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PS/2® to USB Mouse Translator

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OVERVIEW

This Technical Brief details the translation of a PS/2® mouse to a USB mouse using the PIC16C745/765. The PIC16C745/765 is Microchip's low-speed USB microcontroller. All of the USB descriptors for the mouse translator are listed in the tables in **Appendix A: "Device Descriptors"**. A detailed byte-by-byte description is given for each descriptor to assist USB peripheral designers in understanding USB descriptors. For the basics of USB descriptors, refer to TB054, *"An Introduction to USB Descriptors with a Game Port to USB Game Pad Translator Example"*.

Note: This Technical Brief is the second in a series of five technical briefs. This series is meant to familiarize developers with USB. For the best understanding of USB, read the briefs in order: TB054, TB055, TB056, TB057 and TB058.
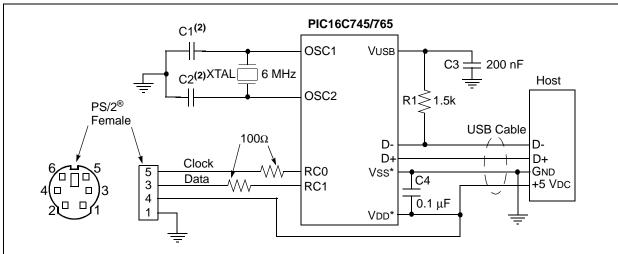
IMPLEMENTATION

Hardware

The PS/2 port is a 6-pin DIN. Only four pins are used:

• Ground
• Power
• Clock
• Data

The power and ground pins are tied directly to V$_{DD}$ and V$_{SS}$ of the microcontroller. The clock and data pins are connected to RC0 and RC1, respectively, via current limiting resistors. The clock is driven by the PS/2 mouse regardless of the direction of the transaction. Figure 1 shows the complete system.

FIGURE 1:   PS/2® TO USB MOUSE TRANSLATOR HARDWARE DIAGRAM[1]

Note 1: There are two V$_{SS}$ and V$_{DD}$ pins on PIC16C765.

2: C1 and C2 values selected according to crystal load capacitance.

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Software

PS/2 DATA FORMAT

Before explaining how PS/2 mouse data is translated to USB, it is necessary to touch upon the PS/2 data format. Data is sent via PS/2 one byte at a time regardless of direction, host-to-device or vice-versa. The data has the following form:

• Start bit (always low)
• Data byte (Least Significant bit to Most Significant bit)
• Parity bit (high for an even number of high bits in the data byte and low for an odd number)
• Stop bit (always high)

In the case of host-to-device communication, the Stop bit is immediately followed by an ACK bit (low), which is sent by the device to the host. The bits are read on the falling edge of the clock for device-to-host communication and on the rising edge for host-to-device communication. In the Idle state, the clock and data lines are held high by the device. See Figure 2 and Figure 4 for device-to-host and host-to-device communication, respectively.

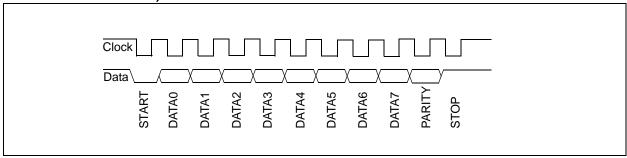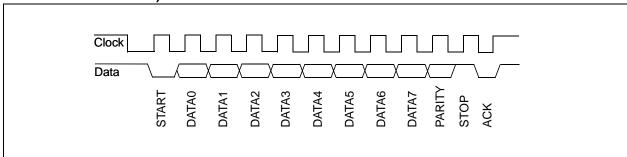**FIGURE 2:** **DEVICE-TO-HOST COMMUNICATION (DATA BIT READ ON FALLING EDGE OF CLOCK)**

FIGURE 3: **HOST-TO-DEVICE COMMUNICATION (DATA BIT READ ON FALLING EDGE OF CLOCK)**

INTERRUPT SERVICE ROUTINE

The portion of the firmware that deals with PS/2 reception and translation is entirely interrupt driven. An interrupt is generated when the PS/2 Start bit is received from the mouse. At this point, the receive routine is initiated. In addition to this interrupt, every 683 µs, a timer overflow interrupts the normal program flow and implements one state of the mouse state machine. This state machine handles sending bytes to and translating bytes received from the PS/2 mouse. These two interrupts essentially handle everything, except for transferring the translated PS/2 data to the PC via USB.

Table 1 and Table 2 show the PS/2 and USB mouse report formats respectively. They are nearly identical so a very short and simple routine translates the PS/2 mouse data format to the USB mouse data format. Table 2 corresponds directly to the report format information described by the report descriptor. The mouse report descriptor is listed in **Appendix A: "Device Descriptors"**.

