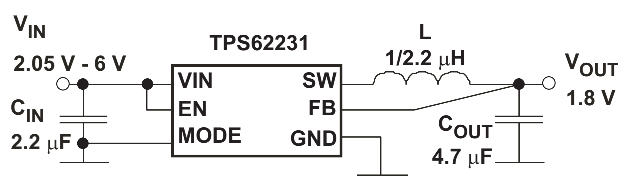
2 MHz / 3 MHz Ultra Small Step Down Converter in 1x1.5 SON Package

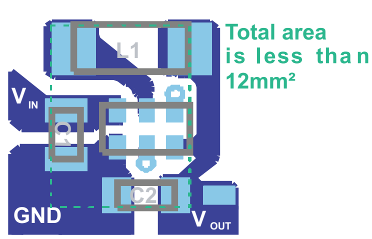
FEATURES

- **2 MHz / 3 MHz Switch Frequency**
- **Up to 94% Efficiency**
- **Output Peak Current up to 500mA**
- **Excellent AC and Transient Load Regulation**
- **High PSRR (up to 90dB)**
- **Small External Output Filter Components 1µH/ 4.7µF**
- **V_{IN} range from 2.05V to 6V**
- **Optimized Power Save Mode For Low Output Ripple Voltage**
- **Forced PWM Mode Operation**
- **Typ. 22 µA Quiescent Current**
- **100% Duty Cycle for Lowest Dropout**
- **Small 1 × 1.5 × 0.6mm^3 SON Package**
- **12 mm^2 Minimum Solution Size**
- **Supports 0.6 mm Maximum Solution Height**
- **Soft Start with typ. 100µs Start Up Time**

APPLICATIONS

- **LDO Replacement**
- **Portable Audio, Portable Media**
- **Cell Phones**
- **Low Power Wireless**
- **Low Power DSP Core Supply**
- **Digital Cameras**





DESCRIPTION

The TPS6223X device family is a high frequency synchronous step down DC-DC converter optimized for battery powered portable applications. It supports up to 500mA output current and allows the use of tiny and low cost chip inductors and capacitors.

With a wide input voltage range of 2.05V to 6V the device supports applications powered by Li-Ion batteries with extended voltage range. The minimum input voltage of 2.05V allows as well the operation from Li-primary or two alkaline batteries. Different fixed output voltage versions are available from 1.0V to 3.3V.

The TPS6223X series features switch frequency up to 3.8MHz. At medium to heavy loads, the converter operates in PWM mode and automatically enters Power Save Mode operation at light load currents to maintain high efficiency over the entire load current range.

Because of its excellent PSRR and AC load regulation performance, the device is also suitable to replace linear regulators to obtain better power conversion efficiency.

The Power Save Mode in TPS6223X reduces the quiescent current consumption down to 22µA during light load operation. It is optimized to achieve very low output voltage ripple even with small external component and features excellent ac load regulation.

For very noise sensitive applications, the device can be forced to PWM Mode operation over the entire load range by pulling the MODE pin high. In the shutdown mode, the current consumption is reduced to less than 1µA. The TPS6223X is available in a 1 × 1.5mm^2 6 pin SON package.

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

ORDERING INFORMATION(1)

T_A	PART NUMBER(2)	OUTPUT VOLTAGE	FREQUENCY [MHz]	PACKAGE DESIGNATOR	ORDERING	PACKAGE MARKING
–40°C to 85°C	TPS62230	2.5 V	3	DRY	TPS62230DRY	GV
	TPS62231	1.8 V	3	DRY	TPS62231DRY	GW
	TPS62232	1.2 V	3	DRY	TPS62232DRY	GX
	TPS62239	1.0 V	3	DRY	TPS62239DRY	OP
	TPS622311	1.1V	2	DRY	TPS622311DRY	PA
	TPS622315	1.15V	2	DRY	TPS622315DRY	RI
	TPS62235	1.2V	2	DRY	TPS62235DRY	OQ
	TPS622318	1.25V	3	DRY	TPS622318DRY	ST
	TPS622313	1.3 V	3	DRY	TPS622313DRY	QF
	TPS622314	1.5 V	3	DRY	TPS622314DRY	QG
	TPS62236	1.85V	2	DRY	TPS62236DRY	OR
	TPS622312	2.0 V	3	DRY	TPS622312DRY	QE
	TPS62234	2.1 V	3	DRY	TPS62234DRY	OH
	TPS62238	2.25 V	3	DRY	TPS62238DRY	ON
	TPS622310	2.3 V	3	DRY	TPS622310DRY	OT
	TPS622316	2.7 V	3	DRY	TPS622316DRY	RJ
	TPS622317	2.9 V	3	DRY	TPS622317DRY	RK
	TPS62233	3.0 V	3	DRY	TPS62233DRY	OG
	TPS62237	3.3V	2	DRY	TPS62237DRY	OS

(1) For detailed ordering information see the PACKAGE OPTION ADDENDUM at the end of this data sheet.
(2) The DRY package is available in tape on reel. Add R suffix to order quantities of 3000 parts per reel, T suffix for 250 parts per reel.

ABSOLUTE MAXIMUM RATINGS

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

			VALUE	UNIT
V_I	Voltage at VIN and SW Pin(2)		–0.3 to 7	V
	Voltage at EN, MODE Pin(2)		–0.3 to V_{IN} +0.3, ≤7	V
	Voltage at FB Pin (2)		–0.3 to 3.6	V
	Peak output current		internally limited	A
	ESD rating(3)	HBM Human body model	2	kV
		CDM Charge device model	1	
		Machine model	200	V
	Power dissipation		Internally limited	
T_J	Maximum operating junction temperature		–40 to 125	°C
T_{stg}	Storage temperature range		–65 to 150	°C

(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) All voltage values are with respect to network ground terminal.
(3) The human body model is a 100-pF capacitor discharged through a 1.5-kΩ resistor into each pin. The machine model is a 200-pF capacitor discharged directly into each pin.

DISSIPATION RATINGS[1]

PACKAGE	$R_{\theta JA}$	POWER RATING FOR $T_A \le 25°C$	DERATING FACTOR ABOVE $T_A = 25°C$
1 × 1.5 SON	234°C/W[2]	420 mW	4.2 mW/°C

(1) Maximum power dissipation is a function of $T_{J(max)}$, θ_{JA} and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = [T_{J(max)} – T_A] / \theta_{JA}$.
(2) This thermal data is measured with high-K board (4 layers board according to JESD51-7 JEDEC standard).

RECOMMENDED OPERATING CONDITIONS

operating ambient temperature T_A = –40 to 85°C (unless otherwise noted)[1]

			MIN	NOM	MAX	UNIT
Supply voltage V_{IN} [2]			2.05		6	V
Effective inductance				2.2		µH
Effective capacitance			2.0	4.7		µF
Recommended minimum supply voltage	$V_{OUT} \le V_{IN}$ -1 V[3]	500 mA maximum I_{OUT} [4]		3.0	3.6	V
		350mA maximum I_{OUT} [5]		2.5	2.7	
	$V_{OUT} \le 1.8V$	60 mA maximum output current[5]			2.05	
Operating virtual junction temperature range, T_J			–40		125	°C

(1) In applications where high power dissipation and/or poor package thermal resistance is present, the maximum ambient temperature may have to be derated. Maximum ambient temperature ($T_{A(max)}$) is dependent on the maximum operating junction temperature ($T_{J(max)}$), the maximum power dissipation of the device in the application ($P_{D(max)}$), and the junction-to-ambient thermal resistance of the part/package in the application (θ_{JA}), as given by the following equation: $T_{A(max)} = T_{J(max)} – (\theta_{JA} \times P_{D(max)})$.
(2) The minimum required supply voltage for startup is 2.05 V. The part is functional down to the falling UVL (Under Voltage Lockout) threshold.
(3) For a voltage difference between minimum V_{IN} and V_{OUT} of ≥ 1 V
(4) Typical value applies for T_A = 25°C, maximum value applies for T_A = 70°C with $T_J \le$ 125°C, PCB layout needs to support proper thermal performance.
(5) Typical value applies for T_A = 25°C, maximum value applies for T_A = 85°C with $T_J \le$ 125°C, PCB layout needs to support proper thermal performance.

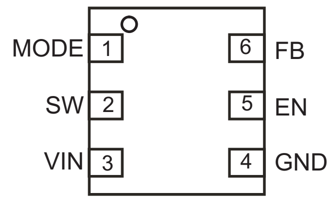
ELECTRICAL CHARACTERISTICS

V_{IN} = 3.6V, V_{OUT} = 1.8V, EN = V_{IN}, MODE = GND, T_A = –40°C to 85°C(1) typical values are at T_A = 25°C (unless otherwise noted), C_{IN} = 2.2µF, L = 2.2µH, C_{OUT} = 4.7µF, see parameter measurement information

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
SUPPLY							
V_{IN}	Input voltage range (2)			2.05		6	V
I_Q	Operating quiescent current	I_{OUT} = 0mA. PFM mode enabled (Mode = 0) device not switching			22	40	µA
		I_{OUT} = 0mA. PFM mode enabled (Mode = 0) device switching, V_{IN} = 3.6V, V_{OUT} = 1.2V			25		µA
		I_{OUT} = 0 mA. Switching with no load (MODE/DATA = V_{IN}), PWM operation, V_{OUT} = 1.8V, L = 2.2µH			3		mA
I_{SD}	Shutdown current	EN = GND(3)			0.1	1	µA
UVLO	Undervoltage lockout threshold	Falling			1.8	1.9	V
		Rising			1.9	2.05	V
ENABLE, MODE THRESHOLD							
$V_{IH\ TH}$	Threshold for detecting high EN, MODE	2.05 V ≤ V_{IN} ≤ 6V , rising edge			0.8	1	V
$V_{IL\ TH\ HYS}$	Threshold for detecting low EN, MODE	2.05 V ≤ V_{IN} ≤ 6V , falling edge		0.4	0.6		V
I_{IN}	Input bias Current, EN, MODE	EN, MODE = GND or V_{IN} = 3.6V			0.01	0.5	µA
POWER SWITCH							
$R_{DS(ON)}$	High side MOSFET on-resistance	V_{IN} = 3.6V, T_{Jmax} = 85°C; $R_{DS(ON)}$ max value			600	850	mΩ
	Low Side MOSFET on-resistance				350	480	
I_{LIMF}	Forward current limit MOSFET high-side	V_{IN} = 3.6V, open loop		690	850	1050	mA
	Forward current limit MOSFET low side			550	840	1220	mA
T_{SD}	Thermal shutdown	Increasing junction temperature			150		°C
	Thermal shutdown hysteresis	Decreasing junction temperature			20		°C
CONTROLLER							
t_{ONmin}	Minimum ON time	V_{IN} 3.6V, V_{OUT} = 1.8V, Mode = high, I_{OUT} = 0 mA			135		ns
t_{OFFmin}	Minimum OFF time				40		ns
OUTPUT							
V_{REF}	Internal Reference Voltage				0.70		V
V_{OUT}	Output voltage accuracy(4)	V_{IN} = 3.6V, Mode = GND, device operating in PFM Mode, I_{OUT} = 0mA			0%		
		V_{IN} = 3.6V, MODE = V_{IN}, I_{OUT} = 0 mA	T_A = 25°C	–2.0%		2.0%	
			T_A = –40°C to 85°C	–2.5%		2.5%	
	DC output voltage load regulation	PWM operation, Mode = V_{IN} = 3.6V, V_{OUT} = 1.8 V			0.001		%/mA
	DC output voltage line regulation	I_{OUT} = 0 mA, Mode = V_{IN}, 2.05V ≤ V_{IN} ≤ 6V			0		%/V
t_{Start}	Start-up Time	Time from active EN to V_{OUT} = 1.8V, V_{IN} = 3.6V, 10Ω load			100		µs
I_{LK_SW}	Leakage current into SW pin	V_{IN} = V_{OUT} = V_{SW} = 3.6 V, EN = GND(5)			0.1	0.5	µA

(1) In applications where high power dissipation and/or poor package thermal resistance is present, the maximum ambient temperature may have to be derated. Maximum ambient temperature ($T_{A(max)}$) is dependent on the maximum operating junction temperature ($T_{J(max)}$), the maximum power dissipation of the device in the application (PD(max)), and the junction-to-ambient thermal resistance of the part/package in the application (θ_{JA}), as given by the following equation: $T_{A(max)} = T_{J(max)} – (\theta_{JA} \times P_{D(max)})$.
(2) The minimum required supply voltage for startup is 2.05V. The part is functional down to the falling UVL (Under Voltage Lockout) threshold
(3) Shutdown current into VIN pin, includes internal leakage
(4) $V_{IN} = V_O + 1.0$ V
(5) The internal resistor divider network is disconnected from FB pin.

