Powering Isolated Gate Drivers in HEV/EV Traction Inverters

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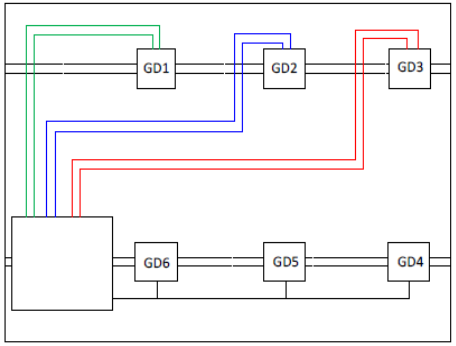
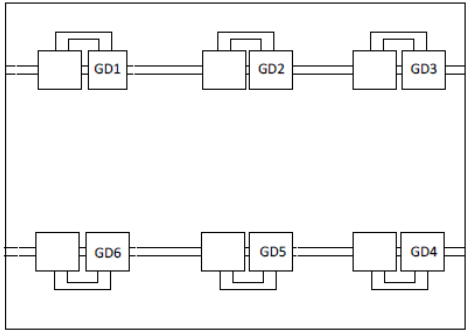
Bias Supply Architecture

Power Architecture:

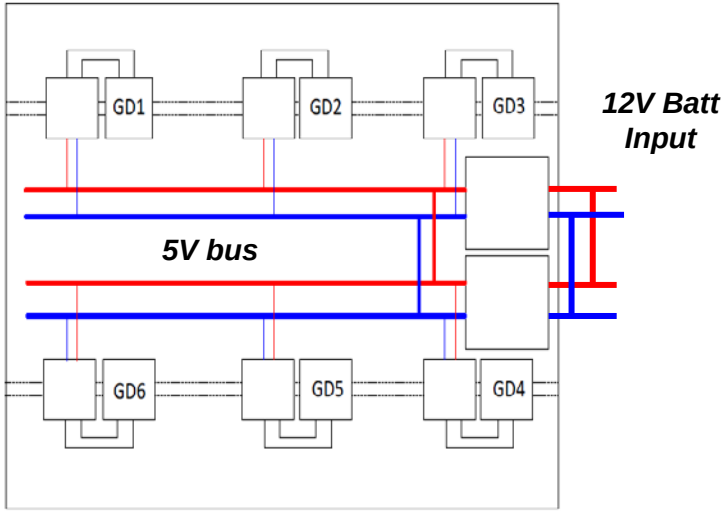
- Centralized: 1 Iso-supply for 6 drivers
- Distributed: 6 Iso-supplies for 6 drivers
- 2-Stage: 2 Buck Converter + 6 Simpler Iso-supplies for 6 drivers
- Two-stage architecture in redundancy for increased level of safety



Centralized Power



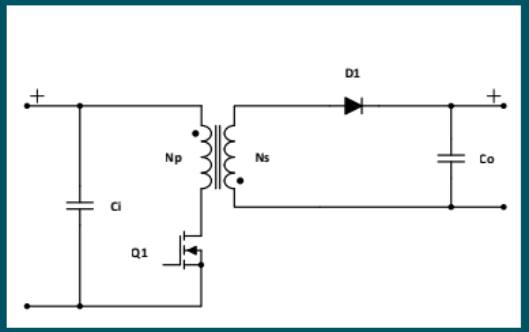
Distributed Power



Two-stage Power Architecture

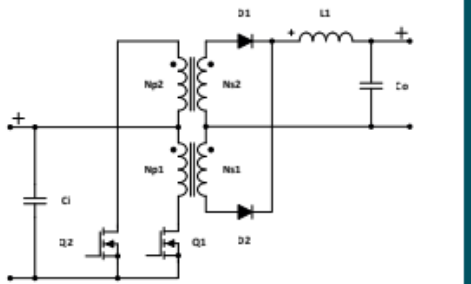
Bias Supply Topologies

Flyback



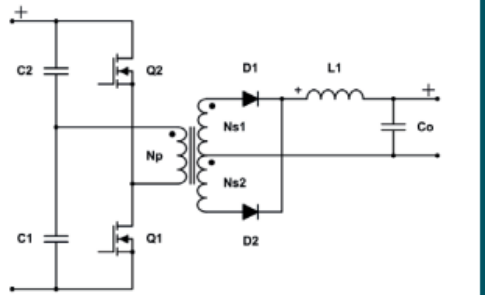
- Simple topology with Single FET
- Fewer component counts
- Easiness in control
- **Relatively large transformer size**
- **FETs need to withstand the input voltage plus fly back voltage**

Push-Pull



- Better utilization of transformer core hence smaller transformer size
- **Potential flux walking issue.**
- **Two FETs need to be used.**
- **FETs need to withstand twice of the input voltage.**

Half - Bridge



- Better utilization of transformer core hence smaller transformer size
- **Over Current Protection needs to be at high side**
- **Two FETs need to be used with high side driver.**
- **Current mode control not suitable.**

BIAS SUPPLY PERFORMANCE COMPARISON (BASED ON TIDA-020014 AND FLYBUCK SOLUTIONS)

TIDA-020014

HEV/EV traction inverter power stage with 3 types of IGBT/SiC bias supply solutions reference design

Design Features

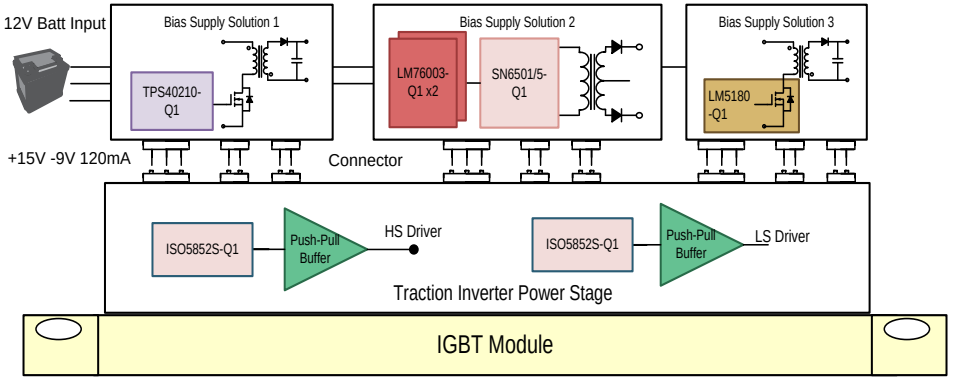
- 4.2W single channel, +15V and -8V outputs, configurable into +20V, -4V outputs
- Directly driven by 12V car battery with increased level of safety
- Wide-Vin during very low dips in input voltage of 4.5V and up to 42V DC (Refer to ISO7637 for 12V battery input transients, full power not required when Vin<6V)
- PSR power supplies with no Opto coupler
- Low IQ operation at no-load current
- High efficiency cross loads

Tools & Resources

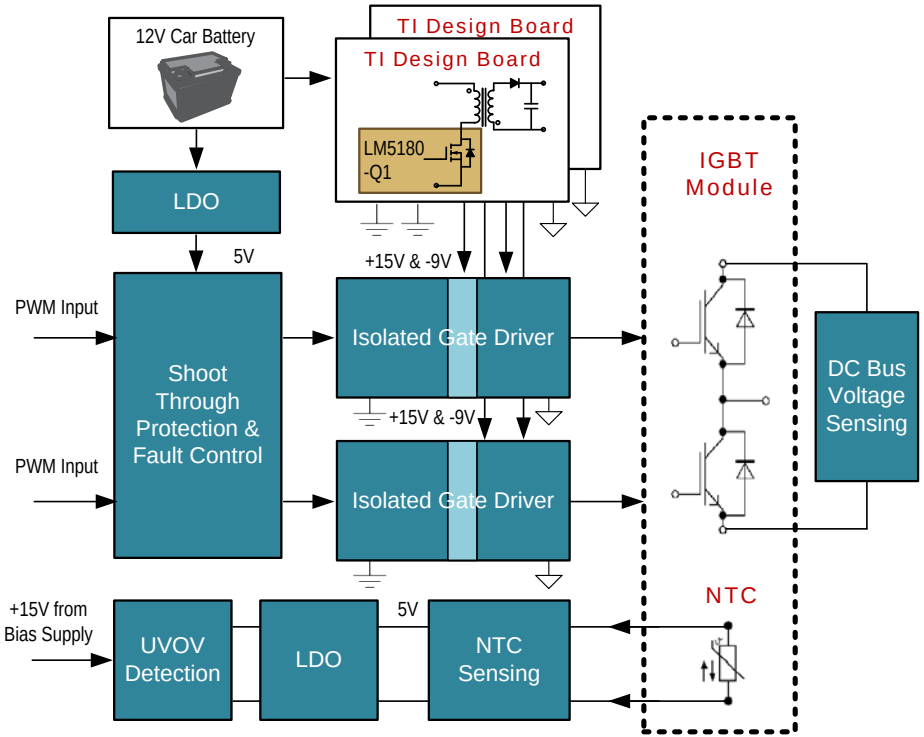
- Expected complexity of the TI Design
  - Main ICs: ISO5852S-Q1, AMC1311-Q1, AMC1301-Q1,LM5180-Q1, TPS40210-Q1, LM46002-Q1, SN6505-Q1, LM74700-Q1, TL431-Q1
  - # of passives: ~140 into 3 boards
  - PCB dimensions: ~60mm*40mm each board
  - # of PCB layers: 2
  - Firmware needs: N/A

Design Benefits

- A comprehensive design with multiple bias supply solutions for IGBT/SiC isolated gate drivers in HEV/EV
- Multiple solutions including PSR Flyback Converter, Flyback Controller, Buck + Push-pull
- Small size, compact, cost effective
- Plug in connection to IGBT driver board for easy HV evaluation
- Compatible Isolated Gate Driver board included for customer evaluation



