4.5-V to 14.5-V Input, 3-A Synchronous Buck, Integrated Power Solution

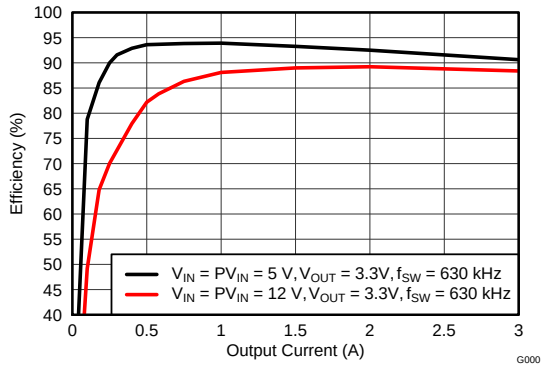
Check for Samples: TPS84320

FEATURES

- **Complete Integrated Power Solution Allows Small Footprint, Low-Profile Design**
- **Efficiencies Up To 95%**
- **Wide-Output Voltage Adjust 0.8 V to 5.5 V, with 1% Reference Accuracy**
- **Optional Split Power Rail Allows Input Voltage Down to 1.6 V**
- **Adjustable Switching Frequency (330 kHz to 780 kHz)**
- **Synchronizes to an External Clock**
- **Adjustable Slow-Start**
- **Output Voltage Sequencing / Tracking**
- **Power Good Output**
- **Programmable Undervoltage Lockout (UVLO)**
- **Overcurrent Protection - Hiccup-Mode**
- **Over Temperature Protection**
- **Pre-bias Output Start-up**
- **Operating Temperature Range: –40°C to 85°C**
- **Enhanced Thermal Performance: 13°C/W**
- **Meets EN55022 Class B Emissions**
- **For Design Help Including SwitcherPro™ visit http://www.ti.com/TPS84320**

APPLICATIONS

- **Broadband & Communications Infrastructure**
- **Automated Test and Medical Equipment**
- **Compact PCI / PCI Express / PXI Express**
- **DSP and FPGA Point of Load Applications**
- **High Density Distributed Power Systems**



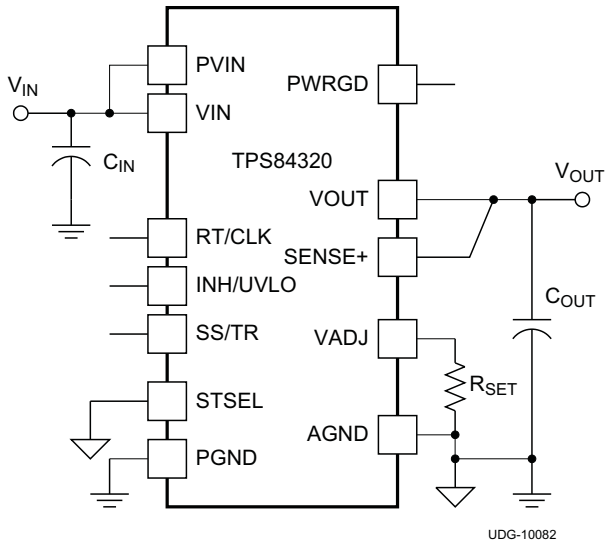
DESCRIPTION

The TPS84320RUQ is an easy-to-use integrated power solution that combines a 3-A DC/DC converter with power MOSFETs, an inductor, and passives into a low profile, BQFN package. This total power solution allows as few as 3 external components and eliminates the loop compensation and magnetics design process.

The 9×15×2.8 mm BQFN package is easy to solder onto a printed circuit board and allows a compact point-of-load design with up to 95% efficiency and excellent power dissipation with a thermal impedance of 13°C/W junction to ambient. The device delivers the full 3-A rated output current at 85°C ambient temperature without airflow.

The TPS84320 offers the flexibility and the feature-set of a discrete point-of-load design and is ideal for powering performance DSPs and FPGAs. Advanced packaging technology afford a robust and reliable power solution compatible with standard QFN mounting and testing techniques.

SIMPLIFIED APPLICATION



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

SwitcherPro is a trademark of Texas Instruments.

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

ORDERING INFORMATION

For the most current package and ordering information, see the Package Option Addendum at the end of this datasheet, or see the TI website at www.ti.com.

ABSOLUTE MAXIMUM RATINGS(1)

over operating temperature range (unless otherwise noted)			
		VALUE	UNIT
Input Voltage	VIN	–0.3 to 16	V
	PVIN	–0.3 to 16	V
	INH/UVLO	–0.3 to 6	V
	VADJ	–0.3 to 3	V
	PWRGD	–0.3 to 6	V
	SS/TR	–0.3 to 3	V
	STSEL	–0.3 to 3	V
	RT/CLK	–0.3 to 6	V
Output Voltage	PH	–1 to 20	V
	PH 10ns Transient	–3 to 20	V
V_{DIFF} (GND to exposed thermal pad)		–0.2 to 0.2	V
Source Current	RT/CLK	±100	µA
	PH	Current Limit	A
Sink Current	PH	Current Limit	A
	PVIN	Current Limit	A
	PWRGD	–0.1 to 5	mA
Operating Junction Temperature		–40 to 125(2)	°C
Storage Temperature		–65 to 150	°C
Mechanical Shock	Mil-STD-883D, Method 2002.3, 1 msec, 1/2 sine, mounted	1500	G
Mechanical Vibration	Mil-STD-883D, Method 2007.2, 20-2000Hz	20	

(1) Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under recommended operating conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) See the temperature derating curves in the Typical Characteristics section for thermal information.

THERMAL INFORMATION

THERMAL METRIC[1]		TPS84320 RUQ47 47 PINS	UNIT
θ_{JA}	Junction-to-ambient thermal resistance[2]	13	°C/W
ψ_{JT}	Junction-to-top characterization parameter[3]	2.5	
ψ_{JB}	Junction-to-board characterization parameter[4]	5	

(1) For more information about traditional and new thermal metrics, see the IC Package Thermal Metrics application report, SPRA953.
(2) The junction-to-ambient thermal resistance, θ_{JA}, applies to devices soldered directly to a 100 mm x 100 mm double-sided PCB with 1 oz. copper and natural convection cooling. Additional airflow reduces θ_{JA}.
(3) The junction-to-top characterization parameter, ψ_{JT}, estimates the junction temperature, T_J, of a device in a real system, using a procedure described in JESD51-2A (sections 6 and 7). $T_J = \psi_{JT} * Pdis + T_T$; where Pdis is the power dissipated in the device and T_T is the temperature of the top of the device.
(4) The junction-to-board characterization parameter, ψ_{JB}, estimates the junction temperature, T_J, of a device in a real system, using a procedure described in JESD51-2A (sections 6 and 7). $T_J = \psi_{JB} * Pdis + T_B$; where Pdis is the power dissipated in the device and T_B is the temperature of the board 1mm from the device.

PACKAGE SPECIFICATIONS

TPS84320		UNIT
Weight		1.26 grams
Flammability	Meets UL 94 V-O	
MTBF Calculated reliability	Per Bellcore TR-332, 50% stress, T_A = 40°C, ground benign	40.1 MHrs

ELECTRICAL CHARACTERISTICS

Over -40°C to 85°C free-air temperature, PVIN = VIN = 12 V, V_{OUT} = 1.8 V, I_{OUT} = 3A,
C_{IN1} = 2x 22 µF ceramic, C_{IN2} = 68 µF poly-tantalum, C_{OUT1} = 4x 47 µF ceramic (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
I_{OUT}	Output current	T_A = 85°C, natural convection		0		3	A
VIN	Input bias voltage range	Over I_{OUT} range		4.5		14.5	V
PVIN	Input switching voltage range	Over I_{OUT} range		1.6 (1)		14.5	V
UVLO	VIN Undervoltage lockout	VIN = increasing			4.0	4.5	V
		VIN = decreasing		3.5	3.85		
$V_{OUT(adj)}$	Output voltage adjust range	Over I_{OUT} range		0.8		5.5	V
V_{OUT}	Set-point voltage tolerance	T_A = 25°C, I_{OUT} = 0A				±1.0% (2)	
	Temperature variation	-40°C ≤ T_A ≤ +85°C, I_{OUT} = 0A			±0.3%		
	Line regulation	Over PVIN range, T_A = 25°C, I_{OUT} = 0A			±0.1%		
	Load regulation	Over I_{OUT} range, T_A = 25°C			±0.1%		
	Total output voltage variation	Includes set-point, line, load, and temperature variation				±1.5% (2)	
η	Efficiency	PVIN = VIN = 12 V, I_O = 1.5 A	V_{OUT} = 5V, f_{SW} = 780kHz		91.5 %		
			V_{OUT} = 3.3V, f_{SW} = 630kHz		89.0 %		
			V_{OUT} = 2.5V, f_{SW} = 480kHz		86.9 %		
			V_{OUT} = 1.8V, f_{SW} = 480kHz		85.2 %		
			V_{OUT} = 1.2V, f_{SW} = 480kHz		82.1 %		
			V_{OUT} = 0.8V, f_{SW} = 330kHz		78.7 %		
		PVIN = VIN = 5 V, I_O = 1.5 A	V_{OUT} = 3.3V, f_{SW} = 630kHz		93.3 %		
			V_{OUT} = 2.5V, f_{SW} = 480kHz		91.4 %		
			V_{OUT} = 1.8V, f_{SW} = 480kHz		88.8 %		
			V_{OUT} = 1.2V, f_{SW} = 480kHz		85.2 %		
			V_{OUT} = 0.8V, f_{SW} = 330kHz		81.8 %		
	Output voltage ripple	20 MHz bandwith			35		mV_{PP}
I_{LIM}	Overcurrent threshold				5.8		A
	Transient response	1.0 A/µs load step from 50 to 100% $I_{OUT(max)}$	Recovery time		190		µs
			V_{OUT} over/undershoot		35		mV
V_{INH-H}	Inhibit Control	Inhibit High Voltage		1.30		Open (3)	V
V_{INH-L}		Inhibit Low Voltage		–0.3		1.05	
	INH Input current	INH < 1.1 V			-1.15		µA
	INH Hysteresis current	INH > 1.26 V			-3.4		µA
$I_{I(stby)}$	Input standby current	INH pin to AGND			2	4	µA
Power Good	PWRGD Thresholds	V_{OUT} rising	Good		94%		
			Fault		109%		
		V_{OUT} falling	Fault		91%		
			Good		106%		
	PWRGD Low Voltage	I(PWRGD) = 2 mA				0.3	V
f_{SW}	Switching frequency	Over VIN and I_{OUT} ranges, RT/CLK pin OPEN		270	330	390	kHz
f_{CLK}	Synchronization frequency	CLK Control		330		780	kHz
V_{CLK-H}	CLK High-Level Threshold			2.0		5.5	V
V_{CLK-L}	CLK Low-Level Threshold					0.8	V
D_{CLK}	CLK Duty cycle			20%		80%	
	Thermal Shutdown	Thermal shutdown		160	175		°C
		Thermal shutdown hysteresis			10		°C

(1) The minimum PVIN voltage is 1.6V or (V_{OUT}+ 0.7V) , whichever is greater. VIN must be greater than 4.5V.
(2) The stated limit of the set-point voltage tolerance includes the tolerance of both the internal voltage reference and the internal adjustment resistor. The overall output voltage tolerance will be affected by the tolerance of the external R_{SET} resistor.
(3) This control pin has an internal pullup. If this pin is left open circuit, the device operates when input power is applied. A small low-leakage (<300 nA) MOSFET is recommended for control. See the application section for further guidance.

ELECTRICAL CHARACTERISTICS (continued)

Over -40°C to 85°C free-air temperature, PVIN = VIN = 12 V, V_{OUT} = 1.8 V, I_{OUT} = 3A,
C_{IN1} = 2x 22 µF ceramic, C_{IN2} = 68 µF poly-tantalum, C_{OUT1} = 4x 47 µF ceramic (unless otherwise noted)

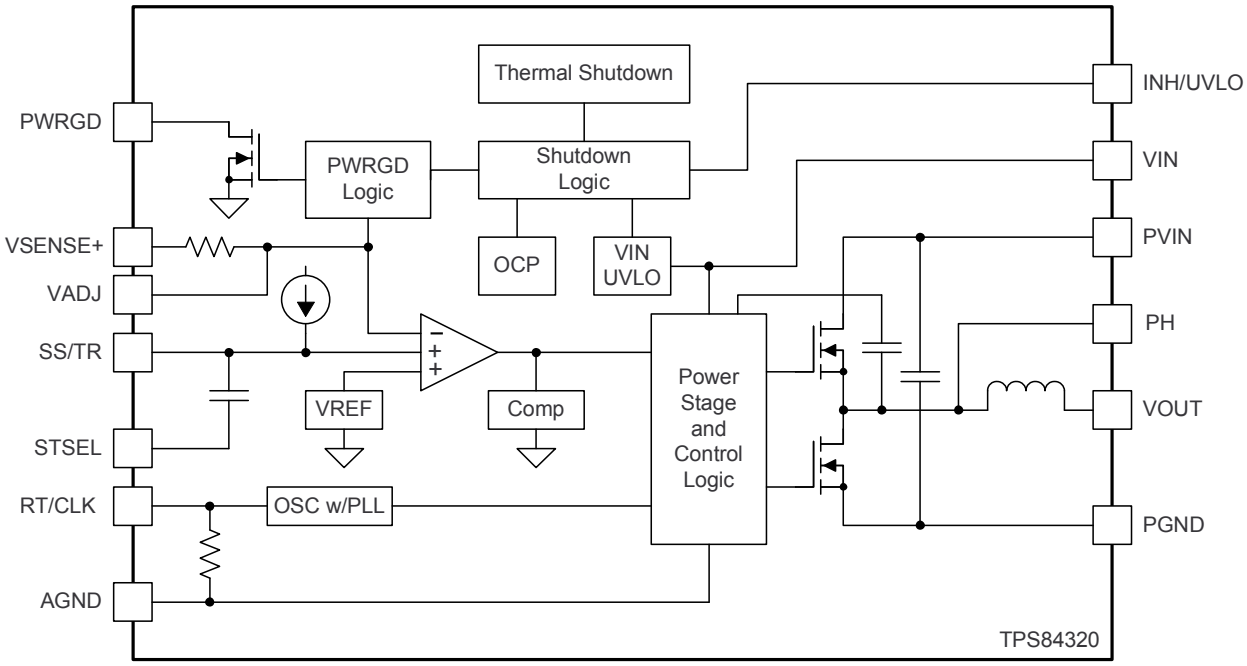
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
C_{IN}	External input capacitance	Ceramic	22 (4)			µF
		Non-ceramic	68 (4)			
C_{OUT}	External output capacitance	Ceramic	200 (5)		1500	µF
		Non-ceramic			5000	
		Equivalent series resistance (ESR)			35	mΩ

(4) A minimum of 68µF of polymer tantalum and/or ceramic external capacitance is required across the input (VIN and PGND connected) for proper operation. Locate the capacitor close to the device. See Table 5 for more details. When operating with split VIN and PVIN rails, place 4.7µF of ceramic capacitance directly at the VIN pin to PGND.

(5) The amount of required output capacitance varies depending on the output voltage (see Table 3). The amount of required capacitance must include ceramic capacitance. Locate the capacitance close to the device. Adding additional capacitance close to the load improves the response of the regulator to load transients. See Table 3 and Table 5 more details.

