Future Technology Devices International Ltd.

Application Note AN_177

User Guide For

LibMPSSE – I2C

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This application note is a guide to using the LibMPSSE-I2C – a library which simplifies the design of firmware for interfacing to the FTDI MPSSE configured as an I2C interface. The library is available for Windows and for Linux

Future Technology Devices International Ltd.

Unit 1, 2 Seaward Place, CenturionBusinessPark,Glasgow, G41 1HH, United Kingdom
Tel.: +44 (0) 141 429 2777 Fax: + 44 (0) 141 429 2758
E-Mail (Support): admin1@ftdichip.com Web: http://ftdichip.com

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1 Introduction

The Multi Protocol Synchronous Serial Engine (MPSSE) is generic hardware found in several FTDI chips that allows these chips to communicate with a synchronous serial device such an I2C device, an SPI device or a JTAG device. The MPSSE is currently available on the FT2232D, FT2232H, FT4232H and FT232H chips, which communicate with a PC (or an application processor) over the USB interface. Applications on a PC or on an embedded system communicate with the MPSSE in these chips using the D2XX USB drivers.

The MPSSE takes different commands to send out data from the chips in the different formats, namely I2C, SPI and JTAG. LibMPSSE is a library that provides a user friendly API to enable users to write applications to communicate with the I2C/SPI/JTAG devices without needing to understand the MPSSE and its commands. However, if the user wishes then he/she may try to understand the working of the MPSSE and use it from their applications directly by calling D2XX functions.

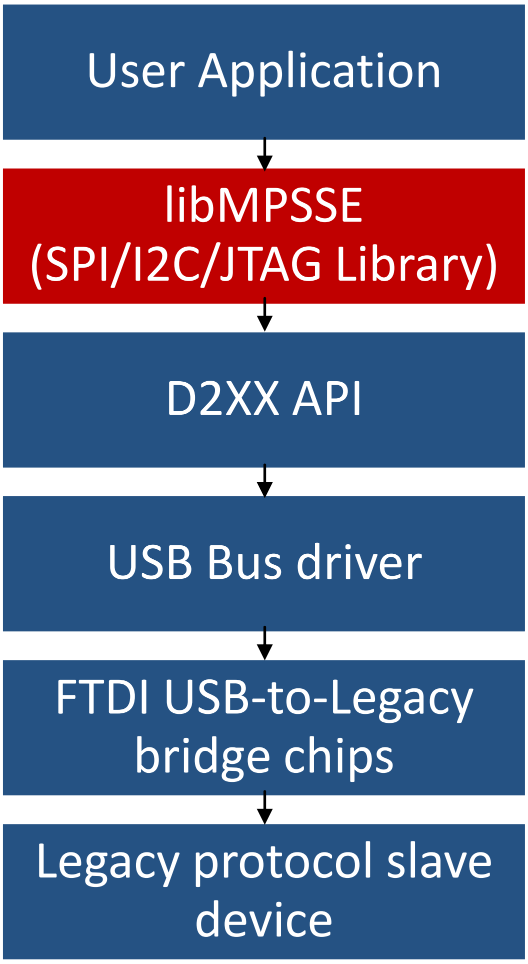


Diagram 1: The software and hardware stack through which legacy protocol data flows

As shown in the the above diagram, libMPSSE has three different APIs, one each for I2C, SPI and JTAG. This application note only describes the I2C section.

The libMPSSE.dll (Linux or Windows versions), sample code, release notes and all necessary files can be downloaded from the FTDI website at :

http://www.ftdichip.com/Support/SoftwareExamples/MPSSE/LibMPSSE-I2C/LibMPSSE-I2C_DLL_linux.zip

http://www.ftdichip.com/Support/SoftwareExamples/MPSSE/LibMPSSE-I2C/LibMPSSE-I2C_DLL_Windows.zip

The sample source code contained in this application note is provided as an example and is neither guaranteed nor supported by FTDI.

