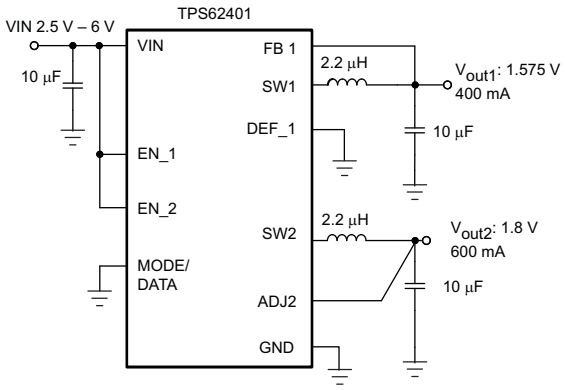
2.25MHz 400mA/600mA Dual Step-Down Converter In Small 3x3mm QFN Package

FEATURES

- **High Efficiency—Up to 95%**
- **V_{IN} Range From 2.5 V to 6 V**
- **2.25 MHz Fixed Frequency Operation**
- **Output Current 400 mA and 600 mA**
- **Adjustable Output Voltage From 0.6V to V_{IN}**
- **Pin Selectable Output Voltage Supports Simple Dynamic Voltage Scaling**
- **EasyScale™ Optional One-Pin Serial Interface**
- **Power Save Mode at Light Load Currents**
- **180° Out of Phase Operation**
- **Output Voltage Accuracy in PWM Mode ±1%**
- **Typical 32-µA Quiescent Current for Both Converters**
- **100% Duty Cycle for Lowest Dropout**
- **Available in a 10-Pin QFN (3×3mm)**

APPLICATIONS

- **Cell Phones, Smart-phones**
- **PDAs, Pocket PCs**
- **OMAP™ and Low Power DSP Supply**
- **Portable Media Players**
- **Digital Radio**
- **Digital Cameras**



DESCRIPTION

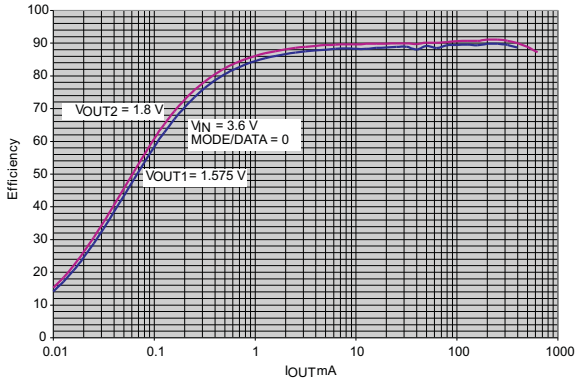
The TPS6240x device series are synchronous dual step-down DC-DC converters optimized for battery powered portable applications. They provide two independent output voltage rails powered by 1-cell Li-Ion or 3-cell NiMH/NiCD batteries. The devices are also suitable to operate from a standard 3.3V or 5V voltage rail.

With an input voltage range of 2.5V to 6V the TPS62400 is ideal to power portable applications like smart phones, PDAs and other portable equipment.

With the EasyScale™ serial interface the output voltages can be modified during operation. The fixed output voltage versions TPS62401, TPS62402, TPS62403 support one pin controlled simple Dynamic Voltage Scaling for low power processors.

The TPS6240x operates at 2.25MHz fixed switching frequency and enters the power save mode operation at light load currents to maintain high efficiency over the entire load current range. For low noise applications the devices can be forced into fixed frequency PWM mode by pulling the MODE/DATA pin high. In the shutdown mode, the current consumption is reduced to 1.2µA, typical. The devices allow the use of small inductors and capacitors to achieve a small solution size.

The TPS62400 is available in a 10-pin leadless package (3×3mm QFN)



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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

T_A	PART NUMBER	DEFAULT OUTPUT VOLTAGE (1)			OUTPUT CURRENT	QFN(2) PACKAGE	ORDERING(3)	PACKAGE MARKING
–40°C to 85°C	TPS62400	OUT1	Adjustable		400mA	DRC	TPS62400DRC	BQE
		OUT2			600mA			
	TPS62401	OUT1	Fixed default	DEF_1 = High 1.1V	400mA	DC	TPS62401DRC	BRN
				DEF_1 = Low 1.575V				
		OUT2	Fixed default 1.8V		600mA			
	TPS62403	OUT1	Fixed default	DEF_1 = High 1.1V	400mA	DRC	TPS62403DRC	BYI
				DEF_1 = Low 1.575V				
		OUT2	Fixed default 2.8V		600mA			
	TPS62402	OUT1	Fixed default	DEF_1 = High 1.8V	400mA	DRC	TPS62402DRC	BYH
				DEF_1 = Low 1.2V				
		OUT2	Fixed default 3.3V		600mA			

(1) Contact TI for other fixed output voltage options.
(2) The DRC (QFN 10 PIN) package is available in tape on reel. Add R suffix to order quantities of 3000 parts per reel.
(3) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI Web site at www.ti.com.