DEVICE INFORMATION

FUNCTIONAL BLOCK DIAGRAM



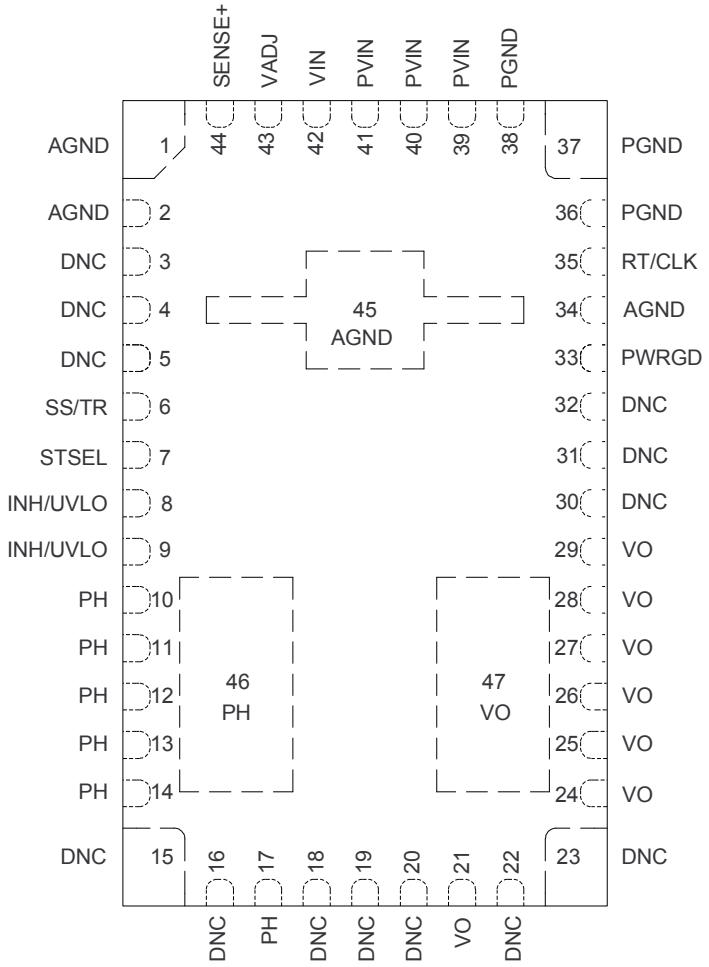
PIN DESCRIPTIONS

TERMINAL		DESCRIPTION
NAME	NO.	
AGND	1	Zero VDC reference for the analog control circuitry. Connect AGND to PGND at a single point. Connect near the output capacitors. See Figure 43 for a recommended layout.
	2	
	34	
	45	
INH/UVLO	8	Inhibit and UVLO adjust pin. Use an open drain or open collector output logic to control the INH function. A resistor divider between this pin, AGND and VIN adjusts the UVLO voltage. Tie both pins together when using this control.
	9	
DNC	3	Do Not Connect. Do not connect these pins to AGND, to another DNC pin, or to any other voltage. These pins are connected to internal circuitry. Each pin must be soldered to an isolated pad.
	4	
	5	
	15	
	16	
	18	
	19	
	20	
	22	
	23	
	30	
	31	
	32	
PGND	36	Common ground connection for the PVIN, VIN, and VOUT power connections. See Figure 43 for a recommended layout.
	37	
	38	
PH	10	Phase switch node. These pins should be connected to a small copper island under the device for thermal relief. Do not place any external component on this pin or tie it to a pin of another function.
	11	
	12	
	13	
	14	
	17	
	46	
PWRGD	33	Power good fault pin. Asserts low if the output voltage is low. A pull-up resistor is required.
PVIN	39	Input switching voltage. This pin supplies voltage to the power switches of the converter. See Figure 43 for a recommended layout.
	40	
	41	
RT/CLK	35	This pin automatically selects between RT mode and CLK mode. An external timing resistor adjusts the switching frequency of the device. In CLK mode, the device synchronizes to an external clock.
SENSE+	44	Remote sense connection. Connect this pin to VOUT at the load for improved regulation. This pin must be connected to VOUT at the load, or at the module pins.
SS/TR	6	Slow-start and tracking pin. Connecting an external capacitor to this pin adjusts the output voltage rise time. A voltage applied to this pin allows for tracking and sequencing control.
STSEL	7	Slow-start or track feature select. Connect this pin to AGND to enable the internal SS capacitor with a SS interval of approximately 1.1 ms. Leave this pin open to enable the TR feature.
VADJ	43	Connecting a resistor between this pin and AGND sets the output voltage.
VIN	42	Input bias voltage pin. Supplies the control circuitry of the power converter. See Figure 43 for a recommended layout.

PIN DESCRIPTIONS (continued)

TERMINAL		DESCRIPTION
NAME	NO.	
VOUT	21	Output voltage. Connect output capacitors between these pins and PGND.
	24	
	25	
	26	
	27	
	28	
	29	
	47	

RUQ PACKAGE
47 PINS
(TOP VIEW)



TYPICAL CHARACTERISTICS (PVIN = VIN = 12 V)(1) (2)

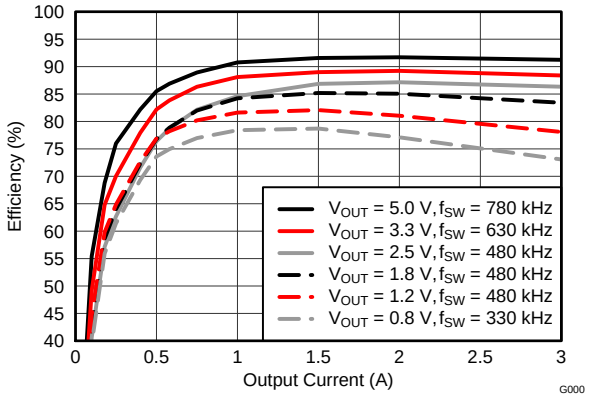


Figure 1. Efficiency vs. Output Current

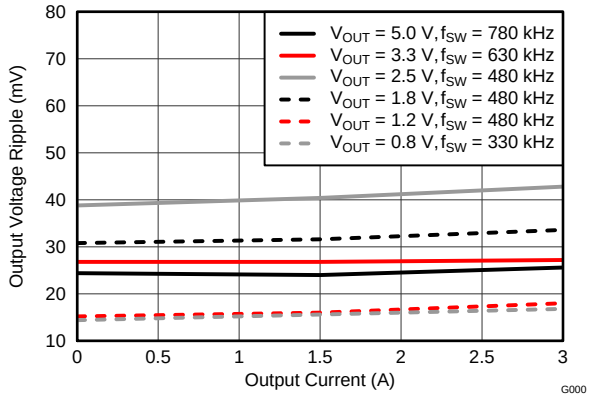


Figure 2. Voltage Ripple vs. Output Current

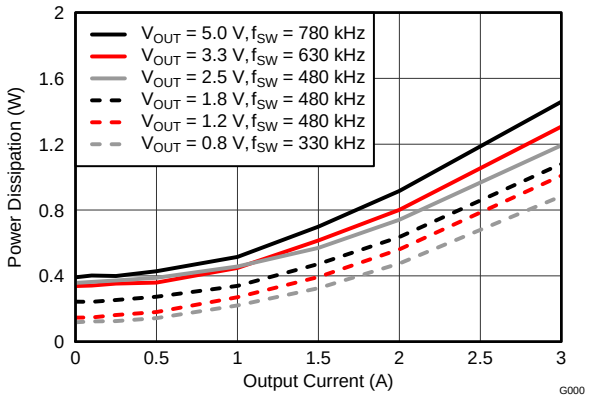


Figure 3. Power Dissipation vs. Output Current

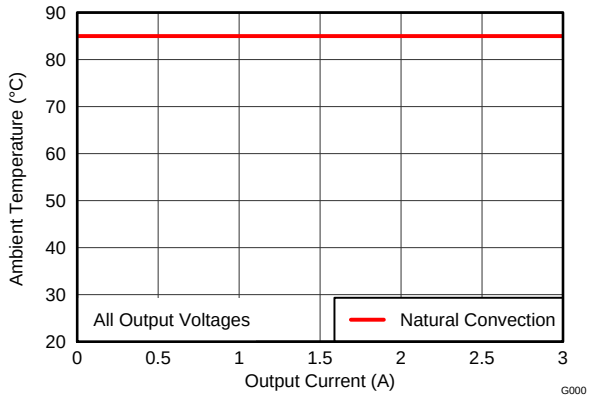


Figure 4. Safe Operating Area

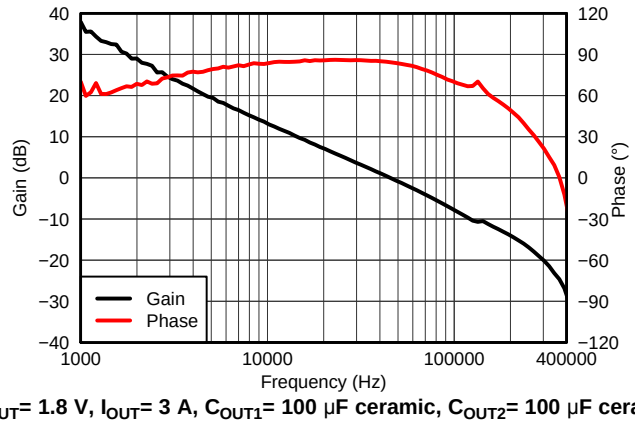


Figure 5. V_{OUT}= 1.8 V, I_{OUT}= 3 A, C_{OUT1}= 100 µF ceramic, C_{OUT2}= 100 µF ceramic, f_{SW}= 480 kHz

(1) The electrical characteristic data has been developed from actual products tested at 25°C. This data is considered typical for the converter. Applies to Figure 1, Figure 2, and Figure 3.

(2) The temperature derating curves represent the conditions at which internal components are at or below the manufacturer's maximum operating temperatures. Derating limits apply to devices soldered directly to a 100 mm × 100 mm double-sided PCB with 1 oz. copper. Applies to Figure 4.

TYPICAL CHARACTERISTICS (PVIN = VIN = 5 V)(1) (2)

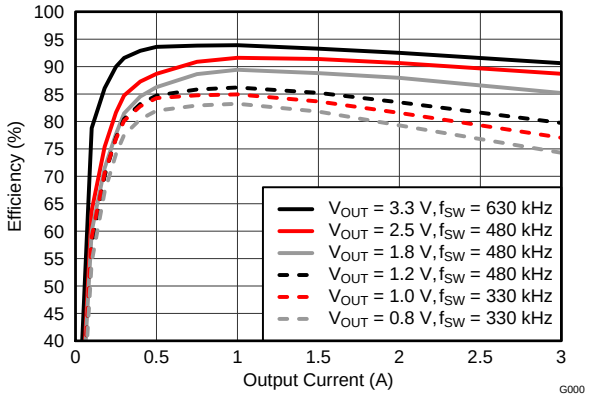


Figure 6. Efficiency vs. Output Current

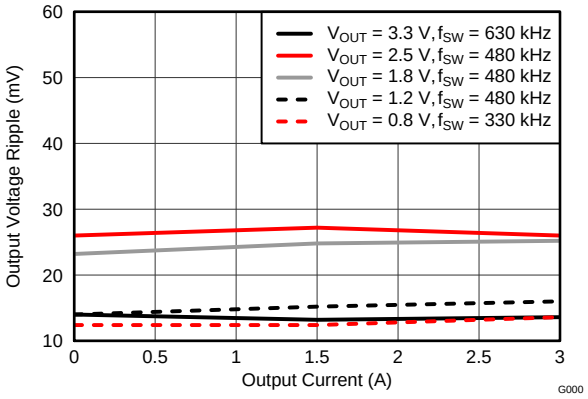


Figure 7. Voltage Ripple vs. Output Current

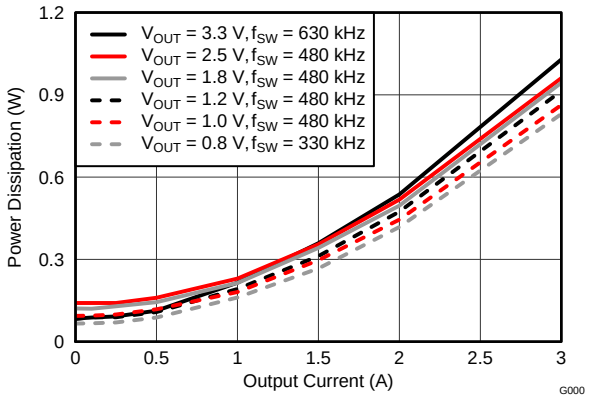


Figure 8. Power Dissipation vs. Output Current

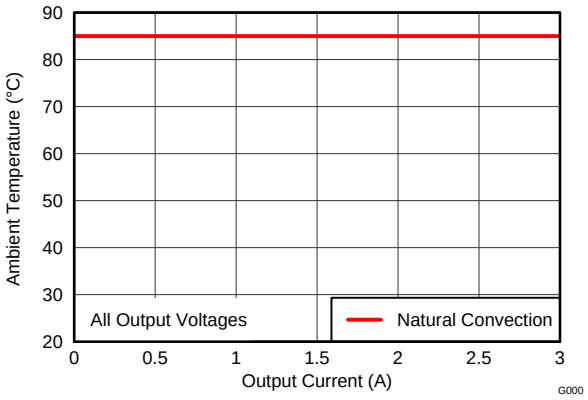


Figure 9. Safe Operating Area

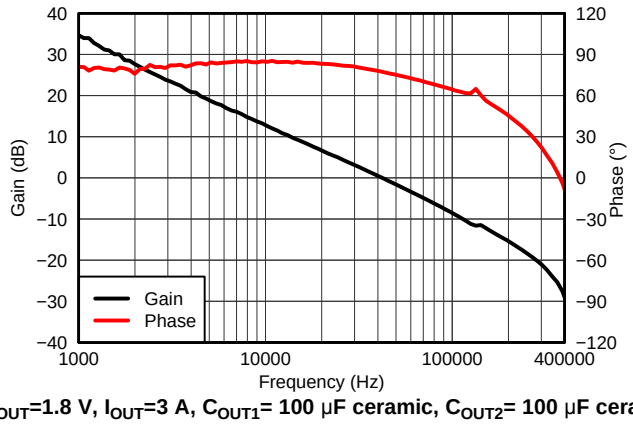


Figure 10. V_{OUT}=1.8 V, I_{OUT}=3 A, C_{OUT1}= 100 µF ceramic, C_{OUT2}= 100 µF ceramic, f_{SW}= 480 kHz

(1) The electrical characteristic data has been developed from actual products tested at 25°C. This data is considered typical for the converter. Applies to Figure 6, Figure 7, and Figure 8.

(2) The temperature derating curves represent the conditions at which internal components are at or below the manufacturer's maximum operating temperatures. Derating limits apply to devices soldered directly to a 100 mm × 100 mm double-sided PCB with 1 oz. copper. Applies to Figure 9.

