Application Note

BRT_AN_008

FT81x Creating a Simple Library For PIC MCU

Version 1.0

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This application note provides an example of creating a simple library for interfacing the FT81x device to a PIC MCU. It builds on the framework provided in BRT_AN_006, with the addition of a new API layer to support instructions in a similar format to the FT81x Programmers guide. The library consists of a series of C and header files and can be ported to other MCUs and host platforms which have an SPI Master.

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1 Introduction

1.1 Overview

This application note provides an example of creating a simple library for interfacing the FT81x device to a PIC MCU. It builds on the framework provided in BRT_AN_006, with the addition of a new API layer to support instructions in a similar format to the FT81x Programmers guide and the EVE Screen Editor. The library consists of a series of C and header files and can be ported to other MCUs and host platforms which have an SPI Master.

1.2 Scope

This application note is a guide to the functions provided in each layer of the library. The library is intended as a starting point for users to develop further to meet the needs of their application. All of the code is provided allowing each layer to be customised.

The main.c file can be edited to produce the final application, calling the functions from the underlying layers. If porting to another MCU platform, the code in MCU_Layer.c can be changed to match the peripheral API of the chosen controller.

For further background on how the FT8xx's API and SPI data formatting are implemented in the code, please refer to BRT_AN_006. It is recommended that the reader be familiar with the concepts discussed in BRT_AN_006 before using, porting or further developing this library.

1.3 Compatibility

The code provided is primarily targeted at the FT81x series of devices but can also be run on the FT80x series as they have similar APIs. The start-up code within APP_EVE_Init has some small differences defined for the FT80x series. Note that FT81x has some new commands and features not present on the FT80x series. Application note AN_320 is also available for the FT80x series.

This library is written for the PIC family of MCUs (using the PIC18F46K22 in this particular example) using MPLABX IDE and a PICKit3 debugger. It can be ported both to other PIC devices and to other MCU types without major modification. The main tasks would be to import the C source and header files into the project of the target MCU and to edit the MCU layer code so that it interacts with the correct registers on the chosen MCU.

Other FT8xx libraries and examples are available for other platforms such as FT900 MCU and Visual Studio on the EVE Examples page.

Note: This code is intended to act as a starting point for developers to create their own libraries rather than being a complete library package. It is necessary that developers of the final application incorporating this library review all layers of the code as part of their product validation. By using any part of this code, the customer agrees to accept full responsibility for ensuring that their final product operates correctly and complies with any safety requirements, and accepts full responsibility for any consequences resulting from its use.

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2 Hardware

The hardware used for developing this code is based around a PIC MCU and an FT81x module. The schematic is shown below.

The schematic includes an optional UART interface connector for debug purposes. This can be used to connect the PIC MCU to a PC via an FTDI C232H series cable. For example, the PIC application could output debug strings to a terminal on the PC.

The hardware is discussed in greater detail in BRT_AN_006.

