Future Technology Devices International Ltd.

Technical Note TN_116

USB Data Packet Structure

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The intention of this technical note is to give a brief overview of the construction and format of a USB message packet.

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1 Introduction

Many devices on the market today connect via the USB interface. This technical note will attempt to explain the protocol used for data transfers between USB hosts and USB devices.

2 USB Speed

There are 3 speed USB grades currently on the market:

Slow speed – 1.5Mbps
Full speed – 12Mbps
High speed – 480mbps
A 4th class specification – super speed at 4.8Gbps has now been ratified, which should result in even faster devices coming to the market soon.

3 USB DATA FORMAT

USB data is sent in packets Least Significant Bit (LSB) first.

There are 4 main USB packet types :Token, Data, Handshake and Start of Frame.

Each packet is constructed from different field types, namely SYNC, PID, Address, Data, Endpoint, CRC and EOP.

The packets are then bundled into frames to create a USB message.

4 USB Data States

The USB data is transferred on a differential serial line (USB DP and USB DM), using NRZI coding.

Many documents refer to the J and K states on the USB data lines. These are used for USB packet synchronisation and defining the end of USB packets.

A J state has a differential signal on USB DP and USB DM >= +300mV.

A K state has a differential signal on USB DP and USB DM >= -300mV.

A Single Ended Zero (SE0) is where both USB DM and USB DM are at 0V.

5 Fields

Fields are the building blocks of a USB packet. These describe the data at individual bit level.

5.1 Sync Field

Each USB packet starts with a SYNC field. This is basically used to synchronise the transmitter and the receiver so that the data can be transferred accurately.

In a USB slow / full speed system this SYNC field consists 3 KJ pairs followed by 2 K's to make up 8 bits of data.

In a USB Hi-Speed system the synchronisation requires 15 KJ pairs followed by 2 K's to make up 32 bits of data.

5.2 Packet Identifier Field

Following on directly after the SYNC field is the Packet Identifier Field. The Packet Identifier Field consists of a 4 bit identifier and a further 4 bits which are the one's compliment of the identifier.

PID0	PID1	PID2	PID3	/PID0	/PID1	/PID2	/PID3

Figure 5.2: PID Field.

5.3 Address Field

The address field is 7 bits long. It is used with the endpoint field to address a function.
Address 0 is a special case reserved for access immediately after power up and reset.

ADDR0	ADDR1	ADDR2	ADDR3	ADDR4	ADDR5	ADDR6

Figure 5.3: Address Field.

5.4 Endpoint Field

The endpoint field is 4 bits long and allows for additional flexibility in addressing. Endpoints are usually split for data going IN or OUT. Endpoint 0 is a special case referred to as the CONTROL endpoint and every device has an endpoint 0.

EP0	EP1	EP2	EP3

Figure 5.4: Endpoint Field.

5.5 Data Field

The data field is not a fixed length. It is within the range of 0 - 8192 bits long, and always an integral number of bytes.

5.6 CRC Field

There are two CRC fields.

The CRC5 is 5 bits long and used with the token packet and the start of frame packet.

CRC0	CRC1	CRC2	CRC3	CRC4

Figure 5.6.1: CRC5 Field

The CRC16 is 16 bits long and used with the data packet.

CRC 0	CRC 1	CRC 2	CRC 3	CRC 4	CRC 5	CRC 6	CRC 7	CRC 8	CRC 9	CRC 10	CRC 11	CRC 12	CRC 13	CRC 14	CRC 15

Figure 5.6.2: CRC16 Field

These fields are used for cyclic redundancy checking, that is they are used for error detection

5.7 EOP Field

Each packet is terminated with an End of Packet (EOP) field. This consists of a single ended zero (SE0) for two bit times followed by a J for 1 bit time.

6 USB Packets

6.1 USB TOKEN Packets

The USB token packet is used to access the correct address and endpoint. It is constructed with the SYNC, PID, an 8 bit PID field, followed by a 7 bit address, followed by a 4 bit endpoint and a 5 bit CRC.

FIELD	SYNC	PID	ADDRESS	ENDPOINT	CRC5	EOP
#BITS	8/32	8	7	4	5	3

Figure 6.1: TOKEN Packet.

Both the address and endpoint field must be correctly decoded for correct operation.

6.2 USB DATA Packets

The data packet may be of variable length, dependent upon the data. However, the data field will be an integral number of bytes.

FIELD	SYNC	PID	DATA	CRC16	EOP
#BITS	8/32	8	0-8192	16	3

Figure 6.2: DATA Packet.

6.3 USB Handshake Packets

Handshake packets are used to signal the status of a transaction ie pass/fail.

FIELD	SYNC	PID	EOP
#BITS	8/32	8	3

Figure 6.3: Handshake Packet.

6.4 USB Start of Frame Packets

To complete a full message the packets are grouped into frames. To identify the frame you need a Start of Frame packet (SOP). The frame number is 11 bits long.

FIELD	SYNC	PID	Frame Number	CRC5	EOP
#BITS	8/32	8	11	5	3

Figure 6.4: Start of Frame Packet.

The start of frame packet is sent every 1ms on a USB full speed system to help synchronisation.

On a USB Hi-Speed peed system a packet frame is transferred every 125us, resulting in 8 packets every 1ms. These 8 sub frames all contain the same frame number.

7 How FTDI Help

The construction of a USB message is not trivial as can be seen from the previous chapters. FTDI silicon handles this packet construction and deals with the USB protocol within the FTDI ICs. There is no need for a user to create drivers or software to encode or decode a USB message. It is all done for the designer, thus reducing development time and costs. For a complete listing of FTDI products please visit the website at: http://www.ftdichip.com/FTProducts.htm

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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 – Terminology

CRC	Cyclic Redundancy Check
EOP	End of Packet
FTDI	Future Technology Devices International
PID	Product Identifier Field
SE0	Single ended Zero
USB	Universal Serial Bus

Appendix B – References

USB Implementers Forum – www.usb.org

USB Specification - http://www.usb.org/developers/docs/usb_20_052709.zip

Appendix C – Revision History

Version Draft	First Draft	30/09/2009
Version 1.0	First Release	11/11/2009