TYPICAL CHARACTERISTICS (PVIN = 12 V, VIN = 5 V)(1) (2)

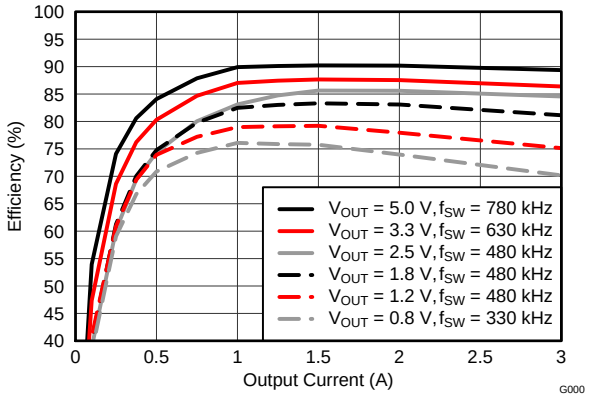


Figure 11. Efficiency vs. Output Current

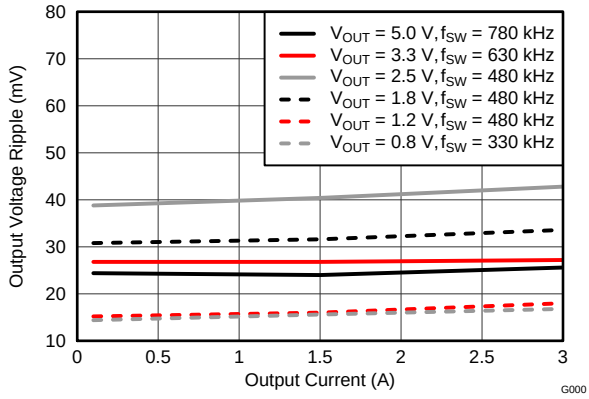


Figure 12. Voltage Ripple vs. Output Current

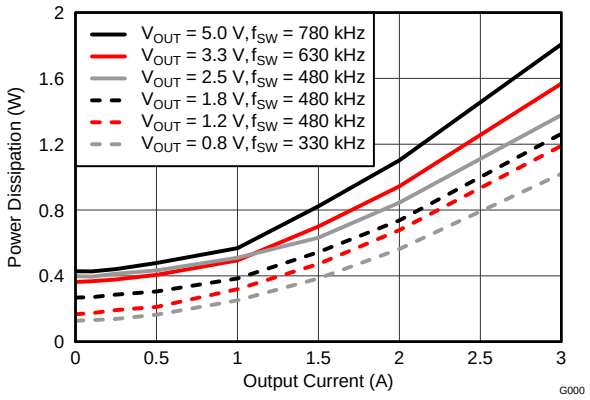


Figure 13. Power Dissipation vs. Output Current

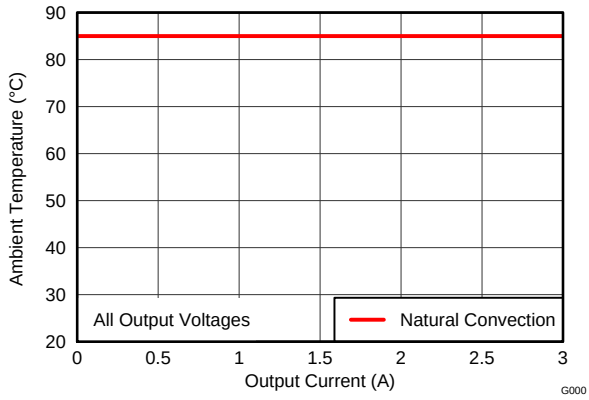


Figure 14. Safe Operating Area

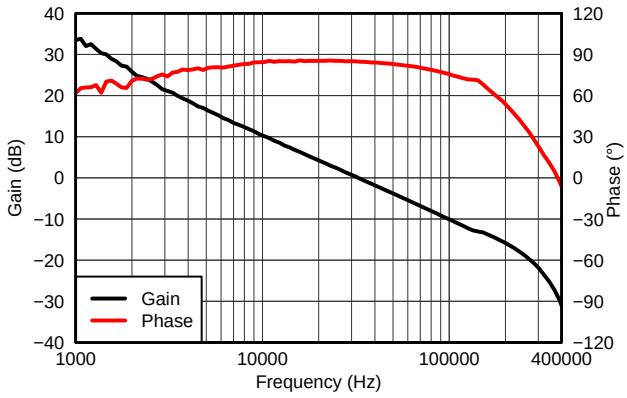


Figure 15. V_{OUT}=2.5 V, I_{OUT}=3 A, C_{OUT1}= 100 µF ceramic, C_{OUT2}= 100 µF ceramic, f_{SW}= 480 kHz

(1) The electrical characteristic data has been developed from actual products tested at 25°C. This data is considered typical for the converter. Applies to Figure 11, Figure 12, and Figure 13.

(2) The temperature derating curves represent the conditions at which internal components are at or below the manufacturer's maximum operating temperatures. Derating limits apply to devices soldered directly to a 100 mm × 100 mm double-sided PCB with 1 oz. copper. Applies to Figure 14.

APPLICATION INFORMATION

ADJUSTING THE OUTPUT VOLTAGE

The VADJ control sets the output voltage of the TPS84320. The output voltage adjustment range is from 0.8V to 5.5V. The adjustment method requires the addition of R_{SET}, which sets the output voltage, the connection of SENSE+ to VOUT, and in some cases R_{RT} which sets the switching frequency. The R_{SET} resistor must be connected directly between the VADJ (pin 43) and AGND (pin 45). The SENSE+ pin (pin 44) must be connected to VOUT either at the load for improved regulation or at VOUT of the module. The R_{RT} resistor must be connected directly between the RT/CLK (pin 35) and AGND (pin 34).

Table 1 gives the standard external R_{SET} resistor for a number of common bus voltages, along with the required R_{RT} resistor for that output voltage. For other output voltages, the value of the required resistor can either be calculated using Equation 1, or selected from the values given in Table 2.

Table 1. Standard R_{SET} Resistor Values for Common Output Voltages

RESISTORS	OUTPUT VOLTAGE V_{OUT} (V)							
	0.8	1.0	1.2	1.5	1.8	2.5	3.3	5.0
R_{SET} (kΩ)	open	5.76	2.87	1.62	1.13	0.665	0.453	0.267
R_{RT} (kΩ)	open	open	324	324	324	324	158	105

$$R_{SET} = \frac{1.43}{\left(\left(\frac{V_{OUT}}{0.8}\right) - 1\right)} \ (k\Omega) \quad (1)$$

Table 2. Standard R_{SET} Resistor Values

V_{OUT} (V)	R_{SET} (kΩ)	R_{RT}(kΩ)	f_{SW}(kHz)	V_{OUT} (V)	R_{SET} (kΩ)	R_{RT}(kΩ)	f_{SW}(kHz)
0.8	open	open	330	3.2	0.475	191	580
0.9	11.3	open	330	3.3	0.453	158	630
1.0	5.76	open	330	3.4	0.442	158	630
1.1	3.83	open	330	3.5	0.422	158	630
1.2	2.87	324	480	3.6	0.402	158	630
1.3	2.26	324	480	3.7	0.392	158	630
1.4	1.91	324	480	3.8	0.374	137	680
1.5	1.62	324	480	3.9	0.365	137	680
1.6	1.43	324	480	4.0	0.357	137	680
1.7	1.27	324	480	4.1	0.348	137	680
1.8	1.13	324	480	4.2	0.332	118	730
1.9	1.02	324	480	4.3	0.324	118	730
2.0	0.953	324	480	4.4	0.316	118	730
2.1	0.866	324	480	4.5	0.309	118	730
2.2	0.806	324	480	4.6	0.301	118	730
2.3	0.750	324	480	4.7	0.294	118	730
2.4	0.715	324	480	4.8	0.287	105	780
2.5	0.665	324	480	4.9	0.280	105	780
2.6	0.634	237	530	5.0	0.267	105	780
2.7	0.604	237	530	5.1	0.267	105	780
2.8	0.562	237	530	5.2	0.261	105	780
2.9	0.536	237	530	5.3	0.255	105	780
3.0	0.511	191	580	5.4	0.249	105	780
3.1	0.499	191	580	5.5	0.243	105	780

CAPACITOR RECOMMENDATIONS FOR THE TPS84320 POWER SUPPLY

Capacitor Technologies

Electrolytic, Polymer-Electrolytic Capacitors

When using electrolytic capacitors, high-quality, computer-grade electrolytic capacitors are recommended. Polymer-electrolytic type capacitors are recommended for applications where the ambient operating temperature is less than 0°C. The Sanyo OS-CON capacitor series is suggested due to the lower ESR, higher rated surge, power dissipation, ripple current capability, and small package size. Aluminum electrolytic capacitors provide adequate decoupling over the frequency range of 2 kHz to 150 kHz, and are suitable when ambient temperatures are above 0°C.

Ceramic Capacitors

The performance of aluminum electrolytic capacitors is less effective than ceramic capacitors above 150 kHz. Multilayer ceramic capacitors have a low ESR and a resonant frequency higher than the bandwidth of the regulator. They can be used to reduce the reflected ripple current at the input as well as improve the transient response of the output.

Tantalum, Polymer-Tantalum Capacitors

Polymer-tantalum type capacitors are recommended for applications where the ambient operating temperature is less than 0°C. The Sanyo POSCAP series and Kemet T530 capacitor series are recommended rather than many other tantalum types due to their lower ESR, higher rated surge, power dissipation, ripple current capability, and small package size. Tantalum capacitors that have no stated ESR or surge current rating are not recommended for power applications.

Input Capacitor

The TPS84320 requires a minimum input capacitance of 68 µF of ceramic and/or polymer-tantalum capacitors. The ripple current rating of the capacitor must be at least 450 mArms. Table 5 includes a preferred list of capacitors by vendor.

Output Capacitor

The required output capacitance is determined by the output voltage of the TPS84320. See Table 3 for the amount of required capacitance. The required output capacitance must be comprised of all ceramic capacitors. When adding additional non-ceramic bulk capacitors, low-ESR devices like the ones recommended in Table 5 are required. The required capacitance above the minimum is determined by actual transient deviation requirements. See Table 4 for typical transient response values for several output voltage, input voltage and capacitance combinations. Table 5 includes a preferred list of capacitors by vendor.

Table 3. Required Output Capacitance

V_{OUT} RANGE (V)		MINIMUM REQUIRED C_{OUT} (µF)
MIN	MAX	
0.8	< 1.2	6x 47 µF ceramic
1.2	< 3.0	4x 47 µF ceramic
3.0	< 4.0	2x 47 µF ceramic
4.0	5.5	47 µF ceramic

Table 4. Output Voltage Transient Response

C_{IN1} = 22 µF CERAMIC, C_{IN2} = 68 µF POSCAP, LOAD STEP = 1.5 A, 1 A/µs						
V_{OUT} (V)	PV_{IN} (V)	C_{OUT1} Ceramic	C_{OUT2} BULK	VOLTAGE DEVIATION (mV)	PEAK-PEAK (mV)	RECOVERY TIME (µs)
0.8	5	6x 47 µF	None	25	55	170
		6x 47 µF	330 µF	15	30	160
	12	6x 47 µF	None	20	35	180
		6x 47 µF	330 µF	15	30	170
1.0	5	6x 47 µF	None	20	40	170
		6x 47 µF	330 µF	15	30	170
	12	6x 47 µF	None	20	45	180
		6x 47 µF	330 µF	15	30	170
1.2	5	4x 47 µF	None	30	55	170
		4x 47 µF	220 µF	25	45	170
	12	4x 47 µF	None	30	55	180
		4x 47 µF	220 µF	25	50	170
1.8	5	4x 47 µF	None	35	65	180
		4x 47 µF	220 µF	30	55	180
	12	4x 47 µF	None	35	65	190
		4x 47 µF	220 µF	30	55	180
3.3	5	2x 47 µF	None	65	130	190
		2x 47 µF	100 µF	55	110	190
	12	2x 47 µF	None	65	130	200
		2x 47 µF	100 µF	60	120	200
5.0	12	1x 47 µF	None	100	200	210
		1x 47 µF	100 µF	85	170	210

Table 5. Recommended Input/Output Capacitors(1)

VENDOR	SERIES	PART NUMBER	CAPACITOR CHARACTERISTICS		
			WORKING VOLTAGE (V)	CAPACITANCE (µF)	ESR (2) (mΩ)
Murata	X5R	GRM32ER61E226K	16	22	2
TDK	X5R	C3225X5R0J476K	6.3	47	2
Murata	X5R	GRM32ER60J476M	6.3	47	2
Sanyo	POSCAP	16TQC68M	16	68	50
Kemet	T520	T520V107M010ASE025	10	100	25
Sanyo	POSCAP	6TPE100MI	6.3	100	25
Sanyo	POSCAP	2R5TPE220M7	2.5	220	7
Kemet	T530	T530D227M006ATE006	6.3	220	6
Kemet	T530	T530D337M006ATE010	6.3	330	10
Sanyo	POSCAP	2TPF330M6	2.0	330	6
Sanyo	POSCAP	6TPE330MFL	6.3	330	15

(1) **Capacitor Supplier Verification**
Please verify availability of capacitors identified in this table.
RoHS, Lead-free and Material Details
Please consult capacitor suppliers regarding material composition, RoHS status, lead-free status, and manufacturing process requirements.
(2) Maximum ESR @ 100kHz, 25°C.

