
UCS1002 Fundamentals of Custom Charger Emulation

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1.0 INTRODUCTION

This application note discusses the fundamental concepts of UCS1002 custom charger emulation. Key to understanding UCS1002 custom charger emulation are the relationships between emulation cycling, emulation timeouts, stimulus / response pairs, and current thresholds.

1.1 References

This application note references the following items:

- The UCS1002 Data Sheet
- The UCS1002 Schematic Reference Design
- UCS1002 evaluation board (EVB) and graphical user interface (GUI), which are included in the UCS1002 EVB package

Note: It is important to refer to the most recent revision of these items for complete and current information regarding the custom charger emulation capability of the UCS1002.

1.2 Background

Traditionally, OEM portable device battery chargers are specific to the requirements of a particular portable device model (e.g., AC-DC wall adapters). Newer chargers are being developed that can charge portable devices based on industry standards (such as USB-IF BC1.2), but these chargers do not have the flexibility to accommodate older or proprietary portable devices (e.g., 'Legacy' devices). The UCS1002 was designed to address these problems.

The UCS1002 is a user-programmable charger emulator in an integrated circuit. It comes with preloaded charger emulation profiles that meet battery charging standards, as well as Legacy portable device protocols; thus, it will supply power or 'charge enable' many of today's portable devices (cell phones, smart phones, video games, tablets, disc drives, etc.). By using the UCS1002, the physical number of different chargers can be reduced and offered in a single application.

Because there are and will be portable devices that require unique or unforeseen voltage, current, resistance, or multi-step handshaking protocols on the USB data lines (and using USB voltage) in order to charge, the UCS1002 also provides a user-customizable charger emulation profile. This profile can either be used singularly (i.e., with all the preloaded profiles disabled), or in concert with any or all preloaded profiles. This results in a highly flexible and capable methodology to enable portable devices now and in the future.

1.3 Document Organization

Sections 2 and 3 cover the fundamentals for utilizing this new custom charger emulation functionality, using references to the EVB GUI. Sections 4 and 5 outline the steps and registers to configure the UCS1002 for custom charger emulation.

2.0 CHARGER EMULATION BASICS

This chapter presents the concepts and relationships used in UCS1002 dedicated charger emulation, such as applied charger emulation profile sequence, charger emulation profile timeout, charging current threshold, charger emulation retry, wait time between charger emulation profile application, and stimulus / response pairs. A thorough understanding of these concepts and relationships is required in order to implement effective solutions.

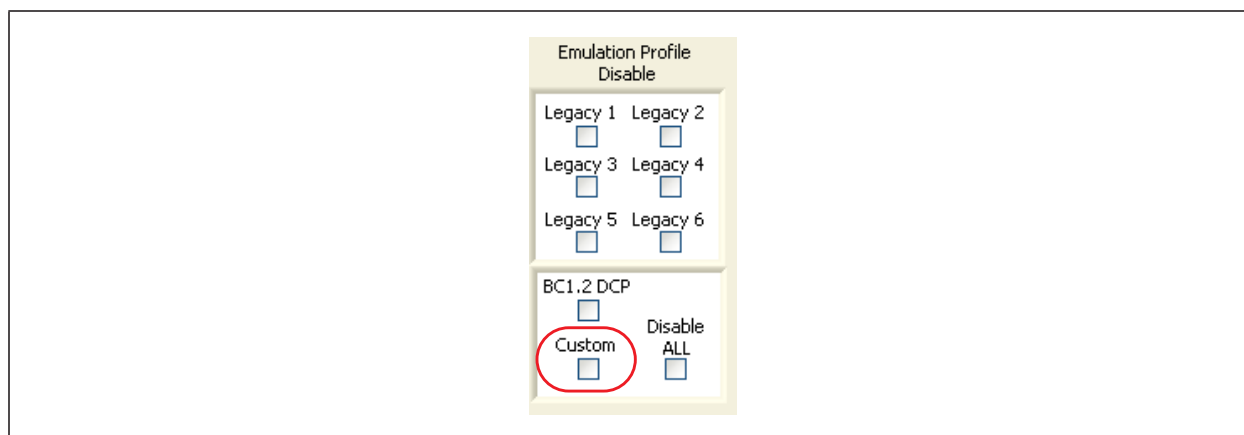
2.1 Overview

The UCS1002 Dedicated Charger Emulation Cycle (DCE Cycle) applies enabled charger emulation profiles in sequence. Charger emulation profiles are comprised of stimulus / response pairs which make up a defined set of signatures or handshaking protocols. When a charger emulation profile is applied, a programmable timer for the charger emulation profile is started. When timeout occurs, the UCS1002 checks the IBUS current against a programmable threshold. If the current is below the threshold, the VBUS line is reset and the next charger emulation profile is applied. If the current is above the threshold, the charger emulation profile is accepted and the associated current limiting behavior, which establishes voltage-current operating boundaries, is applied.

2.2 Charger Emulation Cycle

The Custom charger emulation profile can be included in the DCE Cycle. It is disabled by default. In the EVB GUI, it can be enabled by clearing the “Emulation Profile Disable Custom” check box, as shown in [Figure 1](#).

FIGURE 1: Configuration & General Status Tab: Enable Custom Profile

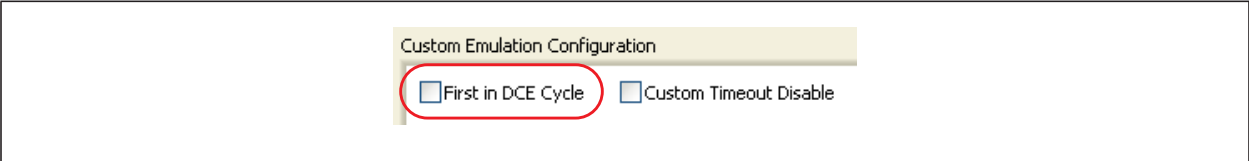


When all charger emulation profiles are enabled, the sequence in which they are applied in the DCE Cycle is:

1. Custom (disabled by default; position if CS1_FIRST is set)
2. Legacy 1
3. DCP
4. Legacy 2
5. Legacy 3
6. Legacy 4
7. Legacy 5
8. Legacy 6
9. Custom (default; position if CS1_FIRST bit not set)

The Custom charger emulation profile is listed twice; however, it can be placed either first or last in the sequence via the “First in DCE Cycle” check box in the EVB GUI, as shown in [Figure 2](#). It is positioned last by default.

FIGURE 2: Custom Charging Tab: First in DC EM Cycle

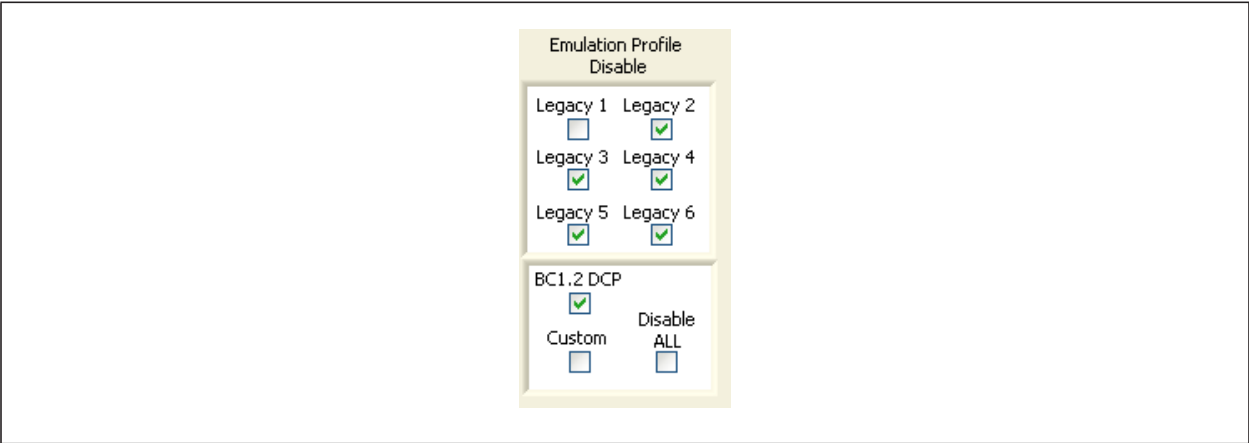


This feature can be used to speed up the recognition of a portable device that is most frequently used with an application. For example, if Brand X portable device is most frequently attached and it charges optimally using Legacy 2, the Custom charger emulation profile can be configured as Legacy 2 and be placed first in the sequence.

