

Power module design challenge anatomy and optimized

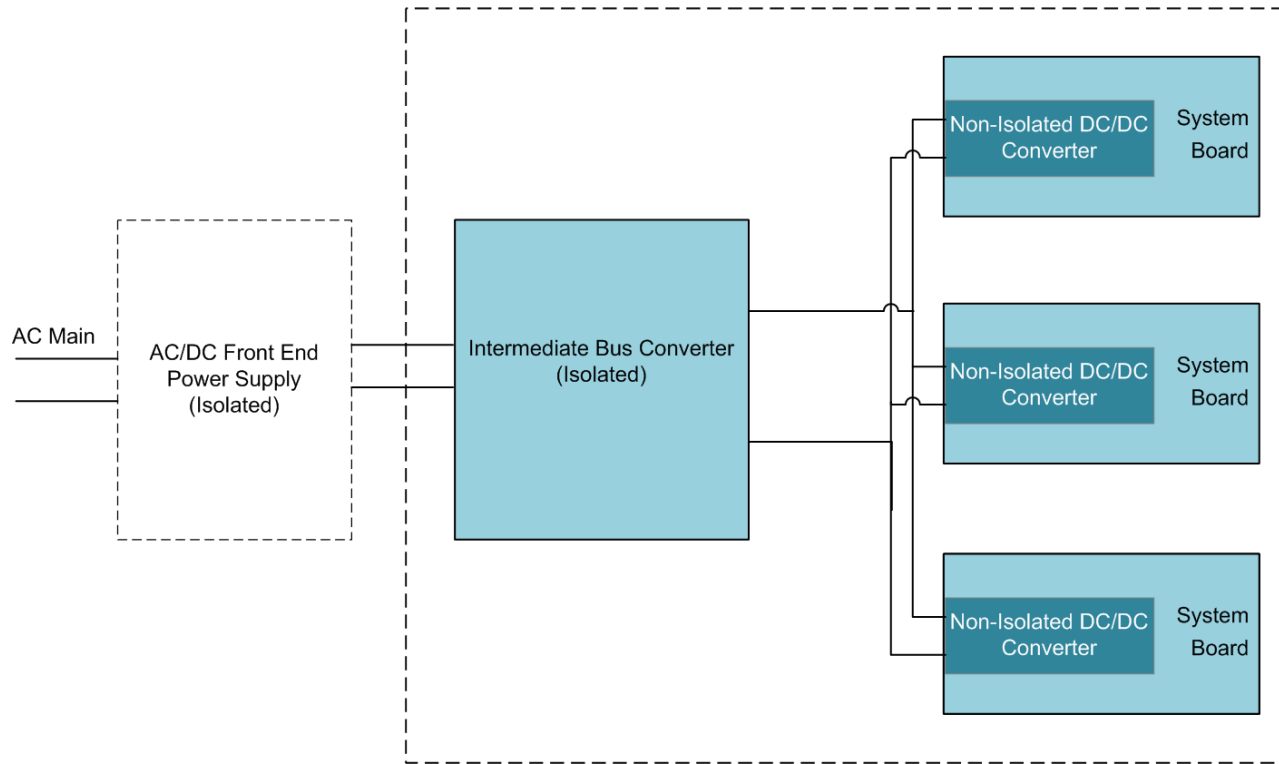
Industrial Systems Power Delivery

Sept 2019

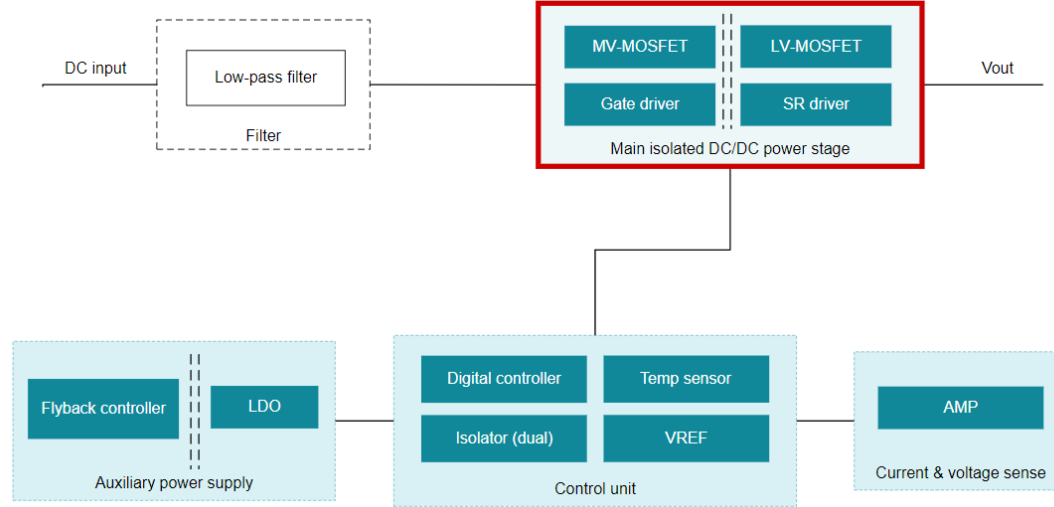
Agenda:

- Merchant DC/DC converter overview
- Non-isolated DC/DC converter
- Low power isolated DC/DC converter
- High power isolated DC/DC converter

Merchant DC/DC Converter Application



Merchant DC/DC Converter System Introduction



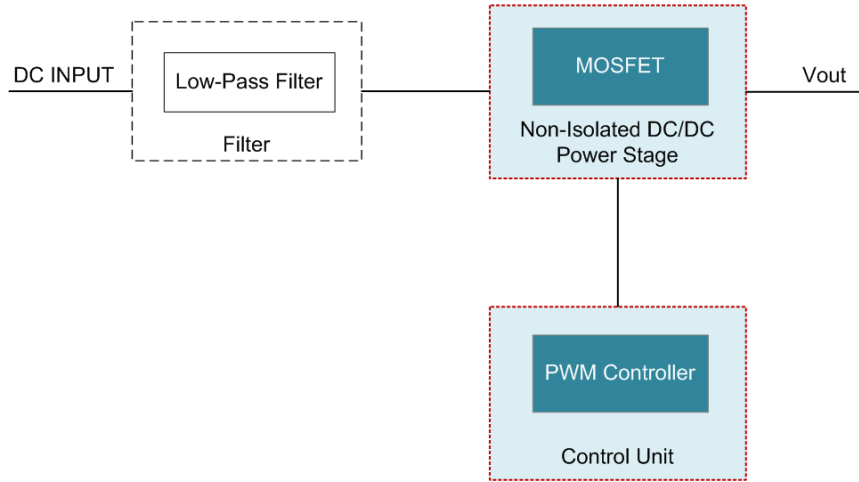
System Requirements

- Super-high Power Density
- High Energy Efficiency
- Less component count

Key Challenges

- Higher efficiency
- Thermal Performance in super compact size

Target application 1 : Non-isolated DC/DC converter



System requirement:

- Less component count;
- Easy circuit structure;
- High efficiency;

Topology:

Buck Topology:

TPS543C20, LM27403, LM5160, LM5161, TPS40400, TPS40101, TPS40195, TPS40303, TPS40304, TPS40305

Boost Topology:

LM5121, LM5122, TPS43060, TPS43061, LM5150, LM5175, LM5155, LM5022

Buck-Boost Topology:

LM5176, LM34936, TPS55288

TPS543C20

4V to 14V Input, 40A Stackable SWIFT™ Synchronous Buck Converter with Differential Remote Sense

