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UCS1002 Highest Current Algorithm Using a PIC® Microcontroller

Author: *Adrian Toader*
Microchip Technology Inc.

INTRODUCTION

The UCS1002 device automatically connects with an attached portable device. However, sometimes the connection may not be the charger emulation profile that provides the highest current to the portable device.

This application note will explain how to use a microcontroller connected to UCS1002 through the SMBus/I^{2}C™ interface to apply multiple charger emulation profiles and to select the one that provides the highest current to the attached device.

The firmware programmed in the microcontroller contains a list of the UCS1002 register values that represent custom charger emulation profiles. After an Attach event is detected, the first profile is applied. The MCU reads the charging current measurement provided by the UCS1002 device. Depending on the charging current value and the profile number, the MCU applies the next profile in the list or stops searching.

The algorithm can handle situations when the portable device has a drained battery, in which the charging current for all profiles can have low values. The device is charged for a period of time with the highest current profile applied and then the search cycle restarts.

UCS1002 REGISTER CONFIGURATION

The MCU sets the PIN_IGNORE bit from Register 17h in the UCS1002 device. This determines the PWR_EN, M1, M2 and EM_EN pin states to be ignored. The MCU sets these controls by writing the corresponding bits in Register 17h.

The UCS1002 device is configured by the microcontroller in Dedicated Charger Emulation mode (see *Table 9.1 – "Active Mode Selection"* in the device data sheet)[1].

M1	M2	EM_EN	Active Mode
0	0	1	Dedicated Charger Emulation Cycle

This mode of operation does not allow USB data communication between the portable device and the host.

By default, when commanded to Dedicated Charger Emulation Cycle mode (DCE), the UCS1002 applies specific charger emulation profiles in a predefined sequence. All the profiles in the sequence are preloaded except for one profile: the Custom Charger Emulation profile, that can be configured by writing specific registers. The MCU configures the UCS1002 to apply only the Custom Charger Emulation profile in the DCE cycle by modifying the following default settings in UCS1002:

- The Custom charger emulation profile is enabled by clearing the CS1_EM_DIS bit in Register 40h (default setting: Disabled).
- Legacy 1 to Legacy 7 Charger Emulation profiles are disabled by setting the LG1_EM_DIS to LG7_EM_DIS bits in Register 21h (default setting: Enabled).
- The BC1.2 DCP (Battery Charging 1.2 Dedicated Charger Port) charger emulation profile is disabled during the DCE Cycle by setting the DCP_EM_DIS bit in Register 20h (default setting: Enabled).
- The emulation circuitry timeout is disabled when the Custom Charger Emulation profile is applied by setting the CS1_TIMEOUT_DIS bit in Register 40h (default setting: Enabled).

FLOWCHART

Figure 1 shows a simplified flowchart of the highest current algorithm. Some details have been omitted to keep the picture simple.

