Getting Started Guide

Getting Started With C2000™ Real-Time Control Microcontrollers (MCUs)

TEXAS INSTRUMENTS

ABSTRACT

This guide is a valuable reference that contains all of the necessary information to get started with C2000™ real-time Microcontrollers (MCUs). This guide covers all aspects of development with C2000 devices from hardware to support resources. In addition to key reference documents, each section provides relevant links and resources to further expand on the information covered.

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1 Introduction

C2000 real-time MCUs are a portfolio of high-performance microcontrollers that are purpose-built to control power electronics and provide advanced digital signal processing for industrial and automotive applications. With more than 25 years of experience in developing microcontrollers optimized for real-time control, C2000 enables engineers to create the world's most efficient power conversion and motor drive solutions.

C2000's product selection spans more than 100 devices to meet all levels of requirements. The available software packages make it easy for anyone to start their own software development. In addition, the reference designs and application kits enable highly optimized application specific solutions. This getting started guide is intended to provide all of the needed resources to take advantage of these resources and start development with C2000.

For a deeper look and understanding into the components that differentiate C2000 real-time microcontrollers as it pertains to Real-Time Control Systems, see the *The Essential Guide for Developing with C2000 Real-Time Microcontrollers* [Chinese].

2 Ecosystem

C2000's ecosystem is composed of various applications, products, hardware platforms, development tools, and software development kits. For more information on the specific sections of this ecosystem, see the respective chapters within this document. For general information about C2000, visit the C2000's overview page.
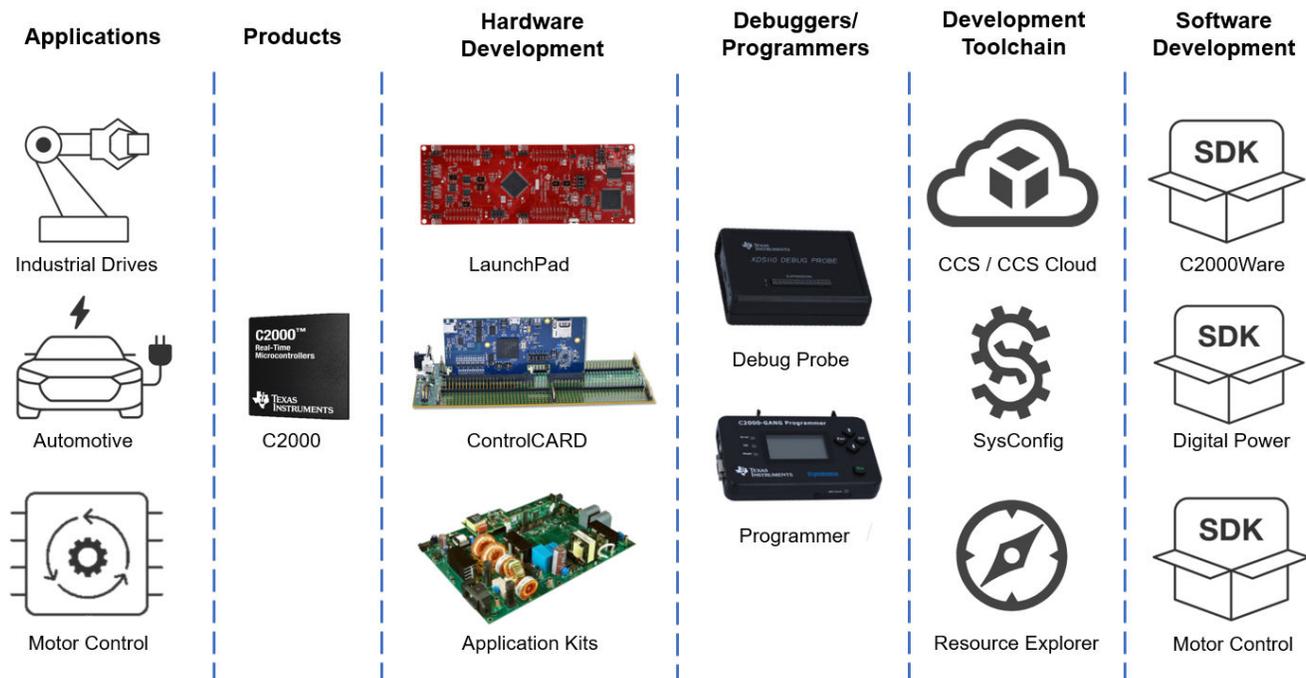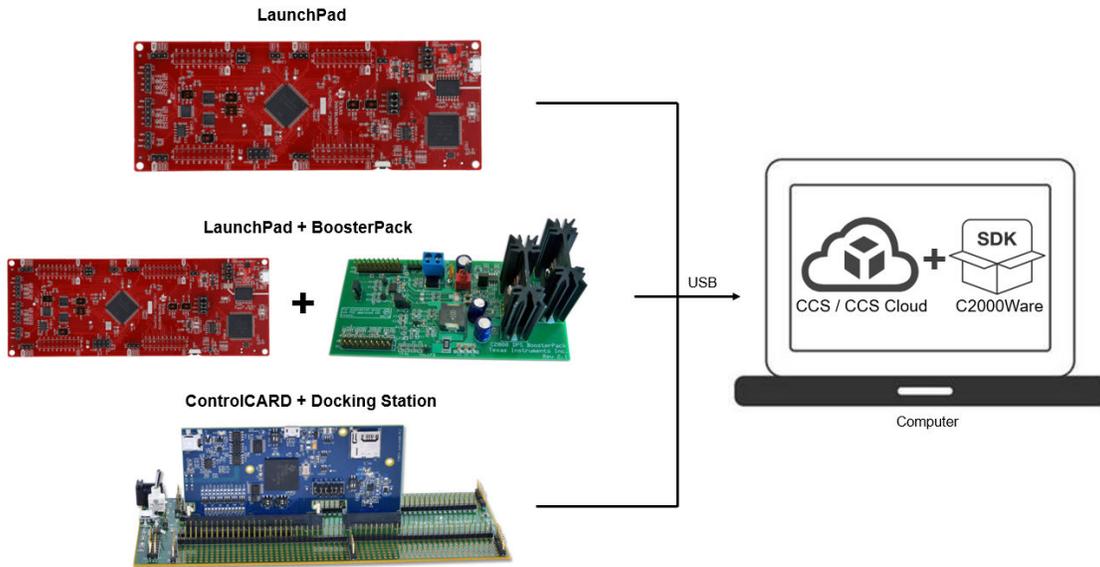

