Motor Drive and Control Solutions

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→ Introduction

Texas Instruments (TI) is a global market leader that provides complete motor-drive and control solutions along with broad analog and microcontroller portfolios. TI offers comprehensive tools, software and support to deliver efficient, reliable, cost-effective motor solutions. Customers can get the right products with the right per-formance to quickly spin motors such as AC induction motors (ACIMs), brushed DC motors, brushless DC (BLDC) motors, permanent-magnet synchronous motors (PMSMs) and stepper motors.

When you want the broadest motor expertise, breadth of selection and comprehensive support, you want TI as your partner for efficient, reliable and cost-effective motor-drive and control solutions.
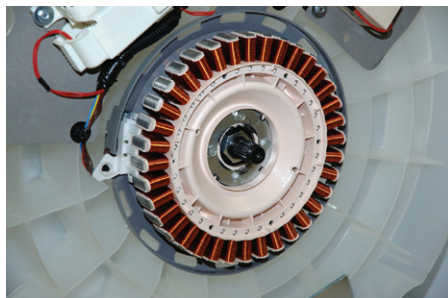
www.ti.com/motor
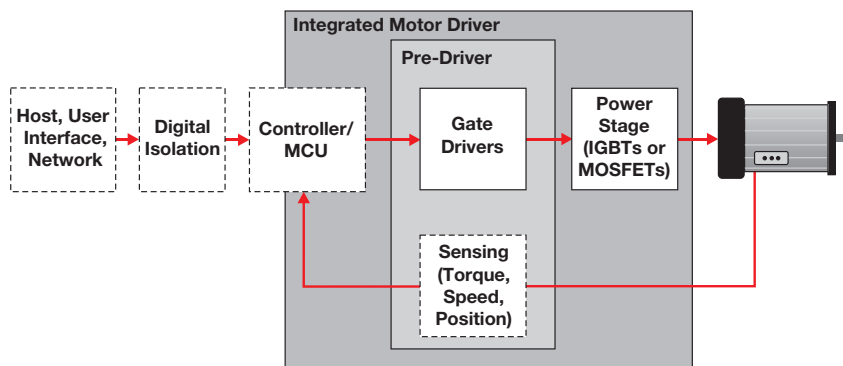
Motor Control System Functions

Host – Motion profile, logic controller or user interface, often communicating over a standard or proprietary field bus (CAN, serial, and Ethernet such as EtherCAT, Ethernet POWERLINK or EtherNet/IP).

Digital Isolation – Protection and level shifting between different voltage levels.

Controller – Generates the proper switching patterns to control the motor's motion based on feedback and motion profile information from the host.

Gate Drivers – Generate the necessary voltage and current required to accu-rately and efficiently drive the MOSFETS or IGBTs.

Power Stage – IGBTs or MOSFETS

Sensing – Analog circuitry which pro-cesses/conditions the feedback from the motor to control torque, speed or position.

Pre-Driver – Gate drivers, sensing and protection circuitry integrated into a single device or package that may also include control logic.

Integrated Motor Driver – Gate driver, FETs and protection circuitry integrated into a single device or package that may also include control logic and sensing circuitry.

Complete TI Motor-Drive Solutions

➔ Stepper Motors

Steppers are a cost-effective solution for open-loop position-control applications such as printers, scanners, home/office appliances and scientific or medical equipment.

DRV8818EVM – $99
- DRV8818-based motor driver capable of 2.5 A at 35 V
- On-board MSP430™ MCU
- Updated user interface for acceleration and deceleration profiles
- Open source: BOM, schematics, Gerbers, MSP430 code

New/Improved GUI

RDK-Stepper – $199
- Fully integrated comm/indexer/ drive for NEMA23/34 motors up to 80 V at 3 A
- Step rates up to 10,000 steps/s
- Full-step, half-step and wave drive modes
- Professionally engineered software
- PC GUI for dynamic tuning and motor configuration
- 50-MHz Stellaris® LM3S617 MCU

DRV8412-C2-KIT – $199
- DRV8412-based motor driver capable of 2× 6 A at 50 V
- Includes two brushed DC motors, one stepper motor and a Piccolo™ F28035 controlCARD, which can accept any TI MCU-based controlCARD
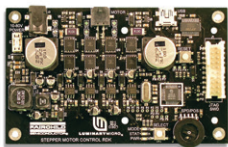- Professionally developed GUI and firmware
- Open source: BOM, schematics, Gerbers, controlSUITE™ software and Code Composer Studio™ Integrated Development Environment (IDE)
- Control: Outer speed, inner current closed loop
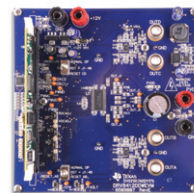
DRV8829EVM – $149
- Two 5-A H-bridge motor drivers
- Phase/enable control interface and low component count
- On-board MSP430 MCU supports up to 512 microsteps
- Easy-to-use GUI for quick setup with most motors
- Open source: BOM, schematics, Gerbers
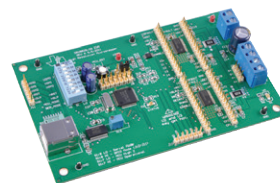
➔ Brushed DC Motors

DC motors are used when simple control and cost effectiveness are required in applications such as toys and small consumer appliances.

DRV8837EVM – $25
- Low-voltage DRV8837 evaluation module operates from 1.8 V to 11 V and delivers up to 1.8 A
- Evaluate driver performance with on-board MSP430™ MCU or external MCU
- On-board speed and direction controls; Micro-USB connection for easy evaluation/power up
- Open source: BOM, schematics, Gerbers
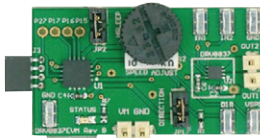
DRV8412-C2-KIT – $299
- DRV8412-based motor driver capable of up to 2× 6 A or 1× 12 A at 50 V
- Includes two brushed DC motors, one stepper motor and a Piccolo™ F28035 controlCARD, which can accept any TI MCU-based controlCARD
- Professionally developed GUI and firmware
- Open source: BOM, schematics, Gerbers, controlSUITE™ software and Code Composer Studio™ IDE
- Control: Outer speed, inner current closed loop
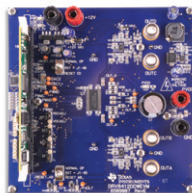
RDK-BDC24 – $219
- Controls brushed 24-V DC motors with up to 40 A continuous
- Three options for open-loop voltage control and two options for closed-loop, speed, position or current control
- CAN and RS-232 communication

DRV8801EVM – $99
- DRV8801-based motor driver capable of 2.0 A at 36 V
- On-board MSP430™ MCU
- Easy-to-use GUI for quick setup with most motors
- Open source: BOM, schematics, Gerbers
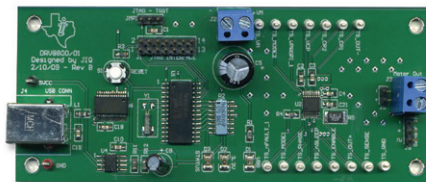
Easy-to-Use Graphical User Interface (GUI)
- Stand-alone GUI requires no IDE
- Immediate verification of motor-control operation
- Configurable capabilities
- Sliders and input fields
- Real-time graphing of key variables
- Free with most motor-control kits

Complete TI Motor-Drive Solutions
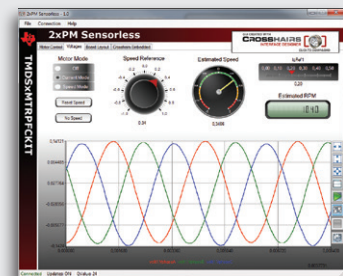
→ Brushless DC (BLDC) Motors

BLDC motors are widely used in speed-control applications where reliability and ruggedness are required, such as in fans, pumps and compressors.

TMDSHVMTRPFCKIT – $599
- Piccolo™ controlCARD-based hardware
- 350-V, 1.5-kW three-phase inverter
- 700-W bypassable PFC (DC bus) front
- Isolated JTAG and CAN on board
- Open source: BOM, schematics, Gerbers, controlSUITE™ software (sensored and sensorless, trapezoidal, PFC) and Code Composer Studio™ IDE
- Control: Supports sensored (Hall)/sensorless feedback control with trapezoidal or speed closed loop

RDK-BLDC – $219
- Advanced motor control for three-phase brushless DC motors up to 36 V, 500 W
- Uses a Stellaris® LM3S8971 microcontroller
- 10/100 Ethernet and CAN interfaces
- Hall effect, quadrature and sensorless operation modes
- JTAG/SWD port for software debugging
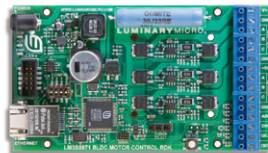
DRV8312-Based Kits – $299 Each
- InstaSPIN™-BLDC solution with DRV8312-based driver capable of 3.5 A continuous at 50 V
- Includes one of the following control-CARDs: Piccolo F28035, Stellaris LM3S818 or LM4F211, or MSP430™ FR5739 respectively and can accept many MCU-based processors
- Professionally developed GUI and firmware
- Open source: BOM, schematics, Gerbers, controlSUITE software and Code Composer Studio IDE

DRV8301/2-Based Kits – $299 to $499 Each
- InstaSPIN-BLDC solution with DRV8301- or DRV8302-based pre-driver capable of driving external FETs up to 60 A at 60 V
- Includes Piccolo F28035, Hercules RM48 or TMS570LS31 controlCARD and can accept any MCU-based processor
- Professionally developed GUI and firmware
- Open source: BOM, schematics, Gerbers, controlSUITE software and Code Composer Studio IDE
- Control: Supports sensored/sensorless trapezoidal, current or speed closed loop

→ Permanent Magnet Synchronous Motors (PMSMs)

PMSMs are used in applications requiring precise control and low torque ripple, such as robotics, servo systems and electric power steering.

