New Product Update:
Latest cost-optimized C2000™ real-time MCU family: F28003x overview, offerings and more

Meghana Manavazhi, Nima Eskandari
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Agenda

• C2000 real-time MCU identity and portfolio overview
• F28003x real-time MCU family deep-dive
  – Spec
  – Strengths and target application overview
  – Scalability, compatibility, migration options
  – Getting started
  – Newly released content & collaterals
• C2000 + GAN
• Key features and new IPs on F28003x
  – Embedded Pattern Generator (EPG)
  – Configurable Logic Block (CLB)
Where is C2000™ Real-time Control?

Energy Delivery
- Solar Power
- Wind Power
- Charging Infrastructure

Digital Power
- DC/DC Converters
- Uninterruptable Power Supplies
- Telecom / Server AC/DC Rectifiers
- Power Motor

Motor Control
- Appliances
- Drones
- E-bike
- Servo Drive
- Robotics

Industrial Drives
- Pumps
- AC Drives
- Automation
- Sensors

Automotive
- Lighting
- On-Board Charging
- HV DCDC
- Charging Stations
- Traction Drive
- Compressors
- Pumps
- Power-Steering / Fans
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

**Highly accurate sensing**
- 12-/16-bit ADCs, up to 24 channels
- Full analog comparators with built in DACs
- Quadrature Encoders and Capture Logic

**Highly flexible, high-resolution PWMs:**
- Up to 32 outputs
- Tightly coupled with sensing domain for fast response time
- Buffered Output DACs

**Expertise and support:**

**C2000 Real-Time MCUs**

- Sense
- Process
- Control
- Interface

**High performance processing**
Floating-point DSP C28x™ core + parallel multi-core architecture + instructions set optimized for control math, Up to 925 MIPs

**Can, CAN-FD, LIN, FSI, UART, SPI, I2C, PMBus, USB, 10/100 Ethernet MAC, EtherCAT®, EMIF**

**Innovative features:**
Configurable Logic Block for peripheral customization, Fast Serial Interface for high-speed communication, ERAD for enhanced diagnostics and profiling

**25 years expertise in real-time control systems**

- 1.2-V core, 3.3-V I/O design
- Up to 1.5 MB Flash, 256 kB RAM (ECC protected)
- QFN, QFP, BGA packages
- -40 to 125°C temperature range
- Q100 automotive qualified options

- Billions of units shipped for industrial and automotive applications with compatible software
- Multi-source FAB strategy for safe supply and future expansion
- High quality silicon being used by thousands of customers worldwide
New F28003x: Expanding the C2000 Real-Time Microcontrollers Portfolio

High-Performance
above 600 MIPS for real-time control performance

F2837xD
800 MIPS
1 MB

F2838xD
125 MIPS
1.5 MB

Mid-Performance
150 to 600 MIPS for real-time control performance

F2837xS
400 MIPS
1 MB

F2838xS
525 MIPS
1.5 MB

Entry-Performance
up to 150 MIPS for real-time control performance

F2806x
180 MIPS
256 k

F2807x
240 MIPS
512 k

F2804x
200 MIPS
512 k

F28002x
130 MIPS
128 k

F28003x
240 MIPS
304 k

Performance + Integration + Cost

Future expansions reduce cost

Code & peripheral compatible

Generation 2

Generation 3

REAL-TIME CONTROL WITHOUT COMPROMISE

Push the limits in power density and efficiency with new C2000 real-time MCUs

Discover more
C2000™ F28003x

**Launch complete!**

Production: Starting Mar-2022

http://www.ti.com/product/TMS320F280039C

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**Differentiation**

<table>
<thead>
<tr>
<th>Cost-Optimized Mid Performance C2000</th>
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<tbody>
<tr>
<td><strong>Improved performance</strong></td>
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<tr>
<td>• 120 MHz with CLA option</td>
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<tr>
<td>• 240 MIPS DSP Processing Power</td>
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<tr>
<td>• 384kB Flash and 69kB RAM</td>
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<tr>
<td>• Better ADC Performance - Effective throughput</td>
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</table>

<table>
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<tr>
<th>Advanced actuation and design flexibility</th>
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<tbody>
<tr>
<td>• Premium Type 4 ePWM modules with more instances and channels</td>
</tr>
</tbody>
</table>

**Premium analog**

| 8 Sigma Delta Decimation Filters (with separate Data and Comparator filters) |
| 2 * Buffered DAC 12-bit , 3* 12 bit ADC @ 4MSPS |