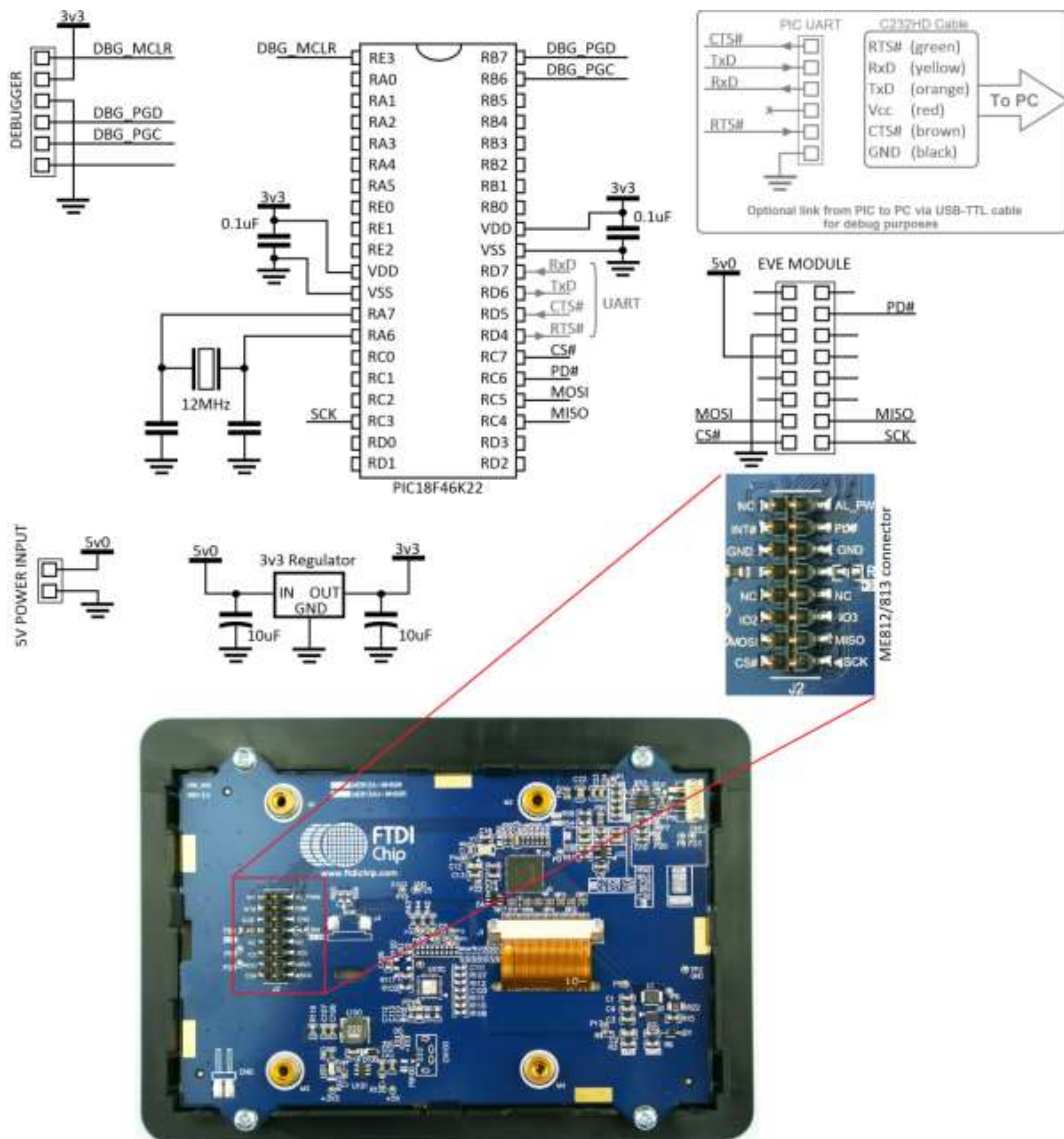

Figure 1 - Schematic of the PIC MCU with ME812-WH50R

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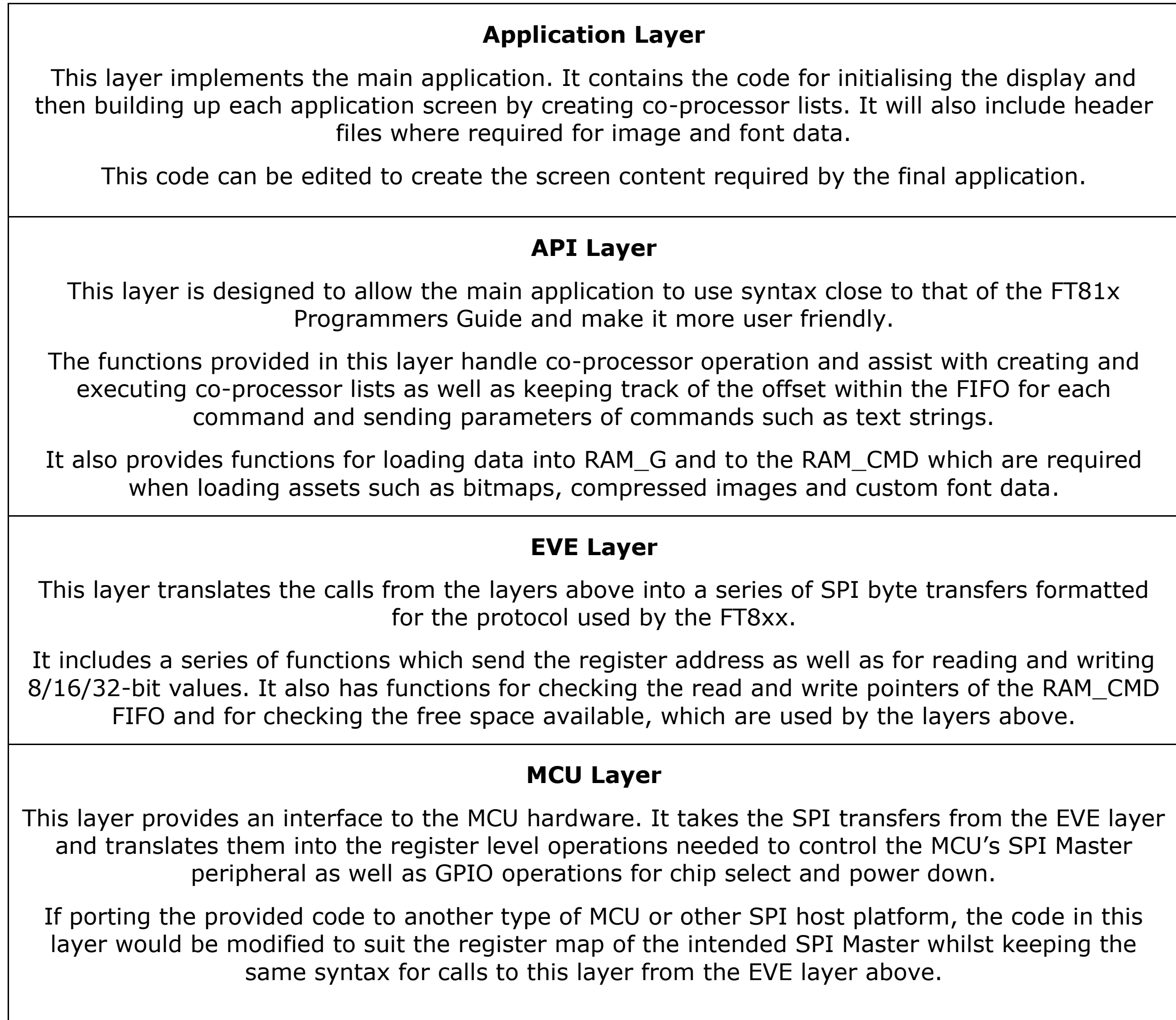
3 Library Architecture

3.1 Layers



Application Layer

This layer implements the main application. It contains the code for initialising the display and then building up each application screen by creating co-processor lists. It will also include header files where required for image and font data.

This code can be edited to create the screen content required by the final application.

API Layer

This layer is designed to allow the main application to use syntax close to that of the FT81x Programmers Guide and make it more user friendly.

The functions provided in this layer handle co-processor operation and assist with creating and executing co-processor lists as well as keeping track of the offset within the FIFO for each command and sending parameters of commands such as text strings.

It also provides functions for loading data into RAM_G and to the RAM_CMD which are required when loading assets such as bitmaps, compressed images and custom font data.

EVE Layer

This layer translates the calls from the layers above into a series of SPI byte transfers formatted for the protocol used by the FT8xx.

It includes a series of functions which send the register address as well as for reading and writing 8/16/32-bit values. It also has functions for checking the read and write pointers of the RAM_CMD FIFO and for checking the free space available, which are used by the layers above.

MCU Layer

This layer provides an interface to the MCU hardware. It takes the SPI transfers from the EVE layer and translates them into the register level operations needed to control the MCU's SPI Master peripheral as well as GPIO operations for chip select and power down.

If porting the provided code to another type of MCU or other SPI host platform, the code in this layer would be modified to suit the register map of the intended SPI Master whilst keeping the same syntax for calls to this layer from the EVE layer above.

Figure 2 - Layers of the software example

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3.2 Folder Structure

The project provided contains the following files in addition to any MPLAB-specific files:

Source Files

Main.c	Contains the Application layer
API_Layer.c	Contains the API Layer
EVE_Layer.c	Contains the EVE layer
MCU_Layer.c	Contains the MCU layer

Header Files

Library.h	Contains function definitions etc. for the MCU/EVE/API layers
FT8xx.h	Contains the EVE register defines and bit-shifting functions to combine commands with parameters. It has defines for both FT80x and FT81x and so FT_81X_ENABLE must be defined for this demonstration.

Note: The project is provided with each layer in a different .c file as detailed above, for ease of readability and when porting to other MCU platforms. However, the content from API_Layer, EVE_Layer.c and MCU_Layer.c can be combined into the main.c file to make a single source file if preferred.

3.3 Header Files

The header file FT81x.h was based on the from the main EVE Sample application. This file provides definitions for the memory map, register names and for the EVE primitives and commands.

In addition, since many EVE commands include not only the command opcode but also some parameters mapped into a single 32-bit value, the definitions help to make the main application code more readable.

E.g. the call `EVE_Write32 (COLOR_RGB(255,0,0));` is manipulated as follows:

```
#define COLOR_RGB(red,green,blue)
((4UL<<24) | (((red)&255UL)<<16) | (((green)&255UL)<<8) | (((blue)&255UL)<<0))
```

This results in a final value of `0x04FF0000` which combines the instruction 0x04 and the red, green and blue values.

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4 Usage Examples

The main application uses the following syntax when performing these common actions:

GPIO

Setting PD# low or high using the dedicated functions from the MCU layer, which in turn perform a GPIO operation on the MCU port pin.

```
MCU_PDlow();

MCU_PDhigh();
```

Registers

Writing a register with a 16-bit data value. This function handles chip select, address to write, and data. Similar functions are available for writing 8-bit and 32-bit data sizes.

```
EVE_MemWrite16(REG_HOFFSET, lcdHoffset);
```

Reading an 8-bit value from a register. This function performs the chip select operation, writing of the address and reading of the value. The value read is returned in variable GPIO.

```
GPIO = EVE_MemRead8(REG_GPIO);
```

Host Commands

Host commands on the FT81x can be sent using the following syntax:

```
EVE_CmdWrite(FT81x_ACTIVE, 0x00);        // Send 00 00 00 to wake FT8xx
```

Display Lists

32-bit writes are also often used for writing to RAM_DL, for example a small display list which clears the screen to red. Note that the instructions such as CLEAR(1,1,1) are translated into hex values by the operators at the end of FT8xx.h.

```
EVE_MemWrite32(RAM_DL+0, CLEAR_COLOR_RGB(0xFF,0,0));  // 0x02FF0000

EVE_MemWrite32(RAM_DL+4, CLEAR(1,1,1));               // 0x26000007

EVE_MemWrite32(RAM_DL+8, DISPLAY));                   // 0x00000000

EVE_MemWrite32(REG_DLSWAP, DLSWAP_FRAME);      // Swap DL to make active
```

Alternatively, an SPI burst write can be used to send the same list more efficiently.

```
MCU_CSlow();

EVE_AddrForWr(RAM_DL);                         // Starting address

EVE_Write32(CLEAR_COLOR_RGB(0xFF,0,0));        // Clear Color RGB

EVE_Write32(CLEAR(1,1,1);                      // Clear(1,1,1)

EVE_Write32(DISPLAY);                          // Display

MCU_CShigh();

EVE_MemWrite32(REG_DLSWAP, DLSWAP_FRAME);
```


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Create Screen with Co-Processor List

The list follows a similar syntax to the FT81x Programmers Guide API with the prefix API_ on each instructions/command. The API_LIB commands as highlighted in green and red allow new lists to be easily started and finished/executed respectively.

```
API_LIB_BeginCoProList();                Beginning List
API_CMD_DLSTART();
API_CLEAR_COLOR_RGB(0,0,0);
API_CLEAR(1,1,1);
// Create screen content below, for example
API_COLOR_RGB(255,255,255);
API_CMD_TEXT(196, 33, 30, 0, "Text!");
// End of screen content
API_DISPLAY();
API_CMD_SWAP();
API_LIB_EndCoProList();                  Ending List
API_LIB_AwaitCoProEmpty();               Awaiting completion
```

Run a Co-Processor command

Some commands can be used individually via the co-processor to configure the FT81x. These use the same APIs as above to begin the command and execute it. One example is to set the screen orientation to portrait via CMD_SETROTATE.

```
API_LIB_BeginCoProList();                Beginning List
API_CMD_SETROTATE(2);
API_LIB_EndCoProList();                  Ending List
API_LIB_AwaitCoProEmpty();               Awaiting completion
```

Loading data to RAM_G

The API_LIB_WriteDataRAMG allows an array of data to be written to a sequential block of RAM_G. This is useful when loading image or font files for example.

