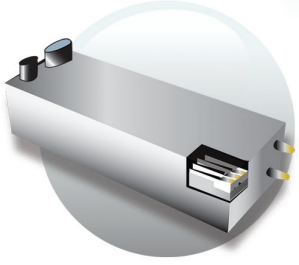
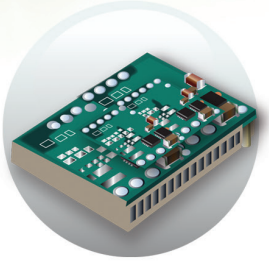
# Hybrid and Electric Vehicle Solutions Guide


Texas Instruments

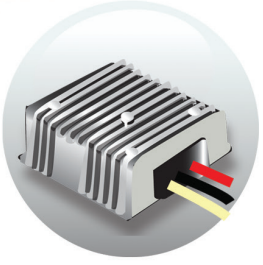


Battery

Infrastructure



Inverter



DC/DC

www.ti.com/hev

2013

# System Solutions for Hybrid and Electric Vehicles
Table of Contents

# System Solutions for Hybrid and Electric Vehicles

## Texas Instruments in Automotive Applications

Texas Instruments (TI ) is committed to providing superior cost-efficient solutions to the transportation market, along with excellent product documentation, on-time delivery and conformance to specifications.

TI supports transportation industry requirements and continues to add to our transportation portfolio. With more than 30 years of experience serving customers with demanding requirements, TI can help you achieve the quality, reliability and cost goals to succeed in today's marketplace.

TI is fully committed to automotive quality; we have a dedicated quality organization and a zero-defect strategy in place. We are TS16949 certified and a preferred supplier to major car manufacturers.

## Introduction to Electric Transportation

Electric transportation is not a new phenomena; in fact, the concept has been around for more than 100 years. However, given growing environmental sensitivities, long-term supply concerns, fossil fuel prices and improved technology, there is a strong motivation to further accelerate this market segment.

Government regulations like the 130-g/km (and future planned 95-g/km) CO2 average emission limits for car manufacturers in Europe are also catalysts behind new electrified transportation alternatives. With the adoption of more electronics, vehicles become safer, exhibit higher performance, and are more efficient. Electric transportation is a key element within the overall renewable energy landscape. Energy for charging is expected to come from renewable sources like wind-, solar- or water-powered plants. Home and public charging stations will also become more prevalent and can take advantage of off-peak charging (nighttime) and green energy sources such as wind.

With a full range of analog and embedded processing products, TI is at the forefront of helping to bring safer, affordable and more efficient electric transportation solutions to market. TI's solutions for this industry range from optimized and dedicated integrated circuits to full system-level solutions to help our customers optimize and accelerate product development.

TI's experience in diverse markets such as industrial control, industrial motor drives, digital power supplies, smart metering and grids, wired and wireless communications, consumer electronics, and energy efficiency enables engineers to meet increasing needs for higher speeds, higher precision, lower power and more robust equipment – all while maintaining the high standards of quality and reliability that the automotive and transportation market demands.

Within this guide, you will find solutions and support for your hybrid and electric vehicle application designs in the following categories:

### Different types of hybrid and electric vehicles

| Feature | Start/ Stop | Micro Hybrid | Mild Hybrid | Full Hybrid (Parallel) | Full Hybrid (Serial) | Full Electric |
|---|---|---|---|---|---|---|
| Start/stop alternator | ✔ | ✔ | ✔ | ✔ | | |
| Regenerative breaking | | ✔ | ✔ | ✔ | ✔ | ✔ |
| Electric torque assist | | | ✔ | ✔ | | |
| Electric and combustion drive | | | | ✔ | | |
| Only electric drive possible | | | | | ✔ | ✔ |
| Plug-in capability | | | | ✔ | ✔ | ✔ |

Different types of hybrid and electric vehicle concepts exist in the market. Texas Instruments offers leading-edge solutions for all systems, from a basic start/stop function to a fully integrated plug-in electric vehicle. This guide will give an overview of the various functions and also cover product highlights from various areas. For the latest information, see TI's website, **www.ti.com**.

# System Solutions for Hybrid and Electric Vehicles
## Why TI?

### Innovative semiconductor solutions
- Making advanced automotive and transportation devices more flexible, affordable and accessible.
- Addressing growing needs in energy efficiency, power and battery management, wired and wireless connectivity, and performance and precision.

### Complete portfolio
- Amplifiers, data converters, interfaces, power management, isolation, logic, DSPs, MCUs and wireless connectivity.
- Catalog, application-specific, enhanced and custom IC options.
- Experienced automotive and transportation sector supplier with a full range of AEC Q-100-certified analog and embedded processing technologies and products.

### Quality and reliability
- Experience in serving the automotive market for more than 30 years.
- Ability to serve customers of all sizes with a variety of supplier chains and needs.
- Long product lifetimes and a flexible product obsolescence policy, ensuring continuity of supply.
- Worldwide manufacturing and R&D capabilities.
- Member of industry-standard organizations and alliances.

### Commitment
- Design support
- Tools
- Training
- Distribution

### Introduction to the guide

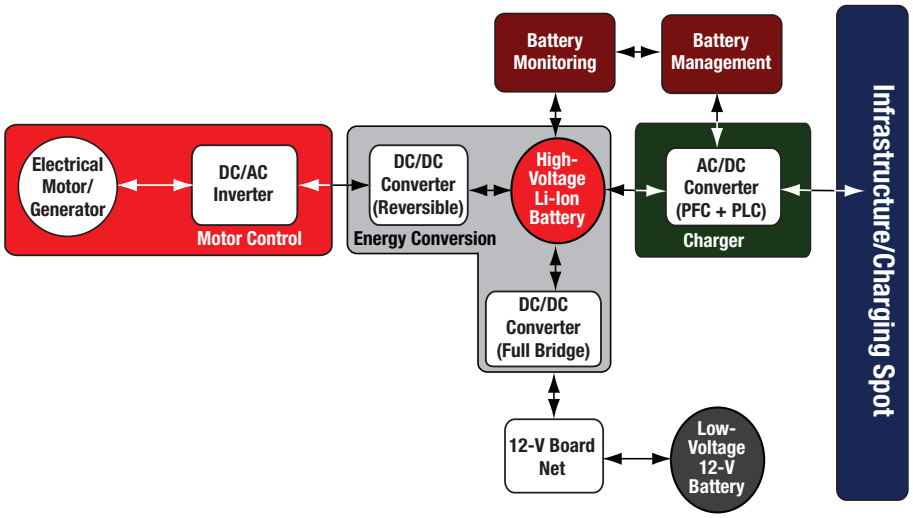
This Hybrid and Electric Vehicle Solutions Guide is intended to help you explore TI's IC solutions as the various transportation sectors become increasingly electrified on a path toward energy efficiency and sustainability. This guide features several system block diagrams, followed by details about key devices and support functions.

## System Architecture of HEV/EV

The hybrid and electric vehicle system is built of several modules to form the drive train and energy storage system. The battery block (typically a Li-ion chemistry in the range of 400 V) is managed and monitored by the battery management system (BMS) and charged via an on-board AC/DC converter module, with voltages ranging from 110-V single-phase to 380-V three-phase systems. The DC/AC inverter uses the high voltage of the battery to drive the electric motor, but also is used for regenerative breaking, storing energy back into the battery.

To connect the high-voltage battery to the conventional 12-V board net requires a DC/DC converter. The connection of a high-voltage battery to the inverter also requires a reversible DC/DC converter in most cases. The complete HEV system has to meet specific safety requirements (up to ASIL-D) that are specifically relevant for managing the high-voltage battery pack, as well as the drive train used for breaking.

TI is very active in the industrial control segment and can combine extensive application experience with a strong background in the automotive space. Several evaluation modules with hardware and software support will speed up development, while the product roadmap addresses future requirements.

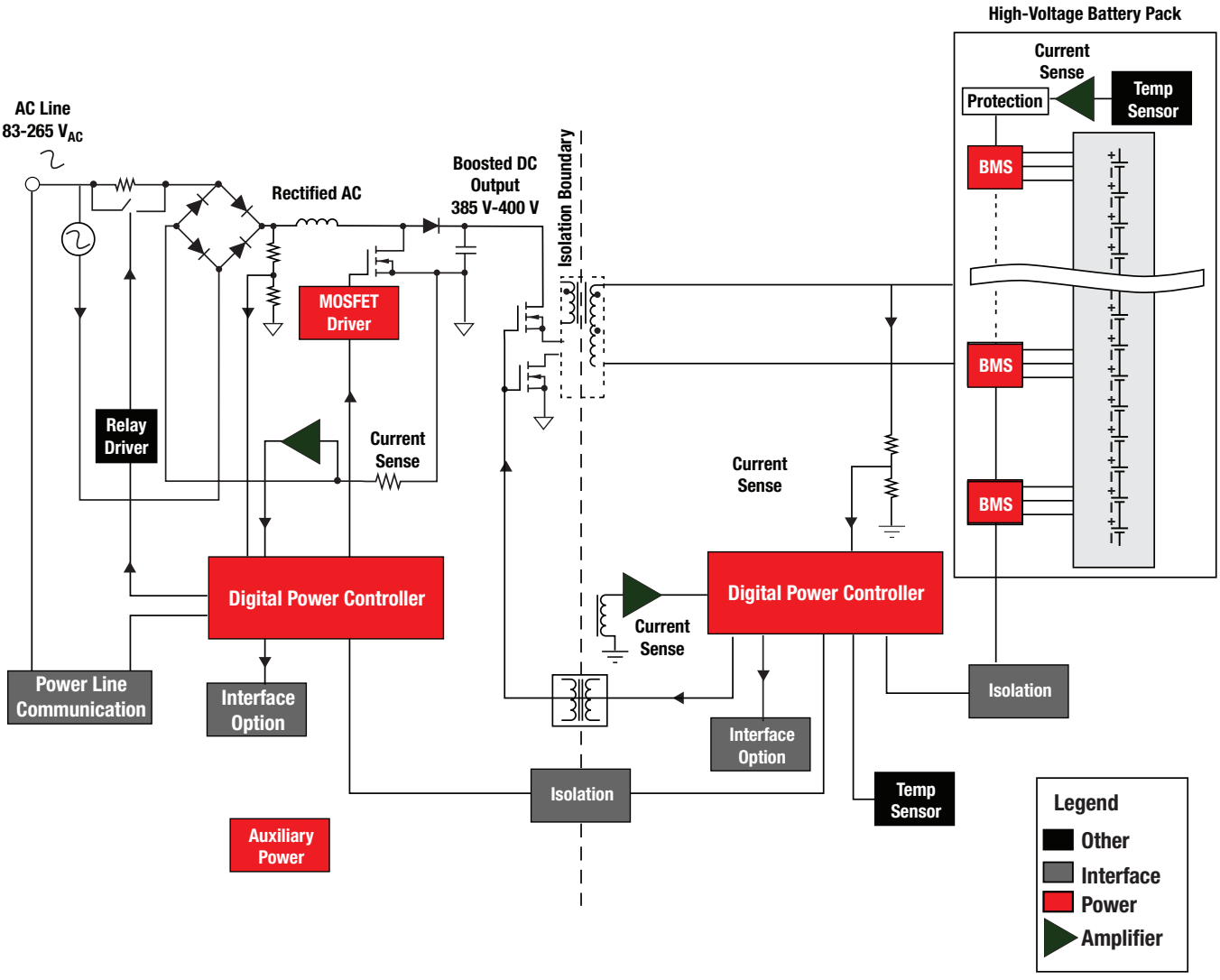


# Battery Management
## Introduction to Battery Management

Plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) are two quickly emerging technologies that use powerful electric motors as the propulsion source. In order to power these electric motors, large battery packs are made up of hundreds of cells, totaling 300-400 V installed in the vehicle.

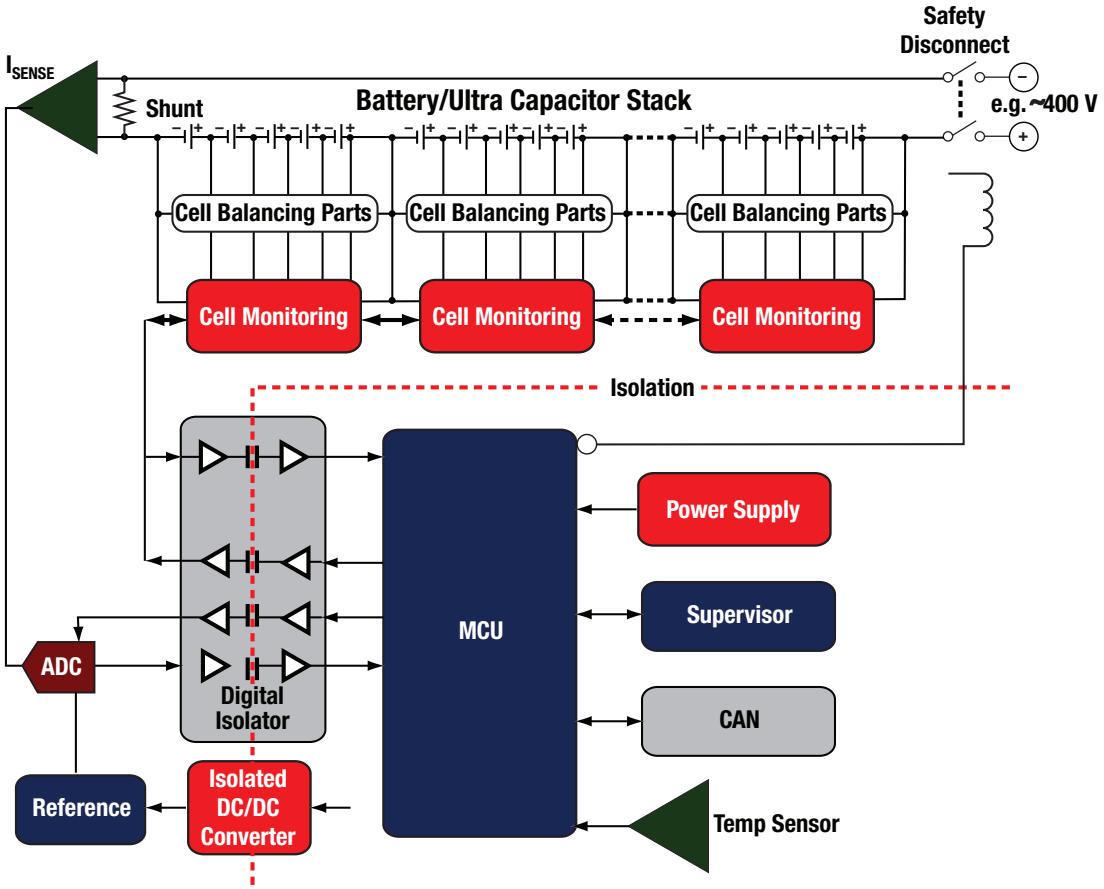
Because batteries have a finite energy capacity, PHEVs and BEVs must be recharged on a periodic basis, typically by connecting to the power grid. The charging system for these vehicles consists of an AC/DC rectifier to generate a DC voltage from the AC line, followed by a DC/DC converter to generate the DC voltage required by the battery pack. Additionally, advanced charging systems might also communicate with the power grid using power line communication (PLC) modems to adjust charging based on power grid conditions. The battery pack must also be carefully monitored during operation and charging in order to maximize energy usage and prolong battery life.

High-performance analog parts are also available to provide critical system functions and features such as sensor feedback, isolation, chip power supplies and communication transceivers.



# Battery Management
## Battery Management Systems

The bq76PL536A family of voltage and temperature monitors and balancers is designed for high-cell-count battery packs. They can handle the voltages and currents found in high-power applications like electronic mobility. The more cells a pack has in a series, the greater the difference in state of charge, impedance, and capacity affecting the health and energy delivery of the pack. The bq76PL536A device includes circuitry for bringing the cells back into balance. This increases the lifetime of the pack and can help deliver as much energy to the application as possible. Each bq76PL536A device protects from overcharge, over discharge, and over-temperature for pack and system safety.




BMS is a key element in the overall HEV architecture. Not only will an intelligent implementation extend the battery's lifetime, but it can also extend the possible range of the vehicle in fully electric drive mode, which is a key selling point to end users.

The battery system is often divided into several submodules that can be placed in various positions in the vehicle. All of these modules require battery supervision and battery cell-balancing features, often connected through different communication paths to ensure system redundancy. Built-in temperature management is also a crucial element for the system lifetime, and for safety.

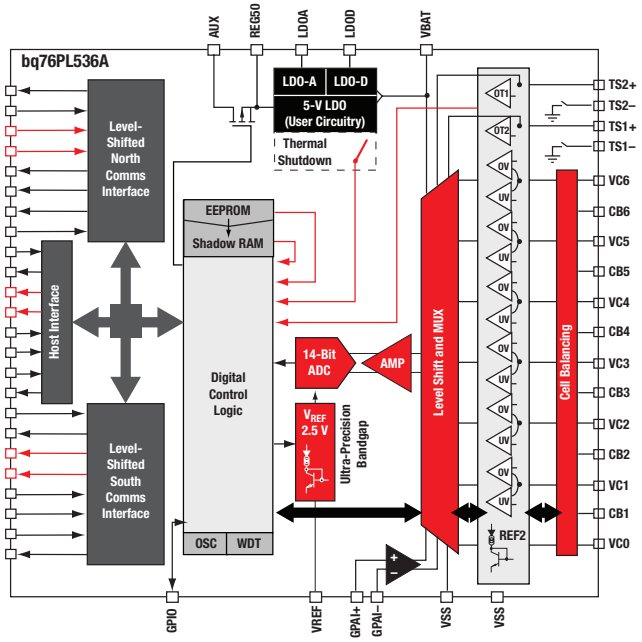
The complete battery system represents a highly safety-critical function; therefore, the microcontroller needs to meet specific safety requirements.

# Battery Management
## Battery Management: Applications

### bq76PL536A-Q1 Stackable Monitor, Protector and Balancer for Three- to Six-Series Li-Ion Cells

The bq76PL536A is a stackable, three- to six-series cell lithium-ion battery pack protector and analog front end (AFE) that incorporates a precision analog-to-digital converter (ADC), independent cell voltage and temperature protection, cell balancing, and a precision 5-V low dropout regulator (LDO) to power user circuitry. The bq76PL536A provides full protection (secondary protection) for overvoltage, undervoltage and overtemperature conditions. When safety thresholds are exceeded, the bq76PL536A sets the fault output. No external components are needed to configure or enable the protection features.

Cell voltage and temperature protection functions are independent of the ADC. The bq76PL536A is intended to be used with a host controller to maximize the functionality of the battery management system. However, the protection functions do not require a host controller. The bq76PL536A can be stacked vertically to monitor as many as 192 cells without additional isolation components between ICs.




Learn more at: **www.ti.com/sc/device/bq76PL536A-Q1**

#### Key Features

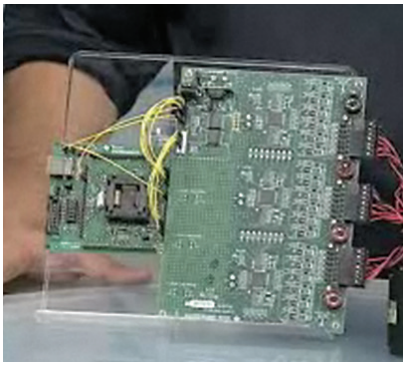
- Three- to six-series cell support, all chemistries hot-pluggable
- Stackable vertical SPI interface
- No isolation components required
- High-speed SPI for data communications
- Dedicated fault signals
- High-accuracy ADC:
  - ±1-mV typical, ±3-mV max
  - 14-bit resolution
  - 6-µs conversion time
- Nine ADC inputs: six cell voltages, one six-cell “brick,” voltage, two temperatures,one general-purpose input
- Built-in comparators (secondary protector) for overvoltage, undervoltage and over-temperature protection
- Programmable thresholds and delay times
- Supply voltage range from 5.5 V to 30 V
- Low power:
  - 12-µA sleep current typical
  - 48-µA idle current typical
- Integrated precision 5.0-V 3-mA LDO

---

### bq76PL536A Evaluation Module

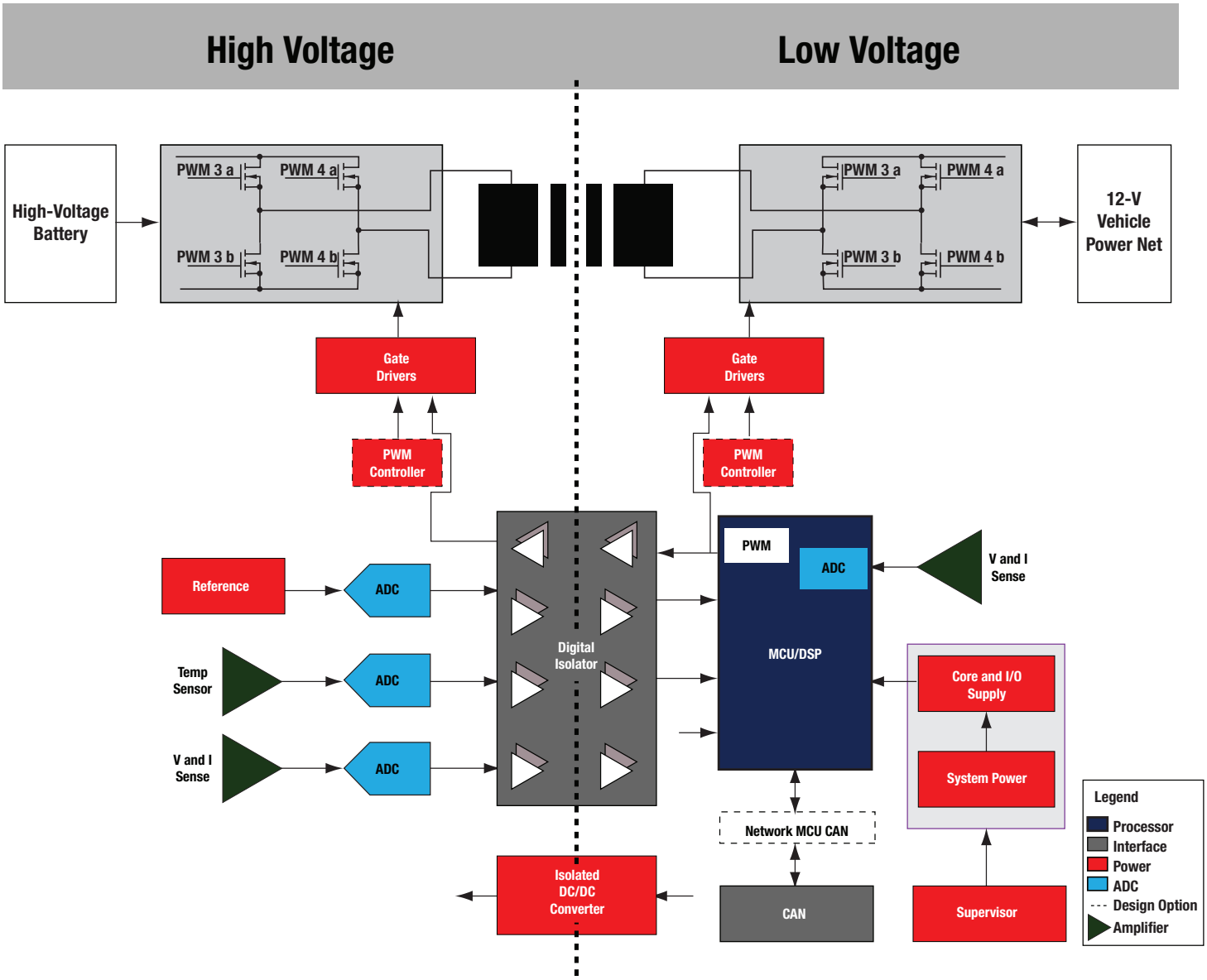
- Can handle up to 18 cells, three PL536 on the board
- Works with battery cells or power supply input
- Includes 2.5-kV galvanic isolation for host CPU or PC
- Software interface for easy system evaluation
- Order part number: bq76PL536AEVM
- MSP430EVM + bq76PL536AEVM App Note includes basic battery management code

Learn more at: **www.ti.com/sc/device/bq76PL536A**



*MSP430EVM + bq76PL536AEVM (see application note)*

The DC/DC converter module is used to connect the high-voltage battery to the 12-V vehicle power net. The system can either be realized with fixed PWM controllers or an MCU controlling both the high- and low-voltage side of the converter. This method offers more flexibility using a common hardware platform, with adjustments done in the software only and additional capabilities like diagnostic features.

