User's Guide

TMDSCNCD28P65X controlCARD Information Guide

ABSTRACT

The F28P65x ControlCARD (TMDSCNCD28P65X) from Texas Instruments (TI) provides a great way to learn and experiment with the F28P65x devices. The F28P65x device is a member of TI's C2000™ family of microcontrollers (MCUs). This 180-pin controlCARD is intended to provide a well-filtered, robust design capable of working in most environments. This document provides the hardware details of the F28P65x controlCARD and explains the functions, locations of jumpers, and connectors present on the board.

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1 Introduction

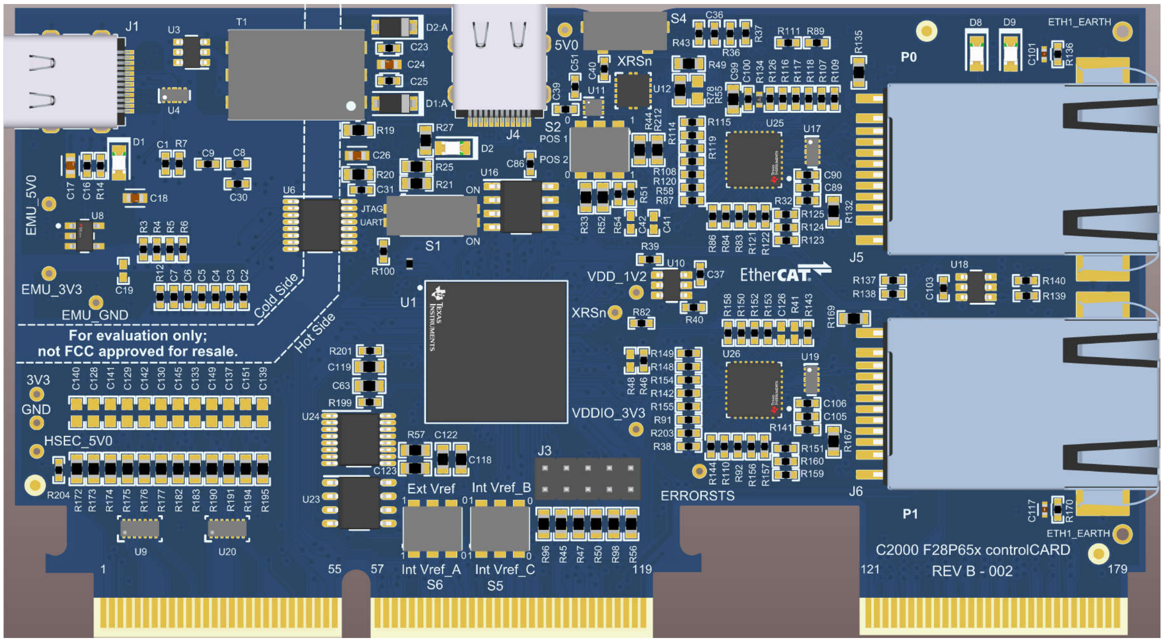

Figure 1-1. F28P65x controlCARD

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 TMDSCNCD28P65X-Schematic
- Bill of Materials (BOM) TMDSCNCD28P65X-design files
- Layout PCB files - Designed in Altium TMDSCNCD28P65X-design files
- Gerber files TMDSCNCD28P65X-design files
- TMDSCNCD28P65X_Revx_180cCARD_pinout TMDSNCD28P65X EVM Pinout Map

The Hardware Developer's Kit for the controlCARD can also be found in the C2000Ware at the following location:
- <install directory>\c2000\C2000Ware_x_xx_xx_xx\boards\controlCARDs\TMDSCNCD28P65X\Rx_x

Note

This kit is designed to explore the functionality of the F28P65x microcontroller. The controlCARD can be treated as a good reference design and 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 provides power to the F28P65x device; no additional hardware is required. Optionally, an external 5V supply can be provided to power the F28P65x device. For a detailed explanation of the hardware configuration, see Section 4.3.

WARNING

When the controlCARD is used in a high-voltage setup, the user is responsible to confirm that the voltages and isolation requirements are identified and understood prior to energizing the board or simulation. When energized, the controlCARD or components connected to the controlCARD cannot be touched. Furthermore, the capacitor C34 must be removed to minimize the possibility of leakage current flowing across the isolation barrier of the controlCARD.

2.1 Configuration 1: Standalone

1. Connect a USB-C cable to J1.
2. Connect the other end of the USB cable to a USB2.0/USB3.x port.
3. LEDs D1, D2, D6 and D7 on the controlCARD illuminate.