2 System Overview

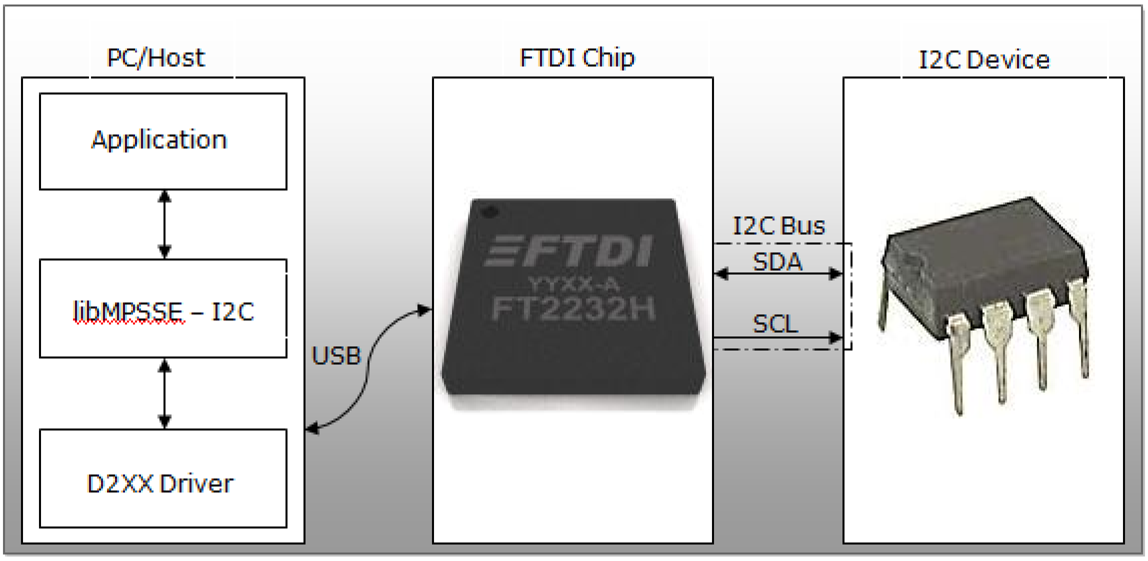


Diagram 2: System organisation

The above diagram shows how the components of the system are typically organised. The PC/Host may be desktop/laptop machine or an embedded system. The FTDI chip and the I2C device would usually be on the same PCB. Though only one I2C device is shown in the diagram above, many devices can actually be connected to the bus if each device has a different I2C address. I2C devices that support configurable addresses will have pins which can be hardwired to give a device an appropriate address; this information may be found in the datasheet of the I2C device chip.

3 Application Programming Interface (API)

The libMPSSE-I2C APIs can be divided into two broad sets. The first set consists of five control APIs and the second set consists of two data transferring APIs. All the APIs return an FT_STATUS. This is the same FT_STATUS that is defined in the D2XX driver.

3.1 Functions

3.1.1 I2C_GetNumChannels

FT_STATUS **I2C_GetNumChannels** (uint32 **numChannels*)

This function gets the number of I2C channels that are connected to the host system. The number of ports available in each of these chips is different.

Parameters:

out	**numChannels*	The number of channels connected to the host

Returns:

Returns status code of type FT_STATUS

Note:

FTDI's USB-to-legacy bridge chips may have multiple channels in it but not all these channels can be configured to work as I2C masters. This function returns the total number of channels connected to the host system that has a MPSSE attached to it so that it may be configured as an I2C master.

For example, if an FT2232D (1 MPSSE port), a FT232H (1 MPSSE port), a FT2232H (2 MPSSE port) and a FT4232H (2 MPSSE ports) are connected to a PC, then a call to I2C_GetNumChannels would return 6 in numChannels.

Warning:

This function should not be called from two applications or from two threads at the ` same time.

3.1.2 I2C_GetChannelInfo

FT_STATUS **I2C_GetChannelInfo** (uint32 *index*,FT_DEVICE_LIST_INFO_NODE **chanInfo*)

This function takes a channel index (valid values are from 0 to the value returned by I2C_GetNumChannels – 1) and provides information about the channel in the form of a populated FT_DEVICE_LIST_INFO_NODE structure.

Parameters:

in	*index*	Index of the channel
out	**chanInfo*	Pointer to FT_DEVICE_LIST_INFO_NODE structure

Returns:

Returns status code of type FT_STATUS

Note:

This API could be called only after calling I2C_GetNumChannels.

See also:

Structure definition of FT_DEVICE_LIST_INFO_NODE is in the D2XX Programmer's Guide.

Warning:

This function should not be called from two applications or from two threads at the ` same time.

3.1.3 I2C_OpenChannel

FT_STATUS **I2C_OpenChannel** (uint32 *index*, FT_HANDLE **handle*)

This function opens the indexed channel and provides a handle to it. Valid values for the index of channel can be from 0 to the value obtained using I2C_GetNumChannels – 1).

Parameters:

in	*index*	Index of the channel
out	*handle*	Pointer to the handle of type FT_HANDLE

Returns:

Returns status code of type FT_STATUS

Note:

Trying to open an already open channel returns an error code.

3.1.4 I2C_InitChannel

FT_STATUS **I2C_InitChannel** (FT_HANDLE *handle*, ChannelConfig **config*)

This function initializes the channel and the communication parameters associated with it.

Parameters:

in	*handle*	Handle of the channel
in	*config*	Pointer to ChannelConfig structure with the value of clock and latency timer updated
out	*none*	

Returns:

Returns status code of type FT_STATUS

See also:

Structure definition of ChannelConfig

Note:

This function internally performs what is required to get the channel operational such as resetting and enabling the MPSSE.

