TI High-Voltage Seminar

Unleashing digital control: TI's digital power MCUs and controllers

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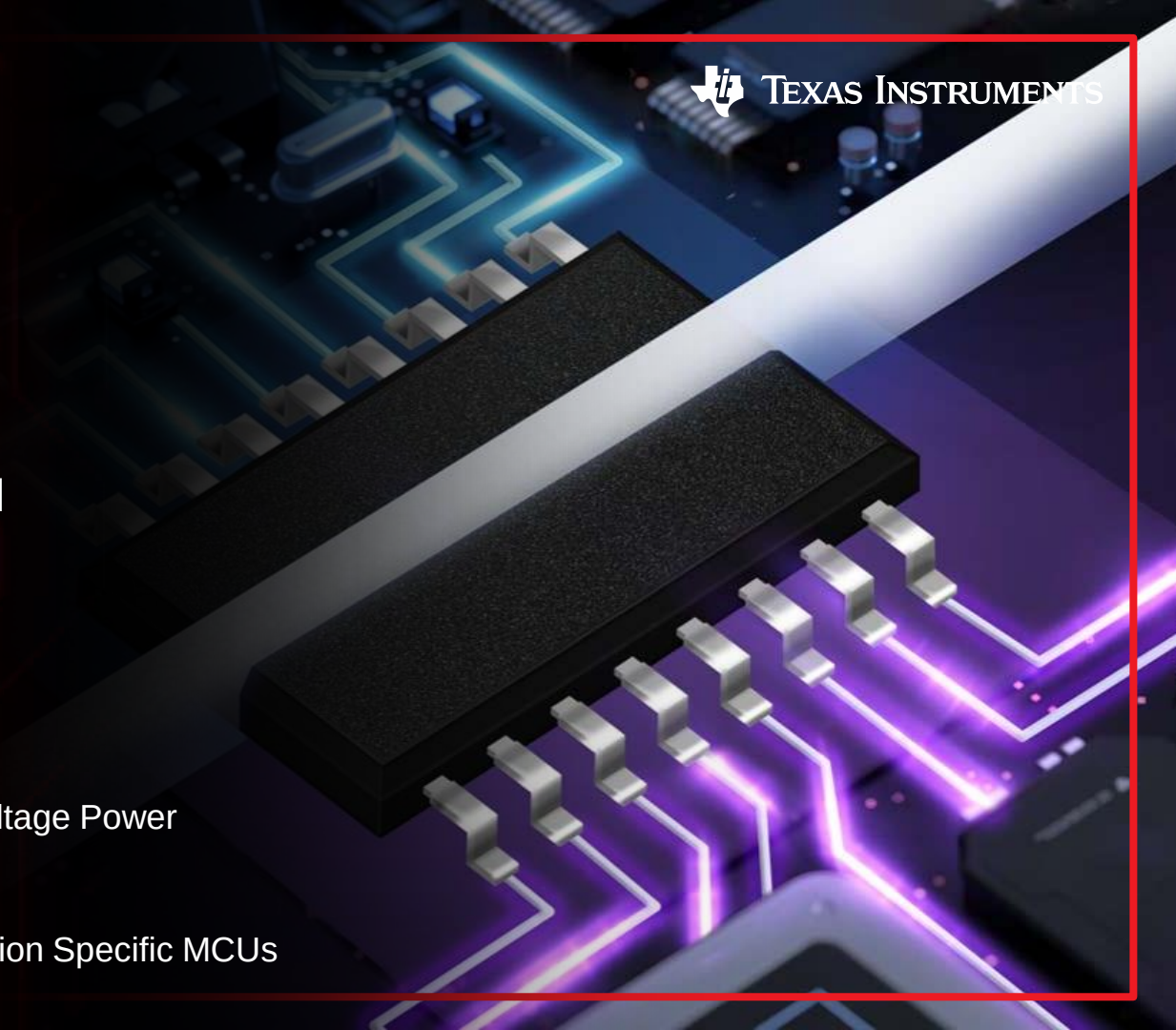
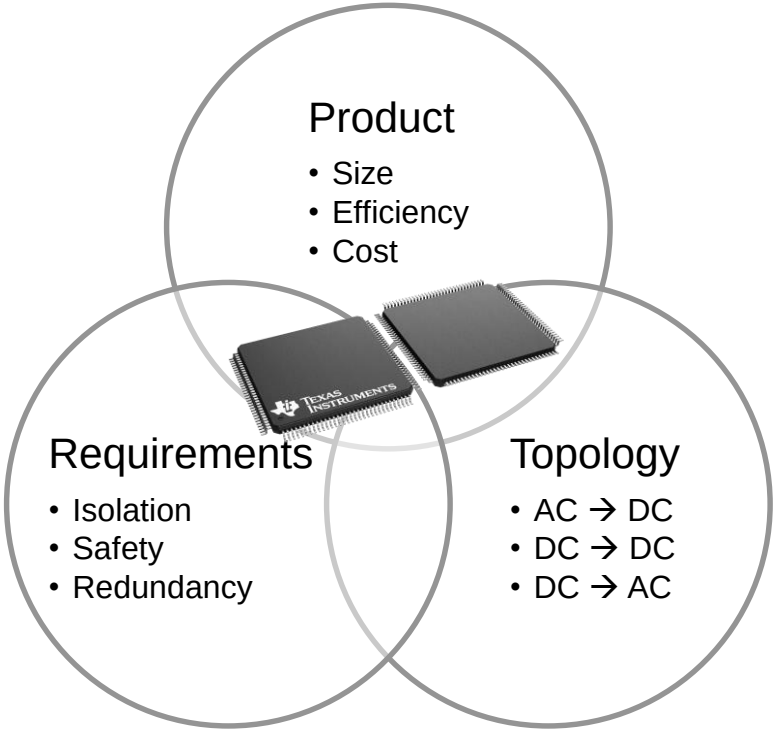


