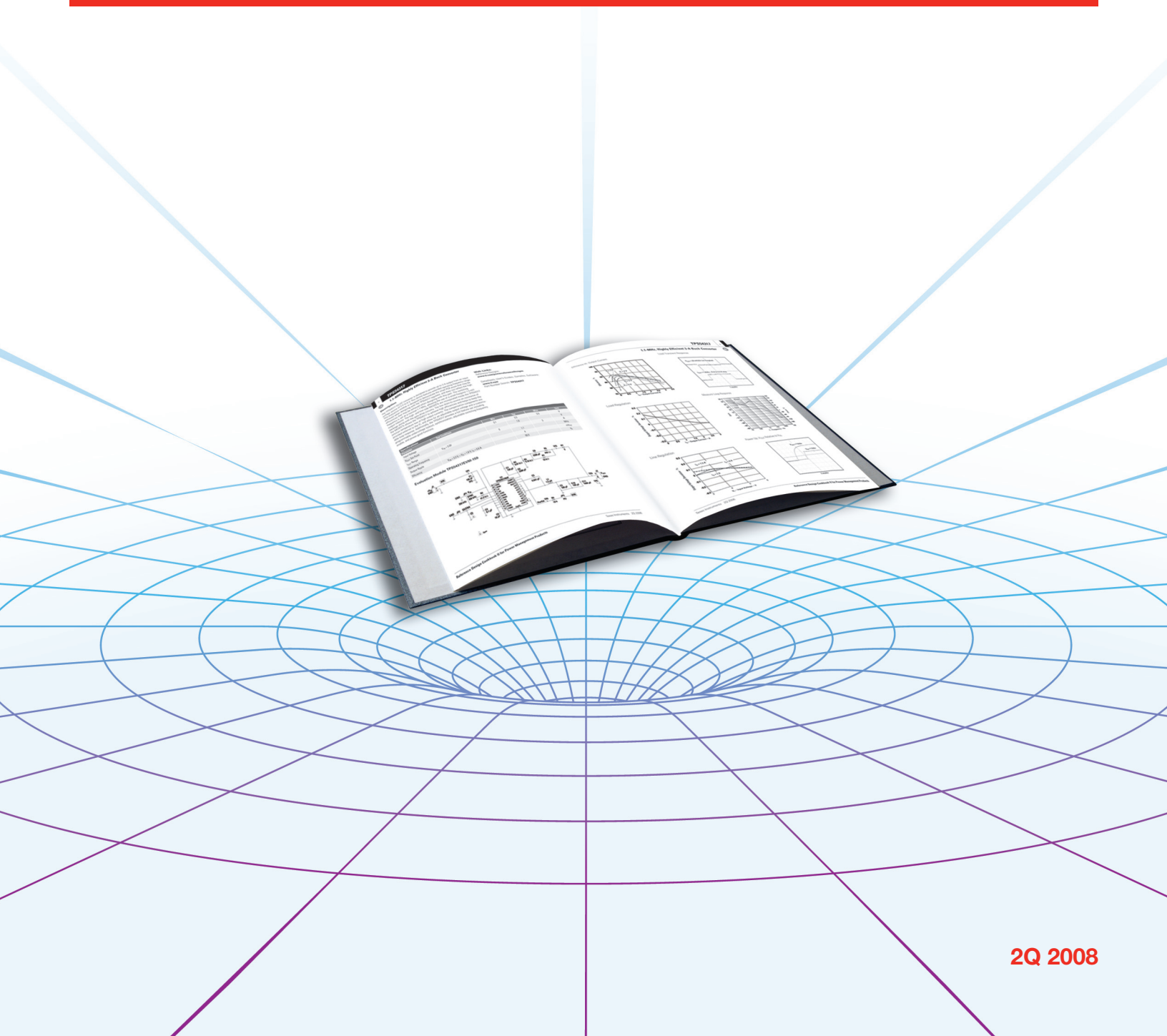
Power Management Reference Design Cookbook III

Texas Instruments



2Q 2008

Power Management Products from Texas Instruments

TI provides a broad portfolio of high-performance power management products ranging from standard linear regulators to plug-in and integrated power solutions. Together with superior applications knowledge, extensive local technical support and easy to use design tools, TI can help you differentiate your designs and get to market faster.

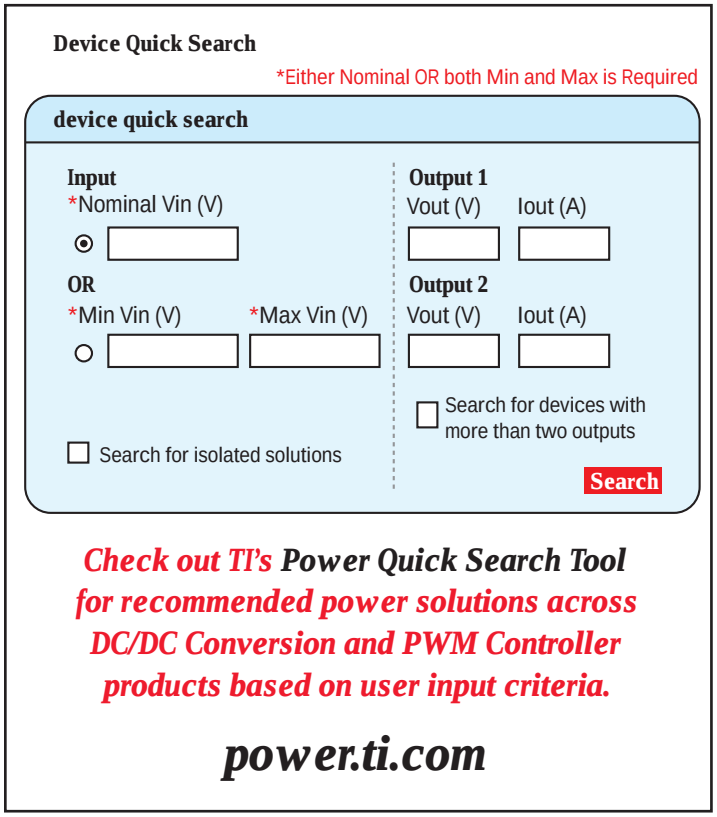
Introducing TI's Reference Design Cookbook III

Welcome to TI's latest Power Management Cookbook, the third in the series. This is a collection of complete power solutions and design documentation from TI's extensive library of reference designs and evaluation modules (EVMs) available to our customers. For hundreds of other TI reference designs, visit: **www.ti.com/powerreferencedesigns**. This website is frequently updated with new circuits.

Also, if you would like copies of the first and second issues of the Reference Design Cookbook, please download them at the URL referenced above, or request copies by calling: **972-644-5580 and mention Lit #: SLUB009 (I)** or **SLUB012 (II)**.

TI hopes you enjoy these latest "recipes", and that this Cookbook will help you simplify and streamline your power supply designs.

Device Quick Search Tool



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Inside

TI has many other reference designs that may be found at:

www.ti.com/powerreferencedesigns

6-A Synchronous Buck Converter with Minimal External Components

Description

The TPS40190 controller is a cost-optimized synchronous controller that operates from 4.5 V to 15 V nominally, and implements a fixed frequency voltage mode power supply. The controller uses an adaptive anti-cross conduction scheme to prevent both the high-side and the rectifier MOSFET to be turned on at the same time, preventing shoot through current in the two MOSFETs. The controller also provides a short circuit protection threshold that is user selectable among one of three values. When the controller senses an output short circuit, both MOSFETs are turned off and a timeout period is observed before attempting to restart. This provides limited power dissipation in the event of a sustained fault.

Additionally, the chip features a 591-mV reference with 1% accuracy over temperature.

The TPS40190 provides strong drivers to minimize switching losses in the power stage, reducing heat build up in the MOSFETs and allowing larger MOSFETs to be used without undue switching time penalty.

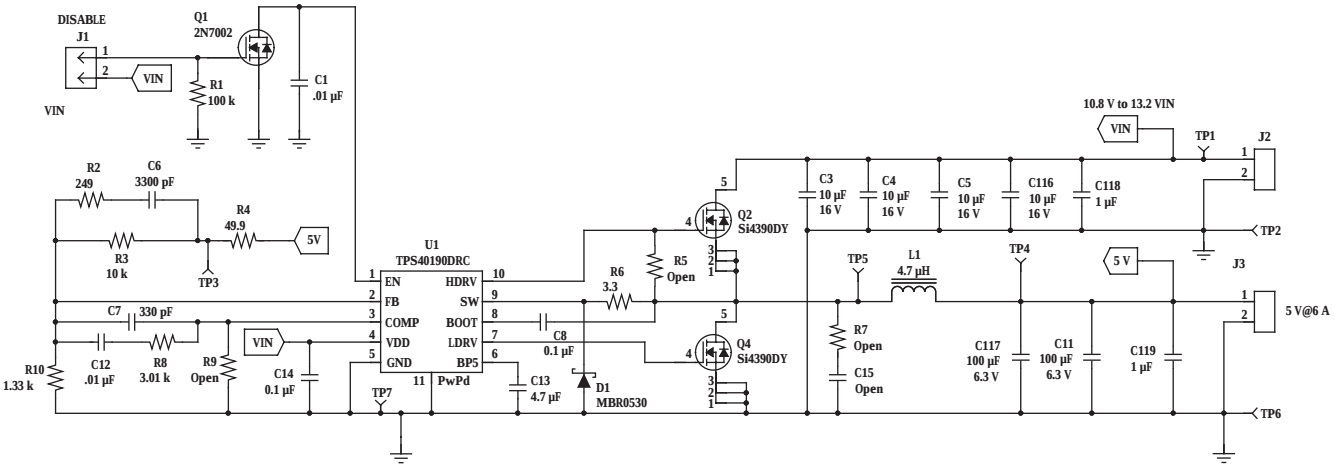
Web Links:

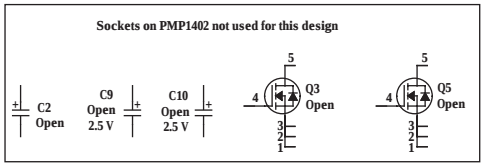
Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **TPS40190**

Specifications					
Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		10.8	12	13.2	Volts
Output Voltage	$0 < I_{OUT}, < 6$ A	5.05	5.05	5.05	Volts
Output Ripple				12	mV_{P-P}
Output Current		0		6	Amps
Switching Frequency			300		kHz
Efficiency	$0.5 A < I_{OUT}, < 6$ A	90.5	95	96	%

PMP2942 Schematic



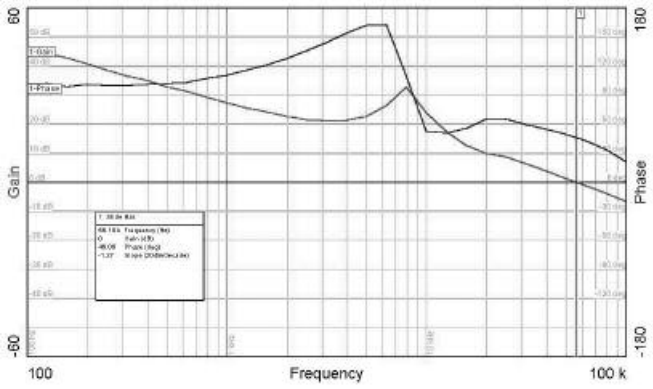


fs = 300 kHz

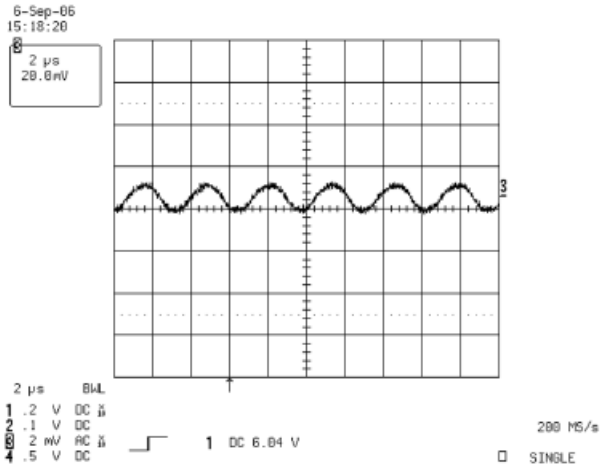
Build based on universal PMP1402

6-A Synchronous Buck Converter with Minimal External Components

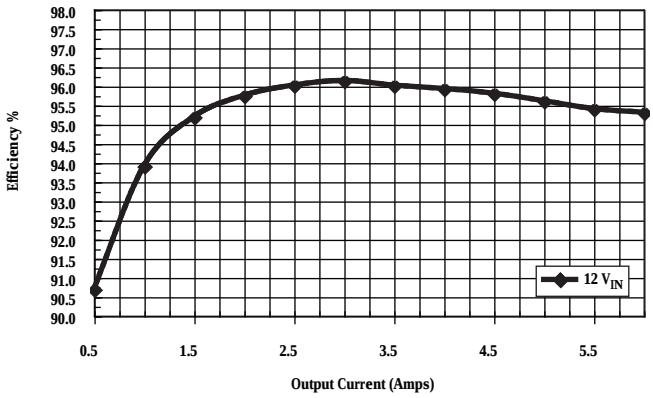
Control Loop (Gain and Phase)



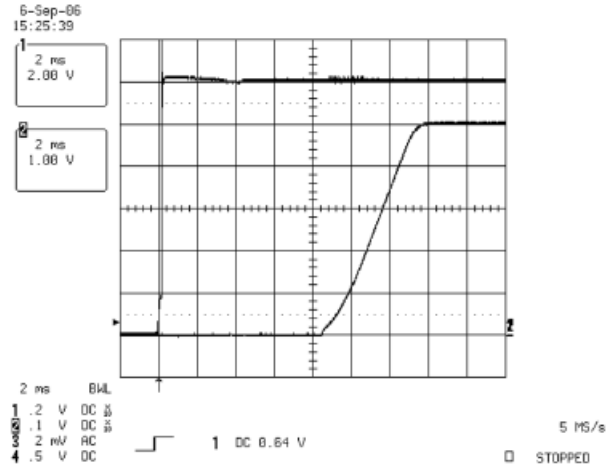
Output Ripple Voltage (5 V)



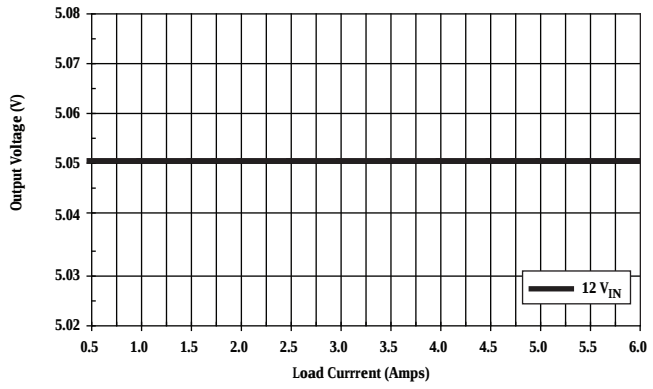
Efficiency (5 V Output)



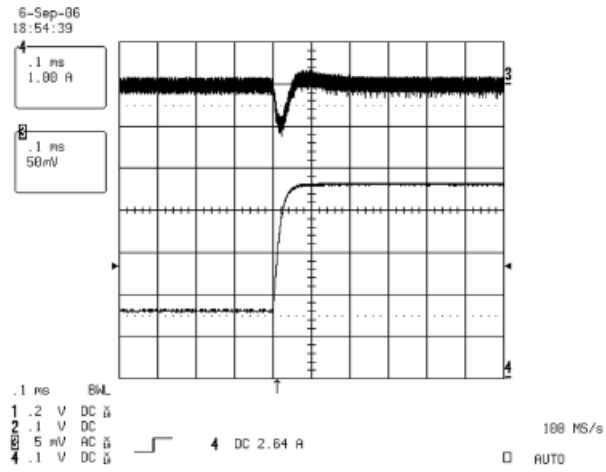
Startup (5 V)



Load/Line Regulation (5 V Output)



Load Transient (5 V)



High-Frequency Synchronous Buck Converter for Optimized Efficiency

Description

The TPS40195 controller is used in high-frequency, synchronous buck power supplies. It is intended for input voltages between 4.5 and 20 V and load currents up to 20 A. It can operate at switching frequencies between 100 and 600 kHz allowing the circuit designer the option of optimizing for efficiency and higher power at the lower frequency or smaller size and lower cost at the high frequency. This chip uses voltage mode control for lower mid-frequency source impedance and quicker recovery from load transients.

This circuit uses the TPS40195 in the synchronous buck configuration. A synchronous buck is typically used when the output voltage is always lower than the input voltage and at currents where a catch diode would dissipate too much heat. This design switches at 600 kHz which allows the use of a small inductor and ceramic output capacitors. With this high switching frequency, the control loop can be closed at a high frequency with good gain (> 10 dB) and good phase margin (> 45 degrees).

Web Links:

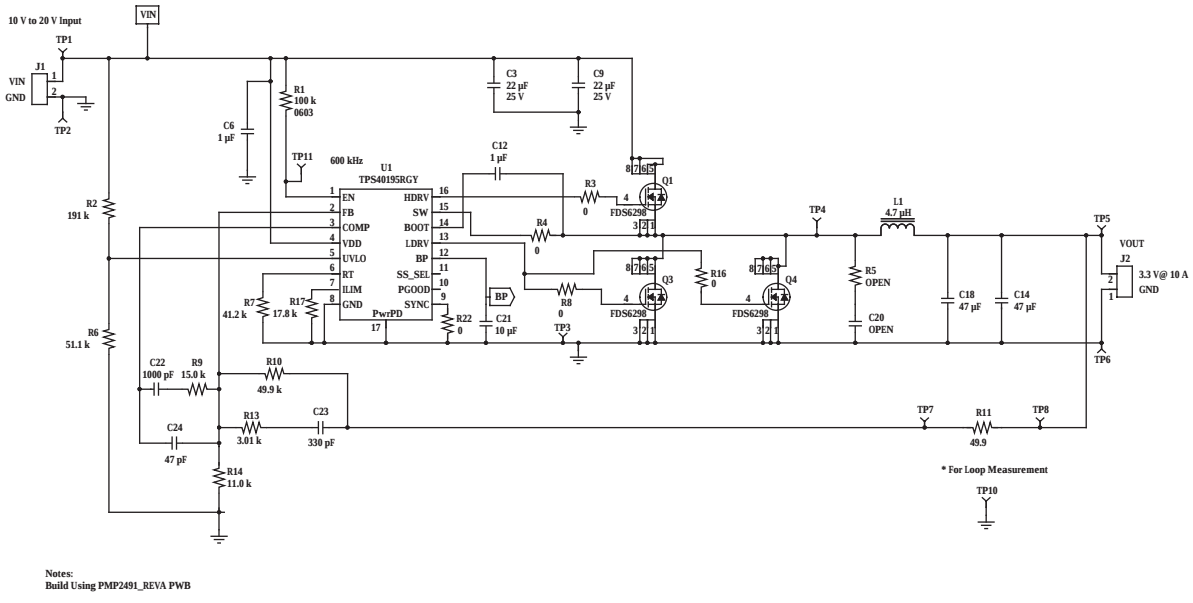
Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **TPS40195**

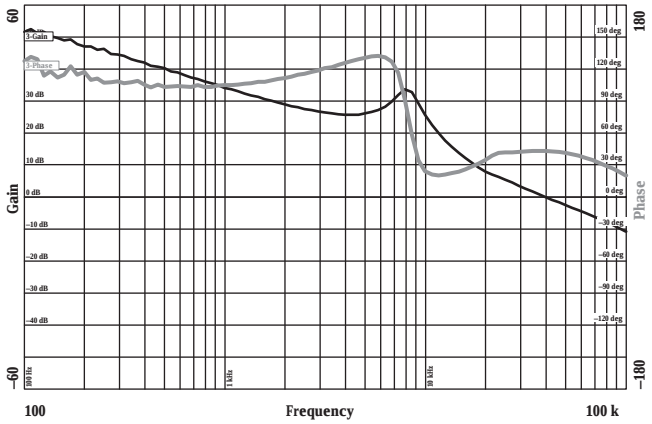
Specifications

Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		10	12	20	Volts
Output Voltage	$0 < I_{OUT} < 10$ A	3.15	3.3	3.45	Volts
Output Ripple				50	mV_{P-P}
Output Current		0		10	Amps
Switching Frequency			600		kHz
Efficiency	$2 A < I_{OUT} < 10$ A	90			%

PMP3080 Schematic

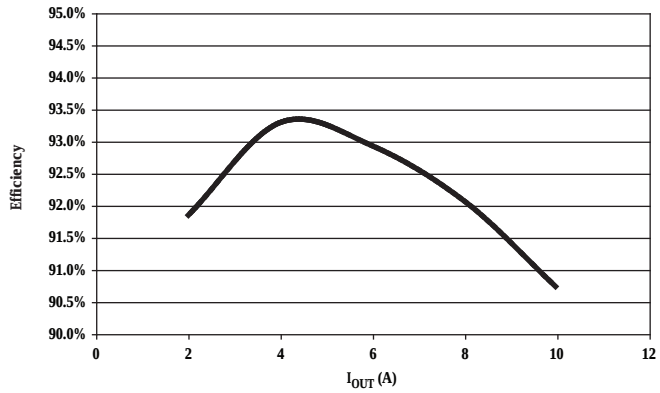


Control Loop (Gain and Phase), 40 KHz Crossover, 45° Phase Margin

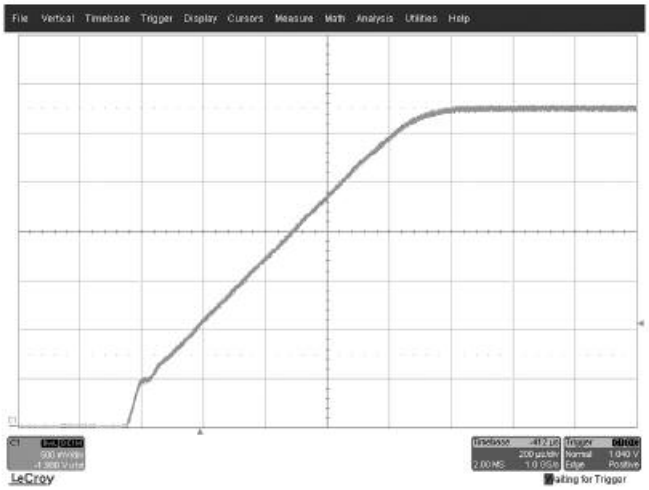


Output Ripple Voltage, Vertical: 10 mV/DIV, Horizontal: 1 µS/DIV

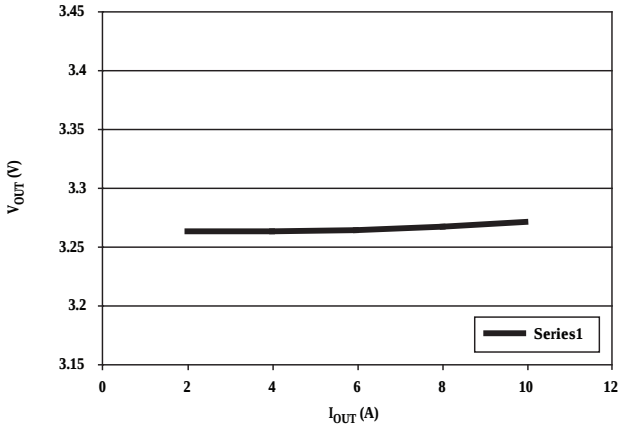
Efficiency



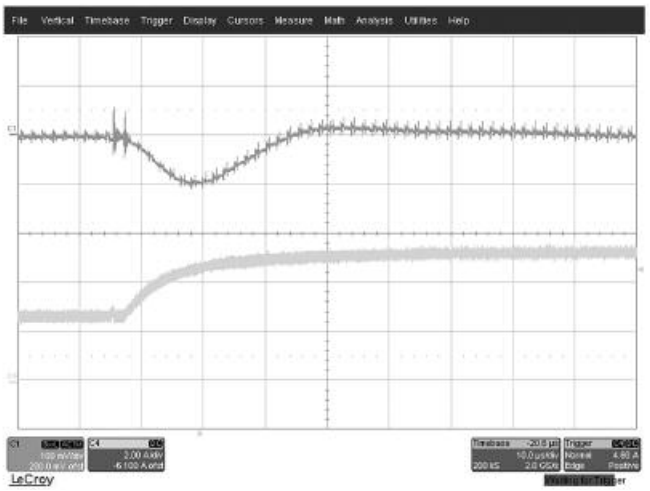
Startup, Vertical: 500 mV/DIV, Horizontal: 200 µs/DIV



Regulation



Transient Load Response, Upper Vertical: 100 mV/DIV, Lower Vertical: 2 A/DIV,Horizontal: 10 µs/DIV



Dual Synchronous Buck Converter Stackable Up to 16 Phases

Description

The TPS40140 is a dual synchronous buck controller that can be used for a two-phase single output or for two independent outputs. The controller has an input voltage rating of 4.5 to 15 V for the chip V_{CC} and 2 to 40 V for the power stage. It will work in many applications with 5, 12 and 24 V inputs. The controller can also accept input voltages from two different sources. Current mode control uses the inductor DCR to minimize impacts on the efficiency. A current sense resistor could be used for improved accuracy. Additionally, the chip features a 700-mV reference with better than 1% accuracy over temperature.

This circuit uses the TPS40140 in the dual synchronous buck configuration. A buck is typically used when the output voltage is always lower than the input voltage. Key considerations for this design are low output noise and synchronized switching. The TPS40140 provides a CLKIO pin that can be connected between devices to create up to 16 phases that are optimally shifted. The converter in this case is 5 V to 2.5 V @ 2 A and 3.3 V to 1.2 V @ 4 A.