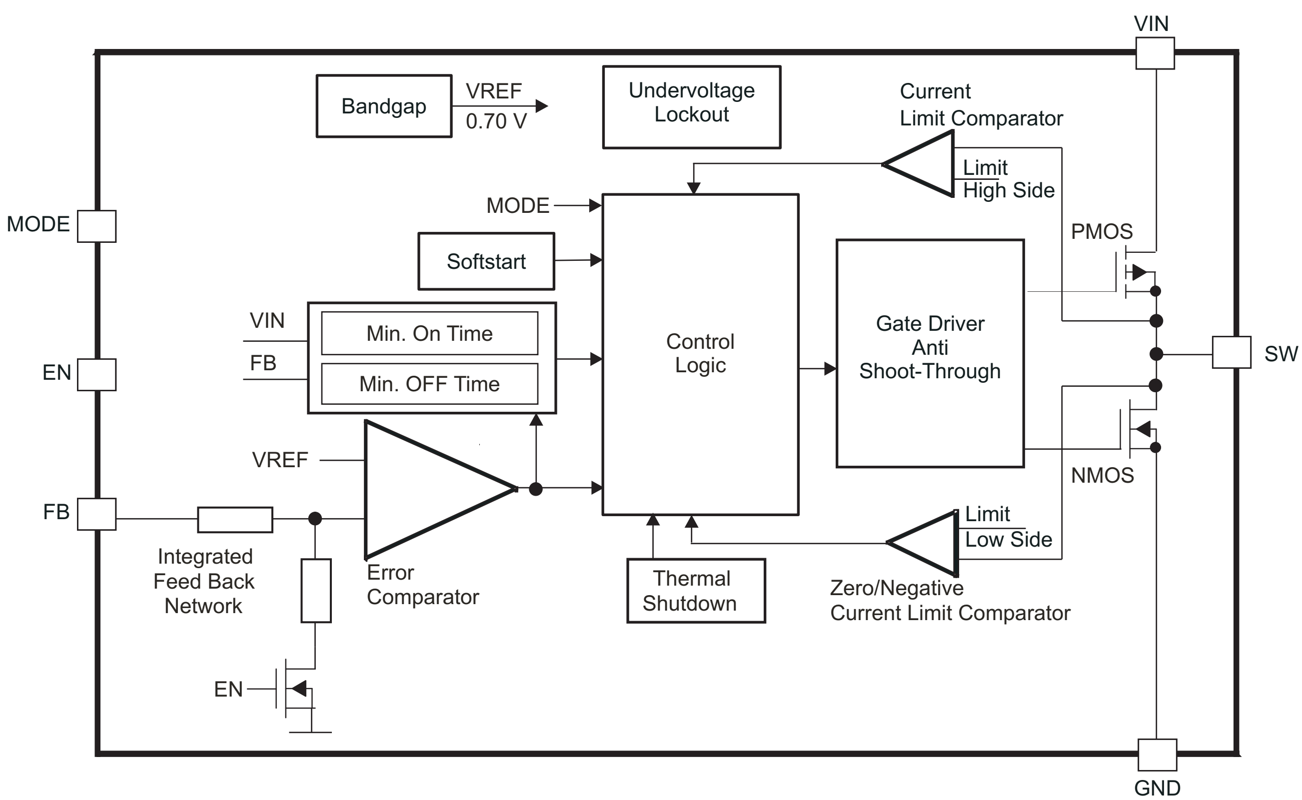
DRY PACKAGE
(TOP VIEW)



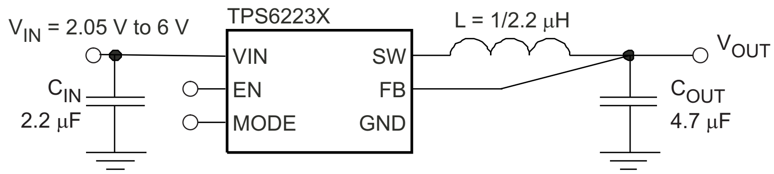
PIN FUNCTIONS

PIN		I/O	DESCRIPTION
NAME	NO		
VIN	3	PWR	V_{IN} power supply pin.
GND	4	PWR	GND supply pin
EN	5	IN	This is the enable pin of the device. Pulling this pin to low forces the device into shutdown mode. Pulling this pin to high enables the device. This pin must be terminated.
SW	2	OUT	This is the switch pin and is connected to the internal MOSFET switches. Connect the inductor to this terminal
FB	6	IN	Feedback Pin for the internal regulation loop. Connect this pin directly to the output capacitor.
MODE	1	IN	MODE pin = high forces the device to operate in PWM mode. Mode = low enables the Power Save Mode with automatic transition from PFM (Pulse frequency mode) to PWM (pulse width modulation) mode.

FUNCTIONAL BLOCK DIAGRAM



PARAMETER MEASUREMENT INFORMATION



C_{IN}: Murata GRM155R60J225ME15D 2.2 µF 0402 size
C_{OUT}: Murata GRM188R60J475ME 4.7 µF 0603 size, VOUT >= 1.8 V
C_{OUT}: Taiyo Yuden AMK105BJ475MV 4.7 µF 0402 size, VOUT = 1.2 V
l: Murata LQM2HPN1R0MJ0 1 µH, LQM2HPN2R2MJ0 2.2 µH,
size 2.5x2.0x1.2mm^3

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
η	Efficiency	vs Load current	1, 2, 3, 4, 5, 6, 7
η	Efficiency	vs Output Current	8, 9, 10, 11
V_O	Output voltage	vs Output current	12, 13, 14, 15, 16, 17
	Switching frequency	vs Output current	18, 19, 20, 21, 22, 23, 24, 25, 26, 27
	Output voltage peak to peak	vs Output current	28,29
I_Q	Quiescent current	vs Ambient temperature	30
I_{SD}	Shutdown current	vs Ambient temperature	31
$r_{DS(ON)}$	PMOS Static drain-source on-state resistance	vs Supply voltage and ambient temperature	32
	NMOS Static drain-source on-state resistance	vs Supply voltage and ambient temperature	33
PSRR	Power supply rejection ratio	vs Frequency	34
	Typical operation		35, 36, 37
	Line transient response	PFM	38
		PWM	39
	Mode transition PFM / forced PWM		40
	AC - load regulation performance		41 42, 43
	Load transient response		44, 45, 46, 47
	Start-up		48, 49
	Spurious Output Noise, 12R Load		50
	Spurious Output Noise, 100R Load		51

TYPICAL CHARACTERISTICS (continued)

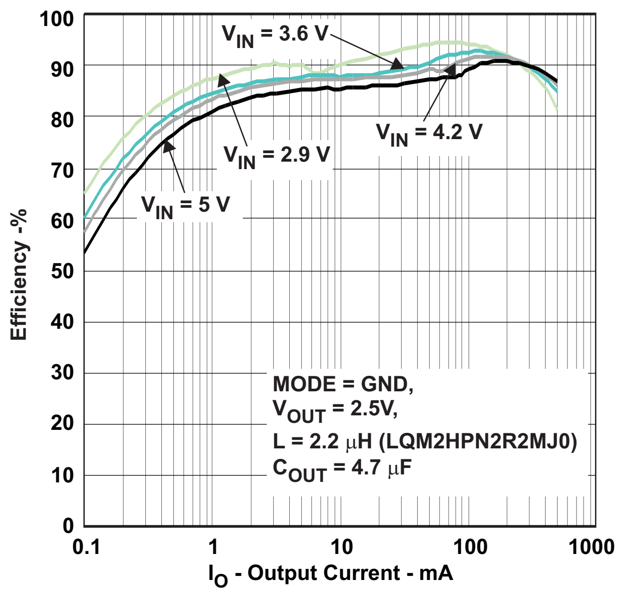


Figure 1. Efficiency PFM/PWM Mode 2.5V Output Voltage

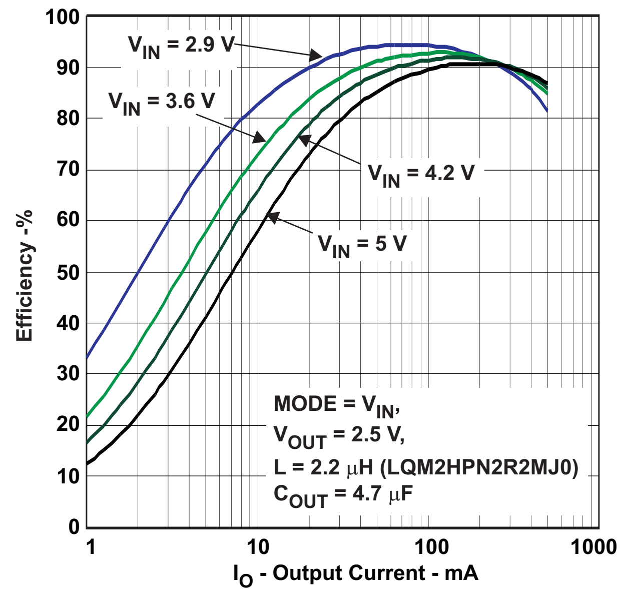


Figure 2. Efficiency Forced PWM Mode 2.5V Output Voltage

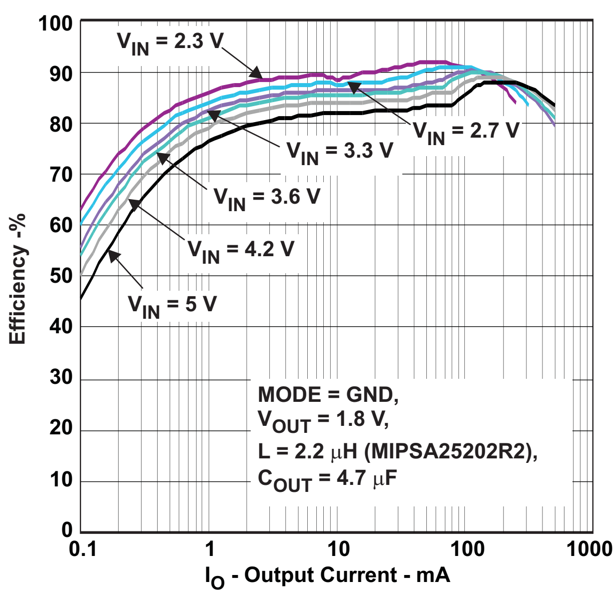


Figure 3. Efficiency PFM/PWM MODE 1.8V Output Voltage

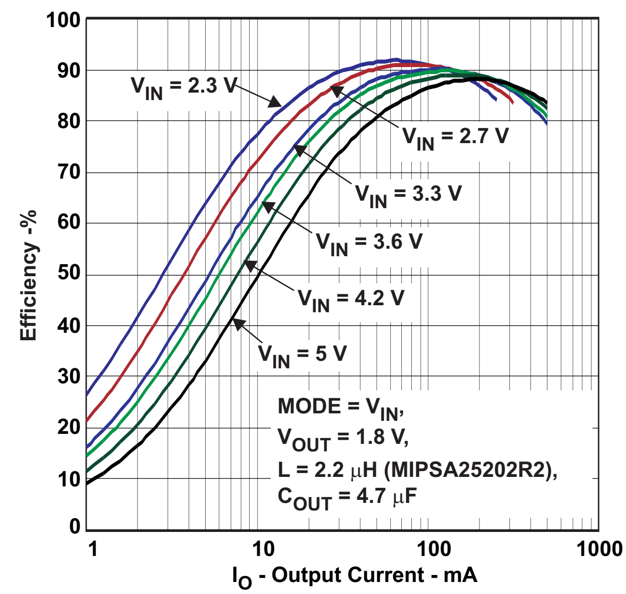


Figure 4. Efficiency Forced PWM Mode 1.8V Output voltage

TYPICAL CHARACTERISTICS (continued)

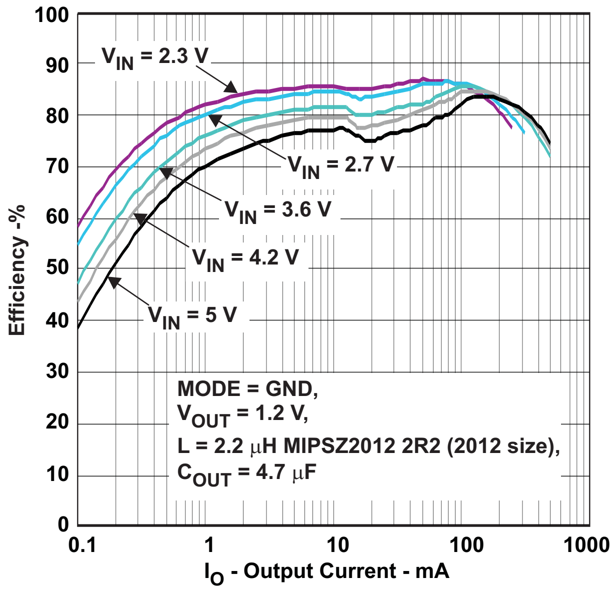


Figure 5. Efficiency PFM/PWM Mode 1.2V Output voltage

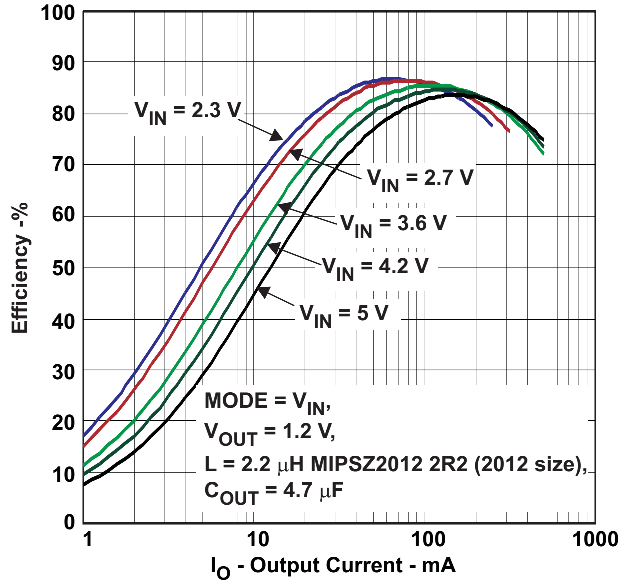


Figure 6. Efficiency Forced PWM Mode 1.2V Output Voltage

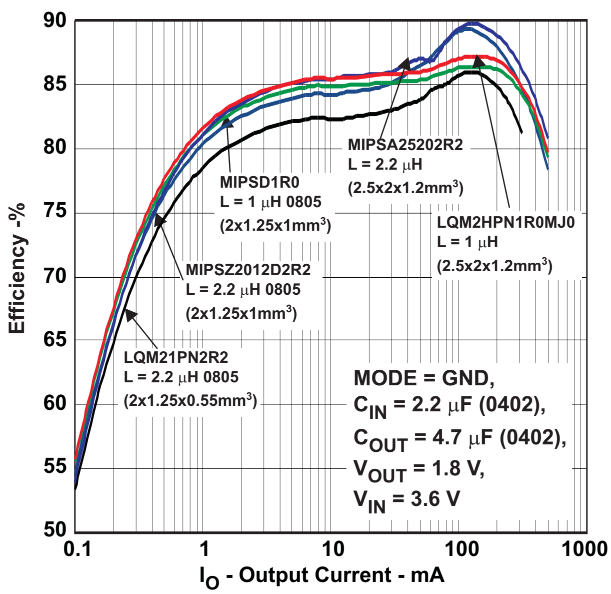


Figure 7. Comparison Efficiency vs Inductor Value and Size

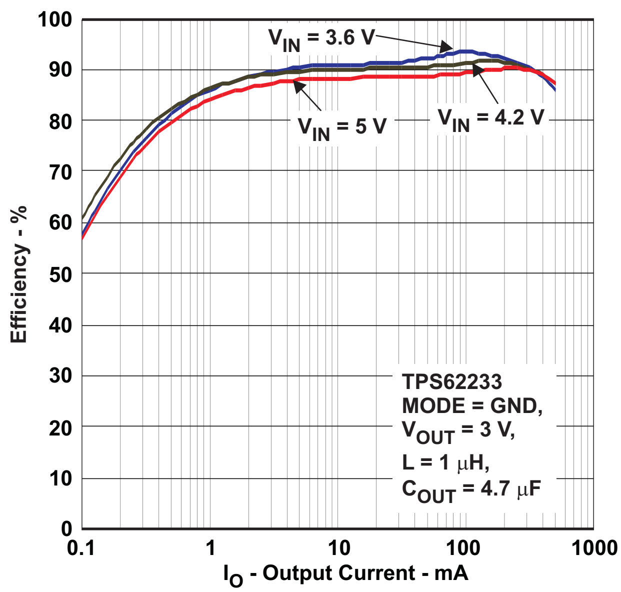


Figure 8. Comparison Efficiency vs I_{OUT} – TPS62233

TYPICAL CHARACTERISTICS (continued)