Figure 2-1. C2000 Ecosystem Diagram

The following sections discuss simplified ecosystem maps based on the familiarity level with C2000.

2.1 Entry Level

If you are new to C2000 and wanting to explore device capabilities and features then the best options to start with are any of the three low cost development platforms that would include a LaunchPad, LaunchPad + BoosterPack, or ControlCard + Docking Station. This will be coupled with Code Composer Studio (CCS) and the C2000Ware software development kit.

Figure 2-2. C2000 Entry Level Ecosystem Diagram

2.2 Intermediate Level

For those new to C2000, but exploring application specific development the best place to begin is with Section 3.5. These kits are categorized by power conversion and motor drive applications. Each category of application kits has its own software development kit (SDK), Digital Power SDK and Motor Control SDK, respectfully. These SDKs provide example code for each of the application kits enabling easy integration between hardware and software.
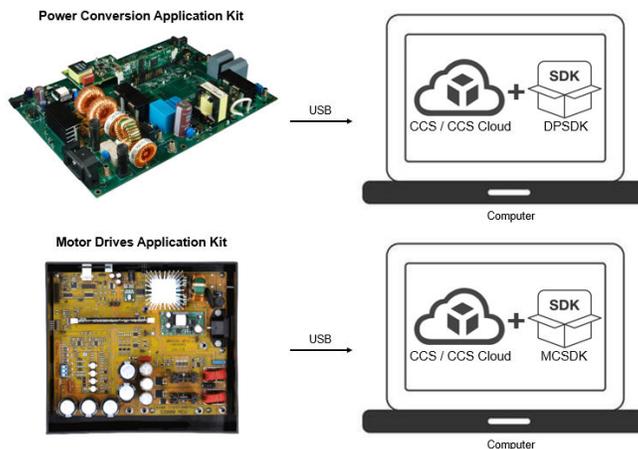
Figure 2-3. C2000 Intermediate Level Ecosystem Diagram

