

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



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 simple real-time control, C2000 enables engineers to quickly 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 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. To learn about the essentials of C2000 devices and why C2000 is a leader in real-time control, watch the [C2000™ Ecosystem 5-Minute Overview](#).

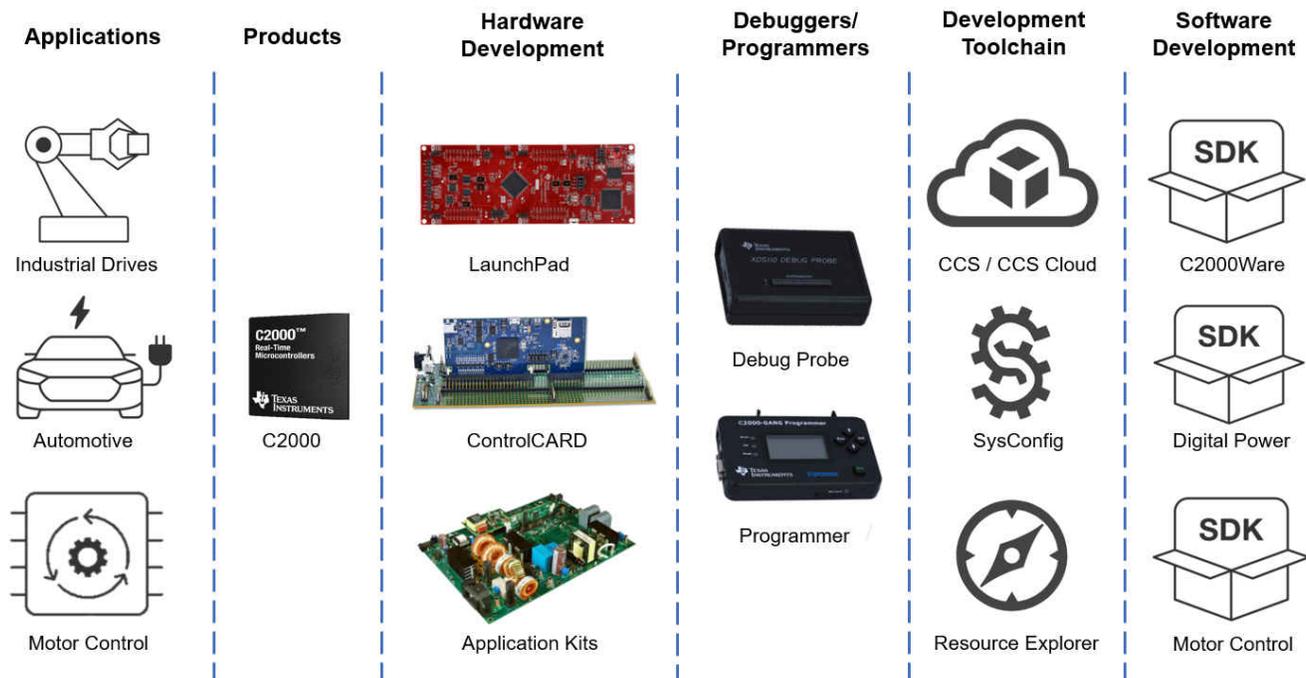


Figure 2-1. C2000 Ecosystem Diagram

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 want to quickly explore device capabilities and features, then the best options to start with are any of the three low cost development platforms. These include a [LaunchPad™](#), [LaunchPad + BoosterPack](#), or [ControlCARD + Docking Station](#). This will be coupled with [Code Composer Studio \(CCS\)](#) and the [C2000Ware](#) software development kit.

