AN 25.4

UCS1002 Advanced Custom Charging

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INTRODUCTION

This application note extends application note 24.14 (UCS1002 Fundamentals of Custom Charger Emulation) by presenting two examples of using the UCS1002 Custom charger emulation profile. The first example shows how to analyze portable device behavior and configure the Customer profile to enable charging. The second example shows charger profile optimization.

References

This application note references the following items:

- UCS1002 Data Sheet
- UCS1002 Schematic Reference Design
- UCS1002 EVB Package
- AN 24.14 UCS1002 Fundamentals of Custom Charger Emulation

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 devices.

CREATING A CUSTOM CHARGER EMULATION PROFILE

This first example will create a Custom charger emulation profile that looks like a leading “Brand X” dedicated charger.

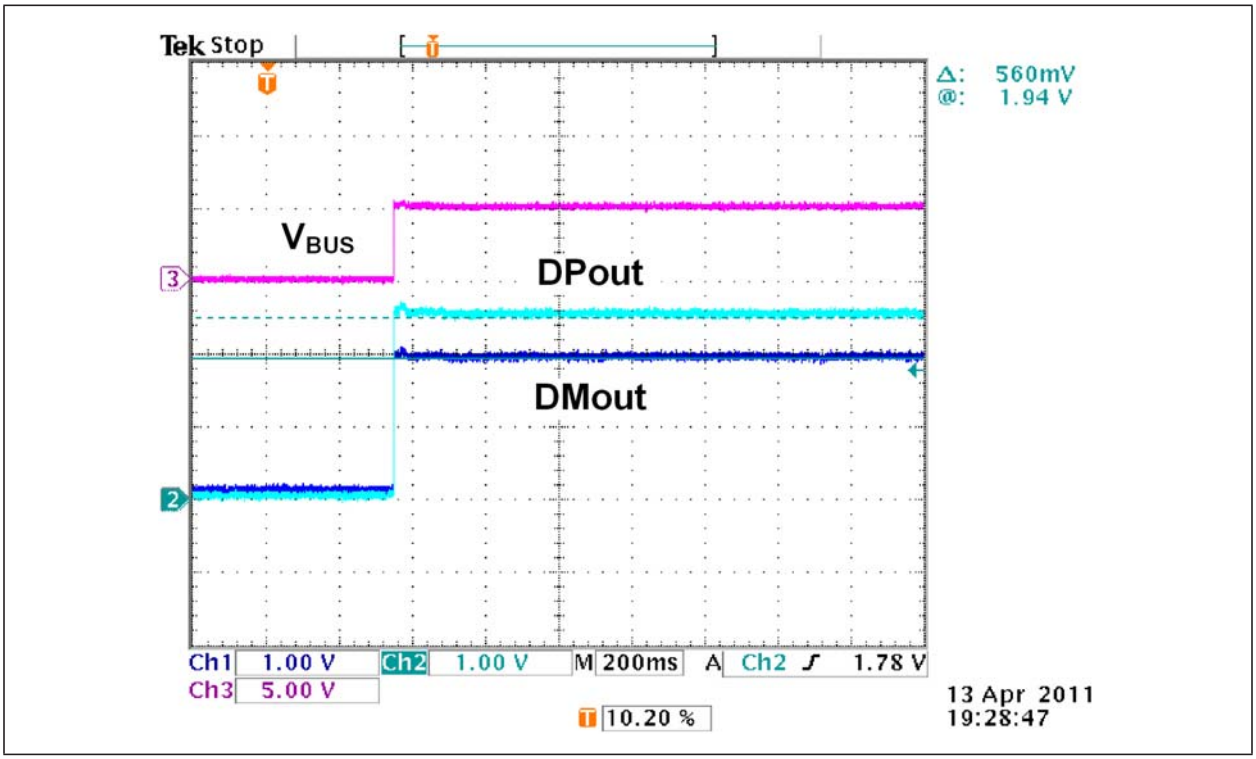
Determining Portable Device and Charger Behavior

To create a Custom charger emulation profile, the user must first understand how the portable device interacts with its charger. This information will be used later to configure the profile.

When a Brand X portable device is connected to its dedicated “wall wart” charger, the following occurs (see Figure 1):

1. The charger supplies VBUS and applies ~2.7 V to the DPOUT pin and ~2.0 V to the DMOUT pin.
2. As soon as VBUS is applied, the portable device samples the voltage on the DPOUT pin and the DMOUT pin.
3. If the voltage on the DPOUT and DMOUT pins is greater than some internal threshold (different for each pin), the portable device draws charging current between 200 mA and 300 mA.
4. If the voltage on the DPOUT and DMOUT pins is less than this internal threshold (for each pin), the portable device draws current < I_{BUS_CHG}.
5. However, if the DPOUT and DMOUT pins are shorted together (such as a BC1.2 DCP or YDT1591 charger), the portable device will draw current > I_{BUS_CHG} but will not charge optimally.