Features

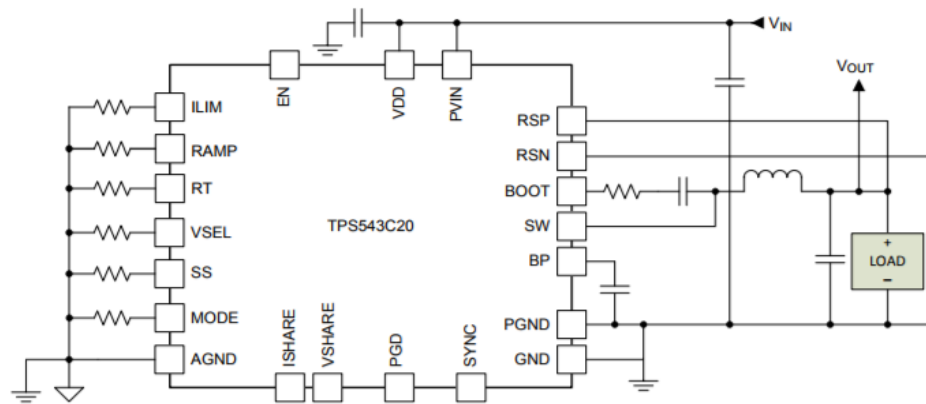
- 0.6V to 5.5V Output
- Internally-Compensated Advanced Current Mode (ACM)
- 0.6V Vref with $\pm 0.5\%$ Tolerance from -40°C to 125°C Tj
- 10 Vref choices: 0.6V; 0.7 to 1.1V in 50mV steps
- 3.0m Ω /0.9m Ω High/Low Side FET Rds(on)
- Selectable Fsw: 300kHz to 2MHz (1Ph) /1MHz (2Ph)
- True Fixed Frequency with CLK Sync
- 2-phase stackable with Ishare, Vshare, Fsync
- 10 SS choices: 0.5, 1, 2, 4, 5, 8, 12, 16, 24, 32ms
- High accuracy Over Current Limit (Hiccup Ilim)
- Asynchronous Pulse Injection (API) / Body Braking
- 5mm x 7mm x 1.5mm Stacked-Clip Package

Applications

- Communications RRU, Switches, Routers
- Enterprise Computing, Servers, Datacom
- ASIC, SoC, FPGA, DSP core and I/O Voltage Rails
- High-Power Programmable Logic Controllers

Benefits

- No External Compensation
- Flexibility to Optimize for Efficiency or BOM Size
- Wide Range of Switching Frequencies
- Option to better manage undershoot/ overshoot
- High Accuracy for Multiple Vouts
- $\pm 10\%$ Ilim Accuracy Over Temp & Process
- Up to 80A POL needs with flexible sync positions
- 90+% Efficiency Over a Wide Load Range



TIDA-01444:

180-W, Dual-Channel, Step-Down Converter Reference Design with 97% Efficiency for Server PSU

Features

- Designed using TPS543C20, device with integrated High-side and Low-side MOSFET
- Low BoM count
- Differential remote sensing and frequency Sync
- No external compensation control
- Lossless Low-side MOSFET current sensing with thermal compensation
- Protection: Output OVP/UVP & Output OCP
- Planner Inductor for elevating higher output power rating

Target Applications

- Server PSU
- PC PSU, non-isolated DCDC module
- Industrial power supplies

Tools & Resources

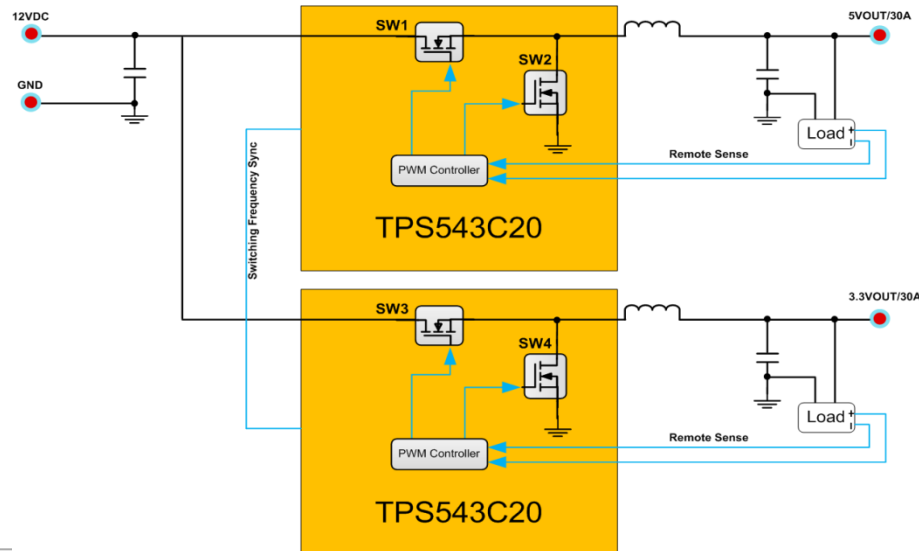
Board Image(for reference)



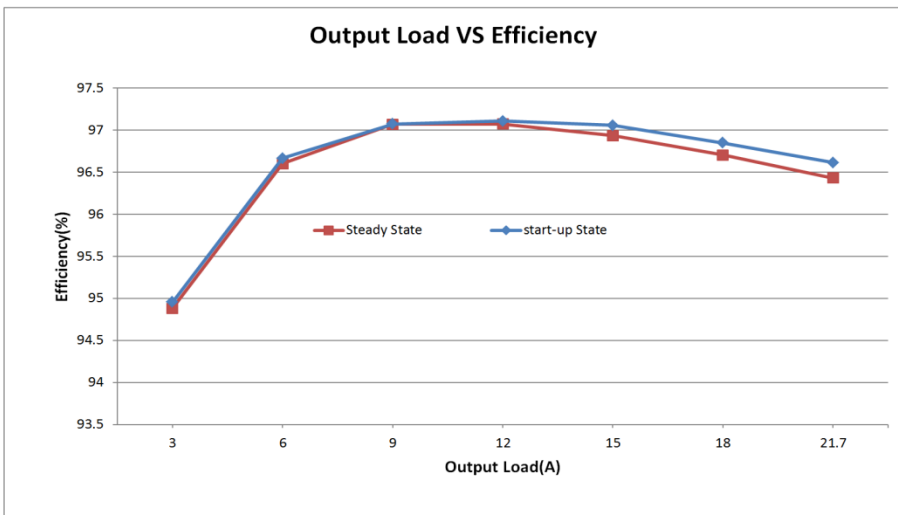
- [TIDA-01444 Tools Folder](#)
- [Design Guide](#)
- [Design Files](#): Sch, BOM, Gerber
- [Device Datasheets](#):
 - [TPS543C20](#), [TL432BQDBZR](#),
 - [LM20BIM7](#),

Benefits

- Super Low BoM Count makes design more reliable and easier
- High efficiency of 96%_typ@180W; 97%_typ@83W
- Compact Form factor for compatible with compact server PSU application
- Planner inductor design for easily elevating higher output power



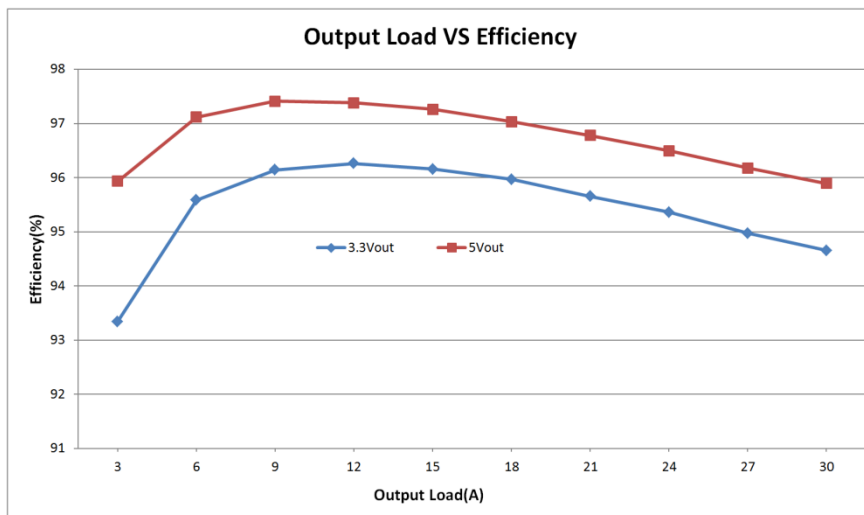
Efficiency



Test condition:

$V_{in} = 12V_{dc}$ $V_{out} = 3.3V_{dc}/21.7A + 5V_{dc}/21.7A$

Test Result: 97.07% at 10A load current.



