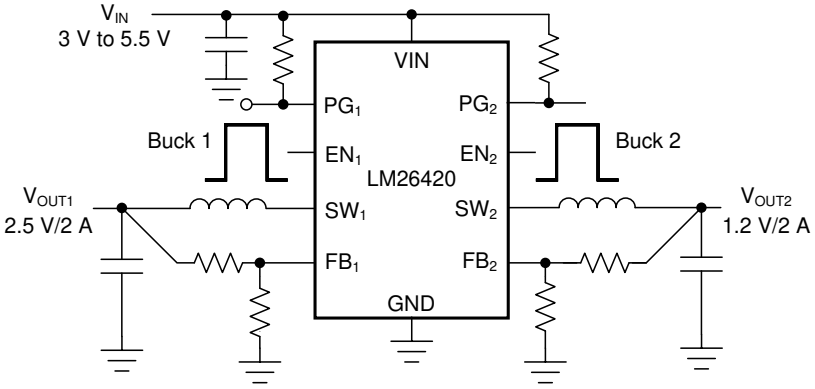
LM26420-Q1 デュアル 2A、車載用認定済み、高効率同期整流 DC/DC コンバータ

1 特長

- 車載アプリケーション認定済み
- 以下の結果で AEC Q100 認定済み:
  - デバイス温度グレード 0 (Q0):-40℃～+150℃の動作時周囲温度
  - デバイス温度グレード 1 (Q1):-40℃～+125℃の動作時周囲温度
- 機能安全対応
  - 機能安全システムの設計に役立つ資料を利用可能
- CISPR25 class 5 伝導エミッションに準拠
- 入力電圧範囲:3V～5.5V
- 出力電圧範囲:0.8V～4.5V
- レギュレータごとに 2A の出力電流
- 2.2MHz の固定スイッチング周波数
- 0.8V、1.5% 精度の内部基準電圧
- 内部ソフトスタート
- 出力ごとに独立のパワー グッドと高精度のイネーブル
- 電流モード、PWM 動作
- サーマル シャットダウン
- 過電圧保護
- 出力負荷をプリバイアスして起動可能
- レギュレータは 180°の位相差
- WEBENCH® Power Designer により、LM26420-Q1 を使用するカスタム設計を作成

2 アプリケーション

- 車載用インフォテインメントおよびクラスタ
- 先進運転支援システム (ADAS)



LM26420 デュアル降圧 DC/DC コンバータ

3 概要

LM26420-Q1 レギュレータはモノリシック、高効率のデュアル PWM 降圧型 DC/DC コンバータです。このデバイスは、最先端の BICMOS テクノロジを使用して、内蔵の 75mΩ MOS 上部スイッチと、内蔵の 50mΩ MOS 下部スイッチにより 2 つの 2A 負荷を駆動し、可能な最高の電力密度を実現しています。世界最高レベルの制御回路により、最短で 30ns のオン時間が可能なため、3V～5.5V の入力動作範囲全体から、最小出力電圧の 0.8V に非常に高周波で変換できます。

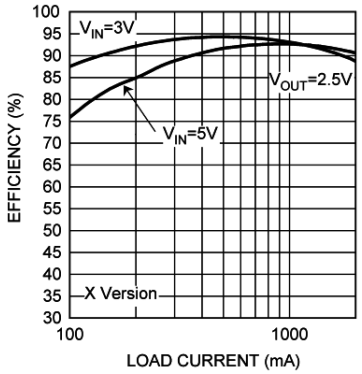
動作周波数が高いにもかかわらず、93%までの高い効率を簡単に実現できます。外部からのシャットダウン機能を備えており、非常に低いスタンバイ電流が特長です。LM26420-Q1 は電流モード制御と内部補償を使用し、広範な動作条件にわたって高性能のレギュレーションを行います。

LM26420-Q1 はスイッチング周波数が 2MHz を超えることが保証されているため、AM 周波数帯域に干渉することなく車載用アプリケーションで使用できます。

パッケージ情報

部品番号	パッケージ (1)	パッケージ サイズ(2)
LM26420-Q1	PWP (HTSSOP、20)	6.5mm × 6.4mm
	RUM (WQFN、16)	4mm × 4mm

(1) 詳細については、セクション 10 を参照してください。
(2) パッケージ サイズ (長さ × 幅) は公称値であり、該当する場合はピンも含まれます。



LM26420 の効率(最高 93%)

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4 Pin Configuration and Functions

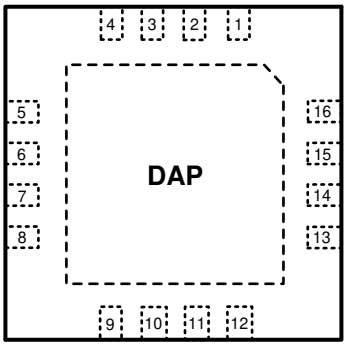


図 4-1. RUM Package 16-Pin WQFN Top View

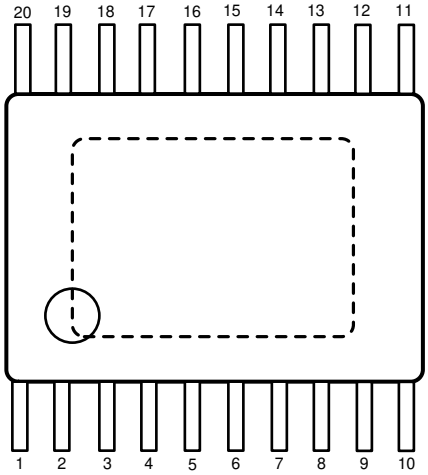


図 4-2. PWP Package 20-Pin HTSSOP Top View

表 4-1. Pin Functions: 16-Pin WQFN

PIN		TYPE(1)	DESCRIPTION
NUMBER	NAME		
1,2	$VIND_1$	P	Power input supply for Buck 1
3	SW_1	P	Output switch for Buck 1. Connect to the inductor.
4	$PGND_1$	G	Power ground pin for Buck 1
5	FB_1	A	Feedback pin for Buck 1. Connect to external resistor divider to set output voltage.
6	PG_1	G	Power-Good Indicator for Buck 1. Pin is connected through a resistor to an external supply (open-drain output).
7	PG_2	G	Power-Good Indicator for Buck 2. Pin is connected through a resistor to an external supply (open-drain output).
8	FB_2	A	Feedback pin for Buck 2. Connect to external resistor divider to set output voltage.
9	$PGND_2$	G	Power ground pin for Buck 2
10	SW_2	P	Output switch for Buck 2. Connect to the inductor.
11, 12	$VIND_2$	A	Power Input supply for Buck 2
13	EN_2	A	Enable control input. Logic high enable operation for Buck 2. Do not allow this pin to float or be greater than V_{IN} + 0.3 V.
14	AGND	G	Signal ground pin. Place the bottom resistor of the feedback network as close as possible to pin.
15	VINC	A	Input supply for control circuitry
16	EN_1	A	Enable control input. Logic high enable operation for Buck 1. Do not allow this pin to float or be greater than V_{IN} + 0.3 V.
DAP	Die Attach Pad	—	Connect to system ground for low thermal impedance and as a primary electrical GND connection.

(1) A = analog, P = power, G = ground

表 4-2. Pin Functions: 20-Pin HTSSOP

PIN		TYPE(1)	DESCRIPTION
NUMBER	NAME		
1	VINC	A	Input supply for control circuitry
2	EN_1	A	Enable control input. Logic high enable operation for Buck 1. Do not allow this pin to float or be greater than V_{IN} + 0.3 V.
3, 4	$VIND_1$	A	Power Input supply for Buck 1
5	SW_1	P	Output switch for Buck 1. Connect to the inductor.
6,7	$PGND_1$	G	Power ground pin for Buck 1
8	FB_1	A	Feedback pin for Buck 1. Connect to external resistor divider to set output voltage.
9	PG_1	G	Power Good Indicator for Buck 1. Pin is connected through a resistor to an external supply (open-drain output).
10, 11, DAP	Die Attach Pad	—	Connect to system ground for low thermal impedance, but this pin cannot be used as a primary GND connection.
12	PG_2	G	Power Good Indicator for Buck 2. Pin is connected through a resistor to an external supply (open-drain output).
13	FB_2	A	Feedback pin for Buck 2. Connect to external resistor divider to set output voltage.
14, 15	$PGND_2$	G	Power ground pin for Buck 2
16	SW_2	P	Output switch for Buck 2. Connect to the inductor.
17, 18	$VIND_2$	A	Power Input supply for Buck 2
19	EN_2	A	Enable control input. Logic high enable operation for Buck 2. Do not allow this pin to float or be greater than V_{IN} + 0.3 V.
20	AGND	G	Signal ground pin. Place the bottom resistor of the feedback network as close as possible to pin.

(1) A = analog, P = power, G = ground

5 Specifications

5.1 Absolute Maximum Ratings

Over operating free-air temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
Input voltages	VIN	–0.5	7	V
	FB	–0.5	3	
	EN	–0.5	7	
Output voltages	SW	–0.5	7	V
Infrared or convection reflow (15 sec)	Soldering Information		220	°C
Storage temperature T_{stg}		–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

5.2 ESD Ratings

				VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per AEC Q100-002(1)		±2000	V
		Charged-device model (CDM), per AEC Q100-011	Other pins	±750	
			Corner pins 1, 10, 11, and 20	±750	

(1) AEC Q100-002 indicates that HBM stressing must be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

5.3 Recommended Operating Conditions

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

	MIN	MAX	UNIT
V_{IN}	3	5.5	V
Junction temperature (Q1)	–40	125	°C
Junction temperature (Q0)	–40	150	

5.4 Thermal Information

THERMAL METRIC(1)		LM26420-Q1		UNIT
		PWP (HTSSOP)	RUM (WQFN)	
		20 PINS	16 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	38.5	36.2	°C/W
$R_{\theta JC(top)}$	Junction-to-case thermal resistance	21.0	32.7	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	19.9	14.1	°C/W
ψ_{JT}	Junction-to-top characterization parameter	0.7	0.3	°C/W
ψ_{JB}	Junction-to-board characterization parameter	19.7	14.2	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	3.5	4.1	°C/W

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

5.5 Electrical Characteristics Per Buck

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{FB}	Feedback voltage		0.788	0.8	0.812	V
$\Delta V_{FB}/V_{IN}$	Feedback Voltage line regulation	V_{IN} = 3 V to 5.5 V		0.05		%/V
I_B	Feedback input bias current			0.4	100	nA
UVLO	Undervoltage lockout	V_{IN} rising, HTSSOP-20 package		2.628	2.9	V
		V_{IN} Rising, WQFN-16 Package		2.75	2.9	V
		V_{IN} falling, HTSSOP-20 package	2	2.3		V
		V_{IN} Falling, WQFN-16 Package	2	2.5		V
	UVLO hysteresis	HTSSOP-20 Package		330		mV
		WQFN-16 Package		260		mV
F_{SW}	Switching frequency		2.01	2.2	2.65	MHz
F_{FB}	Frequency foldback	HTSSOP-20 Package		300		kHz
D_{MAX}	Maximum duty cycle		86%	91.5%		
R_{DSON_TOP}	TOP switch on resistance	WQFN-16 package		75	135	mΩ
		HTSSOP-20 package		70	135	
R_{DSON_BOT}	BOTTOM switch on resistance	WQFN-16 package		55	100	mΩ
		HTSSOP-20 package		45	80	
I_{CL_TOP}	TOP switch current limit	V_{IN} = 3.3 V	2.4	3.3		A
I_{CL_BOT}	BOTTOM Switch reverse current limit	V_{IN} = 3.3 V, HTSSOP-20 Package	0.4	0.75		A
		V_{IN} = 3.3V, WQFN-16 Package	0.4	1.0		A
ΔΦ	Phase shift between SW_1 and SW_2		160	180	200	°
V_{EN_TH}	Enable threshold voltage		0.97	1.04	1.12	V
	Enable threshold hysteresis			0.15		
I_{SW_TOP}	Switch leakage			–0.7		µA
I_{EN}	Enable pin current	Sink/source		5		nA
$V_{PG\text{-}TH\text{-}U}$	Upper Power-Good threshold	FB pin voltage rising	848	925	1,008	mV
	Upper Power-Good hysteresis			40		mV
$V_{PG\text{-}TH\text{-}L}$	Lower Power-Good threshold	FB pin voltage rising	656	710	791	mV
	Lower Power-Good hysteresis			40		mV
I_{QVINC}	VINC quiescent current (non-switching) with both outputs on	V_{FB} = 0.95 V		3.3	5	mA
	VINC quiescent current (switching) with both outputs on	V_{FB} = 0.7 V		4.7	6.2	
	VINC quiescent current (shutdown)	V_{EN} = 0 V		0.05		µA
I_{QVIND}	VIND quiescent current (non-switching)	V_{FB} = 0.95 V		0.9	1.5	mA
	VIND quiescent current (switching)	V_{FB} = 0.7 V		11	15	
I_{QVIND}	VIND Quiescent Current (switching)	LM26420Q0 V_{FB} = 0.7 V		11	18	mA
I_{QVIND}	VIND quiescent current (shutdown)	V_{EN} = 0 V		0.1		µA
T_{SD}	Thermal shutdown temperature			165		°C

5.6 Typical Characteristics

All curves taken at V_{IN} = 5 V with configuration in typical application circuits shown in セクション 7. T_J = 25°C, unless otherwise specified.