This line of code writes 8700 bytes of data from array rawData[] to RAM_G with the destination beginning at address RAM_G +0. rawData[] could be an array in a header file included in the project.

```
API_LIB_WriteDataRAMG(rawData,8700,0);
```

The data will now exist in RAM_G beginning at address 0 and can be referenced by bitmap drawing commands etc.

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Inflate an image

When inflating an image, the INFLATE command is first written to the co-processor and the REG_CMD_WRITE pointer is updated. In this case, the parameter of INFLATE tells the co-processor to inflate the data to address (RAM_G + 0). Although the REG_CMD_WRITE is updated, the code does not await the REG_CMD_READ to catch up yet.

Next, the data is written by API_LIB_WriteDataToCMD which takes as parameters the array to be sent and the size of the data. It writes the data into the circular RAM_CMD FIFO after the INFLATE command. This function will provide handling of the co-processor's FIFO in order to transfer the data. It will send data in chunks to avoid overflowing the 4K of FIFO space in the case of larger amounts of data.

```
API_LIB_BeginCoProList();         // New list

API_CMD_INFLATE(0);               // Inflate command with parameter 0

API_LIB_EndCoProList();           // Update REG_CMD_WRITE

API_LIB_WriteDataToCMD(LeaveItToEVE, sizeof(LeaveItToEVE)); // write data

API_LIB_AwaitCoProEmpty();        // Wait until co-processor has finished
```

The inflated data will now exist in RAM_G beginning at address 0. Note that the size may be significantly larger than the size of the compressed data loaded and so the developer should ensure that enough space is available without overwriting any other assets written to the RAM_G.

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5 Main Application

5.1 Overview

This layer is implemented in main.c. In the provided example code, this layer contains an initialisation section and then calls one of the demo routines.

```
MCU_Init();
APP_Init();
APP_FlashingDot();
```

The functions MCU_Init() and APP_Init() initialise the MCU and FT81x respectively, and the code then remains in the flashing dot application which represents a very basic main application. MCU_Init is covered under the MCU Layer in section 8.

5.2 APP_Init()

This function performs the application's configuration of the FT81x including starting up and writing the display settings registers in the FT81x. It finishes by writing a short display list to clear the screen.

First, the PD# line is asserted for 20msec and then de-asserted. This resets the FT81x and provides a clean start-up. The Active host command is then sent to wake up the FT81x. Note that the external oscillator mode may also be selected via a host command if required at this stage. Some modules use the internal oscillator and others may have an external crystal.

The FT81x requires a delay of at least 300ms to perform housekeeping actions including configuring the font/bitmap handles. This delay must be observed to ensure correct operation of the device. The example code uses a 500ms delay at this point.

After this, a read of the Chip ID register is performed and this must return the expected 0x7C value before proceeding. Failure to read this value could indicate an issue with the SPI connections or power to the EVE circuit for example. A read of REG_CPURESET is also performed and must read value 0x00 before proceeding, which confirms that the FT81x is ready.

The display registers are then written to set the display parameters to match the connected LCD. The values provided are for 800x480 screens and will work with the ME812-WH50R, ME813-WH50C and VM810C50A-D modules but can be changed to suit other screens.

The GPIO lines are configured to enable the display, along with the touch threshold for resistive screens. The audio is not used here and so the volume is turned down. Note that the writing of the PCLK register and the PWM of the backlight can be done after the first display list to provide a cleaner start-up appearance to the user.

Finally, a short display list is created which clears the screen. Note that the commands begin at RAM_DL + 0 and are added to each sequential 4-byte offset. In this case, the Clear Colour RGB specifies a black colour and then Clear(1,1,1) clears the colour, stencil and tag buffers. The Display command marks the end of the list, and the Swap will result in this display list becoming active. It is only after execution of the Swap that any change will be apparent on the screen.

At this point, the SPI clock rate may be increased above 11MHz up to a maximum of 30MHz if required.

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5.3 APP_FlashingDot()

This example draws a very simple dot on the screen which alternates in colour between red and black, thereby appearing to flash red against the black background.

Note that the code here works in exactly the same way as the flashing dot illustrated in BRT_AN_006 but the main code is simpler due to the addition of the new API layer. The APIs such as API_LIB_BeginCoProList(); take care of awaiting the co-pro FIFO being empty, sending the address and handling chip select. Each API_ call which sends a GPU instruction or command takes care of keeping track of the new offset. This makes programming the screen content much more user-friendly.

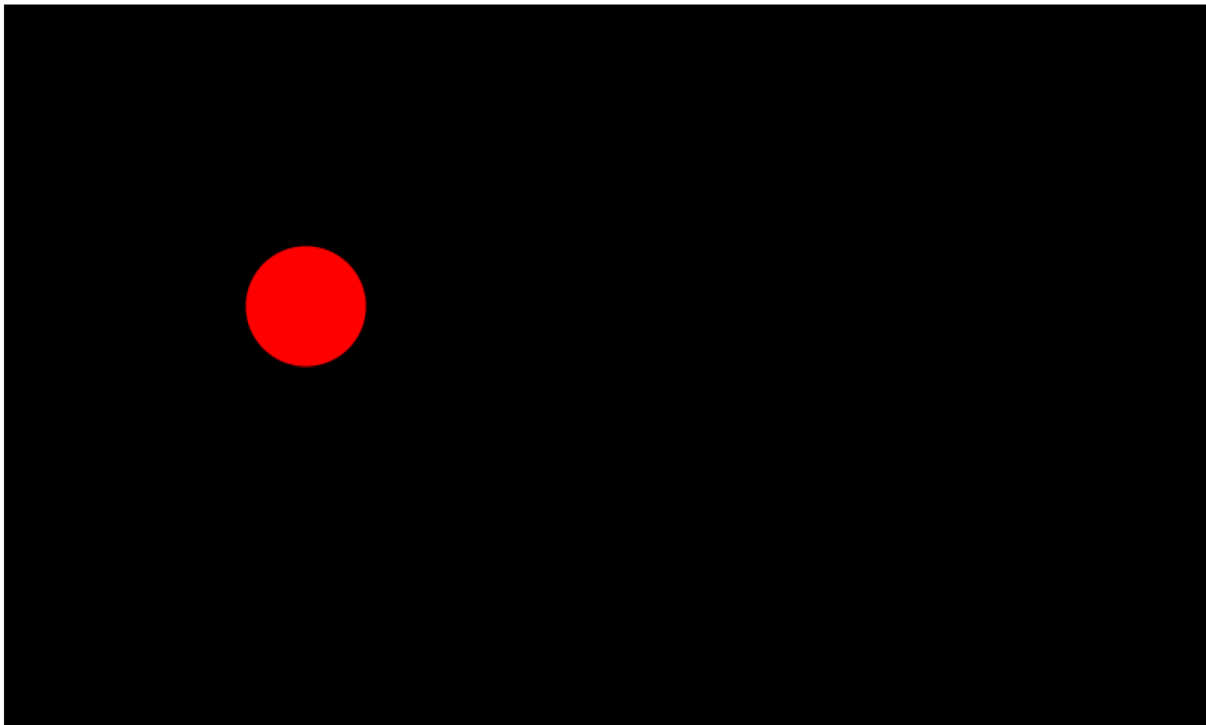

Figure 3 - Flashing Dot demo

The code runs in a constant while(1) loop. First, a variable is toggled which will be used to determine the colour of the dot on each screen update.

```
void APP_FlashingDot(void)
{
    uint8_t color = 0;

    while(1)
    {
        if(color == 0x00)
            color = 0xFF;
        else
            color = 0x00;
```

It then goes on to create the new co-processor list to generate the screen content. The API_LIB_BeginCoProList function waits for the co-processor FIFO to be empty (whereby the write and read pointers are equal). The place within the circular co-processor FIFO to which they

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currently point is also obtained. It uses this value as the starting point for the new co-processor list. It will assert the CS# line and send the address thereby beginning a burst write cycle to the CMD_FIFO.

