User's Guide
SPRUIR3A–September 2019–Revised March 2020

F280025 controlCARD Information Guide

The F280025 controlCARD (TMDSCNCD280025C) from Texas Instruments (TI) provides a great way to learn and experiment with the F28002x devices. The F28002x device is a member of TI'sC2000™ 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 F280025 controlCARD and explains the functions, locations of jumpers, and connectors present on the board.

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1 Introduction

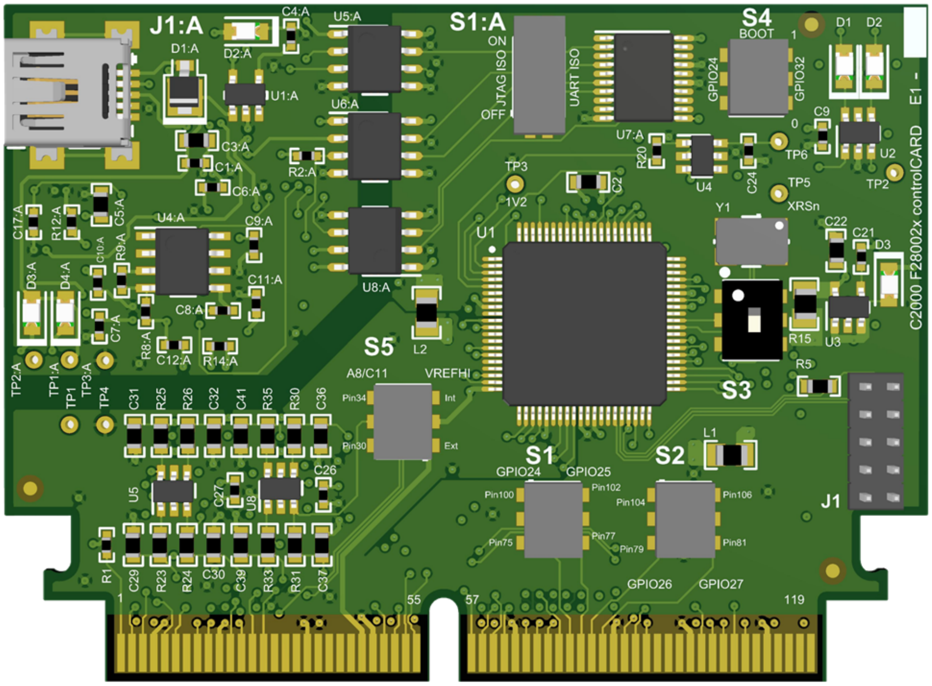

Figure 1. F280025 controlCARD

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

NOTE: This kit is designed to explore the functionality of the F28002x 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.

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2 Hardware Quick Setup Guide

1. Connect and power embedded emulator.
   a. Connect USB-B "mini" connector to J1:A
2. Provide power to the isolated F280025C device.
   a. Insert the TMDSCNCD280025C controlCARD into a TMDSHSECDOCK, or other compatible docking station.
   b. Connect USB-B "mini" connector to J17 of the TMDSHSECDOCK.
   c. Flip S1 to the "USB-ON" position. D3 of the controlCARD should illuminate.
3. For a detailed explanation of the hardware configuration, see Section 4.3.

3 Errata

Current revision of controlCARD as of 3/20/2020: PCB rev - A , ASSY rev - none

3.1 Warnings, Notes, and Errata

- The F280025 Experimenter's 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 docking station. 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. A compatible supply such as:
  - Phihong PSAC05R-050(P)-R-C2 + Phihong RPBAG

3.2 Warnings About Specific controlCARD Revisions

MCU072E1

- 1.2V and 3.3V monitor pins(HSEC pins 118 and 119 respectively) were not implimented

MCU072A

- None

4 Getting Familiar With the controlCARD

4.1 F280025 controlCARD Features

- **F280025 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 TMDSADAP180TO100 adapter card (sold separately).
- **Built-in Isolated JTAG Emulation –** An XDS100v2 emulator provides a convenient interface to Code Composer Studio™ without additional hardware. Flipping a switch allows an external JTAG emulator to be used.
- **Connectivity –** The controlCARD contains connectors that allow the user to experiment with isolated universal asynchronous receiver/transmitter (UART)/SCI with the F28002x 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 most often done by inputting 5 V through the HSEC connector via an accompanying baseboard. For example, if using a 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 1).

