





Support & training



**TPS61094** 

ZHCSN56A - JANUARY 2021 - REVISED FEBRUARY 2021

## 具有旁路模式的 TPS61094 60nA 静态电流双向降压/升压转换器

## 1 特性

- 宽电压范围和电流范围
  - 输入电压范围: 0.7V 至 5.5V
  - 启动时的最小输入电压为 1.8V
  - 可编程升压输出电压,设置范围: 2.7V 至 5.4V
  - 可编程降压充电端接电压,设置范围:1.7V至 5.4V
  - 可编程降压充电输出电流,设置范围: 2.5mA 至 600mA
- 超低静态电流
  - 在升压模式或降压充电模式下为 60nA
  - 在强制旁路模式下为 4nA
- 较高的效率和功率容量
  - 最小 1.4A 的电感器谷值电流限制
  - 两个 60m Ω (LS)/140m Ω (HS) MOSFET
  - 100m Ω 旁路开关电阻
  - 1MHz 开关频率
  - 轻负载下采用自动贪睡模式运行
  - V<sub>IN</sub> = 3V、V<sub>OUT</sub> = 3.6V 且 I<sub>OUT</sub> = 10 µ A 时效率 高达 92.3%
  - V<sub>IN</sub> = 3V、V<sub>OUT</sub> = 3.6V 且 I<sub>OUT</sub> = 100mA 时效 率高达 96.3%
- 由 MODE 和 EN 引脚控制的四个运行模式
- 丰富的保护特性 •
  - 输出短路保护
  - 热关断保护
- 2mm x 3mm 12 引脚 WSON 封装

## 2 应用

- 燃气表、水表
- 便携式医疗设备
- 能量收集



TPS61094 是一款具有旁路开关的同步双向降压/升压 转换器。该器件为智能仪表和超级电容器备用电源应用 提供了一个电源解决方案。

TPS61094 具有宽输入电压范围和高达 5.5V 的输出电 压。当 TPS61094 在降压模式下为超级电容器充电 时,可通过两个外部电阻器对充电电流和充电终止电压 进行编程。当 TPS61094 在升压模式下工作时,可使 用一个外部电阻器对输出电压进行编程。

在自动降压或升压模式下(EN=1,MODE=1),当 应用输入电源后,该器件会将输入电压旁路到输出,同 时还能为备用超级电容器充电。当输入电源已断开或低 于输出目标电压时,TPS61094 将进入升压模式,并通 过备用超级电容器调节输出电压。TPS61094 在此模式 下消耗 60nA 静态电流。

TPS61094 支持真正关断模式(EN=0, MODE=1) 和强制旁路模式(EN=0,MODE=0)。在真正关断 模式下,TPS61094 将负载与输入电源完全断开。在支 持强制旁路模式时,TPS61094 通过旁路开关直接将负 载连接到输入电压并且仅消耗 4nA 电流,从而延长电 池寿命。

哭件信息

器件型号	<b>封装</b> <sup>(1)</sup>	封装尺寸(标称值)
TPS61094	WSON (12)	2.0mm x 3.0mm

(1)如需了解所有可用封装,请参阅数据表末尾的可订购产品附 录。





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## **4 Revision History**

C	hanges from Revision * (January 2021) to Revision A (February 2021)	Page
•	将 100nA 的所有实例更改为 60nA	1
•	将 15nA 的所有实例更改为 4nA	1
•	Changed I <sub>SD</sub> max values	5



## **5** Pin Configuration and Functions



## 图 5-1. 12-Pin WSON DSS Package (Top View)

#### 表 5-1. Pin Functions

PIN		TYPE	DESCRIPTION		
NO.	NAME	ITPE	DESCRIPTION		
1	OSEL	I	Boost output voltage selection pin. Connect a resistor between this pin and ground to select one of sixteen output voltages of boost mode.		
2	MODE	I	Operation mode selection pin. The MODE pin and EN pin work together to set device operation mode. See  7-4.		
3	EN	I	Operation mode selection pin. The MODE pin and EN pin work together to set device operation mode. See  7-4.		
4	VIN	PWR	IC power supply input		
5	SW	PWR	The switching node pin of the converter. It is connected to the drain of the internal low-side power MOSFET and the source of the internal high-side power MOSFET.		
6	SUP	I	Output of buck converter to sense the voltage of the supercap		
7	PGND	PWR	Power ground		
8	AGND	PWR	Signal ground		
9, 10	VOUT	PWR	Output of the device		
11	ICHG	I	Charging current selection pin. Connect a resistor between this pin and ground to select one of sixteen output current of buck mode.		
12	VCHG	I	Charging voltage selection pin. Connect a resistor between this pin and ground to select one of sixteen regulation voltages of buck mode.		

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## **6** Specifications

## 6.1 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
V <sub>IN</sub>	Input voltage	0.7		5.5	V
V <sub>OUT</sub>	Boost output voltage	1.8		5.4	V
V <sub>SUP</sub>	Buck output voltage	2.0		5.4	V
TJ	Junction temperature	- 40		125	°C
L	Effective Inductance	0.7	2.2	2.86	μH
C <sub>IN</sub>	Effective Input Capacitance at the VIN pin	2.2			μF
C <sub>OUT</sub>	Effective Output Capacitance at the OUT pin	20	30		μF
C <sub>SUP</sub>	Effective Output Capacitance at the SUP pin	2.2			μF

## 6.2 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

		MIN	MAX	UNIT
	VIN, VOUT, SW, SUP, MODE, EN, OSEL, VCHG, ICHG	- 0.3	6.5	V
Voltage	SW spike at 10 ns	-0.7	8	V
	SW spike at 1 ns	-0.7	9	V
TJ	Operating Junction Temperature	- 40	125	°C
T <sub>stg</sub>	Storage temperature	- 65	150	°C

(1) Stresses beyond those listed under Absolute Maximum Rating 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 Condition. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

## 6.3 ESD Ratings

			VALUE	UNIT
V	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/ JEDEC JS-001, allpins <sup>(1)</sup>	±2000	V
V(ESD)		Charged device model (CDM), per JEDEC specificationJESD22-C101, all pins <sup>(2)</sup>	±500	v

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process. [Following sentence optional; see the wiki.] Manufacturing with less than 500-V HBM is possible with the necessary precautions.

(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process. [Following sentence optional; see the wiki.] Manufacturing with less than 250-V CDM is possible with the necessary precautions.

## 6.4 Thermal Information

		TPS61094	TPS61094	
	THERMAL METRIC <sup>(1)</sup>	DSS 12-PINS	DSS 12-PINS	UNIT
		Standard	EVM	
R <sub>0 JA</sub>	Junction-to-ambient thermal resistance	58.4	55.3	°C/W
R <sub>0</sub> JC(top)	Junction-to-case (top) thermal resistance	23.0	N/A	°C/W
R <sub>0 JB</sub>	Junction-to-board thermal resistance	55.6	N/A	°C/W
ΨJT	Junction-to-top characterization parameter	1.6	1.5	°C/W
Y <sub>JB</sub>	Junction-to-board characterization parameter	22.9	22.3	°C/W



		TPS61094	TPS61094	
	THERMAL METRIC <sup>(1)</sup>	DSS 12-PINS	DSS 12-PINS	UNIT
		Standard	EVM	
R <sub>0</sub> JC(bot)	Junction-to-case (bottom) thermal resistance	10.0	N/A	°C/W

