

# High **VOLT** Interactive

Where power supply design meets collaboration

High Voltage Solutions in HEV/EV Part I:  
- On Board Chargers and Charging Stations

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## What will I get out of this session?

- Purpose:

To provide an overview of complete high voltage power solutions in on board chargers and charging stations

- Introduction
- Devices
- Reference Designs

- Part numbers mentioned:

- UCC28070-Q1, UCC28951-Q1, LM25037-Q1
- UCC28700-Q1, UCC28730-Q1, UCC280x-Q1, UCC28C4x-Q1, LM5021-Q1
- UCC27201A-Q1, UCC21520-Q1

- Reference designs mentioned:

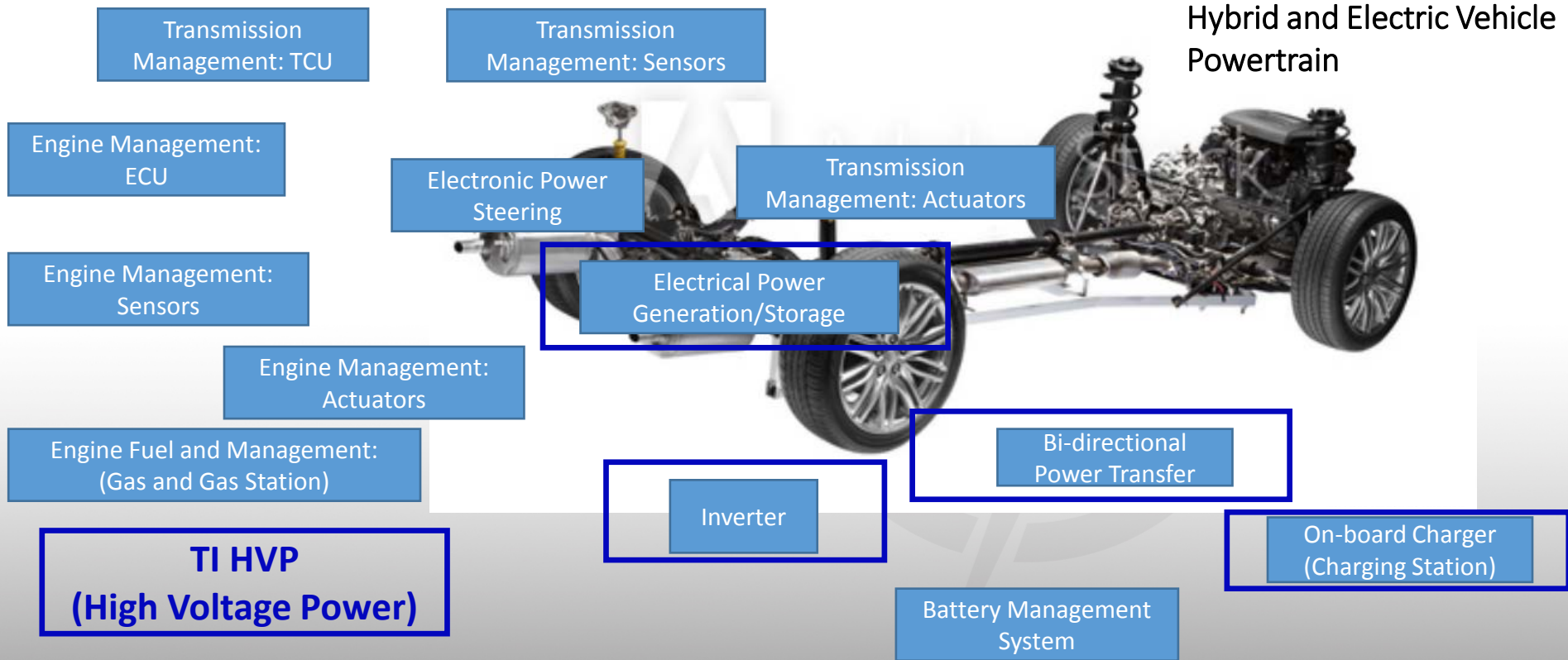
- TIDA-00558
- TIDA-01159
- TIDM-1007

- Relevant End Equipments:

- On Board Chargers
- Charging Stations

On Board Charger		PFC	DC-DC Conversion	Drivers (MOSFET, IGBT, SiC, GaN)							
	Non-isolated DC/DC Power Supply	Isolated DC/DC Power Supply	Isolated AC/DC Power Supply	PMIC	Current-Voltage Sense	Power Stage	Signal Isolation	Digital Processing	Input Power Protection	Self-Diagnostics / Monitoring	Wired Interface
Description	Non-isolated DC/DC Power Supply including power stage, incl. LDO	Isolated power supply between DC potentials including power stage, incl. LDO	Isolated 115/230V AC/DC Power Supply including power stage, , incl. LDO	Processor Power, Supporting Multi-rails and System Level Safety	Current/Voltage sensing including ADC, OPA, Hall sensors, Fluxgate, INA, (Current shunts), REF, COMP, MUX, Switch	Output power transistor and drivers including gate drivers, Dianostics, Protection etc.	- Provide galvanic isolation to High Voltage	Micro Controller who does the signal processing and control algorithm	Protection for main power supply including eFUSE, HotSwap, (PTC, Diodes, Fuse)	Temperature sensor, Humidity sensor, Voltage & Reset Supervisor	Wired signal interface to external devices or internal boards including CAN, LIN
Comments	Most preferred solution	Based on system architetur	Based on system architetur	Based on system architetur							
TI P/N	LM5118-Q1 LM5085-Q1 TPS54540-Q1 TPS7B6733-Q1	LM25037-Q1 LM5160-Q1 LM5022-Q1 SN6501-Q1 SN6505-Q1 UCC28070-Q1 UCC28951-Q1	UCC28700-Q1 UCC28730-Q1 UCC280x-Q1 UCC28C4x-Q1 LM5021-Q1	TPS653850-Q1 TPS653852/S-Q1	AMC1301-Q1 AMC1311-Q1 INA199-Q1 INA138-Q1 OPA376-Q1	UCC27210-Q1 UCC21520-Q1 UCC27524A-Q1 ISO53605-Q1 ISO5452-Q1	ISO7220A-Q1 ISO7221C-Q1 ISO7330C-Q1	TMS320F28052 TMS570x	LM5060-Q1 LM74610-Q1 LM74700-Q1	TMP102-Q1	SN65HVDA100 TPIC1021A-Q1 TCAN1042*-Q1

### Hybrid and Electric Vehicle Powertrain



## What is the On-board Charger & the Charging station?

- An On Board Charger is used in an electric vehicle (EV) or hybrid electric vehicle (HEV) to charge the traction battery (48V or HV usually ~400V)
- This includes:
  - Converts the grid 50/60Hz into DC
  - Adjusts the DC level to the levels required by the battery and provides the galvanic isolation
  - Usually includes a Power Factor correction (PFC)



- A charging station is to provide a battery charger equipment at home or on the road, like a gas station.

## What does this EE consist of?

- **PFC Controller and Rectification**
  - High Efficiency rectification with lowest harmonic impact to the grid
- **Controller**
  - Analog or Digital Control (<2kW to >100kW)
  - Adjusts the DC level to the levels required by the battery
- **Galvanic Isolation**
  - Galvanic Isolation Grid to Battery
  - Bias Supply
- **Diagnostics**
  - Temperature Sensing
  - Current & Voltage Sensing
  - Iso Barrier

## On Board Charger Classification

Power source Infrastructure	Category	OBC Power	Connector	Comments
~110V AC ~230V AC	Level 1 Single phase	12A to 20A <4 kW	Convenient cable as per OEM/Region	Based on battery, charging times >6hours
~230V AC ~400V AC	Level 2 1 to 3 phase	17A to 80A <20 kW	Dedicated EVSE	Based on battery, charging times <3hours
DC Fast Charging	Level 3 3 Phase Grid Power/ Relevant	>50 kW	Dedicated EVSE	Based on battery, charging times are targeted for <1hour

### Standards for On Board Chargers

- SAE J1772, IEC 62196
- CHAdeMO
- CCS (GB/T 20234)
- Tesla/OEM specific etc..