ABSOLUTE MAXIMUM RATINGS

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

			VALUE	UNIT
	Input voltage range on V_{IN}(2)		–0.3 to 7	V
	Voltage range on EN, MODE/DATA, DEF_1		–0.3 to V_{IN} +0.3, ≤ 7	V
	current into MODE/DATA		≤ 0.5	mA
	Voltage on SW1, SW2		–0.3 to 7	V
	Voltage on ADJ2, FB1		–0.3 to V_{IN} +0.3, ≤ 7	V
	ESD rating(3)	HBM Human body model	2	kV
		Charge device model CDM	1	kV
		Machine model	200	V
T_J(max)	Maximum operating junction temperature		150	°C
T_A	Operating ambient temperature range		–40 to 85	°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 100pF capacitor discharged through a 1.5kΩ resistor into each pin. The machine model is a 200pF capacitor discharged directly into each pin.

DISSIPATION RATINGS

PACKAGE	$R_{\theta JA}$	POWER RATING FOR $T_A \le 25°C$	DERATING FACTOR ABOVE $T_A = 25°C$
DRC	49°C/W	2050mW	21mW/°C

RECOMMENDED OPERATING CONDITIONS

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

		MIN	NOM	MAX	UNIT
VIN	Supply voltage	2.5		6	V
	Output voltage range for adjustable voltage	0.6		VIN	V
T_A	Operating ambient temperature	-40		85	°C
T_J	Operating junction temperature	-40		125	°C

ELECTRICAL CHARACTERISTICS

V_{IN} = 3.6V, V_{OUT} = 1.8V, EN = V_{IN}, MODE = GND, L = 2.2µH, C_{OUT} = 20µF, T_A = –40°C to 85°C typical values are at T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
SUPPLY CURRENT						
V_{IN}	Input voltage range		2.5		6.0	V
I_Q	Operating quiescent current	One converter, I_{OUT} = 0mA. PFM mode enabled (Mode = 0) device not switching, EN1 = 1 OR EN2 = 1		19	29	µA
		Two converter, I_{OUT} = 0mA. PFM mode enabled (Mode = 0) device not switching, EN1 = 1 AND EN2 = 1		32	48	µA
		I_{OUT} = 0mA, MODE/DATA = GND, for one converter, V_{OUT} 1.575V(1)		23		µA
		I_{OUT} = 0mA, MODE/DATA = V_{IN}, for one converter, V_{OUT} 1.575V (1)		3.6		mA
I_{SD}	Shutdown current	EN1, EN2 = GND, V_{IN} = 3.6V(2)		1.2	3	µA
		EN1, EN2 = GND, V_{IN} ramped from 0V to 3.6V(3)		0.1	1	
V_{UVLO}	Undervoltage lockout threshold	Falling		1.5	2.35	V
		Rising			2.4	
ENABLE EN1, EN2						
V_{IH}	High-level input voltage, EN1, EN2		1.2		V_{IN}	V
V_{IL}	Low-level input voltage, EN1, EN2		0		0.4	V
I_{IN}	Input bias current, EN1, EN2	EN1, EN2 = GND or VIN		0.05	1.0	µA
DEF_1 INPUT						
V_{DEF_1H}	DEF_1 high level input voltage	DEF_1 pin is a digital input at TPS62401 fixed output voltage option	0.9		V_{IN}	V
V_{DEF_1L}	DEF_1 low level input voltage	DEF_1 pin is a digital input at TPS62401 fixed output voltage option	0		0.4	V
I_{IN}	Input bias current DEF_1	DEF_1 GND or VIN		0.01	1.0	µA
MODE/DATA						
V_{IH}	High-level input voltage, MODE/DATA		1.2		V_{IN}	V
V_{IL}	Low-level input voltage, MODE/DATA		0		0.4	V
I_{IN}	Input bias current, MODE/DATA	MODE/DATA = GND or VIN		0.01	1.0	µA
V_{OH}	Acknowledge output voltage high	Open drain, via external pullup resistor			V_{IN}	V
V_{OL}	Acknowledge output voltage low	Open drain, sink current 500µA	0		0.4	V
INTERFACE TIMING						
t_{Start}	Start time		2			µs
t_{H_LB}	High time low bit, logic 0 detection	Signal level on MODE/DATA pin is > 1.2V	2		200	µs

(1) Device is switching with no load on the output, L = 3.3µH, value includes losses of the coil
(2) These values are valid after the device has been already enabled one time (EN1 or EN2 = high) and supply voltage V_{IN} has not powered down.
(3) These values are valid when the device is disabled (EN1 and EN2 low) and supply voltage V_{IN} is powered up. The values remain valid until the device has been enabled first time (EN1 or EN2 = high). After first enable, Note 3 becomes valid.

