TI Motor Controller Innovation Technology

-----C2000 InstaSPIN & Motor Driver

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The 3 Brands of C2000 MCUs

Piccolo™ MCUs

Performance:
40-90MHz 28x CPU
Floating Point Unit (optional)
CLA Co-Processor (optional)
VCU Accelerator (optional)
Memory:
16kB-256kB Flash
6kB-100kB SRAM
Key Peripherals:
ADC, PWM, QEP, DMA, SPI, UART, I2C, CAN, USB
Package:
38 TSSOP, 48 QFP, 56 QFN, 64 QFP, 80 QFP, 100 QFP

Delfino™ MCUs

Performance:
100-300MHz 28x CPU
Floating Point Unit
Memory:
Up to 512kB Flash
Up to 516 kB SRAM
Key Peripherals:
ADC, PWM, QEP, DMA, SPI, UART, I2C, CAN, EMIF
Package:
176 QFP, 176 BGA, 179 u*BGA, 256 BGA

Concerto™ MCUs

Performance:
Dual Core
Up to 150MHz 28x CPU
Up to 125MHz ARM Cortex M3 CPU
Floating Point Unit
VCU Accelerator
Memory:
256kB-1.5MB Flash
Up to 296kB SRAM
Key Peripherals:
ADC, PWM, QEP, DMA, EMIF, SPI, UART, I2C, CAN, USB, EMAC
Package:
144 QFP, 289nBGA

150+ Devices, Software Compatibility

C2000 MCUs for Real-Time Control

Renewable Energy

Solar Power Inverters

Wind Power Inverters

Motor Control

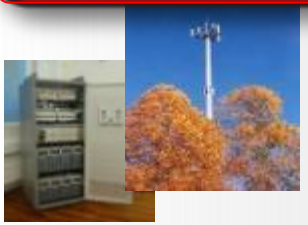
White Goods

Industrial Drives & Motion Control

Power Tools

E-bike

Digital Power



Telecom / Server AC/DC Rectifiers

Uninterruptable Power Supplies

DC/DC Converters

C2000

Lighting

LED Street & Area Lighting

Entertainment

Auto HID

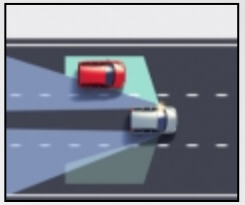
High/Low Bay Lighting

Automotive

Hybrid Electric Vehicles

Electric Power Steering

Radar / Collision Avoidance



Smart Grid & PLC

Power Line Communication

Smart Metering

RF Communication

28 Years at the Forefront of ADVANCED Motor Control

TMS320 Cx

1985
Hard Disk Drive Servo and Automotive Active Suspension go DSP

F24x 16-bit DSP

1997
First SOC for AC Inverter & Servo starts Motor Control Revolution

LF240x 16-bit DSP

2000
Efficiency paramount

28x CPU

2003
FOC starts to broaden

Delfino™ FPU

2007
Performance leadership

Piccolo™

2010
FOC adoption increasing due to efficiency

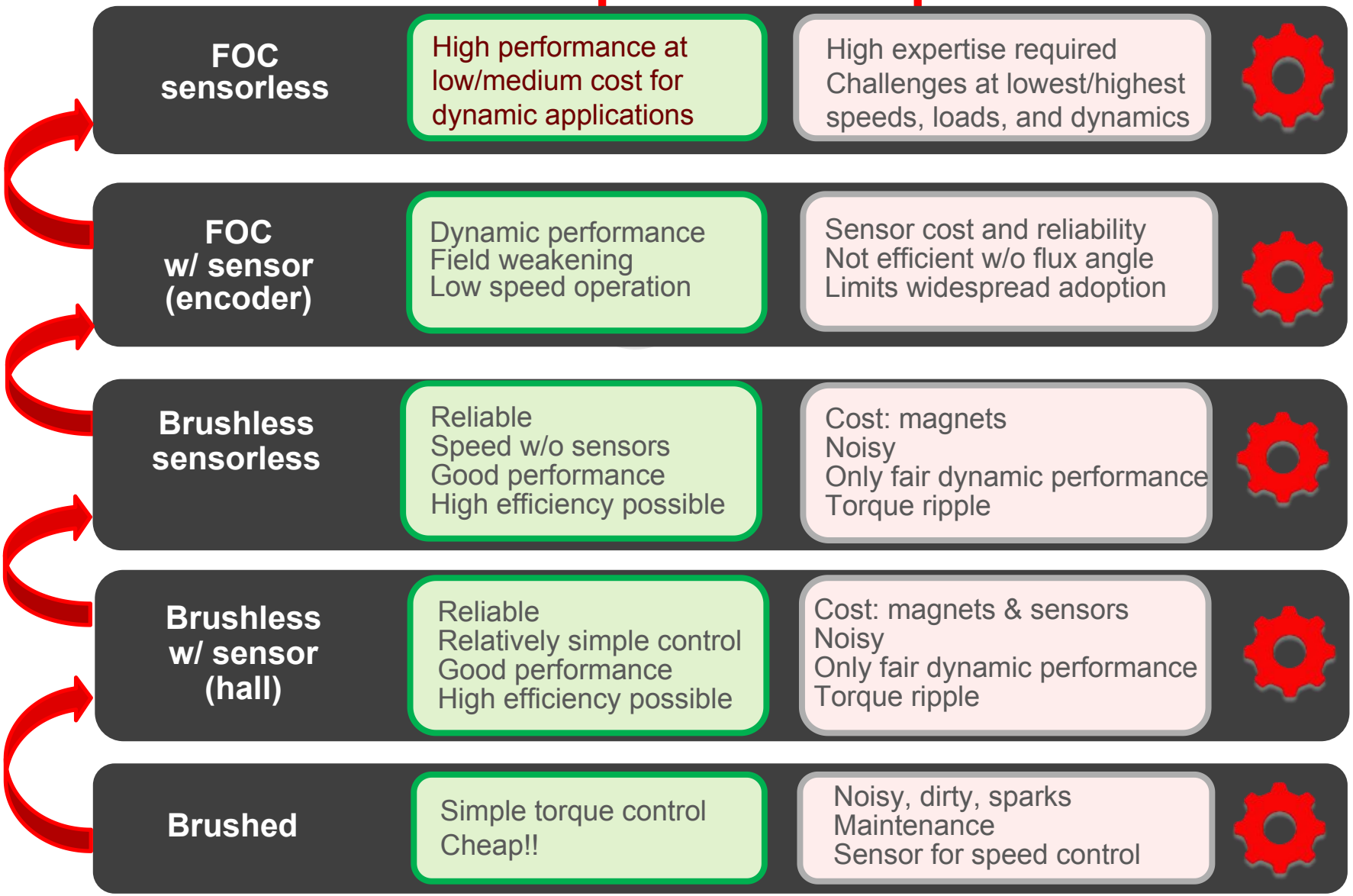
2011
InstaSPIN! Customers spinning *their* motors instantly

