User’s Guide

TMS320F280039C controlCARD Information Guide

ABSTRACT

The F280039 controlCARD (TMDSCNCD280039C) from Texas Instruments (TI) provides a great way to learn and experiment with the F28003x devices. The F28003x device is a member of TI’s C2000™ family of microcontrollers (MCUs). This 120-pin controlCARD is intended to provide a well-filtered robust design that is capable of working in most environments. This document provides the hardware details of the F280039 controlCARD and explains the functions, locations of jumpers, and connectors present on the board.

Table of Contents

1 Introduction ............................................................................................................................................................................2
2 Hardware Quick Setup Guide ................................................................................................................................................2
3 Errata ..........................................................................................................................................................................................3
  3.1 Warnings, Notes, and Errata ........................................................................................................................................3
  3.2 Warnings About Specific controlCARD Revisions ..................................................................................................3
4 Getting Familiar With the controlCARD ................................................................................................................................3
  4.1 F280039 controlCARD Features ................................................................................................................................3
  4.2 Assumed Operating Conditions ................................................................................................................................4
  4.3 Using the controlCARD ..................................................................................................................................................4
  4.4 Experimentation Software ..............................................................................................................................................5
5 Special Notes ..........................................................................................................................................................................5
  5.1 XDS110 Emulator and SCI (UART) Connectivity ....................................................................................................5
  5.2 Clocking Methodology ....................................................................................................................................................5
  5.3 Evaluation of the Analog-to-Digital Converters (ADCs) ............................................................................................5
6 Hardware References ..............................................................................................................................................................7
7 Revision History ......................................................................................................................................................................9

List of Figures

Figure 1-1. F280039 controlCARD ........................................................................................................................................2
Figure 5-1. Female SMA Connector ........................................................................................................................................6
Figure 6-1. Key Components on the controlCARD - Front .................................................................................................7
Figure 6-2. Key Components on the controlCARD - Back .................................................................................................7

List of Tables

Table 4-1. Emulator Switch Selections ..................................................................................................................................4
Table 6-1. Hardware Connections ........................................................................................................................................8
Table 6-2. S2, Bootmode Selection Table ................................................................................................................................9

Trademarks

C2000™ and Code Composer Studio™ are trademarks of Texas Instruments.
All trademarks are the property of their respective owners.
1 Introduction

Each controlCARD comes with a Hardware Developer’s Kit, which is a full set of files necessary to evaluate and develop with a C2000 device. These files include:

- Schematics – Designed in Altium
- Bill of Materials (BOM)
- Layout PCB files - Designed in Altium
- Gerber files

Note
This kit is designed to explore the functionality of the F28003x microcontroller. The controlCARD can be treated as a good reference design; it is not intended to be a complete customer design. Full compliance to safety, EMI/EMC, and other regulations are left to the designer of the customer’s system.

2 Hardware Quick Setup Guide

The controlCARD can be completely powered and operated from the USB-C connector. In this stand-alone mode the on-board isolated power supply will provide power to the F280039C device; no additional hardware is required. Optionally, an external 5 V supply can be provided to power the F280039C device. For a detailed explanation of the hardware configuration, see Section 4.3.

Configuration 1: Stand-alone
1. Connect a USB-C cable to J1:A.
2. Connect the other end of the USB cable to a USB2.0/USB3.x port.
3. LED1:A and D3 on the controlCARD will illuminate.

Configuration 2: External 5V supply
1. Insert the TMDSCNCD280039C controlCARD into a TMDSHSECDOCK, or other compatible docking station.
2. Connect a USB-B “mini” connector to J17 on the TMDSHSECDOCK.
3. Flip S1 to the "USB-ON" position. The controlCARD will automatically switch to the external 5 V supply.
4. LED1:A and D3 on the controlCARD will illuminate.
3 Errata


3.1 Warnings, Notes, and Errata

The F280039 evaluation kit ships with a USB cable and is designed to be powered via USB. However, in extreme cases the board/controlCARD may require more power than the 5 V @ 500 mA (USB 3.0 - 900 mA) that a computer’s USB port can provide. This is especially true when additional circuitry has been added to the TMDSHSECDOCK. In such cases, it is recommended to use an external 5 V power supply (2.5 mm inner diameter x 5.5 mm outer diameter) and plug it into J1 on the TMDSHSECDOCK. A compatible supply such as:

- Phihong PSAC05R-050(P)-R-C2 + Phihong RPBAG

5 V power supply instability may lead to device resets

The 5 V rail on the TMDSCNCD280039C controlCARD can be powered from an on-board USB connector or from a baseboard like the TMDSHSECDOCK. A switch device on the controlCARD automatically selects the 5 V input power source for the controlCARD without the need for user configuration.