## Solutions

### AC/DC (PFC) Controller

- Less losses
- Regulatory requirement
- Different topologies for power levels

Topology	Power
DCM Flyback	< 100 W
TM Boost	To ~350 W
CCM Boost	> 300 W
Interleaved TM Boost	To 1000 W
Interleaved CCM Boost	> 1000 W

### Isolated DC/DC Controller

- 400 V → 48 / 12 V
- 48/54/24 → 48/12V Buck
- 12V/5V → 48V/54V Boost Topology

Topology	Power
Active Clamp Forward	To 300 W
Push-Pull Flyback power level	To 500 W To 100W
Half-Bridge	100 – 300 W
(Phase shifted) Full Bridge	> 500 W
LLC	< 1 kW

Premium Audio

On-Board Charger / Charging Station

Question #1: What power levels, topologies, devices challenges, ref designs have you used or are you using?

- A) TI products like UCC28070-Q1, UCC28951-Q1, LM25037-Q1, UCC28C4x-Q1, UCC28730-Q1, UCC280x-Q1, UCC27201A-Q1, UCC21520-Q1, and?
- B) 500W, 3kW, 20kW, or higher?
- C) Any reference designs, and what are they?
- D) Other (for those that answered “other”, would someone share?)



~500W

### Applications:

- Premium Audio

### TI Solutions:

- UCC280x/A/
- LM5030, LM5033
- TL494/TL594

### Solution Benefits:

- High efficiency
- High-speed
- Low power
- Minimal external parts count

< 3.3kW

### Applications:

- On-Board Charger
- Charging Piles
- Electric Vehicle Inverters

### TI Solutions:

- UCC28951-Q1
- UCC28070-Q1

### Solution Benefits:

- Best in class efficiency
- Automotive qualification
- active control of the SR
- Enhanced ZVS
- Best in class interleaving solution
- current synthesis and quantized voltage feed-forward

