Application Note

AN_345

FT51A Keyboard Sample

Version 1.2

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This document provides a guide for using the FT51A development environment to emulate a HID Keyboard device in firmware.

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1 Introduction

This application note documents an example firmware project for the FT51A. The source code is available in the "examples\AN_345_Keyboard_Sample" folder of the FT51A Software Development Kit.

1.1 Overview

The Keyboard firmware project demonstrates a method for emulating a keyboard using an FT51A device. The FT51A need only be connected to a host PC via the USB interface. The demonstration code sends key presses defined at compilation time to the host PC. The host PC treats these as real key presses and will send them to the active application.

An example application would be to embed an FT51A in a device that sends HID (Human Interface Device) reports from a sensor to a host PC. The PC would receive this data as key presses which would be interpreted by a program. For example, a rotary encoder could be attached allowing cursor-up or page-up key presses to be sent when a dial is turned.

The example code also includes the DFU functionality from AN_344 FT51A DFU Sample.

1.2 Features

The keyboard example has the following features:

- Open source firmware layered on FT51A USB library.
- Configurable HID report descriptor.
- HID report structure can be modified as required.
- Implements an interrupt IN endpoint using timers.

1.3 Limitations

The firmware emulates a HID "boot protocol" device which uses a predefined report format. The report descriptor has little room for adding additional functionality without switching to "report protocol".

1.4 Scope

The guide is intended for developers who are creating applications, extending FTDI provided applications or implementing example applications for the FT51A.

In the reference of the FT51A, an "application" refers to firmware that runs on the FT51A; "libraries" are source code provided by FTDI to help user, access specific hardware features of the chip.

The FT51A Tools are currently only available for Microsoft Windows platforms and are tested on Windows 7 and Windows 8.1.

2 HID Keyboard Overview

The HID protocol and requirements are documented in the HID 1.1 specification:

http://www.usb.org/developers/hidpage/HID1_11.pdf

The FT51A implementation is for a USB device which emulates a "Boot Protocol" keyboard. This is a special class of HID device which has a restricted set of features in order to reduce the complexity of the host. This allows a HID device to be used with simpler hosts without requiring the host to decode report descriptors. The format of the report descriptor is therefore fixed.

Configuration descriptors for HID devices will have an interface descriptor containing a HID descriptor along with at least one endpoint descriptor. This firmware has a single interrupt IN endpoint which returns report packets to the host.

2.1 Firmware Overview

The firmware will enumerate as a HID keyboard and receive a Set_Idle request from the host. After a short delay it will send key presses to simulate the typing of a predefined string to the host. The string can be modified and may include alpha numeric keys and control keys.

2.1.1 FT51A Libraries

The keyboard firmware uses the FT51A USB library, DFU library, general config library and the IOMUX library. The IOMUX library is not used in the example code but is included to allow further functionality to be added.

DFU functionality is implemented as described in AN_344 DFU Sample.

3 Keyboard Firmware

The firmware included in the example code demonstrates a boot protocol keyboard.

A report descriptor is included for a standard boot protocol keyboard. HID devices, especially boot protocol devices, do not normally require additional drivers on modern operating systems. The USB class, subclass and protocol must therefore be set to identify the device as the correct HID compatible keyboard providing boot protocol reports.

3.1 USB Descriptors

The keyboard firmware stores two sets of device descriptors and configuration descriptors. It stores a single table of string descriptors as the strings for run time and DFU modes can be selected by the descriptors as needed from the same table.

The control endpoint max packet size is defined as 8 bytes. The interrupt IN endpoint for reporting is also set to a maximum of 8 bytes. Both settings are in line with other HID keyboard devices.

```
// USB Endpoint Zero packet size (both must match)
#define USB_CONTROL_EP_MAX_PACKET_SIZE 8
#define USB_CONTROL_EP_SIZE USB_EP_SIZE_8
```

The Product IDs (PIDs) for run time (0x0FEA) and DFU mode (0x0FEE – the same as the AN_344 DFU Sample interface) are also defined in the source code. Note AN_346 FT51A Mouse Sample uses the same PID number, so drivers uninstall is required if both examples are used.

These are example PID values and **must not** be used in a final product. VID and PID combinations must be unique to an application.

The USB class, subclass and protocols along with other general USB definitions are found in the file "ft51_usb.h" library include file.