2013
More InstaSPIN flavors with more expertise on-chip

Now Leveraging motor expertise in:

- Power MOSFETs
- Audio
- MCU
- Laser printers
- Hard disk drive, DVD platters
- Mixed signal automotive

Move to 3-ph Motors for Reliable Variable Speed & Torque



InstaSPIN Solutions
instantly spin, then control *your* 3-ph motor

	Control technique & motor support	Required feedback	Motor parameters	Key features	TI supported devices	
InstaSPIN BLDC Start spinning in seconds with InstaSPIN-BLDC	Trapezoidal Commutation for BLDC	Simple Voltage Bemf, Current optional fort torque control	None required	› Robust start-up › Simple tuning › Easily add speed or current control	Stellaris ARM Cortex LM4F2x Piccolo F2803x, F2806x, F2802x Hercules RM46x, RM48x, 570LS12, 570LS31	Learn more
InstaSPIN FOC The motor ID & auto tuning solution	FOC torque controller using TI's FAST software encoder (observer) for ACI, PMSM, IPM, BLDC	Voltage and Current (2-3 shunt or phase)	Motor parameters automatically identified	› Automatic current loop tuning › Full torque start-up › Stable at and through 0 speed › Max Torque Per Amp › ACI PowerWarp™	Piccolo F28069F, F28068F, F28062F	Learn more
InstaSPIN MOTION Maximum control with minimal effort	Accurate velocity using SpinTAC™ and FAST software encoder (observer) or rotor sensor for ACI, PMSM, IPM, and BLDC	Voltage and Current (2-3 shunt or phase)	Single variable speed loop tuning – tune your motor in minutes.	› Robust speed control › Cancels disturbances before they happen › Sustains performance across different speeds and changing dynamics › Trapezoidal, S-curve, ST-curve Motion Profile Generation	Piccolo F28069M, F28068M	Learn more

Stay tuned…

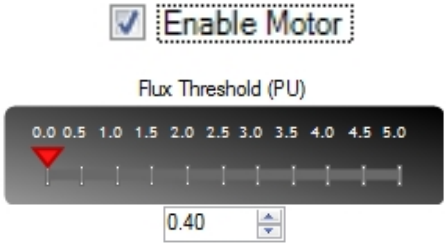
- InstaSPIN™ on more Piccolo devices
- New InstaSPIN™ solutions

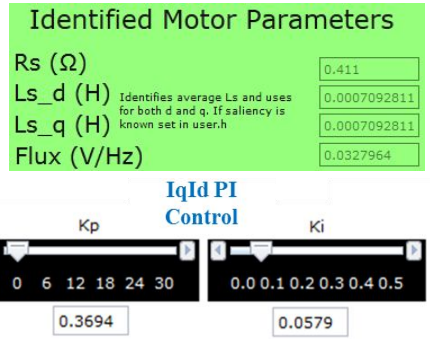
Performance pinnacle of the InstaSPIN™ family

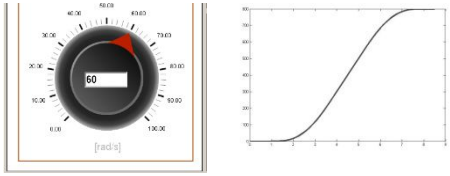
www.ti.com/instaspin

Texas Instruments

Instantly Enabling Superior 3-phase Motor & Motion Solutions







Entry BLDC & sensorless
Simplified commutation
Bemf software sensor

Motor Parameter ID
Automatic FOC torque tuning
Robust software encoder

Simplified speed tuning
Premium performance
Motion & Planning

with FAST™ and SpinTAC™

with FAST™

staSPIN™-FOC

+ [sensorless]
+ 6-step [commutate]

+ better [sensorless]
+ sinewave [commutate]
+ ideal [torque]

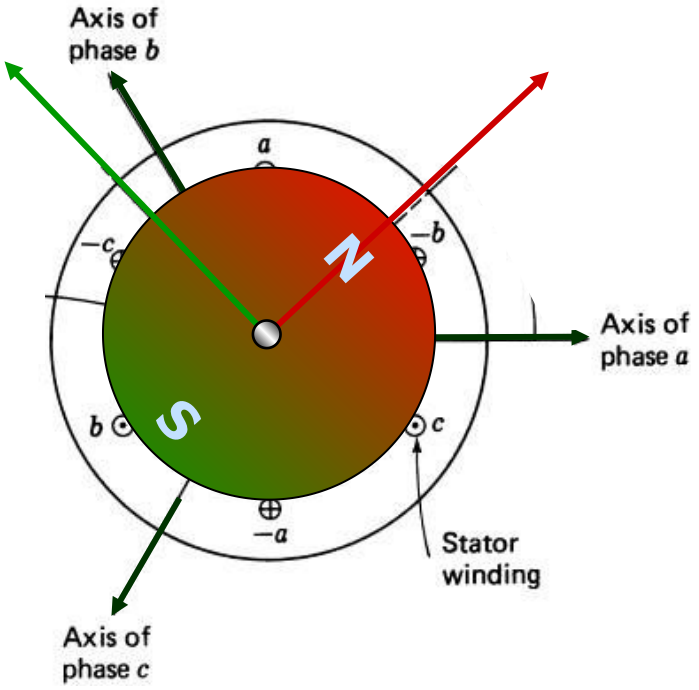
+ ideal [speed]
+ on-chip [motion]
+ integrated [plan]

Expertise Provided

FOC & Sensorless Challenges

FOC requires precise position knowledge of rotor magnetic field to create appropriate stator magnetic field, oriented to produce maximum torque.