Web Links:

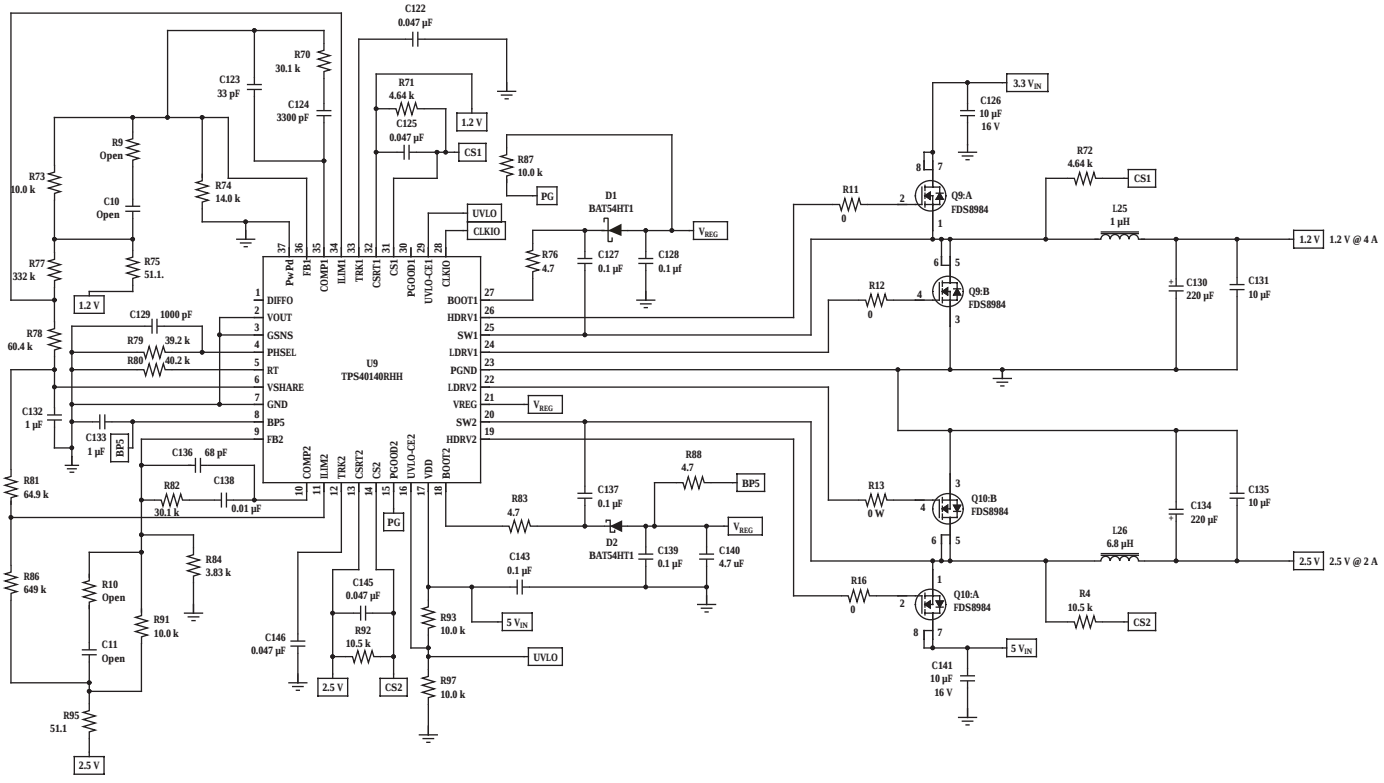
Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **TPS40140**

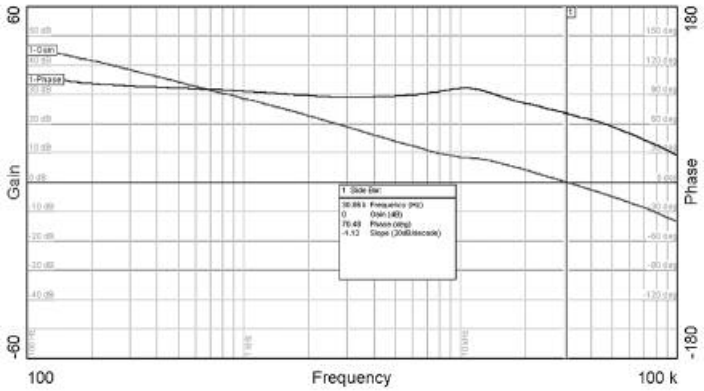
Specifications

Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		4.5/3.0	5/3.3	5.5/3.6	Volts
Output Voltage		2.43/1.17	2.5/1.2	2.57/1.23	Volts
Output Ripple				10	mV_{P-P}
Output Current		0		2/4	Amps
Switching Frequency			750		kHz

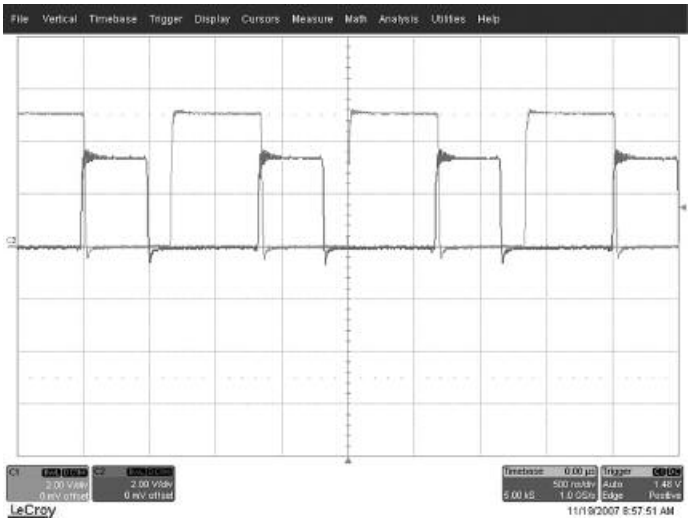
PMP2942 Schematic



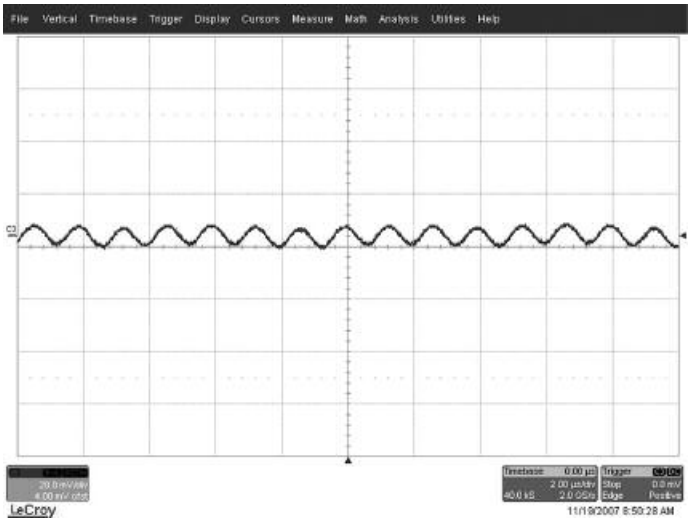
Control Loop (Gain and Phase), 30 KHz Cross Over



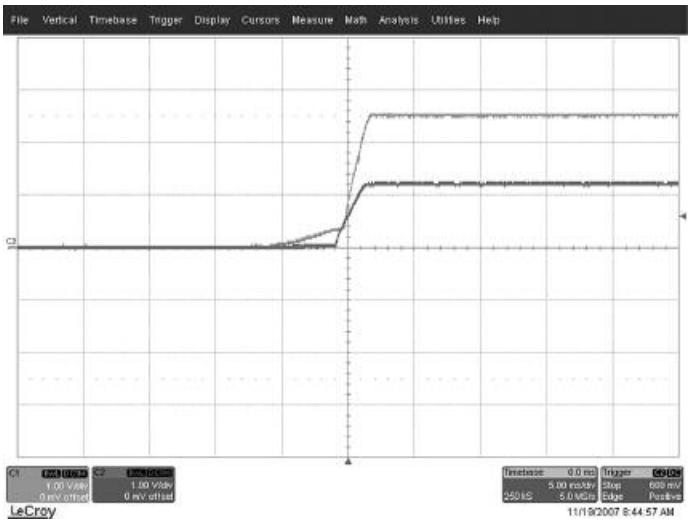
Switch Node



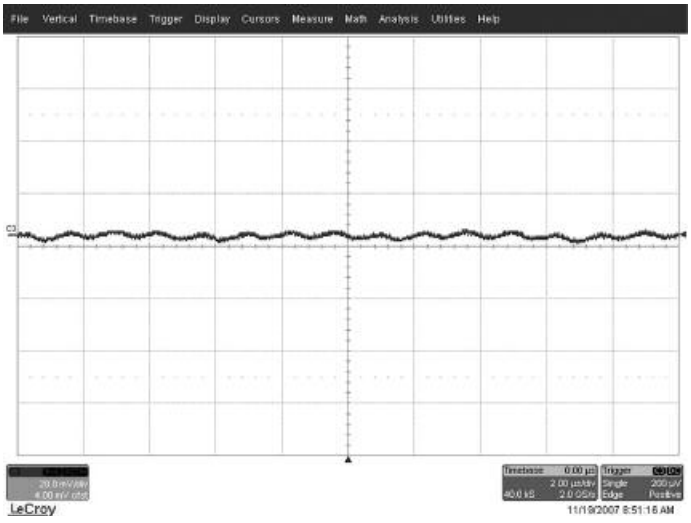
Output Ripple Voltage, 1.2 V (5 V_{IN}, 4 A Load, Ripple < 10 mV)



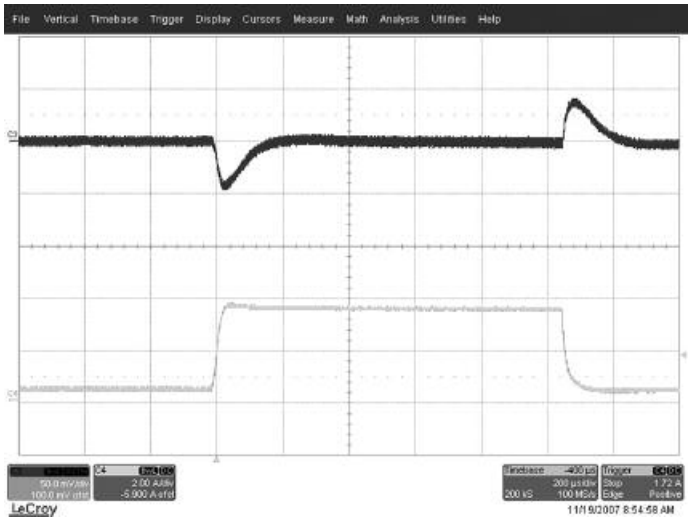
Turn On



Output Ripple Voltage, 2.5 V (3.3 V_{IN}, 2 A Load, Ripple < 10 mv)



Load Step (1.2 V)



Dual Converter with High Efficiency and Few External Components

Description

The TPS6240x converter series provides two low voltage outputs, one up to 400 mA and the other up to 600 mA with high efficiency, small size and very few external parts. Input range covers the popular 5 V and 3. 3 V logic levels and the full range of the Lithium Ion battery range. To keep the size of external components small, switching frequency is set to 2.25 MHz. This allows chokes to be 2.2 µHy and input/output caps to be 10 µF. Topology is synchronous buck with both the high side and low side FETs inside the TPS6240x.

There are three fixed voltage versions and an "EasyScale™" serial interface that avoid voltage sense resistors. With the EasyScale interface, outputs can be changed while running. The TPS62400 itself is the adjustable version allowing output voltages to be set with resistors.

The specific design provides for all the TPS6240x versions and for adjustment with resistors or the EasyScale interface. Each output also has its own enable pin.

The TPS6240x allows for rapid provision for the low output voltages, freeing the designers to focus on other parts of the system.

Web Links:

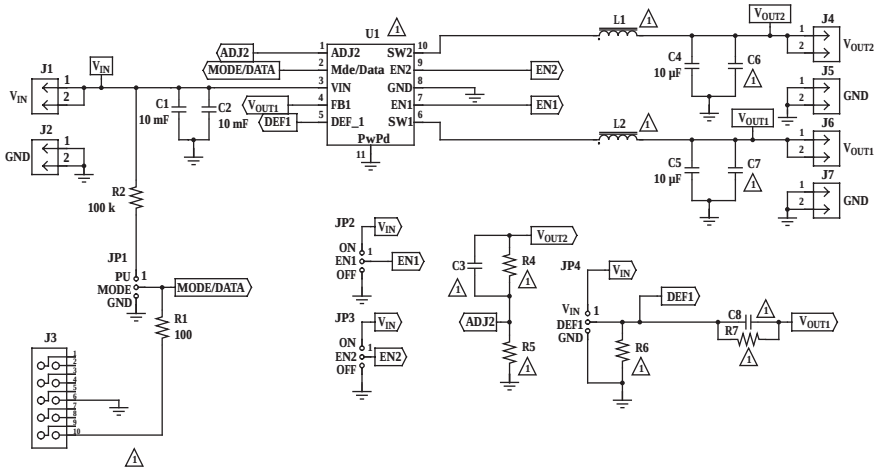
Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **TPS6240x**

Specifications

Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		2.5		6	Volts
Output Voltage	TPS62400	0.6		V_{IN}	Volts
Output Current		0		400/600	mA
Ripple Voltage	PWM Mode		< 10		mV_{P-P}
Switching Frequency			2.25		MHz
Efficiency	1.8 V Output		> 90		%
Step Load Response Time	PWM Mode				
	PFM Mode		10 µs		
			50 µs		

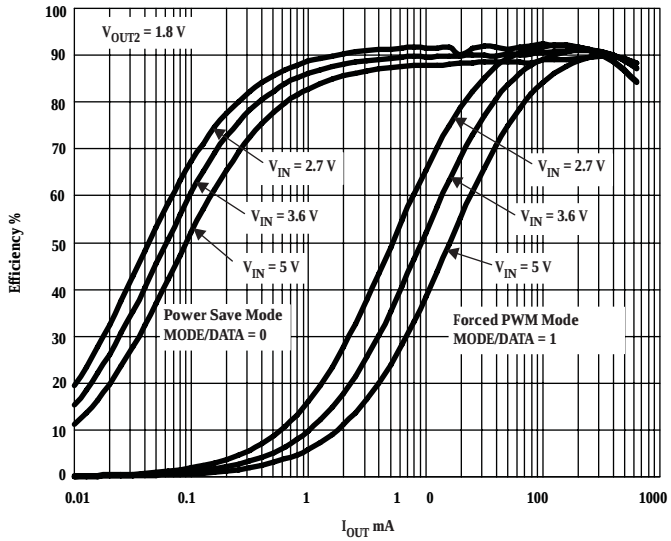
TPS62400EVM-167 Schematic



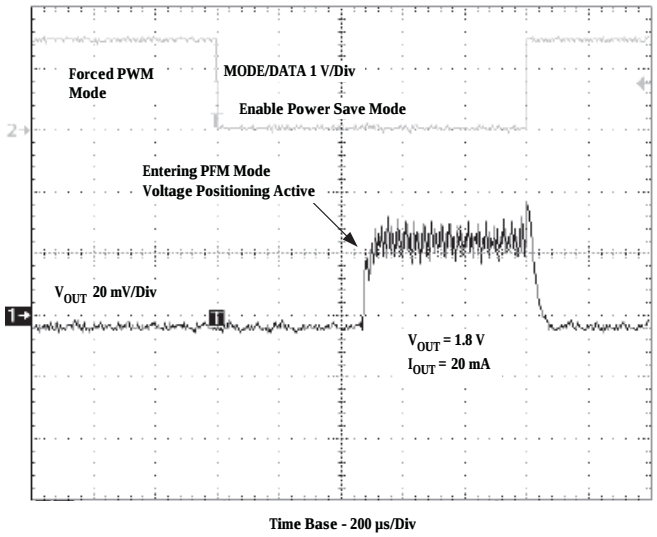
ASSY	U1	C3	C6	C7	L1	L2	R4	R5	R6	R7
-001	TPS62400DRC	33 pF	Open	Open	LPS3010-222	LPS3010-222	681 k	182 k	332 k	332 k
-002	TPS62401DRC	Open	Open	Open	LPS3010-222	LPS3010-222	0	Open	100 k	Open
-003	TPS62420DRC	33 pF	10 µF	10 µF	LPS3015-222	LPS3015-222	681 k	182 k	332 k	332 k

Dual Converter with High Efficiency and Few External Components

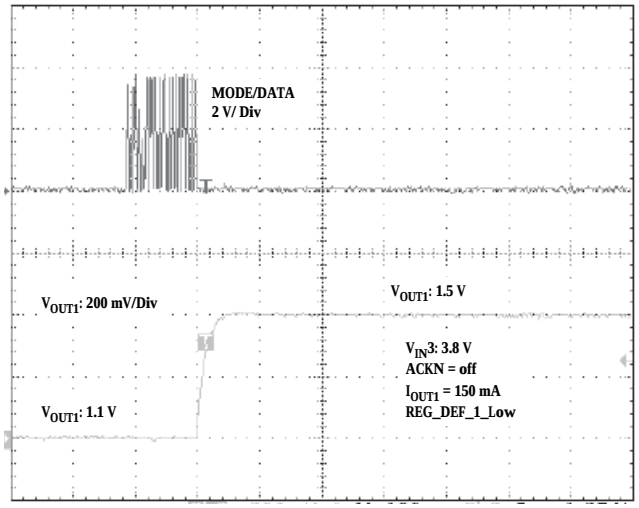
Efficiency (V_{OUT} 2 = 1.8 V)



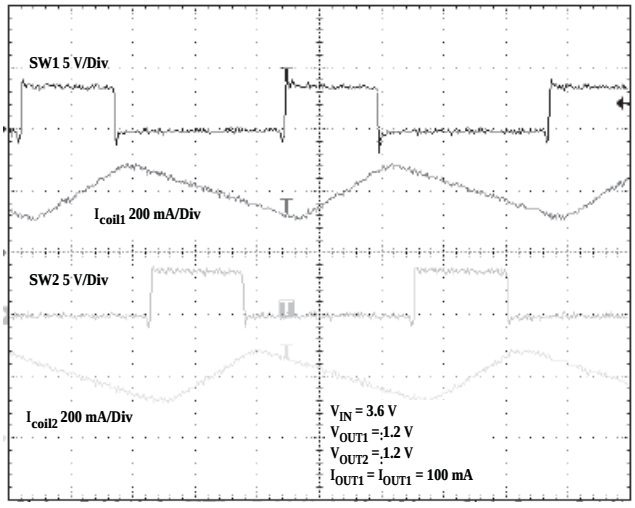
Output Ripple Voltage: PWM/PFM Mode Transition



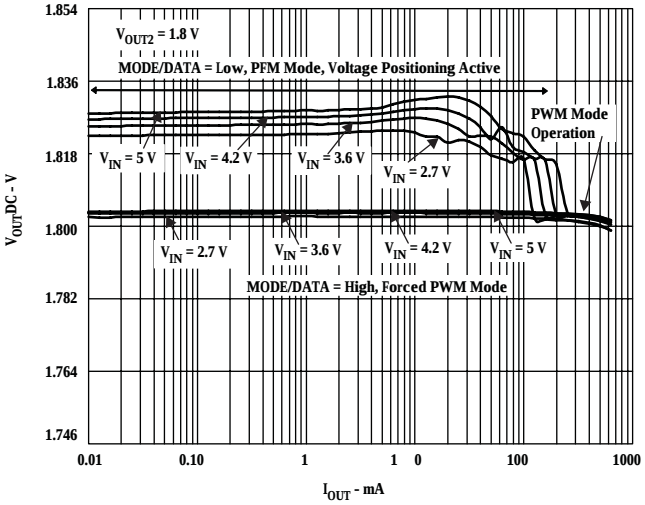
V_{OUT} 1 Change with EasyScale™



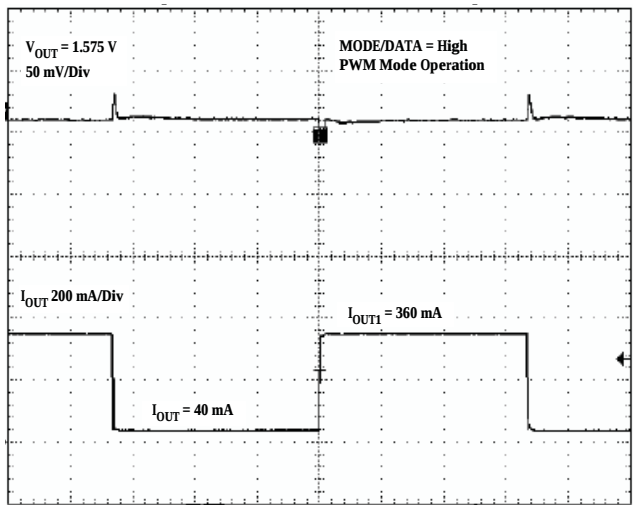
Internal Switching Waveforms



Regulation: PFM and PWM Modes



Step Load Response: PWM Mode



60-A Three-Phase Synchronous Buck Converter

Description

The TPS40180 is a single synchronous buck controller that can be stacked for a multi-phase output. The controller has an input voltage rating of 4.5 to 15 V for the chip V_{CC} and 2 to 40 V for the power stage. It will work in many applications with 5, 12 and 24 V inputs. The controller can be used to make single output systems up to 8 phases. Current mode control uses the inductor DCR to minimize impacts on the efficiency. A current sense resistor could be used for improved accuracy. Additionally, the chip features a 700 mV-reference with better than 1% accuracy over temperature.

This circuit uses three TPS40180s to create a three-phase synchronous buck. A buck is typically used when the output voltage is always lower than the input voltage. Key considerations for this design are high output current and synchronized switching. The TPS40180 provides a CLKIO pin that can be connected between devices to create up to 8 phases that are optimally shifted. The converter in this case is 12 V to 1.8 V @ 60 A.