Table 1. Emulator Switch Selections

	Debug Using CCS and the On-Card XDS100v2 Emulator	**Debug Using CCS and an External Emulator via the Baseboard**	**Standalone (Boot From FLASH or Other Boot Mode)**
S1:A	Position 1: ON (up)	Position 1: OFF (down)	Position 1: OFF (down)
J1:A	Connect a mini USB cable between J1:A and your computer. In CCS, use this target configuration: TMS320F280025C device with an XDS100v2 emulator.	---	---
S4	Position 1: up- Logic 1 Position 2: down- Logic 0 Putting the C2000 device into WaitMode can reduce the risk of connectivity issues.	Position 1: down- Logic 1 Position 2:up- Logic 0 Putting the C2000 device into Wait Mode can reduce the risk of connectivity issues.	Set 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.

The following PDF documents are provided,as part of C2000Ware, to describe where each of the F28002x MCU's pins will appear on the controlCARD connector/docking station:

- **TMDSCNCD280025C_120cCARD_map–** Tells where easeveralch MCU pin will go on the HSEC controlCARD connector or the 120/180-pin controlCARD docking station.
- **TMDSCNCD280025C_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_xx\boards\controlCARDs\TMDSCNCD280025C\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 F28002x 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: \ti\c2000\C2000Ware_XXXX\device_support\F28002x\examples
- Driverlib programming examples are located at: \ti\c2000\C2000Ware_XXXX\driverlib\F28002x\examples

5 Special Notes

5.1 XDS100v2 Emulator and SCI (UART) Connectivity

The F280025 controlCARD provides emulation and USB-to-UART adapter functionality on the controlCARD. This allows for a convenient method to debug and demonstrate the F28002x MCU.

Note that the FTDI chip, its support circuitry, and associated isolation 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 4).

The configuration of the switches on S1:A determine if the on-board emulator is active, if an external emulator can be used, or if the device will boot from FLASH/peripherals (see Table 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 (S3) 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 circuity for a given system.

5.3 Evaluation of the Analog to Digital Converters(ADCs)

When using the F280025 on-chip ADCs there are some useful guideline to follow to realize the performance numbers listed in the 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 F280025 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 NPO(Negative-Positive 0 PPM/°C) or COG(Ceramic On Glass) 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 and for this reason are not ideal to show the performance of a higher bit ADC, like the one on the F280025. This does also not take into account that many times the supply in question is providing the main voltage to power the MCU itself; 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 it samples the input. Ideally an input to an ADC would have 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 solution to isolate the source impedance from the ADC sampling network is to place an operational amplifier in the signal path. Not only does this isolate the impedance of the signal from the ADC, it also shields the source itself from any effects the sampling network may have on the system.

Recommended source for evaluation: The Precision Signal Injector (PSI) EVM from TI was used to validate the ADC performance on the F280025C 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 its output. The outputs are routed through single or dual SMA type connectors; it is highly recommended to place an additional female SMA connector (Figure 2) on the controlCARD docking station to receive the signal via SMA for best noise immunity. For the local RC network 30-Ω resistors and 300pF capacitors were used. Using this setup the ADC parameters were observed to be consistent with the numbers in the data sheet.