FIGURE 1: BRAND X CHARGER UNDER LOAD



Configuring Stimulus / Response Settings

Now that the system is understood, the sections below explain how to select UCS1002 stimulus / response configurations to enable the portable device to charge.

STIMULUS / RESPONSE PAIR #1

For this example, the UCS1002 will need to perform two actions in order to enable charging of the portable device: Apply voltages to the DPOUT and DMOUT pins. However, the Custom charger emulation profile configuration requires that all three of the stimulus / response pairs be configured correctly. Therefore, we’ll set the first pair to, in effect, “do nothing” by setting registers 41h through 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.

Table 1 shows a summary of the settings for stimulus #1 and response #1.

TABLE 1: EXAMPLE 1 STIMULUS / RESPONSE PAIR #1 SETTINGS

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
41h	R/W	Custom Emulation Stimulus 1 - Config 1	-	CS1_S1_TD_ TYPE	CS1_S1_TD[2:0]			CS1_STIM1[2:0]			00h
			0	0	0	0	0	0	0	0	
42h	R/W	Custom Emulation Stimulus 1 - Config 2	CS1_S1_R1MAG[3:0]				CS1_S1_R1[3:0]				00h
			0	0	0	0	0	0	0	0	
43h	R/W	Custom Emulation Stimulus 1 - Config 3	-	-	CS1_S1_PUPD[1:0]		CS1_S1_TH[3:0]				00h
			0	0	0	0	0	0	0	0	
44h	R/W	Custom Emulation Stimulus 1 - Config 4	-	-	-	-	-	CS1_S1_RATIO[2:0]			00h
			0	0	0	0	0	0	0	0	

STIMULUS / RESPONSE PAIR #2

Response #2 corresponds to the UCS1002 action to put a voltage on DPOUT. Because the portable device samples the DPOUT pin as soon as VBUS is applied, Response #2 must be applied prior to VBUS and be retained for the duration of the Custom charger emulation profile. This limits the stimulus option to “VBUS (PRE)”. This stimulus has the added bonus that the response is not removed and that the next stimulus is checked immediately. Therefore, stimulus #2 = *VBUS (PRE).* Thus, the CS1_STIM2[2:0] bits should be programmed to 000b (register 45h, bits 2 - 0).

To make sure that response #2 is applied immediately, the timer type should be set to act as a delay and the timer value set to 0 ms. Therefore, the CS1_S2_TD_TYPE bit should be ‘0’ (45h, bit 6) and the CS1_S2_TD[2:0] bits should be 000b (45h, bits 5 - 3).

For the portable device to charge properly, the value on DPOUT needs to be 2.7 V. There are two ways that the UCS1002 may drive the pin to this value, and this will directly affect both the response #2 setting as well as the magnitude setting.

The first way is to command the UCS1002 to directly drive a voltage onto the DPOUT pin. This is done by setting the response #2 settings to “Apply Vdc -> DP” and the magnitude setting to “2.7 V”. This voltage is not a robust voltage source and can only sink or source ~250 µA of current.

The second way requires a little more thought on how the system loading will function. This way is to command the UCS1002 to place a resistor divider from VBUS to GND with the center point at the DPOUT pin effectively creating a voltage divider. When this response (“Conn Vdivider -> DP”) is selected, the magnitude setting represents the *minimum* impedance of the resistor string from VBUS to GND. To determine the voltage itself, the response #2 ratio setting must also be set to 0.54 (assuming VBUS = 5 V, 0.54 * 5 V = 2.7 V).

Note:	Some devices prefer a particular impedance and some impedance selections may work better than others.

APPLICATION NOTE: The stimulus / response ratio controls are only used if the response is to apply a voltage divider on DPOUT or DMOUT. The UCS1002 BC1.2 compliant pre-defined profiles do not use the ratio controls; however, they are used by most of the pre-defined Legacy profiles.

This example will use the second way to better emulate the actual hardware used in a “wall wart” charger. Therefore, response #2 will be “Conn Vdivider -> DP”, so the CS1_S2_R2[3:0] bits should be 0110b (46h, bits 3 - 0). The response #2 magnitude will be “125 kΩ”, so the CS1_S2_R2MAG[3:0] bits should be 0010b (46h, bits 7 - 4). Finally, because response #2 is *Connect voltage divider from VBUS to GND with “center” at DPOUT* and the DPOUT voltage needs to be 2.7 V, the response #2 ratio settings will be 0.54, so the CS1_S2_RATIO[2:0] bits should be 100b (47h, bits 2 - 0).

The other configuration controls are not used and should be left at 0’s (CS1_S2_PUPD[1:0] and CS1_S2_TH[3:0]). Table 2 shows a summary of the settings for stimulus #2 and response #2.