3.1.5 I2C_CloseChannel

FT_STATUS **I2C_CloseChannel** (FT_HANDLE *handle*)

Closes a channel and frees all resources that were used by it

Parameters:

in	*handle*	Handle of the channel
out	*none*	

Returns:

Returns status code of type FT_STATUS

3.1.6 I2C_DeviceRead

FT_STATUS **I2C_DeviceRead**(FT_HANDLE *handle*, uint32 *deviceAddress*, uint32 *bytesToTransfer*, uint8 **buffer,* uint32 **bytesTransfered,* uint32 *options*)

This function reads the specified number of bytes from an addressed I2C slave

Parameters:

in	*handle*	Handle of the channel
in	*deviceAddress*	Address of the I2C slave. This is a 7bit value and it should not contain the data direction bit.
In	*bytesToTransfer*	Number of bytes to be read
out	*buffer*	Pointer to the buffer where data is to be read
out	*bytesTransfered*	Pointer to variable containing the number of bytes read
in	*options*	This parameter specifies data transfer options. The bit positions defined for each of these options are: BIT0: if set then a start condition is generated in the I2C bus before the transfer begins. A bit mask is defined for this options in file ftdi_i2c.h as I2C_TRANSFER_OPTIONS_START_BIT BIT1: if set then a stop condition is generated in the I2C bus after the transfer ends. A bit mask is defined for this options in file ftdi_i2c.h as I2C_TRANSFER_OPTIONS_STOP_BIT BIT2 – BIT31: reserved

Returns:

Returns status code of type FT_STATUS

Note:

This function internally performs the following operations:

- Write START bit (if BIT0 of *options* flag is set)
- Write device address
- Get ACK from device
- LOOP until *noOfBytes*
  - Read byte to buffer
  - Give ACK
- Write STOP bit(if BIT1 of *options* flag is set)

Warning:

This is a blocking function and will not return until either the specified amount of data are read or an error is encountered.

3.1.7 I2C_DeviceWrite

FT_STATUS **I2C_DeviceWrite**(FT_HANDLE *handle*, uint32 *deviceAddress*, uint32 *bytesToTransfer*, uint8 **buffer,* uint32 **bytesTransfered,* uint32 *options*)

This function writes the specified number of bytes to an addressed I2C slave.

Parameters:

in	*handle*	Handle of the channel
in	*deviceAddress*	Address of the I2C slave
in	*noOfBytes*	Number of bytes to be written
out	*buffer*	Pointer to the buffer from where data is to be written
out	*bytesTransfered*	Pointer to variable containing the number of bytes written
in	*options*	This parameter specifies data transfer options. The bit positions defined for each of these options are: BIT0: if set then a start condition is generated in the I2C bus before the transfer begins. A bit mask is defined for this options in file ftdi_i2c.h as I2C_TRANSFER_OPTIONS_START_BIT BIT1: if set then a stop condition is generated in the I2C bus after the transfer ends. A bit mask is defined for this options in file ftdi_i2c.h as I2C_TRANSFER_OPTIONS_STOP_BIT BIT2: if set then the function will return when a device nAcks after a byte has been transferred. If not set then the function will continue transferring the stream of bytes even if the device nAcks. A bit mask is defined for this options in file ftdi_i2c.h as I2C_TRANSFER_OPTIONS_BREAK_ON_NACK

Returns:

Returns status code of type FT_STATUS

Note:

This function internally performs the following operations:

- Write START bit (if BIT0 of *options* flag is set)
- Write device address
- Get ACK
- LOOP until noOfBytes (or until device nAcks, if BIT2 in *options* is set)
    - Write byte from buffer
    - Get ACK
- Write STOP bit(if BIT1 of *options* flag is set)

Warning:

This is a blocking function and will not return until either the specified amount of data are read or an error is encountered.

3.2 GPIO functions

Each MPSSE channel in the FTDI chips are provided with a general purpose I/O port having 8 lines in addition to the port that is used for synchronous serial communication. For example, the FT223H has only one MPSSE channel with two 8-bit busses, ADBUS and ACBUS. Out of these, ADBUS is used for synchronous serial communications (I2C/SPI/JTAG) and ACBUS is free to be used as GPIO. The two functions described below have been provided to access these GPIO lines(also called the higher byte lines of MPSSE) that are available in various FTDI chips with MPSSEs.

3.2.1 FT_WriteGPIO

FT_STATUS FT_WriteGPIO(FT_HANDLE handle, uint8 dir, uint8 value)

This function writes to the 8 GPIO lines associated with the high byte of the MPSSE channel

Parameters:

in	*handle*	Handle of the channel
in	dir	Each bit of this byte represents the direction of the 8 respective GPIO lines. 0 for in and 1 for out
in	value	If the direction of a GPIO line is set to output, then each bit of this byte represent the output logic state of the 8 respective GPIO lines. 0 for logic low and 1 for logic high

Returns:

Returns status code of type FT_STATUS

3.2.2 FT_ReadGPIO

FT_STATUS FT_ReadGPIO(FT_HANDLE handle,uint8 *value)

This function reads from the 8 GPIO lines associated with the high byte of the MPSSE channel

Parameters:

in	*handle*	Handle of the channel
out	**value*	If the direction of a GPIO line is set to input, then each bit of this byte represent the input logic state of the 8 respective GPIO lines. 0 for logic low and 1 for logic high

Returns:

Returns status code of type FT_STATUS

Note:

The direction of the GPIO line must first be set using FT_WriteGPIO function before this function is used.