Transient Response

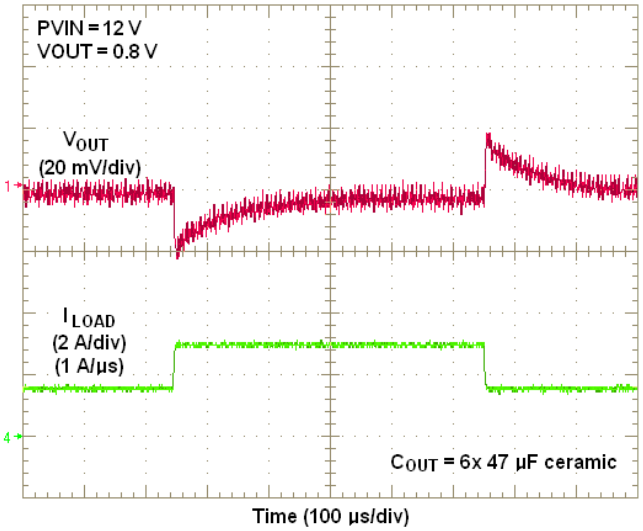


Figure 16. PVIN = 12V, VOUT = 0.8V, 1.5A Load Step

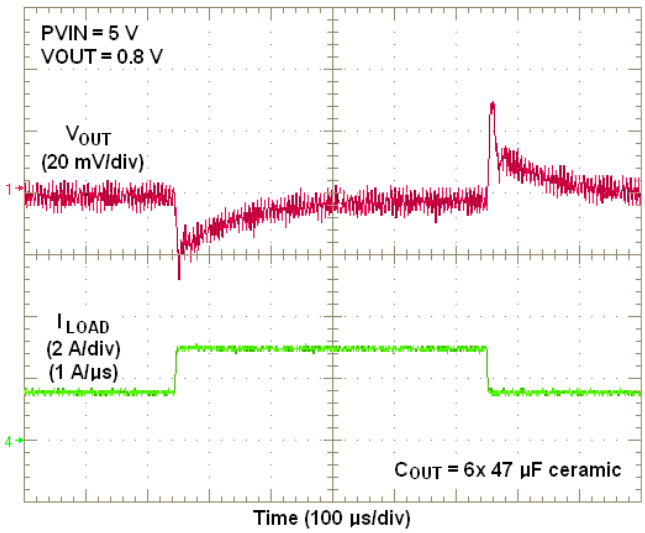


Figure 17. PVIN = 5V, VOUT = 0.8V, 1.5A Load Step

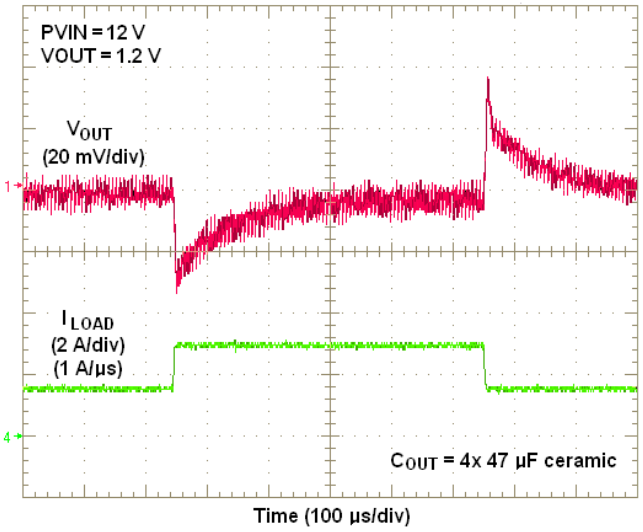


Figure 18. PVIN = 12V, VOUT = 1.2V, 1.5A Load Step

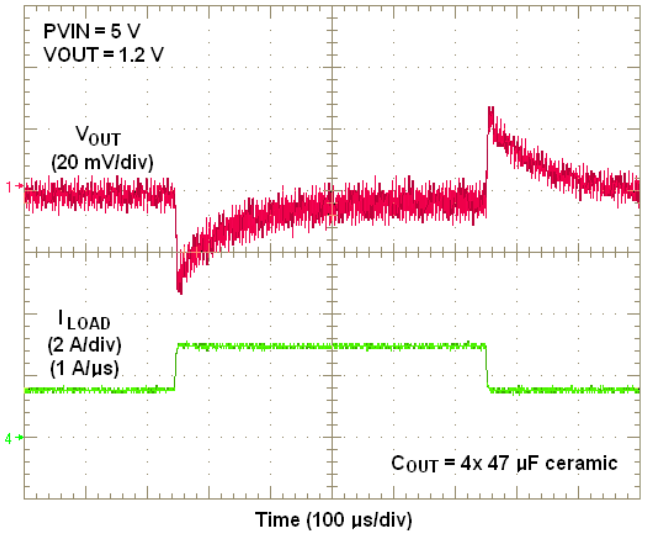


Figure 19. PVIN = 5V, VOUT = 1.2V, 1.5A Load Step

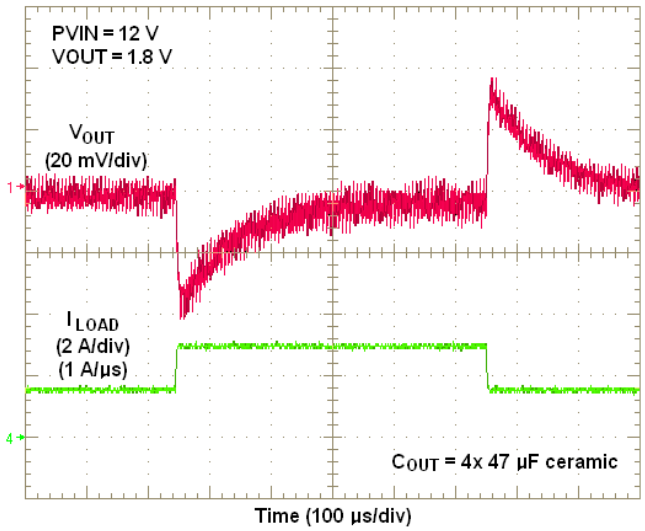


Figure 20. PVIN = 12V, VOUT = 1.8V, 1.5A Load Step

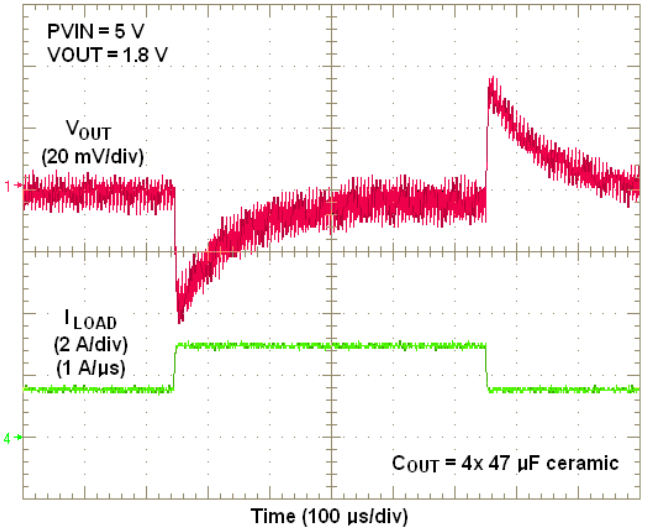


Figure 21. PVIN = 5V, VOUT = 1.8V, 1.5A Load Step

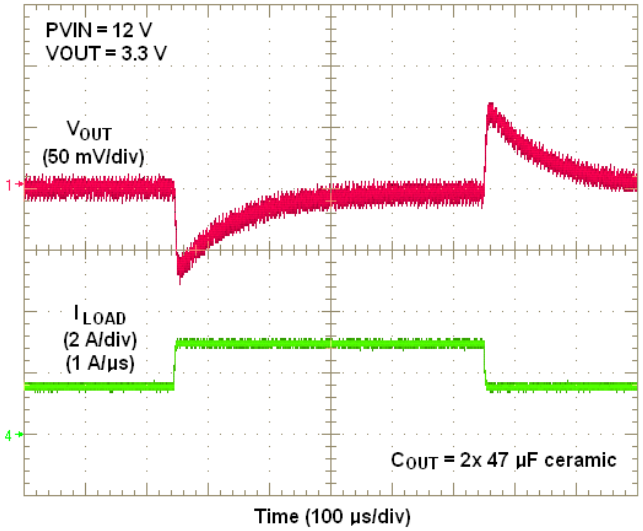


Figure 22. PVIN = 12V, VOUT = 3.3V, 1.5A Load Step

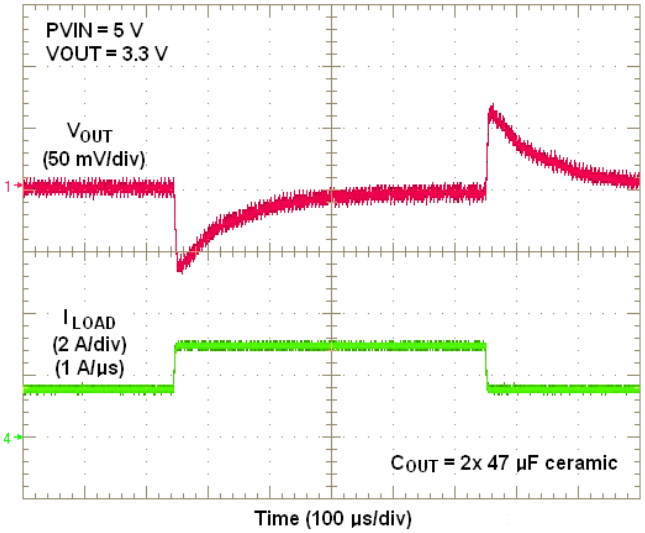


Figure 23. PVIN = 5V, VOUT = 3.3V, 1.5A Load Step

Application Schematics

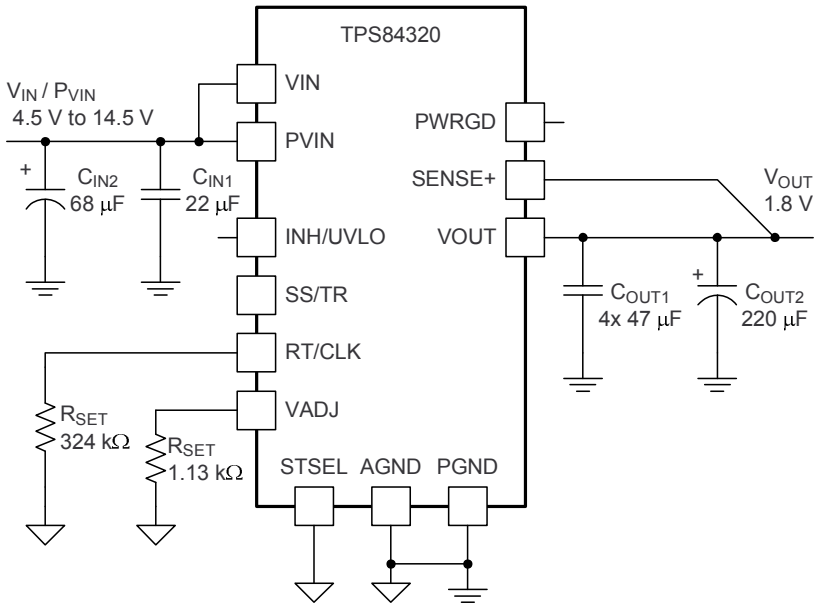


Figure 24. Typical Schematic
PVIN = VIN = 4.5 V to 14.5 V, VOUT = 1.8 V

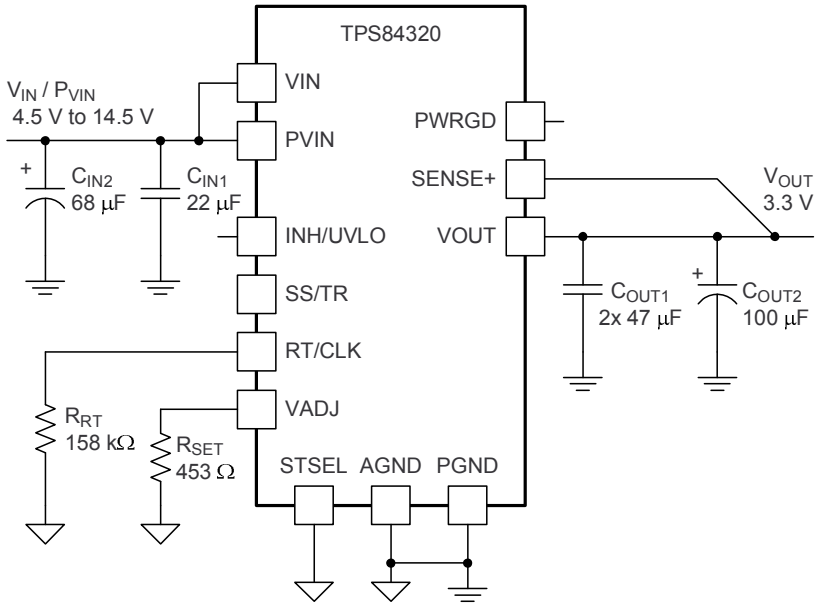


Figure 25. Typical Schematic
PVIN = VIN = 4.5 V to 14.5 V, VOUT = 3.3 V

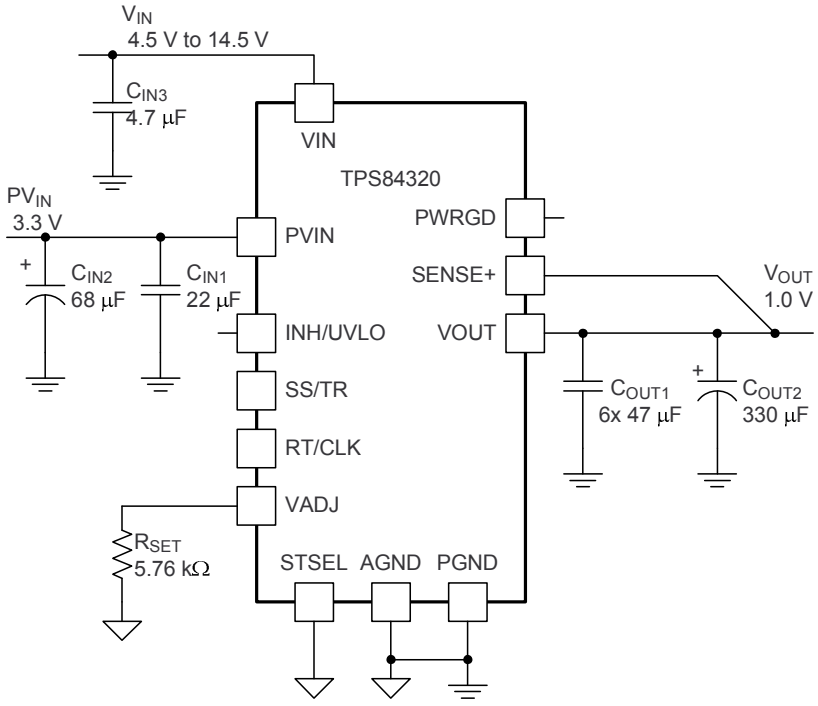


Figure 26. Typical Schematic
PVIN = 3.3 V, VIN = 4.5 V to 14.5 V, VOUT = 1.0 V

VIN and PVIN Input Voltage

The TPS84320 allows for a variety of applications by using the VIN and PVIN pins together or separately. The VIN voltage supplies the internal control circuits of the device. The PVIN voltage provides the input voltage to the power converter system.

If tied together, the input voltage for the VIN pin and the PVIN pin can range from 4.5 V to 14.5 V. If using the VIN pin separately from the PVIN pin, the VIN pin must be between 4.5 V and 14.5 V, and the PVIN pin can range from as low as 1.6 V to 14.5 V. A voltage divider connected to the INH/UVLO pin can adjust the either input voltage UVLO appropriately. See the Programmable Undervoltage Lockout (UVLO) section of this datasheet for more information.

Power Good (PWRGD)

The PWRGD pin is an open drain output. Once the voltage on the SENSE+ pin is between 94% and 106% of the set voltage, the PWRGD pin pull-down is released and the pin floats. The recommended pull-up resistor value is between 10 kΩ and 100 kΩ to a voltage source that is 5.5 V or less. The PWRGD pin is in a defined state once VIN is greater than 1.0 V, but with reduced current sinking capability. The PWRGD pin achieves full current sinking capability once the VIN pin is above 4.5V. The PWRGD pin is pulled low when the voltage on SENSE+ is lower than 91% or greater than 109% of the nominal set voltage. Also, the PWRGD pin is pulled low if the input UVLO or thermal shutdown is asserted, the INH pin is pulled low, or the SS/TR pin is below 1.4 V.

Power-Up Characteristics

When configured as shown in the front page schematic, the TPS84320 produces a regulated output voltage following the application of a valid input voltage. During the power-up, internal soft-start circuitry slows the rate that the output voltage rises, thereby limiting the amount of in-rush current that can be drawn from the input source. The soft-start circuitry introduces a short time delay from the point that a valid input voltage is recognized. Figure 27 shows the start-up waveforms for a TPS84320, operating from a 5-V input (PVIN=VIN) and with the output voltage adjusted to 1.8 V. Figure 28 shows the start-up waveforms for a TPS84320 starting up into a pre-biased output voltage. The waveforms were measured with a 2-A constant current load.