Web Links:

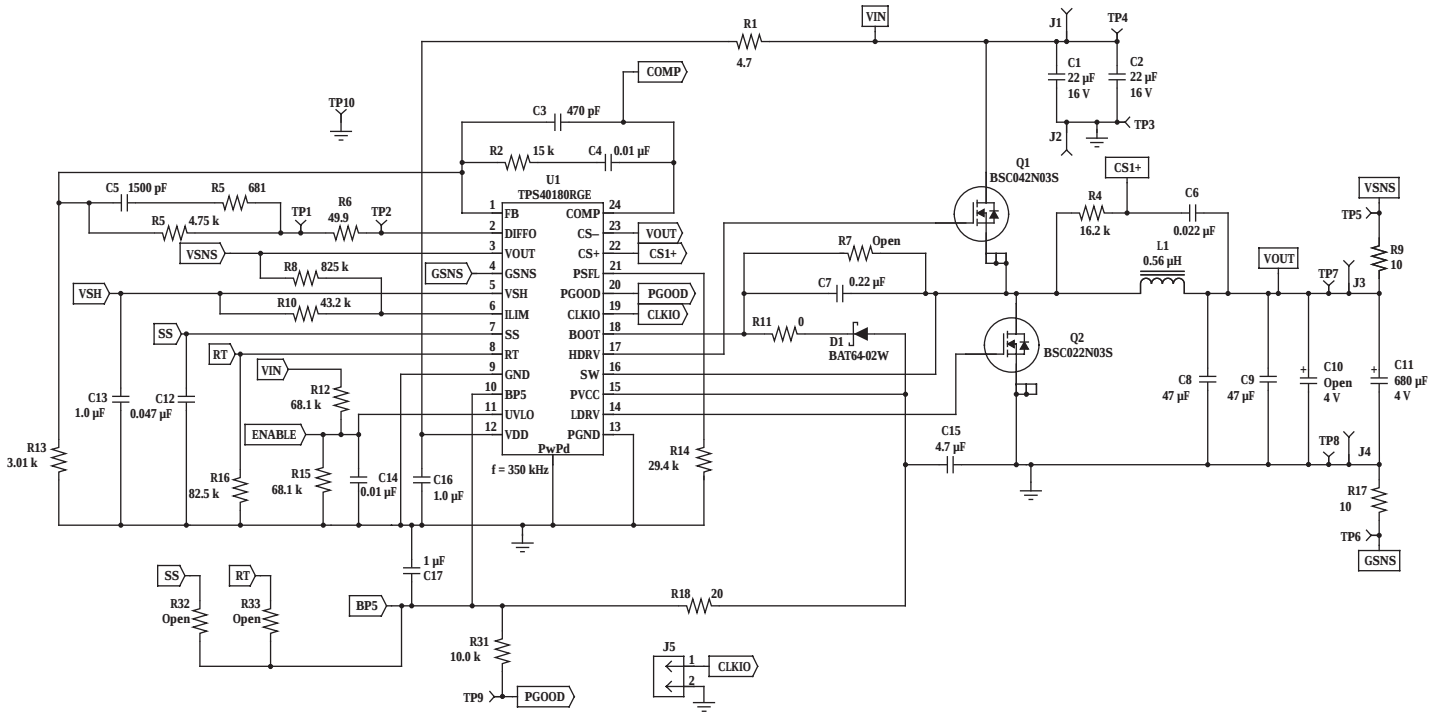
Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **TPS40180**

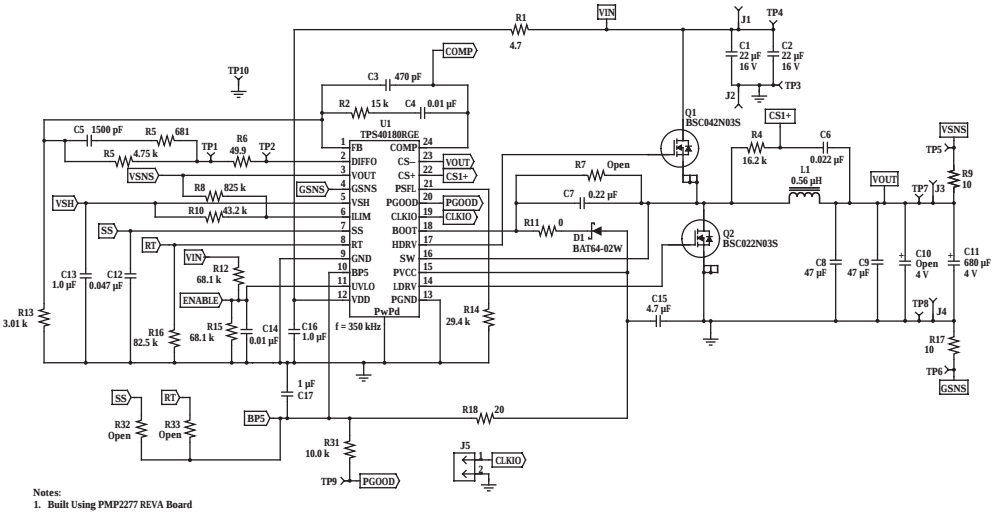
Specifications

Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		10.8	12	13.2	Volts
Output Voltage		1.75	1.8	1.85	Volts
Output Ripple				20	mV_{P-P}
Output Current		0		60	Amps
Switching Frequency			300		kHz/Phase

PMP2277 Master Phase Schematic

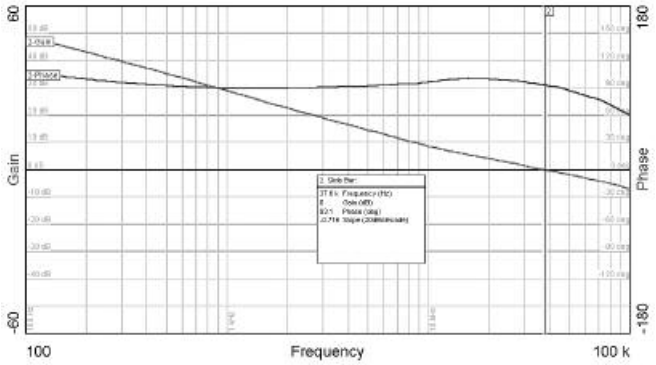


PMP2277 Slave Phase Schematic

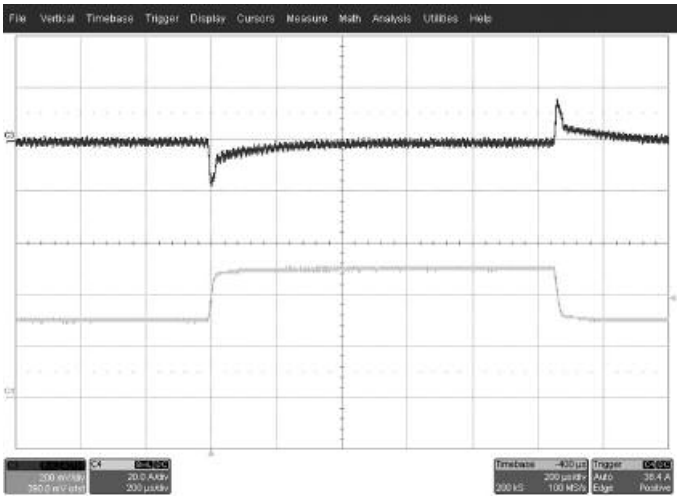


Notes:
1. Built Using PMP2277 REVA Board

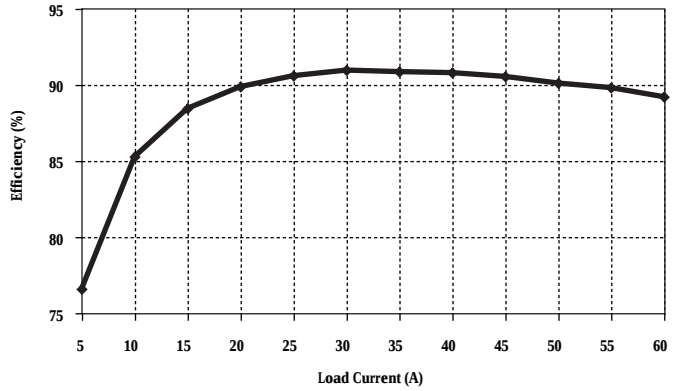
Control Loop (Gain and Phase), Cross Over 37 KHz



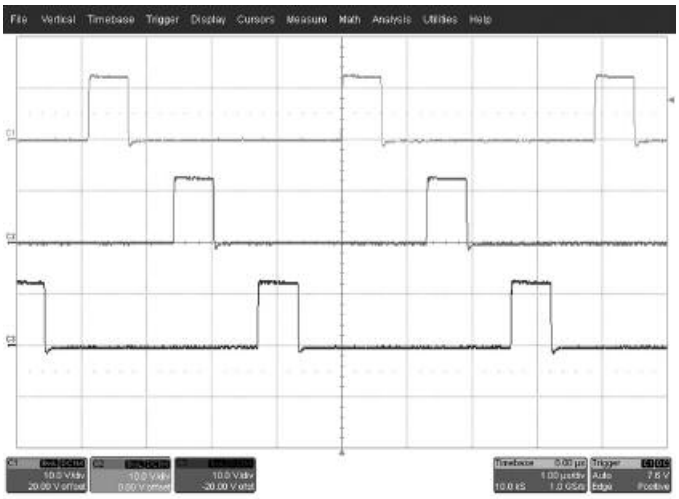
Transient Response



Efficiency vs. Load Current (12 VIN)



Switch Node



40-A Digital-Power Synchronous Buck Converter

Description

The UCD9112 is a dual-phase synchronous buck digital PWM controller designed for point-of-load power applications. This device integrates dedicated circuitry for DC/DC digital control loop with a microcontroller core, flash memory and a PMBus™ interface to support configurability, monitoring and management of a point of load. The UCD9112 evaluation module comes with the Fusion Digital Power™ Designer graphical user interface (GUI). This GUI allows the designer to configure the operating parameters and non-linear loop response of the power-supply controller. This configuration can then be stored to the devices on chip non-volatile memory.

The UCD7230 synchronous buck driver has been designed to work with the UCD9112 controller to provide a highly integrated digital power solution. In addition to 4-A output drive capability, the driver integrates current limit, short circuit protection as well as under-voltage lockout protection. The UCD7230 also has a 3.3-V, 10-mA linear regulator that provides the supply current for the controller.

Web Links:

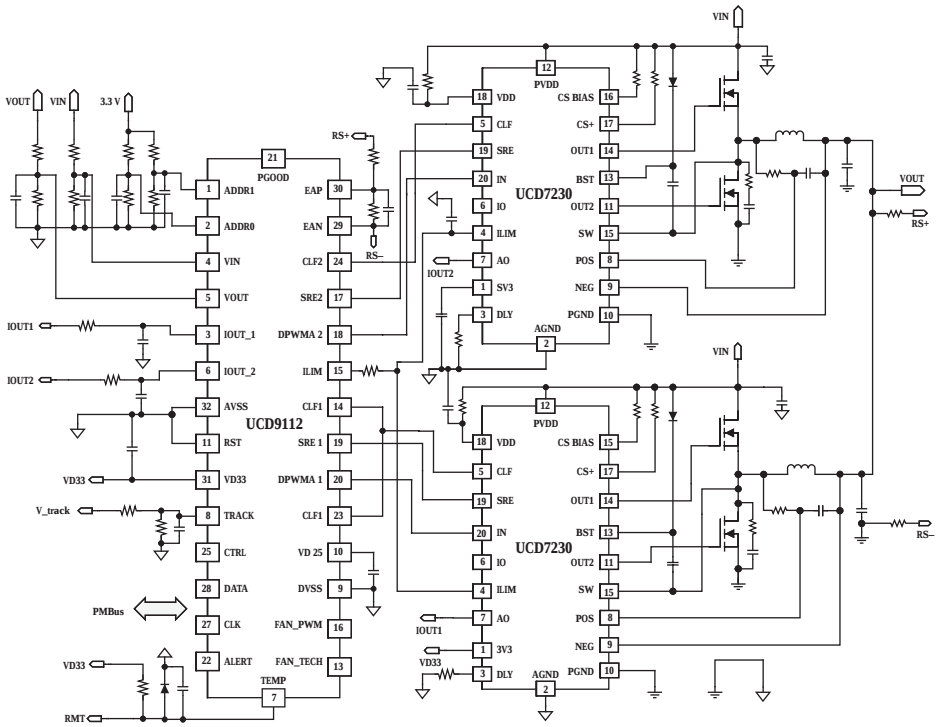
Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **UCD9112**

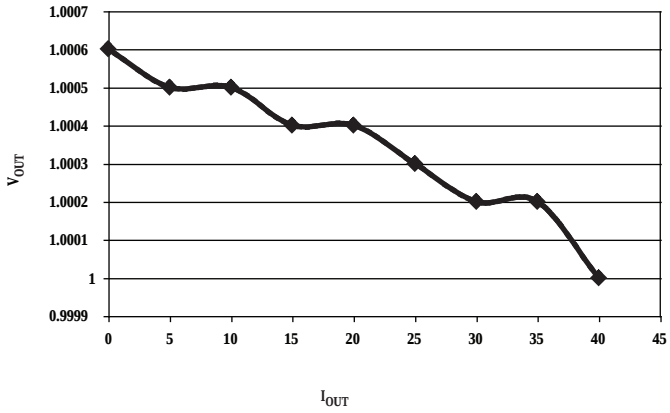
Specifications

Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage Range	I_{OUT} = 30 A, V_{OUT} = 1 V	5	12	14	Volts
Output Voltage Range	V_{IN} = 12 V, I_{OUT} = 20 A	0.4	1.0	4	Volts
Output Current	V_{IN} = 12 V, V_{OUT} = 1 V	0		40	Amps
Output Voltage Ripple	V_{IN} = 12 V, BW = 20 KHz, I_{OUT} = 30 A		±10		mV
Undershoot/Overshoot	V_{OUT} = 1 V, V_{IN} = 12 V, 50% Step Load		±30		mV
Load Regulation	V_{IN} = 12 V, V_{OUT} = 1 V, I_{OUT} from 0 A to 40 A		±5		mV
Efficiency	V_{IN} = 12 V, V_{OUT} = 1 V, I_{OUT} = 30 A, F_{SW} = 500 kHz		85		%

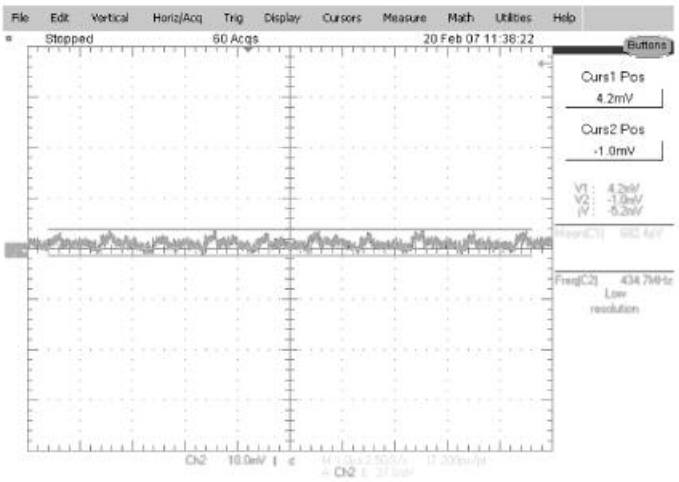
UCD9112EVM Schematic



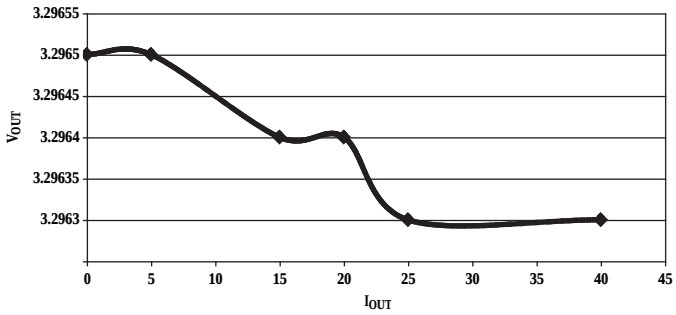
Load Regulation (V_{IN} = 12 V, Δ V = 1 mV)



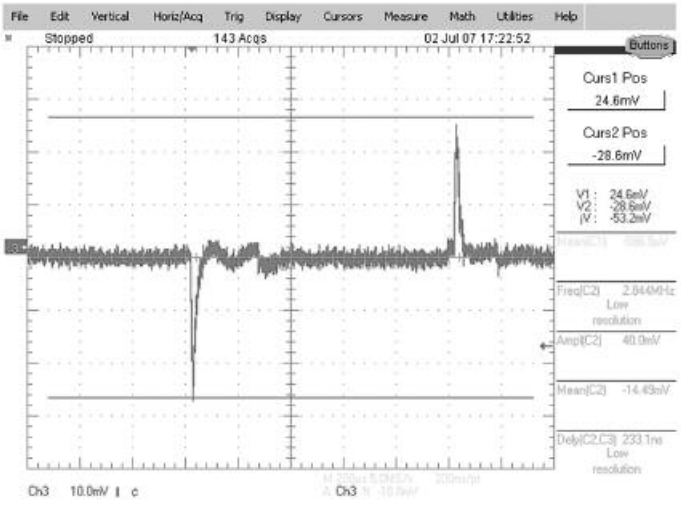
Output Voltage Ripple (V_{P-P} = 5.2 mV)



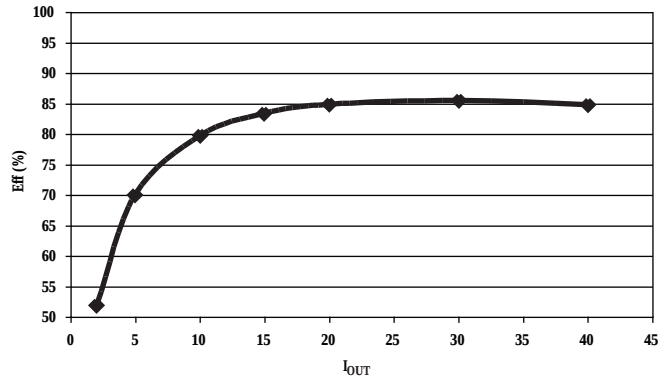
Load Regulation (V_{IN} = 12 V, V_{OUT} = 3.3 V, Δ V = 2 mV)



Load Transient (V_{P-P} = 53.2 mV @ 50% Step Load)



Efficiency vs. I_{OUT} (V_{OUT} = 1 V, V_{IN} = 10 V)



3-A, 600-kHz Dual Wide-Input Buck Converter

Description

The TPS54386 is a dual-output, non-synchronous buck converter capable of supporting 3-A output applications that operate from a 4.5-V to 28-V input supply voltage, and require output voltages between 0.8 V and 90% of the input voltage.

With an internally-determined operating frequency, soft start time, and control loop compensation, the converter provides many features with a minimum of external components. Channel 1 over-current protection is set at 4.5 A, while Channel 2 over-current protection level is selectable. The setting levels are used to allow for scaling of external components for applications that do not need the full load capability of both outputs.

The outputs may be enabled independently, or may be configured to allow either ratiometric or sequential startup sequencing. Additionally, the two outputs may be powered from different sources.

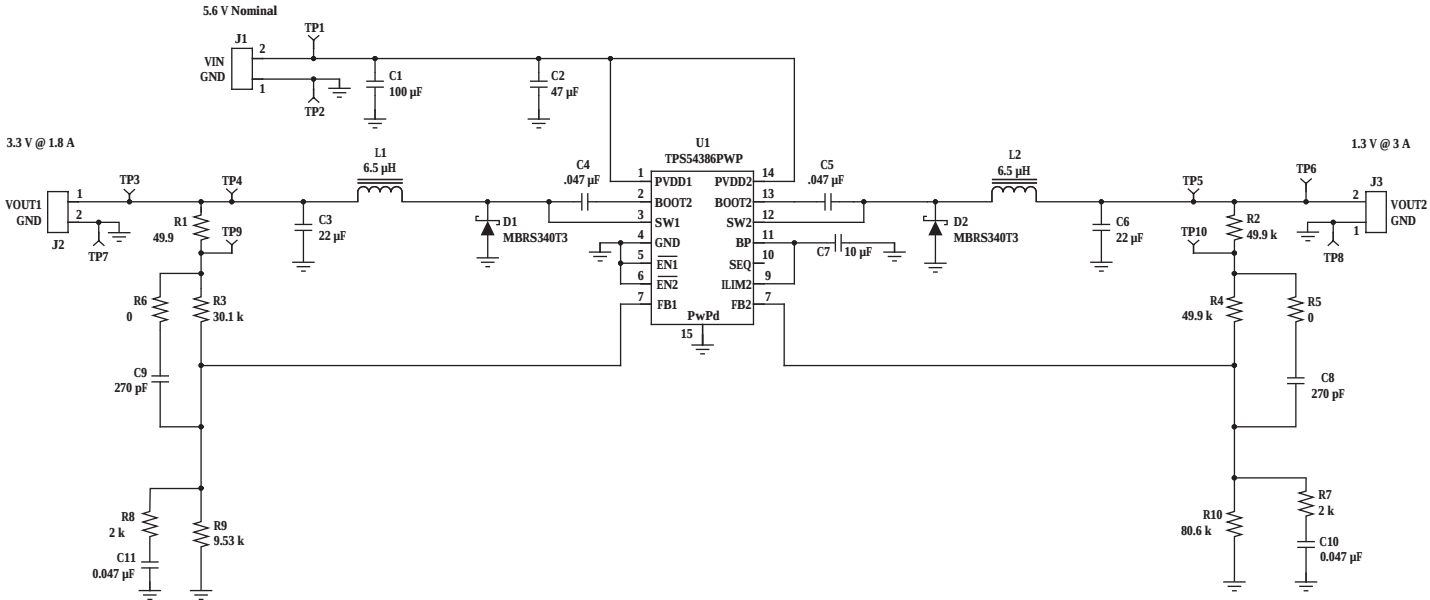
Web Links:

Reference Designs:
www.ti.com/powerreferencedesigns

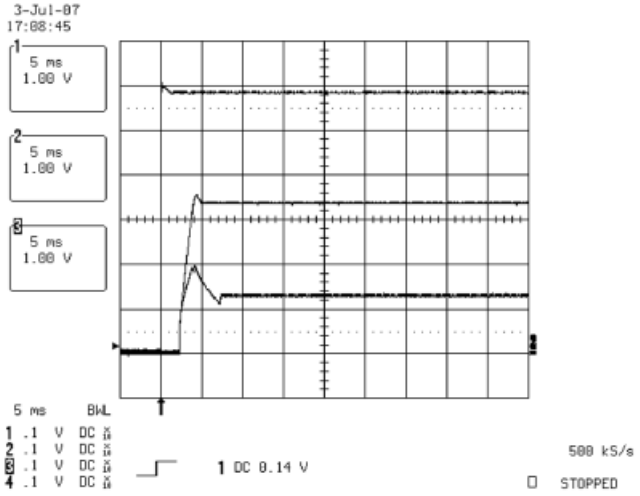
Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **TPS54386**

Specifications					
Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		5	5.6	6	Volts
Output 1 Voltage	$0 < I_{OUT}, < 1.8$ A	3.58	3.64	3.68	Volts
Output 2 Voltage	$0 < I_{OUT}, < 3$ A	1.303	1.305	1.307	Volts
Output 1 Ripple				12	mV_{P-P}
Output 2 Ripple				5	mV_{P-P}
Output Current		0		3	Amps
Switching Frequency			600		kHz
Efficiency	0.5 A $< I_{OUT} < 3$ A	80	85	87	%

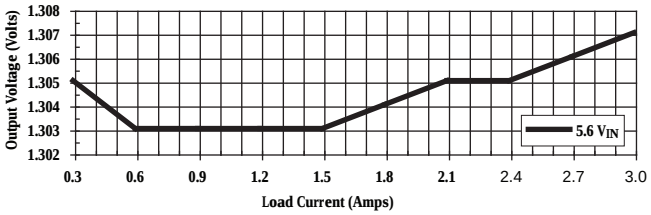
PMP2808 Schematic



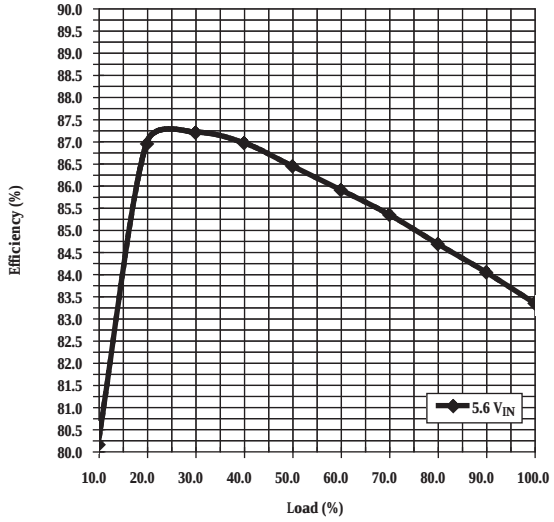
Startup (V_{IN} 5.6 V, with No Load On the Output)
Channel 1: V_{OUT}/ Channel 2: V_{IN}



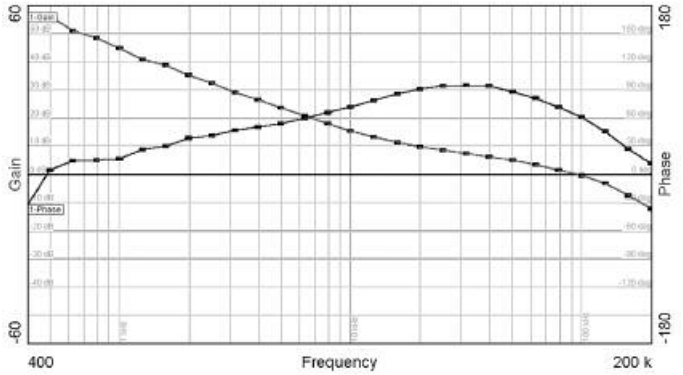
Load Regulation (1.3-VCD Output)



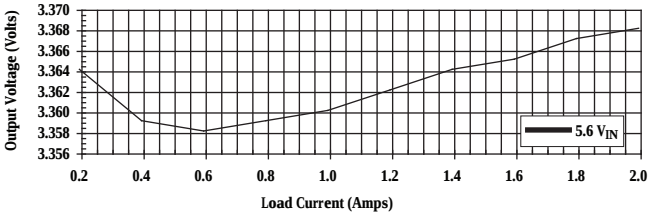
Efficiency (3.3 V_{OUT}/1.3 V_{OUT})



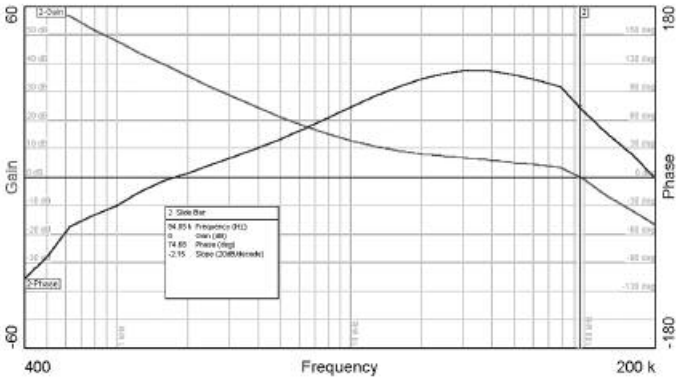
Loop Response (Gain and Phase), 90 KHz Cross Over (3.3 V Output with a 5.6 V Input and a 1.8 A Load)



Load Regulation (3.3-VCD Output)



Loop Response (Gain and Phase), 94° Cross Over, 1.3 V Output with a 5.6 V Input and a 3 A Load))



Buck Converter with Minimum Component Count to Drive LEDs

Description

The TPS40200 controller can be used as a low-cost LED driver. With an input voltage rating of 4.5 to 52 V, it can power LED strings with regulated current and up to a 45-V drop across the string. Current is sensed across a resistor between the cathode of the string and ground and is compared against a 696-mV reference to provide regulated current. Because the driver is a buck and not a boost or flyback, an open string will not produce voltages above the input voltage and over-voltage protection is not needed.

The driver can operate in either the continuous or discontinuous mode. For output voltages above 35 V, the discontinuous mode is needed due to duty cycle limitation above 35 V. The circuit shown has a pulse width modulator (PWM) input for dimming purposes. Targeted current can be set with jumpers.