Single Phase Inverter Power Stage



System Block Diagram

Include:

- Gate Driver, Power, Protection, Temp Sensing, Logic Shoot through protection, and Diagnostics
- 1.2KV 225A IGBT Power Module (FF150R12MS4G)

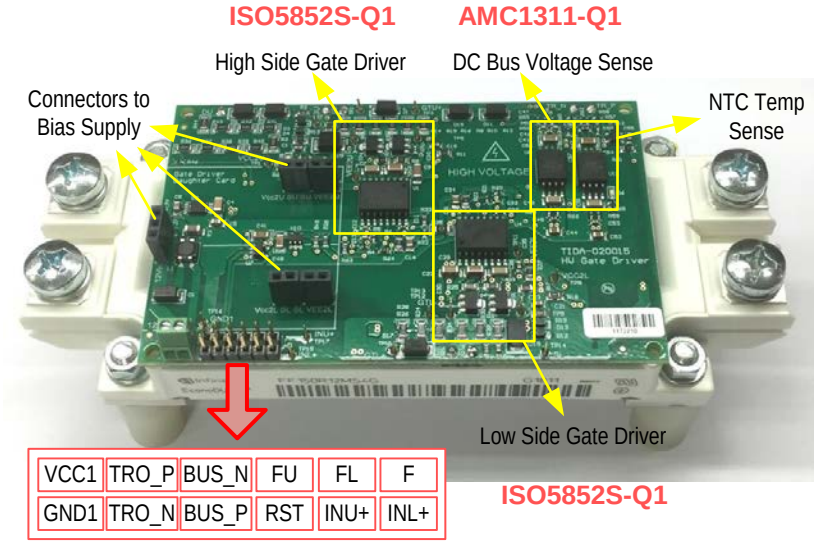
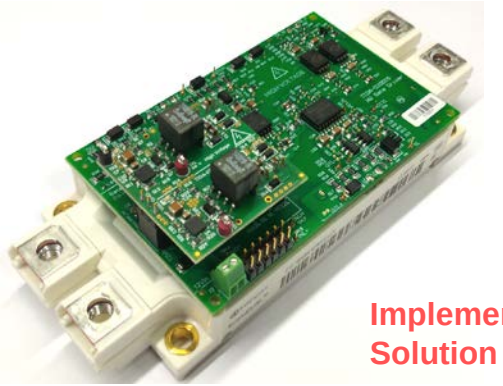
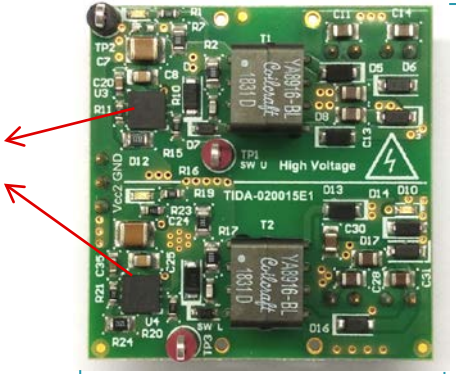


Image of the power stage

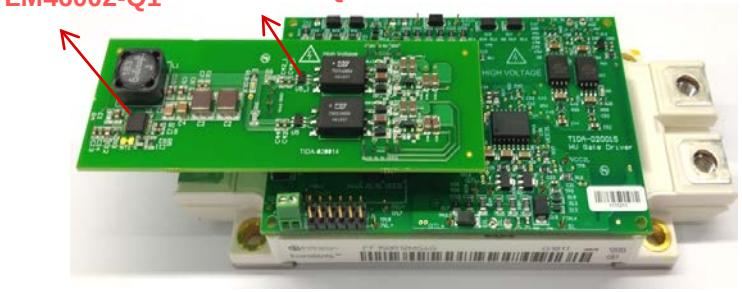
TIDA-020014 Board Image



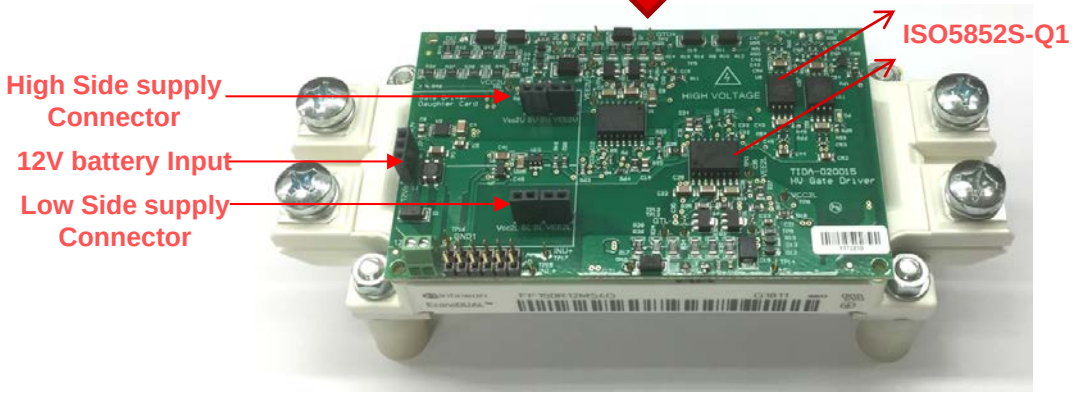
Implementation of Bias Supply Solution 1 (LM5180-Q1 flyback)



Plug on top

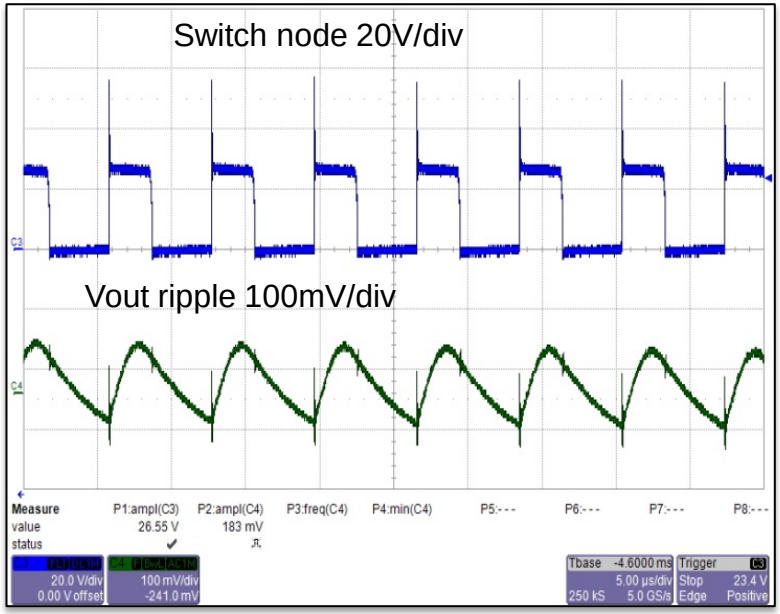


Implementation of Bias Supply Solution 3 (Buck + Push-pull)

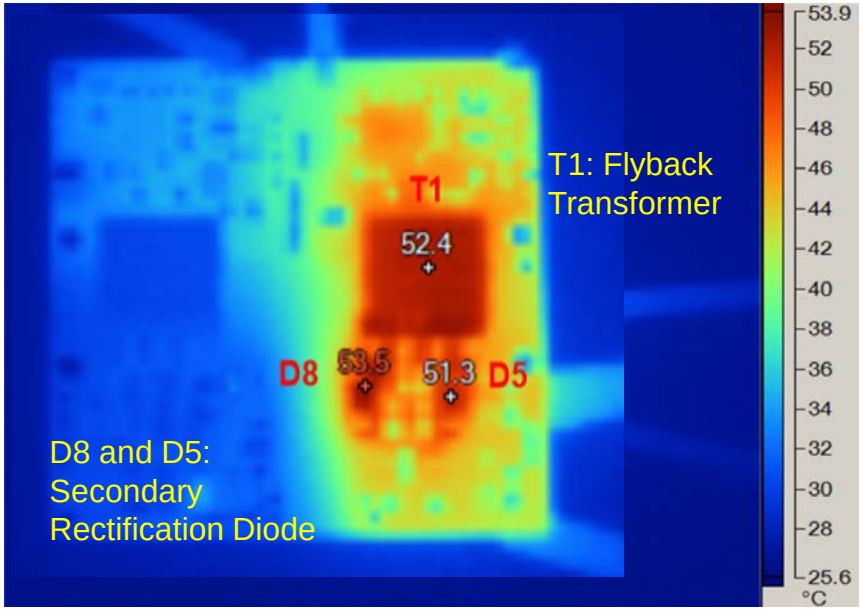


FLYBACK BASED ON LM5180-Q1 CONVERTER

Bias Solution 1 (LM5180-Q1 Flyback Converter)

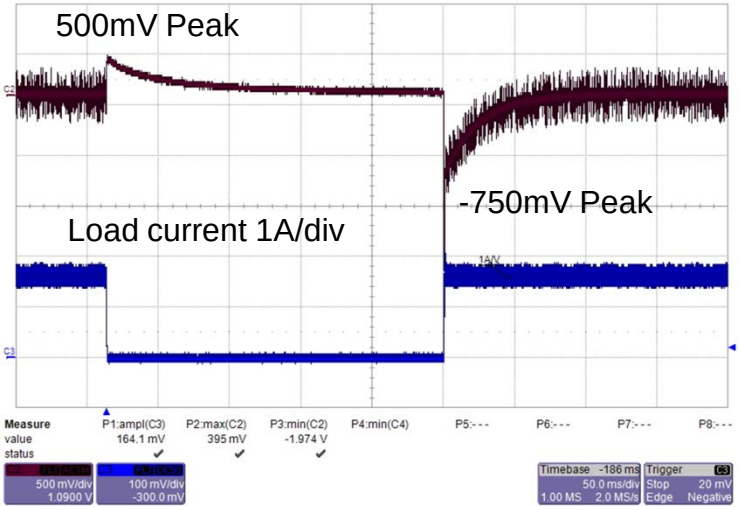


Switching node waveform and output voltage ripple of +15V rail Ripple with Vin=12V and 180mA Iout (5µs/div)

