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

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

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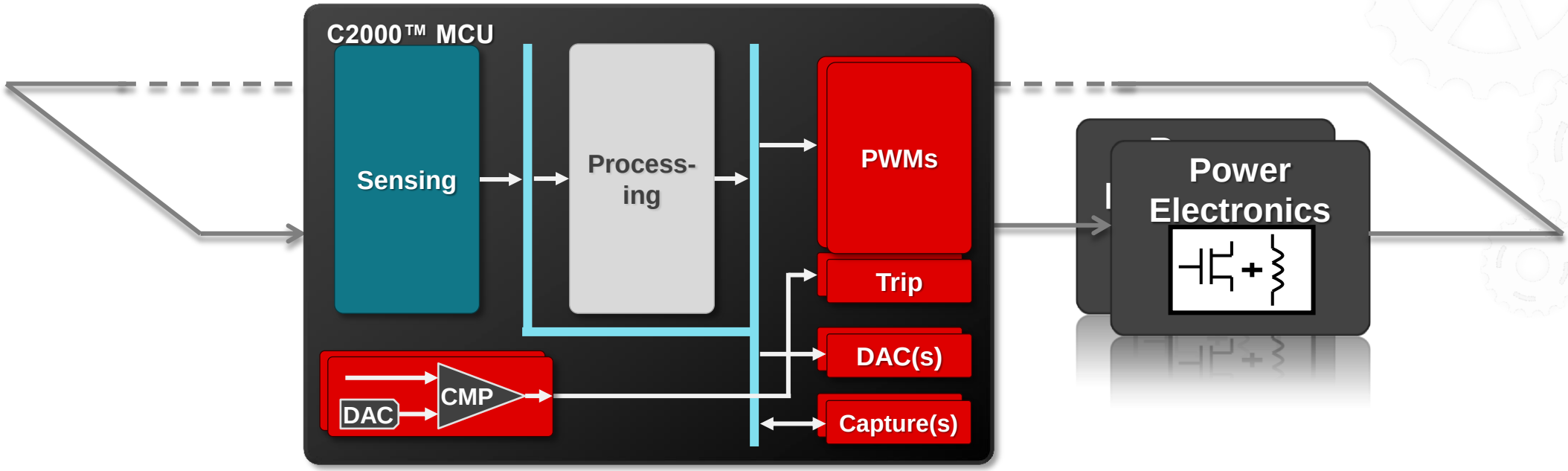
C2000™ 32-bit MCU for real time control



Precision control	Flexible interfacing	Advanced protection
• High resolution PWM duty cycle • High resolution PWM period • High resolution PWM phase control • High resolution PWM dead-band • Advanced time synchronization between PWMs	• Advanced inter-PWM and ADC synchronization • Variety of timer count modes • Customizable triggering • External DACs for reference bias waveform generation	• 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