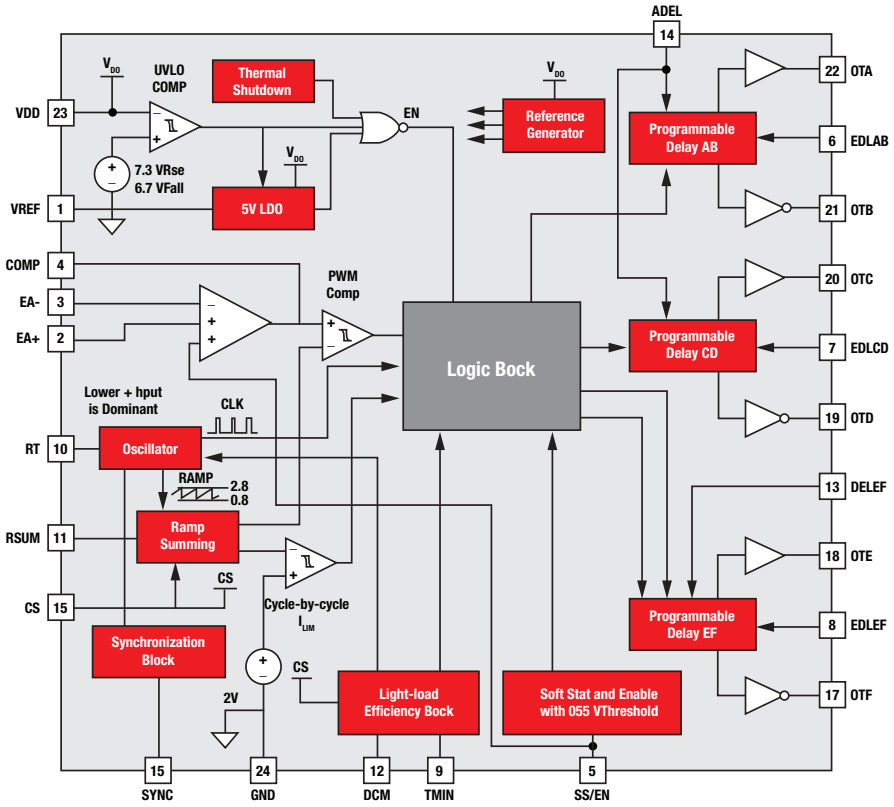


# Power Conversion Systems
## DC/DC Converter Using UCC28950-Q1

### UCC28950-Q1 Green Phase-Shifted Full-Bridge Controller with Synchronous Rectification

The UCC28950-Q1 enhanced phase-shifted controller builds upon Texas Instruments' industry-standard UCCx895 phase-shifted controller family with enhancements that offer best-in-class efficiency in today's high-performance power systems. The UCC28950-Q1 implements advanced control of the full bridge along with active control of the synchronous-rectifier output stage.

The primary-side signals allow programmable delays to ensure ZVS operation over wide load-current and input-voltage ranges, while the load current naturally tunes the secondary-side switching delays of the secondary-side switching delays of the synchronous rectifiers, maximizing overall system efficiency.




### Key Features

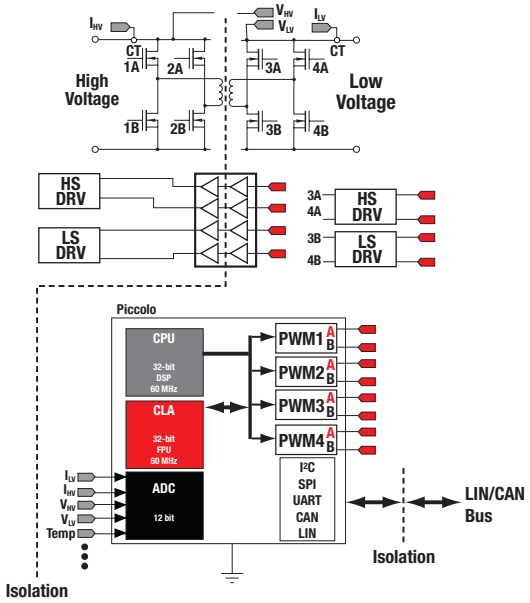
- Qualified for automotive applications
- AEC-Q100 qualified with the following results:
  - Device temperature grade 1: –40°C to 125°C ambient operating temperature range
  - Device HBM ESD classification level H2
  - Device CDM ESD classification level C3B
- Enhanced wide-range resonant zero-voltage switching (ZVS) capability
- Direct synchronous rectifier (SR) control
- Light-load efficiency management
- Average- or peak-current mode control with programmable slope compensation and voltage-mode control
- Closed-loop soft-start and enable function
- Programmable switching frequency up to 1 MHz with bidirectional synchronization
- (±3%) Cycle-by-cycle current limit protection with hiccup mode support
- 150-µA start-up current
- $V_{DD}$ undervoltage lockout

Learn more at: **www.ti.com/sc/device/UCC28950-Q1**

# Power Conversion Systems

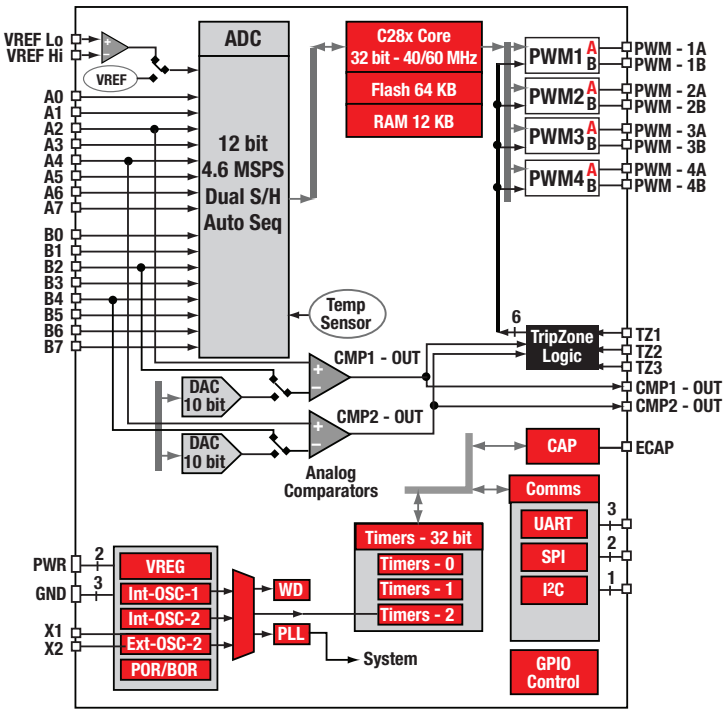
## DC/DC Converter Using C2000™ Piccolo™ MCUs

In automotive solutions, a bidirectional DC/DC converter is useful in many applications. For example, on the high-voltage side, an H-bridge topology is used to drive an inverter for the electric motor. When the driver steps on the brake, an H-bridge on the secondary side can use the back electromotoric force (EMF) to recharge the battery. Alternatively, a bidirectional DC/DC converter can be used in systems that have both a high-voltage lithium-ion battery and an automotive 12-V battery to add more capabilities, as well as increase flexibility.




### C2000™ Piccolo™ F2802x Family

TMS320F2802x devices feature architectural advancements and enhanced peripherals in packages from 38 pins to bring the benefits of 32-bit real-time control to applications typically unable to justify the associated cost. Real-time control offers greater system efficiency and precision through the implementation of advanced algorithms. For more information, see a full C2000 Piccolo part list on page 34, or visit **www.ti.com/c2000**.




### Key Features

- Qualified for automotive applications
- C28x™ MCU 32-bit CPU
- Single-cycle 32-bit MAC
- Up to 60-MHz performance
- Full software compatibility with previous generations

### Memory

- Flash: 16, 32, 64 KB
- RAM: 4, 6, 10, 12 KB

### Peripheral highlights

- Single 3.3-V supply
- Two high-accuracy on-chip oscillators (10 MHz)
- Best-in-class PWM and event capture
- 150-ps resolution on PWM duty and frequency
- 12-bit ratio-metric ADC with individual channel triggers and 4.6-MSPS speed
- Two analog comparators with 10-bit reference
- Robust serial communication interfaces
- Up to 22 general-purpose I/Os
- Packages: 38-pin TSSOP, 48-pin LQFP

PWMs: Includes ePWM channels and captures used as basic PWMs.

Timers: Timers include CPU, PWM and watchdog timers.

# Power Conversion Systems
## DC/DC Converter Using C2000™ Piccolo™ MCUs

### C2000™ Digital Power DC/DC Developer Kits

**Digital power experimenter's kit ($229) offers:**
- Two-rail DC/DC EVM using TI PowerTrain™ modules (10 A), F2808 controlCARD™ controller subsystem
- On-board digital multimeter and active load for transient response tuning

Order part number: TMDSDCDC2KIT

**DC/DC developer's kit ($325) offers:**
- Eight-rail DC/DC EVM using TI PowerTrain modules (10 A)
- Application software with example code and full hardware details
- Demonstrates multirail and multiphase applications
- Includes F28044 controlCARD controller subsystem

Order part number: TMDSDCDC8KIT

**Resonant DC/DC developer's kit ($229) offers:**
- Single transformer LLC resonant DC/DC converter
- Four different feedback methods for experimentation
- Lossless current sensing circuit for fault protection
- Active load for transient response tuning
- Includes F2808 controlCARD controller subsystem

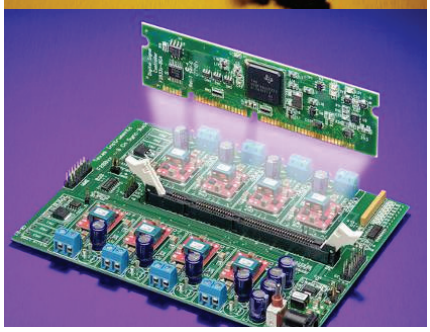
Order part number: TMDSRESDCKIT

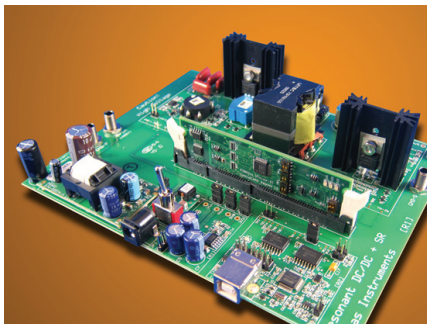
**Phase-shifted full-bridge developer's kit ($550) offers:**
- 300- to 400-V DC input / 12-V output, up to 600 W
- Synchronous rectification
- Efficiency: 95 percent at peak
  - 90 percent at 10 percent to 90 percent of rated power
- Output transient response:
  - <+-3 percent, <0.2 mS, on 10 to 80 percent load change at 1.0 A/µs
- Control methods:
  - Peak current-mode control with on-chip slope compensation (no external circuitry)
  - Optimized sync, rectification control
  - Voltage-mode control

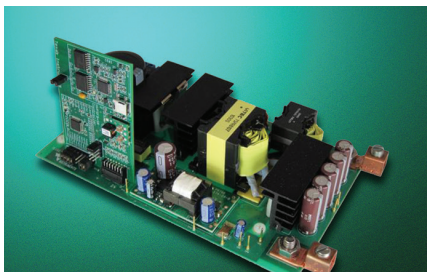
Order part number: TMDSHVPSFBKIT

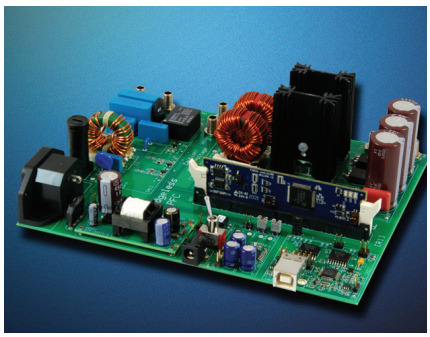
**LLC resonant developer's kit ($400) offers:**
- 300- to 400-V DC input 12-V DC output, up to 300 W
- Half-bridge with synchronous rectification
- Efficiency: 93.6 percent peak, 85 percent at 10 percent load
- Output transient response:
- <+-3 percent , <0.2 mS, on 10 to 80 percent load change at 1.0 A/µs
- Control methods:
  - Soft start
  - Resonant mode control
  - Adaptive ZVS
- Optimized synchronous rectification control
- Protection: overcurrent, overvoltage, undervoltage

Order part number: TMDSHVRESLLCKIT









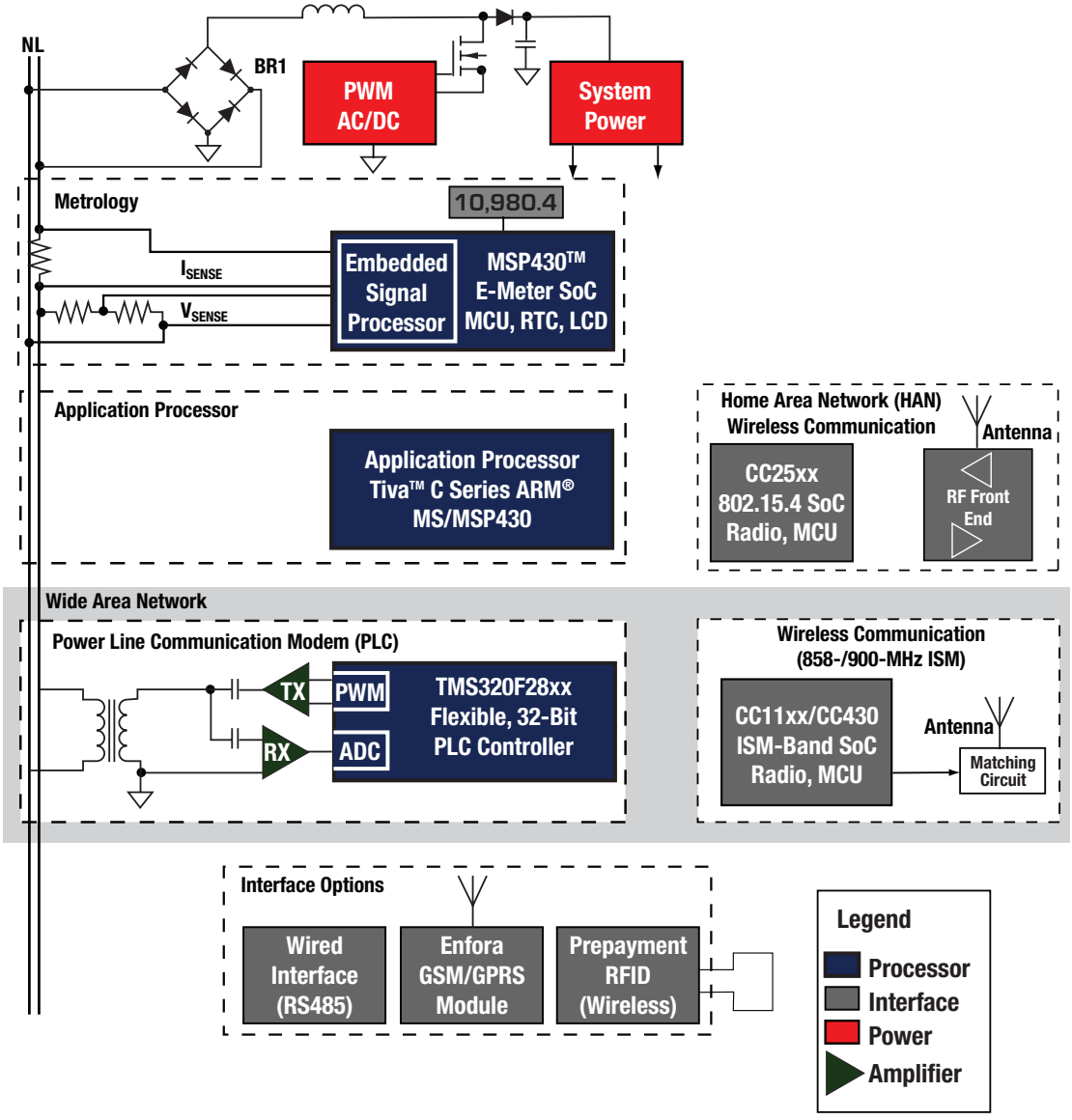
# Charging and Charging Infrastructure
## Introduction to Charging and Charging Infrastructure

The charging infrastructure connects the car to the smart power grid. The cost for the individual charging spot has to be balanced with the additional expansion capabilities on the communication side. The obvious choice for communication is a wired system via the charging cable, where power line communication is a widely used method. In that area, several activities for standardization are ongoing at the utilities side.

Texas Instruments is actively involved in standards development and offers solutions for SFSK and narrowband OFDM systems for the CENELEC A and B band, with OFDM standards like PRIME/G3.

The TMS320F28x microcontroller family is a flexible platform meeting these standards, with reference designs available.

Other options like RF communication using ZigBee or ISM band solutions are available, as are RFID systems for customer identification and prepayment options at the charging spot. The metering function for single-phase up to complex three-phase solutions can be realized with single-chip solutions out of the MSP430™ MCU family.



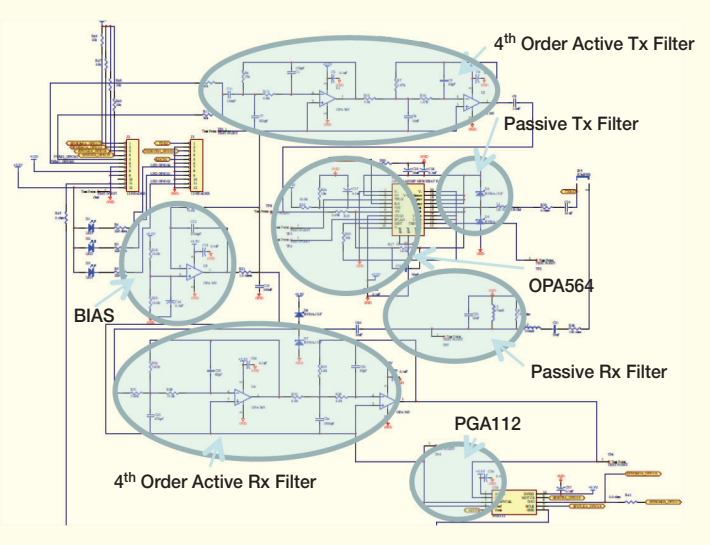

For more information, see **www.ti.com/metering**

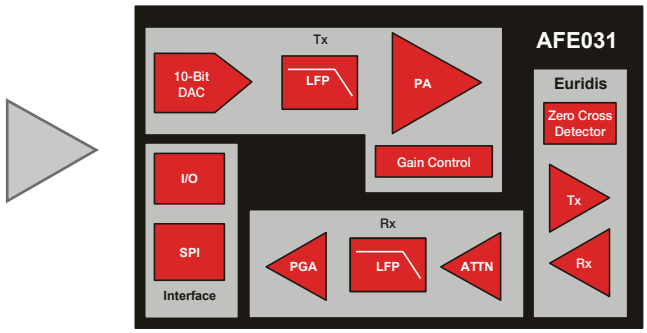
# Charging and Charging Infrastructure

## AFE031 Integrated PLC Analog Front End

### PLC Developer Kit

The new AFE031 integrates all PLC analog front end functionality into a single chip. Discrete implementation today ~100 parts. Sampling 2Q11.