2.2 Configuration 2: External 5V Supply

1. Insert the TMDSCNCD28P65X controlCARD into a TMDSHSECDOCK or other compatible docking station.
2. Connect a USB cable to J17 on the TMDSHSECDOCK.
3. Flip S1 to the *USB-ON* position on the TMDSHSECDOCK. The controlCARD automatically switches to the external 5V supply.
4. LEDs D2 and D7 on the controlCARD illuminate.

Note

TMDSCNCD28P65X controlCARD automatically switches to the external 5V supply when present. No additional configuration is required.

3 Errata

3.1 Warnings, Notes, and Errata

External power supply is needed when power requirements exceed USB limits.

The F28P65X Experimenter's Kit ships with a USB cable and is designed to be powered via USB. However, in extreme cases, the board/controlCARD can require more power than the 5V at 500mA (USB 3.0 - 900mA) that a computer USB port can provide. This is especially true when additional circuitry has been added to the docking station. In such cases, TI recommends to use an external 5V power supply (2.5mm inner diameter x 5.5mm outer diameter) and plug into J1. A compatible supply such as:

- CUI SMM6-5-K-P6 + SMI-US-5

5V power supply instability can lead to device resets.

The 5V rail on the TMDSCNCD28P65X 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 5V input power source for the controlCARD without the need for user configuration.

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

CAN boot mode requires use of on-board BAW oscillator.

The TMDSCNCD28P65X controlCARD supports the use of the CAN boot mode. This boot mode can be selected through switch S3. The CAN boot mode requires the use of an on-board 25MHz BAW oscillator Y2 to clock the F28P65x device. See Section 6 for more information on the S3 Switch. There is no on-board CAN transceiver on the controlCARD; an external transceiver is required.

SCI Boot Option.

By default, in Boot-from-SCI mode, the MCU expects GPIO12 and GPIO13 to be the IO pins responsible for sending the program to the device. But, on this controlCARD GPIO28 and GPIO29 are used for Boot from SCI. These GPIOs are connected to the isolated USB-to-serial interface via the XDS110 emulator.

CAUTION

Silicon Revision 0 Advisories

Impact: MCU114A, MCU114E2, MCU114E1

ADC-C does not meet 16-bit mode specifications; but ADC-C does meet 12-bit specifications. Refer *TMS320F28P65x - Errata* for more information.

Workaround: Either operate ADC-C at a lower frequency of 44MHz to meet specifications or use ADC-C in 12-bit mode without having to lower the operating frequency.

3.2 Warnings About Specific controlCARD Revisions

Table 3-1. MCU114B

Issue	Description
Differentiating F28P650DK9 silicon on EVMs	Initial F28P650DK9 has ADC-C specification issue. **Fix:** ADC-C issue as noted in errata has been resolved, functionality is identical to later versions of the controlCARD.
5V power supply instability can lead to device resets	See Section 3.1 about power supply instability.

Table 3-2. MCU114A

Issue	Description
5V power supply instability can lead to device resets	See Section 3.1 about power supply instability.

Table 3-3. MCU114E2

Issue	Description
USB-C data peripheral signals connected incorrectly to MCU	USB-C data peripheral signals (GPIO42 & GPIO43) are connected to U1 incorrectly. Remove R80 and R81, then switch the traces using blue wire. **Fix:** None.
5V power supply instability can lead to device resets	See Section 3.1 about power supply instability.

Table 3-4. MCU114E1

Issue	Description
XDS_DP and XDS_DN are swapped	The E1 version of the controlCARD contains an error. These controlCARDs have had two cut traces and a blue wire soldered between J1 and U4 to correct this issue. **Fix:** None; functionality is identical to later versions of the controlCARD.
USB SCI/UART not supported	The SCI RX and TX signals are connected to U6 incorrectly. **Fix:** None; this functionality is not supported on this E1 revision of the controlCARD.
XDS JTAG signals connected incorrectly	The XDS JTAG signals are connected to U6 incorrectly. These controlCARDs have been reworked to use different U6 isolator to correct the issue. **Fix:** None; functionality is identical to later versions of the controlCARD.
Voltage monitoring on VDD (1.2V) is not supported.	Incorrect voltage monitoring part was used for U12. These controlCARDs have been reworked to remove R49. Voltage monitoring of VDD_1V2 rail is not supported. **Fix:** If voltage monitoring on VDD_1V2 is needed, then replace U12 with TPS3850G12DRCR and populate R49.
Ethercat yellow LINKSTATUS LEDs not supported	R135 & R169 have to be removed to address the boot-up issue. As a result, the yellow LINKSTATUS LED on RJ45 connectors RJ1 and RJ2 is not supported. **Fix:** None.
USB-C data peripheral signals connected incorrectly to MCU	USB-C data peripheral signals (GPIO42 & GPIO43) are connected to U1 incorrectly. Remove R80 and R81, then switch the traces using blue wire. **Fix:** None.
5V power supply instability can lead to device resets	See Section 3.1 about power supply instability.

