Simplify 3-D Imaging Designs Using Cypress FX3

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Introduction

3-D Imaging presents a new opportunity for designers of human-machine interfaces to change the way consumers interact with content on computers, tele-presence systems, game consoles, and other electronic products. 3-D Imaging enables the perception of depth in video, tracking of body movement, and tracking of finger gestures – all beyond the capability of traditional interface devices such as mice, joysticks, keyboards, track-pads, and touch screens. 3-D imaging already factors strongly in consumers' buying decisions in video, gaming, and motion-sensing applications.

3-D imaging uses two image sensors to track movement and to capture 3 dimensional images. Common dual-sensor configurations for 3-D imaging can be found in the table below:

Application	Column Pixels	Row Pixels	Resolution	Frame Rate	Color Depth	Bandwidth
Video	1,920	1,080	2.07 megapixels	30 fps	24 bits (RGB)	3.0 Gbps
Gaming	1,280	720	0.92 megapixels	120 fps	8 bits (B&W)	1.8 Gbps
Motion Sensing	640	480	0.31 megapixels	60 fps	8 bits (B&W)	0.3 Gbps

Even at lower resolution and color depth, applications requiring more precise motion-sensing require a higher frame rate, which can push bandwidth requirements up to 1.8 Gbps.

Design Problems Engineers Face Today

3-D imaging requires up to 3 Gbps of bandwidth: USB 2.0 provides only 480 Mbps of bandwidth. As a result, most USB 2.0 based 3-D imaging solutions have limited capabilities and performance.

3-D imaging requires multiple ICs: 3-D imaging requires two sensors to capture parallel image streams that are then combined to form a 3-D image. In addition to the multiple sensors, they often use multiple camera controllers (one for each image sensor) as well as a hub to transfer the data to the host system. Multiple ICs increase the cost of the system, and also require more PCB real estate.

3-D imaging designs must be flexible: 3-D imaging systems often interface to various image sensors with differing resolutions, frame rates, and bus widths. Additionally, they may transfer data over USB and use different data types to transfer image data. The system may also need to be modified to use standard **USB Video Class** (UVC) protocol or a custom USB protocol. These requirements increase the complexity of the imaging system and may need additional software and firmware development.

Cypress' EZ-USB FX3

Cypress' EZ-USB FX3 provides a compact, one-chip solution that solves the above issues by providing a high bandwidth, flexible solution for 3-D imaging. The FX3 provides USB 3.0 connectivity, thereby removing the bandwidth constraint that is faced by current 3-D imaging designs. The FX3 is a highly flexible system that can be used to interface and operate with various different image sensors and USB protocols, providing a single-chip solution for any 3-D imaging application.

The block diagram for the FX3 is shown below:

