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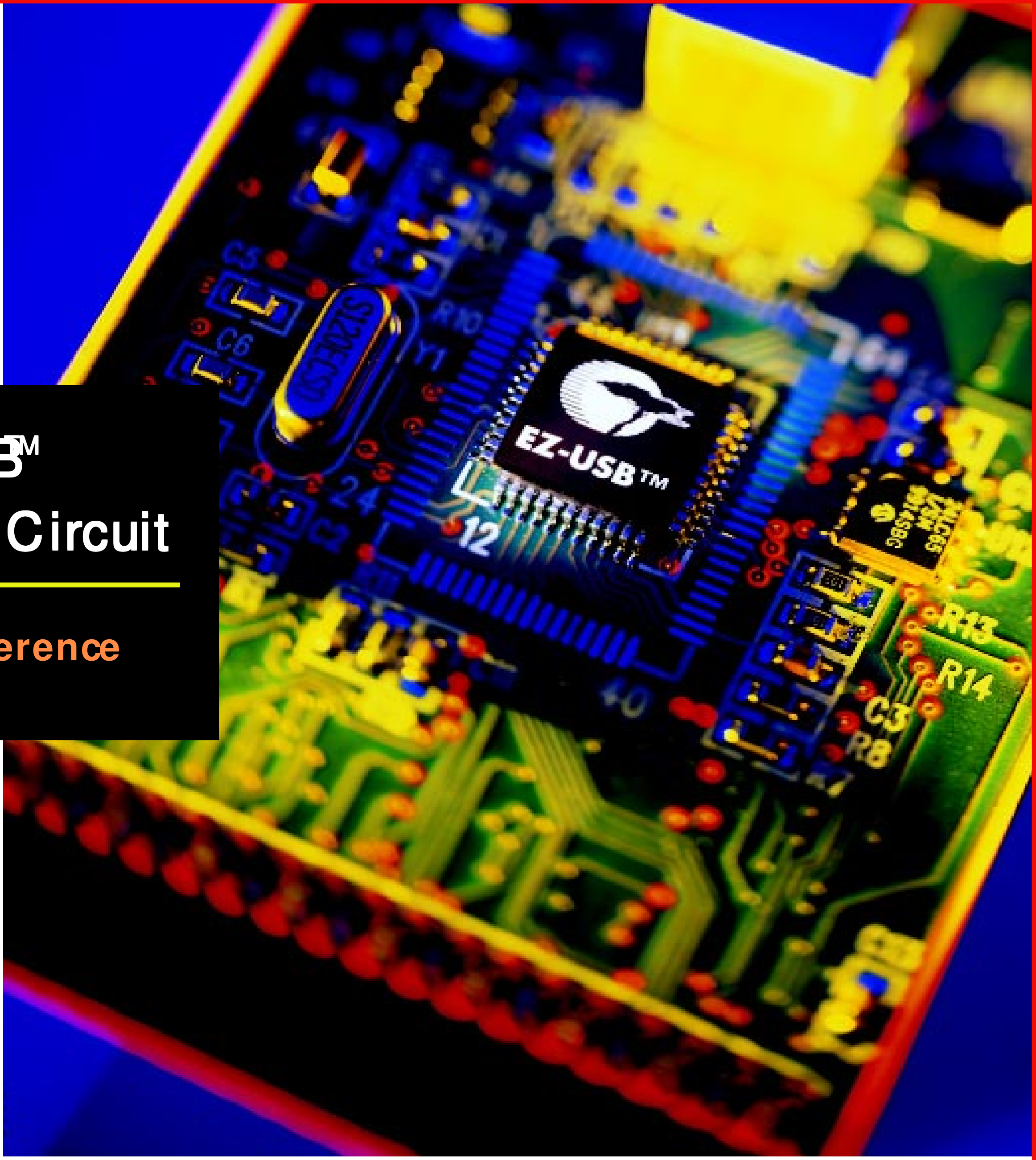
The EZ-USB™ Integrated Circuit

Technical Reference



CYPRESS

Development Kit — Getting Started

Documentation for the EZ-USB™ Xcelerator™ Development it. Includes an overview of the kit, descriptions of kit components with installation instructions, and details about the development board.

Technical Reference

Documentation of the EZ-USB controller. Includes details about the CPU, memory, input/output, ReNumeration™, bulk transfers, endpoint zero, isochronous transfers, interrupts, resets, power management, registers, AC/DC parameters, and packages.