3.3 Library Infrastructure Functions

The two functions described in this section typically do not need to be called from the user applications as they are automatically called during entry/exit time. However, these functions are not called automatically when linking the library statically using Microsoft Visual C++. It is then that they need to be called explicitly from the user applications. The static linking sample provided with this manual uses a macro which checks if the code is compiled using Microsoft 11 oolchain, if so then it automatically calls these functions.

3.3.1 Init_libMPSSE

void Init_libMPSSE(void)
Initializes the library

Parameters:

in	none	
out	none	

Returns:

void

3.3.2 Cleanup_libMPSSE

void Cleanup_libMPSSE(void)
Cleans up resources used by the library

Parameters:

in	none	
out	none	

Returns:

void

3.4 Data types

3.4.1 ChannelConfig

ChannelConfig is a structure that holds the parameters used for initializing a channel. The following are members of the structure:

- I2C_CLOCKRATE **ClockRate**

  Valid range for clock divisor is from 0 to 3400000

  The user can pass either I2C_CLOCK_STANDARD_MODE, I2C_CLOCK_FAST_MODE, I2C_CLOCK_FAST_MODE_PLUS or I2C_CLOCK_HIGH_SPEED_MODE for the standard clock rates; alternatively a value for a non standard clock rate may be passed directly.

- uint8 **LatencyTimer**

Required value, in milliseconds, of latency timer. Valid range is 0 – 255. However, FTDI recommend the following ranges of values for the latency timer:

Full speed devices (FT2232D) Range 2 – 255

Hi-speed devices (FT232H, FT2232H, FT4232H) Range 1 - 255

- uint32 **Options**
- Bits of this member are used in the way described below:

Bit number	Description	Value	Meaning of value	Defined macro(if any)
BIT0	These bits specify if 3-phase-clocking is enabled or disabled	0	3-phase-clocking enabled*	
		1	3-phase-clocking is disabled*	I2C_DISABLE_3PHASE_CLOCKING
BIT1 – BIT31	Reserved			

*Please note that 3-phase-clocking is available only on the hi-speed devices and not on the FT2232D

3.4.2 I2C_CLOCKRATE

I2C_CLOCKRATE is an enumerated data type that is defined as follows

- enum I2C_ClockRate_t { I2C_CLOCK_STANDARD_MODE = 100000,
- I2C_CLOCK_FAST_MODE = 400000,
- I2C_CLOCK_FAST_MODE_PLUS = 1000000,
- I2C_CLOCK_HIGH_SPEED_MODE = 3400000 }

3.4.3 Typedefs

Following are the typedefs that have been defined keeping cross platform portability in view:

- typedef unsigned char **uint8**
- typedef unsigned short **uint16**
- typedef unsigned long **uint32**
- typedef signed char **int8**
- typedef signed short **int16**
- typedef signed long **int32**
- typedef unsigned char **bool**

4 Usage example

This example demonstrates how to connect the MPSSE of the FT2232H configured as I2C to an I2C device (24LC024H – EEPROM) and how to program it using libMPSSE-I2C library.