Two development paths

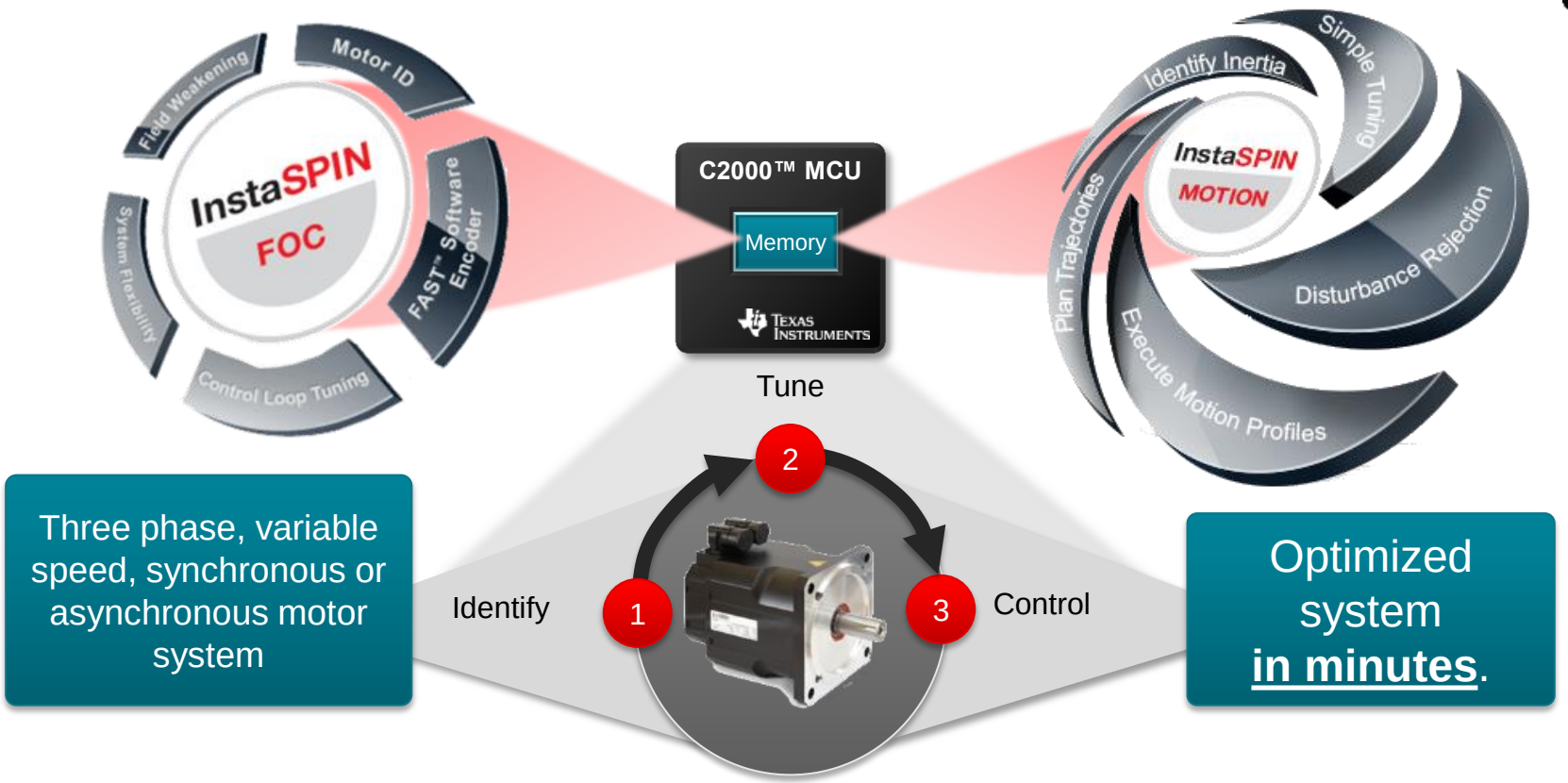
InstaSPIN-FOC & -MOTION ***Easiest to use, more complete solutions*** ***Premium sensorless and motion control*** ***Expertise included***	**DesignDRIVE** ***Motor control building blocks*** ***Premium fast current loop control solution*** ***Customer provides all other expertise***
Specific C2000 devices (low-mid end MCU)	Any C2000 (usually mid-high end MCU)
On-chip ROM libraries and source code	Motor control library with source code
Motor Parameters & Inertia Identification	No motor commissioning
Unified sensorless observer for all 3ph motors	Standard observers
Self-tuned sensorless observer	User-tuned sensorless observers
Self-tuned current controller	User-tuned; servo fast current loop (FCL) option
Premium velocity/position controller	User-tuned standard PID controllers
Motion generation and state machine	User-provided motion control

InstaSPIN™ microcontrollers

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

InstaSPIN™ 32-bit MCUs

Texas Instruments



Challenges of sensorless 3-ph motor control

More details in this technical reference manual

Customer challenges	InstaSPIN solutions
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

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

www.ti.com/instaspin-foc

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

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

InstaSPIN-MOTION: SpinTAC™ components

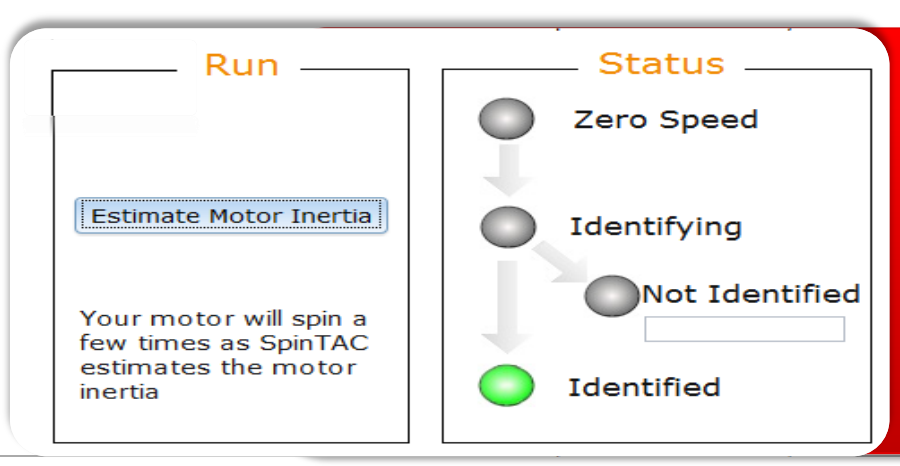
Account for mechanical inertia - Robust speed control - Simplified tuning