Web Links:

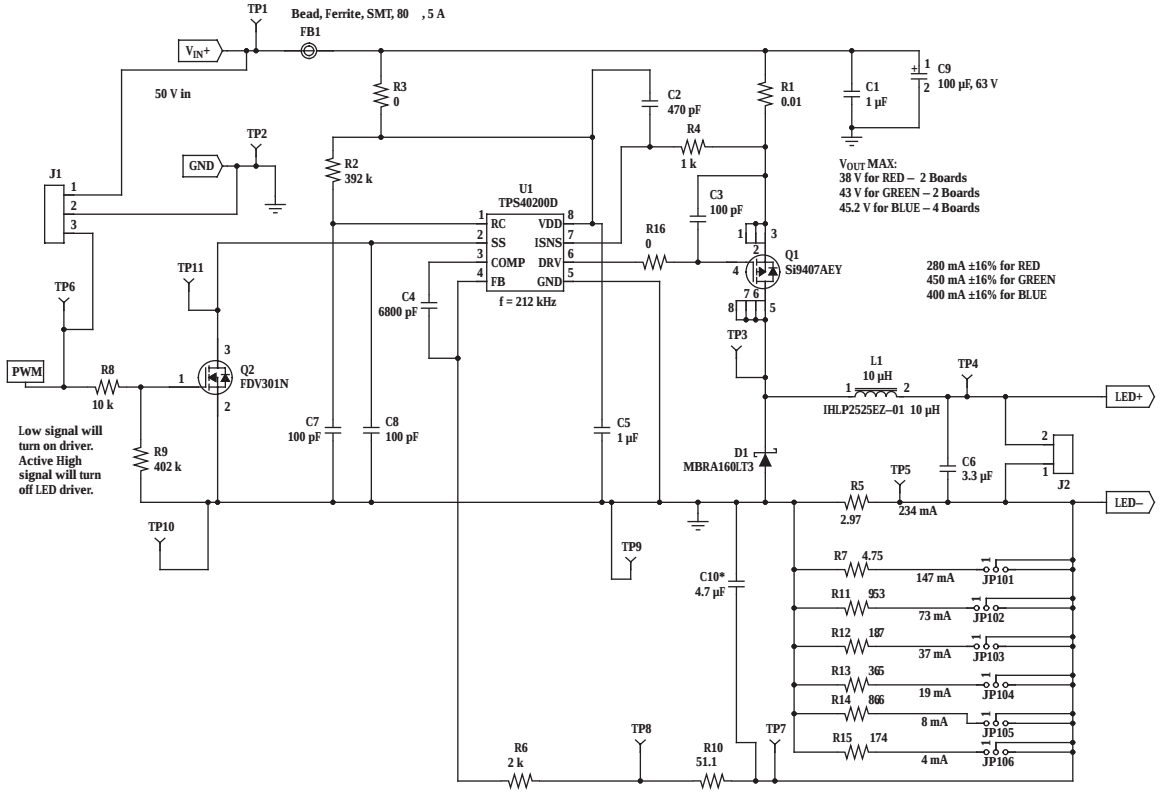
Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **TPS40200**

Specifications

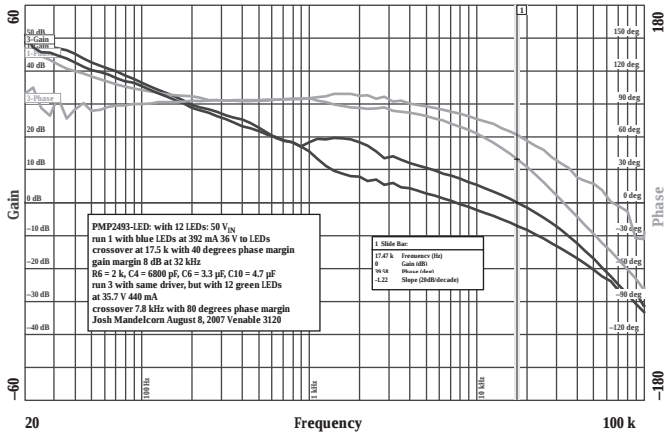
Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		48	50	52	Volts
Output Voltage	Targeted LED Current	20		45	Volts
Output Current		234		520	mA
Ripple Current			120		mA_{P-P}
Switching Frequency			210		kHz
Efficiency	Targeted LED Current		> 90		%
PWM Response Time			100		µs

PMP2493-LED Schematic

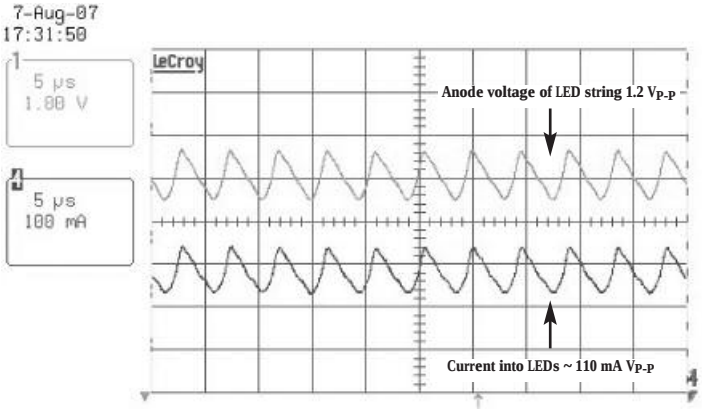


Buck Converter with Minimum Component Count to Drive LEDs

Control Loop (Gain and Phase), Cross Over = 7.9 KHz and 17.5 KHz

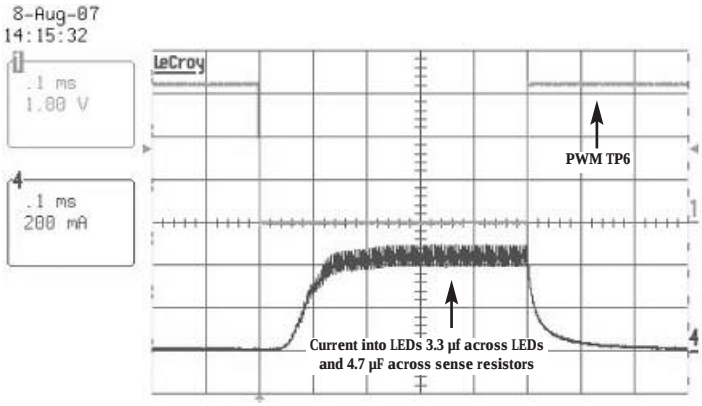


Ripple, LED 50 V_{IN} with actual LEDs: 12 Blue LEDs with 380 mA Average Current



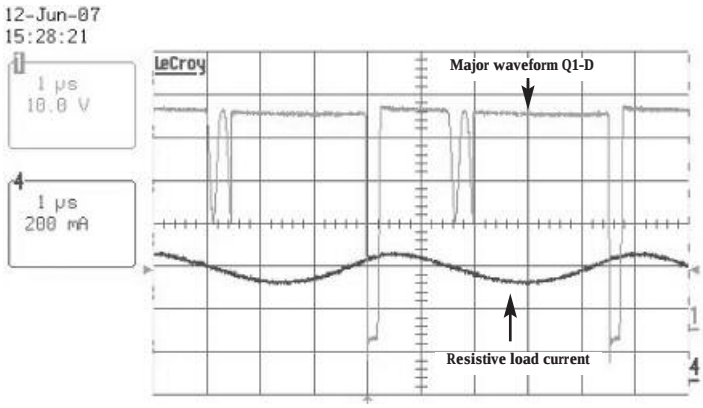
Note: 3.3 µF across LEDs and 4.7 µF across sense resistors C4 = 6800 pF

PWM Response, LED 50 V_{IN} with actual LEDs: 12 Green LEDs with ~ 430 mA



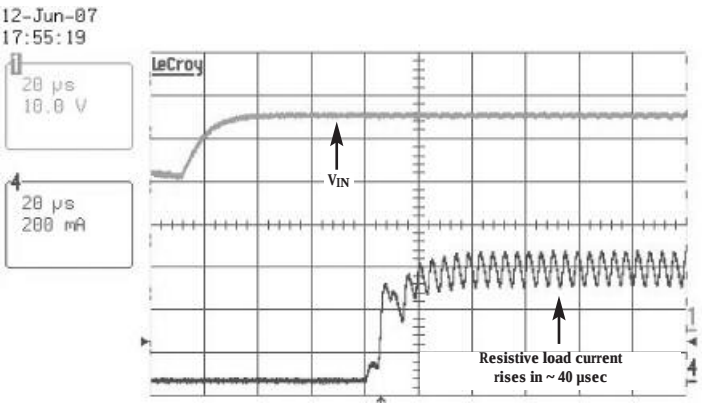
Note: C4 = 6800 pF, R6 = 2 k, C8 = 100 pF ~ 100 µsec turn on delay < 50 µsec turn off delay

Internal Waveform, 50V_{IN}, 506 mA_{OUT}, 94% Efficiency



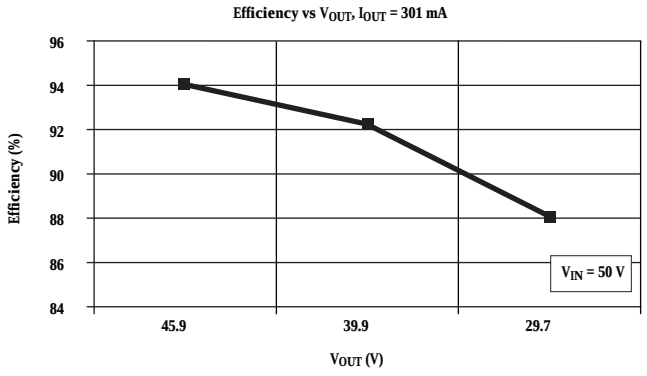
Note: Discontinuous mode

Startup, 50 V_{IN} 407 mA_{IN}, 35.3 V_{OUT} 520 mA_{OUT}



Note 90% efficiency Startup V_{IN} applied

Efficiency Graph



Boost Converter Provides 22 V_{OUT} at 1 A from 15-V Bus

Description

The TPS40210 controller can be used for boost, SEPIC and flyback configurations as it can drive a low side N-channel MOSFET. With an input voltage rating of 4.5 to 52 V, it will find many applications in 5, 12 and 24 V systems. Current mode control with a 150-mV sense voltage provides good dynamic line response with minimal efficiency impact. Over-current protection is by hiccup with automatic restart. Additionally, the chip features a 700-mV reference with 2% accuracy over temperature.

This circuit uses the TPS40210 in the boost configuration. A boost is typically used when the output voltage is always higher than the input voltage. In considering the boost, the designer most also consider the ramifications of a short on the output of the power supply as there is a direct path from the input source through the boost inductor and diode. The boost can not provide short circuit protection by itself.

Web Links:

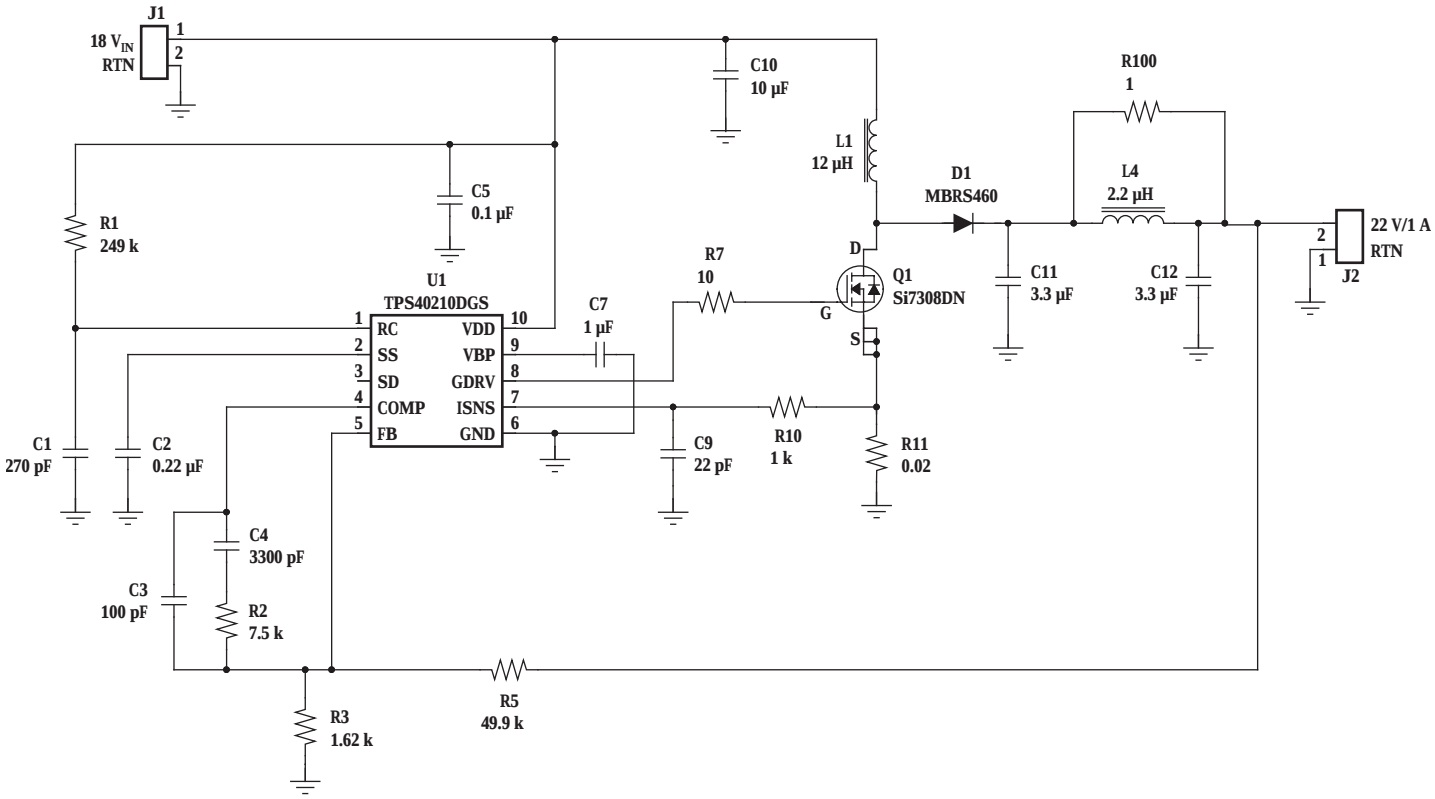
Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **TPS40210**

Specifications

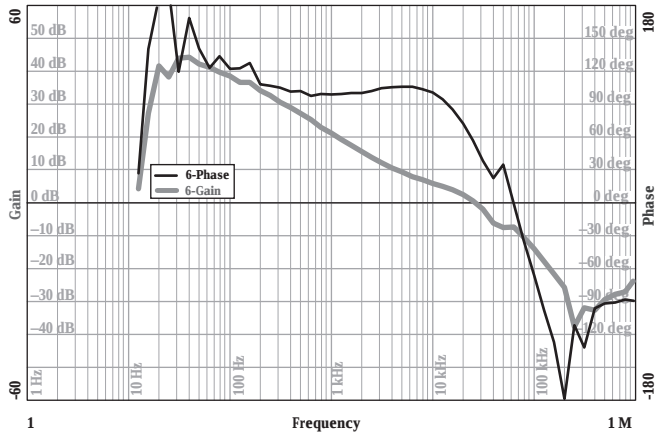
Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		10	15	18	Volts
Output Voltage	0 < I_{OUT}, < 1 A	21, 25	22	22.75	Volts
Output Ripple				200	mV_{P-P}
Output Current		0		1	Amps
Switching Frequency			250		kHz
Efficiency	0.1 A < I_{OUT}, < 1 A	90			%

PMP2942 Schematic

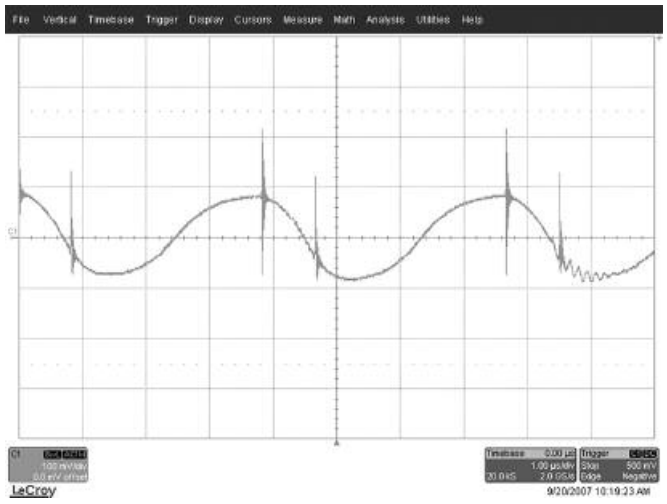


Boost Converter Provides 22 V_{OUT} at 1 A from 15-V Bus

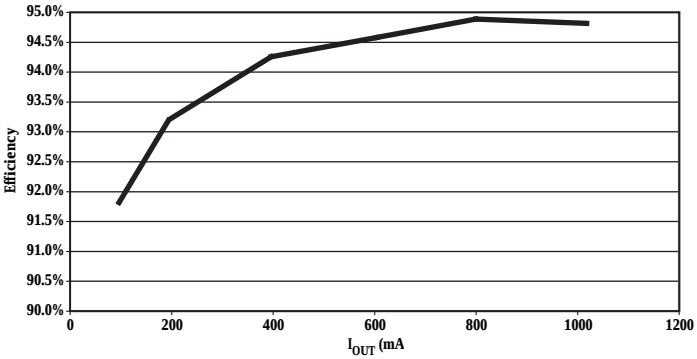
Control Loop (Gain and Phase), 30 KHz Cross Over, 45° Phase Margin



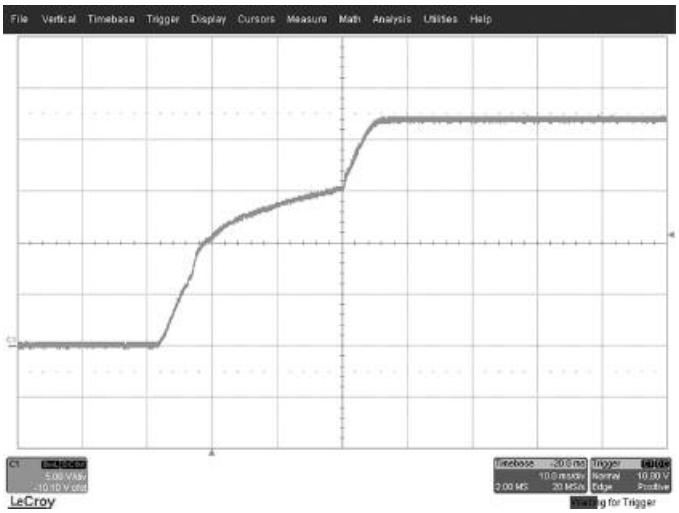
Output Ripple Voltage, Vertical: 100 mV/DIV, Horizontal: 1us/DIV



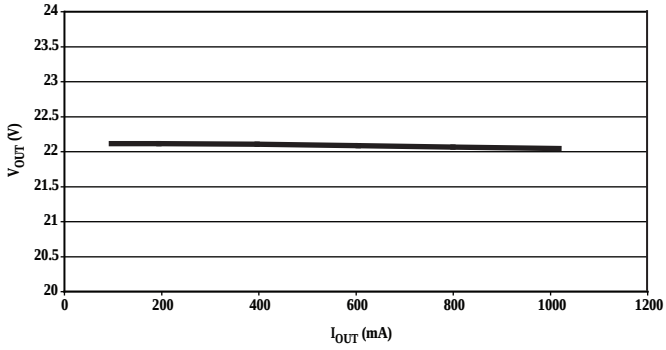
Efficiency



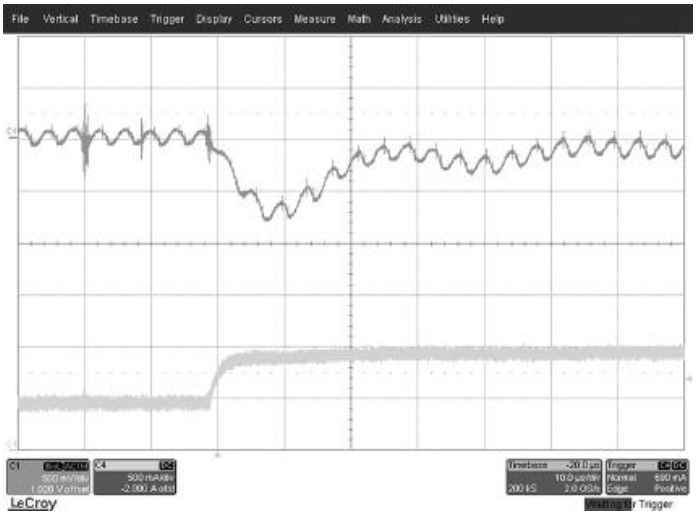
Startup Vertical: 5 V/DIV, Horizontal: 10 ms/DIV



Regulation



Transient Load Response, Upper Vertical: 500 mV/DIV, Lower Vertical: 0.5 A/DIV, Horizontal: 10 µs/DIV



Small Boost Converter for Ultra-Low Input Voltage Battery Applications

Description

The TPS61200 step-up converter is ideal for small-size, ultra-low input voltage applications. With an input voltage range of 0.3 to 5.5 V, it will work in many applications operating from 1-AA, 2-AA and Li-Ion battery inputs. Additionally, the TPS61200 starts up into a full load from inputs as low as 0.5 V. This low input voltage allows the TPS61200 to be used in "energy harvesting" applications such as single solar cells (0.5 V) and fuel cells (0.6 V). Average current mode control and internal compensations significantly simplify design and provide good dynamic line and load response with efficiency up to 90%. The load-disconnect during shutdown allows for current limiting. During an over-current event, the output is disconnected from the input, eliminating the DC conduction path that exists in typical boost converters circuits.

This circuit uses the TPS61200 in a 1-AA application. It produces a 3.3-V output over the entire 1-AA range and supplies 100-mA loads with input voltages between 0.9 V and 1.5 V. Additionally, the UVLO circuit halts operation when the input falls to 0.9 V to prevent damage to the input source. Power save mode is enabled for the highest efficiency for this battery-powered application.

Web Links:

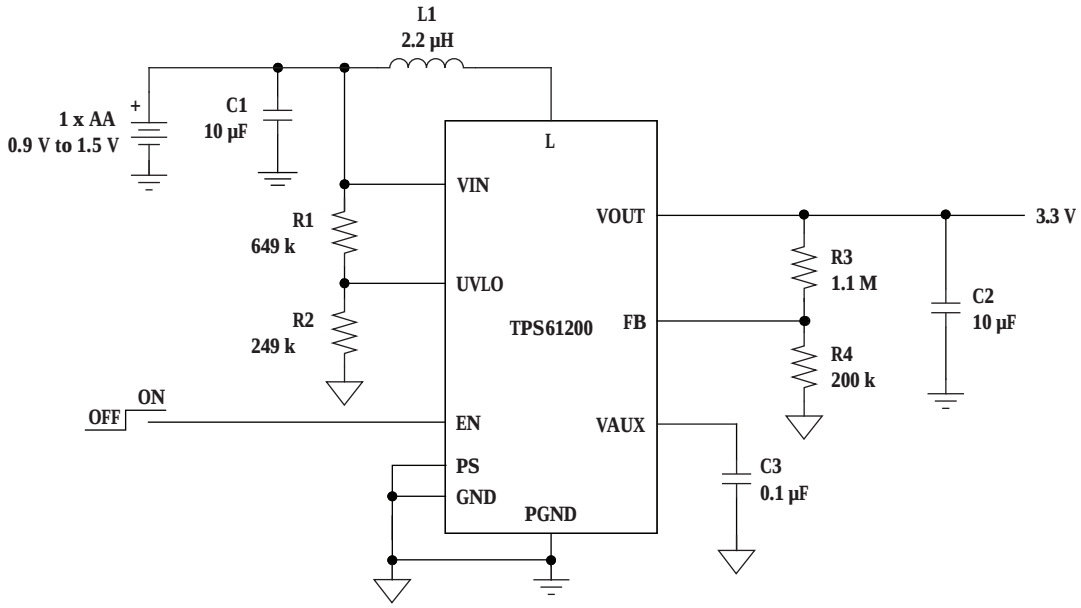
Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **TPS61200**

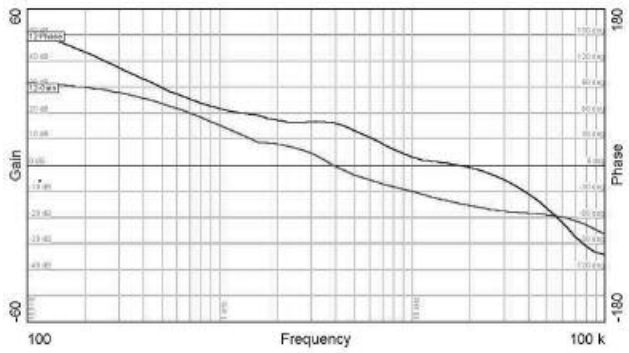
Specifications

Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		0.9	1	1.5	Volts
Output Voltage	$0 < I_{OUT}, < 100$ mA	3.27	3.30	3.33	Volts
Output Ripple				40	mV_{P-P}
Output Current		0		100	mAmp
Switching Frequency		1.25	1.50	1.65	MHz

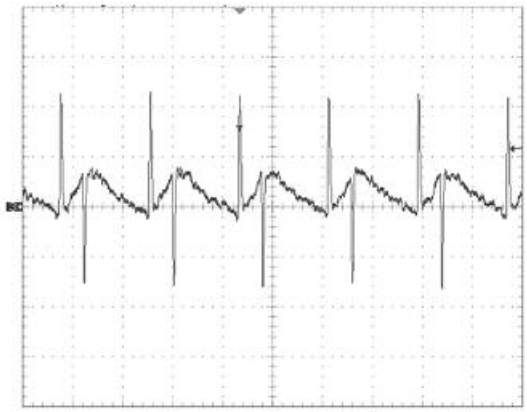
TPS61200 Reference Design Schematic



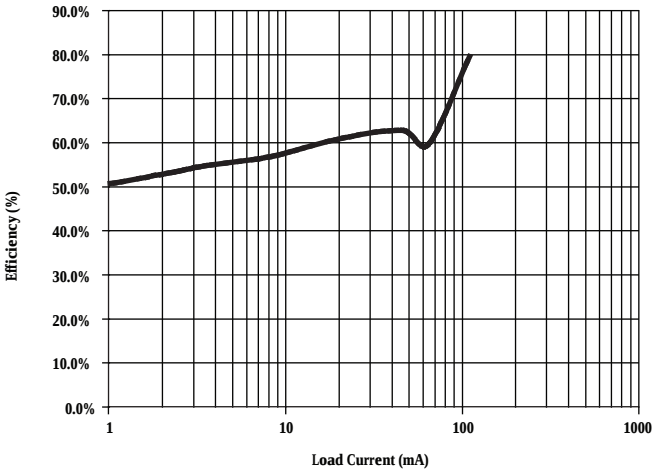
Control Loop (Gain and Phase), 4 KHz Cross Over, 45° Phase



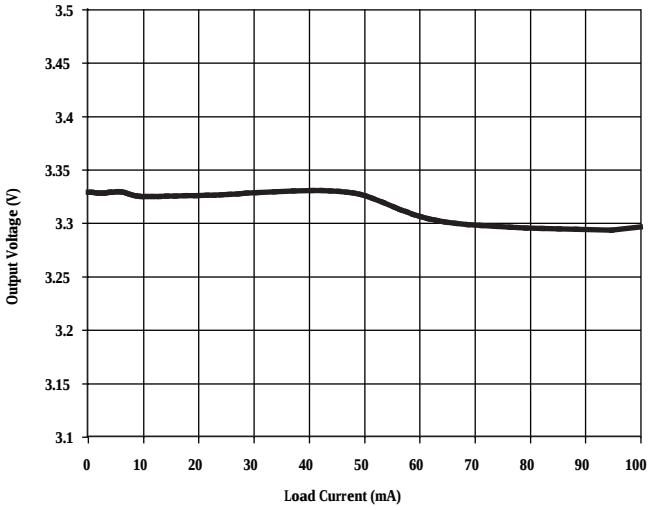
Output Ripple Voltage, I Load = 100 mA 10 mV/DIV



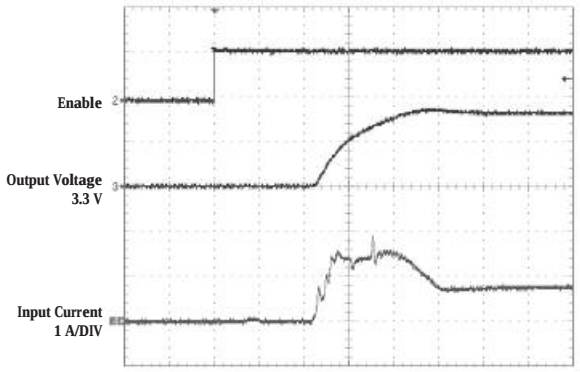
Efficiency vs. Load Current (V_{IN} = 1 V)



Output Voltage vs. Load Current (V_{IN} = 1 V)



Startup Waveforms



Load Transient

Fixed-Frequency Boost Converter with Multiple Protection Features

Description

The TPS61080/1 is a 1.2-MHz/600-kHz fixed-frequency boost regulator that integrates a power switch, an input/output isolation switch and a power diode. When a short-circuit condition is detected, the isolation switch opens up to disconnect the output from the input. As a result, the IC protects itself and the input source from any pin, except V_{IN}, from being shorted to ground. The isolation switch also disconnects the output from input during shutdown to prevent any leakage current. Other provisions for protection include 0.5-A/1.3-A peak-to-peak over-current protection, programmable soft start (SS), over-voltage protection (OVP), thermal shutdown and under-voltage lockout (UVLO).