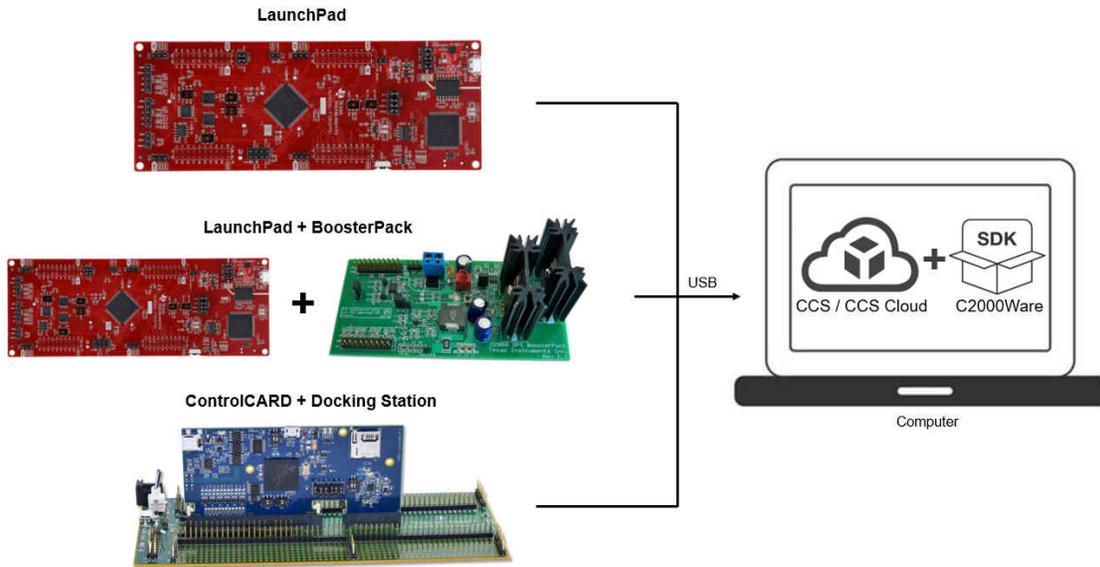


Figure 2-2. C2000 Entry Level Ecosystem Diagram

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](#), respectively. These SDKs provide guided example code for each of the application kits enabling easy integration between hardware and software.

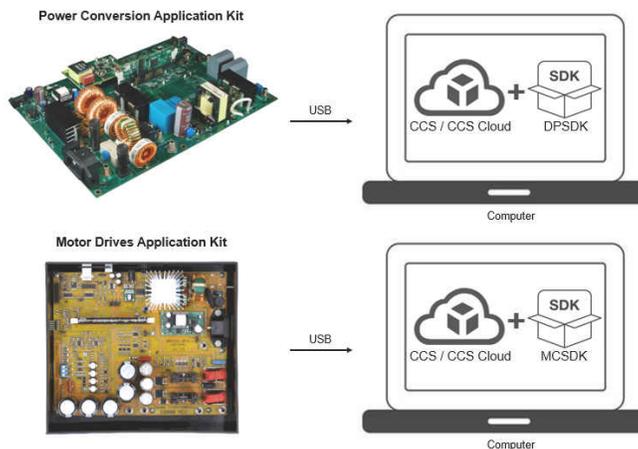


Figure 2-3. C2000 Intermediate Level Ecosystem Diagram

2.3 Advanced Level

If you are experienced with C2000 development, and are interested in quickly implementing a specific system then start with [Section 3.6](#) and [Section 3.7](#). These designs include all of the required files to jump start your development.

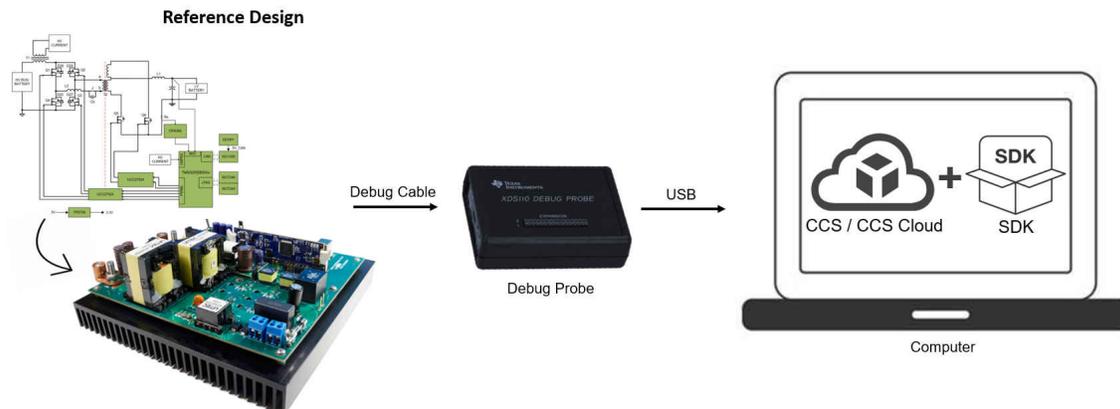


Figure 2-4. C2000 Advanced Level Ecosystem Diagram

3 Hardware Development

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

3.1 LaunchPad

LaunchPads are low-cost development boards for the C2000 real-time microcontroller 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 debug 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 C2000 BoosterPacks see the [Full-featured evaluation modules](#) section within C2000's design and development page.