The first command (CMD_DLSTART) will tell the co-processor to make a new display list beginning at offset RAM_DL + 0. The first entries in this list are to set the colour to be used when clearing the screen and to clear the colour, stencil and tag buffers. In most cases, a new co-processor list will begin in a similar way to the four commands shown.

The API_ function call in each case will send the associated command over SPI and will update a variable to keep track of the number of bytes sent.

```
        API_LIB_BeginCoProList();
        API_CMD_DLSTART();
        API_CLEAR_COLOR_RGB(0,0,0);
        API_CLEAR(1,1,1);
```

Now, the colour of the dot to be drawn is set and a point is drawn on the screen, using standard commands from the FT81x Programmers Guide.

```
        API_COLOR_RGB(color, 0, 0);
        API_BEGIN(FTPOINTS);
        API_POINT_SIZE(40*16);
        API_VERTEX2F(200*16, 200*16);
        API_END();
```

The co-processor list finishes with a DISPLAY command which, when actioned by the co-processor and added to the display list, tells the FT8xx that this is the end of the set of display items. The SWAP command performs the same task as writing to the swap register; once the display list has been written to the RAM_DL, this command will swap the foreground and background display list memory so that the newly written display list is now active on the screen.

```
        API_DISPLAY();
        API_CMD_SWAP();
```

The display creation finishes with two API_LIB function calls. The first one will bring CS# high to finish the burst write over SPI and will then perform a write to the REG_CMD_WRITE register to point it to the end of the new commands added. The call to API_LIB_AwaitCoProEmpty will then wait until the FT81x's internal REG_CMD_READ pointer has caught up with REG_CMD_WRITE and therefore until the co-processor has consumed all of the commands.

```
        API_LIB_EndCoProList();
        API_LIB_AwaitCoProEmpty();
```

Finally, a delay is provided so that the screen refreshes approximately every 500ms and so the flashing of the dot is visible to the user.

```
        MCU_Delay_500ms();
    }
}
```


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6 Library - API Layer

This layer can be found in API_Layer.c and provides a simpler and higher-level interface between the main application and the EVE layer.

This layer contains a series of APIs for beginning and finishing co-processor lists which avoid the main application needing to handle the specifics of the co-processor.

Additional APIs are provided to help with loading data to RAM_G and to the RAM_CMD FIFO, as well as for sending text strings which are used in several co-processor commands.

The layer also includes a function call for each GPU instruction and Co-Processor command which can be used when sending these via the co-processor FIFO. This function sends the command and any parameters and also keeps track of the size of the command which is used to update the REG_CMD_WRITE when finishing the list.

6.1 Functions

- void API_LIB_BeginCoProList(void)
- void API_LIB_EndCoProList(void)
- void API_LIB_AwaitCoProEmpty(void)
- void API_LIB_WriteDataRAMG(const uint8_t *ImgData, uint32_t DataSize, uint32_t DestAddress)
- uint8_t API_SendString(const char* string)
- void API_LIB_WriteDataToCMD(const uint8_t *ImgData, uint32_t TotalDataSize)
- This layer also includes a separate function for every GPU Instruction and Co-Processor command as discussed later in this section

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6.2 Co-Processor Lists

These functions are used by the main application when creating screens to set up a new co-processor list and then to execute it.

void API_LIB_BeginCoProList(void)

This function carries out the tasks necessary to create a new co-processor command list. It waits for the REG_CMD_WRITE and REG_CMD_READ pointers to become equal to confirm that the co-processor has completed all previous tasks. This also determines the current value of these pointers to be used as the starting point for the new list.

It then asserts CS# and sends the starting address determined above with the write bits set to tell the FT81x that data is to be written.

An SPI burst write will continue with the FT81x incrementing its internal address until CS# is de-asserted.

void API_LIB_EndCoProList(void)

This function is used to end a co-processor list. It de-asserts CS# and then writes the value maintained by the MCU's own counter into the REG_CMD_WRITE. This causes the co-processor to execute the commands written in the preceding burst write.

The API functions in the API layer will have updated the aforementioned counter (cmdOffset) as each command is sent so that the value to be written to REG_CMD_WRITE can be determined.

void API_LIB_AwaitCoProEmpty(void)

This function performs two main tasks. Firstly, it sits in a loop reading the REG_CMD_WRITE and REG_CMD_READ registers. Then, it reads the current state of REG_CMD_WRITE and updates global variable cmdOffset so that this variable can be used by the subsequent code as the starting point for the next co-processor list.

6.3 Writing Data

These functions are used by the main application to perform writing of data blocks to RAM_G and via the co-processor buffer.

void API_LIB_WriteDataRAMG(const uint8_t *ImgData, uint32_t DataSize, uint32_t DestAddress)

This function writes a block of 8-bit data from the specified array in the MCU to the FT81x. The parameters also specify the starting address in RAM_G for the data to be written to and the size of the data to be written.

Internally, this function uses an SPI burst write whereby the CS# is asserted followed by a write of the register address to be written in the FT81x. The data can then be written as a burst by keeping CS# low and the FT81x will increment the address internally. The burst is completed by de-asserting CS#.

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uint8_t API_SendString(const char* string)

This function sends a string over SPI to the FT81x. It is intended to be called from other command functions such as API_CMD_TEXT where the SPI transfer is already set up and in progress and the string is part of the parameter set of the function. The API_SendString function does not therefore carry out addressing or CS# operations.

It works by sending out the string character-by-character as a series of sequential 8-bit SPI writes. An additional 0x00 byte is sent at the end of the string as a null terminator. Finally, as every command in EVE must have a multiple of 4 bytes including parameters, the string is padded with extra 0x00 bytes if it is not an even multiple of 4. This makes the total length including string, null and padding to a multiple of four bytes to maintain the 32-bit alignment of the co-processor. The resulting command size is returned to the calling function where it will be added to the size of the overall command.

void API_LIB_WriteDataToCMD(const uint8_t *ImgData, uint32_t TotalDataSize)

This function is used to write a block of data to the co-processor FIFO. For example, this would be used for loading the compressed image data immediately after a CMD_INFLATE or CMD_LOADIMAGE command.

As described in BRT_AN_006, the co-processor uses a 4K circular FIFO with write and read pointers. The MCU controls the write pointer and the FT8xx controls the read pointer as it removes data from the FIFO. In most cases, the FIFO is used to send commands which the co-processor processes to create display lists etc.

However, some commands which inflate compressed data require the image data to be fed into the co-processor itself which will carry out the inflate operation on the data. This requires more specific handling compared to writing to RAM_G due to the circular nature and the limited size (4K) of the buffer.

This function takes care of the buffer handling and also splits the data into smaller chunks if the overall data size is greater than the buffer. A simplified flow chart is shown in **Figure** 4.

The function runs in a loop until all requested data has been sent. The data is written to the RAM_CMD FIFO in the same way as commands, whereby the current write pointer is determined and the data is written as a burst beginning at that address. The FT8xx increments its internal counter in parallel with the MCU keeping its own count, both of which also account for the rollover at RAM_CMD + 4K. The MCU then advances the REG_CMD_WRITE to the end of the newly written data.

In this example, if the data is greater than 1000 bytes, it is split into chunks of 1000 and will therefore be written as a series of 1000 bytes bursts followed by the remainder. One difference occurs here compared to the algorithm normally used when creating a screen. Between sending 1000 byte chunks, the function waits for sufficient free space for the next chunk instead of awaiting the FIFO being empty (read and write pointers equal). This is because the algorithm used internally by the co-processor does not always make REG_CMD_READ equal to REG_CMD_WRITE in the middle of a data set. They will however become equal once the full set of compressed data has been written.

Note that the size of each chunk can be set as required up to a maximum of (4K-4). However, increasing the 1000 used in this example would not make a significant difference to efficiency.