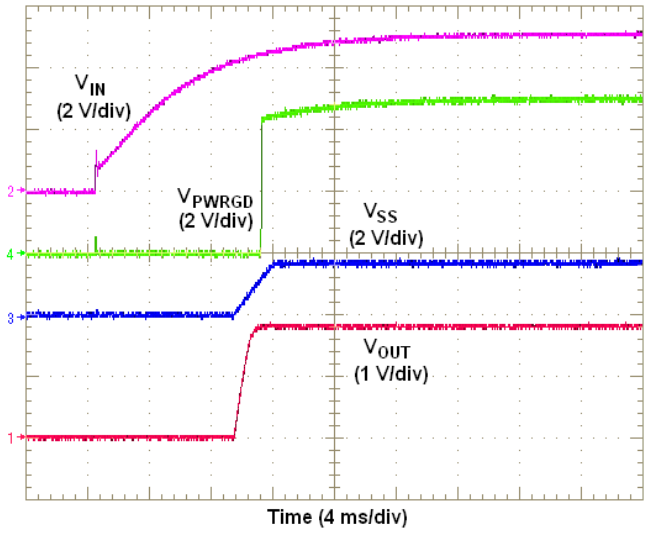


Figure 27. Start-Up Waveforms

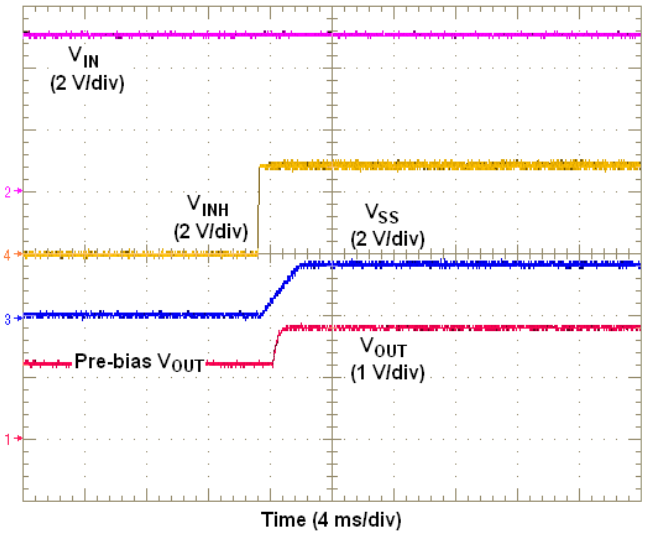


Figure 28. Start-up into Pre-bias

Pre-Biased Start-Up

The TPS84320 has been designed to prevent discharging a pre-biased output. During monotonic pre-biased startup, the TPS84320 does not allow current to sink until the SS/TR pin voltage is higher than 1.4 V.

Remote Sense

The SENSE+ pin must be connected to V_{OUT} at the load, or at the device pins.

Connecting the SENSE+ pin to V_{OUT} at the load improves the load regulation performance of the device by allowing it to compensate for any I-R voltage drop between its output pins and the load. An I-R drop is caused by the high output current flowing through the small amount of pin and trace resistance. This should be limited to a maximum of 300 mV.

NOTE

The remote sense feature is not designed to compensate for the forward drop of nonlinear or frequency dependent components that may be placed in series with the converter output. Examples include OR-ing diodes, filter inductors, ferrite beads, and fuses. When these components are enclosed by the SENSE+ connection, they are effectively placed inside the regulation control loop, which can adversely affect the stability of the regulator.

Output On/Off Inhibit (INH)

The INH pin provides electrical on/off control of the device. Once the INH pin voltage exceeds the threshold voltage, the device starts operation. If the INH pin voltage is pulled below the threshold voltage, the regulator stops switching and enters low quiescent current state.

The INH pin has an internal pull-up current source, allowing the user to float the INH pin for enabling the device. If an application requires controlling the INH pin, use an open drain/collector device, or a suitable logic gate to interface with the pin.

Figure 29 shows the typical application of the inhibit function. The Inhibit control has its own internal pull-up to VIN potential. An open-collector or open-drain device is recommended to control this input.

Turning Q1 on applies a low voltage to the inhibit control (INH) pin and disables the output of the supply, shown in Figure 30. If Q1 is turned off, the supply executes a soft-start power-up sequence, as shown in Figure 31. A regulated output voltage is produced within 10 ms. The waveforms were measured with a 2-A constant resistance load.

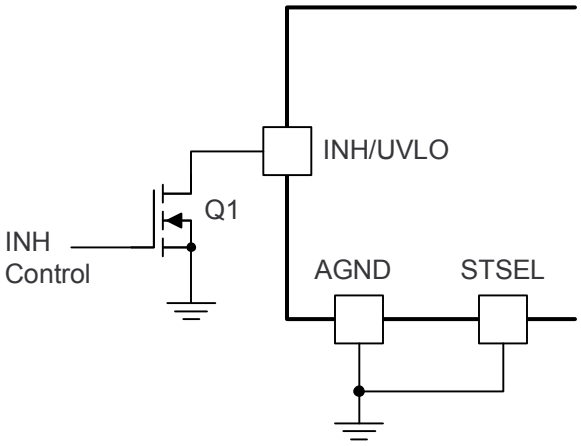


Figure 29. Typical Inhibit Control

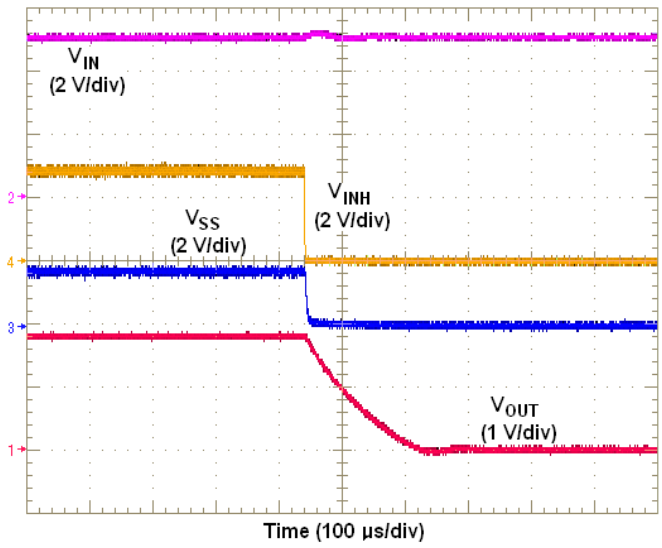


Figure 30. Inhibit Turn-Off

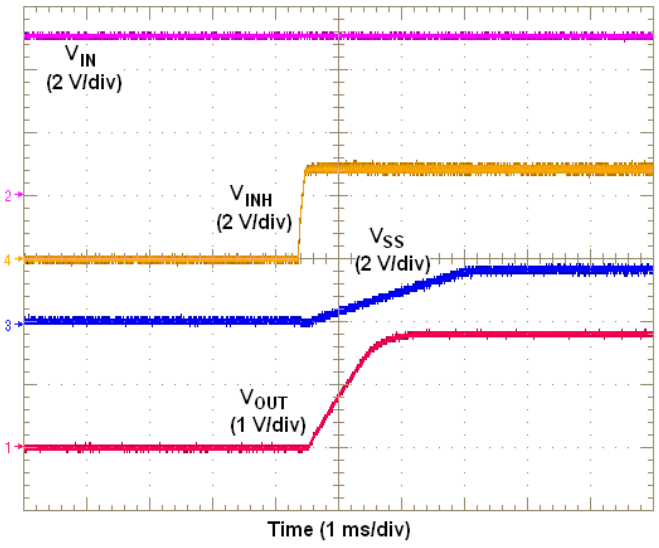


Figure 31. Inhibit Turn-On

Slow Start (SS/TR)

Connecting the STSEL pin to AGND and leaving SS/TR pin open enables the internal SS capacitor with a slow start interval of approximately 1.1 ms. Adding additional capacitance between the SS pin and AGND increases the slow start time. Table 6 shows an additional SS capacitor connected to the SS/TR pin and the STSEL pin connected to AGND. See Table 6 below for SS capacitor values and timing interval.

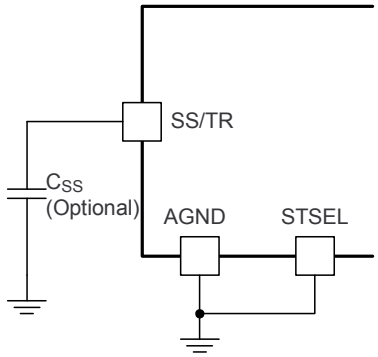


Figure 32. Slow-Start Capacitor (C_{SS}) and STSEL Connection

Table 6. Slow-Start Capacitor Values and Slow-Start Time

C_{SS} (pF)	open	2200	4700	10000	15000	22000	25000
SS Time (msec)	1.1	1.9	2.8	4.6	6.4	8.8	9.8

Overcurrent Protection

For protection against load faults, the TPS84320 incorpoates output overcurrent protection. Applying a load that exceeds the regulator's overcurrent threshold causes the regulated output to shut down. Following shutdown, the output voltage periodically attempts to recover by initiating a soft-start power-up. This is described as a *hiccup* mode of operation, whereby the module continues in a cycle of successive shutdown and power up until the load fault is removed, as shown in Figure 33. During this period, the average current flowing into the fault is significantly reduced. Once the fault is removed, the module automatically recovers and returns to normal operation, as shown in Figure 34.

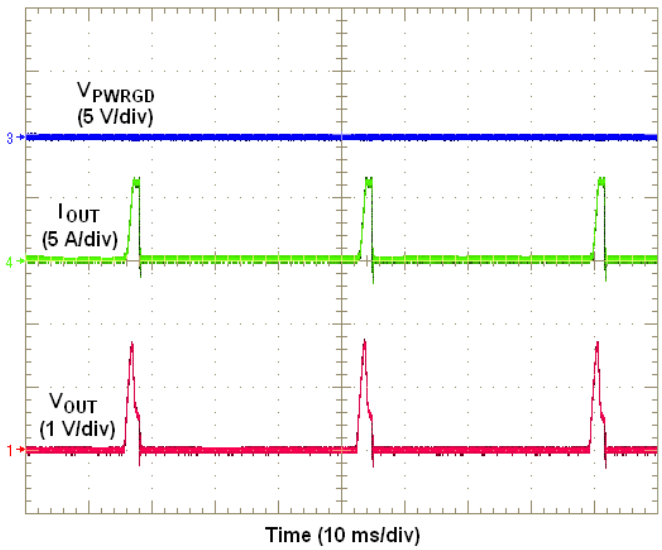


Figure 33. Overcurrent - Hiccup Mode

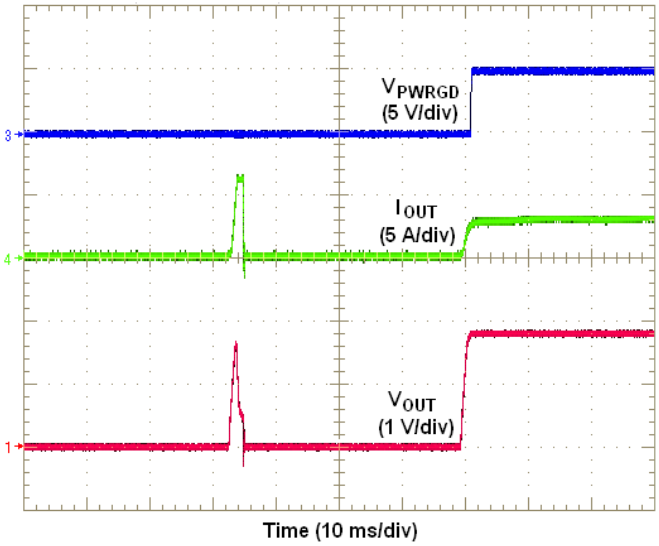


Figure 34. Removal of Overcurrent Condition

Synchronization (CLK)

An internal phase locked loop (PLL) has been implemented to allow synchronization between 330 kHz and 780 kHz, and to easily switch from RT mode to CLK mode. To implement the synchronization feature, connect a square wave clock signal to the RT/CLK pin with a duty cycle between 20% to 80%. The clock signal amplitude must transition lower than 0.8 V and higher than 2.0 V. The start of the switching cycle is synchronized to the falling edge of RT/CLK pin. In applications where both RT mode and CLK mode are needed, the device can be configured as shown in .

Before the external clock is present, the device works in RT mode and the switching frequency is set by RT resistor (R_{RT}). When the external clock is present, the CLK mode overrides the RT mode. The first time the CLK pin is pulled above the RT/CLK high threshold (2.0 V), the device switches from RT mode to th CLK mode and the RT/CLK pin becomes high impedance as the PLL starts to lock onto the frequency of the external clock. It is not recommended to switch from CLK mode back to RT mode because the internal switching frequency drops to 100 kHz and may shut-down due to internal protection circuits before returning to the switching frequency set by the RT resistor.

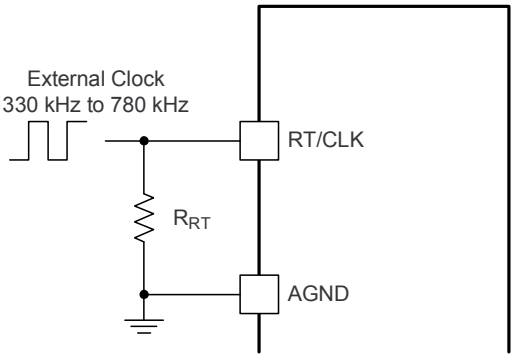


Figure 35. CLK/RT Configuration

The synchronization frequency must be selected based on the output voltages of the devices being synchronized. Table 7 shows the allowable frequencies for a given range of output voltages. For the most efficient solution, always synchronize to the lowest allowable frequency. For example, an application requires synchronizing three TPS84320 devices with output voltages of 1.2 V, 1.8 V and 2.5 V, all powered from PVIN = 12 V. Table 7 shows that all three output voltages can be synchronized to frquencies between 480 kHz to 630 kHz. For best efficiency, choose 480 kHz as the sychronization frequency.

Table 7. Synchronization Frequency vs Output Voltage

SYNCHRONIZATION FREQUENCY (kHz)	R_{RT} (kΩ)	PVIN = 12 V		PVIN = 5 V	
		V_{OUT} RANGE (V)		V_{OUT} RANGE (V)	
		MIN	MAX	MIN	MAX
330	OPEN	0.8	1.5	0.8	4.3
380	1000	0.8	1.7		
430	499	0.8	2.1		
480	324	0.9	2.5		
530	237	1.0	2.9		
580	191	1.1	3.2		
630	158	1.2	3.7		
680	137	1.3	4.1		
730	118	1.4	4.7		
780	105	1.5	5.5		

Sequencing (SS/TR)

Many of the common power supply sequencing methods can be implemented using the SS/TR, INH and PWRGD pins. The sequential method is illustrated in Figure 36 using two TPS84320 devices. The PWRGD pin of the first device is coupled to the INH pin of the second device which enables the second power supply once the primary supply reaches regulation. Figure 37 shows sequential turn-on waveforms of two TPS84320 devices.