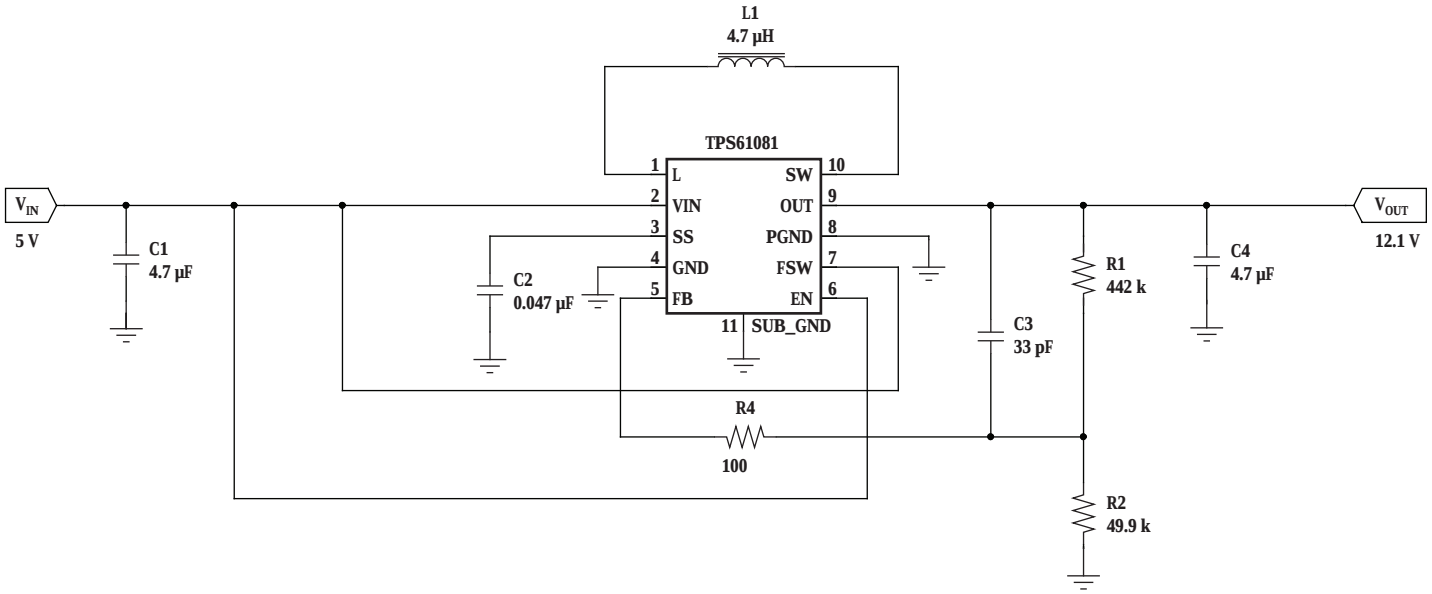
Web Links:

Reference Designs:
www.ti.com/powerreferencedesigns

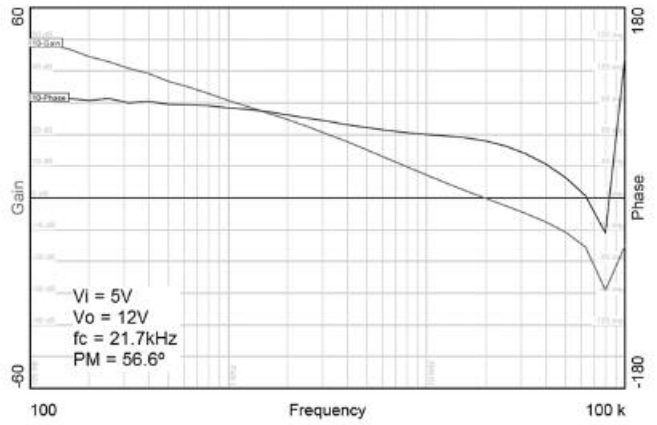
Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **TPS61080 and TPS61081**

Specifications					
Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		2.5 V	5	6.0	Volts
Output Voltage	V_{IN} = 5 V, 1 mA < I_{OUT} < 0.4 A		12.1		Volts
Output Ripple				10	mV_{P-P}
Output Current	V_{IN} = 5 V	1.0		440	mA
Switching Frequency			1.2	1.5	MHz
Efficiency	V_{IN} = 5 V, I_{OUT} = 100 mA		85		%

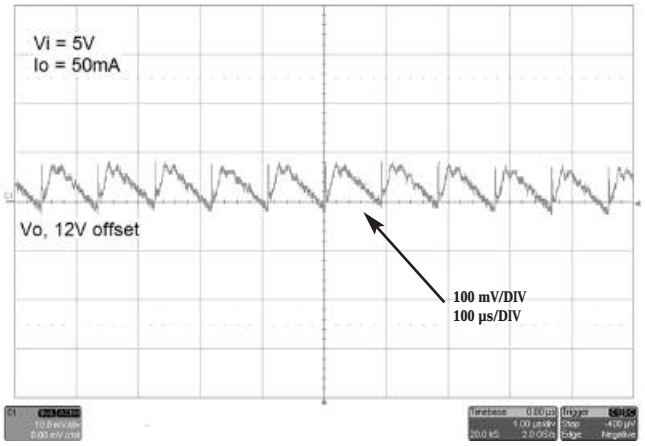
TPS61081EVM-147 Schematic



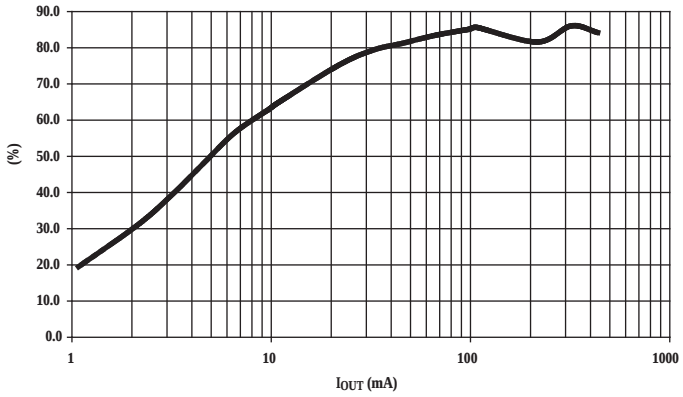
Control Loop (Gain and Phase), Cross Over 21.7 KHz, V_{IN} = 5 V, I_O = 100 mA



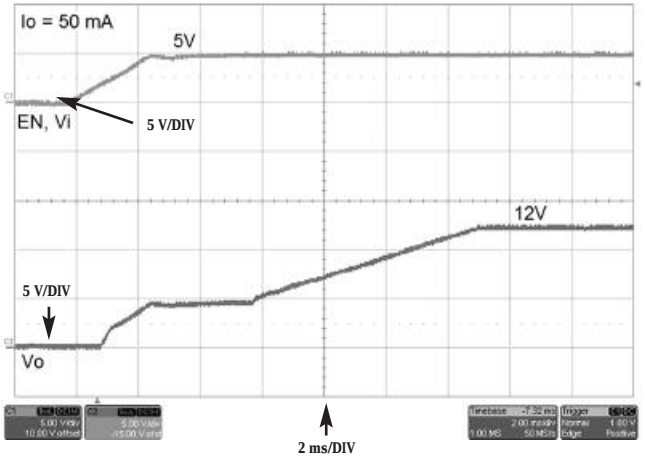
Output Ripple Voltage with I_O = 50 mA, V_{IN} = 5V



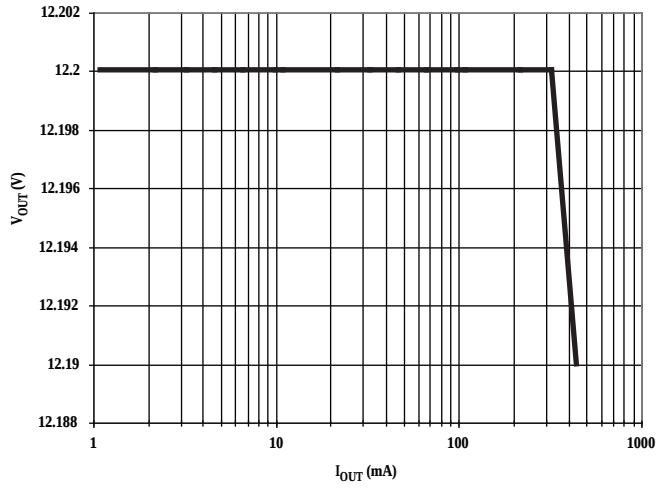
Efficiency with V_{IN} = 5 V and L1= VLCF502UT-4R7N1e7-1 (L1 is the inductor)



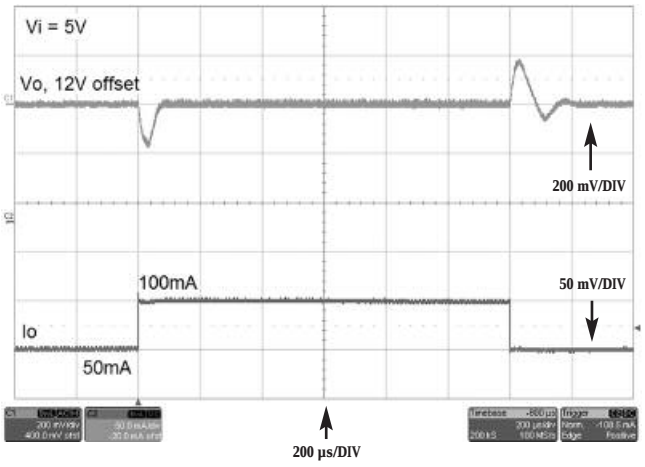
Startup Response with I_O = 50 mA, V_{IN} = 5V



Load Regulation with V_{IN} = 5 V



Load Transient Response with V_{IN} = 5 V



Battery Powered Buck-Boost Converter Regulates the Current in White LEDs

Description

The TPS63000 is a single-inductor (non-inverting) buck-boost converter with 1.8-A internal switches. It can be powered from either a two-cell or three-cell alkaline, NiCd or NiMH battery, or a one-cell Li-Ion or Li-polymer battery. Output currents can go as high as 1200 mA while using a single-cell Li-Ion or Li-polymer battery, and discharge it down to 2.5 V or lower. The buck-boost is based on a fixed-frequency, pulse-width-modulation (PWM) controller using synchronous rectification to obtain maximum efficiency. At low load currents, the converter enters Power Save mode to maintain high efficiency over a wide load current range. The Power Save mode can be disabled, forcing the converter to operate at a fixed switching frequency. The maximum average current in the switches is limited to a typical value of 1800 mA. The output voltage is programmable using an external resistor divider, or is fixed internally on the chip. The converter can be disabled to minimize battery drain. During shutdown, the load is disconnected from the battery.

This circuit uses the TPS63000 to regulate the current in a white LED to either of two fixed current levels, selectable by switch S2. When S2 is closed, the LED current is regulated to 0.7 A and when open the current is 0.35-A. D2 provides a 2.048-V reference voltage to lower the current sense resistor dc operating point. R2 sets a fixed current between the 2.048-V reference voltage and the 0.5-V FB pin voltage. This current must flow through R5, R6 and R3/R4 to ground. The voltage drop across R5 and R6 subtracts from the fixed regulation voltage at the FB pin, effectively lowering the dc regulation voltage across current sense resistors R3/R4. The current sense voltage across R3/R4 will be regulated to 0.106 V, which is much less than the FB voltage of 0.5 V. This reduces power dissipation and greatly improves efficiency.

Web Links:

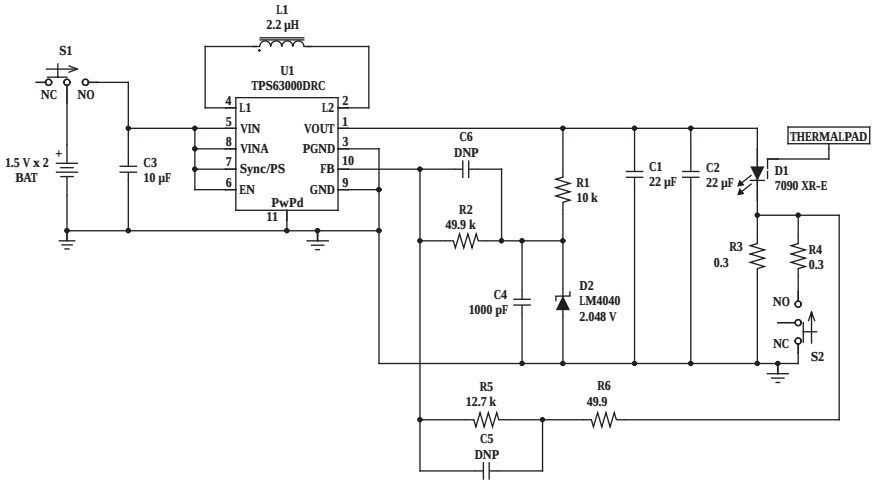
Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **TPS63000**

Specifications

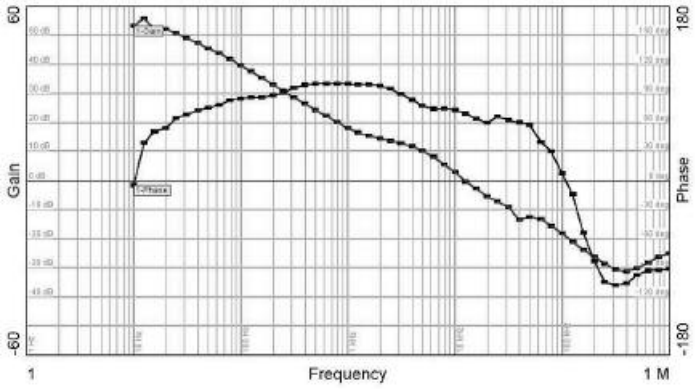
Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		2.0	3.0	4.5	Volts
Output Current	S2 Closed	0.56	0.70	0.83	Amps
Output Current	S2 Open	0.28	0.35	0.42	Amps
Switching Frequency		1.25	1.375	1.5	MHz
Efficiency	V_{IN} = 3 V				
	I_{OUT} = 0.35 A		91		%

PMP2809 REVA Schematic

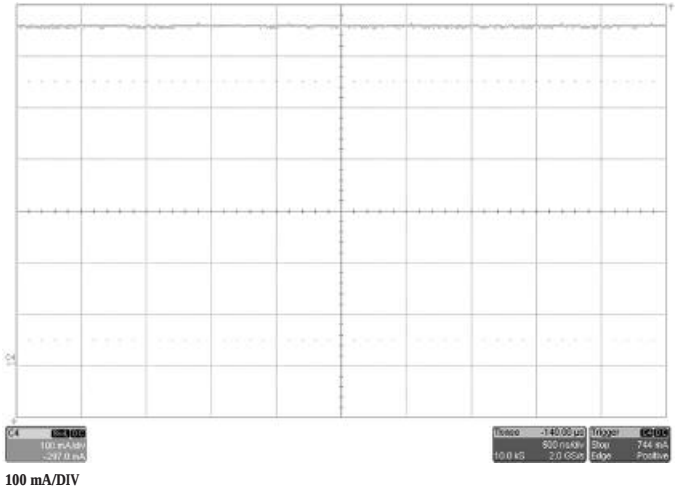


Battery Powered Buck-Boost Converter Regulates the Current in White LEDs

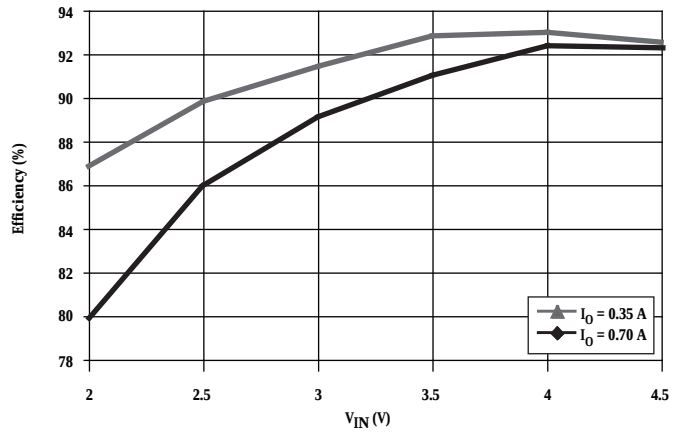
Control Loop (Gain and 67° Phase) (I_O = 0.35 A) Cross Over 12 KHz



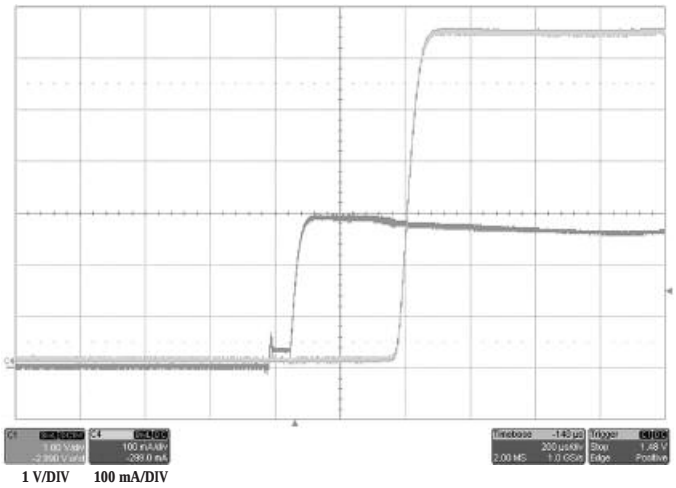
LED Ripple Current (V_{IN} = 4 V)



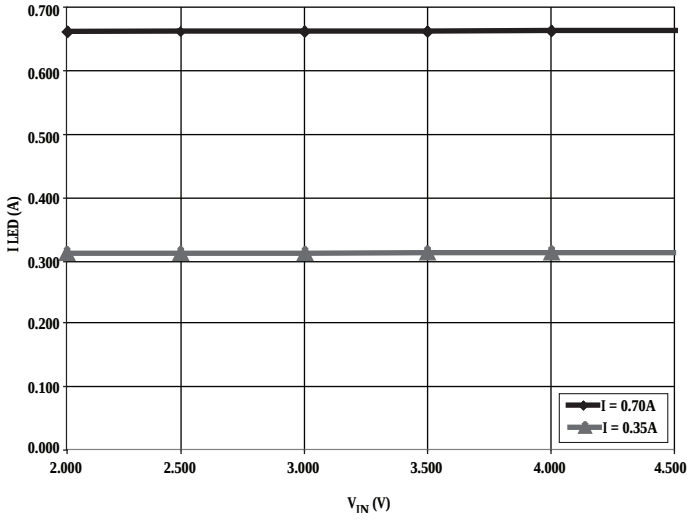
Efficiency



Output Current Turn On Response (V_{IN} vs LED Current, I_O = 0.7 A)



LED Current Regulation vs Input Voltage



Synchronous Buck Controller Doubles as a 2-A Buck Boost Inverter

Description

The TPS54550 is a medium output current synchronous buck PWM converter with an integrated high-side MOSFET and a gate driver for a low-side external MOSFET. Features include a high-performance voltage error amplifier that enables maximum performance under transient conditions and flexibility in choosing the output filter inductors and capacitors. The TPS54550 has an under-voltage lockout circuit to prevent start-up until the input voltage reaches 4.5 V; a slow-start circuit to limit in-rush currents; and a power good output to indicate valid output conditions. The synchronization feature is configurable as either an input or an output for easy 180° out-of-phase synchronization.

This circuit uses the TPS54550 in a buck-boost configuration. A buck-boost (often called a negative flyback) provides a negative output voltage. During the on-time of the internal top FET, the input voltage is applied across the inductor. When the top FET turns off and the bottom FET on, the inductor's voltage reverses, which pulls the output voltage negative. The sum of the input and output voltage is applied across the control circuit's V_{IN} to GND pins since it is referenced to the negative output voltage rail. Care must be taken not to exceed the maximum V_{IN} rating. This circuit operates at approximately 50% duty cycle.