4 Getting Familiar with the controlCARD

4.1 F28P65X controlCARD Features

- **F28P65X Microcontroller –** High performance C2000 microcontroller is located on the controlCARD.
- **180-pin HSEC8 Edge Card Interface –** Allows for compatibility with all of C2000 180-pin controlCARD-based application kits and controlCARDs. Compatibility with 100-pin controlCARDs can be accomplished using the TMDSADAP180TO100 adapter card (sold separately).
- **Built-in Isolated JTAG Emulation –** An XDS110 emulator provides a convenient interface to Code Composer Studio™ IDE without additional hardware. Flipping a switch allows an external JTAG emulator to be used.
- **Built-in Isolated Power Supply -** Passes the 5V 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 F28P65X is fully isolated from the USB port.
- **Automatic Power Supply Switch -** The controlCARD automatically switches to external 5V 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 F28P65x 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 5V input supply powers an on-card 3.3V 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.

The controlCARD uses DP83826 10/100M Ethernet PHY for EtherCAT communication. This PHY has reduced and more deterministic round trip (TX+RX) latency of < 210ns ± 2ns. In addition the XI to TX_CLK clock phase delay is ± 2ns. These features, along with robust EMI/EMC performance, make DP83826E/I an excellent choice for real time applications. For more details, see DP83826 Deterministic, Low-Latency, Low-Power, 10/100 Mbps, Industrial Ethernet PHY Data Sheet.

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.

4.2.1 External Power Supply or Accessory Requirements

Nominal Output Voltage: *5 VDC*

Maximum Output Current: *3A*

Efficiency Level V

Note

TI recommends using an external power supply or power accessory that complies with applicable regional safety standards such as (by example) UL, CSA, VDE, CCC, PSE.

4.3 Using the controlCARD

For the controlCARD to operate, the controlCARD MCU must be powered. This is done through the USB-C connector on the controlCARD or by inputting 5V through the HSEC connector using the accompanying baseboard. For example, if using a TMDSHSECDOCK docking station baseboard, 5 VDC can be input into the docking station J1 or J17. Then, S1 needs to be toggled to the appropriate position.

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

MCU is not powered via the type C USB connector on the controlCARD (J4). This USB has to be used only for data- peripheral connection with C2000 MCU. If this USB data peripheral is not used across application, depopulating R93 can provide better 5V rails.

Table 4-1. Emulator Switch Selections

Switch	Debug using CCS IDE and the on-card XDS110 Emulator (4-pin JTAG mode only)	Debug using CCS IDE and an External Emulator using the Baseboard	Standalone (Boot from FLASH or other Boot Mode)
S1	Position 1: ON (right, **default**) to connect the embedded XDS110 emulator to the MCU Position 2: ON (right, **default**) to connect the embedded XDS110 UART COM port to the MCU GPIO28 pin.	Position 1: OFF (left) to disconnect the embedded XDS110 emulator from the MCU Position 2: OFF (left) to disconnect the embedded XDS110 UART COM port to the MCU GPIO28 pin.	Position 1: OFF (left) Position 2: OFF (left)
J1	Connect a USB-C cable between J1 and your computer In CCS, use this target configuration: TMS320F28P650DK9 device with an XDS110 emulator, 4-pin JTAG mode only.	---	---
S3	Position 1 (GPIO72): down- Logic 0 Position 2 (GPIO84): up- Logic 1 Putting the C2000 device into Wait Mode can reduce risk of connectivity issues	Position 1 (GPIO72): down- Logic 0 Position 2 (GPIO84): up- Logic 1 Putting the C2000 device into Wait Mode can reduce risk of connectivity issues	Setup S3 as desired
Baseboard 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. CCS IDE can be downloaded from the following link: http://www.ti.com/tool/ccstudio.

The following PDF documents are provided, as part of C2000Ware, to describe where each of the F28P65x MCU pins appears on the controlCARD connector/docking station:

- **TMDSCNCD28P65X_<rev>_180cCARD_pinout –** Indicates where each MCU pin goes on the HSEC controlCARD connector or the 120/180-pin controlCARD docking station.
- **TMDSCNCD28P65X_<rev>_100DIM_map –** Indicates where each MCU pin goes 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 in the C2000Ware at the following location: <install directory>\c2000\C2000Ware_<rev>\boards\controlCARDs\TMDSCNCD28P65X\Rx_x.