Figure 2. Female SMA Connector

6 Hardware References

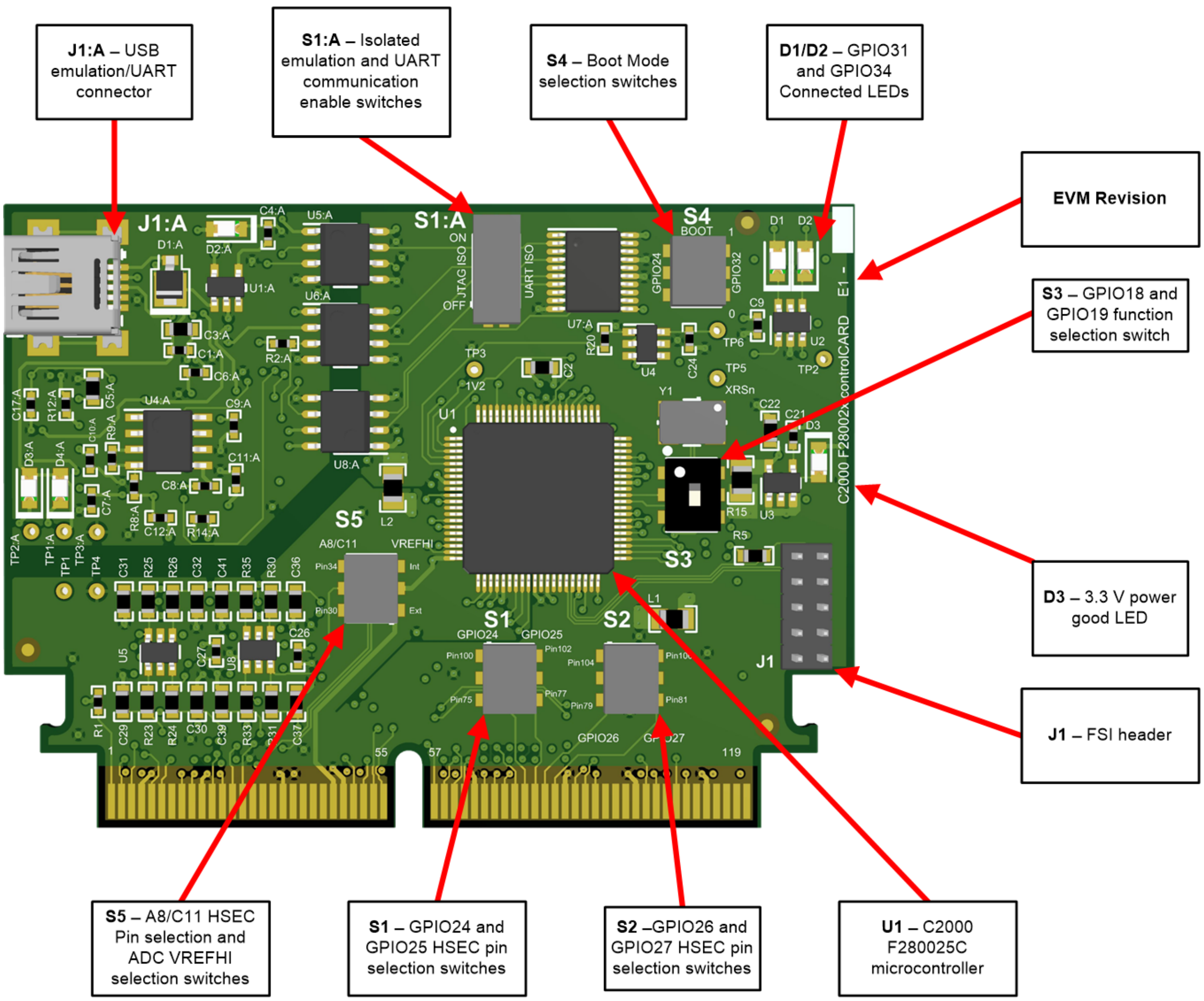

Figure 3. Key Components on the controlCARD - Front

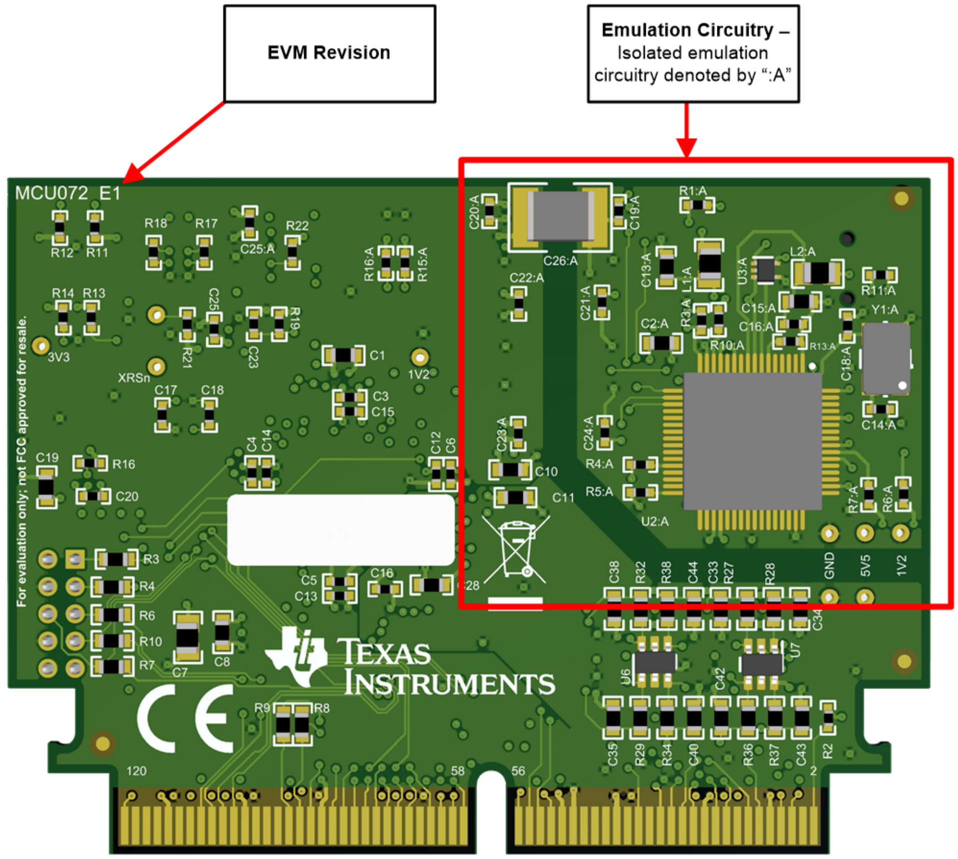

Figure 4. Key Components on the controlCARD - Back

Table 2. Hardware Connections

Connectors	
J1:A	Emulation/UART connector - USB mini A connector used to provide XDS100v2 emulation and USB-to-UART (SCI) communication through FTDI logic. S1:A determines which connections are enabled to the MCU.
J1	FSI Header – Updated over previous designs. This header is now keyed, contains 2 data lines, and has 3.3 V power.

LEDs	
D2:A	Turns on when ISO JTAG logic is powered on (green)
D3:A	JTAG/UART RX toggle indicator (blue)
D4:A	JTAG/UART TX toggle indicator (blue)
D1	Controlled by GPIO–31 with negative logic (red)
D2	Controlled by GPIO–34 with negative logic (red)
D3	Turns on when the controlCARD is powered ON (green)

Resistors and Capacitors	
R23-R38	**ADC RC input filter resistors:** Series resistors which can be used to create an RC filter on the ADC's input.
C29-C44	**ADC RC input filter capacitors :** Optional capacitors, not populated by default, for the ADC input's RC filters.

Switches	
S1:A	Isolated emulation and UART communication enable switches:
	S1:A Position 1 – JTAG Enable: • **ON –** All signals between the XDS100v2 emulation logic and the MCU will be connected. This setting is valid when the MCU is being debugged or programmed via the on-card XDS100v2 emulator. • **OFF –** The XDS100v2 emulation logic will NOT be connected to the MCU. 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.
	S1:A Position 2 – ISO UART communication enable: • **ON –** The C2000 MCU's GPIO-28 (and pin 76 of the 180-pin controlCARD connector) will be coupled to the FTDI's USB-to-Serial adapter. This allows UART communication to a computer via the FTDI chip. However, in this position, GPIO-28 will be forced high by the FTDI chip. Functionality of pin 76 of the connector will be limited. • **OFF –** The C2000 MCU will NOT be connected to the FTDI USB-to-Serial adapter. Pin 76 of the 180-pin controlCARD connector will be directly connected to GPIO-28.
