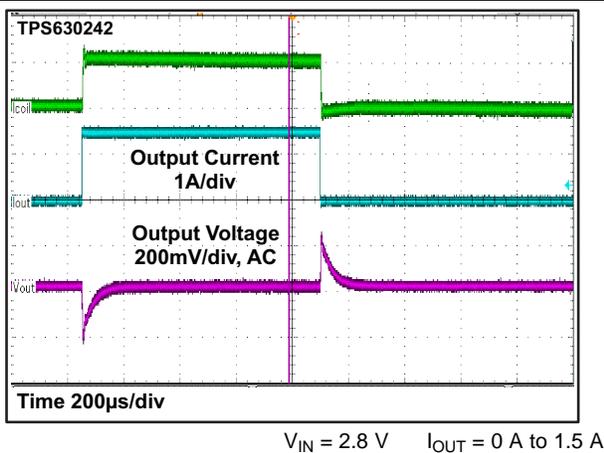
Figure 25. Load Transient Response Boost Mode

V_{IN} = 2.8 V I_{OUT} = 0 A to 1.5 A
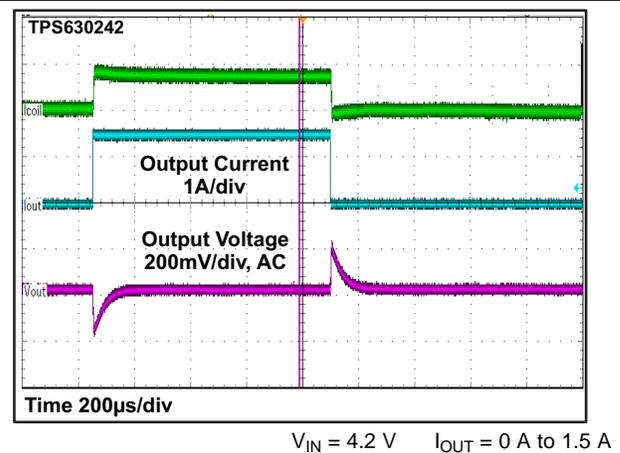
Figure 26. Load Transient Response Buck Mode

V_{IN} = 4.2 V I_{OUT} = 0 A to 1.5 A
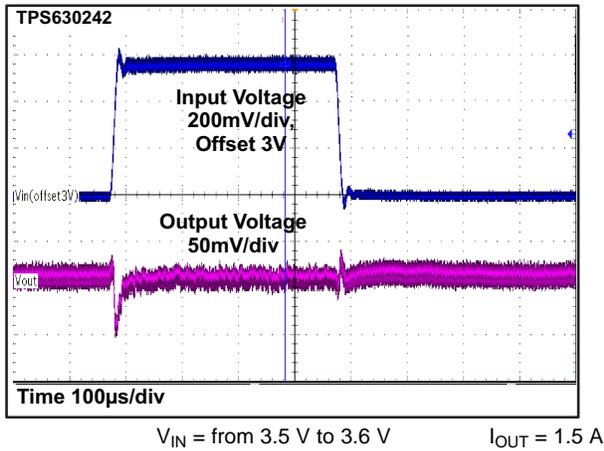
Figure 27. Line Transient Response

V_{IN} = from 3.5 V to 3.6 V I_{OUT} = 1.5 A
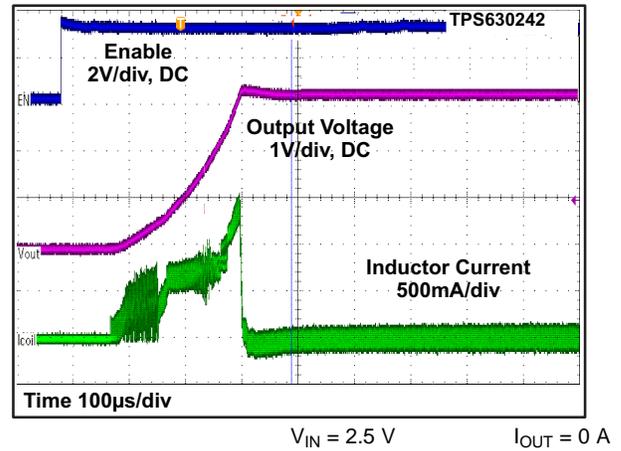
Figure 28. Start Up After Enable