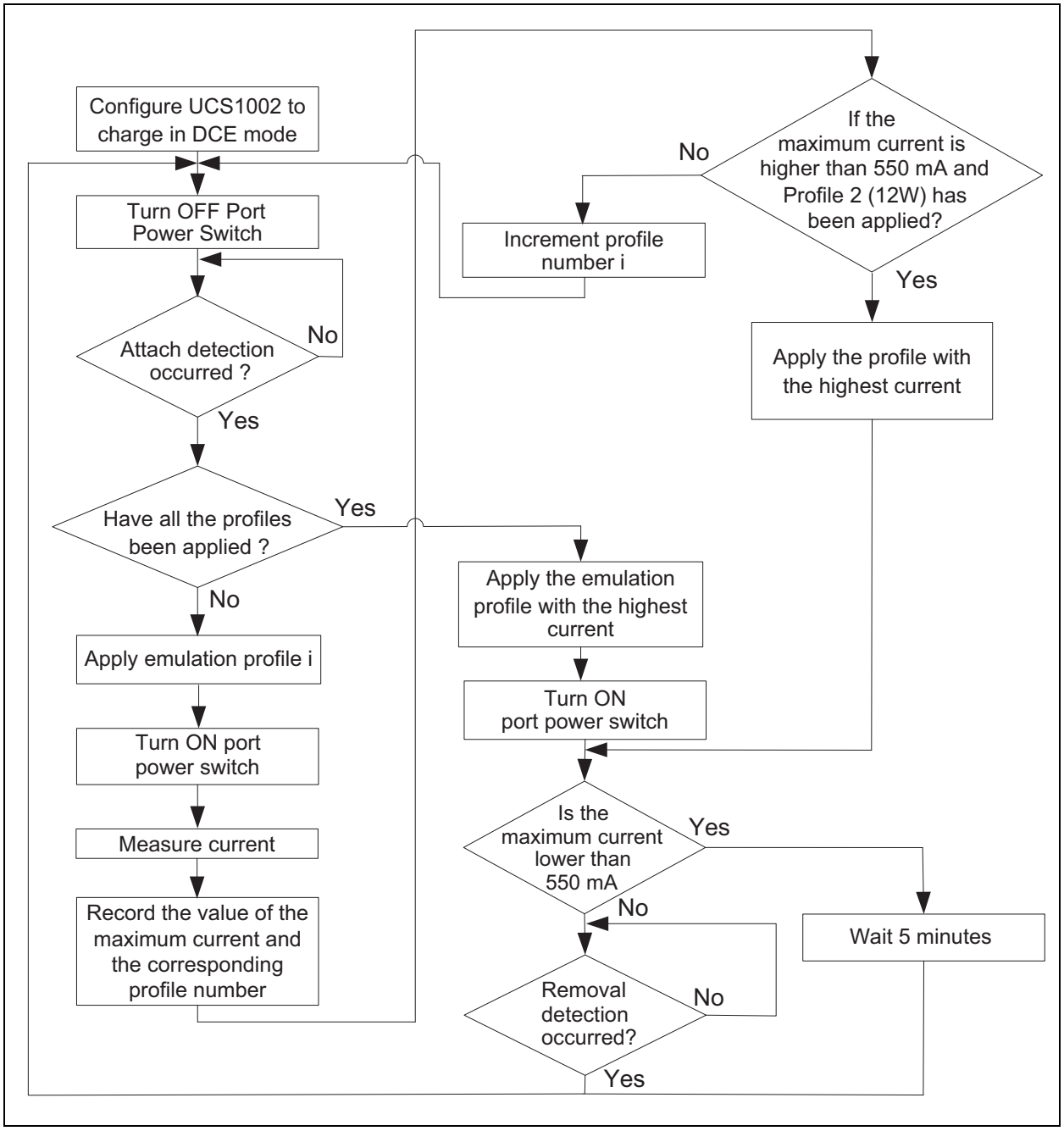

FIGURE 1: *Highest Current Algorithm - Simplified Flowchart.*

MEASURING THE CURRENT FOR A SPECIFIC CHARGER EMULATION PROFILE

During the profile cycling phase, after each profile is applied and the port power switch is enabled, the microcontroller reads the Current Measurement Register from the UCS1002 device at regular intervals (by default, 0.5 seconds).

Each profile has a certain timeout value (set within the algorithm, and not in the UCS1002 device). When this timeout expires, the MCU computes the charging current specific to the corresponding emulation profile.

The microcontroller compares two values:

- the average value of the measurements
- the last measurement.

The highest value between the two is considered specific for the profile.This is necessary for some portable devices that draw lower currents initially, and higher currents after several seconds.

SAVING AND APPLYING THE LAST PROFILE BEFORE REMOVAL

The Highest Current Algorithm saves the last charger emulation profile applied before portable device removal. When a new device is attached, the profile with the highest current before removal has priority in the profile list. This way, the searching time for the highest current profile decreases if the same device is used with the charger.

When a portable device is attached for the first time, the MCU applies the first two custom charger emulation profiles, in the following order:

- Profile 1 (DCP)
- Profile 2 (12W)

According to Figure 1, if the maximum charging current measured with these profiles is above the threshold (550 mA), then one of these profiles is applied and the searching stops. If not, the MCU will continue applying the other profiles until it finds a profile with the charging current above the threshold. If that profile is found, the microcontroller will record its index.