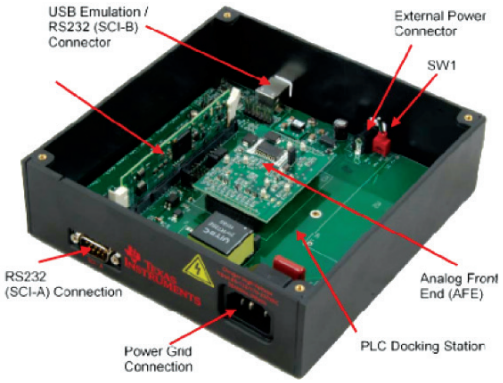



Learn more at: **www.ti.com/sc/device/AFE031**

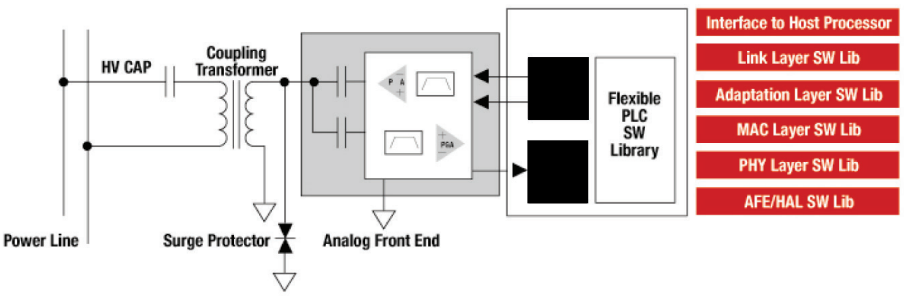
---

### TI PLC Modem Development Kit (TI PLC DK)




**The TI PLC DK contains:**

- Two PLC modems
- Power supply and cables
- GUI and documentations
- Run any IP applications through PC host
- Order part number: TMDSPLCKIT-V2
- Price: $599 US
- Distribution and TI eStore
- plcSUITE software available via download




- Robust narrowband PLC modem over low-/medium-voltage power line
- PLC standards/modulation supported
  - PRIME
  - G3
  - FlexOFDM
  - IEC61334 S-FSK
- Scalable data rates up to 128 Kbps for single phase
- Software reference design package: plcSUITE APIs, libraries, source codes
- AFE operating frequency range 9-500 kHz (different filters)
- Easy integration into endpoint or
- network devices of AMR/AMI systems
- NRE- and royalty-free

Learn more at: **www.ti.com/plc**

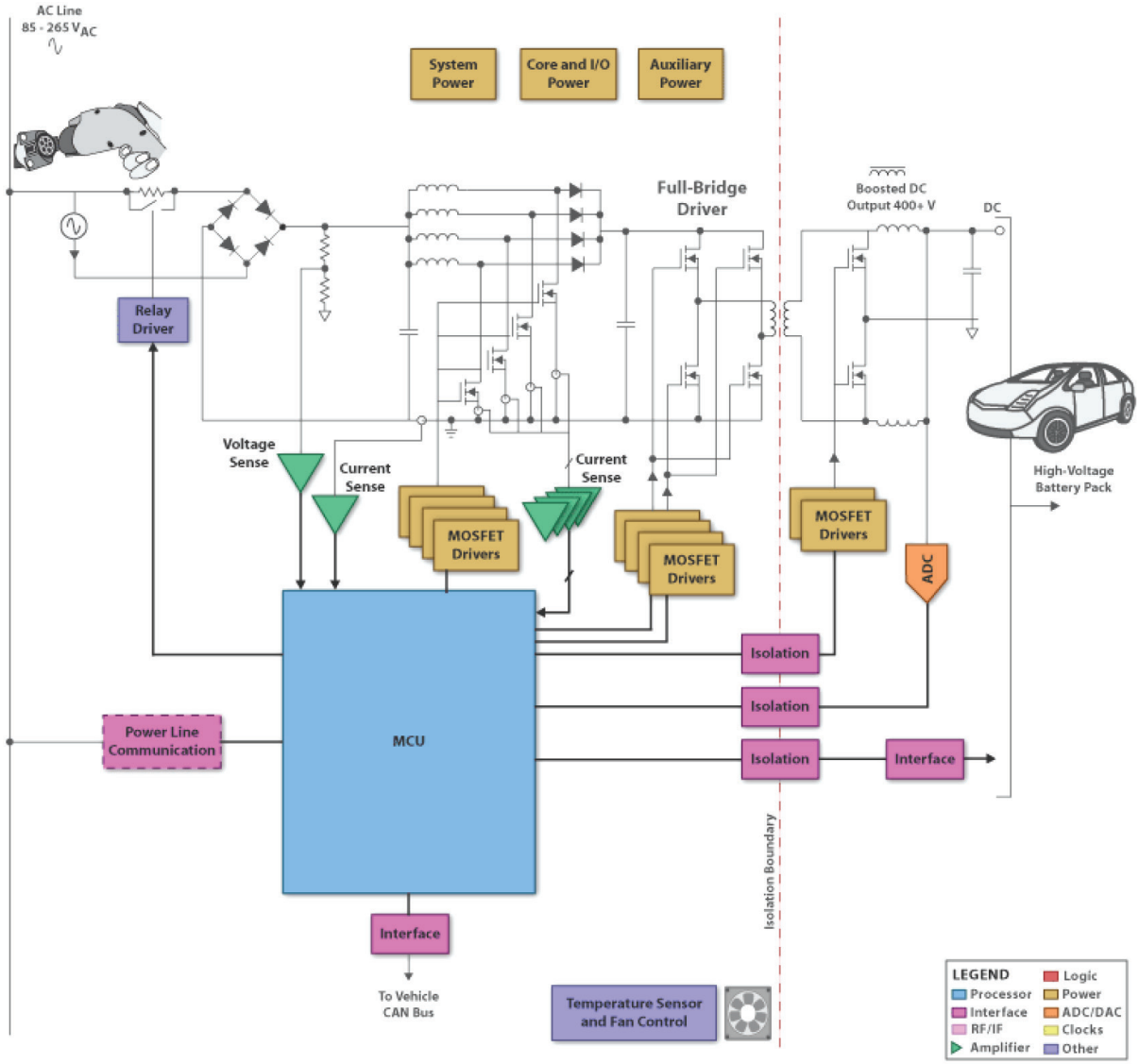
# Charging and Charging Infrastructure

## Charger Systems – AC Levels 1 and 2 (Onboard)

Since batteries have a finite energy capacity, PHEVs and BEVs must be recharged on a periodic basis, typically by connecting to the power grid in some form. For most users, Level 1 charging (120 VAC at 15 A-20 A) will be the most available power supply that all onboard chargers should be capable of handing, as it will be easily accessible to all users. In its current state, most users would prefer to take advantage of the faster charging Level 2 (240 VAC at 40 A) that will allow for faster charging times compared to the Level 1, but will require a larger power source to supply the appropriate current and voltage. By having the capacity to handle both types of charging, you provide users with more flexibility in their charging options and a larger number of locations where a charge can be delivered.

The Level 1 and 2 charging system for these vehicles consists of an AC/DC converter to generate a DC voltage from the AC line. This incoming power needs to undergo power factor correction (PFC) to boost the power factor to meet regional regulatory standards.

At the heart of the inverter is a real-time C2000™ microcontroller. This controller is programmed to perform the control loops for all necessary power management functions, including AC/DC with PFC and DC/DC to create the necessary charge profile for the battery. The C2000 controller contains advanced peripherals such as high-precision PWM outputs and ADCs, and is designed to read the ADC and adjust the PWM within a single clock cycle, making real-time control possible.



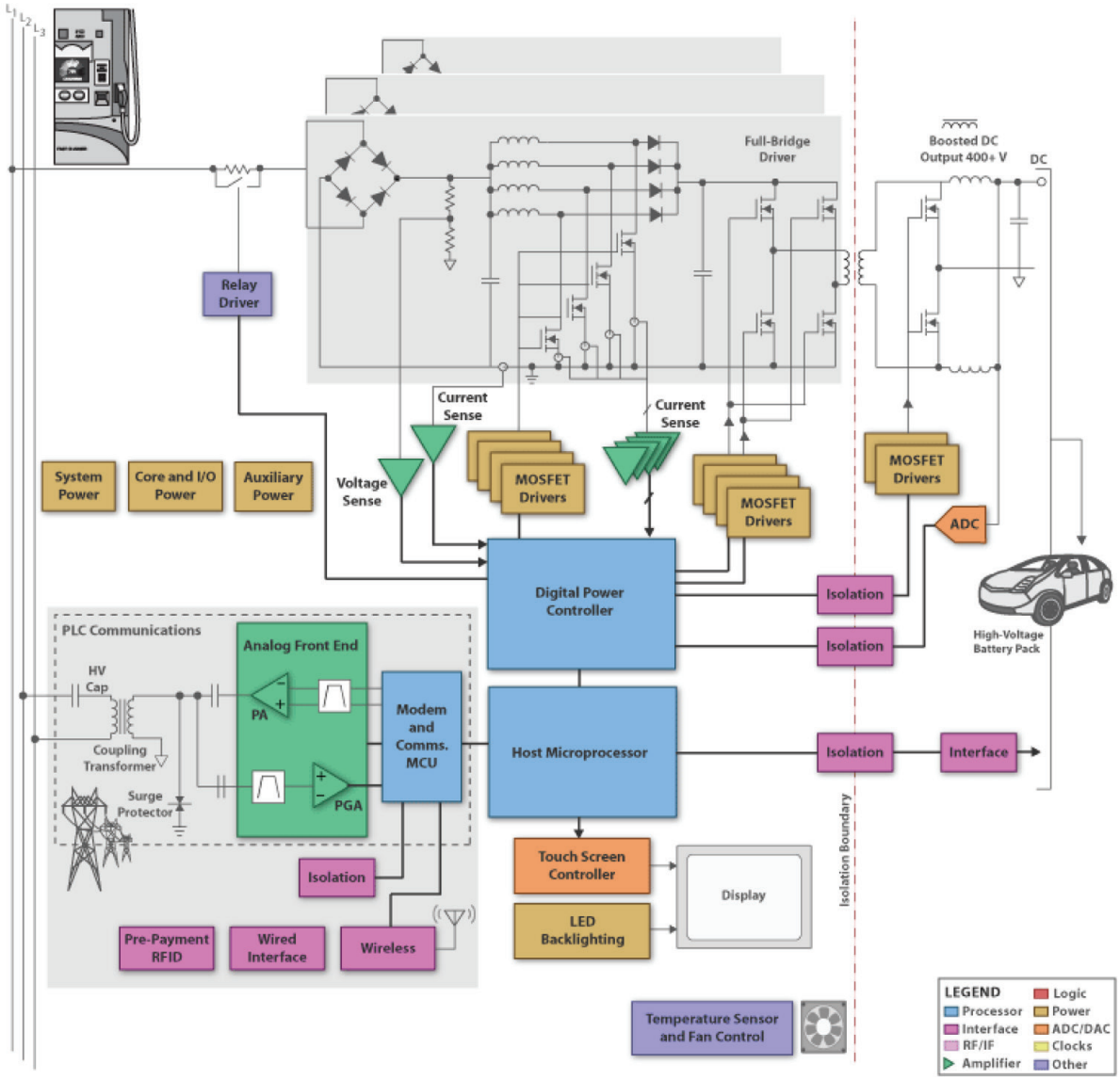
# Charging and Charging Infrastructure

## Charger Systems – DC Level 3 (Offboard)

Level 3 charging will play a key role in the public charging area in order to reduce charging time and make it more feasible for users to benefit from on-the-go charging.

The Level 3 charging system for these vehicles consists of an AC/DC converter to generate a DC voltage from the AC line. This incoming power needs to undergo power factor correction (PFC) to meet regional regulatory standards. At the heart of the inverter is a real-time C2000™ microcontroller. This controller is programmed to perform the control loops for all necessary power management functions, including AC/DC with PFC and DC/DC to create the necessary charge profile for the battery. The C2000 controller contains advanced peripherals such as high-precision PWM outputs and ADCs, and is designed to read the ADC and adjust the PWM within a single clock cycle, making real-time control possible.

Communications on a simple system can be handled by a single processor. More elaborate systems with complex displays and online billing/reporting, such as Level 3 charging, may require a secondary controller. Implementing a low-frequency narrow-band PLC (LF NB PLC) solution provides an optimal fit in terms of bandwidth, power and cost requirements. Operating in the narrowband domain (frequencies up to 500 kHz) ensures data integrity while minimizing system cost. In doing so, this standard would leverage the existing power line infrastructure and provide a cost-effective means of integrating intelligent monitoring and control into new automotive systems. Data rates can vary from 1.2 Kbps up to hundreds of Kbps based on the existing standards.

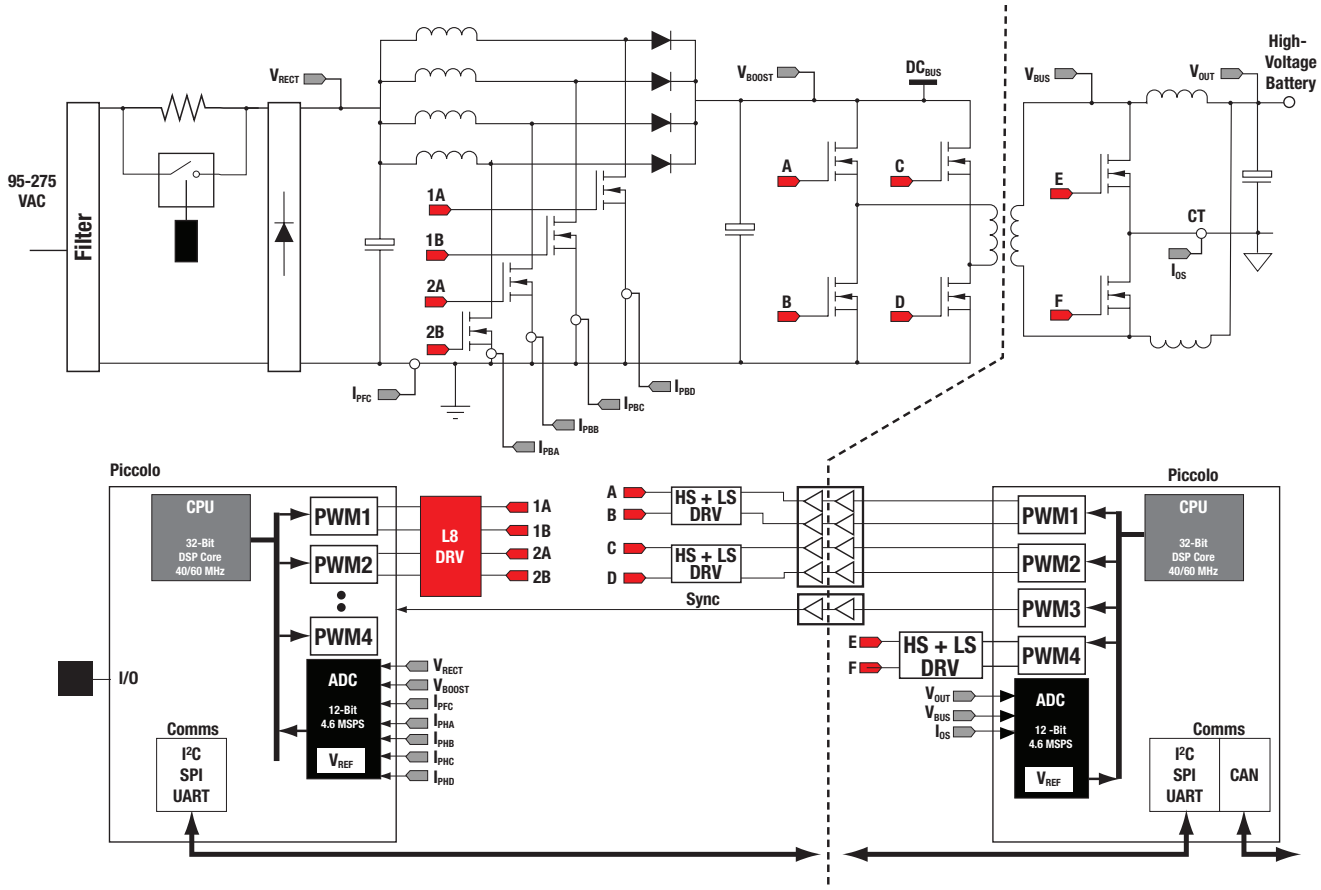


# Charging and Charging Infrastructure

## AC/DC Converter with PFC Using C2000™ Piccolo™ MCUs

The charging of the HEV/EV via the main grid demands a flexible setup to meet the various voltage levels in single-phase (120 V, 230 V) and three-phase 380-V systems with different current levels (16 A to 63 A). The charging time is certainly an important feature for the car's end customer, but has to be balanced with the long-term aging behavior of the battery pack.

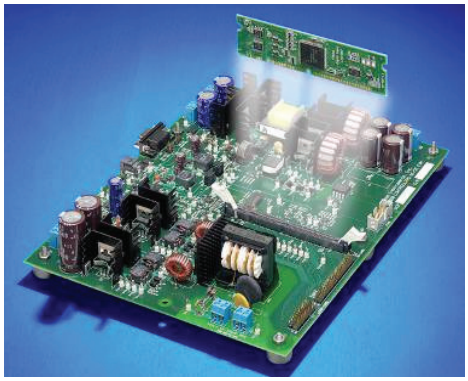
The AC/DC charging system shown offers a power factor control (PFC) function along with high-voltage power conversion to directly generate the battery's DC charging voltage. An optional power line communication (PLC) to communicate with the charging infrastructure can be implemented as well. This setup demands a high number of pulse-width modulation and analog-to-digital converter channels, along with powerful CPU performance.




### AC/DC Development Kits with C2000™ MCUs

- Complete, low-power rectifier development platform for prototyping communications systems
- AC/DC EVM with interleaved PFC and phase-shifted full bridge
- Primary side control, synchronous rectification, peak current-mode control, two-phase PFC with current balancing
- Contains an 80-W (max) system that uses a two-phase interleaved PFC front end and a phase-shifted full-bridge rectifier stage
- Includes F2808 controlCARD™ controller subsystem
- Available for $695

Order part number: TMDSACDCKIT



Learn more at: **www.ti.com/c2000tools**

# Charging and Charging Infrastructure

## AC/DC Converter with PFC Using C2000™ Piccolo™ MCUs

### AC/DC Development Kits with C2000™ MCUs

**Power factor correction developer's kit ($550) offers:**

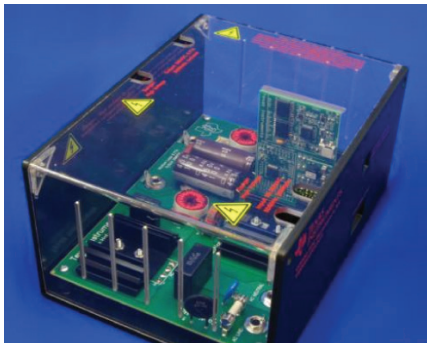
- Two-phase interleaved power factor correction
- 90-260 VAC input, 300-W output up to 390 V
- Full load efficiency >90 percent
- Power factor correction at 50 percent or greater load – 0.9 min
- Supports multiple control topologies

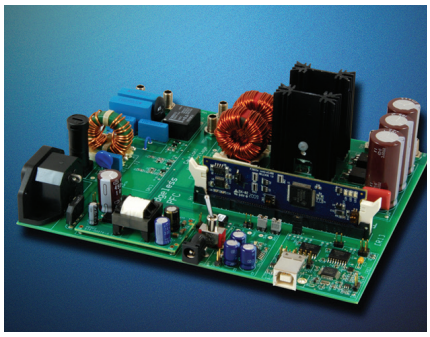
Order part number: TMDSHVPFCKIT

**Bridgeless PFC developer's kit ($450) offers:**

- Higher efficiency – no bridge losses
- 90-260 VAC input, 300-W output up to 400 V
- Power factor correction at 50 percent or greater load – 0.9 min
- Supports multiple control topologies
- Half-cycle (AC) RMS feed-forward loop
- Faster DC bus voltage response without sacrificing PF
- RMS input VF monitoring
- Onboard EMI filter
- Protection: overcurrent, overvoltage, undervoltage

Order part number: TMDSHVBLPFCKIT





### Why Piccolo™ MCUs?

The Piccolo™ F2802x/F2803x family of C2000™ MCUs provides a low-cost, high-integration solution to help drive processor-intensive real-time control into cost-sensitive applications. With a host of industry-leading integrated modules, such as a powerful ADC, dedicated high-resolution PWMs and the unique control law accelerator (CLA), Piccolo MCUs are ideal for power conversion in electric vehicles. For more complex systems, like those with integrated power line communication, several additional members of the C2000 family are available, offering floating-point performance up to 300 MHz and high-performance peripherals like a 12.5-MSPS 12-bit ADC.

| Benefit | Enabling Feature |
|---|---|
| **Improved system efficiency/accuracy** | • High-performance C28xTM core supports adaptive control algorithms for efficiency across load curve<br>• High-resolution 150-ps PWM modules and high-speed on-chip ADC |
| **Added functions/features** | • Communication with outside systems: CAN, LIN, $I^2C$, UART, SPI<br>• Multiple PWMs allow multiple DC output rails |
| **Better R&D efficiency** | • Software control adaptable to multiple topologies and power ratings |
| **Increased reliability** | • Digital control can adapt to environmental conditions and be recalibrated in software<br>• Software can implement failure prediction |

*Take a look on page 34 for a full configuration table of Piccolo MCUs for hybrid and electric vehicles.*

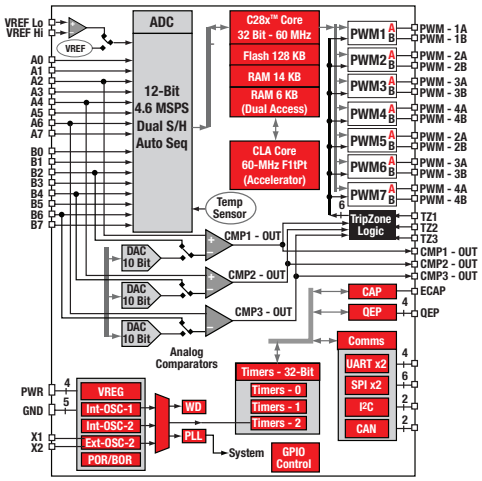
Learn more at: **www.ti.com/c2000**

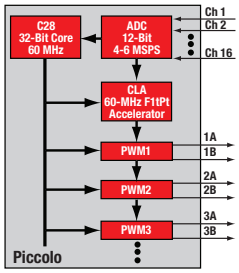
# Charging and Charging Infrastructure

## AC/DC Converter with PFC Using C2000™ Piccolo™ MCUs

### Piccolo™ MCUs F2802x vs. F2803x

The TMS320F2803x includes the same C28x™ MCU core, enhanced high-resolution PWM technology and a high-speed ADC, but combines more features and additional memory.