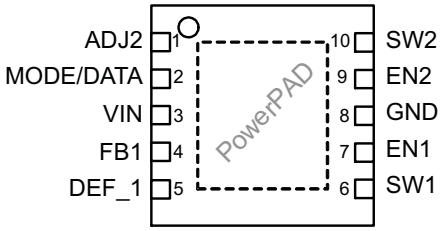
ELECTRICAL CHARACTERISTICS (continued)

V_{IN} = 3.6V, V_{OUT} = 1.8V, EN = V_{IN}, MODE = GND, L = 2.2µH, C_{OUT} = 20µF, T_A = –40°C to 85°C typical values are at T_A = 25°C (unless otherwise noted)

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{L_LB}	Low time low bit, logic 0 detection		Signal level on MODE/DATA pin < 0.4V	2x t_{H_LB}		400	µs
t_{L_HB}	Low time high bit, logic 1 detection		Signal level on MODE/DATA pin < 0.4V	2		200	µs
t_{H_HB}	High time high bit, logic 1 detection		Signal level on MODE/DATA pin is > 1.2V	2x t_{L_HB}		400	µs
T_{EOS}	End of Stream		T_{EOS}	2			µs
t_{ACKN}	Duration of acknowledge condition (MODE/DATE line pulled low by the device)		V_{IN} 2.5V to 6V	400		520	µs
t_{valACK}	Acknowledge valid time					2	µs
$t_{timeout}$	Timeout for entering power save mode		MODE/DATA Pin changes from high to low			520	µs
POWER SWITCH							
$R_{DS(ON)}$	P-Channel MOSFET on-resistance, Converter 1,2		V_{IN} = V_{GS} = 3.6V		280	620	mΩ
I_{LK_PMOS}	P-Channel leakage current		V_{DS} = 6.0V			1	µA
$R_{DS(ON)}$	N-Channel MOSFET on-resistance Converter 1,2		V_{IN} = V_{GS} = 3.6V		200	450	mΩ
$I_{LK_SW1/SW2}$	Leakage current into SW1/SW2 pin		Includes N-Chanel leakage current, V_{IN} = open, V_{SW} = 6.0V, EN = GND(4)		6	7.5	µA
I_{LIMF}	Forward Current Limit PMOS and NMOS	OUTPUT 1	2.5V ≤ V_{IN}≤ 6.0V	0.68	0.8	0.92	A
		OUTPUT 2		0.85	1.0	1.15	
T_{SD}	Thermal shutdown		Increasing junction temperature		150		°C
	Thermal shutdown hysteresis		Decreasing junction temperature		20		°C
OSCILLATOR							
fSW	Oscillator frequency		2.5V ≤ VIN ≤ 6V	2.0	2.25	2.5	MHz
OUTPUT							
V_{OUT}	Adjustable output voltage range			0.6		V_{IN}	V
V_{ref}	Reference voltage				600		mV
$V_{OUT\ (PFM)}$	DC output voltage accuracy adjustable and fixed output voltage(5)		Voltage positioning active, MODE/DATA = GND, device operating in PFM mode, VIN = 2.5V to 5.0V (6)(7)	–1.5%	1.01 V_{OUT}	2.5%	
$V_{OUT(PWM)}$			MODE/DATA = GND; device operating in PWM Mode, VIN = 2.5V to 6.0V(7)	–1%	0%	1%	
			V_{IN} = 2.5V to 6.0V, Mode/Data = V_{IN} , Fixed PWM operation, 0mA < I_{OUT1} < 400mA ; 0mA < I_{OUT2} < 600mA(8)	–1%	0%	1%	
	DC output voltage load regulation		PWM operation mode			0.5	%/A
$t_{Start\ up}$	Start-up time		Activation time to start switching(9)		170		µs
t_{Ramp}	V_{OUT} Ramp UP time		Time to ramp from 5% to 95% of V_{OUT}		750		µs

(4) On pins SW1 and SW2 an internal resistor of 1MΩ is connected to GND.
(5) Output voltage specification does not include tolerance of external voltage programming resistors
(6) Configuration L typ 2.2µH, C_{OUT} typ 20µF, see parameter measurement information, the output voltage ripple in PFM mode depends on the effective capacitance of the output capacitor, larger output capacitors lead to tighter output voltage tolerance.
(7) In Power Save Mode, PWM operation is typically entered at I_{PSM} = V_{IN}/32Ω.
(8) For V_{OUT} > 2V, V_{IN} min = V_{OUT} +0.5V
(9) This time is valid if one converter turns from shutdown mode (EN2 = 0) to active mode (EN2 = 1) AND the other converter is already enabled (e.g., EN1 = 1). In case both converters are turned from shutdown mode (EN1 and EN2 = low) to active mode (EN1 and/or EN2=1) a value of typ 80 µs for ramp up of internal circuits needs to be added. After t_{Start} the converter starts switching and ramps V_{OUT}.