TABLE 2: EXAMPLE 1 STIMULUS / RESPONSE PAIR #2 SETTINGS

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
45h	R/W	Custom Emulation Stimulus 2 - Config 1	-	CS1_S2_TD_TYPE	CS1_S2_TD[2:0]			CS1_STIM2[2:0]			00h
			0	0	0	0	0	0	0	0	
46h	R/W	Custom Emulation Stimulus 2 - Config 2	CS1_S2_R2MAG[3:0]				CS1_S2_R2[3:0]				26h
			0	0	1	0	0	1	1	0	
47h	R/W	Custom Emulation Stimulus 2 - Config 3	-	-	CS1_S2_PUPD[1:0]		CS1_S2_TH[3:0]				00h
			0	0	0	0	0	0	0	0	
48h	R/W	Custom Emulation Stimulus 2 - Config 4	-	-	-	-	-	CS1_S2_RATIO[2:0]			04h
			0	0	0	0	0	1	0	0	

STIMULUS / RESPONSE PAIR #3

Response #3 corresponds to the UCS1002 action to put a voltage on DMOUT. Because the portable device also samples the DMOUT pin as soon as VBUS is applied, Response #3 must also be applied prior to VBUS and be retained for the duration of the Custom charger emulation profile. Since response #3 is linked to stimulus #3, stimulus #3 must be the same as stimulus #2 ("VBUS (PRE)"). Thus, the CS1_STIM3[2:0] bits should be programmed to 000b (register 49h, bits 2 - 0).

APPLICATION NOTE: Note that even though these two stimuli are the same, they are not checked simultaneously. Stimulus #1 is always checked before stimulus #2, which is always checked prior to stimulus #3.

To make sure that response #3 is applied immediately, the timer type should be set to act as a delay and the timer value set to 0 ms. Therefore, the CS1_S3_TD_TYPE bit should be '0' (49h, bit 6) and the CS1_S3_TD[2:0] bits should be 000b (49h, bits 5 - 3).

For the portable device to charge properly, the value on DMOUT needs to be 2.0 V. To match response #2 and the implementation of the "wall wart" that the UCS1002 is emulating, response #3 will be "Conn Vdivider -> DM", so the CS1_S3_R3[3:0] bits should be 1001b (4Ah, bits 3 - 0). The response #3 magnitude will be "125 kΩ", so the CS1_S3_R2MAG[3:0] bits should be 0010b (4Ah, bits 7 - 4). Finally, because response #3 is *Connect voltage divider from VBUS to GND with "center" at DMOUT*, and the DMOUT voltage needs to be 2.0 V, the response #3 ratio settings will be 0.4 (VBUS = 5 V * 0.4 = 2.0 V), so the CS1_S3_RATIO[2:0] bits should be 010b (4Ch, bits 2 - 0).

The other configuration fields are not used and should be left at 0's (CS1_S3_PUPD[1:0] and CS1_S3_TH[3:0]). Table 3 shows a summary of the settings for stimulus #3 and response #3.

TABLE 3: EXAMPLE 1 STIMULUS / RESPONSE PAIR #3 SETTINGS

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
49h	R/W	Custom Emulation Stimulus 3 - Config 1	-	CS1_S3_TD_ TYPE	CS1_S3_TD[2:0]			CS1_STIM3[2:0]			00h
			0	0	0	0	0	0	0	0	
4Ah	R/W	Custom Emulation Stimulus 3 - Config 2	CS1_S3_R3MAG[3:0]				CS1_S3_R3[3:0]				29h
			0	0	1	0	1	0	0	1	
4Bh	R/W	Custom Emulation Stimulus 3 - Config 3	-	-	CS1_S3_PUPD[1:0]		CS1_S3_TH[3:0]				00h
			0	0	0	0	0	0	0	0	
4Ch	R/W	Custom Emulation Stimulus 3 - Config 4	-	-	-	-	-	CS1_S3_RATIO[2:0]			02h
			0	0	0	0	0	0	1	0	

CONSIDERING CHARGE LEVEL

This second example illustrates one method to optimize charging performance of a particular class of portable devices. Some portable devices can use different profiles depending on the level of battery charge when connected.

With a dead battery, “Brand Y” portable device can only charge using the Legacy 1 profile. Once the portable device has a very small, but “boot-able” charge, the portable device turns on and boots the operating system (OS). Once this occurs, the “Brand Y” portable device can charge using both Legacy 1 and Legacy 2, although it charges more optimally using Legacy 2.

The battery was completely discharged to begin this example. The first attachment of the Brand Y portable device to the UCS1002 is shown in Figure 2. The following observations may be made:

1. Upon power up, the portable device raises DPOUT at V_{BUS}. The resistive divider for Legacy 1 is applied to the pin by the UCS1002, and the voltage at the pin is approximately 2.4 V. The 2.7 V level is not visible at this point because the application of the divider is “pre-VBUS”, meaning the transition from unloaded to loaded occurred very quickly and is masked by the 1S/div setting on the oscilloscope.
2. This profile does not conform to Legacy 1 perfectly. The Brand Y portable device begins to draw charging current at approximately 250 mA for 15 seconds or so, then the current draw increases to 536 mA or so. The partial EVB GUI control panel in Figure 3 shows this change in current after the profile has locked on Legacy 1.