**Key Features**

- Up to 128-KB flash, 20-KB RAM
- All-new CLA: independent, floating-point processing unit with direct access to ADC and PWMs enables parallel control loop execution
- Additional three ePWM modules (six PWM outputs)
- Quadrature encoder interface (eQEP)
- Three on-chip comparators
- Added communication ports – CAN 2.0B with up to 16 mailboxes, LIN/UART and additional SPI
- Packages: 64-pin TQFP, 80-pin LQFP

Learn more at: **www.ti.com/piccolo**

---

### ControlSuite™ Software

ControlSuite™ software for C2000™ microcontrollers is a cohesive set of infrastructure and software tools designed to minimize software development time. From device-specific drivers and support software to complete system examples in sophisticated system applications, ControlSuite software provides libraries and examples at every stage of development and evaluation. ControlSuite software contains a full digital motor control library as well as motor control kits.

**One stop for all C2000 MCU software:**

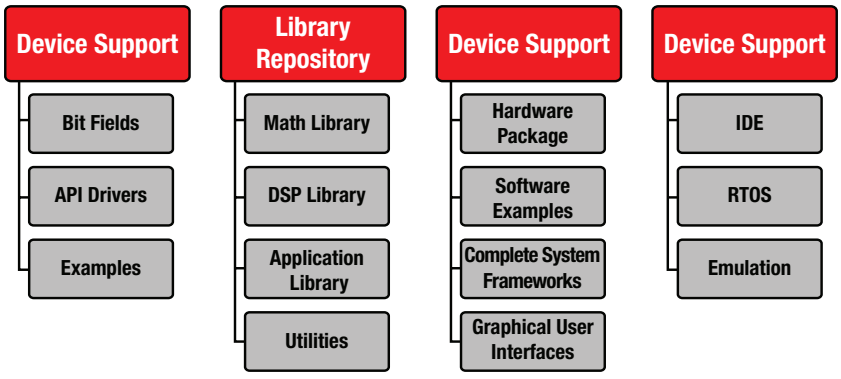
- Single, centralized location
- Intelligent installer eliminates the search for dependencies

**Open, real-world systems:**

- Compilation of 15 years of systems and applications expertise
- Unique, optimized libraries for math, filtering, DSP and specific applications, with complete system examples utilizing incremental builds
- Allows developers to focus on differentiation, not basics

**Program the MCU your way:**

- Significantly reduce development time with hardware abstraction and extensive libraries
- Four interusable levels of hardware abstraction




**ControlSuite Software Support for Motor Control**

| Motor | Technique | Type | Feedback |
|---|---|---|---|
| ACI | FOC | Speed and Torque | Tachometer |
| | FOC | Speed and Torque | Sensorless |
| BLDC | Trapezoidal | Speed | Half Effect |
| | Trapezoidal | Speed | Sensorless |
| | Sinusoidal | Speed | Half Effect |
| | Sinusoidal | Speed | Sensorless |
| PMSM | FOC | Speed and Torque | Encoder |
| | FOC | Position | Encoder |
| | FOC | Speed and Torque | Sensorless |
| Stepper | Microstep | Position | Sensorless |
| Brushed | DirectDrive | Speed and Position | Encoder |

Learn more at: **www.ti.com/controlsuite**

# Charging and Charging Infrastructure

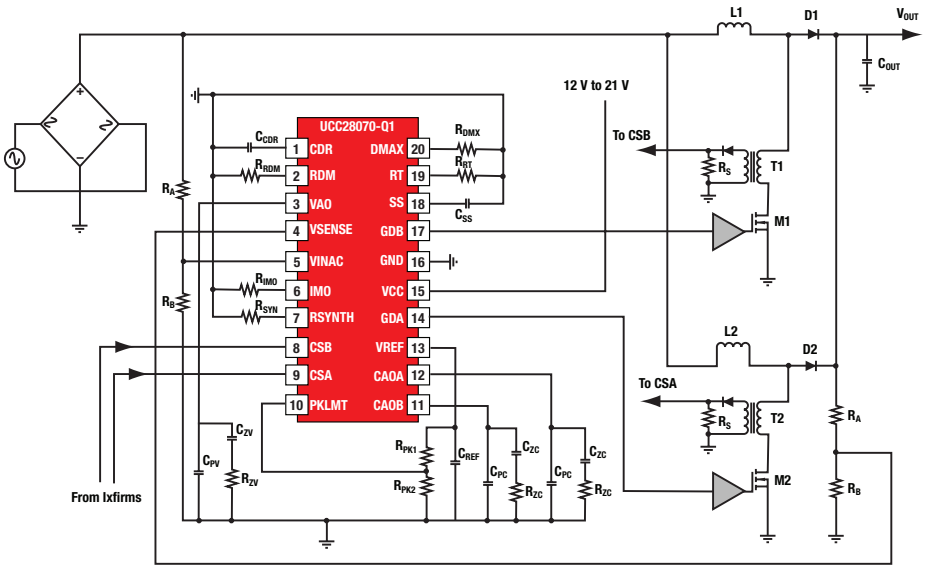
## Power Factor Correction with UCC

### UCC28070-Q1 Two-Phase Interleaved Constant-Current-Mode (CCM) Power Factor

The UCC28070-Q1 is an advanced PFC device that integrates two pulse-width modulators (PWMs) operating 180 degrees out of phase. This interleaved PWM operation generates substantial reduction in the input and output ripple currents, and the conducted EMI filtering becomes easier and less expensive. A significantly improved multiplier design provides a shared current reference to two independent current amplifiers, ensuring matched average current-mode control in both PWM outputs while maintaining a stable, low-distortion sinusoidal input line current.

The UCC28070-Q1 contains multiple innovations, including current synthesis and quantized voltage feed-forward correction to promote performance enhancements in PF, efficiency, THD and transient response. Features including frequency dithering, clock synchronization and slew-rate enhancement further expand the potential performance.

The UCC28070-Q1 also contains a variety of protection features, including output overvoltage detection, programmable peak-current limit, undervoltage lockout and open-loop protection.

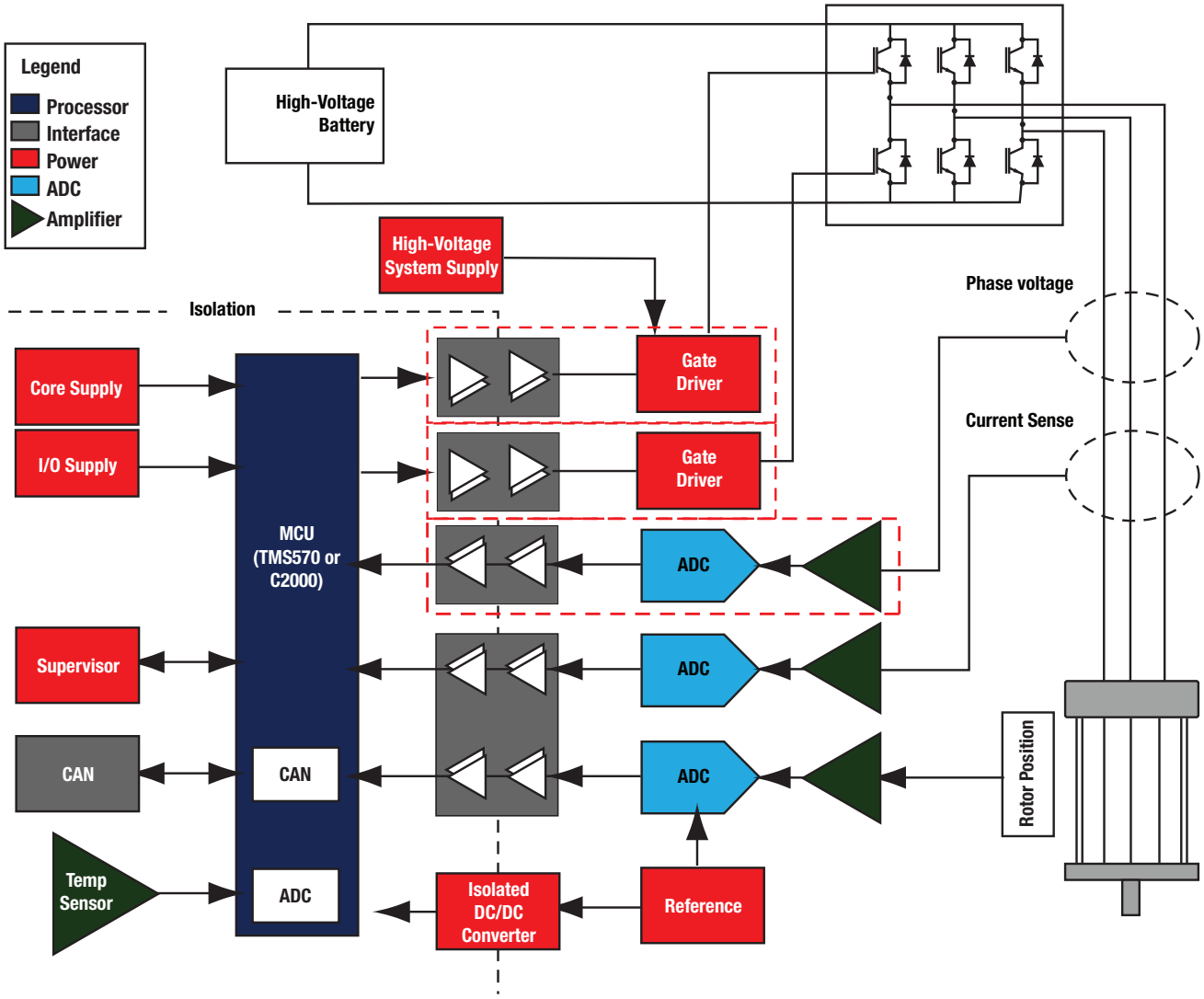



### Key Features

- Interleaved average current-mode PWM control with inherent current matching
- Advanced current synthesizer current sensing for superior efficiency
- Highly linear multiplier output with internal quantized voltage feed-forward correction for near-unity PF
- Programmable frequency (10 kHz to 300 kHz)
- Programmable maximum duty-cycle clamp
- Programmable frequency dithering rate and magnitude for enhanced EMI reduction
- Magnitude: 3 kHz to 30 kHz
- Rate: up to 30 kHz
- External clock synchronization capability
- Enhanced load and line transient response through voltage amplifier output slew-rate correction
- Programmable peak-current limiting
- Bias-supply UVLO, overvoltage protection, open-loop detection and PFC-enable monitoring
- External PFC-disable interface
- Open-circuit protection on VSENSE and VINAC pins
- Programmable soft start
- 20-lead TSSOP/SOIC package

Learn more at: **www.ti.com/piccolo**

The inverter will drive the electric motor for fully electric operation in full hybrids and EVs as well as for torque assist in a mild hybrid car concept. This can be done with a single motor positioned to drive one axis, but also using in-wheel motors to individually drive each wheel of the car. The microcontroller used may be required to meet strict safety requirements/standards, as not only the driving but also recuperative braking is controlled through this unit. In addition, the PWM's output signals and sensing inputs have to be controlled, still embedded in the overall safety concept. Like with any other element in the HEV/EV space, isolation is especially important in the inverter module. Learn more about motor drive and control solutions from Texas Instruments at **www.ti.com/motor**.



# Motor Control

## Safe Motor Control with TMS570 ARM® Cortex™-R4F

### TMS570 Microcontroller

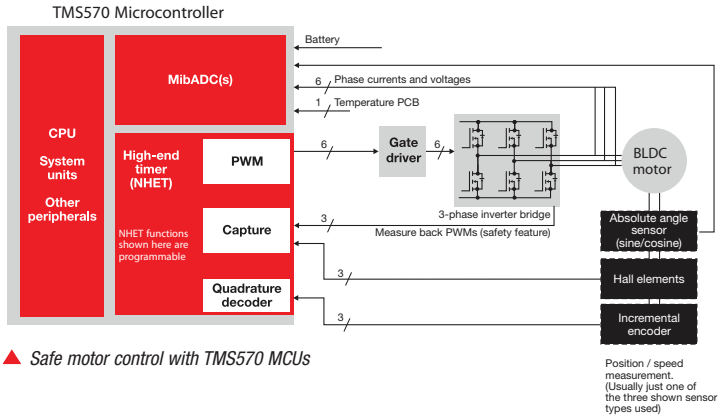
#### TMS570 MCU motor control benefits

**32-bit ARM Cortex-R4F with floating-point unit**

- IEEE 754-compliant floating-point unit (ARM VFPv3D16)
  - Supports both single and double precision

**Timer coprocessor – high-end timer (HET)**

- Effective support of many different motor control concepts due to HET programmability
  - PWM generation – symmetric, asymmetric, deadband
  - Single- or multiple-shunt systems
  - Quadrature decoding
  - HET can trigger the ADC(s) with many configuration possibilities




▲ *Safe motor control with TMS570 MCUs*

**Dual 12-bit buffered ADCs**

- 12-bit resolution SAR
- 400-ns conversion time / 200-ns sampling time
- 24 total channels (MibADC1 = 8, MibADC2 = 8, Shared = 8)
  - Shared channels can be used for oversampling using both ADCs
  - Continuous multichannel or single-channel conversion modes

#### TMS570 key features

**ARM Cortex-R4F CPU**

- Up to 160 MHz with floating-point support
- Dual CPUs in lockstep

**Memory**

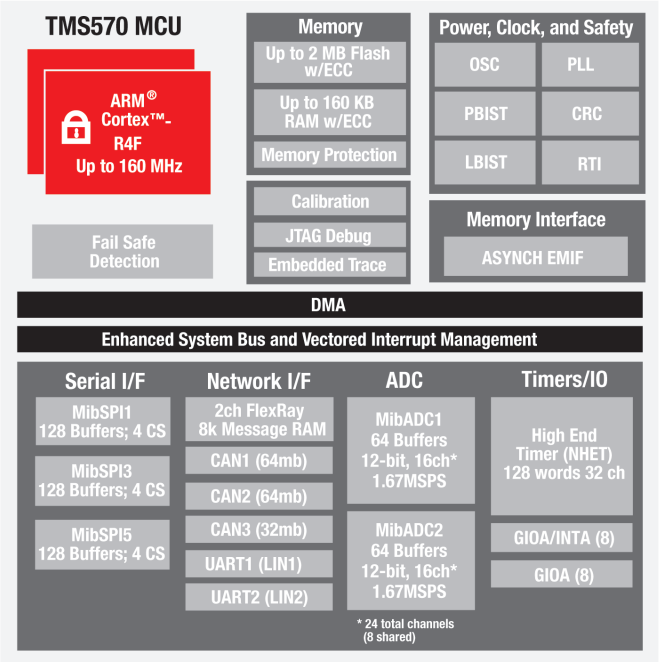
- Flash: 1 MB and 2 MB with ECC protection
- RAM: 128 KB and 160 KB with ECC protection
- Roadmap from 768-KB to 4-MB flash

**Peripheral highlights**

- FlexRay with 8-KB message RAM
- Three CAN interfaces
- Three Multibuffered SPI (MibSPI)
- Two UARTs – both with LIN 2.1
- Two 12-bit buffered ADCs (MibADC)
- Flexible timer module with up to 32 channels
- Trace and calibration interfaces

**Packages**

- 144 QFP, 337 nFBGA (16 × 16 mm)




#### TMS570 enables safe motor control

The TMS570 microcontroller family enables customers to easily build safety-related motor control applications. Devices are available today with up to 160 MHz of floating-point performance and an integrated safety concept.

A wide choice of communication peripherals like CAN, FlexRay and LIN – in combination with a powerful timer coprocessor module – (HET) makes the family a flexible solution for safety-critical control applications.

Learn more at: **www.ti.com/TMS570**

# Motor Control

## Safe Motor Drive with DRV32xx family

### Key Features

- Built-in diagnostics: The DRV32xx-Q1 family integrates hard-wired diagnostic circuits including a pre-FET driver short, over/under voltage and over temperature. The system's microcontroller can quickly communicate with the DRV32xx-Q1 family and monitor internal status through serial peripheral interface (SPI).
- Devices help customers design applications to meet the functional safety requirements of ISO 26262: DRV3201-Q1 can help TI customers design critical-safety applications, such as electric power steering and electric braking systems, to meet ASIL-D requirements , and the DRV3204-Q1 and DRV3203-Q1 can help customers design safety applications, such as oil pump and water pump, to meet the ASIL-B requirements.
- Design simplicity for start-stop and cold crank applications: With an integrated boost regulator, the DRV3201-Q1 eliminates the need for a large capacitor to hold battery voltage. With an integrated low drop-out linear regulator (LDO) and an external FET, the DRV3203-Q1 and DRV3204-Q1 also eliminate the need for a large capacitor or external boost regulator. This integration simplifies design and speeds up development time.
- Optimized component count and board space for cost- and space-sensitive applications: The DRV3202-Q1 integrates a voltage regulator and CAN Interface to reduce component count and minimize system cost and board space.

## DRV32xx Product Overview

| Function | DRV3201 | DRV3204 | DRV3203 | DRV3210 | DRV3202 | DRV3211 |
|---|---|---|---|---|---|---|
| **Gate Driver Stage** | 140 mA to 1 A, programmable current sources | 1 A gate driver switches | 1 A gate driver switches | 1 A gate driver switches | 1 A gate driver switches | 1 A gate driver switches |
| **Current Sense Amplifiers** | 2 ch, low side | 1 ch, high side | 1 ch, high side | 1 ch, high side | 1 ch, high side | 1 ch, high side |
| **Short protectiong** | VDS | High side over current, phase comparator | High side over current, phase comparator | High side over current, phase comparator | High side over current, phase comparator | High side over current, phase comparator |
| **Watchdog** | No watchdog | Pulse, WD input | Pulse, WD input | Pulse, WD input | Pulse, WD input | Pulse, WD input |
| **Phase comparators** | Three phase comparators | Three phase comparators | Three phase comparators | Three phase comparators | Three phase comparators | Three phase comparators |
| **Voltage Monitoring** | VS | VB,VCC5 | VB,VCC3 | VB,VCC5 | VB,VCC5 | VB,VCC5 |
| **Others** | ASIL D system target | 5 V MCU LDO | 3.3 V MCU LDO | 5 V low power MCU LDO | CAN, 5 V MCU LDO | 5 V MCU LDO |
| **Maxmum Supply Voltage** | 40 V | 40 V | 40 V | 40 V | 40 V | 40 V |
| **Maximum Operating Temperature** | Ta = 125ºC | Ta = 125ºC<br>Ta = 150ºC option | Ta = 12ºC<br>Ta = 150ºC option | Ta = 125ºC | Ta = 125ºC | Ta = 125ºC |
| **Package** | 64-pin HTQFP PowerPADTM | 48-pin HTQFP PowerPADTM | 48-pin HTQFP PowerPADTM | 48-pin HTQFP PowerPADTM | 80-pin HTQFP PowerPADTM | 80-pin HTQFP PowerPADTM |
| **Target application** | EPS, Brake, Pumps, Transmission | Transmission, Pumps, FAN | Transmission, Pumps, FAN | Transmission, Pumps, FAN | Transmission, Pumps, FAN | Transmission, Pumps, FAN |

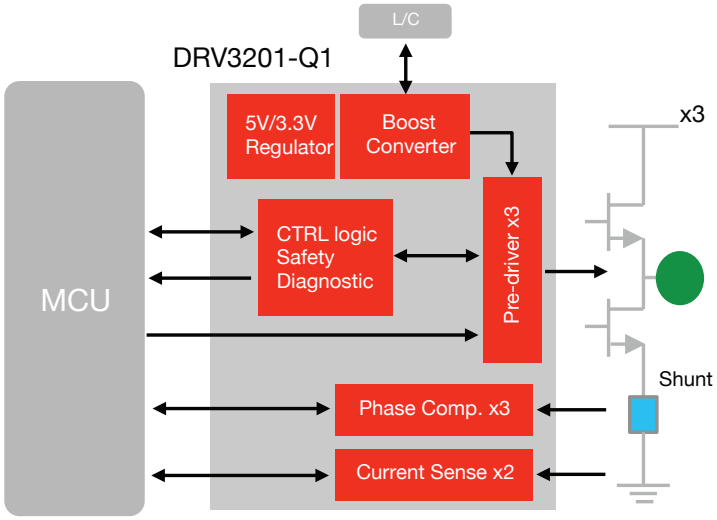
Learn more at: **www.ti.com/automotordriver**

# Motor Control

## Safe Motor Drive with DRV32xx family

### Key Features

- 3 phase pre-FET drivers
- Programmable 140 mA to 1 A gate current drive
- Gate driver with low supply voltage operation with integrated boost converter
- 2 Modes of gate drivers
  - Direct mode (6 x inputs)
  - PWM mode to 20 KHZ, 100% duty operation (3 x inputs)
- High accuracy current sense amplifiers (2 ch)
- Real time phase comparator (3 ch)
- Shoot through protection
- Pre-FET driver short circuit protection
- Over-/Under-voltage protection
- Over temperature warning and shut down
- AEC-Q100 grade-1 (-40ºC to 125ºC)
- Operating supply voltage: 4.75 V to 30 V
- 3.3 V/5 V MCU interface
- -7 V to 40 V tolerance for all FET driver pins
- Logic functional down to 3 V
- Package: 64-pin HTQFP PowerPAD™

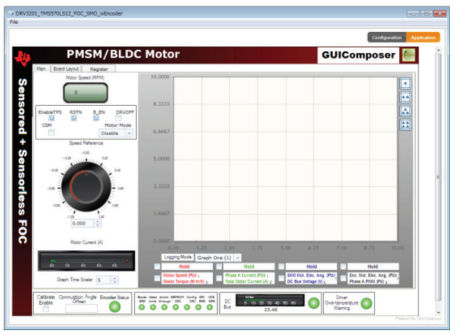



---

### DRV3201 Development Tools

### DRV3201EVM ($499)

The Texas Instruments DRV3201 evaluation module (DRV3201EVM) helps designers evaluate the operation and performance of the DRV3201-Q1 bridge driver for electronic power steering applications. The DRV3201EVM can accept many of the TI Micro-Control Unit (MCU) Control Cards. The device with the MCU offers configurability and can turn a motor via a Graphical User Interface (GUI).