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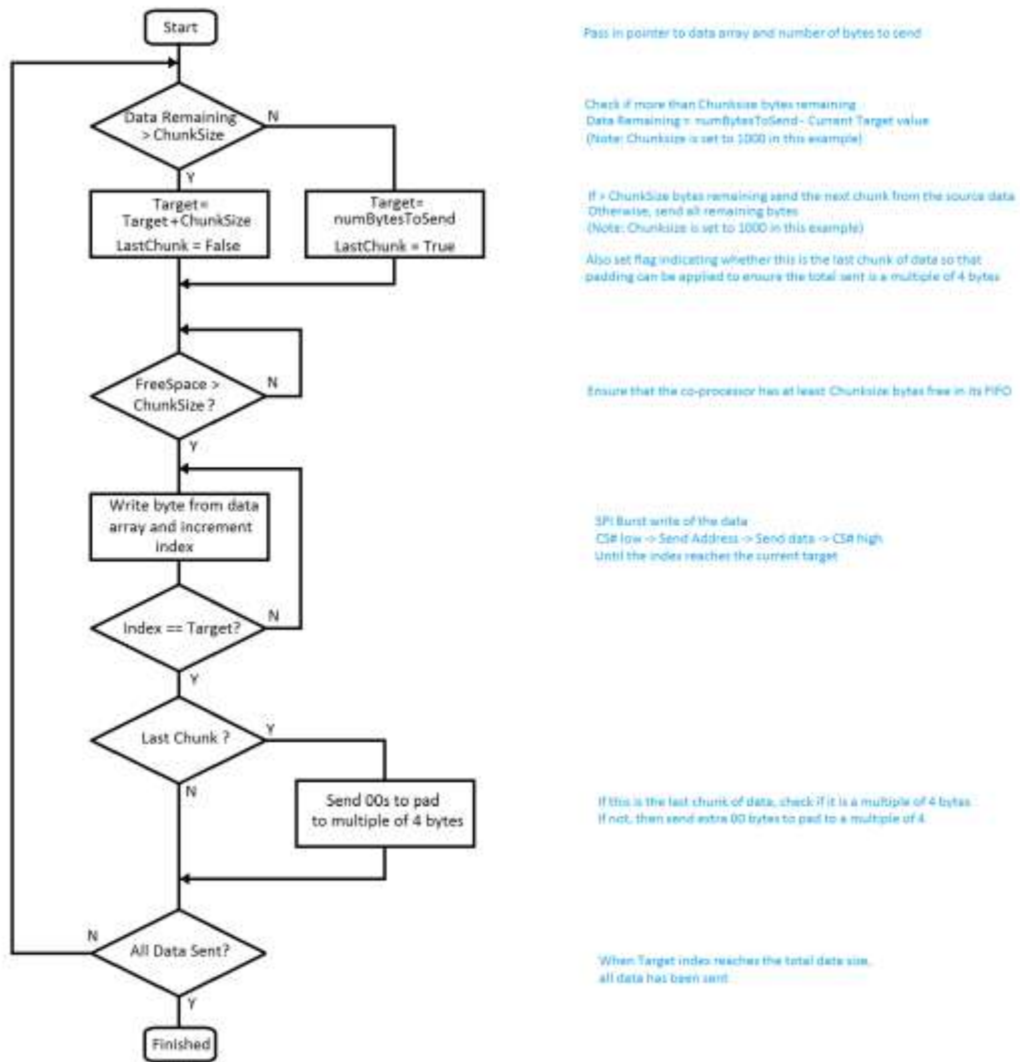

Figure 4 - Sending data to the Co-Processor

When called, the function takes a pointer to the data array and the size of the data as parameters. It loops continuously until the specified number of bytes from the source data have been sent.

A variable called 'Target' is used to control the loading of the data and acts as a running total of the data as it is sent. The target begins at value 0 initially. Each time round the overall loop, the target is incremented by the size of the next chunk of data to be sent. The inner data streaming loop then writes data from incrementing locations in the source data until the target is reached. If more data remains to be sent, the target will be incremented again. When the Target becomes equal to the total number of bytes to be sent, then all data has been sent successfully.

After the last chunk of the data has been sent, the code checks if the total data size is a multiple of 4 bytes. If not, the data is padded with extra 00 bytes to ensure that it is a multiple of 4 bytes. This is necessary as otherwise the next FIFO command to be written would not be correctly aligned to a 4-byte offset and a co-processor error would occur.

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6.4 GPU Instructions

The GPU instructions can be used either directly by the GPU in a display list or can be passed in via the co-processor. The latter technique is used in most cases as it allows mixing of GPU and Co-Processor commands.

An API_ function is provided for each GPU command which allows it to be written to the RAM_CMD FIFO in the same way as Co-Processor commands and keeps track of the offset in the buffer. e.g.

```
void API_COLOR_RGB(uint8_t R, uint8_t G, uint8_t B)
{
    EVE_Write32(COLOR_RGB(R,G,B));
    cmdOffset = EVE_IncCMDOffset(cmdOffset, 4);
}
```

The function uses the bit shifting operations defined near the bottom of FT8xx.h to format the parameters into their bit positions in the command. e.g.

```
#define COLOR_RGB(red,green,blue)
((4UL<<24)|(((red)&255UL)<<16)|(((green)&255UL)<<8)|(((blue)&255UL)<<0))
```

These functions are listed in Appendix B– List of GPU and Co-Processor Commands

6.5 Co-Processor Commands

Each Co-Processor command has an API_ function in this layer which handles writing of the command and any parameters. It takes the command in a user-friendly syntax which is compatible with the FT81x programmers guide and then formats the parameters into the SPI transfers which the FT81x requires. It also updates the variable which keeps track of the pointer position. E.g.

```
void API_CMD_NUMBER(int16_t x, int16_t y, int16_t font, uint16_t options, int32_t
n)
{
    EVE_Write32(CMD_NUMBER);
    EVE_Write32( (((uint32_t)y<<16)|(x & 0xffff)));
    EVE_Write32( (((uint32_t)options<<16)|(font&0xffff)));
    EVE_Write32( n);
    cmdOffset = EVE_IncCMDOffset(cmdOffset, 16);
}
```

These functions are listed in Appendix B– List of GPU and Co-Processor Commands

6.6 GPU Instructions (FT81x)

These instructions are included in a separate define as they are for the FT81x series only. These functions are listed along with the other commands in Appendix B– List of GPU and Co-Processor Commands.

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6.7 Co-Processor Commands (FT81x)

These commands are included in a separate define as they are for the FT81x series only. These functions are listed along with the other commands in Appendix B– List of GPU and Co-Processor Commands.

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7 Software - EVE Layer

The EVE functions can be found in EVE_Layer.c. They provide the interface between the Application layer and the MCU layer, allowing the application to use a simpler syntax so that the developer can focus on the screen content. At the same time, the EVE functions are independent of MCU type as they use the MCU layer for all MCU-specific accesses.

BRT_AN_006 has further details on how these functions work.

7.1 Functions

- void EVE_AddrForWr(uint32_t ftAddress)
- void EVE_AddrForRd(uint32_t ftAddress)
- void EVE_Write32(uint32_t ftData32)
- void EVE_Write16(uint16_t ftData16)
- void EVE_Write8(uint8_t ftData8)
- uint32_t EVE_Read32(void)
- uint16_t EVE_Read16(void)
- uint8_t EVE_Read8(void)
- void EVE_MemWrite32(uint32_t ftAddress, uint32_t ftData32)
- void EVE_MemWrite16(uint32_t ftAddress, uint16_t ftData16)
- void EVE_MemWrite8(uint32_t ftAddress, uint8_t ftData8)
- uint32_t EVE_MemRead32(uint32_t ftAddress)
- uint16_t EVE_MemRead16(uint32_t ftAddress)
- uint8_t EVE_MemRead8(uint32_t ftAddress)
- void EVE_CmdWrite(uint8_t EVECmd, uint8_t Param)
- uint16_t EVE_IncCMDOffset(uint16_t currentOffset, uint16_t commandSize)
- uint8_t EVE_WaitCmdFifoEmpty(void)
- uint32_t EVE_GetCurrentWritePointer(void)
- uint16_t EVE_CheckFreeSpace(uint16_t CmdOffset)

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7.2 Addressing Functions

These functions send the address which is to be written or read. They take an unsigned long parameter which should have the address in the lower three bytes. The function configures the upper two bits of this 24-bit address to indicate to the FT8xx whether this is a write or a read operation and then sends the resulting three bytes.

void EVE_AddrForWr(uint32_t ftAddress)

Sends the 24-bit address, with the two MSBs of the address forced to '10' to indicate that the address is to be written to.

void EVE_AddrForRd(uint32_t ftAddress)

Sends the 24-bit address, with the two MSBs of the address forced to '00' to indicate that the address is to be read from.

