TI Motor Drive Webinar
May 2017
Tips and component recommendations: Easier, faster motor drive integration

Innocent Irakoze
Product marketing engineer for TI’s integrated motor controllers
Electric motor control system overview

Motor control
- Microcontroller
- Manages the control system, motor commutation, driver settings, fault handling

Gate driver
- MOSFET or IGBT gate driver
- Level shifts logic control signals
- Power stage fault detection and handling

Feedback
- Signals from motor
- Position, torque, voltage, current

Power stage
- Power MOSFET or IGBT
- Interface main power rail to electric motor
- Often in half-bridge, H-bridge, or inverter configuration
Motor Types

**Brushed motor**
- Low cost
- Easy to design
- Brushes wear out
- Inefficient

**Brushless motor**
- Very efficient
- Long life / reliable
- Expensive
- Complex design

**Stepper motor**
- Open loop position / speed control
- Simple control
- Resonance
- Noise

DRV integrated drivers & gate drivers

Integrated driver
- Smallest board space
- Easy to design
- Excellent performance
- Fully protected

Gate driver
- Scalable / higher currents
- Better thermals
- Lower RDSON
- Reduced board space
- Fully protected

On-chip motor commutation
Customer benefits

- Optimal **efficiency**, ultra-low acoustic noise, minimal vibration to provide excellent system performance and reliability
- **Code-free** tunability provides minimum design efforts and use of the device
- **Small board** space usage and **BOM count** to save customer overall system cost
Motor Driver Device: DRV10983
+24V, 3-phase Sensorless BLDC Motor Driver

- Direction
- Speed
- FG Output
- I2C
- +8 to 28V

- Fan / Pump Controller
- Build-in Protection
- Current sense
- 100mA Buck

✓ More compact board space
Single chip solution vs. discrete enables >50% form factor saving

✓ High performance BLDC control algorithm
Code-free for high efficiency & low acoustics, fast time to market

TIDA01223
Smart gate drive technology

Challenge:

Solution: Integrated, adjustable, and protected gate driver

Benefits:
- High gate drive current and minimized dead time (efficiency)
- Easy, adjustable slew rate control (flexibility)
- Gate driver short and dV/dt protection (robustness)
- Removes external gate drive components (cost)
Motor Driver device: DRV832x family
65-V 3-Phase BLDC Smart Gate Driver

- 6 to 60 V
- 3½-H Bridge
- Smart Gate Driver
- PWM Gate Drive
- Current Sense
- Sense output
- ENABLE
- SPI or H/W
- nFAULT
- 0.8 to 60 V
- 600 mA

- Built In Protection
- 3x Shunt Amp
- Buck Regulator

- H/W for simple operation, SPI for more configuration
- Smart Gate Drive, no gate drive resistors, gate current is adjustable
- Up to 1A source, 2A sink
- Can drive >300 nC FETs sinusoidal @ 25 kHz

The DRV832x family:
DRV8320R
DRV8320
DRV8323R
DRV8323
Broad portfolio of Motor Drivers

**Brushed-DC**
- Supply voltage support: Low voltage, 12, 24, 36, 48 V
- Technologies: Integrated Current Sensing, Smart Gate Drive
- Differentiation: Small footprint & high efficiency, Inrush current protection, Low-cost
- Hero devices: DRV8837, DRV8870/8871, DRV8701

**Stepper**
- Supply voltage support: Low voltage, 12, 24, 36, 48 V
- Technologies: Integrated Current Sensing, AutoTune, & Smart Gate Drive
- Differentiation: Automatic decay selection, Indexers & precision microsteps, Passive component integration
- Hero devices: DRV8833, DRV8866AT, DRV8880

**Brushless-DC**
- Supply voltage support: Low voltage, 12, 24, 36, 48 V
- Technologies: Integrated state machine control, Low voltage support (start-stop), Smart Gate Drive
- Differentiation: Sensorless & sensored support, Integrated shunt amplifiers, Integrated power management, SafeTI™ ASILB, D
- Hero devices: DRV832x, DRV8305-Q1, DRV10983/10970, DRV3205