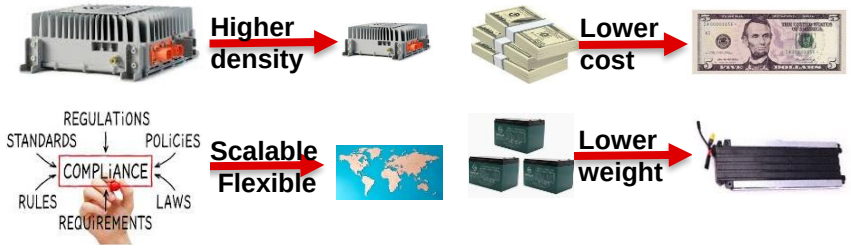
Agenda

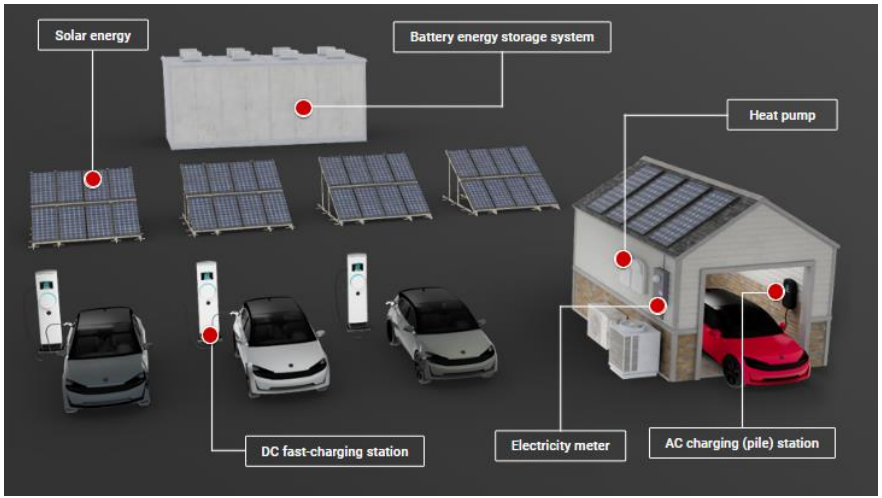
- Introduction of digital power
  - Why digital power?
  - Where do you find digital power?
- TI digital power solutions
  - TI portfolio selection guide
  - UCD3138A & C2000
    - IP & system level advantages
    - Hardware and firmware ecosystem
    - Reference design landscape
- Summary & getting started



Design challenges

- Regulatory standards
  - Safety over lifetime
    - Quality & risk control
  - Power density
    - Form factor
- Product lifecycle
  - Development time & cost
  - Modularity / reusability





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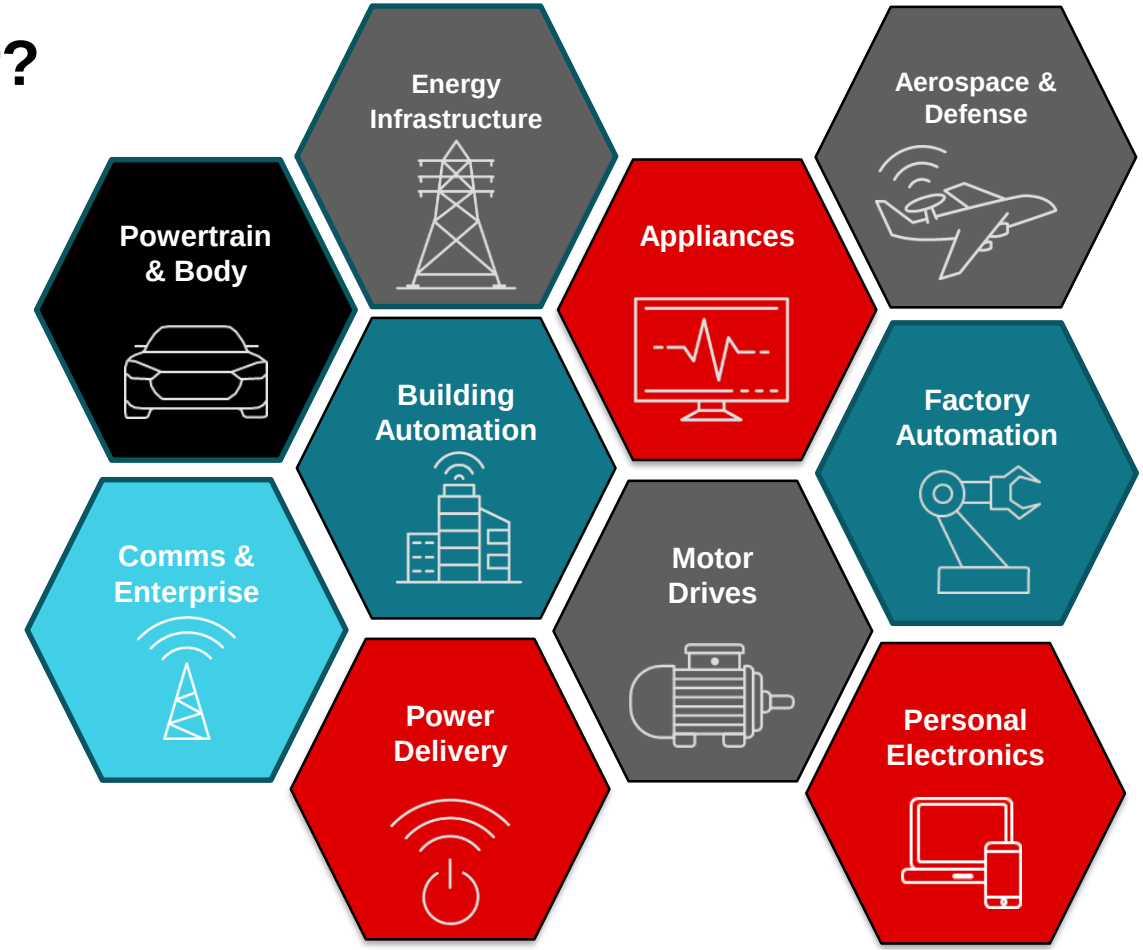
Why digital power?