### Key Features

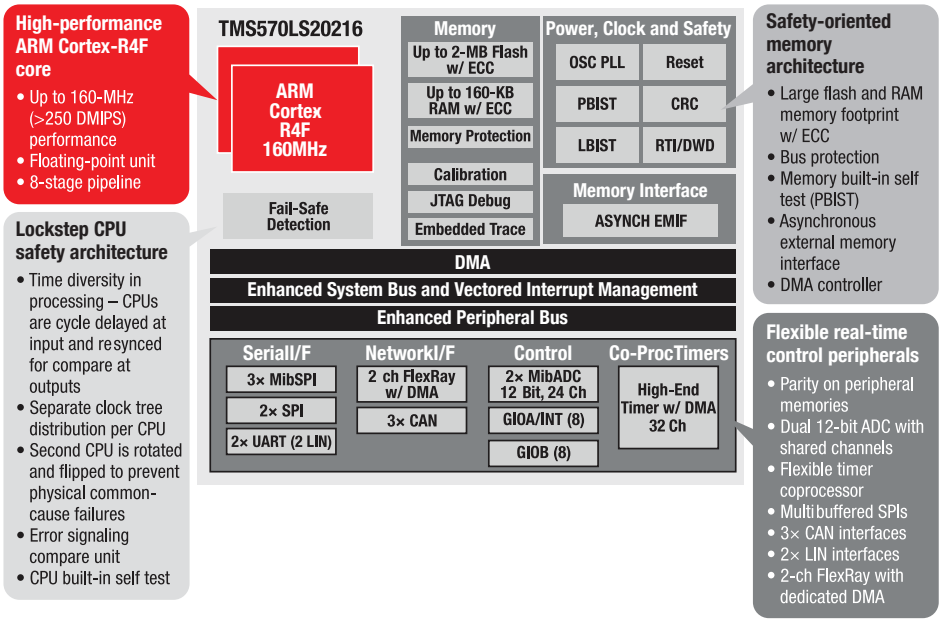
- Max 1 A (programmable) pre-drive with 2x Internal programmable gain amplifiers for shunt current sensing
- Operating supply voltage 4.75 V to 30 V
- 5-V step down converter(2.5-A) and 3.3 V LDO (400-mA)
- Six N-channel MOSFETs
- Isolated 5-V controller area network (CAN) transceiver
- DIMM-100 socket using control card of Texas Instruments
- Sockets for sensor input

Learn more at: **www.ti.com/automotordriver**

# Motor Control
## Introduction to Functional Safety

### TMS570 Built-In SIL3 Certified Safety Concept

The TMS570 family is specifically designed to meet IEC61508 SIL3 for safety critical applications like HEV/EV. A SIL3 certificate and the required documentation are available. A dual CPU lockstep architecture simplifies development while eliminating redundant system requirements to reduce cost. CPU hardware built-in self test (BIST) detects latent defects without complex safety drivers or code size overhead. Hardware comparison of CPU outputs provides exceptional safety response time without additional software overhead. An enhanced ECC logic is integrated in the CPU to protect both memories and buses. All memories can be tested using hardware BIST for high diagnostic coverage and an integrated memory protection unit (MPU) protects against deterministic errors in application software.




### Certified safety

The TMS570 family was assessed by exida to the IEC 61508 safety standard and certified that the device family is suitable for use in SIL3 based systems.

The complete TMS570 Safety Manual with FMEDA, FIT rates and several guidelines how to make the safety implementation as easy as possible is available on demand.

The TMS570 family is used in a variety of safety related automotive applications like braking and steering – a safe choice.


Certificate / Certificat
Zertifikat / 合格証
TI 071227 C001
exida hereby confirms that the:
TMS570LS20216S Microcontroller
Texas Instruments, AEC Safety Systems
Has been assessed per the relevant requirements of:
IEC 61508 Parts 1, 2
and meets requirements providing a level of integrity to:
Systematic Integrity: SIL 3 Capable
Random Integrity: Type B Device
PFH and Architecture Constraints must be verified for each application
Safety Function:
The safety function of the device must be defined for each application.
Application Restrictions:
The unit must be properly designed into a Safety Function per the Safety Manual requirements.
Reports:
TI 07-12-27 R001 V2 R1 FMEDA Report
TI 07-12-27 R003 V2 R1 IEC 61508 Assessment Report
Validity:
This assessment is valid for the TMS570LS20216S Microcontroller
This assessment is valid until June 1, 2012
Revision 1.1 January, 2010
exida Certification S.A.
Product Assessor
Auditor
Page 1 of 2

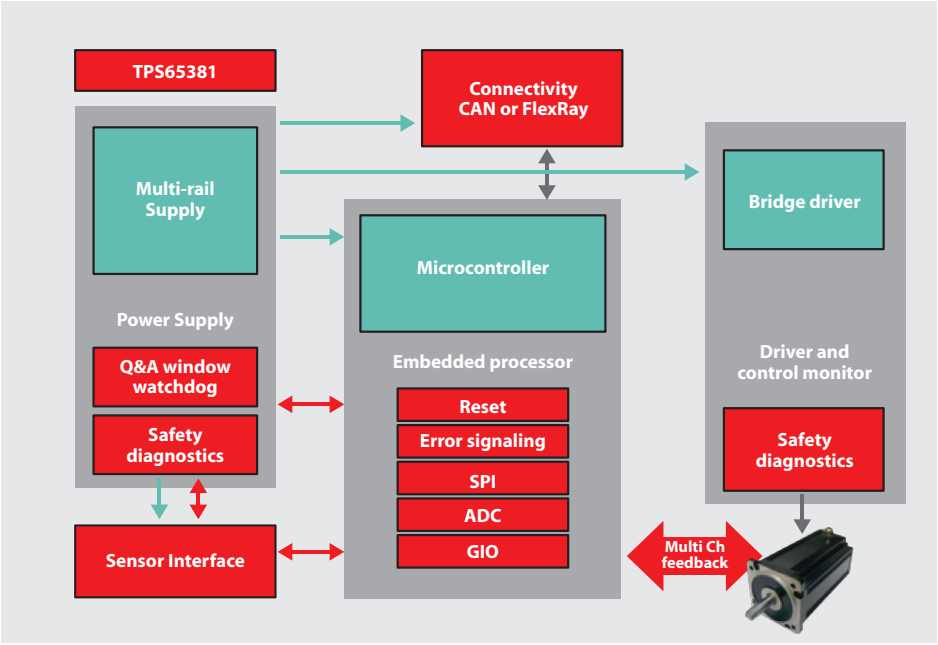
# Motor Control

## Safe Motor Control using TPS65381-Q1

### TPS65381-Q1 Power Management Unit for Safety MCUs

The TPS65381-Q1 device is a power management unit for safety MCUs meeting ASIL-D safety level requirements. It is ideally suited for automotive as well as industrial safety applications, such as electric power steering (EPS), braking, transmission and industrial motor control. It is qualified for Automotive Applications according AEC-Q100.

Since the TPS65381 fulfills ASIL-D (ISO26262) safety level and provides a high level of integration of all main power rails required by safety MCUs in safety systems, it enables easy implementation and quick verification of functional safety in a small footprint.




### Key Features

- Multi-rail power supply supporting among others
- Supply rails:
  - Input voltage range:
- 5.8 V to 36 V (CAN, I/O, MCU core, and sensor supply regulators functional)
- 4.5 V to 5.8 V (3.3-V I/O and MCU core voltage functional)
- Power supply/system monitoring:
  - Under- and Over-voltage monitoring on all regulator outputs, battery voltage, and internal supplies
  - Self-check on all voltage monitoring (during power up and after power up initiated by external MCU)
- Microcontroller Interface
- SPI Interface
- Package: 32-pin HTSSOP PowerPAD™ package

# Motor Control

## Safe Motor Control with TMS570 ARM Cortex-R4F

### TMS570 MCU Development Tools


**TMDX570LS20SUSB ($79)**

**Low-cost TMS570 evaluation kit**

- USB powered
- Onboard USB XDS100 JTAG debug
- Onboard SCI-to-PC serial communication
- Access to select signal pin test points
- LEDs, temp sensor, light sensor and CAN transceiver
- TMS570 in QFP package
-

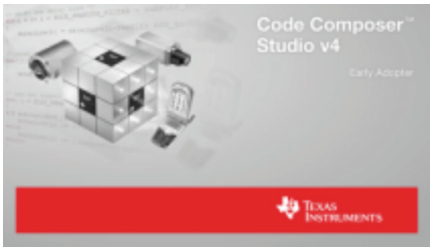

**TMDX570LS20SMDK ($695)**

**Full-featured TMS570 microcontroller development kit**

- Separate CPU card and IO card
- XDS100 emulator onboard
- External high-speed emulation via JTAG
- TRACE connectors for ETM/RTP/DMM
- Interfaces: FlexRay/CAN/LIN transceivers
- Color touch-screen TFT
- TMS570 in BGA package

**Software included in both kits:**

- Code Composer Studio™ IDE
- Includes C/C++ compiler/linker/debugger
- HalCoGen peripheral driver generation tool
- Flash programming integrated
- Demo projects
- Code examples




Learn more at: **www.ti.com/TMS570**

# Motor Control

## Safe Motor Control with TMS570 ARM Cortex-R4F

### TMS570 Product Overview

| Device | Speed (MHz) | Flash | RAM (kB) | Data Flash (kB) | EMAC | FlexRay™ | CAN | MibSPI (cs) | SPI (cs) | I²C | UART (LIN) | HET (ch) | PWM (ch) | CAP/QEP | MibADC 12 bit (ch) | EMIF (16 bit) | Total GIO (Interrupt) | TRACE (ETM/RTP/DMM) | Package | Temperature Range (°C) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TMS570LS04x/03x series** | | | | | | | | | | | | | | | | | | | | |
| **TMS5700332PZQQ1** | 80 | 256KB | 32 | 16 | _ | _ | 2 | 1(4) | 2(8) | _ | 1(1) | 19 | _ | –/2 | 1(16) | _ | 45(8) | _ | 100 QFP | –40 to 125 |
| **TMS5700432PZQQ1** | 80 | 384KB | 32 | 16 | _ | _ | 2 | 1(4) | 2(8) | _ | 1(1) | 19 | _ | –/2 | 1(16) | _ | 45(8) | _ | 100 QFP | –40 to 125 |
| **TMS570LS12x/11x series** | | | | | | | | | | | | | | | | | | | | |
| **TMS5701114PGEQQ1** | 160 | 1MB | 128 | 64 | _ | _ | 3 | 3(12) | 1(1) | 1 | 2(1) | 2(40) | 14 | 6/2 | 2(24) | _ | 64(10) | _ | 144QFP | –40 to 125 |
| **TMS5701114ZWTQQ1** | 180 | 1MB | 128 | 64 | _ | _ | 3 | 3(16) | 2(3) | 1 | 2(1) | 2(44) | 14 | 6/2 | 2(24) | Yes | 101(16) | _ | 337BGA | –40 to 125 |
| **TMS5701115PGEQQ1** | 160 | 1MB | 128 | 64 | _ | 2 ch | 3 | 3(12) | 1(1) | 1 | 2(1) | 2(40) | 14 | 6/2 | 2(24) | _ | 58(4) | _ | 144QFP | –40 to 125 |
| **TMS5701115ZWTQQ1** | 180 | 1MB | 128 | 64 | _ | 2 ch | 3 | 3(16) | 2(3) | 1 | 2(1) | 2(44) | 14 | 6/2 | 2(24) | Yes | 101(16) | _ | 337BGA | –40 to 125 |
| **TMS5701224PGEQQ1** | 160 | 1.25MB | 192 | 64 | _ | _ | 3 | 3(12) | 1(1) | 1 | 2(1) | 2(40) | 14 | 6/2 | 2(24) | _ | 64(10) | _ | 144QFP | –40 to 125 |
| **TMS5701224ZWTQQ1** | 180 | 1.25MB | 192 | 64 | _ | _ | 3 | 3(16) | 2(3) | 1 | 2(1) | 2(44) | 14 | 6/2 | 2(24) | Yes | 101(16) | _ | 337BGA | –40 to 125 |
| **TMS5701225PGEQQ1** | 160 | 1.25MB | 192 | 64 | _ | 2 ch | 3 | 3(12) | 1(1) | 1 | 2(1) | 2(40) | 14 | 6/2 | 2(24) | _ | 58(4) | _ | 144QFP | –40 to 125 |
| **TMS5701225ZWTQQ1** | 180 | 1.25MB | 192 | 64 | _ | 2 ch | 3 | 3(16) | 2(3) | 1 | 2(1) | 2(44) | 14 | 6/2 | 2(24) | Yes | 101(16) | _ | 337BGA | –40 to 125 |
| **TMS5701227PGEQQ1** | 160 | 1.25MB | 192 | 64 | 10/100 | 2 ch | 3 | 3(12) | 1(1) | 1 | 2(1) | 2(40) | 14 | 6/2 | 2(24) | _ | 58(4) | _ | 144QFP | –40 to 125 |
| **TMS5701227ZWTQQ1** | 180 | 1.25MB | 192 | 64 | 10/100 | 2 ch | 3 | 3(16) | 2(3) | 1 | 2(1) | 2(44) | 14 | 6/2 | 2(24) | Yes | 101(16) | _ | 337BGA | –40 to 125 |
| **TMS570LS31x/21x series** | | | | | | | | | | | | | | | | | | | | |
| **TMS5702124APGEQQ1** | 160 | 2MB | 192 | 64 | _ | _ | 3 | 3(12) | 1(1) | 1 | 2(1) | 2(40) | _ | _ | 2(24) | _ | 64(10) | _ | 144QFP | –40 to 125 |
| **TMS5702124AZWTQQ1** | 180 | 2MB | 192 | 64 | _ | _ | 3 | 3(16) | 2(3) | 1 | 2(1) | 2(44) | _ | _ | 2(24) | Yes | 120(16) | Yes | 337BGA | –40 to 125 |
| **TMS5702125APGEQQ1** | 160 | 2MB | 192 | 64 | _ | 2 ch | 3 | 3(12) | 1(1) | 1 | 2(1) | 2(40) | _ | _ | 2(24) | _ | 58(4) | _ | 144QFP | –40 to 125 |
| **TMS5702125AZWTQQ1** | 180 | 2MB | 192 | 64 | _ | 2 ch | 3 | 3(16) | 2(3) | 1 | 2(1) | 2(44) | _ | _ | 2(24) | Yes | 120(16) | Yes | 337BGA | –40 to 125 |
| **TMS5702134APGEQQ1** | 160 | 2MB | 256 | 64 | _ | _ | 3 | 3(12) | 1(1) | 1 | 2(1) | 2(40) | _ | _ | 2(24) | _ | 64(10) | _ | 144QFP | –40 to 125 |
| **TMS5702134AZWTQQ1** | 180 | 2MB | 256 | 64 | _ | _ | 3 | 3(16) | 2(3) | 1 | 2(1) | 2(44) | _ | _ | 2(24) | Yes | 120(16) | Yes | 337BGA | –40 to 125 |
| **TMS5702135APGEQQ1** | 160 | 2MB | 256 | 64 | _ | 2 ch | 3 | 3(12) | 1(1) | 1 | 2(1) | 2(40) | _ | _ | 2(24) | _ | 58(4) | _ | 144QFP | –40 to 125 |
| **TMS5702135AZWTQQ1** | 180 | 2MB | 256 | 64 | _ | 2 ch | 3 | 3(16) | 2(3) | 1 | 2(1) | 2(44) | _ | _ | 2(24) | Yes | 120(16) | Yes | 337BGA | –40 to 125 |
| **TMS5703134APGEQQ1** | 160 | 3MB | 256 | 64 | _ | _ | 3 | 3(12) | 1(1) | 1 | 2(1) | 2(40) | _ | _ | 2(24) | _ | 64(10) | _ | 144QFP | –40 to 125 |
| **TMS5703134AZWTQQ1** | 180 | 3MB | 256 | 64 | _ | _ | 3 | 3(16) | 2(3) | 1 | 2(1) | 2(44) | _ | _ | 2(24) | Yes | 120(16) | Yes | 337BGA | –40 to 125 |
| **TMS5703135APGEQQ1** | 160 | 3MB | 256 | 64 | _ | 2 ch | 3 | 3(12) | 1(1) | 1 | 2(1) | 2(40) | _ | _ | 2(24) | _ | 58(4) | _ | 144QFP | –40 to 125 |
| **TMS5703135AZWTQQ1** | 180 | 3MB | 256 | 64 | _ | 2 ch | 3 | 3(16) | 2(3) | 1 | 2(1) | 2(44) | _ | _ | 2(24) | Yes | 120(16) | Yes | 337BGA | –40 to 125 |
| **TMS5703137APGEQQ1** | 160 | 3MB | 256 | 64 | 10/100 | 2 ch | 3 | 3(12) | 1(1) | 1 | 2(1) | 2(40) | _ | _ | 2(24) | _ | 58(4) | _ | 144QFP | –40 to 125 |
| **TMS5703137AZWTQQ1** | 180 | 3MB | 256 | 64 | 10/100 | 2 ch | 3 | 3(16) | 2(3) | 1 | 2(1) | 2(44) | _ | _ | 2(24) | Yes | 120(16) | Yes | 337BGA | –40 to 125 |

*Note: Above refl ects max confi guration of each module – some functions are multiplexed.*

# Start/Stop Function
## Introduction to Start/Stop

A start/stop system automatically shuts down and restarts an automobile's internal combustion engine to reduce the amount of time the engine spends idling, thereby improving fuel economy. This is most advantageous for vehicles that spend significant amounts of time waiting at traffic lights or that frequently come to a stop in traffic jams.

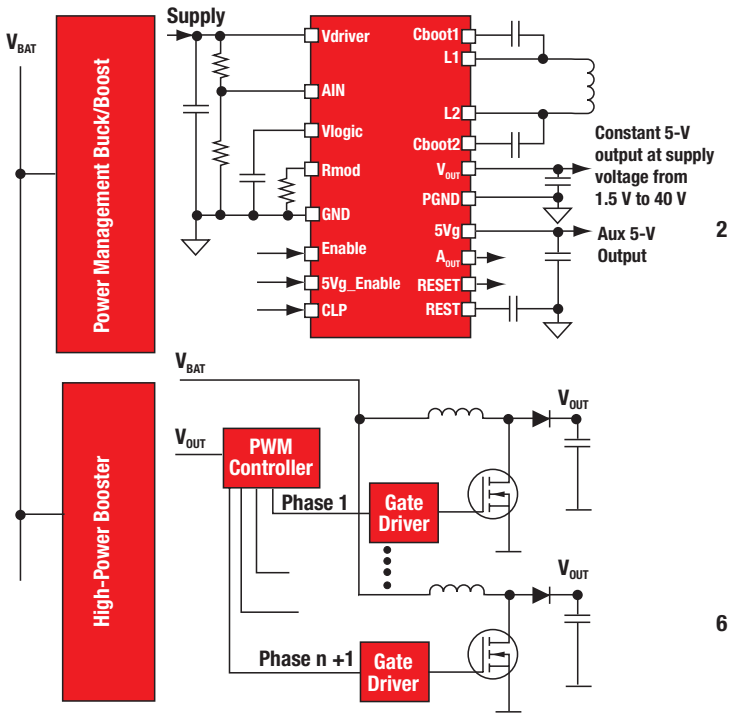
This feature is present in hybrid electric vehicles, but has also appeared in vehicles that lack a hybrid electric powertrain. For nonelectric vehicles (called micro hybrids), fuel economy gains from this technology are typically in the range of 5 to 10 percent. But because automobile accessories like air conditioners and water pumps have typically been designed to run off a serpentine belt on the engine, these systems must be redesigned to function properly when the engine is turned off. Typically, an electric motor is used to power these devices instead.

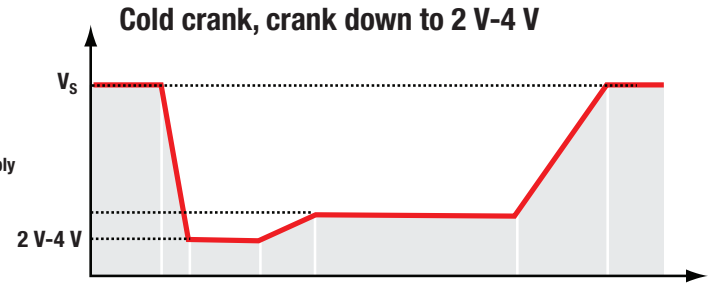
### Power Management for Start/Stop Function

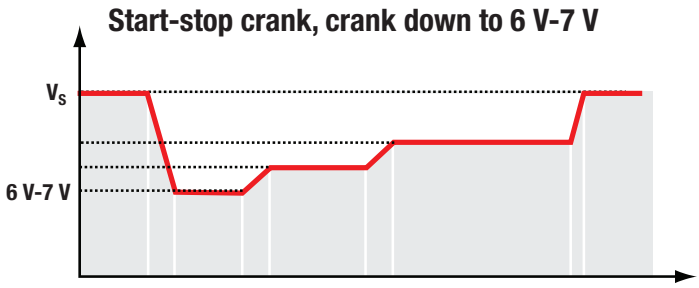
More and more modules inside a car have to be defended from voltage drop during cranking. This problem has increased with the implementation of start/stop (micro hybrid) systems, a trend seen in the automotive industry to improve fuel efficiency.

TI offers a variety of products in the power management area that can solve this system/customer problem.