4.3.1 Clocking Configuration

The Clocking tree on this controlCARD is configurable. Both a 20MHz clock source and a 25MHz (default) clock source can be provided to the F28P650DK9 device. To change this configuration, the R75 0Ω resistor must be de-soldered and moved to the R70 location.

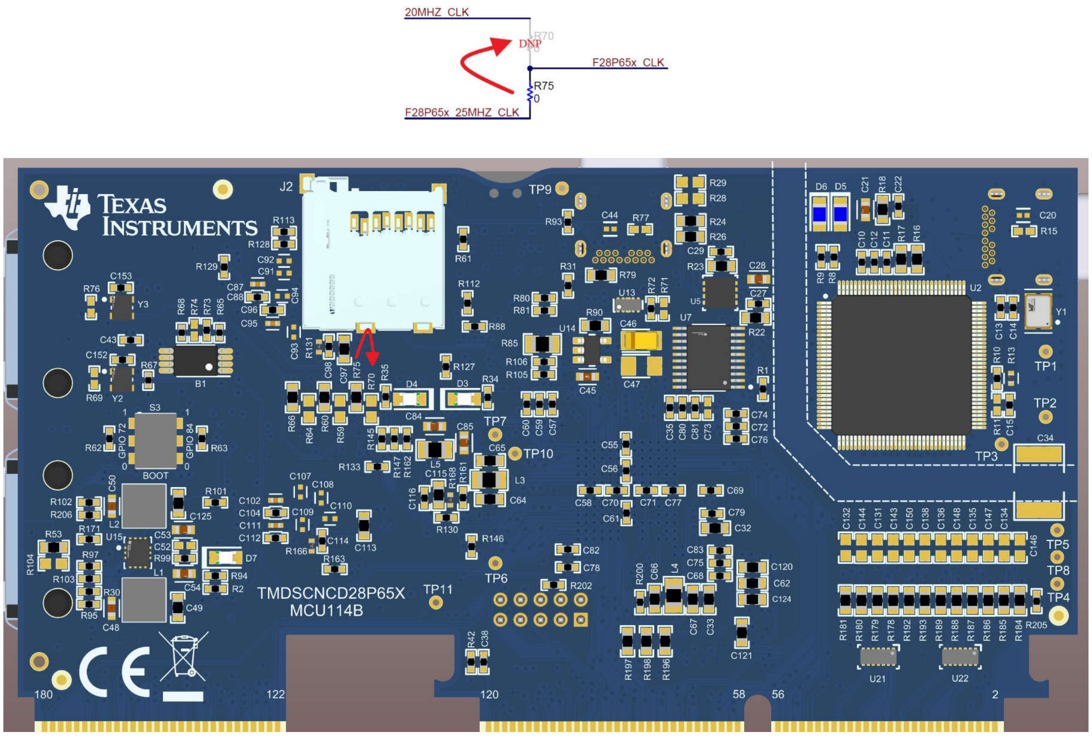

Figure 4-1. Changing the Clock Source From 25MHz to 20MHz

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. The CCS IDE is free to download and use with the controlCARD. Introductory videos for CCS IDE are available at training.ti.com.

C2000Ware contains a full suite of example software designed to work with the F28P65x 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:
  <install_directory>\ti\c2000\C2000Ware_<rev>\device_support\F28P65x\examples
- Driverlib programming examples are located at:
  <install_directory>\ti\c2000\C2000Ware_<rev>\driverlib\F28P65x\examples

For users new to the F28P65x series of devices and CCS IDE, TI's C2000 Academy provides several easy-to-follow training modules and hands-on lab exercises to help users get started quickly.

5 Special Notes

5.1 XDS110 Emulator and SCI (UART) Connectivity

The F28P65X controlCARD provides emulation and USB-to-UART adapter functionality on the controlCARD. This allows for a convenient method to debug and demonstrate the F28P65x MCU.

Note that the MSP432 chip, support circuitry, and associated components are placed toward the left section of the controlCARD. (see Figure 5-1).

The configuration of the switches on S1 determines 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).

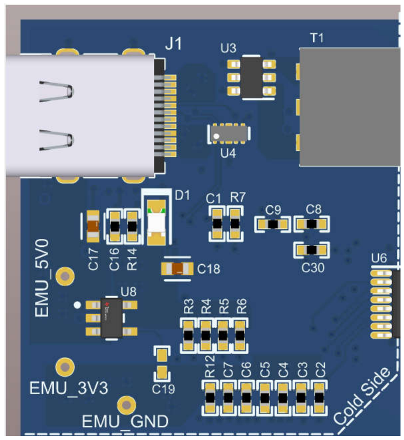

Figure 5-1. XDS110 Emulation Circuitry and Isolation Circuitry

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

When using the F28P65X on-chip ADCs, there are some useful guideline to follow to realize the performance numbers listed in the device-specific data manual. This is especially true for the AC parameters such as: SNR, THD, and SINAD. Furthermore, 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 improve the range and standard deviation of a DC input as well. Finally, while topics addressed are with respect to the controlCARD, the topics are applicable to other implementations using the F28P65x MCU as well.