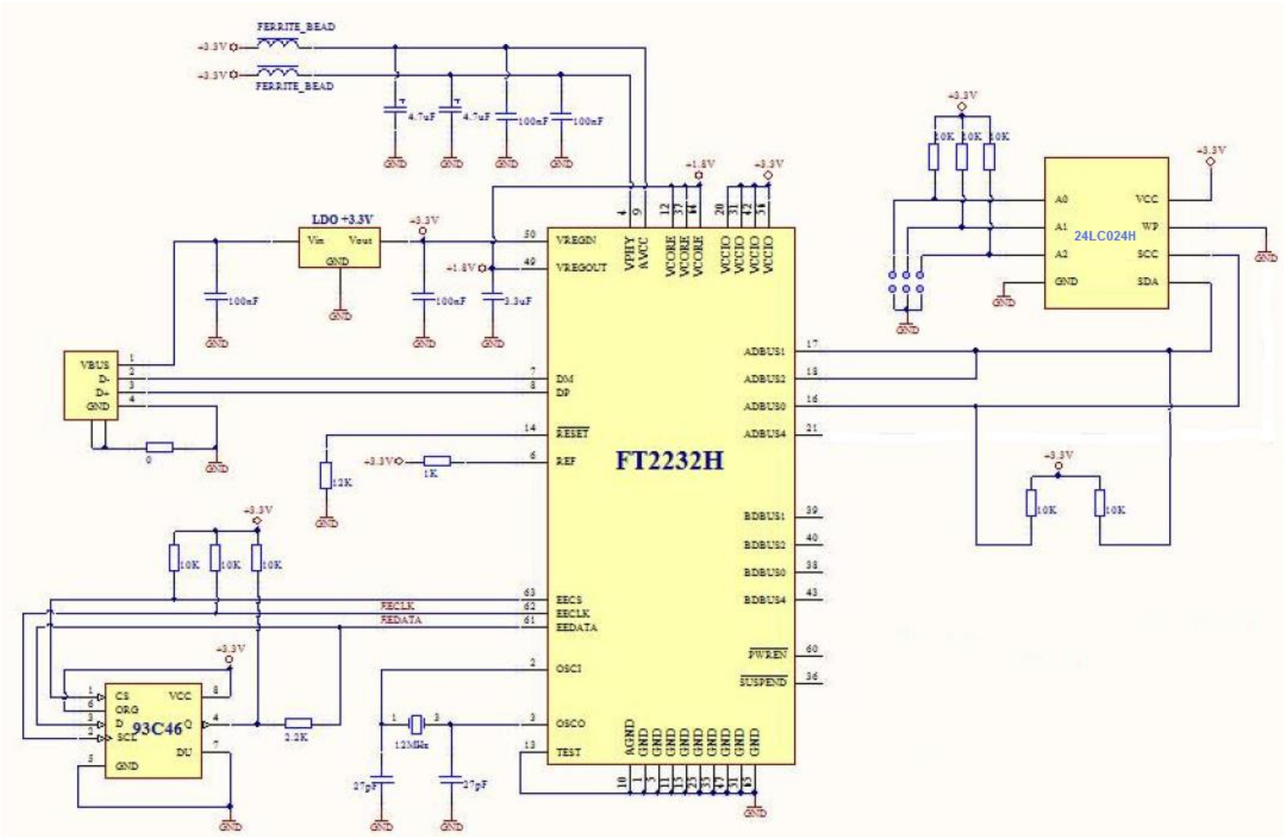


Diagram 3: Schematic for connecting FT2232H to I2C EEPROM device(24LC024H)

The above schematic shows how to connect a FT2232H chip to an I2C EEPROM. Please note that the FT2232 chip is also available as a module which contains all the components shown in the above schematic (except the 24LC024H and its address line pull-up resistors). This module is called *FT2232H Mini Module* and details about it can be found in the device datasheet. The FT2232H chip acts as the I2C master here and is connected to a PC using USB interface. For the example we connected lines A0, A1 and A2 of 24LC024H chip to logic HIGH (using the 10K pull-up resistors), this gave the chip an I2C device address of 0x57.

The required D2XX driver should be installed into the system depending on the OS that is already installed in the PC/host. If a linux PC is used then the default drivers usbserial and ftdi_sio must be removed (using rmmod command).