DRV8312-Based Kits – $299 Each
- DRV8312-based driver capable of 3.5 A continuous at 50 V
- Includes Piccolo™ F28035 or Stellaris® LM4F211 controlCARD and accepts any TI MCU-based controlCARD
- Professionally developed GUI and firmware
- Open source: BOM, schematics, Gerbers, controlSUITE™ software and Code Composer Studio™ IDE
- Control: FOC sensored (requires shaft encoder), sensorless (SMO two-shunt current), speed and torque closed loop

TMDSHVMTRPFCKIT – $599
- Piccolo and Delfino™ controlCARD-based hardware
- Delfino F28335 controlCARD compatible
- 350-V, 1.5-kW three-phase inverter
- 700-W bypassable PFC (DC bus) front end
- Isolated JTAG and CAN on board

- Open source: BOM, schematics, Gerbers, controlSUITE software supports sensored and sensorless field-oriented control (FOC) and PFC, and Code Composer Studio IDE
- Sensored (encoder)/Sensorless (sliding mode observer [SMO]) FOC speed control: Inner current, outer speed closed loop; CLA example

DRV8301/2-Based Kits – $299 to $499
- DRV8301- or DRV8302-based pre-driver for 8 to 60 V with 60-A MOSFETs
- Includes Piccolo F28035, Hercules™ RM48 or TMS570LS31 controlCARD and can accept many TI MCU-based controlCARDs
- Hercules kits include 3-phase servo motor with built-in Hall effect and encoder
- Professionally developed GUI and firmware
- Open source: BOM, schematics, Gerbers, controlSUITE software and Code Composer Studio IDE
- Control: Sensorless FOC (SMO two-shunt current), speed and torque closed loop; encoder sensored FOC, speed and torque closed loop

Complete TI Motor-Drive Solutions

➜ AC Induction Motors (ACIMs)

The ACIM is the industrial "muscle motor" that enabled the industrial revolution. This rugged motor is used in a vast array of applications from home appliances to high-horse-power factory automation.

RDK-ACIM – $379
- Fully integrated comm/motion controller/drive
- Up to 1-HP commercial-grade ACIMs
- Precise speed control
- Galvanic isolation of MCU-side electronics
- 115- or 230-VAC inputs
- 50-MHz Stellaris® LM3S818 MCU
- Professionally engineered software
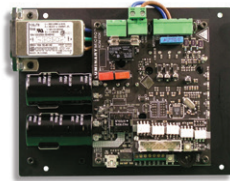
TMDSHVMTRPFCKIT – $599
- Piccolo™ and Delfino™ controlCARD-based hardware
- Delfino F28335 controlCARD compatible
- 350-V, 1.5-kW three-phase inverter
- 700-W bypassable PFC (DC bus) front end
- Isolated JTAG and CAN on board
- Open source: BOM, schematics, Gerbers, controlSUITE™ software (sensored and sensorless FOC, PFC) and Code Composer Studio™ IDE
- Sensored (Hall)/sensorless (motor model) FOC speed control: Inner current, outer speed closed loop; CLA example

Third-Party Network Developers

MathWorks Model-Based Design

Target for C2000™ Microcontrollers
Model-based design integrates MATLAB® and Simulink® with TI's Code Composer Studio™ IDE and C2000™ microcontrollers.

Key Features
- Generates documented, readable and editable C code in Code Composer Studio IDE project format
- Automates the testing and execution of Simulink models
- Enables the real-time evaluation of system designs on TI motor kits
- Provides block-level access to on-chip peripherals
- Provides block-level access to the TI IQMath library for simulation and code generation

www.mathworks.com/c2000

VisSim/Embedded Controls Developer™
VisSim/Embedded Controls Developer is a visual develop-ment environment for the rapid prototyping and development of motion-control systems.

Key Features
- VisSim/Motion block set that includes pre-built motor, amplifier, sensor, encoder, dynamic load and closed-loop PID models
- DMC block set includes all of the TI DMC library in block form
- Peripheral blocks generate code for C2000, MSP430™ and soon other TI MCUs
- Automatic C-code generation of production-quality fixed-point code
- Real-time visualization while code executes
- Code Composer Studio IDE plug-in for automatic project creation

www.vissim.com/c2000

TI Motor Design Network Developers

Third Party	Website	Service
D3 Engineering	www.d3engineering.com	Design services, consulting, algorithms, The MathWorks
Drivetech	www.drivetechinc.com	Design services, consulting, DMC expertise
Pentad Design	www.pentaddesign.com	Design services, DPS and CLA expertise
Powersim	www.powersimtech.com	Power electronics simulation and C2000 auto code generation
Simma Software	www.simmasoftware.com	Network protocol software
The MathWorks	www.mathworks.com	Embedded target, auto code generation
Visual Solutions	www.vissim.com	Rapid prototyper: Visual application development

DRV8x Integrated Motor Drivers

The DRV8x family of integrated motor drivers enables customers to quickly and easily spin their motors. Integrated drivers have higher performance, better protection, and require less board space than traditional discrete solutions. Futhermore, integrated drivers do not require discrete drive-stage design experience, which greatly simplifies and speeds the design process.

The Right Part for Each Application
TI has a broad portfolio of motor drivers with different levels of integration, multiple control interfaces and a wide range of power ratings. The DRV8x family includes both drivers and pre-drivers that support voltage ranges from 1.8 to 60 V and load currents up to 60 A.

Robust, Reliable and Fully Protected
All of TI's motor drivers include fast-acting protection against short circuits, thermal overload, undervoltage and shoot-through. When a fault condition is detected, the H-Bridge is quickly shut down to protect the motor and driver IC.

www.ti.com/drv8x

The TI Advantage

Quicker Time to Spin
With an integrated drive stage, current sensing, on-chip control logic, simple control interfaces, easy-to-use EVMs and design-in documentation, customers can quickly get their motors up and spinning.

DRV8x Integrated Motor Driver

Featured Drivers

Motor Type	Device	Voltage	Description
Brushed	DRV8832	2.75 to 6.8 V	1-A driver with on-chip speed regulation
	DRV8833	2.7 to 10.8 V	Dual 2-A or single 4-A driver
	DRV8835	2.0 to 11 V	Dual 1.5-A or single 3-A driver with dual supplies
	DRV8837	1.8 to 11 V	1.8-A driver with dual supplies
Stepper	DRV8833	2.7 to 10.8 V	2-A driver (full and half step)
	DRV8834	2.5 to 10.8 V	2.2-A driver (32 microsteps)
	DRV8835	2.0 to 11 V	1.5-A driver with dual supplies (full and half step)

3-Phase Brushless Motor Pre-Driver
DRV8301

Key Features
- Integrated three-phase gate driver with dual current-shunt amplifiers and buck converter for MCU or system power needs
- Wide input-voltage range (8 to 60 V)
- Supports up to 1.7-A gate current
- Intelligent gate drive and cross-conduction prevention
- Overcurrent (OC) protection of external FETs with programmable cycle-by-cycle current limit
- SPI interface for programmability

Benefits
- Reduced board space and improved performance
- Automatic handshake of high-side and low-side FET transition to prevent shoot-through, simplify gate control and improve system reliability

- External FETs improve thermal performance and efficiency and can easily scale to support both low- and high-current platforms

Signal Chain Solutions
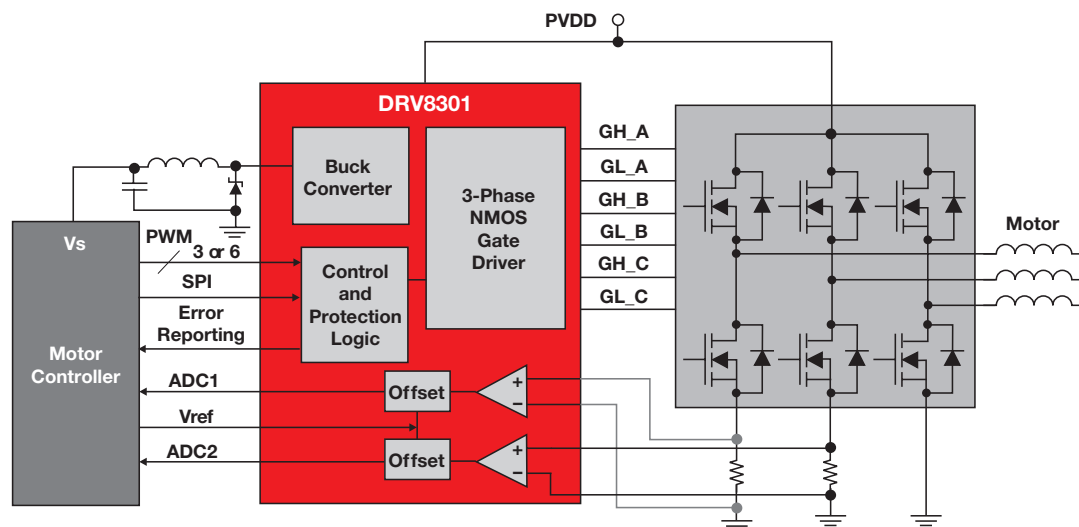
➔ Current-Sense Amplifiers

Low Offset is the TI Advantage

Offset and offset-drift performance are factors that determine the full-scale input voltage to the current-sense amplifier and, subsequently, the size of the shunt resistor. Lower offset allows for smaller shunt resistors and results in less voltage drop and power loss.

To avoid errors introduced by external gain resistors, all TI current-sense amplifiers have gain set internally through TI's precision manufacturing processes. Total component count and board space are reduced as well. In addition to the standard configuration of current-sense amplifiers, TI has a line of digital-output current-sense devices. These devices make isolation easy by limiting the interface to two digital lines, which frees embedded data converters for other system activities.

High Precision for Large Common-Mode Current Measurements
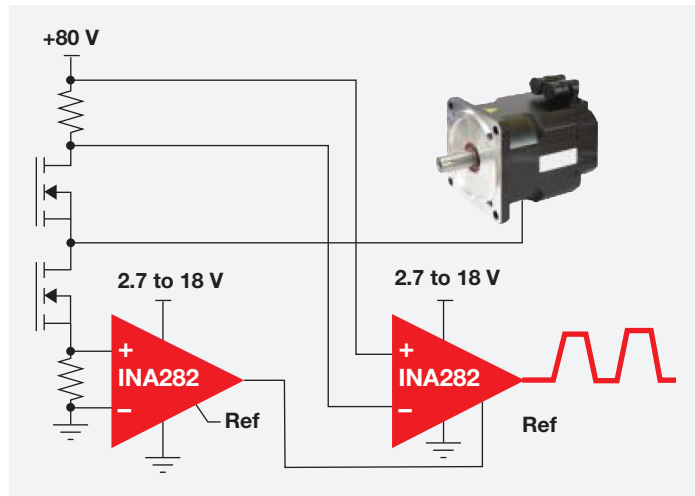
Wide Common-Mode Current-Sense Amplifiers

Device	CMR	Offset	Offset Drift	Bidirectional
INA282	−14 to 80 V	70 µV	0.5 µV/°C	Yes
INA138/INA139	2.7 to 36 V	1 mV	1 µV/°C	No
INA168/INA169	2.7 to 60 V	1 mV	1 µV/°C	No
INA170	2.7 to 60 V	1 mV	1 µV/°C	Yes
INA193-INA198	−16 to 80 V	2 mV	2.5 µV/°C	No
INA149	−275 to +275 V	1.1 mV	3 µV/°C	Yes
LMP8640HV	−2 to 76 V	1.16 mV	2.6 µV/°C	No
LMP8645HV	−2 to 76 V	1.7 mV	7 µV/°C	No
LMP8601	−22 to 60 V	1 mV	10 µV/°C	Yes
LMP8603	−22 to 60 V	1 mV	10 µV/°C	Yes