On-board resistors and capacitors: By default, all inline resistors to the ADC pins are a simple 0Ω 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) need to be populated based on the voltage source characteristics. Referring to the ADC Input Model, the ADC input has an 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, TI recommends to use Negative-Positive 0PPM/°C (NP0/C0G) capacitors 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 16-bit architecture (65536 distinct codes when converting an analog signal to the digital domain) or 12-bit architecture (4096 distinct output codes), the translation only is as precise as the input provided to the ADC. The typical guideline 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 means that the analog input can 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 this reason, typical voltage supplies are not the best choice to show the performance of a higher bit ADC, such as the one on the F28P65x. Many times, the supply in question is providing the main voltage to power the MCU, which also introduces noise and other artifacts into the signal.

In addition to the quality of the input signal, there is also the aspect of the load presented to the ADC when the ADC samples the input. An input to an ADC has zero impedance so as not to impact the internal R/C network when the sampling event takes place. In many applications, however, the voltages that are sampled by the ADC are derived from a series of resistor networks, often large in value to decrease the active current consumption of the system. A method to isolate the source impedance from the ADC sampling network is to place an operational amplifier in the signal path. Placing an operational amplifier in the signal path does not only isolate the impedance of the signal from the ADC, but also shields the source from any effects the sampling network can have on the system.

Recommended source for evaluation: The Precision Signal Injector (PSI) EVM from TI can be used to validate the ADC performance on the F28P65x ControlCARD. This EVM supports both single ended as well as differential ended outputs using a 16-bit DAC as the signal source then passed through a High Precision Op-Amp with post amplifier filtering. The EVM is powered and controlled through a standard USB connection from a host PC and includes a GUI to control the output. The outputs are routed through single or dual SMA type connectors; TI highly recommends to place an additional female SMA connector (Figure 5-2) on the controlCARD docking station to receive the signal by way of SMA for best noise immunity. For the local RC network, 30Ω resistors and 300pF capacitors were used. Using this setup, the ADC parameters were observed to be consistent with the numbers in the device-specific data sheet.