Benefits of digital power

- System level integrations
  - Communications
  - Monitoring / diagnostics
  - Protection
- Flexibility
  - By topology / architecture
- Scalability
  - Across projects



TI.com/DigitalPower

TI Power Controller | Portfolio

Controller type	Fixed-function	Arm-based MCU		DSP-based (MCU)
				
Firmware required	Simplest No firmware	FW for power 1-core, 3 loops	Software defined Can have multiple cores	
Topology options	Few 1 or 2 per controller	Multiple AC→DC, DC→DC	Many Any converter or inverter	

UCD3138 | Ecosystem

Hardware

- Multiple board types available for jumpstarting development regardless of project stage

Debuggers (PMBus or JTAG)

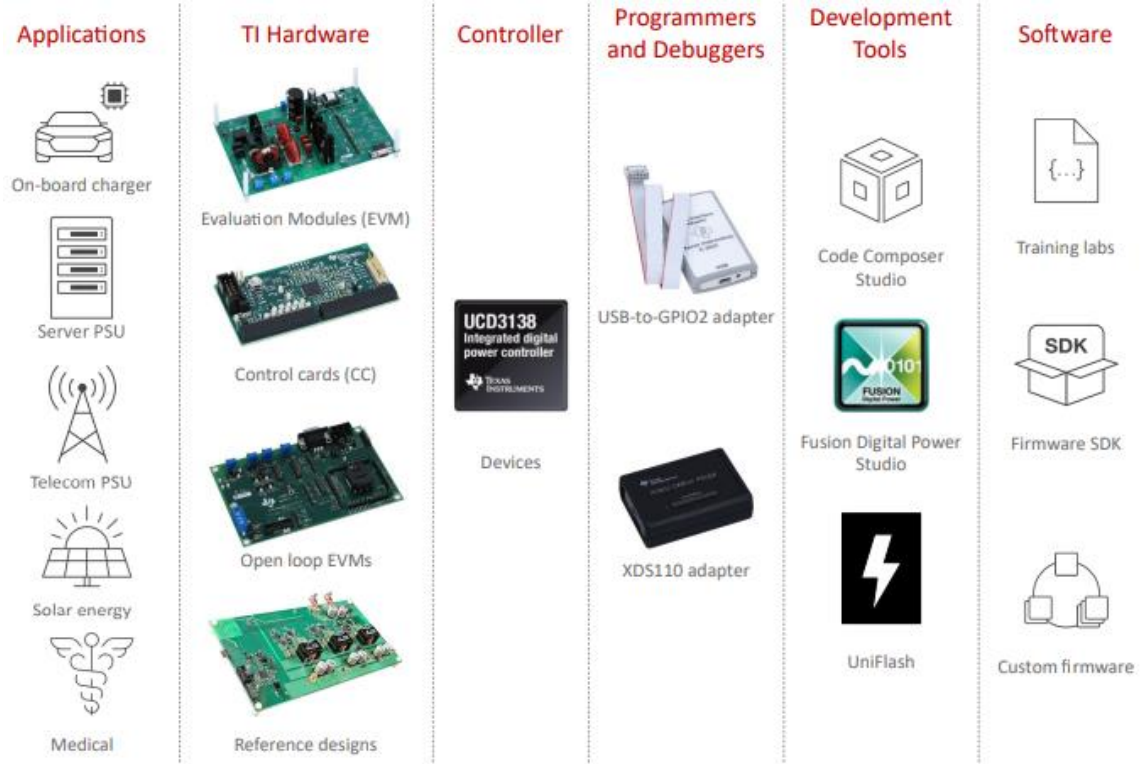
- Options available for flashing & programming in prototyping or production environment

Tools

- Development support & debugging
- Power topology control loop development

Software

- Variety of firmware pre-developed & tested for a number of power topologies and control loop architecture



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UCD3138A | Digital Power Controller

Features

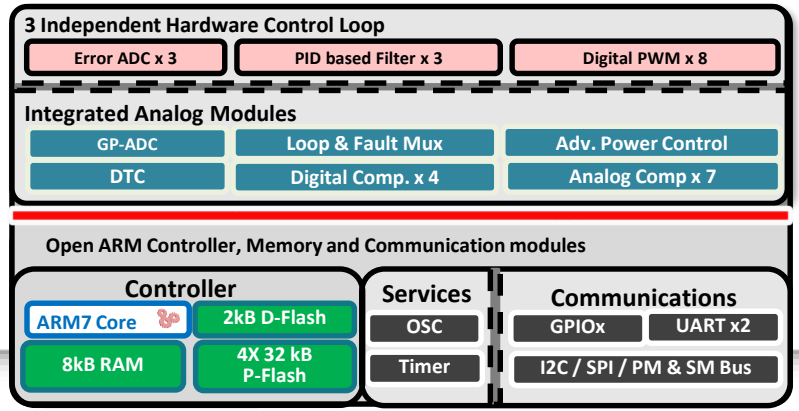
- **3 Independent hardware control loop with 450ns loop latency**
  - 16MHz Error Analog to Digital Converter (EADC)
  - 14-Bit Effective DAC with 4 Bits of dither for H/W loop ref.
  - 8 High-Resolution (250ps Pulse Width) DPWM Outputs
- Integrated analog modules
  - 14 Channel, 12-bit, 267ksps General Purpose ADC
  - **Synchronous Rectifier Dead Time Control (DTC)**
  - 7x 50ns Analog Comparators, 14x cycle-by-cycle I_{LIMIT}
  - External Interrupt + fault input & output
- Open ARM controller, memory and communication modules
  - **Live firmware update with dual bank architecture**
  - On-chip (BOD / POR), Single Supply Operation (3.3V)
  - 2 UARTs (HW Auto Baud)+ PMBus Interface

