High VOLT Interactive

Where power supply design meets collaboration

High Voltage Solutions in HEV/EV Part II:
- DC/DC Converters and Traction Inverters

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What will I get out of this session?

- Purpose:

To provide an overview of complete high voltage power solutions in DC-DC Conversions and Tractions Inverters

- **Introduction**
- **Devices**
- **Reference Designs**

- Part numbers mentioned:
  - UCC28951-Q1, LM25037-Q1, UCC280x-Q1, UCC28C4x-Q1, LM5021-Q1
  - UCC27201A-Q1, UCC21520-Q1
- Reference designs mentioned:
  - TIDA-00281, TIDA-01505. TIDA-00366
  - PMP7797, PMP8657
- Relevant End Equipment:
  - DC-DC Converters
    - Car Trunk Audio Amplifier
    - Car Heater
    - Auxiliary Power for Traction Inverter
  - Traction Inverters

What is the DC/DC Converter?

- The DC/DC converter provides transfer of energy between the higher voltage battery system and the lower voltage (typically 12V) systems.
- The higher voltage supplies large loads such as traction motor, air-conditioning, and starters. Lower-power components such as infotainment and safety systems will remain on 12V supplies.

What does this EE do?

- **Down Conversion**
  - Converts energy from HV 48V or 100V ~ 800V to 12V
  - Switching regulator for efficiency, a *converter* with integrated switch, or a *controller* with external switch
- **Up Conversion**
  - Converts energy from 12V battery system to HV (48 or 100 to 800V)
  - *A converter* with integrated switch, or a *controller* with external switch
  - Flyback configuration if isolation needed between HV and LV
- **Bi-directional**
  - 48V or 100 to 800V ↔ 12V

PMP7797: LM25037-Q1/Car Trunk Audio Amp Dual-Mode PWM Controller With Alternating Outputs

Key Features

TIDesigns

Customer Challenges:

- High performance with integrated strong sink/source gate driver
- Higher duty cycle and longer Soft Start
- Customer liked Automotive TI Design PMP7797
- Higher duty cycle, strong gate drivers and programmable soft start,

PMP7797 is a wide-input SEPIC converter designed for automotive applications. This design uses the LM25037Q push-pull controller as an interleaved boost, which incorporates two gate drivers for controlling two sets of MOSFET switches.

End Equipment:

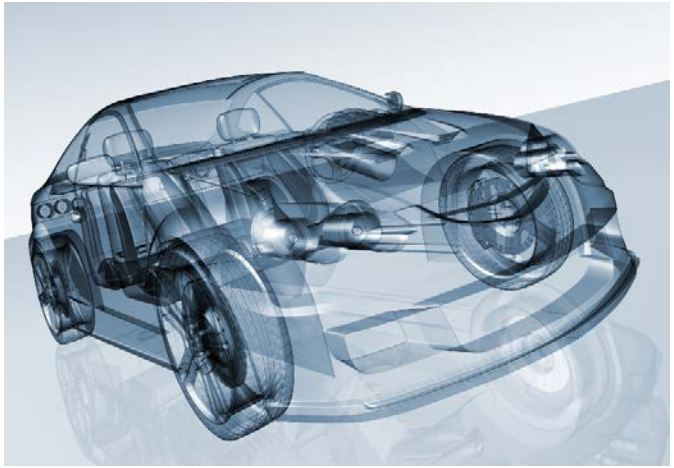
* High-eff Boost for trunk amplifier
* Car Heater
* Car Audio Amplifier

Question #1: What type of dc-dc converter or inverter are you using/designing?

- A) Push-pull, phase-shifted full bridge, LLC, or what, using which devices?
- B) Three-phase inverter for synchronous AC motor (permanent magnet?) or asynchronous AC motor (squirrel cage, or what type)?
- C) What is control algorithm for the inverter and for the motor?
- D) Other (for those that answered “other”, would someone to share?)

What is the (Traction) Inverter ?