**Rich digital options**

| CAN-FD, 4 * CLB tiles, flexible standard interfaces |

**Safety**

| ASIL-B/ SIL-2 safety enablers |

**Security**

| AES, JTAG Lock & Secure boot |

**Perfect portfolio**

| Pin-pin to F28002x 64-pin (non-Q) and 80-pin(non-Q) and almost compatible to 48-pin and 64-pin (Q) |
| 100-pin option |

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**Software**

- C2000Ware™ Software Package
- Application SDKs

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**Package**

- 48-pin LOFP: 9 x 9 mm
- 64-pin LOFP: 12 x 12 mm
- 80-pin LOFP: 14 x 14 mm
- 100-pin LOFP: 16 x 16 mm

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**Functional Safety Compliant Product**

<table>
<thead>
<tr>
<th>Target Systematic Capability</th>
<th>ASIL-D/SIL-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Diagnostic Coverage (DC)</td>
<td>ASIL-B/SIL-2</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Temperature</th>
</tr>
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<tbody>
<tr>
<td>125C</td>
</tr>
<tr>
<td>Q100</td>
</tr>
</tbody>
</table>

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**Processing**

- C28x™ DSP core
- 120 MHz
- FPU, FastDIV, VCRC
- TMU + NLPID

**Actuation**

- 8x ePWM Modules
- 10x Outputs (4x High-Res)
- Fault Trip Zones
- 2 x 12-bit Buffered DAC |

**Connectivity**

- 2x SCI, 2x LIN/SCI
- 2x I2C, 1x PMBus
- 2x SPI, 1x FSI-TX , 1x FSI-RX
- 1x CAN-FD, 1 CAN 2.0B

**Power & Clocking**

- 2x 10 MHz OSC
- 1.2V VREG
- POR/BOR Protection

**Debug**

- cJTAG / Real-time JTAG
- ERAD

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**System Modules**

| 3x 32-bit CPU Timers |
| NMI Watchdog Timer |
| 192 Interrupt PIE |

**Configurable Logic Block**

| 4 Tiles |

**Memory**

| 384 kB FLASH (3 bank) + ECC |
| 69 kB SRAM + ECC |
| ROM with parity |
| Dual Security Zones |
| Secure boot and JTAG lock |
| AES |
| Host Interface Controller (HIC) |

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**Sensing**

| ADC1: 12-bit, 4 MSPS, |
| ADC2: 12-bit, 4 MSPS |
| ADC3: 12-bit, 4 MSPS |
| 4x CMPSS: 12-bit DAC |
| 8 COMP, 8 digital filters |
| 8x Sigma Delta Channels (2x Filters per ch) |
| Temperature Sensor |
| 2x eCAP |
| 3x eCAP, 1x HRCAP |

**Actuation**

| 64 DWA |
| BGCRC & HMBIST |

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**Temperature**

| 125°C |

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| 100°C |

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Tools

- Experimenter’s Kit
  - Part Number: TMDSNCD280039C
  - https://www.ti.com/tool/TMDSCNCD280039C
- LaunchPad
  - Part Number: LAUNCHXL-F280039C, 2Q22
F28003x strengths

85% Improvement With TMU

- Quality MIPS Processing
  - Floating point (32b/64b) DSP math
  - Control Law accelerator (Background loop)
  - Trigonometric Math Unit (TMU)
  - Viterbi Complex math & CRC Unit (VCU)
  - CPU+CLA pairs & multi-loops in parallel
  - Predictable shortest latency

- Robust Connectivity
  - Fast Serial interface (FSI), for reliable & high speed connection
  - CAN-FD for automotive and industrial

- Safety
  - ECC memory, Redundancy, ASIL-B, SIL-2 Safety, HWBIST

- Security
  - DCSM, Secure Boot, JTAG Lock, AES256

- Configurable Logic Block (CLB):
  - Custom logic building including state-machines, sequencers, counters to replace FPGA

- Fast & Precise Sensing
  - 12b ADC, post processing, early interrupt
  - Autonomous triggering & trip operation
  - Fast comparator (< 50ns), Windowed Comp
  - O/P filtering & blanking; Peak Current Mode Control
  - Simultaneous ADC-Comp
  - Fault protection with Comp Trip
  - Integrated Sigma Delta Filters

- Shortest Predictable latency system arch.
  - Optimal latency architecture for peripherals & memories
  - Highly interconnected trip-trigger circuits