A loss of power or glitching on the baseboard 5 V power source can cause the automatic switch to disconnect from both power sources for several milliseconds. This momentary loss of power may cause a brownout condition on the MCU, triggering a device reset. To avoid this condition, ensure that the baseboard power supply remains at 0 V or 5 V during code execution.

3.2 Warnings About Specific controlCARD Revisions

MCU100E1
- TP4 is incorrectly labeled as 5V5 on the front side of the controlCARD. TP4 corresponds to device ground (GND).
- TP1 is incorrectly labeled as device ground (GND) on the front side of the controlCARD. TP1 corresponds to the HSEC 5.0 V input.
- The TPD6E05U06RVZR ESD protection devices (U5, U6, U7, and U8) are not populated on the controlCARD. Take the necessary precautions to protect the ADC channels on the controlCARD from ESD and overvoltage damage.
- See warning above about power supply stability

MCU100A
- See warning above about power supply stability

4 Getting Familiar With the controlCARD

4.1 F280039 controlCARD Features

- **F280039 Microcontroller** – High performance C2000 microcontroller is located on the controlCARD.
- **120-pin HSEC8 Edge Card Interface** – Allows for compatibility with all of C2000’s 180-pin controlCARD-based application kits and controlCARDs. Compatibility with 100-pin controlCARDs can be accomplished using the TMDSDAP180TO100 adapter card (sold separately).
- **Built-in Isolated JTAG Emulation** – An XDS110 emulator provides a convenient interface to Code Composer Studio™ without additional hardware. Flipping a switch allows an external JTAG emulator to be used.
- **Built-in Isolated Power Supply** - Passes the 5 V supply from the USB-C connector through an isolation barrier. Allows for the controlCARD to be completed powered and operated from the USB-C connector. The F280039c is fully isolated from the USB port.
- **Automatic Power Supply Switch** - The controlCARD automatically switches to external 5 V power when present. No additional configuration is required.
- **Connectivity** – The controlCARD contains connectors that allow the user to experiment with isolated universal asynchronous receiver/transmitter (UART)/SCI with the F28003x MCU.
- **Key Signal Breakout** – Most GPIO, analog-to-digital converter (ADC) and other key signals routed to hard gold connector fingers.
• **Robust Power Supply Filtering** – Single 5 V input supply powers an on-card 3.3 V LDO. All MCU inputs are then decoupled using LC filters near the device.

• **ADC Clamping** – ADC inputs are clamped by protection diodes.

• **Anti-Aliasing Filters** – Noise filters (small RC filters) can be easily added on ADC input pins.

### 4.2 Assumed Operating Conditions

This kit is assumed to run at standard room conditions. Standard ambient temperature and pressure (SATP) with moderate-to-low humidity is assumed.

### 4.3 Using the controlCARD

In order for the controlCARD to operate, the controlCARD’s MCU must be powered. This is can be done through the USB-C connector on the controlCARD or by inputting 5 V through the HSEC connector via an accompanying baseboard. For example, if using a TMDSHSECDOCK docking station baseboard, 5 V DC should be input into the docking station’s J1 or J17. Then, SW1 needs to be toggled to the appropriate position.

Based on the way the controlCARD is used, additional hardware settings will be necessary (see Table 4-1).