- EV/HEV Traction inverter converts energy stored in a battery to instantaneous multiphase AC power for a traction drive



Mandatory Sub Systems

- **Front-End**
  - Battery
  - Input power protection
  - Signal Isolation
- **Power Stage**
  - Isolated DC/DC power supply
  - Non-isolated DC/DC power supply
  - Current & Voltage Sense
  - Digital Processing
- **Self-Diagnostics / Monitoring**
  - Signal Isolation

HEV/EV Motor and Inverter Example

Motor:

- Max. power 60 kW
- Max. torque 240Nm
- Max. rpm 13,000 min–1
- Peak current 410Arms
- Nominal voltage 200 VAC
- Motor length 250 mm
- Motor diameter 246 mm minimum
- Motor weight 49 kg
- Max. efficiency 95 %

Inverter:

- Operating voltage range 270 – 420 V DC
- Ambient temperature operating range
  – 40 °C to + 85 °C
- AC peak current 10 s 430 Arms
- AC continuous current 185 Arms
- Degree of protection IP6K9K
- Weight < 7 kg

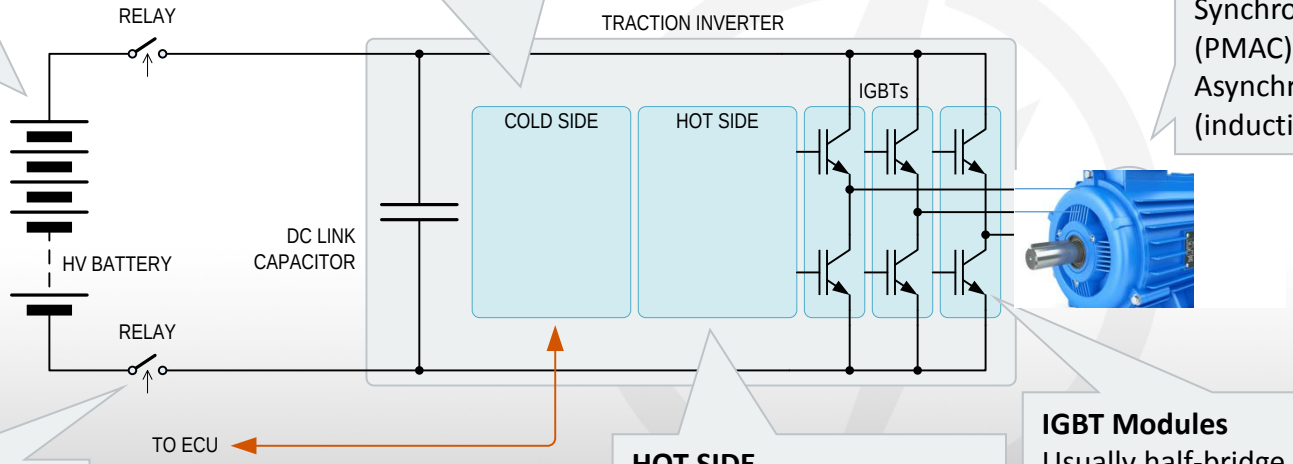
Traction Inverter Overview

EV/HEV Traction inverter converts energy stored in a battery to instantaneous multiphase AC power for a traction drive.

COLD SIDE
MCU, safety logic, interfaces

HV Battery
48 V for low voltage or several hundred volts for high voltage systems

Traction Motor
Synchronous (PMAC) or Asynchronous (induction) motor



HV Relay (contactor)
Allows to disconnect the battery from the system

HOT SIDE
IGBT Drivers, voltage, current and temperature measurements

IGBT Modules
Usually half-bridge configuration per module. Three modules are needed to get 3-phase full bridge.