V_{IN} = 2.5 V I_{OUT} = 0 A

Figure 29. Start Up After Enable

V_{IN} = 4.5 V I_{OUT} = 0 A

9 Power Supply Recommendations

The TPS63024x device family has no special requirements for its input power supply. The input power supply's output current needs to be rated according to the supply voltage, output voltage and output current of the TPS63024x.
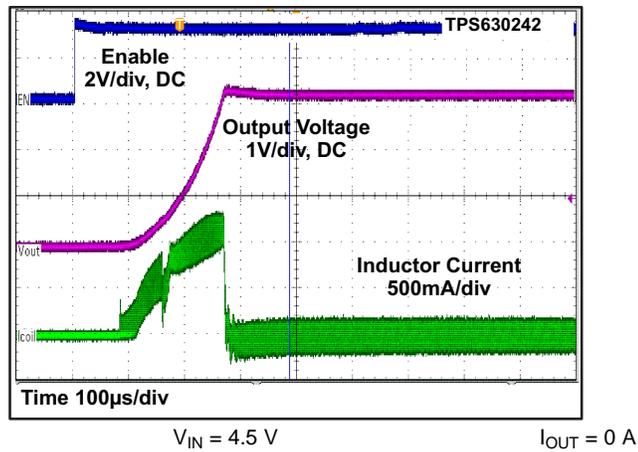
10 Layout

10.1 Layout Guidelines

The PCB layout is an important step to maintain the high performance of the TPS63024x devices.

- Place input and output capacitors as close as possible to the IC. Traces need to be kept short. Routing wide and direct traces to the input and output capacitor results in low trace resistance and low parasitic inductance.
- Use a common-power GND.
- The sense trace connected to FB is signal trace. Keep these traces away from L1 and L2 nodes.
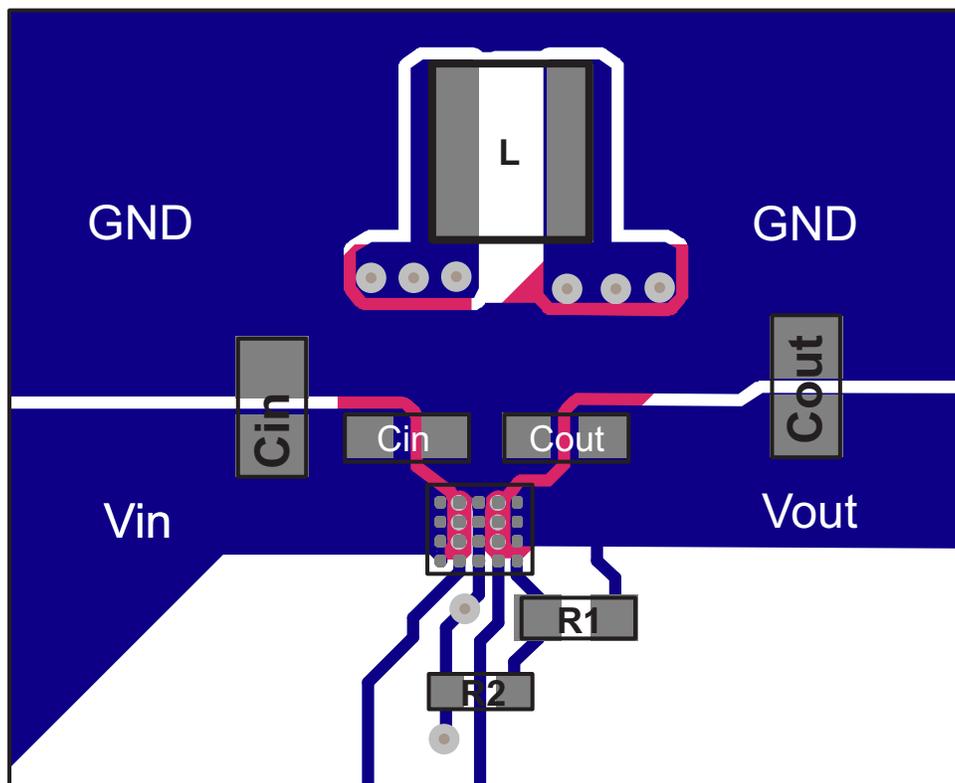
10.2 Layout Example

Figure 30. TPS63024x Layout

11 器件和文档支持

11.1 器件支持

11.1.1 Third-Party Products Disclaimer

TI'S PUBLICATION OF INFORMATION REGARDING THIRD-PARTY PRODUCTS OR SERVICES DOES NOT CONSTITUTE AN ENDORSEMENT REGARDING THE SUITABILITY OF SUCH PRODUCTS OR SERVICES OR A WARRANTY, REPRESENTATION OR ENDORSEMENT OF SUCH PRODUCTS OR SERVICES, EITHER ALONE OR IN COMBINATION WITH ANY TI PRODUCT OR SERVICE.

