AN2438

USB-to-I^{2}C Bridging with USB47xx/USB49xx Hubs

Author: Mick Davis and Jeffrey Hunt
Microchip Technology Inc.

INTRODUCTION

The USB-to-I^{2}C Bridging feature gives system designers using Microchip hubs expanded system control and potential BOM reduction. The use of a separate USB-to-I^{2}C device is no longer required and a downstream USB port is not lost as occurs when a standalone USB-to-I^{2}C device is implemented. This feature is available on the Microchip USB47xx/ USB49xx Automotive Hubs.

Commands may be sent from the USB host to the internal Hub Feature Controller device in the Microchip hub to perform the following functions:

- Configure I^{2}C Pass-Through Interface
- I^{2}C Write
- I^{2}C Read

SECTIONS

REFERENCES

Consult the following documents for details on the specific parts referred to in this application note:

- *Microchip USB4712 Data Sheet*
- *Microchip USB4715 Data Sheet*
- *Microchip USB4912 Data Sheet*
- *Microchip USB4914 Data Sheet*
- *Microchip USB4916 Data Sheet*
- *Microchip USB4925 Data Sheet*
- *Microchip USB4927 Data Sheet*
- *Microchip Configuration Options for USB491x/492x/4715 Application Note*

GENERAL INFORMATION

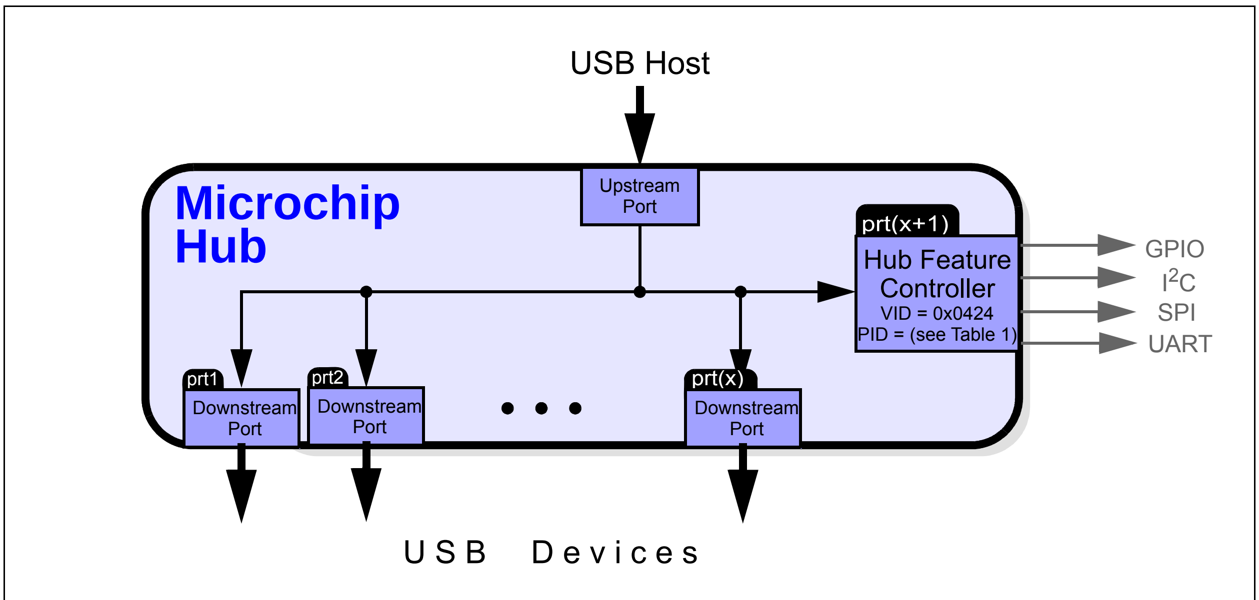
The USB-to-I^{2}C Bridging features in Microchip hubs work via host commands sent to a Hub Feature Controller embedded within the hub located on an additional internal USB port. For the bridging features to work correctly, this internal Hub Feature Controller must be enabled by default. Table 1 provides details on default Hub Feature Controller setters by device.