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

## **6.5 Electrical Characteristics**

 $T_J = -40^{\circ}$ C to 125°C,  $V_{IN} = 2.0$  V,  $V_{OUT} = 3.6$  V and VSUP = 2.0 V, with 2.2 uH inductor. Typical values are at  $T_J = 25^{\circ}$ C (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
POWER SUP	PLY						
V <sub>IN</sub>	Input voltage range		0.7		5.5	V	
V <sub>IN_UVLO</sub>	Under voltage lockout (UVLO) threshold at the VIN pin	V <sub>IN</sub> rising, T <sub>J</sub> up to 85 °C		1.7	1.8	V	
V	Under voltage lockout (UVLO)	V <sub>SUP</sub> rising		0.85		V	
SUP_UVLO	threshold at the SUP pin	V <sub>SUP</sub> falling		0.6	0.7	V	
I <sub>Q_BOOST</sub>	Quiescent current into VIN pin at Boost mode	IC enabled, no load, no switching, V <sub>IN</sub> = 0.7 V to 5.5 V, V <sub>SUP</sub> = V <sub>IN</sub> , V <sub>OUT</sub> = V <sub>OUT_REG</sub> + 0.1 V, T <sub>J</sub> up to 85 °C		1		nA	
	Quiescent current into VOUT pin at Boost mode	IC enabled, no load, no switching, $V_{OUT}$ = 1.8 V to 5.4 V, $T_{J}$ up to 85 $^{\circ}\mathrm{C}$		60	300	nA	
I <sub>Q_BUCK</sub>	Quiescent current into VIN pin at Buck mode	IC enabled, no load, no switching, $V_{IN}$ = 1.8 V to 5.5 V, $V_{SUP}$ = $V_{CHG_{REG}}$ + 0.1 V, T <sub>J</sub> up to 85 °C		60	300	nA	
	Quiescent current into SUP pin at Buck mode	IC enabled, no load, no switching, $V_{SUP}$ = 1.7 V to 5.4 V, $T_J$ up to 85 °C		1		nA	
	Quiescent current into VIN pin at forced bypass mode	$V_{EN}$ = 0 V, $V_{MODE}$ = 0 V, no load, $V_{IN}$ = $V_{SUP}$ = 1.8 V to 5.5 V, T <sub>J</sub> up to 85 °C		2	50	nA	
IQ_BYPASS	Quiescent current into SUP pin at forced bypass mode	$V_{EN}$ = 0 V, $V_{MODE}$ = 0 V, no load, $V_{IN}$ = $V_{SUP}$ = 1.8 V to 5.5 V, T <sub>J</sub> up to 85 °C		2	50	nA	
	Shutdown current into VIN pin	IC disabled, $V_{IN}$ = 1.8 V to 5.5 V, $V_{OUT}$ = 0 V, T <sub>J</sub> up to 85 °C		100	550	nA	
SD	Shutdown current into SUP pin	IC disabled, $V_{SUP}$ = 0.7 V to 5.5 V, V <sub>OUT</sub> = 0 V, T <sub>J</sub> up to 85 °C		100	250	nA	
	Leakage current into SW pin (from SW pin to VOUT)	$V_{IN}$ = 1.8 V, $V_{SW}$ = $V_{SUP}$ = 1.8 V to 5.5 V, $V_{OUT}$ = 0 V, no switching, $T_J$ = 25 °C		1	40	nA	
I <sub>LKG_SW_VOUT</sub>		$V_{IN}$ = 1.8 V, $V_{SW}$ = $V_{SUP}$ = 1.8 V to 5.5 V, $V_{OUT}$ = 0 V, no switching, $T_{J}$ up to 85 °C		1	250	nA	
ILKG_SW_GND	Leakage current into SW pin (from SW pin to GND)	$V_{\text{IN}}$ = 1.8 V, $V_{\text{SW}}$ = $V_{\text{SUP}}$ = 1.8 V to 5.5 V, $V_{\text{OUT}}$ = $V_{\text{SW}}$ , no switching, $T_{\text{J}}$ = 25 $^{\circ}\text{C}$		1	20	nA	
		$\label{eq:VIN} \begin{array}{l} V_{IN} = 1.8 \text{ V},  \text{V}_{\text{SW}} = \text{V}_{\text{SUP}} = 1.8 \text{ V to } 5.5 \\ \text{V},  \text{V}_{\text{OUT}} = \text{V}_{\text{SW}}, \text{ no switching, } \text{T}_{\text{J}} \text{ up to } \\ 85 \ ^{\circ}\text{C} \end{array}$		1	220	nA	
BOOST OUTF	BOOST OUTPUT						
V <sub>OUT</sub>	Output voltage setting range	16 options	2.7		5.4	V	
	Under voltage lockout (UVLO)	V <sub>OUT</sub> rising	1.6	1.7	1.8	V	
VOUT_UVLO	threshold at the VOUT pin	V <sub>OUT</sub> falling	1.5	1.6	1.7	V	



## $T_J = -40^{\circ}$ C to 125°C, $V_{IN} = 2.0$ V, $V_{OUT} = 3.6$ V and VSUP = 2.0 V, with 2.2 uH inductor. Typical values are at $T_J = 25^{\circ}$ C (unless otherwise noted)