3.1.1 Keyboard Descriptors

The first set of descriptors is the run time set for the keyboard function. The device descriptor contains the VID and PID for the keyboard.

```
__code USB_device_descriptor device_descriptor_keyboard =
{
    .bLength = 0x12,
    .bDescriptorType = USB_DESCRIPTOR_TYPE_DEVICE,
    .bcdUSB = USB_BCD_VERSION_2_0,          // V2.0
    .bDeviceClass = USB_CLASS_DEVICE,       // Defined in interface
    .bDeviceSubClass = USB_SUBCLASS_DEVICE, // Defined in interface
    .bDeviceProtocol = USB_PROTOCOL_DEVICE, // Defined in interface
    .bMaxPacketSize0 = USB_CONTROL_EP_MAX_PACKET_SIZE,
    .idVendor = USB_VID_FTDI,   // idVendor: 0x0403 (FTDI)
    .idProduct = USB_PID_KEYBOARD, // idProduct: 0x0fea
    .bcdDevice = 0x0101,        // 1.1
    .iManufacturer = 0x01,  // String 1
    .iProduct = 0x02,       // String 2
    .iSerialNumber = 0x03,  // String 3
    .bNumConfigurations = 0x01
};
```

The configuration descriptor contains an interface descriptor, a HID descriptor and an endpoint descriptor for the run time function.

It also has an interface descriptor for a DFU interface. This includes a DFU functional descriptor.

```
// Structure containing layout of configuration descriptor
__code struct config_descriptor_keyboard
{
        USB_configuration_descriptor configuration;
        USB_interface_descriptor interface;
        USB_hid_descriptor hid;
        USB_endpoint_descriptor endpoint;
        USB_interface_descriptor dfu_interface;
        USB_dfu_functional_descriptor dfu_functional;
};

struct config_descriptor_keyboard config_descriptor_keyboard =
{
        .configuration.bLength = 0x09,
        .configuration.bDescriptorType = USB_DESCRIPTOR_TYPE_CONFIGURATION,
        .configuration.wTotalLength = sizeof(struct config_descriptor_keyboard),
        .configuration.bNumInterfaces = 0x02,
        .configuration.bConfigurationValue = 0x01,
        .configuration.iConfiguration = 0x00,
        .configuration.bmAttributes =  USB_CONFIG_BMATTRIBUTES_VALUE,
        .configuration.bMaxPower = 0xFA, // 500mA

        // ---- INTERFACE DESCRIPTOR for Keyboard ----
        .interface.bLength = 0x09,
        .interface.bDescriptorType = USB_DESCRIPTOR_TYPE_INTERFACE,
        .interface.bInterfaceNumber = 0,
        .interface.bAlternateSetting = 0x00,
        .interface.bNumEndpoints = 0x01,
        .interface.bInterfaceClass = USB_CLASS_HID, // HID Class
        .interface.bInterfaceSubClass = USB_SUBCLASS_HID_BOOT_INTERFACE, // Boot Protocol
        .interface.bInterfaceProtocol = USB_PROTOCOL_HID_KEYBOARD, // Keyboard
        .interface.iInterface = 0x02, // String 2
        // ---- HID DESCRIPTOR for Keyboard ----
        .hid.bLength = 0x09,
        .hid.bDescriptorType = USB_DESCRIPTOR_TYPE_HID,
        .hid.bcdHID = USB_BCD_VERSION_HID_1_1,
        .hid.bCountryCode = USB_HID_LANG_NOT_SUPPORTED,
        .hid.bNumDescriptors = 0x01,
        .hid.bDescriptorType_0 = USB_DESCRIPTOR_TYPE_REPORT,
        .hid.wDescriptorLength_0 = 0x0041,
        // ---- ENDPOINT DESCRIPTOR for Keyboard ----
        .endpoint.bLength = 0x07,
        .endpoint.bDescriptorType = USB_DESCRIPTOR_TYPE_ENDPOINT,
        .endpoint.bEndpointAddress = 0x81,
        .endpoint.bmAttributes = USB_ENDPOINT_DESCRIPTOR_ATTR_INTERRUPT,
        .endpoint.wMaxPacketSize = 0x0008,
        .endpoint.bInterval = 0x0a,

        // ---- INTERFACE DESCRIPTOR for DFU Interface ----
        .dfu_interface.bLength = 0x09,
        .dfu_interface.bDescriptorType = USB_DESCRIPTOR_TYPE_INTERFACE,
        .dfu_interface.bInterfaceNumber = DFU_USB_INTERFACE_RUNTIME,
        .dfu_interface.bAlternateSetting = 0x00,
        .dfu_interface.bNumEndpoints = 0x00,
        .dfu_interface.bInterfaceClass = USB_CLASS_APPLICATION, // Application Specific
        .dfu_interface.bInterfaceSubClass = USB_SUBCLASS_DFU,   // Device Firmware Update
        .dfu_interface.bInterfaceProtocol = USB_PROTOCOL_DFU_RUNTIME, // Runtime Protocol
        .dfu_interface.iInterface = 0x05, // String 5
        // ---- FUNCTIONAL DESCRIPTOR for DFU Interface ----
        .dfu_functional.bLength = 0x09,
        .dfu_functional.bDescriptorType = USB_DESCRIPTOR_TYPE_DFU_FUNCTIONAL,
        .dfu_functional.bmAttributes = USB_DFU_BMATTRIBUTES_CANDNLOAD |
```

```
                USB_DFU_BMATTRIBUTES_WILLDETACH, // bitCanDnload and bitWillDetach
        .dfu_functional.wDetatchTimeOut = DFU_TIMEOUT, // suggest 8192ms
        .dfu_functional.wTransferSize = DFU_BLOCK_SIZE,// typically 64 bytes
        .dfu_functional.bcdDfuVersion = USB_BCD_VERSION_DFU_1_1, // DFU Version 1.1
};
```

