WHITEPAPER

Evolution and challenges of USB

Jimmy Chou, Infineon Technologies AG

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Abstract

Since its launch in 1996, USB evolved from a simple plug-and-play interface for keyboard and mouse connectivity to becoming essential across countless applications and industries, so much so that it is one of the only words we understand regardless of the languages we speak. However, following the introduction of USB 3.1 specifications in 2013, it entered a "dark age", resulting in a decade-long stagnation in new applications adopting the new spec. This whitepaper, the first of a three-part series, maps the growth of USB and takes a closer look at what caused the stagnation, and possible solutions to get through it.

1 Rise of USB

The boom in USB applications started with USB 2.0 in the beginning of this century. USB 2.0 boasted a data rate of 480 Mbps, a 40x performance improvement to its predecessor (USB 1.1), making many applications, like mass storage devices, feasible. Performance was not the only thing making it a success; its backward compatibility was crucial, making USB 2.0 devices work across all USB platforms without changing cable assemblies. It was a considerable achievement to carry both 12 MHz 3.3 V USB 1.1 signals or 480 MHz 400 mV USB 2.0 signals using the same two copper wires in a USB cable.

The complexity behind the simple cable connection between a PC and a USB peripheral would take years of experienced engineers to develop; and similar technologies either existed or were being developed by several tech giants, including IEEE 1394 of FireWire led by Apple Inc. FireWire had a transfer rate equivalent to that of USB, could connect up to 63 devices via a daisy-chain using a single controlling device, and enabled two devices to transfer files without interfacing with a PC.

1.1 The cost advantage

So how did USB stand out and win over other wired connectivity? The short answer is cost. Following are a few reason USB became the preferred choice for manufacturers:

- **Topology:** To better understand why USB cost lower, we need to delve deeper into its building blocks. USB uses a tiered-star topology centered at a host (typically a PC) that handles the most complex tasks like managing the entire bus system. The host is connected to many (up to 127) USB devices, including USB hubs, whose main job is to expand the connection nodes — requiring lower computing power. Firewire, being a peer-to-peer network required every device to have higher computing power.
- **Affordable chipset:** Long before USB 3.1 came into the picture, manufacturers had to choose between USB 2.0 or FireWire. But the chipset for implementing FireWire was significantly (almost 5X) more expensive than that of USB, so manufacturers naturally went with the more affordable option.
- **Integration into Intel chipsets:** Back in the day, Intel dominated the PC industry and they decided to integrate USB over FireWire into their chipsets due to the latter's high licensing fees ($1 per port). Therefore, USB connectivity came free to PCs, making USB an industry standard.
- **Device class drivers:** USB device classes are grouped into classes based on common functions such as mass storage and human interface such as keyboard or mouse. The drivers required for these device classes to function were developed by USB working groups and were directly integrated into the PC's operating system. Therefore, common device class drivers were included by default for each host system, meaning that a PC peripheral manufacturer only needed to develop the function without worrying about both the hardware and software on the other side of a USB cable.

All of this made USB the preferred choice for wired interfacing.

2 When did progress start to slow down?

USB 3.0, released in 2008, continued this momentum with a bandwidth of 5 Gbps. However, the industry saw a slowdown in new applications after USB 3.1 was released in 2013, despite the introduction of USB 3.1 Gen 2 (dubbed SuperSpeed Plus) with a more efficient encoding scheme and 10 Gbps of bit rate, which offered a maximum bandwidth twice than that of USB 3.1 Gen 1 (dubbed SuperSpeed). Although the naming convention certainly did create confusion in the industry, it was not the reason the momentum halted.

The primary reason for the stagnation lies in the absence of general-purpose USB device controllers, a critical yet often overlooked component. For a USB device to function properly in a USB bus system (i.e., a PC), it must comply to both electrical and communication protocols defined by its device class. For example, a USB web camera must identify itself as a USB video class (UVC) device during enumeration and follow the supported commands to stream images to software applications.

While application-specific standard product (ASSP) controllers are available for common functions such as mass storage, emerging applications lack ASSPs or SoCs when a new USB specification is released because the market for such applications is still small. A general-purpose USB device controller abstracts the need to understand the USB specification, enabling quick development of emerging applications by integrating with common interfaces like FIFO or memory bus in embedded systems. Once the application becomes popular, ASSPs integrate the necessary functions for a cost-effective solution.

The following figure shows how a general-purpose USB device controller is used to create an HDMI video-to-USB capture card – a video conferencing and gaming capture solution – before an integrated ASSP is available.