Once the hardware shown above is connected to a PC and the drivers are installed, the user can place the following code (sample-win32-static.c), D2XX.h, libMPSSE_i2c.h and libMPSSE.a into one folder, compile the sample and run it.

```
/*!
 * \file sample-static.c
 *
 * \author FTDI
```

```
 * \date 20110512
 *
 * Copyright © 2011 Future Technology Devices International Limited
 * Company Confidential
 *
 * Project: libMPSSE
 * Module:  I2C Sample Application - Interfacing 24LC02B I2C EEPROM
 *
 * Rivision History:
 * 0.1 - initial version
 * 0.2 - 20110801 - Changed LatencyTimer to 255
 *                  Attempt to open channel only if available
 *                  Added & modified macros
 *                 Change in APIs I2C_GetChannelInfo & OpenChannel to start indexing from 0
 */

#include<stdio.h>
#include<stdlib.h>
#ifdef _WIN32
#include<windows.h>
#endif
#include "libMPSSE_i2c.h"
#include "ftd2xx.h"

#define APP_CHECK_STATUS(exp) {if(exp!=FT_OK){printf("%s:%d:%s(): status(0x%x) != FT_OK\n",__FILE__,
__LINE__, __FUNCTION__,exp);}else{;}};
#define CHECK_NULL(exp){if(exp==NULL){printf("%s:%d:%s():  NULL expression encountered \n",__FILE__,
__LINE__, __FUNCTION__);exit(1);}else{;}};

#define I2C_DEVICE_ADDRESS_EEPROM           0x57
#define I2C_DEVICE_BUFFER_SIZE              256
#define I2C_WRITE_COMPLETION_RETRY          10
#define START_ADDRESS_EEPROM        0x00
#define END_ADDRESS_EEPROM          0x10

#define RETRY_COUNT_EEPROM          10
#define CHANNEL_TO_OPEN                     0       /*0 for first available channel, 1 for next... */

uint32 channels;
FT_HANDLE ftHandle;
ChannelConfig channelConf;
FT_STATUS status;
uint8 buffer[I2C_DEVICE_BUFFER_SIZE];

uint32 write_byte(uint8 slaveAddress, uint8 registerAddress, uint8 data)
{
        uint32 bytesToTransfer = 0;
        uint32 bytesTransfered;
        bool writeComplete=0;
        uint32 retry=0;

        bytesToTransfer=0;
        bytesTransfered=0;
        buffer[bytesToTransfer++]=registerAddress; /*Byte addressed inside EEPROM's memory*/
        buffer[bytesToTransfer++]=data;
        status = I2C_DeviceWrite(ftHandle, slaveAddress, bytesToTransfer, buffer, &bytesTransfered,
I2C_TRANSFER_OPTIONS_START_BIT|I2C_TRANSFER_OPTIONS_STOP_BIT);
        APP_CHECK_STATUS(status);

        while((writeComplete==0) && (retry<I2C_WRITE_COMPLETION_RETRY))
        {
                bytesToTransfer=0;
                bytesTransfered=0;
                buffer[bytesToTransfer++]=registerAddress; /*Byte addressed inside EEPROM's memory*/
                status = I2C_DeviceWrite(ftHandle, slaveAddress, bytesToTransfer, buffer, &bytesTransfered,
I2C_TRANSFER_OPTIONS_START_BIT|I2C_TRANSFER_OPTIONS_BREAK_ON_NACK);

                if(bytesToTransfer==bytesTransfered)
                {
                        writeComplete=1;
                        printf("... Write done\n");
                }
```

```
                    retry++;
          }
          return 0;
}

FT_STATUS read_byte(uint8 slaveAddress, uint8 registerAddress, uint8 *data)
{
          FT_STATUS status;
          uint32 bytesToTransfer = 0;
          uint32 bytesTransfered;

          bytesToTransfer=0;
          bytesTransfered=0;
          buffer[bytesToTransfer++]=registerAddress; /*Byte addressed inside EEPROM's memory*/
          status = I2C_DeviceWrite(ftHandle, slaveAddress, bytesToTransfer, buffer, &bytesTransfered,
I2C_TRANSFER_OPTIONS_START_BIT);
          bytesToTransfer=1;
          bytesTransfered=0;
          status |= I2C_DeviceRead(ftHandle, slaveAddress, bytesToTransfer, buffer, &bytesTransfered,
I2C_TRANSFER_OPTIONS_START_BIT);
          *data = buffer[0];
          return status;
}


int main()
{
          FT_STATUS status;
          FT_DEVICE_LIST_INFO_NODE devList;
          uint8 address;
          uint8 data;
          int i,j;
#ifdef _MSC_VER
          Init_libMPSSE();
#endif
          channelConf.ClockRate = I2C_CLOCK_FAST_MODE;/*i.e. 400000 KHz*/
          channelConf.LatencyTimer= 255;
          //channelConf.Options = I2C_DISABLE_3PHASE_CLOCKING;

          status = I2C_GetNumChannels(&channels);
          APP_CHECK_STATUS(status);
          printf("Number of available I2C channels = %d\n",channels);

          if(channels>0)
          {
                    for(i=0;i<channels;i++)
                    {
                              status = I2C_GetChannelInfo(i,&devList);
                              APP_CHECK_STATUS(status);
                              printf("Information on channel number %d:\n",i);
                              /*print the dev info*/
                              printf("          Flags=0x%x\n",devList.Flags);
                              printf("          Type=0x%x\n",devList.Type);
                              printf("          ID=0x%x\n",devList.ID);
                              printf("          LocId=0x%x\n",devList.LocId);
                              printf("          SerialNumber=%s\n",devList.SerialNumber);
                              printf("          Description=%s\n",devList.Description);
                              printf("          ftHandle=0x%x\n",devList.ftHandle);/*always 0 unless open*/
                    }

                    status = I2C_OpenChannel(CHANNEL_TO_OPEN,&ftHandle);/*Open the first available channel*/
                    APP_CHECK_STATUS(status);
                    printf("\nhandle=%d status=%d\n",ftHandle,status);
                    status = I2C_InitChannel(ftHandle,&channelConf);

                    for(address=START_ADDRESS_EEPROM;address<END_ADDRESS_EEPROM;address++)
                    {
                              printf("writing byte at address = %d   ",address);
                              write_byte(I2C_DEVICE_ADDRESS_EEPROM,address,address+1);
                    }
```

```
			for(address=START_ADDRESS_EEPROM;address<END_ADDRESS_EEPROM;address++)
			{
				status = read_byte(I2C_DEVICE_ADDRESS_EEPROM,address, &data);
				for(j=0; ((j<RETRY_COUNT_EEPROM) && (FT_OK !=status)); j++)
				{
					printf("read error... retrying \n");
					status = read_byte(I2C_DEVICE_ADDRESS_EEPROM,address, &data);
				}
				printf("address %d data read=%d\n",address,data);
			}
			status = I2C_CloseChannel(ftHandle);
		}

#ifdef _MSC_VER
		Cleanup_libMPSSE();
#endif

		return 0;
}
```