➔ Industrial Communications (Interface)

RS-485/RS-422
- Broad portfolio
- Improved speed, performance and robustness

Speed
- Speeds of up to 50 Mbps

Functionality
- Lower unit load: Up to 256 devices on bus
- 3.3-V supply: No need for extra voltage regulators
- True fail-safe: No need for external biasing resistors
- Slow-rate control reduces EMI
- Receiver equalization enables long cable transmission

Robustness
- Best-in-class ESD protection: Improved reliability
- 400-W transient voltage protection: No need for external components
- Extended common mode: Extends transmission distance

CAN
- Broad portfolio of standard industry upgrades and TI-unique CAN devices
- 5-V CAN transceiver offers the highest ESD protection in the industry: 14 kV

Second-Generation 3.3-V CAN Transceivers
- Lowest power and ±36-V protection
- Low-power standby with bus wake-up
- 5-µA standby power

Isolated Interface
- Integrated interface with isolation
- Uses TI's new differential capacitive technology
- High performance, superior to optical and magnetic isolation
- Integrated design saves board space and simplifies board design

PROFIBUS
- Certified PROFIBUS solution
- PROFIBUS transceiver with isolation

Industrial Ethernet
- Broad portfolio of Ethernet transceivers
- Support for standards such as EtherCAT, Ethernet POWERLINK, EtherNet/IP and more

→ # *Discrete Analog-to-Digital Converters (ADCs)*

Delta-Sigma Modulators in Current Measurement and Motor Control

TI's portfolio of delta-sigma modulators offers both isolated and non-isolated modulators enabling both direct measurement of current through shunt resistors and indirect measurement with Hall or magnetic sensors. The AMC1210 provides a quad-programmable digital filter enabling a seamless interface to the modulators, including a fast over-current detection path. Additionally, the AMC1210 provides PWM excitation for resolvers to enable an analog front-end solution for motor control.

Current-Measurement Applications

Delta-Sigma Modulators

TI's 16-Bit Delta-Sigma Modulators

Device	Channels	Style	Isolated	Input Range
AMC1203	1	10-MHz isolated	Yes	±280 mV
AMC1204	1	20-MHz Isolated	Yes	±280 mV
ADS1203	1	10-MHz non-isolated	No	±250 mV
ADS1204	4	10-MHz non-isolated	No	±2.0 V
ADS1205	2	10-MHz non-isolated	No	±2.0 V
ADS1208	1	10-MHz non-isolated	No	±100 mV
ADS1209	2	10-MHz non-isolated	No	±2.3 V
AMC1210	4	Digital filter	—	—
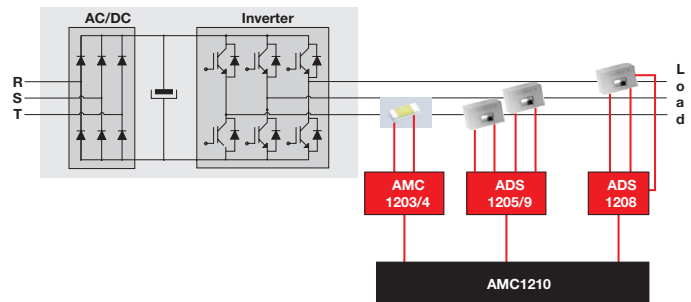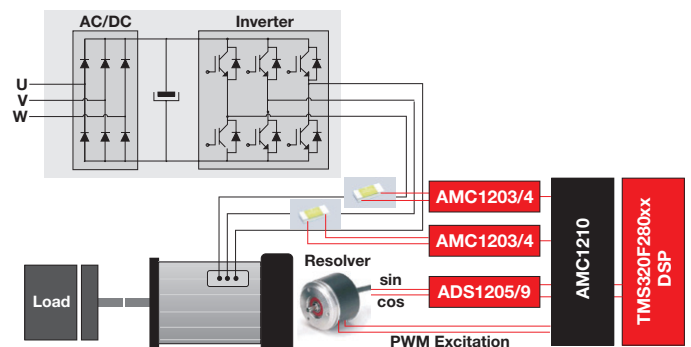
Simultaneous-Sampling ADCs for High-End Motor Drives

With up to eight simultaneously sampled channels and up to 2-MSPS sampling rate, TI's simultaneous-sampling ADC portfolio provides a wide range of ADCs for the most demanding high-end motor-drive applications. An integrated programmable reference simplifies system-level gain calibration without compromising the dynamic range.

Simultaneous-Sampling SAR ADCs

TI's Newest Simultaneous Sampling ADCs

Device	Resolution	Speed	Channels
ADS7223	12	1 MSPS/ADC	4×2, 2×2
ADS7863/5	12	2 MSPS/ADC	3×2, 2×2
ADS8528	12	650 kSPS/ADC	8
ADS8558	12	800 kSPS/ADC	6
ADS8568	12	650 kSPS/ADC	8
ADS7263	14	1 MSPS/ADC	4×2, 2×2
ADS8548	14	600 kSPS/ADC	8
ADS8557	14	800 kSPS/ADC	6
ADS8363	16	1 MSPS/ADC	4×2, 2×2
ADS8556	16	800 kSPS/ADC	6

Signal Chain Solutions
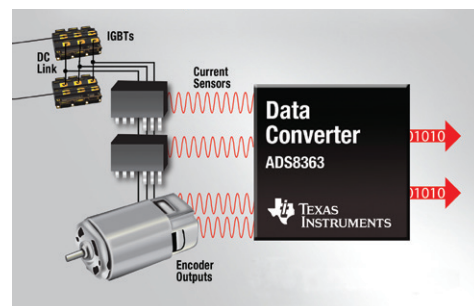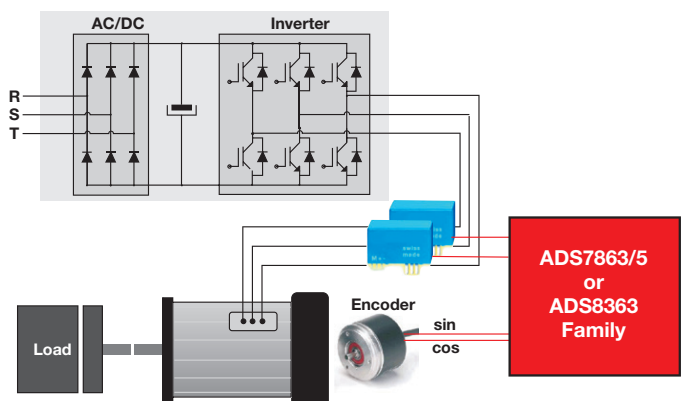
→ Digital Isolators

The TI Edge

Reliability

TI offers proven reliability of silicon-dioxide (SiO_2) insulation that is stable over temperature and moisture and has a life span of over 25 years.

Highest Noise Immunity

TI uses differential signals to cross the isolation barrier, giving the highest immunity from external magnetic and electric fields to prevent data corruption.

Signaling Rate

TI offers digital isolators with high signaling rates of up to 150 Mbps, with low skew and pulse-width distortion.

Lowest Jitter

To ensure signal integrity, jitter reduction is a priority. ISO7xxx products offer the lowest jitter of 1-ns jitter at 150-Mbps PRBS NRZ data input.

TI ISO Life Expectancy vs. Voltage
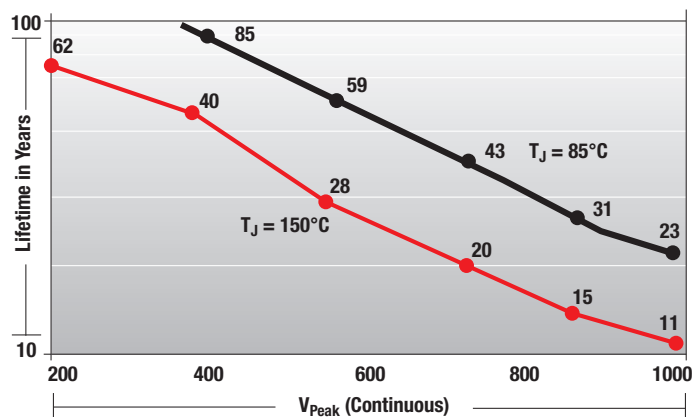
Resources Available

- EVMs
- IBIS models
- Application notes on high-voltage life-time and magnetic-field immunity

Isolated Gate Drivers
ISO5500 Family

TI's ISO5500 products are isolated gate drivers for IGBTs with power ratings up to 150 A and 1200 V.

The input TTL logic and output power stage are separated by TI's silicon-dioxide (SiO_2) isolation barrier.

When used in conjunction with isolated power supplies, the device blocks high voltage, isolates grounds and prevents noise currents from entering the local ground and interfering with or damaging sensitive circuitry.

Key Features

- Soft IGBT turn-off
- Isolated fault feedback
- V_{CE} DESAT protection/adjustability
- Undervoltage lock-out (UVLO) protection with hysteresis
- ±50-kV/µs typical transient immunity
- 6000-V_{peak} maximum isolation per UL
- Operates with 3.3- or 5-V input supply
- –40 to 125°C operating range

Microcontrollers for Motor Control
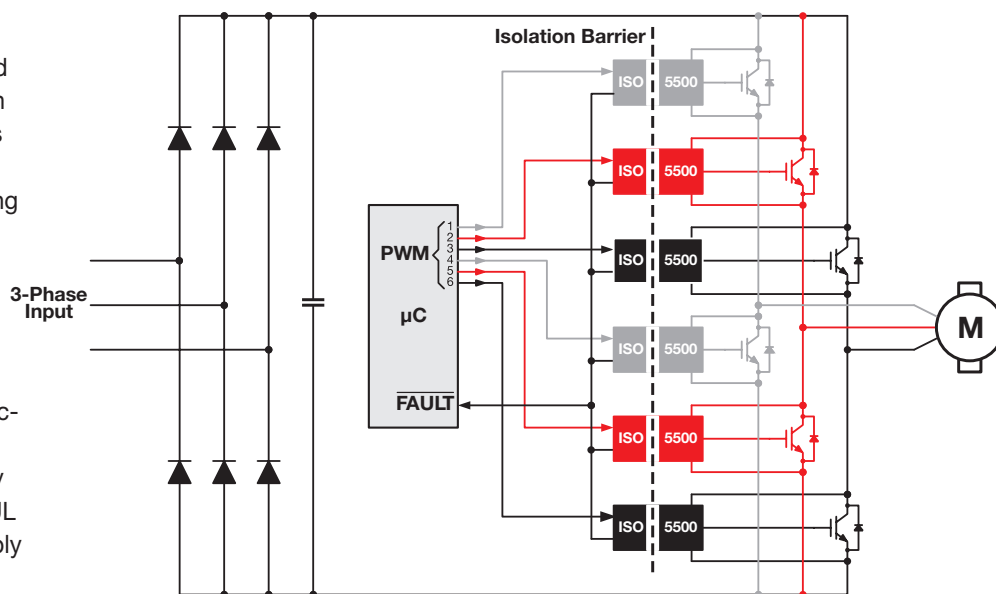
→ C2000™ 32-Bit Real-Time Microcontrollers