2.3 Advanced Level

If you are experienced with C2000 development, and are interested in implementing a specific system (see Section 3.7) then start with Section 3.6. These designs include all of the required files to jump start your development.
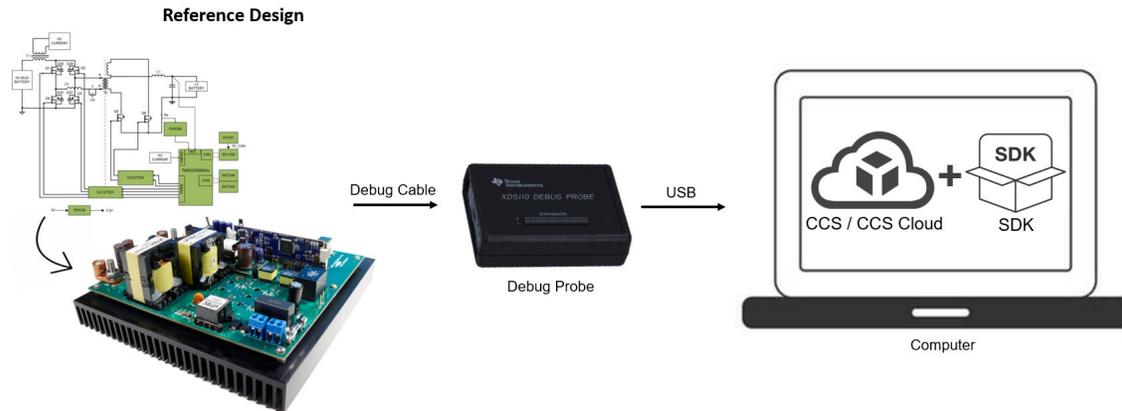
Figure 2-4. C2000 Advanced Level Ecosystem Diagram

3 Hardware Development

This section will help you understand C2000's entire hardware offering and how to get started with hardware development.

3.1 LaunchPad

LaunchPads are low-cost development boards for C2000 real-time microcontrollers series of devices. Ideal for initial evaluation and prototyping, it provides a standardized and easy-to-use platform to develop an application.

For more information on available LaunchPads, see the LaunchPad development kits section of C2000's design and development page. Each LaunchPad comes with getting started materials that showcase how to setup your environment. LaunchPads also come with an onboard deug probe that allows for real-time debug and flash programming.

3.2 BoosterPack

BoosterPacks are pluggable add-on boards for the LaunchPad ecosystem that follow a pin-out standard created by Texas Instruments. The TI and third-party ecosystem of BoosterPacks greatly expands the peripherals and potential applications that you can explore with our various LaunchPads.

For a complete list of TI's BoosterPacks, see the BoosterPack Checker. To filter for just C2000, select C2000 from the category field.

To find the LaunchPads that are supported for each BoosterPack, see the 'Supported products' tab on the BoosterPack's page within TI.com.

3.3 ControlCARD

ControlCARDs are ideal to use for initial evaluation and system prototyping. controlCARDs are complete board-level modules that utilize one of two standard form factors (100-pin DIMM or 180-pin HSEC) to provide a low-profile single-board controller solution.

ControlCARDs require either a Docking Station, baseboard that powers the controlCARD and has a bread-board area for prototyping with an adequate DIMM or HSEC connection, or a compatible kit. For a complete package option, see Section 3.4 and Section 3.5.