**Comprehensive designs:**
- Schematic or block diagram, Test data, Bill of materials and design files that explain the circuit’s function and performance
- Benefits: Expedites grounds-up designs, Saves on development cost

**Key Motor Designs:**
- Sunroof
- Power Tools
- HVAC Damper
- Pump
- Drones
- 3D printer

http://www.ti.com/lsds/ti/analog/motordrivers/overview.page
Motor Driver Design Support

- TI E2E™ Community
- TI Designs
- App Notes
- Guides
- Videos
- EVMs

TI Information – Selective Disclosure
Enabling advanced motor control designs

Chris Clearman
Product marketing engineer, C2000™ microcontrollers, Motor control
C2000™ 32-bit MCU for Real Time Control

**Precision Control**
- High resolution PWM duty cycle
- High resolution PWM period
- High resolution PWM phase control
- High resolution PWM dead-band
- Advanced time synchronization between PWMs

**Flexible Interfacing**
- Advanced inter-PWM and ADC synchronization
- Variety of timer count modes
- Customizable triggering
- External DACs for reference bias waveform generation

**Advanced Protection**
- Directly trip PWMs without CPU intervention, nor clocking
- Supports PWM shutdown or cycle-by-cycle PWM modification
- Peak current mode control support
## C2000 3-ph Motor Control Applications

### PUMPS

<table>
<thead>
<tr>
<th>Automotive</th>
<th>Industrial/Consumer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission</td>
<td>Constant pressure</td>
</tr>
<tr>
<td>Brake/Boost</td>
<td>Water/Waste/Chemical</td>
</tr>
<tr>
<td>Oil</td>
<td>Spa/pool pump</td>
</tr>
<tr>
<td>Turbo</td>
<td>Geothermal pump</td>
</tr>
<tr>
<td>Fuel/Water</td>
<td>Dishwashers</td>
</tr>
</tbody>
</table>

### COMPRESSORS

<table>
<thead>
<tr>
<th>Automotive</th>
<th>Industrial/Consumer</th>
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<tbody>
<tr>
<td>Refrigeration</td>
<td>Air/Con</td>
</tr>
<tr>
<td>Air/Con</td>
<td>Refrigeration</td>
</tr>
</tbody>
</table>

### BLOWERS/FANS

<table>
<thead>
<tr>
<th>Automotive</th>
<th>Industrial/Consumer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air/Con Blowers</td>
<td>Respiratory</td>
</tr>
<tr>
<td>Cooling Fan</td>
<td>Vacuum</td>
</tr>
<tr>
<td></td>
<td>Fans</td>
</tr>
<tr>
<td></td>
<td>Air/Con Blowers</td>
</tr>
<tr>
<td></td>
<td>Exhaust</td>
</tr>
</tbody>
</table>

### LAUNDRY

- Washers
- Dryers

### HIGH TORQUE

<table>
<thead>
<tr>
<th>Transit</th>
<th>Conveyors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traction</td>
<td>Escalators</td>
</tr>
<tr>
<td>eBike/Moped/Scooter</td>
<td>Elevators</td>
</tr>
<tr>
<td>Off-highway Vehicles</td>
<td>Treadmill</td>
</tr>
<tr>
<td>Carts, Transport</td>
<td>Tools</td>
</tr>
<tr>
<td>Fork lifts</td>
<td>AC Drive / Inverter</td>
</tr>
<tr>
<td>Wheel chairs</td>
<td>Assembly Line</td>
</tr>
</tbody>
</table>
# Two Development Paths