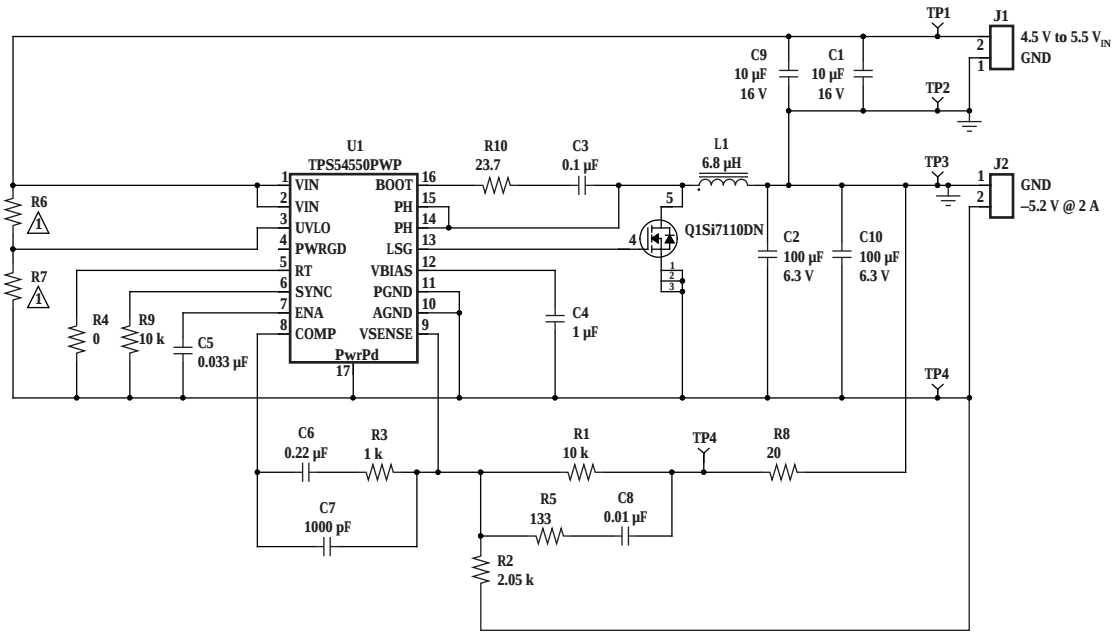
Web Links:

Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **TPS54550**

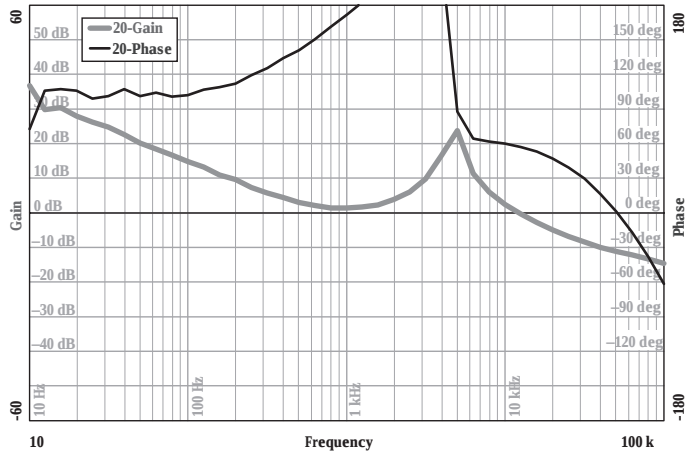
Specifications					
Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		4.5	5	5.5	Volts
Output Voltage	$0 < I_{OUT} < 2$ A	–5.356	–5.2	–5.044	Volts
Output Ripple			50	75	mV_{P-P}
Output Current		0		2	Amps
Switching Frequency			250		kHz
Efficiency	$0.5 \text{ A} < I_{OUT} < 2$ A	88			%

PMP2933 Schematic

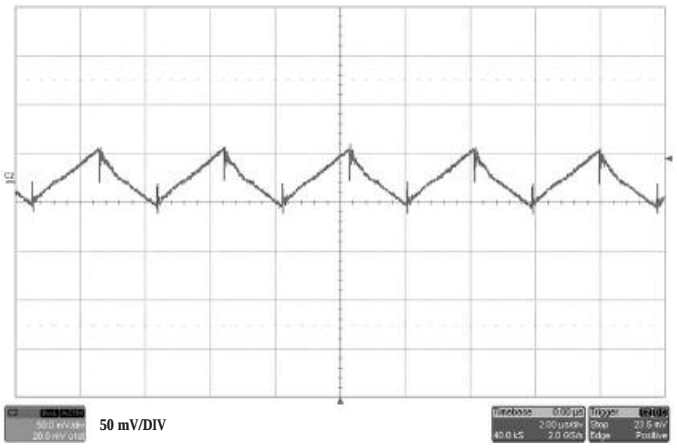


Synchronous Buck Controller Doubles as a 2-A Buck Boost Inverter

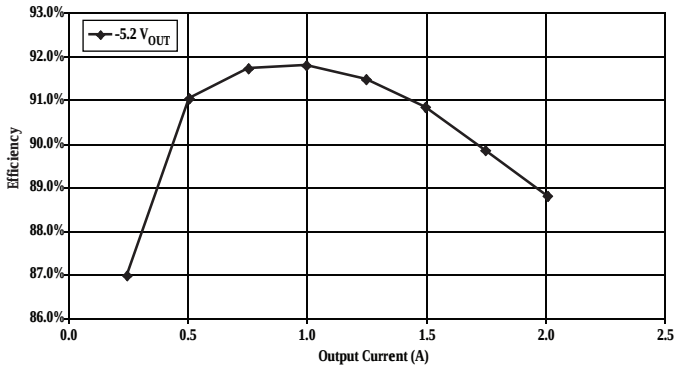
Control Loop (Gain and 55° Phase) Cross Over 12 KHz



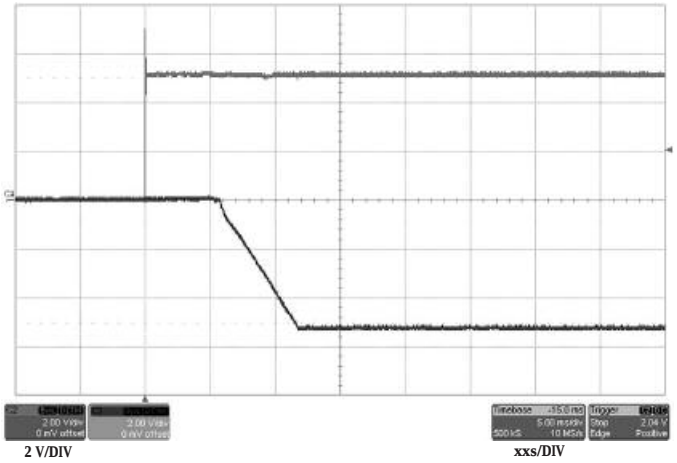
Output Ripple Voltage



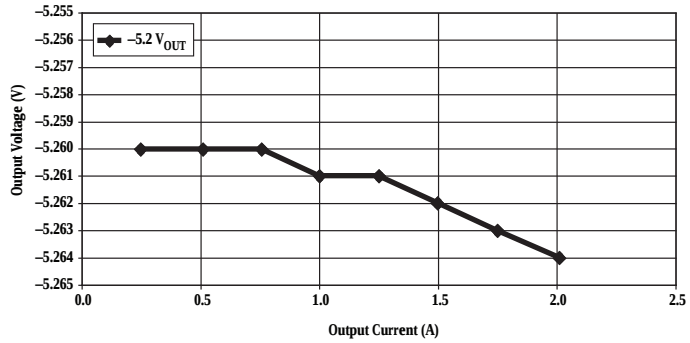
Efficiency



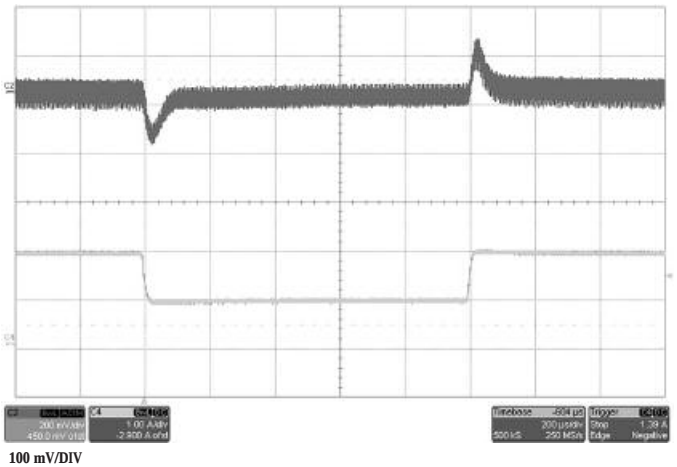
Output Voltage Turn On Response (V_{IN} vs V_{OUT})



Output Voltage Load Regulation (V_{IN} = 5 V)



Load Step (V_{OUT} vs I_{OUT})



Inverting Buck Boost Provides –5 V at 2.25 A from a 12-V or 15-V Bus

Description

The wide input voltage range SWIFT™ DC/DC converters are typically used as step- down converters where the derived output is a positive voltage less than the input voltage source. In some cases it may be required to generate a negative voltage from the input voltage source. In such instances it is possible to configure the TPS5430/20/10 devices in an inverting buck-boost topology, where the output voltage is negative with respect to ground.

In this design, the TPS5430 is designed as an inverting buck-boost converter with a 15-V input voltage and a –5-V output voltage. To implement the buck-boost topology, the ground pin of the device is now the output while what would normally be the output is ground. The TPS5430 is nominally rated for 3-A continuous output. However, when used as a buck-boost converter, the output current must be derated by a factor of 1-D. The duty cycle is given by $D = V_{OUT} / (V_{OUT} - V_{IN})$. For this design the duty cycle is .25 and the maximum output current is 2.25 A. The TPS5430 is an internally compensated, voltage mode control device. It includes a precision 1.221 V reference voltage, over-current and over-voltage protection.

Web Links:

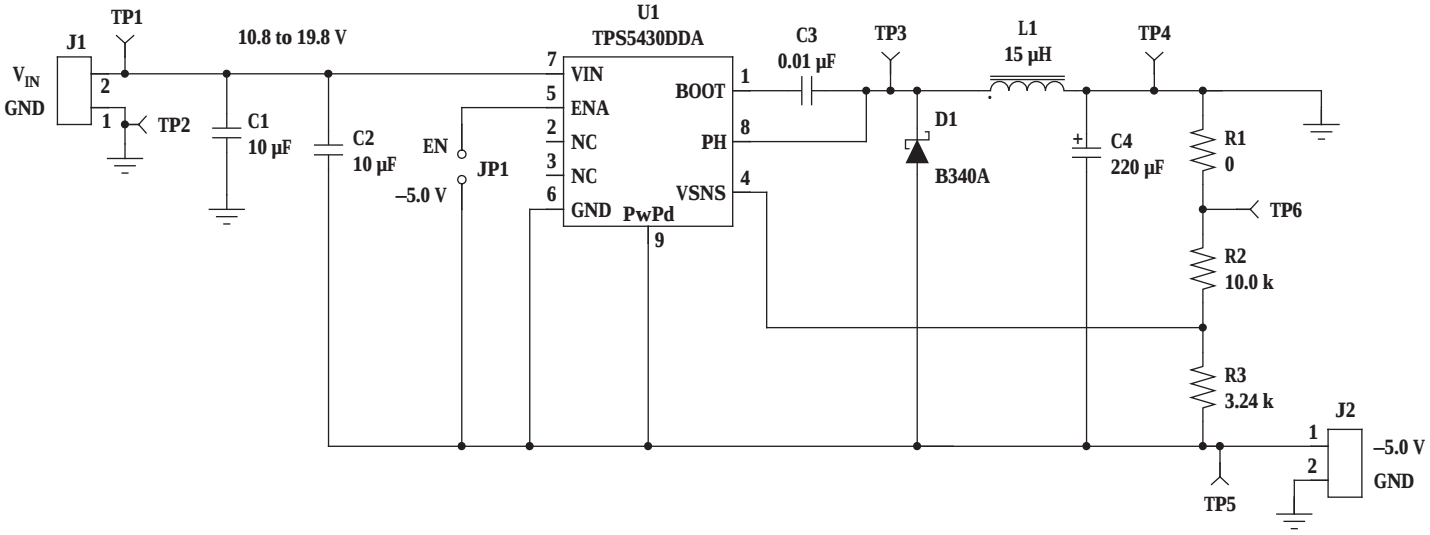
Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **TPS5430**

Specifications

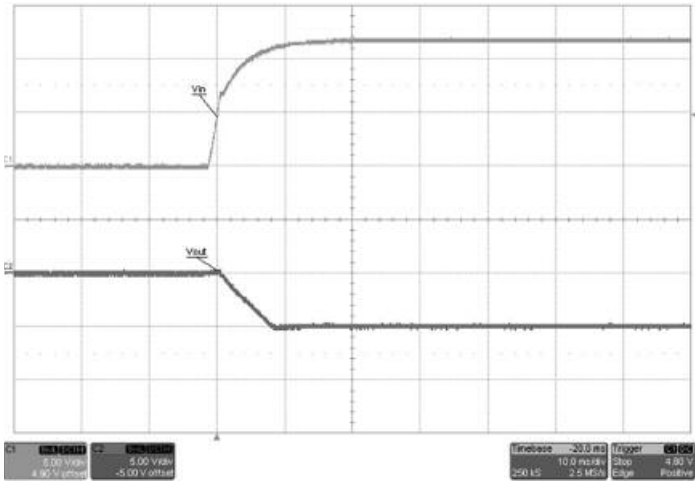
Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		10.8	12 or 15	19.8	Volts
Output Voltage	$0 < I_{OUT}, < 2.25$ A	–5.15	–5	–4.85	Volts
Output Ripple			200		mV_{P-P}
Output Current		0		2.25	Amps
Switching Frequency			500		kHz
Efficiency	$0.2A < I_{OUT}, < 2.25$ A			87	%

PR705 Schematic

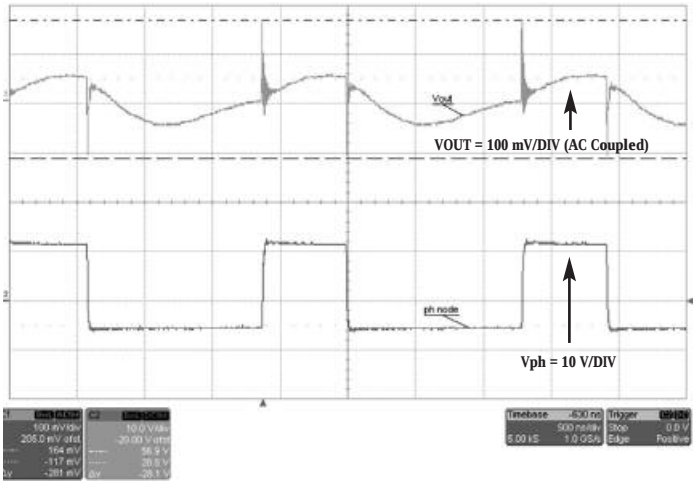


Inverting Buck Boost Provides –5 V at 2.25 A from a 12-V or 15-V Bus

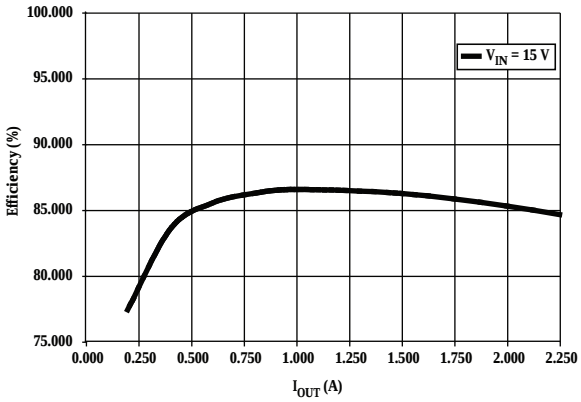
Startup Wave Form, V_{IN} = 0 to 12 V Step at No Load



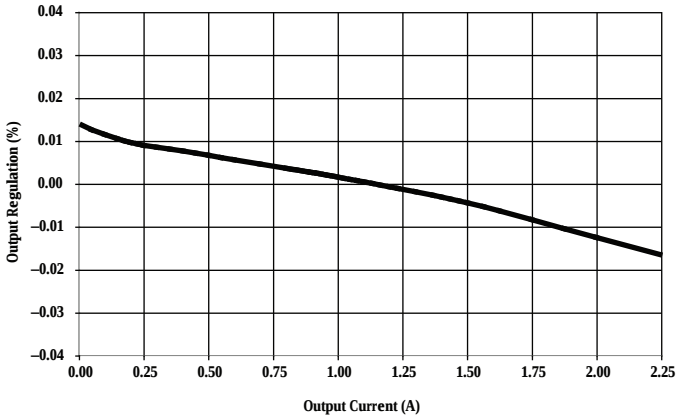
Output Ripple Voltage, I_{OUT} = 2 A, V_{IN} = 12 V



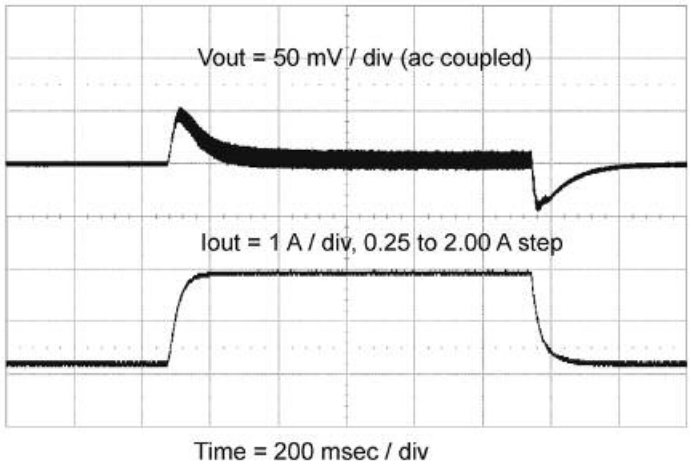
Efficiency vs Output Current, V_{IN} = 15 V



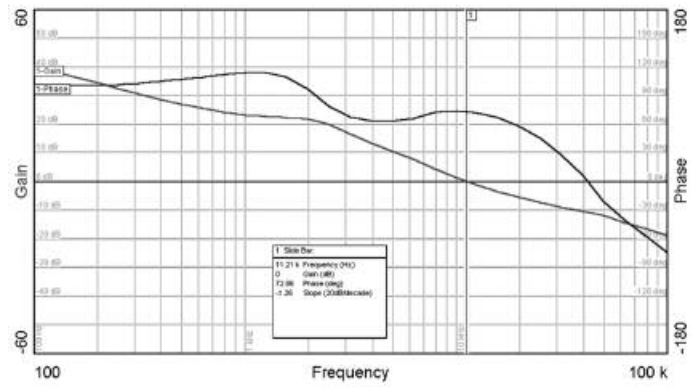
Load Regulation vs. Output Current



Load Transient Response, V_{IN} = 12 V



Control Loop (Gain and Phase), Cross Over 11.21 KHz



SEPIC Converter for a 24-V Industrial Bus with Battery Backup

Description

The UCC3807 is a family of high-speed, low-power PWM controllers that contain all of the control and drive circuitry for fixed-frequency off-line and DC/DC current-mode converters. These devices feature programmable maximum duty cycle, internal soft-start, and leading edge blanking of the current sense signal. UVLO levels are offered for off-line converters, DC/DC converters, and battery powered systems.

This circuit uses the UCC3807-3 to implement a non-isolated, non-synchronous, SEPIC converter for an industrial control application. The input is a 3 to 32 VDC, derived from a 24-V industrial bus with battery backup. The minimum start-up voltage is 6 V, but can drop to 3 V after startup. The output is 5 V at 300 mA and is shown with an optional 3.3-V output from and LDO. The operating frequency selected to be 500 KHz to minimize component size. The ENABLE circuit limits the off state current to less than 2 mA, reducing battery drain.

Web Links:

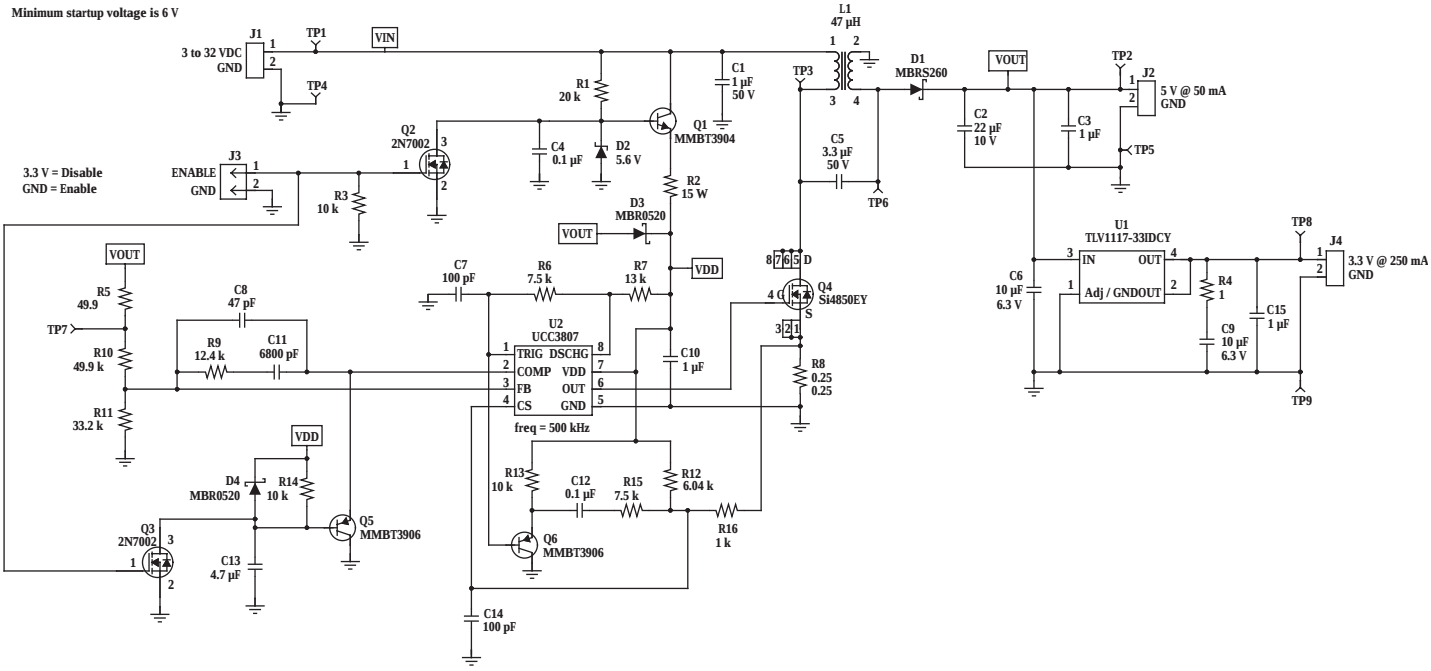
Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **UCC3807**

Specifications

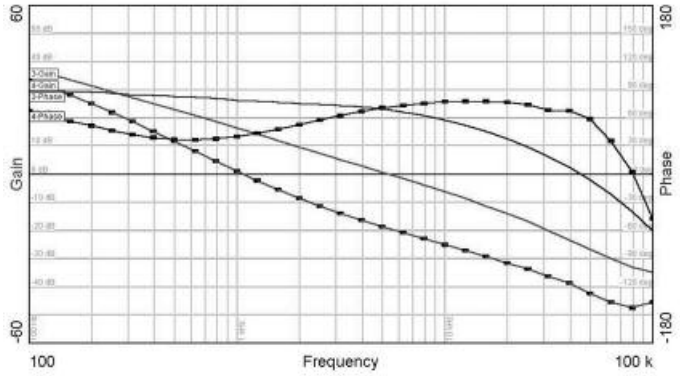
Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		3	24	32	Volts
Output Voltage	$0 < I_{OUT}, < 1$ A	4.85	5.0	5.15	Volts
Output Ripple				50	mV_{P-P}
Output Current		0		300	mAmp
Switching Frequency			500		kHz
Efficiency	12-VDC Input		82		%
I_{OUT} = 0.3 A, No LDO	24-VDC Input		76		%

PMP2289 Schematic

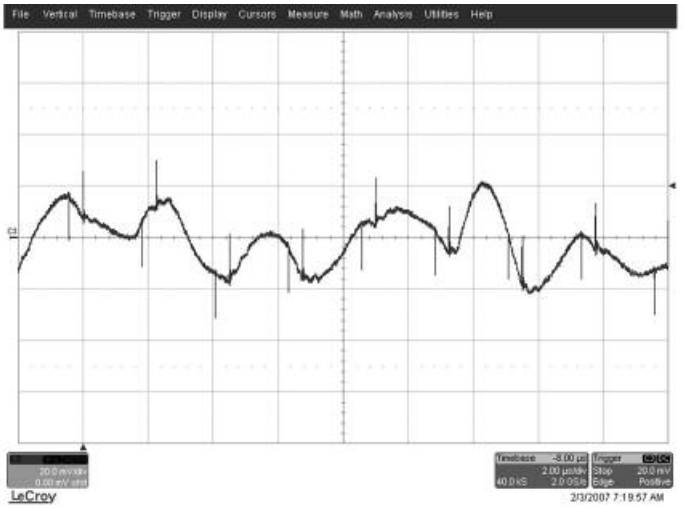


SEPIC Converter for a 24-V Industrial Bus with Battery Backup

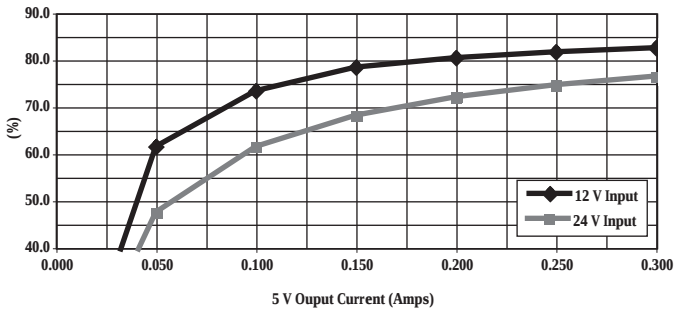
Control Loop (Gain and Phase) (24 V_{IN}, Min/Max Load), Cross Over 1 KHz for Min Load and 5 KHz for Max Load



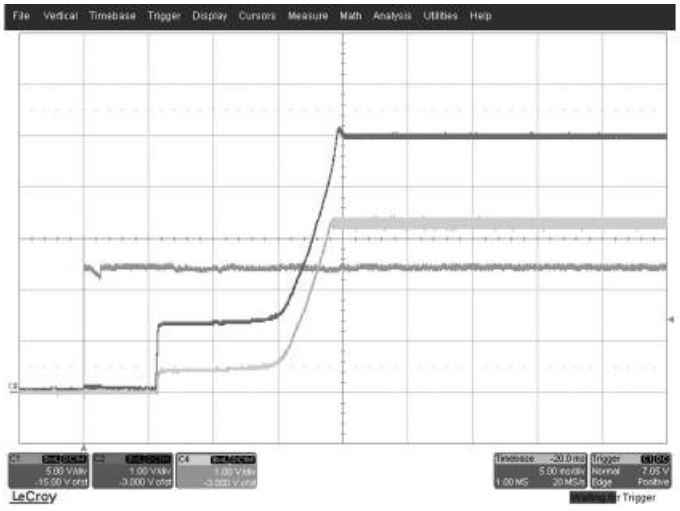
5 V Output Ripple, 24 V_{IN}, 300 mA Load, (20 mV/DIV, 2µs/DIV)



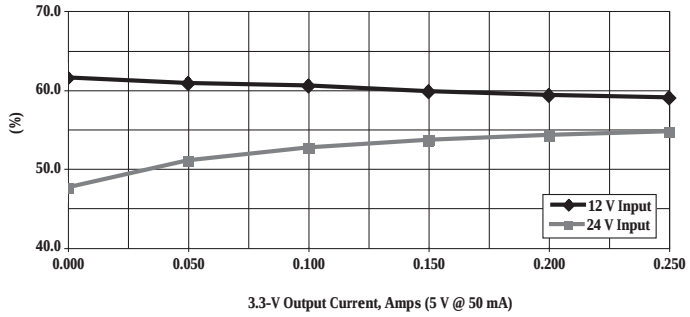
Efficiency vs 5 V Output Current (12 V_{IN} and 24 V_{IN}, No LDO



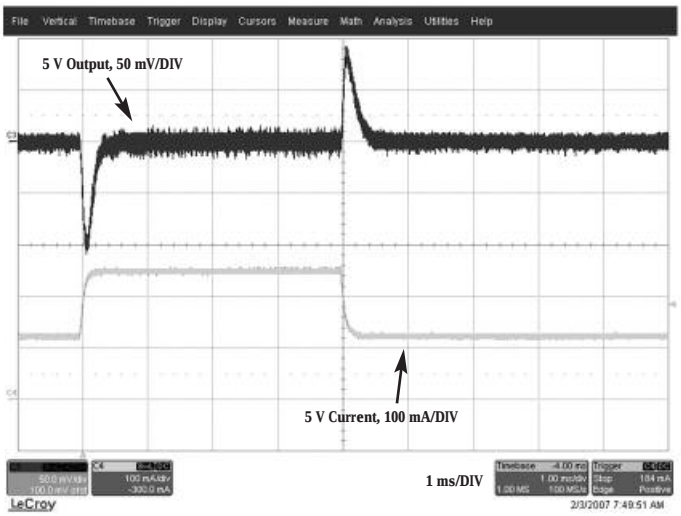
Turn On with 24 V_{IN}, 3.3 V/250 mA, 5 V/50 mA (1 V/DIV, 5 ms/DIV)



Efficiency vs 3.3 V Output Current (LDO) (5 V/50 mA)



Transient Response (24 V_{IN})



Isolated Flyback Converter for Power-over-Ethernet PD Applications

Description

The TPS23750 integrates the functionality of the TPS2375 PoE PD controller with a primary-side DC/DC PWM controller. The designer can create a front-end solution for PoE PD applications with a minimum of external components. The PoE front-end has all the necessary IEEE802.3af functions including detection, classification, UVLO and inrush control. The PoE input switch is integrated within the TPS23750. The DC/DC controller section is designed to support flyback, forward and non-synchronous low-side switch-buck topologies.