TABLE 1: DEFAULT SETTINGS FOR THE HUB FEATURE CONTROLLER ENABLE

Part Number	Part Summary	Hub Feature Controller Default Setting
USB4712	One USB upstream port and one USB Flex port	Enabled by default PID = 0x4940
USB4715	One USB upstream port and four USB Flex ports	Enabled by default PID = 0x4940
USB4912	One USB upstream port, one USB CarPlay port, and one non-removable standard USB port	Enabled by default PID = 0x4940
USB4914	One USB upstream port, two USB CarPlay ports, and one non-removable standard USB port	Enabled by default PID = 0x4940
USB4916	One USB upstream port, four USB CarPlay ports, and one non-removable standard USB port	Enabled by default PID = 0x4940
USB4925	One USB upstream port, one secondary USB downstream port, two USB CarPlay ports, and one non-removable standard USB port	Enabled by default PID = 0x4940
USB4927	One USB upstream port, one secondary USB downstream port, four USB CarPlay ports, and one non-removable standard USB port	Enabled by default PID = 0x4940

The Hub Feature Controller is a USB 2.0 WinUSB class device connected to an internal USB 2.0 port in the hub. For example, in a four-port hub, the Hub Controller is connected to port 5 of the USB 2.0 portion of the hub. The Product ID (PID) for the Hub Controller is 0x4940. All bridging commands are addressed to the Hub Controller and not the hub. See Figure 1.

FIGURE 1: MICROCHIP HUB CONTROLLER EXAMPLE



I^{2}C Bridging Commands

The following I^{2}C functions are supported:

- I2C Write
- I2C Read

I^{2}C WRITE

The I^{2}C interface works as a complete pass-through. This means that the host must properly arrange data payloads in the appropriate I^{2}C-compatible format and bit order, including the I^{2}C slave device address. Up to 255 bytes of data payload may be sent per I^{2}C write command sequence.

I^{2}C READ

The I^{2}C interface works as a complete pass-through. This means that the host must properly arrange data payloads in the appropriate I^{2}C-compatible format and bit order, including the I^{2}C slave device address. Up to 255 bytes of data payload may be sent per I^{2}C read command sequence.

I^{2}C INTERFACE SETUP REQUIREMENTS

The I^{2}C interface operates at 100 kHz clock speed by default. Refer to Clock Configuration for other supported speeds.The I^{2}C interface is supported in all configuration options.

PART NUMBER-SPECIFIC INFORMATION

Part Summary

Table 2 and Table 3 display the I^2C interface pins by part number.

TABLE 2: USB4712/USB4715/USB4912/USB4914/USB4925 I^2C Interface Pins

Pin Number	Name	Notes
37	PROG_FUNC1	This pin is the I^2C Data, SMB1_DAT.
38	PROG_FUNC8	This pin is the I^2C Clock, SMB1_CLK.

TABLE 3: USB4916/4927 I^2C INTERFACE PINS

Pin Number	Name	Notes
26	PROG_FUNC17	This pin is the I^2C Data, SMB1_DAT.
15	PROG_FUNC7	This pin is the I^2C Clock, SMB1_CLK.

MICROCHIP SOFTWARE SOLUTIONS

Microchip currently offers two publicly available software solutions to facilitate USB-to-I^{2}C Bridging in a USB47xx/ USB49xx series hub on Windows and Linux.

MPLAB® Connect Configurator Package (For Windows)

The MPLAB® Connect Configurator (MPLABC) package consists of both GUI-based and CLI-based tools which support USB-to-I^{2}C Bridging in a standalone form. In addition to these, it contains a Dynamically Linked Library (DLL) for Windows which can be used for implementing USB-to-I^{2}C Bridging feature in custom applications using C programming language. The MPLABC DLL consists of the following:

- User's guide: A detailed description of how to use the DLL API to call each function
- Release notes
- Library files: A .dll and a .lib file
- Example code

Application Code Examples (For Linux)

For implementing USB-to-I^{2}C Bridging on Linux, you can use the following USB47xx/USB49xx Linux Application Code Example (ACE):

- ACE009 USB-to-I^{2}C Bridging: This ACE demonstrates how to use the I^{2}C Master interface of the hub to perform read/write operations. It also allows the user to select from a range of I^{2}C clock frequencies.

This application example uses libusb library for Linux to build and send USB packets as described in Manual Implementation. It is a full-feature code example that consists of:

- Example code with minimal abstraction and in-line comments describing the various steps involved
- A Makefile
- README

This ACE can be used as a standalone application and can be integrated into existing applications.