- Flexible & high resolution actuation
  - High resolution duty, phase, dead-band, period control
  - Flexible Action Qual., Trip-zone config.
  - Shadow registers, one shot or global loading
  - PWM phase, timer Synchronization
  - Cycle by cycle trip, One shot trip
  - Advanced protection and control

- Package and Pin Scalability
  - More packages and small footprint
  - ~35% more number of GPIOs and analog function vs previous devices

- More system flexibility
  - Live Firmware update with no reset
  - Fast 169ms flash bank erase time @ 20k cycles (~10 times better than prior devices)
  - Reliable High-speed comms with ~1.5% internal clock accuracy
Applications: F28003x + F28003x-Q1 real-time MCUs a good fit
just some key EEs, not limited to this list

<table>
<thead>
<tr>
<th>INDUSTRIAL</th>
<th>AUTOMOTIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial HVAC</td>
<td>Automotive lighting (headlight, rear light)</td>
</tr>
<tr>
<td>Industrial drives</td>
<td>Heating &amp; Cooling (eCompressor, HVAC compressor)</td>
</tr>
<tr>
<td>Server + telecom power</td>
<td>EV/HEV on-board charging and DC/DC converters</td>
</tr>
<tr>
<td>Solar inverters</td>
<td>Traction Inverter</td>
</tr>
<tr>
<td></td>
<td>Pumps, blowers, fans</td>
</tr>
</tbody>
</table>

Industrial drives: Motor drives for various applications requiring precise control and high efficiency. They are often used in applications such as lifts, pumps, and other machinery where smooth and efficient operation is critical.

Solar inverters: Convert the direct current (DC) generated by solar panels to alternating current (AC) that can be used in homes and businesses. They play a crucial role in the integration of renewable energy into the grid.

Server + telecom power: These devices are essential for data centers and telecommunications infrastructure, providing reliable power and protection for critical systems.

Commercial HVAC: HVAC systems are used to control the temperature, humidity, and air quality in commercial and industrial buildings, ensuring comfort and efficiency.

EV/HEV: Electric and hybrid vehicles require specific power management systems, including on-board chargers and DC/DC converters, to optimize battery usage and efficiency.

Heating & Cooling: HVAC systems are crucial for maintaining comfortable indoor environments in buildings, including homes, offices, and commercial spaces.

Traction Inverter: Used in electric vehicles to convert DC power from the battery into AC power for the electric motor, enabling efficient power delivery and control.

Pumps, blowers, fans: These devices are fundamental in various applications, from industrial processes to residential ventilation and air conditioning systems, providing necessary fluid or gas movement.
Feature comparison between closest Generation 3 devices: F28002x/3x/4x

<table>
<thead>
<tr>
<th>Feature</th>
<th>F28004x</th>
<th>F28002x</th>
<th>F28003x</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU (MHz)</td>
<td>100</td>
<td>100</td>
<td>120</td>
</tr>
<tr>
<td>FPU32</td>
<td>Yes</td>
<td>Yes + FastDIV</td>
<td>YES + FastDIV</td>
</tr>
<tr>
<td>TMU32</td>
<td>Type 0</td>
<td>Type 1</td>
<td>Type 1</td>
</tr>
<tr>
<td>CLA</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>DMA</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CLB</td>
<td>4 tiles</td>
<td>2 tiles</td>
<td>4 tiles</td>
</tr>
<tr>
<td>Flash (KB)</td>
<td>256</td>
<td>128</td>
<td>384</td>
</tr>
<tr>
<td>JTAG Lock</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>RAM (KB)</td>
<td>100.5</td>
<td>24</td>
<td>69</td>
</tr>
<tr>
<td>ADC</td>
<td>3 × 12-bit</td>
<td>2 × 12-bit</td>
<td>3 × 12-bit</td>
</tr>
<tr>
<td>ADC channels (Max)</td>
<td>21</td>
<td>16</td>
<td>23</td>
</tr>
<tr>
<td>CMPSS</td>
<td>7</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>CAN (DCAN)-Type 0</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>CANFD (MCAN)-Type 2</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>FSI</td>
<td>1 (1 RX and 1 TX)</td>
<td>1 (1 RX and 1 TX)</td>
<td>1 (1 RX and 1 TX)</td>
</tr>
<tr>
<td>I^2C Type 1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>LIN Type 1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>HIC</td>
<td>0</td>
<td>Type 0*</td>
<td>Type 1*</td>
</tr>
<tr>
<td>SCI</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>eCAP/HRCAP modules</td>
<td>7 (2 with HRCAP capability) – Type 1*</td>
<td>3 (1 with HRCAP capability) – Type 2*</td>
<td>3 (1 with HRCAP capability) Type 3*</td>
</tr>
<tr>
<td>ePWM/HRPWM Type 4</td>
<td>16 (16 with HRPWM)</td>
<td>14 (8 with HRPWM)</td>
<td>16 (8 with HRPWM)</td>
</tr>
</tbody>
</table>
Easy Hardware and Software migration between the F28002x, F28003x and F28004x device families

For more details about migration, download the migration guides for F28002x to F28003x and F28004x to F28003x.