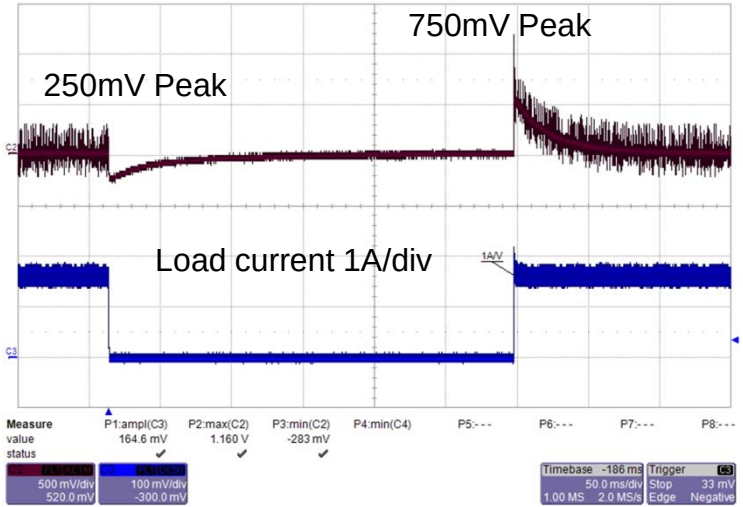


Thermal Image with Vin = 12V and Iout=180mA

Bias Solution 1 (LM5180-Q1 Flyback Converter)

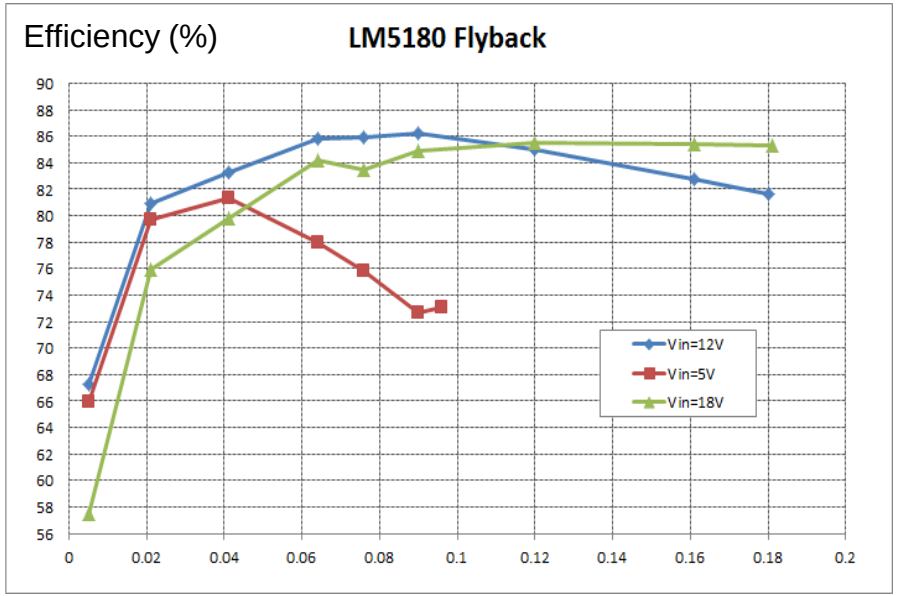


Load transient response of the +15V rail under Vin = 12V and Iout switching between 0 and 180mA (50ms/div)

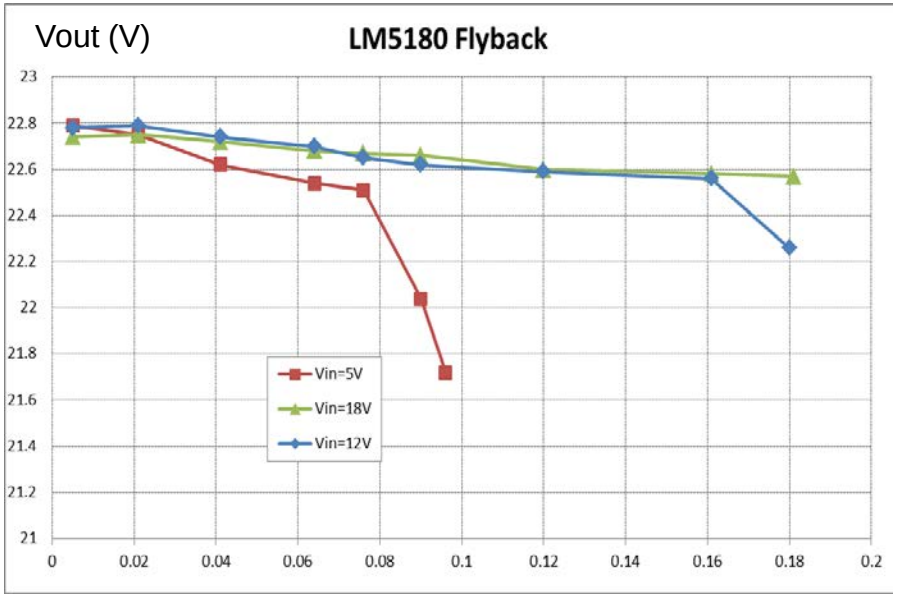


Load transient response of the -9V rail under Vin = 12V and Iout switching between 0 and 180mA (50ms/div)

Bias Solution 1 (LM5180-Q1 Flyback Converter)

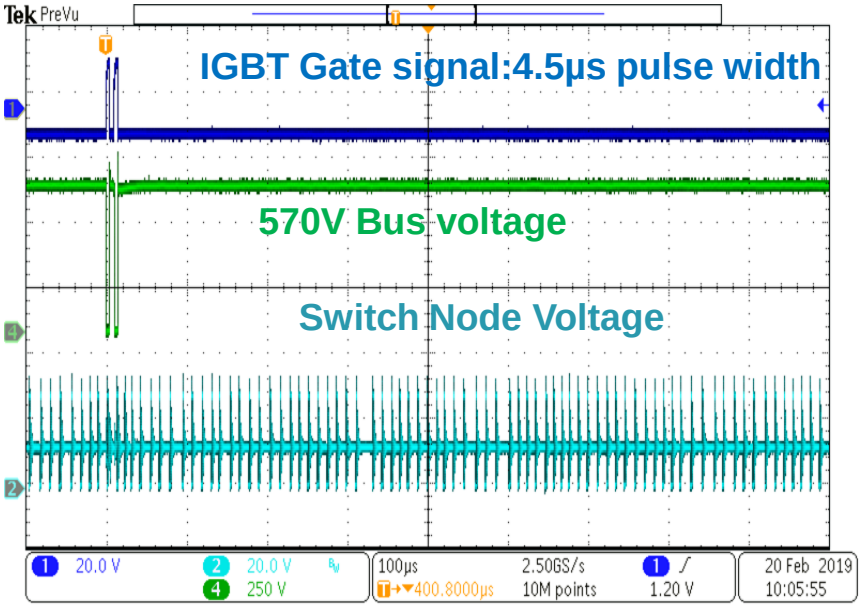


Efficiency
(86.2% peak at 12Vin)

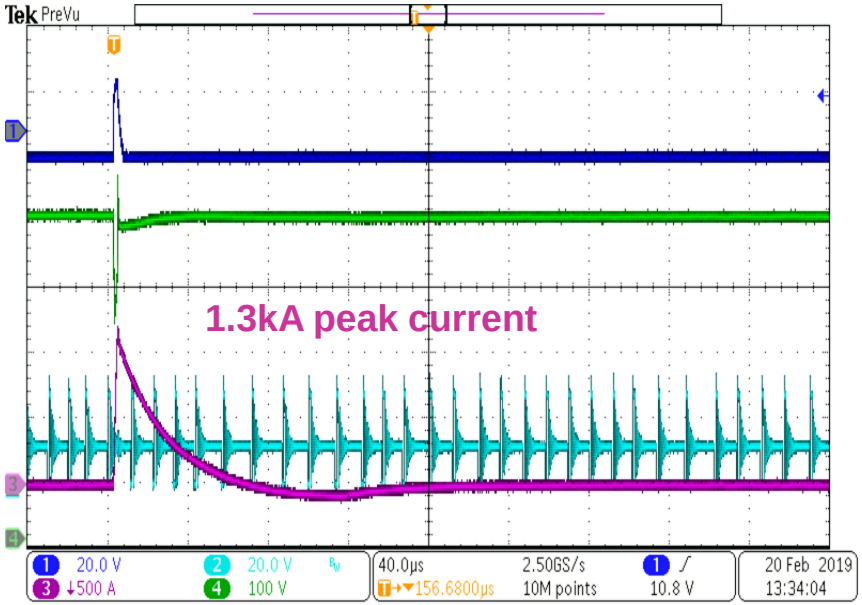


Load Regulation
(2.28% decrease between 0 and 180mA load)

Bias Solution 1 (LM5180-Q1 Flyback Converter)