7.3 Data Functions

These functions can be used to write/read data to/from a register, or other memory area such as the RAM_DL or RAM_CMD. The address must have been send using the functions from the section above. The MCU's SPI hardware always writes a byte whenever it reads a byte and so dummy zero bytes are sent.

void EVE_Write32(uint32_t ftData32)

This function sends a 32-bit data value to the FT8xx starting with the least significant byte.

void EVE_Write16(uint16_t ftData16)

This function sends a 16-bit data value to the FT8xx starting with the least significant byte.

void EVE_Write8(uint8_t ftData8)

This function sends an 8-bit data value to the FT8xx.

uint32_t EVE_Read32(void)

This function reads a 32-bit data value from a previously addressed register in the FT8xx.

uint16_t EVE_Read16(void)

This function reads a 16-bit data value from a previously addressed register in the FT8xx.

uint8_t EVE_Read8(void)

This function reads an 8-bit data value from a previously addressed register in the FT8xx.

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7.4 Combined Address and Data functions

These functions combine the chip select, addressing and data operations to provide a single call which can write a value to a specified address or read a value from a specified address. These are ideal for writing/reading a single value to/from a register in the FT8xx.

Note: Chip select is asserted before the address and de-asserted after last data byte in all of these functions. For burst writes or reads where data is streamed to/from memory the individual addressing and data functions from the previous sections can be used instead.

void EVE_MemWrite32(uint32_t ftAddress, uint32_t ftData32)

e.g. EVE_MemWrite32 (0x102428, 0x12345678);

void EVE_MemWrite16(uint32_t ftAddress, uint16_t ftData16)

e.g. EVE_MemWrite16 (0x102428, 0x1234);

void EVE_MemWrite8(uint32_t ftAddress, uint8_t ftData8)

e.g. EVE_MemWrite8 (0x102428, 0x12);

uint32_t EVE_MemRead32(uint32_t ftAddress)

e.g. MyValue = EVE_MemRead32 (0x102428);

uint16_t EVE_MemRead16(uint32_t ftAddress)

e.g. MyValue = EVE_MemRead16 (0x102428);

uint8_t EVE_MemRead8(uint32_t ftAddress)

e.g. MyValue = EVE_MemRead8 (0x102428);

7.5 Host Command

This function sends the specified Host Command to the FT8xx. The command itself is passed into the function as an unsigned char. The FT81x uses the second uint8_t as a parameter for the command. A third byte, of value 0x00, is also sent to complete the host command.

void EVE_CmdWrite(uint8_t EVECmd, uint8_t Param)

Sends three bytes [EVECmd] [Param] 0x00 for example, CMD_ACTIVE is 0x00 0x00 0x00

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7.6 Co-Processor FIFO Supporting Functions

These functions provide handling for the co-processor's circular buffer.

uint16_t EVE_IncCMDOffset(uint16_t currentOffset, uint16_t commandSize)

This function is used when adding commands to the Command FIFO of the Co-Processor and handles the wraparound of the circular buffer. It takes in the current offset and the size of the last command. It returns the offset at which the next command will be written.

When a command is added to the FIFO, the MCU must calculate the offset at which the next command will be written. Normally, if a 4-byte command was written at (RAM_CMD + Offset), then the next command would start at (RAM_CMD + Offset + 4). However, since the FT8xx uses a circular buffer of 4096 bytes, the offset also needs to wrap around when offset 4095 is reached.

Note: This function allows the MCU to keep track of the FIFO write pointer. The FT8xx also keeps track internally. If performing a burst write of a co-processor list, the FT8xx will keep count of the bytes received including taking account of the internal rollover of the FIFO whilst CS# is held low. If the MCU uses this function to keep track of its internal counter cmdOffset, the FT8xx's internal pointer and variable cmdOffset will remain in sync even with FIFO rollover in the middle of a burst.

uint8_t EVE_WaitCmdFifoEmpty(void)

This function reads the values of the REG_CMD_WRITE and REG_CMD_READ pointers and waits for them to be equal. This indicates that the co-processor has consumed and processed all of the commands given to it.

The function blocks until either the pointers become equal or will return if REG_CMD_READ reads as 0xFFF which is an invalid value indicating an error (for example, if a command or data send to the co-processor was not padded to a multiple of 4 bytes and so the next command began at an invalid offset). The FT81x Programmers guide and Datasheet have further details of error conditions.

A return value of 0 indicates that the pointers became equal and the FIFO is empty, a non-zero value indicates error.

uint32_t EVE_GetCurrentWritePointer(void)

This function returns the current value of the FT81x's REG_CMD_WRITE. This can be used as the starting offset (RAM_CMD + offset) for the next command, so that the RAM_CMD is used as a true circular FIFO.

This function is typically called after the EVE_WaitCmdFifoEmpty function so that the calling code can determine that the FIFO is empty and then where to begin the next set of co-processor instructions.

uint16_t EVE_CheckFreeSpace(uint16_t CmdOffset)

This function returns the amount of free space in the RAM_CMD FIFO. It determines the fullness of the FIFO by comparing the write and read pointers and then subtracting this from the total size of the FIFO gives the free space. The function also takes account of the roll-over at (RAM_CMD + 4K) when calculating this value.

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8 Software - MCU Layer

The MCU layer can be found in file MCU_Layer.c and contains all of the code which directly accesses the MCU's register map for configuration, GPIO and SPI. The code in this section can be changed to suit a different PIC microcontroller or another type of microcontroller so that the layers above can access the relevant registers and peripherals. This example uses the standard SPI interface found on most MCUs and so should be portable across a wide variety of devices without significant changes.

Note: These functions are intended to perform a basic set-up of the PIC so that the EVE functionality can be demonstrated. The designer must consult the product documentation provided by the manufacturer of their selected MCU to confirm the correct set-up and best practices are followed so that reliable operation of the final product can be assured. The latest documentation for the selected EVE device and module should also be consulted. In the case of differences between the information provided in this document/code and the datasheets of the devices used, the product datasheet should take precedence.

8.1 Functions

- void MCU_Init(void)
- void MCU_CSlow(void)
- void MCU_CShigh(void)
- void MCU_PDlow(void)
- void MCU_PDhigh(void)
- uint8_t MCU_SPIReadWrite(Uint8_t DataToWrite)
- void UART_Init(void)
- void UART_Tx(Uint8_t SerialTxByte)
- uint8_t UART_Rx(void)
- void Delay_20ms(void)
- void Delay_500ms(void)

8.2 Data Types

This code uses the following data types, which may need to be converted depending on the types supported by the target MCU's development tools:

int32_t	32-bit signed number
int16_t	16-bit signed number
int8_t	8-bit signed number
uint32_t	32-bit unsigned number
uint16_t	16-bit unsigned number
uint8_t	8-bit unsigned number

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8.3 Initialisation

void MCU_Init(void)

This function, along with the definitions at the top of the main.c file, performs a relatively basic configuration of the MCU to set the GPIO port pins used for the EVE signals and to configure the SPI peripheral. The definitions at the top of the code also set the oscillator for use with a 12MHz crystal and x4 PLL which runs the PIC at 48MHz.

The code was also tested and ran well with only the internal oscillator of the PIC. Note that when changing clock settings, the delays specified (especially the at-least-500ms delay on start-up) must be maintained. Also, the SPI clock rate must be kept below 11MHz during initial start-up and until after the MCU_Init and EVE_Init functions have been called. If running on a faster PIC, adjustments to delays and prescalers may be required.

8.4 GPIO Functions

These functions set or clear a GPIO line on the MCU for PD# and CS#

void MCU_CSlow(void)

This function will put the port pin assigned to the Chip Select of the FT81x to the low state.

void MCU_CShigh(void)

This function will put the port pin assigned to the Chip Select of the FT81x to the high state.

void MCU_PDlow(void)

This function will put the port pin assigned to the Power Down pin of the FT81x to the low state.

void MCU_PDhigh(void)

This function will put the port pin assigned to the Power Down pin of the FT81x to the high state.

8.5 SPI Functions

Uint8_t MCU_SPIReadWrite(Uint8_t DataToWrite)

This function writes a byte to the PIC's SPI peripheral which will be clocked out of MOSI. The peripheral will simultaneously clock in a byte on MISO which is returned by the function.