Pin to pin and SW compatibility across F28002x/ F28003x/ F28004x on the 64-pin package!
F28003x Getting Started

• **F28003x brief (1-pager/brochure)** – Brief on the device…. 1 stop shop to immediate F28003x information – what the device offers, block diagram, device configurations, comparisons with prior devices, migration & more….

• **How to find on TI.com**
  – [TMS320F280039C product page](https://www.ti.com/product/TMS320F280039C#order-quality) – includes access to datasheet, technical reference manual, spec table, etc
  – Order samples:
    • 64,80,100 pin: [https://www.ti.com/product/TMS320F280039C#order-quality](https://www.ti.com/product/TMS320F280039C#order-quality)
    • 48 pin: [https://www.ti.com/product/TMS320F280037C#order-quality](https://www.ti.com/product/TMS320F280037C#order-quality)
  – HW / EVMs – [TMS320F28003x controlCARDS product page](https://www.ti.com/product/TMS320F28003x#order-quality)
  – SW (SDKs include the new device projects + features for new designs)
    • [C2000Ware](https://www.ti.com/product/TMS320F28003x#order-quality) (Version: 4.00.00.00)
    • [Digital Power SDK](https://www.ti.com/product/TMS320F28003x#order-quality) (Planned for Dec 2021)
    • [Motor Control SDK](https://www.ti.com/product/TMS320F28003x#order-quality) (Planned for Dec 2021)
Newly released content & collaterals

- **C2000 Academy** integrates the rich history of the C2000 hands-on workshops into TI Resource Explorer for an easy to use customer self-paced learning experience

- **Speed Up Development With C2000™ Real-Time MCUs Using SysConfig**: shows how the SysConfig graphical user interface (GUI) tool is developed to facilitate the development process for designers.

- **C2000 SysConfig** For developers getting started, having technical questions and needing guidance

- **Designing With the C2000™ Embedded Pattern Generator (EPG)**: New peripheral on F28003x

- **Getting Started with the MCAN (CAN FD) Module**: Now also on the mid performance F28003x

- **Reduce EV cost and improve drive range by integrating powertrain systems**: Revamped technical article on how F28003x can help designers achieve various discrete and integrated powertrain topologies

- **Bring performance, integration and cost savings to your server power-supply design with a real-time MCU**: New technical article showcasing how F28003x can be a good fit for Industrial system applications

- Technical **introductory overview video** on the C2000 embedded pattern generator or EPG.

- **Real-Time Control Pocket Reference Guide**: valuable quick guide for often used system-level design formulae and real-time control concepts in order to help facilitate real-time control application design
**GaN + C2000: Maximize Power Density and Efficiency**

**TI GaN:**
- 10x higher switching frequency + reduction of losses
- 5x reduction in magnetics
- Seamless interfacing + design scalability

**C2000:**
- Flexible high-resolution PWM generation and premium analog to digital conversion
- Processing performance for highest possible control loop frequencies: CPU/FPU/TMU + tight coupling of core peripherals
- Quick prototyping with Reference designs + C2000 scalable platform

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**SiC PFC**

Full system: 15 W/in³

**GaN + C2000 PFC**

3x Higher Density

Full system: 41 W/in³

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**TIDA-010062 GaN, C2000 Parts**
LMG3410, TMS320F280049
(*TMS320F280039 planned)*
Embedded Pattern Generator (EPG)
Embedded Pattern Generator

- The Embedded Pattern Generator (EPG) module is a customizable pattern and clock generator.
- EPG could serve many test and application scenarios that require:
  - Simple pattern generators
  - Periodic clock generators
- The EPG module can also be used to capture an incoming serial stream of data.