1. Costly sensor (encoder/resolver)
   - Mechanical alignment
   - Not necessarily magnetic unless “absolute”
2. Complex software algorithms (model observers)
   + Lower cost and no repair or replacement
   + Can be used where sensors can’t be
   - Not appropriate for FOC with position control



TI’s new FAST software sensor is Superior

+ Works with synchronous & asynchronous motors
+ Model relies on fewer motor parameters
  + Optional start-up parameter ID tool
  + Optional run-time parameter tracking
+ Observer requires no tuning
+ More accurate, more dynamically robust
+ Stable at and through zero speed
+ Stall recovery
+ Better at start-up under load
+ Parameters used to set FOC current controllers
+ Highest fidelity feedback signals
- / + Proprietary technique, no source given

www.ti.com/fast

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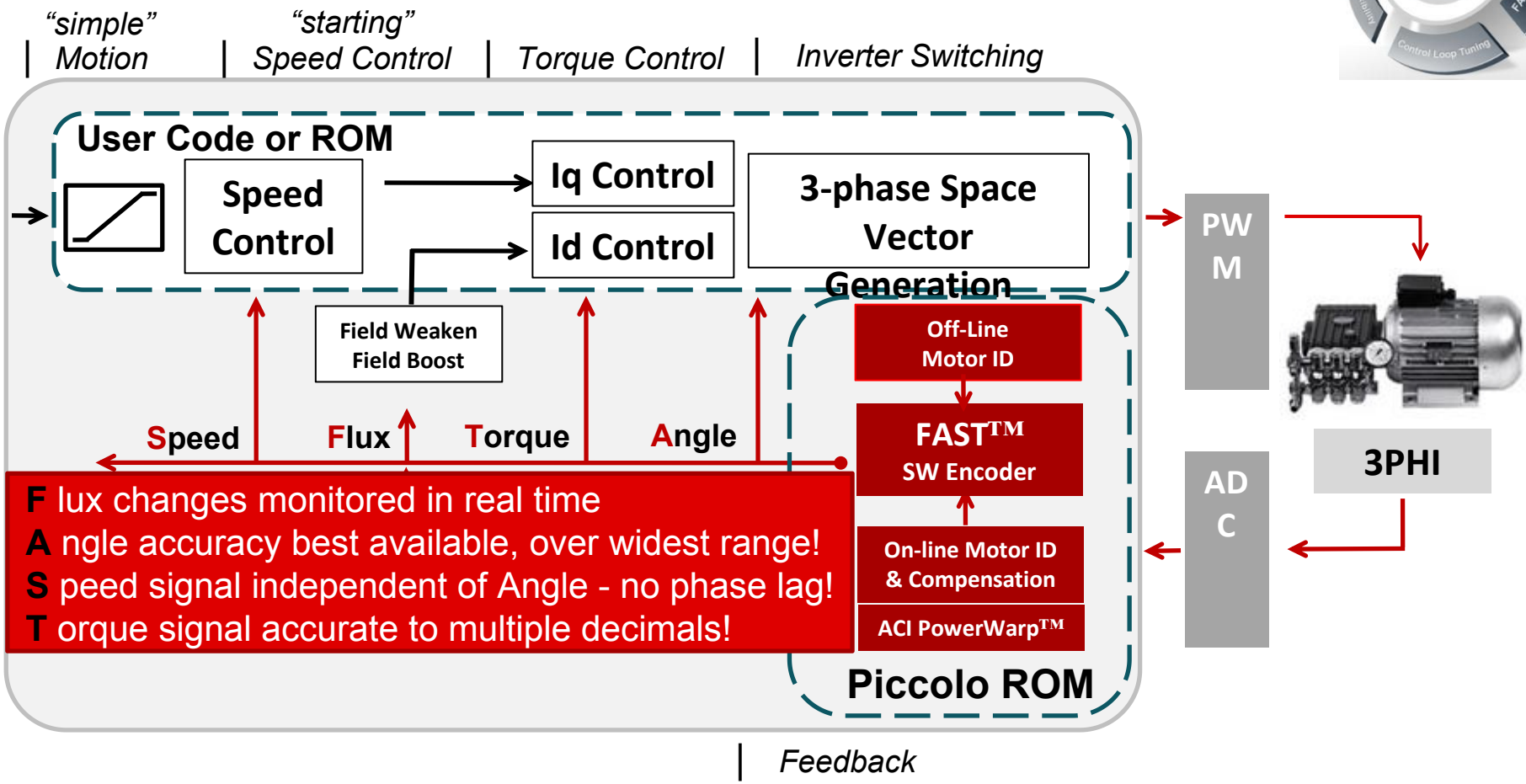
InstaSPIN™-FOC with FAST

simplify design of a sensorless torque controller



F lux changes monitored in real time
A ngle accuracy best available, over widest range!
S peed signal independent of Angle - no phase lag!
T orque signal accurate to multiple decimals!

Full load start-up features, 100% duty cycle, stable at and through 0 speed, four quadrant

InstaSPIN™-FOC: FAST™ replaces rotor sensor or software observer techniques of the past

Dramatically reduce challenges of sensorless FOC system development

- Motor parameters identified
- No tuning of FAST required (vs. other algos)
- Current loop automatically tuned
- Speed loop set for evaluation
- “Instant” stable system to start development
- Run-time parameter compensation
- Modes & features for common system challenges: start-up, at & through zero speed, field weakening, high modulation, PowerWarp™ for induction motors

Easy to use flexible software architecture

- Novice can call full system from ROM adjusting control gains
- Expert can fully customize control system calling only FAST from ROM

Benefit from high fidelity, low latency feedback signals

- Flux signal for field weakening / boosting
- Angle accuracy over widest range
- Speed of rotor with near zero phase lag
- Torque signal is high bandwidth and high accuracy, enabling monitoring and control of loads and flows

Our customers: InstaSPIN™-FOC in action

videos at www.ti.com/instaspin-support

CONTRONICS

- Fans for agricultural flow control
- Replaced triac single phase ACIs with 3-ph ACI and CoMoCo inverters
- Replaced flow sensors by using Torque signal from FAST
- PowerWarp mode for adaptive energy savings
- 80% energy savings!!!
- 45% savings over FOC from PowerWarp!!
- 2-yr payback

Gazelle

- Electric assisted bikes
- Hall based → Sensorless BLDC with gear → sensorless FOC direct drive
- Full torque from 0 speed
- Smaller motors producing correct torque with longer battery life
- Command torque, motor provides
- Focus on enhancing rider features, not on motor control expertise