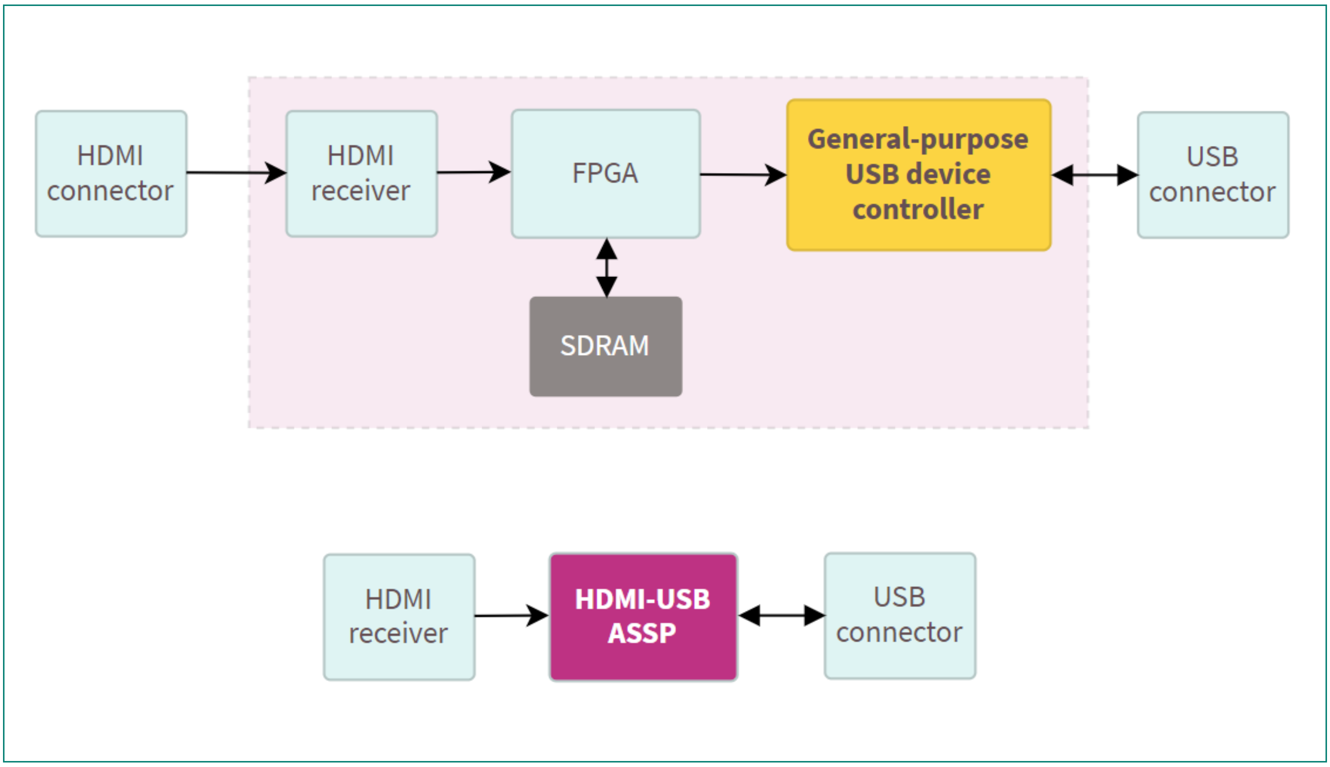

Figure 1 HDMI video-to-USB capture card using a general-purpose USB controller

3 Infineon's innovations and the future

Infineon's EZ-USB™ FX3 is a great example of a general-purpose USB controller that has bridged the gap between the release of a new USB specification and the availability of ASSPs or SoCs. FX3 was the first USB controller used for many USB 3.0 HDMI video capture cards with UVC support; these solutions were later replaced by ASSPs as the devices gained in popularity.

However, since the release of USB 3.1 in 2013, only a few applications could benefit from the fast 10 Gbps bus due to the lack of a general-purpose USB 10 Gbps device controller. Recognizing the need to bridge this gap, Infineon, a leader in the USB industry, has developed the next generation of advanced USB controllers — EZ-USB™ FX10 USB 10 Gbps peripheral controller — boasting a 300 percent performance boost to its predecessor. In addition to enhancing the performance of existing applications, these new controllers aim to enable emerging applications, facilitating the transition to USB4 and addressing the current challenges in USB development.

By tackling these issues, the USB ecosystem can continue to expand, innovate, and solidify its position as a fundamental technology in the digital age. The next part of the series delves into the intricacies of Infineon's EZ-USB™ FX10 USB 10 Gbps peripheral controller, including its key features and benefits, and how it addresses high bandwidth demands of both existing and emerging applications.

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