> 20kW

### Applications:

- Fast/Charging Piles
- Charging Stations

### TI Solutions:

- **C2000 with Digital Controller**
- **UCC28070-Q1 (1ph? 3ph?)**
- UCC28951-Q1

### Solution Benefits:

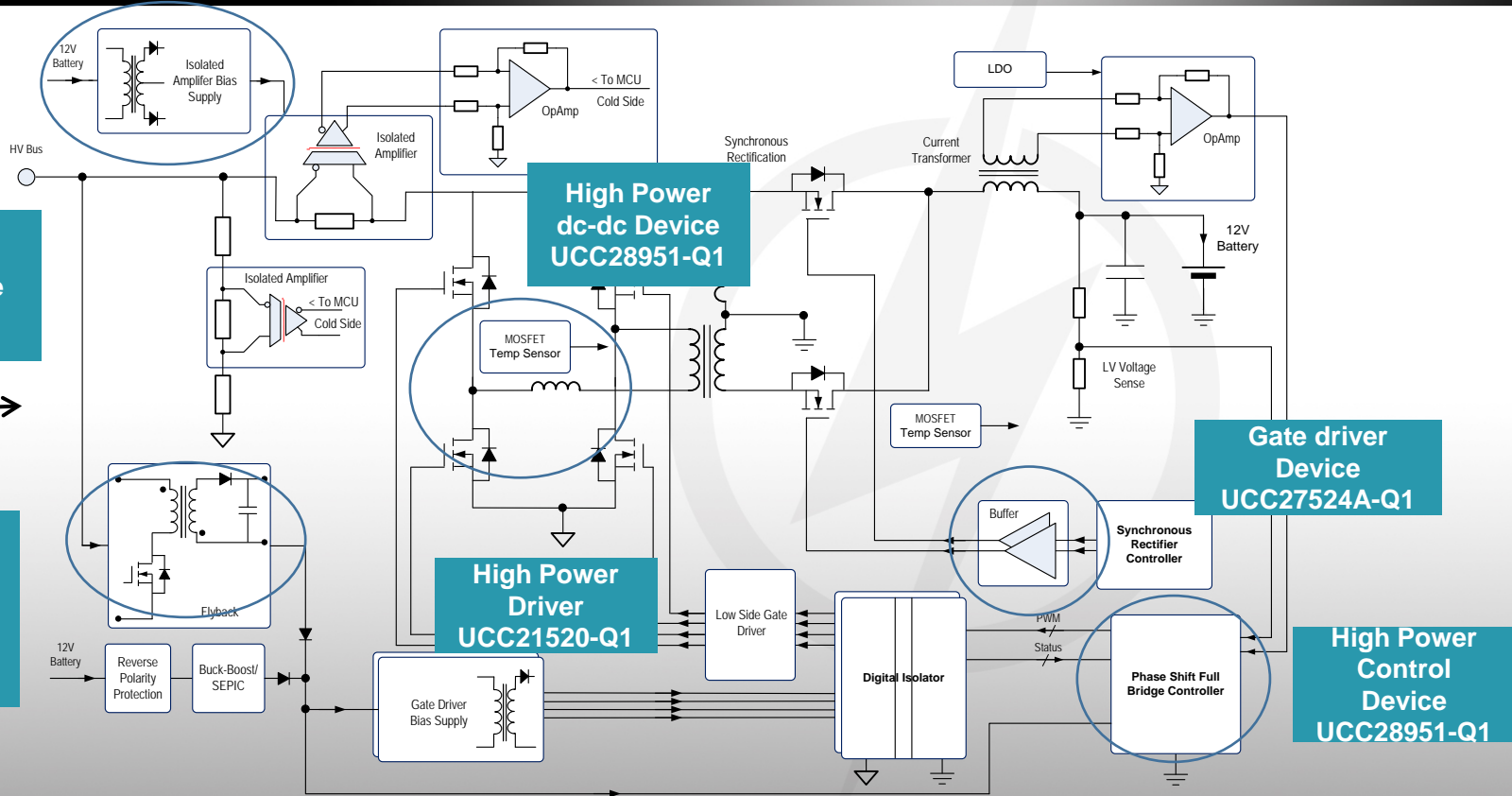
- High efficiency
- Best in class interleaving solution
- current synthesis and quantized voltage feed-forward

Isolated  
UCC280x-Q1  
UCC28C4x-Q1

High Power  
Control Device  
UCC28070-Q1

Interleaved CCM  
PFC

Flyback Device  
UCC28700-Q1  
UCC28730-Q1  
UCC280x-Q1  
UCC28C4x-Q1  
LM5021-Q1



#### Solutions for Flyback

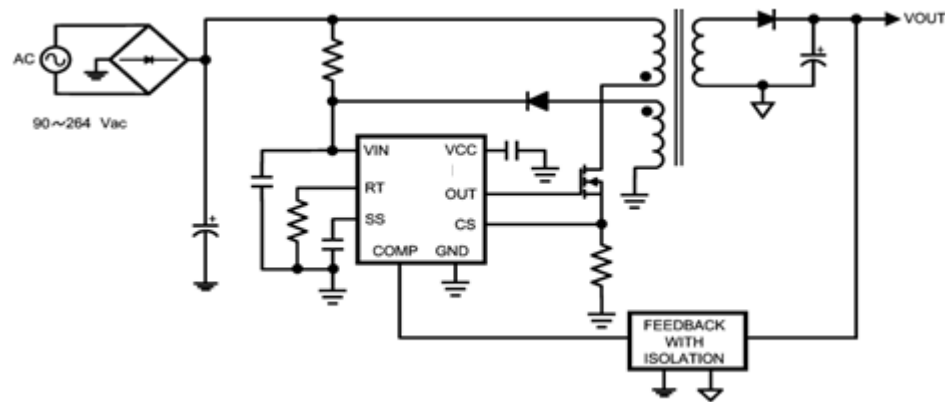
- UCC28C4x-Q1
- UCC280x-Q1
- UCC28730-Q1
- UCC28700-Q1
- LM5021-Q1
  