The HID descriptor tells the host that there is a report descriptor of length 0x41 bytes to read which will describe the report format of the keyboard.

This descriptor will be read with a GET_DESCRIPTOR request for a report descriptor.

```
/**
See Device Class Definition for Human Interface Devices (HID) Version 1.11
 from USB Implementers' Forum USB.org
 0x05, 0x01,             Usage Page: Generic Desktop Controls
 0x09, 0x06,             Usage: Keyboard
 0xA1, 0x01,             Collection: Application
 0x05, 0x07,               Usage Page: Keyboard
 0x19, 0xE0,               Usage Minimum: Keyboard LeftControl
 0x29, 0xE7,               Usage Maximum: Keyboard Right GUI
 0x15, 0x00,               Logical Minimum: 0
 0x25, 0x01,               Logical Maximum: 1
 0x75, 0x01,               Report Size: 1
 0x95, 0x08,               Report Count: 8
 0x81, 0x02,               Input: Data (2)
 0x95, 0x01,               Report Count: 1
 0x75, 0x08,               Report Size: 8
 0x81, 0x01,               Input: Constant (1)
 0x95, 0x03,               Report Count: 3
 0x75, 0x01,               Report Size: 1
 0x05, 0x08,               Usage Page: LEDs
 0x19, 0x01,               Usage Minimum: Num Lock
 0x29, 0x03,               Usage Maximum: Scroll Lock
 0x91, 0x02,               Output: Data (2)
 0x95, 0x05,               Report Count: 5
 0x75, 0x01,               Report Size: 1
 0x91, 0x01,               Output: Constant (1)
 0x95, 0x06,               Report Count: 6
 0x75, 0x08,               Report Size: 8
 0x15, 0x00,               Logical Minimum: 0
 0x26, 0xFF, 0x00,         Logical Maximum: 255
 0x05, 0x07,               Usage Page: Keyboard/Keypad
 0x19, 0x00,               Usage Minimum: 0
 0x2A, 0xFF, 0x00,         Usage Maximum: 255
 0x81, 0x00,               Input: Data (0)
 0xC0                    End collection
 **/
__code uint8_t hid_report_descriptor_keyboard[65] =
{ 0x05, 0x01, 0x09, 0x06, 0xA1, 0x01, 0x05, 0x07, 0x19, 0xE0, 0x29, 0xE7, 0x15,
        0x00, 0x25, 0x01, 0x75, 0x01, 0x95, 0x08, 0x81, 0x02, 0x95, 0x01, 0x75,
        0x08, 0x81, 0x01, 0x95, 0x03, 0x75, 0x01, 0x05, 0x08, 0x19, 0x01, 0x29,
        0x03, 0x91, 0x02, 0x95, 0x05, 0x75, 0x01, 0x91, 0x01, 0x95, 0x06, 0x75,
        0x08, 0x15, 0x00, 0x26, 0xFF, 0x00, 0x05, 0x07, 0x19, 0x00, 0x2A, 0xFF,
        0x00, 0x81, 0x00, 0xC0, };
```