For an application that retains memory of which charger emulation profile was last successfully applied, this feature can be used to speed up recognition of a portable device that has been disconnected and then reconnected. For example, the Custom charger emulation profile can be configured as the last charger emulation profile applied and be placed first in the sequence.

If a profile is disabled, it is skipped in the sequence. Disabling profiles, shown in Figure 3, for portable devices that will not be supported by the system, can speed up the charger emulation cycle, making it faster for charging to commence for portable devices that are supported by the system.

FIGURE 3: Configuration & General Status Tab: Disabling Profiles



2.3 Emulation Retry and Wait Time

Both the charger emulation retry and the ability to specify the wait time between the application of successive charger emulation profiles can be useful in some charging situations and in tailoring to specific applications.

2.3.1 EMULATION RETRY

For portable devices not drawing enough current to be recognized as 'charging', the charger emulation retry feature, denoted as EM_RETRY in the UCS1002 Data Sheet, is useful in the DCE Cycle. When EM_RETRY is enabled, the UCS1002 continuously cycles through all of the enabled charger emulation profiles to attempt to provide enough cumulative charge for the portable device to start charging at a level above the charging threshold. For example, a portable device with a dead battery may need to accumulate enough charge to boot the operating system before it can reach the charging threshold.

Alternatively, an application could limit the number of cycles and turn off the charger emulation retry feature entirely. In this case, the portable device would be identified as a "No Handshake" and remain in this state until physically removed from the charger emulation application or the application retries charger emulation. The charger emulation retry feature is controlled in the EVB GUI by the "EM_RETRY" check box, as shown in Figure 4.

FIGURE 4: Configuration & General Status Tab: Retry & Discharge Time

The screenshot shows the 'Configuration & General Status' tab of the EVB GUI. The 'Emulation Behavior' section has 'EM_RETRY' checked and circled in red. The 'General Emulation/Charging Settings' section has 'Discharge Time' set to 400ms and 'EM Reset Time' set to 125ms, both circled in red. Other settings include 'Attach Threshold' at 200uA, 'Charging Threshold Current' at 9.76 mA, and 'HSW_DCE' unchecked.

2.3.2 WAIT TIME

Wait time refers to the time delay between completion of one charger emulation profile and application of the next charger emulation profile. It is a combination of t_{EM_RESET} and $t_{DISCHARGE}$ as stated in the UCS1002 Data Sheet. In some applications, a portable device may require longer times between each charger emulation profile application (e.g., in order to discharge a large portable device input capacitor). In the EVB GUI, the t_{EM_RESET} is set by the “EM Reset Time” pull-down list and $t_{DISCHARGE}$ is set by the “Discharge Time” pull-down list, as shown in Figure 4.

2.4 Stimulus / Response Pairs

Charger emulation profiles are comprised of two or three stimulus / response pairs. Stimulus / response pairs refers to a sequence of operations: an event (stimulus) detected by the UCS1002 and the action (response) performed by the UCS1002 via the USB data lines. All preloaded Legacy charger emulation profiles utilize two stimulus / response pairs. Battery Charging 1.2 (BC1.2) profiles use either two stimulus / response pairs (Dedicated Charging Port) or three (Charging Downstream Port variant). The Custom charger emulation profile requires 3 stimulus / response pairs.

2.4.1 STIMULUS / RESPONSE PAIR CONFIGURATION

After Attach Detection of a portable device, charger emulation starts. VBUS is discharged, and then VBUS is applied to the portable device. The stimulus / response pairs are applied in order. The following sections present stimulus / response pairs in the logical steps that a user would create them. The order and selection of stimulus / response pairs determines the charger emulation sequence. In the following, the nomenclature in parentheses after the title is what is used to denote the variable in the UCS1002 Data Sheet. The step numbers correspond to the steps shown in the EVB GUI Custom Charging tab.

2.4.1.1 Step 1: Stimulus (STIMX)

The types of stimuli that can be selected are as follows. The stimulus names in bold match the EVB GUI STIMX drop-down lists on the Custom Charging tab.

1. **VBUS (PRE):** In effect, there is no stimulus. The UCS1002 applies the response before it applies VBUS to the attached portable device. The UCS1002 looks for the next stimulus.
2. **DP > TH:** The voltage applied by the attached portable device to the UCS1002 DPOUT pin must be greater than a defined threshold voltage in order for charger emulation to continue.
3. **COMPARE:** Window comparator. The voltage applied by the attached portable device to the UCS1002 DPOUT pin must both be greater than 400 mV and also less than a predefined threshold voltage in order for charger emulation to continue.
4. **DM > TH:** The voltage applied by the attached portable device to the UCS1002 DMOUT pin must be greater than a defined threshold voltage in order for charger emulation to continue.
5. **DP > TH:** The voltage applied by the attached portable device to the UCS1002 DPOUT pin must be greater than a defined threshold voltage in order for charger emulation to continue.
6. **VBUS (POST):** In effect, there is no stimulus. The UCS1002 has already applied VBUS to the attached portable device, and then applies the response. The UCS1002 looks for the next stimulus.

2.4.1.2 Step 2: Stimulus Threshold (SX_TH)

For stimuli other than #1 VBUS (PRE) and #6 VBUS (POST) in the list above, the required threshold must be specified. Stimulus threshold's can be selected within a range of 300 mV to 2.2 V.

2.4.1.3 Step 3: Response (SX_RX)

Response options are as follows. The response names in bold match the EVB GUI RX_SX drop-down lists on the Custom Charging tab.

1. **Remove Response DP & DM:** Remove any previous response on DPOUT & DMOUT (e.g., if any were applied by a previous stimulus / response pair and are no longer needed).
2. **Apply Vdc -> DP:** Apply a particular voltage to the DPOUT pin, including zero volts (via a particular pull-down current).
3. **Apply Vdc -> DM:** Apply a particular voltage to the DMOUT pin, including zero volts (via a particular pull-down current).
4. **Apply Vdc -> DP & DM:** Apply the same voltage to both the DPOUT and DMOUT pins, including zero volts (via a particular pull-down current).
5. **Conn Res. DP -> GND:** Connect a pull-down resistor from DPOUT to GND.
6. **Conn Vdivider -> DP:** Connect a VBUS-based voltage divider to DPOUT (having a particular ratio and some minimum impedance between VBUS to GND).
7. **Conn Res. DM -> GND:** Connect a pull-down resistor from DMOUT to GND.
8. **Conn Vdivider -> DM:** Connect a VBUS-based voltage divider to DMOUT (having a particular ratio and some minimum impedance between VBUS and GND).
9. **Conn Short DP -> DM:** Connect a 'short' between DPOUT and DMOUT.
10. **Conn Vdivider -> DP & DM:** Connect two VBUS-based voltage dividers to both DPOUT & DMOUT (with both having a particular ratio and some minimum impedance between VBUS and GND).
11. **Conn Res. DP & DM -> GND:** Connect a same valued pull-down resistor to both DPOUT and DMOUT (to GND).
12. **Emulation Reset Resistors:** This response depends on the stimulus selected. If STIMX[2:0] = 000b, the 15 k Ω pull-down resistors applied to DPOUT and DMOUT during emulation reset are not removed. If STIMX[2:0] = 111b, the 15 k Ω pull-down resistors applied to DPOUT and DMOUT are removed. For all other STIMX[2:0] settings, whatever was applied is not changed.

2.4.1.4 Step 4a: Response Delay Time (SX_TD)

A response time delay (from when the stimulus is determined to be valid) can be specified from zero (default) to 100 ms. It can be specified as being one of two types of delay.