PIN ASSIGNMENTS

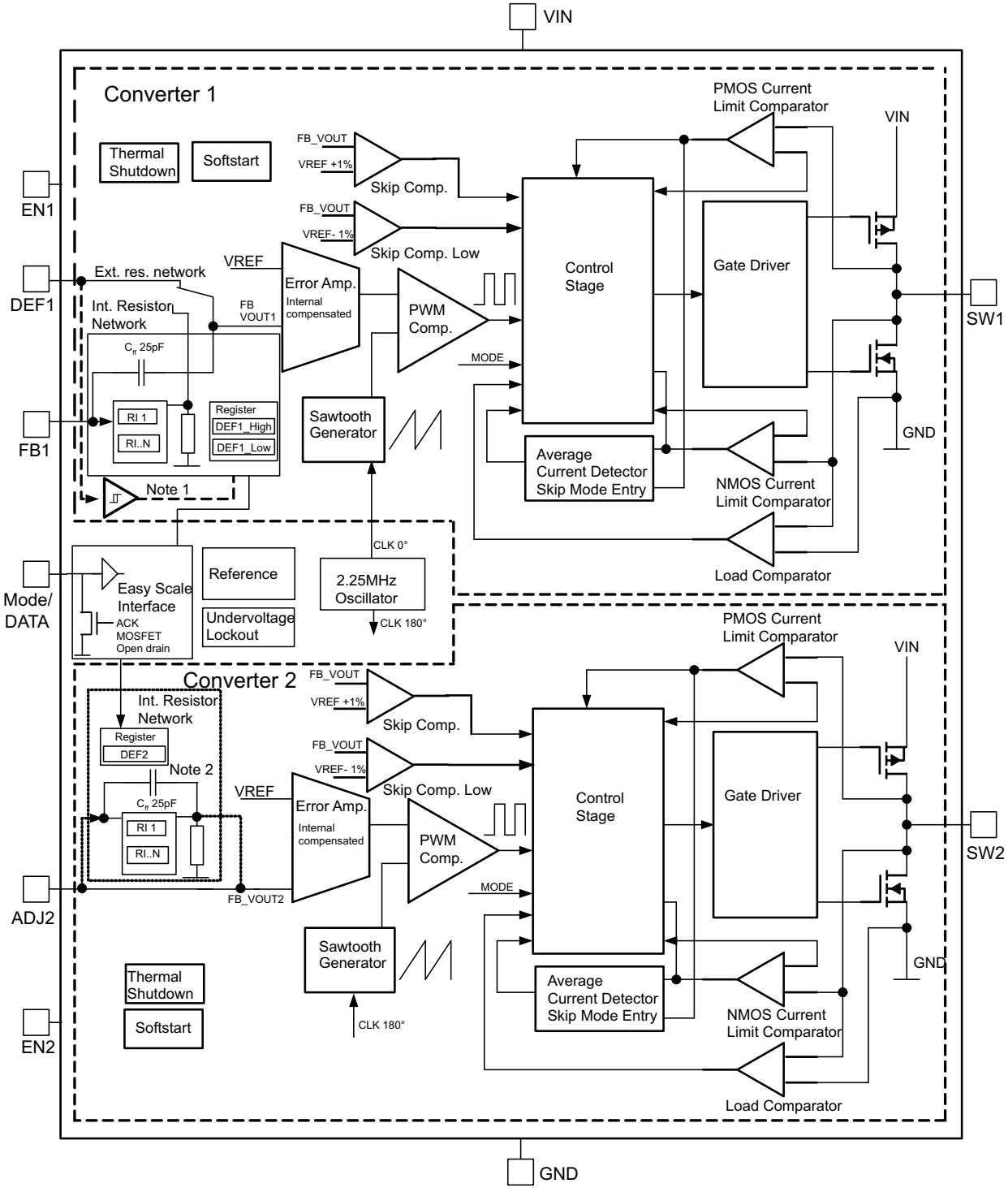


Top view DRC package

TERMINAL FUNCTIONS

TERMINAL		I/O	DESCRIPTION
NAME	NO. (QFN)		
ADJ2	1	I	Input to adjust output voltage of converter 2. In adjustable version (TPS62400) connect a external resistor divider between VOUT2, this pin and GND to set output voltage between 0.6V and VIN. At fixed output voltage version (TPS62401) this pin MUST be directly connected to the output. If EasyScale Interface is used for converter 2, this pin must be directly connected to the output, too.
MODE/DATA	2	I/0	This Pin has 2 functions: 1. Operation Mode selection: With low level, Power Save Mode is enabled where the device operates in PFM mode at light loads and enters automatically PWM mode at heavy loads. Pulling this PIN to high forces the device to operate in PWM mode over the whole load range. 2. EasyScale™ Interface function: One wire serial interface to change the output voltage of both converters. The pin has an open drain output to provide an acknowledge condition if requested. The current into the open drain output stage may not exceed 500µA. The interface is active if either EN1 or EN2 is high.
VIN	3		Supply voltage, connect to VBAT, 2.5V to 6V
FB1	4	I	Direct feedback voltage sense input of converter 1, connect directly to Vout 1. An internal feed forward capacitor is connected between this pin and the error amplifier. In case of fixed output voltage versions or when the Interface is used, this pin is connected to an internal resistor divider network.
DEF_1	5	I	This pin defines the output voltage of converter 1. The pin acts either as analog input for output voltage setting via external resistors (TPS62400), or digital input to select between two fixed default output voltages (TPS62401, TPS62402, TPS62403). For the TPS62400, an external resistor network needs to be connected to this pin to adjust the default output voltage. Using the fixed output voltage device options this pin selects between two fixed default output voltages, see table ordering information
SW1	6	I/O	Switch Pin of Converter1. Connect to Inductor
EN1	7	I	Enable Input for Converter1, active high
GND	8		GND for both converters; connect this pin to the PowerPAD™
EN2	9	I	Enable Input for Converter 2, active high
SW2	10	I/O	Switch Pin of Converter 2. Connect to Inductor.
PowerPAD™			Connect to GND