#### TI's solution



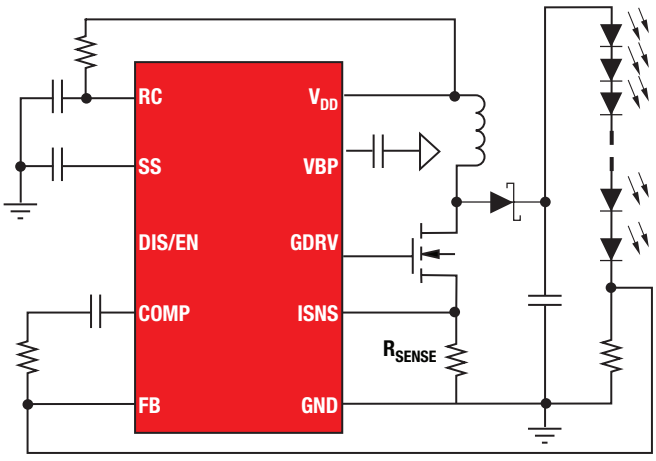



# Start/Stop Function

## Start/Stop Function Using TI Analog Products

### TPS40210-Q1 Boost Converter




*TPS40210-Q1 controller configured as a high-efficiency constant-current LED driver. EVM available*

Learn more at: **www.ti.com/sc/device/TPS40210-Q1**

**Key features**

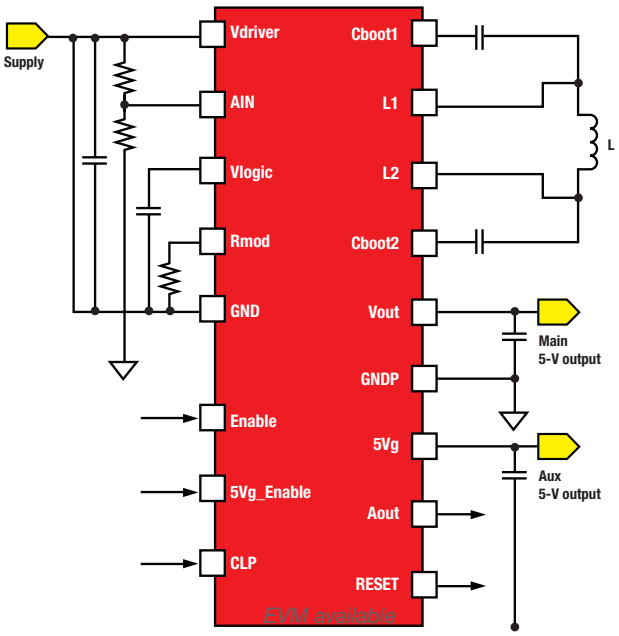
- Wide-input voltage range: 4.5 V to 52 V
- Current-mode controller
- TPS40210-Q1: internal reference voltage: 0.70 V
- Internal undervoltage lockout
- Programmable frequency 35 kHz to 500 kHz
- Frequency synchronization
- Closed-loop soft start
- Overcurrent protection
- Integrated NMOS-FET driver
- Small package size: 10-pin MSOP

**Benefits**

- Suitable for any type of boost application
- Boost, flyback and SEPIC topologies possible

---

### TPIC74100-Q1 Buck-Boost-Converter Integrated Switches




Learn more at: **www.ti.com/sc/device/TPIC74100-Q1**

**Key features**

- Wide-input voltage range: 1.5 V to 40 V
- Max. load current: 1 A (TPIC74100-Q1) 500 mA (TPS55065-Q1)
- Max. load current: 200 mA @ VIN = 2.0 V
- Max. load current: 120 mA @ VIN = 1.5 V
- Fixed output voltage: 5 V
- Enable function, shutdown current < 20 µA
- Switching frequency 440 kHz nom
- Slew-rate control and frequency modulation for EMI reduction
- Alarm function for undervoltage detection
- Switched 5-V output with current limit
- Thermally enhanced 20-pin PowerPAD™ packag

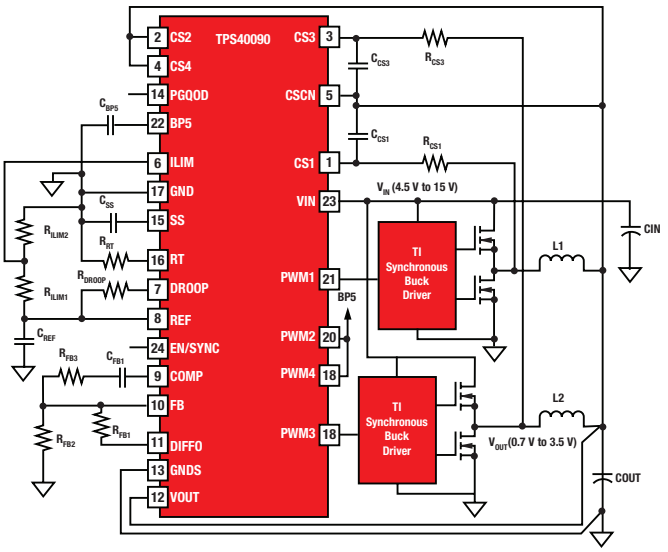
**Benefits**

- Stable 5-V line, also during cranking pulse
- Wide-input voltage range, no external protection required
- Reset integrated, additional alarm threshold integrated
- Output voltage switched to second pin (auxiliary 5-V output)
- Designed for harsh automotive environments (protections for overtemperature, overvoltage)

# Start/Stop Function

## Start/Stop Function Using TI Analog Products

### TPS40090-Q1 Four-Channel Multiphase Buck DC/DC Controller (or Boost)




*EVM available*

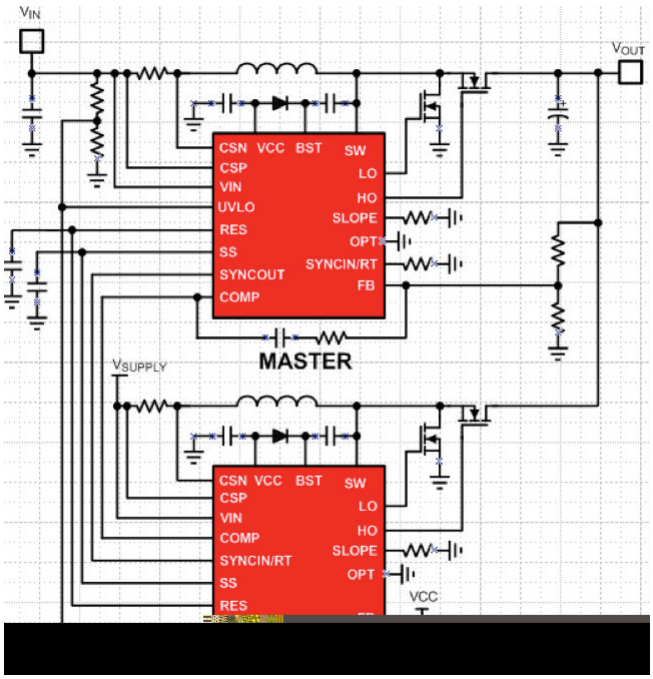
#### Key features

- Qualified for automotive applications
- Two-, three- or four-phase operation
- 5-V to 15-V operating range
- Programmable switching frequency up to 1 MHz/phase
- Current-mode control with forced current sharing (1)
- 1 percent internal 0.7-V reference
- Resistive divider set output voltage
- True remote sensing differential amp
- Resistive or DCR current sensing
- Current-sense fault protection
- Programmable load line
- Compatible with TI's UCC37222 Predictive Gate Drive™ technology drivers
- 24-pin space-saving TSSOP package
- Binary outputs

Learn more at: **www.ti.com/sc/device/TPS40090-Q1**

---

### LM5122 Wide Input Range Synchronous Boost Controller with Multiphase Capability




#### Key features

- Wide input voltage range: 3V to 65V
- Output voltage up to 100V
- Robust 3A integrated gate drivers
- Multi-phase capable
- Bypassing feature
- Free-run or synchronizable FSW to 1MHz
- Low shutdown IQ: 10uA
- Programmable slope compensation and skip cycle mode
- Programmable cycle-by-cycle current limit
- eTSSOP-20 package

#### Benefits

- Wide input/output range well suited for automotive applications
- Multiphase capability supports higher power requirements with flexibility
- Synchronous operation improves efficiency and power density

Learn more at: **www.ti.com/sc/device/LM5122**

# Start/Stop Function

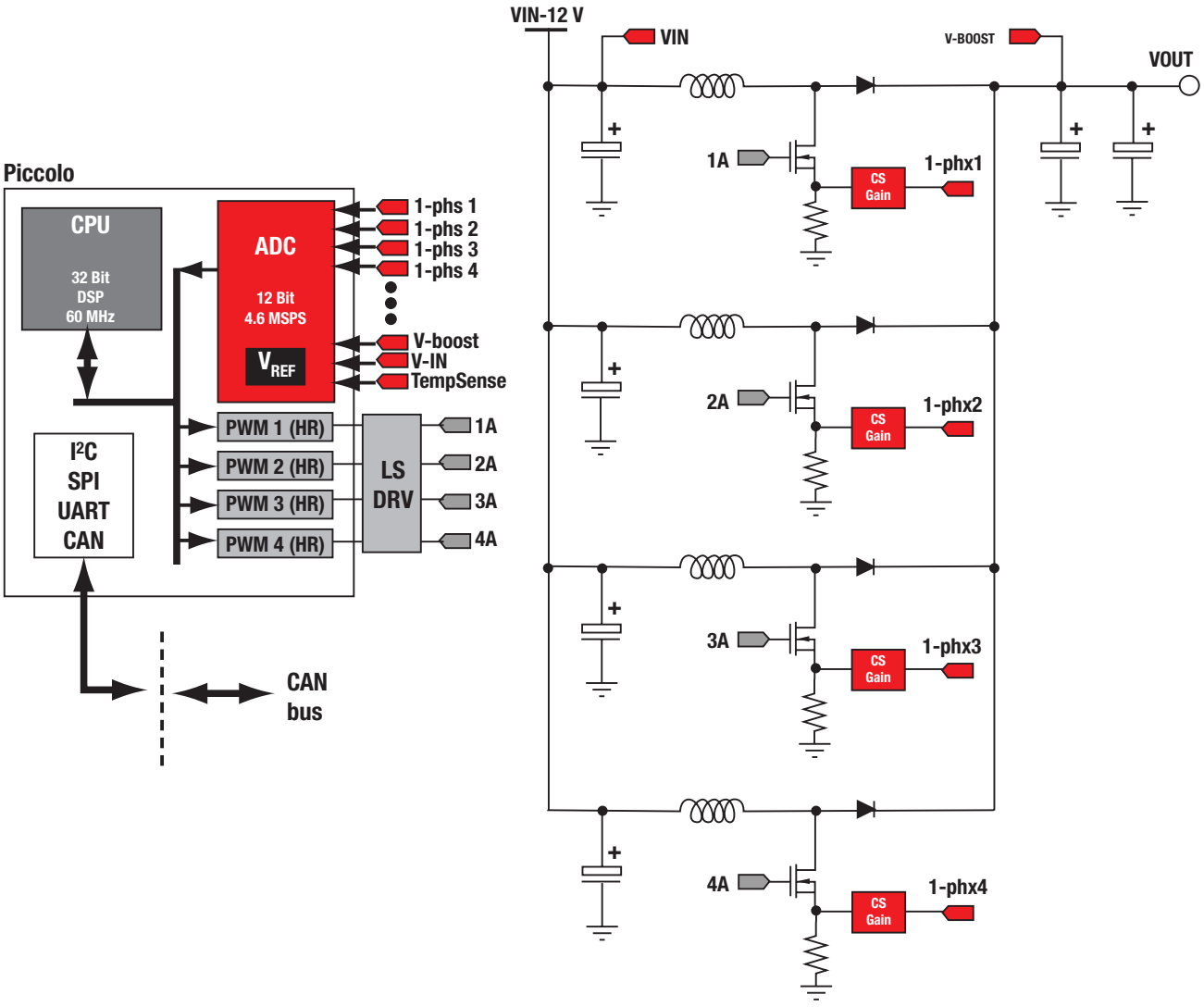
## Start/Stop Function Using the C2000™ Piccolo™ MCU

Using a C2000™ MCU with enhanced real-time features brings both high-speed loop control and system management capabilities in a single device. The Piccolo MCU's math-efficient CPU, closely coupled with high-performance pulse-width modulators (PWMs) and ADCs, can control multiphase boost stages over a wide range of operating points. Digital control schemes with feed-forward, three-pole/three-zero compensators, PID, etc., allows power designers to realize complex and flexible loop control strategies that can be adaptive and managed for efficiency, transient performance, light-load operation, fault handling and rich diagnostics.

Independent control of each phase allows for current balancing within each phase, spreading the load evenly and improving reliability. This also adds phase-shedding capability, where at light loads one or two phases are used, hence increasing efficiency.

Under these conditions, "intelligent" management software can retune control loops by dynamically changing compensator coefficients. The above diagram shows a four-phase boost implementation where each MOSFET is controlled with a high-resolution PWM capable of 150-pS edge-placement accuracy, ensuring smooth PWM switching speeds from 100 KHz to beyond 500 KHz without the undesirable limit-cycle oscillations often associated with low-resolution PWMs.

**Please contact your local sales office for kit information.**

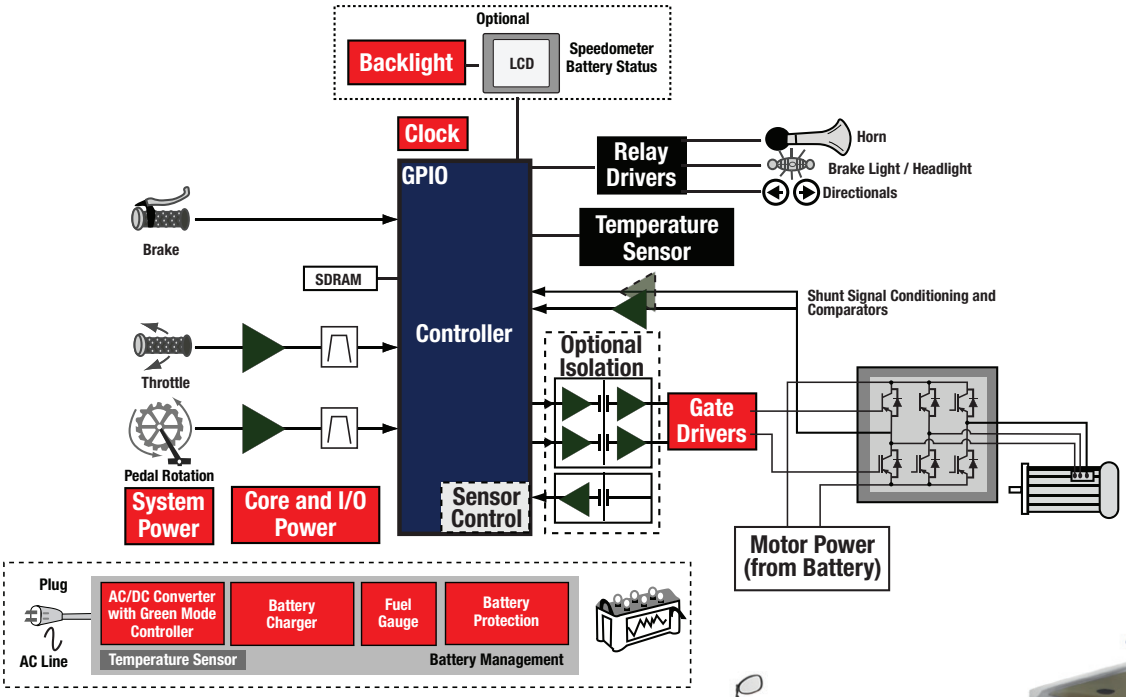


# E-Bikes and Small Task-Oriented Vehicles (STOVs)

## Introduction to E-Bikes and Small Task-Oriented Vehicles (STOVs)

Electric transportation is not only relevant for cars, but already used in many millions of simple task-oriented vehicles around the world. The systems are more basic compared to those on the hybrid and electric car side, but consist of the same functional blocks.

For motor control, the Piccolo™ MCU family is a good choice, offering the combination of a powerful CPU engine with the required PWM and ADC capabilities for the control loop at an economical price point. The battery systems are typically operating at lower voltages with less cells, so integrated solutions like the bq77910 or bq77908 managing and protecting as many as 10 cells are a good fit.




## Selection Guide

| Device | Number of Series Cells | Protection Method | Shutdown Current (µA) | Description | Package | Price* |
|---|---|---|---|---|---|---|
| **bq77PL900** | 5 to 10 | External PFET | — | Standalone or host-controlled protector with cell balancing | 48-pin SSOP | **$2.95** |
| **bq77908** | 4 to 8 | External NFET | 5 | Standalone protector with cell balancing (internal or external) | 38-pin TSSOP | **$2.60** |
| **bq77910** | 4 to 10 | External NFET | 5 | Standalone protector with cell balancing (internal or external) | 38-pin TSSOP | **$2.70** |
| **bq77PL157A4225** | 3 to 6 | External NFET or Fuse | 3 | Stackable overvoltage protection with FET or fuse output activation | 16-pin TSSOP | **$0.65** |
| **bq78PL116** | 3 to 16 | External PFET | 1 | Standalone high-power gas gauge with advanced protection and PowerPump™ cell balancing | 48-pin QFN | **$4.50** |
| **bq76PL536AB** | 3 to 6 | Integrated | 12 | Stackable battery monitor, protector and cell balancer for high-cell applications | 64-pin TQFP | **$5.05** |
| **bq78412** | — | N/A | — | Pb-acid battery state-of-charge indicator with run-time display | 44-pin TSSOP | **$3.90** |

*See individual datasheets for full details. *Suggested resale price in U.S. dollars in quantities of 1,000.*

*New devices are listed in **bold red**.*

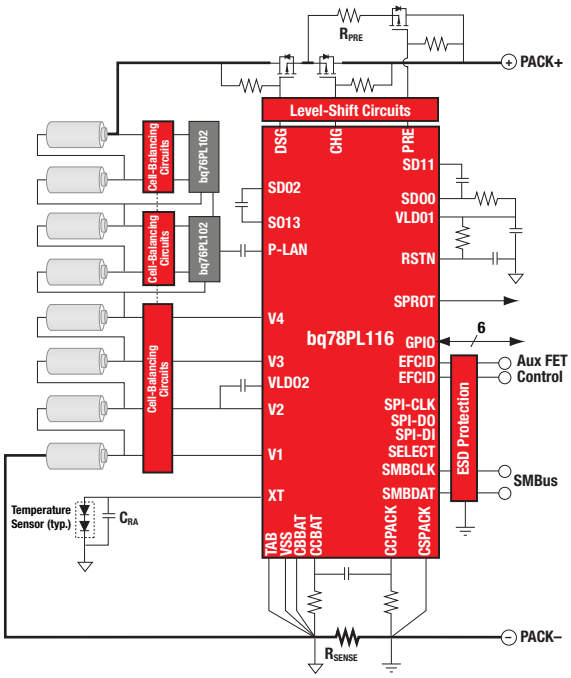
# E-Bikes and Small Task Oriented Vehicles (STOVs)
## STOV Products

### bq78PL116 Integrated Gas Gauge, Protection and Active Cell Balancing Controller for Up to 16-Series Li-Ion Cells

**Key features**

- Three- to 16-series cell systems
- PowerPump™ technology cell balancing for longer run time and cell life
- Supports discharge current  levels of 10 A, 35 A and 110 A
- Gauges up to 328-Ahr capacity batteries
- High resolution 18-bit integrating delta-sigma Coulomb counter for precise charge-flow measurements and gas gauging
- Multiple independent delta-sigma A/Ds: one-per-cell voltage, plus separate temperature, current and safety
- Fully programmable voltage, current, balance and temperature protection
- Remaining capacity indicators: LCD, LED, EPD

Learn more at: **www.ti.com/sc/device/bq78PL116**



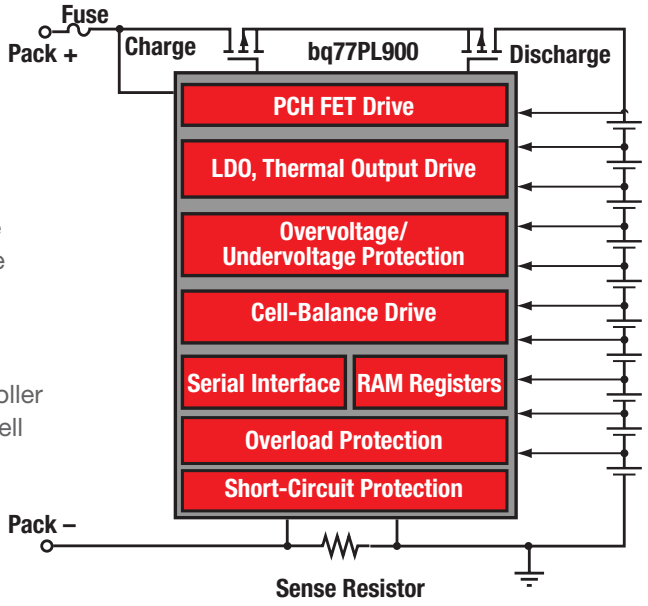
# E-Bikes and Small Task Oriented Vehicles (STOVs)

## STOV Products

### bq77PL900 Standalone and Host-Controlled Battery Protector for Five- to 10-Series Li-Ion Cells

**Key features**

- Five-, six-, seven-, eight-, nine- or 10-series cell primary protection
- PMOS FET drive for charge and discharge FETs
- Capable of operation with 1-mΩ sense resistor
- Supply voltage range from 7 V to 50 V
- Integrated 5-V, 25-mA LDO
- Standalone mode
  - Pack protection control and recovery
  - Individual cell monitoring
  - Integrated cell balancing
  - Programmable threshold and delay time for:
    - Overvoltage
    - Undervoltage
    - Overcurrent in discharge
    - Short circuit in discharge
  - Fixed overtemperature protection
- Host control mode
  - I2C interface to host controller
  - Analog interface for host cell measurement and system charge/discharge current
  - Host-controlled protection recovery
  - Host-controlled cell balancing




Learn more at: **www.ti.com/sc/device/bq77PL900**

---

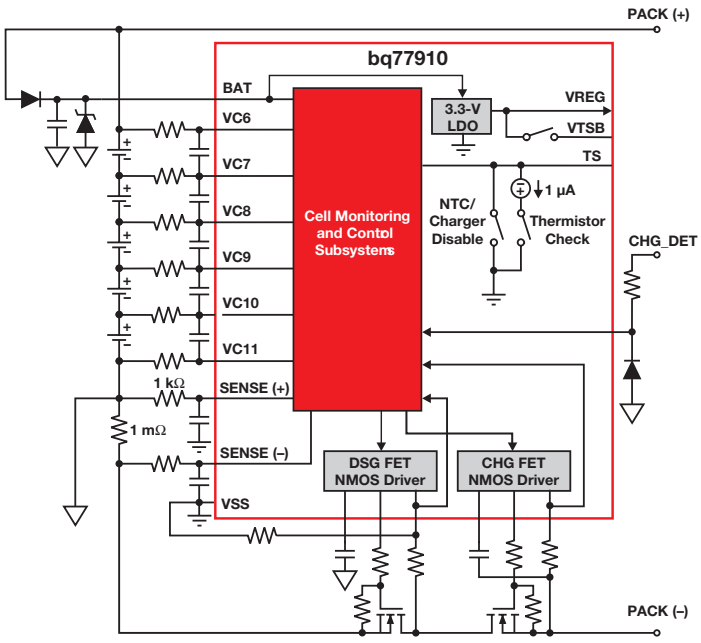
### bq77910 and bq77908 Standalone Precision Protector for Four- to 10-Series Li-Ion/Phosphate Cells

The bq77910 precision protector is a complete standalone, self-contained battery-protection and cell-balancing device intended for Li-ion/Li-polymer battery packs.