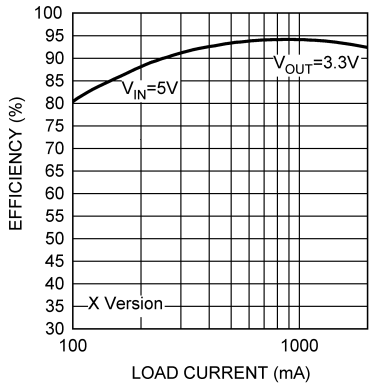


図 5-1. Efficiency vs Load

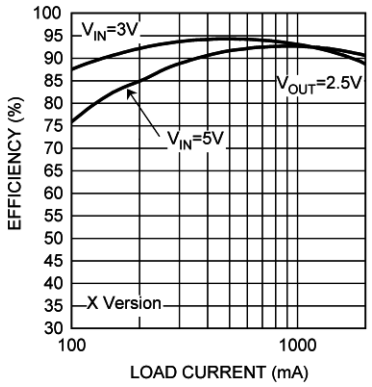


図 5-2. Efficiency vs Load

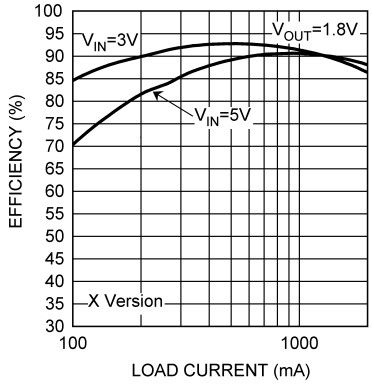


図 5-3. Efficiency vs Load

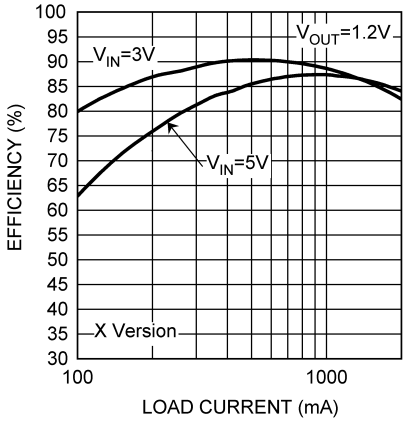


図 5-4. Efficiency vs Load

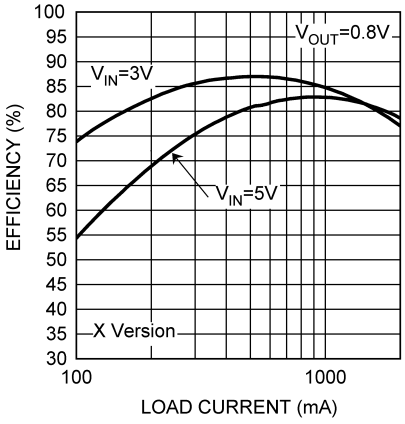
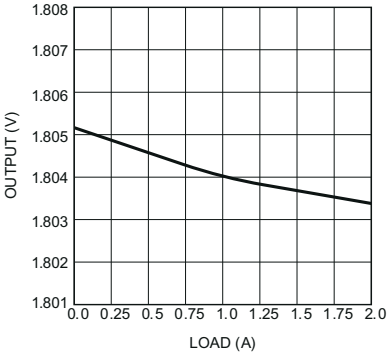


図 5-5. Efficiency vs Load

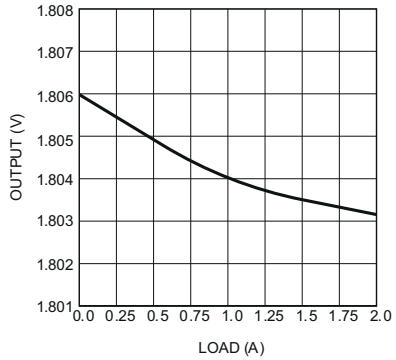


V_{IN} = 5 V V_{OUT} = 1.8 V

図 5-6. Load Regulation

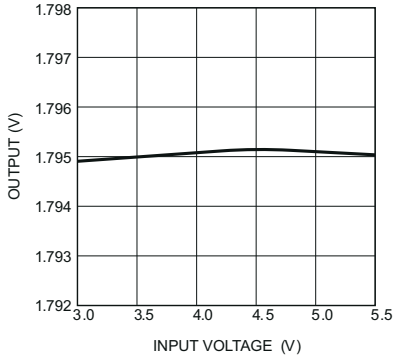
5.6 Typical Characteristics (continued)

All curves taken at V_{IN} = 5 V with configuration in typical application circuits shown in セクション 7. T_J = 25°C, unless otherwise specified.



V_{IN} = 3 V V_{OUT} = 1.8 V

図 5-7. Load Regulation



V_{OUT} = 1.8 V I_{OUT} = 1000 mA

図 5-8. Line Regulation

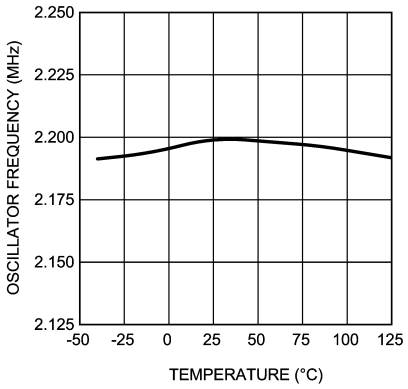


図 5-9. Oscillator Frequency vs Temperature,

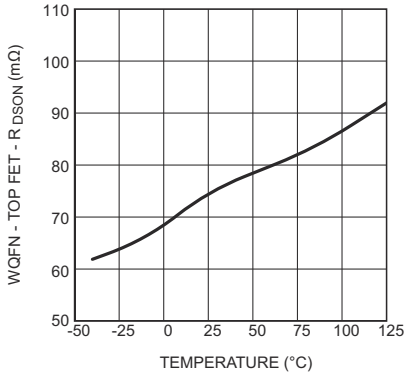


図 5-10. R_{DSON} Top Vs Temperature (WQFN-16 Package)

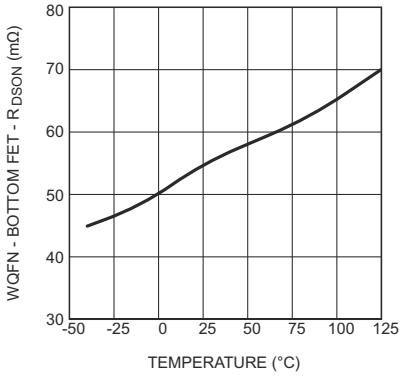


図 5-11. R_{DSON} Bottom Vs Temperature (WQFN-16 Package)

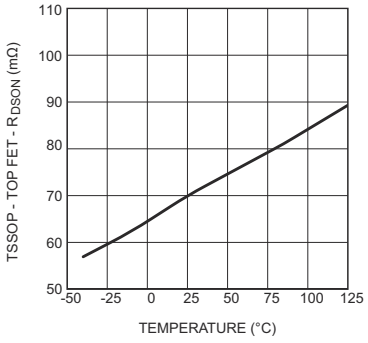


図 5-12. R_{DSON} Top Vs Temperature (HTSSOP-20 Package)

5.6 Typical Characteristics (continued)

All curves taken at V_{IN} = 5 V with configuration in typical application circuits shown in セクション 7. T_J = 25°C, unless otherwise specified.

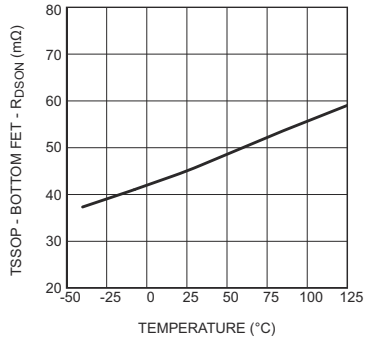


図 5-13. R_{DSON} Bottom vs Temperature (HTSSOP-20 Package)

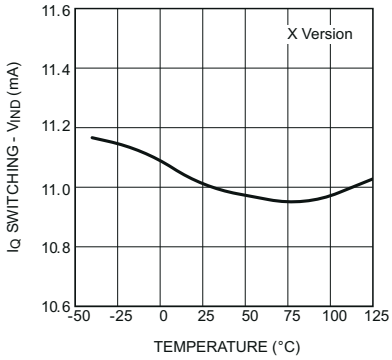


図 5-14. I_Q (Quiescent Current Switching)

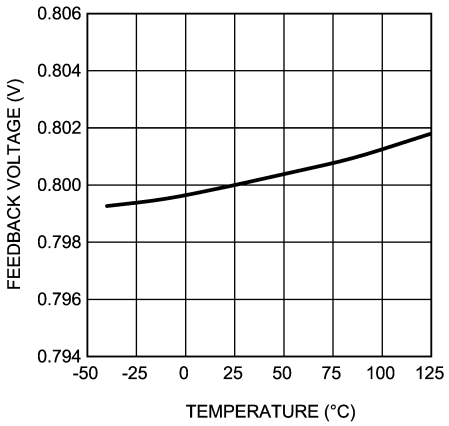
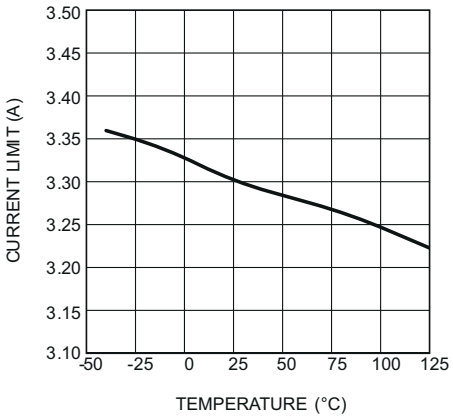


図 5-15. V_{FB} vs Temperature



V_{IN} = 5 V and 3.3 V

図 5-16. Current Limit vs Temperature

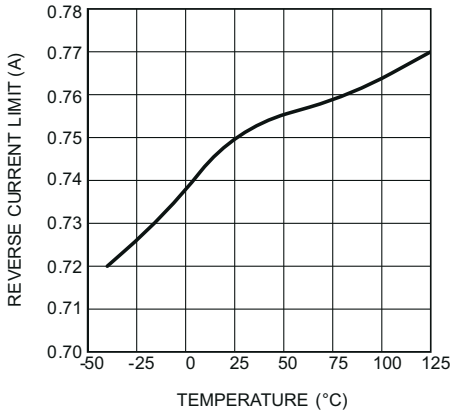


図 5-17. Reverse Current Limit vs Temperature

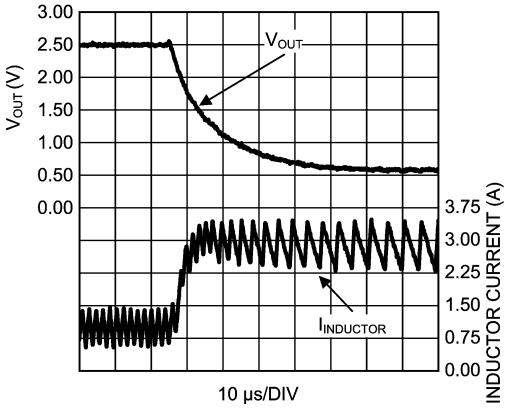


図 5-18. Short-Circuit Waveforms

5.6 Typical Characteristics (continued)

All curves taken at V_{IN} = 5 V with configuration in typical application circuits shown in セクション 7. T_J = 25°C, unless otherwise specified.

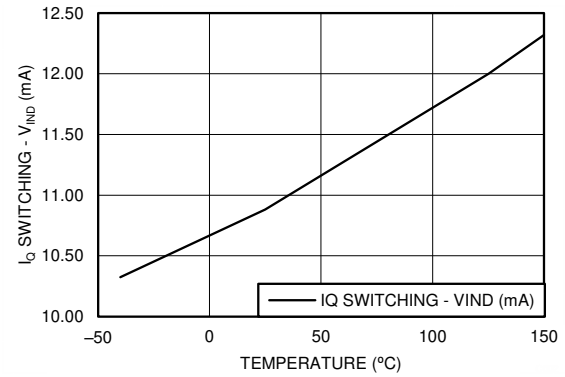


図 5-19. I_Q (Quiescent Current) vs Temperature (Q0 Grade)

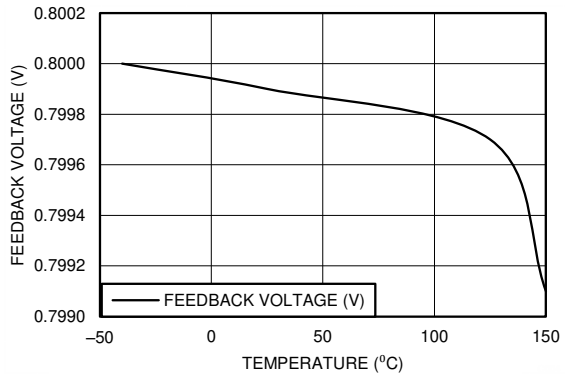


図 5-20. V_{FB} vs Temperature (Q0 Grade)

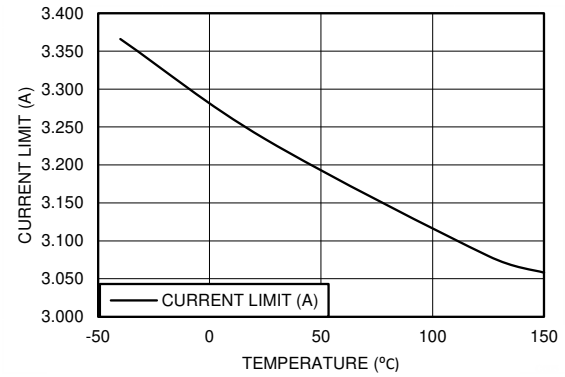


図 5-21. Current Limit vs Temperature (Q0 Grade)

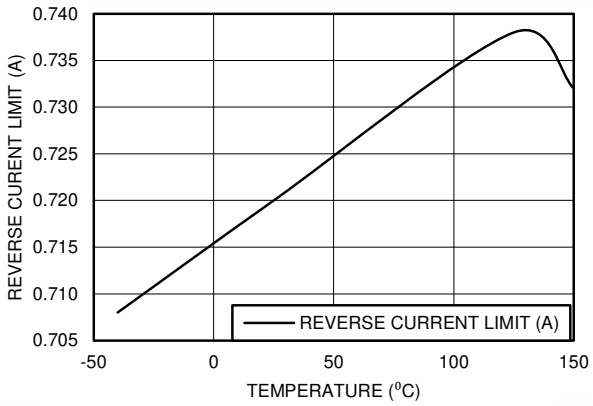


図 5-22. Reverse Current Limit vs Temperature (Q0 Grade)

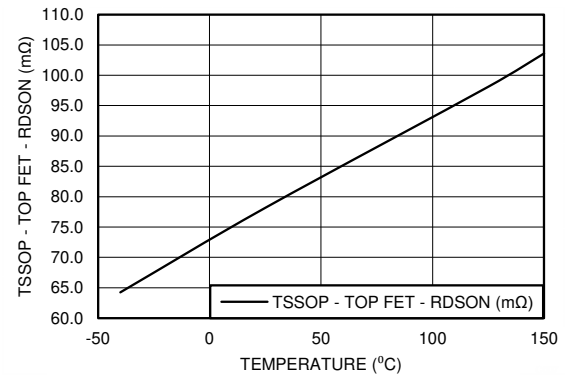


図 5-23. R_{DSON} Top vs Temperature (Q0 Grade)

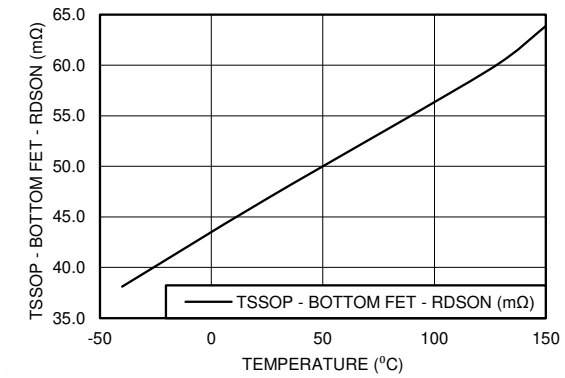


図 5-24. R_{DSON} Bottom vs Temperature (Q0 Grade)

5.6 Typical Characteristics (continued)

All curves taken at V_{IN} = 5 V with configuration in typical application circuits shown in セクション 7. T_J = 25°C, unless otherwise specified.

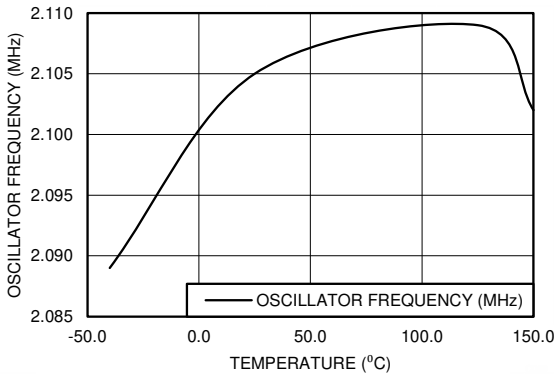


図 5-25. Oscillator Frequency vs Temperature (Q0 Grade)

6 Detailed Description

6.1 Overview

The LM26420-Q1 is a constant frequency dual PWM buck synchronous regulator device that can supply two loads at up to 2 A each. The regulator has a preset switching frequency of 2.2 MHz . This high frequency allows the LM26420-Q1 to operate with small surface mount capacitors and inductors, resulting in a DC/DC converter that requires a minimum amount of board space. The LM26420-Q1 is internally compensated, so LM26420-Q1 is simple to use and requires few external components. The LM26420-Q1 uses current-mode control to regulate the output voltage. The following operating description of the LM26420-Q1 refers to the *セクション 6.2*, which depicts the functional blocks for one of the two channels, and to the waveforms in 図 6-1. The LM26420-Q1 supplies a regulated output voltage by switching the internal TOP and BOTTOM MOS switches at constant frequency and variable duty cycle. A switching cycle begins at the falling edge of the reset pulse generated by the internal clock. When this pulse goes low, the output control logic turns on the internal TOP switch. During this on-time, the SW pin voltage (V_{SW}) swings up to approximately V_{IN}, and the inductor current (I_L) increases with a linear slope. I_L is measured by the current sense amplifier, which generates an output proportional to the switch current. The sense signal is summed with the corrective ramp of the regulator and compared to the output of the error amplifier, which is proportional to the difference between the feedback voltage and V_{REF}. When the PWM comparator output goes high, the TOP Switch turns off and the BOTTOM switch turns on after a short delay, which is controlled by the Dead-Time-Control Logic, until the next switching cycle begins. During the TOP switch off-time, inductor current discharges through the BOTTOM switch, which forces the SW pin to swing to ground. The regulator loop adjusts the duty cycle (D) to maintain a constant output voltage.