Identify:
Measure Inertia

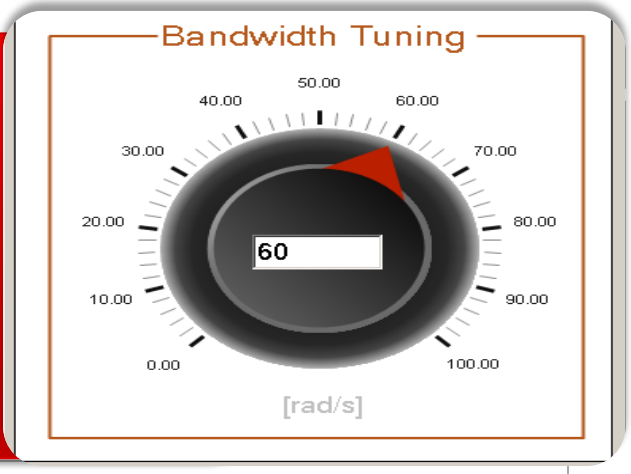
- Inertia is important for accurate control
- Short acceleration test to identify system inertia

Control:
Maximum control, minimum effort

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



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

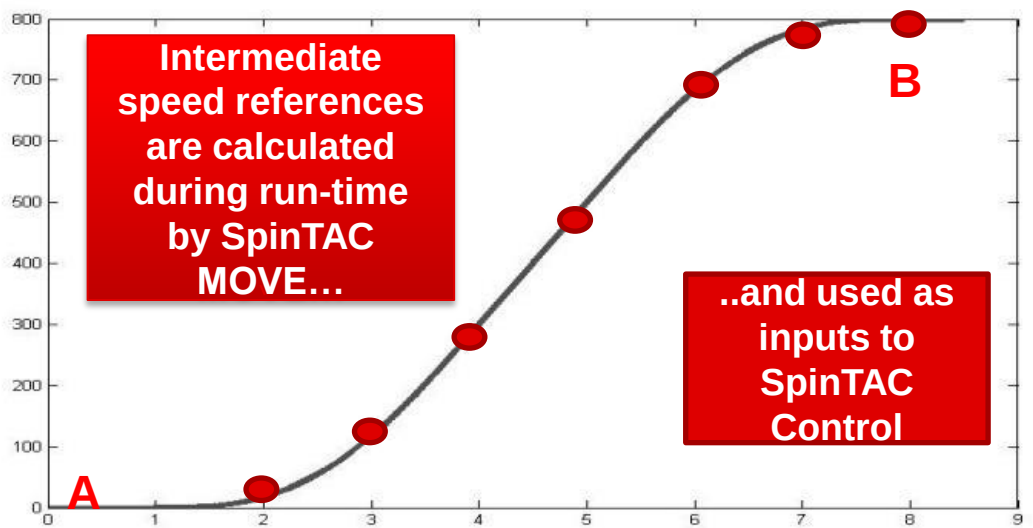


InstaSPIN-MOTION: SpinTAC™ components

Integrated movement and motion design

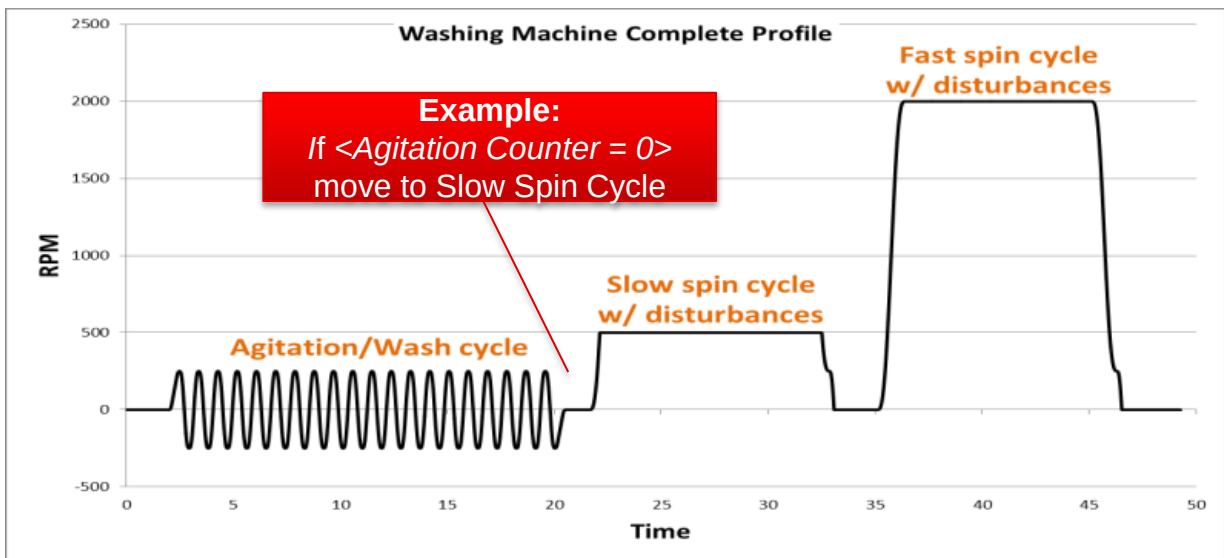
Move:
Build trajectories

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



Plan:
Design motion sequence

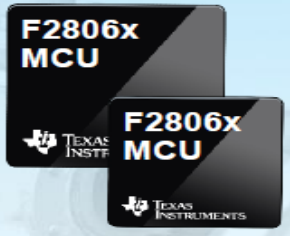
- Define operating states and transitions
- Connect logic-based Moves
- Execute the motion sequence



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 sensored (position, velocity and torque) motor control applications.