Note:	Visit the product page on www.microchip.com for any of the hubs listed in this document to download the software solution for the desired operating system.

MANUAL IMPLEMENTATION

The USB-to-I^{2}C Bridging features may be implemented at the lowest level if you have the ability to build USB packets. This approach is required if you are not using a Windows host system and cannot use the solutions specified in Microchip Software Solutions.

The details of the I^{2}C pass-through control packets are shown below. All USB-to-I^{2}C Bridging commands must be sent directly to Endpoint 0 of the Hub Feature Controller connected to the last downstream port of the Microchip hub (i.e.: located on port 5 of a 4-port hub).

I^{2}C Control Flags

Both the Read and Write commands have a special control flag parameter which is defined in Table 4:

TABLE 4: I^{2}C CONTROL FLAGS

Bits	Control	Usage
2–7	Reserved	N/A
2	SEND_NACK	If asserted, NACK the last byte in the transfer.
1	SEND_START	If asserted, send a Start condition as the first step in the I^{2}C command.
0	SEND_STOP	If asserted, send a Stop condition as the last step of this command.

I^{2}C Write Command

This command is used to send data to an I^{2}C peripheral connected to the USB hub. Both the I^{2}C control flags (defined in I2C Control Flags) and the I^{2}C slave address are bundled into the wValue field. See Table 5.

TABLE 5: USB SETUP COMMAND

SETUP Parameter	Value	Description
bmRequestType	0x41	Vendor-specific command, host-to-device data transfer
bRequest	0x71	Register read command: CMD_I2C_WRITE
wValue	0xXXYY	MSB (XX): I^{2}C Control Flags (See I2C Control Flags.) LSB (YY): I^{2}C Slave device address
wIndex	0x0000	Reserved
wLength	0xNN	N bytes of data to be sent in the data stage (in the OUT EP0 control transfer packets)

I^{2}C WRITE USB TRANSACTION SEQUENCE

Command Phase: The Hub Feature Controller receives the SETUP packet with the parameters specified above.

Data Phase: The host sends multiple EP0 OUT packets of 64 bytes each with a total length of N bytes.

Status Phase: If an IN-ZERO length packet is sent from the Hub Feature Controller, the transfer was a success. If an IN-STALL packet is sent from the Hub Feature Controller, there was an error during the transfer, likely due to missing ACK from the I^{2}C slave.

I^2C Read Command

This command is used to read data from an I^2C peripheral connected to the USB hub. Both the I^2C control flags (defined in I2C Control Flags) and the I^2C slave address are bundled into the wValue field. (See Table 6.)

TABLE 6: USB SETUP COMMAND

SETUP Parameter	Value	Description
bmRequestType	0xC1	Vendor-specific command, device-to-host data transfer
bRequest	0x72	Register read command: CMD_I2C_READ
wValue	0xXXYY	MSB (XX): I^2C Control Flags (See I2C Control Flags.) LSB (YY): I^2C Slave device address
wIndex	0x0000	Reserved
wLength	0xNN	N bytes of data to be sent in the data stage (in the OUT EP0 control transfer packets)

I^2C READ USB TRANSACTION SEQUENCE

Command Phase: The Hub Feature Controller receives the SETUP packet with the parameters specified above.

Data Phase: The Hub Feature Controller sends Multiple EP0 IN packets of 64 bytes each with a total length of N bytes.

Status Phase: The host sends an OUT-Zero length ACK packet to acknowledge receipt of data.