FIGURE 2: BRAND Y DEAD BATTERY HANDSHAKE

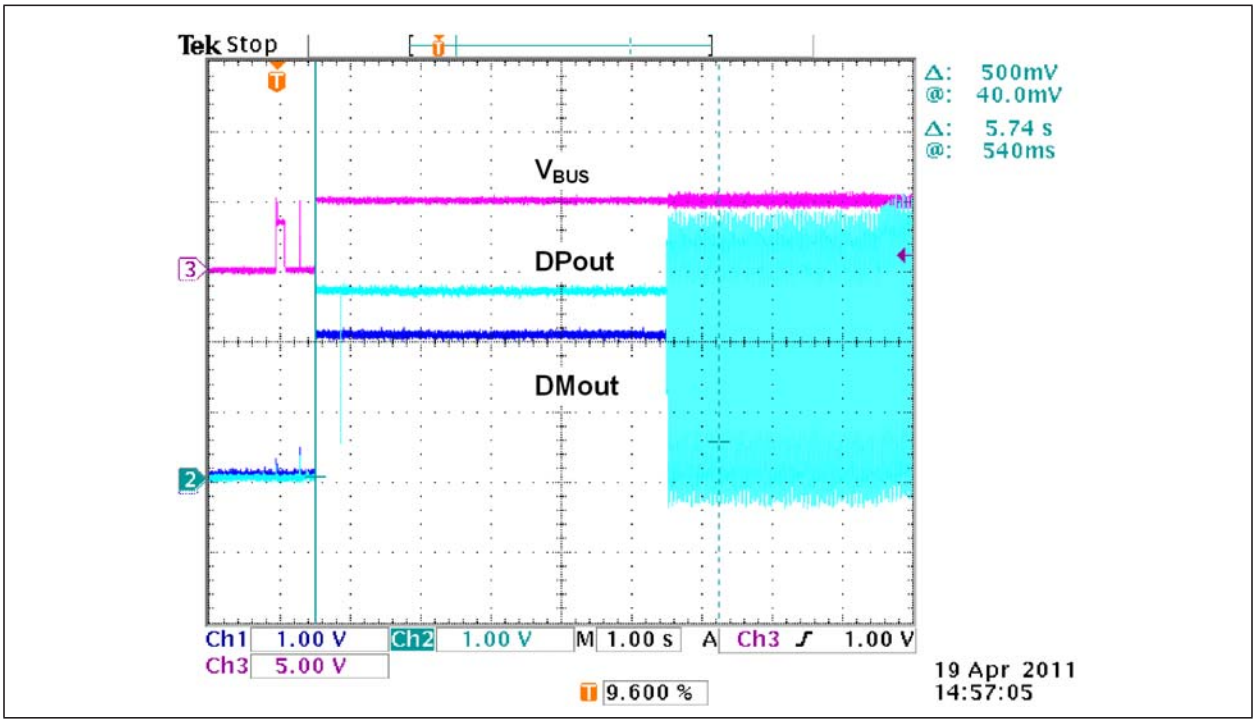
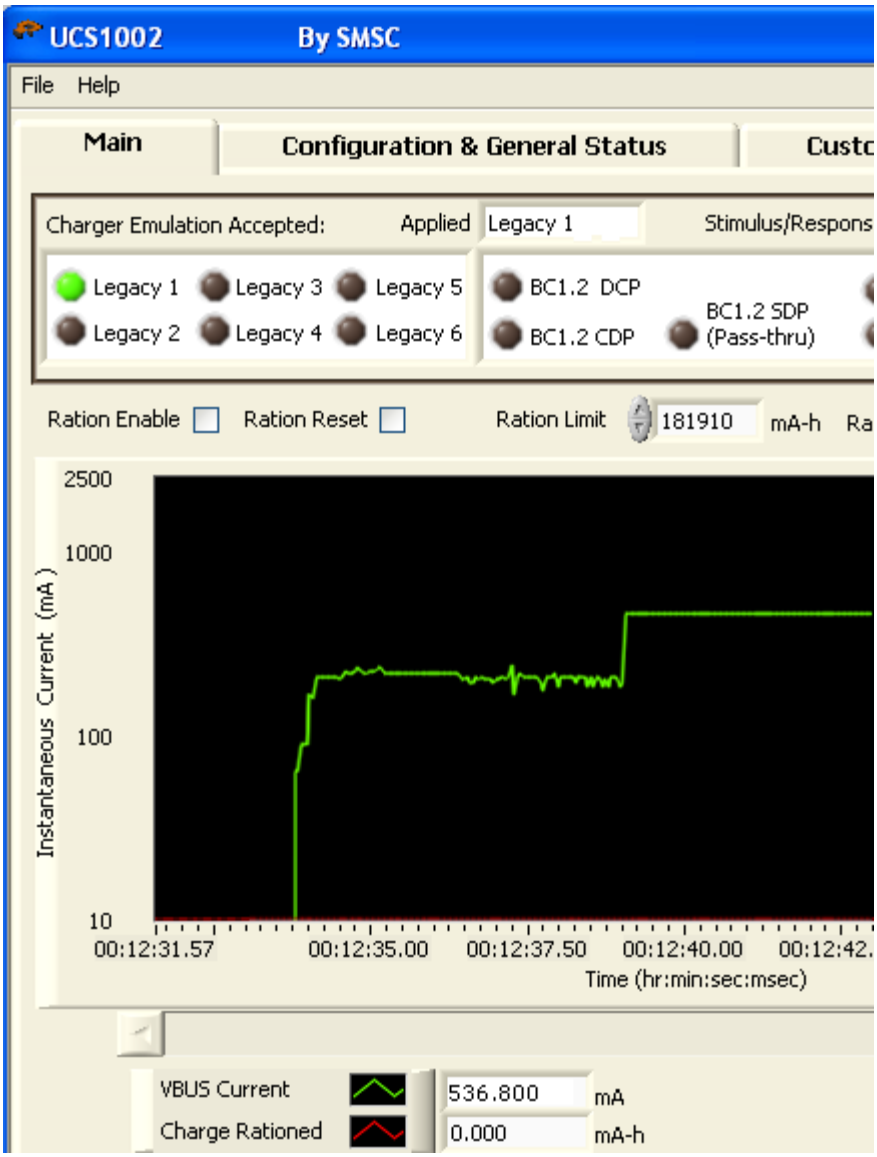