11.2 文档支持

11.2.1 相关文档

相关文档如下：

《*TPS63024EVM-553 用户指南，TPS63024 高电流、高效率单电感器降压-升压转换器*》，SLVUA24

11.3 相关链接

下面的表格列出了快速访问链接。范围包括技术文档、支持与社区资源、工具和软件，以及样片或购买的快速访问问。

表 **4.** 相关链接

器件	产品文件夹	样片与购买	技术文档	工具与软件	支持与社区
TPS63024	请单击此处	请单击此处	请单击此处	请单击此处	请单击此处
TPS630241	请单击此处	请单击此处	请单击此处	请单击此处	请单击此处
TPS630242	请单击此处	请单击此处	请单击此处	请单击此处	请单击此处

11.4 商标

All trademarks are the property of their respective owners.

11.5 静电放电警告

这些装置包含有限的内置 ESD 保护。 存储或装卸时，应将导线一起截短或将装置放置于导电泡棉中，以防止 MOS 门极遭受静电损伤。

11.6 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 机械、封装和可订购信息

以下页中包括机械、封装和可订购信息。这些信息是针对指定器件可提供的最新数据。这些数据会在无通知且不对本文档进行修订的情况下发生改变。欲获得该数据表的浏览器版本，请查阅左侧的导航栏。

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TPS630241YFFR	ACTIVE	DSBGA	YFF	20	3000	RoHS & Green	SNAGCU	Level-1-260C-UNLIM	-40 to 125	TPS 630241	Samples
TPS630241YFFT	ACTIVE	DSBGA	YFF	20	250	RoHS & Green	SNAGCU	Level-1-260C-UNLIM	-40 to 125	TPS 630241	Samples
TPS630242YFFR	ACTIVE	DSBGA	YFF	20	3000	RoHS & Green	SNAGCU	Level-1-260C-UNLIM	-40 to 125	TPS 630242	Samples
TPS630242YFFT	ACTIVE	DSBGA	YFF	20	250	RoHS & Green	SNAGCU	Level-1-260C-UNLIM	-40 to 125	TPS 630242	Samples
TPS63024YFFR	ACTIVE	DSBGA	YFF	20	3000	RoHS & Green	SNAGCU	Level-1-260C-UNLIM	-40 to 125	TPS 63024	Samples
TPS63024YFFT	ACTIVE	DSBGA	YFF	20	250	RoHS & Green	SNAGCU	Level-1-260C-UNLIM	-40 to 125	TPS 63024	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.
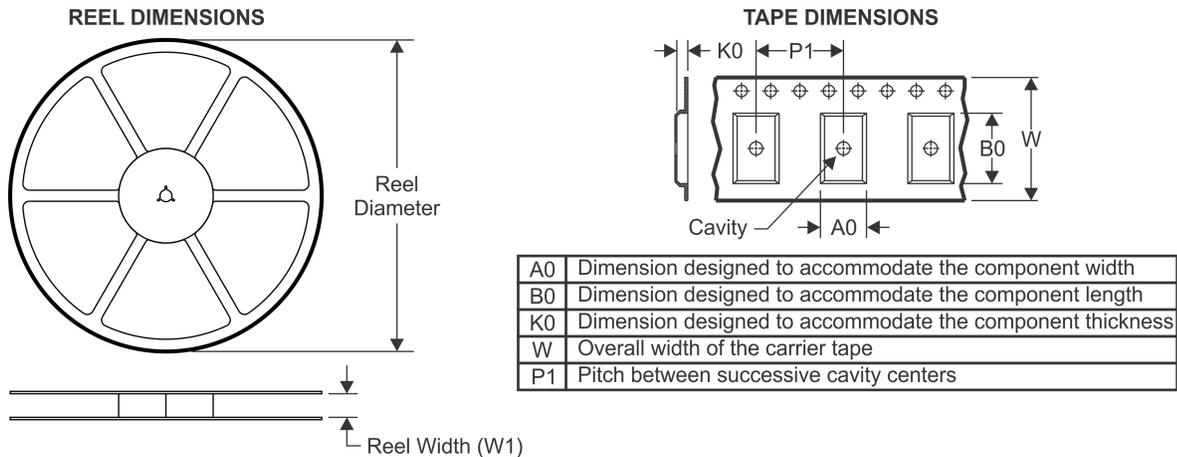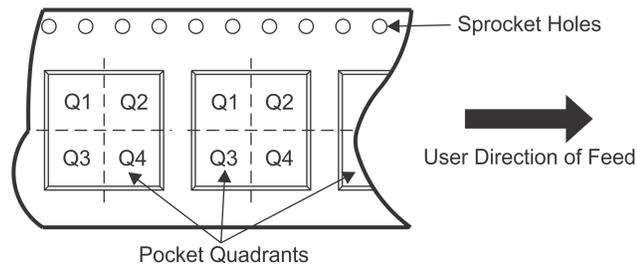
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(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 finish/Ball material - Orderable Devices 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.