$\begin{split} \begin{array}{c} eq:product of the set of the$		PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	V <sub>OUT_PWM_AC</sub>		V <sub>IN</sub> = 1.8 V, PWM mode	-2	0	2	%
Volur_swoore Act vVolur_stanceVolur_stanceVolur_stanceVolur_stance%Usinger Buck outputOutput short circuit current15010030000mABuck OUTPUTCharge voltage range16 options1.75.4VVsup_Acr VCharge termination voltage accuracy in buck mode150507.5100mVVsup_Mr Vsup_MrCharge termination voltage hysteresis options15 options; iC enabled, no load, Vis 5 V, Vsup = 0.8 V to 4 V, T, up to 85°2.5600mAVsup_Acr Vsup_Mr Chice_acr Concerververververververververververververve	V <sub>OUT_PFM_AC</sub> Y	Output voltage accuracy in boost mode	V <sub>IN</sub> = 1.8 V, PFM mode	N N	/ <sub>OUT_PW</sub> ₄_ACY +1		%
IsinGet         Output short circuit current         16 options         190         300         500         mA           BUCK OUTPUT         Vsup         Charge tormination voltage accuracy in back mode         16 options         1.7         5.4         V           Vsup_Acy Vsup_Ary         Charge termination voltage hysteresis in back mode         1.0         .2         0         .2         %           Vsup_Mrs         Charge termination voltage hysteresis in back mode         15 options; IC enabled, no load, V <sub>M</sub> = 5         .2.5         .600         mA           IcHG_SETII of charge termination voltage hysteresis in back mode         15 options; IC enabled, no load, V <sub>M</sub> = 5, V         .2.2         0         .2         .0         .0         .0           IcHG_SETII of nA         ICHG = 2.5 mA or 5 mA; V <sub>M</sub> = 5 V, V <sub>SUP</sub> = 0.8 V to 4 V         .20         .0         .20         .0         .0         .0         .0           IcHG-ACY         ICHG = 2.5 mA or 5 mA; V <sub>M</sub> = 5 V, V <sub>ICHG</sub> = 2.5 mA or 5 mA, V <sub>SUP</sub> = 0.8         .20         .0         .20         .0	V <sub>OUT_SNOOZE</sub>		V <sub>IN</sub> = 1.8 V, snooze mode	N	/ <sub>OUT_PW</sub> /_ACY +1 .5		%
BUCk OUTPOUT         Charge outplage range         16 options         1.7         5.4         V           Vsup_ACY         Charge termination voltage accuracy in buck mode         in constant of the programmable charging current options         Topping termination voltage hysteresis in buck mode         in constant of the programmable charging current options         Topping termination voltage hysteresis in buck mode         in constant of the programmable charging current options         in constant of the programmable charging current options         in constant of the programmable charging current in the programmable charging current at ICHG > Vsup = 0.8 V to 4 V, 1, up to 85 'C         in CHG = 2.5 m Ar of 5 m A; Vsup = 0.8 V to 4 V, 1, up to 85 'C         in CHG = 2.5 m Ar of 5 m A; Vsup = 0.8 V to 4 V, 1, up to 85 'C         in CHG = 2.5 m Ar of 5 m A; Vsup = 0.8 V to 4 V, 1, up to 85 'C         in CHG = 2.5 m Ar of 5 m A; Vsup = 0.8 V to 4 V, 1, up to 85 'C         in CHG = 2.5 m Ar of 5 m A; Vsup = 0.8 V to 4 V, 1, up to 85 'C         in CHG = 2.5 m Ar of 5 m A; Vsup = 0.8 V to 4 V, 1, up to 85 'C         in CHG = 2.5 m Ar of 5 m A; Vsup = 0.8 V to 4 V, 1, up to 85 'C         in CHG = 2.5 m Ar of 5 m A; Vsup = 0.8 V to 4 V, 1, up to 85 'C         in CHG = 2.5 m Ar of 5 m A; Vsup = 0.8 V to 4 V, 1, up to 85 'C         in CHG = 2.5 m Ar of 5 m A; Vsup = 0.8 V to 4 V, 1, up to 85 'C         in CHG = 2.5 m Ar of 5 m A; Vsup = 0.8 V to 4 V, 1, up to 85 'C         in CHG = 2.5 m Ar of 5 m A; Vsup = 0.8 V to 4 V, 1, up to 85 'C         in CHG = 2.5 m Ar of 5 m A; Vsup = 0.8 V to 4 V, 1, up to 85 'C         in CHG = 2.5 m Ar of 5 m A; Vsup = 0.8 V to 4 V, 1, up to 85 'C         in CHG = 2.5 m Ar of 5 m A; Vsup = 0.	I <sub>SHORT</sub>	Output short circuit current		190	300	500	mA
VsupCharge termination voltage accuracy in back mode16 options1.75.4VVsup_ACV in back modeCharge termination voltage hysteresis in buck modeCharge termination voltage hysteresis is V, Vsup = 0.8 V to 4 V, T_J up to 8575100mVVsup_ACSProgrammable charging current options5 options; IC enabled, no load, V <sub>M</sub> = V, Vsup = 0.8 V to 4 V, T_J up to 85 C2.5600mAIcH6_SETProgrammable charging current accuracy5 options; IC enabled, no load, V <sub>M</sub> = V, Vsup = 0.8 V to 4 V, T_J up to 85 C2.202MAIcH6_SETProgrammable charging current at ICH6 To mACHG >= 10 mA; V <sub>M</sub> = 5 V, Vsup = 0.8 V to 4 V-2020%IcH6_SETTerminate charging current at ICH6 To mACenabled, no load, V <sub>M</sub> = 1.8 V to 5.5 V, ICHG >= 10 mA, Vsup > VCH6 - 6010mAIcH6_SETTerminate charging current at ICH6 To mAVour = 5.0 V150mQIcH6_SETNewside FET on resistanceVour = 5.0 V2.5mARos(m)_L1SMgass FET on resistanceVour = 5.0 V100mDVour = 3.6 V2.6 V100mDmDIsw_L1MHigh side switch valley current limit in lock mode10mAIsw_L1MHigh side switch valley current limit in lock mode102.5AIsw_L1MHigh side switch valley current limit in lock mode102.5AIsw_L1MHigh side switch valley current limit in lock mode102.5A<	BUCK OUTPU	т					
VSUP_ACV VSUP_INSCharge termination voltage accuracy in buck modeCharge termination voltage accuracy in buck modeCharge termination voltage hysteresis is buck modeSol75100mVVSUP_INSCharge termination voltage hysteresis in buck mode15 options; IC enabled, no load, V <sub>N</sub> = S', V <sub>SUP</sub> = 0.8 V to 4 V, T <sub>J</sub> up to 852.5600mAVcHG_ACVPOGrammable charging current 	V <sub>SUP</sub>	Charge voltage range	16 options	1.7		5.4	V
VSUP_HYSCharge termination voltage hysteresis15075100mVUcHG_SETProgrammable charging current options15 options; IC enabled, no load, $V_{N} = 5$ 2.5600mAICHG_SETProgrammable charging current accuracyICHG = 2.5 mA or 5 mA; $V_{N} = 5$ V, $V_{SUP} = 0.8$ V to 4 V, T_u up to 852.50209ICHG_ACVICHG setting charging current accuracyICHG = 10 mA; $V_{N} = 5$ V, $V_{SUP} = 0.8$ V to 4 V-200209%ICHG_SETTerminate charging current at ICHG 10 mAICHG = 10 mA, $V_{SUP} > VCHG - 50$ 10mAmAICHG_TERMTerminate charging current at ICHG 10 mAICHG = 2.5 mA or 5 mA, $V_{SUP} > VCHG - 50$ mAmAPOWER SWITCHICensbled, no load, $V_N = 1.8$ V to 5.5 V, ICHG = 2.5 mA or 5 mA, $V_{SUP} > VCHG - 50$ mAmAROS(on), ISHigh-side FET on resistanceVour = 5.0 V150mDROS(on), ISVION-side FET on resistanceVour = 5.0 V150mDVour = 3.6 VVOUT = 3.6 V7000ROS(on), ISVHigh side switch valley current limit in boost modeICHG = 2.5 mA or 5 mA, $V_{SUP} > 0.8$ 2.5AIsonION-side FET on resistanceVOUT = 5.0 V150mDVour = 3.6 VION1.722.6AIsonInductor peak current limit in boost modeICHG = 2.5 mA or 5 mA, $V_{SUP} > 0.8$ 2.50mAIsonInductor peak current limit in low chamedICHG = 2.5 mA or 5 mA, $V_{SUP}$	V <sub>SUP_ACY</sub>	Charge termination voltage accuracy in buck mode		-2	0	2	%
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	V <sub>SUP_HYS</sub>	Charge termination voltage hysteresis in buck mode		50	75	100	mV
$\begin{array}{c c} \label{eq:charge} \begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	I <sub>CHG_SET</sub>	Programmable charging current options	15 options; IC enabled, no load, V <sub>IN</sub> = 5 V, V <sub>SUP</sub> = 0.8 V to 4 V, T <sub>J</sub> up to 85 $^{\circ}\text{C}$	2.5		600	mA
$ \begin{array}{c chG_ACV} & accuracy & [CHG > = 10 m, V_{N} + 5 V, V_{SUP} = 0.8 & -20 & 0 & 20 & \% \\ \hline Vto 4 V & Vto 4 & $	lava vav	ICHG setting charging current	ICHG = 2.5 mA or 5 mA; $V_{IN}$ = 5 V, $V_{SUP}$ = 0.8 V to 4 V	-2	0	2	mA
$ \frac{1}{1 \text{CHG\_TERM}} \begin{array}{c} \frac{1}{10 \text{ mA}} \text{ arcminate charging current at ICHG} > 10 \text{ Cenabled, no load, V_N = 1.8 V to 5.5 } \\ V_1 \text{ CHG} > 10 \text{ mA}, V_{SUP} > V \text{CHG} - 50 \\ W_1, V_1, V_U \text{ to 85 °C} \end{array} \end{array} \begin{array}{c} 10 \text{ mA} \end{array} \right) \\ \frac{1}{10 \text{ mA}} \text{ arcminate charging current at ICHG} < V_1 \text{ CHG} = 2.5 \text{ mA or 5 mA, V_{SUP} > } \\ \frac{1}{10 \text{ mA}} \text{ arcminate charging current at ICHG} < V_1 \text{ CHG} = 2.5 \text{ mA or 5 mA, V_{SUP} > } \\ \frac{1}{10 \text{ mA}} \text{ mA} \end{array} \\ \frac{1}{10 \text{ mA}} \text{ arcminate charging current at ICHG} < V_1 \text{ CHG} = 2.5 \text{ mA or 5 mA, V_{SUP} > } \\ \frac{1}{10 \text{ mA}} \text{ arcminate charging current at ICHG} < V_2 \text{ cCHG} - 50 \text{ mV}, J_1 \text{ up to 85 °C} \end{array} \\ \frac{1}{10 \text{ mA}} \text{ arcminate charging current at ICHG} < V_2 \text{ cCHG} - 50 \text{ mA}, V_{SUP} > \\ \frac{1}{10 \text{ mA}} \text{ mB} \text{ mB}$	ICHG_ACY	accuracy	ICHG >= 10 mA; $V_{IN}$ = 5 V, $V_{SUP}$ = 0.8 V to 4 V	-20	0	20	%
$\begin{tabular}{ c \ HG_TERM} \hline \ Herminate charging current at ICHG < \ C enabled, no load, V_N = 1.8 V to 5.5 \ V, ICHG = 2.5 mA or 5 mA, V_{SUP} > \ 2.5 \ mA \ MA \ VCHG = 2.5 mA or 5 mA, V_{SUP} > \ 2.5 \ MA \ MA \ VCHG = 2.5 mA or 5 mA, V_{SUP} > \ 2.5 \ MA \ MA \ VCHG = 2.5 mA or 5 mA, V_{SUP} > \ 2.5 \ MA \ MA \ VCHG = 2.5 mA or 5 mA, V_{SUP} > \ 2.5 \ MA \ MA \ VCHG = 2.5 mA or 5 mA, V_{SUP} > \ 2.5 \ MA \ MA \ MA \ VCHG = 2.5 mA or 5 mA, V_{SUP} > \ 2.5 \ MA \ M$		Terminate charging current at ICHG >= 10 mA	IC enabled, no load, $V_{IN}$ = 1.8 V to 5.5 V, ICHG >= 10 mA, $V_{SUP}$ > VCHG - 50 mV, T <sub>J</sub> up to 85 °C		10		mA
$\begin{array}{ c c c c c c } \hline POWER SWITCH & & & & & & & & & & & & & & & & & & &$	ICHG_TERM	Terminate charging current at ICHG < 10 mA	IC enabled, no load, $V_{IN}$ = 1.8 V to 5.5 V, ICHG = 2.5 mA or 5 mA, $V_{SUP}$ > VCHG - 50 mV, T <sub>J</sub> up to 85 °C		2.5		mA
$\begin{array}{cccc} & & & & & & & & & & & & & & & & & $	POWER SWIT	ГСН	· · · · ·			I	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Read and	High-side FET on resistance	V <sub>OUT</sub> = 5.0 V		150		mΩ
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	R <sub>DS(on)_HS</sub>	High-side FET on resistance	V <sub>OUT</sub> = 3.6 V		180		mΩ
$ \frac{1}{10S(on)\_LS} = \frac{1}{10} \frac{1}{10}$	P	Low-side FET on resistance	V <sub>OUT</sub> = 5.0 V		60		mΩ
$ \begin{array}{c c c c c c } R_{DS(on)\_BYP} & Pagas FET on resistance & V_{OUT} = 5.0 \ V & 120 & m \ \Omega $	DS(on)_LS		V <sub>OUT</sub> = 3.6 V		70		mΩ
$\frac{ V_{OUT} = 3.6 \text{ V} }{ V_{OUT} = 3.6 \text{ V} } = 150 \text{ m} \Omega$ $\frac{ V_{OUT} = 3.6 \text{ V} }{ V_{OUT} = 3.6 \text{ V} } = 150 \text{ m} \Omega$ $\frac{ V_{OUT} = 3.6 \text{ V} }{ V_{OUT} = 3.6 \text{ V} } = 150 \text{ m} \Omega$ $\frac{ V_{OUT} = 3.6 \text{ V} }{ V_{OUT} = 3.6 \text{ V} } = 150 \text{ m} \Omega$ $\frac{ V_{OUT} = 3.6 \text{ V} }{ V_{OUT} = 3.6 \text{ V} } = 150 \text{ m} \Omega$ $\frac{ V_{OUT} = 3.6 \text{ V} }{ V_{OUT} = 1.6 \text{ V} } = 150 \text{ m} \Omega$ $\frac{ V_{OUT} = 1.6 \text{ V} }{ V_{OUT} = 5.0 \text{ V} } = 150 \text{ V}  = 150 \text{ m} \Omega$ $\frac{ V_{OUT} = 1.6 \text{ V} }{ V_{OUT} = 5.0 \text{ V} } = 100 \text{ m} \Omega$ $\frac{ V_{OUT} = 1.6 \text{ V} }{ V_{OUT} = 5.0 \text{ V} } = 100 \text{ m} \Omega$ $\frac{ V_{OUT} = 1.6 \text{ V} }{ V_{OUT} = 5.0 \text{ V} } = 100 \text{ m} \Omega$	P	Bypass FET on resistance	V <sub>OUT</sub> = 5.0 V	·	120		mΩ
$ \begin{array}{                                    $	DS(on)_BYP		V <sub>OUT</sub> = 3.6 V		150		mΩ
$\begin{split} & \begin{array}{c} eq:linear_li$	CURRENT LI	МІТ					
$\frac{1}{10 \text{ mode}} = \frac{1}{10 \text{ mode}} + \frac{1}{10 \text{ mode}} + \frac{1}{10 \text{ mode}} + \frac{1}{10 \text{ mod}} + \frac{1}{10$		High side switch valley current limit in boost mode		1.7	2	2.6	А
$\begin{tabular}{ c c c c c } \hline ICHG = 2.5 \mbox{ mA, V_{SUP} > 0.8 V} & 250 & mA \\ \hline I0 \mbox{ mA <=ICHG <= 250 \mbox{ mA, V_{SUP} >} & 500 & mA \\ \hline I0 \mbox{ mA <=ICHG <= 250 \mbox{ mA, V_{SUP} >} & 500 & mA \\ \hline I0 \mbox{ mA <=ICHG <= 250 \mbox{ mA, V_{SUP} >} & 500 & mA \\ \hline I0 \mbox{ mA <=ICHG <= 250 \mbox{ mA, V_{SUP} >} & 500 & mA \\ \hline I0 \mbox{ mA <=ICHG <= 250 \mbox{ mA, V_{SUP} >} & 500 & mA \\ \hline I0 \mbox{ mA <=ICHG <= 250 \mbox{ mA, V_{SUP} >} & 500 & mA \\ \hline I0 \mbox{ mA <=ICHG <= 250 \mbox{ mA, V_{SUP} >} & 500 & mA \\ \hline I0 \mbox{ mA <=ICHG <= 250 \mbox{ mA, V_{SUP} >} & 500 & mA \\ \hline I0 \mbox{ mA <=ICHG <= 250 \mbox{ mA, V_{SUP} >} & 500 & mA \\ \hline I0 \mbox{ mA <=ICHG <= 250 \mbox{ mA, V_{SUP} >} & 500 & mA \\ \hline I0 \mbox{ mA <=ICHG <= 250 \mbox{ mA <} & 500 & mA \\ \hline I0 \mbox{ mA <=ICHG <= 250 \mbox{ mA <} & 500 & mA \\ \hline I0 \mbox{ mA <=ICHG <= 250 \mbox{ mA <} & 500 & mA \\ \hline I0 \mbox{ mA <=ICHG <= 250 \mbox{ mA <} & 500 & mA \\ \hline I0 \mbox{ mA <= 100 \mbox{ mA <} & 500 & mA \\ \hline I0 \mbox{ mA <= 100 \mbox{ mA <} & 500 & mA \\ \hline I0 \mbox{ mA <= 100 \mbox{ mA <} & 500 & mA \\ \hline I0 \mbox{ mA <} & 500 & mA \\ \hline I0 \mbox{ mA <= 100 \mbox{ mA <} & 500 & mA \\ \hline I0 \mbox{ mA <= 100 \mbox{ mA <} & 500 & mA \\ \hline I0 \mbox{ mA <= 100 \mbox{ mA <} & 500 & mA \\ \hline I0 \mbox{ mA <} & 500 & mA \\ \hline I0 \mbox{ mA <} & 500 & 10 & mA \\ \hline I0 \mbox{ mA <} & 500 & 10 & mA \\ \hline I0 \mbox{ mA <} & 500 & 10 & 0.5 & mHz \\ \hline I0 \mbox{ mA <} & 500 & 10 & 0.5 & mHz \\ \hline I0 \mbox{ mA <} & 500 & 10 & 0.5 & mHz \\ \hline I0 \mbox{ mA <} & 500 & 10 & 0.5 & mA \\ \hline I0 \mbox{ mA <} & 500 & 10 & 0.5 & mA \\ \hline I0 \mbox{ mA <} & 500 & 10 & 0.5 & mA \\ \hline I0 \mbox{ mA <} & 500 & 10 & 0.5 & mA \\ \hline I0 \mbox{ mA <} & 500 & 10 & 0.5 & mA \\ \hline I0 \mbox{ mA <} & 500 & 10 & 0.5 & mA \\ \hline I0 \mbox{ mA <} & 500 & 10 & 0.5 & mA \\ \hline I0 \mbox{ mA <} & 500 & 10 & 0.5 & mA \\ \hline I0 \mbox{ mA <} & 500 & 10 & 0.5 & mA \\ \hline I0 \mbox{ mA <} & 500 & 10 & 0.5 & mA \\ \hline I0 \mbox{ mA <} & 500 & 10 & 0.5 & mA \\ \hline I0 \mbox{ mA <} & 500 & 10 & 0.5 & mA \\ \hline I0 \mbox{ mA <} & 10 & 10 & 10 & 10 \\ \hline I0 \$	'SW_LIM	High side switch peak current limit in buck mode			2.5		А
$\begin{tabular}{ c c c c } \hline Inductor peak current at PFM & $10 mA <=ICHG <= 250 mA, V_{SUP} > $500$ mA \\ \hline I_{SS} & $Pre-charge current at soft start & $V_{IN} = 1.8 V to 5.5 V, V_{OUT} < 0.4 V$ $300$ mA \\ \hline V_{IN} = 3.6 V, V_{OUT} = 1.8 V$ $500$ mA \\ \hline MA \\ \hline SWITCHING CHARACTERISTIC & $VIN = V_{SUP} = 3.6V, V_{OUT} = 5.0 V, PWM$ $10$ MHz \\ \hline I_{SW} = $VIN = V_{SUP} = 1 V, V_{OUT} = 5.0 V, PWM$ $0.5$ MHz \\ \hline I_{OFF} = $MIN_BOO$ Minimum off time at boost mode & $V_{OUT} = 5.0 V$ $V_{OUT} = 5.0 V$ $V_{OUT} = 0.5$ MHz \\ \hline I_{OUT} = $VIN = 5.0 V$ $V_{OUT} = 0.5$ MHz \\ \hline I_{OUT} = $V_{OUT} = $V_{OUT$			ICHG = 2.5 mA or 5 mA, $V_{SUP}$ > 0.8 V		250		mA
$ \frac{V_{IN} = 1.8 \ V \ 0.55 \ V, \ V_{OUT} < 0.4 \ V}{V_{IN} = 3.6 \ V, \ V_{OUT} < 0.4 \ V}  300  \text{mA} }{500} $ $ \frac{V_{IN} = 3.6 \ V, \ V_{OUT} = 1.8 \ V}{V_{IN} = 3.6 \ V, \ V_{OUT} = 1.8 \ V}  550  \text{mA} }{500}  \text{mA} $ $ \frac{SWTCHING \ CHARACTERISTIC}{V_{IN} = V_{SUP} = 3.6 \ V, \ V_{OUT} = 5.0 \ V, \ PWM}  1  MHz $ $ \frac{V_{IN} = V_{SUP} = 1 \ V, \ V_{OUT} = 5.0 \ V, \ PWM}{Mode}  0.5  MHz $ $ \frac{V_{IN} = V_{SUP} = 1 \ V, \ V_{OUT} = 5.0 \ V, \ PWM}{M}  0.5  MHz $	I <sub>PEAK</sub>	Inductor peak current at PFM	10 mA <=ICHG <= 250 mA, V <sub>SUP</sub> > 0.8 V		500		mA
SWITCHING CHARACTERISTIC $V_{IN} = V_{SUP} = 3.6V, V_{OUT} = 5.0 V, PWM$ 1MHz $f_{SW\_BOOST}$ Switching frequency at boost mode $V_{IN} = V_{SUP} = 3.6V, V_{OUT} = 5.0 V, PWM$ 1MHz $V_{IN} = V_{SUP} = 1 V, V_{OUT} = 5.0 V, PWM$ 0.5MHz $t_{OFF\_MIN\_BOO}$ Minimum off time at boost mode $V_{OUT} = 5.0 V$ 80140ns	I <sub>SS</sub>	Pre-charge current at soft start	$V_{IN} = 1.8 V \text{ to } 5.5 V, V_{OUT} < 0.4 V$	500	300		mA
$f_{SW_BOOST}$ Switching frequency at boost mode $V_{IN} = V_{SUP} = 3.6V, V_{OUT} = 5.0 V, PWM$ 1MHz $f_{SW_BOOST}$ $V_{IN} = V_{SUP} = 1 V, V_{OUT} = 5.0 V, PWM$ 0.5MHz $t_{OFF_MIN_BOO}$ Minimum off time at boost mode $V_{OUT} = 5.0 V$ 80140ns	SWITCHING						110 (
fsw_BOOSTSwitching frequency at boost mode $V_{IN} = V_{SUP} = 1 V, V_{OUT} = 5.0 V, PWM$ 0.5MHztoFF_MIN_BOO STMinimum off time at boost mode $V_{OUT} = 5.0 V$ 80140ns		-	V <sub>IN</sub> = V <sub>SUP</sub> = 3.6V, V <sub>OUT</sub> = 5.0 V, PWM mode		1		MHz
$\begin{array}{c c}t_{OFF\_MIN\_BOO}\\sT\end{array} & Minimum off time at boost mode \\ \end{array} & V_{OUT} = 5.0 V \\ \end{array} & \begin{array}{c c}t_{OUT} = 5.0 V \\ &$	f <sub>SW_BOOST</sub>	Switching frequency at boost mode	V <sub>IN</sub> = V <sub>SUP</sub> = 1 V, V <sub>OUT</sub> = 5.0 V, PWM mode		0.5		MHz
	t <sub>OFF_MIN_BOO</sub>	Minimum off time at boost mode	V <sub>OUT</sub> = 5.0 V		80	140	ns