16x16 mm



14x14 mm

14x14 mm

9x9 mm

Click a part number to learn more

	InstaSPIN Solution	MHz	FPU	CLA Co-Processor	Motors	Flash (KB)	12b ADC Chs	PGA	CAN	QEP	USB	SPI	UART	I2C	Pins	Temp
F28069M	-MOTION	90	Y	Y	1 or 2	256	16 or 12	--	1	1	1	2	2	1	100/80	-40 to 105° C
F28068M	-MOTION			--		256										
F28069F	-FOC			Y		256										
F28068F	-FOC			--		256										
F28062F	-FOC			--		128										
F28054M	-MOTION	60	--	--	1 or 2	128	16	4	1	1	--	1	3	1	80	-40 to 125° C Q100
F28054F	-FOC					128										
F28052M	-MOTION					64										
F28052F	-FOC					64										
F28027F	-FOC	60	--	--	1	64	13	--	--	--	--	1	1	1	48	
F28026F	-FOC					32										

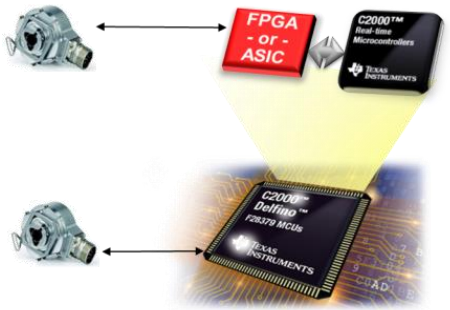
InstaSPIN™ additional resources

TI.com/instaspin

InstaSPIN-FOC & InstaSPIN-MOTION

Part number	controlCARD	Driver	Power range	Software	GUI
BOOSTXL-DRV8301	Piccolo F28027F LaunchPad Piccolo F28069M LaunchPad	DRV8301	6-24V, 10A	MotorWare	UNIVERSAL InstaSPIN GUI
BOOSTXL-DRV8305EVM	Piccolo F28027F LaunchPad Piccolo F28069M LaunchPad	DRV8305	4.4-45V, 15A	MotorWare	UNIVERSAL InstaSPIN GUI
DRV8301-69M-KIT	Piccolo F28069M included Piccolo F28054M supported Piccolo F28027F + Emulator supported	DRV8301	6-60V, 40A	MotorWare	InstaSPIN-FOC & -MOTION UNIVERSAL InstaSPIN GUI
DRV8305-Q1EVM	Soldered on-board TMS320F28027F	DRV8305	4.4-45V, 25A	MotorWare	UNIVERSAL InstaSPIN GUI
DRV8312-69M-KIT	Piccolo F28069M included Piccolo F28054M supported Piccolo F28027F + Emulator supported	DRV8312	12-52V, 3.5A	MotorWare	InstaSPIN-FOC & -MOTION UNIVERSAL InstaSPIN GUI
TMDSHVMTRINSPIN	Piccolo F28069M & Piccolo F28027F included Piccolo F28054M supported	Powerex IPM	50-350V, 10A	MotorWare	InstaSPIN-FOC & -MOTION UNIVERSAL InstaSPIN GUI

C2000™ DesignDRIVE

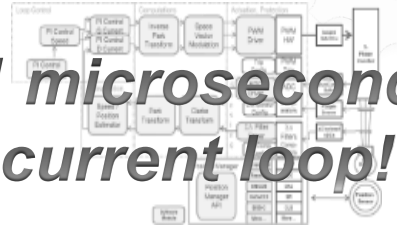


System BOM savings

- 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

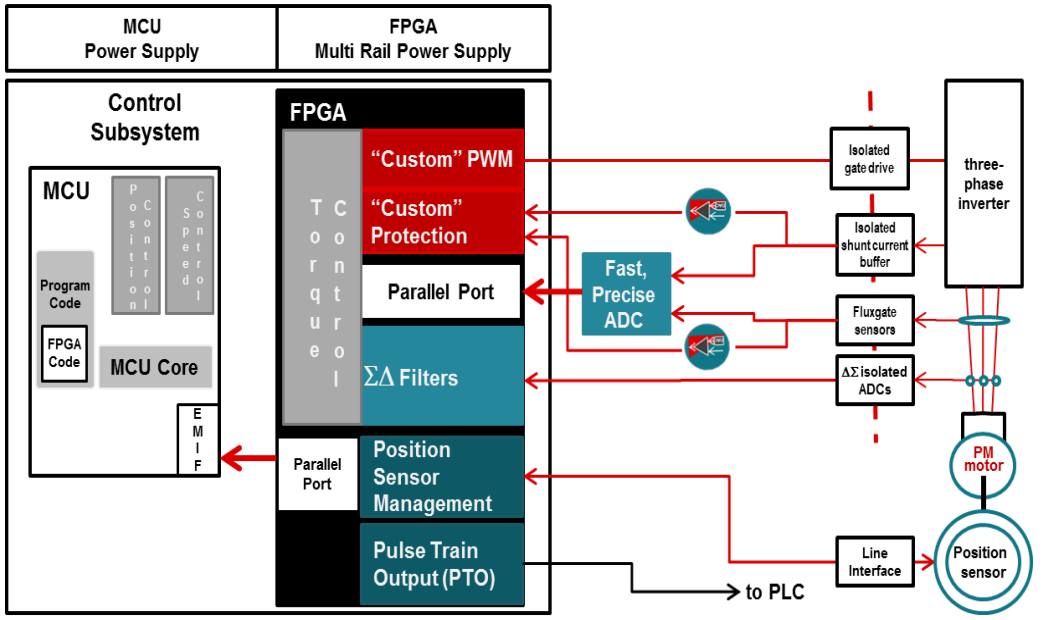
- Integration reduces data latency; improving critical loop times
- Precision analog for precision control
- Differentiated architecture for real-time computational power