Test condition:

$V_{in} = 12V_{dc}$ $V_{out} = 3.3V_{dc}/30A + 5V_{dc}/30A$

LM27403

3V to 20V Buck Controller with Temp Compensated DCR Sensing

Features

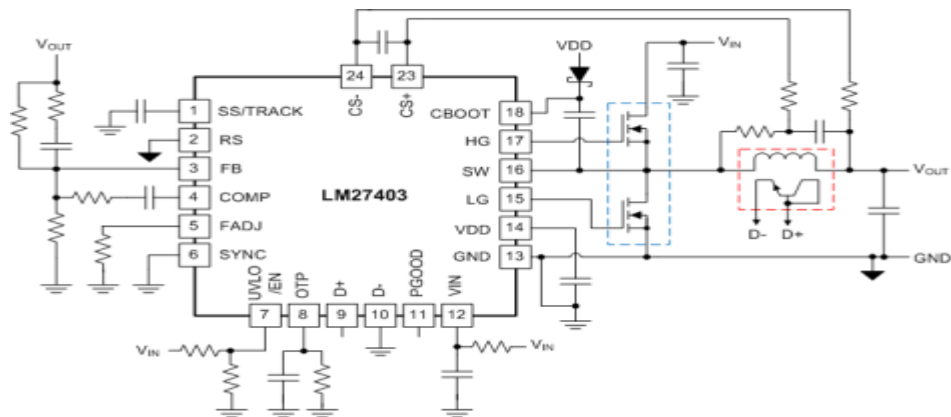
- 3V to 20V Input Voltage Range
- High efficiency operation for 3.3V, 5V, and 12V supply rails.
- 0.6V, 1% Accurate Reference Voltage (-40C to 125C)
- Voltage Mode Control
- 30ns Min On-Time for Low VOUT
- Temperature compensated current limit
- Remote sensing for DCR temp compensation and thermal protection
- Pin programmable over temp shutdown
- 6MHz bandwidth error amplifier improves load transient response
- Differential output sensing for improved load regulation
- Clock Synchronization (200kHz to 1.2MHz)
- Precision enable with hysteresis
- 4x4 QFN24 Package

Applications

- POL modules
- Telecom Infrastructure
- Embedded computing, servers, storage
- Video surveillance

Benefits

- Stable over-current protection without Improved robustness for SW pin voltage spikes
- Accurate, adjustable output from 0.6V
- On-time supports wide input/output ratios
- No sense resistor (DCR sensing) improves efficiency
- Kelvin voltage sense for improved load regulation



LM27403 Reference Design

High Efficiency, Performance, and Density POL Controller for PoL Modules and Comms Infrastructure

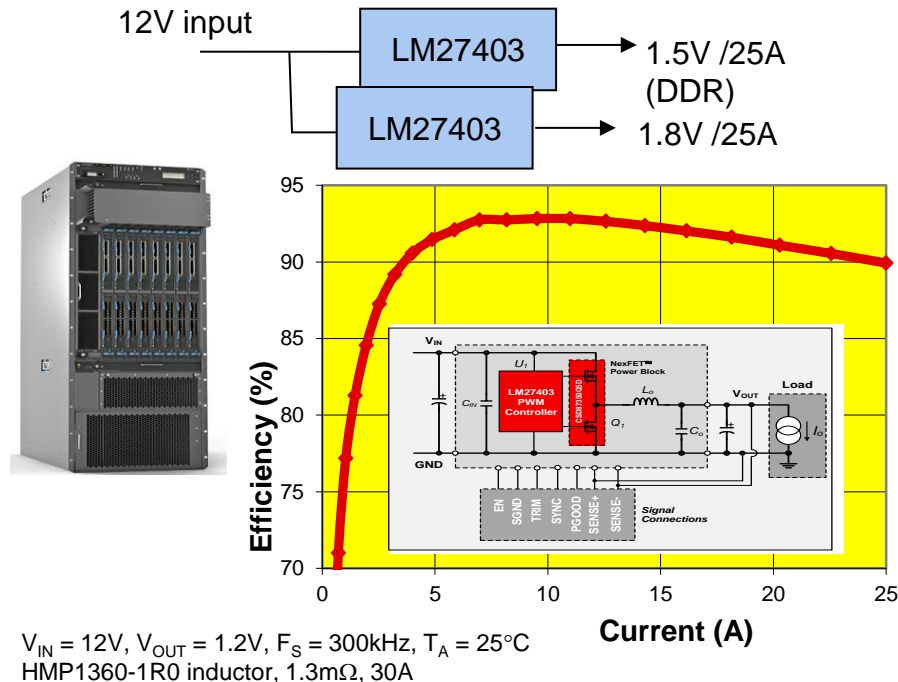
Application Need

- Accurate OCP design and reasonable L_o selection
- Support small duty cycle power conversion
- High efficiency at high frequency operation
- Flexible system configuration
- ASIC and FPGA Vcore supplies from 20A-30A
- High current 3.3V or 2.5V system supplies

TI Product Benefits

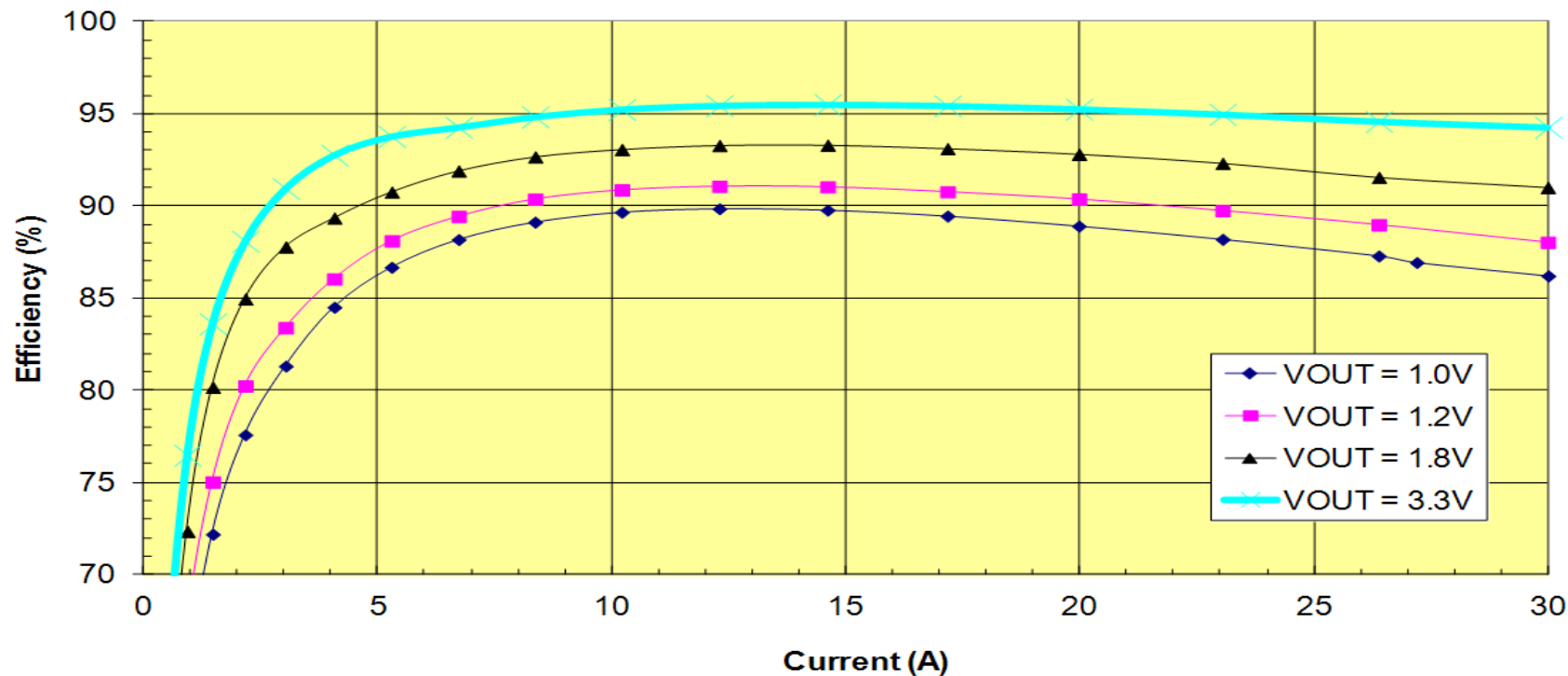
- Temp Compensated OCP trip point → Very accurate OCP trip point within full temp range
- ~30ns T_{on_min} → Support high freq. small duty cycle
- 15ns deadtime → High effi. for high density design
- Rich features for system reliability : Ext Sync, SS, Pre-bias startup, PGOOD, Programmable OTP, F_{adj} , EN/UVLO