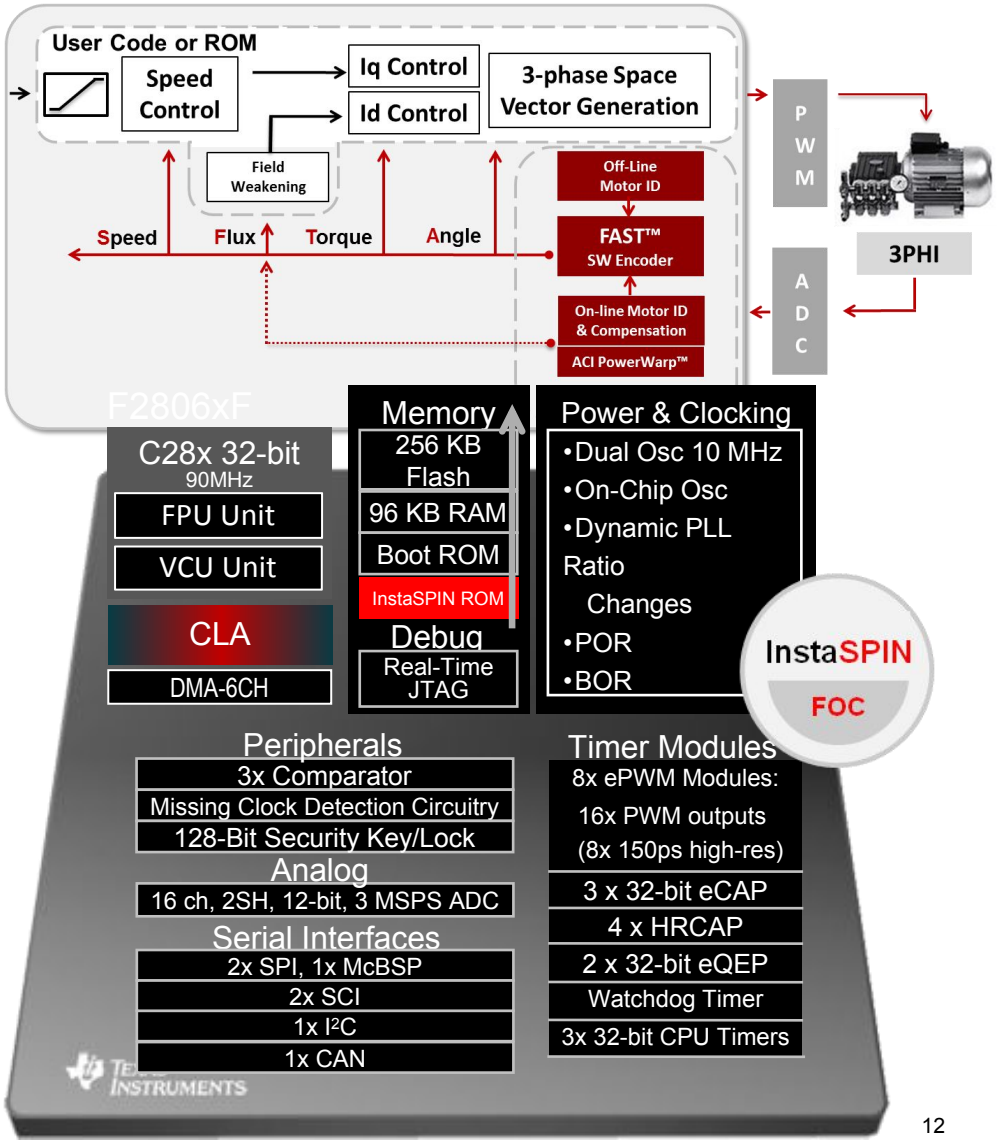
e-Traction®

- Inverters for any motors
- Traction, starter/generator, compressors, pumps, fans
- PM and ACI
- 20A to 600A
- Sensors worst reliability in entire system
- Now all sensorless based on same software
- Flying start, field boosting, field weakening, ultra low speed operation

Piccolo™ F2806x with InstaSPIN™-FOC

Piccolo F2806x: superset Piccolo series

- 90 MHz C28x 32-bit CPU with FPU
- 256 KB FLASH, 96 KB RAM
- Motor Libraries in ROM
  - Call FAST™ software encoder or
  - Full InstaSPIN™-FOC control system
- -40 to 105C (T) or 125C AEC Q100 (Q)
- 80 and 100-pin QFP



- No upfront investment
- No further cost or royalties
- No additional support fee
- No additional maintenance fee
- 100% Pin-compatible devices allow for easy migration to non ROM solution if desired

Broad Piccolo portfolio support in 2013

In fully qualified production NOW

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What does InstaSPIN-FOC not provide?

InstaSPIN-FOC turns your motor into a highly responsive & efficient torque machine, like this high performance Tesla…*but* with a novice driver.
And in some applications that's good enough…

But a machine like this may need an expert driver to control

- the speed
- response/correction to speed
  - [under-damped < Ideal Gain < over-damped]
    slow to react too aggressive
- movements between speeds
- and everything along the way from origin to destination

…this is InstaSPIN-MOTION

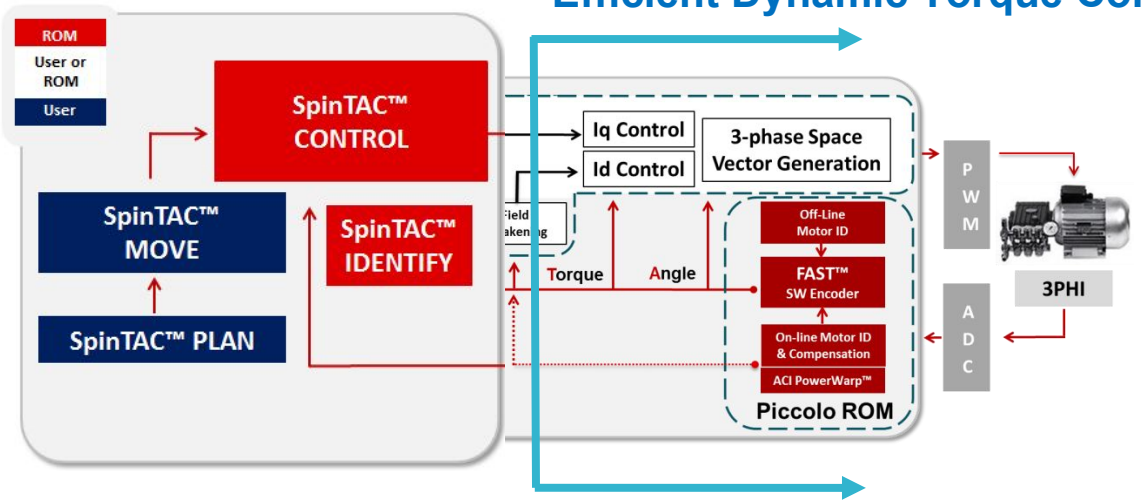
*Simplify **velocity control & motion** design*