<table>
<thead>
<tr>
<th>Table 4-1. Emulator Switch Selections</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S1:A</strong></td>
</tr>
<tr>
<td>Position 1: ON (left)</td>
</tr>
</tbody>
</table>

| **J1:A** | Connect a USB-C cable between J1:A and your computer. In CCS, use this target configuration: TMS320F280039C device with an XDS110 emulator. | --- | --- |
| **S2** | Position 1: up- Logic 1 | Position 1: down- Logic 1 | Set S2 as desired |
| Position 2: down- Logic 0 | Position 2: up- Logic 0 | | |
| Putting the C2000 device into WaitMode can reduce the risk of connectivity issues. | Putting the C2000 device into WaitMode can reduce the risk of connectivity issues. | |

| **S1** | Up - Enables connection to the external XTAL (Y1). Down - Disables connection to the external XTAL (Y1); on-chip INTOSC must be used | Up - Enables connection to the external XTAL (Y1). Down - Disables connection to the external XTAL (Y1); on-chip INTOSC must be used | Up - Enables connection to the external XTAL (Y1). Down - Disables connection to the external XTAL (Y1); on-chip INTOSC must be used |
| Setup S1 as desired. | Setup S1 as desired. | Setup S1 as desired. |

| **Baseboard’s JTAG connector** (J2 on Docking Station) | --- | Connect an external emulator. | --- |

Code Composer Studio is an Integrated Development Environment (IDE) used to debug and develop software for the C2000 series of MCUs. It can be downloaded from the following link: [http://www.ti.com/tool/ccstudio](http://www.ti.com/tool/ccstudio).

The following PDF documents are provided, as part of C2000Ware, to describe where each of the F28003x MCU’s pins will appear on the controlCARD connector/docking station:

- **TMDSCNCD280039C_120cCARD_map** – Tells where each MCU pin will go on the HSEC controlCARD connector or the 120/180-pin controlCARD docking station.

- **TMDSCNCD280039C_100DIM_map** – Tells where each MCU pin will go to on the DIM100 controlCARD connector or the DIM100 docking station. This assumes that the TMDSADAP180TO100 adapter card is used.

More information on the controlCARD docking station can be found at the following location:

- `<install directory>\c2000\C2000Ware_x_xx_xx\boards\controlCARDs\TMDSCNCD280039C\Rx_x`
4.4 Experimentation Software

Code Composer Studio (CCS) Integrated Development Environment (IDE) is recommended for developing and debugging software for the C2000 series of MCUs. CCS is free to download and use with the controlCARD. Introductory videos for CCS are available at training.ti.com.

C2000Ware contains a full suite of example software designed to work with the F28003x controlCARD.

This software package includes many example projects that allow the user to experiment with the ADC, PWM, and other C2000 peripherals.

Support files for both register-level and driver-level programming are included with C2000Ware:

- Register header files are located at: \	i\c2000\C2000Ware_XXXX\device_support\F28003x\examples
- Driverlib programming examples are located at: \	i\c2000\C2000Ware_XXXX\driverlib\F28003x\examples

5 Special Notes

5.1 XDS110 Emulator and SCI (UART) Connectivity

The F280039 controlCARD provides emulation and USB-to-UART adapter functionality on the controlCARD. This allows for a convenient method to debug and demonstrate the F28003x MCU.

Note that the MSP432 chip, its support circuitry, and associated components are placed in Macro A (the left section of the controlCARD). Each of these components contains an additional “:A” within the component reference designator (that is, R2:A for resistor 2 in Macro A) (see Figure 6-1 and Figure 6-2).

The configuration of the switches on S1:A determine if either the on-board emulator or an external emulator is connected to the MCU, and if the SCI (UART) pins on the MCU are connected to the COM port on the USB-C connector (see Table 4-1).

5.2 Clocking Methodology

This controlCARD is required to support a broad range of TI's baseboards. Several designs rely on GPIO18 and GPIO 19 for SPIA, while others require these GPIO to be utilized as a precision clock input source. To accommodate both of these systems a switch (S1) has been added to the design. This methodology should not be used in a final system as it increases EMI emissions and creates robustness susceptibilities. It is up to the system designer to choose the best way to implement the clocking circuitry for a given system.