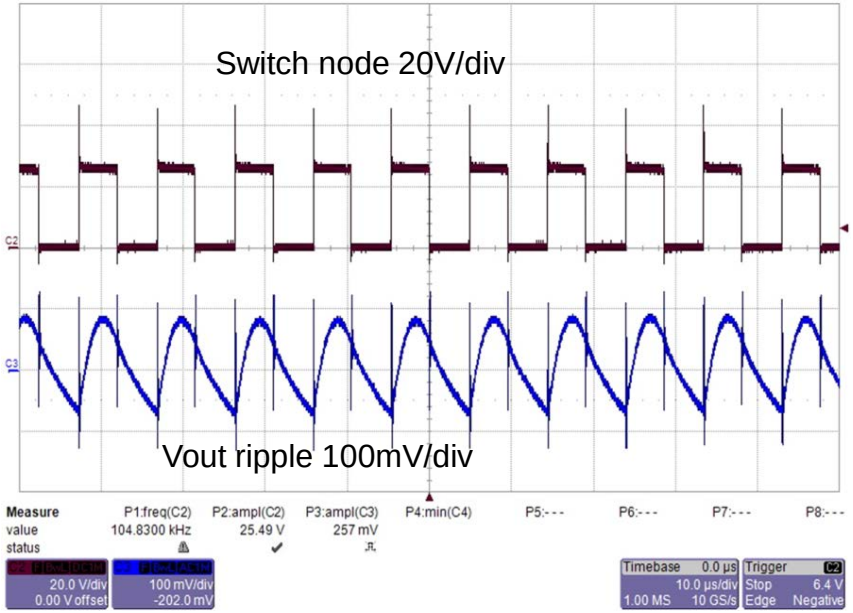
CMTI (570V Bus voltage)



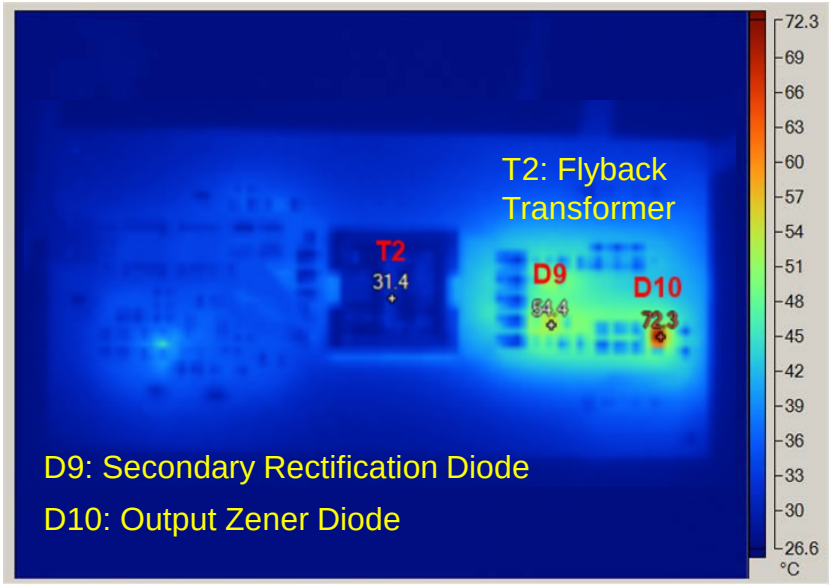
Short Circuit Test

FLYBACK BASED ON TPS40210-Q1 CONTROLLER

Bias Solution 2 (TPS40210-Q1 Flyback Controller)

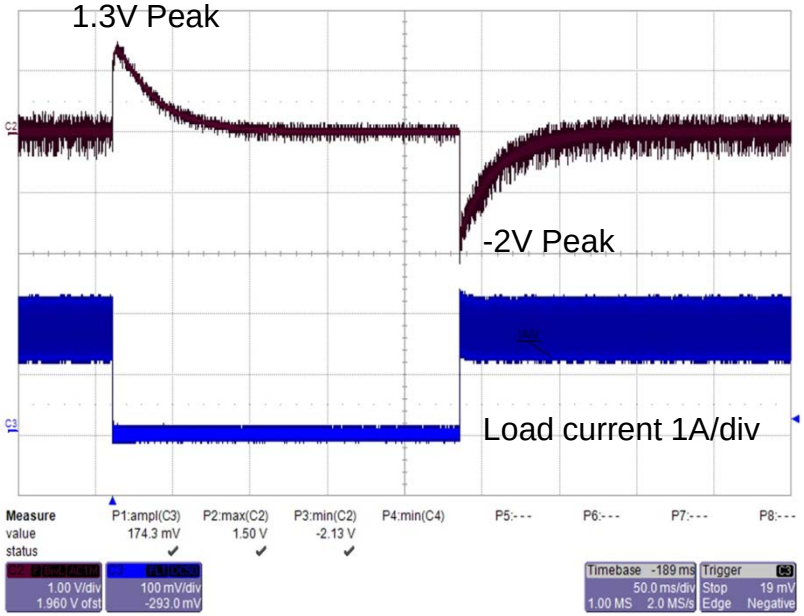


Switching node waveform and output voltage ripple of +15V rail Ripple with 12Vin and 180mA Iout (10µs/div)

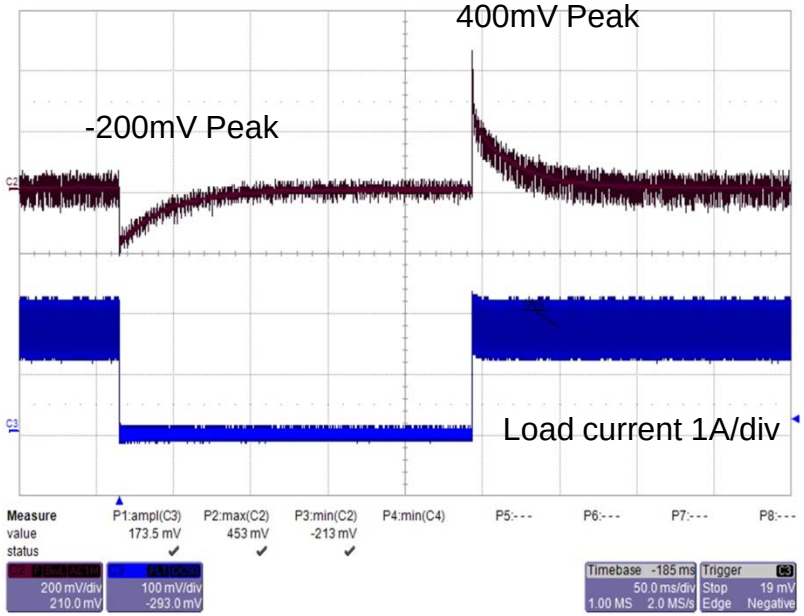


Thermal Image with Vin = 12V and Iout=180mA

Bias Solution 2 (TPS40210-Q1 Flyback Controller)

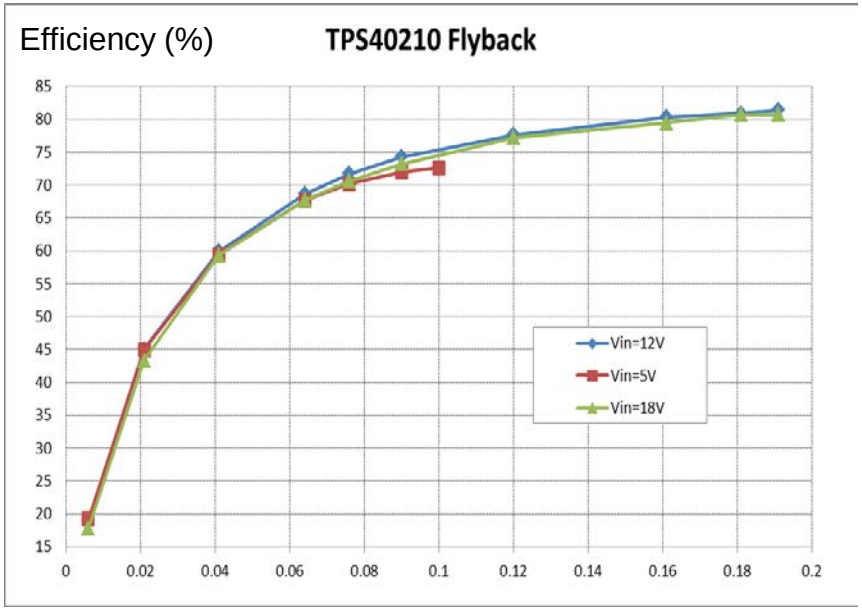


Load transient response of the +15V rail under Vin = 12V and Iout switching between 0 and 180mA (50ms/div)



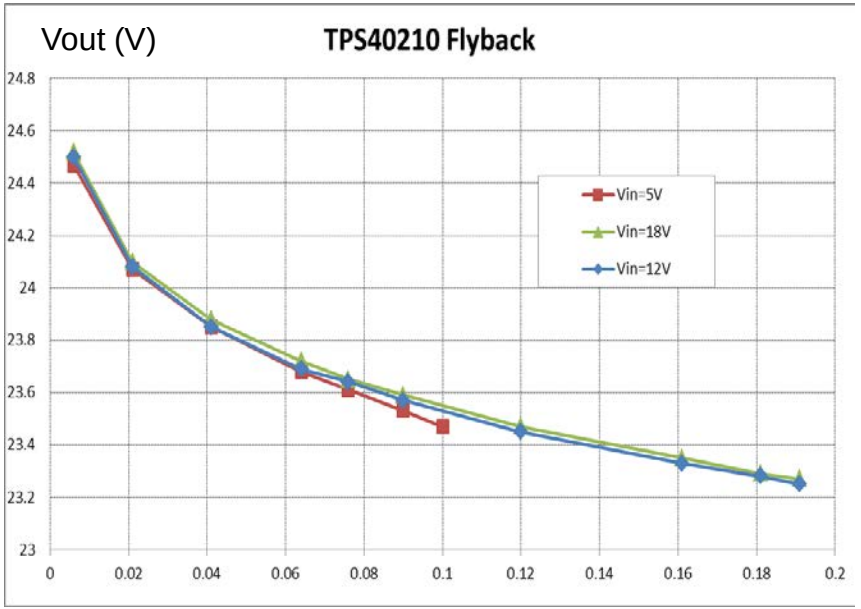
Load transient response of the -9V rail under Vin = 12V and Iout switching between 0 and 180mA (50ms/div)