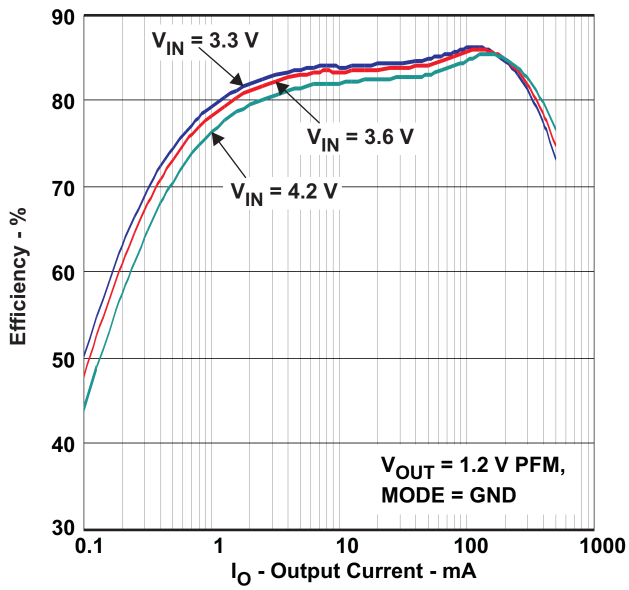


Figure 9. Comparison Efficiency vs I_{OUT} – TPS62235

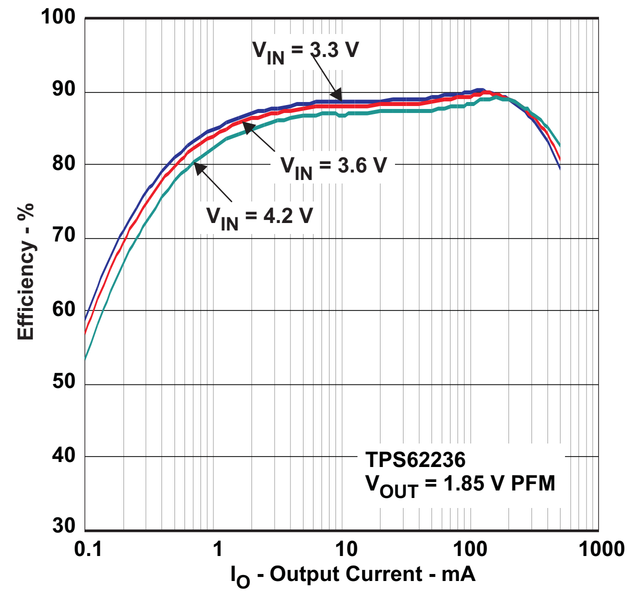


Figure 10. Comparison Efficiency vs I_{OUT} – TPS62236

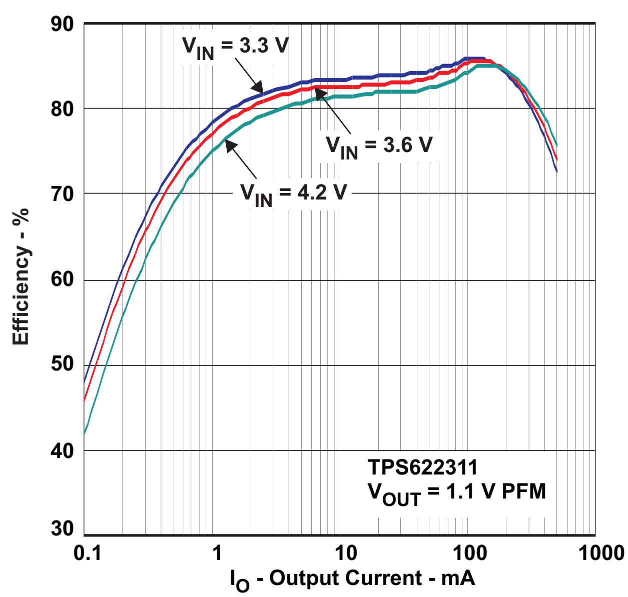


Figure 11. Comparison Efficiency vs I_{OUT} – TPS622311

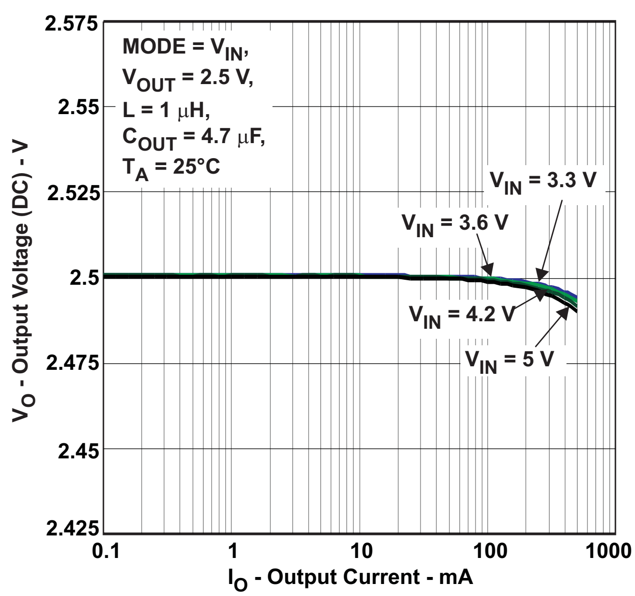


Figure 12. 2.5V Output Voltage Accuracy forced PWM Mode

TYPICAL CHARACTERISTICS (continued)

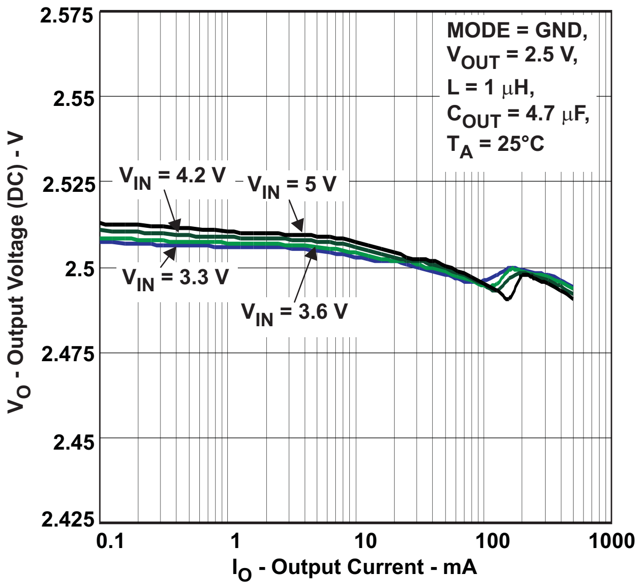


Figure 13. 2.5V Output Voltage Accuracy PFM/PWM Mode

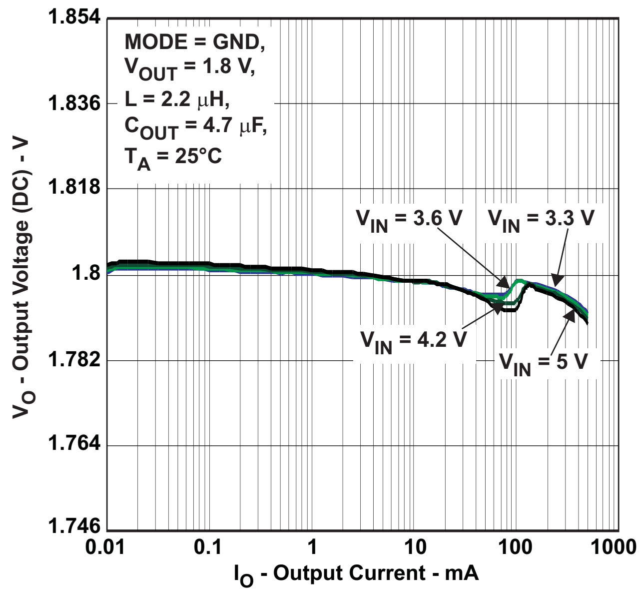


Figure 14. 1.8V Output Voltage Accuracy PFM/PWM Mode

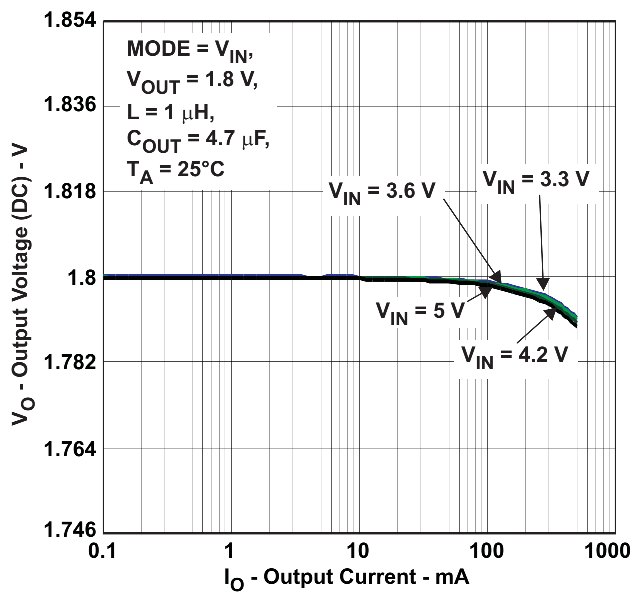


Figure 15. 1.8V Output Voltage Accuracy Forced PWM MODE

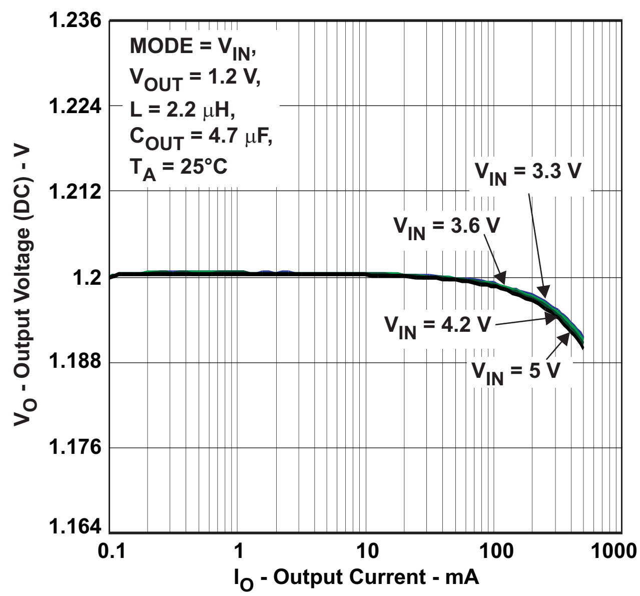


Figure 16. 1.2V Output Voltage Accuracy Forced PWM MODE

TYPICAL CHARACTERISTICS (continued)