- Operating Temperature -40C to 125C
- Packages: SOIC, SOT, VSSOP

#### Benefits

- Low Power dissipation.
- High frequency operation with low startup, operating currents lowers startup loss and power consumption for improved efficiency.
- Feedback accuracy and fast response to transients
- Safety and protection features integrated

#### Applications

- Switch Mode Power Supplies (SMPS)
- DC to DC Converters
- Industrial Power conversion
- Automotive Power Train



### Features

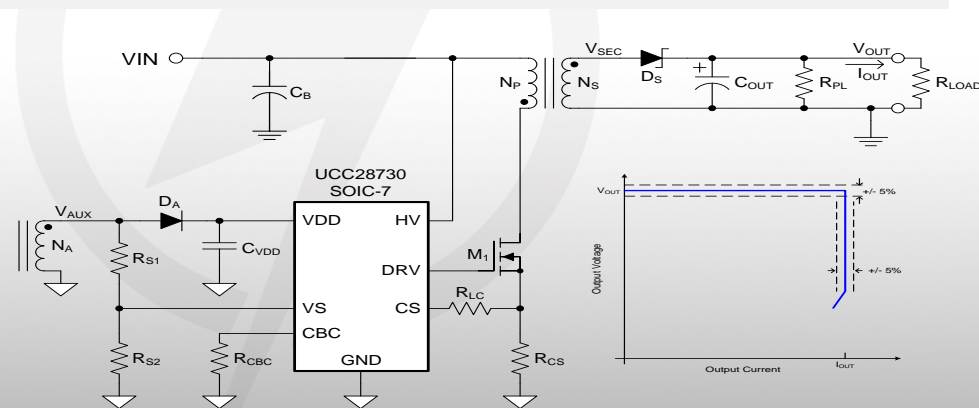
- Primary Side Regulation (PSR) eliminates ALL secondary-side feedback components
- <math>52\mu\text{A}</math> IC current consumption in standby mode
- 5% output voltage regulation accuracy
- Internal 700-V startup switch
- Load short circuit protection
- 83-KHz max switching frequency enables compact power supply designs
- DCM valley switching control scheme
- Wide VDD range allows small bias capacitor
- Protection Functions: Over Voltage, Low Line & Over Current
- Programmable cable compensation
- AEC-Q100, Temperature Grade 1 (-40 to 125 C)
- SOIC-7 Package

### Applications

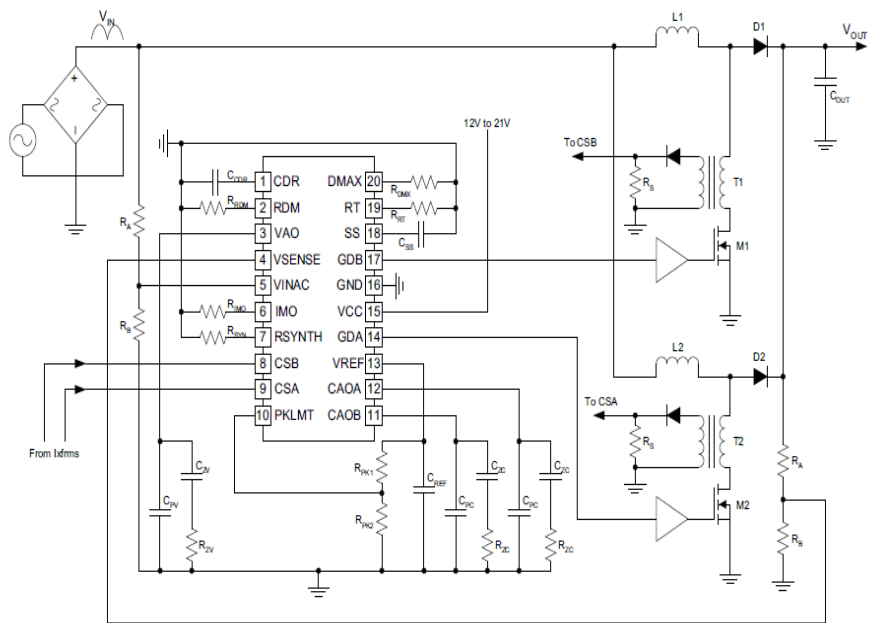
- Automotive AC/DC and DC/DC power
- Auxiliary power supply for Automotive power train in HEV
- Flyback and Buck power converters