EXAMPLES

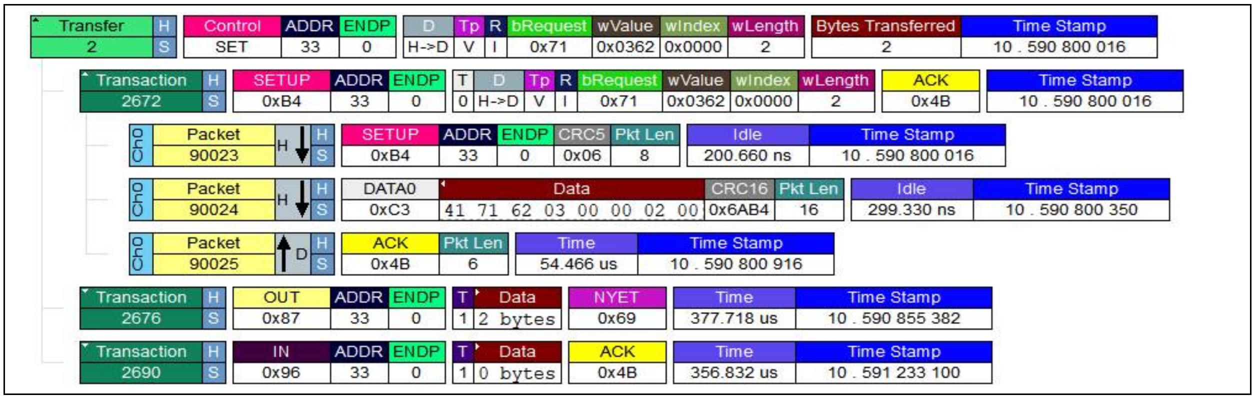
Sending an I^{2}C Write to an attached Device

1. **Command Phase (SETUP Transaction):** I^{2}C address 0x61: Write a value of 0x12 to Register 0x15. Send the following SETUP Register Write command (See Table 7 and Figure 2.) to Endpoint 0 of the Hub Feature Controller to send an I^{2}C Write command to the attached I^{2}C device with the I^{2}C address as defined in the wValue field:

TABLE 7: I^{2}C WRITE SETUP PACKET EXAMPLE

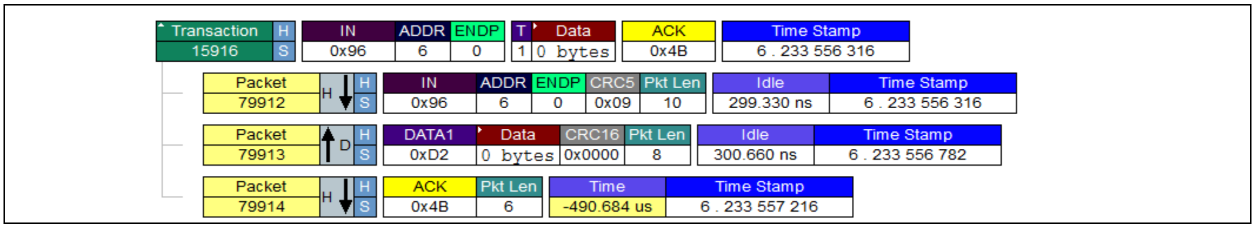
Field	Value	Note
bmRequestType	0x41	—
bRequest	0x71	—
wValue	0x0362	I^{2}C Control Flag 0x03, I^{2}C address 0x62 (0110 0010b)
wIndex	0x0000	—
wLength	0x0002	2 bytes of data (Register address + 1 byte of data)

FIGURE 2: I^{2}C WRITE SETUP TRANSACTION EXAMPLE



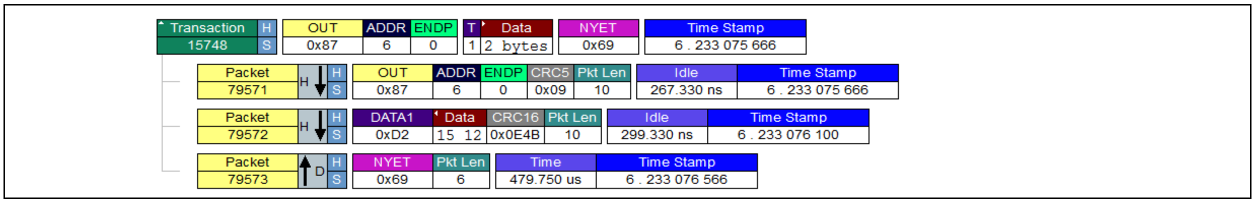
2. **Data Phase (OUT Transaction):** The host sends an OUT packet followed by the data bytes of length wLength starting from the specified address after receiving an IN packet. In this instance, Register 0x12 is being written to Register 0x15 (Data = 0x15, 0x12). The Hub Feature Controller responds with a NYET after receiving the data. (See Figure 3).

FIGURE 3: I^{2}C WRITE OUT TRANSACTION EXAMPLE



3. **Status Phase (IN Transaction):** The host sends an IN packet to complete the USB Transfer. The Hub Feature Controller responds with a zero-length data packet. The host ACKs to complete the bridging command. (See Figure 4).