Appendices

Documentation for the 8051 enhanced core. Includes an introduction, an architectural overview, and a hardware description.

Registers

EZ-USB register maps.

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EZ-USB
Technical Reference Manual
Version 1.9
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EZ-USB
Technical Reference Manual

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1 Introducing EZ-USB

1.1 Introduction

Like a well designed automobile or appliance, a USB peripheral's outward simplicity hides internal complexity. There's a lot going on "under the hood" of a USB device, which gives the user a new level of convenience. For example:

- A USB device can be plugged in anytime, even when the PC is turned on.
- When the PC detects that a USB device has been plugged in, it automatically interrogates the device to learn its capabilities and requirements. From this information, the PC automatically loads the device's driver into the operating system. When the device is unplugged, the operating system automatically logs it off and unloads its driver.
- USB devices do not use DIP switches, jumpers, or configuration programs. There is never an IRQ, DMA, MEMORY, or IO conflict with a USB device.
- USB expansion hubs make the bus available to dozens of devices.
- USB is fast enough for printers, CD-quality audio, and scanners.

USB is defined in the *Universal Serial Bus Specification Version 1.1* (**http://usb.org**), a 268-page document that describes all aspects of a USB device in elaborate detail. This EZ-USB Technical Reference Manual describes the EZ-USB chip along with USB topics that should provide help in understanding the Specification.

The Cypress Semiconductor EZ-USB is a compact integrated circuit that provides a highly integrated solution for a USB peripheral device. Three key EZ-USB features are:

- The EZ-USB family provides a *soft* (RAM-based) solution that allows unlimited configuration and upgrades.
- The EZ-USB family delivers full USB throughput. Designs that use EZ-USB are not limited by number of endpoints, buffer sizes, or transfer speeds.
- The EZ-USB family does much of the USB housekeeping in the EZ-USB core, simplifying code and accelerating the USB learning curve.

This chapter introduces some key USB concepts and terminology that should make reading the rest of this Technical Reference Manual easier.

1.2 EZ-USB Block Diagrams

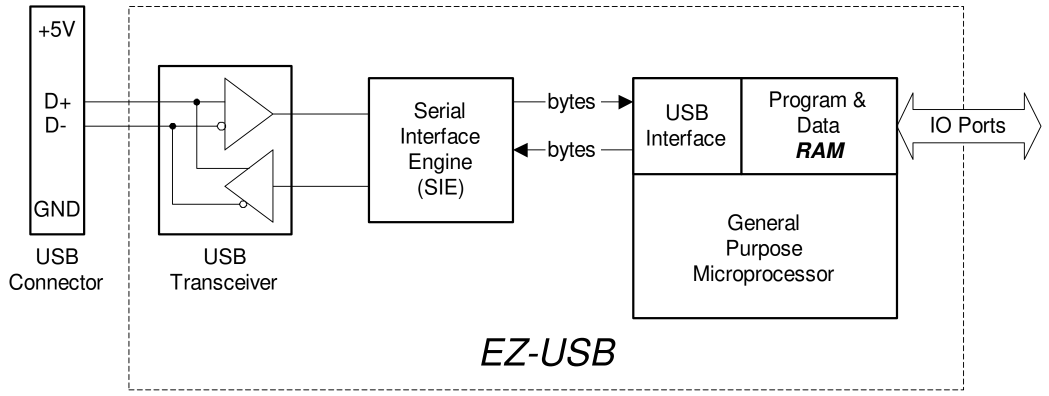

Figure 1-1. AN2131S (44 pin) Simplified Block Diagram

The Cypress Semiconductor EZ-USB chip packs the intelligence required by a USB peripheral interface into a compact integrated circuit. As Figure 1-1 illustrates, an integrated USB transceiver connects to the USB bus pins D+ and D-. A Serial Interface Engine (SIE) decodes and encodes the serial data and performs error correction, bit stuffing, and other signaling-level details required by USB, and ultimately transfers data bytes to and from the USB interface.

The internal microprocessor is enhanced 8051 with fast execution time and added features. It uses internal RAM for program and data storage, making the EZ-USB family a *soft* solution. The USB host downloads 8051 program code and device personality into RAM over the USB bus, and then the EZ-USB chip re-connects as the custom device as defined by the loaded code.