The bq77910 monitors four- to 10-series individual cell voltages and provides fast-acting outputs that can be used to drive n-channel MOSFETs to interrupt the power path. Activation delays and recovery methods for each safety condition are fully programmable in nonvolatile memory.

**Key features**

- Four-, five-, six-, seven-, eight-, nine- or 10-series cell protection
- Individual cell-voltage monitoring
- Low-side NMOS FET drive for charge and discharge control
- Compatible with 1-mW current-sense resistor
- Supply-voltage range: 5.6 V to 50 V
- Integrated 3.3-V micropower LDO regulator
- Internal 50-mA automatic cell balancing
- Low power consumption: 50-µA operating, 5-µA shutdown
- bq77908 is identical but for four- to eight-series cells only




*Five-cell series FET configuration schematic using the bq77910*

Learn more at: **www.ti.com/sc/device/bq77910** or **/bq77908**

# E-Bikes and Small Task Oriented Vehicles (STOVs)

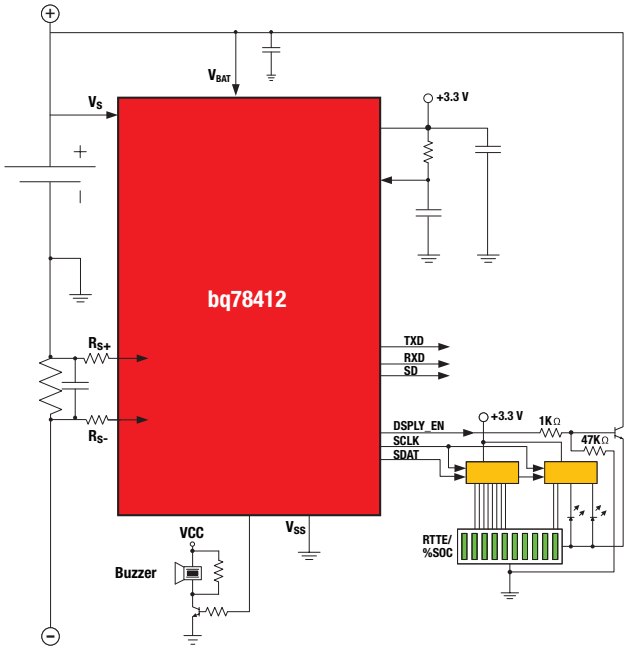
## STOV Products

### bq78412 Pb-Acid Battery State-of-Charge Indicator with Run-Time Display

**Key features**

- Programmable models for cell formulations
- Capacity up to 327 Ah
- 10-LED bar graph capacity display of run-time and percent capacity
- Records cumulative usage data for warranty return analysis
- Data interface for usage data access via UART or InfraRed (IrDA)
- State-of-health determination and status reporting
- Configurable audible indicator for low-capacity, low-voltage or overvoltage warnings
- Supports high-side or low-side current shunt
- Addressable commands for multibattery systems
- Works with single 12-V mono-blocks or external divider permits use with 24-V, 36-V, 48-V and higher blocks
- On-chip temperature sensor

Learn more at: **www.ti.com/sc/device/bq77PL900**

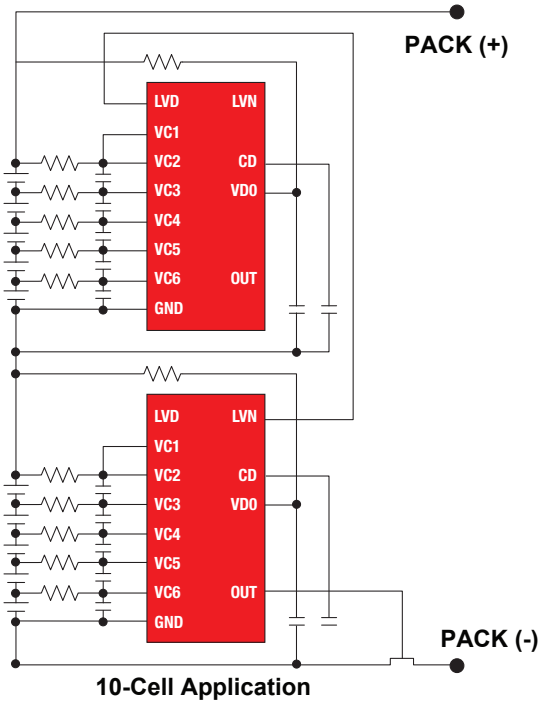



### bq77PL157A Stackable Overvoltage Protector for Three- to Six-Series Li-Ion Cells

**Key features**

- Three-, four-, five- or six-cell overvoltage protection
- Stackable to 18 or more series Li-ion cells
  - No extra components to stack (no Iso/Optos)
- Low power <2.5-µA typical
- Internal noise filter with external capacitor to set activation delay
- Recoverable or permanent latch output options
- High accuracy sensing: +/-20-mV per cell
- Factory-programmed thresholds: 3.75 V to 4.35 V
  - No programming required
- No single pin open or adjacent pin short can prevent failsafe operation

Learn more at: **www.ti.com/sc/device/bq77PL157A**




10-Cell Application

# E-Bikes and Small Task Oriented Vehicles (STOVs)

## STOV Products

### DRV8312-C2-KIT Motor Driver ICs

The DRV8312-C2-KIT is a high-performance, power-efficient, cost-effective sensorless field-oriented control (FOC) and trapezoidal commutation platform that spins motors out of the box, speeding development for quicker time to market. Applications include sub-50-V and 6.5-A brushless motors for driving medical pumps, gates, lifts and small pumps, as well as industrial and consumer robotics and automation. For more information or to place an order, visit **www.ti.com/drv8312-c2-kit-pr.**

#### Key Features

- Out-of-the-box motor control and driver solution includes the DRV8312 motor driver, a 32-bit C2000™ Piccolo™ microcontroller (MCU) controlCARD™ module, a quick-start GUI, full development source code, Code Composer Studio™ integrated development environment (IDE) and a three-phase BLDC motor.
- Flexible control platform that supports sensorless FOC and sensorless and sensored trapezoidal commutation control for rapid evaluation and development of three-phase motors. By adding a separate shaft encoder, the DRV8312-C2-KIT can also support sensored FOC.
- DRV8312 three-phase, fractional-horsepower motor driver provides the highest current output in its class, delivering up to 6.5 A without the need for a costly external heat sink. Its intelligent gate drive circuitry minimizes dead time to 5 ns, providing high linearity and maximizing motor performance. The DRV8312 motor driver is robust, reliable and fully protected with cycle-by-cycle overcurrent, over-temperature, cross-conduction and undervoltage protection, reducing design complexity and board spaceand ensuring higher system reliability.
- The C2000 Piccolo MCU performs control, communications and debugging. The industry-leading 32-bit C2000 MCU integrates the most advanced analog feedback, digital control peripherals and CPU capability in an embedded MCUdevice family starting under $2. This includes access to the most thorough set of motor control software modules, real-time debugging capabilities and open-tooled reference designs via free ControlSuite™ software.

Learn more at: **www.ti.com/sc/device/DRV8312-C2-KIT**

---

### DRV8301 Brushless DC Motor Pre-Driver with Dual-Shunt Amplifiers and a Buck Converter

The DRV8301 is a gate driver IC for three-phase motor drive applications. It provides three half-bridge drivers, each capable of driving two N-type MOSFETs, one for the high side and one for the low side. It supports up to 2.3-A sink and 1.7-A source peak current capability and only needs a single power supply with a wide range from 8 to 60 V. The DRV8301 includes two current shunt amplifiers for accurate current measurement. The DRV8301 also has an integrated switching- mode buck converter with adjustable output and switching frequency to support MCU or additional system power needs.

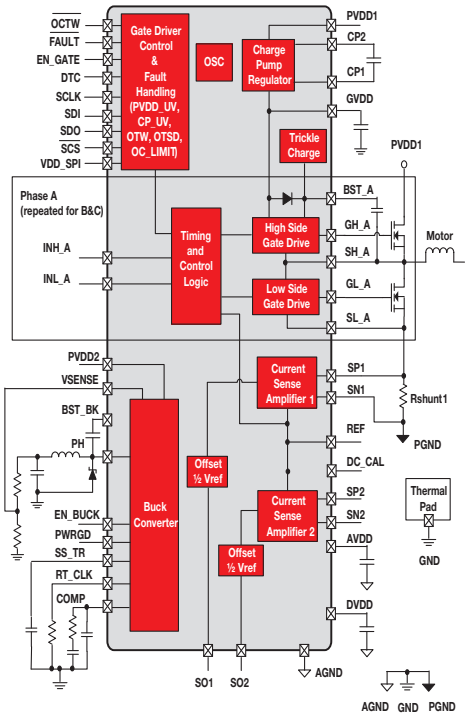
Learn more at: **www.ti.com/sc/device/DRV8301**

#### Key features

- Gate driver with 8- to 60-V supply voltage and 1.7-A gate current drives up to 60-A external FETs
- Dual-shunt current-sense amplifiers
- Integrated buck converter with 3.5- to 60-V input, adjustable output, up to 1-A load
- Bootstrap structure with trickle charge
- Intelligent gate driver and cross-conduction prevention
- OC protection of external FETs with programmable cycle-by-cycle current limit
- Independent control of six external MOSFETs
- SPI interface for programmability

#### Applications

- PMSM and BLDC motors
- CPAP
- E-bike
- Power tools




*DRV8301 simplified application diagram*

# E-Bikes and Small Task Oriented Vehicles (STOVs)
## STOV Products

### Digital Motor Control for E-Bikes, Scooters and STOVs Evaluation Module

The C2000™ MCU platform of real-time controllers has been the industry leader in digital motor control since the inception of the TMS320F24x generation in 1996. Debuted in 2000, the F281x series is based on the C28x™ MCU engine, becoming the first 32-bit architecture specifically built for high-performance, math-intensive power electronics control. Based on the C28x MCU, this code-compatible family of devices meet application needs across performance, price, pinout and peripherals. To find out more, visit **www.ti.com/c2000dmc**.

---

### C2000™ High-Voltage PFC and Motor Control Developer Kit

**Key features**

- Piccolo™ MCU-based power factor correction (PFC) and motor control integrated into one development platform
- Support for three brushless motor types,AC induction, permanent magnet
- Synchronous motor, brushless  DC motor
- 1-kW motor driver stage accepting up to 400 V
- 700-W PFC stage (line-level AC input ~110 to ~240 VAC)
- Open-source software for power factor correction stage
- Open-source software for control of all three motor types
- Open-source hardware, including schematics, BOM and gerber files
- Motors of each type available separately from TI
- Available for $599
- Order part number: TMDSHVMTRPFCKIT

Learn more at: **www.ti.com/sc/device/c2000tools**

# Microcontroller

## Microcontroller Product Overview

### C2000™ Microcontrollers

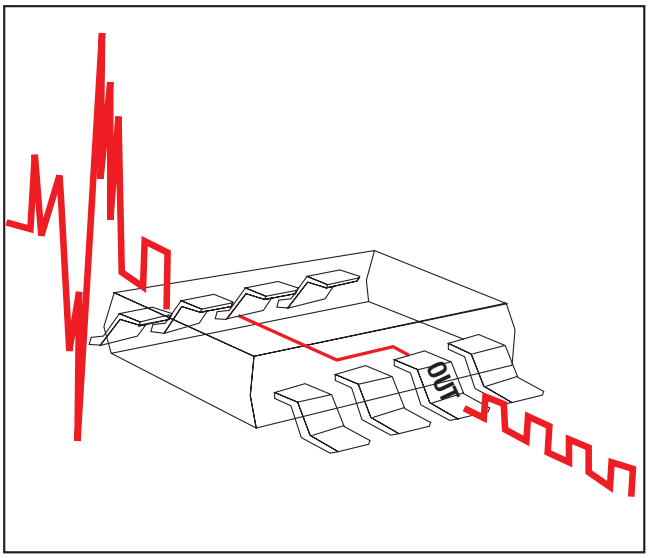
| Device | Speed (MHz) | VCU | DMA | CLA | RAM (KB) | Flash (KB) | ROM (KB) | PWM Channels | HiRes PWM | Quadrature Encoder | Event Captures | Timers* | 12-Bit ADC Channels/ Conversion Time (ns) | Mc-BSP | $I^2C$ | UART/ SCI | SPI | Lin | CAN | External Memory Bus (bit) | Core Supply (volts) | GPIO Pins | On-Chip Oscillator/ Regulator | Package |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Piccolo™ MCUs** | | | | | | | | | | | | | | | | | | | | | | | | |
| TMS320F28022DAQ | 40 | — | — | — | 12 | 32 | Boot | 9 | 4 | — | 1 | 9 | 7/ 325 | — | 1 | 1 | 1 | — | — | — | 3.3 | 20 | Yes / Yes | 38TSSOP |
| TMS320F28022PTQ | 40 | — | — | — | 12 | 32 | Boot | 9 | 4 | — | 1 | 9 | 13/ 325 | — | 1 | 1 | 1 | — | — | — | 3.3 | 22 | Yes / Yes | 48LQFP |
| TMS320F28023DAQ | 40 | — | — | — | 12 | 64 | Boot | 9 | 4 | — | 1 | 9 | 7/ 325 | — | 1 | 1 | 1 | — | — | — | 3.3 | 20 | Yes / Yes | 38TSSOP |
| TMS320F28023PTQ | 40 | — | — | — | 12 | 64 | Boot | 9 | 4 | — | 1 | 9 | 13/ 325 | — | 1 | 1 | 1 | — | — | — | 3.3 | 22 | Yes / Yes | 48LQFP |
| TMS320F28026DAQ | 60 | — | — | — | 12 | 32 | Boot | 9 | 4 | — | 1 | 9 | 7/ 217 | — | 1 | 1 | 1 | — | — | — | 3.3 | 20 | Yes / Yes | 38TSSOP |
| TMS320F28026PTQ | 60 | — | — | — | 12 | 32 | Boot | 9 | 4 | — | 1 | 9 | 13/ 217 | — | 1 | 1 | 1 | — | — | — | 3.3 | 22 | Yes / Yes | 48LQFP |
| TMS320F28027DAQ | 60 | — | — | — | 12 | 64 | Boot | 9 | 4 | — | 1 | 9 | 7/ 217 | — | 1 | 1 | 1 | — | — | — | 3.3 | 20 | Yes / Yes | 38TSSOP |
| TMS320F28027PTQ | 60 | — | — | — | 12 | 64 | Boot | 9 | 4 | — | 1 | 9 | 13/ 217 | — | 1 | 1 | 1 | — | — | — | 3.3 | 22 | Yes / Yes | 48LQFP |
| TMS320F28030PAGQ | 60 | — | — | — | 12 | 32 | Boot | 13 | — | 1 | 1 | 11 | 14/ 500 | — | 1 | 1 | 1 | 1 | 1 | — | 3.3 | 33 | Yes / Yes | 64TQFP |
| TMS320F28030PNQ | 60 | — | — | — | 12 | 32 | Boot | 15 | — | 1 | 1 | 12 | 16/ 500 | — | 1 | 1 | 2 | 1 | 1 | — | 3.3 | 45 | Yes / Yes | 80LQFP |
| TMS320F28031PAGQ | 60 | — | — | — | 16 | 64 | Boot | 13 | — | 1 | 1 | 11 | 14/ 500 | — | 1 | 1 | 1 | 1 | 1 | — | 3.3 | 33 | Yes / Yes | 64TQFP |
| TMS320F28031PNQ | 60 | — | — | — | 16 | 64 | Boot | 15 | — | 1 | 1 | 12 | 16/ 500 | — | 1 | 1 | 2 | 1 | 1 | — | 3.3 | 45 | Yes / Yes | 80LQFP |
| TMS320F28032PAGQ | 60 | — | — | — | 20 | 64 | Boot | 13 | 6 | 1 | 1 | 11 | 14/ 217 | — | 1 | 1 | 1 | 1 | 1 | — | 3.3 | 33 | Yes / Yes | 64TQFP |
| TMS320F28032PNQ | 60 | — | — | — | 20 | 64 | Boot | 15 | 7 | 1 | 1 | 12 | 16/ 217 | — | 1 | 1 | 2 | 1 | 1 | — | 3.3 | 45 | Yes / Yes | 80LQFP |
| TMS320F28034PAGQ | 60 | — | — | — | 20 | 128 | Boot | 13 | 6 | 1 | 1 | 11 | 14/ 217 | — | 1 | 1 | 1 | 1 | 1 | — | 3.3 | 33 | Yes / Yes | 64TQFP |
| TMS320F28034PNQ | 60 | — | — | — | 20 | 128 | Boot | 15 | 7 | 1 | 1 | 12 | 16/ 217 | — | 1 | 1 | 2 | 1 | 1 | — | 3.3 | 45 | Yes / Yes | 80LQFP |
| TMS320F28033PAGQ | 60 | — | — | Yes | 20 | 64 | Boot | 13 | 6 | 1 | 1 | 11 | 14/ 217 | — | 1 | 1 | 1 | 1 | 1 | — | 3.3 | 33 | Yes / Yes | 64TQFP |
| TMS320F28033PNQ | 60 | — | — | Yes | 20 | 64 | Boot | 15 | 7 | 1 | 1 | 12 | 16/ 217 | — | 1 | 1 | 2 | 1 | 1 | — | 3.3 | 45 | Yes / Yes | 80LQFP |
| TMS320F28035PAGQ | 60 | — | — | Yes | 20 | 128 | Boot | 13 | 6 | 1 | 1 | 11 | 14/ 217 | — | 1 | 1 | 1 | 1 | 1 | — | 3.3 | 33 | Yes / Yes | 64TQFP |
| TMS320F28035PNQ | 60 | — | — | Yes | 20 | 128 | Boot | 15 | 7 | 1 | 1 | 12 | 16/ 217 | — | 1 | 1 | 2 | 1 | 1 | — | 3.3 | 45 | Yes / Yes | 80LQFP |
| **Piccolo F2806x (Floating-Point) MCUs** | | | | | | | | | | | | | | | | | | | | | | | | |
| TMS320F28069PFPQ | 80 | Yes | Yes | Yes | 100 | 256 | Boot | 15 | 6 | 1 | 3 | 12 | 12 / 325 | 1 | 1 | 1 | 2 | — | 1 | — | 3.3 | 44 | Yes / Yes | 80HTQFP |
| TMS320F28069PZPQ | 80 | Yes | Yes | Yes | 100 | 256 | Boot | 19 | 8 | 2 | 7 | 16 | 16 / 325 | 1 | 1 | 2 | 2 | — | 1 | — | 3.3 | 58 | Yes / Yes | 100HTQFP |
| TMS320F28068PFPQ | 80 | Yes | Yes | — | 100 | 256 | Boot | 15 | 6 | 1 | 3 | 12 | 12 / 325 | 1 | 1 | 1 | 2 | — | 1 | — | 3.3 | 44 | Yes / Yes | 80HTQFP |
| TMS320F28068PZPQ | 80 | Yes | Yes | — | 100 | 256 | Boot | 19 | 8 | 2 | 7 | 16 | 16 / 325 | 1 | 1 | 2 | 2 | — | 1 | — | 3.3 | 58 | Yes / Yes | 100HTQFP |
| TMS320F28067PFPQ | 80 | Yes | Yes | — | 100 | 256 | Boot | 15 | 6 | 1 | 3 | 12 | 12 / 325 | 1 | 1 | 1 | 2 | — | 1 | — | 3.3 | 44 | Yes / Yes | 80HTQFP |
| TMS320F28067PZPQ | 80 | Yes | Yes | — | 100 | 256 | Boot | 19 | 8 | 2 | 7 | 16 | 16 / 325 | 1 | 1 | 2 | 2 | — | 1 | — | 3.3 | 58 | Yes / Yes | 100HTQFP |
| TMS320F28066PFPQ | 80 | — | Yes | — | 68 | 256 | Boot | 15 | 6 | 1 | 3 | 12 | 12 / 325 | 1 | 1 | 1 | 2 | — | 1 | — | 3.3 | 44 | Yes / Yes | 80HTQFP |
| TMS320F28066PZPQ | 80 | — | Yes | — | 68 | 256 | Boot | 19 | 8 | 2 | 7 | 16 | 16 / 325 | 1 | 1 | 2 | 2 | — | 1 | — | 3.3 | 58 | Yes / Yes | 100HTQFP |
| TMS320F28065PFPQ | 80 | Yes | Yes | Yes | 100 | 128 | Boot | 15 | 6 | 1 | 3 | 12 | 12 / 325 | 1 | 1 | 1 | 2 | — | 1 | — | 3.3 | 44 | Yes / Yes | 80HTQFP |
| TMS320F28065PZPQ | 80 | Yes | Yes | Yes | 100 | 128 | Boot | 19 | 8 | 2 | 7 | 16 | 16 / 325 | 1 | 1 | 2 | 2 | — | 1 | — | 3.3 | 58 | Yes / Yes | 100HTQFP |
| TMS320F28064PFPQ | 80 | Yes | Yes | — | 100 | 128 | Boot | 15 | 6 | 1 | 3 | 12 | 12 / 325 | 1 | 1 | 1 | 2 | — | 1 | — | 3.3 | 44 | Yes / Yes | 80HTQFP |
| TMS320F28064PZPQ | 80 | Yes | Yes | — | 100 | 128 | Boot | 19 | 8 | 2 | 7 | 16 | 16 / 325 | 1 | 1 | 2 | 2 | — | 1 | — | 3.3 | 58 | Yes / Yes | 100HTQFP |
| TMS320F28063PFPQ | 80 | Yes | Yes | — | 68 | 128 | Boot | 15 | 6 | 1 | 3 | 12 | 12 / 325 | 1 | 1 | 1 | 2 | — | 1 | — | 3.3 | 44 | Yes / Yes | 80HTQFP |
| TMS320F28063PZPQ | 80 | Yes | Yes | — | 68 | 128 | Boot | 19 | 8 | 2 | 7 | 16 | 16 / 325 | 1 | 1 | 2 | 2 | — | 1 | — | 3.3 | 58 | Yes / Yes | 100HTQFP |
| TMS320F28062PFPQ | 80 | — | Yes | — | 36 | 128 | Boot | 15 | 6 | 1 | 3 | 12 | 12 / 325 | 1 | 1 | 1 | 2 | — | 1 | — | 3.3 | 44 | Yes / Yes | 80HTQFP |
| TMS320F28062PZPQ | 80 | — | Yes | — | 36 | 128 | Boot | 19 | 8 | 2 | 7 | 16 | 16 / 325 | 1 | 1 | 2 | 2 | — | 1 | — | 3.3 | 58 | Yes / Yes | 100HTQFP |

### The problem

- **No endurance** – existing isolation devices have a life expectancy of only seven to 10 years
- **No high speed or precision** – existing isolation devices – low speed, high skew, high jitter and high pulse distortion
- **No high temp** – existing isolation devices cannot operate at 150 Mbps at 125°C. Only a few can operate at >100°C at any speed
- **Low EMI immunity** – existing high-speed isolators are susceptible to EMI interference

### The solution

- The TI integrated SiO2 isolation barrier technology provides the fastest, highest precision, highest temperature, high EMI immunity and longest life solution



# Isolation, Analog and Power Management Products

## TI Isolated Products

### ISO722X Dual-Channel, 25-Mbps Digital Isolator

The ISO7220 and ISO7221 are dual-channel digital isolators. To facilitate PCB layout, the channels are oriented in the same direction in the ISO7220 and in opposite directions in the ISO7221. These devices have a logic input and output buffer separated by TI's silicon-dioxide (SiO2) isolation barrier, providing galvanic isolation of up to 4,000 V. Used in conjunction with isolated power supplies, these devices block high voltage, isolate grounds and prevent noise currents on a data bus or other circuits from entering the local ground and interfering with or damaging sensitive circuitry.