Broadest MCU Architecture
- Three MCU families: Piccolo™, Delfino™ and Concerto™ series
- 40- to 300-MHz performance
- Dual-core MCUs with CLA coprocessor
- Communications and math acceleration with VCU accelerator
- ARM® Cortex™-M3 and C28x™ dual-core

Real-Time Control
- Optimized DSP core with fast interrupts
- Flexible interrupt system
- Best-in-class ADC performance
- Real-time debugging
- Robust, high-resolution PWMs
- Sensor interfaces
- Serial, CAN, LIN, USB and Ethernet
- Integrated safety features

Overall System-Performance Optimization
- High level of integration
- Control and supervision
- Variable-speed real-time control
- Better dynamic and transient control
- Simulation, prototyping and automatic code generation from The MathWorks, VisSim and PowerSim
- Software libraries for industrial safety certification such as IEC60730 and IIEC61508

Piccolo MCU Family for Lowest System Cost
- Integrated OSC, watchdogs, POR/BOR
- Analog comparators and fault detection
- Reduced life-support costs
- No external GPIO filters needed

- High-resolution PWMs and fast ADC
- CLA coprocessor and VCU accelerator
- Floating-point unit
- Serial, USB, CAN, and LIN communications

Delfino MCU Family for High Performance
- High-performance C28x core
- Floating-point unit
- Leading high-resolution PWM
- Industry-leading fast ADC
- Fault detection

Concerto MCU Family for Maximum System Flexibility
- C28x CPU + ARM Cortex M3
- Integrated safety features
- Ethernet, USB and CAN communications peripherals
- Compatible with existing C2000™ application libraries
- Dual, fast ADCs
- High-resolution PWMs

- Floating-point unit and VCU accelerator
- Analog comparators, fault detection, integrated OSC, watchdogs, POR/BOR

Application Libraries
Specialized, application-specific software functions:
- Modular macros with variable I/Os
- At initialization, all variables are defined and outputs of one block are set as inputs to the next
- Complete documentation – including source code, use and technical theory – is provided for every module

Applications
- HVAC compressors and blowers
- Industrial motors
- Variable-speed fans and pumps
- Automotive power steering, traction and pumps
- Premium e-bikes
- Laundry machines
- Medical pumps and blowers

C2000™ Device Features
www.ti.com/c2000

Feature	Fixed-Point			Piccolo™ Series			Delfino™ Series		Concerto™ Series
	F281x	F280x	F2823x	F2802x	F2803x	F2806x	F2833x	C2834x	F28M35x
Mass Production	2003	2005	2008	2009	2010	2011	2008	2009	2013
C28x™ CPU	Fixed	Fixed	Fixed	Fixed	Fixed + CLA Option	Floating Point + CLA + VCU	Float	Float	Floating Point + ARM® Cortex™-M3
MHz	150	60 to 100	100 to 150	40 to 60	60 + 60 (CLA)	80	100 to 150	200 to 300	60 to 150 (C28x) 60 to 100 (ARM M3)
Pins	128 to 179	100	176 to 179	38 to 56	56 to 80	80 to 100	176 to 179	176 to 256	144
Flash (KB)	128 to 256	32 to 256	128 to 512	16 to 64	32 to 128	128 to 256	128 to 512	0	512 to 1024
RAM (KB)	36	12 to 36	52 to 68	4 to 12	12 to 20	52 to 100	52 to 68	196 to 516	72 to 136
Budgetary Pricing ($)	13 to 15	3 to 13	13 to 14	1.85 to 3	3 to 4.50	4.95 to 7	14 to 16	9 to 16	7 to 20

Digital Motor Control (DMC) Library

Transforms and Estimators
- Clarke, Park, sliding mode observer (SMO), phase voltage, resolver, flux, speed calculators and estimators

Control
- Signal generation, closed-loop PID, BEMF commutation, space vector generators, microstep SIN/COB tables

Peripheral Drivers
- Different modes and topology support
- ADC, PWM, encoders, sensor captures, DAC outputs

Is1 → Is2 → Is3 → **Clarke** → Iα / Iβ → **Park** → Id (flux component) / Iq (torque component) →

Three-Phase Rotating Domain — Two-Phase Rotating Domain — Stationary Domain
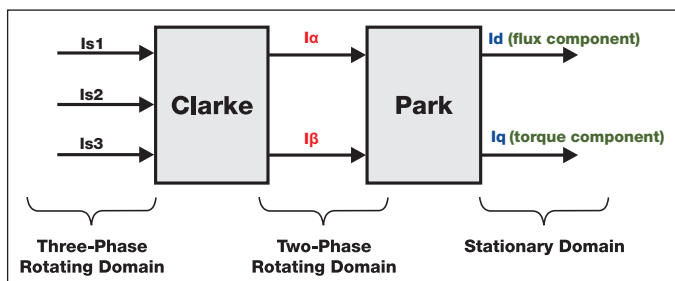
www.ti.com/c2000dmc

Ex: Using "Park" from DMC Library

```
//initialization code, define macro per library
    #define PARK_MACRO(v)
    v.Ds = _IQmpy(v.Alpha,v.Cosine) + _IQmpy(v.Beta,v.Sine);
    v.Qs = _IQmpy(v.Beta,v.Cosine) - _IQmpy(v.Alpha,v.Sine);
//incremental build code, connect outputs and inputs
    park1.Alpha = clarke1.Alpha;
    park1.Beta = clarke1.Beta;
//run-time code, call the function
    PARK_MACRO(park1)
```

➔ Stellaris® 32-Bit ARM® Cortex™-M Microcontrollers

Texas Instruments is the industry leader in bringing 32-bit capabilities and the full benefits of ARM® Cortex™-M-based microcontrollers to market. Stellaris® MCUs with Cortex-M offer a direct path to the strongest ecosystem of development tools, software and knowledge in the industry. Designers who migrate to Stellaris MCUs will benefit from great tools, small code footprint and outstanding performance. Even more important, designers can enter the ARM ecosystem with full confidence in a compatible roadmap from $1 to 1 GHz. You will never need to change architectures again.

With large on-chip memories, enhanced power management and expanded I/O and control capabilities, Stellaris MCUs are optimized for industrial applications requiring reliable connectivity, precise motor/motion control and remote monitoring. Some typical applications are factory automation, HVAC and building control, gaming equipment, medical instrumentation, consumer appliances, CCTV monitoring and fire security.

Precision Motion Control

The Stellaris family of ARM Cortex-M4F microcontrollers features deterministic performance and IP especially designed for simultaneous advanced motion control and real-time connectivity. These microcontrollers include up to 16 full channels of control with deadband

generators and shoot-through protection for applications such as three-phase inverter bridges. Fault-condition handling in hardware quickly provides low-latency shutdown and synchronization of timers to enable precise alignment of all edges.

- Motion-control PWMs with deadband and fault detection support safe and efficient operation of motors
- Quadrature encoder inputs (QEIs) support incremental encoders, tachometers, generators/resolvers and TDC detectors
- High-speed ADCs support current measurement using Hall sensors or shunts to optimize algorithms
- Independent integrated analog comparators can be configured to drive an output or generate an ADC interrupt event

Key Features
- Industry-leading ARM Cortex-M4F core
- 32 to 256KB of flash
- 80-MHz CPU clock speeds
- Deterministic fast-interrupt processing (12 cycles)
- Real-time multitasking capabilities
- Integrated analog peripherals
- 12-bit analog-to-digital converter
- Pulse-width modulators (PWMs) with programmable deadband timers
- Operating modes with clock gating for lower power
- Single-cycle multiply/accumulate (MAC)
- IEEE 754 single-precision floating-point unit (FPU)

Unique Stellaris MCU Capabilities
- Advanced communication capabilities, including UARTs, synchronous serial interfaces, USB, USB OTG, CAN controllers and I²C
- 5-V tolerant GPIOs with programmable drive capability
- Single-cycle flash up to 40 MHz
- Royalty-free StellarisWare® software with serial bootloaders and DriverLib available in ROM
- Open-tooled reference design kits and quick-start evaluation kits
- Up to two quadrature encoder inputs

StellarisWare Software
- Extensive suite of software designed to reduce development cycle time
- Stellaris peripheral libraries
- Stellaris USB libraries
- Stellaris graphics libraries
- Stellaris code examples
- Stellaris IEC 60730 library
- Available as object library and source code

Hardware Kits
- Schematics, BOM and Gerber files are available for all hardware kits and include all accessories to start evaluation right out of the box.

Reference Designs

Design	Description
DK-LM4F-DRV8312	ARM® Cortex™ Motor controlCARD Kit for 3-phase Brushless DC (BLDC) Motors
DK-LM3S-DRV8312	Sensorless InstaSPIN™ BLDC Kit
RDK-Stepper	Stepper Motor Reference Design Kit
RDK-ACIM	AC Induction Motor Reference Design Kit
RDK-BLDC	Brushless DC Motor Reference Design Kit
RDK-BDC	Brushed DC Motor Reference Design Kit
RDK-S2E	Serial-to-Ethernet Reference Design Kit
RDK-IDM	Intelligent Display Module Reference Design Kit

For more information on Stellaris MCUs for motor-control applications, visit
www.ti.com/stellarismotorcontrol

Stellaris® Robotic Evaluation Boards
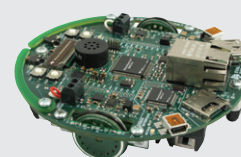
A fun way for serious embedded-systems programmers, consumers, hobbyists and students to work with and learn Stellaris ARM® Cortex™-M3 embedded programming with a variety of operating systems and ARM tool options. Order now at
www.ti.com/evalbot

→ Hercules™ TMS570 32-Bit ARM® Cortex™-R4 Safety Microcontrollers

Hercules™ TMS570 Safety MCUs Enable Safe Motor Control

The Hercules TMS570 microcontroller family enables customers to easily build motor-control applications that meet specific safety standards. Devices are available today with up to 220 MHz of floating-point performance and include an integrated safety concept.