InstaSPIN-FOC to InstaSPIN-MOTION

InstaSPIN-FOC provides
Efficient Dynamic Torque Control

Speed PI tuning
Complex
Inconsistent across use

Building Motions
Even more complex
Only as good as control



InstaSPIN-MOTION SpinTAC™ suite

- Builds upon InstaSPIN-FOC
  - •and/or use with sensors
- IDENTIFY: system inertia identification for enhanced feedback into controller
- CONTROL: single variable controller replaces PI and typically works across system conditions
- MOVE: generation of Speed A to Speed B with various trajectories (trap, S-curve, ST-curve)
- PLAN: logic-based execution of different MOVEs

InstaSPIN-FOC Speed Control

- Initial PI gains are just a first starting point
- Does not incorporate real inertia of system
- Control requires
  - Tuning of 2-variable PI controller
  - “gain staging”, different sets of tuning at various operating points
- Movements / Trajectories
  - Only offers constant fixed acceleration

InstaSPIN-MOTION builds on -FOC
Premium control, expertise on-chip

SpinTAC™ Components

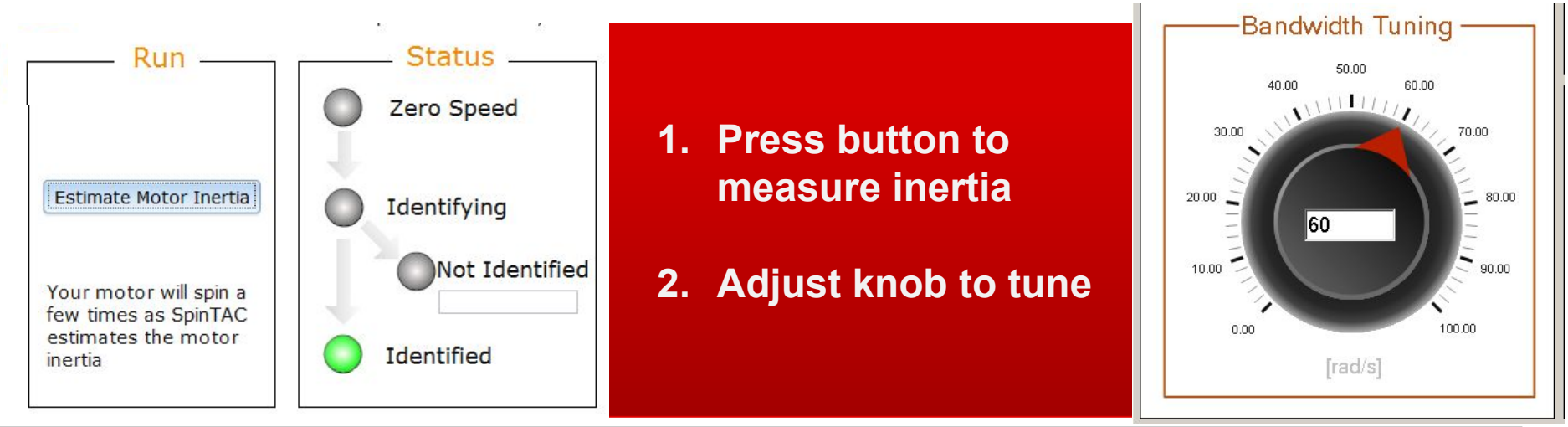
Account for mechanical inertia - Robust speed control - Simplified tuning

Identify:
Measure Inertia

- Inertia is important for accurate control
- Short acceleration test to identify system inertia

Control:
Maximum control, minimum effort

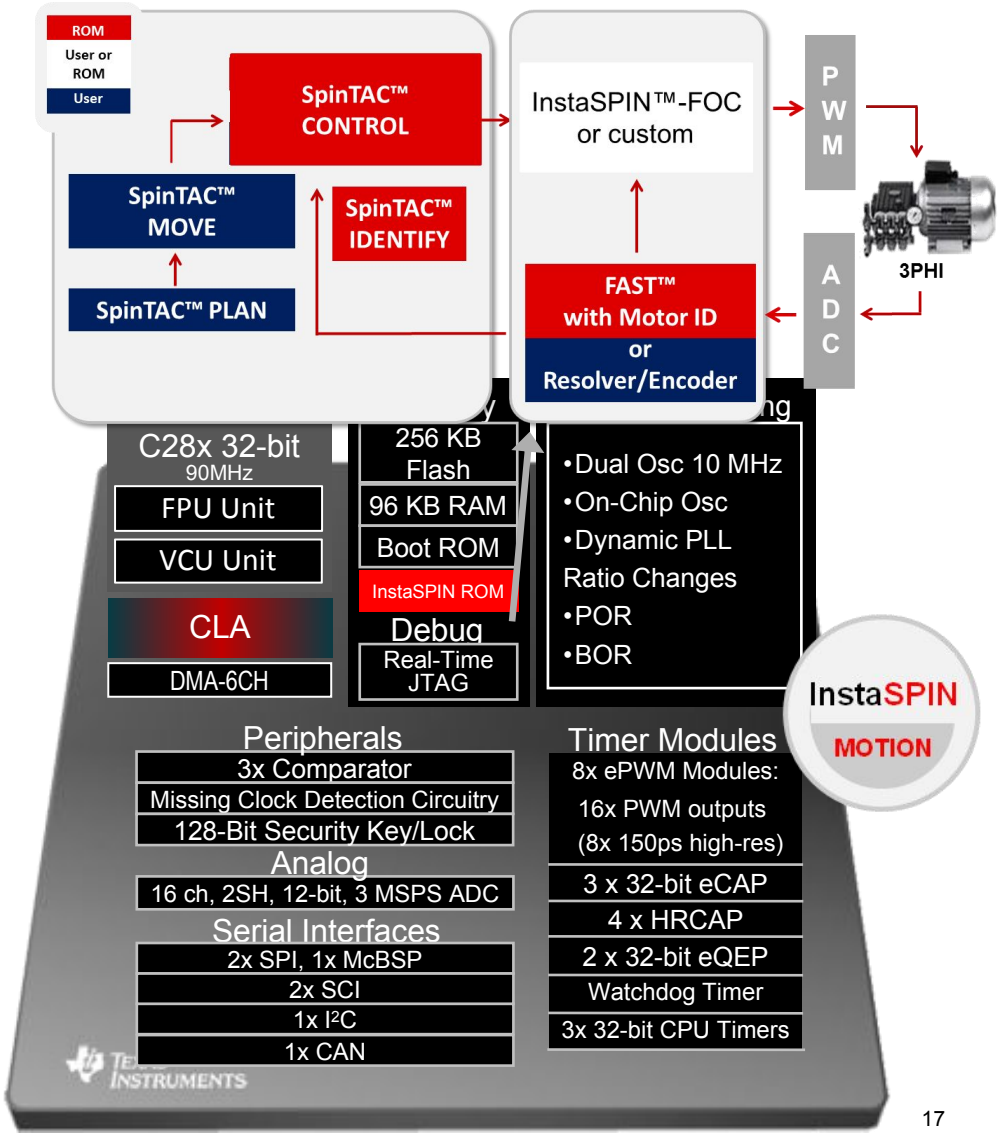
- Disturbance-rejecting controller
- Single variable to tune response
- Typically effective across full variable speed and load range