5.3 Evaluation of the Analog-to-Digital Converters (ADCs)

When using the F280039 on-chip ADCs there are some useful guideline to follow to realize the performance numbers listed in the device-specific data sheet. This is especially true for the AC parameters such as: SNR, THD, and SINAD. Furthermore, it can also be shown that there is a direct correlation between the SNR of the ADC result and the spread of ADC codes seen for a DC input; as such these tips will improve the range and standard deviation of a DC input as well. Finally, while topics addressed will be with respect to the controlCARD, they are applicable to other implementations using the F280039 MCU as well.

On-board resistors and capacitors: By default all inline resistors to the ADC pins are a simple 0-Ω shunt and all capacitors to the ground plane are not populated. While this circuit can be used to supply the ADC inputs with a voltage, likely both the resistor(R) and capacitor(C) will need to be populated based on the voltage source’s characteristics. Referring to the ADC Input Model, the ADC input has its own RC network made up of the internal sample and hold capacitor, switch resistance, and parasitic capacitance. By changing the inline resistance and parallel capacitor we can optimize the input circuit to assist with settling time and/or filtering the input signal. Finally, it is recommended in general to use either Negative-Positive 0 PPM/°C (NPO) or Ceramic On Glass (COG) as these have better stability over temperature and across input frequencies than other types of capacitors.

Voltage source and drive circuitry: While the on-chip ADCs are 12-bit architecture (4096 distinct output codes when converting an analog signal to the digital domain); the translation will only be as precise as the input provided to the ADC. The typical rule of thumb when defining the source resolution to realize the full specification of an ADC is to have a 1-bit better source than the converter. In this case that would mean that ideally the analog input should be accurate to 13-bits.
Typically voltage supplies or regulators are not designed to be precise, but rather accommodate a wide range of current loads within a certain tolerance. For the local RC network, ±0.1% resistors and ±0.01% capacitors were used. Using this setup, the ADC parameters were observed to be consistent with the numbers in the device-specific data sheet. The device-specific data sheet may have some discrepancy with the actual performance. The ADC, like the one on the F280039, is designed to do its job well, even when the supply voltage is lower than the specified minimum. However, the impact on the ADC's performance is not ideal to show the performance of a higher bit resolution ADC. Typically voltage supplies of regulators are not designed to be precise, but rather accommodate a wide range of current loads within a certain tolerance. For this reason, it is not ideal to show the performance of a higher bit resolution ADC.
6 Hardware References

Figure 6-1. Key Components on the controlCARD - Front

Figure 6-2. Key Components on the controlCARD - Back
Table 6-1. Hardware Connections