### Benefits

- **Primary-side regulation** → Eliminates 9 feedback components (TL431, opto, etc.) and issues with opto long term reliability and temperature shifts
- **Zero\* standby (52 $\mu\text{A}$ ) current consumption** → Ultra low power drain from battery in standby mode
- **Load short circuit protection** → Robust solution with integrated protection
- **MOSFET valley switching** → High efficiency



#### Key Features for Targeted Applications



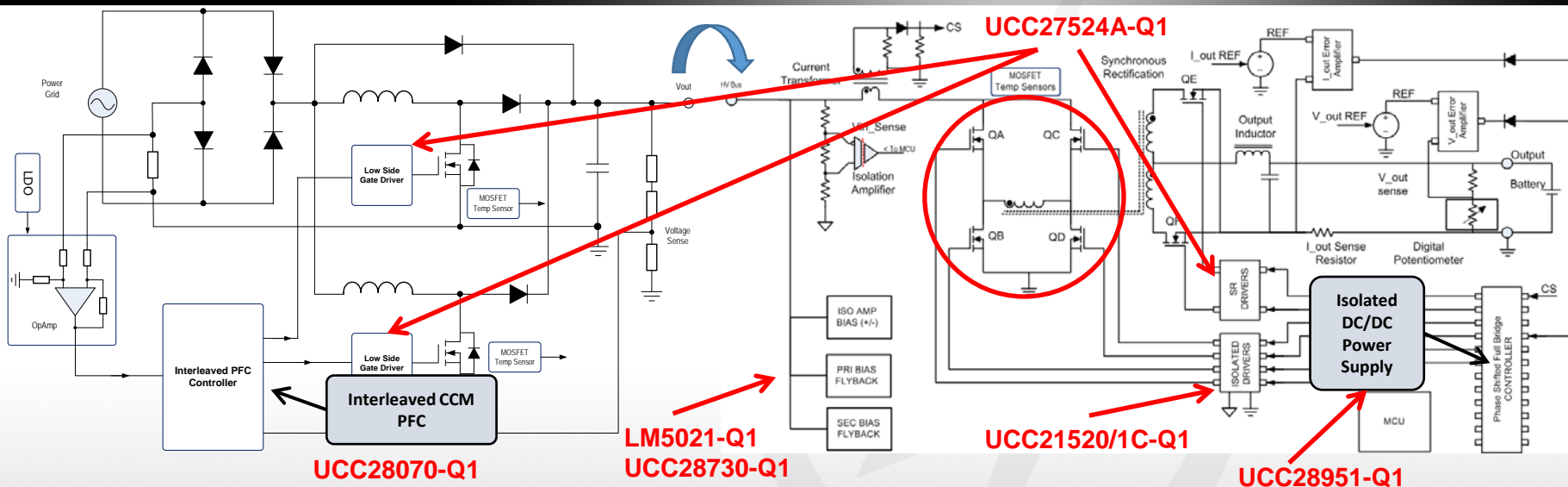
#### Application Need/ Care About

##### Customer Problems:

- Charger has to meet automotive standards and standard rules: EN61000-3-2 Harmonics Standard, CISPR25 – Conducted and Radiated Emissions (automotive), ISO 11452 - Conducted and Radiated Immunity (automotive), EN61000-6-3 - Conducted and Radiated Emissions for component connected to HVAC power lines
- For better efficiency and lower EMC disturbance a two stage interleaved PFC has been used in this solution
- Programmable switching frequency (30k – 300kHz ) allow the customer to optimize the efficiency
- Output voltage sensing to improve reliability since it allows to :
  - Improved transient response
  - Output over voltage protection with fail-safe pin
  - Open loop protection
- Interleaved allow the customer to have lower rms current with fewer/cheaper caps → higher reliability → lower cost
- Frequency dithering to reduce EMI peak signatures, allowing smaller filter design. Reduced ripple allows smaller EMI filter design. → higher power density