<table>
<thead>
<tr>
<th>Expertise Included</th>
<th>Customer Provides Expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>MotorWare</td>
<td>controlSUITE</td>
</tr>
<tr>
<td>InstaSPIN solutions</td>
<td>motor_control library</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Requirement</th>
<th>MotorWare</th>
<th>Customer Provides Expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Piccolo devices</td>
<td>Any C2000 device</td>
<td></td>
</tr>
<tr>
<td>On-chip ROM libraries and source code</td>
<td>Source code modules</td>
<td></td>
</tr>
<tr>
<td>Motor &amp; Inertia Identification</td>
<td>No motor commissioning</td>
<td></td>
</tr>
<tr>
<td>Unified sensorless observer</td>
<td>Multiple observers for different motors</td>
<td></td>
</tr>
<tr>
<td>Automatically tuned sensorless observer</td>
<td>User tuned sensorless observers</td>
<td></td>
</tr>
<tr>
<td>Automatically tuned current controller</td>
<td>User tuned; servo fast current loop option</td>
<td></td>
</tr>
<tr>
<td>Single variable high performance velocity/position controller (IS-MOTION)</td>
<td>User tuned standard PID controllers</td>
<td></td>
</tr>
<tr>
<td>Motion trajectory generation and state machine framework (IS-MOTION)</td>
<td>No advanced motion trajectory provided</td>
<td></td>
</tr>
</tbody>
</table>
InstaSPIN™ Microcontrollers

C2000™ microcontrollers with embedded InstaSPIN™ motion control software to identify, tune, and fully control three phase motors in minutes.
# Challenges of Sensorless 3-ph Motor Control

<table>
<thead>
<tr>
<th>Customer Challenges</th>
<th>InstaSPIN Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensorless observer relies on accurate knowledge of motor parameters</td>
<td>Off-line and Run-time motor parameter identification feature</td>
</tr>
<tr>
<td></td>
<td>FAST observer relies on fewer parameters</td>
</tr>
<tr>
<td>Tuning observer is extremely challenging, multiple tuning sets over operating range</td>
<td>FAST observer self-tunes and works over entire operating range</td>
</tr>
<tr>
<td>Observers are not high performance</td>
<td>FAST observer reliable at much lower frequency, under dynamic transients, can recover from stalls, and can track an already moving motor even with inverter un-powered (flying-start)</td>
</tr>
<tr>
<td>Start-up from zero speed and transitions through zero speed are extremely challenging</td>
<td>Start-up from zero speed with 100% torque capability, angle convergence within 1 electrical cycle, stable through zero speed during CW/CCW movements</td>
</tr>
<tr>
<td>Tuning torque/current controllers challenging, especially when unsure of observer tuning</td>
<td>Torque/current controllers automatically set to stable values, user adjustable after performance testing</td>
</tr>
<tr>
<td>Tuning velocity controller challenging for inexperienced</td>
<td>Simple step response how-to provided, or advanced single-variable tuning available</td>
</tr>
<tr>
<td>Low fidelity speed estimates based on estimated angle</td>
<td>High fidelity speed estimate calculated independent of angle, with high speed angle compensation feature and unique torque estimate</td>
</tr>
</tbody>
</table>

**InstaSPIN-FOC:** Identify, tune, and run best sensorless FOC in minutes

*More details SPRUHI9*
InstaSpin™-FOC

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

InstaSpin™-MOTION

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

Motor Parameter ID
Automatic FOC torque tuning
Robust software encoder

Simplified speed tuning
Premium performance
Motion & Planning

www.ti.com/instaspin

TI Information – Selective Disclosure
InstaSPIN-FOC to InstaSPIN-MOTION

InstaSPIN-MOTION
- Builds upon InstaSPIN-FOC (or use with sensors)
- SpinTAC™ Suite component for high performance motion control

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

Speed PI tuning
- Complex
- Inconsistent across use

Building Motions
- Even more complex
- Only as good as control
SpinTAC™ Components

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

1. Press button to measure inertia
2. Adjust knob to tune

Account for mechanical inertia - Robust speed control - Simplified tuning
**Move:**

**Build Trajectories**
- Select Motion Type for Speed A to B
- Define constraints (accel, jerk)
- Move generates the ideal curve

**Intermediate speed references are calculated during run-time by SpinTAC MOVE...**

**Plan:**

**Design Motion Sequence**
- Define operating states and transitions
- Connect logic-based Moves
- Execute the motion sequence

**Example:**
If \(<\text{Agitation Counter} = 0>\) move to Slow Spin Cycle

**Intermediate speed references are calculated during run-time by SpinTAC MOVE...**
**InstaSPIN™-enabled, real-time controllers**

TI's InstaSPIN three-phase motor control solutions are enabled by special libraries in the read-only memory (ROM) of Piccolo microcontrollers (MCUs) that allow you to create products with improved efficiency, performance, and reliability, while reducing development time from months to minutes. TI's InstaSPIN-enabled MCUs provide expertise to designers of sensorless (velocity and torque) or sensored (position, velocity and torque) motor control applications.