The format of the report is matched to a C structure containing bitmaps and byte fields described in the report descriptor.

```
typedef struct hid_report_structure_t
{
    unsigned char kbdLeftControl :1;
    unsigned char kbdLeftShift :1;
```

```
    unsigned char kbdLeftAlt :1;
    unsigned char kbdLeftGUI :1;
    unsigned char kbdRightControl :1;
    unsigned char kbdRightShift :1;
    unsigned char kbdRightAlt :1;
    unsigned char kbdRightGUI :1;

    unsigned char arrayNotUsed;  // [1]
    unsigned char arrayKeyboard; // [2]
    unsigned char arrayResv1;
    unsigned char arrayResv2;
    unsigned char arrayResv3;
    unsigned char arrayResv4;
    unsigned char arrayResv5;
} hid_report_structure_t;
```

Filling in the members of this structure will produce a report for the host with the desired data.

3.1.2 DFU Descriptors

The device descriptor contains the VID and PID for the DFU function. This may or may not be the same as the run time VID and PID.

```
USB_device_descriptor device_descriptor_dfumode =
{
        .bLength = 0x12,
        .bDescriptorType = USB_DESCRIPTOR_TYPE_DEVICE,
        .bcdUSB = USB_BCD_VERSION_2_0,
        .bDeviceClass = USB_CLASS_DEVICE,
        .bDeviceSubClass = USB_SUBCLASS_DEVICE,
        .bDeviceProtocol = USB_PROTOCOL_DEVICE,
        .bMaxPacketSize0 = USB_CONTROL_EP_MAX_PACKET_SIZE,
        .idVendor = USB_VID_FTDI,   // 0x0403 (FTDI)
        .idProduct = DFU_USB_PID_DFUMODE, // 0x0fee
        .bcdDevice = 0x0101,
        .iManufacturer = 0x01,
        .iProduct = 0x04,
        .iSerialNumber = 0x03,
        .bNumConfigurations = 0x01
};
```

The configuration descriptor for DFU will contain only an interface descriptor and a functional descriptor for the DFU interface.

The USB class, subclass and protocol indicate that this device is now in DFU mode.

```
// Structure containing layout of configuration descriptor
struct config_descriptor_dfumode
{
    USB_configuration_descriptor configuration;
    USB_interface_descriptor interface;
    USB_dfu_functional_descriptor functional;
};

struct config_descriptor_dfumode config_descriptor_dfumode =
{
        .configuration.bLength = 0x09,
        .configuration.bDescriptorType = USB_DESCRIPTOR_TYPE_CONFIGURATION,
        .configuration.wTotalLength = sizeof(struct config_descriptor_dfumode),
        .configuration.bNumInterfaces = 0x01,
        .configuration.bConfigurationValue = 0x01,
```

```
        .configuration.iConfiguration = 0x00,
        .configuration.bmAttributes = USB_CONFIG_BMATTRIBUTES_VALUE,
        .configuration.bMaxPower = 0xFA, // 500 mA

              // ---- INTERFACE DESCRIPTOR for DFU Interface ----
        .dfu_interface.bLength = 0x09,
        .dfu_interface.bDescriptorType = USB_DESCRIPTOR_TYPE_INTERFACE,
        .dfu_interface.bInterfaceNumber = DFU_USB_INTERFACE_DFUMODE,
        .dfu_interface.bAlternateSetting = 0x00,
        .dfu_interface.bNumEndpoints = 0x00,
        .dfu_interface.bInterfaceClass = USB_CLASS_APPLICATION, // Application Specific
        .dfu_interface.bInterfaceSubClass = USB_SUBCLASS_DFU,   // Device Firmware Update
        .dfu_interface.bInterfaceProtocol = USB_PROTOCOL_DFU_DFUMODE, // Runtime Protocol
        .dfu_interface.iInterface = 0x05, // String 5

        // ---- FUNCTIONAL DESCRIPTOR for DFU Interface ----
        .dfu_functional.bLength = 0x09,
        .dfu_functional.bDescriptorType = USB_DESCRIPTOR_TYPE_DFU_FUNCTIONAL,
        .dfu_functional.bmAttributes = USB_DFU_BMATTRIBUTES_CANDNLOAD |
                USB_DFU_BMATTRIBUTES_WILLDETACH, // bitCanDnload and bitWillDetach
        .dfu_functional.wDetatchTimeOut = DFU_TIMEOUT, // suggest 8192ms
        .dfu_functional.wTransferSize = DFU_BLOCK_SIZE,// typically 64 bytes
        .dfu_functional.bcdDfuVersion = USB_BCD_VERSION_DFU_1_1,
};
```