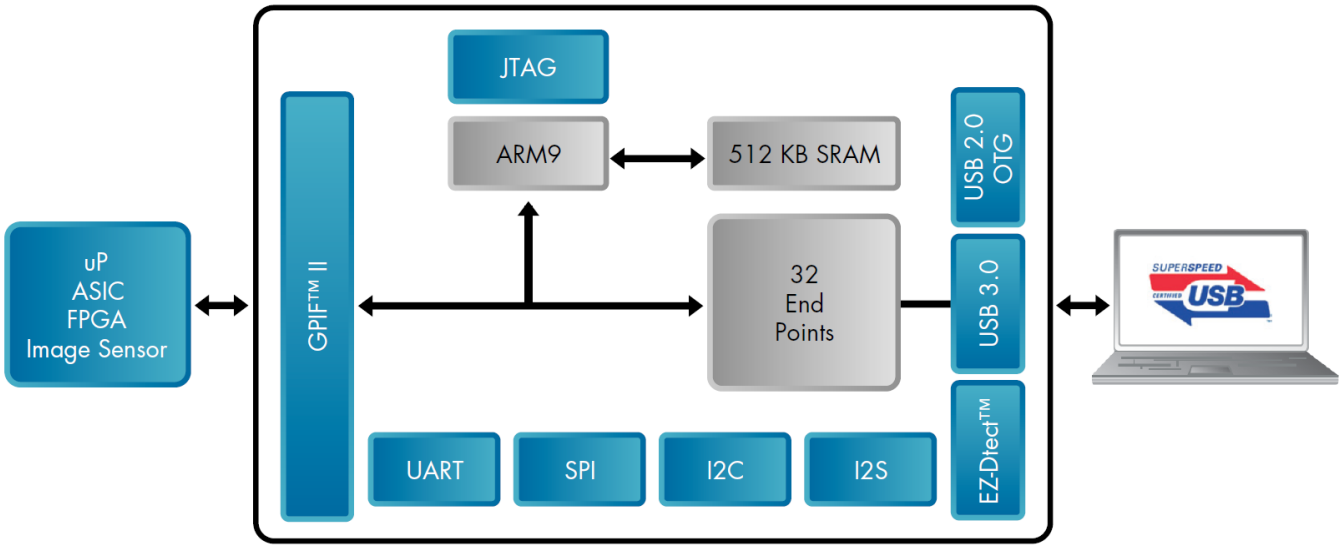

Figure 1: FX3 block diagram

FX3-Based 3-D Imaging Design Development

The FX3's highly configurable General Programmable Interface II (GPIF II) is a 32-bit parallel bus running at 100 MHz, allowing the FX3 to communicate with systems that have a parallel interface. This provides engineers with the flexibility to connect dual image sensors without the need for additional ICs.

The GPIF II Designer is Cypress design software that contains a simple GUI to configure the GPIF II. Refer to **Appendix B** for a link to download this software. The overall steps to connect to two image sensors with GPIF II are shown below:

1. Initiate a new project using Cypress-supplied interfaces, or start a new project from scratch.

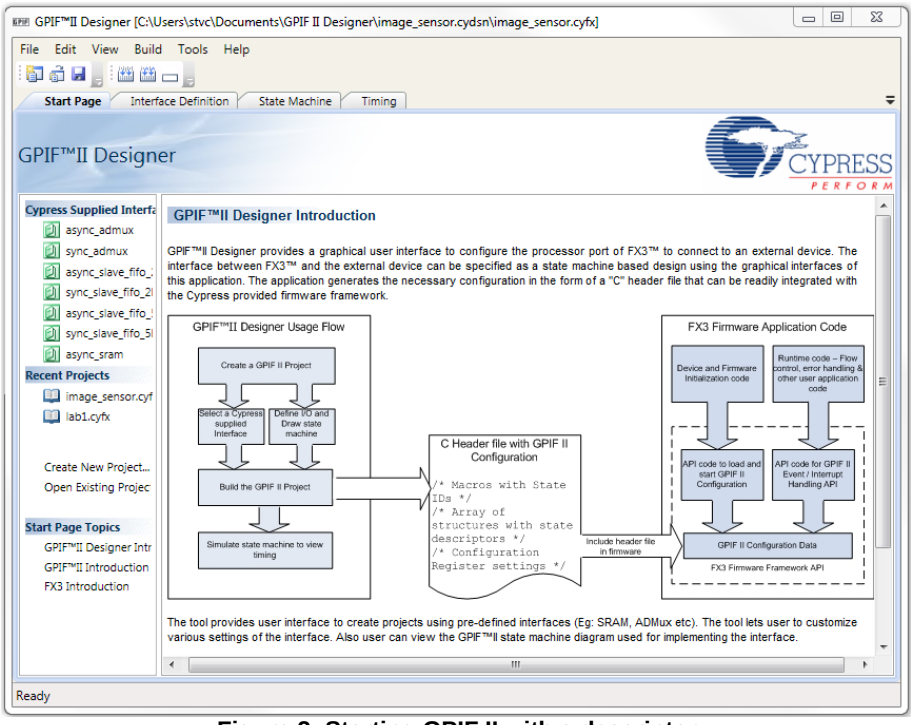

Figure 2: Starting GPIF II with a descriptor

2. Select the type, bus width, and I/Os of the desired interface.

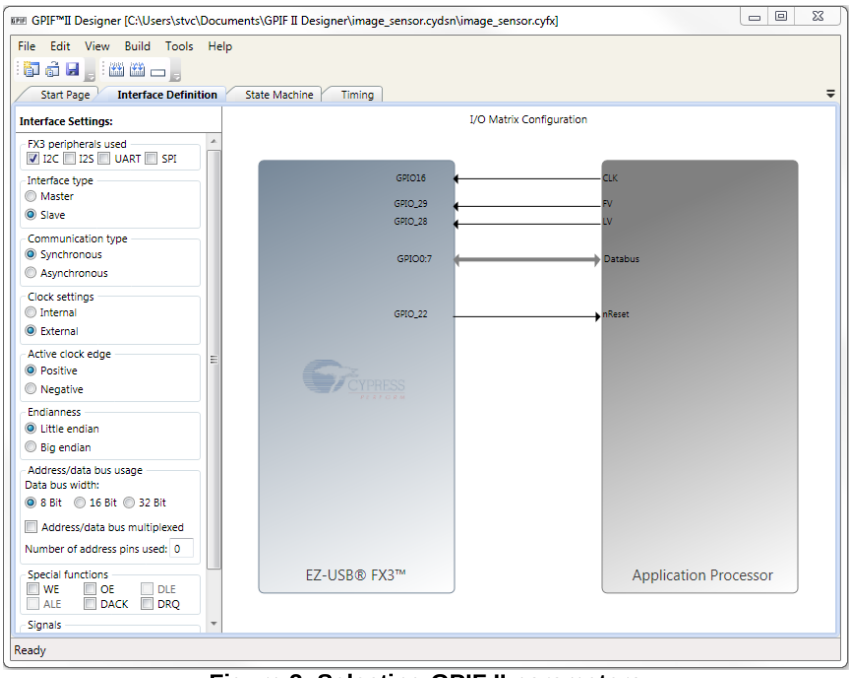

Figure 3: Selecting GPIF II parameters

3. Create a state machine that matches interface timing by adding state blocks and transitional conditions.

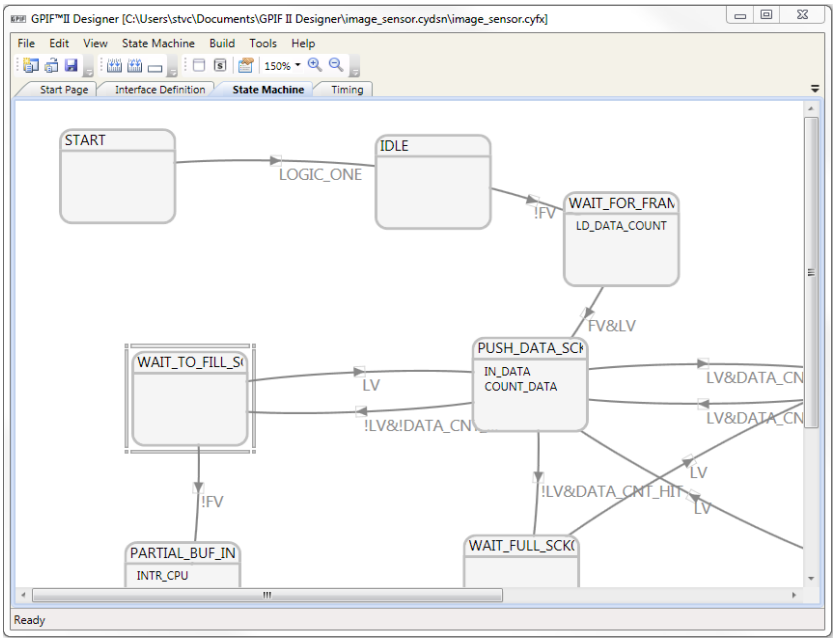

Figure 4: Creating GPIF II state machine

4. Visualize state transitions and associated output signals.

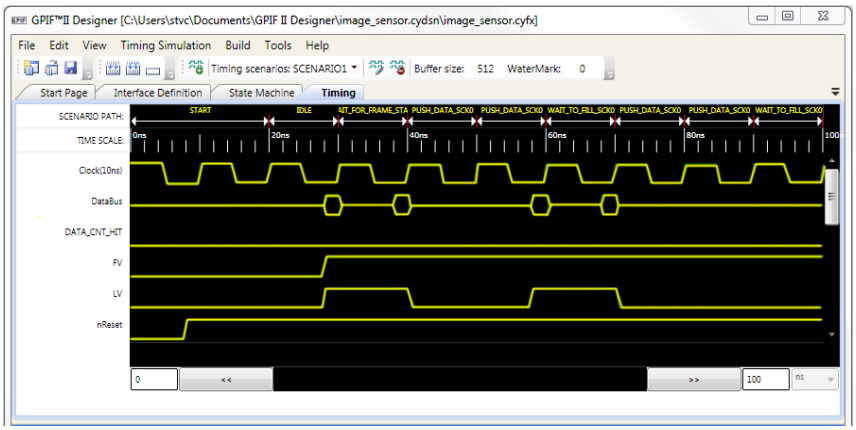

Figure 5: State transitions

5. Generate the GPIF II descriptor, which will be used in the firmware development.

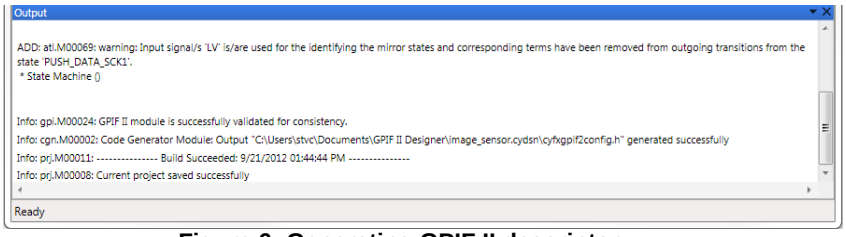

Figure 6: Generating GPIF II descriptor

Writing Firmware for 3-D Imaging Design

All 3-D imaging applications require firmware for the FX3. This firmware that is loaded onto FX3 controls the way FX3 interacts with the image sensors and the USB 3.0 host. Any custom 3-D imaging application will require additional firmware development.

Cypress provides a powerful Software Development Kit (SDK) that allows engineers to quickly get their firmware started. Refer to **Appendix B** for a link to download the SDK. It contains the complete software and firmware stack for FX3. It also comes with tools, documents, drivers and application examples, which can accelerate 3-D application development.

3-D imaging firmware can be developed using the FX3 SDK by following the steps below:

1. The FX3 SDK includes sample UVC code that can be used as a reference to develop 3-D imaging firmware. The GPIF II descriptor (see section above) will be used here.

2. Different image sensors and custom 3-D applications will require firmware modification. Once the firmware is complete, the firmware image can be generated by building the project.

3. Complete design guidelines can be found in the application note “How to Implement an Image Sensor Interface with FX3 in a UVC Framework”. Refer to **Appendix B** for the link to download the application note.

4. FX3 comes with a large list of firmware APIs that can be used to develop custom 3-D applications. More information about this can be found in the “FX3 Programmers Manual” and the “Firmware API Guide”. These documents are included in the FX3 SDK.