FIGURE 3: EVB GUI PANEL DURING BRAND Y INITIAL CHARGE



Determining Optimal Charging Behavior

Using Legacy 1, the portable device will continue to charge at the 530 mA rate until the battery is fully charged. Experiments were conducted to determine if other profiles resulted in more optimal charging. This was done by disabling a profile and then connecting the Brand Y portable device with enough battery charge to boot the OS. This was repeated for each of the profiles.

When Legacy 1 was disabled to observe responses to the remaining profiles, the Brand Y portable device acknowledged the Legacy 2 handshake, began charging at 530 mA, and then rapidly shifted to a 907 mA charge rate. The handshake is shown in Figure 4 and the corresponding charge plot is shown in Figure 5. Note the small glitch coincident with VBUS application. This glitch indicates the Legacy 2 charger emulation profile “VBUS (PRE)” stimulus and the short between DP and DM response.

FIGURE 4: BRAND Y LEGACY 2 HANDSHAKE

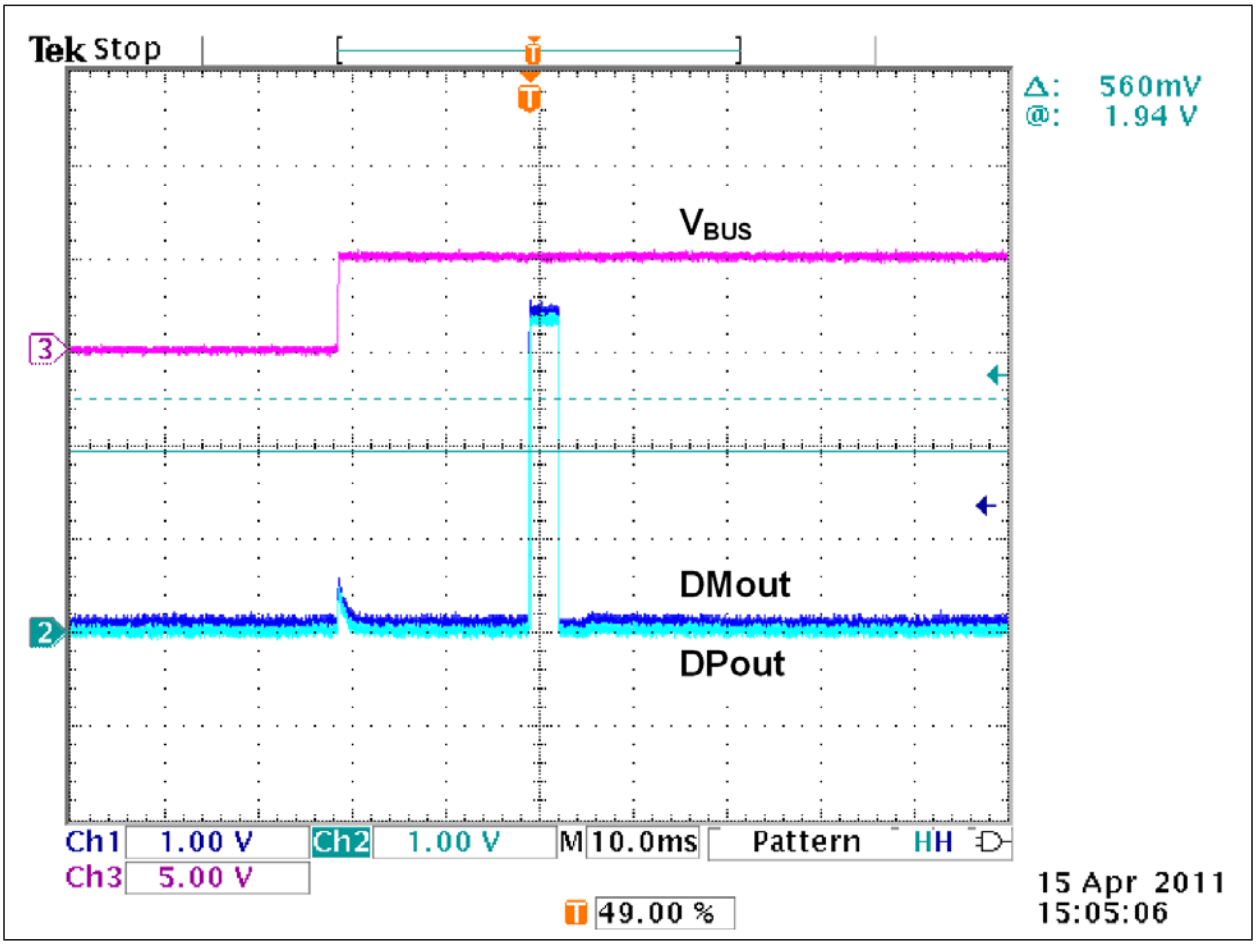
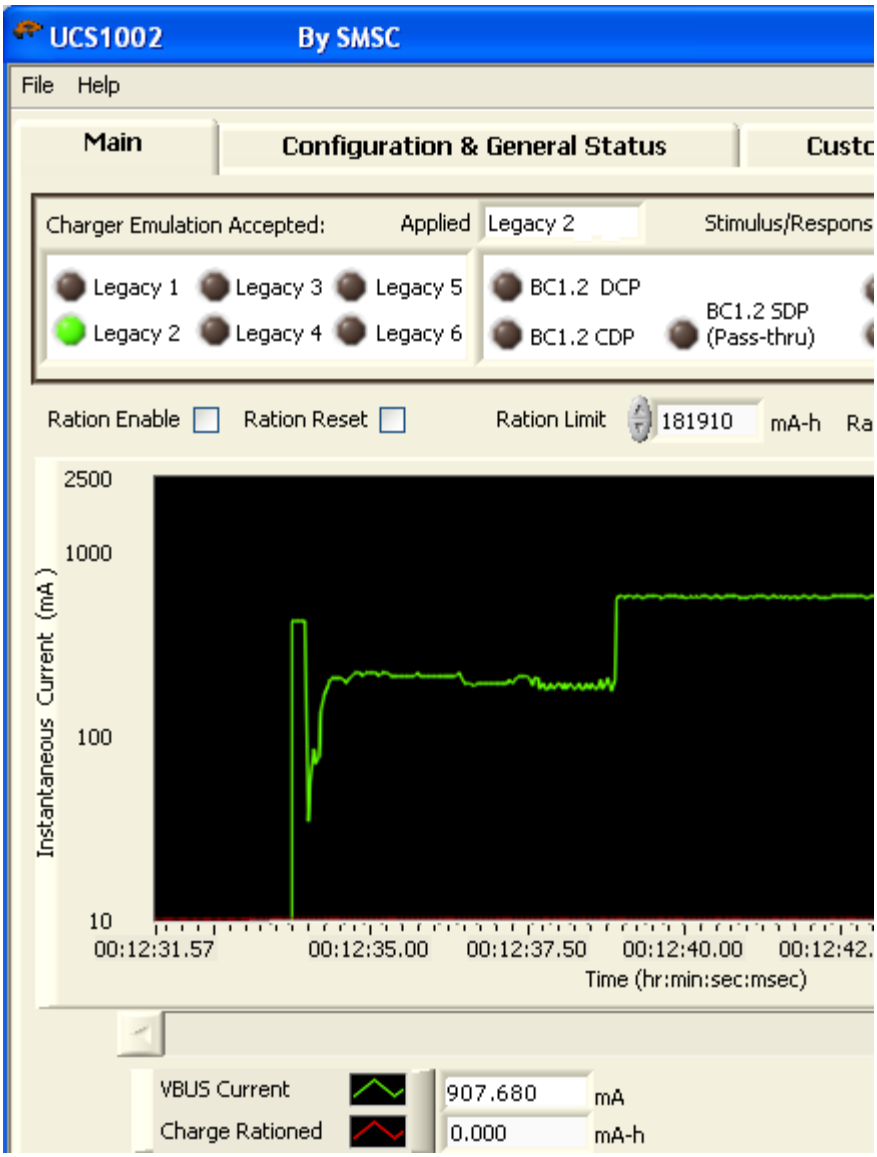


FIGURE 5: BRAND Y LEGACY 2 CHARGING CURRENT



The result is that Legacy 2 produces the most optimal charge (907 mA charge rate) once the Brand Y portable device has enough charge to boot the OS.