# $T_J = -40^{\circ}$ C to 125°C, $V_{IN} = 2.0$ V, $V_{OUT} = 3.6$ V and VSUP = 2.0 V, with 2.2 uH inductor. Typical values are at $T_J = 25^{\circ}$ C (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
f <sub>sw_виск</sub>	Switching frequency at buck mode	$V_{SUP}$ = 3.6V, $V_{IN}$ = $V_{OUT}$ = 5.0 V, PWM mode		1		MHz
VOLTAGE MO	DNITORING					
V <sub>BYPASS</sub>	Enter bypass mode when V <sub>IN</sub> >= V <sub>OUT_TARGET</sub> + V <sub>BY_PASS</sub>		50	100	150	mV
V <sub>BYPASS_HYS</sub>	Hysteresis of V <sub>BYPASS</sub>			50		mV
VPASS THROU	Enter pass-through mode when $V_{SUP} >= V_{OUT} + V_{PASS_THROUGH}$			-30		mV
GH	Exit pass-through mode when V <sub>SUP</sub> < V <sub>OUT_TARGET</sub> + V <sub>PASS_THROUGH</sub>			-100		mV
LOGIC INTER	FACE		·		·	
M	EN logic high threshold	V <sub>OUT</sub> > 1.8 V			0.58	V
VEN_H	EN logic high threshold	V <sub>OUT</sub> < 1.8 V			1.0	V
		V <sub>OUT</sub> > 1.8 V	0.2			V
VEN_L		V <sub>OUT</sub> < 1.8 V	0.45			V
I <sub>EN_LKG</sub>	Leakage current into EN pin	$V_{EN}$ = 1.2 V, T <sub>J</sub> up to 85°C		1		nA
R <sub>EN</sub>	EN pin pull down resistor	$V_{EN} = 0 V, T_{J} up to 85^{\circ}C$		800		kΩ
N/	MODE logic high threshold	V <sub>OUT</sub> > 1.8 V			0.58	V
VMODE_H	NODE logic high threshold	V <sub>OUT</sub> < 1.8 V			1.0	V
V	MODE logic low threshold	V <sub>OUT</sub> > 1.8 V	0.2			V
VMODE_L		V <sub>OUT</sub> < 1.8 V	0.45			V
I <sub>MODE_LKG</sub>	Leakage current into MODE pin	V <sub>MODE</sub> = 1.2 V, T <sub>J</sub> up to 85°C		1		nA
R <sub>MODE</sub>	MODE pin pull down resistor	V <sub>MODE</sub> = 0 V, T <sub>J</sub> up to 85°C		800		kΩ
PROTECTION	l l					
T <sub>SD</sub>	Thermal shutdown	Junction temperature rising		150		°C
T <sub>SD_HYS</sub>	Thermal shutdown hysteresis	Junction temperature falling below $T_{SD}$		20		°C