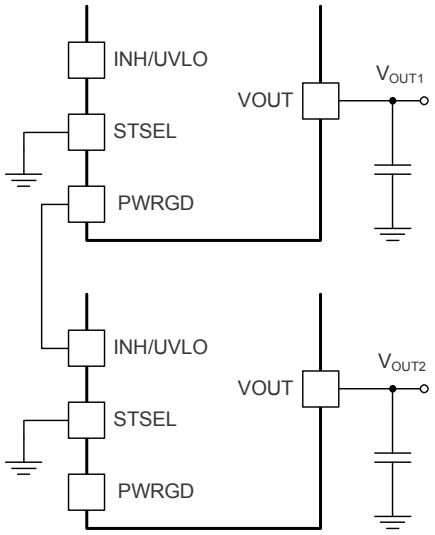


Figure 36. Sequencing Schematic

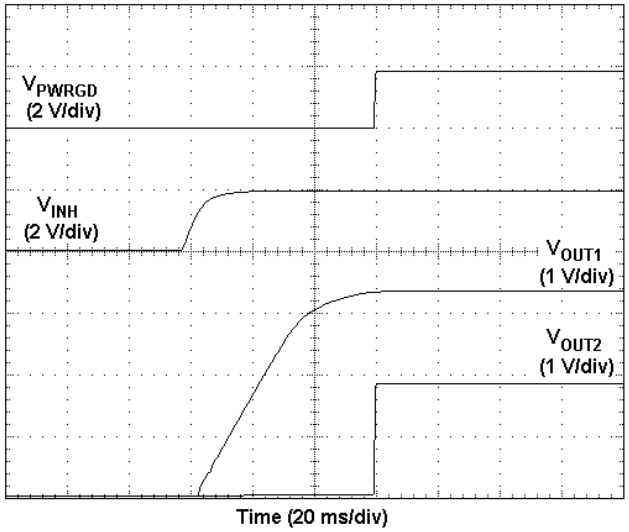


Figure 37. Sequencing Waveforms

Simultaneous power supply sequencing can be implemented by connecting the resistor network of R1 and R2 shown in Figure 38 to the output of the power supply that needs to be tracked or to another voltage reference source. Figure 39 shows simultaneous turn-on waveforms of two TPS84320 devices. Use Equation 2 and Equation 3 to calculate the values of R1 and R2.

$$R1 = \frac{(V_{OUT2} \times 12.6)}{0.8} (k\Omega) \quad (2)$$

$$R2 = \frac{0.8 \times R1}{(V_{OUT2} - 0.8)} (k\Omega) \quad (3)$$

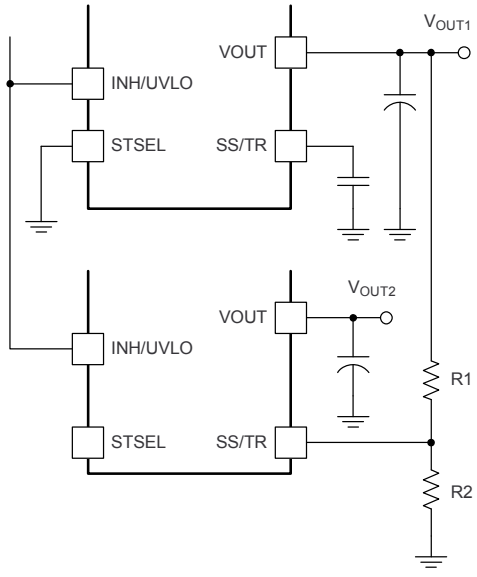


Figure 38. Simultaneous Tracking Schematic

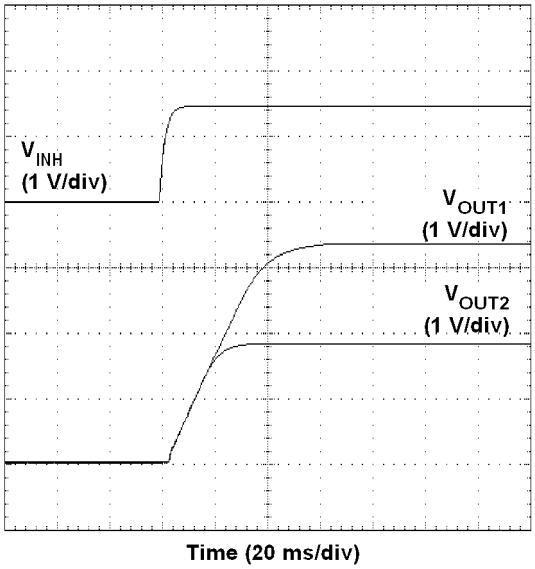


Figure 39. Simultaneous Tracking Waveforms

Programmable Undervoltage Lockout (UVLO)

The TPS84320 implements internal UVLO circuitry on the VIN pin. The device is disabled when the VIN pin voltage falls below the internal VIN UVLO threshold. The internal VIN UVLO rising threshold is 4.5 V(max) with a typical hysteresis of 150 mV.

If an application requires either a higher UVLO threshold on the VIN pin or a higher UVLO threshold for a combined VIN and PVIN, then the UVLO pin can be configured as shown in Figure 40 or Figure 41. Table 8 lists standard values for R_{UVLO1} and R_{UVLO2} to adjust the VIN UVLO voltage up.

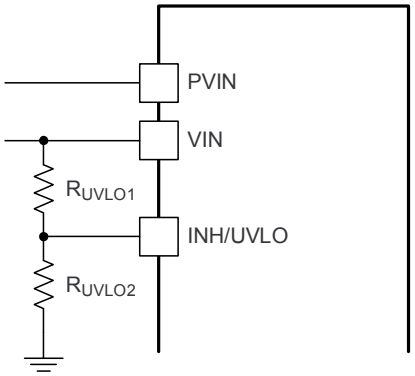


Figure 40. Adjustable VIN UVLO

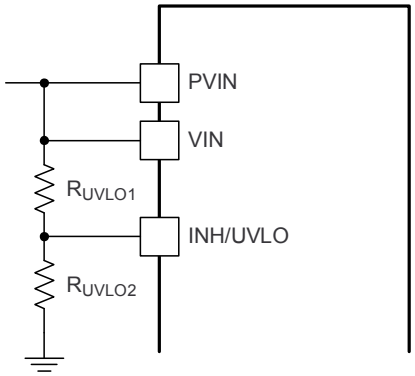


Figure 41. Adjustable VIN and PVIN Undervoltage Lockout

Table 8. Standard Resistor values for Adjusting VIN UVLO

VIN UVLO (V)	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
R_{UVLO1} (kΩ)	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1
R_{UVLO2} (kΩ)	21.5	18.7	16.9	15.4	14.0	13.0	12.1	11.3	10.5	9.76	9.31
Hysteresis (mV)	400	415	430	450	465	480	500	515	530	550	565

For a split rail application, if a secondary UVLO on PVIN is required, VIN must be ≥ 4.5V. Figure 42 shows the PVIN UVLO configuration. Use Table 9 to select R_{UVLO1} and R_{UVLO2} for PVIN. If PVIN UVLO is set for less than 3.0 V, a 5.1-V zener diode should be added to clamp the voltage on the UVLO pin below 6 V.

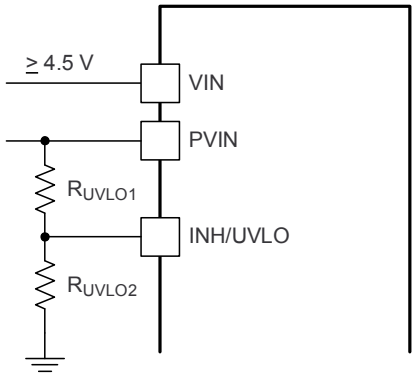


Figure 42. Adjustable PVIN Undervoltage Lockout, (VIN ≥4.5 V)

Table 9. Standard Resistor Values for Adjusting PVIN UVLO, (VIN ≥4.5 V)

PVIN UVLO (V)	2.0	2.5	3.0	3.5	4.0	4.5	
R_{UVLO1} (kΩ)	68.1	68.1	68.1	68.1	68.1	68.1	For higher PVIN UVLO voltages see Table UV for resistor values
R_{UVLO2} (kΩ)	95.3	60.4	44.2	34.8	28.7	24.3	
Hysteresis (mV)	300	315	335	350	365	385	

Thermal Shutdown

The internal thermal shutdown circuitry forces the device to stop switching if the junction temperature exceeds 175°C typically. The device reinitiates the power up sequence when the junction temperature drops below 165°C typically.

Layout Considerations

To achieve optimal electrical and thermal performance, an optimized PCB layout is required. Figure 43, shows a typical PCB layout. Some considerations for an optimized layout are:

- Use large copper areas for power planes (VIN, VOUT, and PGND) to minimize conduction loss and thermal stress.
- Place ceramic input and output capacitors close to the module pins to minimize high frequency noise.
- Locate additional output capacitors between the ceramic capacitor and the load.
- Place a dedicated AGND copper area beneath the TPS84320.
- Isolate the PH copper area from the VOUT copper area using the AGND copper area.
- Connect the AGND and PGND copper area at one point; near the output capacitors.
- Place R_{SET}, R_{RT}, and C_{SS} as close as possible to their respective pins.
- Use multiple vias to connect the power planes to internal layers.

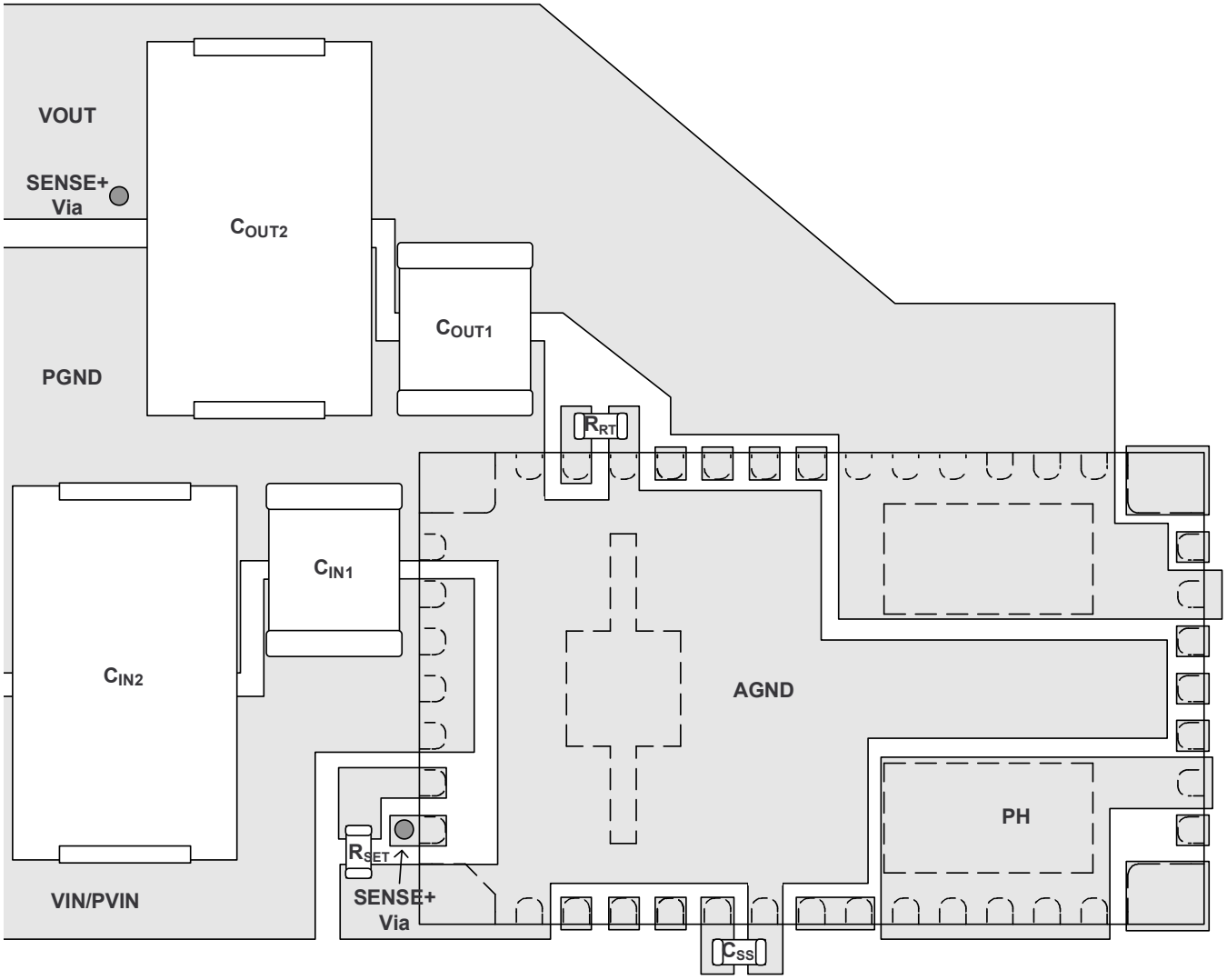


Figure 43. Typical Recommended Layout

EMI

The TPS84320 is compliant with EN55022 Class B radiated emissions. Figure 44 and Figure 45 show typical examples of radiated emissions plots for the TPS84320 operating from 5V and 12V respectively. Both graphs include the plots of the antenna in the horizontal and vertical positions.

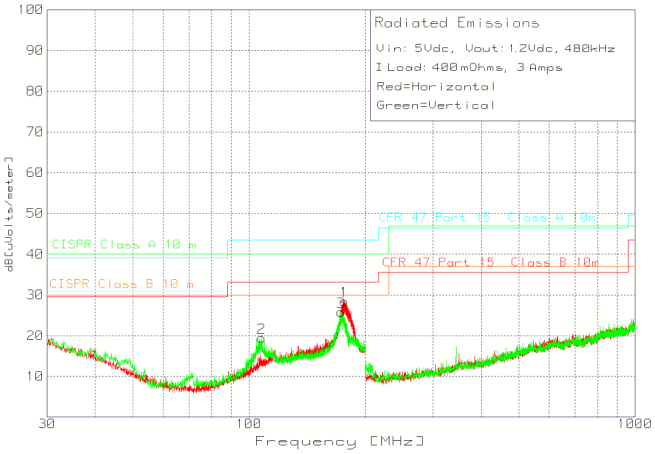


Figure 44. Radiated Emissions 5-V Input, 1.2-V Output, 3-A Load (EN55022 Class B)

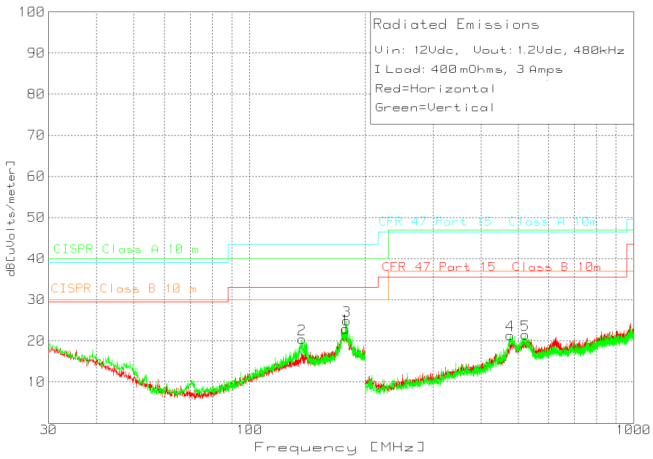


Figure 45. Radiated Emissions 12-V Input, 1.2-V Output, 3-A Load (EN55022 Class B)