Applications

- Server PSU: Offline AC/DC and Isolated DC/DC Power Supplies
- Telecom PSU: 48Vin DC/DC Converters
- Power topologies: Totem Pole PFC, Phase Shifted Full Bridge, Two Switch Forward, Hard Switching Full Bridge, Resonant LLC

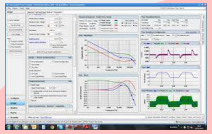
Benefits

- **Eliminates processor from power loop control for:**
  - fast transient response
  - minimized output filter
  - high-power density
- Offers best value with integrated analog modules for robust fault protection and **high precision dead time control**
- ARM7 Core with up to 128Kb flash available for housekeeping
- **Minimize power supply down time**

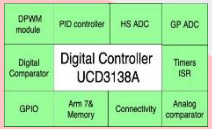


UCD3138A | Flexible ARM core with 3x independent loops, GUI configurable

- **Hardware implemented** digital power peripherals
- Faster time to market with fusion power GUI
- Enable smaller teams with few FW engineers



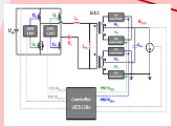
Ease of use



Best value $

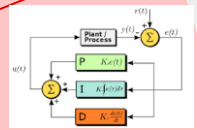
- **Optimized peripherals** for power supply applications
- Lowest footprint for highest power density
- Scalable portfolio to address wider power platforms

- 450ns of control loop execution latency
- Enables **superior transient response**
- Permits higher BW and stability margins



Best loop latency

UCD3138x
Integrated Digital Power Controller
TEXAS INSTRUMENTS

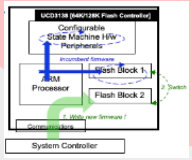


Most optimized power arch

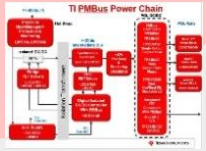
- Topology agnostic with H/W PID loop
- Support many control loop arch:
  - Voltage and peak current mode
- **Flexible and configurable power modules**

Easy live F/W update

- Seamless live FW update with **zero downtime**
- Dual memory bank architecture
- Architecture inherently support live firmware updates



ARM7 MIPS for housekeeping



- >90% Arm core MIPS usable for housekeeping
- Telemetry + multiple communication peripherals
- **Robust fault detection and event logging**

*voltage control mode
**peak current mode control

UCD3138 | Software tool workflow

1. Develop

CCS

- Quick start with base F/W codes
- Code debugging
- Compile F/W
- Generate HEX file

2. Download

Device GUI

- Code download
- F/W debug
- F/W migration with F/W reusability across devices

3. Configure

Designer GUI

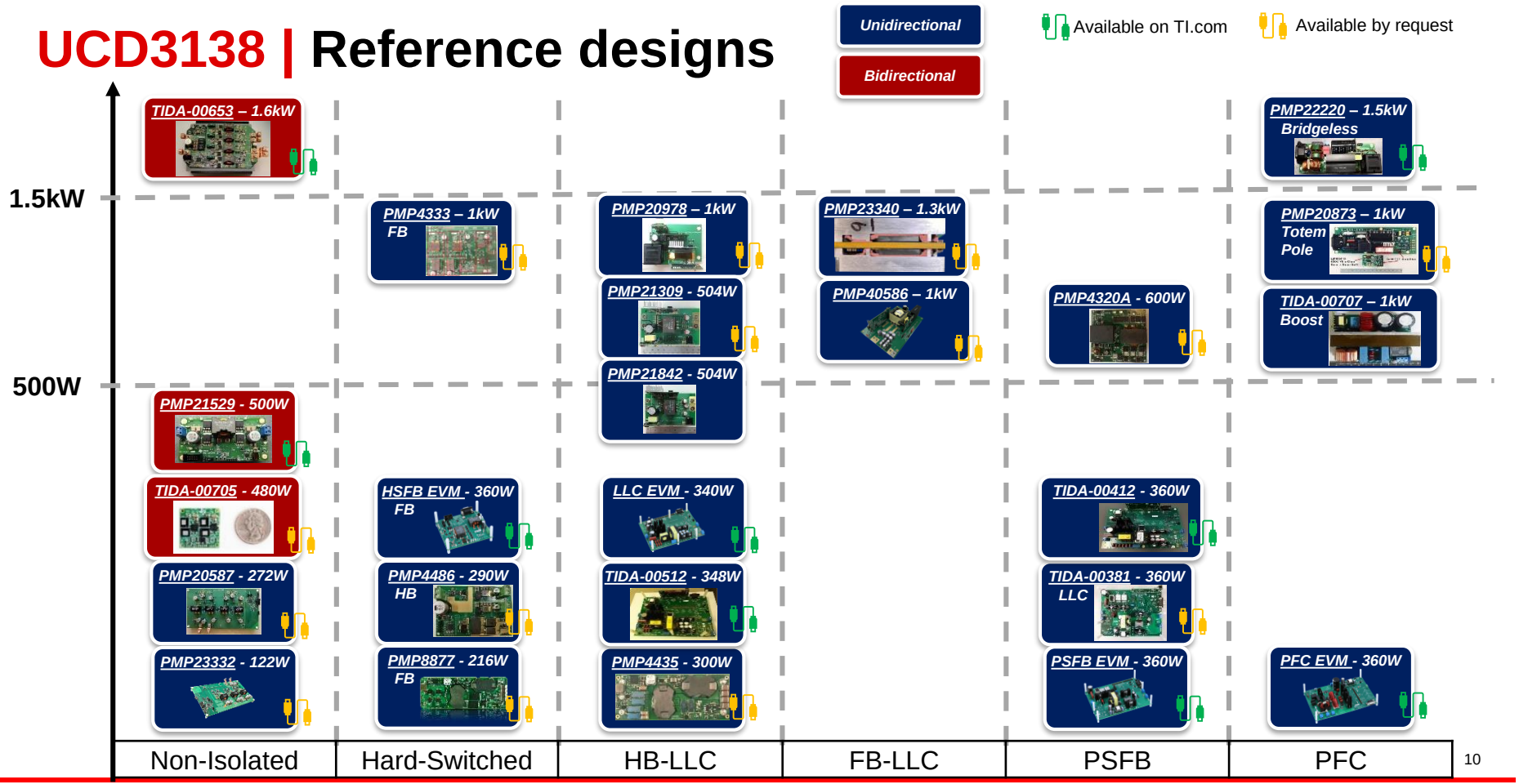
- Real time telemetry data
- Configuration of compensation loop design