## **6.6 Typical Characteristics**









## 7 Detailed Description

### 7.1 Overview

The TPS61094 is a 60-nA quiescent current synchronous bi-directional buck/boost converter with a bypass switch between the input and output. The TPS61094 can operate with a wide input voltage from 0.7 V to 5.5 V and output voltage from 2.7 V to 5.4 V. The device provides a ultra-low power solution optimized for applications that require ultra-low quiescent current, use a supercap or battery as a backup power supply, or both.

The TPS61094 has four operation modes by the EN pin and MODE pin selection:

- Auto buck or boost mode (EN = 1; MODE = 1)
- Forced buck mode (EN = 1; MODE = 0)
- Forced bypass mode (EN = 0; MODE = 0)
- True shutdown mode (EN = 0; MODE = 1)

In auto buck or boost mode, the TPS61094 can automatically transform between buck charging mode and boost mode based on input voltage. When the input voltage is lower than the setting boost regulation voltage, the TPS61094 generates a regulation voltage from the low input voltage of a supercap or a battery. When the input voltage is 0.1 V higher than the setting boost regulation voltage, the output voltage of the TPS61094 equals the input voltage. Meanwhile, the TPS61094 charges the backup supercap by buck mode.

When the TPS61094 works in forced buck mode, the TPS61094 connects the output of the device directly to the input while the buck converter outputs a setting constant current charging a backup supercap. When the supercap is charged to a pre-set termination voltage, the buck converter stops charging. When the supercap voltage drops 75 mV below the setting voltage, the buck converter starts charging the supercap again.

In forced bypass mode, the TPS61094 turns on bypass MOSFET, thus the output voltage equals to input voltage. The TPS61094 has about 4-nA Iq in this mode.

In true shutdown mode, the TPS61094 can disconnect the load from the input and SUP pin.

#### 7.1.1 The Configuration of VCHG Pin, ICHG Pin, and OSEL Pin

The TPS61094 supports sixteen internal setting options for charging termination voltage (VCHG), charging current (ICHG), and output voltage (OSEL) by connecting a resistor between the VCHG, ICHG, or OSEL pin and ground.

During start-up, when output voltage reaches close to input voltage, the device starts to detect the configuration conditions of the VCHG, ICHG, and OSEL pins (in that order). The TPS61094 checks the VCHG, ICHG, and OSEL pins by lowering setting options to higher setting options until you find the setting configuration by a 10  $\mu$ s clock. After detecting the configuration, the TPS61094 latches the charging current in buck mode, the charging termination voltage in buck mode, and the setting output regulation voltage in boost mode. To save detection time, TI suggests shorting the VCHG and ICHG pins to ground when buck mode is not used.

The TPS61094 does not detect the VCHG, ICHG, and OSEL pins during operation, so changing the resistor during operation does not change the VCHG, ICHG, and OSEL settings. Toggling the EN pin during operation is one way to refresh the VCHG, ICHG, and OSEL settings.

For proper operation, TI suggests that the setting resistance accuracy must be 1% and the parasitic capacity of the VCHG, ICHG, and OSEL pins should be less than 10 pF.

#### 7.1.1.1 OSEL: Output Voltage Selection

In boost mode operation, the device supports sixteen internally-set output voltages by connecting a resistor between the OSEL pin and ground. 7-1 lists the output voltage options with respect to resistance.

RESISTANCE (KΩ)	V <sub>OUT_REG</sub> (V)						
0	2.7	9.53	3.45	28.7	3.8	150	4.8
3.09	3.0	13.0	3.5	49.9	4.0	205	5.0
4.75	3.3	17.4	3.6	75.0	4.2	274	5.2
6.65	3.4	22.1	3.7	107	4.5	open	5.4

#### 7.1.1.2 VCHG: Charging Termination Voltage Selection

In buck mode operation, the device supports sixteen internally-set charging termination voltages by connecting a resistor between the VCHG pin and ground. 7-2 lists the termination voltage options with respect to resistance.

		•	0 0	U			
RESISTANCE (KΩ)	V <sub>CHG_REG</sub> (V)						
0	1.7	9.53	2.6	28.7	3.7	150	4.9
3.09	2.0	13.0	2.7	49.9	4.1	205	5.0
4.75	2.2	17.4	3.6	75.0	4.15	274	5.1
6.65	2.5	22.1	3.65	107	4.2	open	5.4

#### 表 7-2. Charging Termination Voltage Options

#### 7.1.1.3 ICHG: Charging Output Current Selection

In buck mode operation, the device supports sixteen internally-set charging currents by connecting a resistor between the ICHG pin and ground.  $\ddagger$  7-3 lists the charging current options with respect to resistance.

RESISTANCE (KΩ)	I <sub>CHG</sub> (MA)										
0	0 (disabled)	9.53	25	28.7	150	150	350				
3.09	2.5	13.0	50	49.9	200	205	400				
4.75	5	17.4	75	75.0	250	274	500				
6.65	10	22.1	100	107	300	open	600				

#### 表 7-3. Charging Current Options



## 7.2 Functional Block Diagram



#### 7.3 Feature Description

#### 7.3.1 Undervoltage Lockout

The TPS61094 has a built-in undervoltage lockout (UVLO) circuit to ensure the device works properly. When the voltage at the VIN pin is above the undervoltage lockout (UVLO) rising threshold (typically 1.7 V), the TPS61094 can be enabled. After the TPS61094 starts up and the output voltage is above 1.7 V typically, the TPS61094 can work with SUP pin voltage as low as 0.6 V and input voltage down to 0 V. When the voltage at the VIN pin is down to 0 V and the voltage at the SUP pin are below the undervoltage lockout falling threshold (typically 0.6 V), the TPS61094 goes into shutdown mode to avoid malfunction. In this condition and in auto boost mode, the TPS61094 disconnects the bypass switch and high-side switch to prevent the reverse current from the VOUT pin to the VIN pin and SW pin when the V<sub>OUT</sub> voltage is above 1.6 V.

When the voltages at the VIN pin and SUP pin are below 1.7 V (typical) and the voltage at  $V_{OUT}$  is below 1.6 V (typical), the TPS61094 goes into shutdown mode.

#### 7.3.2 Enable and Soft Start

When the voltage at the VIN pin is above the undervoltage lockout (UVLO) rising threshold (typically 1.7 V) and the EN pin is pulled to logic high voltage, the TPS61094 is enabled and starts ramping up the output voltage.

At auto boost mode, the TPS61094 starts charging the output capacitor with a 300-mA constant current through the bypass switch when the output voltage is below 0.5 V. When the output voltages is charged above 0.5 V, the output current is changed to have output current capability to drive the  $3.6-\Omega$  resistance load until the output voltage reaches close to input voltage. After the output voltage reaches close to the input voltage, the TPS61094 starts to detect the configuration conditions of the VCHG, ICHG, and OSEL pins, then latches the configuration. According to the configurations and setup, the TPS61094 enters boost mode or buck mode. When input voltage is less than the output voltage setting, the TPS61094 enters boost mode soft start. The TPS61094 starts

switching and output ramps up further. The soft-start time in boost mode varies with the different output capacitance, load condition, and configuration conditions. When input voltage is higher than output voltage setting adding 100 mV, the TPS61094 enters buck mode soft start. The charging current can increase slowly.

The start-up of the forced buck mode is similar to buck mode in auto boost mode except the TPS61094 enters buck mode after the output voltage is close to the input voltage and does not need to have the input voltage higher than the output voltage setting adding 100 mV.

At forced bypass mode, there is no soft start. The bypass switch is always on and the output is connected to the input directly.