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

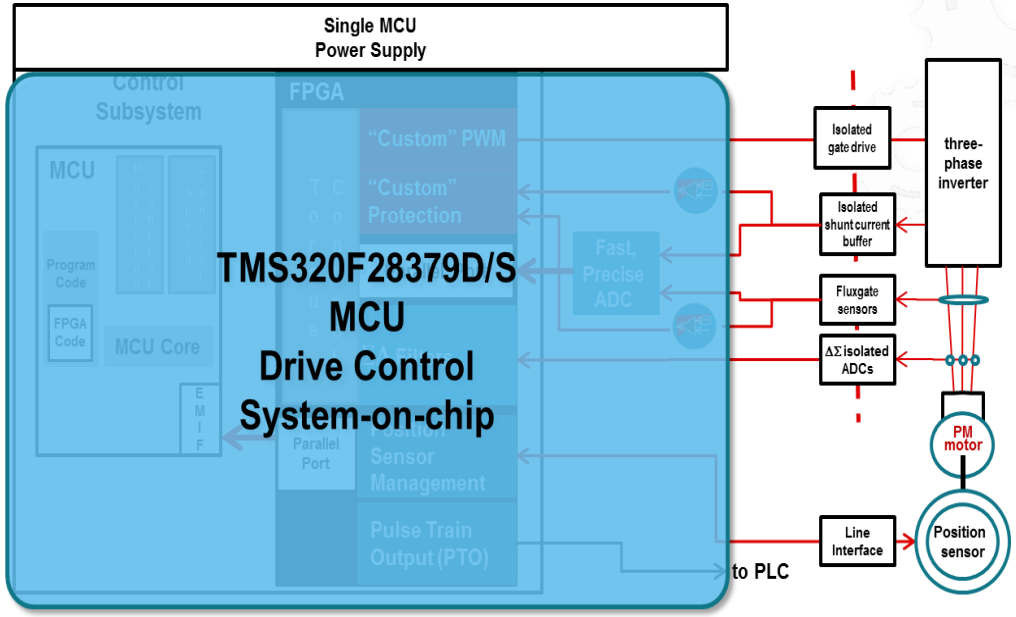
Innovative integration

DesignDRIVE BOM savings

Today's Industrial Drives $$$$$



C2000™ DesignDRIVE-enabled Industrial Drives $$



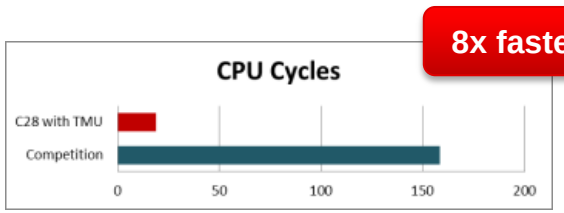
High performance delivers high value

DesignDRIVE system performance

DesignDRIVE

C28x™ TMU accelerated Park transform

$$\text{Park} \quad \begin{bmatrix} i_d \\ i_q \\ i_o \end{bmatrix} = \begin{bmatrix} \cos(\theta) & \sin(\theta) & 0 \\ -\sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{bmatrix} X \begin{bmatrix} i_\alpha \\ i_\beta \\ i_o \end{bmatrix}$$