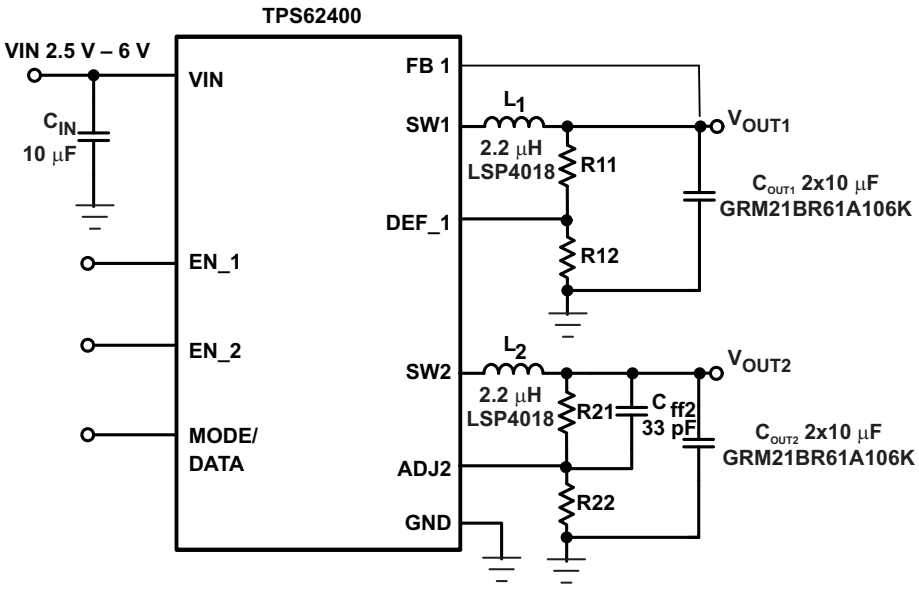
FUNCTIONAL BLOCK DIAGRAM



(1) In fixed output voltage version, the PIN DEF_1 is connected to an internal digital input and disconnected from the error amplifier

(2) To set the output voltage of Converter 2 via EasyScale™ Interface, ADJ2 pin must be directly connected to VOUT2

PARAMETER MEASUREMENT INFORMATION



TYPICAL CHARACTERISTICS

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EFFICIENCY TPS62401 VOUT1 = 1.1V

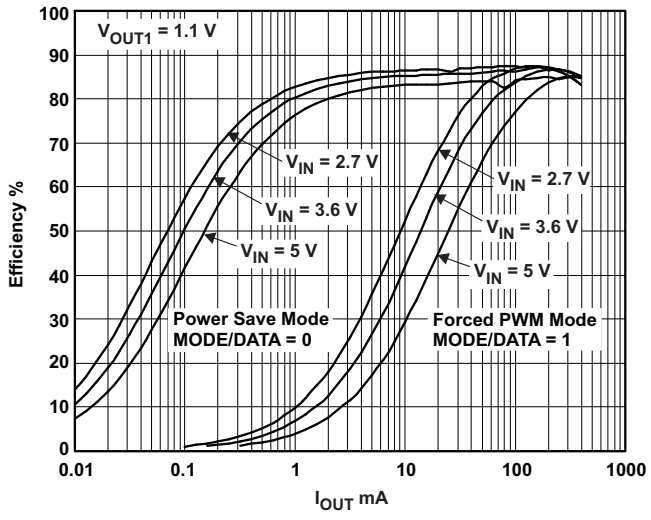


Figure 1.

EFFICIENCY TPS62401 VOUT1 = 1.575V

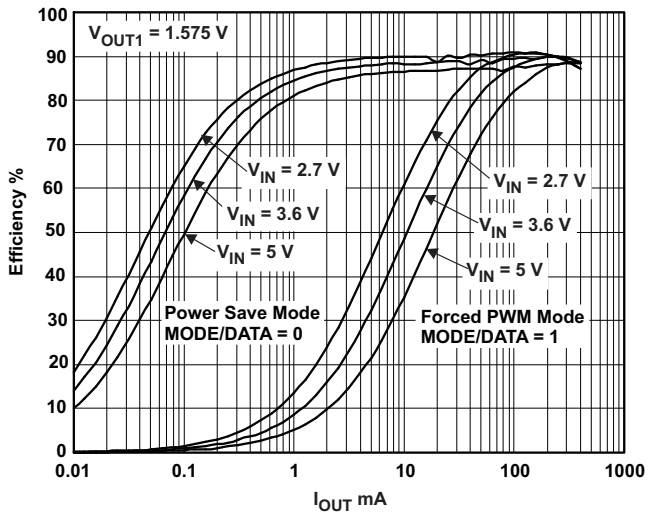


Figure 2.