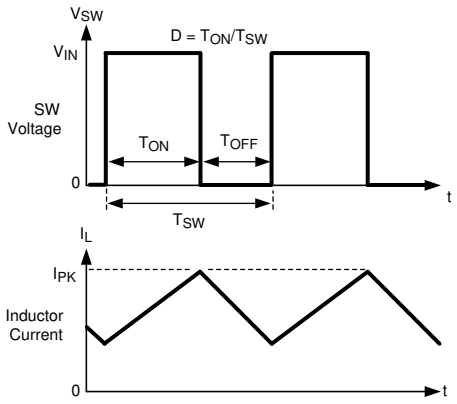


図 6-1. LM26420-Q1 Basic Operation of the PWM Comparator

6.2 Functional Block Diagram

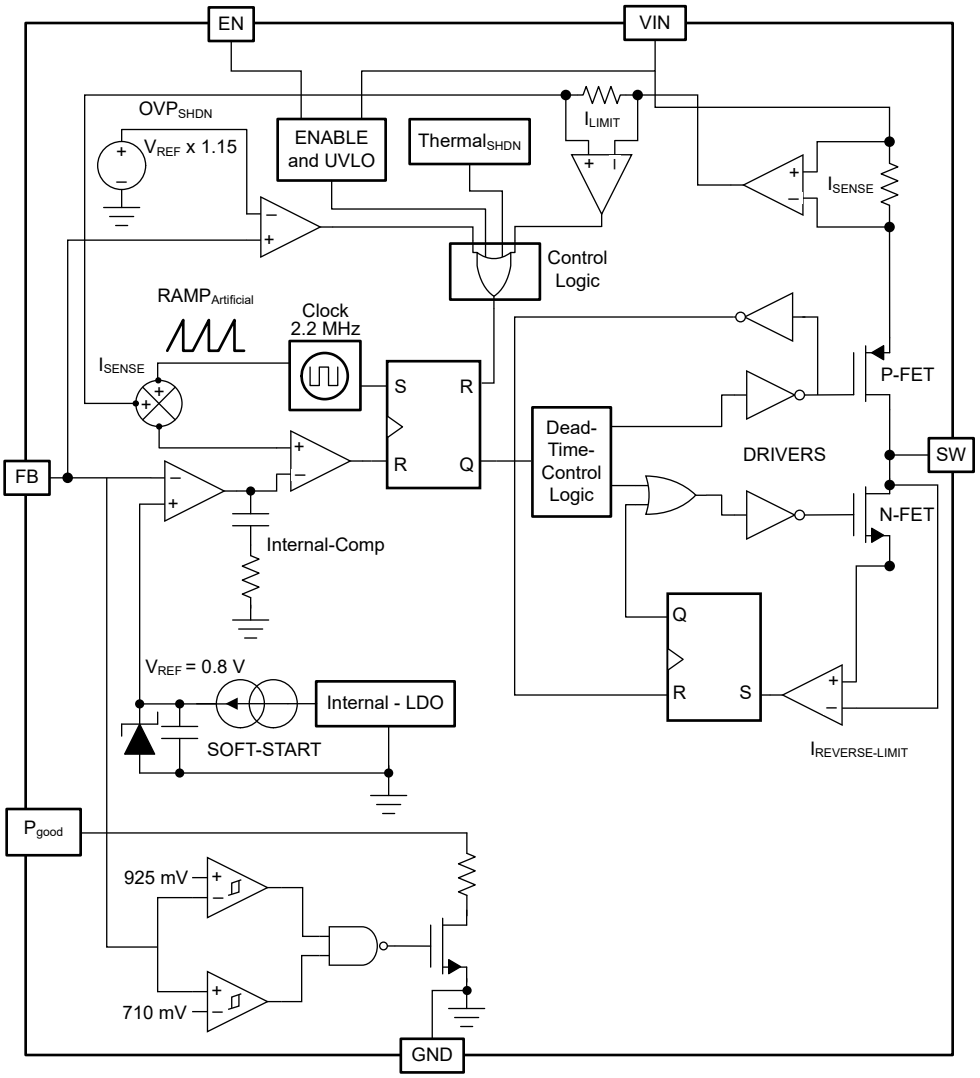


図 6-2. HTSSOP-20 Package

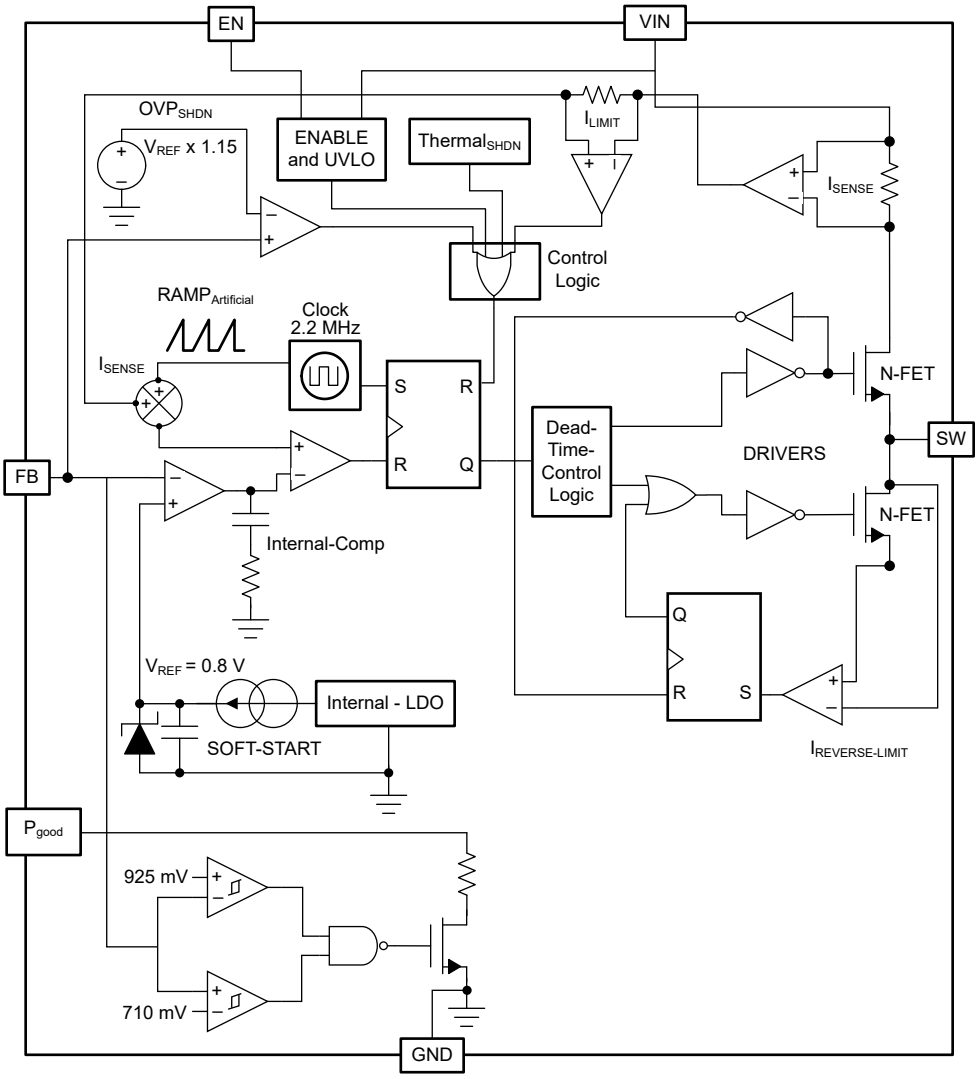


図 6-3. WQFN-16 Package

6.3 Feature Description

6.3.1 Soft Start

This function forces V_{OUT} to increase at a controlled rate during start-up in a controlled fashion, which helps reduce inrush current and eliminate overshoot on V_{OUT}. During soft start, reference voltage of the error amplifier ramps from 0 V to the nominal value of 0.8 V in approximately 600 µs. If the converter is turned on into a prebiased load, then the feedback begins ramping from the prebias voltage, but at the same rate as if started from 0 V. The two outputs start up ratiometrically if enabled at the same time, see the following figure.

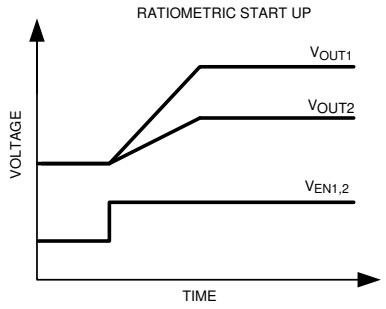


図 6-4. LM26420 Soft Start

6.3.2 Power Good

The LM26420-Q1 features an open-drain power-good (PG) pin to sequence external supplies or loads and to provide fault detection. This pin requires an external resistor (R_{PG}) to pull PG high when the output is within the PG tolerance window. Typical values for this resistor range from 10 kΩ to 100 kΩ.

6.3.3 Precision Enable

The LM26420-Q1 features independent precision enables that allow the converter to be controlled by an external signal. This feature allows the device to be sequenced either by a external control signal or the output of another converter in conjunction with a resistor divider network. This feature can also be set to turn on at a specific input voltage when used in conjunction with a resistor divider network connected to the input voltage. The device is enabled when the EN pin exceeds 1.04 V and has a 150-mV hysteresis.

6.4 Device Functional Modes

6.4.1 Output Overvoltage Protection

The overvoltage comparator compares the FB pin voltage to a voltage that is approximately 15% greater than the internal reference, V_{REF}. Once the FB pin voltage goes 15% above the internal reference, the internal TOP switch is turned off, which allows the output voltage to decrease toward regulation.

6.4.2 Undervoltage Lockout

Undervoltage lockout (UVLO) prevents the LM26420-Q1 from operating until the input voltage exceeds 2.628 V (typical) for HTSSOP-20 package or 2.75 V (typical) for WQFN-16 package. The UVLO threshold has a hysteresis of approximately 330 mV (typical) for HTSSOP-20 package or 260 mV (typical) for WQFN-16 package, so the device operates until V_{IN} drops below 2.3 V (typical) for HTSSOP-20 package or 2.5 V (typical) for WQFN-16 package. Hysteresis prevents the part from turning off during power up if V_{IN} is non-monotonic.

6.4.3 Current Limit

The LM26420-Q1 uses cycle-by-cycle current limiting to protect the output switch. During each switching cycle, a current limit comparator detects if the output switch current exceeds 3.3 A (typical), and turns off the switch until the next switching cycle begins.

6.4.4 Thermal Shutdown

Thermal shutdown limits total power dissipation by turning off the output switch when the device junction temperature exceeds 165°C. After thermal shutdown occurs, the output switch does not turn on until the junction temperature drops to approximately 150°C.

7 Application and Implementation

注

以下のアプリケーション情報は、TI の製品仕様に含まれるものではなく、TI ではその正確性または完全性を保証いたしません。個々の目的に対する製品の適合性については、お客様の責任で判断していただくことになります。お客様は自身の設計実装を検証しテストすることで、システムの機能を確認する必要があります。

7.1 Application Information

7.1.1 Programming Output Voltage

The output voltage is set using 式 1 where R2 is connected between the FB pin and GND, and R1 is connected between V_{OUT} and the FB pin. A good value for R2 is 10 kΩ. When designing a unity gain converter (V_{OUT} = 0.8 V), R1 must be between 0 Ω and 100 Ω, and R2 must be on the order of 5 kΩ to 50 kΩ. 10 kΩ is the suggested value where R1 is the top feedback resistor and R2 is the bottom feedback resistor.

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

$$V_{REF} = 0.80\ V \quad (2)$$

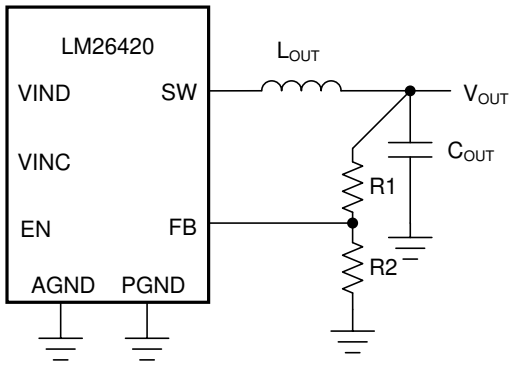


図 7-1. Programming V_{OUT}

To determine the maximum allowed resistor tolerance, use 式 3:

$$\sigma = \left(\frac{1}{1 + 2x\frac{1 - \frac{V_{FB}}{V_{OUT}}}{TOL - \phi}}\right) \quad (3)$$

where

- TOL is the set point accuracy of the regulator, is the tolerance of V_{FB}.

Example:

V_{OUT} = 2.5 V, with a setpoint accuracy of ±3.5%

$$\sigma = \left(\frac{1}{1 + 2x\frac{1 - \frac{0.8V}{2.5V}}{3.5\% - 1.5\%}}\right) = 1.4\% \quad (4)$$

Choose 1% resistors. If R2 = 10 kΩ, then R1 is 21.25 kΩ.

7.1.2 VINC Filtering Components

Additional filtering is required between VINC and AGND to prevent high frequency noise on VIN from disturbing the sensitive circuitry connected to VINC. A small RC filter can be used on the VINC pin as shown in 図 7-2.

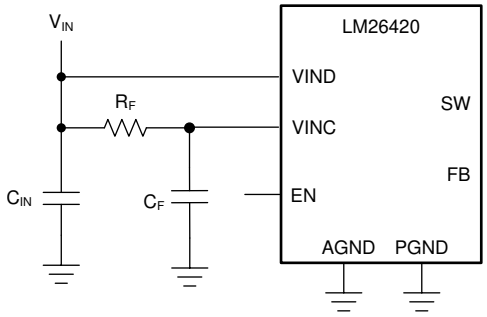


図 7-2. RC Filter On VINC

In general, R_F is typically between 1 Ω and 10 Ω so that the steady state voltage drop across the resistor due to the VINC bias current does not affect the UVLO level. C_F can range from 0.22 µF to 1 µF in X7R or X5R dielectric, where the RC time constant must be at least 2 µs. C_F must be placed as close to the device as possible with a direct connection from VINC and AGND.

7.1.3 Using Precision Enable and Power Good

The LM26420-Q1 device precision EN and PG pins address many of the sequencing requirements required in challenging applications. Each output can be controlled independently and have independent power good. This allows for a multitude of ways to control each output. Typically, the enables to each output are tied together to the input voltage and the outputs ratiometrically ramp up when the input voltage reaches above UVLO rising threshold. There can be instances where the second output (V_{OUT2}) not turning on until the first output (V_{OUT1}) has reached 90% of the desired setpoint is desired. This is easily achieved with an external resistor divider attached from V_{OUT1} to EN_2, see 図 7-3.