## Question #2: What is your PFC solution?

- A) Single Phase, Three-Phase?
- B) UCC28070-Q1
- C) C-2000/UCD3138
- D) Other (for those that answered “other”, would someone to share?)



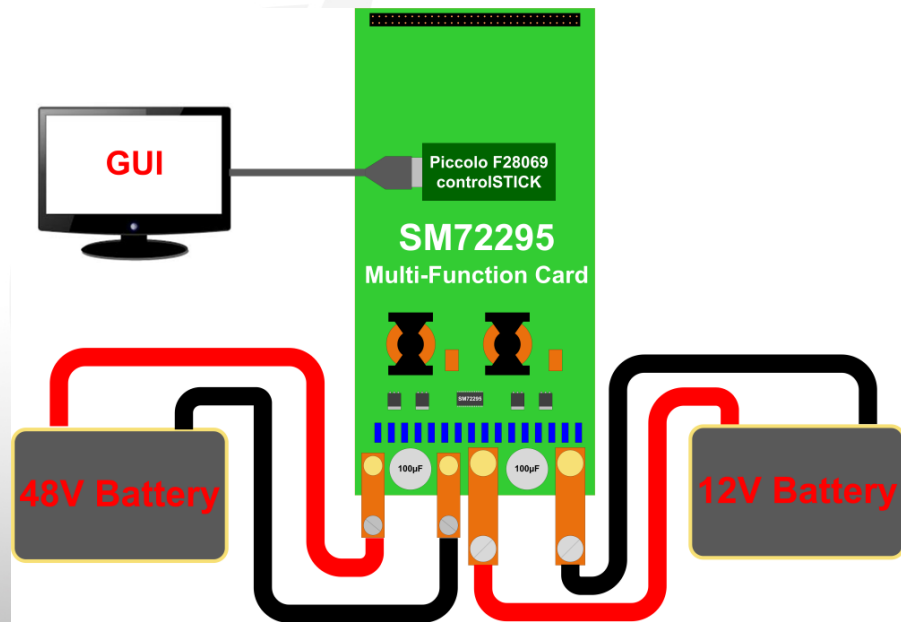
	Isolated AC/DC Power Supply	Isolated DC/DC Power Supply
Description	Isolated 115/230V AC/DC Power Supply incl. power stage,	Isolated power supply between DC potentials incl. power stage, LDO
TI P/N	<b>Interleaved CCM PFC Bias</b>	<b>PSFB; Drivers: Isolated Dr, SR Dr,</b>
	<b>No optocoupler needed → cheaper end solution comparing to competition</b>	<b>UCC28951-Q1 best in class efficiency, reducing BOM</b>

#### Applications



- To address ever tightening fuel economy demands the automotive industry is adopting two battery power systems to facilitate Stop-Start operation in which the internal combustion engine shuts down when stopped or coasting, and automatically restarts when power is applied.
- Typically a 12V lead acid battery will be used to power many of the car's traditional systems, but a 48V Lithium battery will be used to operate the starter. That same 48V battery will provide a storage reservoir to capture regenerative braking or coast down energy. This creates a need to move power bi-directionally between the two batteries depending on overall system needs.
- This design addresses deploying the SM72295 (Full Bridge Driver) in a 48:12 bidirectional charger.