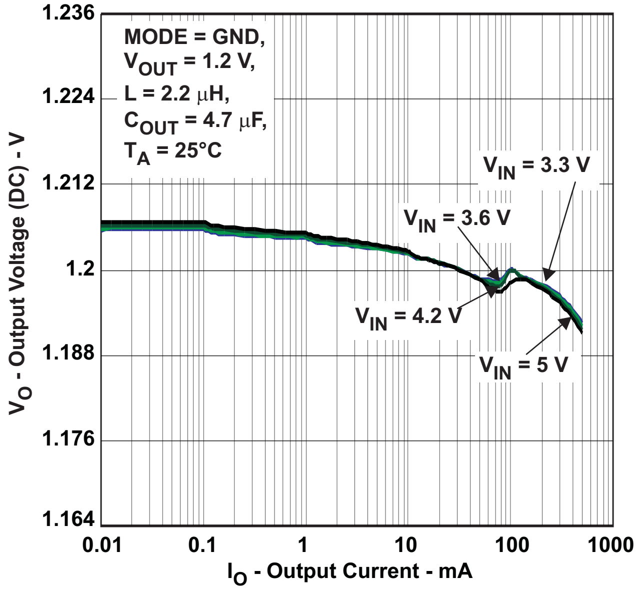


Figure 17. 1.2V Output Voltage Accuracy PFM/PWM MODE

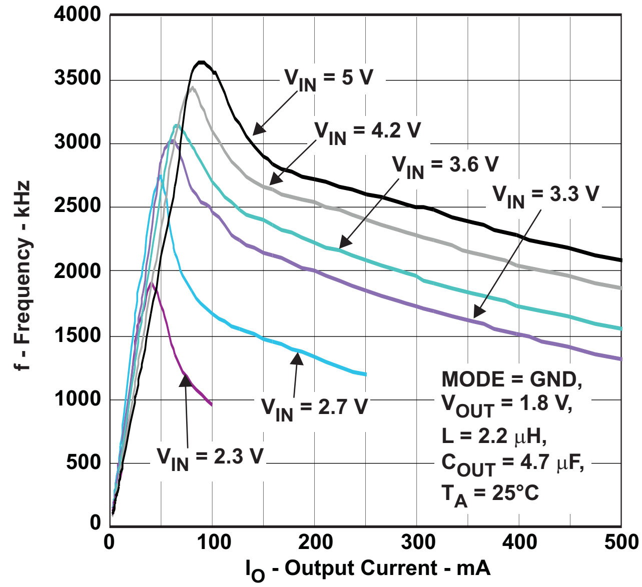


Figure 18. Switching Frequency vs Output Current, 1.8V Output Voltage MODE = GND

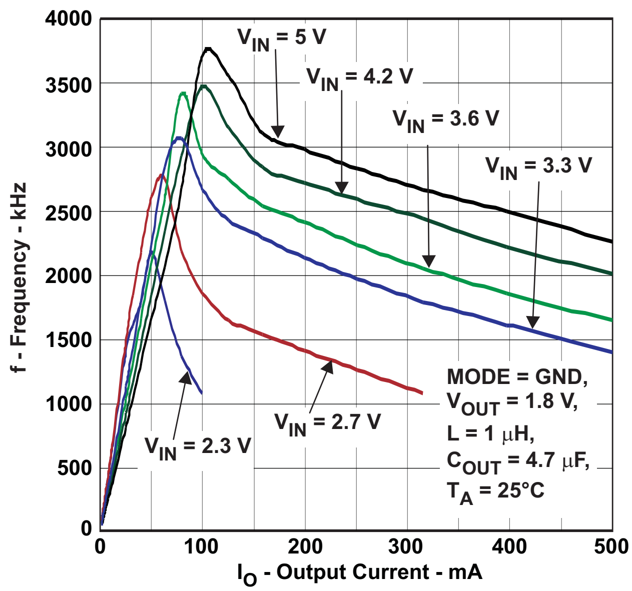


Figure 19. Switching Frequency vs Output Current, 1.8V Output Voltage MODE = GND

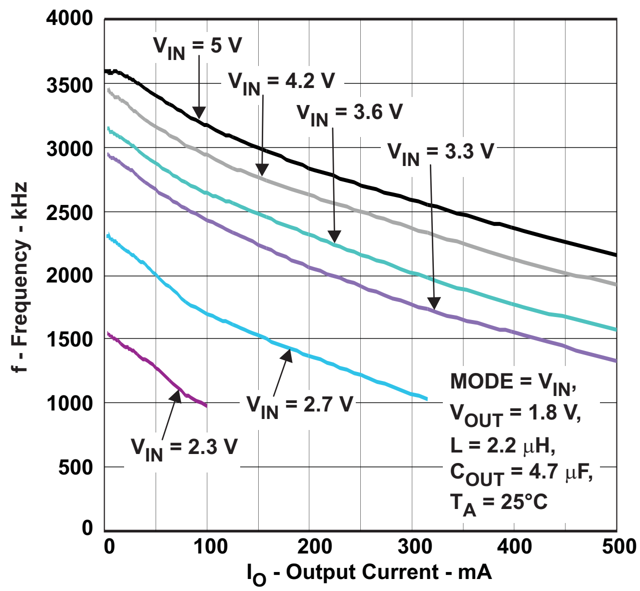


Figure 20. Switching Frequency vs Output Current, 1.8V Output Voltage MODE = V_{IN}

TYPICAL CHARACTERISTICS (continued)

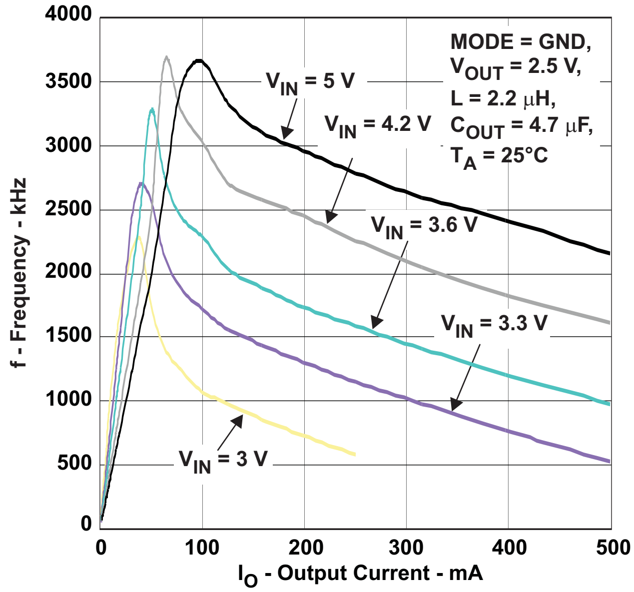


Figure 21. Switching Frequency vs Output Current, 2.5V Output Voltage MODE = GND

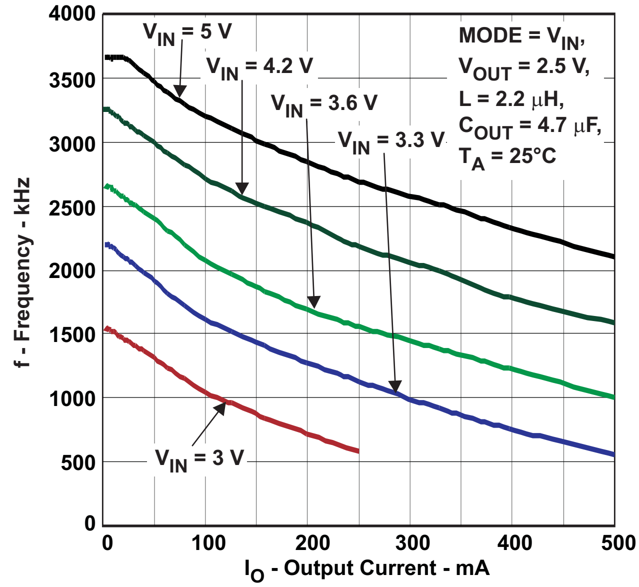


Figure 22. Switching Frequency vs Output Current, 2.5V Output Voltage MODE = V_{IN}

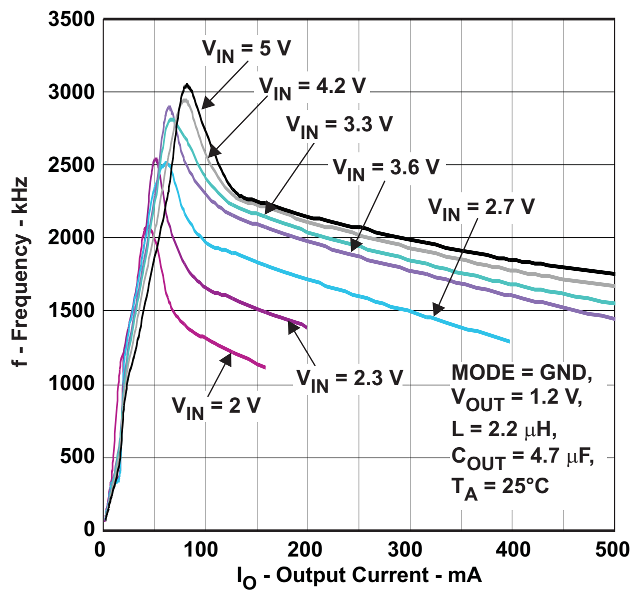


Figure 23. Switching Frequency vs Output Current, 1.2V Output Voltage MODE = GND

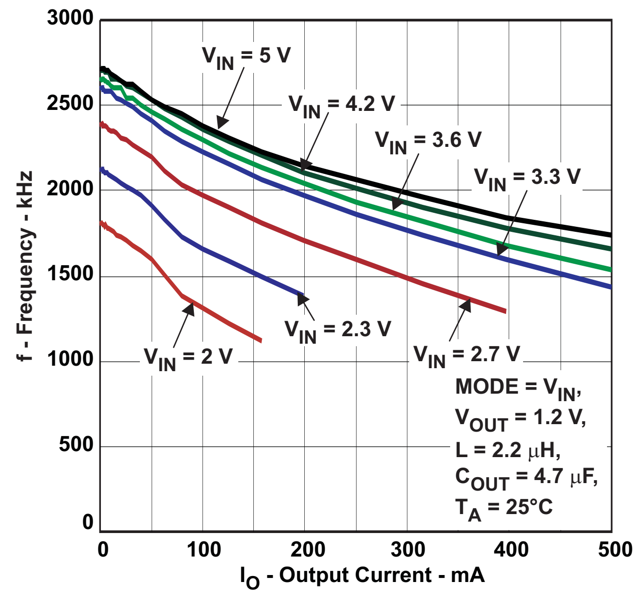


Figure 24. Switching Frequency vs Output Current, 1.2V Output Voltage MODE = V_{IN}

TYPICAL CHARACTERISTICS (continued)

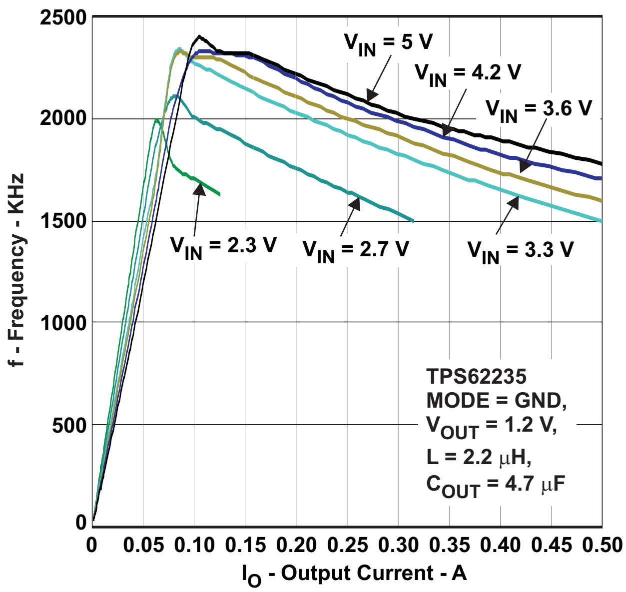


Figure 25. Switching Frequency vs Output Current, 1.2V Output Voltage MODE = PFM – TPS62235

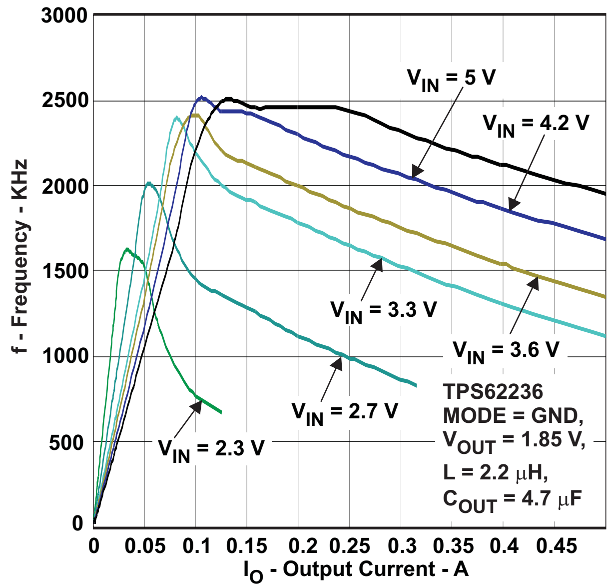


Figure 26. Switching Frequency vs Output Current, 1.85V Output Voltage MODE = PFM –TPS62236

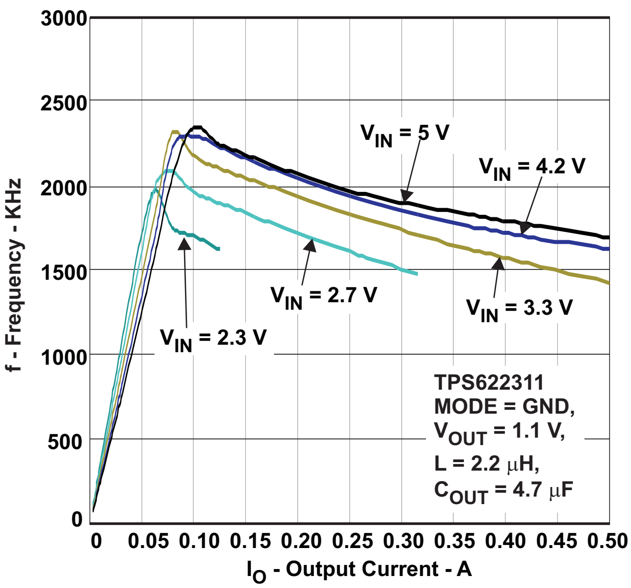


Figure 27. Switching Frequency vs Output Current, 1.1V Output Voltage MODE = PFM – TPS622311

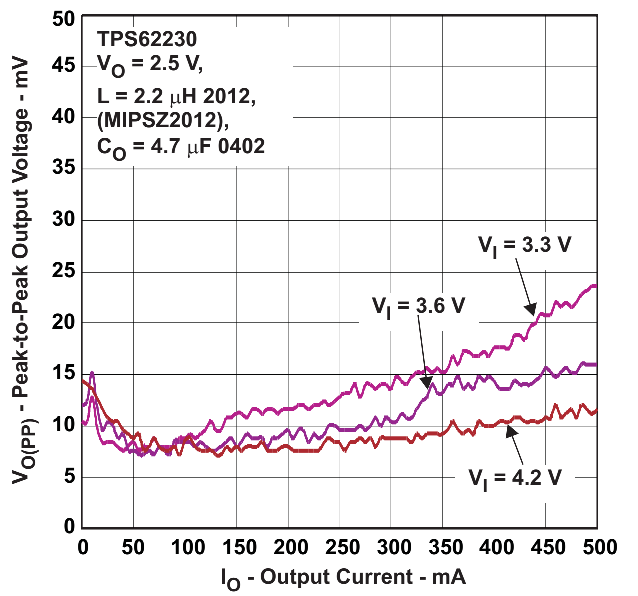


Figure 28. Output Voltage, Peak-to-Peak vs Output Current – TPS62230

TYPICAL CHARACTERISTICS (continued)