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A Driver for every FET

MOSFET

UCC21520-Q1

UCC27201A-Q1
LM5109B-Q1

UCC27517A-Q1
UCC27524A-Q1

AC/DC (PFC)
DC/DC
EV and HEV
Automotive

<650V Motor Drive
Solar Micro Inverters

IGBT

UCC21520-Q1

UCC27531-Q1

>650V Motor Drive
Solar String Inverters
Air Conditioner
Induction Heating

SiC FET

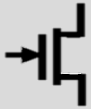
UCC21520-Q1

UCC27531-Q1

High Voltage Motor Drive
EV Power Train Inverters
Solar Inverter
UPS

GaN FET

Nom-ON



Nom-OFF

LM5113-Q1

LMG5200

LMG3410

48V:POL
AC/DC (PFC)
DC/DC

Motor Drive
Audio Amps
Inverters

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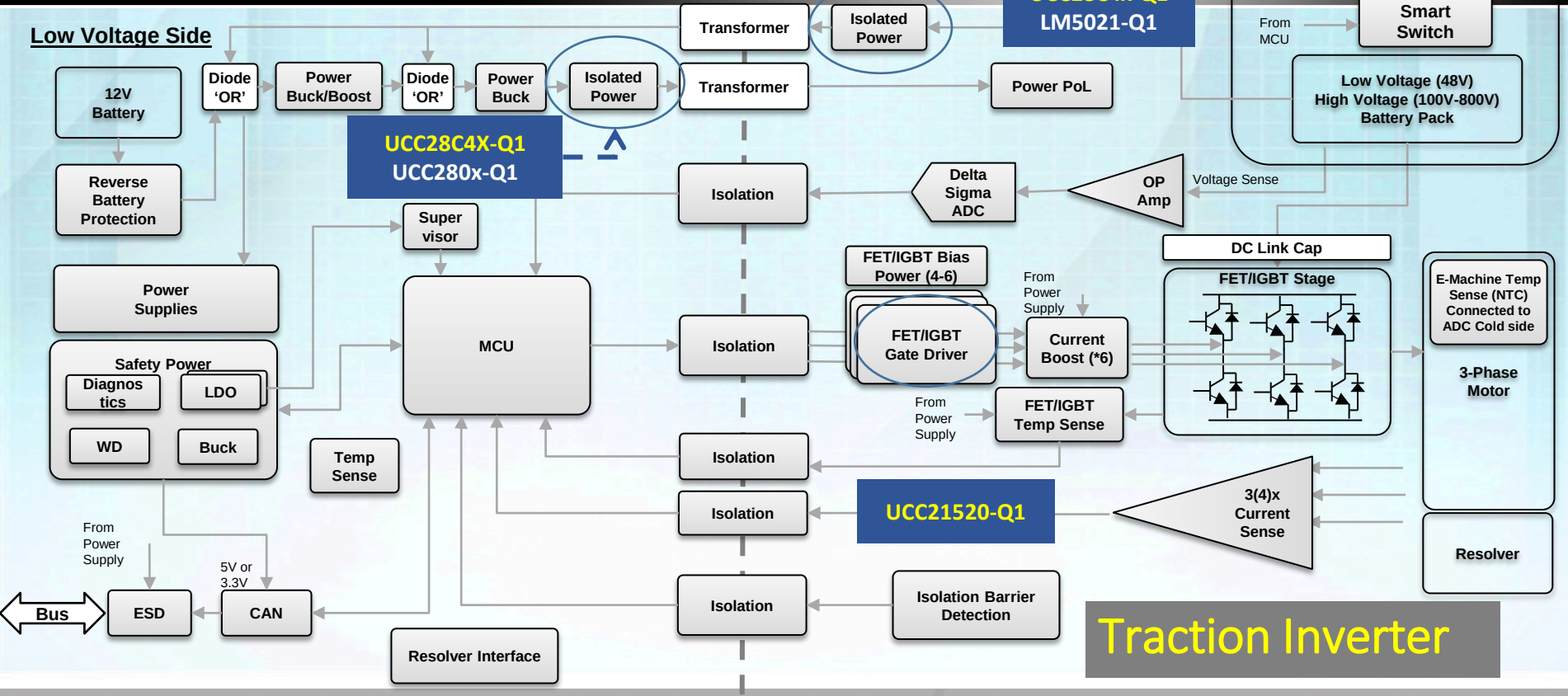
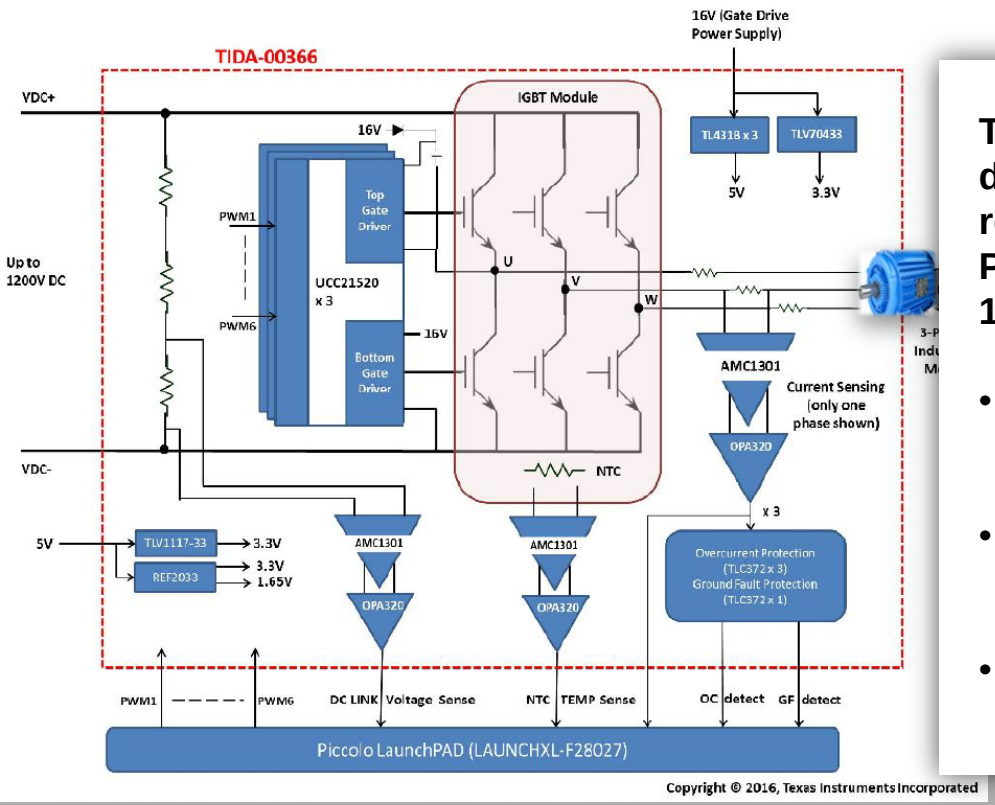