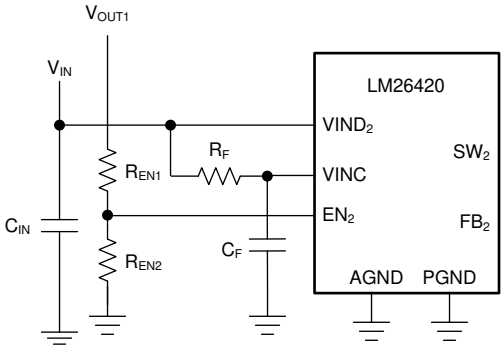


図 7-3. V_{OUT1} Controlling V_{OUT2} With Resistor Divider

If having a resistor divider to control V_{OUT2} with V_{OUT1} is not desired, then the PG_1 can be connected to the EN_2 pin to control V_{OUT2}, see 図 7-4. R_{PG1} is a pullup resistor on the range of 10 kΩ to 100 kΩ. 50 kΩ is the suggested value. This turns on V_{OUT2} when V_{OUT1} is approximately 85% of the programmed output.

注

Using PG_1 to control V_{OUT2} also turns off V_{OUT2} when V_{OUT1} is outside the of the programmed output.

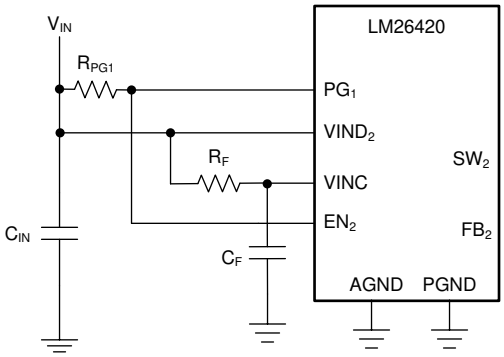


図 7-4. PG_1 Controlling V_{OUT2}

Another example is that the output is not to be turned on until the input voltage reaches 90% of desired voltage setpoint. This verifies that the input supply is stable before turning on the output. Select R_{EN1} and R_{EN2} so that the voltage at the EN pin is greater than 1.12 V when reaching the 90% desired set-point.

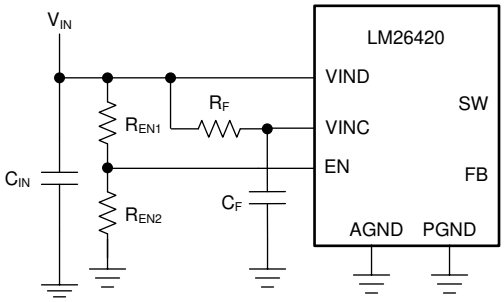


図 7-5. V_{in} Controlling V_{OUT}

The power-good feature of the LM26420-Q1 is designed with hysteresis to make sure no false power-good flags are asserted during large transient. After power good is asserted high, power good is not pulled low until the output voltage exceeds ±15% of the setpoint for a during of approximately 7.5 µs (typical), see 図 7-6.

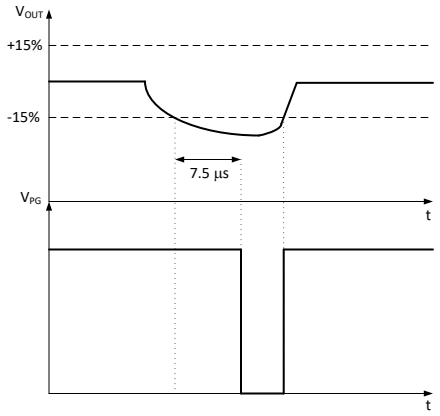


図 7-6. Power-Good Hysteresis Operation

7.1.4 Overcurrent Protection for HTSSOP-20 Package

When the switch current reaches the current limit value, the switch current is turned off immediately. This action effectively reduces the duty cycle and therefore the output voltage dips and continues to droop until the output load matches the peak current limit inductor current. As the FB voltage drops below 480 mV, the operating frequency begins to decrease until the operating frequency hits full on frequency foldback, which is set to approximately 300 kHz . Frequency foldback helps reduce the thermal stress in the device by reducing the switching losses and to prevent runaway of the inductor current when the output is shorted to ground.

Note that when recovering from a overcurrent condition, the converter does not go through the soft-start process. There can be an overshoot due to the sudden removal of the overcurrent fault. The reference voltage at the non-inverting input of the error amplifier always sits at 0.8 V during the overcurrent condition, therefore, when the fault is removed, the converter brings the FB voltage back to 0.8 V as quickly as possible. The overshoot depends on whether there is a load on the output after the removal of the overcurrent fault, the size of the inductor, and the amount of capacitance on the output. The smaller the inductor and the larger the capacitance on the output, the smaller the overshoot.

注

Overcurrent protection for each output is independent.

7.1.5 Current Limit and Short-Circuit Protection for WQFN-16 Package

The converter is not switching with the fixed frequency when the switch current reaches the current limit value. The converter resumes the fixed-frequency operation when the converter leaves current limit condition. If the inductor current exceeds the current limit, I_{CL_TOP}, the TOP switch is turned off and the BOTTOM switch is turned on to ramp down the inductor current. The TOP Switch turns on again only if the current in the BOTTOM Switch has decreased below the low-side current limit, which can cause bursts or single pulses between the high-side and low-side current limit. Due to internal propagation delay, the actual current can exceed the static current limit. The dynamic current limit is given as:

$$I_{peak(typ)} = I_{CL\_TOP} + \frac{V_L}{L} \times t_{PD} \quad (5)$$

where

- I_{CL_TOP} is the static current limit as specified in the electrical characteristics.
- L is the effective inductance at the peak current.
- V_L is the voltage across the inductor ($V_{IN} – V_{OUT}$).
- t_{PD} is the internal propagation delay of typically 50 ns.

The current limit can exceed static values, especially if the input voltage is high and very small inductances are used. The dynamic peak current in the TOP Switch can be calculated as follows:

$$I_{peak(typ)} = I_{CL\_TOP} + \frac{(V_{IN} - V_{OUT})}{L} \times 50ns \quad (6)$$

7.2 Typical Applications

7.2.1 2.2-MHz, 0.8-V Typical High-Efficiency Application Circuit

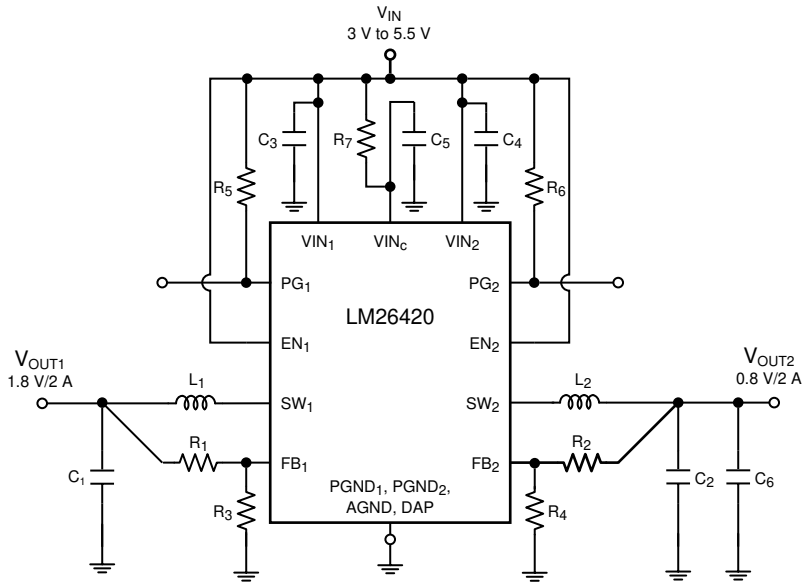


図 7-7. LM26420-Q1 (2.2 MHz): V_{IN} = 5 V, V_{OUT1} = 1.8 V at 2 A and V_{OUT2} = 0.8 V at 2 A

7.2.1.1 Design Requirements

Example requirements for typical synchronous DC/DC converter applications:

表 7-1. Design Parameters

DESIGN PARAMETER	VALUE
V_{OUT}	Output voltage
V_{IN} (minimum)	Maximum input voltage
V_{IN} (maximum)	Minimum input voltage
I_{OUT} (maximum)	Maximum output current
f_{SW}	Switching frequency

7.2.1.2 Detailed Design Procedure

7.2.1.2.1 Custom Design With WEBENCH® Tools

Click here to create a custom design using the LM26420-Q1 device with the WEBENCH® Power Designer.

1. Start by entering the input voltage (V_{IN}), output voltage (V_{OUT}), and output current (I_{OUT}) requirements.
2. Optimize the design for key parameters such as efficiency, footprint, and cost using the optimizer dial.
3. Compare the generated design with other possible solutions from Texas Instruments.

The WEBENCH Power Designer provides a customized schematic along with a list of materials with real-time pricing and component availability.

In most cases, these actions are available:

- Run electrical simulations to see important waveforms and circuit performance
- Run thermal simulations to understand board thermal performance
- Export customized schematic and layout into popular CAD formats
- Print PDF reports for the design, and share the design with colleagues

Get more information about WEBENCH tools at www.ti.com/WEBENCH.

表 7-2. Bill Of Materials

PART ID	PART VALUE	MANUFACTURER	PART NUMBER
U1	2-A buck regulator	TI	LM26420-Q1
C3, C4	15 µF, 6.3 V, 1206, X5R	TDK	C3216X5R0J156M
C1	33 µF, 6.3 V, 1206, X5R	TDK	C3216X5R0J336M
C2, C6	22 µF, 6.3 V, 1206, X5R	TDK	C3216X5R0J226M
C5	0.47 µF, 10 V, 0805, X7R	Vishay	VJ0805Y474KXQCW1BC
L1	1.0 µH, 7.9 A	TDK	RLF7030T-1R0M6R4
L2	0.7 µH, 3.7 A	Coilcraft	LPS4414-701ML
R3, R4	10.0 kΩ, 0603, 1%	Vishay	CRCW060310K0F
R5, R6	49.9 kΩ, 0603, 1%	Vishay	CRCW060649K9F
R1	12.7 kΩ, 0603, 1%	Vishay	CRCW060312K7F
R7, R2	4.99 Ω, 0603, 1%	Vishay	CRCW06034R99F

7.2.1.2.2 Inductor Selection

The duty cycle (D) can be approximated as the ratio of output voltage (V_{OUT}) to input voltage (V_{IN}):

$$D = \frac{V_{OUT}}{V_{IN}} \tag{7}$$

The voltage drop across the internal NMOS (SW_BOT) and PMOS (SW_TOP) must be included to calculate a more accurate duty cycle. Calculate D by using the following formulas:

$$D = \frac{V_{OUT} + V_{SW\_BOT}}{V_{IN} + V_{SW\_BOT} - V_{SW\_TOP}} \tag{8}$$

V_{SW_TOP} and V_{SW_BOT} can be approximated by:

$$V_{SW\_TOP} = I_{OUT} \times R_{DSON\_TOP} \tag{9}$$

$$V_{SW\_BOT} = I_{OUT} \times R_{DSON\_BOT} \tag{10}$$

The inductor value determines the output ripple voltage. Smaller inductor values decrease the size of the inductor, but increase the output ripple voltage. An increase in the inductor value decreases the output ripple current.

Make sure that the minimum current limit (2.4 A) is not exceeded, so the peak current in the inductor must be calculated. The peak current (I_{LPK}) in the inductor is calculated by:

$$I_{LPK} = I_{OUT} + \Delta i_L \tag{11}$$

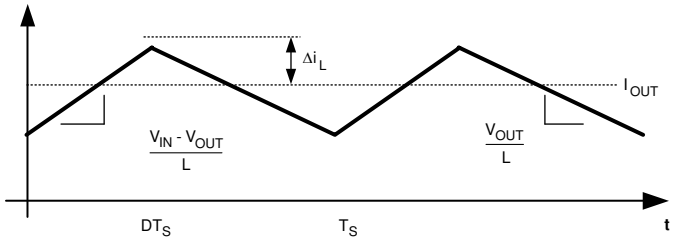


図 7-8. Inductor Current

$$\frac{V_{IN} - V_{OUT}}{L} = \frac{2\Delta i_L}{DT_S} \tag{12}$$

In general,

$$\Delta i_L = 0.1 \times (I_{OUT}) \rightarrow 0.2 \times (I_{OUT}) \tag{13}$$

If Δi_L = 20% of 2 A, the peak current in the inductor is 2.4 A. The minimum specified current limit over all operating conditions is 2.4 A. Either reduce Δi_L, or make the engineering judgment that zero margin is safe enough. The typical current limit is 3.3 A.

The LM26420-Q1 operates at frequencies allowing the use of ceramic output capacitors without compromising transient response. Ceramic capacitors allow higher inductor ripple without significantly increasing output ripple voltage. See the *セクション 7.2.1.2.4* section for more details on calculating output voltage ripple. Now that the ripple current is determined, the inductance is calculated by:

$$L = \left(\frac{DT_S}{2\Delta i_L}\right) \times (V_{IN} - V_{OUT}) \quad (14)$$

where

$$T_S = \frac{1}{f_S} \quad (15)$$

When selecting an inductor, make sure that the inductor is capable of supporting the peak output current without saturating. Inductor saturation results in a sudden reduction in inductance and prevents the regulator from operating correctly. The peak current of the inductor is used to specify the maximum output current of the inductor and saturation is not a concern due to the exceptionally small delay of the internal current limit signal. Ferrite based inductors are preferred to minimize core losses when operating with the frequencies used by the LM26420-Q1. This presents little restriction because the variety of ferrite-based inductors is huge. Lastly, inductors with lower series resistance (R_{DCR}) provides better operating efficiency. For recommended inductors, see 表 7-2.

7.2.1.2.3 Input Capacitor Selection

The input capacitors provide the AC current needed by the nearby power switch so that current provided by the upstream power supply does not carry a lot of AC content, generating less EMI. To the buck regulator in question, the input capacitor also prevents the drain voltage of the FET switch from dipping when the FET is turned on, therefore, providing a healthy line rail for the LM26420-Q1 to work with. Because typically most of the AC current is provided by the local input capacitors, the power loss in those capacitors can be a concern. In the case of the LM26420-Q1 regulator, because the two channels operate 180° out of phase, the AC stress in the input capacitors is less than if operated in phase. The measure for the AC stress is called input ripple RMS current. TI strongly recommends that at least one 10-µF ceramic capacitor be placed next to each of the VIND pins. Bulk capacitors such as electrolytic capacitors or OSCON capacitors can be added to help stabilize the local line voltage, especially during large load transient events. As for the ceramic capacitors, use X7R or X5R types. They maintain most of the capacitance over a wide temperature range. Try to avoid sizes smaller than 0805. Otherwise significant drop in capacitance can be caused by the DC bias voltage. See the *セクション 7.2.1.2.4* section for more information. The DC voltage rating of the ceramic capacitor must be higher than the highest input voltage.