2.4.1.5 Step 4b: Response Delay Type (SX_TD_TYPE)

The two types of delay are:

1. Time from when the stimulus is detected to when the response is applied (and left there while the stimulus is present).
2. Minimum period of time the response is applied starting from when the stimulus is detected. This may cause the response to remain applied after the stimulus is removed.

2.4.1.6 Step 5: Response Magnitude (SX_RXMAG)

The response magnitude can be selected from one of three groups, as determined by what is selected as a response (SX_RX). These groups are:

1. The voltage divider minimum impedance (i.e., between VBUS and GND) to be applied, ranging from 93 k Ω to 200 k Ω .
2. The pull-down resistor value to be applied, ranging from 1.8 k Ω to 150 k Ω .
3. The voltage value to be applied, ranging from zero to 2.2 V.

2.4.1.7 Step 6: Divider Ratio (SX_RATIO)

If any of the voltage divider responses were selected (SX_RX), the divider ratio must be specified. This divider ratio is a selection between 0.25 to 0.66. For example, with VBUS = 5 V, selecting a divider ratio of 0.25 would produce a voltage of $0.25 * 5 \text{ V} = 1.25 \text{ V}$.

2.4.1.8 Response Current Sink Magnitude: SX_PUPD (Alternate Step 6)

If the response magnitude (SX_RXMAG) is selected to be zero volts, a current sink value must be selected to make it zero volts. Current sink values range from 10 μA to 150 μA .

This completes the steps to configure a single stimulus / response pair.

2.5 Charger Emulation Timeout & Charging Current Threshold

A UCS1002 performing charger emulation will first apply the specified stimulus / response pairs and then wait for the attached portable device to start consuming current greater than the specified threshold. The programmable charger emulation timeout and current threshold settings are provided for this purpose.

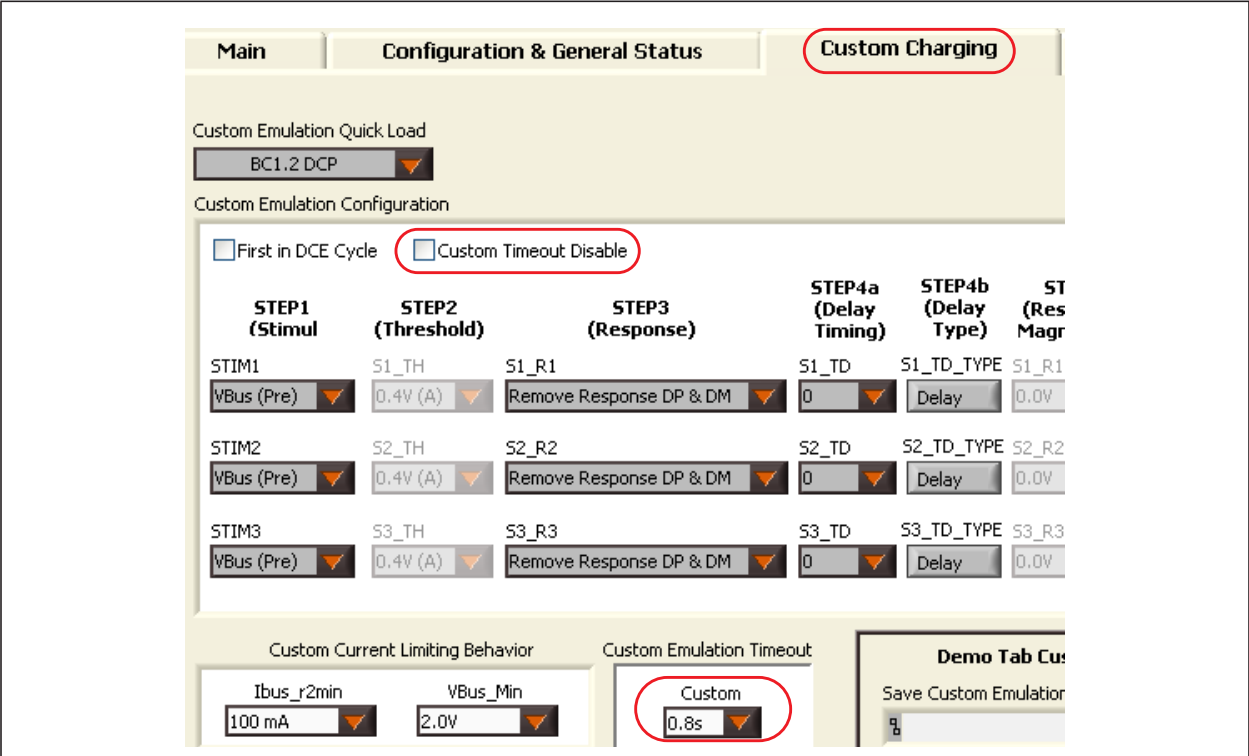
2.5.1 CHARGER EMULATION TIMEOUT

The Custom charger emulation profile timeout can be specified at 800 ms, 1.6 s, 6.4 s, or 12.8 s using the CS1_EM_TIMEOUT[1:0] bits which are controlled by the “Custom” pull-down list in the EVB GUI, as shown in [Figure 5](#). Note that many portable devices will commence charging immediately upon application of the first stimulus / response pair, while others may require a longer timeout after the Custom charger emulation profile is applied. A good example of this is a portable device with a deeply discharged battery that requires quite a long time to ‘trickle charge’ before being able to boot its operating system and commence charging at the normal rate.

The Custom charger emulation profile timeout can be disabled via the CS1_TIMEOUT_DIS bit, which is controlled in the EVB GUI by the “Custom Timeout Disable” check box, as shown in [Figure 5](#). The EM_TIMEOUT_DIS bit can also be used to disable the timeout (in the EVB GUI, this control is on the Configuration & General Status tab). When the timeout is disabled, the UCS1002 will constantly be monitoring the charging current. If the current exceeds the current threshold (see [Section 2.5.2](#)), the UCS1002 will indicate the Custom charger emulation profile was accepted, and then exit or continue application of the Custom charger emulation profile. If the user decides that the last response applied must be left in place while charging is ongoing, the LEAVE_EMU_RESP bit can be set.

When the timeout is disabled, a portable device removal will not be detected after the Custom charger emulation profile is accepted.

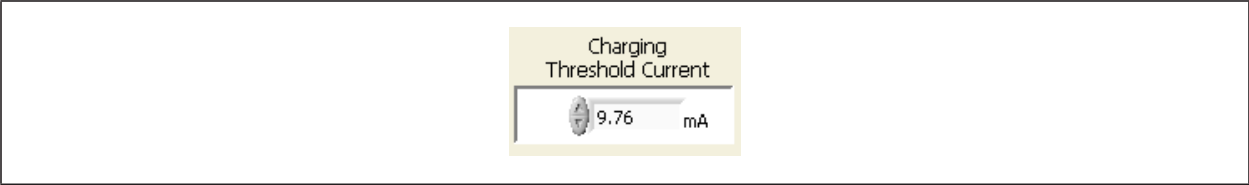
FIGURE 5: Custom Charging Tab: Custom Timeout and Timeout Disable



2.5.2 CHARGING CURRENT THRESHOLD

The specified charger emulation charging current threshold value, I_{BUS_CHG} in the data sheet, is what the UCS1002 uses to determine if an applied charger emulation profile has been successful in enabling the attached portable device to commence charging. Its value can range from 9.76 mA to 156 mA, with a default value of 9.76 mA and resolution of 9.76 mA. This variable is controlled in the EVB GUI by the Charging Threshold Current list on the Configuration and General Status tab, as shown in Figure 6.

FIGURE 6: Configuration & General Status Tab: Charging Current Threshold



2.6 Example 1 - Charger Emulation

As a basic example of these concepts, using a UCS1002 EVB and GUI, configure the UCS1002, as shown in Figure 7, Figure 8, and Figure 9.