TIDA-00366: UCC21520 drive IGBT's in 3-Phase Traction Inverter

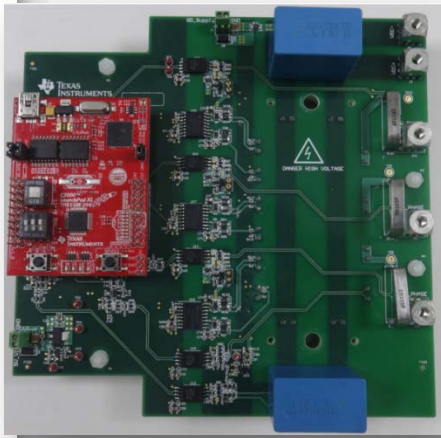


TIDesigns

The TIDA-00366 reference design provides a reference solution for 3-Phase inverter rated up to 10kW designed using

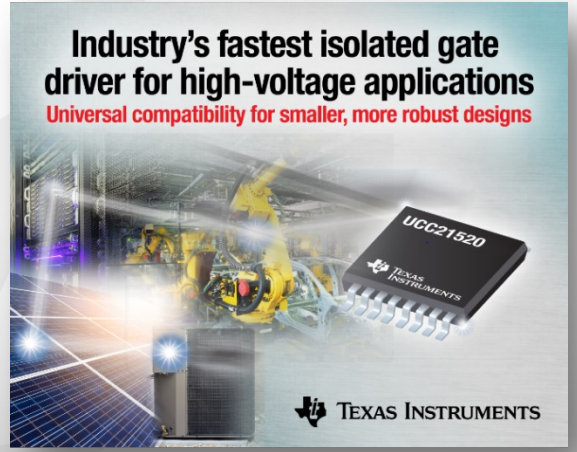
- **reinforced isolated dual gate driver UCC21520-Q1,**
- **reinforced isolated amplifier AMC1301-Q1, and**
- **TMS320F28027.**

Reference Design for Reinforced Isolation 3-Phase Inverter with Current, Voltage and Temp Protection



What is the UCC21520-Q1?

- Industry's fastest 5.7kVrms isolated dual channel gate driver
- The first of a new gate-driver family in TI's isolation portfolio
- Integrated components, advanced protection features and optimized switching performance – allows for faster time to market
- Can be used as a low-side, high-side, high-side/low-side or half-bridge driver.

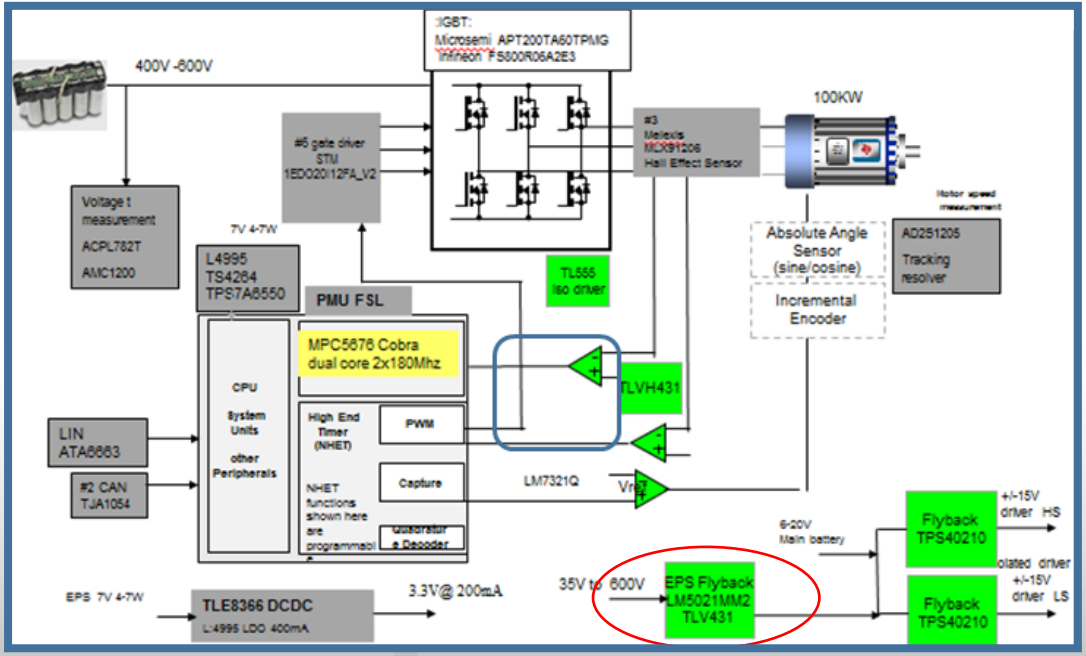


PMP8657: LM5021-Q1
Automotive Power

Key Features to Help

LM5021-Q1 with low start up quiescent current, low current sense threshold, and slope compensation

Leveraging the reference design of the **PMP8657**, and the FAE design support on design calculations / transformer design helped lock down this design win.