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

The Hercules TMS570 Cortex™-R4 microcontroller family was developed according to the ISO26262 ASIL-D and IEC 61508 SIL3 safety standards. Dual-core lockstep CPU architecture, hardware BIST, MPU, ECC and on-chip clock and voltage monitoring are some of the key functional safety features available. A safety manual is available with guidelines on how to make the safety implementation as easy as possible.

Key Features

ARM® Cortex-R4 CPUs
- Up to 220 MHz with floating-point support
- Dual CPUs in lockstep

Memory
- Flash: 1MB, 2MB, and 3MB options with ECC protection
- RAM: 128KB to 256KB with ECC protection
- Roadmap from 256KB to 4MB flash

Peripheral Highlights
- 10/100 Ethernet
- USB host and device
- FlexRay with 8KB message RAM
- Three CAN interfaces
- Two 12-bit multi-buffered ADCs (MibADCs)
- Flexible timer module with up to 44 channels

Packages
- 144 QFP, 337 nFBGA (16.16 mm)

Applications
- Electronic power steering
- Hybrid and electric vehicles
- Medical pumps and blowers
- Industrial motors

Motor Control Benefits

High-End Timer (HET) Coprocessor
- Effective support of many 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

32-bit ARM Cortex-R4 with Floating-Point Unit
- IEEE 754 compliant floating point unit (ARM VFPv3D16)
- Supports both single and double precision

Dual 12-bit Buffered ADCs
- 12-bit resolution SAR
- 400-ns conversion time and 200-ns sampling time
- 24 total channels (Up to 16 shared)
  - Shared channels can be used for oversampling using both ADCs
  - Continuous multi- or single-channel conversion modes

www.ti.com/hercules

Hercules™ TMS570 Safety MCU

Safe island hardware diagnostics (red)
Blended hardware diagnostics (blue)
Non-safely critical functions (black)
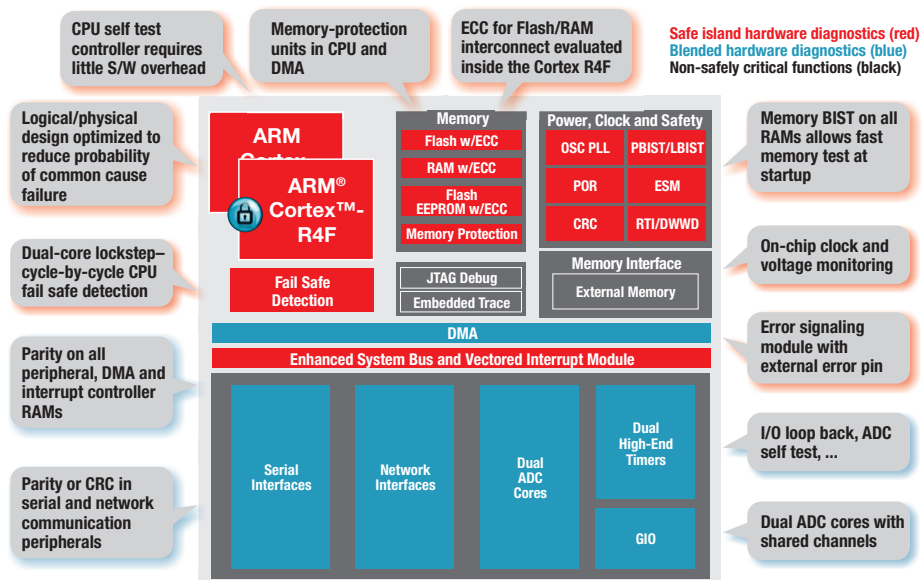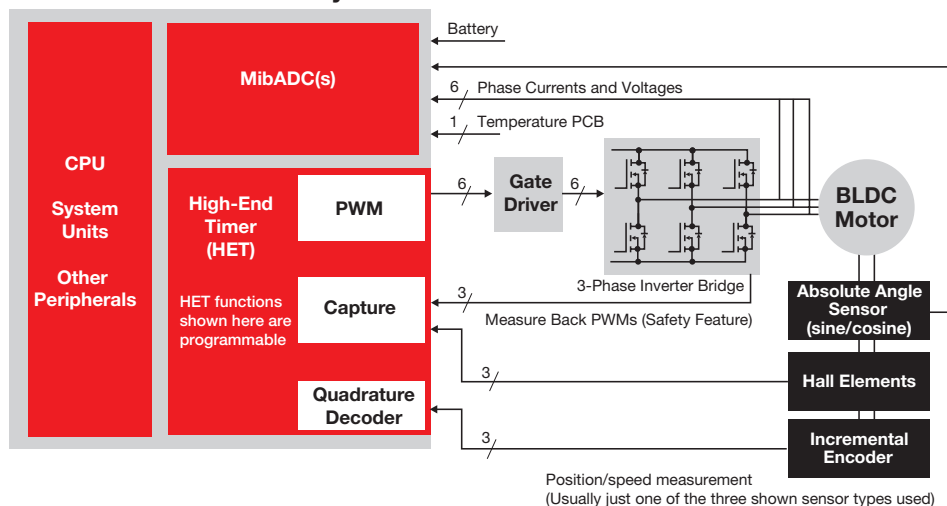
→ MSP430™ 16-Bit Ultra-Low-Power Microcontrollers

The MSP430™ family offers the world's leading ultra-low-power microcontrollers (MCUs) with a 16-bit RISC CPU architecture. These MCUs are optimized for C and assembler programming with ultra-low-power architectures. The ultra-low-power capabilities are available in active, standby and sleep modes. The MCUs are mostly used as general host controllers in simple motor-control applications such as toys.

The highly integrated MSP430 MCUs are ideal for stepper and DC-motor-control applications. Customers have the option to select from low- or high-pin-count MCUs along with different communication and analog peripherals.

MSP430 MCUs offer many different communication peripherals such as USB 2.0, SPI, I²C, IrDA and UART/LIN. In addition, there are timers offering capture/compare/PWM outputs and a wide choice of analog peripherals such as comparators, 10-/12-bit ADCs (up to 200 kSPS), 12-bit DACs and 16-bit sigma-delta modules. These MCUs can be used to control stepper and DC motors in printers, fans, antennas, toys and many other applications.

TI provides robust design support for the MSP430 MCUs in the form of technical documents, training, tools and software.

Key Features
- 0.5 to 256KB flash
- RAM up to 16KB
- Up to 25-MIPS operation
- 12- and 10-bit ADCs
- 12-bit DACs
- Integrated intelligent peripherals including high-performance analog and digital peripherals
- 16-bit and 8-bit timers with PWM capability
- Integrated LCD drivers
- Communication peripherals: UART, SPI, I²C
- 14- to 113-pin package options

Benefits
- Can be used as low-cost solution to drive a stepper motor with DRV8x drivers
- Flexibility to program for optimal motor control
- On-board comparators and op amps
- Ideal for sensorless trapezoidal control of low-power BLDC motors using InstaSPIN™-BLDC

Hardware Kits
- Brushed DC motor EVM with DRV8801
- Stepper motor EVM with DRV8811
- BLDC motor EVM with DRV8312
- MSP430FR5739 and MSP430G2553 are controlCARD compatible with many motor EVMs

Application Notes
- PWM DC Motor Control Using Timer_A of the MSP430 (SLAA120)
- MSP430 Stepper Motor Controller (SLAA223)

MSP430F51x2 Devices Feature New High-Resolution Timer_D for Finer Motor Precision
- Timer_D is a 16-bit timer/counter with multiple capture/compare registers
- Up to 256-MHz/4-ns resolution
- Suitable for precision motor control
- Supports PWM outputs and interval timing and has extensive interrupt capabilities. (Interrupts may be generated from the counter on overflow conditions and from each of the capture/compare registers.)
  www.ti.com/timerd
  www.ti.com/5xx

MSP430™ MCUs with Embedded FRAM Memory
FRAM provides unified memory with dynamic partitioning, memory access speeds 100X faster than flash and it is capable of zero power-state retention in all power modes. With a write endurance of over 100 trillion cycles and less than 100-µA/MHz active power consumption, TI offers a first for the semiconductor industry.
  www.ti.com/fram

Value Line Series = Low Cost and Low Power
MSP430G2xx

TI's new Value Line of MSP430™ MCUs allows customers to take advantage of this family's ultra-low power (ULP) and 16-bit performance for cost-sensitive applications, which traditionally have depended on 8-bit microcontrollers.
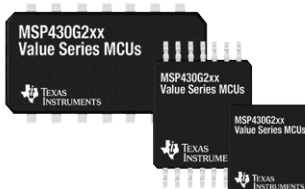
ULP Features
- 300-µA active current (1 MHz, 3 V)
- 0.5-µA standby current (LPM3)
- 0.1-µA power-down current (LPM4)
- 1-µs wake-up time and integrated brownout reset (BOR)
- Watchdog timer (WDT)

Integrated Peripherals
- Comparators, 10-bit ADCs; and SPI, I²C and UART communications. Some Value Line devices also feature integrated capacitive sense I/Os to enable low-cost touch-pad implementations (reduced PCB BOM).

LaunchPad Evaluation Kit
- Meet the lowest-cost and most complete development kit in the industry. LaunchPad includes all of the hardware and software that developers need to start creating applications.
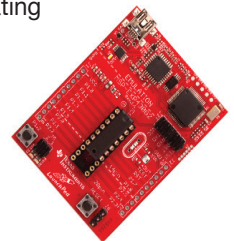
Learn more at
www.ti.com/launchpadwiki