The same `bmAttributes` mask must appear for the DFU functional descriptor in both run time and DFU modes.

3.1.3 Descriptor Selection

The standard request handler for GET_DESCRIPTOR requests needs to select the run time or DFU mode descriptors for device and configuration descriptors. Other descriptors, including the report descriptors and string descriptors, are not affected.

Determining if the firmware is in run time or DFU mode is achieved by calling the `dfu_is_runtime()` function from the DFU library.

A non-zero response will select the run time mode descriptors and a zero response, the DFU mode descriptors.

```
FT51_STATUS standard_req_get_descriptor(USB_device_request *req)
{
    uint8_t   *src = NULL;
    uint16_t   length = req->wLength;
    uint8_t    hValue = req->wValue >> 8;
    uint8_t    lValue = req->wValue & 0x00ff;
    uint8_t    i, slen;

    switch (hValue)
    {
    case USB_DESCRIPTOR_TYPE_DEVICE:

        if (dfu_is_runtime())
        {
            src = (char *)&device_descriptor_runtime;
        }
        else
        {
            src = (char *)&device_descriptor_dfumode;
        }
        if (length > sizeof(USB_device_descriptor)) // too many bytes requested
```

```
            length = sizeof(USB_device_descriptor); // Entire structure.
        break;

    case USB_DESCRIPTOR_TYPE_CONFIGURATION:

        if (dfu_is_runtime())
        {
            src = (char *)&config_descriptor_runtime;
            if (length > sizeof(config_descriptor_runtime)) // too many bytes requested
                length = sizeof(config_descriptor_runtime); // Entire structure.
        }
        else
        {
            src = (char *)&config_descriptor_dfumode;
            if (length > sizeof(config_descriptor_dfumode)) // too many bytes requested
                length = sizeof(config_descriptor_dfumode); // Entire structure.
        }
        break;

    case USB_DESCRIPTOR_TYPE_REPORT:

        src = (char *) &hid_report_descriptor_keyboard;
        if (length > sizeof(hid_report_descriptor_keyboard))
            length = sizeof(hid_report_descriptor_keyboard); // Entire structure.
        break;
```

The FT51A USB library will return the structure pointed to by the standard_req_get_descriptor() function.

Note that string descriptor selection is not shown in this code sample.

3.2 USB Class Requests

The firmware is responsible for handling USB class requests. It must determine if the firmware is in run time or DFU mode and whether a request has been directed to the DFU interface. This must not interfere with other class requests that may be decoded in the firmware.

The first check is that the class request is aimed at an interface:

```
FT51_STATUS class_req_cb(USB_device_request *req)
{
    FT51_STATUS         status = FT51_FAILED;
    uint8_t             interface = LSB(req->wIndex) & 0x0F;

    // For DFU requests ensure the recipient is an interface...
    if ((req->bmRequestType & USB_BMREQUESTTYPE_RECIPIENT_MASK) ==
            USB_BMREQUESTTYPE_RECIPIENT_INTERFACE)
    {
```

If this is correct then the firmware must check if it is in run time or DFU mode before checking the interface number. The interface number for the DFU mode may differ from that of the run time mode.