Changing the Order of Operation

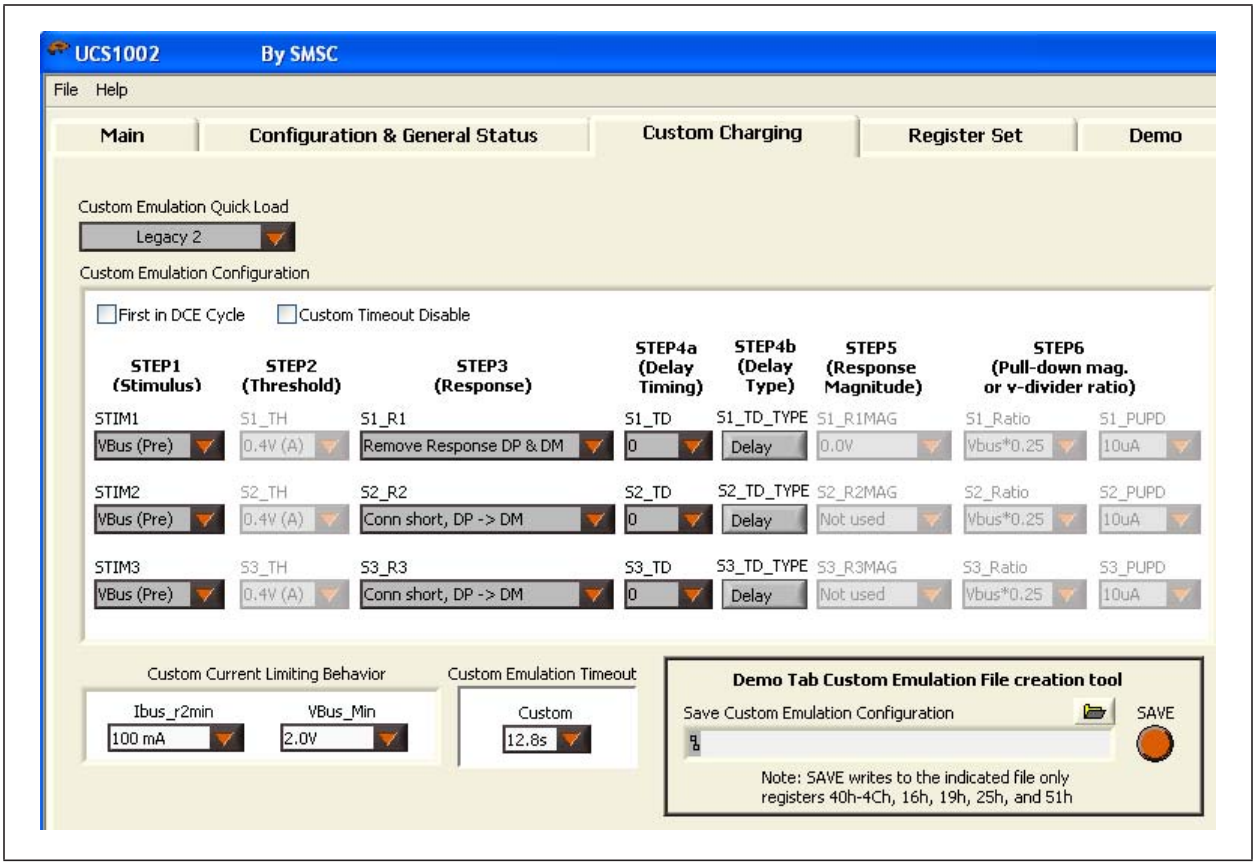
Since profiles are applied in order, Legacy 1 will be applied before Legacy 2. When the Brand Y portable device has a dead battery, this is fine since it will only charge with Legacy 1. When the portable device has a partially charged battery, it would be better to use Legacy 2; however, Legacy 1 will be used by default.

Since the Brand Y portable device charges more optimally with the Legacy 2 profile, the most straightforward method to resolve this issue is to have Legacy 2 be first to execute in the emulation cycle. To do this, load the Custom charger emulation profile with the Legacy 2 parameters, and select the Custom profile to be the first to execute in the emulation cycle.

Select Legacy 2 from the Custom Emulation Quick Load drop-down list located on the Custom Charging tab in the EVB GUI panel. This will transfer all register values from the Legacy 2 charger emulation profile to the Custom profile.

Not all configuration bits are used by the Legacy 2 profile. Therefore, the un-used and hard-coded bits are set to 0b by the GUI in order for the Custom charger emulation profile to work properly. The EVB GUI panel shown in Figure 6 shows the result after the transfer and after placing the hard-coded 0's in the appropriate bit locations.

FIGURE 6: LOADING THE CUSTOM PROFILE FROM LEGACY 2



To ensure the Custom charger emulation profile is used first, set CS1_FIRST (40h, bit 2) to 1b.