FIGURE 7: Custom Charging Tab: Stimulus / Response Pairs

Custom Emulation Configuration

☐ First in DCE Cycle ☒ Custom Timeout Disable

STEP1 (Stimulus)	STEP2 (Threshold)	STEP3 (Response)	STEP4a (Delay Timing)	STEP4b (Delay Type)	STEP5 (Response Magnitude)	STEP6 (Pull-down mag. or v-divider ratio)	
STIM1 VBus (Pre)	S1_TH 0.4V (A)	S1_R1 Apply Vdc -> DP & DM	S1_TD 0	S1_TD_TYPE Delay	S1_R1MAG 2.2V	S1_Ratio Vbus*0.25	S1_PUPD 10uA
STIM2 VBus (Pre)	S2_TH 0.4V (A)	S2_R2 Apply Vdc -> DP & DM	S2_TD 0	S2_TD_TYPE Delay	S2_R2MAG 2.2V	S2_Ratio Vbus*0.25	S2_PUPD 10uA
STIM3 VBus (Pre)	S3_TH 0.4V (A)	S3_R3 Apply Vdc -> DP & DM	S3_TD 0	S3_TD_TYPE Delay	S3_R3MAG 2.2V	S3_Ratio Vbus*0.25	S3_PUPD 10uA

FIGURE 8: Configuration & General Status Tab: Enabling Only the Custom Profile

Emulation Profile
Disable

Legacy 1 Legacy 2

☒ ☒

Legacy 3 Legacy 4

☒ ☒

Legacy 5 Legacy 6

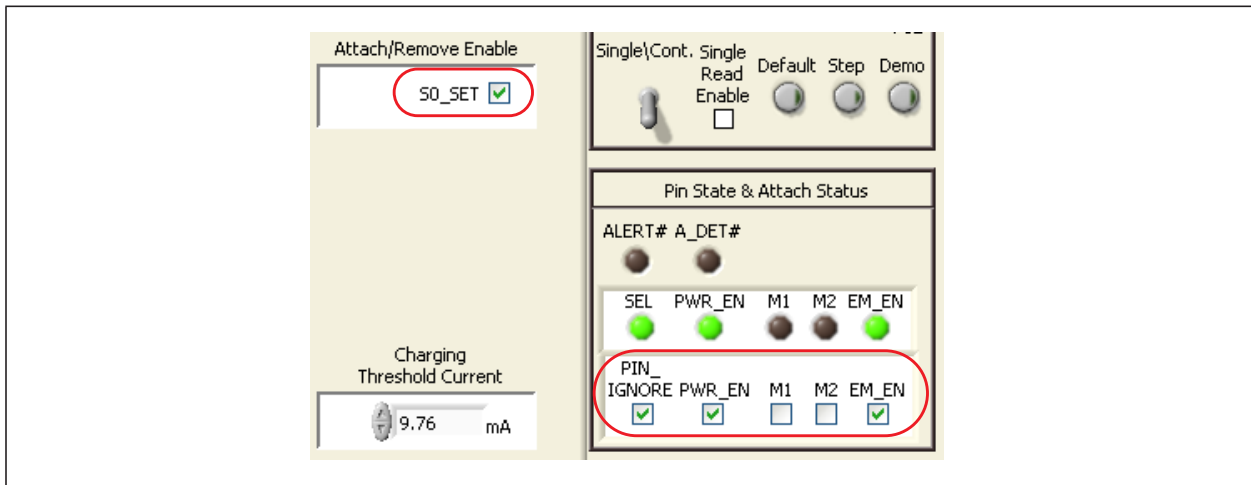
☒ ☒

BC1.2 DCP

☒ Custom

☐ Disable ALL

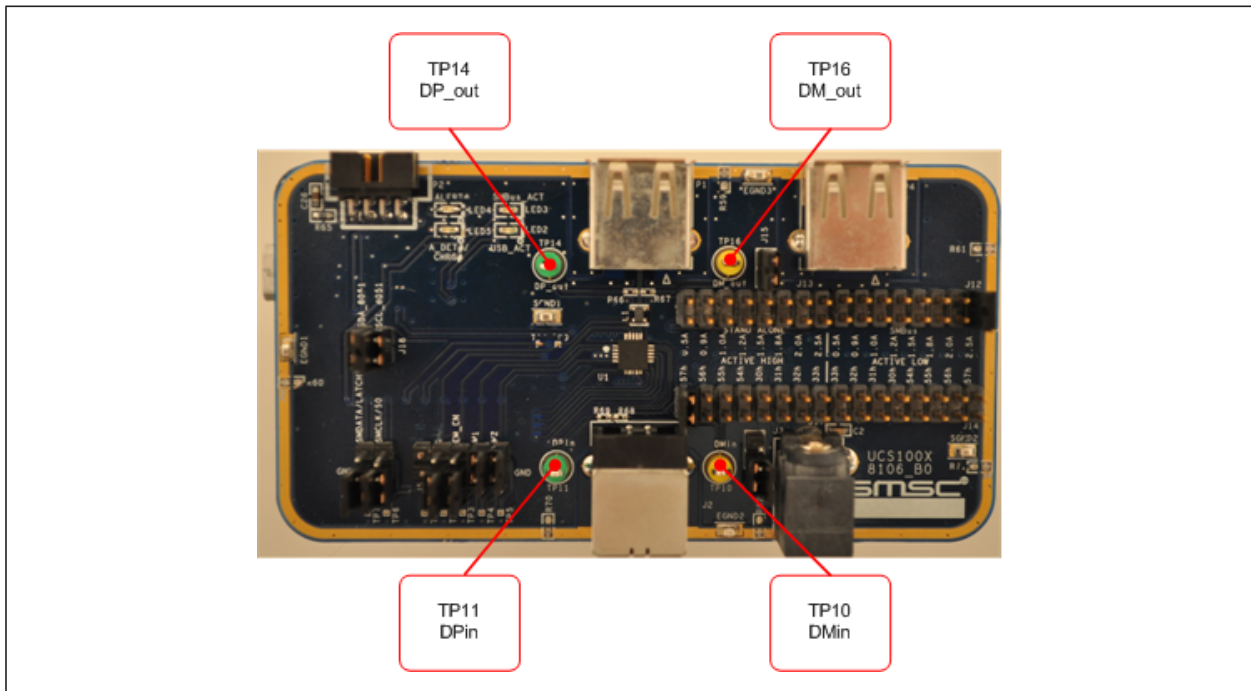
FIGURE 9: Right Sidebar: Enabling the Dedicated Charger



Apply VS and attach a portable device. The A_DET# status indicator should light when the Attach Detection event occurs.

When the UCS1002 applies the Custom charger emulation profile, a voltage of 2.2 Vdc will be observed on the DPOUT test point (TP14) and DMOUT test point (DP16) (see Figure 10). Since VBUS (Pre) is used as the only stimulus, all three stimulus / response pairs are performed in succession, with the third one left in place.

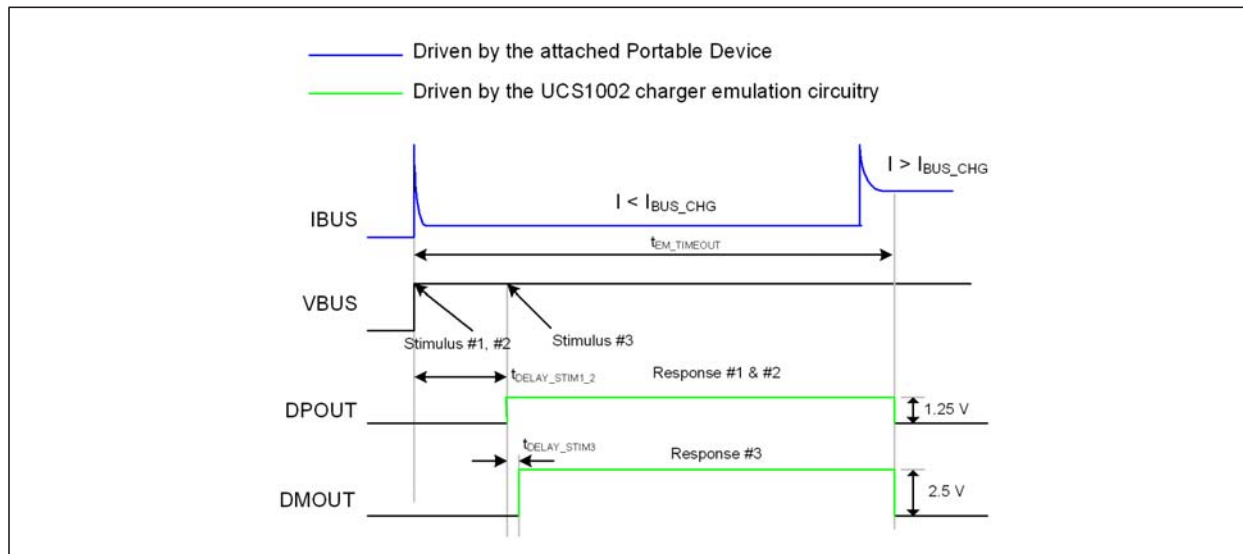
FIGURE 10: UCS1002 EVB DPOUT / DMOUT Test Points