EFFICIENCY VOUT 2 = 1.8V

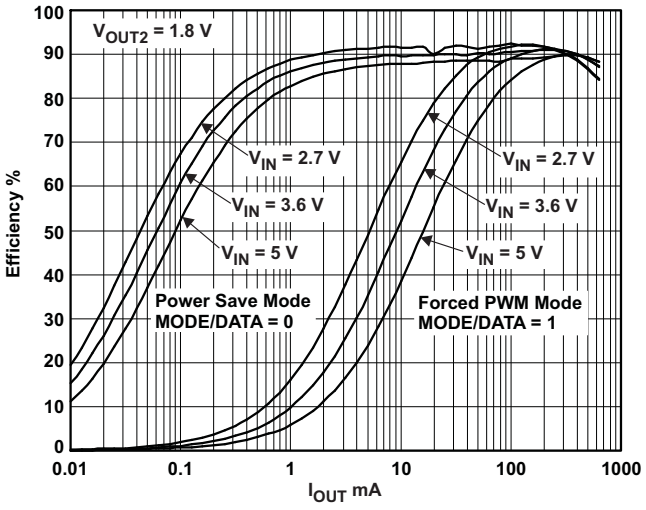


Figure 3.

EFFICIENCY TPS62400 VOUT 2 = 3.3V

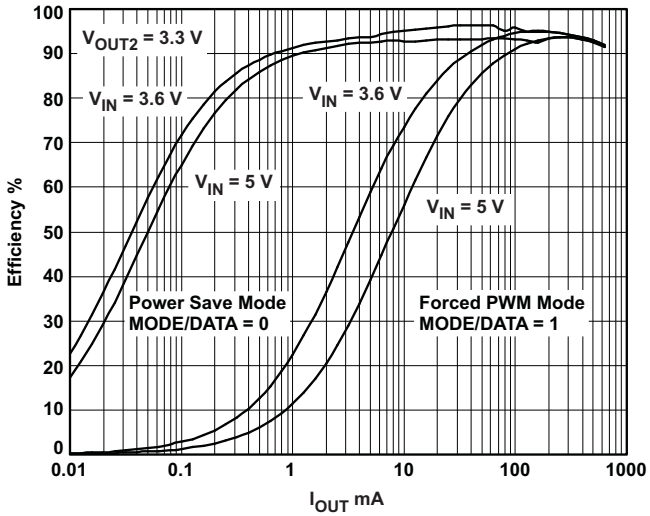


Figure 4.

EFFICIENCY TPS62402 VOUT1/VOUT2

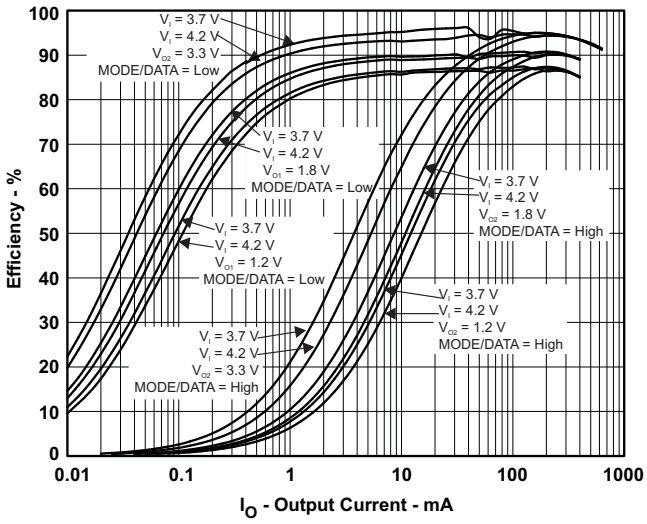


Figure 5.

EFFICIENCY TPS62403 VOUT1/VOUT2

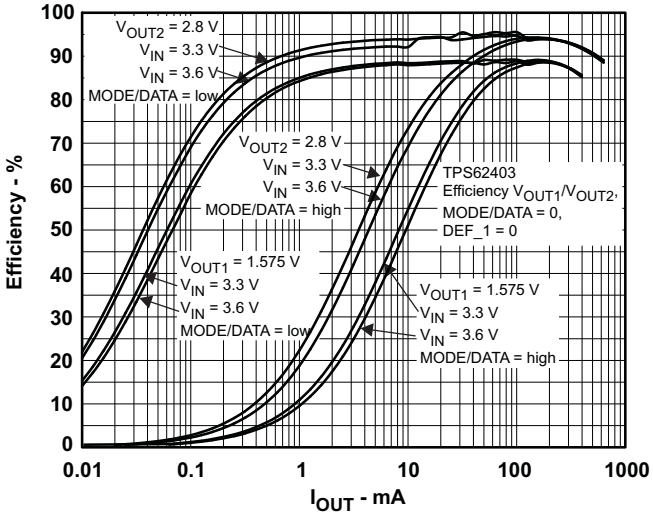


Figure 6.