8x faster

Without CLA (Texas Instruments)

before

C28x – Tradeoffs between control and system tasking

C2000™ With CLA (Texas Instruments)

after

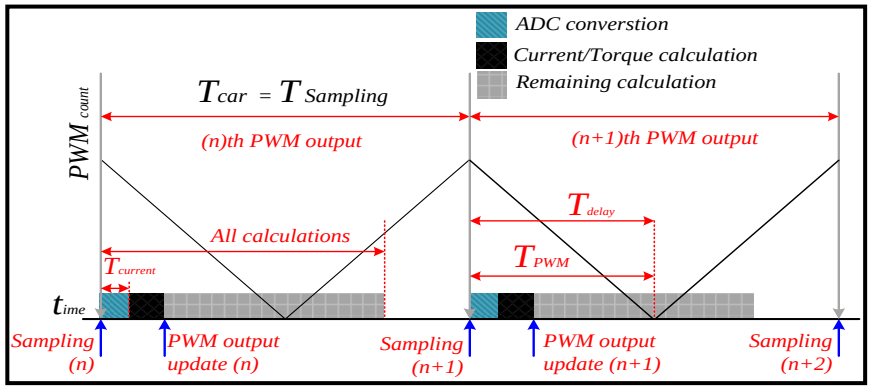
C28x – headroom for more tasks

CLA – loop time improvements

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

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

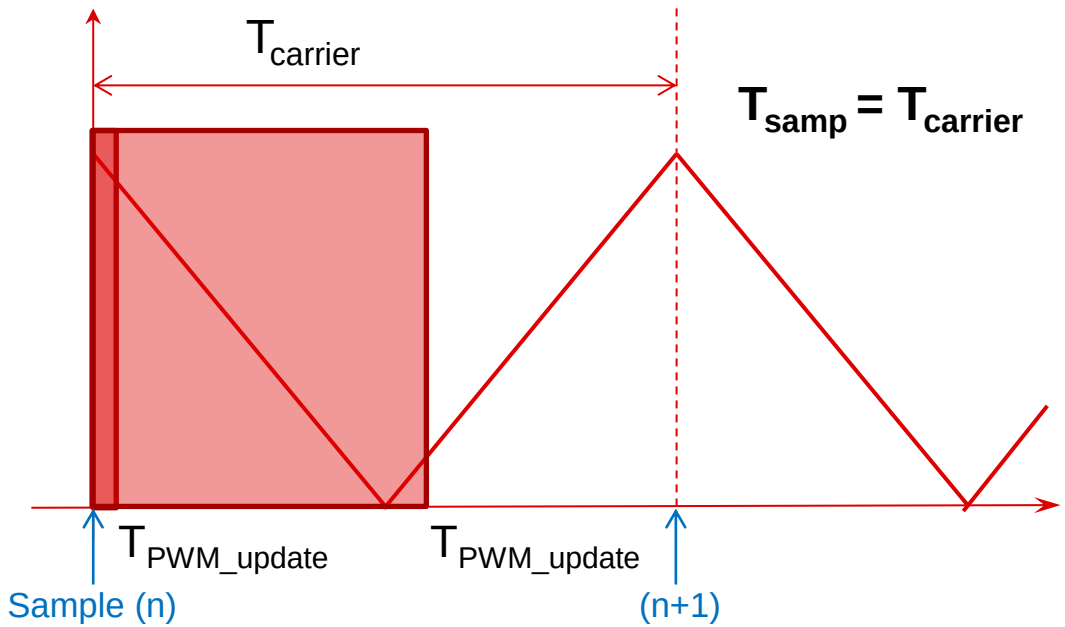


Fastest Current Loop on a Microcontroller (FCL)