Product Configuration



LM27403 Reference Design

DC-DC POL Module Ultra-High Efficiency $V_{IN} = 12V$



LM5176

4-Switch Buck-Boost Controller

Features

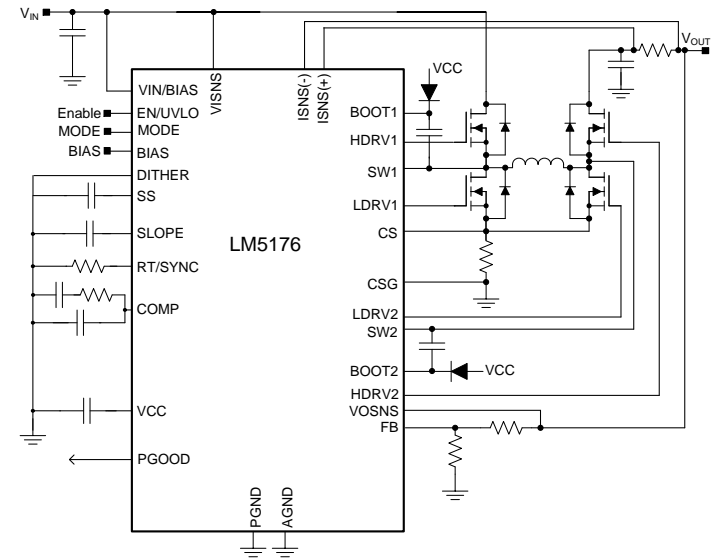
- Wide V_{IN} : 4.0V (2.5V with BIAS) to 55V (60V withstand)
- V_{OUT} : from 0.8V to 55V
- Single inductor design
- Smooth transition buck-boost operation
- V_{OUT} disconnect /Short-circuit protection
- 100 kHz to 600 kHz
- Adjustable UVLO, SS, frequency, current limit
- Average Current Limit for I_{IN} or I_{OUT}
- Optional hiccup current limit
- Optional frequency dither for EMI
- Adjustable Switching Frequency with SYNC
- -40C to +150C T_j ; TSSOP-28

Applications

- USB PD
- Wireless Charging
- Industrial PC

Benefits

- Controller solution for optimum system thermal performance
- Seamless buck, boost, or buck-boost operation
- Controllable I_{IN} or I_{OUT}
- Pin compatible with LM5175.



PMP10629 200W Synchronous Buck-Boost Reference Design

Key Specs: 9V–36V input, 12V @ 17A output, 260kHz

Device: LM5175/6

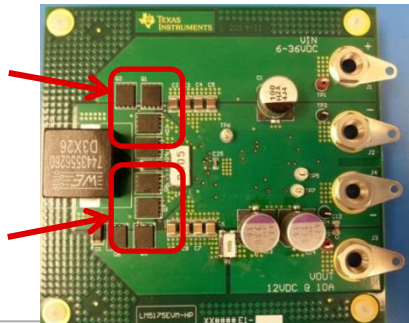
Features

- VIN= 9V to 36V, VOUT=12V
- Efficiency up to 98.4% at 200W
- Peak efficiency is 98.7%
- Inductor size: 8.2mm(L) x 18.2mm(W) x 8.9mm(H)

Applications

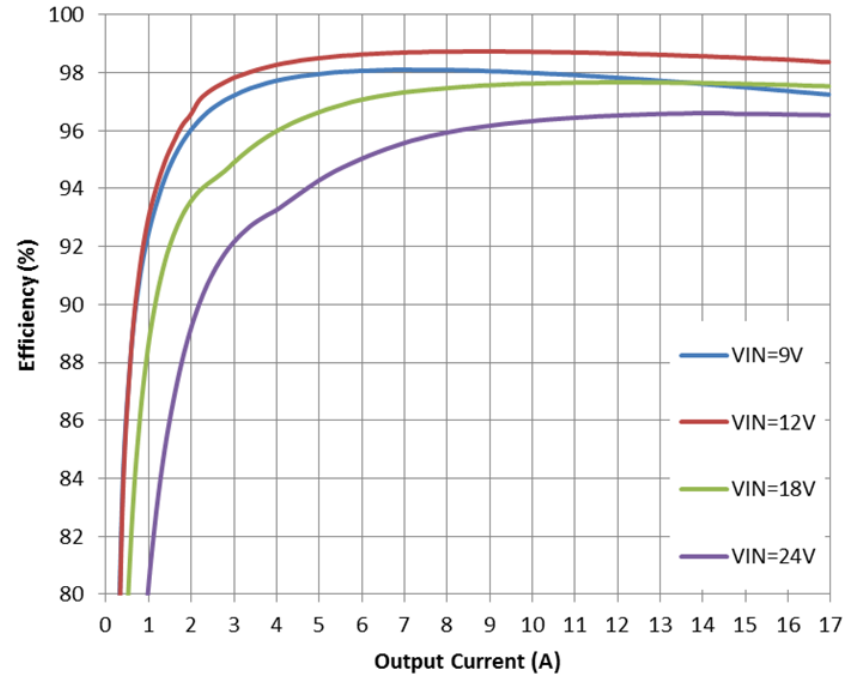
- Industrial PC

Four 5x6mm
60V Buck FETs

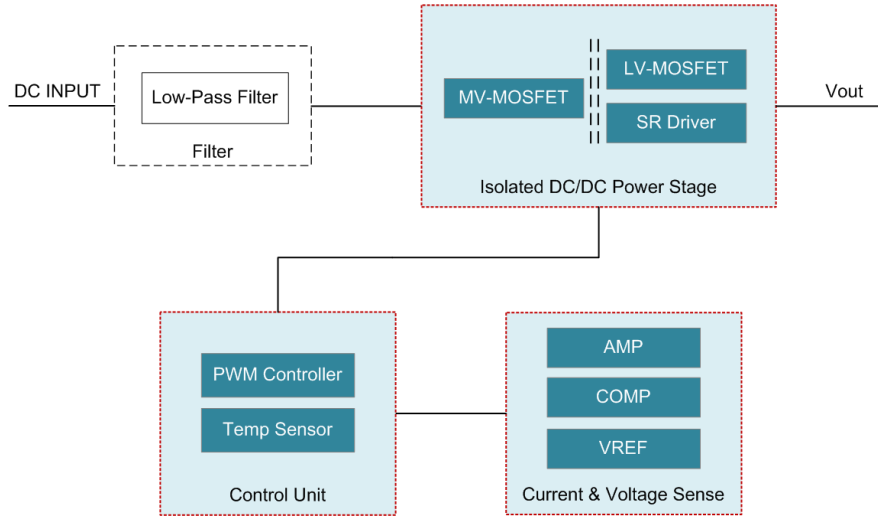


Four 5x6mm
25V Boost FETs

Performance



Target application 2 : Low power isolated DC/DC converter(<~100W)



Topology:

Fly-back Topology:

LM5022, LM5122, LM5020, LM5021,
LM34927

Forward Topology:

UCC2897A, LM5025A, LM5026, LM5034
UCC2891, UCC2892, UCC2893, UCC2894

System requirement:

- High efficiency;
- Easy circuit structure;
- Isolation requirement;

UCC2897A Advanced Current-Mode Active Clamp PWM Controller

Features

- Ideal for Active Clamp/Reset Forward, Flyback and SR Apps
- Complimentary AUX Driver
- Programmable dead time between AUX and MAIN
- Peak Current Mode Control
- Cycle by Cycle & Hiccup Mode Current Limit
- Integrated Direct 120V Startup Circuit
- Package Options: 20QFN, 20TSSOP

Applications

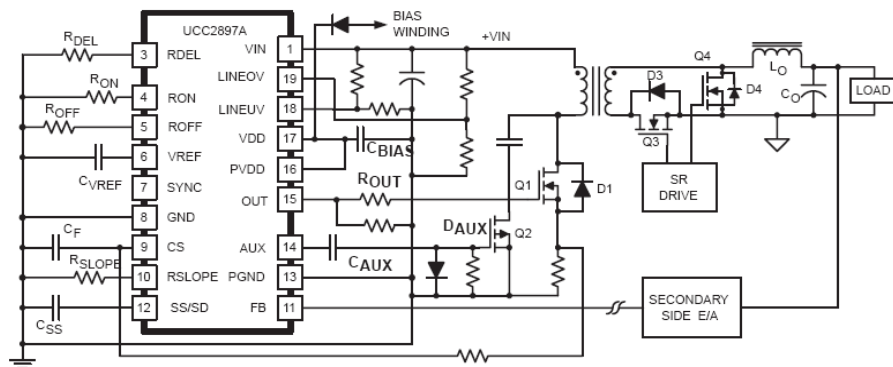
- [Enterprise Switch](#)
- [xDSL DSLAM](#)
- [IP Network Camera](#)