Figure 5-2. Female SMA Connector

6 Hardware References

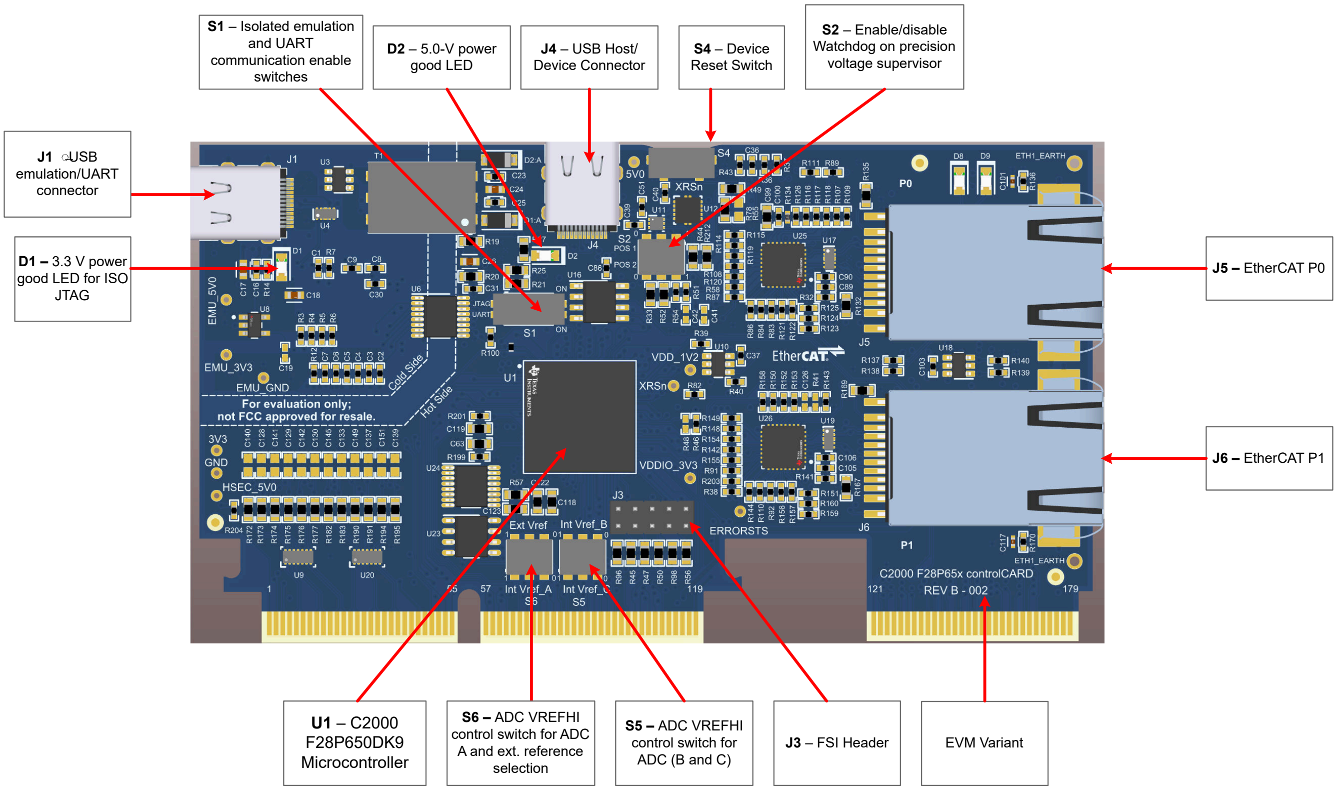

Figure 6-1. Key Components on the controlCARD - Front

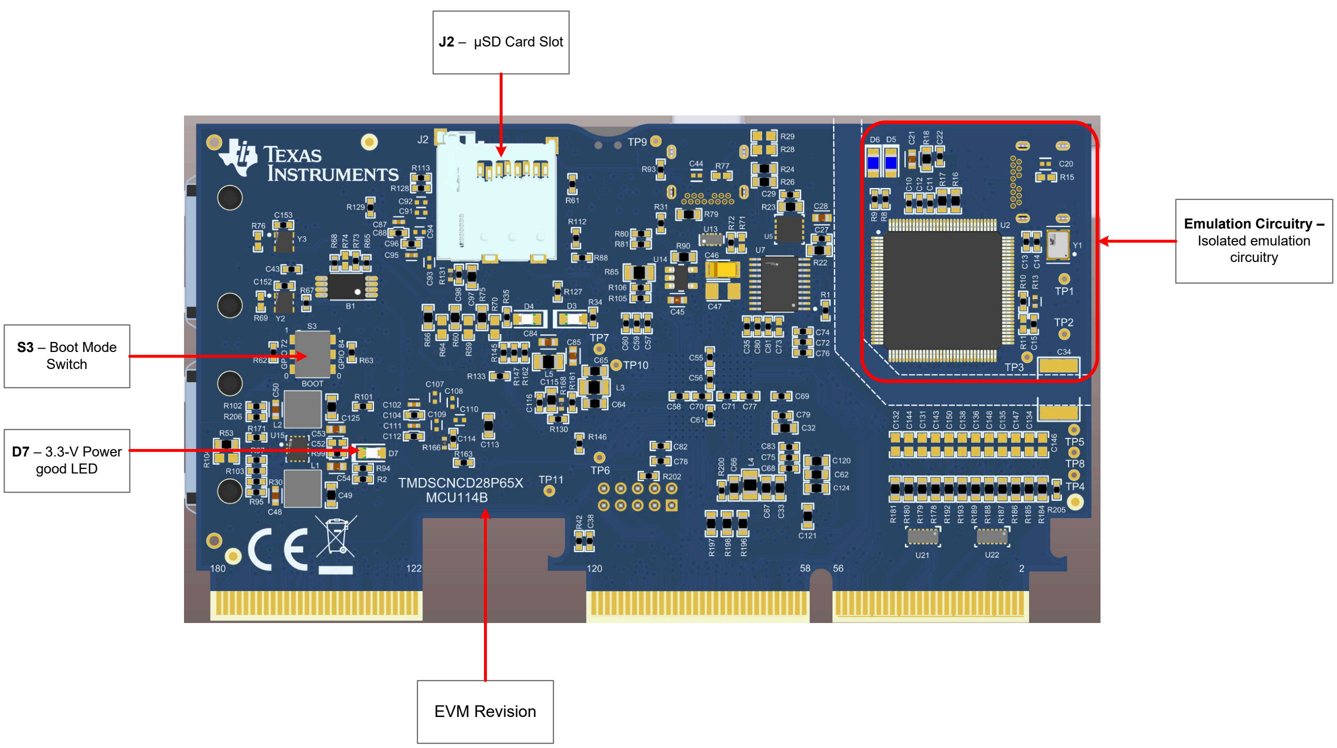

Figure 6-2. Key Components on the controlCARD - Back

Table 6-1. Hardware Connections

Connectors	
J1	Emulation/UART connector/Power - USB-C connector used to provide XDS110 emulation and USB-to-UART (SCI) communication through MSP432 logic. S1 determines which connections are enabled to the MCU. The USB-C connector also provides power on the controlCARD.
J2	microSD card slot – connects to MCU via SPI
J3	FSI Header
J4	Type C USB Connector - Data Peripheral to MCU
J5	EtherCAT P0 – RJ45 connector
J6	EtherCAT P1 – RJ45 connector

Table 6-2. LEDs

LEDs	
D1	Turns on when JTAG logic is powered on (green)
D2	Turns on (red) when 5V is supplied to the controlCARD (5V can be supplied either through the USB-C connector or externally through the HSEC connector)
D3	Controlled by GPIO31 with negative logic (red)
D4	Controlled by GPIO34 with negative logic (red)
D5	JTAG/UART RX toggle indicator (blue)
D6	JTAG/UART TX toggle indicator (blue)
D7	Turns on (green) when 3.3V is supplied to the controlCARD from the on-board DC-DC (U3)
D8	Controlled by GPIO–145, EtherCAT Error LED (red)
D9	Controlled by GPIO–146, EtherCAT Run LED (green)

Table 6-3. Resistors and Capacitors

Resistors and Capacitors	
R172-R195	**ADC RC input filter resistors:** Series resistors which can be used to create an RC filter on the ADC's input.
C128-C151	**ADC RC input filter capacitors:** Optional capacitors, not populated by default, for the RC filter of the ADC input.

Table 6-4. Switches

Switches	
S1	Isolated emulation and UART communication enable switches: **S1 Position 1 – USB JTAG Enable:** • **ON (default)–** All 4 JTAG signals from the embedded XDS110 emulation logic are passed across the isolation barrier and connected to the MCU. This setting is valid when the MCU is being debugged or programmed using the embedded XDS110 emulator. • **OFF –** The 4 JTAG signals from the embedded XDS110 emulation logic are passed across the isolation barrier and are NOT connected to the MCU. This setting is valid when the device boots from FLASH, boots from a peripheral directly, or when an external JTAG emulator is used.