8.6 Delay Functions

Functions are provided for 20ms and 500ms delays. These help to improve readability of the main application by having a single call for each delay. They may require adjustment depending on the bus frequency of the MCU selected.

void Delay_20ms(void)

void Delay_500ms(void)

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8.7 UART Functions

These functions provide a basic UART configuration for debug purposes or outputting data such as screenshot data to the PC. The reader must consult the documentation for their selected PIC in order to confirm the required settings for their application and should also adjust the baud rate divisors based on their crystal and MCU bus frequency to achieve the required baud rate.

The FTDI C232HD or TTL-232R-3v3 cables are ideal for interfacing the UART to a PC via its USB port and can be connected directly to the PIC. 5V signal versions of the TTL-232R cables are also available. The voltage chosen should match that of the PIC VCCIO.

void UART_Init(void)

This function sets the UART up for approximately 57600 baud based on a 12MHz crystal with x4 PLL enabled. It configures UART2 which can be found on pins RD6 (TxD) and RD7 (RxD). RD5 and RD4 can be used as GPIO lines controlled by these UART functions to provide CTS# and RTS# for flow control.

void UART_Tx(Uint8_t SerialTxByte)

This function transmits one byte via the UART.

Uint8_t UART_Rx(void)

This function receives one byte via the UART.

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9 Using the Code Project

To load the project, ensure that MPLAB X is installed on the PC. The latest download can be obtained from Microchip http://www.microchip.com/mplab/mplab-x-ide

The provided source code file (see Appendix A– References) can be un-zipped and the resulting folder copied to the user's normal project workspace directory. E.g. this is often c:\Users\[username]\MPLABXProjects\

Then go to File -> Open Project and select BRT_AN_008_Source. The project should now appear in the Projects window.

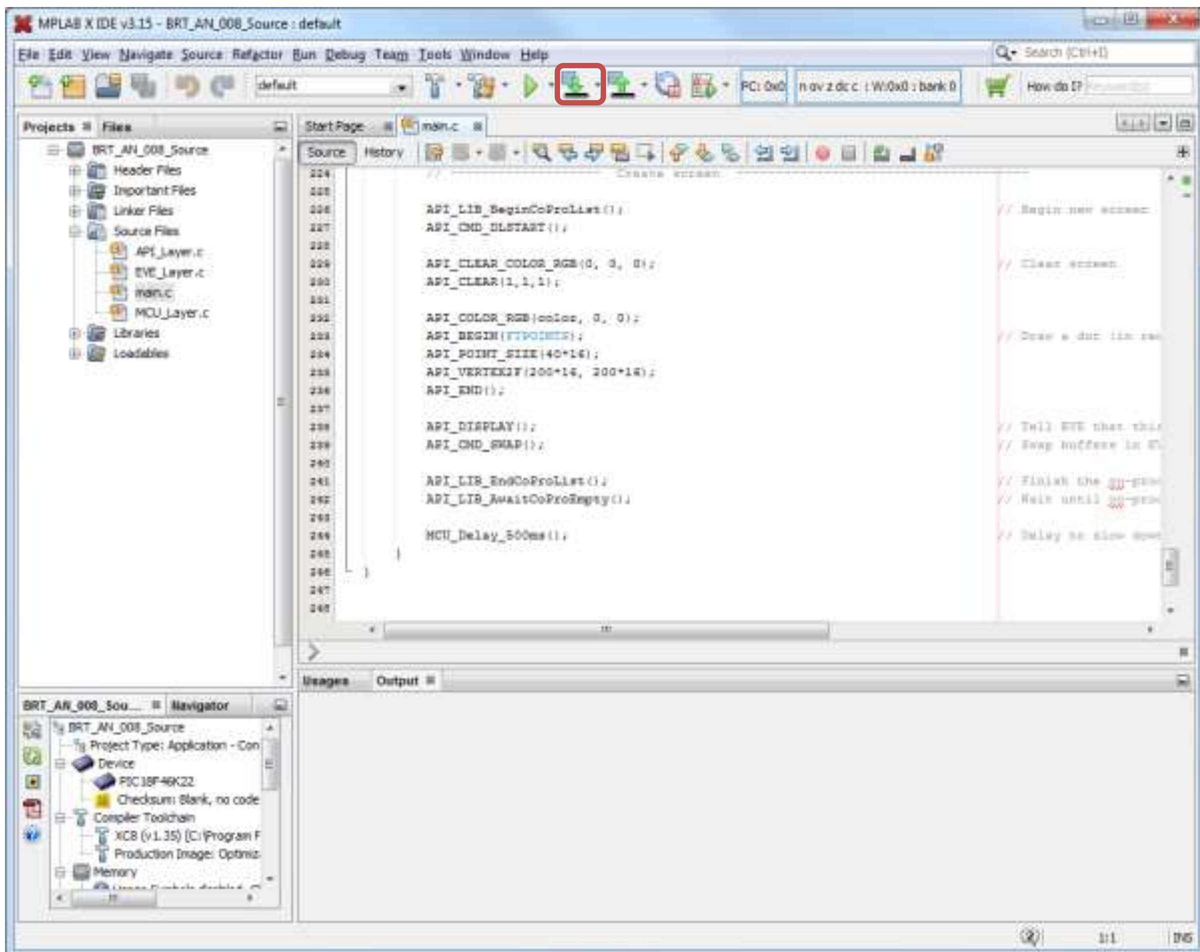

Figure 5 - MPLABX screenshot

Ensure that the debugger is connected to the PC and to the PIC circuit and is showing up correctly under the debug tools section. Select the Run -> Clean and Build option to build the project. The highlighted button 'Make and program Device' can then be used to download the code to the PIC.

After programming is complete, the PIC will reset and begin running the code. The screen of the FT81x module should show a black background with a small red dot flashing as shown in Figure 3.

Note: The instructions above for the Microchip MPLABX tools and debugger tools are correct at the time of writing but may change in the future independent of Bridgetek. Please refer to the MPLABX documentation from Microchip for the latest information on loading/configuring projects and configuration of the debugger tools.

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10 Conclusion

This application note has presented a simple example of a library for interfacing the FT81x series to a PIC microcontroller. It is intended as a starting point for developers to customise in order to create a library for their MCU platform.

The simple flashing dot example provided here in the main application can be extended to produce a more complex real-world application.

It is recommended that readers refer to the application note BRT AN 006 which provides background information on the SPI data formatting used by EVE and an overview of how display lists and co-processor lists are implemented. It is also assumed that the reader is familiar with the FT81x Datasheet and Programmers guide which provide full details of the FT81x devices and their API commands.

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Appendix A– References

Document References

BRT_AN_006

BRT_AN_007

FT81x

ME813-WH50C Datasheet

ME812-WH50R Datasheet

VM810C50A-D

FT81x Programmer Guide

FT81x Datasheet

EVE Examples (including BRT_AN_008.zip)

PIC18F46K22

PICKIT3

BRT_AN_008_Source Code

Acronyms and Abbreviations

Terms	Description
EVE	Embedded Video Engine
FT81x	Latest version of the EVE family with enhanced feature set
LCD	Liquid Crystal Display
MPLAB X	Development environment software for PIC MCUs
PD#	Power Down pin (active low) on the FT8xx
PIC	PIC Microcontroller family from Microchip
SPI	Serial Peripheral Interface
UART	Universal Asynchronous Receiver Transmitter for serial data transfer

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Appendix B– List of GPU and Co-Processor Commands

The following functions are provided in the API layer of the library.