LM5021-Q1

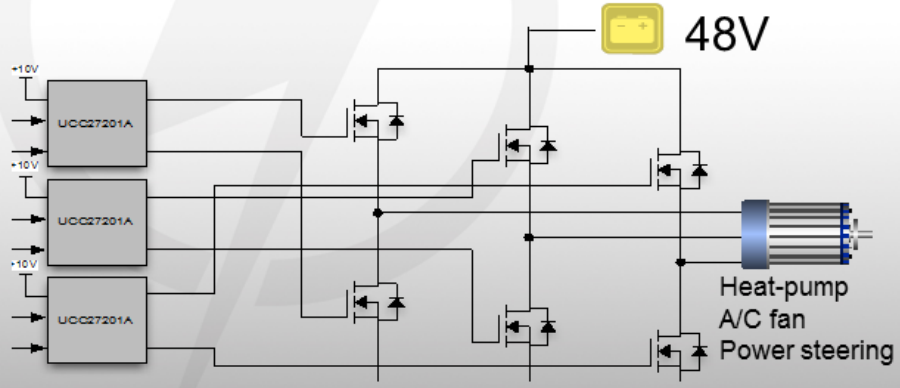
UCC27201A-Q1
120V high- / low-side gate driver for 48V applications

Differentiated Features & Benefits

- **Increased drive current, shorter propagation delays over competition** ➔ Allows best-in-class efficiency in high-frequency converters, inverters
- **Negative voltage capability at switch-node (HS pin)** ➔ Best-in-class robustness
- **Max Boot voltage (HB pin) of 120V, integrated 120V Bootstrap diode, Max VDD of 20V** ➔ Offers highest level of flexibility in automotive power electronics
- **Wider temperatures range: -40°C to 140°C** ➔ Best-in-class reliability and robustness

Target Applications

- **Half bridge and Full bridge for 48V loads** to drive auxiliary inverters – Heat pumps, air-conditioning, power steering, pre-tensioners for seat belts etc
- **48V-12V Bi-directional DC/DC** for high-power (several-kW) battery charging/balancing



Applications / Subsystem

TIDA-00281: UCC27201A-Q1 Design Case
Automotive 48V BLDC Motor Drive – up to 1kW

TIDesigns

Design Features

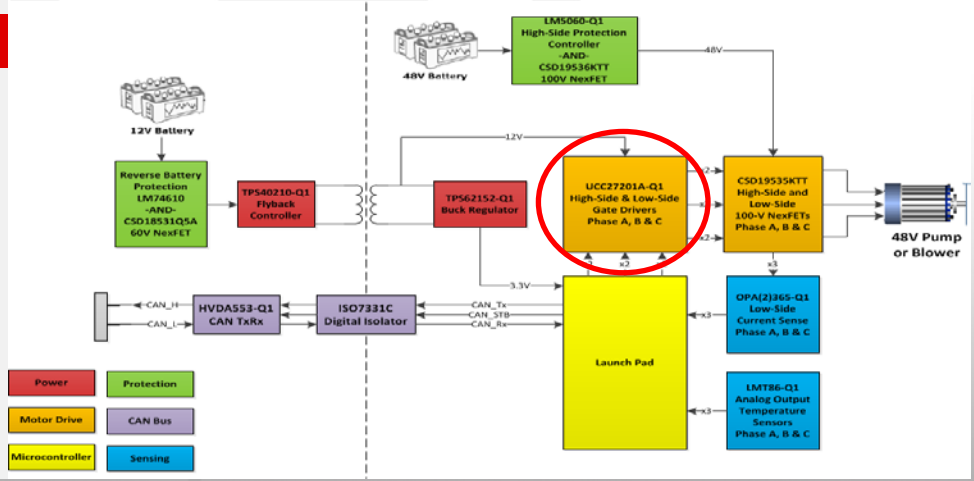
- CISPR 25 EMI test results available
- BLDC motor drive designed to operate on 48V automotive systems
- Isolated CAN interface connects to automotive networks on 12V battery systems
- Automotive (AEC-Q100) qualified components
- **Target Applications:** turbocharger, water pump, oil pump