	S1 Position 2 – USB UART communication enable: • **ON (default)–** The C2000 MCU GPIO28 is connected to the embedded XDS110. This allows UART communication to a computer COM port. However in this position, GPIO28 and GPIO29 are reserved for COM port use. The corresponding pins on the 180-pin controlCARD connector cannot be used for another function. • **OFF –** The C2000 MCU GPIO28 is NOT connected to the embedded XDS110. The corresponding pins on the 180-pin controlCARD connector can be used for another function.

Table 6-4. Switches (continued)

<table>
<tr><th colspan="5">Switches</th></tr>
<tr><td rowspan="11">S2</td><td colspan="4">Note
Watchdog output is disabled (default). To enable watchdog functionality over S2, populate R55.

Enable/Disable watchdog Timer & adjustable programmable delay:
S2 : Position 1 – SET 0 | Position 2 - SET 1
with CWD = 10kΩ (default)</td></tr>
<tr><td rowspan="5">t_{WDL} - window watchdog lower boundary</td><td>SET 0</td><td>SET 1</td><td>Timing Setup</td></tr>
<tr><td>0</td><td>0</td><td rowspan="2">7.65 < t_{WDL} < 10.35ms</td></tr>
<tr><td>0</td><td>1</td></tr>
<tr><td>1</td><td>0</td><td>Watchdog disabled</td></tr>
<tr><td>1 (default)</td><td>1 (default)</td><td>1.48 < t_{WDL} < 2.22ms</td></tr>
<tr><td rowspan="4">t_{WDU} - window watchdog upper boundary</td><td>0</td><td>0</td><td>92.7 < t_{WDU} < 125.4ms</td></tr>
<tr><td>0</td><td>1</td><td>165.8 < t_{WDU} < 224.3ms</td></tr>
<tr><td>1</td><td>0</td><td>Watchdog disabled</td></tr>
<tr><td>1 (default)</td><td>1 (default)</td><td>9.35 < t_{WDU} < 12.65ms</td></tr>
<tr><td colspan="4">Note
For additional hardware configurations, see TPS3850 Precision voltage Supervisory with Programmable Window Watchdog Timer data sheet.</td></tr>
<tr><td>S3</td><td colspan="4">Boot Mode Switch: Controls the Boot Options of the F28P65x device, see Table 6-6. For a full description, see the device specific data sheet.</td></tr>
<tr><td>S4</td><td colspan="4">Reset switch: Switch connected to the XRSn line of the F28P65x device. Pressing this button pulls the device reset low.</td></tr>
<tr><td rowspan="2">S5</td><td colspan="4">ADC VREFHI Control Switch for ADC modules B & C:
S5 Position 1 (lower switch) - VREFHI Control Switch for ADC module C:
• LEFT position - ADC-C is configured to use internal voltage reference can be selected to be 0V to 3.3V or 0V to 2.5V.
• RIGHT (default) position - ADC-C is configured to use an external voltage reference.</td></tr>
<tr><td colspan="4">S5 Position 2 (upper switch) - VREFHI Control Switch for ADC module B:
• LEFT position - ADC-B is configured to use internal voltage reference can be selected to be 0V to 3.3V or 0V to 2.5V.
• RIGHT (default) position - ADC-B is configured to use an external voltage reference.</td></tr>
</table>