This circuit uses the TPS23750 to implement an isolated flyback converter. PoE applications such as security cameras require a 12-V rail. Since the input to the PD is limited to 12.95 W by IEEE802.3af, synchronous rectification is used to reduce losses, providing maximum power at the output. The output of this converter can be scaled to provide lower voltages, such as 3.3 V or 5 V.

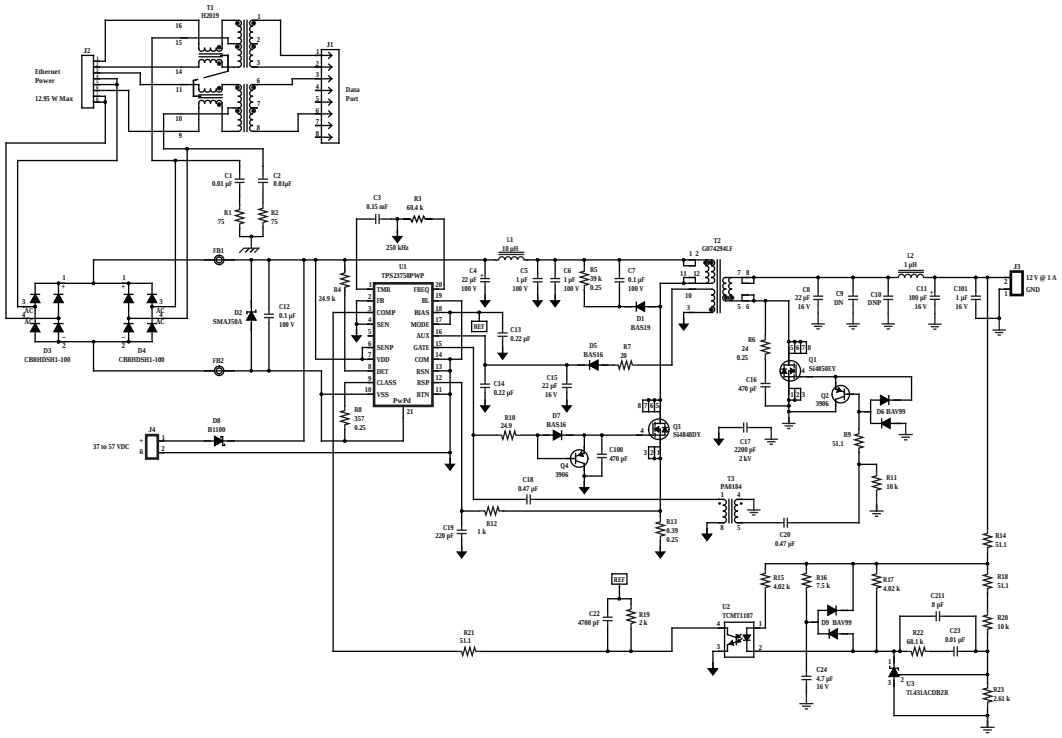
Web Links:

Reference Designs:
www.ti.com/powerreferencedesigns

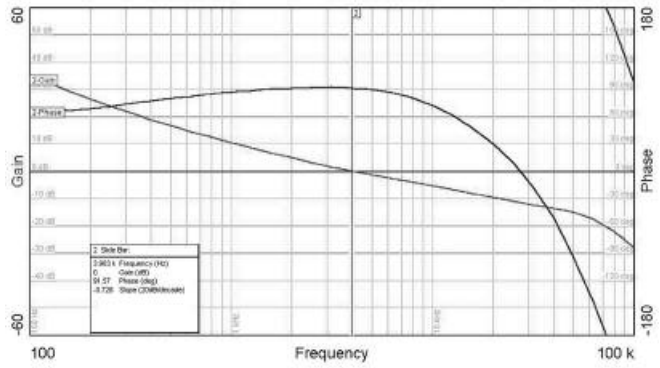
Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **TPS23750**

Specifications					
Parameter	**Test Conditions**	**Min**	**Typ**	**Max**	**Unit**
Input Voltage		37	48	57	Volts
Output Voltage	$0 < I_{OUT}, < 1$ A	11.64	12	12.36	Volts
Output Ripple				60	mV_{P-P}
Output Current		0		1	Amps
Switching Frequency			250		kHz
Efficiency	$I_{OUT} = 1$ A		89.5		%

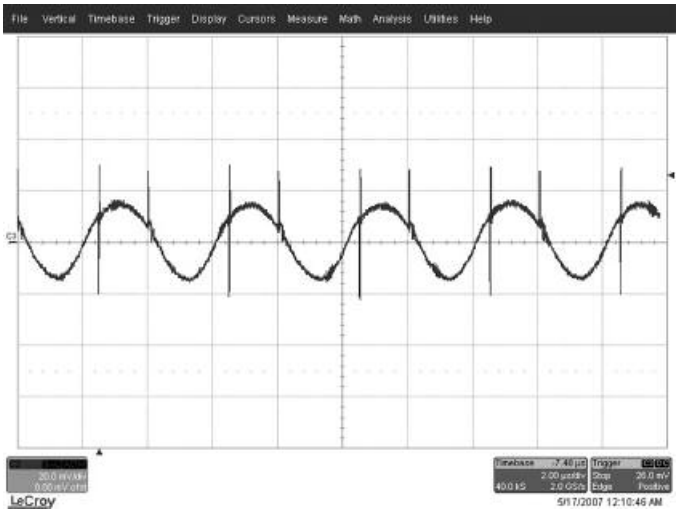
PMP2459 Schematic



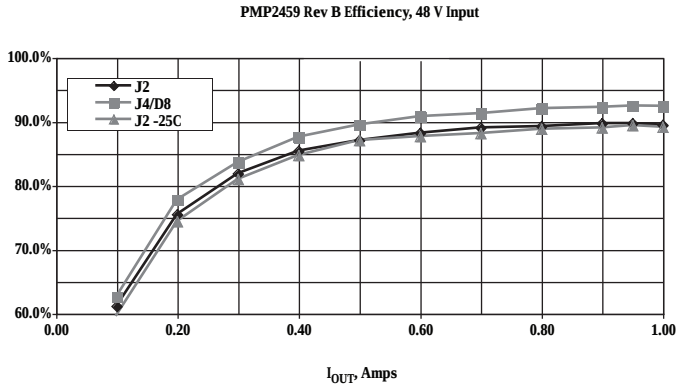
Control Loop (Gain and Phase), 48 V_{IN}, 1 A Load, 4 KHz Cross Over



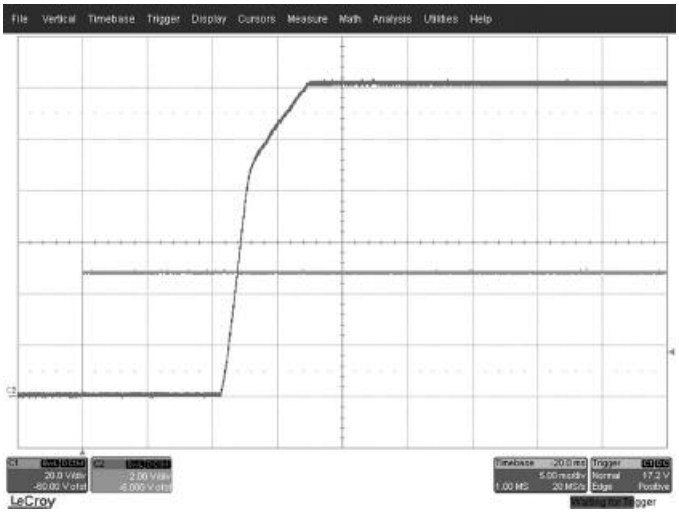
Output Ripple Voltage, 48 V_{IN},1 A Load (20 mV/DIV, 2µs/DIV)



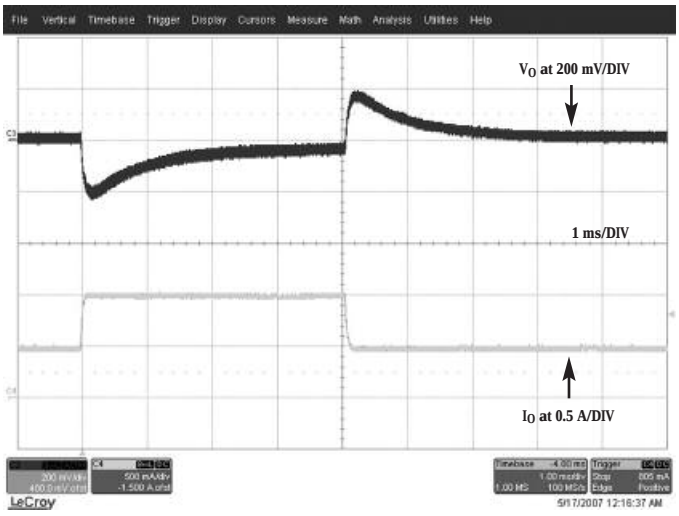
Efficiency vs Output Current, 48 V_{IN}



Turn On, 48 V_{IN},1 A Load, 2 V/DIV, 5 ms/DIV



Transient Response



Isolated Flyback Converter — Primary Side Controller

Description

This reference design uses the UCC3809, a current-mode-controlled synchronous flyback converter that can deliver 5 A of continuous output current at 3.3 V from an input range of 36 to 75 V_{DC}. The UCC3809 provides all necessary functions for the control of isolated offline and DC/DC power converters. This design results in a highly efficient, small, cost-effective solution for low-power isolated applications. Peak efficiency using the UCC3809 and synchronous rectification is greater than 88%.

Web Links:

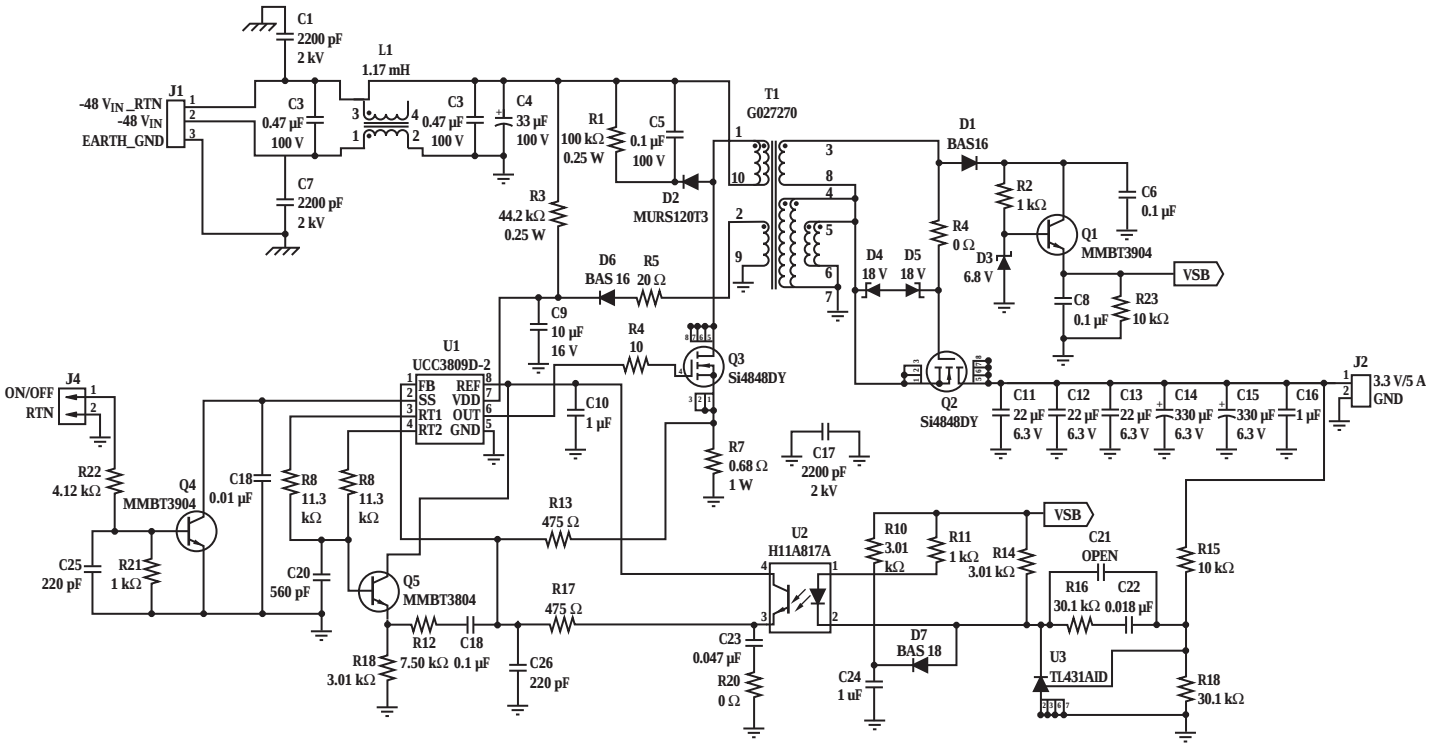
Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **UCC3809**

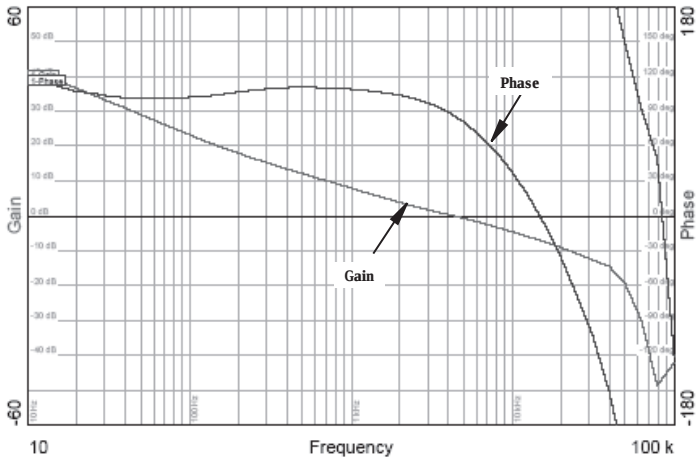
Specifications

Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		36	48	75	Volts
Output Voltage		3.0	3.3	3.6	Volts
Load Current		0		5	Amps
Switching Frequency			100		kHz
Output Ripple Voltage	V_{IN} = 48 V; I_O = 5 A		50		mV_{P-P}
Efficiency	V_{IN} = 48 V; I_O = 5 A		85		%

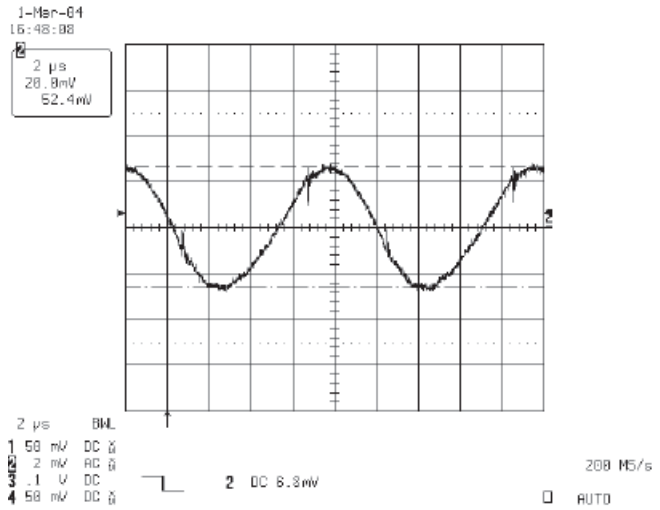
PMP665 Schematic



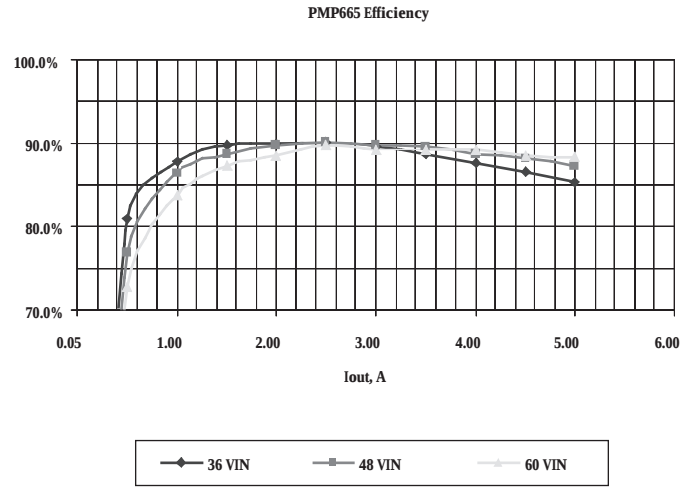
Control Loop (Gain and Phase), Cross Over 4 KHz
(V_{IN} = 5 V; I_O = 15 A)



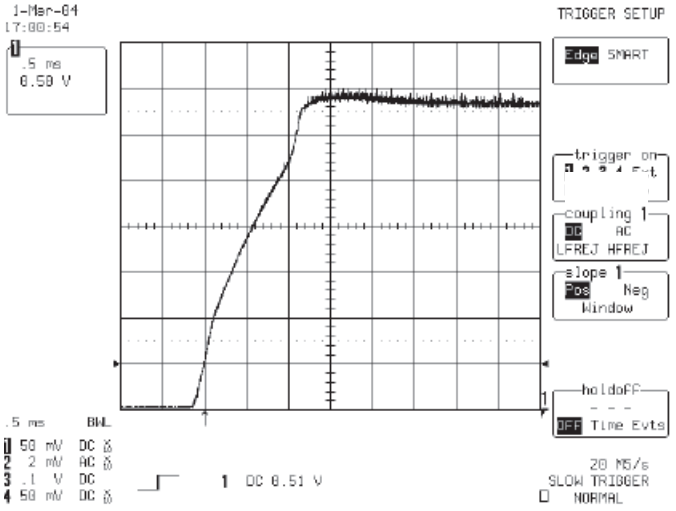
Output Ripple Voltage (V_{IN} = 48 V; I_O = 5 A)



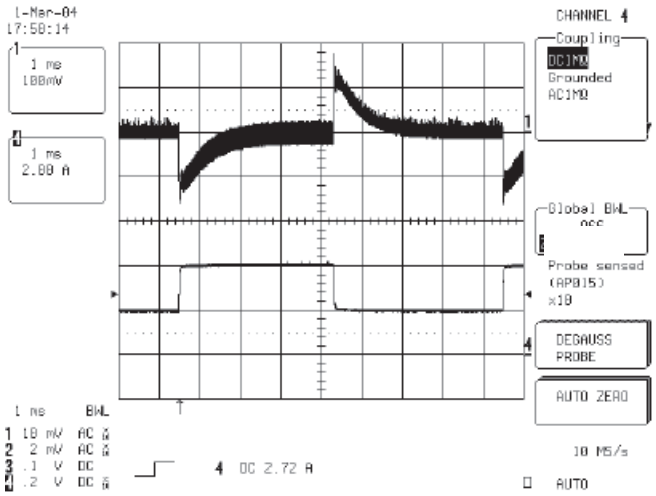
Efficiency



Turn On (V_{IN} = 48 V; No Load)



Transient Response, Top Trace: V_O at 100 mV/DIV
Bottom Trace: I_O at 2 A/DIV



Green-Mode AC Input Flyback Converter

Description

The UCC28600 is a PWM controller with advanced energy features to meet stringent worldwide energy efficiency requirements. UCC28600 integrates built-in advanced energy saving features with high protection level features to provide cost effective solutions for energy efficient power supplies. UCC28600 incorporates frequency fold-back and green-mode operation to reduce the operation frequency at light-load and no-load operations.

This circuit uses the UCC28600 in a universal AC input flyback converter. A single output of 12 V/60 W is generated. The efficiency at maximum load is 86%, and the no load losses are less than 1/4 Watt. At light loads, energy is conserved by transferring energy in bursts of 40-kHz pulses. A 130-kHz maximum switching frequency is imposed by the UCC28600 during operation at heavier loads.