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PACKAGE MATERIALS INFORMATION

TAPE AND REEL INFORMATION

REEL DIMENSIONS

TAPE DIMENSIONS

A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE

*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPS630241YFFR	DSBGA	YFF	20	3000	180.0	8.4	1.89	2.2	0.69	4.0	8.0	Q1
TPS630241YFFT	DSBGA	YFF	20	250	180.0	8.4	1.89	2.2	0.69	4.0	8.0	Q1
TPS630242YFFR	DSBGA	YFF	20	3000	180.0	8.4	1.89	2.2	0.69	4.0	8.0	Q1
TPS630242YFFT	DSBGA	YFF	20	250	180.0	8.4	1.89	2.2	0.69	4.0	8.0	Q1
TPS63024YFFR	DSBGA	YFF	20	3000	180.0	8.4	1.89	2.2	0.69	4.0	8.0	Q1
TPS63024YFFT	DSBGA	YFF	20	250	180.0	8.4	1.89	2.2	0.69	4.0	8.0	Q1

![Texas Instruments logo]

PACKAGE MATERIALS INFORMATION

TAPE AND REEL BOX DIMENSIONS
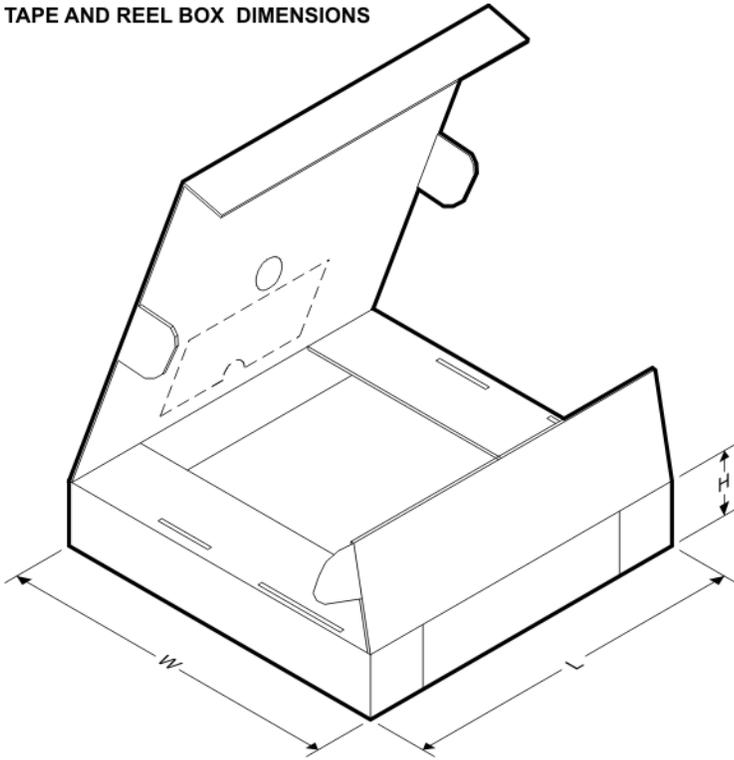
*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS630241YFFR	DSBGA	YFF	20	3000	182.0	182.0	20.0
TPS630241YFFT	DSBGA	YFF	20	250	182.0	182.0	20.0
TPS630242YFFR	DSBGA	YFF	20	3000	182.0	182.0	20.0
TPS630242YFFT	DSBGA	YFF	20	250	182.0	182.0	20.0
TPS63024YFFR	DSBGA	YFF	20	3000	182.0	182.0	20.0
TPS63024YFFT	DSBGA	YFF	20	250	182.0	182.0	20.0