Table 6-4. Switches (continued)

Switches	
S6	**ADC VREFHI Control Switch for ADC modules A and selection of external voltage reference:** **S6 Position 1 (lower switch) - VREFHI Control Switch for ADC module A:** • **LEFT position** - ADC-A is configured to use internal voltage reference can be selected to be 0V to 3.3V or 0V to 2.5V. **CAUTION** *The reference pins, VREFHIA to VREFHIC and VREFLOA to VREFLOC, can be used to supply an external voltage reference to the associated ADCs. VREFHIA can also be used to supply the voltage reference to DAC A, and VREFHIB can be used to supply the voltage reference to DAC C. An internal voltage reference is available and connects to VREFHIA. To use the internal voltage reference on ADC B, ADC C or DAC C, connect VREFHIA to VREFHIB and/or VREFHIC externally.* • **RIGHT (default) position** - ADC-A is configured to use an external voltage reference.
	S6 Position 2 (upper switch) - External VREFHI Control Switch for all ADC modules: • **LEFT position** - External voltage reference is set to use full-scale range of ADC with 0-3.3 V, but the ADC has reduced accuracy/precision. • **RIGHT (default) position** - External voltage reference is set to use an onboard precision 3V voltage reference.

Table 6-5. Test Points

Test Points	
TP1	**USB 5V input:** This is the 5V supply from the USB-C connector
TP2	**Unfiltered 3.3V:** Provides power to the MSP432 device
TP3	**USB GND input:** This GND from the USB-C connector
TP4	**HSEC 5V input:** 5V input provided to the controlCARD
TP5	**Unfiltered 3.3V:** This is the 3.3V rail from the DC-DC converter
TP6	**Filtered 3.3V:** Provides power to the F28P65x device
TP7	**Filtered 1.2V:** VDD *core supply* to the F28P65x device. Note that this controlCARD has been designed to use the external voltage regulator by default. The internal voltage regulator can be also enabled by removing R46 and populating R48
TP8	**Device Ground**
TP9	**5V input:** Output of the power selection switch
TP10	**XRSn of F28P65X device:** Connected to the XRSn pin of the F28P65x device
TP11	**ERRORSTS:** Error status output

Note

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

Table 6-6. S3, Bootmode Selection

Mode	Switch Position 1 (left switch, GPIO72)	Switch Position 2 (right switch, GPIO84)	Boot From
00	0 (down)	0 (down)	Parallel I/O
01	0 (down, **default**)	1 (up, **default**)	SCI / Wait Boot
02	1 (up)	0 (down)	CAN
03	1 (up)	1 (up)	Flash / USB

7 Revision History

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

Changes from Revision A (July 2023) to Revision B (February 2024)	Page
• Updated images throughout the document	1
• Added *MCU114B* table	5
• Added *Caution* note in *Switches* table	11

Changes from Revision * (March 2023) to Revision A (July 2023)	Page
• Changed *Configuration 1: Standalone*	3
• Changed *Configuration 2: External 5V Supply*	3
• Added *MCU114A* table and *MCU114E2* table	5
• Changed S1 switch positions in *Emulator Switch Selections* table	7
• Updated *S3, Bootmode Selection* table	11
• Updated item label formatting in *Hardware Connections, LEDs, Resistors and Capacitors, Switches, Test Points* tables	11

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   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

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WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI's recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI's recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI's instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 *Regulatory Notices:*

3.1 *United States*

3.1.1 *Notice applicable to EVMs not FCC-Approved:*

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d’usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

3.3.2 *Notice for Users of EVMs Considered “Radio Frequency Products” in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry’s Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

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