Tools & Resources

- [Reference Design: PMP20742: 36-60V input ACForward](#)
- [Reference Design: PMP20541: 36-60V input ACForward](#)
- [Application Note: Designing With the UCC2897A](#)
- [Device Datasheets: UCC2897A](#)

Benefits

- Telecom voltage range (36- 72V) compatible which eliminates the need for an external start-up regulator
- TrueDrive™ 2A Sink and Source outputs with Lowest Gate Drive Jitter in the Industry (20ns-30ns)
- Shutdown mode implements Soft Stop
- Accurate Line UV and Line OV protection
- Bidirectional Synchronizable 1 MHz oscillator
- Programmable Maximum Duty Cycle



36V-60V Input 12V/5A Highly Efficient Active Clamp Forward

TI Designs Number: PMP20742



Reference Design Description

The PMP20742 reference design provides 12V at 5A (60W) from a 36V-60Vdc input with over 94% efficiency. This design uses the UCC2897A active clamp controller along with synchronous rectifiers to achieve very high efficiency. Typical applications include Power Over Ethernet, Telecom, and Server systems.

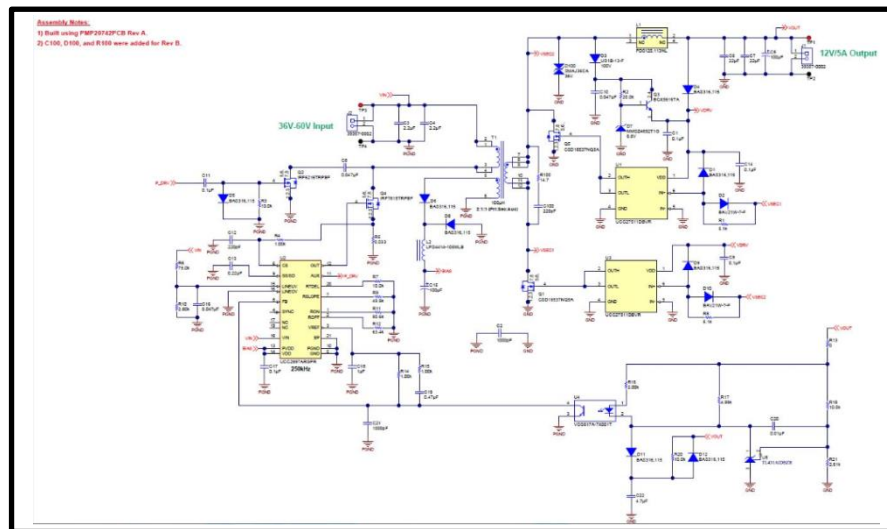
Features and Benefits

- High efficiency, over 94%
- Low profile, 11.43 mm (0.45") maximum height
- Self-driven synchronous rectifiers reduce cost and complexity

TI Parts used

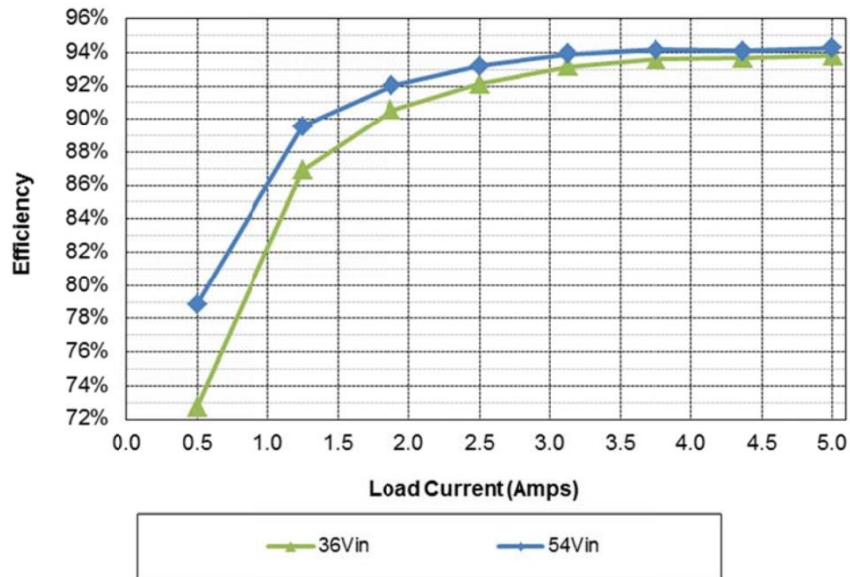
- UCC2897A
- UCC27511
- CSD18537NQ5A

Schematic

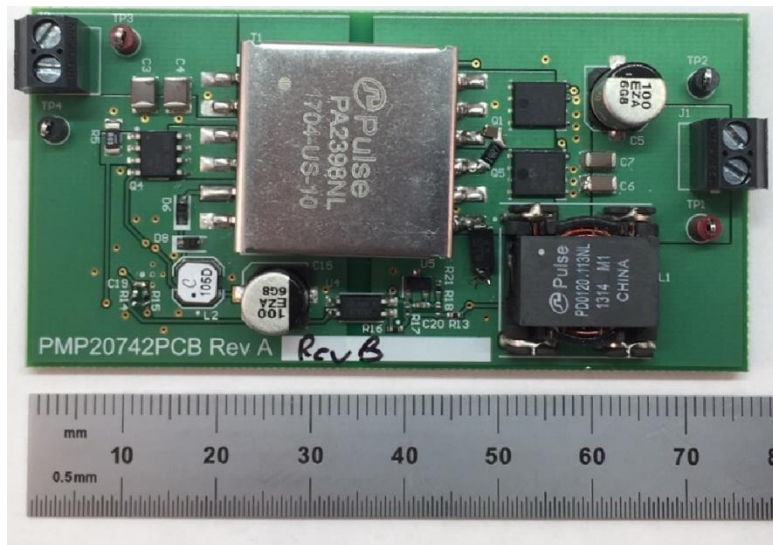


Efficiency

Efficiency curve at 36Vin and 54Vin:



Board Image:



LM5025x Active Clamp Voltage Mode PWM Controller

Features

- Internal 100V Start-up Regulator
- Voltage mode Control w/ Feed-Forward
- Programmable Overlap or Dead-time between the Main and Active Clamp Output
- Programmable Volt*Second Limiting & Line UVLO
- Resistor Programmed 1MHz Oscillator
- Package Options: 16TSSOP, 16TSWON

Applications

- [Telecom DC/DC Module](#)
- [Servo Drive Power Stage](#)
- [Telecom Tower: Remote Radio Unit](#)
- [Automotive DC/DC Converter](#)

Tools & Resources

- [Evaluation Module](#)
- [Reference Design: PMP4468: 18-36Vin ACForward](#)
- [Reference Design: PMP4428: 18-40Vin ACForward](#)
- **Device Datasheets:**
 - [LM5025](#)
 - [LM5025A](#)
 - [LM5025B](#)
 - [LM5025C](#)

Benefits

- Higher efficiency and greater power density than a traditional catch winding forward converter
- Independent programmable dead-times allows the maximum flexibility to improve efficiency
- A fixed oscillator ramp greatly reduces noise susceptibility
- No slope compensation required