Piccolo™ F2806x with InstaSPIN-MOTION

Piccolo F2806x: superset Piccolo series

- 90 MHz C28x 32-bit CPU with FPU
- 256 KB FLASH, 96 KB RAM
- Motor Libraries in ROM
  - InstaSPIN™-FOC with FAST™
  - InstaSPIN™-MOTION with SpinTAC™
- -40 to 105C (T) or 125C AEC Q100 (Q)
- 80 and 100-pin QFP



Zero Risk

- No upfront investment
- No further cost or royalties
- No additional support fee
- No additional maintenance fee
- 100% Pin-compatible devices allow for easy migration to non ROM solution if desired

Broad Piccolo portfolio support in 2013

In fully qualified production NOW

TI tools, software and support further simplify and speed motor system development

Sim & Code Gen

Try before you buy: Interactive simulation at ti.com/instaspin-simulation

- Customize to your motor parameters, loads, and motions

Visual Solutions INCORPORATED

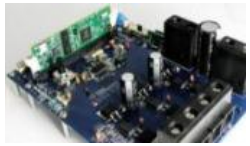
- VisSim stand-alone support Coming Soon!
- Simulate then generate TI APIs and custom code
- Hardware in the loop

Tools

TMDSCNCD28069MISO

50V
3.5A

DRV8312-69M-KIT



60V
40A

DRV8301-69M-KIT

Easy to use GUI with full functionality

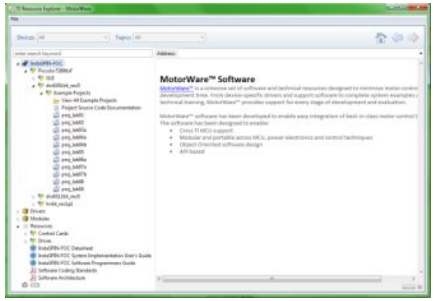
350V
10A

TMDSHVMTRINSPIN

Software & Support

MotorWare™

- Resource Explorer



- Modules & Drivers
- Object oriented APIs
- InstaSPIN™-FOC
  - 10+ C code projects per kit
- Documentation
  - Code & API documentation
  - User Guides & Datasheets
  - System Implementation