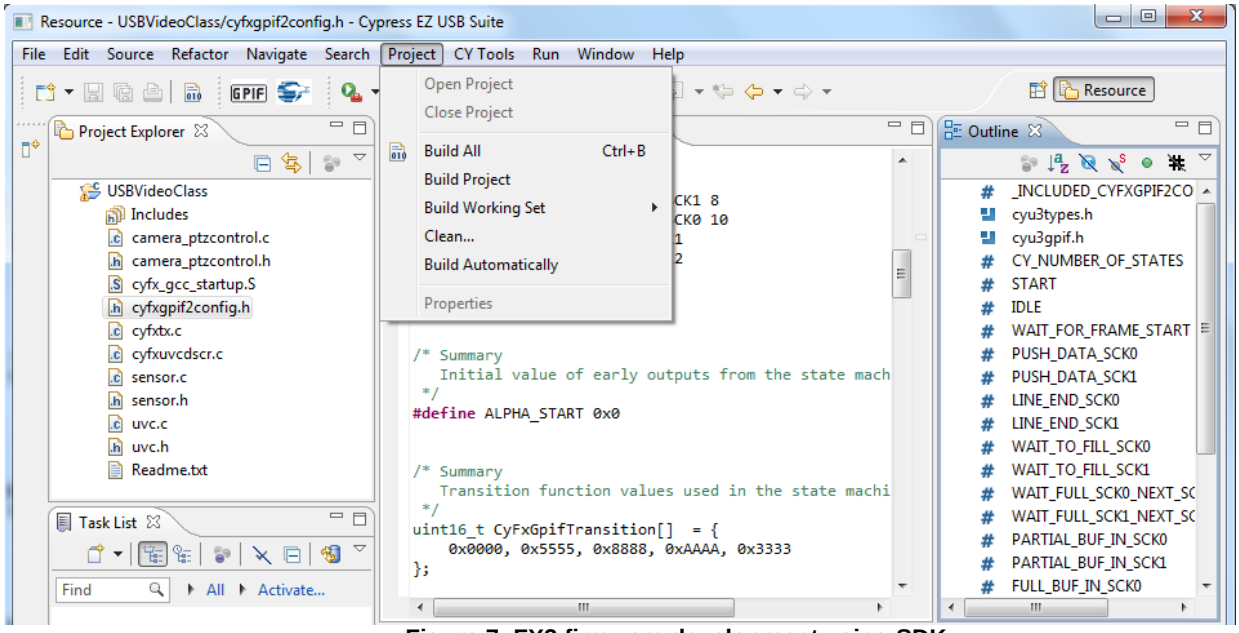

Figure 7: FX3 firmware development using SDK

Prototyping 3-D Imaging Designs Using FX3 DVK

The FX3 Development Kit (DVK) can be used to quickly create hardware prototypes. Refer to **Appendix B** for a link to buy the FX3 DVK. The 3-D imaging firmware (see section above), can be programmed on to the FX3 chip over USB, using Cypress Control Center (included in the FX3 SDK). The FX3 DVK and an example 3-D imaging prototype are shown below:

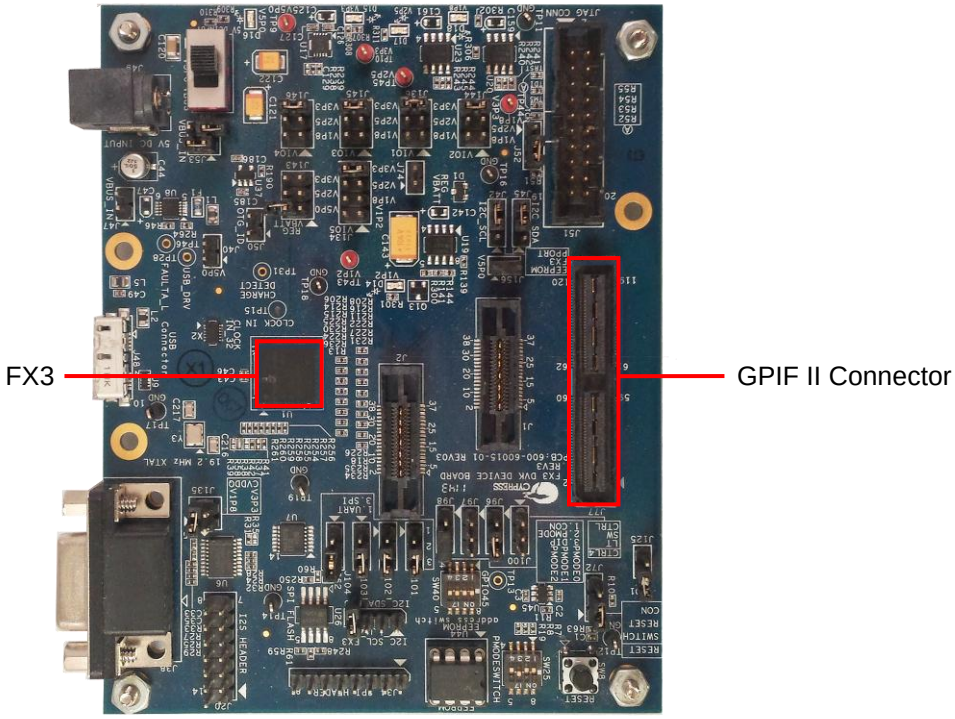

Figure 8: FX3 DVK (CYUSB3KIT-001)

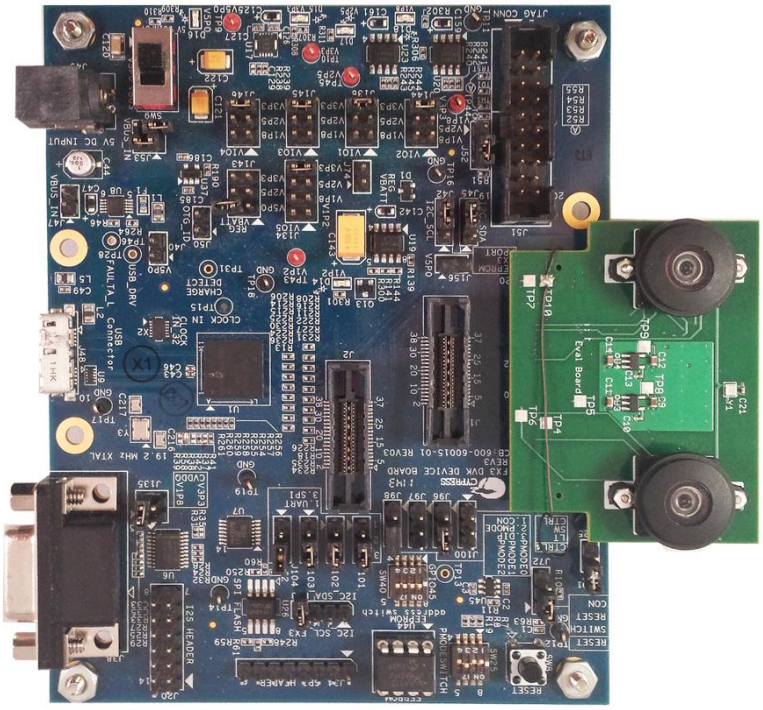

Figure 9: Example 3-D imaging prototype

Conclusion

3-D imaging is emerging as *the* trend in imaging, gaming, interactive peripherals, and human-machine interface design. As consumers seek new and innovative ways to interact with their technology and content, the opportunity for 3-D imaging interfaces will only increase. The Cypress FX3 provides a one-chip solution to help user interface developers and peripheral manufacturers develop and prototype 3-D applications quickly and easily. The day is fast approaching when methods of human-machine interaction that seemed only plausible in sci-fi stories become reality with the help of 3-D imaging applications.

Appendix A: Terms and Definitions

3-D Imaging
3-D Imaging uses two image sensors to capture three-dimensional images or to track movements. It requires more bandwidth than conventional imaging – up to 3.0 Gbps.