FIGURE 4: I^{2}C WRITE IN TRANSACTION EXAMPLE



Sending an I²C Read to an attached Device

A read requires two operations:

- Transaction 1: Write the register to be read using I²C Write
- Transaction 2: Read the register content(s), depending on length

1. **Command Phase 1 (SETUP Transaction 1):** I²C address 0x62: Read Register 0x15. Send the following SETUP Register Read command to Endpoint 0 of the Hub Feature Controller to prepare the I²C device to return data. (See Table 8 and Figure 5.)

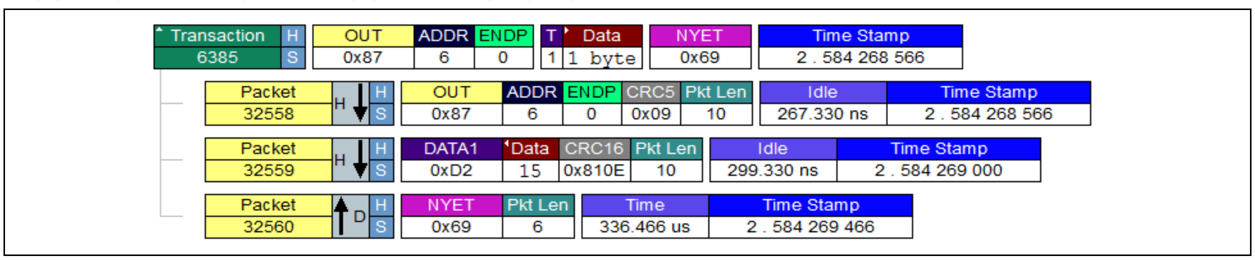
TABLE 8: I²C READ SETUP COMMAND 1 EXAMPLE

SETUP Parameter	Value	Note
bmRequestType	0xC1	—
bRequest	0x72	—
wValue	0x0762	Control Flag = 0x07, I²C address = 0x62 (01100010b)
wIndex	0x0000	—
wLength	0x0001	—

FIGURE 5: I²C READ SETUP TRANSACTION 1 EXAMPLE

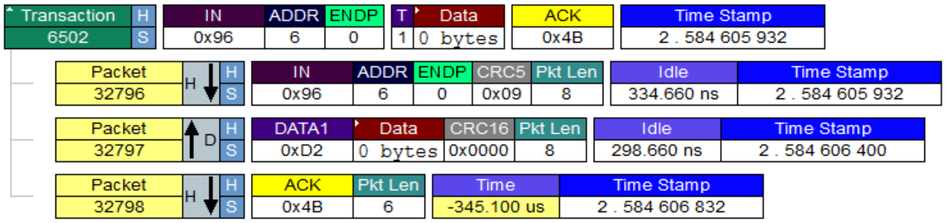
2. **Data Phase 1 (OUT Transaction 1):** The host sends an OUT packet followed by the data. The data in this instance is 0x15. The Hub Feature Controller responds with a NYET. (See Figure 6.)

FIGURE 6: I²C READ OUT TRANSACTION 1 EXAMPLE



3. **Status Phase 1 (IN Transaction 1):** The host sends an IN packet to complete the USB transfer. The Hub Feature Controller responds with a zero-length data packet. The host sends an ACK. (See Figure 7.)

FIGURE 7: I²C READ IN TRANSACTION 1 EXAMPLE

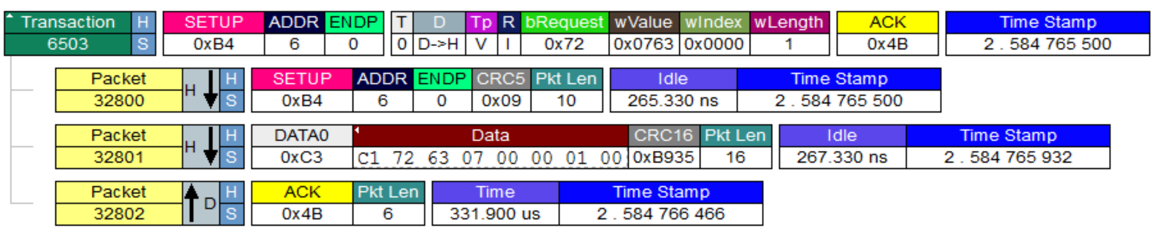


4. **Command Phase 2 (SETUP Transaction 2):** Send the following SETUP Register Read command to Endpoint 0 of the Hub Feature Controller to retrieve the requested data. (See Table 9 and Figure 8.)