Selection Guides for Analog Motor Solutions

DRV8x Motor Drivers

Device	Description	Supply Voltage (V)	I_{OUT} Cont. (A)	I_{OUT} Peak (A)	Control Interface	Drives Solenoids	Price*
Stepper Motors							
DRV8412	6-A high-performance stepper driver	0 to 52	3	6	PWM	Yes (4x)	3.85
DRV8432	12-A high-performance stepper driver	0 to 52	7	12	PWM	Yes (4x)	5.50
DRV8812	1.6-A stepper driver (P2P w/8813)	8 to 45	1.1	1.6	Phase/Enable	No	1.65
DRV8813	2.5-A stepper driver (P2P w/8812)	8 to 45	1.75	2.5	Phase/Enable	No	2.25
DRV8823	Dual 1.5-A stepper driver	8 to 32	1.5	1.5	Serial	No	2.00
DRV8828	3-A stepper driver (need 2x per motor)	8 to 45	2.1	3	Phase/Enable	No	1.65
DRV8829	5-A stepper driver (need 2x per motor)	8 to 45	3.5	5	Phase/Enable	No	2.25
DRV8842	5-A stepper driver (need 2x per motor)	8 to 45	3.5	5	PWM	Yes (2x)	2.25
DRV8843	2.5-A stepper driver	8 to 45	1.75	2.5	PWM	No	2.25
Indexers (On-chip microstepping support)							
DRV8811	1.9-A stepper driver (8 microsteps) (P2P w/8818)	8 to 38	1.4	1.9	Indexer	No	1.80
DRV8818	2.5-A stepper driver (8 microsteps) (P2P w/8811)	8 to 35	1.75	2.5	Indexer	No	2.25
DRV8821	Dual 1.5-A stepper driver (8 microsteps)	8 to 32	1.5	1.5	Indexer	No	2.00
DRV8824	1.6-A stepper driver (32 microsteps) (P2P w/8825)	8 to 45	1.1	1.6	Indexer	No	1.65
DRV8825	2.5-A stepper driver (32 microsteps) (P2P w/8824)	8 to 45	1.75	2.5	Indexer	No	2.40
Unipolar Stepper Drivers							
DRV8803	2-A unipolar stepper driver	8 to 60	2	2	PWM	Yes (4x)	1.40
DRV8804	2-A unipolar stepper driver	8 to 60	2	2	Serial	Yes (4x)	1.40
DRV8805	2-A unipolar stepper driver w/indexer	8 to 60	2	2	Indexer	Yes (4x)	1.40
DRV8806	2-A unipolar stepper driver w/open load detect	8 to 40	2	2	Serial	Yes (4x)	1.50
Low-Voltage Stepper Drivers							
DRV8833	2-A stepper driver	2.7 to 10.8	1.5	2	PWM	No	0.95
DRV8834	2.2-A stepper driver (32 microsteps)	2.5 to 10.8	1.5	2.2	Indexer or Phase/Enable	No	1.15
DRV8835	1.5-A stepper driver w/dual supplies	2.0 to 11	1.5	1.5	PWM or Phase/Enable	No	0.70
DRV8836	1.5-A stepper driver	2.0 to 7	1.5	1.5	PWM or Phase/Enable	No	0.70
Brushed DC Motors							
DRV8301	Pre-driver with 1.5-A step-down voltage regulator and dual current-sense amps (SPI control)	8 to 60	Ext FETs	Ext FETs	PWM	No	2.50
DRV8302	Pre-driver with 1.5-A step-down voltage regulator and dual current-sense amps (H/W control)	8 to 60	Ext FETs	Ext FETs	PWM	No	2.50
DRV8412	12-A high-performance brushed DC driver	0 to 52	6	12	PWM	Yes (4x)	3.85
DRV8432	24-A high-performance brushed DC driver	0 to 52	14	24	PWM	Yes (4x)	5.50
DRV8800	2.8-A brushed DC driver	8 to 36	1.5	2.8	Phase/Enable	No	1.25
DRV8801	2.8-A brushed DC driver w/current-sense pin	8 to 36	1.5	2.8	Phase/Enable	No	1.25
DRV8840	5-A brushed DC driver	8 to 45	3.5	5	Phase/Enable	No	2.25
DRV8842	5-A brushed DC driver	8 to 45	3.5	5	PWM	Yes (2x)	2.25
DRV8844	5-A brushed DC driver w/split supply support (+30/–30)	8 to 60	3.5	5	PWM	Yes (4x)	2.50
Dual/Quad Brushed Drivers							
DRV8412	Dual 6-A high-performance brushed DC driver	0 to 52	3	6	PWM	Yes (4x)	3.85
DRV8432	Dual 12-A high-performance brushed DC driver	0 to 52	7	12	PWM	Yes (4x)	5.50
DRV8802	Dual 1.6-A brushed DC driver (P2P w/8814)	8 to 45	1.1	1.6	Phase/Enable	No	1.65
DRV8814	Dual 2.5-A brushed DC driver (P2P w/8802)	8 to 45	1.75	2.5	Phase/Enable	No	2.25
DRV8823	Quad 1.5-A brushed DC driver	8 to 32	1.5	1.5	Serial	No	2.00
DRV8843	Dual 2.5-A brushed DC driver	8 to 45	1.75	2.5	PWM	No	2.25
DRV8844	Dual 2.5-A brushed DC driver w/split supply support (+30/–30)	8 to 60	1.75	2.5	PWM	Yes (4x)	2.50

*Suggested resale price in U.S. dollars in quantities of 1,000.

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

Selection Guides for Analog Motor Solutions

DRV8x Motor Drivers (Continued)

Device	Description	Supply Voltage (V)	I$_{OUT}$ Cont. (A)	I$_{OUT}$ Peak (A)	Control Interface	Drives Solenoids	Price*
Brushed DC Motors (Continued)							
Low-Voltage Brushed Drivers							
DRV8830	1-A brushed DC driver w/on-chip speed regulation	2.75 to 6.8	1	1	IN/IN	No	0.85
DRV8832	1-A brushed DC driver w/on-chip speed regulation	2.75 to 6.8	1	1	Serial	No	0.85
DRV8833	Dual 2-A or single 4-A brushed DC driver	2.7 to 10.8	3	4	PWM	No	0.95
DRV8835	Dual 1.5-A or single 3-A brushed DC driver w/dual supplies	2.0 to 11	3	3	PWM or Phase/Enable	No	0.70
DRV8836	Dual 1.5-A or single 3-A brushed DC driver	2.0 to 7	3	3	PWM or Phase/Enable	No	0.70
DRV8837	1.8-A brushed DC driver w/dual supplies	1.8 to 11	1.8	1.8	PWM	No	0.45
DRV8851	1.8-A brushed DC driver w/dual supplies and 150-mA LDO	1.8 to 11	1.8	1.8	PWM	No	TBD
3-Phase Brushless Motors							
DRV8301	Pre-driver with 1.5-A step-down voltage regulator and dual current-sense amps (SPI control)	8 to 60	Ext FETs	Ext FETs	PWM	No	2.50
DRV8302	Pre-driver with 1.5-A step-down voltage regulator and dual current-sense amps (H/W control)	8 to 60	Ext FETs	Ext FETs	PWM	No	2.50
DRV8312	6.5-A high-performance 3-phase driver	0 to 52	3.5	6.5	PWM	Yes (3x)	3.30
DRV8313	2.5-A 3-phase driver w/10-mA LDO	8 to 60	1.75	2.5	PWM	Yes (3x)	TBD
DRV8332	13-A high performance 3-phase driver	0 to 52	8	13	PWM	Yes (3x)	4.70

*Suggested resale price in U.S. dollars in quantities of 1,000.   New products are listed in **bold red**. Preview products are listed in **bold blue**.

CAN Transceivers (CANopen systems compliant)

Device	Description	Isolated	Supply Voltage (V)	I/O Levels	Short-Circuit Protection (V)	ESD (kV)	Operating Temp Range (°C)	HiRel Avail.	Price*
SN65HVD255	Turbo CAN: Fast loop times, next gen for '251 and '1050	No	5	5-V TTL	−27 to 40	±12	−40 to 125	No	0.50
SN65HVD256	Turbo CAN: Fast loop times, IO level shifting	No	5	5-V TTL	−27 to 40	±12	−40 to 125	No	0.50
SN65HVD257	Turbo CAN: Fast loop times, bus redundancy	No	5	5-V TTL	−27 to 40	±12	−40 to 125	No	0.60
ISO1050DW	5-kV$_{rms}$ isolated CAN transceiver	Yes	5	5-V TTL	−27 to 40	±4	−55 to 105	No	1.95
SN65HVD251	Improved replacement for PCA82C250 and PCA82C251/small QFN package	No	5	5-V CMOS	−36 to 36	±14	−40 to 125/ −55 to 125	Yes	0.90
SN65HVD1040	Improved TJA1040 with better ESD and bus wake-up	No	5	5-V TTL	−27 to 40	±12	−40 to 125	Yes	0.60
SN65HVD1050	Improved TJA1050 with better ESD	No	5	5-V TTL	−27 to 40	±8	−40 to 125	Yes	0.45
ISO1050DUB	2.5-kV$_{rms}$ isolated CAN transceiver	Yes	5	5-V TTL	−27 to 40	±4	−55 to 105	No	1.55
SN65HVD232	Cost-effective	No	3.3	3.3-V TTL	−4 to 16	±16	−40 to 85	Yes	1.10

*Suggested resale price in U.S. dollars in quantities of 1,000. See **www.ti.com/hirel** for HiRel options.   New products are listed in **bold red.**

Digital Isolators

Device	Description	Isolation Rating (UL, VDE, CSA) (V$_{rms}$)	Channel Direction	Data Rate (max) (Mbps)	Transient Immunity (min) (kV/µs)	Supply Voltage (V)	HiRel Avail.	Price*
ISO721/M	Single channel	2500	1/0	100/150	25	3.3, 5	Yes	1.40
ISO7230C/M	Triple channel	2500	3/0	25/150	25	3.3, 5	No	1.40
ISO7231C/M	Triple channel	2500	2/1	25/150	25	3.3, 5	No	1.40
ISO7240C/CF/M	Quad channel (F = Fail-safe low)	2500	4/0	25/25/150	25	3.3, 5	Yes	1.75
ISO7241C/M	Quad channel	2500	3/1	25/150	25	3.3, 5	Yes	1.75
ISO7242C/M	Quad channel	2500	2/2	25/150	25	3.3, 5	No	1.75
ISO7420E/FE/FCC ISO7421E/FE/FCC	Gen II dual-channel (F = Fail-safe low, CC = noise filter)	2500	2/0 and 1/1	50	50	3.3, 5	No	1.05
ISO7640FM/41FM	Gen II quad-channel (F = Fail-safe low)	4243	4/0 and 3/1	150	75	3.3, 5	No	2.50
ISO5500	Isolated gate drivers	4243	N/A	10	25	3.3, 5	No	3.00

*Suggested resale price in U.S. dollars in quantities of 1,000. See **www.ti.com/hirel** for HiRel options.   New products are listed in **bold red**. Preview products are listed in **bold blue**.

