Part 4: What can I do with digital motor control?

- InstaSPIN™ motor control solutions
- DesignDRIVE software for industrial drives and 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
Three-phase motor control applications

Electric Vehicles
- Traction Drives
- Construction & Agriculture
- Auxiliary Motors
- Power Steering
- Drones
- E-Mobility

Industrial Drives
- Servo Drives
- AC Drives & Inverters
- CNC
- Robotics
- Elevators
- Door controls
- Textile

Appliances
- Fans
- Small household appliances
- Refrigeration
- Laundry
- HVAC

General Motor Control
- Compressors
- Medical pumps
- Dental tools
- Garden & power tools
- Fitness equipment

Field Oriented Control

www.ti.com/c2000motor
## Two development paths

<table>
<thead>
<tr>
<th>InstaSPIN-FOC &amp; -MOTION</th>
<th>DesignDRIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Easiest to use, more complete solutions</strong></td>
<td><strong>Motor control building blocks</strong></td>
</tr>
<tr>
<td><strong>Premium sensorless and motion control</strong></td>
<td><strong>Premium fast current loop control solution</strong></td>
</tr>
<tr>
<td><strong>Expertise included</strong></td>
<td><strong>Customer provides all other expertise</strong></td>
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</table>

<table>
<thead>
<tr>
<th>Feature</th>
<th>InstaSPIN-FOC &amp; -MOTION</th>
<th>DesignDRIVE</th>
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</thead>
<tbody>
<tr>
<td>Specific C2000 devices (low-mid end MCU)</td>
<td>Any C2000 (usually mid-high end MCU)</td>
<td></td>
</tr>
<tr>
<td>On-chip ROM libraries and source code</td>
<td>Motor control library with source code</td>
<td></td>
</tr>
<tr>
<td>Motor Parameters &amp; Inertia Identification</td>
<td>No motor commissioning</td>
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</tr>
<tr>
<td>Unified sensorless observer for all 3ph motors</td>
<td>Standard observers</td>
<td></td>
</tr>
<tr>
<td>Self-tuned sensorless observer</td>
<td>User-tuned sensorless observers</td>
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</tr>
<tr>
<td>Self-tuned current controller</td>
<td>User-tuned; servo fast current loop (FCL) option</td>
<td></td>
</tr>
<tr>
<td>Premium velocity/position controller</td>
<td>User-tuned standard PID controllers</td>
<td></td>
</tr>
<tr>
<td>Motion generation and state machine</td>
<td>User-provided motion control</td>
<td></td>
</tr>
</tbody>
</table>

© Texas Instruments
InstaSPIN™ microcontrollers

C2000™ microcontrollers with embedded InstaSPIN™ motion control software to identify, tune, and fully control three phase motors in minutes.

Identify, tune, and control three phase motors in minutes.

Three phase, variable speed, synchronous or asynchronous motor system

Optimized system in minutes.
# Challenges of sensorless 3-ph motor control

<table>
<thead>
<tr>
<th>Customer challenges</th>
<th>InstaSPIN solutions</th>
</tr>
</thead>
</table>
| Sensorless observer relies on accurate knowledge of motor parameters | Off-line and Run-time motor parameter identification feature  
FAST observer relies on fewer parameters |
| Tuning observer is extremely challenging, multiple tuning sets over operating range | FAST observer self-tunes and works over entire operating range |
| Observers are not high performance | 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) |
| Start-up from zero speed and transitions through zero speed are extremely challenging | Start-up from zero speed with 100% torque capability, angle convergence within 1 electrical cycle, stable through zero speed during CW/CCW movements |
| Tuning torque/current controllers challenging, especially when unsure of observer tuning | Torque/current controllers automatically set to stable values, user adjustable after performance testing |
| Tuning velocity controller challenging for inexperienced | Simple step response how-to provided, or advanced single-variable tuning available |
| Low fidelity speed estimates based on estimated angle | High fidelity speed estimate calculated independent of angle, with high speed angle compensation feature and unique torque estimate |

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

More details in this technical reference manual
FAST™ Sensorless Observer

• Works on all three phase motors
• Field orientation converges within first electrical cycle
• Angle accuracy within +/-1 count of a 1024 encoder steady state
• Start-up from zero speed at full torque
• Stable across all corners in all quadrants
• Stall recovery without losing field orientation

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

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 tuning 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, high-speed, PowerWarp™ for induction motors

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

www.ti.com/instaspin-foc
**InstaSPIN-MOTION**

**Simplifies design, Improves performance for Servo Control**

**Robust position/velocity control for the real mechanics of the system**

- **IDENTIFY**: System inertia identification used as input for the most accurate control
- **CONTROL**: SpinTAC™ replaces standard PI and provides more accurate performance across the full operating range through real-time disturbance estimation and cancellation

**Simple Tuning**

- 1-variable “gain” allows for simple, instant tuning
- Eliminates gain staging – single tuning is effective over the ENTIRE operating range

**Easy motion design**

- **MOVE**: Motion engine calculates the ideal reference signal (with feed forward) based on user-defined parameters. Supports standard industry curves, and LineStream’s proprietary “smooth trajectory” curve
- **PLAN**: Motion Sequence Planner operates user-defined state transition maps
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

InstaSPIN-MOTION: SpinTAC™ components
Account for mechanical inertia - Robust speed control - Simplified tuning
**Plan:**
Design motion sequence