The EZ-USB family uses an enhanced SIE/USB interface (called the “USB Core”) which has the intelligence to function as a full USB device even before the 8051. The enhanced core simplifies 8051 code by implementing much of the USB protocol itself.

EZ-USB chips operate at 3.3V. This simplifies the design of bus-powered USB devices, since the 5V power available in the USB connector (which the USB specification allows to be as low as 4.4V) can drive a 3.3V regulator to deliver clean isolated power to the EZ-USB chip.

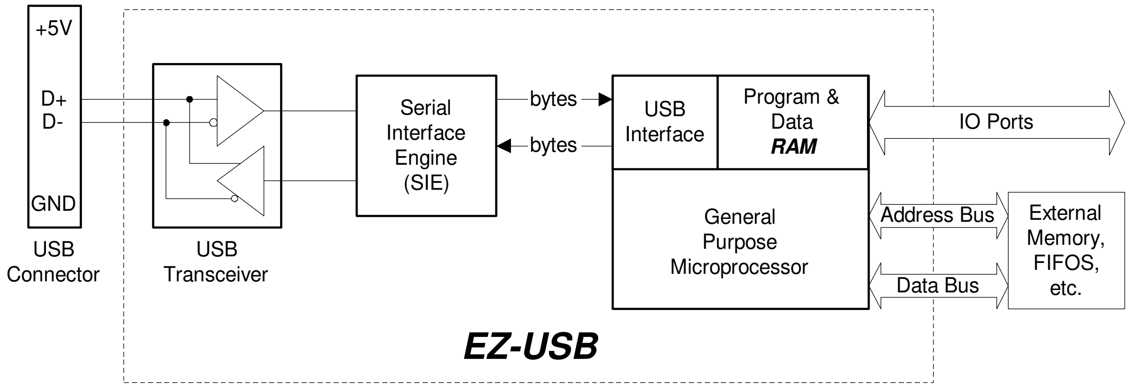

Figure 1-2. AN2131Q (80 pin) Simplified Block Diagram

Figure 1-2 illustrates the An2131Q, an 80-pin version of the EZ-USB family. In addition to the 24 IO pins, it contains a 16-bit address bus and an 8-bit data bus for external memory expansion.

A special *fast transfer* mode moves data directly between external logic and internal USB FIFOs. The fast transfer mode, along with abundant endpoint resources, allows the EZ-USB family to support transfer bandwidths beyond the maximum required by the *Universal Serial Bus Specification Version 1.1.*

1.3 The USB Specification

The *Universal Serial Bus Specification Version 1.1* is available on the Internet at **http://usb.org**. Published in January 1998, the specification is the work of a founding committee of seven industry heavyweights: Compaq, DEC, IBM, Intel, Microsoft, NEC, and Northern Telecom. This impressive list of implementers secures USB as the low to medium speed PC connection method of the future.

A glance at the USB Specification makes it immediately apparent that USB is not nearly as simple as the customary serial or parallel port. The specification uses new terms like "endpoint," isochronous," and "enumeration," and finds new uses for old terms like "configuration," "interface," and "interrupt." Woven into the USB fabric is a software abstraction model that deals with things such as "pipes." The specification also contains detail about the connector types and wire colors.

1.4 Tokens and PIDs

In this manual, you will read statements like, “When the host sends an IN token...” or “The device responds with an ACK.” What do these terms mean? A USB transaction consists of data packets identified by special codes called Packet IDs or PIDs. A PID signifies what kind of packet is being transmitted. There are four PID types, as shown in Table 1-1.

Table 1-1. USB PIDs

PID Type	PID Name
Token Data	IN, OUT, SOF, SETUP, DATA0, DATA1
Handshake	ACK, NAK, STALL
Special	PRE

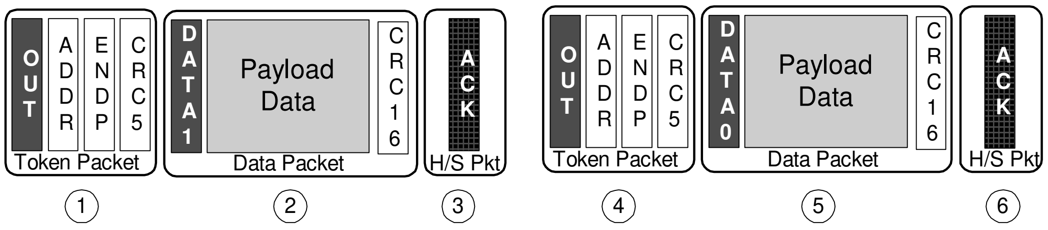

Figure 1-3. USB Packets

Figure 1-3 illustrates a USB transfer. Packet j is an OUT token, indicated by the OUT PID. The OUT token signifies that data from the host is about to be transmitted over the bus. Packet !k contains data, as indicated by the DATA1 PID. Packet l is a handshake packet, sent by the device using the ACK (acknowledge) PID to signify to the host that the device received the data error-free.