Design Benefits

- Operates over a wide range of voltages from 48V battery systems
- Simplifies firmware development and reduced BOM count
- Designed to communicate over industry standard automotive CAN bus

Tools & Resources

- TIDA-00281 Tools Folder
- Test Data/Design Guide
- **Design Files:** Schematics, BOM and BOM Analysis, Design Files



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TIDA-01505 Automotive 40V-1000Vin, 15Vout, 60W Flyback Reference Design for 800V Battery System

Design Features

TIDesigns

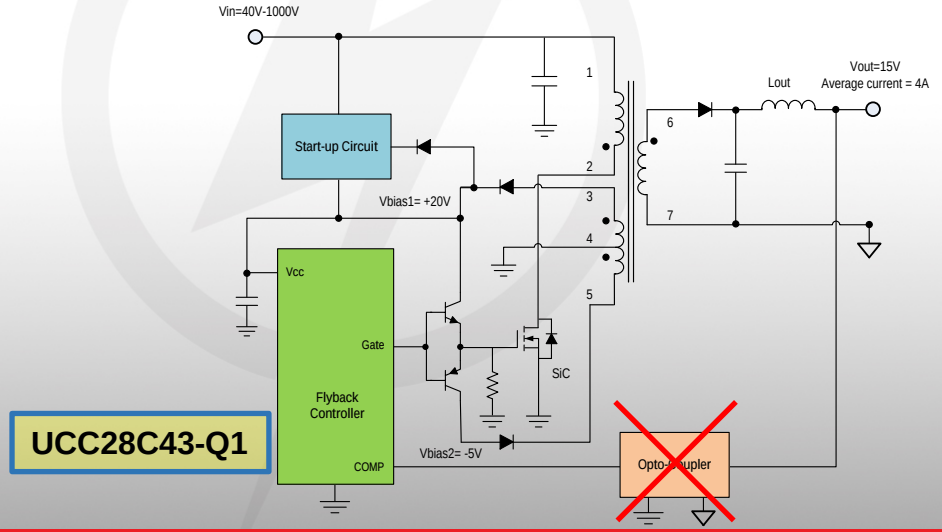
- Wide-Vin isolated Flyback DC/DC converter over the Ultra wide input voltage range of 40V to 1000V DC, up to 1200V transient.
- Regulated output voltage 15V (<5% regulation) and output current up to 4A.
- SiC MOSFET solution with high voltage rating, low gate charge, and fast switching transients.
- SiC gate Driver adaption from an integrated MOSFET gate driver utilizing center-tapped transformer.
- Constant switching frequency with duty cycle range from 15% to 80%.
- Current mode control with cycle-to-cycle over current limitation.
- Automotive Grade 1 qualified Transformer with Reinforced isolation (tested at 5.7kV High-Pot).

Tools & Resources

- **TIDA-01505 Tools Folder**
- **Test Data/Design Guide**
- **Design Files:** Schematics, BOM and BOM Analysis, Design Files

Design Benefits

- Designed for isolated unidirectional power supplies in HEV/EV Traction Inverter systems.
- Support regenerative breaking with the minimum start-up voltage of 40V.
- Extendable to higher voltage and higher power range.
- Automotive Grade 1 qualified Transformer with Reinforced isolation.



Texas Instruments

Question #2: What is the most needed among them?

- A) Reliability
- B) Cost
- C) One stop shopping
- D) Other (for those that answered “other”, would someone to share?)

Summary

- TI is a one stop high voltage solution provider for automotive applications.
- Solutions and Successful Stories are reviewed for DC-DC Converters and Traction Inverters
- Introduced TI Driver Solutions