#### System Structure



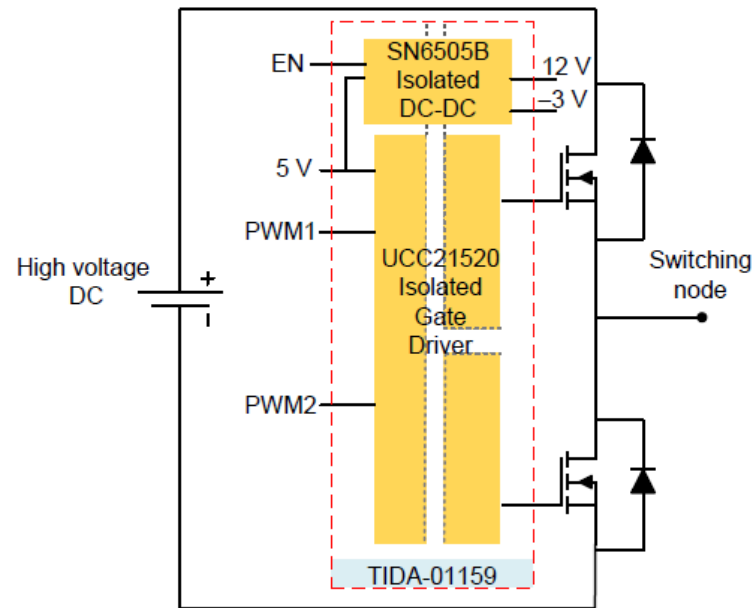


#### Description



- The TIDA-01159 design provides a reference solution for half-bridge isolated gated drivers used in driving power stages of UPS, inverters, server and telecom applications.
- This TI Design is based on the UCC21520 reinforced insulated gate driver from TI, and is capable of driving MOSFETs and SiC-FETs. The reference design contains a built-in isolated push-pull auxiliary power supply for powering the output of the isolated gate driver.
- By bringing together the isolated gate driver and isolated power supply (SN6505B) in a compact board with a form factor (30 mm × 35 mm), this reference design provides a fully tested robust half-bridge driver solution, capable of withstanding >100 kV/μs common-mode transient immunity (CMTI).

#### System Structure



#### Features



- GaN based Totem Pole 1PH PFC with three interleaved phases using LMG3410 & controlled using C2000 MCU
- Power Spec
  - Input: 85-265 Vac , 50/60Hz
  - Output: 400V DC
  - Power: 3.3KW at 220Vrms & 1.6KW at 110Vrms
  - Efficiency : > 99% peak efficiency
- Low total harmonic distortion (THDi) < 2%
- 100 kHz PWM switching
- Soft starting for totem pole bridge
- Phase shedding to enable higher efficiency
- Non Linear control loop to reduce voltage spikes

#### Applications

- On –board chargers for EV
- Telecom Rectifiers
- Other industrial applications

#### Benefits

- **High power density design**, with form factor matching OEM specifications
- Using latest **TI-GaN with integrated gate drivers** offering greater integration for the customers.
- **High performance C2000 controller** enables superior control and enables advanced control scheme to be implemented



- **Key TI Devices:** TMS320F28075, LMG3410, UCC27714D, UCC28740, UCC24636

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Vout	<input type="text" value="12.00"/>	<input type="text" value="V"/>	3.3 to 50.0V
Iout	<input type="text" value="4"/>	<input type="text" value="A"/>	≤ 20A
Ambient Temp	<input type="text" value="30"/>	<input type="text" value="°C"/>	-40 to 105°C

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## Summary

- ❑ TI is a one stop high voltage solution provider for automotive applications.
- ❑ Solutions and Successful Stories are reviewed for OBC and Charging Stations
- ❑ Introduced TI Solutions of PFC, DC-DC, and Bias for Automotive Applications



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