GPU Instructions

- void API_CLEAR_COLOR_RGB(uint8_t R, uint8_t G, uint8_t B);
- void API_CLEAR(uint8_t C, uint8_t S, uint8_t T);
- void API_COLOR_RGB(uint8_t R, uint8_t G, uint8_t B);
- void API_VERTEX2F(int16_t x, int16_t y);
- void API_VERTEX2II(uint16_t x, uint16_t y, uint8_t handle,uint8_t cell);
- void API_BITMAP_HANDLE(uint8_t handle);
- void API_BITMAP_SOURCE(uint32_t addr);
- void API_BITMAP_LAYOUT(uint8_t format, uint16_t linestride, uint16_t height);
- void API_BITMAP_SIZE(uint8_t filter, uint8_t wrapx, uint8_t wrapy, uint16_t width, uint16_t height);
- void API_CELL(uint8_t cell);
- void API_TAG(uint8_t s);
- void API_ALPHA_FUNC(uint8_t func, uint8_t ref);
- void API_STENCIL_FUNC(uint8_t func, uint8_t ref, uint8_t mask);
- void API_BLEND_FUNC(uint8_t src, uint8_t dst);
- void API_STENCIL_OP(uint8_t sfail, uint8_t spass);
- void API_POINT_SIZE(uint16_t size);
- void API_LINE_WIDTH(uint16_t width);
- void API_CLEAR_COLOR_A(uint8_t alpha);
- void API_COLOR_A(uint8_t alpha);
- void API_CLEAR_STENCIL(uint8_t s);
- void API_CLEAR_TAG(uint8_t s);
- void API_STENCIL_MASK(uint8_t mask);
- void API_TAG_MASK(uint8_t mask);
- void API_SCISSOR_XY(uint16_t x, uint16_t y);
- void API_SCISSOR_SIZE(uint16_t width, uint16_t height);
- void API_CALL(uint16_t dest);
- void API_JUMP(uint16_t dest);
- void API_BEGIN(uint8_t prim);
- void API_COLOR_MASK(uint8_t r, uint8_t g, uint8_t b, uint8_t a);
- void API_END(void);
- void API_SAVE_CONTEXT(void);
- void API_RESTORE_CONTEXT(void);
- void API_RETURN(void);
- void API_MACRO(uint8_t m);
- void API_DISPLAY(void);

Co-Processor Commands

- void API_CMD_TEXT(int16_t x, int16_t y, int16_t font, uint16_t options, const char* string);
- void API_CMD_BUTTON(int16_t x, int16_t y, int16_t w, int16_t h, int16_t font, uint16_t options, const char* string);
- void API_CMD_KEYS(int16_t x, int16_t y, int16_t w, int16_t h, int16_t font, uint16_t options, const char* string);
- void API_CMD_NUMBER(int16_t x, int16_t y, int16_t font, uint16_t options, int32_t n);
- void API_CMD_LOADIDENTITY(void);
- void API_CMD_TOGGLE(int16_t x, int16_t y, int16_t w, int16_t font, uint16_t options, uint16_t state, const char* string);
- void API_CMD_GAUGE(int16_t x, int16_t y, int16_t r, uint16_t options, uint16_t major, uint16_t minor, uint16_t val, uint16_t range);
- void API_CMD_REGREAD(uint32_t ptr, uint32_t result);

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- void API_CMD_GETPROPS(uint32_t ptr, uint32_t w, uint32_t h);
- void API_CMD_MEMCPY(uint32_t dest, uint32_t src, uint32_t num);
- void API_CMD_SPINNER(int16_t x, int16_t y, uint16_t style, uint16_t scale);
- void API_CMD_BGCOLOR(uint32_t c);
- void API_CMD_SWAP(void);
- void API_CMD_INFLATE(uint32_t ptr);
- void API_CMD_TRANSLATE(int32_t tx, int32_t ty);
- void API_CMD_STOP(void);
- void API_CMD_SLIDER(int16_t x, int16_t y, int16_t w, int16_t h, uint16_t options, uint16_t val, uint16_t range);
- void API_BITMAP_TRANSFORM_A(long a);
- void API_BITMAP_TRANSFORM_B(long b);
- void API_BITMAP_TRANSFORM_C(long c);
- void API_BITMAP_TRANSFORM_D(long d);
- void API_BITMAP_TRANSFORM_E(long e);
- void API_BITMAP_TRANSFORM_F(long f);
- void API_CMD_INTERRUPT(uint32_t ms);
- void API_CMD_FGCOLOR(uint32_t c);
- void API_CMD_ROTATE(int32_t a);
- void API_CMD_MEMWRITE(uint32_t ptr, uint32_t num);
- void API_CMD_SCROLLBAR(int16_t x, int16_t y, int16_t w, int16_t h, uint16_t options, uint16_t val, uint16_t size, uint16_t range);
- void API_CMD_GETMATRIX(int32_t a, int32_t b, int32_t c, int32_t d, int32_t e, int32_t f);
- void API_CMD_SKETCH(int16_t x, int16_t y, uint16_t w, uint16_t h, uint32_t ptr, uint16_t format);
- void API_CMD_MEMSET(uint32_t ptr, uint32_t value, uint32_t num);
- void API_CMD_GRADCOLOR(uint32_t c);
- void API_CMD_BITMAP_TRANSFORM(int32_t x0, int32_t y0, int32_t x1, int32_t y1, int32_t x2, int32_t y2, int32_t tx0, int32_t ty0, int32_t tx1, int32_t ty1, int32_t tx2, int32_t ty2, uint16_t result);
- void API_CMD_CALIBRATE(uint32_t result);
- void API_CMD_SETFONT(uint32_t font, uint32_t ptr);
- void API_CMD_LOGO(void);
- void API_CMD_APPEND(uint32_t ptr, uint32_t num);
- void API_CMD_MEMZERO(uint32_t ptr, uint32_t num);
- void API_CMD_SCALE(int32_t sx, int32_t sy);
- void API_CMD_CLOCK(int16_t x, int16_t y, int16_t r, uint16_t options, uint16_t h, uint16_t m, uint16_t s, uint16_t ms);
- void API_CMD_GRADIENT(int16_t x0, int16_t y0, uint32_t rgb0, int16_t x1, int16_t y1, uint32_t rgb1);
- void API_CMD_SETMATRIX(void);
- void API_CMD_TRACK(int16_t x, int16_t y, int16_t w, int16_t h, int16_t tag);
- void API_CMD_GETPTR(uint32_t result);
- void API_CMD_PROGRESS(int16_t x, int16_t y, int16_t w, int16_t h, uint16_t options, uint16_t val, uint16_t range);
- void API_CMD_COLDSTART(void);
- void API_CMD_DIAL(int16_t x, int16_t y, int16_t r, uint16_t options, uint16_t val);
- void API_CMD_LOADIMAGE(uint32_t ptr, uint32_t options);
- void API_CMD_DLSTART(void);
- void API_CMD_SNAPSHOT(uint32_t ptr);
- void API_CMD_SCREENSAVER(void);
- void API_CMD_MEMCRC(uint32_t ptr, uint32_t num, uint32_t result);

GPU Instructions (FT81x)

- void API_VERTEX_FORMAT(uint8_t frac);
- void API_BITMAP_LAYOUT_H(uint8_t linestride, uint8_t height);
- void API_BITMAP_SIZE_H(uint8_t width, uint8_t height);
- void API_PALETTE_SOURCE(uint32_t addr);

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- void API_VERTEX_TRANSLATE_X(uint32_t x);
- void API_VERTEX_TRANSLATE_Y(uint32_t y);
- void API_NOP(void);

Co-Processor Commands (FT81x)

- void API_CMD_VIDEOSTART(void);
- void API_CMD_SETROTATE(uint32_t r);
- void API_CMD_SETFONT2(uint32_t font, uint32_t ptr, uint32_t firstchar);
- void API_CMD_MEDIAFIFO(uint32_t ptr, uint32_t size);
- void API_CMD_SNAPSHOT2(uint32_t fmt, uint32_t ptr, int16_t x, int16_t y, int16_t w, int16_t h);
- void API_CMD_INT_SWLOADIMAGE(uint32_t ptr, uint32_t options);
- void API_CMD_CSKETCH(int16_t x, int16_t y, uint16_t w, uint16_t h, uint32_t ptr, uint16_t format,uint16_t freq);
- void API_CMD_ROMFONT(uint32_t font, uint32_t romslot);
- void API_CMD_PLAYVIDEO(uint32_t options);
- void API_CMD_SYNC(void);
- void API_CMD_VIDEOFRAME(uint32_t dst, uint32_t ptr);
- void API_CMD_SETBASE(uint32_t base);
- void API_CMD_SETBITMAP(uint32_t source, uint16_t fmt, uint16_t w, uint16_t h);
- void API_CMD_SETSCRATCH(uint32_t handle);

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Appendix D– Revision History

Document Title: BRT_AN_008 FT81x Creating a Simple Library For PIC MCU
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Revision	Changes	Date
1.0	Initial version	2017-07-07

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