Requests to the DFU interface are passed to the DFU library but others are handled as HID requests.

```
        if (dfu_is_runtime())
        {
            if ((interface == DFU_USB_INTERFACE_RUNTIME))
```

```
            {
                // Handle DFU requests DFU_DETATCH, DFU_GETSTATE and DFU_GETSTATUS
                // when in run time mode.
                switch (req->bRequest)
                {
                case USB_CLASS_REQUEST_DETACH:
                    dfu_class_req_detach(req->wValue);
                    status = FT51_OK;
                    break;
                case USB_CLASS_REQUEST_GETSTATUS:
                    dfu_class_req_getstatus();
                    status = FT51_OK;
                    break;
                case USB_CLASS_REQUEST_GETSTATE:
                    dfu_class_req_getstate();
                    status = FT51_OK;
                    break;
                }
            }
            else
            {
                // Handle HID class requests in run time mode.
                switch (req->bRequest)
                {
                case USB_HID_REQUEST_CODE_SET_IDLE:
                    report_enable = 1;
                    report_idle = req->wValue >> 8;
                    USB_transfer(USB_EP_0, USB_DIR_IN, NULL, 0);
                    status = FT51_OK;
                    break;
                case USB_HID_REQUEST_CODE_GET_IDLE:
                    USB_transfer(USB_EP_0, USB_DIR_IN, &report_idle, 1);
                    status = FT51_OK;
                    break;
                case USB_HID_REQUEST_CODE_SET_PROTOCOL:
                    USB_transfer(USB_EP_0, USB_DIR_IN, NULL, 0);
                    report_protocol = req->wValue & 0xff;
                    status = FT51_OK;
                    break;
                case USB_HID_REQUEST_CODE_GET_PROTOCOL:
                    USB_transfer(USB_EP_0, USB_DIR_IN, &report_protocol, 1);
                    status = FT51_OK;
                    break;
                case USB_HID_REQUEST_CODE_GET_REPORT:
                    USB_transfer(1, USB_DIR_IN, (char *) &report_buffer,
                        sizeof(report_buffer));
                    status = FT51_OK;
                    break;
                case USB_HID_REQUEST_CODE_SET_REPORT:
                    // dummy read of one byte
                    USB_transfer(USB_EP_0, USB_DIR_OUT, &input_report, 1);
                    // Acknowledge SETUP
                    USB_transfer(USB_EP_0, USB_DIR_IN, NULL, 0);
                    status = FT51_OK;
                    break;
                }
            }
        }
```

When the device is in DFU mode the DFU request handlers are called as described in AN 344 DFU Sample.

A boot protocol keyboard must support GET_REPORT, GET_IDLE, SET_IDLE, GET_PROTOCOL and SET_PROTOCOL requests.

The GET_REPORT request will allow a report to be sent from the firmware to the host without using the interrupt IN endpoint.

The SET_REPORT request will allow a report to be sent to the firmware from the host. There is no requirement to have an interrupt OUT endpoint on a HID device as reports can be sent via the control endpoint. In a boot protocol keyboard, the input report (from the host to the device) controls the LEDs on a standard keyboard. This is received in the `input_report` buffer.

The SET_PROTOCOL request is used to switch between boot and report modes of operation. It is required by the specification but is not typically used by standard device drivers. A GET_PROTOCOL will return 0 for boot protocol and 1 for report protocol. It is implemented to allow the firmware to be extended to support report protocol.

A SET_IDLE request is normally the first request received from a device driver for a keyboard. Setting the idle duration to zero is common, indicating the interrupt IN endpoint to NAK indefinitely until a new report with changed data is ready to send. The idle duration is assumed to be zero in the firmware and duplicate reports will not be sent. We are only implementing one report ID so there is no decoding of the rest of the request. Both idle duration and report IDs can be added to the firmware if required.

3.3 USB Reset Handler

The reset function handler is used to make the transition from run time mode to DFU mode.

3.4 Timer

A timer is used to simulate the period of key presses and to await a polling interval before transmitting on the interrupt IN endpoint.