2.7 Example 2 - Charger Emulation

As another example, let's suppose the designer of a custom charging application wants to emulate a charger by utilizing the UCS1002's ability to provide differing responses on its DPOUT & DMOUT pins, as well as utilizing time delays.

FIGURE 11: Example 2 Timing Diagram



For this example, as illustrated in Figure 11, two different VBUS-based voltage divider ratios are applied, at different times, and after different delays, to DPOUT & DMOUT.

Stimulus 1, which occurs after VBUS, is a VBUS voltage divider with ratio 0.25. Once VBUS (5 V) is applied to the attached portable device, and after a delay of t_{DELAY_STIM1} (a 'type 1' delay), response 1 is applied so that a voltage of 1.25 V appears on DPOUT ($5\text{ V} * 0.25 = 1.25\text{ V}$).

Since the second stimulus / response pair is the same as the first, there is no change and the sequence continues on to stimulus / response pair 3 and waits.

Once the UCS1002 detects the presence of stimulus 3 on DPOUT, and after a delay of t_{DELAY_STIM3} , response 3 is applied to DMOUT ($VBUS * 0.5 = 2.5\text{ V}$).

These two voltages could now be measured on DPOUT and DMOUT as in Example 1, but only before the charger emulation timeout expires.

Note that, in this example, the attached portable device starts to draw current (higher than the charging current threshold, I_{BUS_CHG}) as shown in Figure 11, before responses 1-3 are removed. As such, this would be considered a successful charger emulation.

Figure 12 shows the correct UCS1002 stimulus / response pair configuration that will produce the desired output voltages and impedances in this example (using the UCS1002 EVB GUI). Note, however, that the same result can be obtained by using the stimulus / response pair configuration shown in Figure 13. This second method works because of the rules applied to the stimulus / response pairs (see Section 2.8, "Stimulus / Response Pair Rules").

FIGURE 12: Custom Charging Tab: Example 2 (Configuration 1)

Custom Emulation Configuration

☐ First in DCE Cycle ☐ Custom Timeout Disable

STEP1 (Stimulus)	STEP2 (Threshold)	STEP3 (Response)	STEP4a (Delay Timing)	STEP4b (Delay Type)	STEP5 (Response Magnitude)	STEP6 (Pull-down mag. or v-divider ratio)
STIM1 VBUS (Post)	S1_TH 0.4V (A)	S1_R1 Conn Vdivider -> DP	S1_TD 100ms	S1_TD_TYPE Delay	S1_R1MAG 200k min	S1_Ratio Vbus*0.25 S1_PUPD 10uA
STIM2 VBUS (Post)	S2_TH 0.4V (A)	S2_R2 Conn Vdivider -> DP	S2_TD 100ms	S2_TD_TYPE Delay	S2_R2MAG 200k min	S2_Ratio Vbus*0.25 S2_PUPD 10uA
STIM3 DP > TH	S3_TH 0.9V	S3_R3 Conn Vdivider -> DM	S3_TD 10ms	S3_TD_TYPE Delay	S3_R3MAG 93k min	S3_Ratio Vbus*0.50 S3_PUPD 10uA

In Figure 13, stimulus #3 is not tested because the response to stimulus / response pair #2 is not removed. That response is not removed because the stimulus for stimulus / response #2 is not removed. That stimulus is not removed because the response for stimulus / response pair #1 satisfies the condition. This response is not removed because stimulus #1 is related to VBUS.

FIGURE 13: Custom Charging Tab: Example 2 (Configuration 2)

Custom Emulation Configuration

☐ First in DCE Cycle ☐ Custom Timeout Disable

STEP1 (Stimulus)	STEP2 (Threshold)	STEP3 (Response)	STEP4a (Delay Timing)	STEP4b (Delay Type)	STEP5 (Response Magnitude)	STEP6 (Pull-down mag. or v-divider ratio)
STIM1 VBUS (Post)	S1_TH 0.4V (A)	S1_R1 Conn Vdivider -> DP	S1_TD 100ms	S1_TD_TYPE Delay	S1_R1MAG 200k min	S1_Ratio Vbus*0.25 S1_PUPD 10uA
STIM2 DP > TH	S2_TH 0.9V	S2_R2 Conn Vdivider -> DM	S2_TD 10ms	S2_TD_TYPE Delay	S2_R2MAG 93k min	S2_Ratio Vbus*0.50 S2_PUPD 10uA
STIM3 VBUS (Pre)	S3_TH 0.9V	S3_R3 Remove Response DP & DM	S3_TD 0	S3_TD_TYPE Delay	S3_R3MAG 0.8V	S3_Ratio Vbus*0.50 S3_PUPD 10uA

2.8 Stimulus / Response Pair Rules

In general, the UCS1002 employs a set of rules regarding stimulus / response. These are:

1. Stimulus N will not be checked until the response associated with stimulus N-1 has been removed unless stimulus N-1 is related to VBUS.
2. If stimulus N is related to VBUS, response N will be applied and the UCS1002 will look for stimulus N+1.
3. Response N will be applied when stimulus N has been detected based on the response settings. When stimulus N is removed, response N will be removed unless:
 - a. Stimulus N is VBUS-related. In this case, response N will not be removed.
 - b. The timer for response N is set to "Apply response for X time" and the timer has not expired. The response will be removed when the timer has expired, if stimulus N has been removed.
4. Only one stimulus may be looked for at any given time.
5. Only one response may be applied per stimulus detected.

6. When a response is applied, it may be applied to either DPOUT, DMOUT, or both pins simultaneously. When a response is applied to DPOUT and DMOUT in response to the same stimulus, the magnitude and type of response will be the same.
7. All stimuli required to define a profile must be configured. There is no option to “skip” a stimulus.
8. The maximum number of stimuli available for any given profile is three.
9. The last stimulus in the profile does not need to be removed.

2.9 Custom Stimulus / Response Control Registers

Registers 40h - 4Ch in the UCS1002 register map are used to configure the stimulus / response pairs in the Custom charger emulation profile, as shown in [Table 1](#). This table does not include all of the controls discussed above that can be adjusted to configure charger emulation profiles (see the UCS1002 Data Sheet for details on these controls).

Each of the stimulus / response pairs is configured via 4 registers (41h - 44h, 45h - 48h, 49h - 4Ch respectively) with each set of 4 registers containing the same control fields (though they apply to different stimulus / response pairs).

The Custom charger emulation profile has another register, 40h, that is used to enable and control system level aspects of the Custom charger emulation profile, such as the timeout period ($t_{EM_TIMEOUT}$) and the Custom charger emulation profile's order within the emulation cycle.