If the portable device is removed and another one is attached, the MCU applies three profiles before comparing the charging current with the threshold:

- Profile 1 (DCP)
- The profile with the highest current before removal
- Profile 2 (12W)

If the profile with the highest current before removal is Profile 2, then it will be applied only once.

If the maximum current measured with these profiles is above the threshold, then the corresponding profile will be applied and the searching stops.

DEAD BATTERY RECOVERY FEATURE

When a portable device has drained the battery (close to 0% level), the operating system may not boot and the charging current may be lower than in the case of operating system booted.

According to Figure 1, the microcontroller detects the dead battery condition after all the charger emulation profiles were applied. If the maximum charging current is bellow a threshold (550 mA), it will charge the portable device with the highest current profile obtained until that step for a period of time (5 minutes, by default). This allows the battery to recover. Then another searching cycle begins. After one or more cycles, the battery will reach the minimum charging level that allows the portable device to recognize its charger profile and charge with the highest current.

CODE OVERVIEW

Table 1 describes the files contained in the PIC16F1503 code. The code was released for the UCS1002 and PIC16F1503 Reference Design (ARD00550)[2].

TABLE 1-1: PIC16F1503 CODE FILES

File Name	Description
`configBits.c`	Configuration Words bits settings for PIC16F1503
`I2C_custom.c`	Contains functions for initializing and controlling the I^2C interface. These functions are based on XC8 I^2C Libraries Source Code. The modifications were made to add Timeout Detection functionality.
`I2C_custom.h`	Contains pin assignments for I^2C communication and the prototypes for initialization and read/write functions
`UCS1002_HCA.c`	Includes register addresses and settings for configuring UCS1002 and the Highest Current Algorithm Code (implemented as a state machine in `UCS1002HCACharger()` function)
`UCS1002_HCA.h`	Contains the address of the target UCS1002 on I^2C bus, the addresses of the UCS1002 registers used in the code and the prototypes for UCS1002 configuration functions
`main.c`	Contains functions for MCU configuration and the `main()` function. A timer is configured to generate interrupts every 10 milliseconds. In the corresponding Interrupt Service Routine, the variables used by I^2C communication Timeout Detection and Highest Current Algorithm Code are incremented. In the `main()` function, the `UCS1002HCACharger()` is called in an infinite loop.

CUSTOMIZING THE FIRMWARE

The current firmware version communicates with only one UCS1002 device. Its address is defined in the `UCS1002_HCA.h` file. The default value is 33h and it must be changed if the target UCS1002 device has a different address.

The user can update the existing charger emulation profile settings to keep compatibility with the new portable devices launched on the market. New profiles can be added to the list by inserting a new raw in the two-dimensional array called `bProfiles`.

To reduce search time for the Highest Current profile, the following modifications can be done to the `UCS1002_HCA.c` file:

- Remove some profiles from the list and keep only the most common ones
- Change the order in which the profiles are applied
- Decrease the default timings in the firmware (the delays, the number of current measurements taken for computing the average charging current)

Note: After changing these settings, testing may be required to confirm the compatibility with different portable devices.

SUMMARY

Features like current monitoring and programmable charger emulation profiles make the UCS1002 device a good candidate to be used with a PIC Microcontroller for intelligent USB charging solutions. The algorithm described in this document allows the MCU to select the charging profile that provides the highest current to the attached device. The solution can be customized and the charger emulation profiles can be upgraded as new portable devices are released on the market.

REFERENCES

1. UCS1002-2 Data Sheet – *"Programmable USB Port Power Controller with Charger Emulation"*, Microchip Technology Inc., Revision 1.4, 2013
2. *"UCS1002 and PIC16F1503 Reference Design"*, Microchip Technology Inc., DS50002295, 2014
3. AN 24.14 - *"UCS1002 Fundamentals of Custom Charger Emulation"*, Microchip Technology Inc., DS20005234, 2013.

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