YFF (R−XBGA−N20)   DIE−SIZE BALL GRID ARRAY

PIN A1
INDEX AREA

Bottom View

20X Ø 0,30 / 0,20

⊕ Ø 0,015 Ⓜ C A B

0,30 / 0,12

0,625 MAX

SEATING PLANE

⌒ 0,05 C

D: Max = 2.116 mm, Min =2.056 mm

E: Max = 1.796 mm, Min =1.736 mm

4207625−9/A0   12/13
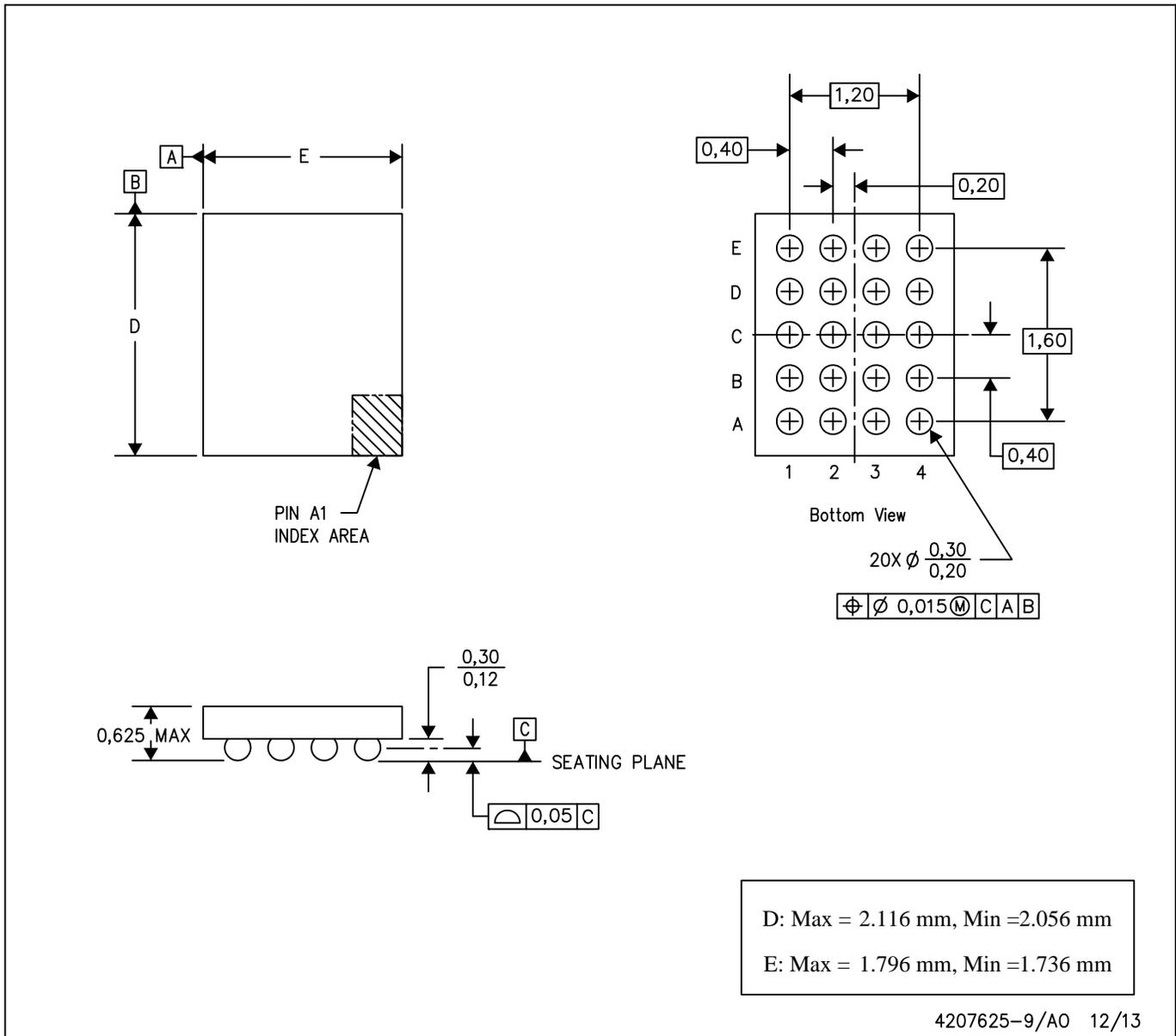
NOTES: A.   All linear dimensions are in millimeters.   Dimensioning and tolerancing per ASME Y14.5M−1994.
         B.   This drawing is subject to change without notice.
         C.   NanoFree™ package configuration.

NanoFree is a trademark of Texas Instruments.

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