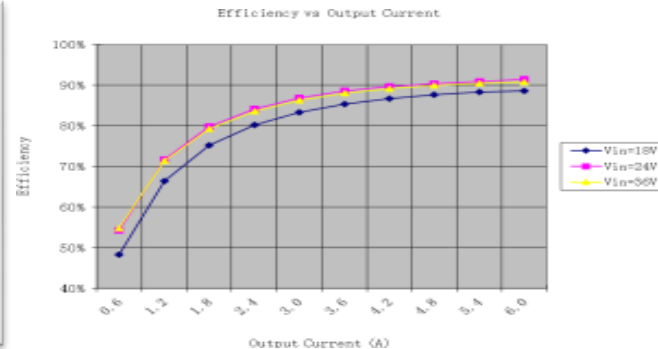
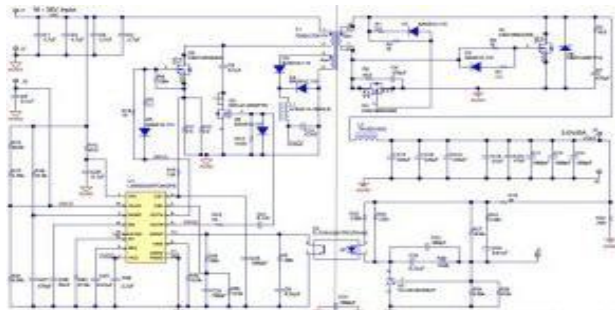
Part Number	Current Limit Thresholds	Max Duty Cycle	Operational Regulators during UVLO
LM5025	0.25V	80%	None
LM5025A	0.50V	80%	V_{CC} and V_{REF}
LM5025B	0.50V	73%	V_{CC}
LM5025C	0.50V	91%	V_{CC} and V_{REF}



PMP4468:

18V-36Vdc Input 5V/30W Active Clamp Forward

TI Parts	V_{in}	P_o	V_o/I_o	Topology	Eff.
LM5025A CSD18504	18~36 V	30W	5.1V/6.0A	ACF with S.R	91.3%



Features

- Fully tested to comply with the industrial requirement
- ACF converter with self-drive S.R
- Protection feature OCP, Input UVLO
- High Efficiency 91.3% @ 24Vin full load
- Good thermal performance with 4-layer design
- Small dimension: 44mm x 68mm x 10mm

Applications

- Industrial DC-DC
- Telecom DC-DC

LM5022

2.2MHz Wide Vin Boost / SEPIC / Flyback Controller

Features

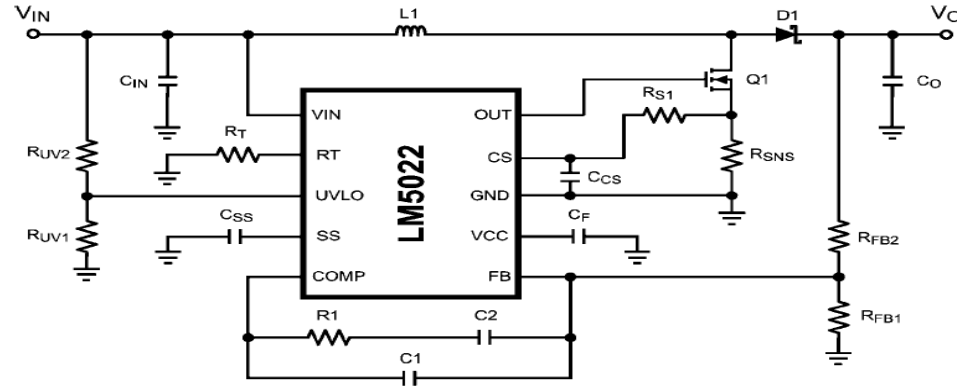
- Wide 6V to 60V input range (65V Abs Max)
(3V after start-up with input bootstrapped to output)
- Programmable frequency up to 2.2MHz with external resistor
- 1A peak MOSFET Gate Driver
- Current Mode Control with Internal Slope Comp
- 90% Maximum Duty Cycle
- External synchronization capability
- Adjustable Soft-Start
- Cycle by cycle current limit
- Enable / Programmable UVLO with Hysteresis
- Package: VSSOP-10
- AEC-Q100, Grade 1

Applications

- Automotive Boost , SEPIC, Flyback configuration
- Automotive Head Unit, Ext Amp, Cluster, Wireless charging
- Automotive Power Train

Benefits

- Supports Wide Voltage Range needs in automotive
(e.g., cold crank, start stop and load dump)
- Switching Frequency Above AM band to Reduce AM Interference
- Frequency Synchronization Eliminates Beat Noise
- High Current MOSFET Drive Capability
- Inherent Input Voltage Feed Forward



PMP20551 – Wide Input 36W Isolated Flyback Industrial PoE Ref Design

Device: LM5022, LMV431

Features

- 12V to 60Vin, 12Vout @ 3A out – IC capable of 6V to 60Vin
- 36W isolated output
- Peak efficiency 92%
- Switching frequency 100kHz
- 2 Layer Board
- Copper thickness: 1oz, 1oz
- Board Size: 3.5" x 1.9"

Applications

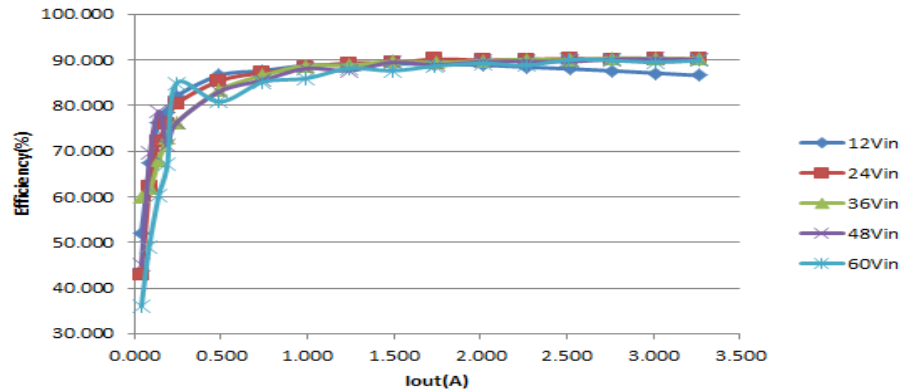
- Industrial POE



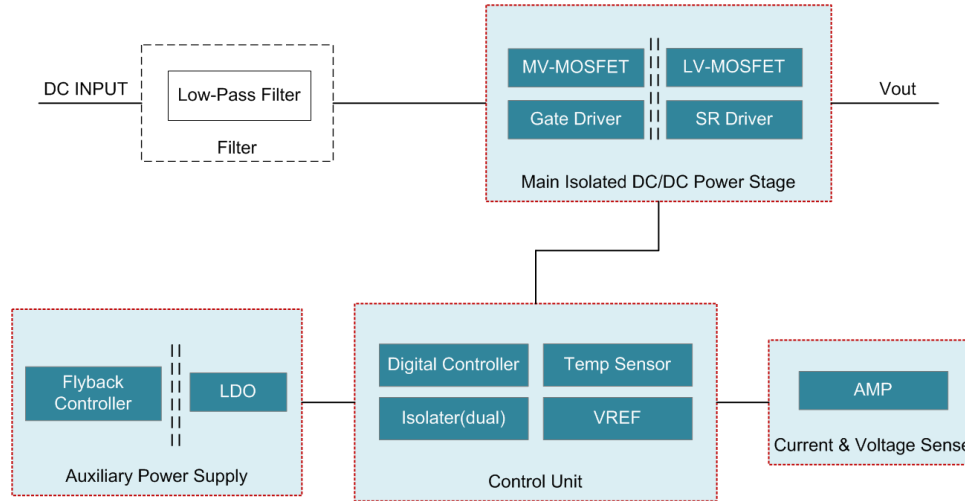
Benefits

- Isolated output for safety
- Small solution size
- Excellent line and load regulation with opto-coupler
- Cycle-by-Cycle current limit
- Secondary soft start

PMP20551 Efficiency



Target application 3 : High power isolated DC/DC converter



Topology:

Half-Bridge Topology:

LM5036, LM5035, LM5039

Full-Bridge Topology:

LM5045, UCC28251, UCC28250,
UCC28230, UCC28231,

Interleaved PWM Topology:

LM5034, LM5032, UCC28220

LLC Topology:

UCD3138

System requirement:

- High power density;
- High efficiency;
- Good thermal performance;

Half-Bridge PWM Controller with Integrated Auxiliary Bias Supply

Features

- 100V auxiliary bias converter (with integrated FETs for aux power)
- Fully regulated pre-biased start-up
- 5V synchronous rectifier PWM outputs with intelligent soft start that allows linear turn-on into pre-biased loads
- Enhanced cycle-by-cycle current limit with pulse matching
- Programmable latching operation
- Optimized maximum duty to improve efficiency
- 100V high voltage startup regulator
- Programmable synchronous rectifier dead time adjustments
- Integrated 100V/2A MOSFET drivers for primary FETs
- Voltage mode control with input voltage feedforward
- Programmable protections: reverse current, hiccup mode OCP, line UVLO and OVP
- Package: 5x5 mm 28-pin QFN