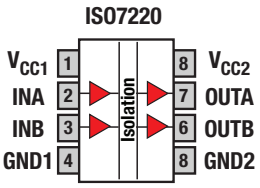
A binary input signal is conditioned, translated to a balanced signal, then differentiated by the capacitive isolation barrier. Across the isolation barrier, a differential comparator receives the logic transition information, then sets or resets a flip-flop and the output circuit accordingly. A periodic update pulse is sent across the barrier to ensure the proper DC level of the output. If this DC refresh pulse is not received every 4 µs, the input is assumed to be unpowered or not being actively driven, and the failsafe circuit drives the output to a logic high state.

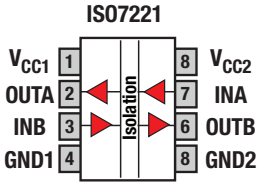
The small capacitance and resulting time constant provide fast operation, with signaling rates available from 0 Mbps (DC) to 25 Mbps. The signaling rate of a line is the number of voltage transitions that are made per second expressed in the unit's BPS (bits per second). The A-option and C-option devices have TTL input thresholds and a noise filter at the input that prevents transient pulses from being passed to the output of the device.

These devices require two supply voltages of 3.3 V, 5 V or any combination. All inputs are 5-V tolerant when supplied from a 3.3-V supply and all outputs are 4-mA CMOS.

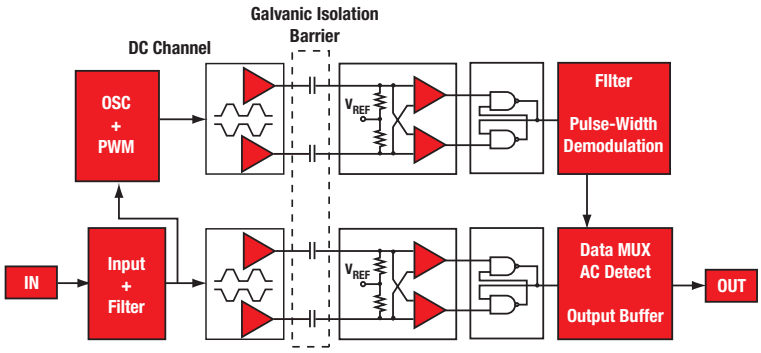
#### Key Features

- Qualified for automotive applications
- 1-Mbps and 25-Mbps signaling rate options
- Low channel-to-channel output skew 1 ns max
- Low pulse-width distortion (PWD) 1 ns max
- Low jitter content: 1 ns typical at 150 Mbps
- 25-year typical life at rated voltage (see application report SLLA197 and Figure 14)
- 4,000-VPEAK isolation, 560-VPEAK VIORM
- UL 1577, IEC 60747-5-2 (VDE 0884, Rev 2), IEC 61010-1, IEC 60950-1 and CSA approved
- 50-kV/µs typical transient immunity
- Operates with 3.3-V or 5-V supplies
- 4-kV ESD protection
- High electromagnetic immunity
- 40°C to 125°C operating free-air temperature range




**Single-Channel Functional Diagram**




## Digital Isolator Selection Guide

| Device | No. of Channels | Channel Configuration | Insulation Rating ($V_{RMS}$) | Supply Voltage (V) | Data Rate (Mbps) | ESD (kV) | Operating Temp Range (°C) | Package | Auto Qual (Q1) |
|---|---|---|---|---|---|---|---|---|---|
| **ISO721-Q1** | 1 | 1/0 | 2,500 | 3.3, 5.0 | 100 | 4 | -40 to 125 | 8/SO | Y |
| **ISO722x-Q1** | 2 | 2/0, 1/1 | 2,500 | 3.3, 5.0 | 1, 5, 25 | 4 | -40 to 125 | 8/SO | Y |
| **ISO724x-Q1** | 4 | 4/0, 3/1, 2/2 | 2,500 | 3.3, 5.0 | 1, 25 | 4 | -40 to 125 | 16/SO | Y |
| **ISO7421A/E-Q1** | 2 | 2/0, 1/1 | 2,500 | 3.3, 5.0 | 1 | 4 | -40 to 125 | 8/SO | Y |

Learn more at: **www.ti.com/ISO7221Cxx**

# Isolation, Analog and Power Management Products
## TI Isolated Products

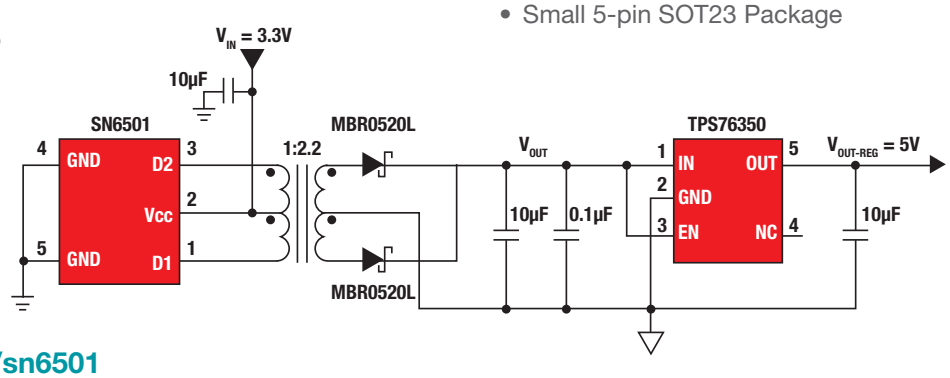
### SN6501 Transformer Driver for Isolated Power Supplies

The SN6501 is a monolithic oscillator/power-driver, specifically designed for small form factor, isolated power supplies in isolated interface applications. It drives a low-profile, center-tapped transformer primary from a 3.3 V or 5 V DC power supply. The secondary can be wound to provide any isolated voltage based on transformer turns ratio.

The SN6501 consists of an oscillator followed by a gate drive circuit that provides the complementary output signals to drive the ground referenced N-channel power switches. The internal logic ensures break-before-make action between the two switches.

The SN6501 is available in a small SOT23-5 package, and is specified for operation at temperatures from –40°C to 125°C.

**Key features**
- Push-Pull Driver for Small Transformers
- Single 3.3 V or 5 V Supply
- High Primary-side Current Drive:
  - 5 V Supply: 350 mA (max)
  - 3.3 V Supply: 150 mA (max)
- Low Ripple on Rectified Output Permits Small Output Capacitors
- Small 5-pin SOT23 Package




Learn more at: **www.ti.com/product/sn6501**

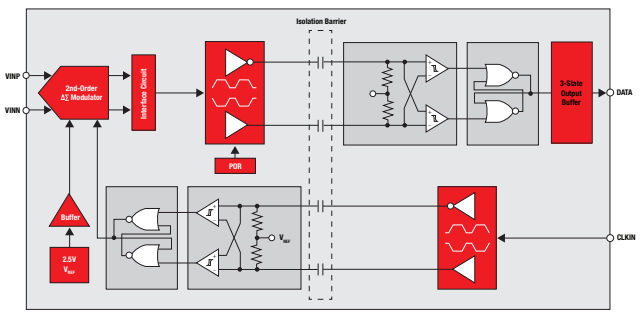
---

### AMC1204-Q1 1-Bit, 20 MHz, Second-Order, Isolated Delta-Sigma Modulator

The AMC1204-Q1 is a 1-bit digital output, isolated delta-sigma (ΔΣ) modulators that can be clocked at up to 20 MHz. The digital isolation of the modulator output is provided by a silicon dioxide (SiO2) barrier that is highly resistant to magnetic interference. This barrier has been certified to provide basic galvanic isolation of up to 4250 VPEAK according to UL1577, IEC60747-5-2, and CSA standards or specifications.

The AMC1204-Q1 provides a single-chip solution for measuring the small signal of a shunt resistor across an isolated barrier. These types of resistors are typically used to sense currents in motor control inverters, green energy generation systems, and other industrial applications. The AMC1204-Q1 differential inputs easily connect to the shunt resistor or other low-level signal sources. An internal reference eliminates the need for external components. When used with an appropriate external digital filter, an effective number of bits (ENOB) of 14 is achieved at a data rate of 78 kSPS.

**Key features**
- AEC-Q100 qualified with the following results
  - Device temperature grade 1: –40°C to 125°C ambient operating temperature range
  - Device HBM ESD classification level H2
  - Device CDM ESD classification level C3B
- ±250-mV input voltage range optimized for shunt resistors
- Certified digital isolation
- Long isolation barrier lifetime (see application report SLLA197)
- High electromagnetic field immunity
- Outstanding AC performance
- Excellent DC precision
- External clock input for easier synchronization
- Fully specified over the extended automotive temperature range




Learn more at:
**www.ti.com/AMC1204**

# Isolation, Analog and Power Management Products

## TI Isolated Products

| Device | Description | AEC-Q100 status |
|---|---|---|
| **Automotive signal chain** | | |
| INA19xA-Q1 | -16-V to 80-V common-mode-range current shunt monitors | Qualified |
| INA213A-Q1 | Voltage output, bidirectional zero-drift series current shunt monitor | Qualified |
| OPA365-Q1 | 2.2-V, 50-MHz, low-noise, single-supply rail-to-rail operational amplifiers | Qualified |
| TLV3502-Q1 | 4.5-ns rail-to-rail high-speed comparator | Qualified |
| LM2902/4-Q1 | Operational amplifier | Qualified |
| LM2901/3-Q1 | Differential comparator | Qualified |
| TL4050yxx-Q1 | Precision micropower shunt voltage reference | Qualified |
| TPS380xx-Q1 | Supply voltage supervisors | Qualified |
| INA282-Q1 | Wide common-mode range, bidirectional, high-accuracy current shunt monitor | Qualified |
| AMC1204-Q1 | Isolated ADC | Qualified |
| AMC1200-Q1 | Isolated ADC | Qualified |
| INA148-Q1 | +/-200V common-mode voltage difference amplifier | Qualified |
| INA20x-Q1 | Current shunt monitor with comparator and reference / dual comparators | Qualified |
| INA16x-Q1 | Current shunt monitor with comparator, current output | Qualified |
| INA27x-Q1 | Voltage output current shunt monitor | Qualified |
| INA214-Q1 | Voltage Output, High/Low-Side Measurement, Bi-Directional Zero-Drift Series | Qualified |
| ADS7841-Q1 | Automotive Catalog 12-Bit, 4-Channel Serial Output Sampling Analog-to-Digital Converter | Qualified |
| **Automotive power management – DC/DC converter, LDO** | | |
| AMC1204-Q1 | 1-Bit, 20 MHz, second-order, isolated delta-sigma modulator | Qualified |
| TPS54x0-Q1 | 1-A/2-A/3-A/5-A wide-input-range step-down SWIFT™ converter | Qualified |
| TPS54x62-Q1 | Low Iq 3-A step-down converter | Qualified |
| TPS54240-Q1 | 2.5A, 4.5-42 VIN DC-DC convert in 3mmx3mm SON package | Preview |
| TPS54540/560/-Q1 | 5.5A, 4.7-42/60 VIN Buck Converter with low drop out operation | Preview |
| TPS54061/3-Q1 | 200-mA/800-mA 4.7-60 VIN Synchronous Buck Converter | Qualified, Preview |
| TPS54340/360-Q1 | 3.5A, 4.7-42/60 VIN buck converter with low drop out operation | Preview |
| TPS40090-Q1-Q1 | 2-, 3-, or 4-phase programmable synchronous buck controller optimized for low-voltage, high-current application | Qualified |
| TPS40170-Q1 | 4.5 V to 60 V Wide-Input Synchronous PWM Buck Controller | Qualified |
| TPS55340-Q1 | Integrated 5-A 40V Boost / SEPIC / Flyback Regulator | Preview |
| TPS57x60-Q1 | 3.5-V to 60-V, 0.5A and 1.5-A step-down SWIFT converter with Eco-mode™ control scheme | Qualified |
| TPS7A16xx-Q1 | 60V, 5-uA Iq, 100-mA, Low-Dropout Voltage Regulator with Enable and Power Good | Qualified |
| TPS7A6xxx-Q1 | 40-V, 300-mA, Low-Dropout Regulator With Ultra-Low Quiescent Current | Qualified |
| TPS7A6950-Q1 | 150mA, High Voltage, Ultra Low Iq (20uA), Low Drop Out Regulator in SOIC Package | Qualified |
| TPS7A6650-Q1 | 150mA, High Voltage, Ultra Low Iq (20uA), Low Drop Out Regulator in MSOP Package | Qualified |
| LM5010AQ0 | 75V 1A, 1MHz buck converter with internal compensation (Tj 150C) | Qualified |
| LM25011Q | 42V, 2A Constant On-Time buck converter with Adjustable Current Limit | Qualified |
| LM5117Q | 65V Synchronous buck controller with current monitor | Qualified |
| LM5118Q | 75V buck-boost controller with 10uA max shutdown current | Qualified |
| LM5119Q | 65V Dual or interleaved synchronous buck controller with programmable current limit | Preview |
| LM5122Q | 65V Synchronous boost controller with mutliphase capability | Preview |
| **Automotive power management – PWM controller** | | |
| UCC28950-Q1 | Green Phase-Shifted Full-Bridge Controller with Synchronous Rectification | Qualified |
| UC2856-Q1 | Improved current-mode PWM controller | Qualified |
| UC2825A-Q1 | High-speed PWM controller | Qualified |
| UC2843-Q1 | Current-mode PWM controller | Qualified |
| UCC2813-Q1 | Low-power BICMOS current-mode PWM | Qualified |
| TPS40210-Q1-Q1 | Wide-input-range current-mode boost controller | Qualified |
| UCC280x-Q1 | Automotive catalog low-power BiCMOS current-mode PWM | Qualified |
| UCC28220-Q1 | Dual interleaved PWM controller with programmable max duty cycle | Qualified |
| UCC2808A-2-Q1 | Low-power current-mode push-pull PWM | Qualified |
| UCC2895-Q10-Q1 | Green Phase-Shifted Full-Bridge Controller with Synchronous Rectification | Qualified |

*Texas Instruments offers a wide range of devices specifically fitted for use in the HEV/EV space.*
*Please check www.ti.com for the latest device announcements.*

# Isolation, Analog and Power Management Products
## TI Isolated Products

| Device | Description | AEC-Q100 status |
|---|---|---|
| **Automotive Protection Devices** | | |
| LM5060Q1 | High-Side Protection Controller with Low Quiescent Current | Qualified |
| LM5050Q1 | Wide-Input-Range Ideal Diode Controller | Preview |
| **Automotive gate driver** | | |
| TPS2811-Q1 | Dual high-speed MOSFET drivers | Qualified |
| TPS28x9-Q1 | High-speed MOSFET driver | Qualified |
| UCC27200/1-Q1 | 120-V boot, 3-A peak, high-frequency, high-side/low-side driver | Qualified |
| UCC27423/4/5-Q1 | Dual 4-A high-speed low-side MOSFET drivers with enable | Qualified |
| UCC27321/2/4-Q1 | Single 9-A peak high-speed low-side power MOSFET drivers | Qualified |
| **Automotive digital isolators** | | |
| SN6501-Q1 | Transformer driver for Isolated Power supplies | Preview |
| ISO721-Q1 | Single 100-Mbps digital isolator | Qualified |
| ISO7221C-Q1 | Dual-channel, 25-Mbps digital isolator | Qualified |
| ISO7240CF/1C-Q1 | Quad-channel, 25-Mbps digital isolator | Qualified |
| ISO7220A/1A-Q1 | Dual-channel, 1-Mbps digital isolator | Qualified |
| ISO7421E-Q1 | Automotive Catalog Low-Power Dual Channel Digital Isolators | Qualified |
| ISO7231C-Q1 | Automotive Catalog Triple Channel, 2/1, 25Mbps, Digital Isolator | Qualified |
| **Automotive CAN interface** | | |
| SN65HVDA1050A-Q1 | EMC-optimized high-speed CAN transceiver | Qualified |
| SN65HVDA1040A-Q1 | EMC-optimized high-speed CAN transceiver | Qualified |
| SN65HVDA540-Q1 | CAN transceiver 5-V to 3.3-V MCU interface | Qualified |
| SN65HVDA541-Q1 | CAN transceiver 5-V to 3.3-V MCU interface, wakeup | Qualified |
| **Automotive Logic** | | |
| SN74AVCxT245-Q1 | Dual-Supply Bus Transceiver w/ Configurable Voltage Translation, Low Power Consumption | Qualified |
| SN74LVCxT45-Q1 | Dual Supply Transceiver with Configurable Voltage Translation | Qualified |
| SN74HC244-Q1 | Octal Buffers And Line Drivers With 3-State Outputs | Qualified |
| SN74HC08-Q1 | Quadruple 2-Input Positive-AND Gates | Qualified |
| SN74HC00-Q1 | Quadruple 2-Input Positive-NAND Gates | Qualified |
| SN74HC14-Q1 | Hex Schmitt-Trigger Inverters | Qualified |
| SN74HC04-Q1 | Hex Inverters | Qualified |

*Texas Instruments offers a wide range of devices specifically fitted for use in the HEV/EV space.*
*Please check www.ti.com for the latest device announcements.*

## *TI Worldwide Technical Support*

### Internet

**TI Semiconductor Product Information Center Home Page**
support.ti.com

**TI E2E™ Community Home Page**
e2e.ti.com

### Product Information Centers

| | | |
|---|---|---|
| **Americas** | Phone | +1(512) 434-1560 |
| **Brazil** | Phone | 0800-891-2616 |
| **Mexico** | Phone | 0800-670-7544 |
| | Fax | +1(972) 927-6377 |
| | Internet/Email | support.ti.com/sc/pic/americas.htm |

**Europe, Middle East, and Africa**

Phone

| | |
|---|---|
| European Free Call | 00800-ASK-TEXAS (00800 275 83927) |
| International | +49 (0) 8161 80 2121 |
| Russian Support | +7 (4) 95 98 10 701 |

**Note:** The European Free Call (Toll Free) number is not active in all countries. If you have technical difficulty calling the free call number, please use the international number above.

| | |
|---|---|
| Fax | +(49) (0) 8161 80 2045 |
| Internet | www.ti.com/asktexas |
| Direct Email | asktexas@ti.com |

**Japan**

| | | |
|---|---|---|
| Phone | Domestic | 0120-92-3326 |
| Fax | International | +81-3-3344-5317 |
| | Domestic | 0120-81-0036 |
| Internet/Email | International | support.ti.com/sc/pic/japan.htm |
| | Domestic | www.tij.co.jp/pic |

**Asia**

Phone

| | |
|---|---|
| International | +91-80-41381665 |
| Domestic | Toll-Free Number |

**Note:** Toll-free numbers do not support mobile and IP phones.

| | |
|---|---|
| Australia | 1-800-999-084 |
| China | 800-820-8682 |
| Hong Kong | 800-96-5941 |
| India | 1-800-425-7888 |
| Indonesia | 001-803-8861-1006 |
| Korea | 080-551-2804 |
| Malaysia | 1-800-80-3973 |
| New Zealand | 0800-446-934 |
| Philippines | 1-800-765-7404 |
| Singapore | 800-886-1028 |
| Taiwan | 0800-006800 |
| Thailand | 001-800-886-0010 |

| | |
|---|---|
| Fax | +8621-23073686 |
| Email | tiasia@ti.com or ti-china@ti.com |
| Internet | support.ti.com/sc/pic/asia.htm |



**B090712**



Texas Instruments

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

| **Products** | | **Applications** | |
|---|---|---|---|
| Audio | www.ti.com/audio | Automotive and Transportation | www.ti.com/automotive |
| Amplifiers | amplifier.ti.com | Communications and Telecom | www.ti.com/communications |
| Data Converters | dataconverter.ti.com | Computers and Peripherals | www.ti.com/computers |
| DLP® Products | www.dlp.com | Consumer Electronics | www.ti.com/consumer-apps |
| DSP | dsp.ti.com | Energy and Lighting | www.ti.com/energy |
| Clocks and Timers | www.ti.com/clocks | Industrial | www.ti.com/industrial |
| Interface | interface.ti.com | Medical | www.ti.com/medical |
| Logic | logic.ti.com | Security | www.ti.com/security |
| Power Mgmt | power.ti.com | Space, Avionics and Defense | www.ti.com/space-avionics-defense |
| Microcontrollers | microcontroller.ti.com | Video and Imaging | www.ti.com/video |
| RFID | www.ti-rfid.com | | |
| OMAP Applications Processors | www.ti.com/omap | **TI E2E Community** | e2e.ti.com |
| Wireless Connectivity | www.ti.com/wirelessconnectivity | | |

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265