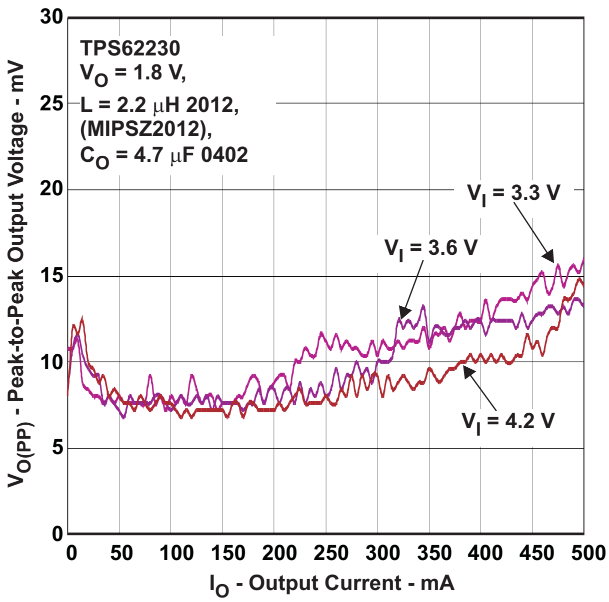


Figure 29. Output Voltage, Peak-to-Peak vs Output Current – TPS62231

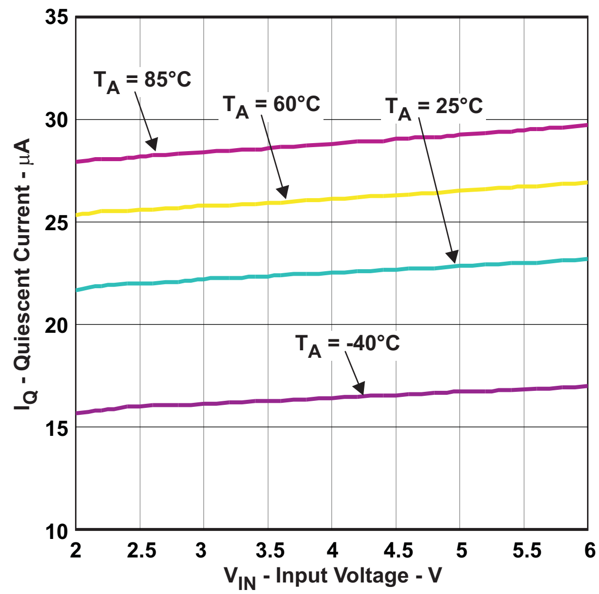


Figure 30. Quiescent Current I_Q vs Ambient Temperature T_A

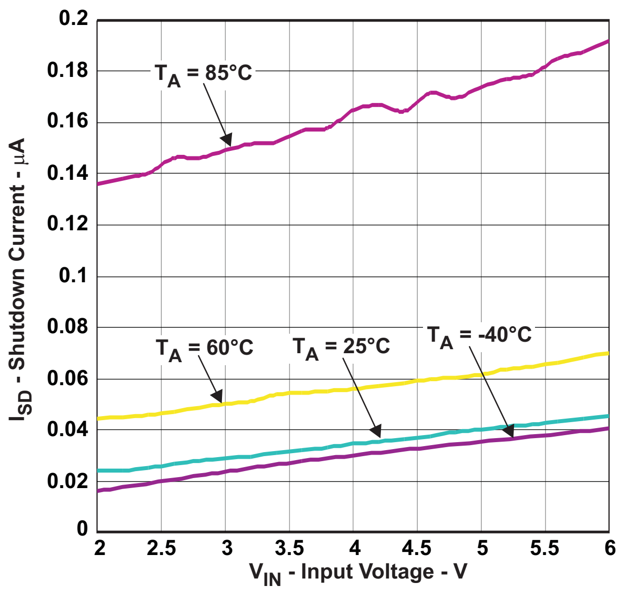


Figure 31. Shutdown Current I_{SD} vs Ambient Temperature T_A

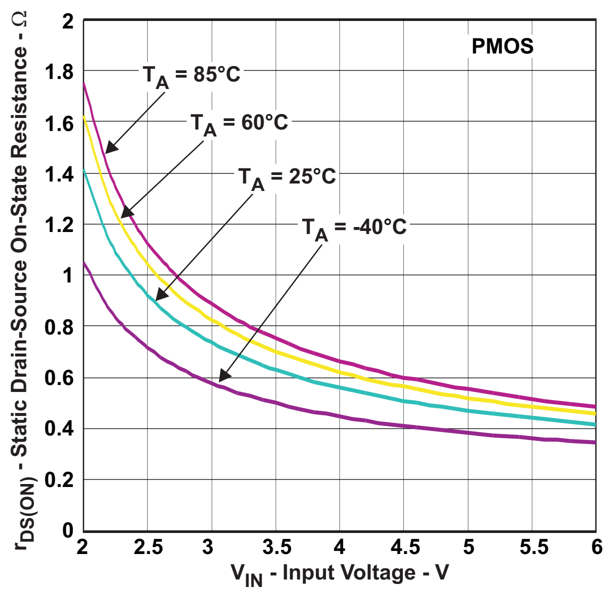


Figure 32. PMOS R_{DSON} vs Supply Voltage V_{IN} and Ambient Temperature T_A

TYPICAL CHARACTERISTICS (continued)

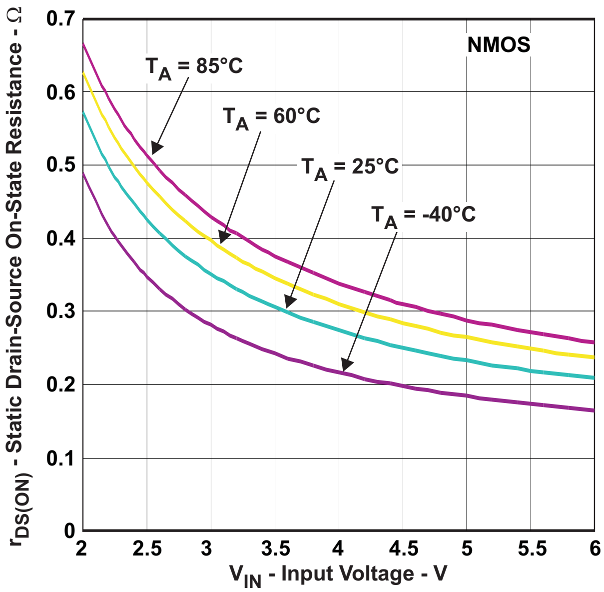


Figure 33. NMOS R_{DSON} vs Supply Voltage V_{IN} and Ambient Temperature T_A

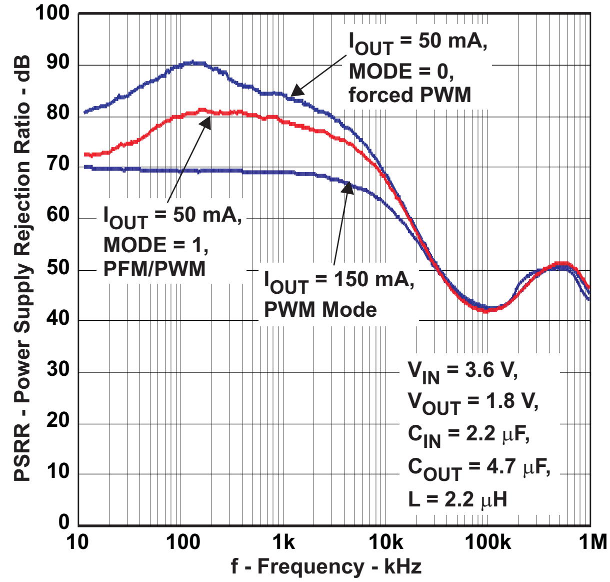


Figure 34. TPS62231 1.8V PSRR

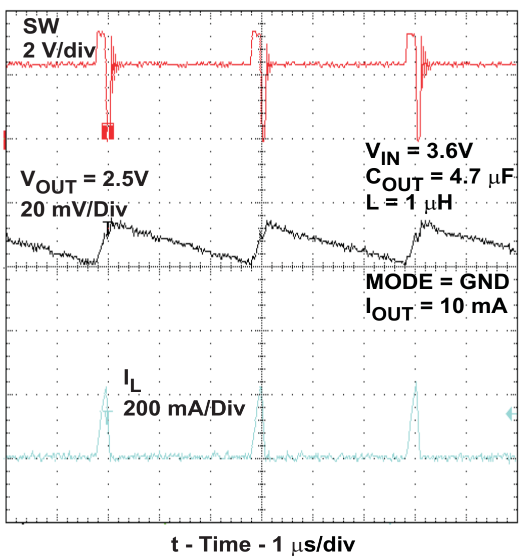


Figure 35. PFM Mode Operation I_{OUT} = 10mA

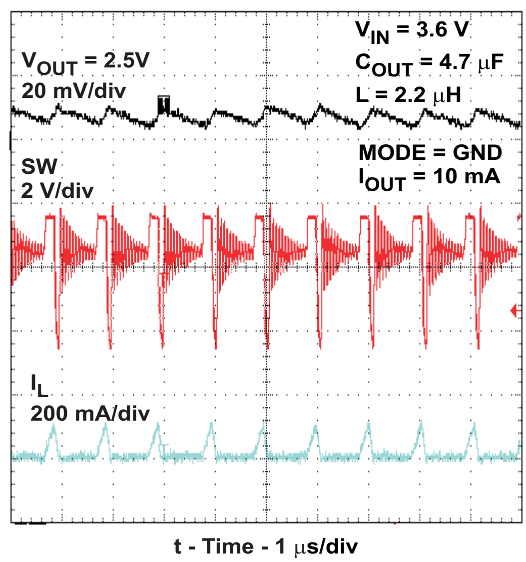


Figure 36. PFM Mode Operation I_{OUT} = 10mA

TYPICAL CHARACTERISTICS (continued)

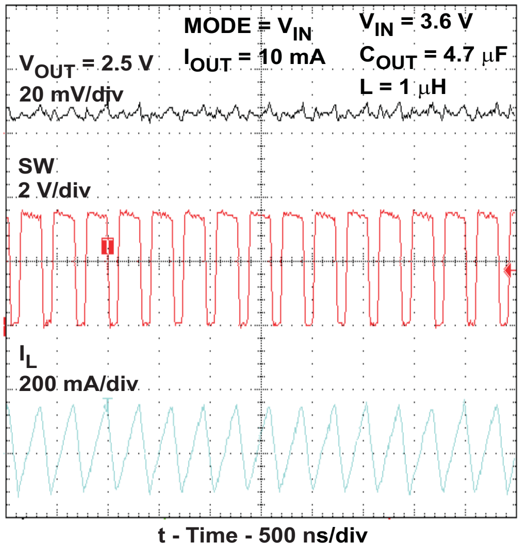


Figure 37. Forced PWM Mode Operation I_{OUT} = 10mA

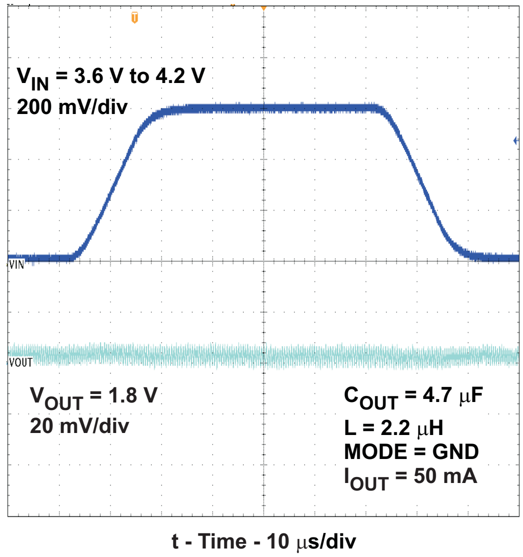


Figure 38. Line Transient Response PFM Mode

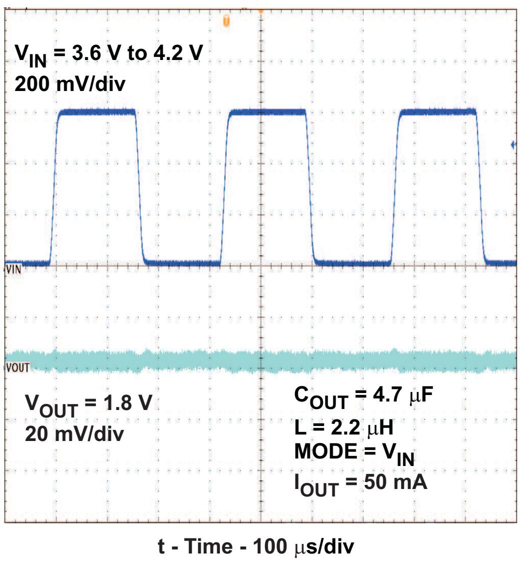


Figure 39. Line Transient Response PWM Mode

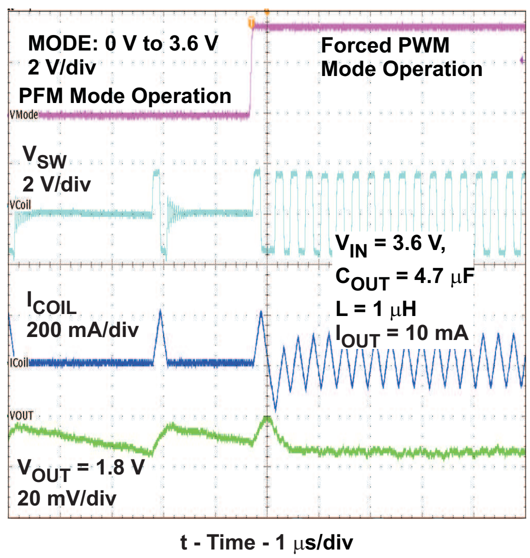


Figure 40. Mode Transition PFM / Forced PWM Mode

TYPICAL CHARACTERISTICS (continued)