TABLE 1: CUSTOM EMULATION CONFIGURATION REGISTERS

ADDR	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
40h	Custom Emulation Config	-	-	CS1_TIME-OUT_DIS	CS1_EM_TIME-OUT[1:0]		CS1_-FIRST	0	CS1_E M_DIS	01h
41h	Custom Emulation Stimulus 1 - Config 1	-	CS1_S1_T D_TYPE	CS1_S1_TD[2:0]			CS1_STIM1[2:0]			00h
42h	Custom Emulation Stimulus 1 - Config 2	CS1_S1_R1MAG[3:0]				CS1_S1_R1[3:0]				00h
43h	Custom Emulation Stimulus 1 - Config 3	-	-	CS1_S1_PUPD[1:0]		CS1_S1_TH[3:0]				00h
44h	Custom Emulation Stimulus 1 - Config 4	-	-	-	-	-	CS1_S1_RATIO[2:0]			00h
45h	Custom Emulation Stimulus 2 - Config 1	-	CS1_S2_T D_TYPE	CS1_S2_TD[2:0]			CS1_STIM2[2:0]			00h
46h	Custom Emulation Stimulus 2 - Config 2	CS1_S2_R2MAG[3:0]				CS1_S2_R2[3:0]				00h
47h	Custom Emulation Stimulus 2 - Config 3	-	-	CS1_S2_PUPD[1:0]		CS1_S2_TH[3:0]				00h
48h	Custom Emulation Stimulus 2 - Config 4	-	-	-	-	-	CS1_S2_RATIO[2:0]			00h
49h	Custom Emulation Stimulus 3 - Config 1	-	CS1_S3_T D_TYPE	CS1_S3_TD[2:0]			CS1_STIM3[2:0]			00h
4Ah	Custom Emulation Stimulus 3 - Config 2	CS1_S3_R3MAG[3:0]				CS1_S3_R3[3:0]				00h
4Bh	Custom Emulation Stimulus 3 - Config 3	-	-	CS1_S3_PUPD[1:0]		CS1_S3_TH[3:0]				00h
4Ch	Custom Emulation Stimulus 3 - Config 4	-	-	-	-	-	CS1_S3_RATIO[2:0]			00h

2.10 Preloaded Emulation Configuration Values

The UCS1002 configures the preloaded profiles in real time. When a preloaded profile is applied, the values for the parameters the profile needs are copied from the internal memory into the applicable controls in the preloaded emulation configuration registers, 31h-3Ch. However, not all parameters are required for all profiles. When a particular parameter is not required for a given preloaded profile, the unused register values are not cleared. The table shown in [Figure 14](#) indicates what register values are valid for each of the profiles.

When BC1.2 DCP or one of the Legacy profiles is selected from the Customer Emulation Quick Load drop-down list, the EVB GUI automatically loads the first stimulus / response pair 1 as VBUS (PRE) and remove response from DP & DM. This is because the Custom charger emulation profile requires three stimulus / response pairs, but DCP and the Legacy profiles only use two (shown in [Figure 14](#)). Stimulus / response pairs 1 and 2 from the selected profile are then loaded into Custom stimulus response registers for pairs 2 and 3 respectively. The BC1.2 profile as loaded by the EVB GUI is shown in [Figure 15](#).

FIGURE 15: Custom Charging Tab: Quick Load BC1.2 DCP

Custom Emulation Quick Load

BC1.2 DCP

Custom Emulation Configuration

☐ First in DCE Cycle ☐ Custom Timeout Disable

STEP1 (Stimulus)	STEP2 (Threshold)	STEP3 (Response)	STEP4a (Delay Timing)	STEP4b (Delay Type)	STEP5 (Response Magnitude)	STEP6 (Pull-down mag. or v-divider ratio)
STIM1 VBus (Pre)	S1_TH 0.4V (A)	S1_R1 Remove Response DP & DM	S1_TD 0	S1_TD_TYPE Delay	S1_R1MAG 0.0V	S1_Ratio Vbus*0.25 S1_PUPD 10uA
STIM2 VBus (Pre)	S2_TH 0.4V (A)	S2_R2 Conn short, DP -> DM	S2_TD 0	S2_TD_TYPE Delay	S2_R2MAG Not used	S2_Ratio Vbus*0.25 S2_PUPD 10uA
STIM3 VBus (Pre)	S3_TH 0.4V (A)	S3_R3 Conn short, DP -> DM	S3_TD 0	S3_TD_TYPE Delay	S3_R3MAG Not used	S3_Ratio Vbus*0.25 S3_PUPD 10uA

2.11 Power-on Reset Effect on Custom Profiles

When a power-on reset (POR) occurs, the UCS1002 registers are reset to their default values and the RESET bit is set. The controls mentioned in this document must be reprogrammed. To determine whether a POR has occurred, monitor a programmed register. For example, choose one of the custom stimulus / response pair configuration registers 41h - 4Ch (see [Figure 14](#)) which is being programmed. When it resets to 00h, a POR has occurred, and the registers must be reprogrammed.

3.0 CURRENT LIMITING BEHAVIOR BASICS

3.1 Overview

After a charger emulation profile is accepted, its associated current limiting mode, trip or constant current (variable slope), is applied. Current limiting modes have distinct voltage-current operation regions defined by “keep-out” and “operation” regions. Two key parameters, V_{BUS_MIN} and I_{BUS_R2MIN} , that help define the voltage-current operation regions are either determined automatically or are loaded from the user-defined custom settings.

The Custom charger emulation profile is associated with the Custom current limiting behavior, which defaults to trip mode.

3.2 Minimum VBUS, Current Limiting, & Limit Behavior

In the BC1.1 specification, an attached portable device is allowed to cause a compliant charger to enter constant current limiting, and thereby reduce its output voltage while increasing its output current. This voltage reduction is down to a specified value, at which time the charger can turn off (if required). Though BC1.2 makes this feature optional (and extends the maximum dedicated charging current beyond 1.5 A), the UCS1002 can operate in either mode depending on the relationships between V_{BUS_MIN} , I_{BUS_R2MIN} , and I_{LIM} (as denoted in the UCS1002 Data Sheet).

3.2.1 MINIMUM VBUS

The Custom current limiting behavior minimum VBUS value (V_{BUS_MIN}) can be specified by the user. This is the value under which the UCS1002 will enter the Error state and turn the port power switch “Off”. The default value for this is 2.0 V. The bit is denoted as CS_VBUS_MIN[1:0] in register 51h in the UCS1002 Data Sheet.

3.2.2 CURRENT LIMIT

The UCS1002's current limit is first established at power up. The value is also stored as ILIM_SW[2:0] in register 19h and can be changed to be lower than the hardware set value. Its relationship to the current limit behavior bits (see [Section 3.2.3](#)) determines whether the custom charger will enter constant current limiting or trip when the current limit is reached.

3.2.3 CURRENT LIMIT BEHAVIOR BOUNDARY

The Custom current limit behavior boundary is set to 100 mA by default. It is denoted as CS_R2_IMIN[2:0] in register 51h in the data sheet. In general, if it is set higher than the current limit (ILIM_SW), the UCS1002 will employ constant current limiting. If it is set equal to or lower than the current limit, the UCS1002 will trip when the current limit is reached. Refer to the UCS1002 Data Sheet for more information on the relationship to ILIM_SW and the capabilities of this variable.

4.0 CONFIGURING A CUSTOM CHARGER EMULATION PROFILE

This section steps through the register settings to configure the Custom charger emulation profile. Note that settings related to the preloaded charger emulation profiles are not included unless they also affect the Custom charger emulation profile.

4.1 Define Charger Emulation Profile Sequence

To enable the custom charger emulation profile and its position in the DCE Cycle (see [Section 2.2, "Charger Emulation Cycle"](#)), complete the following:

1. Ensure CS1_EM_DIS is 0b in register 40h. This enables the Custom charger emulation profile so it will be included in the DCE Cycle.
2. Set CS1_FIRST in register 40h. The default (0b) puts the Custom charger emulation profile last in the sequence. A value of 1b puts it first in the sequence.

4.2 Define Emulation Retry and Wait Time

To define emulation retry and wait time (see [Section 2.3, "Emulation Retry and Wait Time"](#)), complete the following:

1. Set EM_RETRY in register 16h. When using the DCE Cycle, this determines whether to continuously cycle through all the enabled charger emulation profiles or stop after applying the final emulation profile in the sequence.
2. Set EM_RESET_TIME[1:0] in register 16h. This determines the time the VBUS line is held in reset prior to applying the next charger emulation profile.
3. Set DISCHG_TIME_SEL[1:0] in register 18h. This determines the time the VBUS discharge resistor is applied prior to applying the next charger emulation profile.