The sample program shown above writes to address 0 through 14 in the EEPROM chip. The value that is written is *address+1,* i.e. if the address is 5 then a value 6 is written to that address. When this sample program is compiled and run, we should see an output like the one shown below:

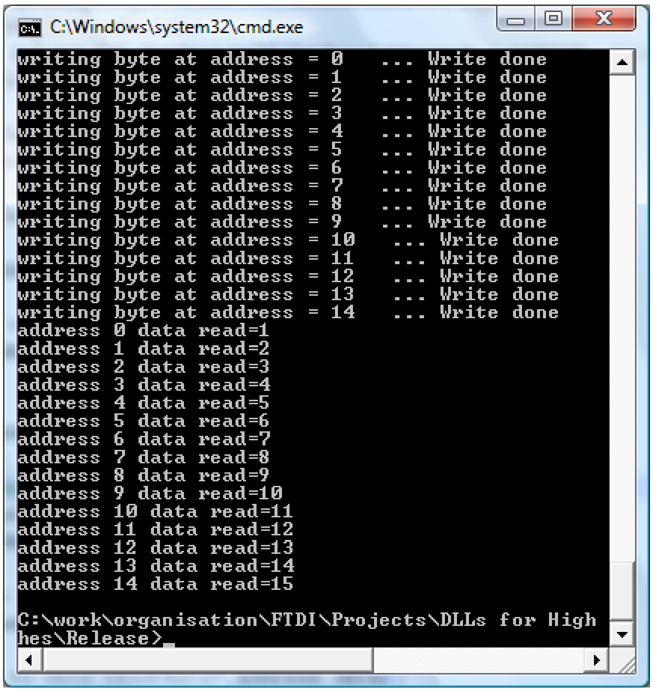
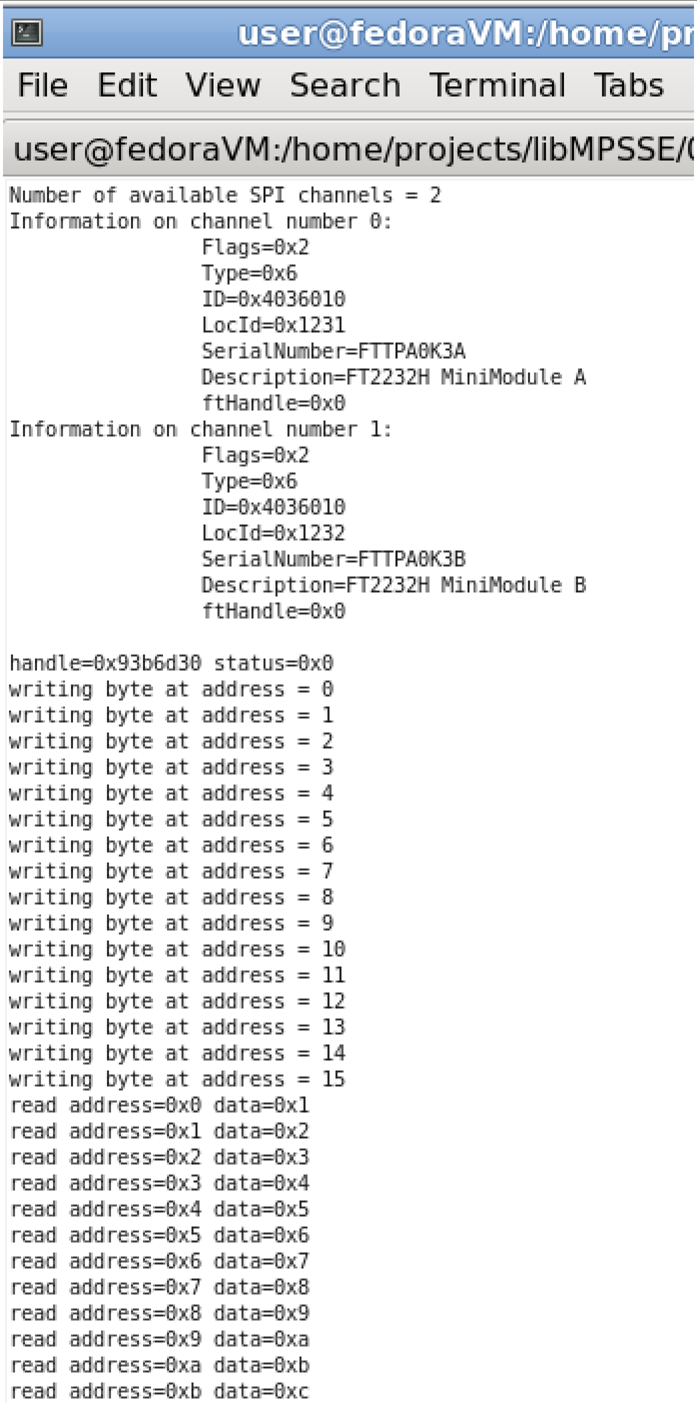