For more information on available ControlCARDs, see the ControlCARD section within C2000's design and development page. Each ControlCARD's page contains all relevant documentation to help you get started on your development.

3.4 Experimenter Kit

Experimenter kits contain both a controlCARD and corresponding Docking Station (100-pin DIMM or 180-pin HSEC). The Docking Station provides power to the controlCARD and has a bread-board area for prototyping. Access to the key device signals are available using a series of header pins.

To find more information about available experimenter kits, see the controlCARD + baseboard section of controlCARDS within C2000's design and development page.

3.5 Application Kit

Applications can be evaluated through BoosterPack modules paired with LaunchPads, experimenter kits, or in some cases EVMs with the MCU soldered directly to the board. Some application kits are aimed at experimentation and concept education, while others provide more real-world power levels similar to the end application. All application kits contain software examples, extensive user's guides, and a hardware development package to enable rapid customization for your product.

For a full list of application kits categorized by power conversion and motor drives, see the Application evaluation section within C2000's design and development page.

3.6 Reference Designs

The TI Reference Design Library is a robust reference design library spanning analog, embedded processor, and connectivity. Created by TI experts to help you jump start your system design, all reference designs include schematic or block diagrams, BOMs, and design files to speed your time to market.

Search and download C2000 Reference Designs

3.7 Custom Design

A great starting reference for a custom design are the design files of C2000 hardware platforms whether that be a reference design, ControlCARD, or LaunchPad platform. For the hardware platform of interest for the schematic, BOM, and other design files, see the web page.

Below are various documentation resources to help you get started with a custom board design:

- *Hardware Design Guidelines for TMS320F28xx and TMS320F28xxx* provides an overview of system level hardware design as well as information on how to transition from schematic design to board layout.
- *How to Maximize GPIO Usage in C2000™ Devices* lists several suggestions on maximizing the GPIO resources on the device to limit the need for IO expanders.
- *An Introduction to IBIS (I/O Buffer Information Specification) Modeling* discusses various aspects of IBIS including its history, advantages, compatibility, model generation flow, data requirements in modeling the input/ output structures, and future trends.

Note

The Design Tools and Simulation section of the design and development tab of each device's product folder offer various downloadable models. These models include I/O Buffer Information Specification (IBIS) Models and Boundary-Scan Description Language (BSDL) Modules.

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4 Software Development

This section helps you understand C2000's entire software offering. The information covered in this section can also be accessed through the C2000™ Software Guide.

4.1 Guides

Below are relevant resources for getting started with C2000 software development:

- *C2000™ C28x optimization Guide* explains how to write optimized code for C28x CPU
- *C2000™ CLA Software Development Guide* showcases how to leverage the Control Law Accelerator (CLA), co-processor for C28x, along with its software development
- *C2000™ Multicore Development User Guide* describes the various cores avaliable in C2000 devices and how other resources such as peripherals, memories, GPIOs are shared among these.
- *C2000™ Real-time MCU Functional Safety Enablers* is the starting point for developing functional safety software as it contains a list of the various functional safety software options.

4.2 C2000Ware

C2000Ware is the core software development kit for C2000. This provides a cohesive set of low level drivers, math and DSP related development software and documentation designed to minimize software development time. C2000Ware also provides Software Diagnostic Library that can be used for Functional Safety software development.

Downloads:

Standalone version: C2000WARE | Online version: C2000Ware TIREX

Resources:

- *C2000Ware Quick Start Guide* explains C2000's package structure, support, and how to access software examples through Code Composer Studio.
- Introduction to C2000Ware is a video overview of the C2000Ware development package.

4.3 Motor Control Software Development Kit (MCSDK)

The MCSDK provides a cohesive set of software infrastructure, tools, and documentation designed to minimize C2000 MCU based motor control system and software development time.

Downloads:

Standalone version: C2000WARE-MOTORCONTROL-SDK | Online version: MCSDK_TIREX

To view all of the solutions + evaluation modules supported in the most current SDK release, click on the 'View all' option within the features section of the MCSDK page.