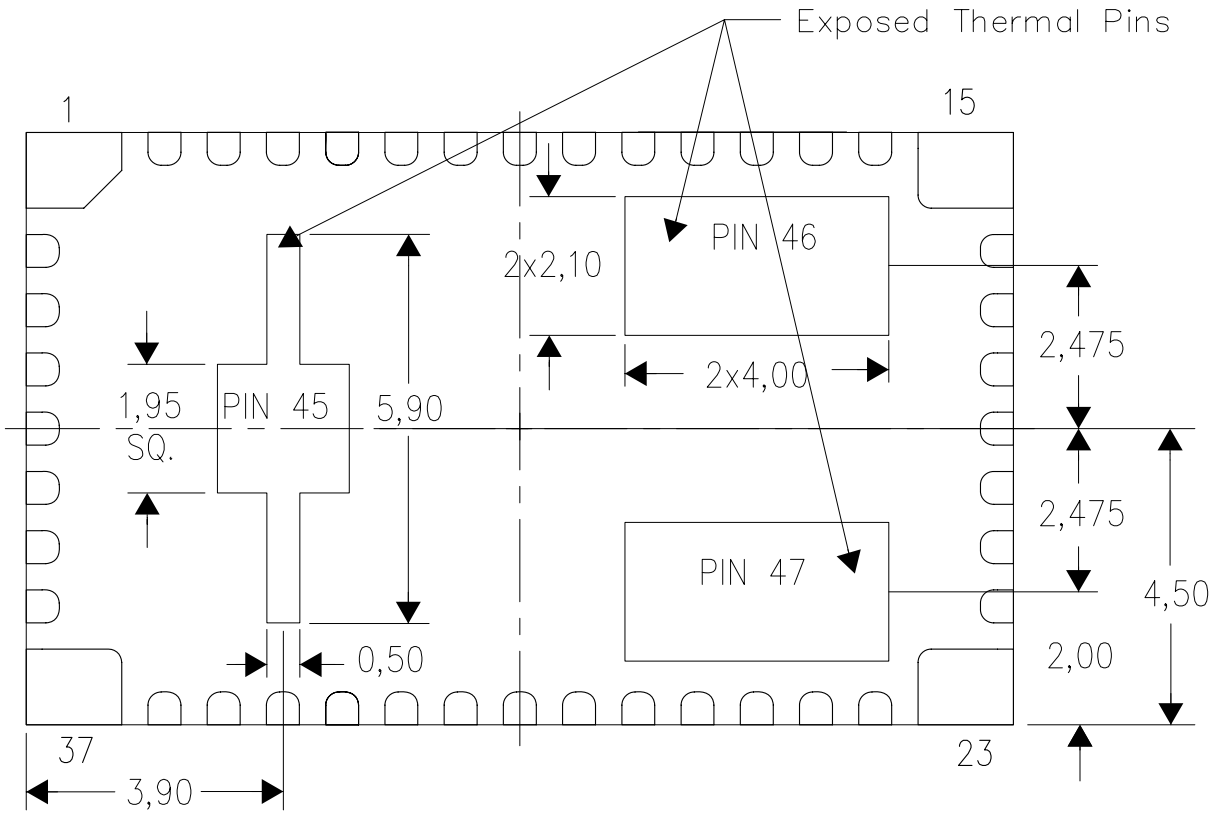
RUQ (R–PB1QFN–N47) PLASTIC QUAD FLATPACK NO–LEAD

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No–Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



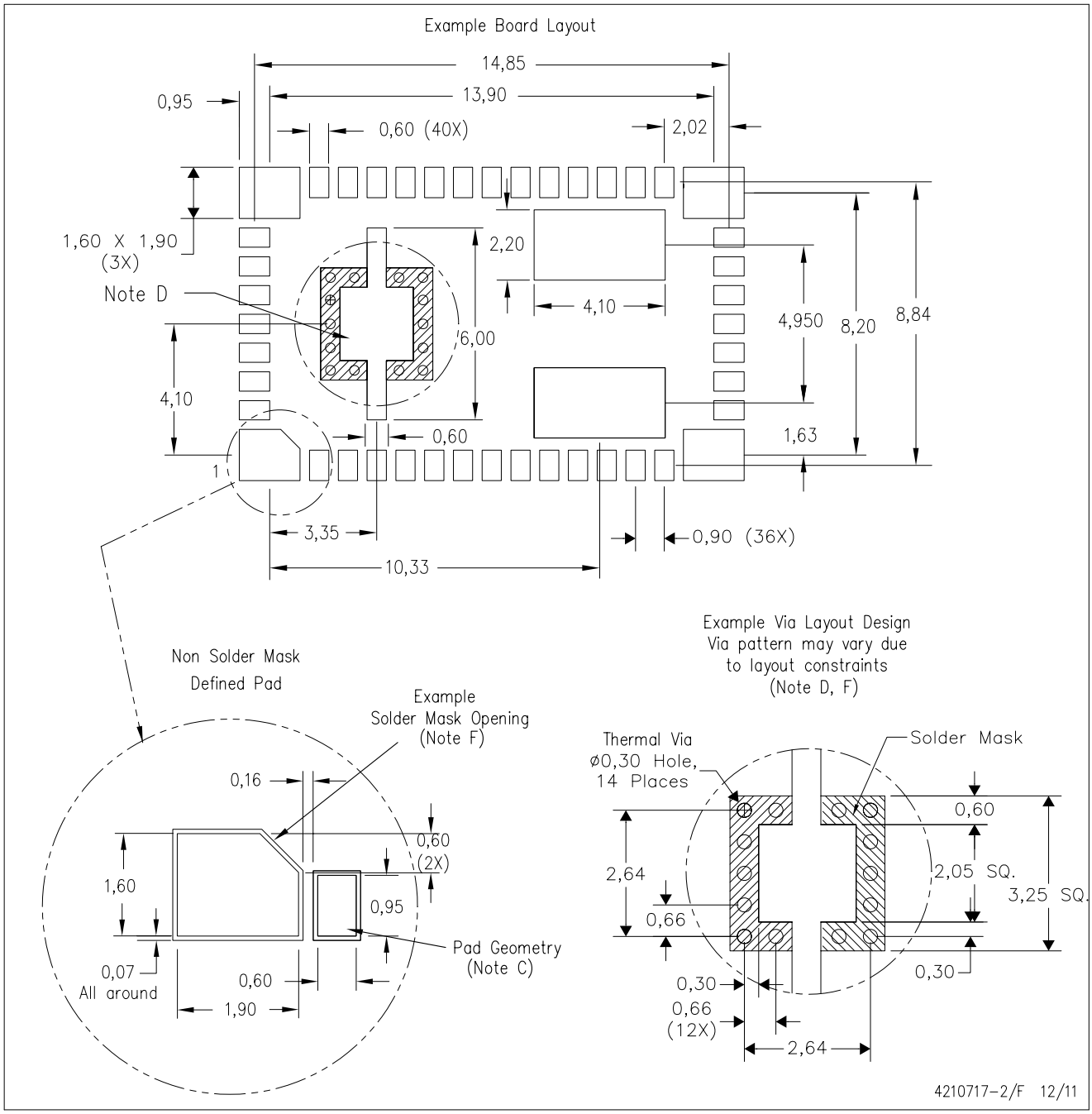
Bottom View

Exposed Thermal Pad Dimensions

4210496/C 09/10

NOTE: A. All linear dimensions are in millimeters

RUQ (R–PB1QFN–N47) PLASTIC QUAD FLATPACK NO–LEAD

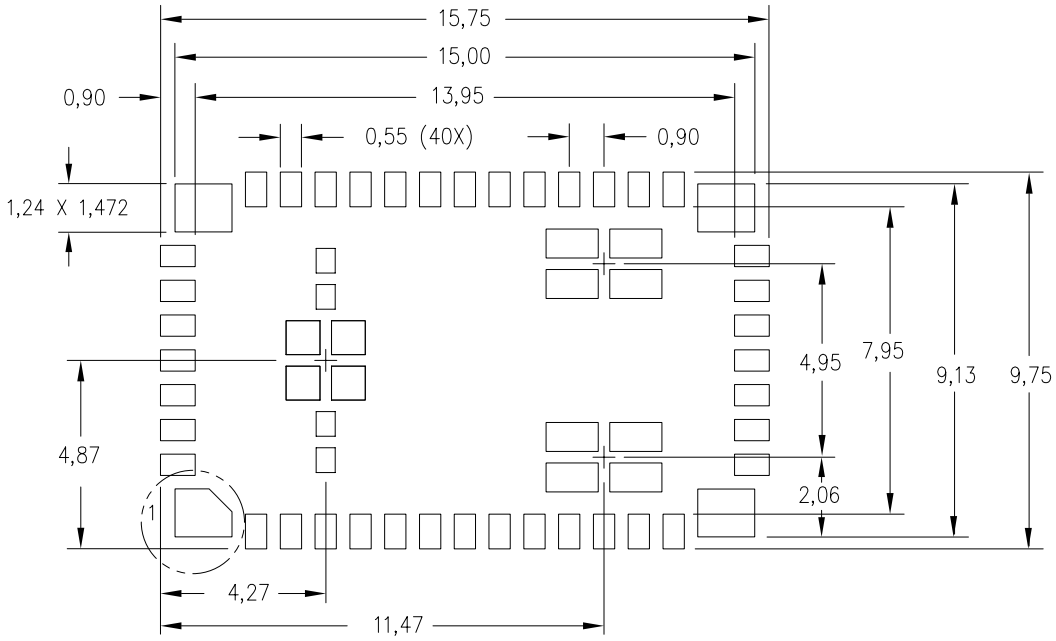


NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat–Pack Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <http://www.ti.com>.
E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
F. Customers should contact their board fabrication site for minimum solder mask web tolerances between signal pads.
G. See sheet 3 for stencil design recommendation..

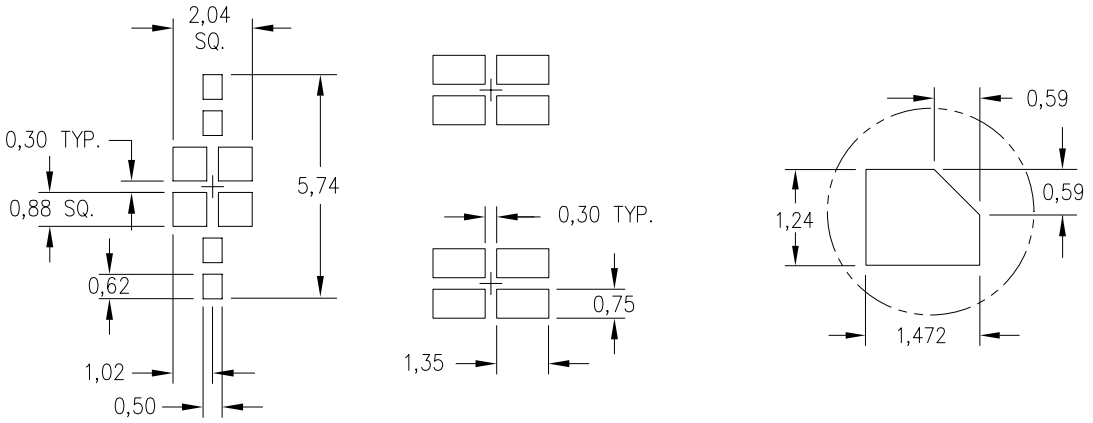
RUQ (R–PB1QFN–N47) PLASTIC QUAD FLATPACK NO–LEAD

DETAIL OF SHEET 2

Example Stencil Design (Note E)
Stencil Thickness = 0,125mm



60% solder coverage on center pads



4210717–3/F 12/11

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat–Pack Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <http://www.ti.com>.
E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
F. Customers should contact their board fabrication site for minimum solder mask web tolerances between signal pads.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TPS84320RUQR	ACTIVE	B1QFN	RUQ	47	500	RoHS (In Work) & Green (In Work)	CU NIPDAU	Level-3-240C-168 HR	-40 to 85	(54320 ~ TPS84320)	Samples
TPS84320RUQT	ACTIVE	B1QFN	RUQ	47	250	RoHS (In Work) & Green (In Work)	CU NIPDAU	Level-3-240C-168 HR	-40 to 85	(54320 ~ TPS84320)	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.

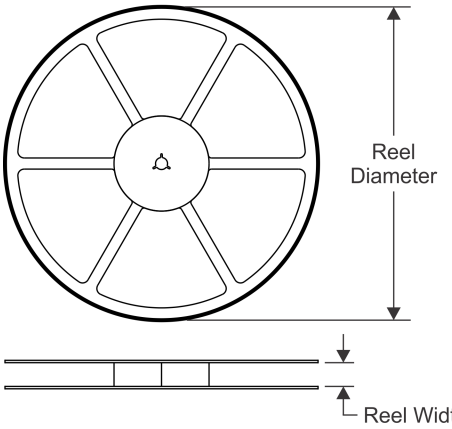
(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

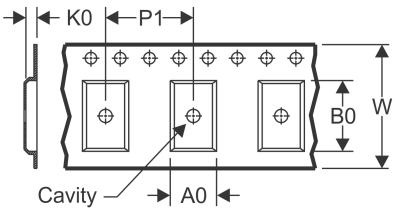
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

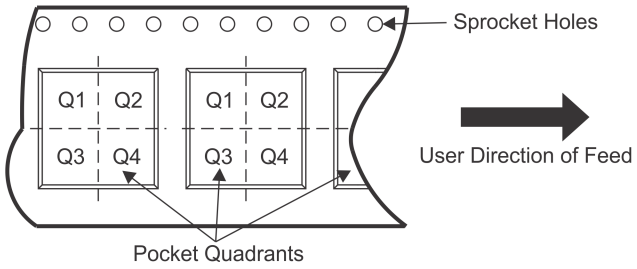


TAPE DIMENSIONS



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

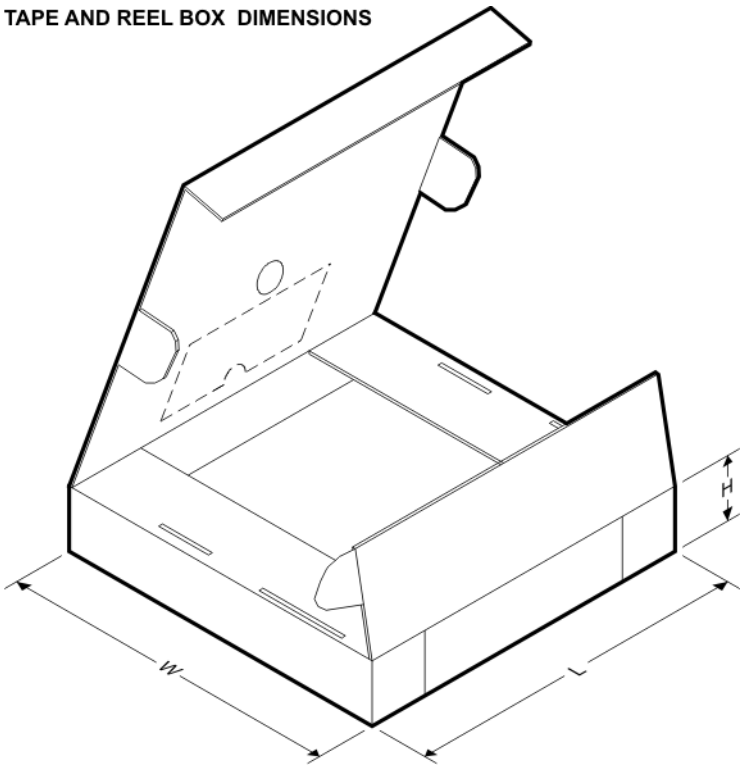
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
TPS84320RUQR	B1QFN	RUQ	47	500	330.0	24.4	9.35	15.35	3.1	16.0	24.0	Q1
TPS84320RUQT	B1QFN	RUQ	47	250	330.0	24.4	9.35	15.35	3.1	16.0	24.0	Q1