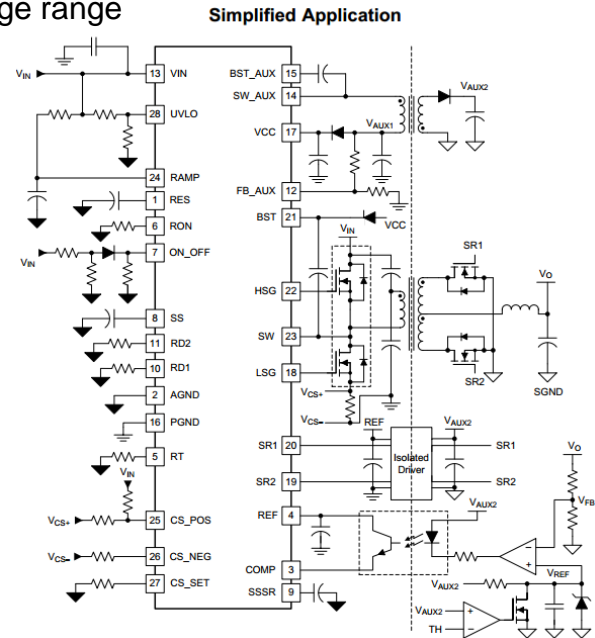
Applications

- Isolated DC/DC brick modules (e.g. 1/16th & 1/8th Brick)
- Telecom, Data Communication Systems
- Industrial Power Supplies

[LM5036 product folder](#)
[Datasheet](#)
[EVM](#)
[Simplis Model](#)
[Design Calculator](#)
[Function Block Diagram](#)

Benefits

- Higher efficiency and greater power density
- Monotonic startup into pre-biased load conditions
- Enhanced OCP with uniform current limit across input voltage range



LM5036 Top Features

High Power Density

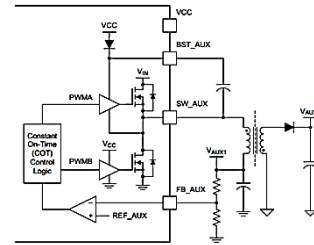
>390W/in³ High power-density isolated DC/DC
(48V_{in}/200W,12V_{out})



>200W in DOSA 1/16 brick

**100V Half-Bridge PWM With
2A integrated Gate Drivers
& 100mA Auxiliary Bias.**

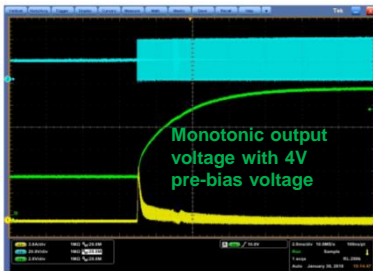
Low System Cost



Integrates a Fly-buck converter inside LM5036 to provide auxiliary bias to power on both primary and secondary sides

Built-in Fly-buck converter with integrated power MOSFETs, high + low side drivers, current sense.

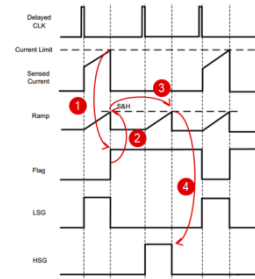
Solve Pre-bias Start-up Challenge



Achieves monotonic output voltage ramp up in pre-bias condition.

Intelligent pre-bias start-up procedure to eliminate the risk of restarting the load or damaging the DCDC converter.

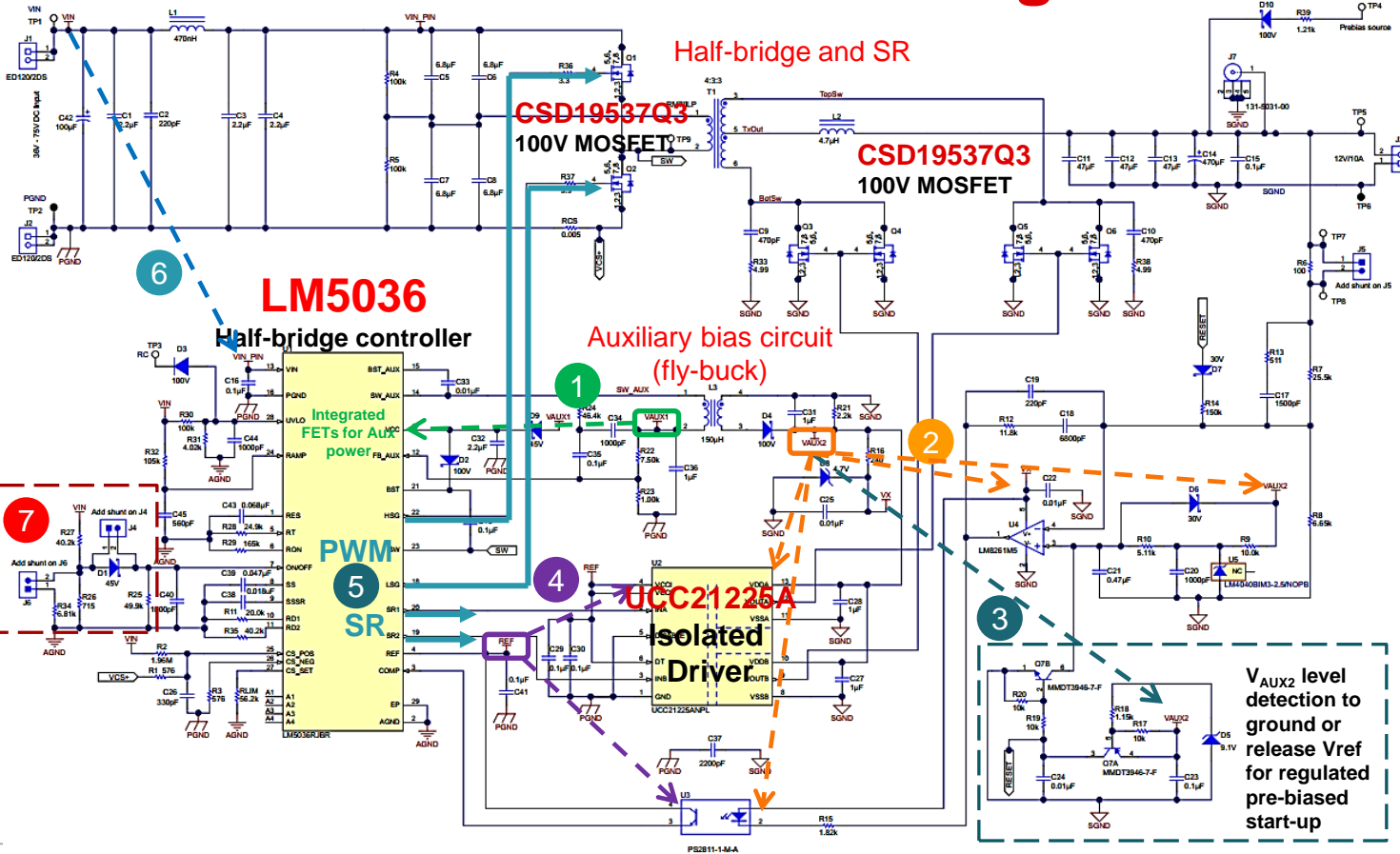
High Reliability



Programmable protections to secure reliability

- **Almost constant output power limit across wide VIN range.**
- **Both positive and reverse current protection and hiccup OCP.**
- **High/low PWMs matching in OCP.**
- **OVP, OTP, ULVO, latching, etc.**

LM5036 DCDC Converter Design



1. V_{AUX1} power to power on LM5036.
2. V_{AUX2} to power isolated driver, opto-coupler, op-amp, etc.
3. V_{AUX2} is also used as ENABLE signal in regulated pre-bias start-up. ([more info](#))
4. 5V REF to bias isolated driver, opto-coupler, and for other housekeeping ICs.
5. 2A primary side FETs drivers. SR outputs.
6. Up to direct 100V VIN range.
7. Configurable Latch or re-start. ([more info](#))

Used in [LM5036EVM-294](#) Design (36-75 VDC input, 12V/8A output)