4. Production

Uniflash

- Support in prod. environment
- JTAG support command line, GUI & scripting

UCD3138 | Reference designs



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Digital controller family development tools

Application EVMs

Software development kit

	PFC EVM (UCD3138PFCEVM-026)	HSFB EVM (UCD3138HSFBEVM-029)	PSFB EVM (UCD3138PSFBEVM-027)	Resonant LLC (UCD3138ALLCEVM150)	Open Loop Board (UCD3138OL40EVM-032)	Open Loop Board (UCD3138OL64EVM-031)	Open Loop Board (80 pin OL EVM)
							
Topology	• Single phase PFC, dual-phase Interleaved PFC or Bridgeless PFC	• Constant current and constant power secondary side control	High efficiency digitally controlled standalone phase shift full-bridge DC-DC power conversion	• LLC resonant half-bridge DC-DC • Supports Synchronous rectification	• Test points for easy access to all pins. • All GPIO and ADC12 pins accessible	• Test points for easy access to all pins. • All GPIO and ADC12 pins accessible	• Test points for easy access to all pins. • All GPIO and ADC12 pins accessible • SPI EEPROM
Power Rating	• 360W, 400VDC rated power • Universal input 95 – 265 VAC.	• Full-load power 360W, or full-load current 30A • DC input 36 -72Vdc	• Full-load power 360W, or full-load current 30A • DC line I/p 350 - 400Vdc	• Full-load power 340W, or full-load current 29A • DC line input from 350 to 400Vdc	N/A	N/A	N/A
Special Features	• High power factor and low iTHD (<5% @ 20% load, <2% @ 100% load) • Can achieve < 1 % power metering accuracy.	• Supports Input voltage feed forward control with constant start time. • Supports voltage mode control as well as peak current mode control	• Constant current and constant power secondary side control with constant start time.	• Burst Mode Cycle-by-Cycle current limiting with Duty Cycle Matching Protection: over voltage, over current, and brownout	• Socket for easy removal/replacement of the device • Hardware terminals: PMBus, JTAG, Logic Analyzer for easy debug	• Socket for easy removal/replacement of the device • Hardware terminals: PMBus, JTAG, UART, and Logic Analyzer to allow easy debug	• Socket for easy removal/replacement of the device • Hardware terminals: PMBus, JTAG, Logic Analyzer to allow easy debug

Where is C2000™ real-time control?