When the voltage at the EN pin is below 0.2 V and MODE is higher than 0.58 V at output voltage higher than 1.8 V, the internal enable comparator turns the device into true shutdown mode. In true shutdown mode, the device is entirely turned off. The output is disconnected from the VIN and SUP pin power supply.

#### 7.3.3 Active Pulldown for the EN and MODE Pins

The EN and MODE pins have an active 800-k $\Omega$  pulldown resistor to ground. When the EN and MODE pins are logic high, there is high impedance to make sure there is no high leakage current in these pins. When the EN and MODE pins are logic low or floating, there is a 800-k $\Omega$  pulldown resistor to make sure the EN and MODE pins cannot be coupled to the logic high by the noise. TI suggests the pulling high capability be stronger than the 800-k $\Omega$  pulldown resistor when enabling the TPS61094.

#### 7.3.4 Current Limit Operation

The TPS61094 has the peak current limit in buck mode and valley current limit in boost mode. Current limit detection occurs when the high-side MOSFET turns on.

In buck mode, the TPS61094 has average output current control, so the current limit in buck mode is hard to reach.

In boost mode, when the load current is increased such that the inductor current is above the current limit within the whole switching cycle time, the off-time is increased to allow the inductor current to decrease to this threshold before the next on-time begins (called the frequency foldback mechanism). When the current limit is reached, the output voltage decreases during further load increase.

The maximum continuous output current ( $I_{OUT(LC)}$ ), before entering current limit (CL) operation, can be defined by 5程式 1.

$$I_{OUT(CL)} = (1 - D) \times \left(I_{LIM} + \frac{1}{2}\Delta I_{L(P-P)}\right)$$

where

- D is the duty cycle
- $\Delta I_{L(P-P)}$  is the inductor ripple current

The duty cycle can be estimated by 方程式 2.

$$D = 1 - \frac{V_{IN} \times \eta}{V_{OUT}}$$

where

- V<sub>OUT</sub> is the output voltage of the boost converter
- V<sub>IN</sub> is the input voltage of the boost converter
- $\eta\,$  is the efficiency of the converter; use 90% for most applications

The peak-to-peak inductor ripple current is calculated by 5程式 3.

(2)

(1)



(3)

$$\Delta I_{L(P-P)} = \frac{V_{IN} \times D}{L \times f_{SW}}$$

where

- · L is the inductance value of the inductor
- f<sub>SW</sub> is the switching frequency
- D is the duty cycle
- V<sub>IN</sub> is the input voltage of the boost converter

#### 7.3.5 Output Short-to-Ground Protection

The TPS61094 starts to limit the output current when the output voltage is below the minimum value ( $V_{IN}$ ,  $V_{OUT\_REG}$ ). The lower the output voltage reaches, the smaller the output current is. When the output voltage is below 0.5 V, the output current is limited to approximately 200 mA. Once the short circuit is released, the TPS61094 goes through the soft start-up again to output the regulated voltage.

#### 7.3.6 Thermal Shutdown

The TPS61094 goes into thermal shutdown once the junction temperature exceeds 150°C. When the junction temperature drops below the thermal shutdown temperature threshold less the hysteresis, typically 130°C, the device starts operating again.

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#### 7.4 Device Functional Modes

#### 7.4.1 Operation Mode Setting

The TPS61094 has four operation modes by the EN pin and MODE pin selection.  $\ddagger$  7-4 lists the operation modes of the device with respect to the status of the EN and MODE pin.

MODES	EN	MODE	BYPASS	BOOST	BUCK	FUNCTION
Forced bypass	0	0	$\checkmark$	×	×	Turn on bypass MOSFET, turn off boost/buck, $V_{OUT} = V_{IN}$
True shutdown	0	1	×	×	×	Bypass disconnect, turn off boost/buck, V <sub>OUT</sub> = 0 V
Forced buck	1	0	~	×	~	Buck enabled, turn on bypass MOSFET, $V_{\text{OUT}}$ = $V_{\text{IN}}$ while charging the supercap or backup battery
Auto buck or boost	1	1	~	×	~	Buck enable, when $V_{\text{IN}}$ > target $V_{\text{OUT}}$ +100 mV and $V_{\text{OUT}}$ > target $V_{\text{OUT}},$ supercap is charged by buck
	1	1	~	~	×	Boost and bypass enabled; when V <sub>OUT</sub> + 100 mV > V <sub>IN</sub> > target V <sub>OUT</sub> and V <sub>OUT</sub> = target V <sub>OUT</sub> , V <sub>OUT</sub> is from both V <sub>IN</sub> through bypass and supercap by boost.
	1	1	×	$\checkmark$	×	Boost enable; when $V_{IN}$ < target $V_{OUT}$ , $V_{OUT}$ is powered from supercap by boost.

#### 7.4.2 Forced Bypass Mode Operation

The TPS61094 works in forced bypass mode when the voltage at the MODE and EN pins are logic low level (EN = low, MODE = low). In forced bypass mode, the bypass switch is turned on, thus the voltage at the VOUT pin equals the input voltage. The TPS61094 has about 4-nA lq in forced bypass mode. The TPS61094 does not detect input voltage and output voltage, so it cannot to protect the reverse current from output to input in forced bypass mode.

#### 7.4.3 True Shutdown Mode Operation

The TPS61094 works in true shutdown mode when the voltage at the MODE pin is logic high level and the voltage at the EN pin is logic low level (EN = low, MODE = high). In true shutdown mode, the TPS61094 is entirely turned off, the bypass MOSFET and high-side MOSFET are true shutdown, and the output is disconnected from the VIN pin and SUP pin power supply.

#### 7.4.4 Forced Buck Mode Operation

When the TPS61094 is enabled working in buck mode (EN = high, MODE = low), the TPS61094 works in constant output current control scheme with the bypass switch always turned on. The TPS61094 supports sixteen internally-set options for charging termination voltage (VCHG) and charging current (ICHG) by connecting a resistor between the VCHG pin, ICHG pin, and ground.

When  $V_{OUT}$  voltage is above the 1.7-V UVLO rising threshold, the buck function starts working to charge the supercap at the SUP pin. The typical charging operation works as shown in [8] 7-1. VCHG is 150 mV less than the input voltage. At t<sub>0</sub>, the TPS61094 starts to charge the SUP pin by constant current. From t<sub>0</sub> to t<sub>1</sub>, when the SUP pin voltage is lower than VSUP\_UVLO, typically 0.85 V, the TPS61094 charges the SUP pin by the constant current (ICHG\_PRE), which is smaller than or equal to 250 mA. From t<sub>1</sub> to t<sub>2</sub>, when the SUP pin voltage reaches VSUP\_UVLO, the TPS61094 charges the SUP pin by constant current (ICHG), which is set by the ICHG pin. If VCHG > VIN-500 mV, the TPS61094 will change the charging current to ICHG\_PRE at t<sub>2</sub> when SUP pin voltage reaches to VIN-500 mV. At t<sub>3</sub>, the SUP pin voltage reaches VCHG (charging termination voltage) and the TPS61094 reduces the charging current to ICHG\_TERM, the device stops switching until the SUP voltage reaches VCHG without the supercap ESR voltage drop. This can be avoided if the supercap is not fully charged when the SUP pin reaches VCHG in high charging current because of supercap ESR voltage drop. The TPS61094 starts switching when the SUP voltage drops 75 mV below the target value (VCHG).





- 1. ICHG\_PRE is 250 mA when ICHG is equal or larger than 250 mA; ICHG\_PRE is ICHG when ICHG is lower than 250 mA.
- ICHG\_TERM is 10 mA when ICHG is equal or larger than 10 mA; ICHG\_TERM is 2.5 mA when ICHG is lower than 10 mA.

When VCHG  $\geq$  VIN-150 mV, the charging operation is as shown in [8] 7-2. Before  $t_3$ , the charging operation is the same as the description in [8] 7-1. At  $t_3$ , when SUP voltage reaches to  $V_{IN}$ -150 mV, the TPS61094 stops buck charging. Connect a resistor about 80  $\Omega$  between the VIN and SUP pins to charge the supercap. If VCHG is between VIN and VIN-150 mV when  $V_{SUP}$  reaches VCHG, the TPS61094 is terminated. If VCHG is higher than VIN, the 80- $\Omega$  resistor keeps connecting the VIN and SUP pin until it exits buck mode or input voltage increases about 1 V above the SUP pin voltage.



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#### 7.4.5 Auto Buck or Boost Mode Operation

The TPS61094 is enabled working in auto buck or boost mode at EN = high and MODE = high.

#### 7.4.5.1 Three States (Boost\_on, Buck\_on, and Supplement) Transition

In auto buck or boost mode operation, there are three states: boost\_on, buck\_on, and supplement, as shown in 图 7-3 to 图 7-5. The boost\_on state occurs when the bypass switch is turned off and the TPS61094 works in boost mode to regulate output voltage to the OSEL setting. The buck\_on state occurs when the bypass switch is turned on and the TPS61094 works in buck mode, charging the SUP pin by an input source according to the charging current and termination voltage settings at the ICHG and VCHG pin in this situation, which is similar to the forced buck mode operation. Supplement mode is the intermediate state when the TPS61094 transfers between boost\_on and buck\_on opetation. In supplement mode, the boost mode is active and bypass MOSFET operates as an LDO, the VIN and SUP power source supply the output load together.



图 7-3. Typical Boost\_on State Circuit



图 7-4. Typical Buck\_on State Circuit





图 7-5. Typical Supplement State Circuit

The TPS61094 can automatically transfer in these three states based on input voltage and output voltage, as shown below in 🛛 7-6.