The DFU also needs a millisecond timer to accurately return to the appIDLE state from the appDETACH state. The dfu_timer() function in the DFU library should be called every millisecond to enable this.

```
void detach_interrupt(const uint8_t flags)
{
    (void)flags; // Flags not currently used

    keypress_counter--;

    // The DFU detach timer must be called once per millisecond
    dfu_timer();
    // Reload the timer
    TH0 = MSB(MICROSECONDS_TO_TIMER_TICKS(1000));
    TL0 = LSB(MICROSECONDS_TO_TIMER_TICKS(1000));
}

void detach_timer_initialise(void)
{
    // Register our own handler for interrupts from Timer 0
    interrupts_register(detach_interrupt, interrupts_timer0);

    // Timer0 is controlled by TMOD bits 0 to 3, and TCON bits 4 to 5.
    TMOD &= 0xF0; // Clear Timer0 bits
    TMOD |= 0x01; // Put Timer0 in mode 1 (16 bit)
    // Set the count-up value so that it rolls over to 0 after 1 millisecond.
    TH0 = MSB(MICROSECONDS_TO_TIMER_TICKS(1000));
    TL0 = LSB(MICROSECONDS_TO_TIMER_TICKS(1000));
    TCON &= 0xCF; // Clear Timer0's Overflow and Run flags
```

```
    TCON |= 0x10; // Start Timer0 (set its Run flag)
}
```

3.5 Keyboard Report Generator

Once a Set_Idle request has been received from the host the firmware will set the `report_mode` flag and start processing key presses. A timer is used to make a delay between sending reports and hence give the effect of a keyboard being typed upon. This timer changes depending on the characters being typed to make a teletype illusion.

A check is made using `USB_ep_buffer_full()` call to see if the previous data sent to the host has been read in. It will not send any reports until the previous report has been received by the host.

The key press algorithm will send a "key down" report followed by a "key up" report for each character in the string which is sent to the host. The characters are encoded using scancodes obtained from lookup tables `ASCII_to_scancode[]` for normal alphanumeric and symbol characters; or `CONTROL_to_scancode[]` for escaped characters for control codes.

The escape character is a '\' (backslash) which is itself a character that needs escaping in C.

The `ASCII_to_scancode[]` has two lookup characters for selecting lower and upper case. For upper case characters the shift key is pressed in the "key down" report.

The structure `report_buffer` is of type `hid_report_structure_t`. This has member fields for shift keys (`kbdRightShift` and `kbdLeftShift`); control keys (`kbdLeftControl` and `kbdRightControl`); alt keys (`kbdLeftAlt` and `kbdRightAlt`); and GUI keys (`kbdLeftGUI` and `kbdRightGUI`).

The scancode is set in the `arrayKeyboard` member. All other members should be zero.

A "key up" report will have the `arrayKeyboard` member set to zero.

Once the report is ready to send it is then transmitted with a `USB_transfer()` call to the interrupt IN endpoint. The host will read from the device periodically in line with the setting of `bInterval` in the endpoint descriptor for the interrupt IN endpoint. It is recommended to continue polling for SETUP tokens while waiting for a transmission to complete. The `USB_transfer()` function will not block if the transmit buffer is empty.

4 Possible Improvements

The current implementation is "boot protocol". This has limited scope for improvements as the functionality of this type of keyboard is fixed.

If the sample were to change to "report protocol" then more flexibility would be gained and more devices could be emulated. For instance, rich multimedia controls could be added potentially with bi-directional reports. A HID driver could be implemented on the host to receive controls and feedback pertinent data about the multimedia selection to display.

A more straight forward extension would be to add a rotary encoder to send cursor control codes to the host. This could use GPIO or even an analog input to affect the motion of the cursor on the host.

Both input and output reports could be combined to make a HID device for a refreshable braille display.

5 Contact Information

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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 – References

Document References

FTDI MCU web page: http://www.ftdichip.com/MCU.html

USB HID 1.1 specifications: http://www.usb.org/developers/hidpage/HID1_11.pdf

USB Device Firmware Update Class specification:
http://www.usb.org/developers/docs/devclass_docs/DFU_1.1.pdf

Acronyms and Abbreviations

Terms	Description
HID	Human Interface Device
MTP	Multiple Time Program – non-volatile memory used to store program code on the FT51A.
USB	Universal Serial Bus
USB-IF	USB Implementers Forum

Appendix B – Revision History

Document Title: AN_345 FT51A Keyboard Sample
Document Reference No.: FT_001123
Clearance No.: FTDI# 434
Product Page: http://www.ftdichip.com/FTProducts.htm
Document Feedback: Send Feedback

Revision	Changes	Date
1.0	Initial Release	2014-12-12
1.1	Update FT51 references to FT51A	2015-11-26
1.2	Updates for DFU	2015-12-21