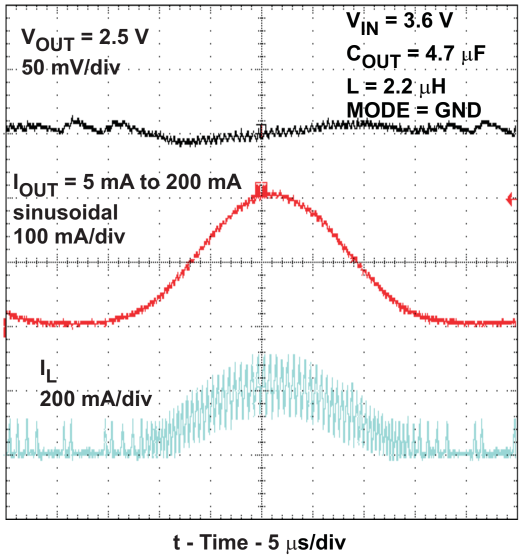


Figure 41. AC – Load Regulation Performance 2.5V V_{OUT} PFM Mode

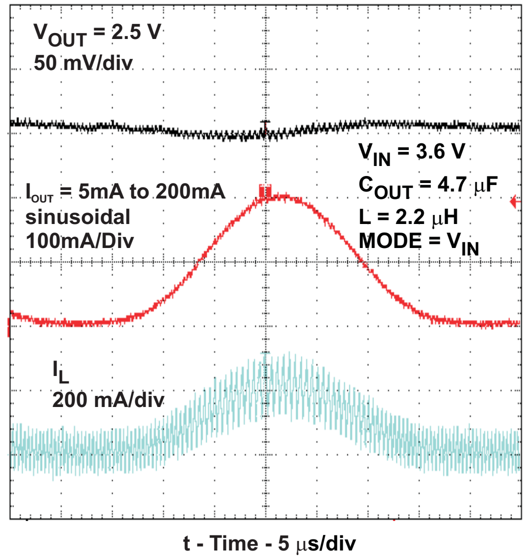


Figure 42. AC – Load Regulation Performance 2.5V V_{OUT} PWM Mode

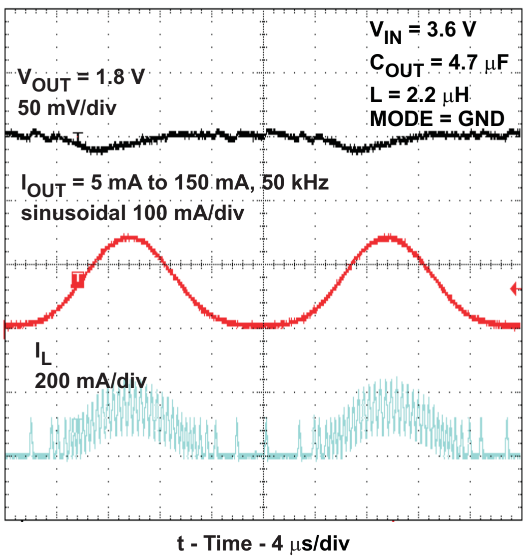


Figure 43. AC – Load Regulation Performance 1.8V V_{OUT} PFM Mode

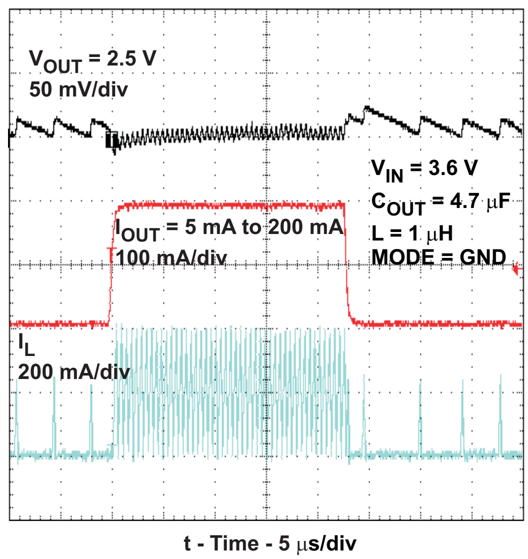


Figure 44. Load Transient Response 5mA to 200mA PFM to PWM Mode, V_{OUT} 2.5V

TYPICAL CHARACTERISTICS (continued)

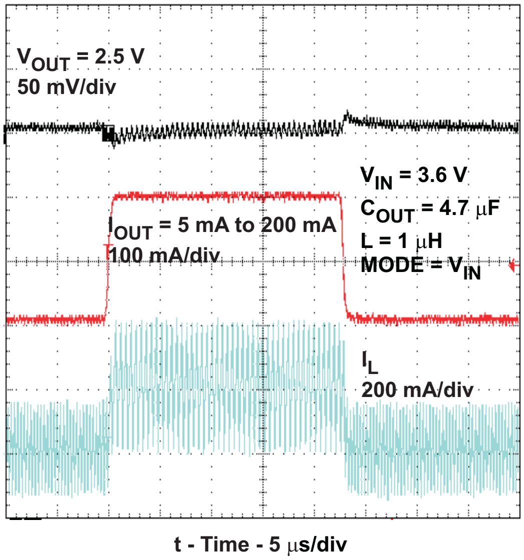


Figure 45. Load Transient Response 5mA to 200mA, Forced PWM Mode, V_{OUT} 2.5V

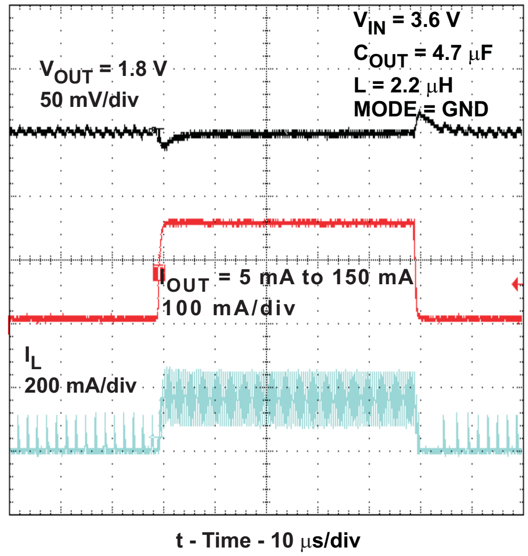


Figure 46. Load Transient Response 5mA to 150mA, PFM to PWM Mode, V_{OUT} 1.8V

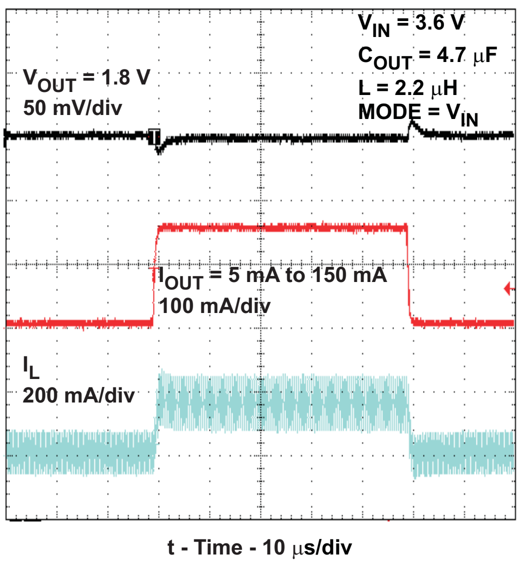


Figure 47. Load Transient Response 5mA to 150mA, Forced PWM Mode, V_{OUT} 1.8V

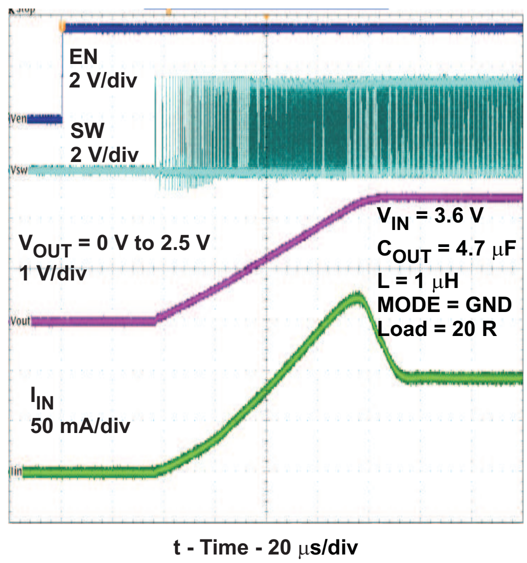


Figure 48. Start Up into 20Ω Load, V_{OUT} 2.5V

TYPICAL CHARACTERISTICS (continued)

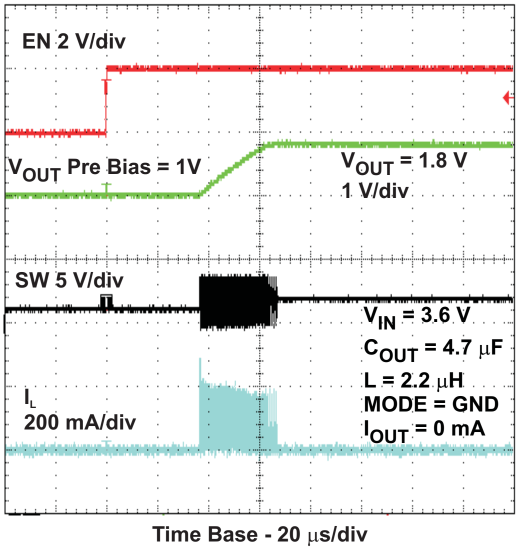


Figure 49. Startup in 1V Pre-biased Output

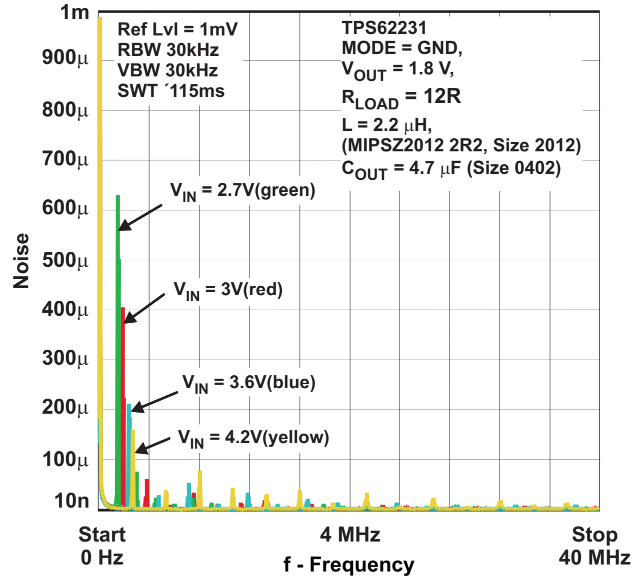


Figure 50. Spurious Output Noise, 12R Load, TPS62231

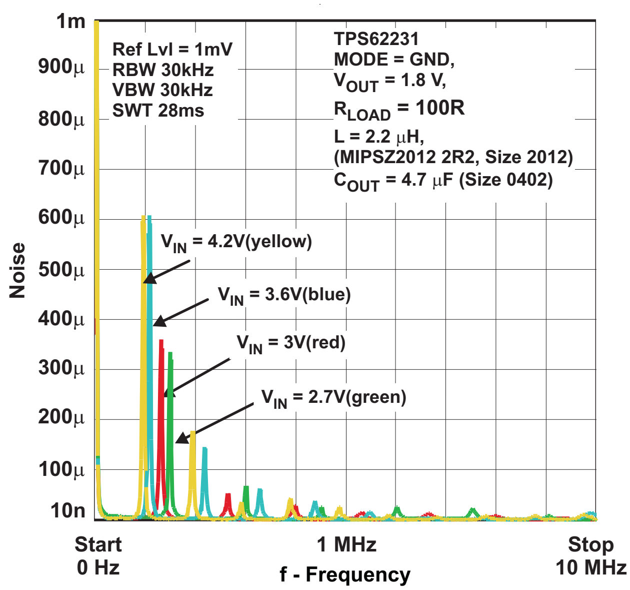


Figure 51. Spurious Output Noise, 100R Load, TPS62231

DETAILED DESCRIPTION

The TPS6223X synchronous step down converter family includes a unique hysteretic PWM controller scheme which enables switch frequencies over 3MHz, excellent transient and AC load regulation as well as operation with cost competitive external components.

The controller topology supports forced PWM Mode as well as Power Save Mode operation. Power Save Mode operation reduces the quiescent current consumption down to 22μA and ensures high conversion efficiency at light loads by skipping switch pulses. In forced PWM Mode, the device operates on a quasi fixed frequency, avoids pulse skipping, and allows filtering of the switch noise by external filter components.

The TPS6223X devices offer fixed output voltage options featuring smallest solution size by using only three external components.

The internal switch current limit of typical 850mA supports output currents of up to 500mA, depending on the operating condition.

A significant advantage of TPS6223X compared to other hysteretic PWM controller topologies is its excellent DC and AC load regulation capability in combination with low output voltage ripple over the entire load range which makes this part well suited for audio and RF applications.

OPERATION

Once the output voltage falls below the threshold of the error comparator, a switch pulse is initiated, and the high side switch is turned on. It remains turned on until a minimum on time of t_{ONmin} expires and the output voltage trips the threshold of the error comparator or the inductor current reaches the high side switch current limit. Once the high side switch turns off, the low side switch rectifier is turned on and the inductor current ramps down until the high side switch turns on again or the inductor current reaches zero.

In forced PWM Mode operation, negative inductor current is allowed to enable continuous conduction mode even at no load condition.

POWER SAVE MODE

Connecting the MODE pin to GND enables the automatic PWM and power-save mode operation. The converter operates in quasi fixed frequency PWM mode at moderate to heavy loads and in the PFM (Pulse Frequency Modulation) mode during light loads, which maintains high efficiency over a wide load current range. In PFM Mode, the device starts to skip switch pulses and generates only single pulses with an on time of t_{ONmin}. The PFM Mode frequency depends on the load current and the external inductor and output capacitor values. The PFM Mode of TPS6223X is optimized for low output voltage ripple if small external components are used. Even at low output currents, the PFM frequency is above the audible noise spectrum and makes this operation mode suitable for audio applications.

The on time t_{ONmin} can be estimated to:

$$t_{ONmin} = \frac{V_{OUT}}{V_{IN}} \times 260\ \text{ns} \tag{1}$$

Therefore, the peak inductor current in PFM mode is approximately:

$$I_{LPFMpeak} = \frac{(V_{IN} - V_{OUT})}{L} \times t_{ONmin} \tag{2}$$

The transition from PFM into PWM mode and vice versa can be estimated to:

$$I_{OUT\_PFM/PWM} = 0.5 \times I_{LPFMpeak} \tag{3}$$

With

t_{ON}: High side switch on time [ns]
V_{IN}: Input voltage [V]
V_{OUT}: Output voltage [V]
L : Inductance [μH]
$I_{LPFMpeak}$: PFM inductor peak current [mA]
$I_{OUT\_PFM/PWM}$: Output current for PFM to PWM mode transition and vice versa [mA]

FORCED PWM MODE

Pulling the MODE pin high forces the converter to operate in a continuous conduction PWM mode even at light load currents. The advantage is that the converter operates with a quasi fixed frequency that allows simple filtering of the switching frequency for noise-sensitive applications. In this mode, the efficiency is lower compared to the power-save mode during light loads.

For additional flexibility, it is possible to switch from power-save mode to forced PWM mode during operation. This allows efficient power management by adjusting the operation of the converter to the specific system requirements.

100% DUTY CYCLE LOW DROPOUT OPERATION

The device starts to enter 100% duty cycle mode once the input voltage comes close to the nominal output voltage. In order to maintain the output voltage, the High Side switch is turned on 100% for one or more cycles.

With further decreasing V_{IN} the High Side MOSFET switch is turned on completely. In this case the converter offers a low input-to-output voltage difference. This is particularly useful in battery-powered applications to achieve longest operation time by taking full advantage of the whole battery voltage range.