Energy Delivery

Solar Power

Charging Infrastructure

Wind Power

Digital Power

Telecom / Server
AC/DC Rectifiers

Uninterruptable
Power Supplies

DC/DC
Converters

Motor Control

Appliance

Drones

E-bike

Pumps

Industrial Drives

Robotics

Automation

Servo Drive

AC Drives

Sensors

C2000™
Real-time
Microcontrollers

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Power

Lighting

On-Board Charging

HV *DCDC*

Charging Stations

Motor

Traction Drive

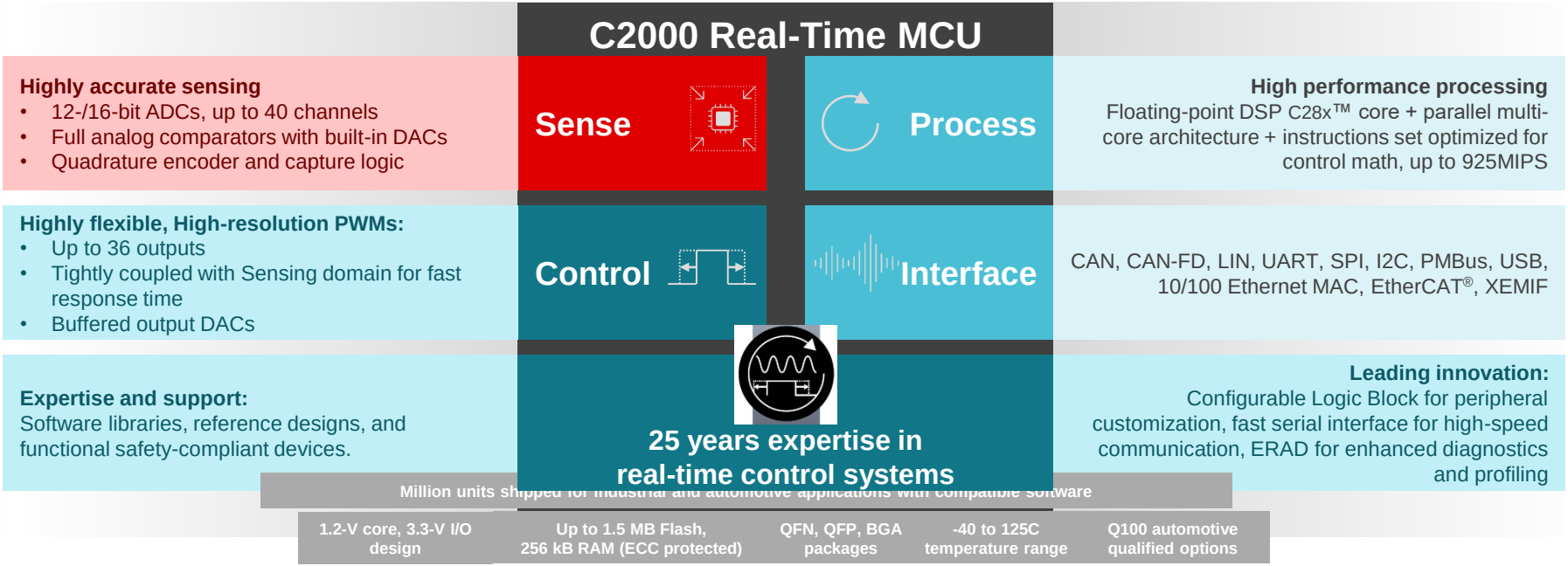
Compressors

Pumps/ Power-Steering / Fans

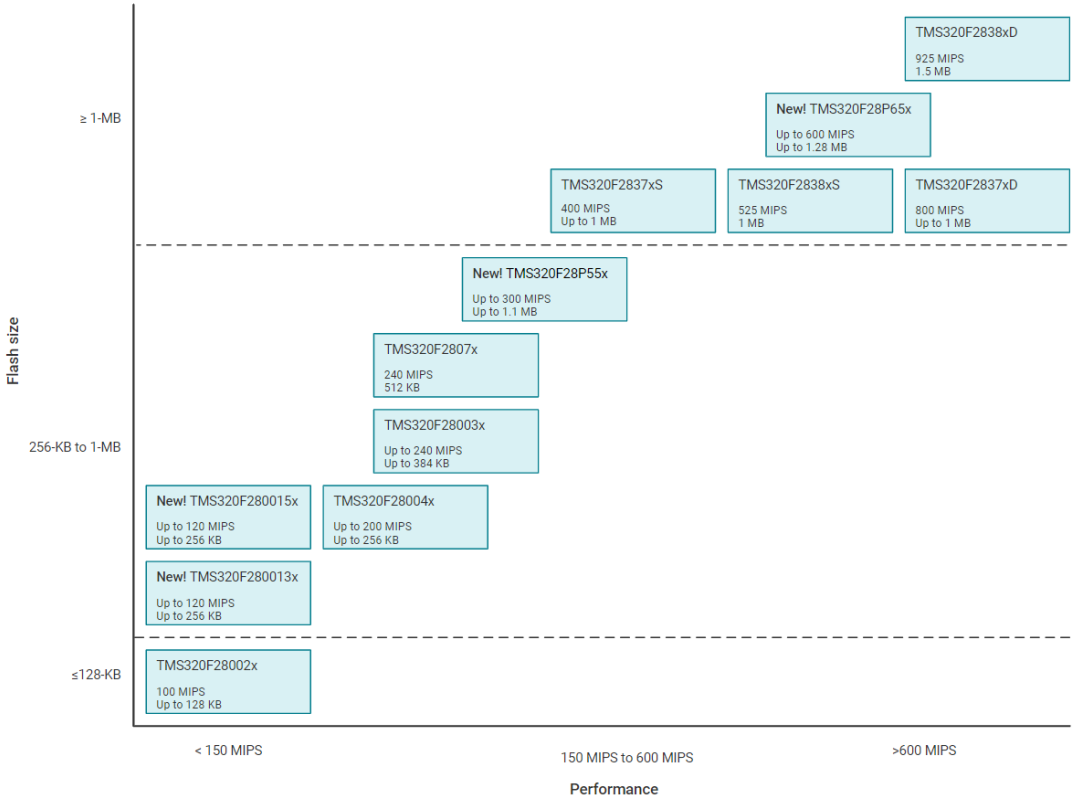
Automotive

C2000™ real-time micro-controllers overview

Scalable, **ultra-low latency**, **real-time controller** platform designed for efficiency in power electronics, such as high power density, high switching frequencies, GaN and SiC technologies



C2000 real-time MCU portfolio



Entry performance

Increase your performance with our low-cost range of devices with integrated peripherals: 150MIPS, 512-kB flash memory support and multiple packaging options.

Mid performance

Improve your design with our devices built with a rich set of integrated peripherals: 150 to 600MIPS, from 128-kB to 1.5-MB flash memory support and multiple packaging options

High performance

Built with extensive integrated peripherals, built to increase performance, 600MIPS, up to 1.5-MB flash memory support and multiple packaging options.

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Get to market fast with extensive development tools

LaunchPad

- Fun, inexpensive and powerful evaluation platform
- Ideal for getting started with real time programming on C2000
- Available on TI Store
- Supported by C2000Ware
- Code Composer Studio IDE

controlCARD

- Platform for extensive evaluation
- Typically give access to a wider range of pins and more robust than LaunchPad
- Available on TI Store
- Supported by C2000Ware, DPSDK & MCSDK
- Code Composer Studio IDE

Application kits

- BoosterPack/Launchpad, controlCARD/EVM paired kits
- Targeted towards in-depth evaluation and prototyping specific applications
- Supported by DPSDK & MCSDK
- Code Composer Studio IDE

C2000 software: Products

C2000Ware

- Peripheral drivers
- Bit-field drivers
- Communication libraries
- Compute libraries
- Examples to get started
- Tools / Utilities
- Documentation

Learn more:
http://www.ti.com/tool/C2000WARE

Motor Control SDK

- Reference for three-phase motor control application
- InstaSPIN FOC, FAST observer, Incremental and Absolute Encoders, Real-time connectivity
- Application specific Libraries and tools
- Built on top of C2000Ware

Learn more:
http://www.ti.com/tool/C2000WARE-MOTORCONTROL-SDK

Digital Power SDK

- Reference for digital power applications targeted for Solar, Industrial power, Server, EV charging
- Application specific libraries and tools
- Built on top of C2000Ware