Bias Solution 2 (TPS40210-Q1 Flyback Controller)



Output Current (A)

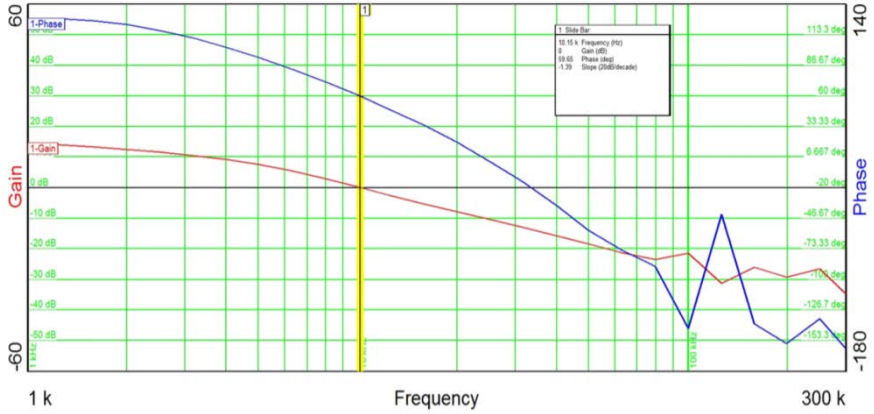
Efficiency
(81.3% peak at 12Vin)



Output Current (A)

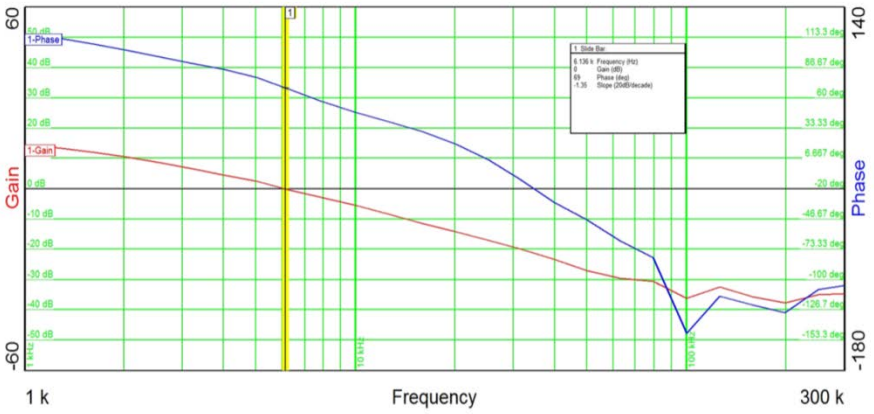
Load Regulation
(5.1% decrease between 0 and 180mA load)

Bias Solution 2 (TPS40210-Q1 Flyback Controller)



Loop Frequency Response With
VIN = 5 V and Iout = 10 mA

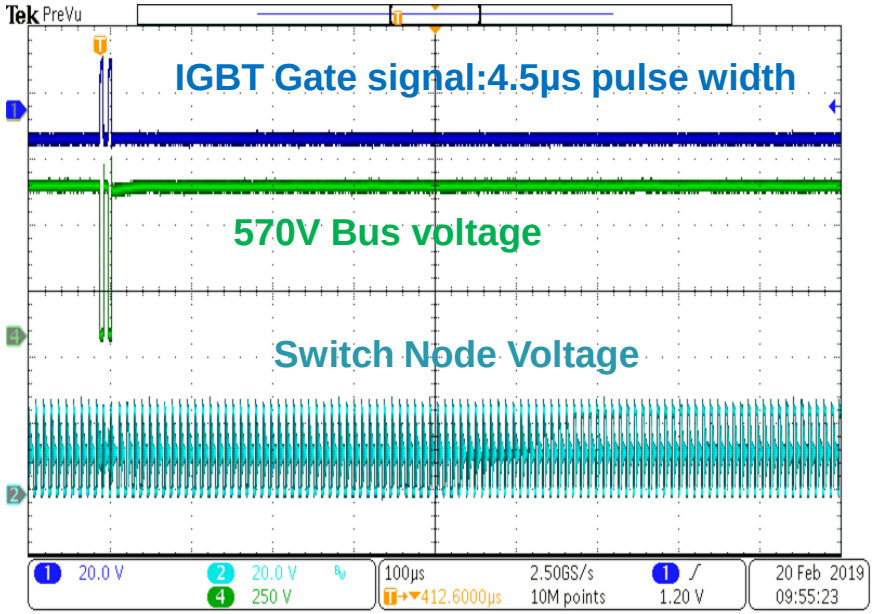
Crossover Frequency: 10.15kHz
Phase Margin: 59 deg
Gain Margin: 15dB



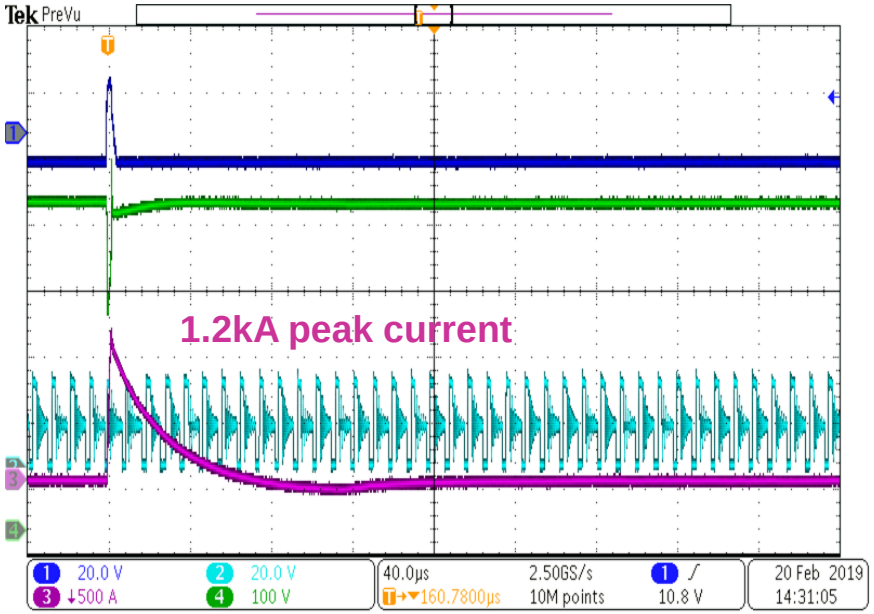
Loop Frequency Response With
VIN = 12 V and Iout = 180 mA

Crossover Frequency: 6.1kHz
Phase Margin: 69 deg
Gain Margin: 23dB

Bias Solution 2 (TPS40210-Q1 Flyback Controller)



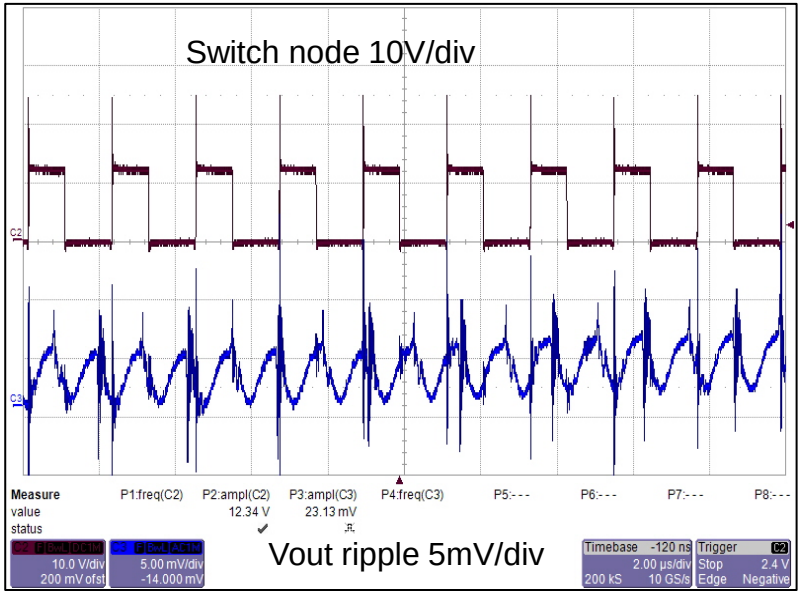
CMTI (570V Bus voltage)



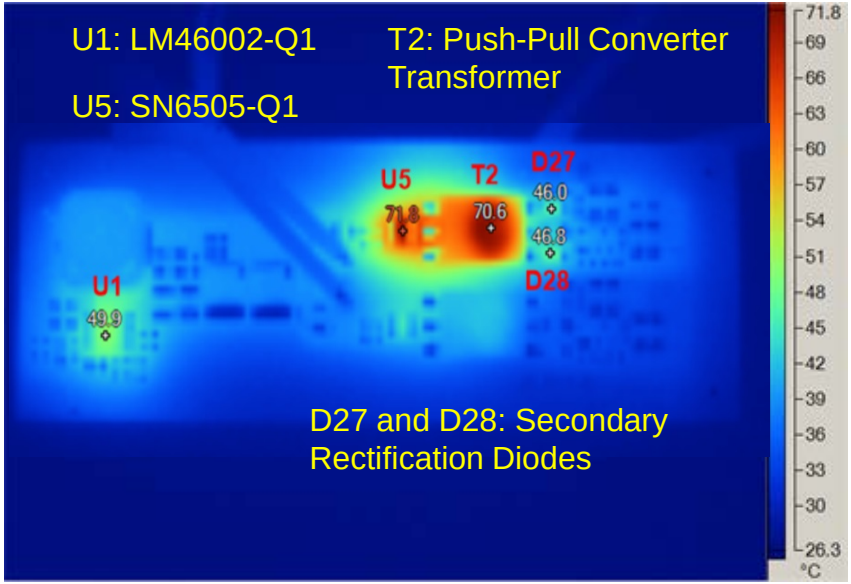
Short Circuit Test

WIDE VIN BUCK + PUSH PULL TRANSFORMER DRIVER

Bias Solution 3 (Buck with Transformer Driver)