**EPG**

**SIGGENx**
- Pattern Data: 0b001101

**CLKGENx**
- Period: 1 µs, Offset: 0 µs
EPG Use-Cases

- **Clock generation:**
  - Independent clock generation and clock division
  - Synchronous clock generation with programmable offsets

- **Pattern generation:**
  - Independent serial data stream generation
  - Serial data stream and the associated clock generation
  - Ability to skew clock with respect to serial data
  - Synchronous data stream with programmable offset with respect to one another
EPG Use-Cases

If needed, EPG can be used to design:

• Additional simple PWM generator
  
  **NOTE:** This will not include shadowing, or any other advanced EPWM features

• Additional clock generator
  – Simple periodic clock generation with duty/period control

• Additional serial communication peripheral
  – SPI controllers can be designed using EPG to capture incoming streams, generate output data and serial clock

  **NOTE:** The controller will not have FIFOs or other advanced SPI features

• Generating test data patterns for internal testing of our peripherals
EPG Connections

• The following can be used as input signals to the EPG:
  – Input XBARs
  – Signals from the internal connections of other peripheral
    **NOTE**: Table available in TRM

• The following resources can be used to output the EPG signals:
  – Output XBARs
  – Signals from the output connections of other peripheral
    **NOTE**: Table available in TRM
EPG Collateral and Example Release

• Technical Reference Manual (F28003x)
• Driverlib API in C2000Ware
• Video Overview: https://training.ti.com/c2000-embedded-pattern-generator

• Application Report:
  – Designing With the C2000™ Embedded Pattern Generator (EPG)
    Step by step guide on how to use the EPG to generate clocks and serial data streams
    This include generating SPI controller data and clock in all 4 SPI modes

• Examples in C2000Ware:
  – Ex1: Very simple periodic clock generator
  – Ex7: Generate two offset clocks (using CLKGEN module)
  – Ex8: Generate two offset clocks (using SIGGEN module)
  – Ex9: Generate SPI transmitter CLK and DATA signals in all 4 POL-PHA modes
  – Ex10: Same as Ex9 but showcasing the design differences between SHIFT and ROTATE modes
Configurable Logic Block (CLB)
**Integrate** custom logic and **Augment** peripheral capability in your real-time MCU applications

Customized logic is usually done in a system by adding FPGAs, CPLDs, or external logic. These systems almost always still include a traditional microcontroller as well.

C2000 Configurable Logic Block (CLB) enables customization in a microcontroller based real-time control system while eliminating or reducing the size of the FPGA, CPLD, or external logic.
Common Usages of CLB

• Replace external hardware (CPLD, FPGA, etc.)
• Customize existing peripherals inside the device (EPWM, EQEP, ECAP, etc.)
  – Insert logic before, after, or even inside of a peripheral
• Design new peripherals inside the device
Replacing CPLD/FPGA, ASICs

- Reduces system cost
- Improves system performance

- Applications which require external FPGAs/CPLDs along with C2000™ Real-Time Controller → Potential replacement with CLB
- Reduces feedback latency thus improving control loop time
- Reduces the cost and board area by removing external devices like FPGAs or ASICs
Insert Custom Logic Inside Existing Peripherals

Without CLB

- ePWMxA_DB
- ePWMxB_DB

With CLB

- ePWMxA_DB
- ePWMxB_DB

Other Signals
Design New Peripherals

- Insert CLB inside a peripheral
  - Override internal peripheral signals using CLB outputs
- GPIO to CLB to GPIO
  - Design new peripherals inside the Real-Time controller
- Precondition signals before entering a peripheral
- Add logic before sending signals outside of the chip
  - Replace CPLD/FPGA
How do you configure the CLB?

- CLB Tool is a Code Composer Studio (CCS) **SysConfig** plug-in
  - **C2000 SysConfig GUI Tool**
- GUI based tool to configure and program each CLB tile
- Simulation and Visualization tool to verify logic
- Feature Examples in **C2000Ware** and System examples in application Software Development Kits
CLB Tool

GUI tool to configure the CLB peripheral
Resources

• C2000Ware including the CLB Tool User’s Guide [SPRUIR8]
• Application Note: How to Design with the CLB [SPRACL3]
• Application Note: How to Migrate from FPGA/CPLD to CLB [SPRACO2]
• Video Training Series
  – Technical CLB Presentation
    • https://training.ti.com/enable-differentiation-configurable-logic-various-automotive-applications
  – Configurable Logic Block (CLB) introduction
  – CLB architecture
    • https://training.ti.com/c2000-configurable-logic-block-clb-architecture
  – CLB Programming Tool
Visit [www.ti.com/npu](http://www.ti.com/npu)

For more information on the New Product Update series, calendar and archived recordings
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