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 ±0.5% Tolerance from -40°C to 125°C Tj
- 10 Vref choices: 0.6V; 0.7 to 1.1V in 50mV steps
- 3.0mΩ/0.9mΩ 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

**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
- +/-10% Ilim Accuracy Over Temp & Process
- Up to 80A POL needs with flexible sync positions
- 90+% Efficiency Over a Wide Load Range

**Applications**

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

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

Tools & Resources
- TIDA-01444 Tools Folder
- Design Guide
- Design Files: Sch, BOM, Gerber
- Device Datasheets:
  - TPS543C20
  - TL432BQDBZR
  - LM20BIM7

Board Image (for reference)
Efficiency

Test condition:
Vin = 12Vdc   Vout = 3.3Vdc/21.7A + 5Vdc/21.7A
Test Result: 97.07% at 10A load current.

Test condition:
Vin = 12Vdc   Vout = 3.3Vdc/30A + 5Vdc/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 (-40°C to 125°C)
• 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

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

Applications

• POL modules
• Telecom Infrastructure
• Embedded computing, servers, storage
• Video surveillance
LM27403 Reference Design
High Efficiency, Performance, and Density POL Controller for PoL Modules and Comms Infrastructure

**Application Need**
- Accurate OCP design and reasonable Lo 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

**Product Configuration**

**TI Product Benefits**
- Temp Compensated OCP trip point → Very accurate OCP trip point within full temp range
- ~30ns Ton_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, Fadj, EN/UVLO

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V\textsubscript{IN} = 12V, V\textsubscript{OUT} = 1.2V, F\textsubscript{S} = 300kHz, T\textsubscript{A} = 25°C
HMP1360-1R0 inductor, 1.3mΩ, 30A
LM27403 Reference Design
DC-DC POL Module Ultra-High Efficiency $V_{IN} = 12V$
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 Tj; TSSOP-28

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.

Applications

- USB PD
- Wireless Charging
- Industrial PC
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

Performance

![Efficiency Graph]

Four 5x6mm 60V Buck FETs

Four 5x6mm 25V Boost FETs
Target application 2: Low power isolated DC/DC converter (~100W)

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

Topology:

**Fly-back Topology:**
LM5022, LM5122, LM5020, LM5021, LM34927

**Forward Topology:**
UCC2897A, LM5025A, LM5026, LM5034
UCC2891, UCC2892, UCC2893, UCC2894
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

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

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

Roadmap
# 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

<table>
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<th>Schematic</th>
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- UCC2897A
- UCC27511
- CSD18537NQ5A
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

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

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
- Device Datasheets:

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

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<tr>
<th>TI Parts</th>
<th>( V_{\text{in}} )</th>
<th>Po</th>
<th>( V_{o/lo} )</th>
<th>Topology</th>
<th>Eff.</th>
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<td>LM5025A</td>
<td>18~36 V</td>
<td>30W</td>
<td>5.1V/6.0A</td>
<td>ACF with S.R</td>
<td>91.3%</td>
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<td>CSD18504</td>
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**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”

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

### Applications
- Industrial POE

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**PMP20551 Efficiency**

![PMP20551 Efficiency Graph](image)
Target application 3: High power isolated DC/DC converter

System requirement:
- High power density;
- High efficiency;
- Good thermal performance;

Topology:

Half-Bridge Topology: LM5036, LM5035, LM5039

Full-Bridge Topology: LM5045, UCC28251, UCC28250, UCC28230, UCC28231,

Interleaved PWM Topology: LM5034, LM5032, UCC28220

LLC Topology: UCD3138
**LM5036**
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

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

### 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](#)
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.
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)
LM5036 EVM, Samples

- 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

### 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

### 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

Roadmap
LM5045EVAL Evaluation Board
Key Specs: 36V–75V input, 3.3V @ 30A output, 420kHz

Device: LM5045

Features
- VIN= 36V to 75V, VOUT=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

Performance

Board size: 2.28 x 1.45 x 0.5 inches
Thank You!