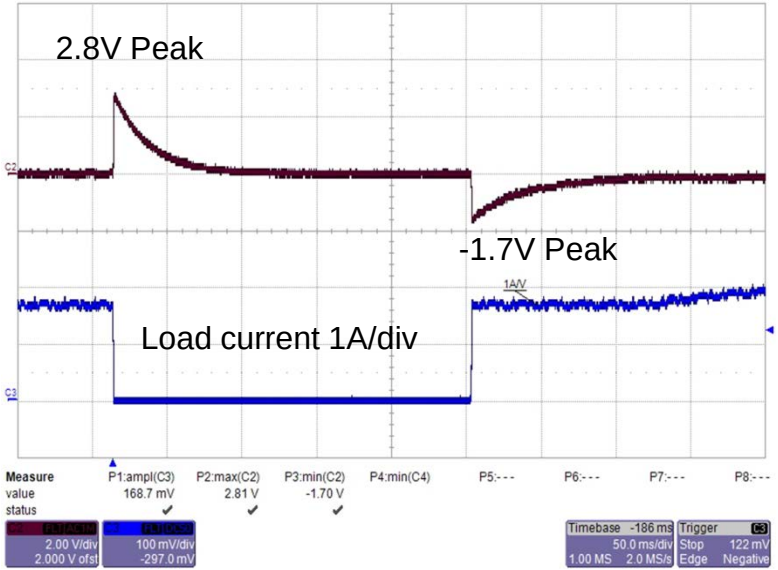


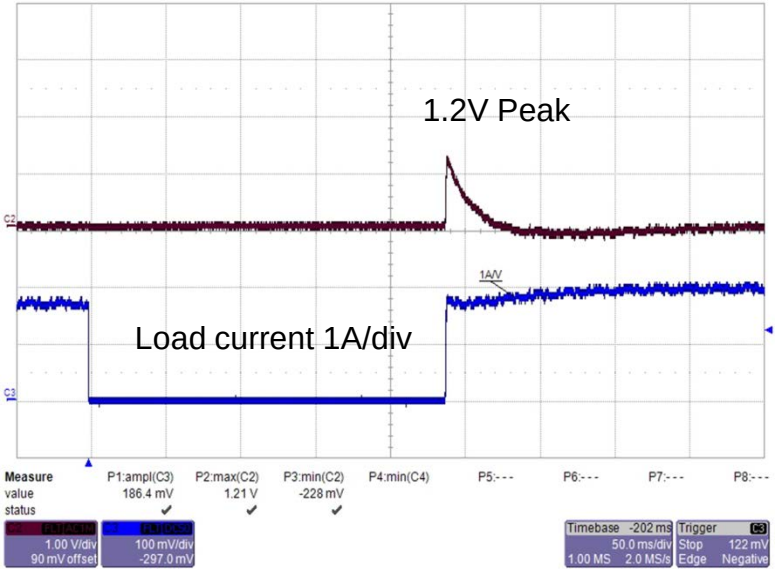
Switching node waveform and output voltage ripple of +15V rail Ripple with Vin=12V and 180mA Iout (2µs/div)



Thermal Image with Vin = 12V and Iout=180mA

Bias Solution 3 (Buck with Transformer Driver)

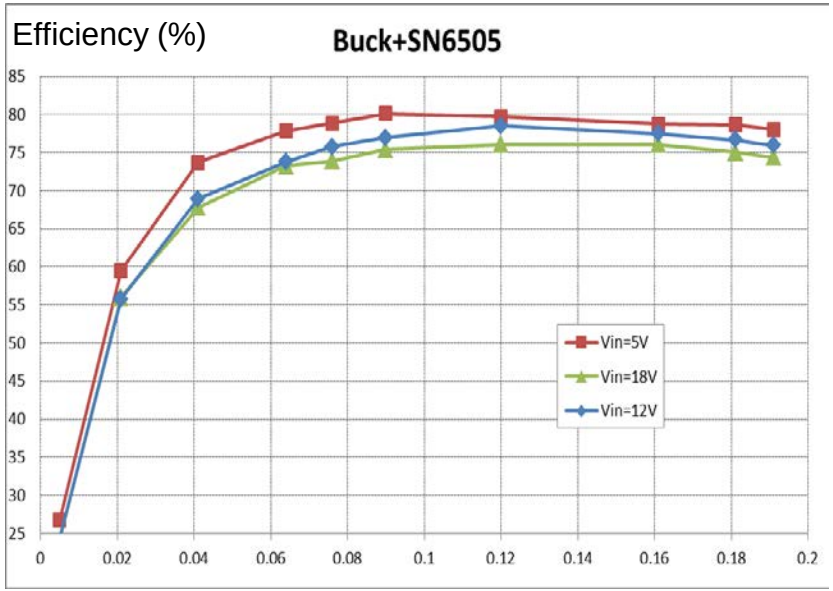




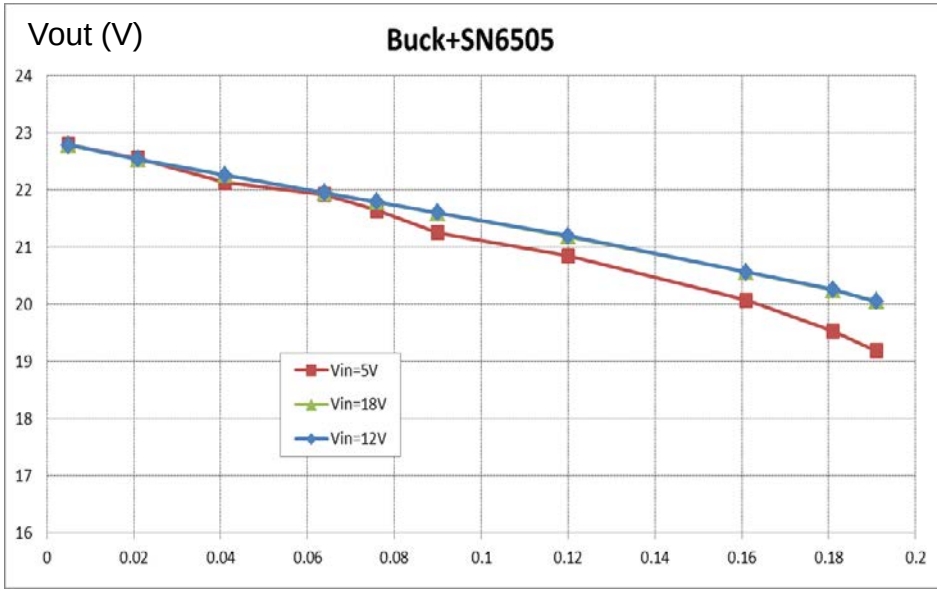
Load transient response of the +15V rail under Vin = 12V and Iout switching between 0 and 180mA(50ms/div)

Load transient response of the -9V rail under Vin = 12V and Iout switching between 0 and 180mA (50ms/div)

Bias Solution 3 (Buck with Transformer Driver)

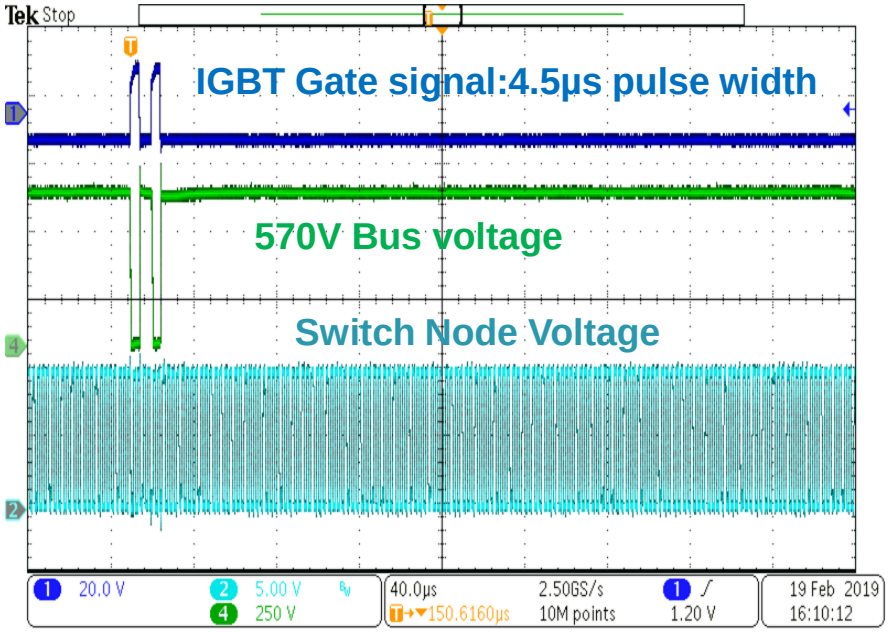


Efficiency
(78.5% peak at 12Vin)