<table>
<thead>
<tr>
<th>Connectors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>J1:A</td>
<td>Emulation/UART connector/Power - USB-C connector used to provide XDS110 emulation and USB-to-UART (SCI) communication through MSP432 logic. S1:A determines which connections are enabled to the MCU. The USB-C connector also provides power on the controlCARD.</td>
</tr>
<tr>
<td>J1</td>
<td>FSI Header – This header is keyed, contains 2 data lines, and has 3.3 V power.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LEDs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED1:A</td>
<td>Turns on (red) when 5 V is supplied to the controlCARD (5 V can be supplied either through the USB-C connector or externally through the HSEC connector)</td>
</tr>
<tr>
<td>LED2:A/LED3:A</td>
<td>JTAG/UART RX/TX toggle indicator (blue)</td>
</tr>
<tr>
<td>D1</td>
<td>Controlled by GPIO–31 with negative logic (red)</td>
</tr>
<tr>
<td>D2</td>
<td>Controlled by GPIO–34 with negative logic (red)</td>
</tr>
<tr>
<td>D3</td>
<td>Turns on (green) when 3.3V is supplied to the controlCARD</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resistors and Capacitors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R25-R47</td>
<td>ADC RC input filter resistors: Series resistors which can be used to create an RC filter on the ADC's input.</td>
</tr>
<tr>
<td>C29-C51</td>
<td>ADC RC input filter capacitors: Optional capacitors, not populated by default, for the ADC input's RC filters.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Switches</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1:A</td>
<td>Isolated emulation and UART communication enable switches:</td>
</tr>
<tr>
<td></td>
<td><strong>S1:A Position 1 – USB JTAG Enable:</strong></td>
</tr>
<tr>
<td></td>
<td>• <strong>ON</strong> – All 4 JTAG signals between the XDS110 emulation logic and the MCU will be connected. This setting is valid when the MCU is being debugged or programmed via the on-card XDS110 emulator.</td>
</tr>
<tr>
<td></td>
<td>• <strong>OFF</strong> – The XDS110 emulation logic will NOT be connected to the MCU JTAG pins. This setting is valid when the device will boot from FLASH, boot from a peripheral directly, or when an external JTAG emulator will be used.</td>
</tr>
<tr>
<td></td>
<td><strong>S1:A Position 2 – USB UART communication enable:</strong></td>
</tr>
<tr>
<td></td>
<td>• <strong>ON</strong> – The C2000 MCU's GPIO-28 and GPIO-29 will be connected to the MSP432 on the XDS110. This allows UART communication to a computer COM port. However, in this position, GPIO-28 and GPIO-29 will be reserved for COM port use. The corresponding pins on the 180-pin controlCARD connector cannot be used for another function.</td>
</tr>
<tr>
<td></td>
<td>• <strong>OFF</strong> – The C2000 MCU's GPIO-28 and GPIO-29 will NOT be connected to the MSP432 on the XDS110. The corresponding pins on the 180-pin controlCARD connector can be used for another function.</td>
</tr>
<tr>
<td>S1</td>
<td>SPIA or external crystal selection switch: This switch enables the use of SPIA or an external crystal. This methodology was required to support the full range of TI's baseboards and is not recommended in a production system. For full details, see Section 5.2.</td>
</tr>
<tr>
<td>S2</td>
<td>Boot Mode Switch: Controls the Boot Options of the F28003x device, see the Table 6-2. For a full description, see the device-specific data sheet.</td>
</tr>
<tr>
<td>S3</td>
<td>VREFHI Source Configuration Switch: This switch selects the source for VREFHI (internal or external through the 180-pin controlCARD connector)</td>
</tr>
<tr>
<td></td>
<td>• <strong>Upward position</strong> – Internal voltage reference</td>
</tr>
<tr>
<td></td>
<td>• <strong>Downward Position</strong> – External voltage reference</td>
</tr>
<tr>
<td></td>
<td>Note that additional software configuration is required to enable the ADC’s internal or external voltage reference.</td>
</tr>
</tbody>
</table>
Test Points

| TP1: A | USB 5.0 V input: This is the 5 V supply from the USB-C connector. |
| TP2: A | USB GND input: This GND from the USB-C connector. |
| TP1  | HSEC 5.0 V input: 5.0 V input provided to the controlCARD. |
| TP2  | Unfiltered 3.3 V: Provides power to the F28003x device. |
| TP3  | HSEC 5.0 V input: 5.0 V input provided to the controlCARD. |
| TP4  | Device Ground |
| TP5  | Unfiltered 3.3 V: Provides power to the F28003x device. |
| TP6  | Overvoltage output: Connected to the overvoltage output from the 3.3 V voltage supervisor. |

---

Note
On the front of the controlCARD test points are indicated by their TPx number.
On the back of the controlCARD test points are indicated by their signal.

Table 6-2. S2, Bootmode Selection Table

<table>
<thead>
<tr>
<th>Mode</th>
<th>Switch Position 1 (left switch, GPIO-24)</th>
<th>Switch Position 2 (right switch, GPIO-32)</th>
<th>Boot From</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0 (down)</td>
<td>0 (down)</td>
<td>Parallel I/O</td>
</tr>
<tr>
<td>01</td>
<td>1 (up)</td>
<td>0 (down)</td>
<td>SCI/Wait Boot</td>
</tr>
<tr>
<td>02</td>
<td>0 (down)</td>
<td>1 (up)</td>
<td>CAN</td>
</tr>
<tr>
<td>03</td>
<td>1 (up)</td>
<td>1 (up)</td>
<td>Flash/USB</td>
</tr>
</tbody>
</table>

7 Revision History

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

Changes from Revision * (May 2021) to Revision A (October 2021)

- Updated the numbering format for tables, figures and cross-references throughout the document...2
- Update was made in Section 3.1..................................................................................................................3
- Update was made in Section 6..........................................................................................................................7
IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2021, Texas Instruments Incorporated