Capacitor temperature is a major concern in board designs. While using a 10-µF or higher MLCC as the input capacitor is a good starting point, check the temperature in the real thermal environment to make sure the capacitors are not overheated. Capacitor vendors can provide curves of ripple RMS current versus temperature rise based on a designated thermal impedance. In reality, the thermal impedance can be very different, so checking the capacitor temperature on the board is always a good idea

Because the duty cycles of the two channels can overlap, calculation of the input ripple RMS current is a little tedious — use 式 16:

$$I_{irrms} = \sqrt{(I_1 - I_{av})^2 d1 + (I_2 - I_{av})^2 d2 + (I_1 + I_2 - I_{av})^2 d3} \quad (16)$$

where

- I_1 is the maximum output current of Channel 1
- I_2 is the maximum output current of Channel 2
- d1 is the non-overlapping portion of the duty cycle, D_1, of Channel 1
- d2 is the non-overlapping portion of the duty cycle, D_2, of Channel 2
- d3 is the overlapping portion of the two duty cycles
- I_{av} is the average input current

$I_{av} = I_1 \times D_1 + I_2 \times D_2$. To quickly determine the values of d1, d2, and d3, refer to the decision tree in 図 7-9. To determine the duty cycle of each channel, use $D = V_{OUT} / V_{IN}$ for a quick result or use 式 17 for a more accurate result.

$$D = \frac{V_{OUT} + V_{SW\_BOT} + I_{OUT} \times R_{DC}}{V_{IN} + V_{SW\_BOT} - V_{SW\_TOP}} \quad (17)$$

where

- R_{DC} is the winding resistance of the inductor

Example:

- V_{IN} = 5 V
- V_{OUT1} = 3.3 V
- I_{OUT1} = 2 A
- V_{OUT2} = 1.2 V
- I_{OUT2} = 1.5 A
- R_{DS} = 170 mΩ
- R_{DC} = 30 mΩ

I_{OUT1} is the same as I_1 in the input ripple RMS current equation and I_{OUT2} is the same as I_2.

First, find out the duty cycles. Plug the numbers into the duty cycle equation and get D1 = 0.75, and D2 = 0.33. Next, follow the decision tree in 図 7-9 to find out the values of d1, d2, and d3. In this case, d1 = 0.5, d2 = D2 + 0.5 – D1 = 0.08, and d3 = D1 – 0.5 = 0.25. $I_{av} = I_{OUT1} \times D1 + I_{OUT2} \times D2 = 1.995$ A. Plug all the numbers into the input ripple RMS current equation and the result is $I_{IR(rms)}$ = 0.77 A.

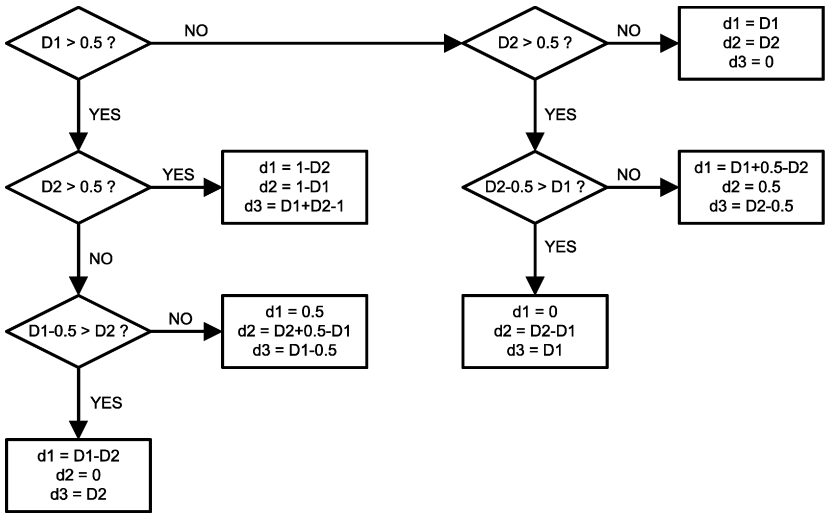


図 7-9. Determining D1, D2, and D3

7.2.1.2.4 Output Capacitor

The output capacitor is selected based upon the desired output ripple and transient response. The initial current of a load transient is provided mainly by the output capacitor. The output ripple of the converter is approximately:

$$\Delta V_{OUT} = \Delta I_L \left(R_{ESR} + \frac{1}{8 \times F_{SW} \times C_{OUT}} \right) \quad (18)$$

When using MLCCs, the ESR is typically so low that the capacitive ripple can dominate. When this occurs, the output ripple is approximately sinusoidal and 90° phase shifted from the switching action. Given the availability

and quality of MLCCs and the expected output voltage of designs using the LM26420-Q1, there is really no need to review any other capacitor technologies. Another benefit of ceramic capacitors is the ability to bypass high frequency noise. A certain amount of switching edge noise couples through parasitic capacitances in the inductor to the output. A ceramic capacitor bypasses this noise while a tantalum capacitor does not. Because the output capacitor is one of the two external components that control the stability of the regulator control loop, most applications require a minimum of 22 µF of output capacitance. Capacitance often, but not always, can be increased significantly with little detriment to the regulator stability. Like the input capacitor, recommended multilayer ceramic capacitors are X7R or X5R types.

7.2.1.2.5 Calculating Efficiency and Junction Temperature

The complete LM26420-Q1 DC/DC converter efficiency can be estimated in the following manner.

$$\eta = \frac{P_{OUT}}{P_{IN}} \tag{19}$$

or

$$\eta = \frac{P_{OUT}}{P_{OUT} + P_{LOSS}} \tag{20}$$

The following equations show the calculations for determining the most significant power losses. Other losses totaling less than 2% are not discussed.

Power loss (P_{LOSS}) is the sum of two basic types of losses in the converter: switching and conduction. Conduction losses usually dominate at higher output loads, whereas switching losses remain relatively fixed and dominate at lower output loads. The first step in determining the losses is to calculate the duty cycle (D):

$$D = \frac{V_{OUT} + V_{SW\_BOT}}{V_{IN} + V_{SW\_BOT} - V_{SW\_TOP}} \tag{21}$$

V_{SW_TOP} is the voltage drop across the internal PFET when on, and is equal to:

$$V_{SW\_TOP} = I_{OUT} \times R_{DSON\_TOP} \tag{22}$$

V_{SW_BOT} is the voltage drop across the internal NFET when on, and is equal to:

$$V_{SW\_BOT} = I_{OUT} \times R_{DSON\_BOT} \tag{23}$$

If the voltage drop across the inductor (V_{DCR}) is accounted for, the equation becomes:

$$D = \frac{V_{OUT} + V_{SW\_BOT} + V_{DCR}}{V_{IN} + V_{SW\_BOT} + V_{DCR} - V_{SW\_TOP}} \tag{24}$$

Another significant external power loss is the conduction loss in the output inductor. The equation can be simplified to:

$$P_{IND} = I_{OUT}^{2} \times R_{DCR} \tag{25}$$

The LM26420-Q1 conduction loss is mainly associated with the two internal FETs:

$$P_{COND\_TOP} = (I_{OUT}^2 \times D)\left(1 + \frac{1}{3} \times \left(\frac{\Delta i_L}{I_{OUT}}\right)^2\right) R_{DSON\_TOP}$$

$$P_{COND\_BOT} = (I_{OUT}^2 \times (1\text{-}D))\left(1 + \frac{1}{3} \times \left(\frac{\Delta i_L}{I_{OUT}}\right)^2\right) R_{DSON\_BOT} \quad (26)$$

If the inductor ripple current is fairly small, the conduction losses can be simplified to:

$$P_{COND\_TOP} = (I_{OUT}^2 \times R_{DSON\_TOP} \times D) \quad (27)$$

$$P_{COND\_BOT} = (I_{OUT}^2 \times R_{DSON\_BOT} \times (1\text{-}D)) \quad (28)$$

$$P_{COND} = P_{COND\_TOP} + P_{COND\_BOT} \quad (29)$$

Switching losses are also associated with the internal FETs. Switching losses occur during the switch on and off transition periods, where voltages and currents overlap, resulting in power loss. The simplest means to determine this loss is empirically measuring the rise and fall times (10% to 90%) of the switch at the switch node.

Switching Power Loss is calculated as follows:

$$P_{SWR} = 1/2(V_{IN} \times I_{OUT} \times F_{SW} \times T_{RISE}) \quad (30)$$

$$P_{SWF} = 1/2(V_{IN} \times I_{OUT} \times F_{SW} \times T_{FALL}) \quad (31)$$

$$P_{SW} = P_{SWR} + P_{SWF} \quad (32)$$

Another loss is the power required for operation of the internal circuitry:

$$P_Q = I_Q \times V_{IN} \quad (33)$$

I_Q is the quiescent operating current, and is typically around 8.4 mA (I_{QVINC} = 4.7 mA + I_{QVIND} = 3.7 mA) for the 2.2-MHz frequency option.

Due to Dead-Time-Control Logic in the converter, there is a small delay (approximately 4 ns) between the turn ON and OFF of the TOP and BOTTOM FET. During this time, the body diode of the BOTTOM FET is conducting with a voltage drop of V_{BDIODE} (approximately 0.65 V). This allows the inductor current to circulate to the output, until the BOTTOM FET is turned ON and the inductor current passes through the FET. There is a small amount of power loss due to this body diode conducting and can be calculated as follows:

$$P_{BDIODE} = 2 \times (V_{BDIODE} \times I_{OUT} \times F_{SW} \times T_{BDIODE}) \quad (34)$$

Typical Application power losses are:

$$P_{LOSS} = \Sigma P_{COND} + P_{SW} + P_{BDIODE} + P_{IND} + P_Q \quad (35)$$

$$P_{INTERNAL} = \Sigma P_{COND} + P_{SW} + P_{BDIODE} + P_Q \quad (36)$$

表 7-3. Power Loss Tabulation

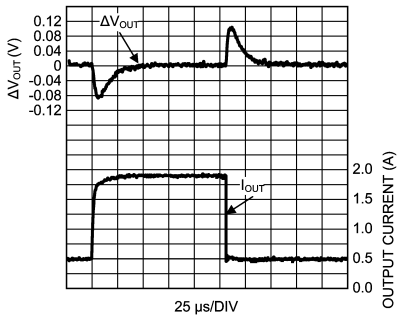
DESIGN PARAMETER	VALUE	DESIGN PARAMETER	VALUE
V_{IN}	5 V	V_{OUT}	1.2 V
I_{OUT}	2 A	P_{OUT}	2.4 W
F_{SW}	2.2 MHz		
V_{BDIODE}	0.65 V	P_{BDIODE}	5.7 mW
I_Q	8.4 mA	P_Q	42 mW
T_{RISE}	1.5 ns	P_{SWR}	4.1 mW

表 7-3. Power Loss Tabulation (続き)

DESIGN PARAMETER	VALUE	DESIGN PARAMETER	VALUE
T_{FALL}	1.5 ns	P_{SWF}	4.1 mW
R_{DSON_TOP}	75 mΩ	P_{COND_TOP}	81 mW
R_{DSON_BOT}	55 mΩ	P_{COND_BOT}	167 mW
IND_{DCR}	20 mΩ	P_{IND}	80 mW
D	0.262	P_{LOSS}	384 mW
η	86.2%	$P_{INTERNAL}$	304 mW

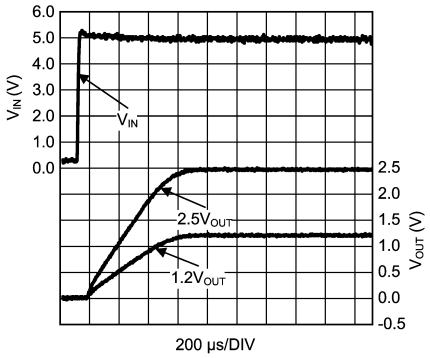
These calculations assume a junction temperature of 25°C. The R_{DSON} values are larger due to internal heating; therefore, the internal power loss ($P_{INTERNAL}$) must be first calculated to estimate the rise in junction temperature.

7.2.1.3 Application Curves



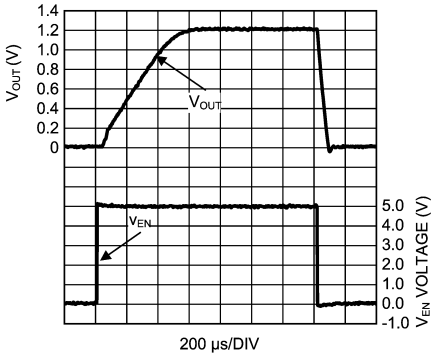
V_{OUT} = 1.2 V 25-100% Load Transient

図 7-10. Load Transient Response



V_{IN} = 5 V V_{OUT} = 1.8 V at 1 A

図 7-11. Start-Up (Soft Start)



V_{IN} = 5 V V_{OUT} = 1.8 V at 1 A

図 7-12. Enable - Disable

7.2.2 2.2-MHz, 1.8-V Typical High-Efficiency Application Circuit

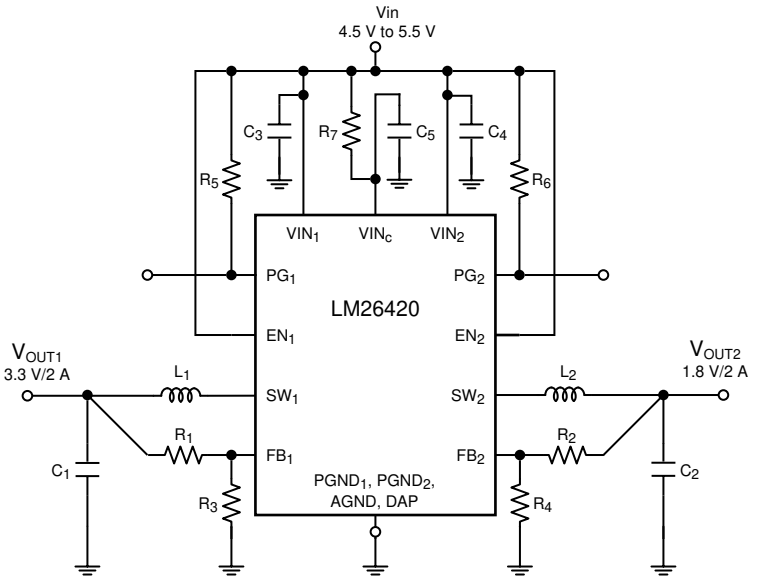


図 7-13. LM26420-Q1 (2.2 MHz): V_{IN} = 5 V, V_{OUT1} = 3.3 V at 2 A and V_{OUT2} = 1.8 V at 2 A

7.2.2.1 Design Requirements

See セクション 7.2.1.1 above.

7.2.2.2 Detailed Design Procedure

表 7-4. Bill Of Materials

PART ID	PART VALUE	MANUFACTURER	PART NUMBER
U1	2-A Buck Regulator	TI	LM26420-Q1
C3, C4	15 µF, 6.3 V, 1206, X5R	TDK	C3216X5R0J156M
C1	22 µF, 6.3 V, 1206, X5R	TDK	C3216X5R0J226M
C2	33 µF, 6.3 V, 1206, X5R	TDK	C3216X5R0J336M
C5	0.47 µF, 10 V, 0805, X7R	Vishay	VJ0805Y474KXQCW1BC
L1, L2	1.0 µH, 7.9 A	TDK	RLF7030T-1R0M6R4
R3, R4	10.0 kΩ, 0603, 1%	Vishay	CRCW060310K0F
R2	12.7 kΩ, 0603, 1%	Vishay	CRCW060312K7F
R5, R6	49.9 kΩ, 0603, 1%	Vishay	CRCW060649K9F
R1	31.6 kΩ, 0603, 1%	Vishay	CRCW060331K6F
R7	4.99 Ω, 0603, 1%	Vishay	CRCW06034R99F

Also see セクション 7.2.1.2 above.

7.2.2.3 Application Curves

See セクション 7.2.1.3 above.