S1	**QEP and SPIB selection switch:** This switch allows GPIO24 and GPIO25 to be routed to one of two locations on the HSEC connector.
S2	**QEP and SPIB selection switch:** This switch allows GPIO26 and GPIO27 to be routed to one of two locations on the HSEC connector.
S3	**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.
S4	**Boot Mode Switch:** Controls the Boot Options of the F28002x device, seeTable 3. For a full description, see the device-specific data sheet.
S5	**Analog Configuration Switch:**
	S4 Position 1 (left switch) – ADC channel A8/C11 HSEC pin selection • **Upward position –** Channel A8/C11 goes to HSEC pin 34 • **Downward Position –** Channel A8/C11 goes to HSEC pin 30
	Position 2 (right switch) - ADC voltage reference selection. • **Upward position –** Internal voltage reference • **Downward Position –** External voltage reference Note that additional software configuration is required to enable the ADC's internal or external voltage reference.

Test Points	
TP1:A	**Emulator 5.0 V input:** This power domain is isolated from the other 5.0V domain.
TP2:A	**Emulator 3.3 V input:** This power domain is isolated from the other 3.3 V domains.
TP3:A	**Emulator ground**
TP1	**HSEC 5.0 V input:** 5.0 V input provided to the 3.3 V voltage regulator to create the unfiltered 3.3 V power.
TP2	**Unfiltered 3.3 V:** Provides power to the F28002x device.
TP3	**MCU 1.2 V:** VDD 'core supply' to the F28002x device. Note that this controlCARD has been designed to use the internal voltage regulator.
TP4	**Device Ground**
TP5	**XRSn of F28002x device:** Connected to the undervoltage output from the 3.3 V voltage supervisor.
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 3. S4, Bootmode Selection Table

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

Revision History

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