Resources:

- *C2000Ware MotorControl SDK Getting Started Guide* explains MCSDK's package structure, support, and how to access software examples through Code Composer Studio

4.4 Digital Power Software Development Kit (DPSDK)

The DPSDK provides a cohesive set of software infrastructure, tools, and documentation designed to minimize C2000 MCU based digital power system and software development time.

Downloads:

Standalone version: C2000WARE-DIGITALPOWER-SDK | Online version: DPSDK TIREX

Within the C2000 software guide you can view all of the solutions + evaluation modules supported in the most current DPSDK release.

Resources:

- *C2000Ware DigitalPower SDK Getting Started Guide* explains DPSDK's package structure, support, and how to access software examples through Code Composer Studio

5 Programmers & Debuggers

5.1 Flash Programming

TI and multiple third parties offer several hardware and software solutions for performing both in-system and off-board programming of C2000 devices.

Resources:

- The Flash Programming Tools page offers general information about flash programming.

- C2000 3P Search Tool contains a full list of the third party options avaliable for production programming.

- Flash: Frequently Asked Questions has answers to frequently asked questions about flash and flash programming.

- *Serial Flash Programming of C2000 Microcontrollers* describes one possible implementation to program the target device's on-chip flash memory.

5.2 Debug Probes

JTAG debug probes allow you to program the memories and communicate with a C2000 real-time MCU during development. While almost all C2000 tools include JTAG emulation on the LaunchPad, controlCARD, or application kit once you build your own board you will need external debug probe.

Resources:

- The 'Emulation/JTAG' section of the datasheet contains information on the various JTAG signals as well as the physical connection implementation.

- The Debug Probes section of C2000's design and development page has a full list of the debug probes applicable to the C2000 family of products.

- *C2000 MCU JTAG Connectivity Debug* provides a brief overview of JTAG implementation and steps to resolve common JTAG connectivity errors when using Code Composer Studio software.

6 Development Toolchain

6.1 Code Composer Studio (CCS)

Code Composer Studio™ is an integrated development environment (IDE) that supports TI's Microcontroller and Embedded Processors portfolio. Code Composer Studio comprises a suite of tools used to develop and debug embedded applications. It includes an optimizing C/C++ compiler, source code editor, project build environment, debugger, profiler, and many other features. The intuitive IDE provides a single user interface taking the user through each step of the application development flow. Familiar tools and interfaces allow users to get started faster than ever before.

Downloads:

Standalone version: CCSTUDIO | Online version CCS Cloud

Resources:

- *Development Tool Versions for C2000 Support* lists the CCS and compiler versions required to develop applications targeting different C2000 features and devices.
- *Code Composer Stuido User's Guide* explains the features and capabilities of the Code Composer Studio IDE.
- C2000 Fundamentals Workshop for CCS [English | Chinese] provides an introduction to CCS and describes how to get started using the environment on a C2000 LaunchPad.

6.2 SysConfig System Configuration Tool (SYSCONFIG)

SysConfig is a comprehensive collection of graphical utilities for configuring pins, peripherals, subsystems, and other components. SysConfig helps you manage, expose and resolve conflicts visually so that you have more time to create differentiated applications. The tool's output includes C header and code files that can be used with software development kit (SDK) examples or used to configure custom software. The SysConfig tool automatically selects the pinmux settings that satisfy the entered requirements.

Downloads:

C2000 SysConfig is delivered through C2000Ware and can be used within CCS. To access SysConfig, either start from an existing C2000 SysConfig-based driverlib project (these projects will contain a .syscfg file once imported into CCS) or add C2000 SysConfig and driverlib support to an existing project.

Resources:

- *SysConfig User's Guide* provides an outline on custom board support using SysConfig.
- *How do I add SYSCONFIG support (Pinmux and Peripheral Initialization) to an already existing driverlib project* has information on adding SysConfig support to an existing software project.