- 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



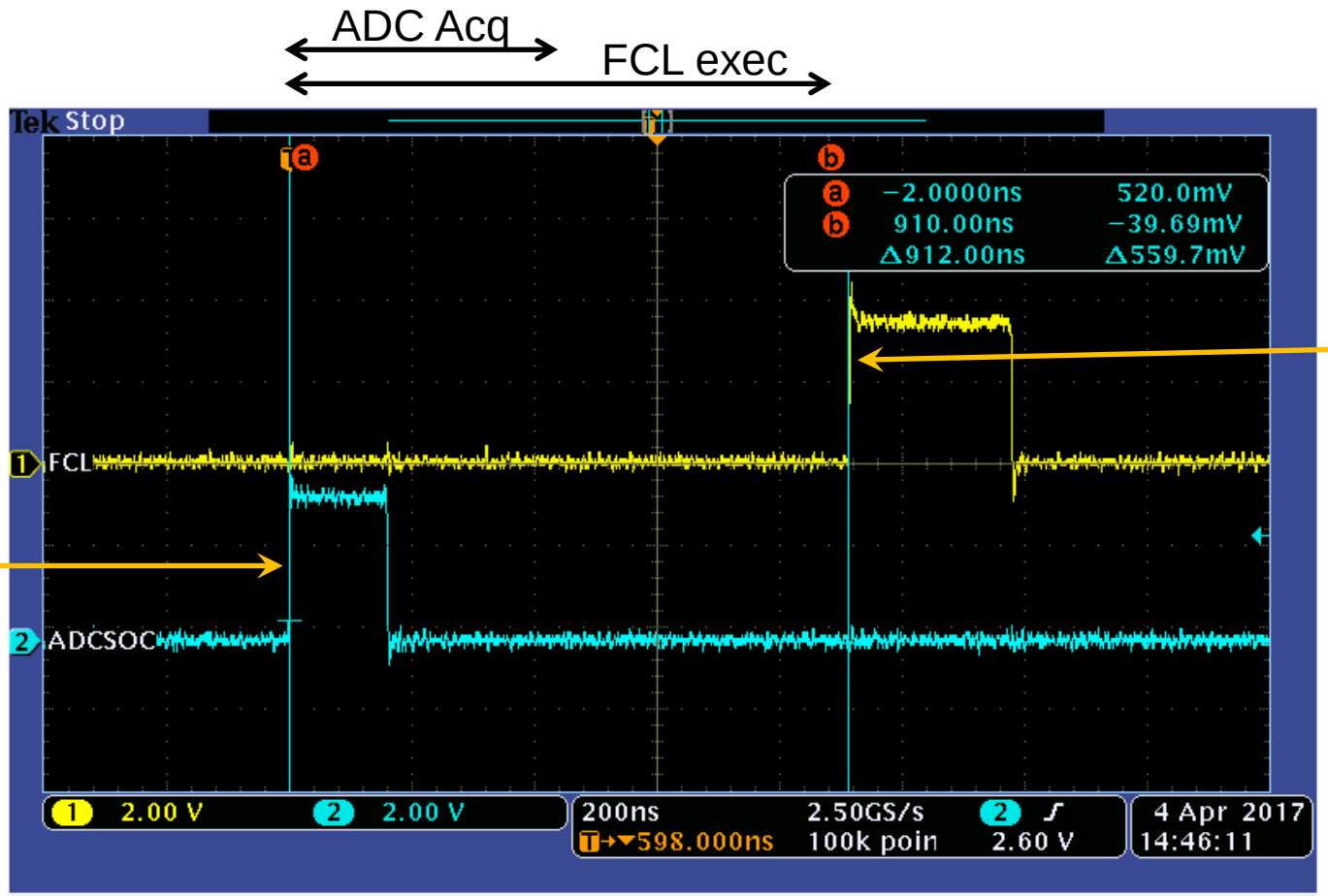
Try to make

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



Ready-to-use on-line solutions and support

DesignDRIVE systems know-how

DesignDRIVE Kits	DesignDRIVE Software	Reference Designs	On-line Training
		TIDesigns	DesignDRIVE
TMDXIDDK379D LAUNCHXL-F28379D	• 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