Bandwidth
Bandwidth = The number of image sensors x resolution x frame rate x color depth

USB 3.0 (SuperSpeed USB)
Operates at 5 Gbps – 10x faster than USB 2.0 (Hi-Speed USB). It distributes 1.8x more power to bus-powered devices than USB 2.0. It is backward compatible with USB 2.0.

USB 3.0 Host, USB 3.0 Device, USB 3.0 Hub
A USB 3.0 Host (e.g., a PC) directs traffic flow and distributes power over the bus. A USB 3.0 Device (e.g., a hard disk drive) is a peripheral on the bus. A USB 3.0 Hub directs data traffic between a USB 3.0 Host and multiple USB Devices.

USB Camera Controller
USB camera controllers are microcontrollers that convert an image sensor data-stream into USB traffic.

USB 3.0 Peripheral Controller
USB 3.0 peripheral controllers are microcontrollers in a USB Device that handle USB 3.0 traffic and communicate with the USB Host**.**

USB 3.0 Driver
A USB 3.0 driver is a software program in the host system that operates or controls the USB 3.0 Device attached to it.

Firmware
Firmware is a set of instructions programmed on a USB 3.0 peripheral controller.

UVC (USB Video Class)
UVC is a widely adopted standard for consumer cameras that is supported by major PC operating systems**.** It defines the behavior of a USB video camera, known as a “UVC camera”.

EZ-USB® FX3™
FX3 is Cypress’s programmable USB 3.0 Peripheral Controller with integrated USB 3.0 transceiver. It includes a powerful on-chip ARM9™ processor and 512KB RAM for firmware storage and data buffering. It provides additional peripheral connectivity via I^2C, I^2S, SPI, and UART. FX3 includes a Software Development Kit (SDK) with example code to reduce design effort.

GPIF™ II: Second-Generation General Programmable Interface
GPIF II is a programmable 100-MHz, 32-bit bus that allows FX3 to communicate with systems that have a parallel interface.

GPIF II Designer
GPIF II Designer is design software that installs on your PC. It contains simple a graphical user interface (GUI) to configure the GPIF II.

GPIF II Descriptor
GPIF II descriptors are sets of commonly predefined GPIF II configurations used to program FX3 quickly.

FX3 Application Programming Interface (API)
APIs are firmware in the SDK library that implements common and specialized USB functions.

Cypress Control Center
Control Center is a simple GUI in the FX3 SDK used to configure the FX3 Development Kit (DVK).

Appendix B: References and Links

FX3 3-D Imaging Demo Video: www.cypress.com/fx3/3dimaging

Maximum Throughput Performance Demo Video: www.cypress.com/fx3

Machine Vision Camera Demo Video: www.cypress.com/?rID=66430

FX3 HD 720p Camera Kit Demo Video: www.cypress.com/?rID=72422

EZ-USB FX3 Development Kit (CYUSB3KIT-001): www.cypress.com/?rID=58321

EZ-USB FX3 HD 720p Camera Kit: www.cypress.com/?rID=72599

Software Development Kit: www.cypress.com/?rID=57990
The SDK includes Eclipse IDE, ARM GCC, Cypress USB 3.0 driver, example code, FX3 Programmers Manual, and API Guide**.**

GPIF II Designer: www.cypress.com/?rID=59628

EZ-USB FX3 Application Notes:

Getting Started with EZ-USB FX3: www.cypress.com/?rID=59979
This application note gives highlights of USB 3.0 technology and an overview of the FX3 architecture, software, and collateral. It shows FX3 SDK setup, Cypress USB driver installation, firmware download, and USB 3.0 traffic verification.

EZ-USB FX3 Hardware Design Guidelines and Schematic Checklist: www.cypress.com/?rID=53203
This application note shows how to design a board with 5-Gbps USB 3.0 traces**.**

How to Implement an Image Sensor Interface with FX3 in a UVC Framework: www.cypress.com/?rID=62824
This application note describes a UVC video streaming application in which FX3 streams images from an image sensor to a USB Host.

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