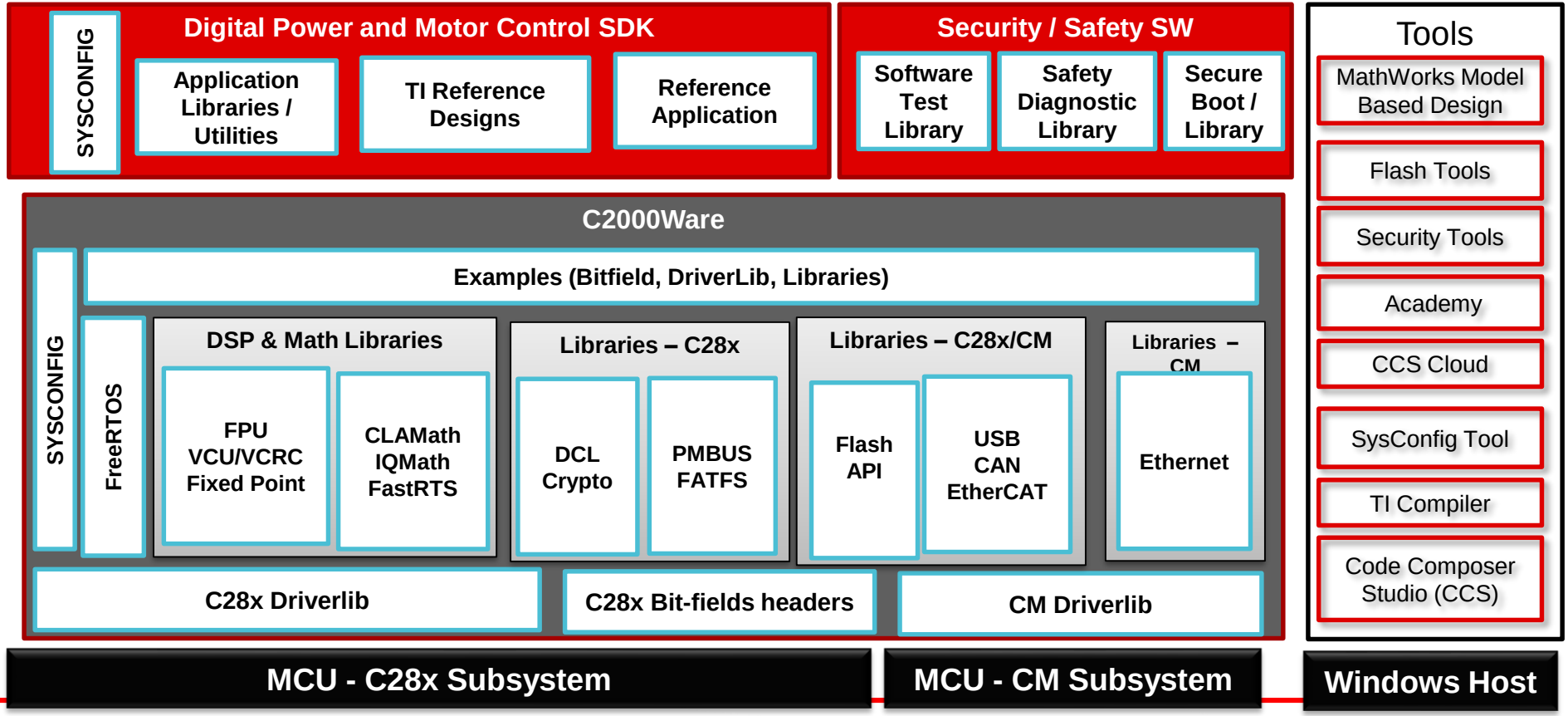
Learn more:
http://www.ti.com/tool/C2000WARE-DIGITALPOWER-SDK

Safety and Security SW

- Software Test Library for C28x and CLA – diagnostic coverage
- Safety Diagnostic Library – Reference implementation
- Secure boot
- Crypto accelerator drivers and software library

Learn more:
http://www.ti.com/tool/C2000-SAFETI-DIAGNOSTICS-LIB

Software interface: Levels



AC/DC, DC/AC, bi-directional solutions by power rating

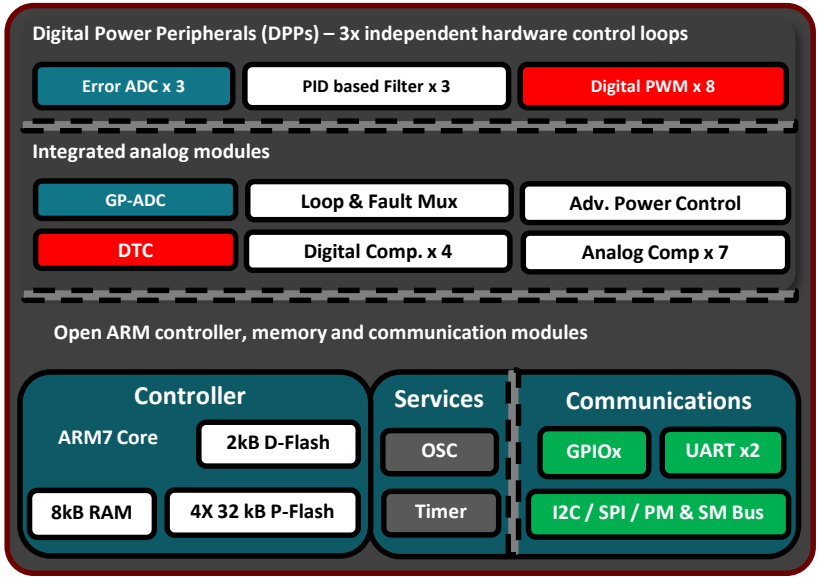
Type	Topology	TI Reference Design #	Power Rating	Input	Output	Efficiency	Supported C2000 Products
DC/AC	1Ph DC/AC	TIDM-HV-1PH-DCAC	600W	400VDC	110Vac/ 220Vac	98%	F28004x F2837x
AC/DC	2PH Interleaved PFC w/ Power Metering	TIDM-2PHILPFC	700W	110Vac/ 220Vac	400VDC	97%	F2803x
AC/DC	Valley Switching Boost PFC	TIDM-1022	750W	110Vac/ 220Vac	400VDC	92%	F28004x
AC/DC	CCM totem pole bridgeless PFC and half-bridge LLC	TIDA-010062	1kW	110Vac/ 220Vac	12VDC	99%	F28004x
AC/DC	Totem-Pole CrM PFC	TIDA-00961	1.6kW	85-265Vac	400VDC	99%	F28004x
AC/DC	Vienna Rectifier-based 3Ph PFC	TIDM-1000	2.4kW	110Vac/ 220Vac	600VDC/ 700VDC	98%	F2837x F28004x F2838x
Bi-directional AC/DC DC/AC	Bi-Directional 3Ph Interleaved Totem-Pole CCM PFC/Inverter	TIDM-02008	3.3kW	110Vac/ 220Vac	380VDC	98%	F28004x F28307x
				380VDC	120Vac/ 220Vac		
AC/DC	3Ph Interleaved Totem-Pole CCM PFC	TIDA-01604	6.6kW	110Vac/ 220Vac	400VDC	98%	F28004x
Bi-directional AC/DC DC/AC	3Ph PFC/Inverter Full-bridge	TIDA-01606	10kW	800VDC/ 1000VDC	400VAC	98%	F2837x
				400VAC	800VDC/ 1000VDC		