7.2.3 LM26420-Q12.2-MHz, 2.5-V Typical High-Efficiency Application Circuit

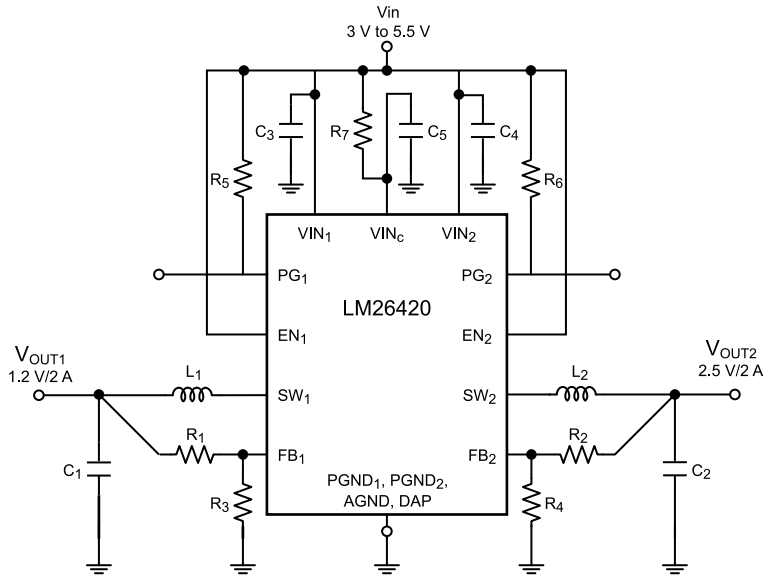


図 7-14. LM26420-Q1 (2.2 MHz): V_{IN} = 5 V, V_{OUT1} = 1.2 V at 2 A and V_{OUT2} = 2.5 V at 2 A

7.2.3.1 Design Requirements

See セクション 7.2.1.1 above.

7.2.3.2 Detailed Design Procedure

表 7-5. Bill Of Materials

PART ID	PART VALUE	MANUFACTURER	PART NUMBER
U1	2-A buck regulator	TI	LM26420-Q1
C3, C4	15 µF, 6.3 V, 1206, X5R	TDK	C3216X5R0J156M
C1	33 µF, 6.3 V, 1206, X5R	TDK	C3216X5R0J336M
C2	22 µF, 6.3 V, 1206, X5R	TDK	C3216X5R0J226M
C5	0.47 µF, 10 V, 0805, X7R	Vishay	VJ0805Y474KXQCW1BC
L1	1.0 µH, 7.9A	TDK	RLF7030T-1R0M6R4
L2	1.5 µH, 6.5A	TDK	RLF7030T-1R5M6R1
R3, R4	10.0 kΩ, 0603, 1%	Vishay	CRCW060310K0F
R1	4.99 kΩ, 0603, 1%	Vishay	CRCW06034K99F
R5, R6	49.9 kΩ, 0603, 1%	Vishay	CRCW060649K9F
R2	21.5 kΩ, 0603, 1%	Vishay	CRCW060321K5F
R7	4.99 Ω, 0603, 1%	Vishay	CRCW06034R99F

Also see セクション 7.2.1.2 above.

7.2.3.3 Application Curves

See セクション 7.2.1.3 above.

7.3 Power Supply Recommendations

The LM26420-Q1 is designed to operate from an input voltage supply range between 3 V and 5.5 V. This input supply must be well regulated and able to withstand maximum input current and maintain a stable voltage. The resistance of the input supply rail must be low enough that an input current transient does not cause a high enough drop at the LM26420-Q1 supply voltage that can cause a false UVLO fault triggering and system reset. If the input supply is located more than a few inches from the LM26420-Q1, additional bulk capacitance can be required in addition to the ceramic bypass capacitors. The amount of bulk capacitance is not critical, but a 47-µF or 100-µF electrolytic capacitor is a typical choice.

7.3.1 Power Supply Recommendations - HTSSOP-20 Package

The LM26420-Q1 contains a high-side PMOS FET and a low-side NMOS FET for each channel, as shown in 図 7-15. The source nodes of the high-side PMOS FETs are connected to $VIND_1$ and $VIND_2$, respectively. VINC is the power source for the high-side and low-side gate drivers. Ideally, VINC is connected to $VIND_1$ and $VIND_2$ by an RC filter as detailed in セクション 7.1.2. If VINC is allowed to be lower than $VIND_1$ or $VIND_2$, the high-side PMOS FETs can be turned on regardless of the state of the respective gate drivers. Under this condition, shoot through occurs when the low-side NMOS FET is turned on and permanent damage can result. When applying input voltage to VINC, $VIND_1$, and $VIND_2$, VINC must not be less than $VIND_{1,2} – V_{TH}$ to avoid shoot through and FET damage.

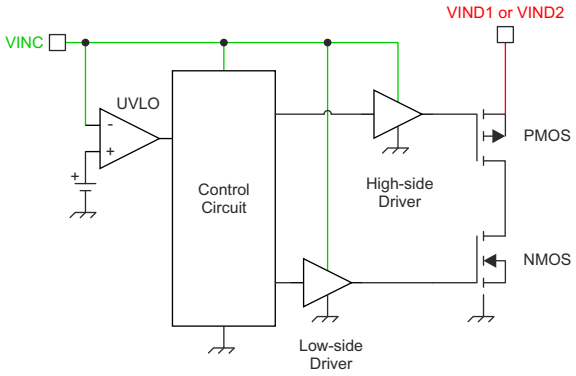


図 7-15. VINC, $VIND_1$, and $VIND_2$ Connection

7.3.2 Power Supply Recommendations - WQFN-16 Package

The LM26420-Q1 contains a high-side NMOS FET and a low-side NMOS FET for each channel. The drain nodes of the high-side NMOS FET, the supply for the gate drivers and the supply for control circuitry for each channel are connected to $VIND_1$ and $VIND_2$, respectively.

7.4 Layout

7.4.1 Layout Guidelines

When planning layout there are a few things to consider when trying to achieve a clean, regulated output. The most important consideration is the close coupling of the GND connections of the input capacitor and the PGND pin. These ground ends must be close to one another and be connected to the GND plane with at least two through-holes. Place these components as close to the device as possible. Next in importance is the location of the GND connection of the output capacitor, which must be near the GND connections of VIND and PGND. There must be a continuous ground plane on the bottom layer of a two-layer board except under the switching node island. The FB pin is a high impedance node, and care must be taken to make the FB trace short to avoid noise pickup and inaccurate regulation. The feedback resistors must be placed as close to the device as possible, with the GND of R1 placed as close to the GND of the device as possible. The VOUT trace to R2 must be routed away from the inductor and any other traces that are switching. High AC currents flow through the VIN, SW, and VOUT traces, so the high AC must be as short and wide as possible. However, making the traces wide increases radiated noise, so the designer must make this trade-off. Radiated noise can be decreased by

choosing a shielded inductor. The remaining components must also be placed as close as possible to the device. See *AN-1229 SIMPLE SWITCHER® PCB Layout Guidelines* application note for further considerations, and the LM26420-Q1 demo board as an example of a four-layer layout.

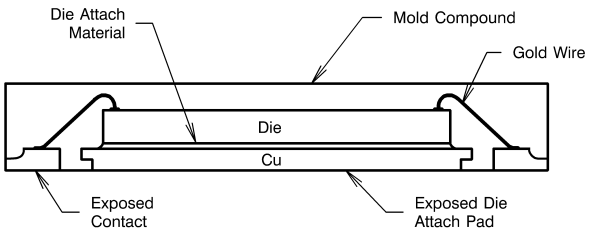


図 7-16. Internal Connection

For certain high power applications, the PCB land can be modified to a *dog bone* shape (see 図 7-17). By increasing the size of ground plane, and adding thermal vias, the $R_{\theta JA}$ for the application can be reduced.

7.4.2 Layout Example

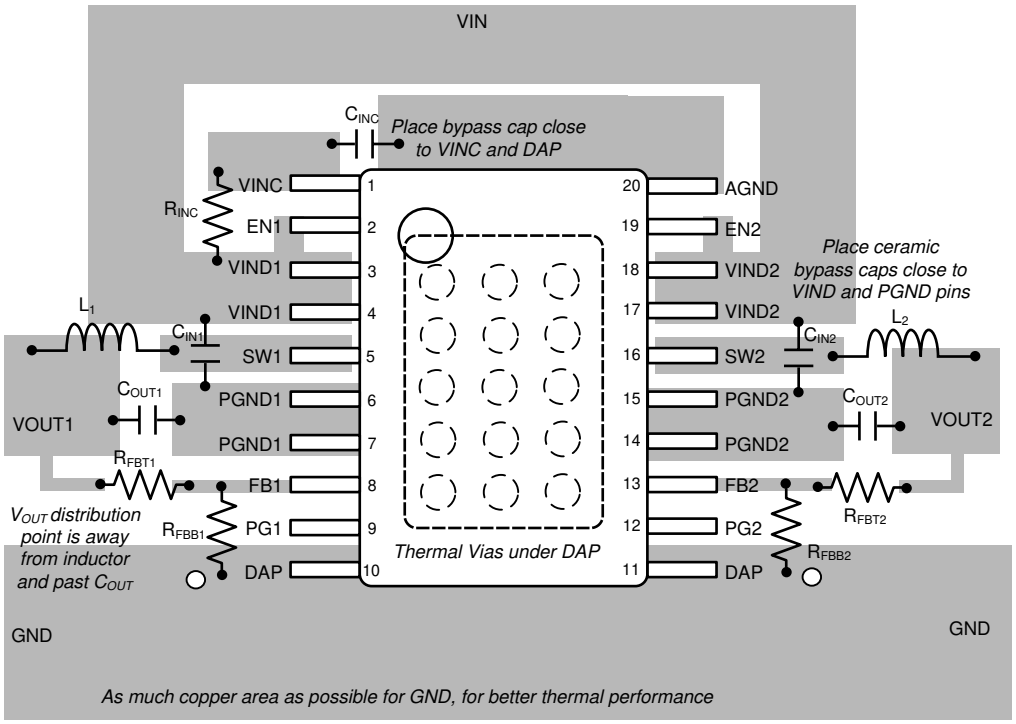


図 7-17. Typical Layout For DC/DC Converter

7.4.3 Thermal Considerations

T_J = Chip junction temperature

T_A = Ambient temperature

$R_{\theta JC}$ = Thermal resistance from chip junction to device case

$R_{\theta JA}$ = Thermal resistance from chip junction to ambient air

Heat in the LM26420-Q1 due to internal power dissipation is removed through conduction and/or convection.

Conduction: Heat transfer occurs through cross sectional areas of material. Depending on the material, the transfer of heat can be considered to have poor to good thermal conductivity properties (insulator vs conductor).

Heat Transfer goes as:

Silicon → package → lead frame → PCB

Convection: Heat transfer is by means of airflow. This can be from a fan or natural convection. Natural convection occurs when air currents rise from the hot device to cooler air.

Thermal impedance is defined as:

$$R_{\theta} = \frac{\Delta T}{Power} \tag{37}$$

Thermal impedance from the silicon junction to the ambient air is defined as:

$$R_{\theta JA} = \frac{T_J - T_A}{P_{INTERNAL}} \tag{38}$$

The PCB size, weight of copper used to route traces and ground plane, and number of layers within the PCB can greatly affect $R_{\theta JA}$. The type and number of thermal vias can also make a large difference in the thermal impedance. Thermal vias are necessary in most applications. Thermal vias conduct heat from the surface of the PCB to the ground plane. Five to eight thermal vias must be placed under the exposed pad to the ground plane if the WQFN package is used. Up to 12 thermal vias must be used in the HTSSOP-20 package for optimum heat transfer from the device to the ground plane.

Thermal impedance also depends on the thermal properties of the application operating conditions (V_{IN}, V_{OUT}, I_{OUT}, and so forth), and the surrounding circuitry.

7.4.3.1 Method 1: Silicon Junction Temperature Determination

To accurately measure the silicon temperature for a given application, two methods can be used. The first method requires the user to know the thermal impedance of the silicon junction to top case temperature.

Some clarification needs to be made before we go any further.

$R_{\theta JC}$ is the thermal impedance from silicon junction to the exposed pad.

$R_{\theta JT}$ is the thermal impedance from top case to the silicon junction.

In this data sheet, $R_{\theta JT}$ is used so that $R_{\theta JT}$ allows the user to measure top case temperature with a small thermocouple attached to the top case.

$R_{\theta JT}$ is approximately 20°C/W for the 16-pin WQFN package with the exposed pad. Knowing the internal dissipation from the efficiency calculation given previously, and the case temperature, which can be empirically measured on the bench we have:

$$R_{\theta JT} = \frac{T_J - T_T}{P_{INTERNAL}} \tag{39}$$

Therefore:

$$T_J = (R_{\theta JT} \times P_{INTERNAL}) + T_C \tag{40}$$

From the previous example:

$$T_J = 20°C/W \times 0.304W + T_C \tag{41}$$

7.4.3.2 Thermal Shutdown Temperature Determination

The second method, although more complicated, can give a very accurate silicon junction temperature.

The first step is to determine $R_{\theta JA}$ of the application. The LM26420-Q1 has over-temperature protection circuitry. When the silicon temperature reaches 165°C, the device stops switching. The protection circuitry has a hysteresis of about 15°C. After the silicon junction temperature has decreased to approximately 150°C, the device starts to switch again. Knowing this, the $R_{\theta JA}$ for any application can be characterized during the early stages of the design one can calculate the $R_{\theta JA}$ by placing the PCB circuit into a thermal chamber. Raise the ambient temperature in the given working application until the circuit enters thermal shutdown. If the SW pin is monitored, when the internal FETs stop switching is obvious, indicating a junction temperature of 165°C. Knowing the internal power dissipation from the above methods, the junction temperature, and the ambient temperature $R_{\theta JA}$ can be determined.

$$R_{\theta JA} = \frac{165° - T_A}{P_{INTERNAL}} \tag{42}$$

After determined, the maximum ambient temperature allowed for a desired junction temperature can be found.

An example of calculating $R_{\theta JA}$ for an application using the LM26420-Q1 WQFN demonstration board is shown below.

The four layer PCB is constructed using FR4 with 1 oz copper traces. The copper ground plane is on the bottom layer. The ground plane is accessed by eight vias. The board measures 3 cm × 3 cm. It was placed in an oven with no forced airflow. The ambient temperature was raised to 152°C, and at that temperature, the device went into thermal shutdown.

From the previous example:

$$P_{INTERNAL} = 304 \text{ mW} \tag{43}$$

$$R_{\theta JA} = \frac{165^oC - 152^oC}{304 \text{ mW}} = 42.8^o \text{ C/W} \tag{44}$$

If the junction temperature is to be kept below 125°C, then the ambient temperature can not go above 112°C.

$$T_J – (R_{\theta JA} \times P_{INTERNAL}) = T_A \tag{45}$$

$$125°C – (42.8°C/W \times 304 \text{ mW}) = 112.0°C \tag{46}$$

8 Device and Documentation Support

8.1 Device Support

8.1.1 サード・パーティ製品に関する免責事項

サード・パーティ製品またはサービスに関するテキサス・インスツルメンツの出版物は、単独またはテキサス・インスツルメンツの製品、サービスと一緒に提供される場合に関係なく、サード・パーティ製品またはサービスの適合性に関する是認、サード・パーティ製品またはサービスの是認の表明を意味するものではありません。

8.1.2 Custom Design With WEBENCH® Tools

Click here to create a custom design using the LM26420-Q1 device with the WEBENCH® Power Designer.

1. Start by entering the input voltage (V_{IN}), output voltage (V_{OUT}), and output current (I_{OUT}) requirements.
2. Optimize the design for key parameters such as efficiency, footprint, and cost using the optimizer dial.
3. Compare the generated design with other possible solutions from Texas Instruments.

The WEBENCH Power Designer provides a customized schematic along with a list of materials with real-time pricing and component availability.