 $V_{IN} < V_{OUT\_TARGET} + 50 \text{ mV} \& V_{OUT} > V_{OUT\_TARGET}$ 

#### 图 7-6. Three States(Boost\_on, Buck\_on and Supplement) Transition

Path 1: The TPS61094 works at buck\_on state first. There is a heavy load transient in output load and input source cannot hold it, which makes the output voltage lower than output target voltage (OSEL pin setting). The TPS61094 transfers from buck\_on to supplement state. Input and SUP power source can supply the heavy load together.

Path 2: In supplement state, if the input voltage is higher than the output target voltage + 100 mV and output voltage is higher than output target voltage, meaning the input power source can support the output load, the TPS61094 transfers from supplement to buck\_on state.

Path 3: In supplement opetaion, if the output load is light, the output voltage is higher than output target voltage. The TPS61094 transfers from supplement to boost\_on state. The TPS61094 has approximately 60-nA lq in boost mode, which can help the system has higher efficiency at light load.



Path 4: In boost\_on state, when the input power source is higher than the output target voltage + 100 mV, the TPS61094 transfers from boost\_on to supplement state.

Path 5: A quick way to transfer from buck\_on to boost\_on state. At buck\_on state, if the load is light and input voltage is lower than the output target voltage + 100 mV, the TPS61094 can enter boost\_on state.

In boost\_on mode, when the SUP pin voltage is higher than output target voltage, the TPS61094 enters passthrough mode. The TPS61094 stops switching and fully turns on high-side MOSFET. The devices stays in boost\_on (pass-through mode) until the SUP pin voltage is lower than output target voltage.

#### 7.4.5.2 Boost, Bypass, and Pass-through

When the voltage at the VIN pin is below the boost regulation voltage, the bypass switch is turned off. The TPS61094 works in boost mode to regulate the output voltage. When the voltage at the VIN pin is 0.1 V above the boost regulation voltage, the boost operation stops and the bypass switch is turned on. To make the transfer between boost mode and bypass mode smooth, there is a pass-through mode when input voltage is close to target output voltage, as shown in  $\mathbb{R}$  7-7.



图 7-7. Typical Supplement Operation Circuit

#### 7.4.5.3 PWM, PFM, and Snooze Modes in Boost Operation

The TPS61094 has three switching operation modes in boost operation: PWM mode in moderate-to-heavy load conditions, pulse frequency modulation (PFM) in light load conditions, and snooze mode in ultra-low load.

#### 7.4.5.3.1 PWM Mode

The TPS61094 uses a quasi-constant 1.0-MHz frequency pulse width modulation (PWM) at moderate-to-heavy load current. Based on the input-to-output voltage ratio, a circuit predicts the required on-time. At the beginning of the switching cycle, the low-side FET turns on. The input voltage is applied across the inductor and the inductor current ramps up. In this phase, the output capacitor is discharged by the load current. When the on-time expires, the low-side FET is turned off and the high-side FET is turned on. The inductor transfers its stored energy to replenish the output capacitor and supply the load. The inductor current declines because the output voltage is higher than the input voltage. When the inductor current hits the valley current threshold determined by the output of the error amplifier, the next switching cycle starts again.

The TPS61094 has a built-in compensation circuit that can accommodate a wide range of input voltage, output voltage, inductor value, and output capacitor value for stable operation.

#### 7.4.5.3.2 PFM Mode

The TPS61094 integrates the one-pulse PFM to improve efficiency and decrease output ripple at light load. When the load current decreases, the inductor valley current setting by the output of the error amplifier no longer regulates the output voltage. When the inductor valley current hits the low limit, the output voltage exceeds the setting voltage as the load current decreases further. The TPS61094 goes into PFM mode. In PFM mode, the



off-time is extended by decreasing load and the TPS61094 regulates output voltage to the PFM reference voltage (typically 101% \* VOUT\_REG). The PFM operation reduces the switching losses and improves efficiency at light load condition by reducing the average switching frequency.

#### 7.4.5.3.3 Snooze Mode

The TPS61094 integrates snooze mode to decrease quiescent current. If the load current is reduced further, the boost converter enters into snooze mode. In snooze mode, the boost converter ramps up the output voltage with several switching cycles. Once the output voltage exceeds a setting threshold, the device stops switching and goes into a sleep status. In sleep status, the device consumes less quiescent current. It resumes switching when the output voltage is below the setting threshold. It exits burst mode when the output current can no longer be supported in this mode. Refer to  $\boxed{8}$  7-8 for burst mode operation details.



图 7-8. Boost Mode Operation



## 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, as well as validating and testing their design implementation to confirm system functionality.

#### 8.1 Application Information

The TPS61094 is a 60-nA quiescent current synchronous bi-directional buck/boost converter with a bypass switch between input and output. The TPS61094 can operate with a wide input voltage from 0.7 V to 5.5 V and output voltage from 1.8 V to 5.5 V. The device provides an ultra-low power solution optimized for applications that require ultra-low quiescent current, use a supercap or battery as backup power supply, or both. The TPS61094 has two typical application circuits. One is the pure boost with bypass function, as shown in 🕅 8-1, which connects the SUP pin and VIN pin together. The other is the supercap backup application, which separates the SUP pin and VIN pin, as shown in 🕅 8-14, which can charge supercap or boost supercap to power the output.

#### 8.2 Typical Application - 3.6-V Output Boost Converter with Bypass



图 8-1. Li-ion Battery to 3.6-V Boost Converter with Bypass

#### 8.2.1 Design Requirements

The design parameters are listed in 表 8-1.

表	8-1.	Desian	Rea	uirem	ents
~	••••	Doorgin			01100

PARAMETERS	VALUES
Input Voltage	2.7 V ~ 4.3 V
Output Voltage	3.6 V
Output Current	500 mA
Output Voltage Ripple	± 50 mV

#### 8.2.2 Detailed Design Procedure

#### 8.2.2.1 Programming the Output Voltage

The output voltage is set by the resistor between the OSEL pin and ground. Take  $\frac{1}{2}$  7-1 as reference, R<sub>1</sub> = 17.4 k $\Omega$  for V<sub>OUT</sub> = 3.6 V. For proper operation, the resistance accuracy must be 1%. TI suggests to short the VCHG pin and ICHG pin to ground at the pure boost with bypass application.



#### 8.2.2.2 Maximum Output Current

The maximum output capability of the TPS61094 is determined by the input-to-output ratio and the current limit of the boost converter. It can be estimated by 方程式 4.

$$I_{OUT(max)} = \frac{V_{IN} \cdot (I_{LIM} - \frac{I_{LH}}{2}) \cdot r}{V_{OUT}}$$

where

- $\eta$  is the conversion efficiency, use 85% for estimation
- I<sub>LH</sub> is the current ripple value
- I<sub>LIM</sub> is the switch current limit

Minimum input voltage, maximum boost output voltage, and minimum current limit  $I_{LIM}$  should be used as the worst case condition for the estimation.

#### 8.2.2.3 Inductor Selection

Because the selection of the inductor affects steady-state operation, transient behavior, and loop stability, the inductor is the most important component in power regulator design. There are three important inductor specifications: inductor value, saturation current, and dc resistance (DCR).

The TPS61094 is designed to work with 1  $\mu$ H or 2.2  $\mu$ H inductor values. Follow 5  $\pm$ d 5 to 5  $\pm$ d 7 to calculate the inductor peak current for the application. To calculate the current in the worst case, use the minimum input voltage, maximum output voltage, and maximum load current of the application. To have enough design margins, choose the inductor value with -30% tolerances and low power-conversion efficiency for the calculation.

In a boost regulator, the inductor dc current can be calculated by 方程式 5.

$$I_{L(DC)} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times \eta}$$

where

- V<sub>OUT</sub> is the output voltage of the boost converter
- I<sub>OUT</sub> is the output current of the boost converter
- V<sub>IN</sub> is the input voltage of the boost converter
- $\eta$  is the power conversion efficiency, use 90% for most applications

The inductor ripple current is calculated by 方程式 6.

$$\Delta I_{L(P-P)} = \frac{V_{IN} \times D}{L \times f_{SW}}$$

where

- D is the duty cycle, which can be calculated by 方程式 2
- L is the inductance value of the inductor
- $f_{SW}$  is the switching frequency
- V<sub>IN</sub> is the input voltage of the boost converter

Therefore, the inductor peak current is calculated by 方程式 7.

$$I_{L(P)} = I_{L(DC)} + \frac{\Delta I_{L(P-P)}}{2}$$

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(7)

(4)

(5)

(6)



Normally, it is advisable to work with an inductor peak-to-peak current of less than 40% of the average inductor current for maximum output current. A smaller ripple from a larger valued inductor reduces the magnetic hysteresis losses in the inductor and EMI, but in the same way, load transient response time is increased. The saturation current of the inductor must be higher than the calculated peak inductor current. 8-2 lists the recommended inductors for the TPS61094.