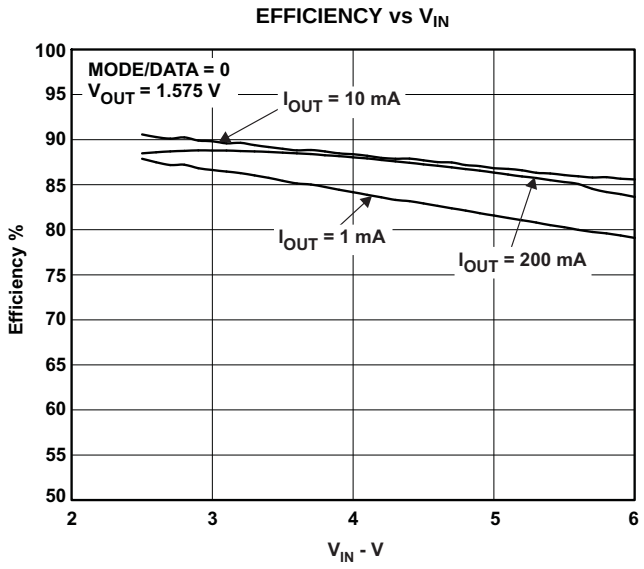


Figure 7.

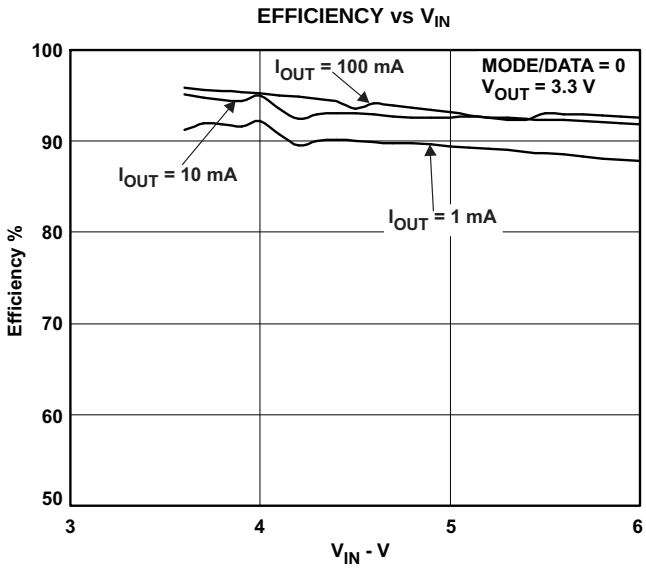


Figure 8.

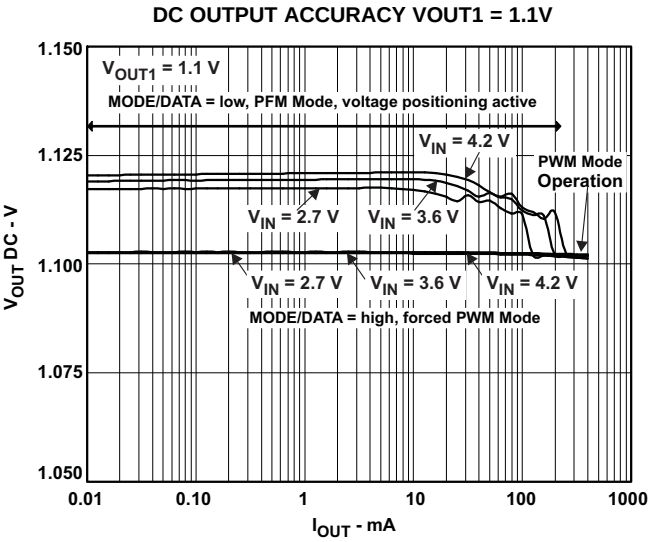


Figure 9.

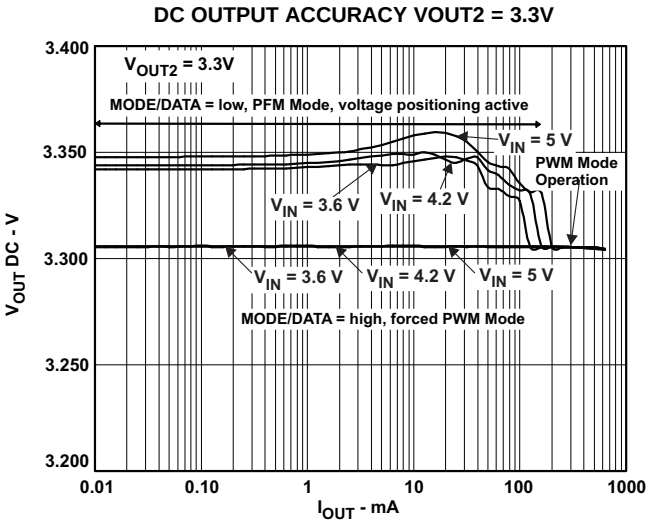


Figure 10.