TABLE 9: I²C READ SETUP COMMAND 2 EXAMPLE

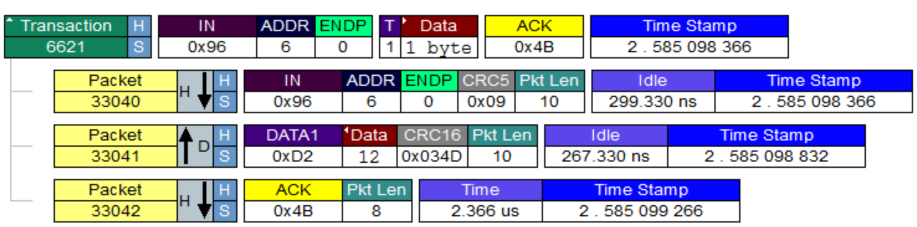
SETUP Parameter	Value	Note
bmRequestType	0xC1	—
bRequest	0x71	—
wValue	0x0763	Control Flag = 0x07, I²C address = 0x63 (01100011b)
wIndex	0x0000	—
wLength	0x0001	—

FIGURE 8: I²C ADDRESS DATA PHASE BYTE 3 TRANSACTION 2 EXAMPLE



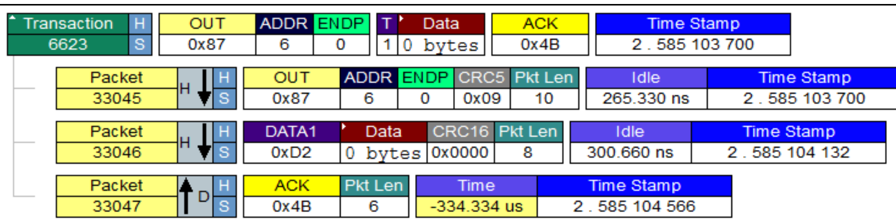
5. **Data Phase 2 (IN Transaction 2):** The host sends an IN packet, and the Hub Feature Controller responds with the register contents (0x12). The host responds with an ACK. (See Figure 9.)

FIGURE 9: I²C READ IN TRANSACTION 2 EXAMPLE



6. **Status Phase 2 (OUT Transaction 2):** The host sends an OUT packet followed by a zero-data length packet. The Hub Feature Controller responds with an ACK to complete the bridging command. (See Figure 10.)

FIGURE 10: I²C READ OUT TRANSACTION 2 EXAMPLE



CLOCK CONFIGURATION

There is a register to control I^2C clock frequency named bI2CInter128Delay located at Address 0xBFD23410. If the DLL API is used, Register bI2CInter128Delay is written automatically. The value of bI2CInter128Delay is determined using this formula:

bI2CInter128Delay = 2 * (Time period of the I2C bus clock in microseconds).

The default value is 0x14 for 100 kHz clock. A value of 0x5A creates a delay of 900 µs.

This value will be multiplied by 10 in the firmware to have some buffer time in order not to miss any byte when operating at a lower speed, thereby ensuring data integrity.

The maximum value that can be programmed in bI2CInter128Delay is 0x63.
(i.e. a maximum of 99 * 10 = 990 µs can be added as the maximum Inter-128Byte delay)

To configure the USB-to-I^2C bridge for 40 kHz clock operation, it is only necessary to write a value of 0x32 to bI2CInter128Delay after any other I^2C bridge setups have been made. The bI2CInter128Delay and Bus Frequency Control register values are provided for various supported clock frequencies in Table 10.

The method for writing to registers (including bI2CInter128Delay) through the SMBus (slave) is explained in *Section 2.4* of *AN2439 Configuration of the USB491x/USB492x/USB4715*. The method for writing to registers (including bI2CInter128Delay) through the SDK (DLL) is explained in "MPLAB Connect Configurator DLL User Manual." An example clock configuration is provided in the Clock Configuration Example.