In most cases, these actions are available:

- Run electrical simulations to see important waveforms and circuit performance
- Run thermal simulations to understand board thermal performance
- Export customized schematic and layout into popular CAD formats
- Print PDF reports for the design, and share the design with colleagues

Get more information about WEBENCH tools at www.ti.com/WEBENCH.

8.2 Documentation Support

8.2.1 Related Documentation

Texas Instruments, *AN-1229 SIMPLE SWITCHER® PCB Layout Guidelines* application note

8.3 ドキュメントの更新通知を受け取る方法

ドキュメントの更新についての通知を受け取るには、www.tij.co.jp のデバイス製品フォルダを開いてください。[通知] をクリックして登録すると、変更されたすべての製品情報に関するダイジェストを毎週受け取ることができます。 変更の詳細については、改訂されたドキュメントに含まれている改訂履歴をご覧ください。

8.4 サポート・リソース

テキサス・インスツルメンツ E2E™ サポート・フォーラムは、エンジニアが検証済みの回答と設計に関するヒントをエキスパートから迅速かつ直接得ることができる場所です。既存の回答を検索したり、独自の質問をしたりすることで、設計で必要な支援を迅速に得ることができます。

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8.5 Trademarks

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WEBENCH® is a registered trademark of Texas Instruments.
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8.6 静電気放電に関する注意事項

この IC は、ESD によって破損する可能性があります。テキサス・インスツルメンツは、IC を取り扱う際には常に適切な注意を払うことを推奨します。正しい取り扱いおよび設置手順に従わない場合、デバイスを破損するおそれがあります。

ESD による破損は、わずかな性能低下からデバイスの完全な故障まで多岐にわたります。精密な IC の場合、パラメータがわずかに変化するだけで公表されている仕様から外れる可能性があるため、破損が発生しやすくなっています。

8.7 用語集

テキサス・インスツルメンツ用語集　この用語集には、用語や略語の一覧および定義が記載されています。

9 Revision History

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

Changes from Revision B (June 2020) to Revision C (November 2024) **Page**

- ドキュメント全体にわたって表、図、相互参照の採番方法を更新 ... 1
- ドキュメント全体を通して PMOS と NMOS を MOS に変更 ... 1
- Changed Parameter UVLO V_{IN} Rising for WQFN-16 Package: TYP value from 2.628V to 2.75V ... 6
- Changed Parameter UVLO V_{IN} Falling for WQFN-16 Package: TYP value from 2.3V to 2.5V. ... 6
- Changed Parameter UVLO hysteresis for WQFN-16 Package: TYP value from 330mV to 260mV ... 6
- Added HTSSOP-20 Package to TEST CONDITIONS for Parameter F_{FB} ... 6
- Changed Parameter I_{CL_BOT} for WQFN-16 Package: TYP value from 0.75A to 1.0A ... 6
- Changed parameter I_{QVINC} VINC Quiescent Current (non-switching) with both outputs on: TEST CONDITION V_{FB} from 0.9V to 0.95V ... 6
- Changed Parameter I_{QVIND} VIND Quiescent Current (non-switching): TEST CONDITION V_{FB} from 0.9V to 0.95V ... 6
- Updated the power-good thresholds in the functional block diagram for the HTSSOP-20 package to match with electrical characteristics ... 13
- Added functional block diagram for the WQFN-16 package ... 13
- Added typical undervoltage lockout threshold values for the WQFN-16 package ... 15
- Changed ±10% into ±15% in the note which describes the usage of PG_1 to control V_{OUT2} ... 17
- Changed ±14% into ±15% in the sentence describing the power-good threshold ... 17
- Updated 図 7-6 ... 17
- Updated the title of section to *Current Limit and Short-Circuit Protection for HTSSOP-20 Package* ... 19
- Added new section, *Current Limit and Short-Circuit Protection for WQFN-16 Package* ... 19
- Added C6 in 図 7-7 in accordance with 表 7-2 ... 20
- Changed V_{OUT2} in 図 7-7 from 1.8V into 0.8V ... 20
- Changed V_{OUT1} in 図 7-7 from 3.3V into 1.8V ... 20
- Changed minimum for V_{IN} in 図 7-7 from 4.5V into 3V ... 20
- Changed 550 kHz into 2.2MHz in the sentence describing internal power-loss calculation and in 表 7-3 ... 25
- Added separate *Power Supply Recommendations* sub-sections for HTSSOP-20 package and WQFN-16 package ... 30

Changes from Revision A (July 2019) to Revision B (June 2020) **Page**

- 機能安全性の箇条書き項目を追加セクション 1 ... 1

10 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.

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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM26420Q0XMH/NOPB	ACTIVE	HTSSOP	PWP	20	73	RoHS & Green	SN	Level-1-260C-UNLIM	-40 to 125	LM26420 Q0XMH	Samples
LM26420Q0XMHX/NOPB	ACTIVE	HTSSOP	PWP	20	2500	RoHS & Green	SN	Level-1-260C-UNLIM	-40 to 125	LM26420 Q0XMH	Samples
LM26420Q1XMH/NOPB	ACTIVE	HTSSOP	PWP	20	73	RoHS & Green	SN	Level-1-260C-UNLIM	-40 to 125	LM26420 Q1XMH	Samples
LM26420Q1XMHX/NOPB	ACTIVE	HTSSOP	PWP	20	2500	RoHS & Green	SN	Level-1-260C-UNLIM	-40 to 125	LM26420 Q1XMH	Samples
LM26420Q1XSQ/NOPB	ACTIVE	WQFN	RUM	16	1000	RoHS & Green	SN	Level-3-260C-168 HR	-40 to 125	L26420Q	Samples
LM26420Q1XSQX/NOPB	ACTIVE	WQFN	RUM	16	4500	RoHS & Green	SN	Level-3-260C-168 HR	-40 to 125	L26420Q	Samples

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

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

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

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

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

OTHER QUALIFIED VERSIONS OF LM26420-Q1 :

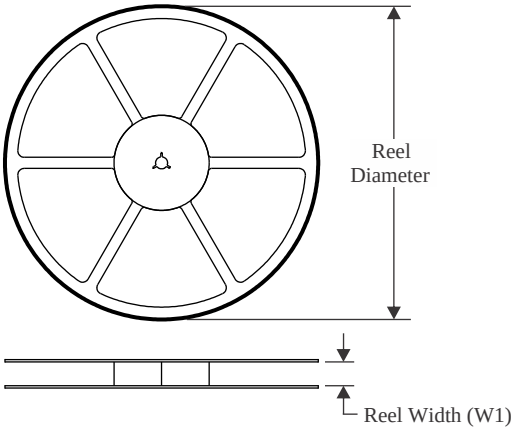
- Catalog : LM26420

NOTE: Qualified Version Definitions:

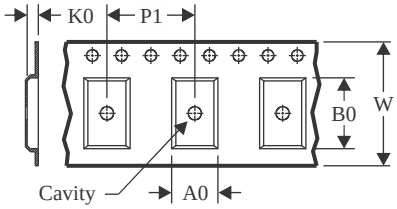
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION

REEL DIMENSIONS

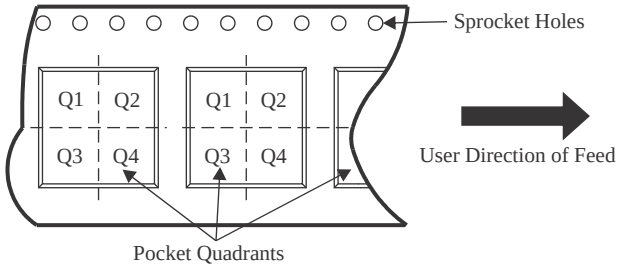


TAPE DIMENSIONS



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

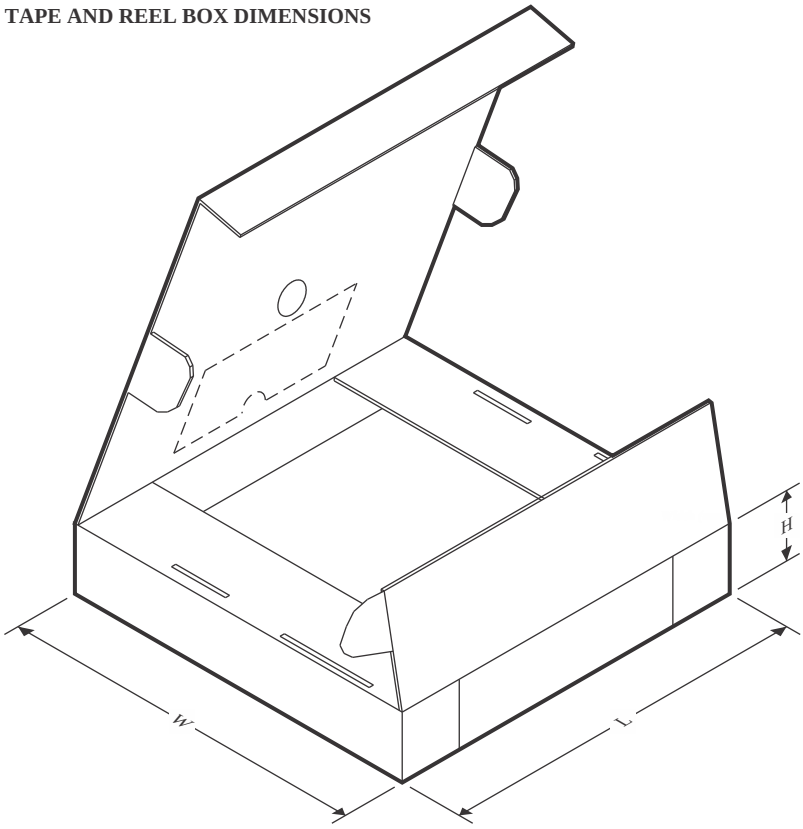
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
LM26420Q0XMHX/NOPB	HTSSOP	PWP	20	2500	330.0	16.4	6.95	7.0	1.4	8.0	16.0	Q1
LM26420Q1XMHX/NOPB	HTSSOP	PWP	20	2500	330.0	16.4	6.95	7.0	1.4	8.0	16.0	Q1
LM26420Q1XSQ/NOPB	WQFN	RUM	16	1000	178.0	12.4	4.3	4.3	1.3	8.0	12.0	Q1
LM26420Q1XSQX/NOPB	WQFN	RUM	16	4500	330.0	12.4	4.3	4.3	1.3	8.0	12.0	Q1

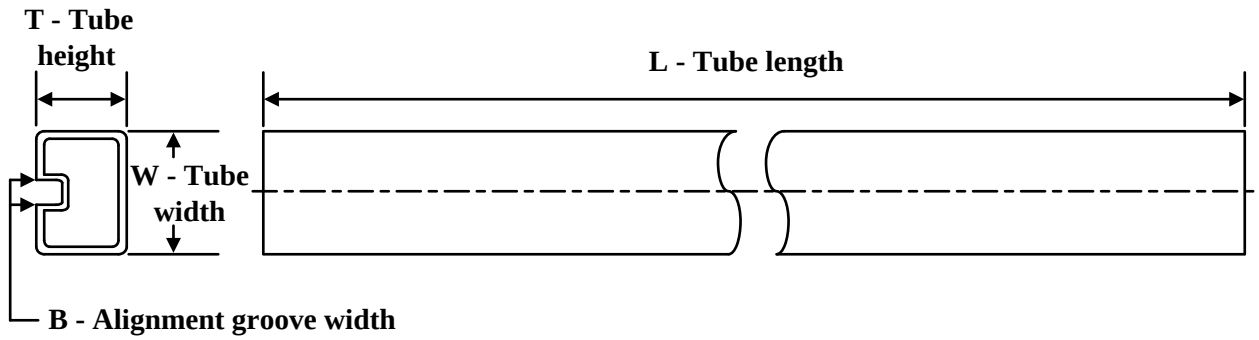
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM26420Q0XMHX/NOPB	HTSSOP	PWP	20	2500	367.0	367.0	35.0
LM26420Q1XMHX/NOPB	HTSSOP	PWP	20	2500	356.0	356.0	35.0
LM26420Q1XSQ/NOPB	WQFN	RUM	16	1000	208.0	191.0	35.0
LM26420Q1XSQX/NOPB	WQFN	RUM	16	4500	356.0	356.0	36.0

TUBE



*All dimensions are nominal

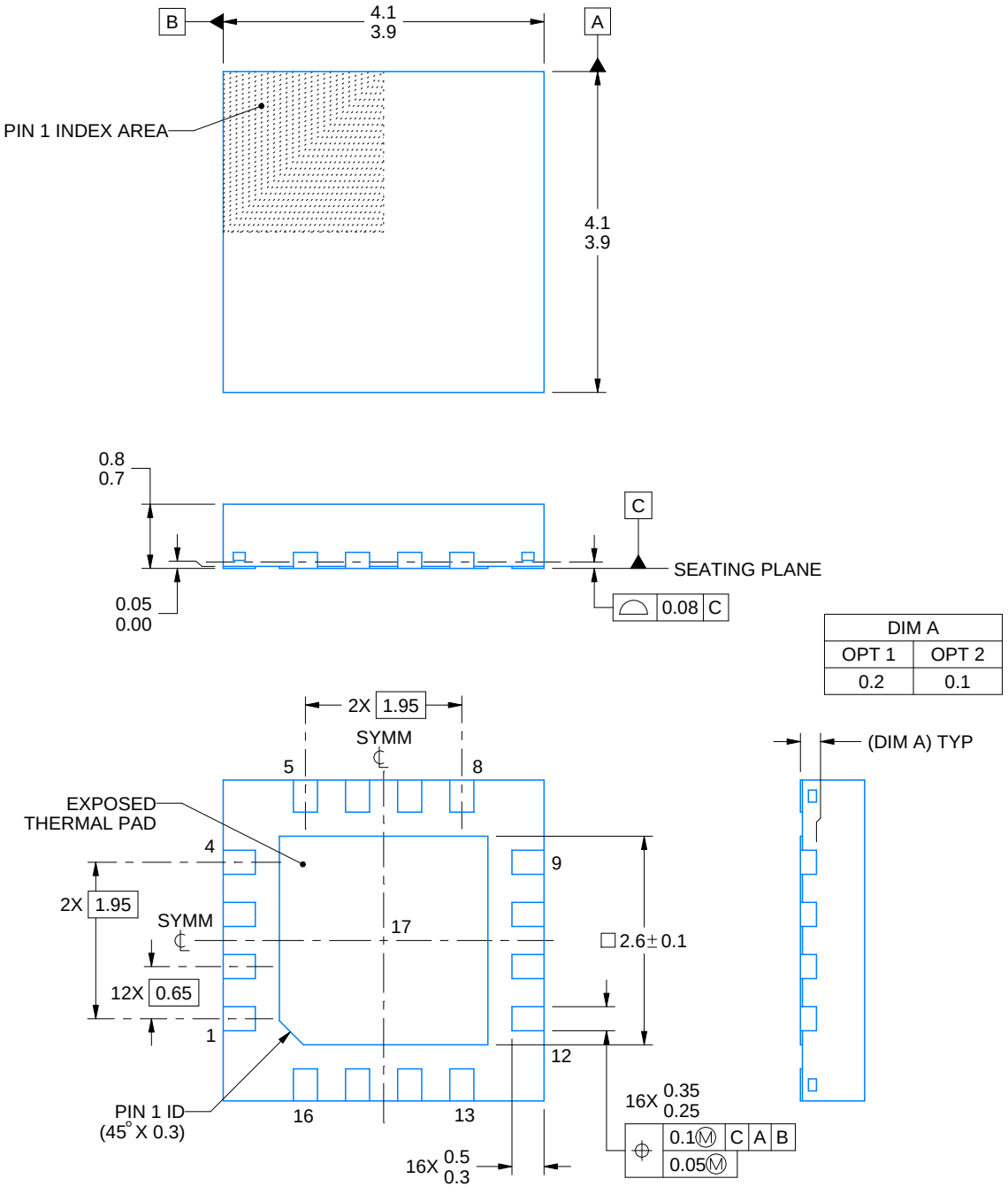
Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
LM26420Q0XMH/NOPB	PWP	HTSSOP	20	73	495	8	2514.6	4.06
LM26420Q1XMH/NOPB	PWP	HTSSOP	20	73	495	8	2514.6	4.06