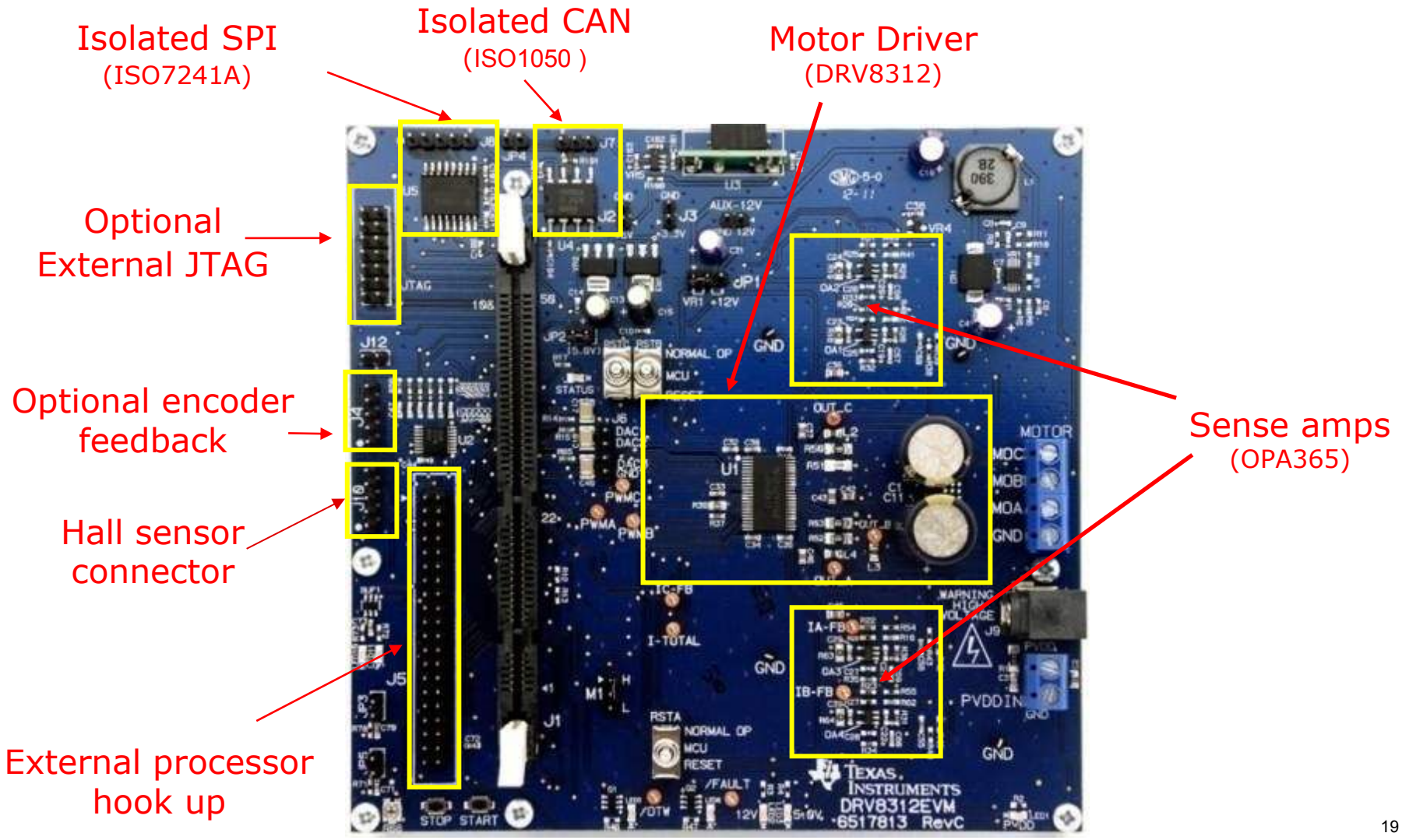
Support & Training

- Workshops
- On-line video training
- 24/7 support via E2E

TI E2E™ Community

Quicker Time to Spin!

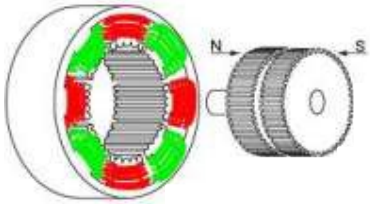
DRV8312-69M-KIT 3-Phase Brushless Motor Drive and Control



TI's Motor Drivers
Support up to 60V/60A

Stepper Drivers

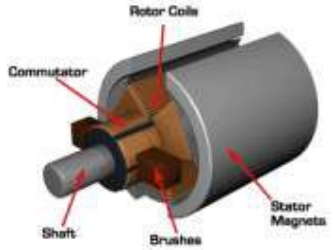
- 1.8V to 60V; Up to 12A
- Indexers / high count microstepping
- Stall Detect / Advanced current control
- Pre-drivers & drivers (w/ integrated FETS)



Open Loop Control

Brushed DC Drivers

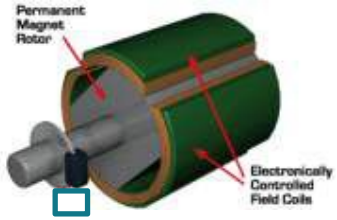
- 1.8V to 60V; Up to 24A
- Inrush current protection
- Pre-drivers & drivers (w/ integrated FETs)



Simplicity & Low Cost

3-Phase Brushless Drivers

- 1.65 to 60V; Up to 13A
- Integrated current sense amps / buck
- Pre-drivers & drivers (w/ integrated FETs)

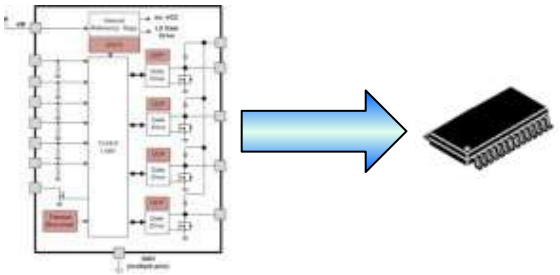


Reliability & Efficiency

Motor Driver Features

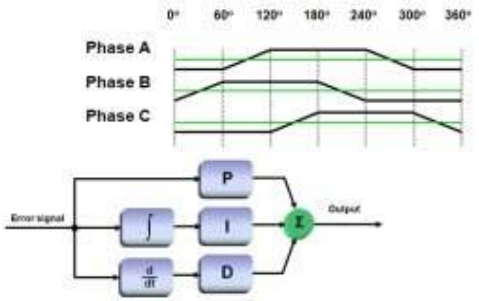
Fully Integrated Solutions

- Reduced Board Space / BOM
- Improved Reliability
- No discrete design experience needed. Just drop in and spin.



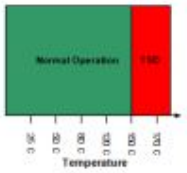
Embedded Intelligence

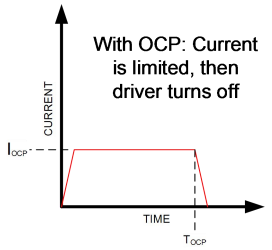
- Minimal MCU support required
- Basic to advanced commutation engines
- Digital control loops



Robust, Reliable & Fully Protected

- Over current / Short circuit protection
- Thermal protection
- Under voltage lock out
- Shoot-through protection





FEATURE PRODUCTS

Stepper Motor Drivers

DRV8412 (6A @ 0 – 52V)
DRV8432 (12A @ 0 – 52V)
High current / performance

DRV8811 (1.9A @ 8 to 38V) 1/8 -ustep
DRV8818 (2.5A @ 8 to 35V) 1/8 -ustep
DRV8824 (1.6A @ 8.2 to 45V) 1/32-ustep
DRV8825 (2.5A @ 8.2 to 45V) 1/32-ustep
Up to 32-µsteps (indexers)

DRV8812 (1.6A @ 8.2 – 45V)
DRV8813 (2.5A @ 8.2 – 45V)
> 32-µsteps w/ MCU support

DRV8833 (2A @ 2.7 – 10.8V) Full and half step
DRV8834 (2.2A @ 2.5 – 10.8V) 1/32-ustep
Low Voltage Steppers

- High Current / High Performance
- Up to 500kHz PWM
- Up to 97% Efficient
- C2000, MSP430, ARM MCU Kits

- No MCU needed for µstepping
- On-chip current regulation

- MCU needed for µstepping
- Battery power target apps
- Low sleep currents
- 8834 has 32-µstep indexer

Production **Sampling**

P2P Compatible

FEATURE PRODUCTS

Stepper Motor Drivers

DRV8412 (6A @ 0 – 52V)
DRV8432 (12A @ 0 – 52V)
High current / performance

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Up to 32-µsteps (indexers)

- No MCU needed for µstepping
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DRV8812 1.6A @ 8.2 – 45V)
DRV8813 (2.5A @ 8.2 – 45V)
> 32-µsteps w/ MCU support

- MCU needed for µstepping
- Battery power target apps
- Low sleep currents
- 8834 has 32-µstep indexer