The minimum input voltage to maintain regulation depends on the load current and output voltage, and can be calculated as:

$$V_{IN}min = V_{OUT}max + I_{OUT}max \times \left(R_{DS(on)}max + R_L\right) \tag{4}$$

With:

$I_{OUT}max$ = maximum output current plus inductor ripple current
$R_{DS(on)}max$ = maximum P-channel switch RDSon.
R_L = DC resistance of the inductor
$V_{OUT}max$ = nominal output voltage plus maximum output voltage tolerance

UNDER VOLTAGE LOCKOUT

The under voltage lockout circuit prevents the device from misoperation at low input voltages. It prevents the converter from turning on the switch or rectifier MOSFET under undefined conditions. The TPS6223X devices have a UVLO threshold set to 1.8V (typical). Fully functional operation is permitted for input voltage down to the falling UVLO threshold level. The converter starts operation again once the input voltage trips the rising UVLO threshold level.

SOFT START

The TPS6223X has an internal soft-start circuit that controls the ramp up of the output voltage and limits the inrush current during start-up. This limits input voltage drops when a battery or a high-impedance power source is connected to the input of the converter.

The soft-start system generates a monotonic ramp up of the output voltage and reaches the nominal output voltage typically 100μs after EN pin was pulled high.

Should the output voltage not have reached its target value by this time, such as in the case of heavy load, the converter then operates in a current limit mode set by its switch current limits.

TPS6223X is able to start into a pre-biased output capacitor. The converter starts with the applied bias voltage and ramps the output voltage to its nominal value.

ENABLE / SHUTDOWN

The device starts operation when EN is set high and starts up with the soft start as previously described. For proper operation, the EN pin must be terminated and must not be left floating.

Pulling the EN pin low forces the device into shutdown, with a shutdown quiescent current of typically 0.1μA. In this mode, the P and N-channel MOSFETs are turned off, the internal resistor feedback divider is disconnected, and the entire internal-control circuitry is switched off.

The EN input can be used to control power sequencing in a system with various DC/DC converters. The EN pin can be connected to the output of another converter, to drive the EN pin high and getting a sequencing of supply rails.

SHORT-CIRCUIT PROTECTION

The TPS6223X integrates a High Side and Low Side MOSFET current limit to protect the device against heavy load or short circuit. The current in the switches is monitored by current limit comparators. When the current in the P-channel MOSFET reaches its current limit, the P-channel MOSFET is turned off and the N-channel MOSFET is turned on to ramp down the current in the inductor. The High Side MOSFET switch can only turn on again, once the current in the Low Side MOSFET switch has decreased below the threshold of its current limit comparator.

THERMAL SHUTDOWN

As soon as the junction temperature, T_J, exceeds 150°C (typical) the device goes into thermal shutdown. In this mode, the High Side and Low Side MOSFETs are turned-off. The device continues its operation when the junction temperature falls below the thermal shutdown hysteresis.

APPLICATION INFORMATION

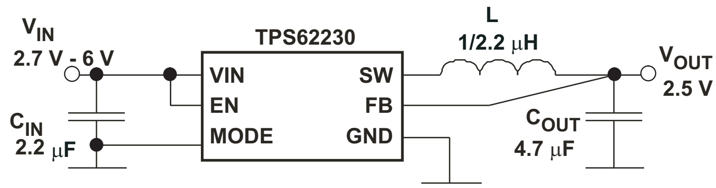


Figure 52. TPS62230 2.5V Output

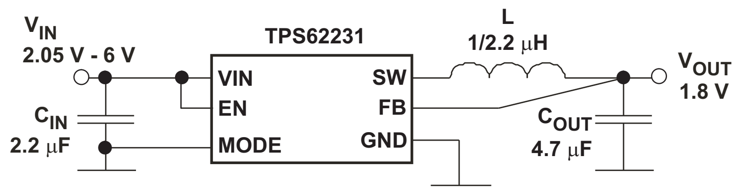


Figure 53. TPS62231 1.8V Output

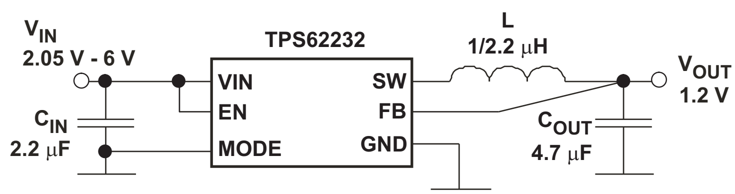


Figure 54. TPS62232 1.2V Output

OUTPUT FILTER DESIGN (INDUCTOR AND OUTPUT CAPACITOR)

The TPS6223X is optimized to operate with effective inductance values in the range of 0.7µH to 4.3µH and with effective output capacitance in the range of 2.0µF to 15µF. The internal compensation is optimized to operate with an output filter of L = 1.0µH/2.2µH and C_{OUT} = 4.7µF. Larger or smaller inductor/capacitor values can be used to optimize the performance of the device for specific operation conditions. For more details, see the *CHECKING LOOP STABILITY* section.

INDUCTOR SELECTION

The inductor value affects its peak-to-peak ripple current, the PWM-to-PFM transition point, the output voltage ripple and the efficiency. The selected inductor has to be rated for its dc resistance and saturation current. The inductor ripple current (ΔI_L) decreases with higher inductance and increases with higher V_{IN} or V_{OUT}. Equation 5 calculates the maximum inductor current under static load conditions. The saturation current of the inductor should be rated higher than the maximum inductor current as calculated with Equation 6. This is recommended because during heavy load transient the inductor current will rise above the calculated value.

$$\Delta I_L = Vout \times \frac{1 - \frac{Vout}{Vin}}{L \times f} \tag{5}$$

$$I_{Lmax} = I_{outmax} + \frac{\Delta I_L}{2} \tag{6}$$

With:

f = Switching Frequency
L = Inductor Value
ΔI_L= Peak to Peak inductor ripple current
I_{Lmax} = Maximum Inductor current

In high-frequency converter applications, the efficiency is essentially affected by the inductor AC resistance (i.e., quality factor) and to a smaller extent by the inductor DCR value. To achieve high efficiency operation, care should be taken in selecting inductors featuring a quality factor above 25 at the switching frequency. Increasing the inductor value produces lower RMS currents, but degrades transient response. For a given physical inductor size, increased inductance usually results in an inductor with lower saturation current.

The total losses of the coil consist of both the losses in the DC resistance, $R_{(DC)}$, and the following frequency-dependent components:

- The losses in the core material (magnetic hysteresis loss, especially at high switching frequencies)
- Additional losses in the conductor from the skin effect (current displacement at high frequencies)
- Magnetic field losses of the neighboring windings (proximity effect)
- Radiation losses

The following inductor series from different suppliers have been used with the TPS6223X converters.

Table 1. List of inductors

INDUCTANCE [µH]	DIMENSIONS [mm3]	INDUCTOR TYPE	SUPPLIER
1.0/2.2	2.5 × 2.0 × 1.2	LQM2HPN1R0MJ0	Murata
2.2	2.0 × 1.2 × 0.55	LQM21PN2R2	Murata
1.0/2.2	2.0 × 1.2 × 1.0	MIPSZ2012	FDK
1.0/2.2	2.0 × 2.5 × 1.2	MIPSA2520	FDK
1.0/2.2	2.0 × 1.2 × 1.0	KSLI2012 series	Hitachi Metal

OUTPUT CAPACITOR SELECTION

The unique hysteretic PWM control scheme of the TPS62230 allows the use of tiny ceramic capacitors. Ceramic capacitors with low ESR values have the lowest output voltage ripple and are recommended. The output capacitor requires either an X7R or X5R dielectric. Y5V and Z5U dielectric capacitors, aside from their wide variation in capacitance over temperature, become resistive at high frequencies.

At light load currents the converter operate in Power Save Mode and the output voltage ripple is dependent on the output capacitor value and the PFM peak inductor current. Higher output capacitor values minimize the voltage ripple in PFM Mode and tighten DC output accuracy in PFM Mode.

INPUT CAPACITOR SELECTION

Because of the nature of the buck converter having a pulsating input current, a low ESR input capacitor is required for best input voltage filtering and minimizing the interference with other circuits caused by high input voltage spikes. For most applications a 2.2µF to 4.7µF ceramic capacitor is recommended. The input capacitor can be increased without any limit for better input voltage filtering. Because ceramic capacitor loses up to 80% of its initial capacitance at 5V, it is recommended to use 4.7µF input capacitors for input voltages > 4.5V.

Take care when using only small ceramic input capacitors. When a ceramic capacitor is used at the input and the power is being supplied through long wires, such as from a wall adapter, a load step at the output or V_{IN} step on the input can induce ringing at the VIN pin. This ringing can couple to the output and be mistaken as loop instability or could even damage the part by exceeding the maximum ratings.

Table 2 shows a list of tested input/output capacitors.

Table 2. List of Capacitor

CAPACITANCE [µF]	SIZE	CAPACITOR TYPE	SUPPLIER
2.2	0402	GRM155R60J225	Murata
4.7	0402	AMK105BJ475MV	Taiyo Yuden
4.7	0402	GRM155R60J475	Murata
4.7	0402	CL05A475MQ5NRNC	Samsung
4.7	0603	GRM188R60J475	Murata

CHECKING LOOP STABILITY

The first step of circuit and stability evaluation is to look from a steady-state perspective at the following signals:

- Switching node, SW
- Inductor current, I_L
- Output ripple voltage, $V_{OUT(AC)}$

These are the basic signals that need to be measured when evaluating a switching converter. When the switching waveform shows large duty cycle jitter or the output voltage or inductor current shows oscillations, the regulation loop may be unstable. This is often a result of board layout and/or L-C combination.

As a next step in the evaluation of the regulation loop, the load transient response is tested. The time between the application of the load transient and the turn on of the P-channel MOSFET, the output capacitor must supply all of the current required by the load. V_{OUT} immediately shifts by an amount equal to $\Delta I_{(LOAD)}$ x ESR, where ESR is the effective series resistance of C_{OUT}. $\Delta I_{(LOAD)}$ begins to charge or discharge C_O generating a feedback error signal used by the regulator to return V_{OUT} to its steady-state value. The results are most easily interpreted when the device operates in PWM mode.

During this recovery time, V_{OUT} can be monitored for settling time, overshoot or ringing that helps judge the converter's stability. Without any ringing, the loop has usually more than 45° of phase margin.

Because the damping factor of the circuitry is directly related to several resistive parameters (e.g., MOSFET $r_{DS(on)}$) that are temperature dependant, the loop stability analysis has to be done over the input voltage range, load current range, and temperature range.

LAYOUT CONSIDERATIONS

As for all switching power supplies, the layout is an important step in the design. Proper function of the device demands careful attention to PCB layout. Care must be taken in board layout to get the specified performance. If the layout is not carefully done, the regulator could show poor line and/or load regulation, stability issues as well as EMI problems. It is critical to provide a low inductance, impedance ground path. Therefore, use wide and short traces for the main current paths. The input capacitor should be placed as close as possible to the IC pins as well as the inductor and output capacitor.

Use a common Power GND node and a different node for the Signal GND to minimize the effects of ground noise. Keep the common path to the GND PIN, which returns the small signal components and the high current of the output capacitors as short as possible to avoid ground noise. The FB line should be connected to the output capacitor and routed away from noisy components and traces (e.g. SW line).

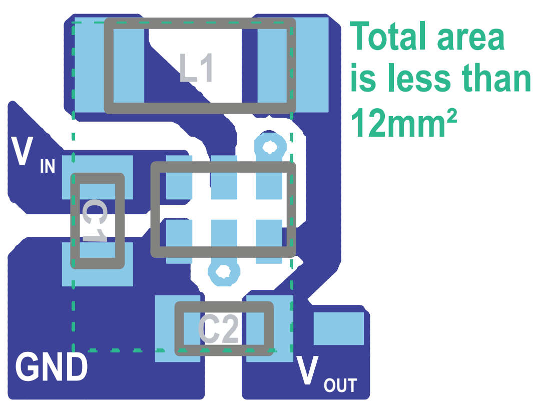


Figure 55. Recommended PCB Layout for TPS6223X

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
TPS62230DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	GV	Samples
TPS62230DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	GV	Samples
TPS622310DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OT	Samples
TPS622310DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OT	Samples
TPS622311DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PA	Samples
TPS622311DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PA	Samples
TPS622312DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	QE	Samples
TPS622312DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	QE	Samples
TPS622313DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	QF	Samples
TPS622313DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	QF	Samples
TPS622314DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	QG	Samples
TPS622314DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	QG	Samples
TPS622315DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	RI	Samples
TPS622315DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	RI	Samples
TPS622316DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	RJ	Samples
TPS622316DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	RJ	Samples
TPS622317DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	RK	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
TPS622317DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	RK	Samples
TPS622318DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	ST	Samples
TPS622318DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	ST	Samples
TPS62231DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	GW	Samples
TPS62231DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	GW	Samples
TPS62232DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	GX	Samples
TPS62232DRYT	ACTIVE	SON	DRY	6	250	TBD	Call TI	Call TI	-40 to 85	GX	Samples
TPS62233DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OG	Samples
TPS62233DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OG	Samples
TPS62234DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OH	Samples
TPS62234DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OH	Samples
TPS62235DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OQ	Samples
TPS62235DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OQ	Samples
TPS62236DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OR	Samples
TPS62236DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OR	Samples
TPS62237DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OS	Samples
TPS62237DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OS	Samples
TPS62238DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	ON	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
TPS62238DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	ON	Samples
TPS62239DRYR	ACTIVE	SON	DRY	6	5000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OP	Samples
TPS62239DRYT	ACTIVE	SON	DRY	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OP	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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

(4) Only one of markings shown within the brackets will appear on the physical device.