PART NUMBER	L (µH)	DCR MAX (m $\Omega$ )	SATURATION CURRENT (A)	SIZE (LxWxH)	VENDOR <sup>(1)</sup>				
XGL4020-222ME	2.2	21.5	4.4	4.0 × 4.0 × 2.1	Coilcraft				
VCHA042A-2R2MS6	2.2	23.0	4.5	4.3 x 4.3 x 2.1	Cyntec				
744383560 22	2.2	35.0	6.2	4.1 x 4.1 x 2.1	Wurth Elecktronik				

表 8-2. Recommended Inductors for the TPS61094

(1) See the *Third-Party Products* disclaimer

#### 8.2.2.4 Output Capacitor Selection

The output capacitor is mainly selected to meet the requirements for output ripple and loop stability. The ripple voltage is related to capacitor capacitance and its equivalent series resistance (ESR). Assuming a ceramic capacitor with zero ESR, the minimum capacitance needed for a given ripple voltage can be calculated by  $\overline{7}$   $\overline{1}$  8.

$$C_{OUT} = \frac{I_{OUT} \times D_{MAX}}{f_{SW} \times V_{RIPPLE}}$$

where

- D<sub>MAX</sub> is the maximum switching duty cycle
- V<sub>RIPPLE</sub> is the peak-to-peak output ripple voltage
- I<sub>OUT</sub> is the maximum output current
- f<sub>SW</sub> is the switching frequency

The ESR impact on the output ripple must be considered if tantalum or aluminum electrolytic capacitors are used. The output peak-to-peak ripple voltage caused by the ESR of the output capacitors can be calculated by  $\overline{f}$ 程式 9.

$$V_{RIPPLE(ESR)} = I_{L(P)} \times R_{ESR}$$

Take care when evaluating the derating of a ceramic capacitor under dc bias voltage, aging, and ac signal. For example, the dc bias voltage can significantly reduce capacitance. A ceramic capacitor can lose more than 50% of its capacitance at its rated voltage. Therefore, always leave margin on the voltage rating to ensure adequate capacitance at the required output voltage. Increasing the output capacitor makes the output ripple voltage smaller in PWM mode.

TI recommends using the X5R or X7R ceramic output capacitor in the range of  $4-\mu$  F to 1000- $\mu$  F effective capacitance. The output capacitor affects the small signal control loop stability of the boost regulator. If the output capacitor is below the range, the boost regulator can potentially become unstable. Increasing the output capacitor makes the output ripple voltage smaller in PWM mode.

#### 8.2.2.5 Input Capacitor Selection

Multilayer X5R or X7R ceramic capacitors are excellent choices for the input decoupling of the step-up converter as they have extremely low ESR and are available in small footprints. Input capacitors must be located as close as possible to the device. While a  $10-\mu$  F input capacitor is sufficient for most applications, larger values can be used to reduce input current ripple without limitations. Take care when using only ceramic input capacitors. When a ceramic capacitor is used at the input and the power is being supplied through long wires, a load step at the output can induce ringing at the VIN pin. This ringing can couple to the output and be mistaken as loop instability or can even damage the part. In this circumstance, place additional bulk capacitance (tantalum or

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(8)



aluminum electrolytic capacitor) between ceramic input capacitor and the power source to reduce ringing that can occur between the inductance of the power source leads and ceramic input capacitor.



#### 8.2.3 Application Curves







#### 8.2.4 Typical Application - 3.3-V Output Boost Converter with Automatic Buck or Boost Function



图 8-14. 5-V Input Source to 3.3-V Boost Converter with Automatic Buck or Boost Function

#### 8.2.4.1 Design Requirements

The design parameters are listed in  $\frac{1}{8}$  8-3.

#### 表 8-3. Design Requirements

PARAMETERS	VALUES			
Input Voltage	5 V ± 0.5 V			
Output Voltage	3.3 V			
Output Current	250 mA			
Output Voltage Ripple	± 50 mV			
Supercap Charging Termination Voltage	2.6 V			
Supercap Charging Current	100 mA			

#### 8.2.4.2 Detailed Design Procedure

#### 8.2.4.2.1 Programming the Voltage and Current

The output voltage is set by the resistor between the OSEL pin and ground. Take as reference  $R_1 = 4.75 \text{ k}\Omega$  for  $V_{OUT} = 3.3 \text{ V}$ . The charging termination voltage is set by the resistor between the VCHG pin and ground. Take as reference  $R_1 = 9.53 \text{ k}\Omega$  for  $V_{CHG\_REG} = 2.6 \text{ V}$ . The charging current is set by the resistor between the ICHG pin and ground. Take as reference  $R_1 = 22.1 \text{ k}\Omega$  for  $I_{CHG\_REG} = 100 \text{ mA}$ . For proper operation, the resistance accuracy must be 1%.



#### 8.2.4.3 Application Curves







![](_page_29_Picture_1.jpeg)

## 9 Power Supply Recommendations

The device is designed to operate from an input voltage supply range between 0.7 V to 5.5 V. This input supply must be well regulated. If the input supply is located more than a few inches from the converter, additional bulk capacitance can be required in addition to the ceramic bypass capacitors. A typical choice is a tantalum or aluminum electrolytic capacitor with a value of 100  $\mu$ F. Output current of the input power supply must be rated according to the supply voltage, output voltage, and output current of the TPS61094.

![](_page_30_Picture_0.jpeg)

## 10 Layout

#### **10.1 Layout Guidelines**

As for all switching power supplies, the layout is an important step in the design, especially at high peak currents and high switching frequencies. If the layout is not carefully done, the regulator can show stability problems as well as EMI problems. Therefore, use wide and short traces for the main current path and for the power ground paths. The input and output capacitor, as well as the inductor should be placed as close as possible to the IC.

#### 10.2 Layout Example

The bottom layer is a large GND plane connected by vias.

![](_page_30_Figure_7.jpeg)

图 10-1. Layout: Boost Converter with Bypass Mode

![](_page_31_Picture_1.jpeg)

![](_page_31_Figure_2.jpeg)

#### 图 10-2. Layout: Boost Converter with Automatic Bypass and Buck function

![](_page_32_Picture_0.jpeg)

## **11 Device and Documentation Support**

#### **11.1 Device Support**

#### 11.1.1 第三方产品免责声明

TI 发布的与第三方产品或服务有关的信息,不能构成与此类产品或服务或保修的适用性有关的认可,不能构成此 类产品或服务单独或与任何 TI 产品或服务一起的表示或认可。

#### **11.2 Documentation Support**

#### 11.2.1 Related Documentation

For related documentation see the following:

- Performing Accurate PFM Mode Efficiency Measurements, SLVA236
- Accurately Measuring Efficiency of Ultra-low-IQ Devices, SLYT558
- IQ: What it is, What it isn ' t, and How to Use it, SLYT412

#### 11.3 接收文档更新通知

要接收文档更新通知,请导航至 ti.com 上的器件产品文件夹。点击*订阅更新*进行注册,即可每周接收产品信息更改摘要。有关更改的详细信息,请查看任何已修订文档中包含的修订历史记录。

#### 11.4 支持资源

TI E2E<sup>™</sup> 支持论坛是工程师的重要参考资料,可直接从专家获得快速、经过验证的解答和设计帮助。搜索现有解 答或提出自己的问题可获得所需的快速设计帮助。

链接的内容由各个贡献者"按原样"提供。这些内容并不构成 TI 技术规范,并且不一定反映 TI 的观点;请参阅 TI 的《使用条款》。

#### 11.5 Trademarks

TI E2E<sup>™</sup> is a trademark of Texas Instruments.

所有商标均为其各自所有者的财产。

#### 11.6 静电放电警告

![](_page_32_Picture_21.jpeg)

静电放电 (ESD) 会损坏这个集成电路。德州仪器 (TI) 建议通过适当的预防措施处理所有集成电路。如果不遵守正确的处理和安装程序,可能会损坏集成电路。

ESD 的损坏小至导致微小的性能降级,大至整个器件故障。精密的集成电路可能更容易受到损坏,这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

#### 11.7 术语表

TI术语表 本术语表列出并解释了术语、首字母缩略词和定义。

![](_page_33_Picture_1.jpeg)

## 12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical packaging and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

![](_page_34_Picture_0.jpeg)

**DSS0012B** 

## PACKAGE OUTLINE

![](_page_34_Figure_3.jpeg)

## WSON - 0.8 mm max height

PLASTIC SMALL OUTLINE - NO LEAD

![](_page_34_Figure_6.jpeg)

#### NOTES:

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. The package thermal pad must be soldered to the printed circuit board for optimal thermal and mechanical performance.

![](_page_34_Picture_11.jpeg)

**DSS0012B** 

![](_page_35_Picture_1.jpeg)

## **EXAMPLE BOARD LAYOUT**

#### WSON - 0.8 mm max height

PLASTIC SMALL OUTLINE - NO LEAD

![](_page_35_Figure_5.jpeg)

NOTES: (continued)

This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
 Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown

on this view. It is recommended that vias under paste be filled, plugged or tented.

![](_page_35_Picture_9.jpeg)

![](_page_36_Picture_0.jpeg)

**DSS0012B** 

## **EXAMPLE STENCIL DESIGN**

#### WSON - 0.8 mm max height

PLASTIC SMALL OUTLINE - NO LEAD

![](_page_36_Figure_5.jpeg)

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

![](_page_36_Picture_8.jpeg)

![](_page_37_Picture_0.jpeg)

9-Mar-2021

## PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TPS61094DSSR	PREVIEW	WSON	DSS	12	3000	Non-RoHS & Non-Green	(6) Call TI	Call TI	-40 to 85		
XTPS61094DSSR	ACTIVE	WSON	DSS	12	3000	Non-RoHS & Non-Green	Call TI	Call TI	-40 to 85		Samples

<sup>(1)</sup> 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.

<sup>(2)</sup> 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 (CI) 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.

<sup>(3)</sup> MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

<sup>(4)</sup> 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.

<sup>(6)</sup> 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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![](_page_38_Picture_0.jpeg)

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## PACKAGE OPTION ADDENDUM

9-Mar-2021

## **GENERIC PACKAGE VIEW**

# WSON - 0.8 mm max height PLASTIC SMALL OUTLINE - NO LEAD

![](_page_39_Picture_4.jpeg)

Images above are just a representation of the package family, actual package may vary. Refer to the product data sheet for package details.

![](_page_39_Picture_6.jpeg)

4209244/D

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