Continuing with Figure 1-3, a second transaction begins with another OUT token m, followed by more data n, this time using the DATA0 PID. Finally, the device again indicates success by transmitting the ACK PID in a handshake packet o.

Why two DATA PIDs, DATA0 and DATA1? It’s because the USB architects took error correction very seriously. As mentioned previously, the ACK handshake is a signal to the host that the peripheral received data without error (the CRC portion of the packet is used to detect errors). But what if a handshake packet itself is garbled in transmission? To detect this, each side, host and device maintains a *data toggle* bit, which is toggled between data packet transfers. The state of this internal toggle bit is compared with the

PID that arrives with the data, either DATA0 or DATA1. When sending data, the host or device sends alternating DATA0-DATA1 PIDs. By comparing the Data PID with the state of the internal toggle bit, the host or device can detect a corrupted handshake packet.

SETUP tokens are unique to CONTROL transfers. They preface eight bytes of data from which the peripheral decodes host Device Requests.

SOF tokens occur once per millisecond, denoting a USB *frame*.

There are three handshake PIDs: ACK, NAK, and STALL.

- ACK means "success;" the data was received error-free.
- NAK means "busy, try again." It's tempting to assume that NAK means "error," but it doesn't. A USB device indicates an error by *not responding*.
- STALL means that something unforeseen went wrong (probably as a result of mis-communication or lack of cooperation between the software and firmware writers). A device sends the STALL handshake to indicate that it doesn't understand a device request, that something went wrong on the peripheral end, or that the host tried to access a resource that isn't there. It's like "halt," but better, because USB provides a way to recover from a stall.

A PRE (Preamble) PID precedes a low-speed (1.5 Mbps) USB transmission. The EZ-USB family supports high-speed (12 Mbps) USB transfers only, so it ignores PRE packets and the subsequent low-speed transfer.

1.5 Host is Master

This is a fundamental USB concept. There is exactly one master in a USB system: the host computer. *USB devices respond to host requests*. USB devices cannot send information between themselves, as they could if USB were a peer-to-peer topology.

Actually, there is one case where a USB device can initiate signaling without prompting from the host. After being put into a low-power suspend mode by the host, a device can signal a remote wakeup. But that's the only way to "yank the host's chain." Everything else happens because the host makes device requests and the device responds to them.

There's an excellent reason for this host-centric model. The USB architects were keenly mindful of cost, and the best way to make low-cost peripherals is to put most of the smarts into the host side, the PC. If USB had been defined as peer-to-peer, every USB device would have required more intelligence, raising cost.

Here are two important consequences of the “host is master” concept:

1.5.1 Receiving Data from the Host

To send data to a USB peripheral, the host issues an OUT token followed by the data. If the peripheral has space for the data, and accepts it without error, it returns an ACK to the host. If it is busy, it instead sends a NAK. If it finds an error, it sends nothing back. For the latter two cases, the host re-sends the data at a later time.

1.5.2 Sending Data to the Host

A USB device never spontaneously sends data to the host. Nevertheless, in the EZ-USB chip, there’s nothing to stop the 8051 from loading data for the host into an endpoint buffer (Section 1.13, "EZ-USB Endpoints") and *arming* it for transfer. But the data will sit in the buffer *until the host sends an IN token to that particular endpoint*. If the host never sends the IN token, the data sits there indefinitely.

1.6 USB Direction

Once you accept that the host is the bus master, it’s easy to remember USB direction: OUT means from the host to the device, and IN means from the device to the host. EZ-USB nomenclature uses this naming convention. For example, an endpoint that sends data to the host is an IN endpoint. This can be confusing at first, because the 8051 *sends* data by loading an IN endpoint buffer, but keeping in mind that an 8051 *out* is IN to the host, it makes sense.