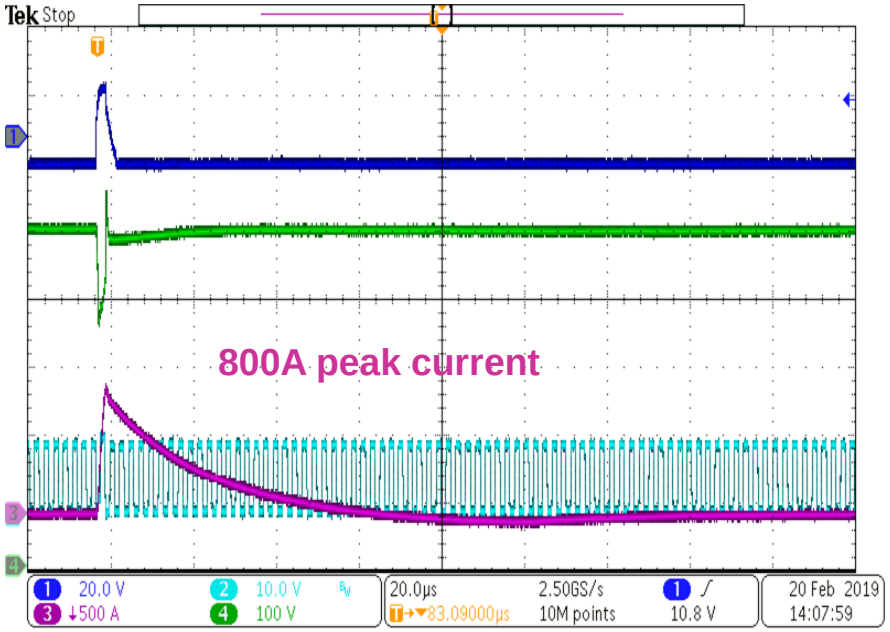


Load Regulation
(11.9% decrease between 0 and full load)

Bias Solution 3 (Buck with Transformer Driver)



CMTI (570V Bus voltage)



Short Circuit Test

PMP10654 – 8V-20Vin Flybuck with LM5160-Q1

1.5A 65V Synchronous Buck Converter or Isolated Flybuck

Features

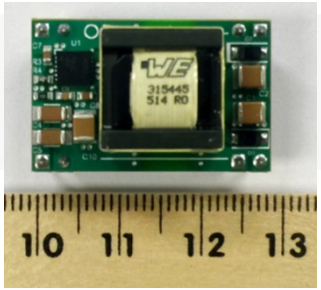
- Dual isolated outputs, +15V/-9V @ 200mA, 4.8W power,
- +/-5% cross regulation, 8V to 20V input range, 210kHz switching frequency.
- LM5160-Q1 wide input 65V, 1.5A sync buck / Fly-Buck regulator
- Integrated Ultralow on-resistance MOSFETs
  - No Schottky diode required
  - 1.5A maximum output current
- **Constant on-time control**
- **CCM option supports Isolated Flybuck**
- Line UVLO with adjustable hysteresis
- Programmable soft-start with prebiased startup
- Near constant frequency adjustable to 1MHz

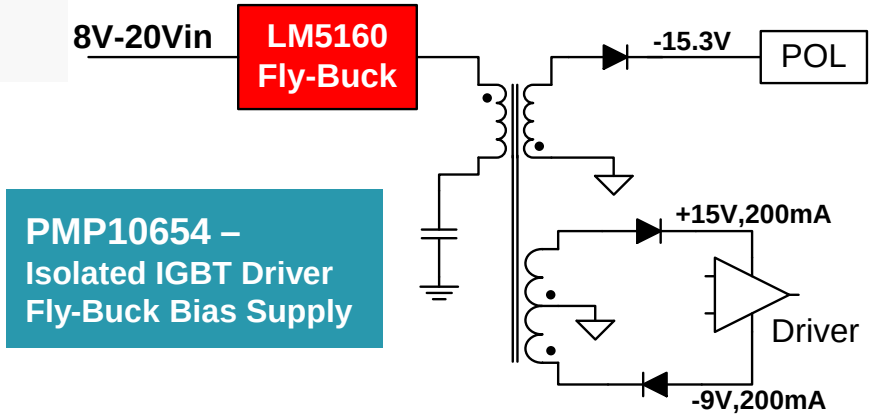
Benefits

- Integrated buck and sync FETs save space and provide ease of use
- COT control easy to use, low component count and fast transient response
- No compensation needed
- Provide easy isolated bias design with Flybuck
- DCM model enhances light load efficiency

Applications

- Industrial PLC
- IGBT Gate Driver Bias
- E-Meters
- Automotive

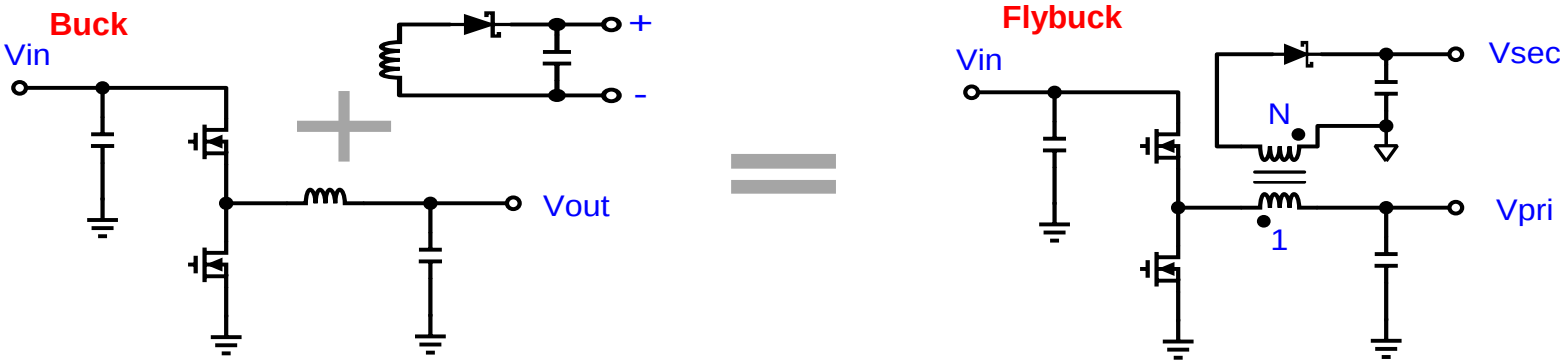




Fly-Buck™: Small, Simple Isolated Bias Power

How It Works:

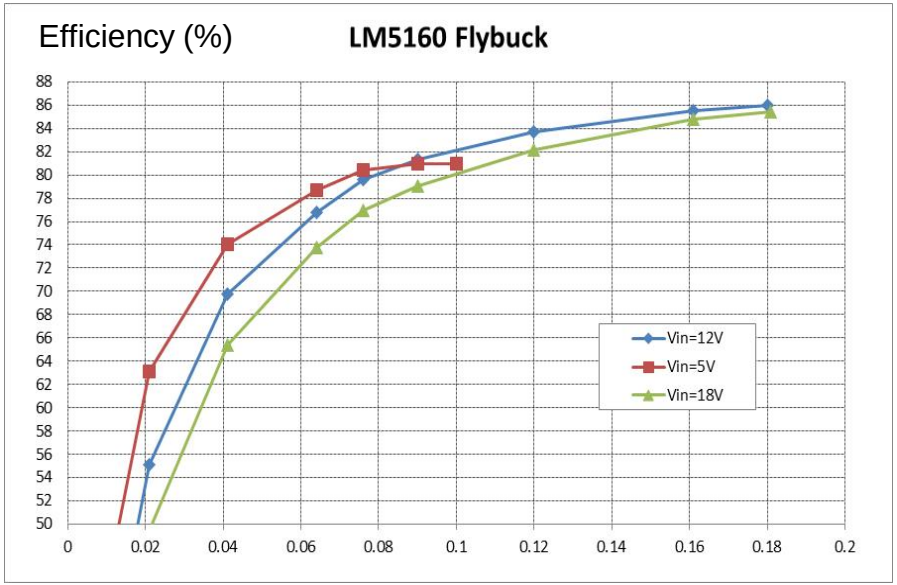
- The Flybuck converter is evolved from a synchronous buck converter by adding coupled windings to the inductor to have flyback-like isolated outputs.
- Supports multiple isolated outputs by adding more secondary windings to the transformer
- A simple and low part count solution for multi-output/isolated power supply design



Why Customers Like It:

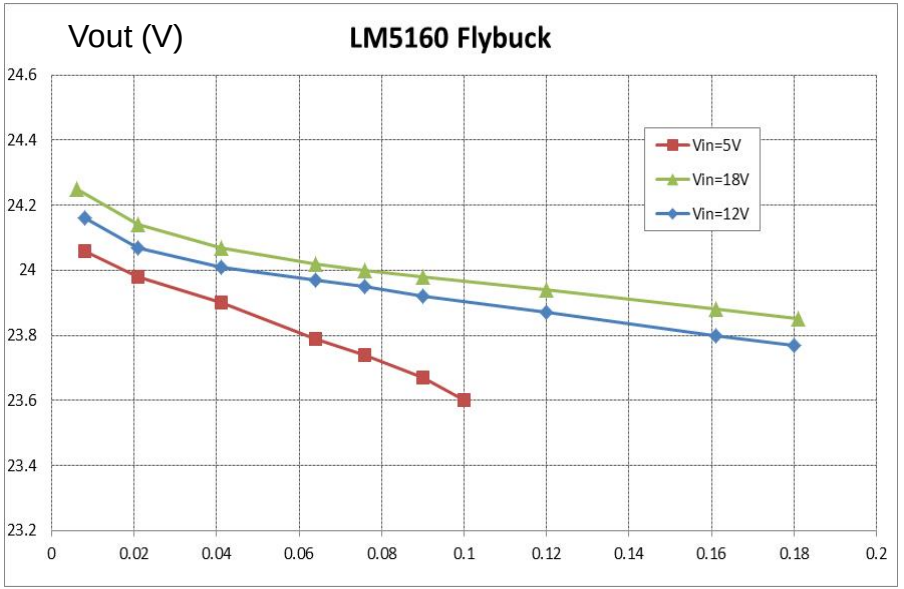
- **Small & simple:** lower parts-count circuit & smaller PCB area vs. flyback circuits
- **No opto-isolator needed** (one of the highest cost and least reliable components)
- **High Performance:** higher efficiency with good regulation
- **Flexible:** use the same device for simple step-down and a wide variety of isolated circuits