4.3 Define Stimulus / Response Pairs

When defining stimulus / response pairs, the user needs to have full knowledge of how the targeted portable device will act and what it will expect to read from the charging port it is connecting to (see [Section 2.4, "Stimulus / Response Pairs"](#)). By the nature of the stimulus / response pair functionality, timing between actions by the portable device is not essential; however, it is important to understand that a stimulus will not be checked until the previous stimulus / response has been removed (with the exception of VBUS-based stimuli).

The user must extrapolate the portable device actions and expected reactions to no more than three stimulus / response pairs.

4.3.1 DETERMINE BEHAVIOR

When creating stimulus / response pairs, it is useful to complete the following:

1. Determine the actions that the portable device will take once VBUS is applied.
2. Determine the timing constraints that these actions will have (How soon after VBUS is applied will they occur? How long between actions?).
3. Determine the magnitude of the action that the portable device will take (How much voltage or current will it apply?).
4. Determine the responses that the UCS1002 will need to apply to the DPOUT and DMOUT lines to enable charging of a portable device.
5. Determine the timing constraints with these responses (How long they must be applied for? How long of a delay before the response is expected? etc.)
6. Determine the magnitude of the responses (What voltage, current, or resistor value is necessary?).

Each of these steps need not be taken in the indicated order, but they all should be considered. As well, it is important to note the constraints and rules used by the UCS1002 custom profile (see [Section 2.8, "Stimulus / Response Pair Rules"](#)).

4.3.2 CONFIGURE STIMULUS / RESPONSE SETTINGS

Once the system has been defined, the user must evaluate the stimulus and response options available, taking into account the limitations. The process for defining stimulus / response pairs is outlined below (for more detail, see [Section 2.4.1, "Stimulus / Response Pair Configuration"](#)):

1. Set CS1_SX_STIMX[2:0] in registers 41h, 45h, and 49h. For each action the portable device is going to take, choose a corresponding stimulus. This stimulus must be one that allows the UCS1002 to detect that the particular portable device action has occurred, and also allows the UCS1002 response to be applied when needed. Recall that, aside from VBUS-related stimuli, a stimulus will not be checked until the response to the previous stimulus has been removed.
2. Set CS1_SX_TH[3:0] in registers 43h, 47h, and 4Bh. Set the stimulus threshold to be equal to the magnitude of the action taken (if a voltage).
3. Set CS1_SX_RX[3:0] in registers 42h, 46h, and 4Ah. For each stimulus that the UCS1002 is going to receive, choose a corresponding response action. Recall that, except for VBUS-related stimuli, responses are removed when the stimulus is removed. Also recall that there are multiple ways to apply a voltage on the DPOUT and DMOUT pins (either directly applying a voltage or creating a resistor divider from VBUS).
4. Set CS1_SX_TD[2:0] and CS1_SX_TD_TYPE in registers 41h, 45h, and 49h. Set the timer type and value of the response to match the expected timing of the portable device. Recall that the timer can act as a delay before the response is applied, or it can act as a minimum time that the response will be applied for.
5. Set CS1_SX_RXMAG[3:0] in registers 42h, 46h, and 4Ah. Set the magnitude of the response to the magnitude expected by the portable device.
6. If CS1_SX_RXMAG[3:0] is set to 0000b, set CS1_SX_PUPD[1:0] in registers 43h, 47h, and 4Bh. Set the magnitude of the response to the magnitude expected by the portable device.
7. If CS1_SX_RX[3:0] is set to 0110b, 1001b, or 1100b, set CS1_SX_RATIO[2:0] in registers 44h, 48h, 4Ch. Set the ratio settings to the right value depending on the response.

Once you have settings in the GUI you like the GUI also allows the following:

- You may check the raw data registers.
- You can save and print out the text file to determine the necessary configuration to recreate the actions.

4.3.3 UNUSED STIMULUS / RESPONSE SETTINGS

Generally speaking, any charger emulation profile will use two or three stimulus / response pairs; however, the Custom charger emulation profile requires that all three stimulus / response pairs be configured. If only two stimulus / response pairs are needed for a profile, set registers 41h, 42h, 43h, and 44h all to 00h. This sets stimulus 1 to VBUS (PRE), response 1 to “remove previous response on DPOUT and DMOUT”, and no other controls are used for stimulus / response pair 1. Then set the second and third stimulus response pairs to the desired settings.

If only one stimulus / response pair is needed, also set registers 45h, 46h, 47h, and 48h all to 00h for stimulus / response pair 2. Then set the third stimulus / response pair to the desired settings.

4.4 Define Emulation Timeout and Charging Current Threshold

To define emulation timeout and charging current threshold (see [Section 2.5, "Charger Emulation Timeout & Charging Current Threshold"](#)), complete the following:

1. Set CS1_EM_TIMEOUT[1:0] in register 40h. This determines the timeout value that is used when the Custom charger emulation profile is applied. Or, set CS1_TIMEOUT_DIS to 1b in register 40h to disable the Custom charger emulation profile timeout. Or, set EM_TIMEOUT_DIS to 1b in register 16h to disable all timeouts in the DCE Cycle.
2. Set a value for register 1Eh. This sets the charger emulation charging current threshold.

5.0 CONFIGURING CUSTOM CURRENT LIMITING BEHAVIOR

This section steps through the register settings to configure the Custom current limiting behavior.

5.1 Define Minimum VBUS

To define the minimum VBUS (see [Section 3.2.1, "Minimum VBUS"](#)) when the Custom current limiting behavior is used, complete the following:

1. Set CS_VBUS_MIN[1:0] in register 51h. If VBUS drops below this value, the port power switch is turned "off".

5.2 Define Current Limit

To define the minimum current limit (see [Section 3.2.2, "Current Limit"](#)), complete the following:

1. Determine the desired current limit (and communications mode), locate the associated ILIM setting in the UCS1002 Data sheet, and then connect the corresponding resistor to the COMM_SEL / ILIM pin. This establishes the hardware set current limit which cannot be exceeded.
2. Set ILIM_SW[2:0] in register 19h if desired. This value defaults to the hardware set value.

5.3 Define Current Limit Behavior

To define the current limit behavior (see [Section 3.2.3, "Current Limit Behavior Boundary"](#)) when the Custom current limiting behavior is used, complete the following:

1. Set CS_R2_IMIN[2:0] in register 51h. This determines whether the UCS1002 will use constant current limiting or trip current limiting. When the current limit, ILIM, is equal to or greater than I_{BUS_R2MIN} , trip mode is used. When the current limit is less than I_{BUS_R2MIN} , constant current mode is used.

6.0 TROUBLESHOOTING A PROFILE

After the Custom charger emulation profile has been configured, it should be tested with an actual portable device to check that the profile is functional. This chapter includes some potential problems and possible solutions.

6.1 Custom Charger Emulation Profile Responds Prior to Portable Device Activation

This problem may be observed as the UCS1002 applying voltage or a pull-down current on the DPOUT and DMOUT pins prior to the portable device activating or detecting a valid VBUS.

6.1.1 POSSIBLE CAUSES

1. Stimulus #1 is always looked for as soon as the UCS1002 has caused the port power switch to be closed. The UCS1002 will not check whether or not the VBUS voltage reaches its proper levels before checking this stimulus.
2. If stimulus #1 is "VBUS (PRE)" or "VBUS (POST)", the response will be applied immediately even if the portable device is not ready for the response. If stimulus #1 is comparing the DPOUT or DMOUT pins against a voltage threshold, the portable device may be indirectly applying this value as it powers up. The UCS1002 has some small amount of filtering on these comparisons, but it is intended to reject fast transient spikes.

6.1.2 POSSIBLE SOLUTIONS

1. Changing the stimulus threshold may remove some of the errant behavior if stimulus #1 is comparing DPOUT or DMOUT against a threshold.
2. Changing the time delay settings will not remove the response or act to filter the detection. It can, however, delay when the response is applied. This may be a viable solution if the response is desired but needs to be delayed so that it does not prevent the portable device from powering up properly.