Selection Guides for Analog Motor Solutions

RS-485/RS-422 Transceivers

Device	Description	DR/RX	Duplex	Supply (V)	Isolated	Signaling Rate (Mbps)	ESD (kV)	Receiver Fail-safe	Nodes	HiRel Avail.	Package(s)	Price*
SN65HVD10/11/12	High/mid/low-speed slew-rate control	1/1	Half	3.3	No	32/10/1	16	Short, Open, Idle	256	Yes	PDIP/SOIC-8	1.50
SN65HVD30/31/32	No enables	1/1	Full	3.3	No	26/5/1	16	Short, Open, Idle	256	Yes	SOIC-8	1.45
ISO35	Isolated 3.3-V full-duplex transceiver	1/1	Full	3.3	Yes	1	16	Short, Open, Idle	256	No	SOIC-16	3.00
ISO35T	Isolated 3.3-V transceiver with transformer driver	1/1	Full	3.3	Yes	1	16	Short, Open, Idle	256	No	SOIC-16	TBD
SN65HVD08	Wide supply range: 3 to 5.5 V	1/1	Half	3 to 5.5	No	10	16	Short, Open, Idle	256	No	PDIP/SOIC-8	1.65
SN65HVD1785/6/7	±70-V protected, wide –20 to +25-V common mode	1/1	Half	5	No	0.115/1/10	16	Short, Open, Idle	256	No	PDIP/SOIC-8	1.85
SN65HVD3082E/5E/8E	Ultra-low-power, optimized for low, medium and high speeds	1/1	Half	5	No	0.2/1/20	16	Short, Open, Idle	256	Yes	SOIC/PDIP/MSOP-8	0.90
SN65HVD20/21/22	±27-V protected and –20 to +25-V common mode	1/1	Half	5	No	25/5/0.5	16	Short, Open, Idle	256	No	PDIP/SOIC-8	1.40
SN65LBC184	ESD protection, IEC 4-2 air, contact and IEC 4-5 surge	1/1	Half	5	No	0.25	30	Open	128	No	PDIP/SOIC-8	1.30
SN65HVD1791/2/3	±70-V protected, wide –20 to +25-V common mode	1/1	Full	5	No	0.115/1/10	16	Short, Open, Idle	256	No	SOIC-14	1.90
SN65HVD3080E/3E/6E	Ultra-low-power, optimized for low, medium and high speeds	1/1	Full	5	No	0.2/1/20	15	Short, Open, Idle	256	No	SOIC-14, MSOP-10	1.20
SN65HVD37	Low-power driver/receiver with enables	1/1	Full	3.3	No	20	16	Short, Open, Idle	256	No	SOIC-14	1.75
SN65HVD72/75/78	IEC ESD protected	1/1	Half	5	No	0.25/20/50	15	Short, Open, Idle	>200	No	SOIC-8	1.00
ISO3086	±4-kV isolated, optimized for low and high speeds	1/1	Full	5	Yes	0.2/20	16	Short, Open, Idle	256	No	Wide SOIC-16	2.60
ISO3086T	Isolated 5-V transceiver with transformer driver	1/1	Full	5	Yes	20	16	Short, Open, Idle	256	No	Wide SOIC-16	TBD
PROFIBUS Transceivers												
SN65HVD1176	PROFIBUS (EN 50170) transceiver	1/1	Half	5	No	40	10	Short, Open, Idle	160	No	SOIC-8	1.55
ISO1176	Isolated PROFIBUS transceiver	1/1	Half	5	Yes	40	16	Short, Open, Idle	160	No	SOIC-16	3.35
ISO1176T	Isolated PROFIBUS transceiver with transformer driver	1/1	Half	5	Yes	40	4	Short, Open, Idle	160	No	SOIC-16	TBD

*Suggested resale price in U.S. dollars in quantities of 1,000. See www.ti.com/hirel for HiRel options.   New products are listed in **bold red**.

Industrial Ethernet

Device	Description	No. of Ports	Interface	Supply Voltage (V)	Special Feature	Operating Temp. Range (°C)	HiRel Avail.	Package	Price*
TLK100	10/100 PHY	1	MII	3.3, 1.8, 1.1	200-meter reach, 16-kV ESD	–40 to +85	No	TQFP-48	2.25
TLK105	10/100 PHY	1	MII/RMII	1.5/3.3 or 3.3	Fast link up/down, 150 m, 16-kV ESD	–40 to +85	No	QFN-32	TBD
TLK106	10/100 PHY	1	MII/RMII	1.5/3.3 or 3.3	Fast link up/down, 150 m, cable dia., 16-kV ESD	–40 to +105	No	QFN-32	TBD
TLK110	10/100 PHY	1	MII/RMII	1.5/3.3 or 3.3	Fast link up/down, 150 m, cable dia., 16-kV ESD	–40 to +85	No	TQFP-48	1.90
DP83620	10/100 fiber PHYTER® device	1	MII/RMII	3.3	FX support	–40 to +85	No	LLP-48	1.60
DP83630	10/100 precision PHYTER device	1	MII/RMII	3.3	IEEE 1588 PTP, FX support	–40 to +85	No	LLP-48	2.50
DP83640	10/100 precision PHYTER device	1	MII/RMII	3.3	IEEE 1588 PTP, FX support	–40 to +85	No	LQFP-48	5.24
DP83848C	10/100 PHYTER device	1	MII/RMII/SNI	3.3		0 to +70	No	LQFP-48	2.50
DP83848H	10/100 mini PHYTER device	1	MII/RMII	3.3		–40 to +125	No	LLP-40	13.80
DP83848I	10/100 PHYTER device	1	MII/RMII/SNI	3.3		–40 to +85	No	LQFP-48	3.29
DP83848J	10/100 mini PHYTER device	1	MII/RMII	3.3		0 to +70	No	LLP-40	1.20
DP83848K	10/100 mini PHYTER device	1	MII/RMII	3.3		–40 to +85	No	LLP-40	1.60
DP83848M	10/100 mini PHYTER device	1	MII/RMII	3.3		0 to +70	No	LLP-40	1.20
DP83848Q	10/100 mini PHYTER device	1	MII/RMII	3.3	AEC-Q100 Grade 2	–40 to +105	No	LLP-40	1.95

*Suggested resale price in U.S. dollars in quantities of 1,000.   New products are listed in **bold red**. Preview products are listed in **bold blue**.

Industrial Ethernet (Continued)

Device	Description	No. of Ports	Interface	Supply Voltage (V)	Special Feature	Operating Temp. Range (°C)	HiRel Avail.	Package	Price*
DP83848T	10/100 mini PHYTER device	1	MII/RMII	3.3		−40 to +85	No	LLP-40	1.60
DP83848VYB	10/100 PHYTER device	1	MII/RMII	3.3		−40 to +105	No	LQFP_EP-48	14.90
DP83848YB	10/100 PHYTER device	1	MII/RMII/SNI	3.3		−40 to +125	No	LQFP_EP-48	17.50
DP83849C	10/100 dual PHYTER device	2	MII/RMII/SNI	3.3	Cable diagnostics	0 to +70	No	TQFP-80	3.50
DP83849I	10/100 dual PHYTER device	2	MII/RMII/SNI	3.3	Cable diagnostics	−40 to +85	No	TQFP-80	4.75
DP83849ID	10/100 dual PHYTER device	2	MII/RMII/SNI	3.3	FX support, cable dia.	−40 to +85	No	TQFP-80	4.20
DP83849IF	10/100 dual PHYTER device	2	MII/RMII/SNI	3.3	FX support, cable dia., flex Port	−40 to +85	No	TQFP-80	5.00
DP83865	10/100/1000 PHYTER device	1	MII/GMII/RGMII	1.8/2.5 or 3.3	1.8 V and 2.5 V or 3.3 V	0 to +70	No	PQFP-128	13.10
DP83816	10/100 MAC+PHY	1	PCI (33 MHz)	3.3	5-V tolerant I/Os	0 to +70	No	LQFP-144	4.90
DP83816EX	10/100 MAC+PHY	1	PCI (33 MHz)	3.3	5-V tolerant I/Os	0 to +85	No	LQFP-144	4.90

Suggested resale price in U.S. dollars in quantities of 1,000.

Power Management

Device	Description	Key Benefits
TPS7A4001	100-V, 50-mA, high-voltage, low-dropout linear regulator	• High 7- to 100-V input voltage reduces the need for protection circuitry • Fast transient response: <500-ns settling time for a 50-V line transient ensures ±1% output accuracy in noisy environments
TPS54062/61	4.7-V to 60-V, 50-mA/200-mA synchronous step-down converter	• Small size • High efficiency • Low I_Q
LM5017	100-V, 600-mA constant on-time synchronous buck regulator	• Transient protection with no clamping circuitry • 50% BOM reduction compared to controller with no external loop compensation required • Smaller magnetics allows higher power density for tight spaces
TPS54060A/ 160A/260/360	3.5-V to 60-V input, 0.5/1.5/2.5/3.5-A DC/DC converters	• Supports 65-V transients • Small size and low I_Q • Eco-mode for light-load efficiency
UCC28070A	Extended frequency range (10 to 300 kHz), interleaving, continuous-conduction-mode PFC controller	• Extended programmable frequency range (10 to 300 kHz) allows the use of high-power IGBT power switches • Advanced current synthesizer current sensing eliminates two current sense transformers, lowering the cost while providing superior power factor and efficiency • Highly linear multiplier output with internal quantized voltage feed-forward correction significantly improves line-transient response and reduces THD; allowing near-unity power factor • Programmable frequency dithering reduces EMI by spreading the energy over a wider range • Numerous protection features increases safety and improves power supply reliability under most potential fault conditions
TPS7A1601	60-V, 5-µA I_Q, 100-mA, low-dropout voltage regulator with Enable and Power Good	• 5-µA of I_Q aides in longer run time for battery • 60-V input (V_{IN}) reduces the need for protection circuitry; stable V_{OUT} during line transients
TPS75005	Power solution for C2000 with dual 500-mA, low-dropout regulators and triple-voltage rail monitor	• Optimized for C2000 MCU series: F2833x (Delfino™), F2823x, F281x, and F280x/F2801x • LDO-1 and SVS-1: 1.8 V or 1.9 V, 0.5 A • LDO-2 and SVS-2: 3.3 V, 0.5 A
TPS62404	High-efficiency, dual-output DC/DC converter for C2000	• Optimized for C2000 MCU series: F2833x (Delfino), F2823x, F281x and F280x/F2801x • Dynamic voltage scaling for both channels independently possible • Separate enable pins support user-defined sequencing
TPS3700	18-V_{DD}, window comparator for overvoltage and undervoltage detection	• Wide supply range: 1.8 to 18 V • High accuracy threshold: 1% (over temp) • Adjustable threshold down to 400 mV • Open-drain OV and UV outputs
LMP8646	Precision current limiter	• Provides circuit protection and current limit • Supports any switching or linear regulator with an available feedback node • Simple design with adjustable gain and bandwidth