- Define operating states and transitions
- Connect logic-based Moves
- Execute the motion sequence

**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...

..and used as inputs to SpinTAC Control

Example:
If <Agitation Counter = 0> move to Slow Spin Cycle

**InstaSPIN-MOTION: SpinTAC™ components**

Integrated movement and motion design
**TI’s 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 sensed (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>
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## InstaSPIN™ additional resources

**TI.com/instaspin**

InstaSPIN-FOC & InstaSPIN-MOTION

<table>
<thead>
<tr>
<th>Part number</th>
<th>controlCARD</th>
<th>Driver</th>
<th>Power range</th>
<th>Software</th>
<th>GUI</th>
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<td>BOOSTXL-DRV8301</td>
<td>Piccolo F28027F LaunchPad</td>
<td>DRV8301</td>
<td>6-24V, 10A</td>
<td>MotorWare</td>
<td>UNIVERSAL InstaSPIN GUI</td>
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<td>BOOSTXL-DRV8305EVM</td>
<td>Piccolo F28027F LaunchPad</td>
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<td>DRV8301</td>
<td>6-60V, 40A</td>
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<td>UNIVERSAL InstaSPIN GUI</td>
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<tr>
<td>DRV8305-Q1EMV</td>
<td>Soldered on-board TMS320F28027F</td>
<td>DRV8305</td>
<td>4.4-45V, 25A</td>
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<td>UNIVERSAL InstaSPIN GUI</td>
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<td>Powerex IPM</td>
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<td>50-350V, 10A</td>
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</table>
**C2000™ DesignDRIVE**

**System BOM savings**
- Integrated analog sensing circuits
- Integrated encoder control for digital and analog sensors
- Reduced PCB space requirements

**System know-how**
- Reference designs
- Development kits
- Example software
- On line training
- Scalable solutions

**System performance**
- Integration reduces data latency; improving critical loop times
- Precision analog for precision control
- Differentiated architecture for real-time computational power

| Reduce system costs by at least 10% | Save months of engineering effort | Create high value industrial drive products |
Innovative integration

DesignDRIVE BOM savings

Today's Industrial Drives $$$$$

C2000™ DesignDRIVE-enabled Industrial Drives $$

[Diagram of MCU and FPGA integration with control subsystems and power supplies]
High performance delivers high value
*DesignDRIVE system performance*

**C28x™ TMU accelerated Park transform**

\[
\begin{bmatrix}
    i_d \\
    i_q \\
    i_s
\end{bmatrix} =
\begin{bmatrix}
    \cos(\theta) & \sin(\theta) & 0 \\
    -\sin(\theta) & \cos(\theta) & 0 \\
    0 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
    i_p \\
    i_p \\
    i_p
\end{bmatrix}
\]

**Integrated Analog to Digital Conversion With Digital Post-Processing**

- Up to 16bit, 4MSPS
- Up to 12bit, 12MSPS
- Zero wait-state reads
- Zero jitter
- Multi-port access

**C2000™ With CLA**

- C28x – Tradeoffs between control and system tasking
- C28x – headroom for more tasks
- CLA – loop time improvements

*With dual C28x and CLA cores, the 'F2837xD MCUs deliver 800 MIPS!*

**Fastest Current Loop on a Microcontroller (FCL)**
- Applies new control techniques
- Leverages C2000 performance features
- Enables sub-microsecond loop times
Pulse Width Modulation (PWM) update traditional vs. sub-cycle

- Sense current and calculate as fast as possible
- Update PWM as soon as the calculation is done

Try to make $T_{PWM\_update} < 1\%$ of $T_{samp}$

But, this needs tremendous compute power

Built for real-time compute performance
FCL - PWM update timing using the ‘F28379D MCU

ADC Acq  <->  FCL exec

PWM update & FCL complete

Sample event
### Ready-to-use on-line solutions and support

*DesignDRIVE systems know-how*

<table>
<thead>
<tr>
<th>DesignDRIVE Kits</th>
<th>DesignDRIVE Software</th>
<th>Reference Designs</th>
<th>On-line Training</th>
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<tbody>
<tr>
<td><img src="image1.png" alt="DesignDRIVE Kits" /></td>
<td><img src="image2.png" alt="DesignDRIVE Software" /></td>
<td><img src="image3.png" alt="Reference Designs" /></td>
<td><img src="image4.png" alt="On-line Training" /></td>
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</tbody>
</table>
| **TMDXIDDK379D** | • Download Sensored-FOC DesignDRIVE software  
  ✓ Fast Current Loop  
  ✓ Position Manager  
  ✓ EtherCAT® support | **TIDM-SERVODRIVE**  
  **TIDM-DELFINO-ETHERCAT** | **Go to video curriculum** |
Get started with C2000 know-how

Know-how to create *MANY* designs for Industrial Drives…

**TI.com/c2000Drives**

Jumpstart industrial drives and servo control evaluation and development with:

- Examples of vector control of motors, incorporating torque, speed and position
- Multiple current sense topologies
- Analog and digital position sensor interfaces
- Flexible real-time connectivity
- Series of platform releases

**TI.com/tool/TMDXIDDK379D**
Reference designs on TI.com

Visit our applications page to find reference designs for your specific end equipments.

Drone Propeller ESC

Servo Drive Power Stage Module
Thank you