Web Links:

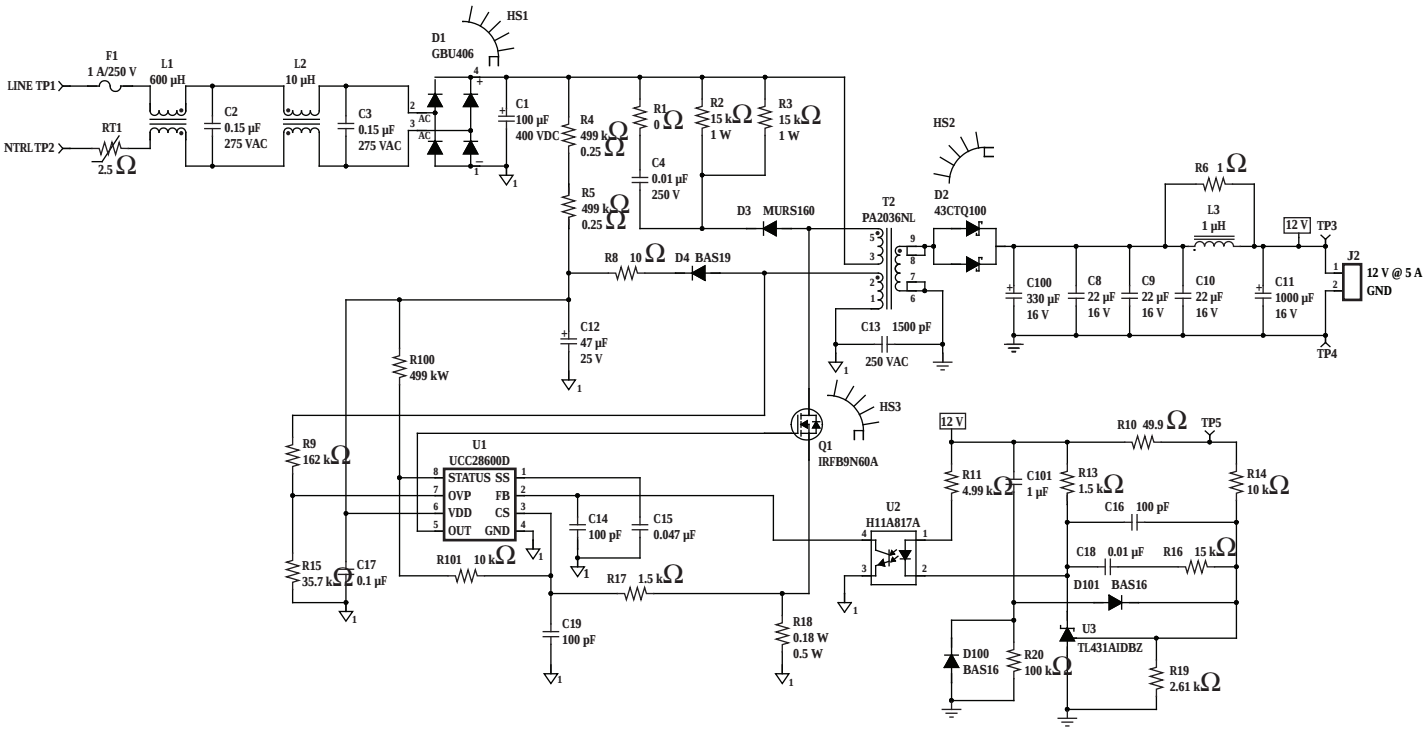
Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **UCC28600**

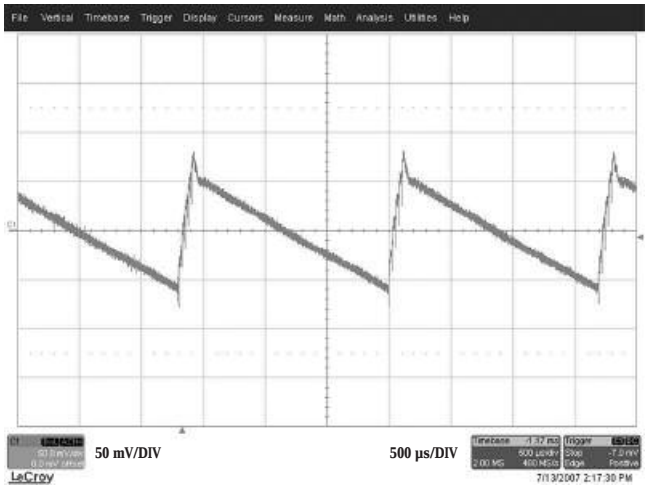
Specifications

Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		85		265	AC Volts
Output Voltage	$0 < I_{OUT} < 5$ A	11.71	12.08	12.44	Volts
Output Ripple				150	mV_{P-P}
Output Current		0		5	Amps
Switching Frequency		40		130	kHz
Efficiency	310 VDC_{IN} I_{OUT} = 5A		86		%
No Load Loss	155 VDC_{IN}		129		
	310 VDC_{IN}		223		mW

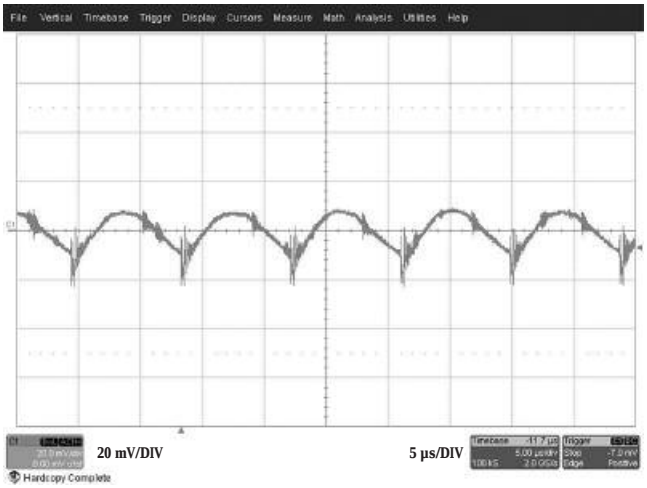
PMP2828 Schematic



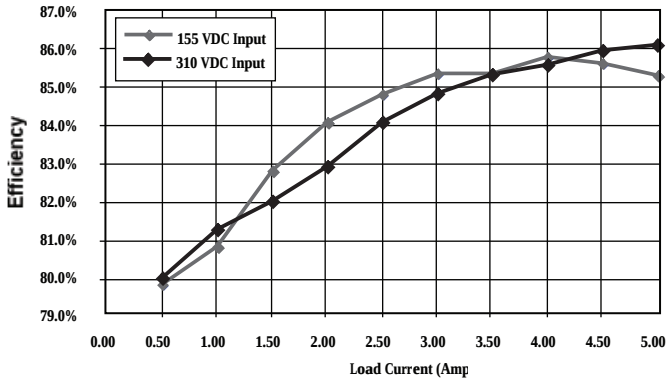
Light Load Ripple (155 VDC_{IN}, 0.1 A Load)



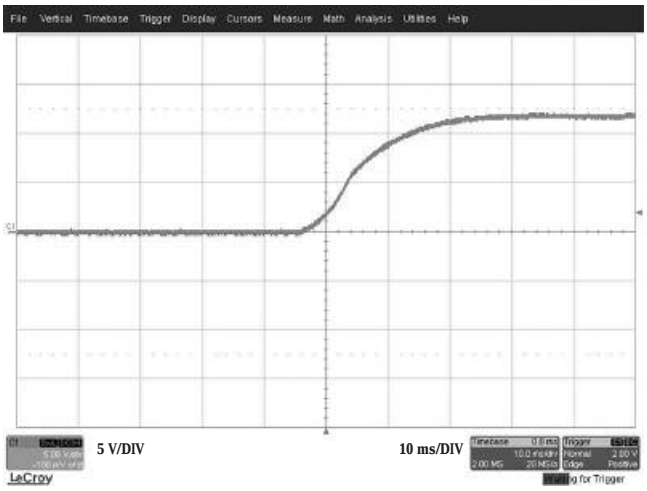
Full Load Ripple 30 mV_{P-P} (155 VDC_{IN}, 5 A Load)



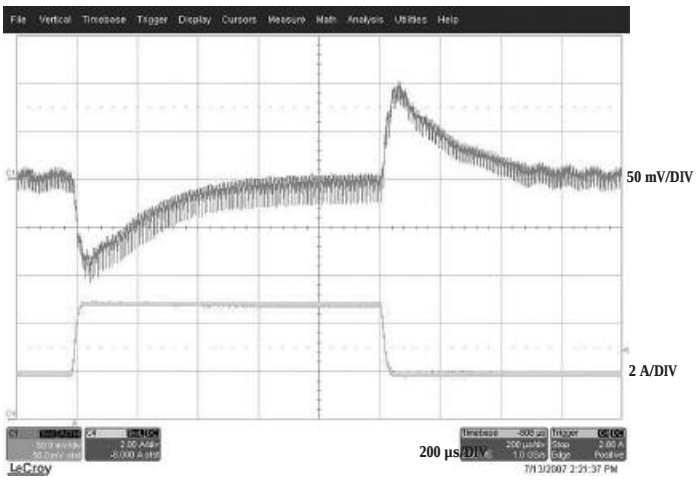
Efficiency



Turn On 110 VAC, No Load'



Load Step,155 VDC_{IN}, 2 A to 5 A Step



Power Management Unit for Portable Applications

Description

The TPS65050 is a Power Management Unit (PMU) with two step-down converters and four low-input voltage LDOs. This PMU is ideal for handheld devices such as cell phones, smart-phones, PDAs and portable media players.

Each step-down converter is capable of delivering 600 mA of continuous current at an output voltage range of 0.6 V up to the input voltage (6 V maximum). The output voltage for each DC/DC converter is set using an external resistor divider connected to the feedback input.

Two of the four LDOs are rated at 400 mA while the other two are rated at 200 mA. The output voltage range of each LDO is set using four discrete inputs as shown in the following table.

Web Links:

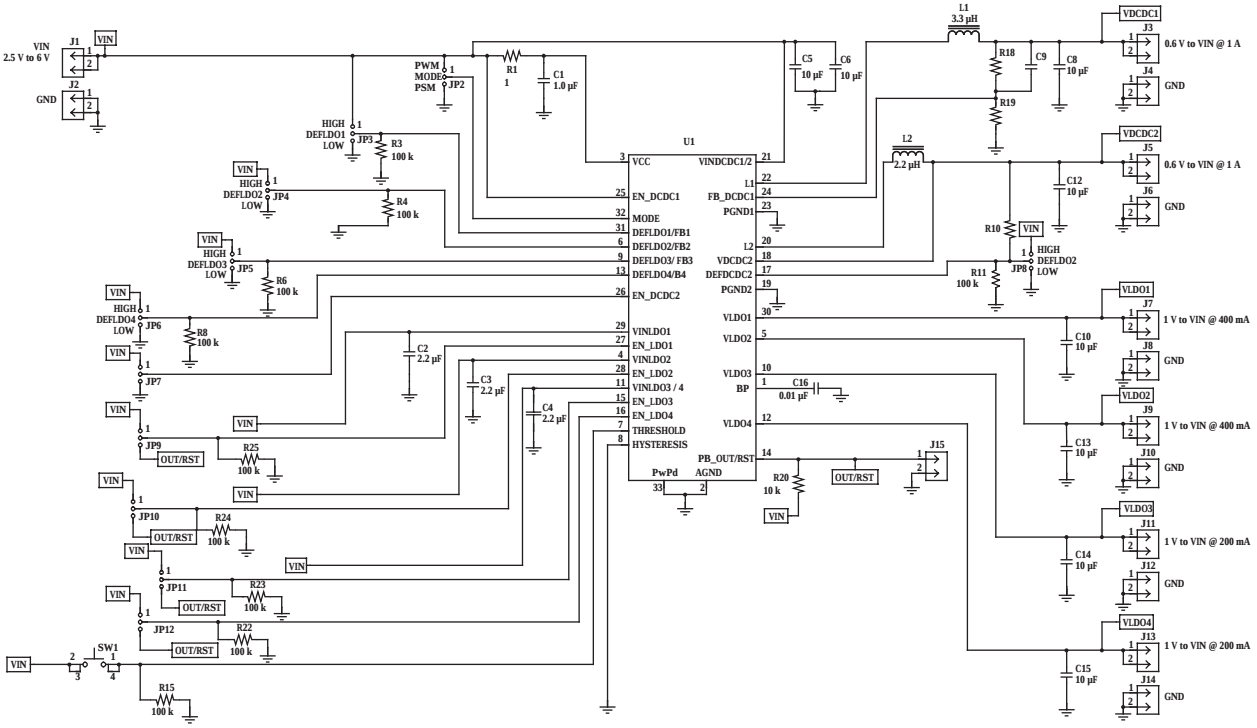
Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **TPS65050**

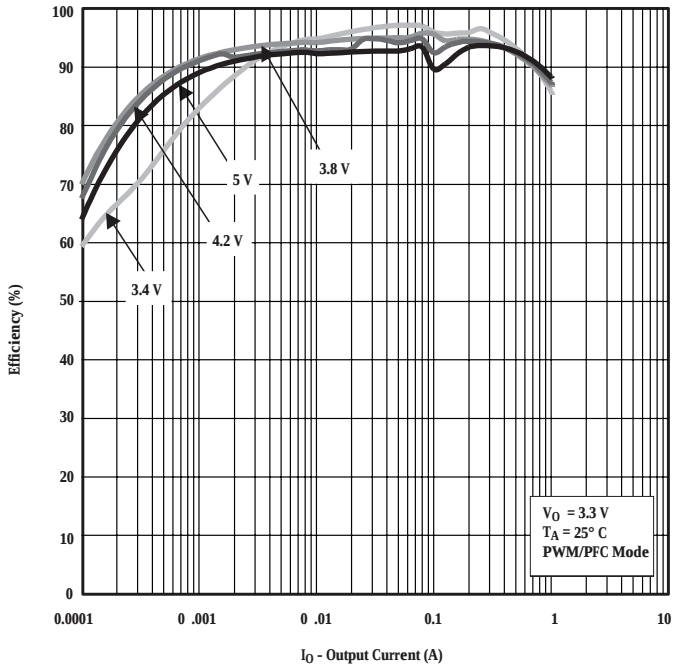
Specifications

Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		2.5	5	6	Volts
Output Voltage	DC/DC1		3.3		Volts
	DC/DC2		1.3		Volts
Output Ripple	DC/DC1		2.0		mV_{P-P}
	DC/DC2		2.0		mV_{P-P}
Switching Frequency	DC/DC1	2.025	2.25	2.475	MHz
Efficiency	DC/DC1		90		
	DC/DC2		80		%

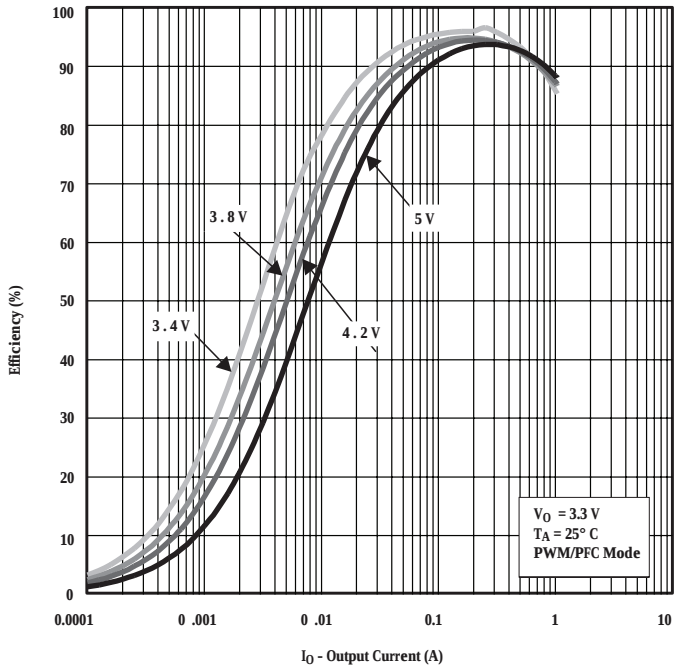
TPS65050EVM-195 Schematic



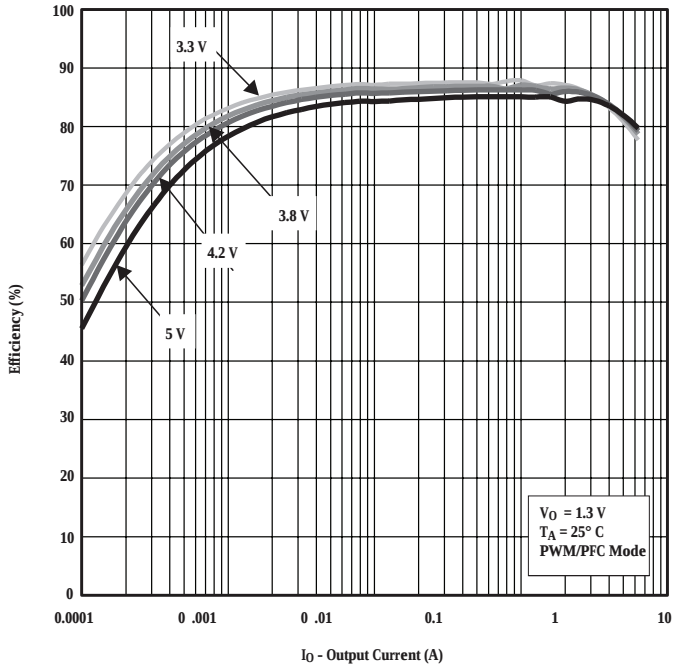
DC/DC1 Converter Efficiency



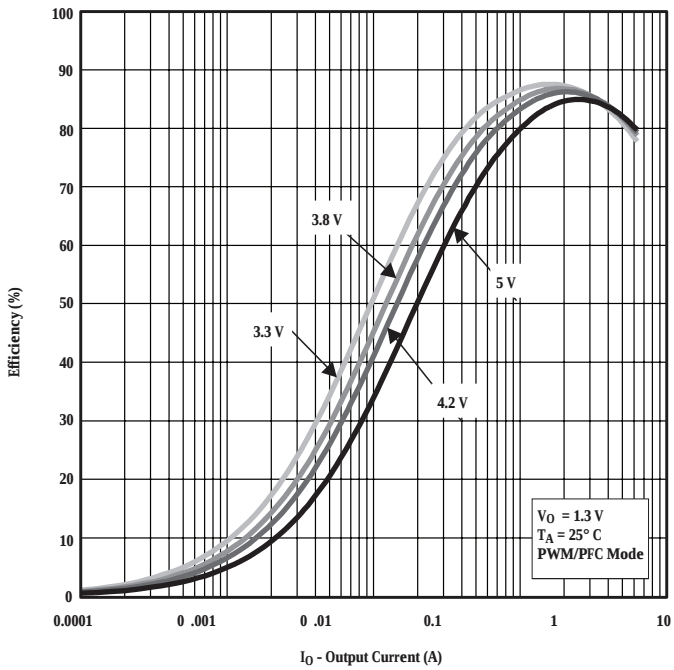
DC/DC1 Converter Efficiency



DC/DC2 Converter Efficiency



DC/DC2 Converter Efficiency



Complete Front-End Protection and Charger Module for Li-Ion Batteries

Description

The bq24314/6 protects the charging system against three types of failures: input over voltage when the AC adapter fails to regulate its voltage or due to adapter hot plug-in; load over current when failures such as a short circuit occur in the charging system; and battery over charge.

This circuit uses the bq24314 and bq24080 devices as a complete charge module for charger front-end (CFE) protection and charging a single-cell Li-Ion battery. The CFE over-current protection set point is 1000 mA by 24.9-kΩ resistor R3 while the fast charge current is set to 700 mA by 1.13-kΩ resistor R8. The CFE input over-voltage protection set point is internally set to 5.85 V and battery over-voltage set point is internally set to 4.35 V. Three 1-µF capacitors are used as the input and output decoupling capacitors. All enable pins are connected to ground to enable the ICs all the time. Three LEDs give status of charge IC. 100-kΩ resistor R4 isolates battery for battery protection if the CFE chip fails. CFE/FAULT pin is pulled up to 5 V through 100-kΩ resistor R2. R1 and D1 generate the 5-V pull up voltage.

Web Links:

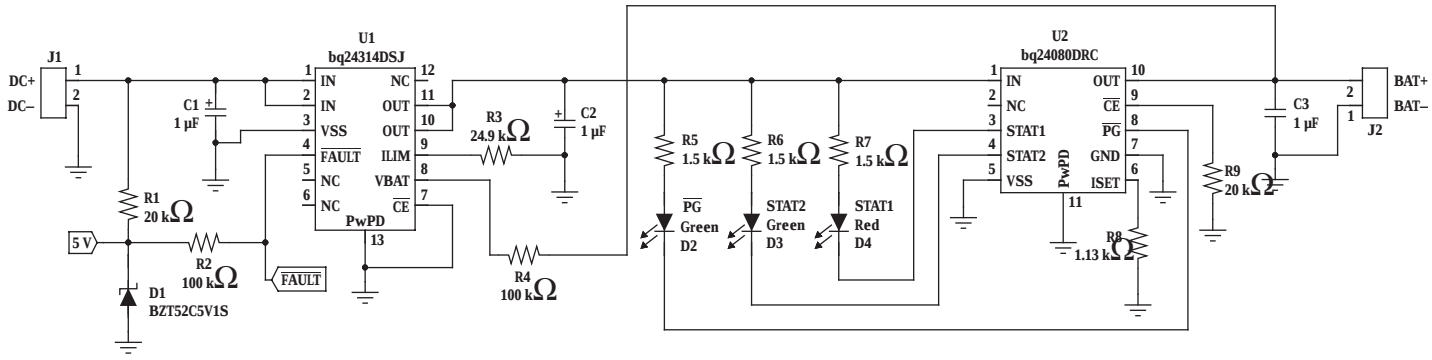
Reference Designs:
www.ti.com/powerreferencedesigns

Datasheets, User's Guides, Samples:
www.ti.com
Part Number Search: **bq24314 and bq24316**

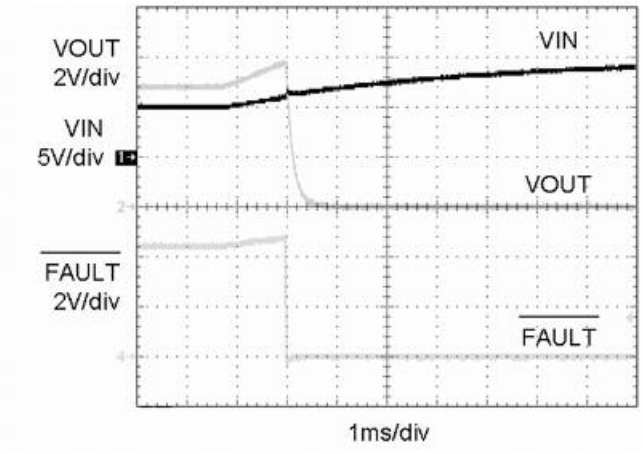
Specifications

Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage		4.5	5	26	Volts
Input Current		0	0.7	1	Amps
Input OVP	V_{IN} from 5 V to 7.5 V	5.71	5.85	6.00	Volts
Input OCP	RILIM = 25KΩ	0.93	1	1.07	Amps
Battery OVP	V_{IN} > 4.4 V	4.30	4.35	4.40	Volts

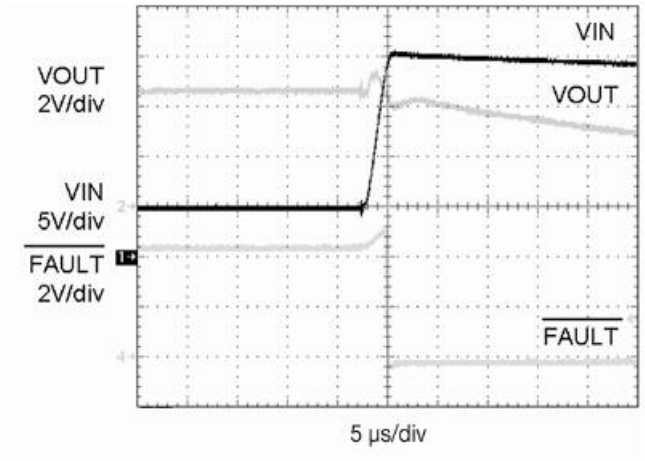
bq24314EVM Schematic



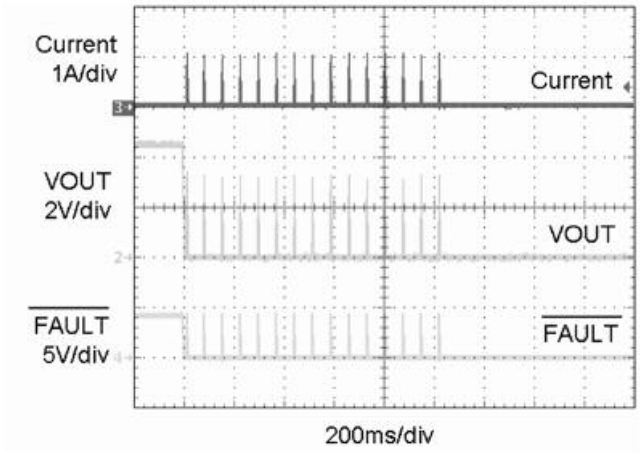
V_{IN} = 5 to 10 V, V_{OUT} = 5.85 to 0 V, Inverted Fault = 5 V to 0 V



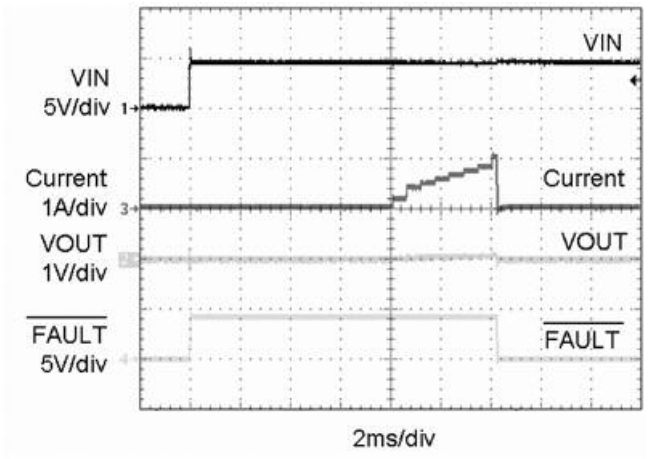
V_{IN} = 5 to 20 V, V_{OUT} = 5.85 to 0 V, Inverted Fault = 5 to 0 V



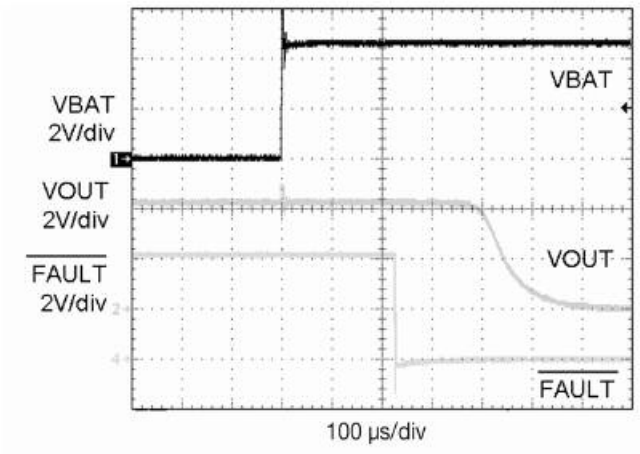
Current 0 to 1 A, V_{OUT} = 4.5 to 0 V, Inverted Fault = 4 V to 0 V



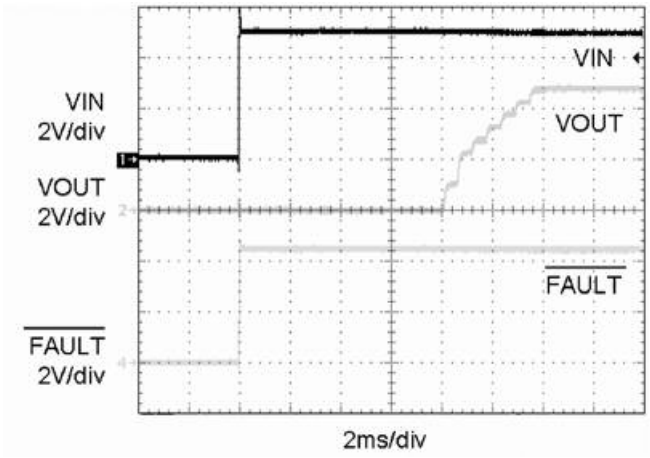
V_{IN} = 0 to 4.5 V, Current = 0 to 1 A, V_{OUT} = 0 V, Inverted Fault = 0 to 4 V



V_{BAT} = 0 to 4.4 V, V_{OUT} = 4.5 V to 0 V, Inverted Fault = 4 to 0 V



V_{IN} = 0 to 5 V, V_{OUT} = 0 to 5 V, Inverted Fault = 0 to 4,5 V



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