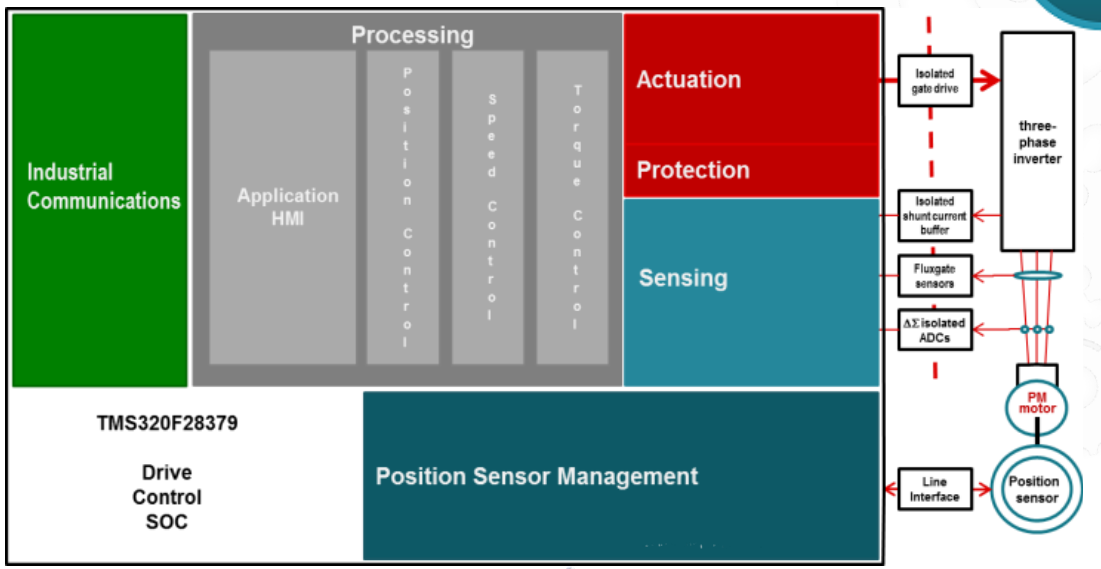
DesignDRIVE

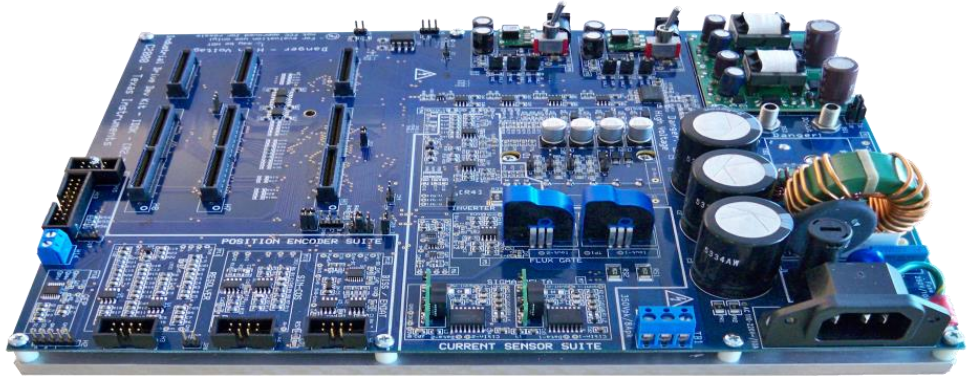
Know-how to create *MANY* designs for Industrial Drives…

TI.com/c2000Drives

Jumpstart industrial drives and servo control evaluation and development with:

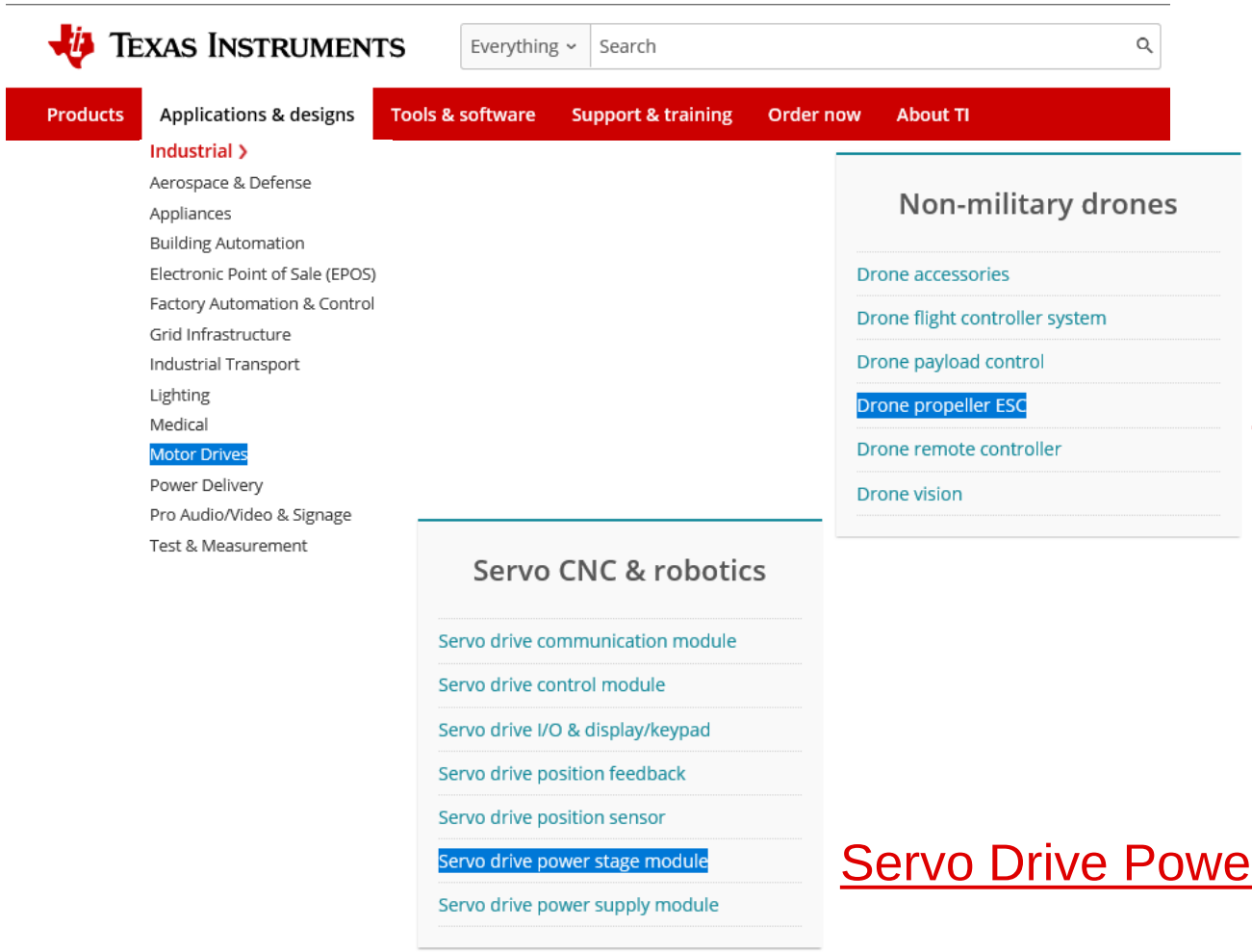
- Examples of vector control of motors, incorporating torque, speed and position
- Multiple current sense topologies
- Analog and digital position sensor interfaces
- Flexible real-time connectivity
- Series of platform releases





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

http://www.ti.com/c2000motor