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Low Voltage Steppers

Production | **Sampling** | *P2P Compatible*

FEATURE
PRODUCTS

Brushed DC Motor Drivers

DRV8412
(12A @ 0 – 52V)
Single or Dual

DRV8432
(24A @ 0 – 52V)
Single or Dual

High Current / performance

High Current / High Performance

Up to 500kHz PWM

Up to 97% Efficient

C2000, MSP430, ARM MCU Kits

DRV8802
(1.6A @ 8.2 – 45V)
Dual Brushed

DRV8814
(2.5A @ 8.2 – 45V)
Dual Brushed

DRV8823
(1.5A @ 8– 32V)
Quad Brushed

Dual & Quad Brushed

Single , Dual, and Quad Options

Brake Support; Sync Rectification

DRV8800
(2.2A @ 8 – 36V)

DRV8840
(5A @ 8.2– 45V)

Single Brushed

Battery power target apps

Low sleep currents

8832 Voltage regulation extends battery life/maintains speed

DRV8832
(1A @ 2.75 – 6.8V)
Voltage regulation

DRV8833
(4A @ 2.7 – 10.8V)

DRV8835
(3A @ 2 – 11V)

Low Voltage

Production

Sampling

P2P Compatible

FEATURE
PRODUCTS

Brushless DC Motor Drivers

DRV8312
(6.5A @ 0 – 52V)

DRV8332
(13A @ 0 – 52V)

High current / performance Integrated drivers

High Current / High Performance

Up to 500kHz PWM

As low as 5ns dead time

C2000, MSP430, ARM Kits

DRV8301
(60A / 60V / SPI Ctrl)
Buck + 2x Sense Amps

DRV8302
(60A / 60V / HW Ctrl)
Buck + 2x Sense Amps

3-Phase pre-drivers

Drive external FETs up to 60A

Integrates 1.5A buck and 2x amps

C2000, MSP430, ARM MCU Kits

Drives brushed DC motors also!

Production

Sampling

DRV8301

EVM Details

3-Phase Brushless Gate Driver with Dual Shunt Amplifiers & 1.5A Buck Converter

Features

- 3-phase gate driver
  - Supply voltage: 8 to 60V
  - Gate Drive Current: 1.7A source / 2.3A sink
  - Adjustable dead time/slew rate; 100% duty cycle
- Dual Bi-directional current shunt amplifiers
  - Adjustable gain (10, 20,40, 80) and offset (up to 3V)
  - DC Calibration
- Integrated buck converter
  - Up to 1.5A (3.5V to 60V) / RDSON of 200mR
- Fully protected
  - 2-stage thermal, CBC over current, UVLO, & shoot through protection with fault feedback
- SPI Management Interface

Benefits

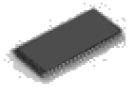
- Wide operating voltage and ability to drive up to 60A external FETs.
- Reduced board space and system cost; DC calibration allows MCU to adjust for DC offset & temperature drift
- Reduced board space and system cost; Buck can be used to power MCU and/or other systems power needs.
- Advanced on-chip protection reduces design complexity and enables higher system reliability
- Access detailed fault reporting and easily configure slew rate, sense amp gain & DC calibration, set overcurrent limit, etc via the SPI interface.

Applications

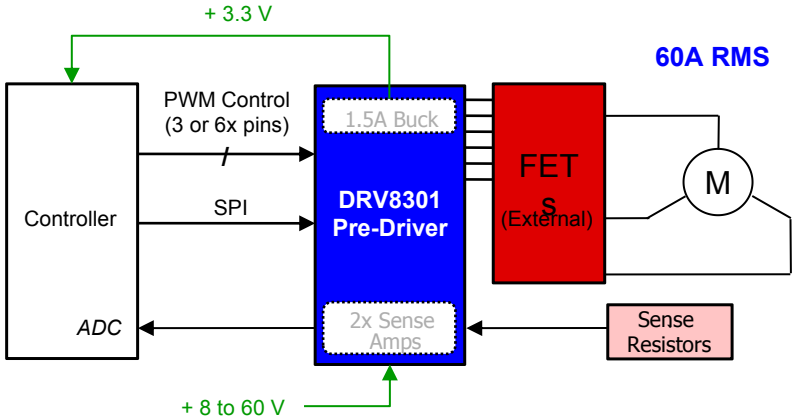
- Brushless DC & PMSM Motors
- Brushed DC (Use 2 of the 3 Half Bridges)

In Production

1K Pricing: $2.50



14 x 8.1mm, 56-pin HTSSOP package



Roadmap

Texas Instruments

DRV8312

3-Phase PWM Motor Driver with Cycle-by-Cycle Overcurrent Protection

EVM Details

Features

- The highest power heatsink-less drive on the market
  - •Supply Voltage up to 52V (50V +/- 5%)
  - •Output Current 3.5A RMS / 6.5A Peak (10ms)
- Advanced architecture with high efficiency up to 97%
  - •PWM operation frequency up to 500kHz
  - •Low Rdson MOSFETs (110mohm)
- Intelligent gate drive and cross conduction prevention
  - •Short dead time (5ns)
  - •Spike voltage control to reduce overshoot
- Integrated Protection Features
  - • Short circuit and cycle-by-cycle current protection
  - •Two stage thermal protection
- No External Snubber or Schottky Diode required

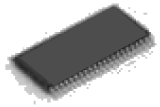
Benefits

- Minimized board space and design time while maximizing performance
- Ultra Low Rdson FETs and thermally efficient package with thermal pad allows for maximum heat dissipation without external heat-sinks
- High linearity of output signals to guarantee precise and smooth operation
- Advanced on-chip protection reduces design complexity and enables higher system reliability

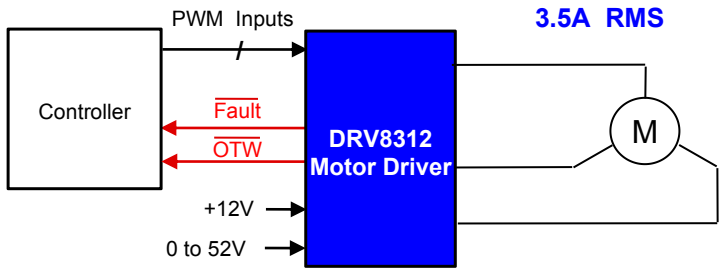
Applications

- Brushless DC Motors
- Permanent magnet synchronous motors

1K Pricing: $3.30



14 x 8.1mm, 44-pin TSSOP, package (PP)



Thank you!