DC/DC, bi-directional solutions by power rating

Type	Topology	TI Reference Design #	Power Rating	Input	Output	Efficiency	Supported C2000 Products
DC/DC	Peak Current Mode Control PSFB Converter	TIDM-02000	300W	200-400VDC	12VDC	92%	F28004x
DC/DC	2Ph Interleaved LLC	TIDM-1001	500W	370-410VDC	12VDC	95%	F2837x F28002x
DC/DC	Phase Shifted Full Bridge	TIDM-PSFB-DCDC	600W	380-400VDC	12VDC	95%	F2802x
DC/DC	Bi-directional Full-Bridge Boost Converter	TIDA-00951	2kW	48VDC	400VDC	94%	F2803x
DC/DC	CLLC Resonant Dual Active Bridge (DAB)	TIDM-02002	6.6kW	400-600VDC	280-450VDC	98%	F28004x
DC/DC	Dual Active Bridge (DAB)	TIDM-010054	10kW	700-800VDC	380-500VDC	98%	F28004x
DC/AC DC/DC	EV Traction Inverter + DC/DC	TIDM-02009	10kW	400VDC	12VDC	/	F2838x
DC/DC DC/AC	Single-Phase String Inverter + ESS	TIDA-010938 NEW	7.2kW	/	/	/	F28003x
DC/DC DC/AC	Micro Inverter	TIDA-010933 NEW	1.6kW	/	/	/	F28003x

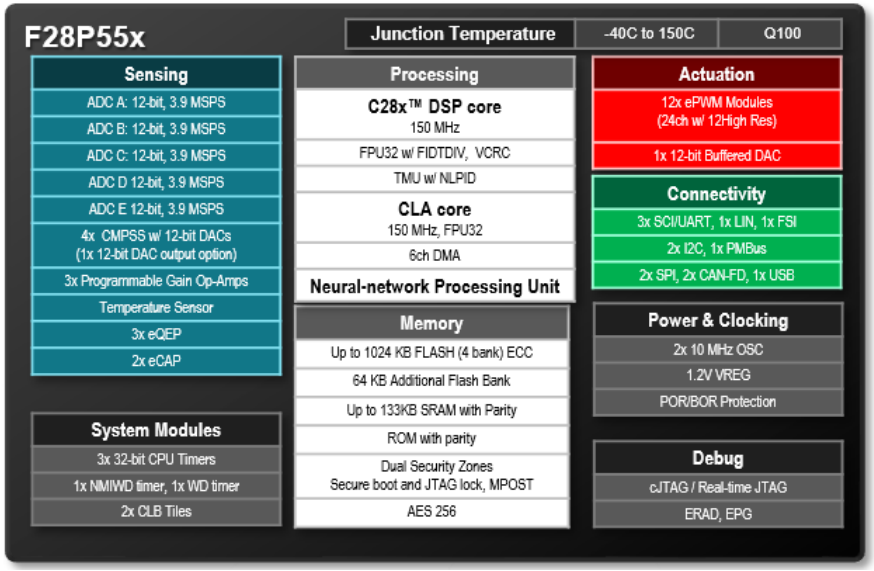
Selecting between digital power solutions

Digital Power Controller (UCD3138A)



- More flexible than analog, with programmability via GUI for reduced firmware development time
- Peripherals dedicated to and optimized for digital power

Real-time MCU (F28P55x)



- Most flexible with rich peripherals for multi-tasks
- Control multiple topologies and run complex algorithms with more processing power

Getting started with TI's digital power solutions

You can start evaluating these devices by leveraging the following:

Content Type	Title	Link
Product folder	Digital Power	Technology Page, UCD7138, F28P55x
Reference design	PMP23340 48V-12V GaN-enabled 1.1kW 1/8 brick	PMP23340UCD PMP23340C2K
Training video series	Introduction to Digital Power	Video series (UCD3138A) Video series (C2000 MCU)
White paper	How real-time control technologies enable reliable, scalable high-voltage designs	https://www.ti.com/lit/ta/ssztd36/ssztd36.pdf
Development tool or evaluation kit	Follow alongside training series EVM firmware available in one place	UCD-TRAINING-LABS UCD3138_FW_SDK C2000 Academy LAUNCHXL-F28P55X

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