TABLE 10: BUS FREQUENCY CONTROL AND B12CINTER128DELAY REGISTER VALUES FOR COMMON 12C CLOCK FREQUENCIES

Frequency (kHz)	Bus Frequency Register Value (Hex)	bI2CInter128Delay Value	
		Decimal	Hexadecimal
400	0A00	5	05
250	081B	8	08
200	1818	10	0A
100 (default)	3131	20	14
80	3D3E	25	19
50	6363	40	28
40	7C7C	50	32
25	C7C7	80	50
20	F9F9	100	64

Clock Configuration Example

An example clock configuration for 40 kHz operation is provided below.

1. Write bI2CInter128Delay located at 0xBFD23410 with a value of 0x32 (40 kHz per Table 10). (See Table 11.)

TABLE 11: CLOCK CONFIGURATION COMMAND 1 EXAMPLE

SETUP Parameter	Value	Note
bmRequestType	0x40	Host-to-device data transfer
bRequest	0x03	CMD_MEMORY_WRITE
wValue	0x3410	Least-significant 16 bits of memory address in *little-endian* format
wIndex	0xBFD2	Most-significant 16 bits of memory address in *little-endian* format
wLength	0x0001	Number of data bytes to write

Data to be written: 0x32

2. Enable I^2C pass-through and set frequency. (See Table 12.)

TABLE 12: CLOCK CONFIGURATION COMMAND 2 EXAMPLE

SETUP Parameter	Value	Note
bmRequestType	0x41	Host-to-device data transfer
bRequest	0x70	CMD_I2C_ENTER_PASSTHRU
wValue	0x7C7C	I^2C Clock Frequency: 40 kHz
wIndex	0x0000	—
wLength	0x0000	—

3. Write the start address from which data needs to be read. (See Table 13.)

TABLE 13: CLOCK CONFIGURATION COMMAND 3 EXAMPLE

SETUP Parameter	Value	Note
bmRequestType	0x41	Host-to-device data transfer
bRequest	0x71	CMD_I2C_WRITE
wValue	0x03A0	03: I^2C Control Flags (START, STOP) A0: Slave address
wIndex	0x0000	—
wLength	0x0001	1 byte of data

Data to be written: 0x00

4. Read 2 bytes of data. (See Table 14.)

TABLE 14: CLOCK CONFIGURATION COMMAND 4 EXAMPLE

SETUP Parameter	Value	Note
bmRequestType	0xC1	Host-to-device data transfer
bRequest	0x72	CMD_I2C_READ
wValue	0x07A1	07: I^2C Control Flags (NACK, START, STOP) A1: Slave address
wIndex	0x0000	—
wLength	0x0002	2 bytes of data

APPENDIX A: APPLICATION NOTE REVISION HISTORY

TABLE A-1: REVISION HISTORY

Revision Level & Date	Section/Figure/ Entry	Correction
DS00002438C (10-11-18)	Title	Changed the document title from “USB to I^2C Bridging with USB491x/USB492x/USB4715” to “USB-to-I2C Bridging with USB47xx/USB49xx Hubs”
	Microchip Software Solutions	This section replaced the MPLAB Connect Configuration section.
	All	Added specifications for USB4917 and USB4712. Made minor text and formatting changes
DS00002438B (05-18-18)	Figure 1	Added UART.
	I2C Interface Setup Requirements	Added sentence: “Refer to Clock Configuration for other supported speeds.”
	MPLAB Connect Configuration	Replaced “PT2 DLL” reference with “MPLABConnect.dll”. Clarified that the MPLAB package is for the Windows operating system. Removed mention of .lib file from section.
	Table 4	Corrected table title to “I^2C Control Flags”.
	Table 6, Table 8, Table 9	Corrected bmRequestType value from 0x41 to 0xC1.
	Figure 2, Figure 5	Updated figures to match table updates.
	Table 9	Corrected bRequest value from 0x71 to 0x72. Corrected wValue value from 0x0762 to 0x0763.
	Figure 8	Changed figure name to “I^2C Address Data Phase Byte 3 Transaction 2 Example”
	Sending an I2C Write to an attached Device	Added “I^2C Address 0x61: Write a value of 0x12 to Register 0x15.” to Command Phase step.
	Sending an I2C Read to an attached Device	Added additional context to beginning of section, before steps. Added “I^2C Address 0x62: Read Register 0x15.” to Command Phase step.
	Clock Configuration	Moved section to end of document, added new clock configuration example and updated Table 10 with frequency configuration register values.
DS00002438A (08-22-17)		Initial release.

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China - Shenzhen
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China - Suzhou
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