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 simple 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, a 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 [Full-featured evaluation modules](#) 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 easily available using a series of header pins.

To find the appropriate baseboard, see the description on the product page for the ControlCARD.

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 convenient software examples, simple user's guides, and a hardware development package to enable rapid customization for your product.

For a full list of application kits, see the [Motor Control SDK](#) and [Digital Power SDK](#).

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 board design is the design files of C2000 hardware platforms, whether that be a reference design, ControlCARD, or LaunchPad platform. For your hardware platform of interest, the schematic, BOM, and other design files can be found on the web page.

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

- [Hardware Design Guide for F2800x C2000™ Real-Time MCU Series](#) 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.

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

For relevant C2000 software collateral, see the [C2000 software reference guides](#).

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 a Software Diagnostic Library that can be used for Functional Safety software development.

Downloads:

Standalone version: [C2000WARE](#) | Online version: [C2000Ware TIREX](#)

Resources:

- [Getting Started with CCS and C2000Ware](#) is a 10-minute video that provides an overview of CCS and C2000Ware. It also explains how to import an example and run it on hardware.
- [Introduction to C2000Ware](#) is a quick video overview of the C2000Ware development package.
- [C2000Ware Quick Start Guide](#) explains C2000's package structure, support, and how to quickly access software examples through Code Composer Studio.

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 and 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:

- [C2000 3P Search Tool](#) contains a full list of the third party options available 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 an 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 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 simple 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 IDE provides a single 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 Studio User's Guide](#) and the [CCS Resources](#) page explain the features and capabilities of the Code Composer Studio IDE.

6.2 SysConfig System Configuration Tool (SYSCONFIG)

C2000 SysConfig is a tool that exists integrated in CCS or as a standalone program that allows the user to generate C header and code files using a GUI. This interface creates a layer above the complex driverlib functions and simplifies the development process significantly. The generated code can be used with SDK examples or to configure custom software. The SysConfig tool also contains simple graphical utilities for configuring pins, peripherals, subsystems, and other components. SysConfig can help you quickly manage, expose, and resolve conflicts visually so that you have more time to create differentiated applications.

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:

- [C2000 SysConfig \(Software Guide\)](#)
- [C2000 SysConfig \(Application Note\)](#)
- [SysConfig Development Tool for C2000 real-time MCUs \(Video Series\)](#)
- [Speed Up Development with C2000 Real-Time MCUs Using SysConfig \(White Paper\)](#)
- [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.

If a hardware platform is connected to your computer, [dev.ti.com](#) will auto detect the device and immediately filter content tailored to that hardware platform as long as TI Cloud Agent is installed. Alternatively, if you do not have the Agent installed, you can manually select the device using the dropdown option below the Get Started section.

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 step-by-step 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 [TI training site](#).

Device/IP Level Training:

- [C2000 Academy](#): The C2000 Academy is a great resource for developers to learn about C2000 real-time microcontrollers platform. The Academy delivers easy-to-use training modules that span a wide range of topics for all C2000 devices. Additionally, C2000 Academy provides hands-on lab exercises and a full solution for each lab exercise.
- [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 Guide for F2800x C2000™ Real-Time MCU Series](#)
- 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](#)

Revision History

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

Changes from Revision B (May 2021) to Revision C (June 2022)	Page
• Updated the numbering format for tables, figures and cross-references throughout the document.....	2
• Updated Section 1	2
• Updated Section 2	2
• Updated Section 3	4
• Updated Section 4	6
• Updated Section 5	7
• Updated Section 6	7
• Updated Section 7	8
• Updated Section 8	9

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