Flybuck Solution (LM5160-Q1 Converter)



Output Current (A)

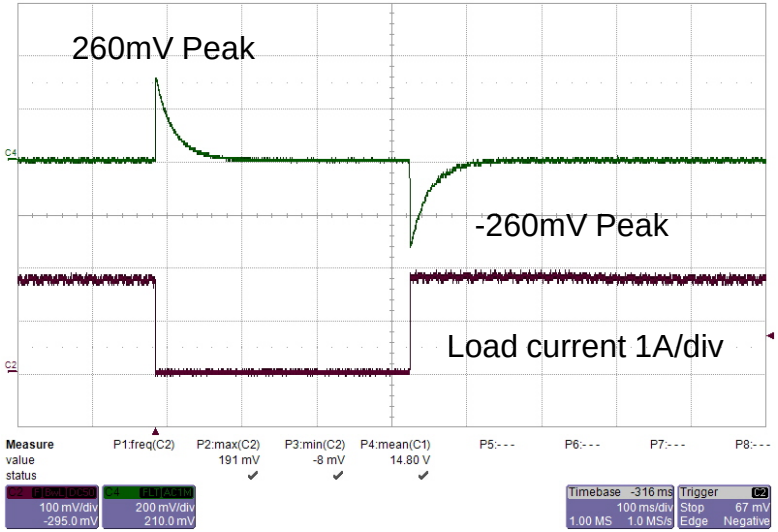
Efficiency
(85.9% peak at 12Vin)



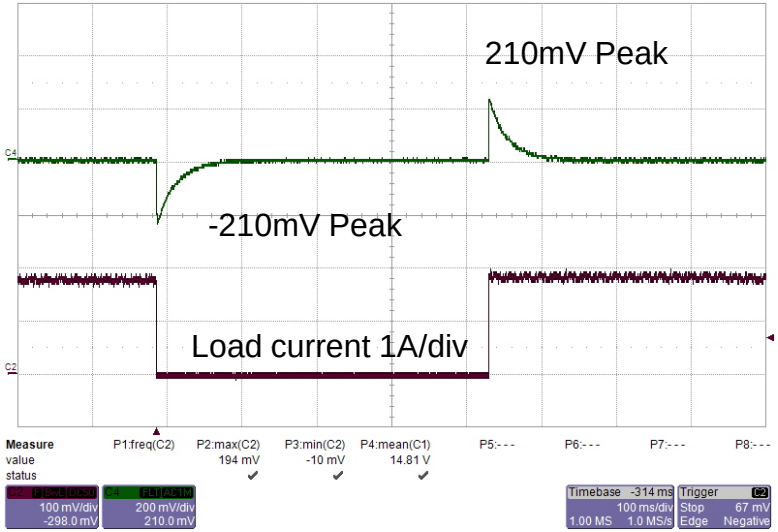
Output Current (A)

Load Regulation
(1.6% decrease between 0 and 180mA load)

Flybuck Solution (LM5160-Q1 Converter)

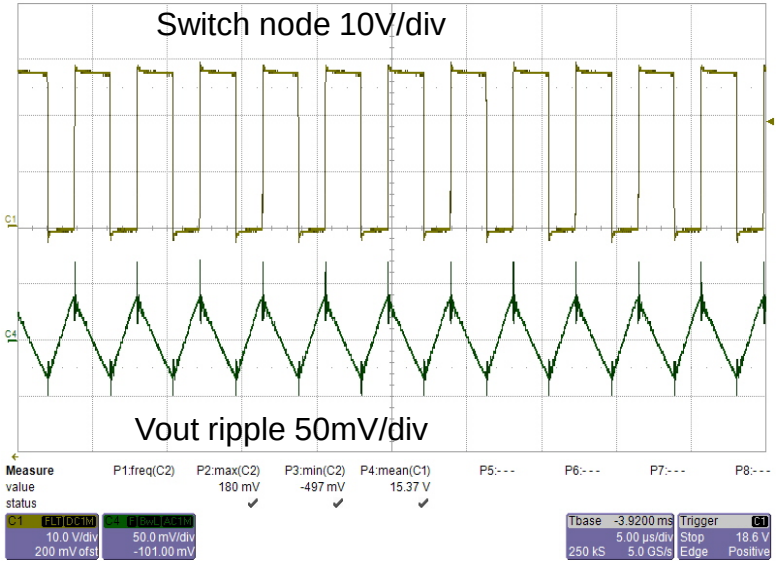


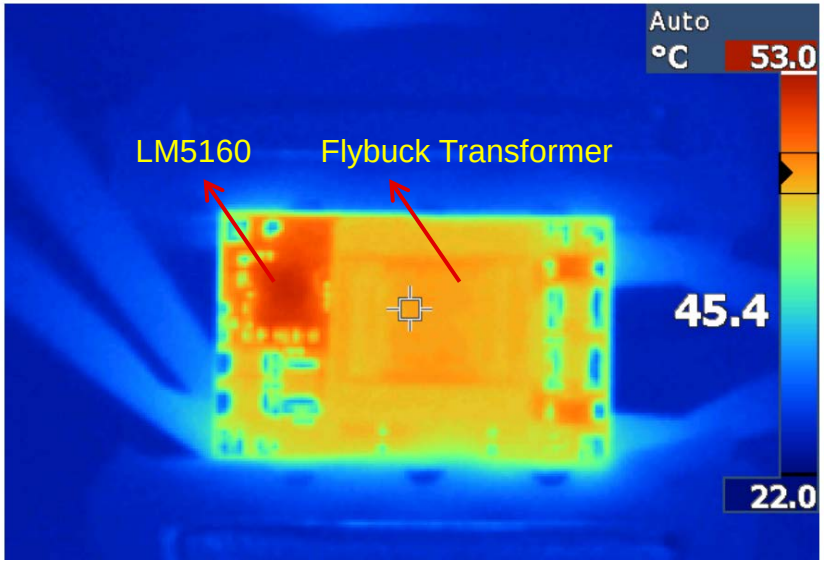
Load transient response of the +15V rail under Vin = 12V and Iout switching between 0 and 180mA (100ms/div)



Load transient response of the -9V rail under Vin = 12V and Iout switching between 0 and 180mA (100ms/div)

Flybuck Solution (LM5160-Q1 Converter)





Switching node waveform and output voltage ripple of +15V rail Ripple with Vin=12V and 180mA Iout (5µs/div)

Thermal Image with Vin = 12V and Iout=180mA

Comparison

Topology	Efficiency	Load Regulation	Load Transients	Solution Size (Dual)	High-lights	Low-lights
LM5180-Q1 Flyback Converter	86.2% peak at 12Vin	2.28% decrease	3.3% Overshoot 5% Undershoot	37mm X38mm	Regulation (++) Tran Response (+) Size (+++) Easy design (+++) Efficiency (++)	Cost (---)
TPS40210-Q1 Flyback Controller	81.3% peak at 12Vin	5.1% decrease	8.6% Overshoot 13% Undershoot	160mm X64mm	Cost (+++) Regulation (+) Efficiency (+)	Size (--) Tran Response (--)
Buck with SN6505-Q1	78.5% peak at 12Vin	11.9% decrease	18.7% Overshoot 11.3% Undershoot	55mm x28mm	Cost (++) Size (++) Easy design (++)	Tran Response (---) Regulation (---) Efficiency (-)
LM5160-Q1 Flybuck Converter	85.9% peak at 12Vin	1.6% decrease	1.7% Overshoot 1.7% Undershoot	42mm X38mm	Regulation (+++) Tran Response (+++) Size (++) Efficiency (++)	Cost (--) Easy design (-) Cold Crank (-)

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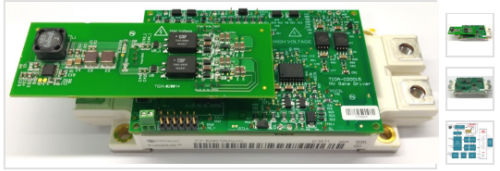

TIDA-020014 HEV/EV traction inverter power stage with 3 types of IGBT/SiC bias-supply solutions reference design side board image

Description

This reference design presents a traction inverter single-phase power stage with three 12-V car battery inputs, 4.2-W bias supply solutions for hybrid electric vehicle and electric vehicle (HEV/EV) systems. All bias-supply solutions accept a wide input range of 4.5 V to 42 V DC from a 12-V car battery, and generate outputs as +15 V, –8 V or +20 V, –4 V configurable and up to 180-mA output current. The power stage includes the isolated gate drivers with 5.7-kVRMS reinforced isolation and designed in 100-mm × 62-mm form factor fitting on SiC/IGBT half bridge modules. It includes isolated DC bus sensing, isolated temperature sensing, logic shoot-through protection and diagnostic features. Apart from startup, efficiency, load regulation tests under low voltage input, all bias supplies are also connected with power stage and IGBT module for CMTI, double pulse, and short-circuit tests under high voltages.

Fully assembled board (shown above) developed for testing and performance validation only, not available for sale.