DC OUTPUT ACCURACY VOUT2 = 1.8V

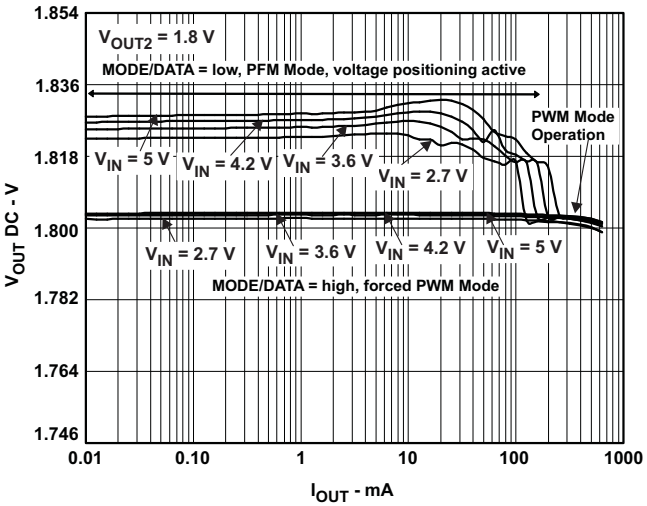


Figure 11.

DC OUTPUT ACCURACY $V_{OUT}1$ = 1.575V,
L = 2.2µH, C_{OUT} = 22µF

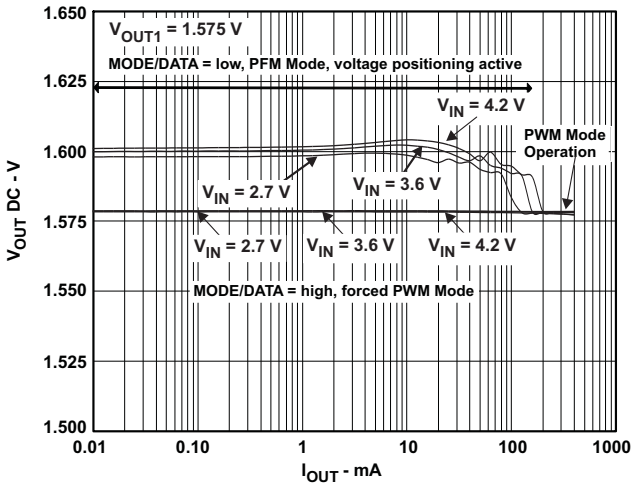


Figure 12.

DC OUTPUT ACCURACY $V_{OUT}1$ = 1.575V,
L = 3.3µH, C_{OUT} = 10µF

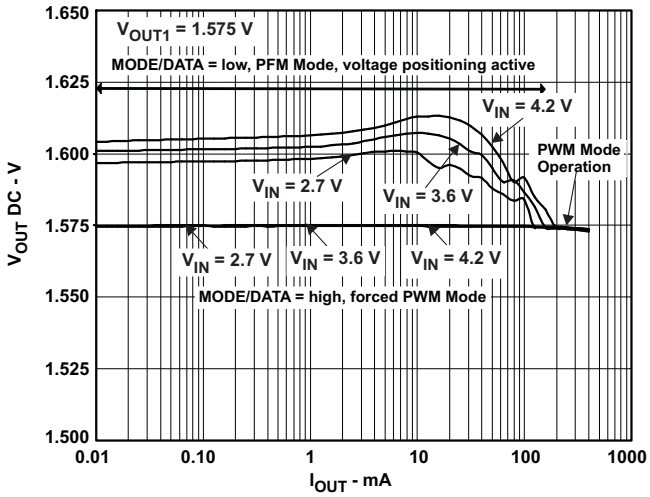


Figure 13.

F_{OSC} vs V_{IN}

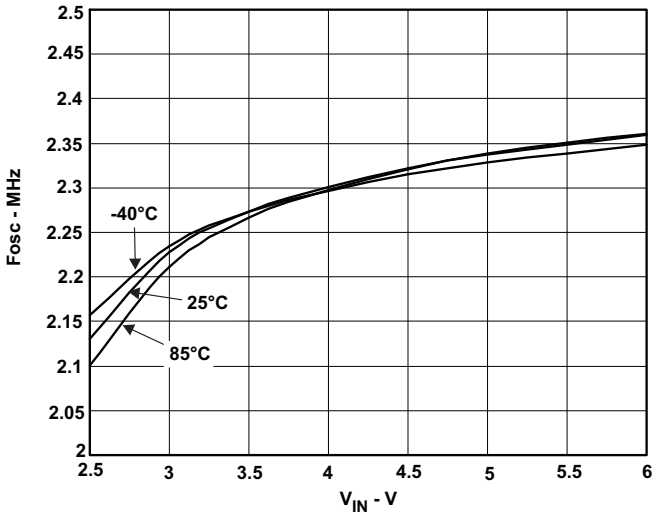


Figure 14.