1.7 Frame

The USB host provides a time base to all USB devices by transmitting a SOF (Start Of Frame) packet every millisecond. The SOF packet includes an incrementing, 11-bit frame count. The 8051 can read this frame count from two EZ-USB registers. SOF-time has significance for isochronous endpoints; it’s the time that the *ping-ponging* buffers switch places. The EZ-USB core provides the 8051 with an SOF interrupt request for servicing isochronous endpoint data.

1.8 EZ-USB Transfer Types

USB defines four transfer types. These match the requirements of different data types delivered over the bus. (Section 1.13, "EZ-USB Endpoints" explains how the EZ-USB family supports the four transfer types.)

1.8.1 Bulk Transfers

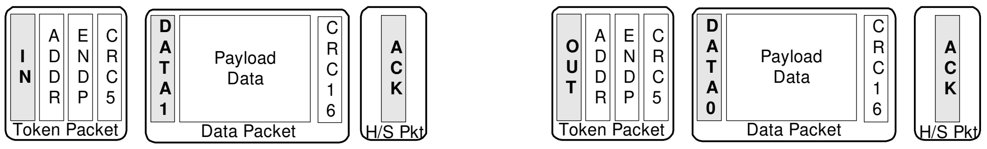

Figure 1-4. Two Bulk Transfers, IN and OUT

Bulk data is *bursty*, traveling in packets of 8, 16, 32, or 64 bytes. Bulk data has guaranteed accuracy, due to an automatic re-try mechanism for erroneous data. The host schedules bulk packets when there is available bus time. Bulk transfers are typically used for printer, scanner, or modem data. Bulk data has built-in flow control provided by handshake packets.

1.8.2 Interrupt Transfers

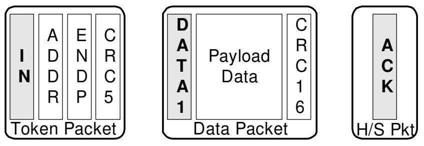

Figure 1-5. An Interrupt Transfer

Interrupt data is like bulk data, but exists only for IN endpoints in the “Universal Serial Bus Specification Version 1.1.” Interrupt data can have packet sizes of 1-64 bytes. Interrupt endpoints have an associated polling interval that ensures that they will be *pinged* (will receive an IN token) by the host on a regular basis.

1.8.3 Isochronous Transfers

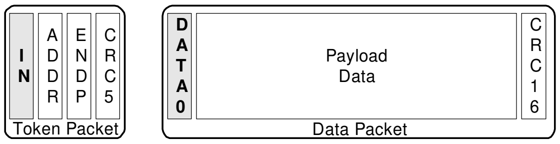

Figure 1-6. An Isochronous Transfer

Isochronous data is time-critical and used for *streaming* data like audio and video. Time of delivery is the most important requirement for isochronous data. In every USB frame, a certain amount of USB bandwidth is allocated to isochronous transfers. To lighten the overhead, isochronous transfers have no handshake (ACK/NAK/STALL), and no retries. Error detection is limited to a 16-bit CRC. Isochronous transfers do not use the data toggle mechanism; isochronous data uses only the DATA0 PID.

1.8.4 Control Transfers

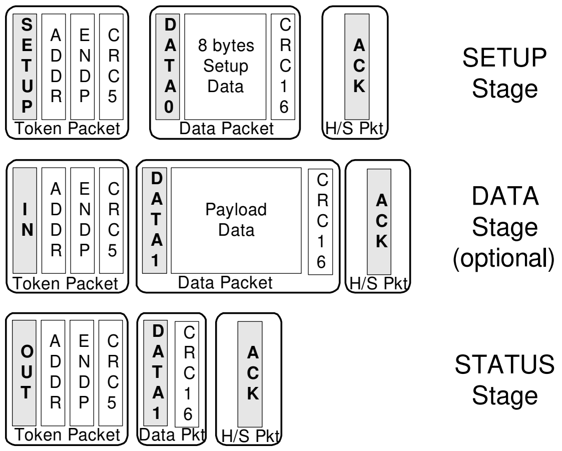

Figure 1-7. A Control Transfer

Control transfers are used to configure and send commands to a device. Being *mission critical*, they employ the most extensive error checking USB offers. Control transfers are delivered on a *best effort* basis by the host (*best effort* is defined by a six-step process in the *Universal Serial Bus Specification Version 1.1, "Section 5.5.4"*). The host reserves a part of each USB frame time for Control transfers.