TABLE 1:   PS/2® MOUSE REPORT

Byte	Bit	Description
3	7	MSB of Y Data
	6-1	Y Data
	0	LSB of Y Data
2	7	MSB of X Data
	6-1	X Data
	0	LSB of X Data
1	7	Y Data Overflow, 1 = overflow
	6	X Data Overflow, 1 = overflow
	5	Y Data Sign, 1 = negative
	4	X Data Sign, 1 = negative
	3	Reserved
	2	Reserved
	1	Right Button Status, 1 = pressed
	0	Left Button Status, 1 = pressed

TABLE 2:   USB MOUSE REPORT

Byte	Bit	Description
3	7	MSB of Y Data
	6-1	Y Data
	0	LSB of Y Data
2	7	MSB of X Data
	6-1	X Data
	0	LSB of X Data
1	7	Reserved
	6	Reserved
	5	Reserved
	4	Reserved
	3	Reserved
	2	Third Button Status, 1 = pressed
	1	Right Button Status, 1 = pressed
	0	Left Button Status, 1 = pressed

MAIN LOOP

The main loop of the firmware sends USB mouse data to the host. This is done with the use of the PutEP1 function. PutEP1 loads the EP1 IN buffer with the USB mouse data. Special Function Register (SFR) BC1IAL is the address pointer to the EP1 IN buffer. After the bytes are loaded into the buffer, the UOWN bit (BD1IST<7>) is set so that the SIE will send the bytes to the host the next time the host polls the device.

A closer look at the source code and endpoint descriptor reveals that PutEP1 sends four bytes to the host instead of three, the number of bytes specified in the report descriptor. If only three bytes are sent, the mouse will never move the cursor. The reason for this stems from the fact that a mouse is a boot device. Since the mouse is such a commonly used peripheral, the host requires a standard length report of four bytes. Therefore, in the mouse example, a null fourth byte is sent with the three data bytes.

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REFERENCES

1. USB Specification, Version 1.1: Chapter 9 (located at www.usb.org)
2. Device Class Definition for Human Interface Devices (located at www.usb.org)
3. HID Usage Tables (located at www.usb.org)
4. USB Firmware User's Guide (located in USB Support Firmware zip file at www.microchip.com)
5. USB Complete, *Second Edition,* Jan Axelson; Lakeview Research, 2001 (www.lvr.com)
6. TB054: *An Introduction to USB Descriptors with a Game Port to USB Game Pad Translator* (DS91054)
7. TB056: *Demonstrating the Set_Report Request with a PS/2® to USB Keyboard Translator Example* (DS91056)
8. TB057: *USB Combination Devices Demonstrated by a Combination Mouse and Game Pad device* (DS91057)
9. TB058: *Demonstrating the Soft Detact Function with a PS/2® to USB Translator Example* (DS91058)

APPENDIX A: DEVICE DESCRIPTORS

Chapter 9 of the USB Specification, V 1.10, defines the standard descriptors (Device, Configuration, Interface, Endpoint and String Descriptors.) The HID Class Definition defines the HID descriptors (HID and Report).

TABLE 3: DEVICE DESCRIPTORS

Offset	Field	Size	Description	Value for Mouse
0	bLength	1	Size of descriptor in bytes	0x12
1	bDescriptorType	1	Descriptor type (DEVICE = 1)	0x01
2	bcdUSB	2	USB specification release (Ver 1.10 = 0x0110)	0x0110
4	bDeviceClass	1	Class code (this field is zero if every interface specifies its own class information)	0x00
5	bDeviceSubClass	1	Subclass code (if the class code is zero this must be zero)	0x00
6	bDeviceProtocol	1	Protocol code (zero if it does not use a class-specific protocols on a device level)	0x00
7	bMaxPacketSize0	1	Maximum packet size (eight for low speed)	0x08
8	idVendor	2	Vendor ID (assigned by the USB-IF)	0x04D8
10	idProduct	2	Product ID (assigned by the manufacture)	0x0001
12	bcdDevice	2	Device release number in binary-coded decimal	0x0441
14	iManufacturer	1	Index of string descriptor describing manufacturer (String 1 is "Microchip")	0x01
15	iProduct	1	Index of string descriptor describing product (String 2 is "PIC16C745/765 USB Mouse")	0x02
16	iSerialNumber	1	Index of string descriptor describing the serial number (none)	0x00
17	bNumConfigurations	1	Number of possible configurations	0x01

TABLE 4: CONFIGURATION DESCRIPTOR

Offset	Field	Size	Description	Value for Mouse
0	bLength	1	Size of descriptor in bytes	0x09
1	bDescriptorType	1	Descriptor type (CONFIGURATION = 2)	0x02
2	bTotalLength	2	Total length of data returned for this configuration (For the mouse example this is the combined length of the configuration, interface, HID and endpoint descriptors)	0x0022
4	bNumInterfaces	1	Number of interfaces supported by this configuration	0x01
5	bConfigurationValue	1	Value to use as an argument to the Set Configuration() request to select this configuration	0x01
6	iConfiguration	1	Index of string descriptor describing this configuration (String 4 is "Cfg1")	0x04
7	bmAttributes	1	Configuration characteristics Bit 7 Always one Bit 6: Self-powered Bit 5: Remote wake-up Bits 4..0: Zero	0xA0
8	bMaxPower	1	Maximum power consumption expressed in 2 mA units (in this case 50 = 100 ma)	0x32