<table>
<thead>
<tr>
<th>InstaSPIN Solution</th>
<th>MHz</th>
<th>FPU</th>
<th>CLA Co-Processor</th>
<th>Motors</th>
<th>Flash (KB)</th>
<th>12b ADC Chs</th>
<th>PGA</th>
<th>CAN</th>
<th>QEP</th>
<th>USB</th>
<th>SPI</th>
<th>UART</th>
<th>I2C</th>
<th>Pins</th>
<th>Temp</th>
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</thead>
<tbody>
<tr>
<td>F28069M -MOTION</td>
<td>90</td>
<td>Y</td>
<td>Y</td>
<td>1 or 2</td>
<td>256</td>
<td>16 or 12</td>
<td>–</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>100/80</td>
<td>-40 to 105°C</td>
</tr>
<tr>
<td>F28069M -MOTION</td>
<td>90</td>
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<td>256</td>
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<td>2</td>
<td>2</td>
<td>1</td>
<td>100/80</td>
<td>-40 to 105°C</td>
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<tr>
<td>F28069F -FOC</td>
<td>60</td>
<td></td>
<td>–</td>
<td></td>
<td>128</td>
<td></td>
<td>–</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>–</td>
<td>1</td>
<td>3</td>
<td>80</td>
<td>-40 to 125°C Q100</td>
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<tr>
<td>F28068F -FOC</td>
<td>60</td>
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<td>64</td>
<td>16</td>
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<tr>
<td>F28062F -FOC</td>
<td>60</td>
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<td>64</td>
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<tr>
<td>F28054M -MOTION</td>
<td>60</td>
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<td>1 or 2</td>
<td>128</td>
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<td>F28054F -FOC</td>
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<tr>
<td>F28052M -MOTION</td>
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<td>1 or 2</td>
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<td>F28052F -FOC</td>
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<tr>
<td>F28027F -FOC</td>
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<tr>
<td>F28026F -FOC</td>
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</table>
InstaSPIN-FOC & -MOTION Evaluation

<table>
<thead>
<tr>
<th>Kit</th>
<th>Voltage Range</th>
<th>ADC Scale</th>
<th>Current Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRV8312-69M-KIT</td>
<td>15-50V</td>
<td>66.32V</td>
<td>3.5A continuous, 6.5A peak, 8.65A ADC Scale</td>
</tr>
<tr>
<td>LAUNCHXL-F28027F or F28069M + BOOSTXL-DRV8301 or BOOSTXL-DRV8305EVM</td>
<td>6-24V Input or 6-42V Input</td>
<td>26.3V or 44.3V ADC Scale</td>
<td>10A or 15A continuous, 16A or 23.5A ADC Scale</td>
</tr>
<tr>
<td>DRV8301-69M-KIT</td>
<td>8-60V Input</td>
<td>66.32V</td>
<td>~40A continuous, 40A peak, 41.25A ADC Scale</td>
</tr>
<tr>
<td>TMDSHVMTRINS PIN</td>
<td>50-350V Input</td>
<td>AC/DC supply included</td>
<td>8A continuous, 9A peak, 9.945A ADC Scale</td>
</tr>
</tbody>
</table>

**InstaSPIN™ projects**

**MotorWare™ code infrastructure**

**C code projects & Lab Guide**
- Labs teach how to use features
- Intuitive drivers, modules & functions

**Object oriented APIs**
- Projects easily scale across MCU family and inverter hardware
- Easy to add custom application code

**Scalable support**

**CCSv5 Eclipse for code gen**

**Online forum support**

$299

$66+

$299

$699
InstaSPIN™ Resources
www.ti.com/instaspin

InstaSPIN™-FOC and –MOTION
• Thorough Reference Manuals and User’s Guide
• MotorWare projects, detailed lab documentation, and code examples provided
• Includes API information
• GUI and CCS

Training
• MotorWare projects offer self-paced workshop style sessions
Thank you!