6.3 Cloud Tools

TI offers a platform of cloud tools found on dev.ti.com. Amongst these various tools is Resource Explorer, which contains development tools, device documentation, and software resources. While these tools are also offered outside TI's cloud tools, dev.ti.com creates a singular tools package page for anyone developing with TI's products.

6.4 Third Party Development Tools

There are several companies who produce C2000 MCU customized interface, simulation (controller, plant, hardware, processor-in-the-loop), and code-generation toolsets for visual, block diagram and model-based design. These products can enable rapid control system prototyping, system modeling and can be used for debug, test and conformance, and to speed time to production.

For a full list of third parties, see the C2000 3P Search Tool. Among these the most popular is MathWorks with Embedded Coder. To get started with Mathworks development, see C2000's Embedded Coder Hardware Support Package.

7 Support Resources

7.1 Documentation Support

The documentation related to a device can be found within the device's page on TI.com/C2000. To access the device's page simply enter the part number into the search bar and click on the part number of interest.

Within the device's page is a Technical Documentation section that contains all relevant documentation to the device. This content can be filtered by literature type or through a keyword search.

The most important documentation for a device is the content listed below:

Data Sheet:	Provides all of the parameters and functional data information for the particular device.
Technical Reference Manual:	Details the integration, environment, functional description, and the programming models for each peripheral and subsystem in the device.
Errata:	Describes known advisories on silicon and provides workarounds.

In order to receive a notification of documentation updates, click on 'Subscribe to updates' located at the top right of the device's page. This registration enables you to receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

7.2 Training

To help assist design engineers in taking full advantage of the C2000 microcontroller features and performance, TI has developed a variety of training resources. These training resources have been designed to decrease the learning curve, while reducing development time, and accelerating product time to market. A subset of resources is presented below. For a complete list of the various training resources, visit the C2000™ real-time control MCUs – Support & training.

Device/IP Level Training:

- C2000 MCU Workshops: These workshops are hands-on technical courses specific to C2000 devices. The workshops start with basic concepts and progresses to more advanced topics in a logical fashion. Each topic and lab exercise builds on the previous one that was presented, running a common theme throughout the workshop.
- Overview Training Videos: These videos contain information about the latest device series, features, key capabilities and peripherals, and foundational safety.

Control Theory Training:

- Control Theory Seminar: This is a four-part technical seminar that offers an introduction to control theory covering fundamental concepts, feedback systems, transient response, and discrete-time systems.
- State Space Control Seminar: This is a four-part course in control theory based on the state space modeling paradigm covering state space models, properties of linear systems, state feedback control, and linear state estimators.

Application Specific Training:

- Motor Control Training Videos: This collection of videos provides information about motor control, InstaSPIN™, DesignDRIVE, and MathWorks®.
- Digital Power Control Training Videos: These videos cover information about digital power, solar inverter, GaN & SiC based reference designs, and MathWorks.
- Electric Vehicle Training Videos: These videos cover EV specific trainings on inverter and charging applications.

7.3 TI E2E Support Forum

An engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need. The Getting Started in E2E page has answers to frequently asked questions for specific tasks in the TI E2E forum in chronological order.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

8 References
- Texas Instruments: *The Essential Guide for Developing with C2000 Real-Time Microcontrollers*
- Texas Instruments: *Hardware Design Guidelines for TMS320F28xx and TMS320F28xxx*
- Texas Instruments: *How to Maximize GPIO Usage in C2000™ Devices*
- Texas Instruments: *An Introduction to IBIS (I/O Buffer Information Specification) Modeling*
- General information on C2000 real-time MCUs - C2000™ Overview
- C2000 Products - C2000™ Products
- C2000 Design and Development Resources – C2000™ Design & Development

9 Revision History
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision A (December 2020) to Revision B (May 2021)	Page
• Updated the numbering format for tables, figures and cross-references throughout the document	2
• Update was made in Section 4	6

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