LM5036 EVM, Samples

EVM Spec

Parameters	Test Conditions	MIN	TYP	MAX	Units
Input Characteristics					
DC voltage range		36	48	75	VDC
Load regulation			0.2%		
Line regulation			0.1%		
UVLO line voltage ON			34		VDC
UVLO line voltage OFF			32		VDC
OVP line voltage ON			80		V
OVP line voltage OFF			78		V
Latch threshold			80		V
V_{AUX1}	Off-state auxiliary output voltage		12.6		V
	On-state auxiliary output voltage		9		V
Max. load current for auxiliary supply			100		mA
Input DC current	Input = 36 VDC, full load = 8 A		2.858		A
	Input = 48 VDC, full load = 8 A		2.161		A
	Input = 75 VDC, full load = 8 A		1.416		A
Output Characteristics					
V_{out} output voltage	No load to full load = 8 A		12		VDC
I_{out} output current	35 to 75 VDC			8	A
Output current limit	35 to 75 VDC		10		A
Output voltage ripple	75 VDC and full load = 8 A		120		mVpp
System Characteristics					
Switching frequency			200		kHz
Peak efficiency	36 VDC, Load = 5.5 A		94.41%		
Maximum load efficiency	48 VDC, Load = 8 A		93.46%		
Operating temperature	Natural convection	-40		85	°C

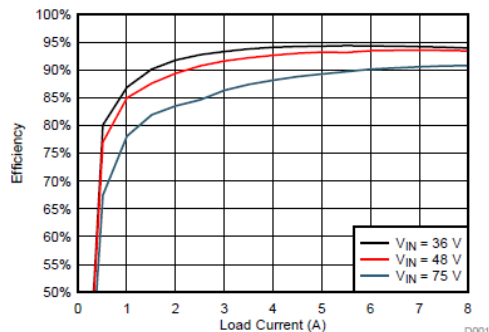
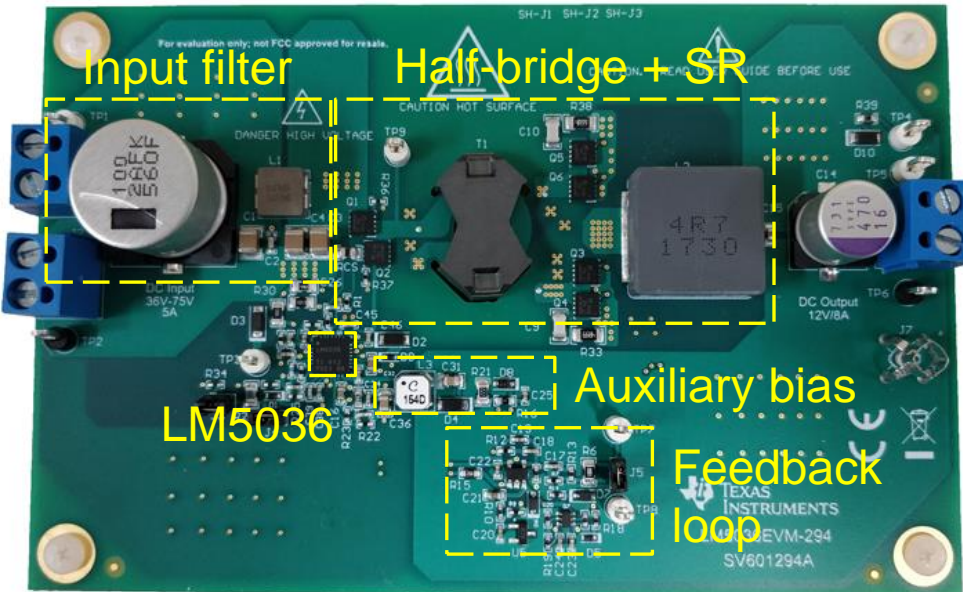


Figure 3. Efficiency vs Load Current (A) at $V_{in} = 36$ VDC, 48 VDC, and 75 VDC



- <http://www.ti.com/tool/LM5036EVM-294>
- [EVM User Guide](#)
- [Samples, TI Store](#) (up to 9999 pcs)

LM5045 Full-Bridge PWM Controller with Integrated MOSFET Drivers

Features

- Hard Switching Full Bridge Controller with Highest Integration
- Four Integrated 2A Bridge Drivers
- High Voltage Startup Regulator and Pre-Biased Startup
- Independent, Programmable Synchronous Rectifier Deadtime Adjustment
- Configurable Voltage/Current Mode Control
- Package Options: TSSOP-28 or WQFN-28

Applications

- [Telecom DC/DC Module](#)
- [Merchant Network & Server PSU](#)
- [Industrial Battery Packs](#)

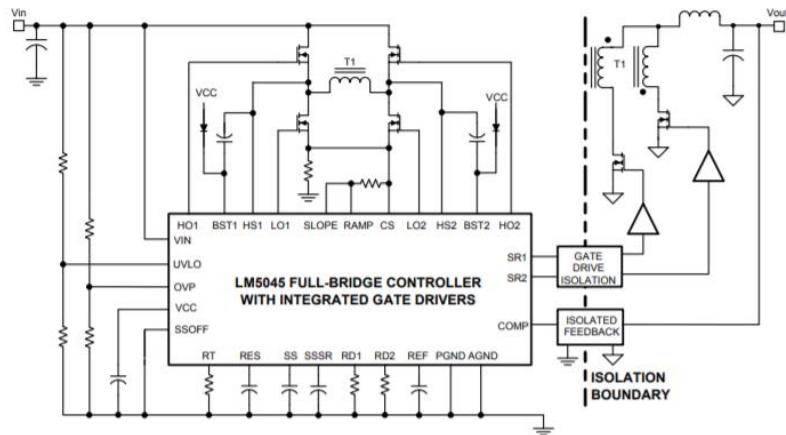
Tools & Resources

- [Evaluation Board](#)
- [User's Guide](#)
- [Tools & Software:](#)
Pspice Model, Design Calculator

- **Device Datasheets:**
– [LM5045](#)

Benefits

- Optimized for primary side operation, ideal for Small Form Factor, High Density Power
- No need for external gate drivers
- Eliminates need for external regulator
- Smooth startup reduces stress and current surge
- Maximum Flexibility - Ability to program primary to secondary and secondary to primary timing
- Design Flexibility



LM5045EVAL Evaluation Board

Key Specs: 36V–75V input, 3.3V @ 30A output, 420kHz

Device: LM5045

Features

- V_{IN} = 36V to 75V, V_{OUT} = 3.3V
- Efficiency up to 92% at 3.3V/30A
- Peak efficiency is 93% for 5V/30A
- Board size: 58mm(L) x 36.8mm(W) x 12.7mm(H)

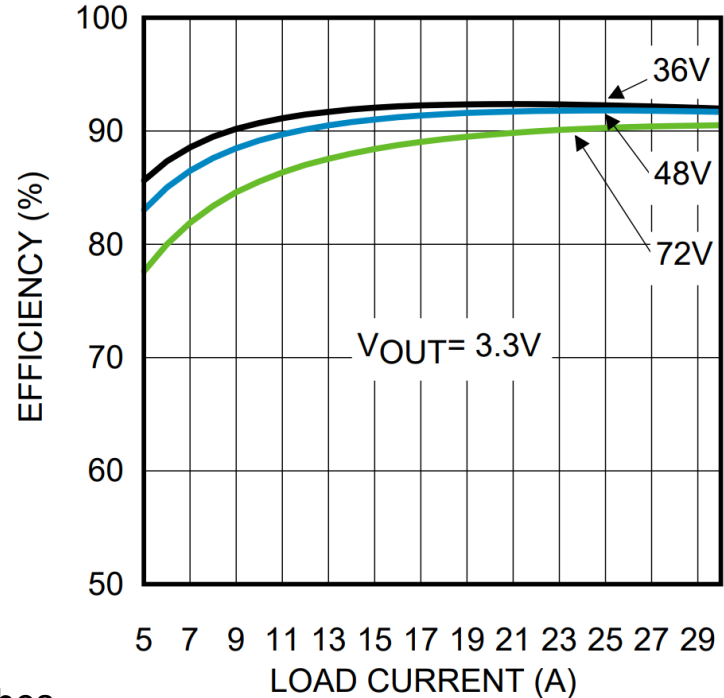
Applications

- Merchant DC/DC Converter



Board size:
2.28 x 1.45 x 0.5 inches

Performance



Thank You!