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TABLE 5: **INTERFACE DESCRIPTOR**

Offset	Field	Size	Description	Value for Mouse
0	bLength	1	Size of descriptor in bytes	0x09
1	bDescriptorType	1	Descriptor type (INTERFACE = 4)	0x04
2	bInterfaceNumber	1	Number of this interface (zero based array)	0x00
3	bAlternateSetting	1	Value used to select this alternate setting for the interface identified in the prior field (there is no alternate setting for this mouse)	0x00
4	bNumEndpoints	1	Number of endpoints used by this interface	0x01
5	bInterfaceClass	1	Class code (assigned by the USB-IF)	0x03
6	bInterfaceSubClass	1	Subclass code (bootdevice = 1)	0x01
7	bInterfaceSubProtocol	1	Protocol code (mouse = 2)	0x02
8	iInterface	1	Index of string descriptor describing this interface (String 5 is "EP1 IN")	0x05

TABLE 6: **HUMAN INTERFACE DEVICE (HID) DESCRIPTOR**

Offset	Field	Size	Description	Value for Mouse
0	bLength	1	Size of descriptor in bytes	0x09
1	bDescriptorType	1	Descriptor type (HID = 21)	0x21
2	bcdHID	2	HID class specification release (Ver 1.00 = 0x0100)	0x0100
4	bCountryCode	1	Country code of localized hardware	0x00
5	bNumDescriptors	1	Number of HID class descriptors	0x01
6	bDescriptorType	1	Type of class descriptor (REPORT = 22)	0x22
7	bDescriptorLength	2	Total size of report descriptor	0x0032

TABLE 7: **ENDPOINT DESCRIPTOR**

Offset	Field	Size	Description	Value for Mouse
0	bLength	1	Size of descriptor in bytes	0x07
1	bDescriptorType	1	Descriptor type (ENDPOINT = 5)	0x05
2	bEndpointAddress	1	Endpoint characteristics Bits 3...0: Always one Bits 6...4: Self-powered Bit 7: Remote wake-up 0 = OUT endpoint 1 = IN endpoint	0x81
3	bmAttributes	1	Endpoint's attributes Bits 1...0: Transfer Type 00 = Control 01 = Isochronous 10 = Bulk 11 = Interrupt Bits 7...2: Always zero for low speed	0x03
4	wMaxPacketSize	2	Maximum packet size Bits 10...0: Maximum packet size in bytes Bits 12...11: Number of additional transaction opportunities per microframe 00 = None 01 = 1 additional 10 = 2 additional 11 = Reserved	0x0004
6	bInterval	1	Interval for polling endpoint for data transfer (in 1 ms increments for low speed devices)	0x0A

FIGURE 4:   REPORT DESCRIPTOR

```
0x05, 0x01  usage page (generic desktop    Choose the usage page "mouse" is on

0x09, 0x02  usage (mouse)                  Device is a mouse

0xA1, 0x01  collection (application)       This collection encompasses the report format

0x09, 0x01  usage (pointer)                Choose the key code usage page

0xA1, 0x00  collection (physical)          Physical collection

0x05, 0x09  usage page (buttons)           Choose the "button" usage page

0x19, 0x01  usage minimum (1)              There are three buttons

0x29, 0x03  usage maximum (3)

0x15, 0x00  logical minimum (0)            Each button is represented by one bit

0x25, 0x01  logical maximum (1)

0x95, 0x03  report count (3)               Three reports, one bit each

0x75, 0x01  report size (1)

0x81, 0x02  input (data, variable, absolute) Defined bits above are data bits

0x95, 0x01  report count (1)               One report, five bits in length

0x75, 0x05  report size (5)

0x81, 0x01  input (constant)               Bit stuff to fill byte

0x05, 0x01  usage page (generic desktop)   Choose the usage pare "X" and "Y" are on

0x09, 0x30  usage (X)                      X direction of pointer

0x09, 0x31  usage (Y)                      Y direction of pointer

0x15, 0x81  logical minimum (-127)         Range of report data is -127 to 127

0x25, 0x7F  logical maximum (127)

0x75, 0x08  report size (8)                Two reports, eight bits each

0x95, 0x03  report count (2)

0x81, 0x06  input (data, variable, absolute) Defined bits above are data bits

0xC0        end collection                 End physical collection

0xC0        end collection                 End application collection
```

APPENDIX B: SOURCE CODE

Due to the length of the source code for the PS/2 to USB Mouse Translator, the source code is available separately. The complete source code is available as a single WinZip archive file, `tb055sc.zip`, which may be downloaded from the Microchip corporate web site at:

www.microchip.com

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