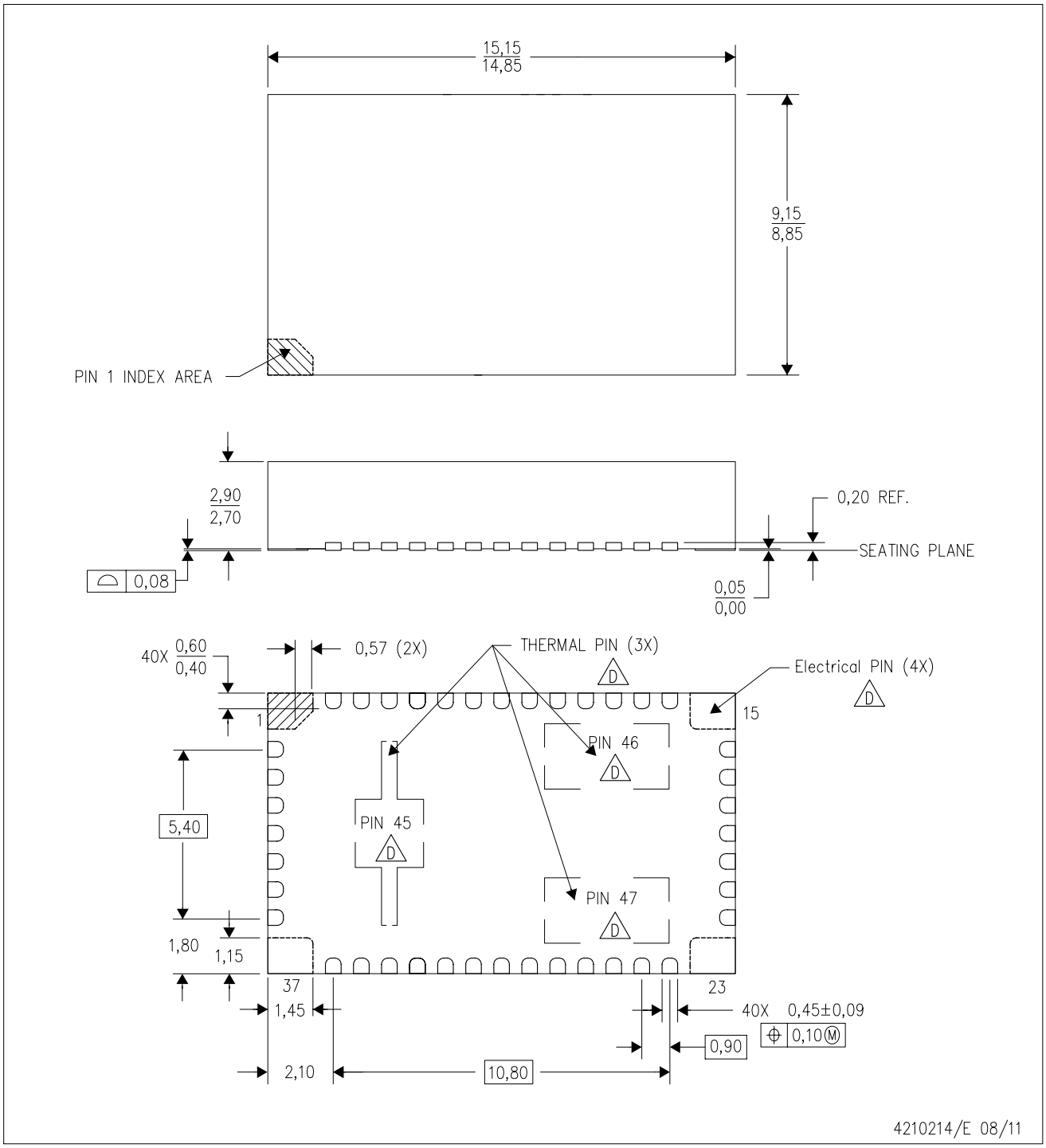
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS84320RUQR	B1QFN	RUQ	47	500	383.0	353.0	58.0
TPS84320RUQT	B1QFN	RUQ	47	250	383.0	353.0	58.0

RUQ (R–PB1QFN–N47) PLASTIC QUAD FLATPACK NO–LEAD



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. Quad Flatpack, No–leads (QFN) package configuration.
D. The package thermal pad must be soldered to the board for thermal and mechanical performance.
E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
F. The package thermal performance may be enhanced by bonding the thermal pad to an external thermal plane.

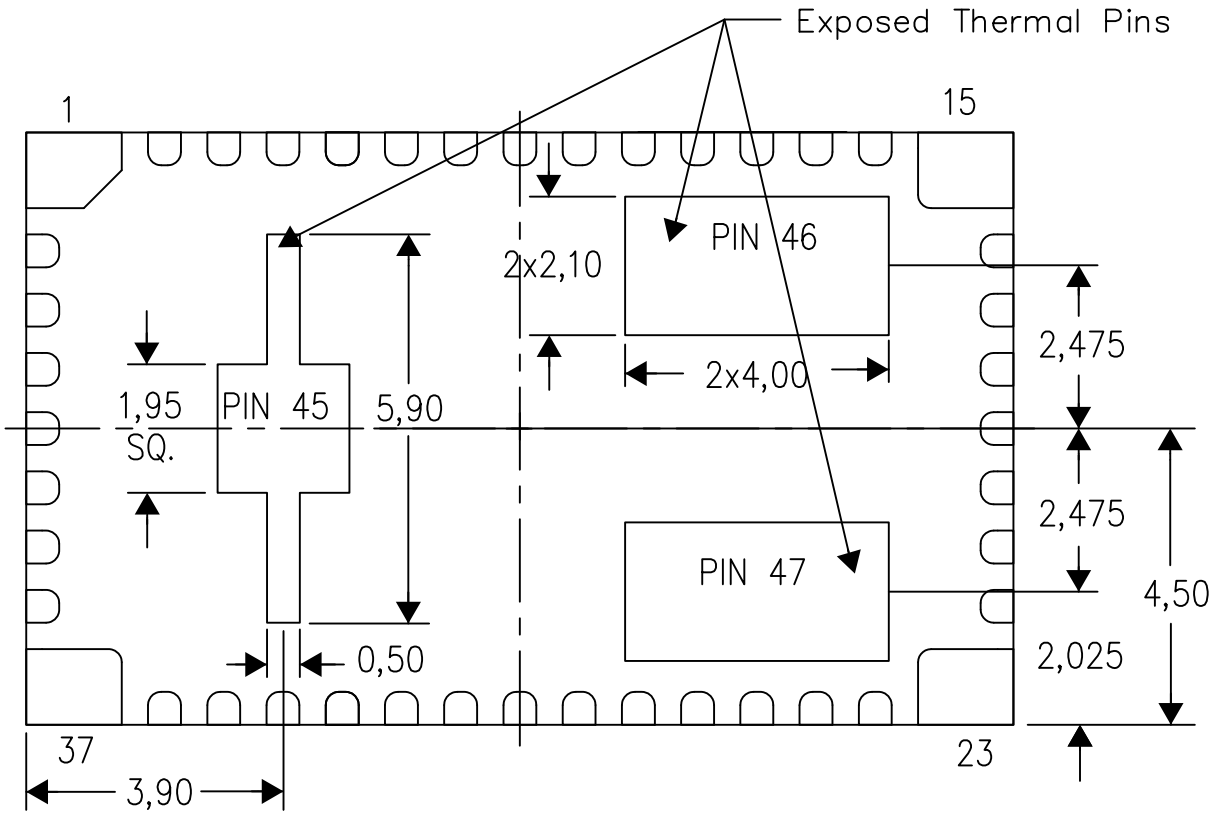
RUQ (R–PB1QFN–N47) PLASTIC QUAD FLATPACK NO–LEAD

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No–Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



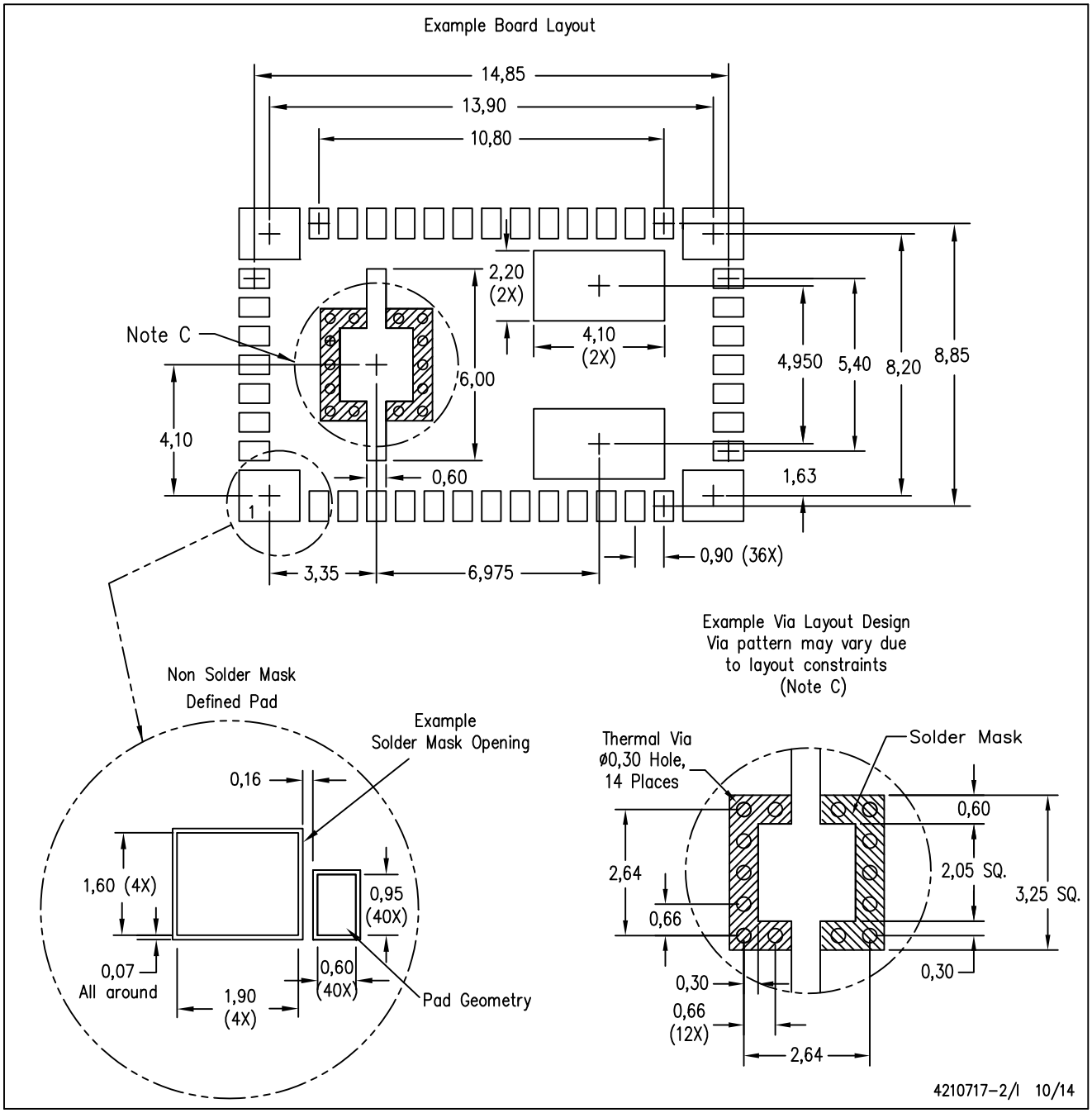
Bottom View

Exposed Thermal Pad Dimensions

4210496/D 07/14

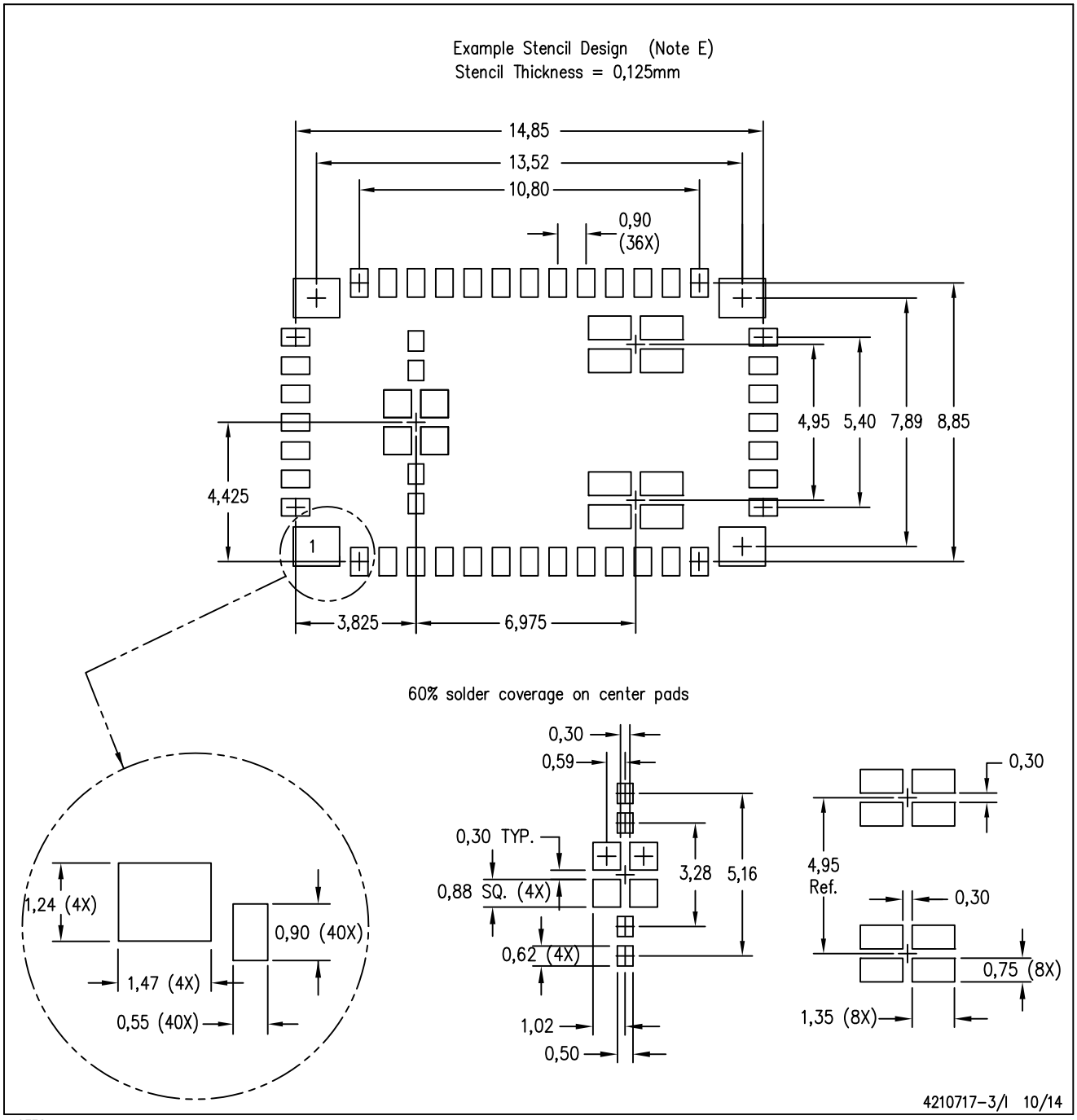
NOTE: A. All linear dimensions are in millimeters

RUQ (R–PB1QFN–N47) PLASTIC QUAD FLATPACK NO–LEAD



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat–Pack Packages, Texas Instruments Literature No. SCBA017, SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <http://www.ti.com>.
D. See next sheet for stencil design recommendation.

RUQ (R–PB1QFN–N47) PLASTIC QUAD FLATPACK NO–LEAD



NOTES:

E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.

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