6.2 Custom Charger Emulation Profile Doesn't Respond to Stimulus

This problem may be observed during a handshake. The portable device applies the expected stimulus but the UCS1002 does not respond (or may appear to respond incorrectly).

6.2.1 POSSIBLE CAUSES

1. The first obvious cause is that the stimulus / response pairs are not configured to look for the stimulus that is being applied.
2. Stimulus #2 will not be checked if stimulus #1 has not been detected AND the response removed (unless stimulus #1 is VBUS-related). The response is removed after stimulus #1 has been removed which means that stimulus #2 will not be checked until stimulus #1 has been detected and subsequently removed (unless stimulus #1 is VBUS-related).
3. It is possible that the UCS1002 is responding to the stimulus that is applied; however, that response cannot be observed. This would occur in a test environment if the response is applied with a voltage source. In such a case, the UCS1002 pull-down current or resistor will not be sufficient to load the voltage source in an observable way.
4. The number of stimulus / response pairs allowed by the UCS1002 is limited to three. Therefore, any stimuli beyond the 3rd will not be looked for, and no response will be generated.

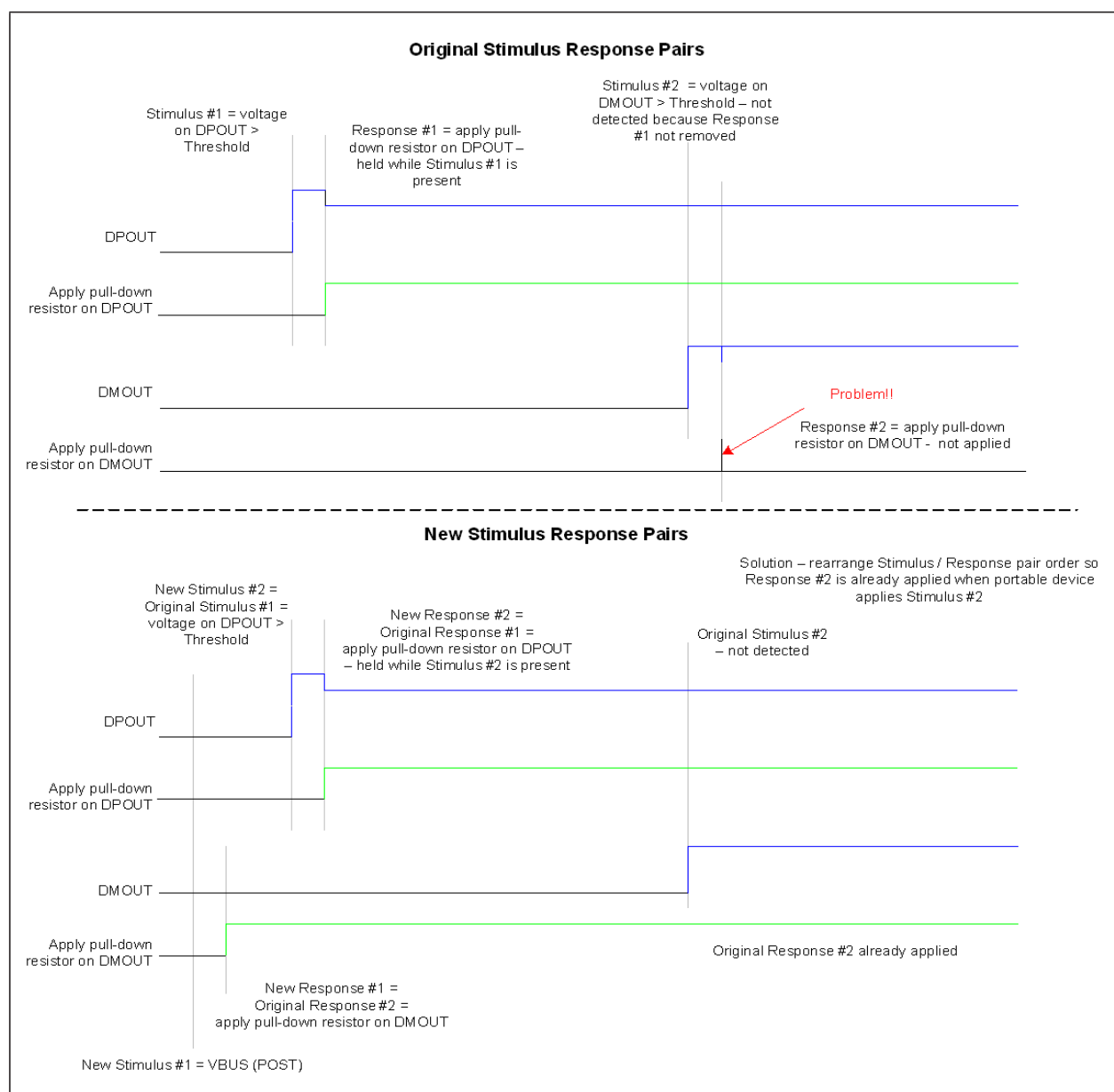
6.2.2 POSSIBLE SOLUTIONS

1. Check that the stimulus / response pairs are in the correct order. This may be difficult and counter-intuitive to determine. Consider what must be presented on the DPOUT and DMOUT pins before and after any actions that the portable device will take using the following guidelines:
 - a. If a response must be present BEFORE the portable device does anything, the stimulus should be "VBUS (PRE)" or "VBUS (POST)". Either one will cause the response to be applied until it is replaced; however, it will not prevent the UCS1002 from evaluating the next stimulus.
 - b. If a response should not be present before the portable device does something OR the response needs to be removed after the portable device has removed something, the stimulus should be related to the action the portable device is taking.
2. Check that the response from the previous stimulus has been removed before the next stimulus is generated by the portable device. If the UCS1002 response must be applied before the previous stimulus has been removed, the following should be done (assuming that response #1 is the response to the stimulus that remains active and response #2 is the response to the stimulus that is applied next while the first stimulus is active). An example of

this solution is shown in Figure 16.

- Evaluate the effect of response #2 on the system prior to stimulus #1 and response #1 being applied.
- Check that response #2 does not command the same pin (DPOUT or DMOUT) as response #1. If response #2 and response #1 need to be applied to the same pin, this solution will not work.
- If response #2 will not load the system in a way that is detrimental to stimulus #1, response #1 or stimulus #2 and it is not on the same pin (DPOUT or DMOUT) as response #1, it may be applied PRIOR to stimulus #1 and held in place through stimulus #1 (in effect, swapping with response #1).
- In the Custom charger emulation profile settings, change stimulus #2 and response #2 to the same values that were in stimulus #1 and response #1.
- In the Custom charger emulation profile settings, change stimulus #1 to “VBUS (POST)” and change response #1 to the original response #2. This response will be held for the duration of the $t_{EM_TIMEOUT}$ period.

FIGURE 16: Example Solution to Stimulus #1 Not Removed Before Response #2 Needs to Be Applied



AN 24.14

3. Adjust the stimulus threshold until the stimulus is detected.
4. Adjust the current driving capability of any voltage sources used to generate a stimulus such that the desired response can overcome the voltage source (if necessary). If generating a voltage via a resistor divider, increase the magnitude of the resistor values by a factor of 10x such that the response has a much larger impact on the pin voltage.
5. Adjust the programming of the UCS1002 to perform the desired handshake in three stimulus / response pairs. Take advantage of the fact that the VBUS-related stimuli apply the response until it is replaced. If a pull-down source is necessary for multiple stimulus / response pairs and it will not adversely load the system, consider setting this up first.

APPENDIX A: APPLICATION NOTE REVISION HISTORY

TABLE 2: CUSTOMER REVISION HISTORY

Revision Level and Date	Section/Figure/Entry	Correction
REV A (10-11-13)	REV A replaces the previous SMSC version 1.0	
Rev. 1.0 (11-08-11)	Formal document release	

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