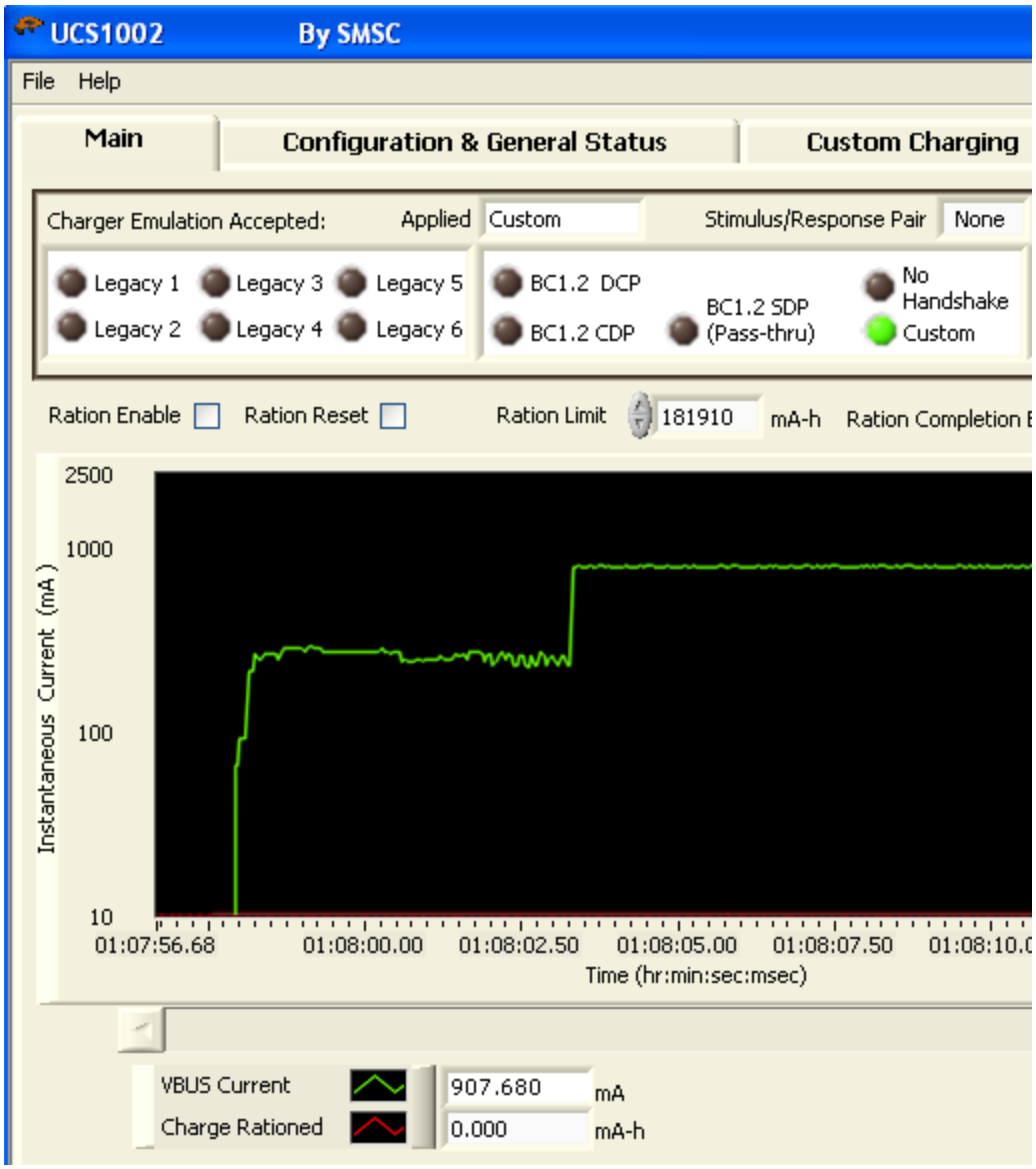
Verifying the Results

To test the effectiveness of this modification, connect a Brand Y portable device with a dead battery. The UCS1002 will then try the first emulation profile in the list, which will be the Custom profile configured to match Legacy 2. Because of the dead battery, the handshake will not be successful and the next profile, Legacy 1, will be used. After the handshake, the portable device will start charging.

Once the battery has reached the "bootable charge level" and the OS is running, in order to switch to the more optimal charging rate, the emulation cycle must be re-started. Disable the power switch using the PWR_EN control and then enable the power switch. The UCS1002 will then use the first emulation profile in the list, which will be the Custom profile configured to match Legacy 2. The charge rate will be 750 mA.

If the portable device is disconnected and then reconnected, the charging current will range between 750 mA and 900 mA, depending on charge rate, and whether or not the portable device is on and running the OS. The EVB GUI panel in Figure 7 shows the results of this example.

FIGURE 7: BRAND Y CHARGING USING THE CUSTOM PROFILE



APPENDIX A: APPLICATION NOTE REVISION HISTORY

TABLE A-1: REVISION HISTORY

Revision Level & Date	Section/Figure/Entry	Correction
REV A (08-10-13)	AN 25.4 REV A replaces the previous SMSC version, Revision 1.0 (03-09-12). Added the following note to Stimulus / Response Pair #2 on page 3: “Some devices prefer a particular impedance and some impedance selections may work better than others.”	
Rev. 1.0 (03-09-12)	Formal document release	

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