RUM0016A

PACKAGE OUTLINE

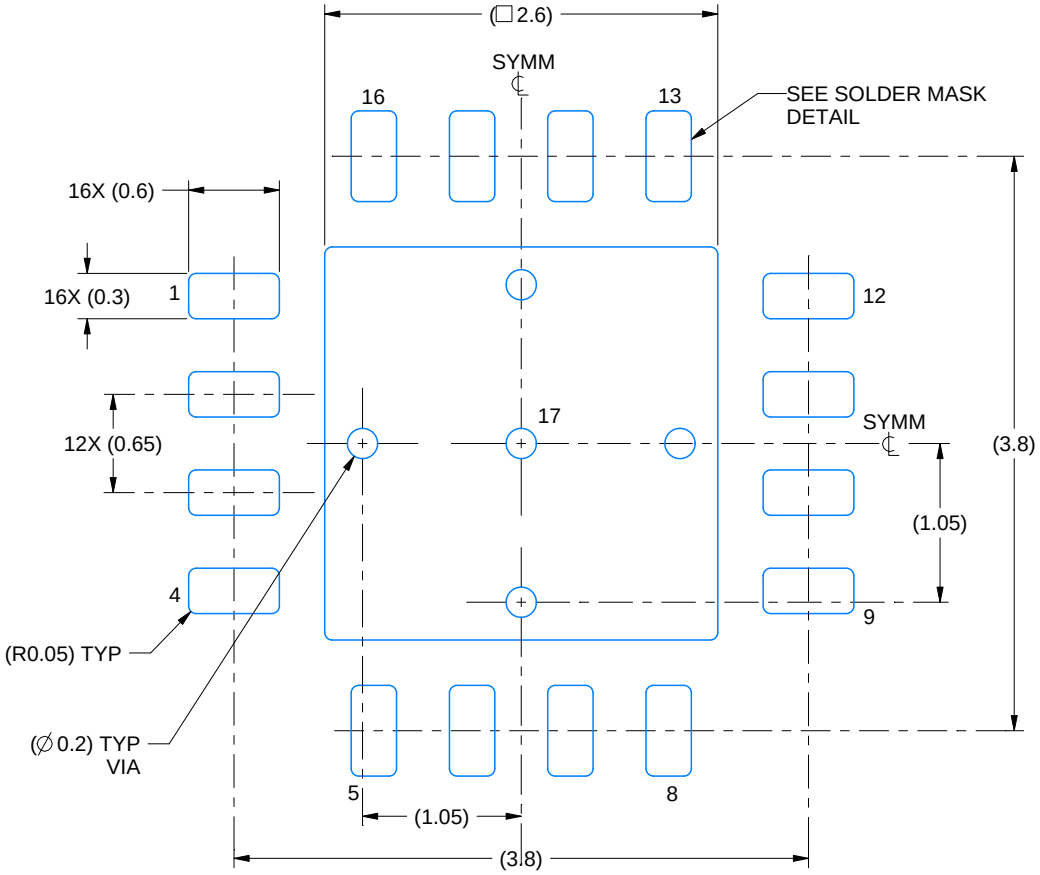
WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

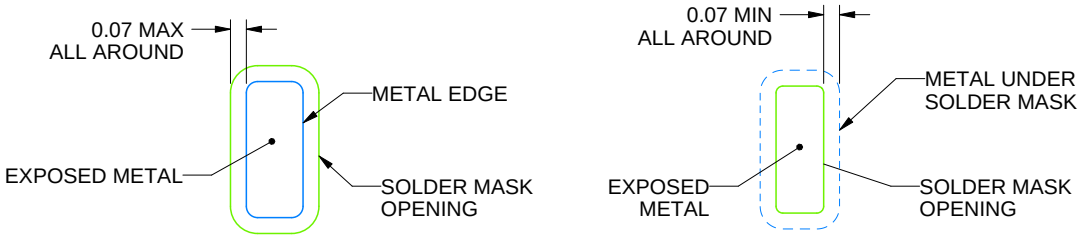


NOTES:

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 thermal and mechanical performance.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 20X



NON SOLDER MASK DEFINED (PREFERRED)

SOLDER MASK DEFINED

SOLDER MASK DETAILS

4214998/A 11/2021

NOTES: (continued)

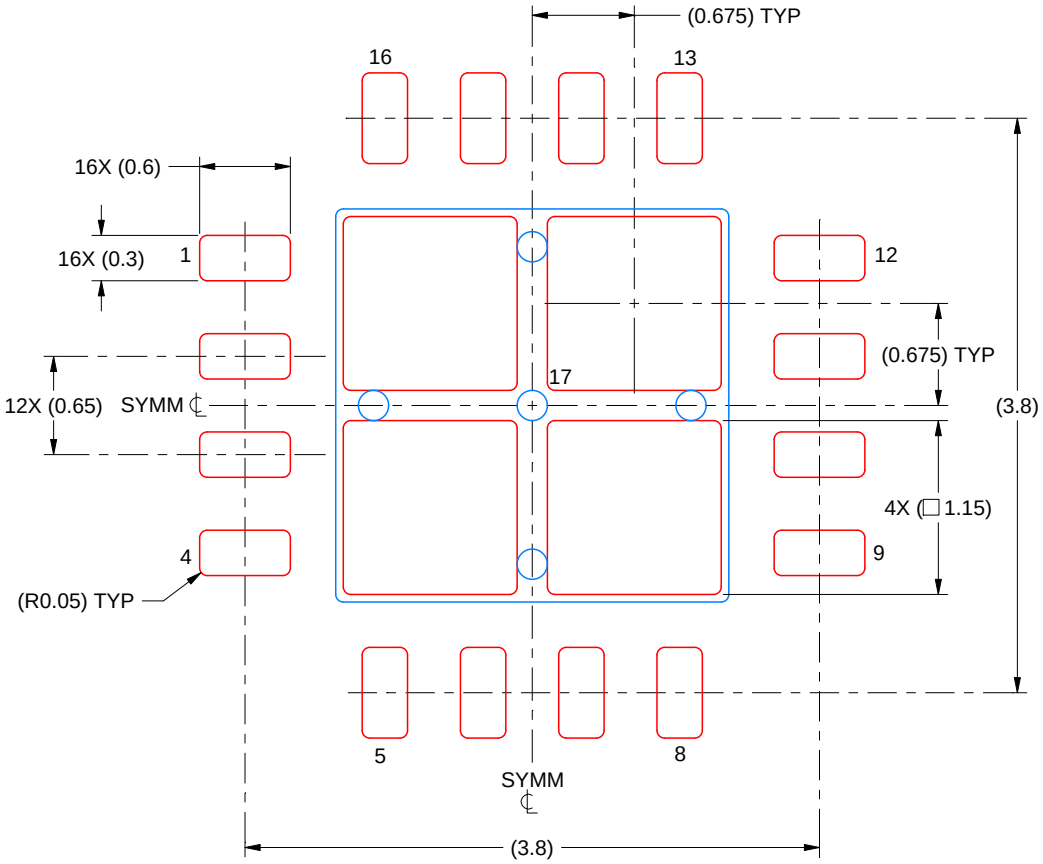
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

EXAMPLE STENCIL DESIGN

RUM0016A

WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE
BASED ON 0.125 MM THICK STENCIL
SCALE: 20X

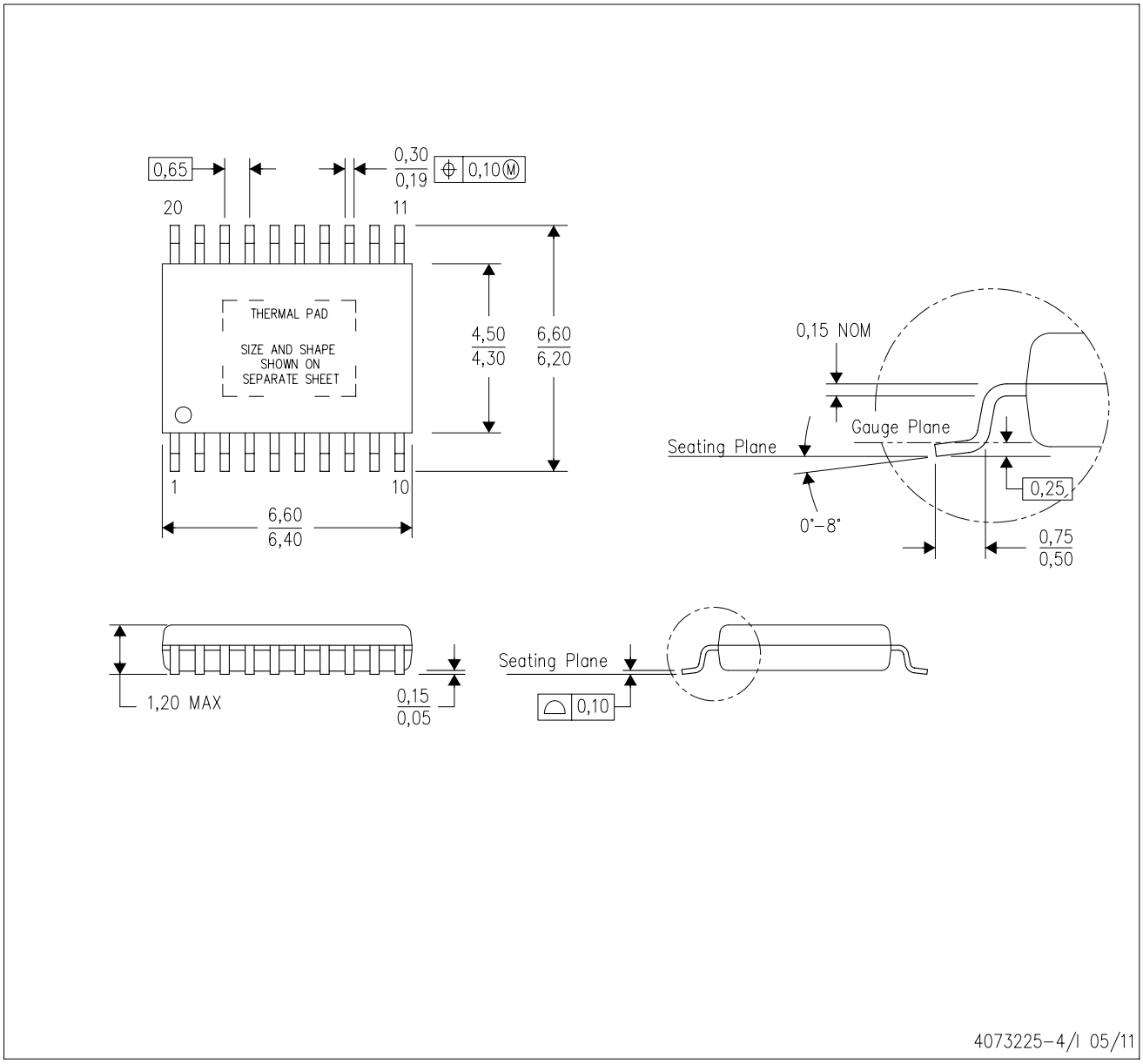
EXPOSED PAD 17
78% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE

4214998/A 11/2021

NOTES: (continued)

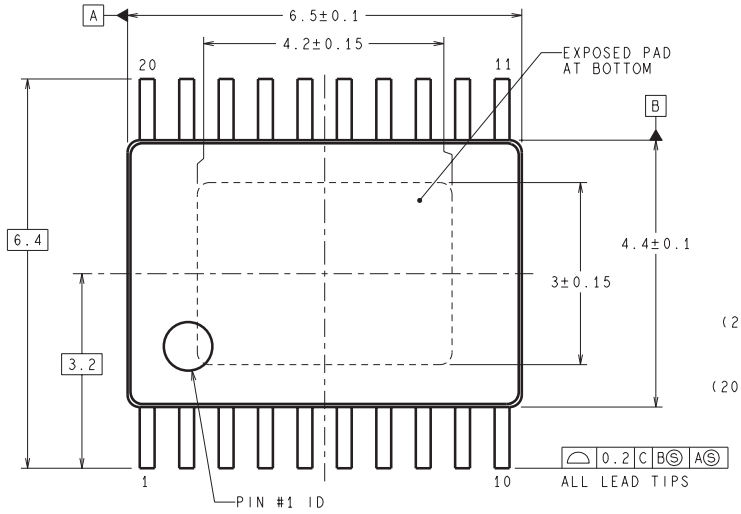
6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

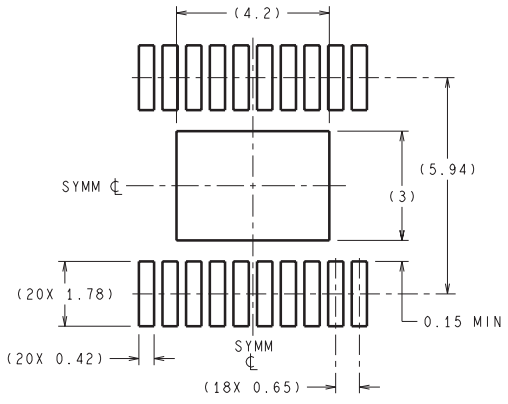
PWP (R–PDSO–G20) PowerPAD™ PLASTIC SMALL OUTLINE



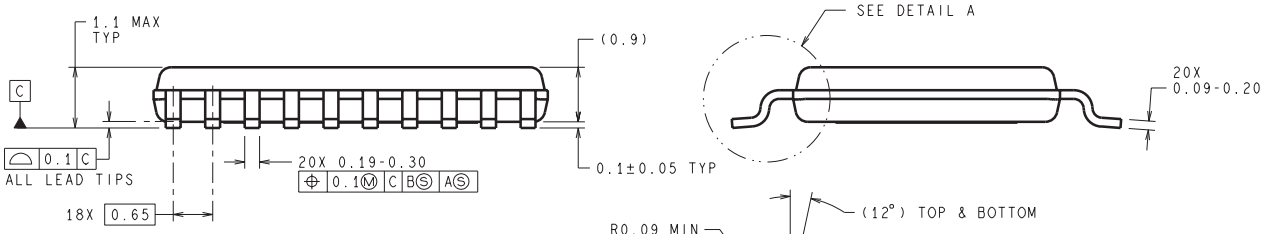
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusions. Mold flash and protrusion shall not exceed 0.15 per side.
D. This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at www.ti.com <http://www.ti.com>.
E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
E. Falls within JEDEC MO–153

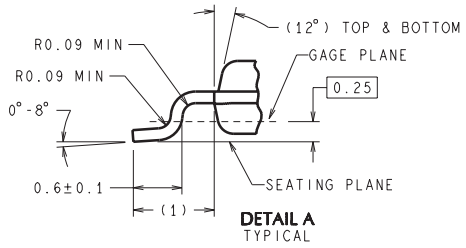
PWP0020A





RECOMMENDED LAND PATTERN





DETAIL A
TYPICAL

DIMENSIONS ARE IN MILLIMETERS
DIMENSIONS IN ( ) FOR REFERENCE ONLY

MXA20A (Rev C)

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