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OTHER QUALIFIED VERSIONS OF TPS62231, TPS622314 :

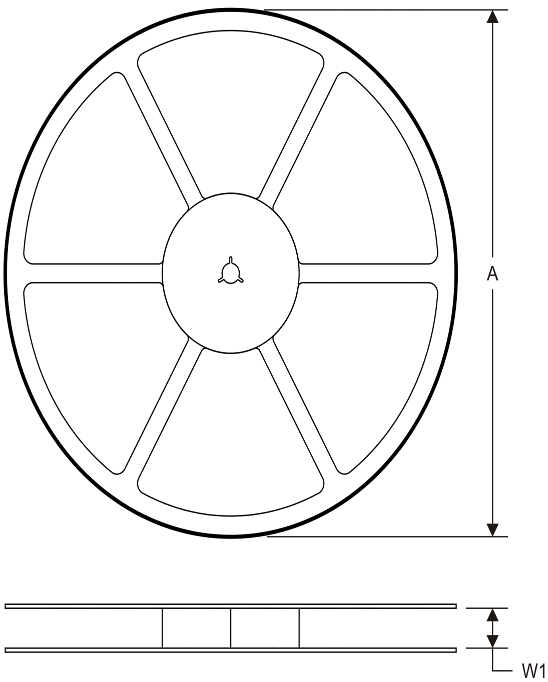
- Automotive: TPS62231-Q1, TPS622314-Q1

NOTE: Qualified Version Definitions:

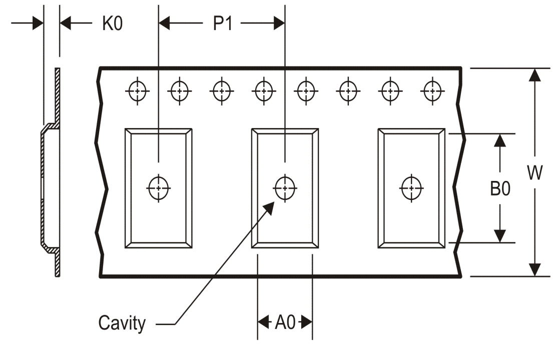
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

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

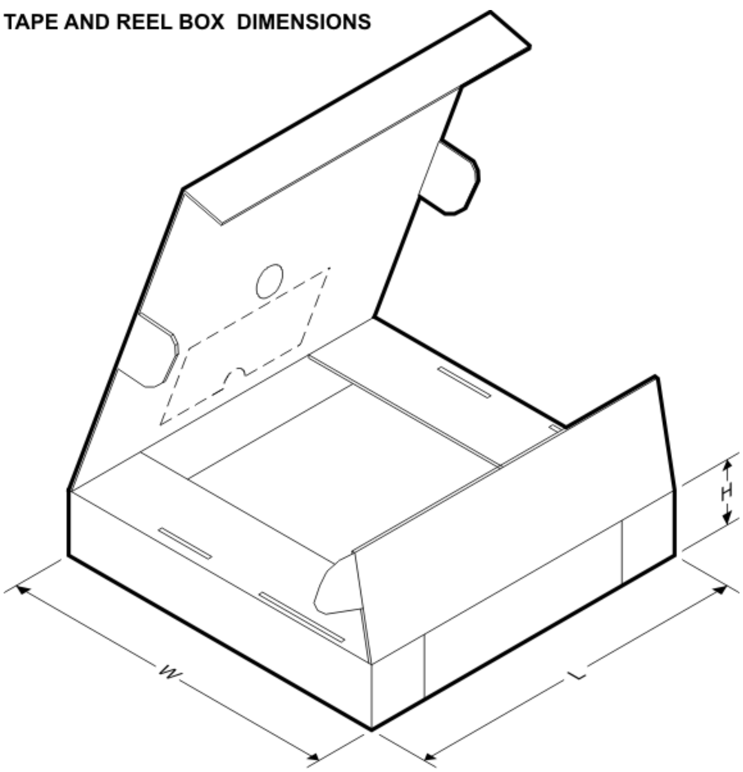
TAPE AND REEL INFORMATION

*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPS62230DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62230DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622310DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622310DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622311DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622311DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622312DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622312DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622313DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622313DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622314DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622314DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622315DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622315DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622316DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622316DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622317DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622317DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1

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
TPS622318DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS622318DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62231DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62231DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62232DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62233DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62233DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62234DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62234DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62235DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62235DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62236DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62236DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62237DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62237DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62238DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62238DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62239DRYR	SON	DRY	6	5000	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1
TPS62239DRYT	SON	DRY	6	250	179.0	8.4	1.2	1.65	0.7	4.0	8.0	Q1

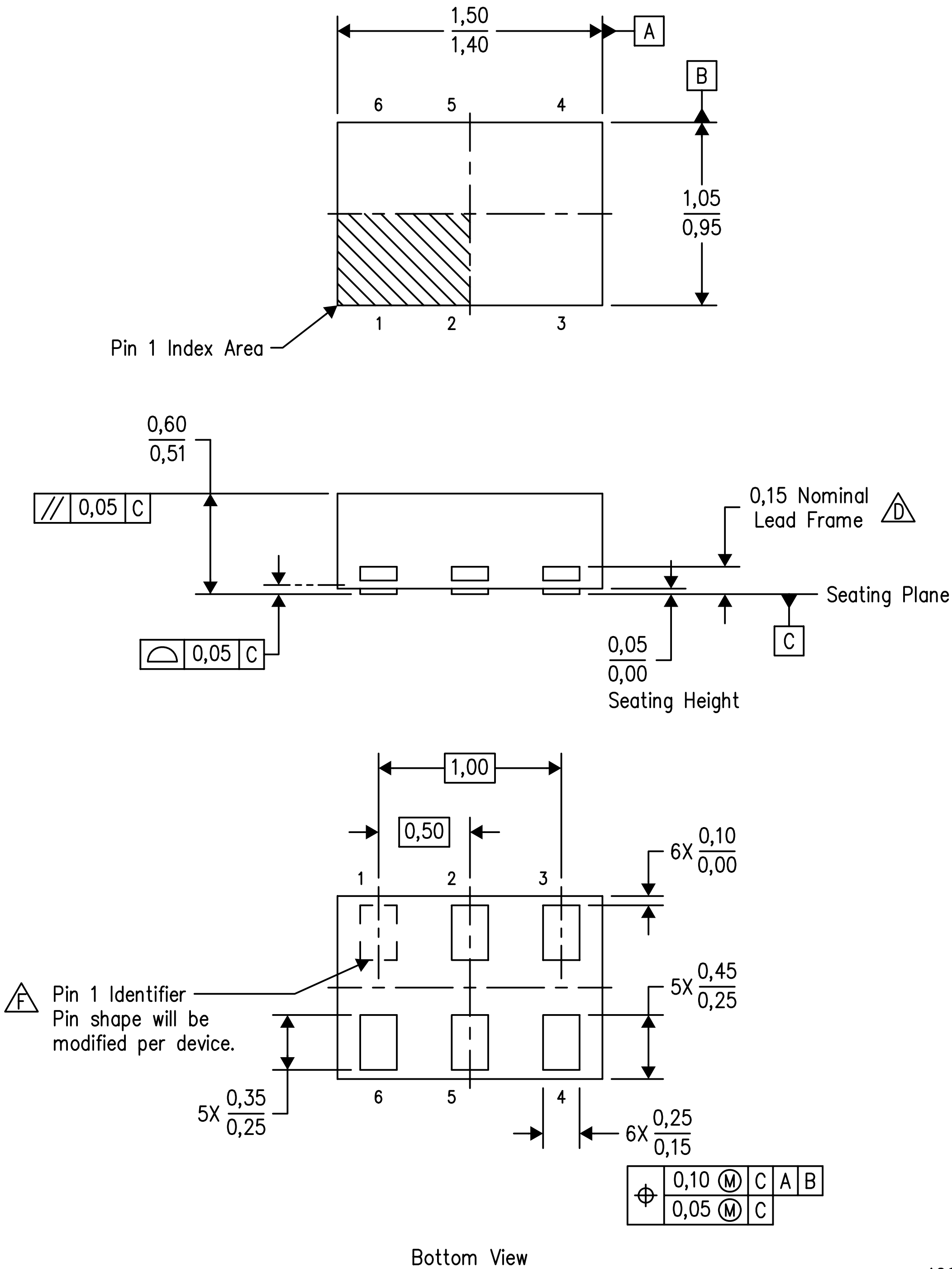
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS62230DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS62230DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS622310DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS622310DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS622311DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS622311DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS622312DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS622312DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS622313DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS622313DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS622314DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS622314DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS622315DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS622315DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS622316DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS622316DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS622317DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS622317DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS622318DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS622318DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS62231DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS62231DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS62232DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS62233DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS62233DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS62234DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS62234DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS62235DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS62235DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS62236DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS62236DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS62237DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS62237DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS62238DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS62238DRYT	SON	DRY	6	250	203.0	203.0	35.0
TPS62239DRYR	SON	DRY	6	5000	203.0	203.0	35.0
TPS62239DRYT	SON	DRY	6	250	203.0	203.0	35.0

DRY (R–PUSON–N6) PLASTIC SMALL OUTLINE NO–LEAD



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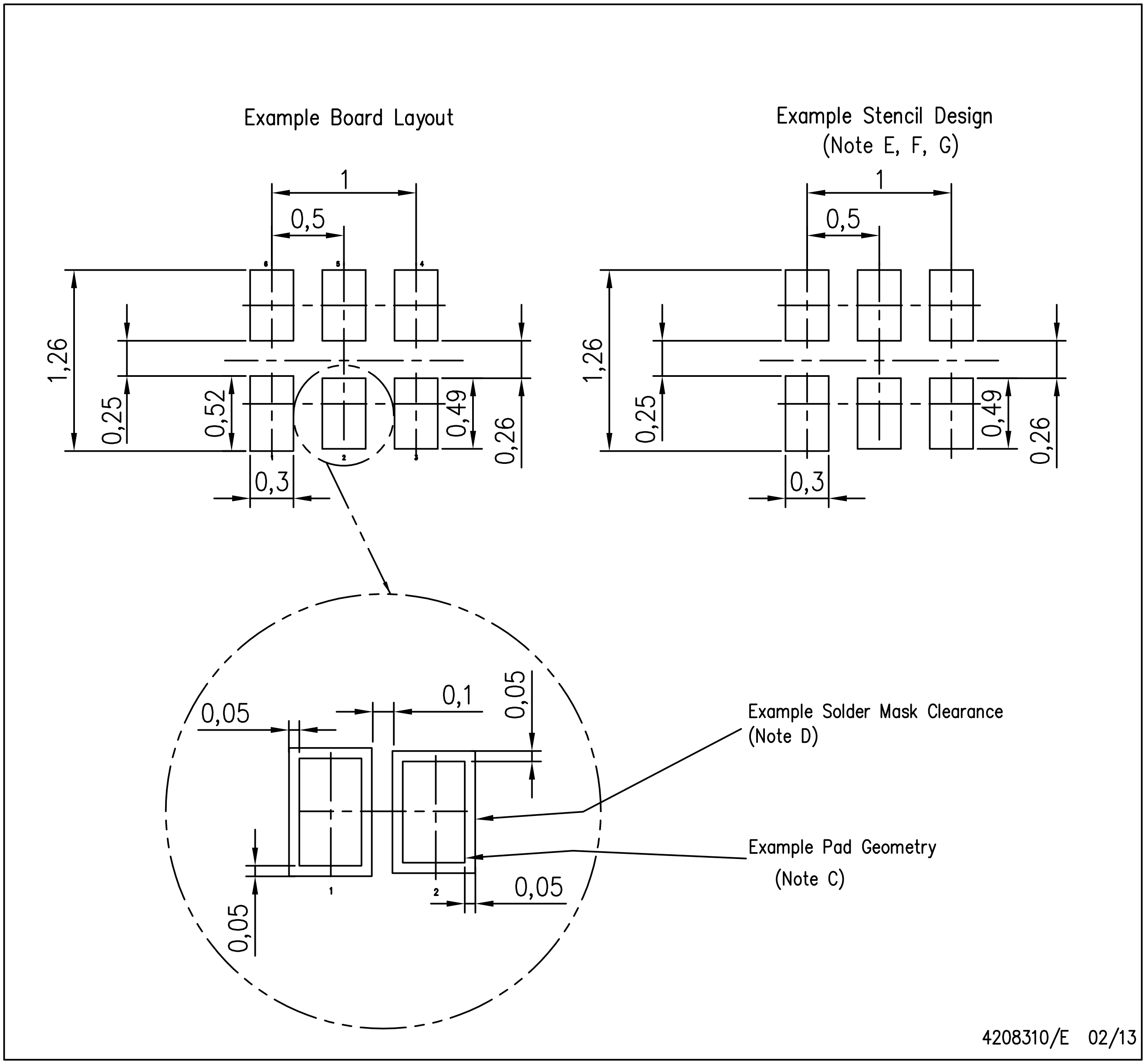
NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
- B. This drawing is subject to change without notice.
- C. SON (Small Outline No–Lead) package configuration.
- D. The exposed lead frame feature on side of package may or may not be present due to alternative lead frame designs.
- E. This package complies to JEDEC MO–287 variation UFAD.
- F. See the additional figure in the Product Data Sheet for details regarding the pin 1 identifier shape.

DRY (R–PUSON–N6) PLASTIC SMALL OUTLINE 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. Customers should contact their board fabrication site for minimum solder mask web tolerances between signal pads.
- E. Maximum stencil thickness 0,127 mm (5 mils). All linear dimensions are in millimeters.
- F. 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.
- G. Side aperture dimensions over–print land for acceptable area ratio > 0.66. Customer may reduce side aperture dimensions if stencil manufacturing process allows for sufficient release at smaller opening.

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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

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Наши преимущества:

- Оперативные поставки широкого спектра электронных компонентов отечественного и импортного производства напрямую от производителей и с крупнейших мировых складов;
- Поставка более 17-ти миллионов наименований электронных компонентов;
- Поставка сложных, дефицитных, либо снятых с производства позиций;
- Оперативные сроки поставки под заказ (от 5 рабочих дней);
- Экспресс доставка в любую точку России;
- Техническая поддержка проекта, помощь в подборе аналогов, поставка прототипов;
- Система менеджмента качества сертифицирована по Международному стандарту ISO 9001;
- Лицензия ФСБ на осуществление работ с использованием сведений, составляющих государственную тайну;
- Поставка специализированных компонентов (Xilinx, Altera, Analog Devices, Intersil, Interpoint, Microsemi, Aeroflex, Peregrine, Syfer, Eurofarad, Texas Instrument, Miteq, Cobham, E2V, MA-COM, Hittite, Mini-Circuits,General Dynamics и др.);

Помимо этого, одним из направлений компании «ЭлектроПласт» является направление «Источники питания». Мы предлагаем Вам помощь Конструкторского отдела:

- Подбор оптимального решения, техническое обоснование при выборе компонента;
- Подбор аналогов;
- Консультации по применению компонента;
- Поставка образцов и прототипов;
- Техническая поддержка проекта;
- Защита от снятия компонента с производства.

Как с нами связаться

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