Diagram 4: Sample output on windows



```
user@fedoraVM:/home/pr
File  Edit  View  Search  Terminal  Tabs
user@fedoraVM:/home/projects/libMPSSE/(
Number of available SPI channels = 2
Information on channel number 0:
                Flags=0x2
                Type=0x6
                ID=0x4036010
                LocId=0x1231
                SerialNumber=FTTPA0K3A
                Description=FT2232H MiniModule A
                ftHandle=0x0
Information on channel number 1:
                Flags=0x2
                Type=0x6
                ID=0x4036010
                LocId=0x1232
                SerialNumber=FTTPA0K3B
                Description=FT2232H MiniModule B
                ftHandle=0x0

handle=0x93b6d30 status=0x0
writing byte at address = 0
writing byte at address = 1
writing byte at address = 2
writing byte at address = 3
writing byte at address = 4
writing byte at address = 5
writing byte at address = 6
writing byte at address = 7
writing byte at address = 8
writing byte at address = 9
writing byte at address = 10
writing byte at address = 11
writing byte at address = 12
writing byte at address = 13
writing byte at address = 14
writing byte at address = 15
read address=0x0 data=0x1
read address=0x1 data=0x2
read address=0x2 data=0x3
read address=0x3 data=0x4
read address=0x4 data=0x5
read address=0x5 data=0x6
read address=0x6 data=0x7
read address=0x7 data=0x8
read address=0x8 data=0x9
read address=0x9 data=0xa
read address=0xa data=0xb
read address=0xb data=0xc
```

Diagram 5: Sample output on linux III

5 Contact Information

Head Office – Glasgow, UK

Future Technology Devices International Limited
Unit 1, 2 Seaward Place, Centurion Business Park
Glasgow G41 1HH
United Kingdom
Tel: +44 (0) 141 429 2777
Fax: +44 (0) 141 429 2758

E-mail (Sales)	sales1@ftdichip.com
E-mail (Support)	support1@ftdichip.com
E-mail (General Enquiries)	admin1@ftdichip.com
Web Site URL	http://www.ftdichip.com
Web Shop URL	http://www.ftdichip.com

Branch Office – Taipei, Taiwan

Future Technology Devices International Limited (Taiwan)
2F, No. 516, Sec. 1, NeiHu Road
Taipei 114
Taiwan , R.O.C.
Tel: +886 (0) 2 8791 3570
Fax: +886 (0) 2 8791 3576

E-mail (Sales)	tw.sales1@ftdichip.com
E-mail (Support)	tw.support1@ftdichip.com
E-mail (General Enquiries)	tw.admin1@ftdichip.com
Web Site URL	http://www.ftdichip.com

Branch Office – Hillsboro, Oregon, USA

Future Technology Devices International Limited (USA)
7235 NW Evergreen Parkway, Suite 600
Hillsboro, OR 97123-5803
USA
Tel: +1 (503) 547 0988
Fax: +1 (503) 547 0987

E-Mail (Sales)	us.sales@ftdichip.com
E-Mail (Support)	us.support@ftdichip.com
E-Mail (General Enquiries)	us.admin@ftdichip.com
Web Site URL	http://www.ftdichip.com

Branch Office – Shanghai, China

Future Technology Devices International Limited (China)
Room 408, 317 Xianxia Road,
Shanghai, 200051
China
Tel: +86 21 62351596
Fax: +86 21 62351595

E-mail (Sales)	cn.sales@ftdichip.com
E-mail (Support)	cn.support@ftdichip.com
E-mail (General Enquiries)	cn.admin@ftdichip.com
Web Site URL	http://www.ftdichip.com

Distributor and Sales Representatives

Please visit the Sales Network page of the FTDI Web site for the contact details of our distributor(s) and sales representative(s) in your country.

Appendix A – Revision History

Revision	Changes	Date
1.0	**Initial Release**	**2011-05-23**
1.1	Corrected section 3.1.2 : I2C_GetNumChannels -1 Corrected section 3.2.3 : wrong typedef uintT32 Corrected heading on sections 3.1.3 to 3.1.7 which had wrong text Corrected TOC	**2011-05-25**
1.2	Added section "Library Infrastructure Functions" Updated sample application Added linux specific guidelines and download files	**2011-06-22**
1.3	Added GPIO functions. Added option to disable 3-phase-clocking. Renamed I2C_Device_Read / I2C_Device_Write to I2C_DeviceRead / I2C_DeviceWrite Added note on latency timer value Updated sample application	**2011-08-01**