Industrial Automation and Motor Control

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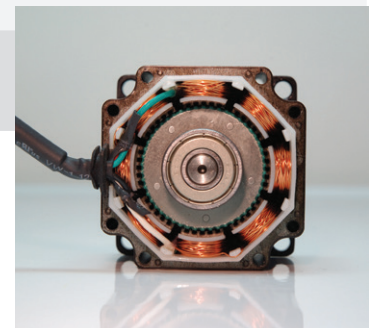
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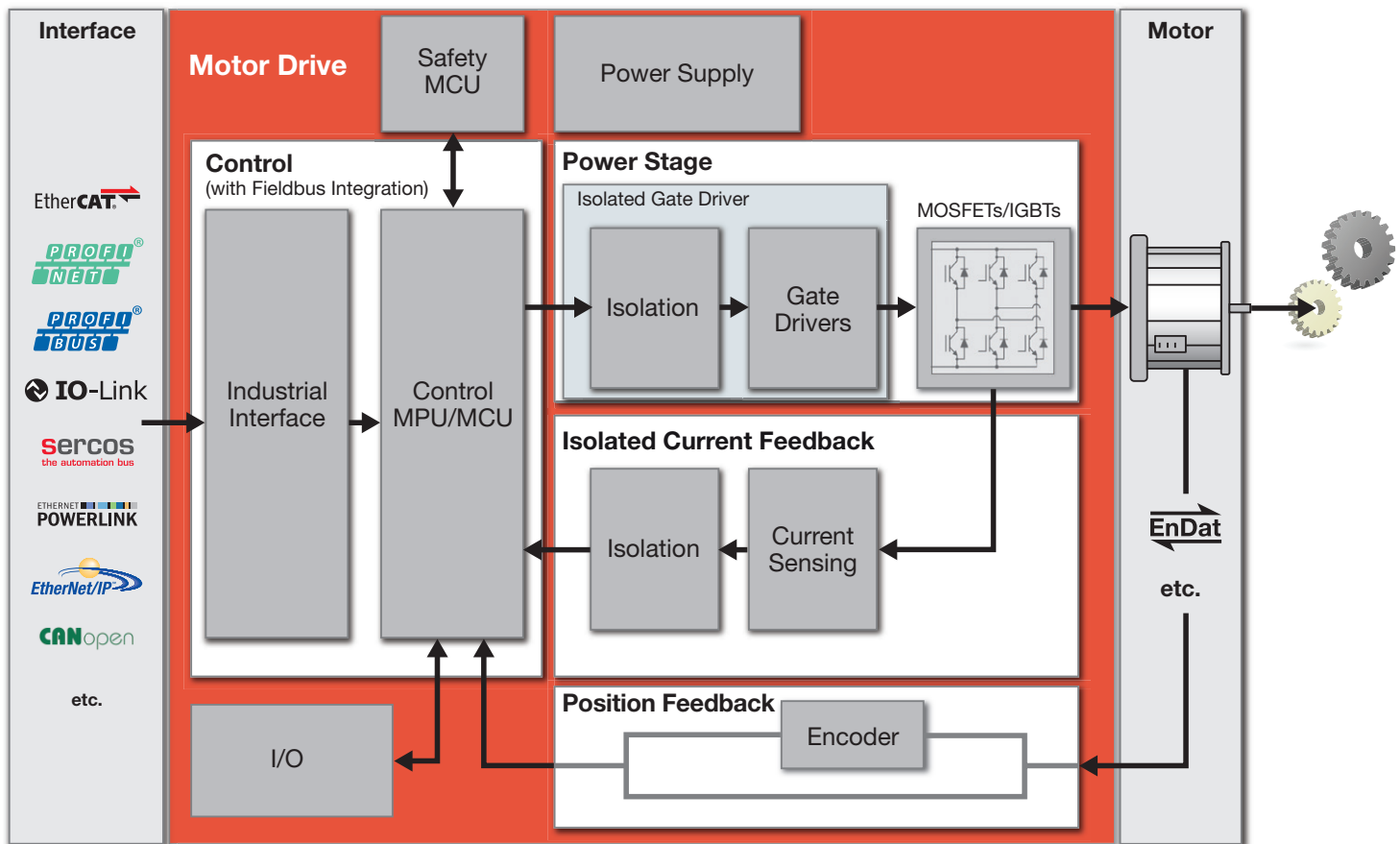
For more information, including selection guides, datasheets, tools and application notes, please visit **www.ti.com/motor**

Recommended Products for Industrial Motor Drive and Control

Description	Device	Key Benefits
Gate Driver and Power Stage		
6-kV$_{PK}$ isolated gate driver for IGBTs and MOSFETs of up to I_C = 150 A and V_{CE} = 1200 V	ISO5500	• Support for high-current/high-voltage operation • Improved safety and system performance • Proven reliability of SiO_2 dielectric with stability over time, temperature and moisture
Three-phase gate driver with dual-shunt amplifiers and buck converter	DRV8301 DRV8302	• Eliminates external current-shunt monitors • Eliminates external power supply for MCU and system accessories • Enhanced protection features and integrated charge pump for 100% duty cycle
High-performance brushed DC or stepper motor driver	DRV8412 DRV8432	• Up to 14-A continuous current (24-A peak) • Up to 97% efficiency (110-mΩ FETs) • Enhanced protection features
High-performance three-phase brushless motor driver	DRV8312 DRV8332	• Up to 8-A RMS current (13-A peak) • Up to 97% efficiency (110-mΩ FETs) and enhanced protection features • Support for both BLDC and PMSM applications
Single and dual, 5-A, high-speed, low-side gate drivers	UCC2751x, UCC2752x	• 4.5- to 18-V single-supply range • 13-ns typical propagation delay with fast (6-ns rise/fall time) • −40 to +140°C operating temperature range
Industrial Communication Interfaces		
Isolated 5-V CAN transceiver	ISO1050DW	• Integrated CAN and isolation for easy system integration • Reduced loop time improves timing margin • Lower power than using opto-couplers
Single-port Ethernet PHY for 10BaseT and 100Base TX signaling	TLK105/TLK106/TLK110	• Low and deterministic latency for real time • Extended cable reach (up to 150 m) • Cable diagnostics (TLK106/TLK110) • 32-pin QFN packages (TLK105/TLK106)
ARM9™ microprocessor	AM1810 or OMAP-L138	• Highly integrated system on chip • Certified PROFIBUS solution in conjunction with the ISO1176(T)
ARM® Cortex™-A8 microprocessor	AM3357 AM3359	• Highly integrated SoC • Certified PROFIBUS solution with ISO1176T • Integrated industrial interfaces such as EtherCAT, EtherNet/IP and Ethernet POWERLINK
Isolated RS-485 PROFIBUS transceiver (ISO1176T with integrated transformer driver)	ISO1176/ISO1176T	• Reduced components and board space • Life span > 25 years @ 125ºC • Hot pluggable without data corruption
ARM Cortex-M4F microcontrollers	Stellaris® LM4F Family	• DSC with floating point, integrated connectivity, advanced motion control, 12-bit ADC and extensive software library
C2000™ 32-bit real-time MCUs	F28M3x Concerto™ Family	• Highly integrated SoC architecture that provides a connectivity MCU and a separate C28x™ MCU to do motor control
Motor Control MCU and MPU with Integrated Fieldbus and Industrial Communication		
C2000 32-bit real-time MCUs	TMS320F283xx/ TMS320F280xx Delfino™/Piccolo™ Families	• Best-in-class capability for sensorless and field-oriented control (FOC) • Motor-control library, documentation and system examples • Up to 12.5-Mbps, 12-bit ADCs and dedicated motor-control timers
Sitara™ 32-bit Cortex-A8 and ARM9 MPUs	AM35x/AM37x/ AM17x/AM18x/AM335x Sitara	• Extensive set of integrated and flexible industrial-control and connectivity interfaces • Available in industrial temperature ranges
Safety MCU		
Hercules™ RM4 ARM® Cortex-R4-based microcontroller for safety critical applications up to 220 MHz and 3-MB Flash	RM48x, RM46x, RM42x	• Support for safety-critical applications up to IEC 61508 SIL-3 • Powerful Cortex™-R4 fixed- and floating-point options • 12-bit ADC, flexible timer module and dedicated motor-control timers • −40 to 105°C ambient operation
Concerto Cortex-M3 + C2000 dual-subsystem MCUs	F28M35x	• Cortex-M3 + F283x floating-point CPUs
Current Sensing		
Single-channel isolated ΔΣ modulator and a quad digital filter with resolver excitation	AMC1203/4 with AMC1210	• Simple system design for combined A-to-D conversion and isolation • Cost savings on active filters and analog comparators • Excellent magnetic immunity
Fully-differential isolation amplifier	AMC1200, AMC1200B	• ±250-mV input voltage range optimized for shunt resistors • Fixed gain: 8 (0.5% accuracy) • Certified galvanic isolation voltage: 4250 V$_{PEAK}$
High-accuracy current shunt monitor (for inline current sensing)	INA282	• High CMRR allows precise bidirectional inline current sensing • Saves system power by allowing for smaller shunt resistors
24-V rail-to-rail I/O low-offset, low-drift operational amplifiers	LM6152/54	• Greater than rail-to-rail input common mode voltage range (−0.25 to +24.25 V) • Wide gain bandwidth (75 MHz) and low supply current (1.4 mA/channel)
Precision high-voltage current sense amp	LMP8640	• Wide common-mode voltage range of −2-V to 76-V CMR and 900-μV offset; with gain of 20, 50, 100 V/V
Position Sensing		
Dual 16-/14-/12-bit, 1-MSPS, 4×2/2×2 simultaneous SAR ADC	ADS8363/7263/7223	• 2-bit counter for safety applications • FIFO allows storage of up to four results per channel

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Recommended Products for Industrial Motor Drive and Control (Continued)   **www.ti.com/motor**

Description	Device	Key Benefits
I/O (24 V, 12 mA)		
Input: Highly integrated digital-input serializer (eight channels from 0 to 34 V to SPI interface)	SN65HVS882	• Simplified PCB design • High-density signal conditioning in a single, compact device
Output: 8-bit shift-register design to drive low-side switched resistive loads	TPIC2810	• Low $R_{DS(on)}$ • Eight power DMOS transistor outputs of 100-mA DC
Turbo CAN transceiver	SN65HVD255/6/7	• Fast loop times with up to 2-Mbps data rate • Next generation for HVD251 and HVD1050 • Special features: I/O level shifting (HVD256); bus redundancy (HVD257)
Isolation		
Low-power dual-channel digital isolator	ISO7420E/ISO7420FE	• Signaling rate above 50 Mbps; Low propagation delay: 7 ns • Low power consumption: 2.5 mA per ch @ 25 Mbps
Temperature Sensing		
Temperature switch and sensor	LM57	• Programmable trip point • Wide operating temperature –50°C to 150°C • External resistors introduce no error • In-situ testing and temperature reading
Analog temperature sensor	LM94022	• Selectable gain • Saves system cost by using available ADCs • Operation down to 1.5 V
Remote diode temperature sensor	LM95235	• Automotive grade 3 qualification ensures robustness in rugged conditions • TruTherm™ improves sub-micron temperature measurements • Diode fault detect notifies system of status • Programmable hysteresis for flexibility

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