USB On-The-Go

A tutorial

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Introduction

Today, an increasing number of mobile consumer electronics products – portable digital assistants (PDAs), mobile phones, digital cameras, portable storage devices, etc. – use the USB interface to exchange data with host PCs. While increased user convenience and functionality could be achieved if these products communicated with each other directly, at present certain aspects of the USB 2.0 Specification make this difficult to achieve.

The popular USB standard was recently enhanced to include 'On-The-Go' (OTG) functionality enabling point-topoint data exchange between mobile products. New products compliant with OTG specifications may support both traditional host-based (PC) and device-to-device connectivity. In addition, by specifying additional cables, connectors, and adapters, the USB OTG enhancements will simplify physical connectivity while increasing mobile device functionality.

This paper overviews the user benefits of USB OTG, summarizes the features of the OTG Rev. 1.0a Supplement to the USB 2.0 Standard, and highlights the efforts of NXP Semiconductors in bringing USB OTG to market

Ubiquitous USB

In the few years since its introduction, USB has become a de facto industry standard for connecting peripherals to PCs and laptops for data exchange. As a result of quick acceptance by manufacturers, over 1 billion USB-enabled products – PCs, PC peripherals, cable set-top boxes, home gateways, portable consumer appliances, etc. – are now in the installed base[1]. USB is inexpensive, reliable, provides good performance, and delivers on its promise to provide a 'plug-and-play' interface backed by compliance testing.
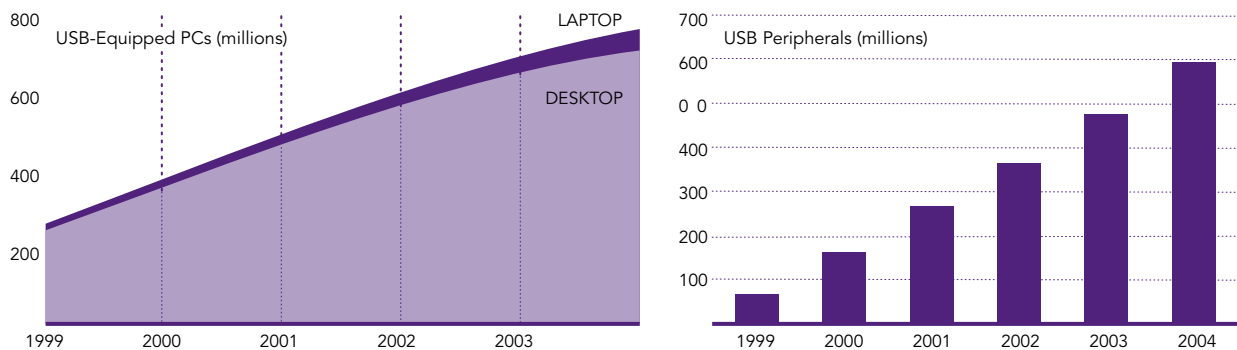

Figure 1: Installed base of USB-equipped PCs (left) and USB peripherals (right) shipped 1999-2004.[1] (Source: Cahners In-Stat Group, 2000)

USB is also gaining wide acceptance as the interface of choice for smaller, more portable or mobile consumer electronics devices – such as cell phones, digital cameras, PDAs, MP3 players, and more – for data exchange with a PC host. Yet as these devices increase in number, sophistication, and portability, there is a growing need to connect them with each other when a PC is not available. For example, many USB digital cameras can download data to a PC-based application, but cannot connect directly to a USB printer or CD burner to print or store the photos. PDAs can exchange data with a host PC, but cannot print, store, or upload files when a PC is not present. Some of these data exchange requirements are met today with removable memory devices, a viable solution but only for specific products such as a digital camera and printer designed to support the same brand of memory.

The latest release of the USB Standard, Rev 2.0., does not support peer-to-peer communication. It is a hostcontrolled standard, that is, communication takes place between a host and a peripheral over a host-initiated connection. So why not just equip portable devices to act as hosts? To function as a USB 2.0 host (PC), a device must include adequate storage for a large number of device drivers, be capable of sourcing a large current, and provide a Series A host connector receptacle. For many portable and almost all mobile devices, it is neither practical nor necessary to support these features.
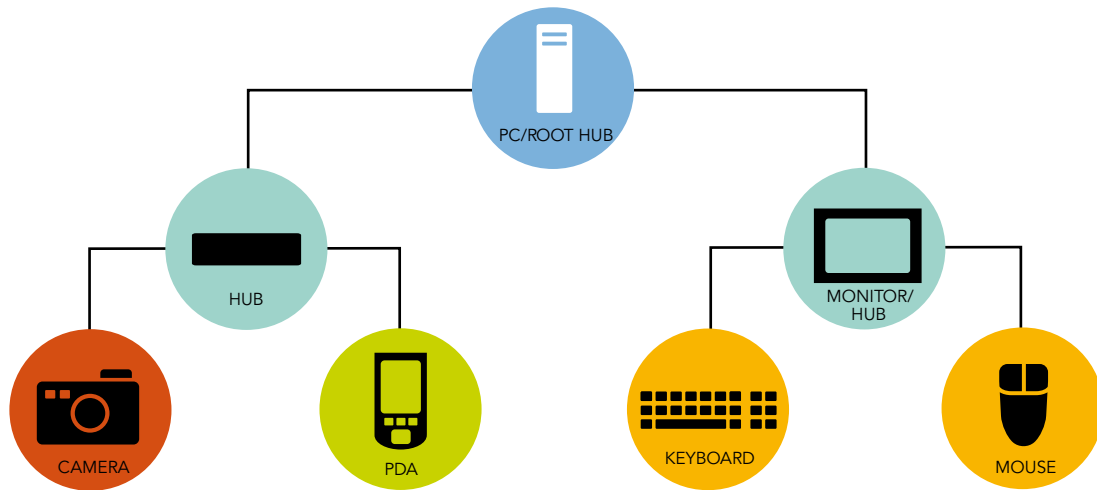
[1] Cahners In-Stat Group, 2000.

Figure 2: Traditional, host-based USB architecture does not support point-to-point device communication.

USB ON-THE-GO (OTG)

In December 2001, the USB Implementers Forum (USB-IF) announced a long-awaited OTG Rev. 1.0a Supplement to the USB 2.0 Standard to address this need. The changes incorporated in the OTG Supplement aim primarily to extend usage of USB by including more practical specifications and user-friendly features for mobile devices. In particular, OTG supports point-to-point connectivity for data exchange, improves power efficiency and thus extends battery life, simplifies cabling, and refines some of the USB 2.0 specifications to Micromize deviations from core spec.

Point-to-Point Connectivity

The OTG Supplement extends the USB standard to enable point-to-point communication between two USB devices: one OTG device and another OTG or traditional USB device. Because the two devices still maintain the roles of host and peripheral, OTG point-to-point communication is not to be confused with peer-to-peer. Unlike traditional USB, OTG allows only one peripheral at a time to be connected to the device acting as host. OTG devices do support USB hubs, a traditional way of enabling multiple USB peripherals to share a single USB host connection. However, some OTG functionality such as swapping host/peripheral roles and peripheral session requests are not supported across today's USB hubs.

USB OTG device types range from battery-powered handheld products to non-portable peripherals. While initial device roles (host/peripheral) are defined by how they are cabled together, some OTG devices can switch roles through the host negotiation protocol (HNP) without changing the cabling.
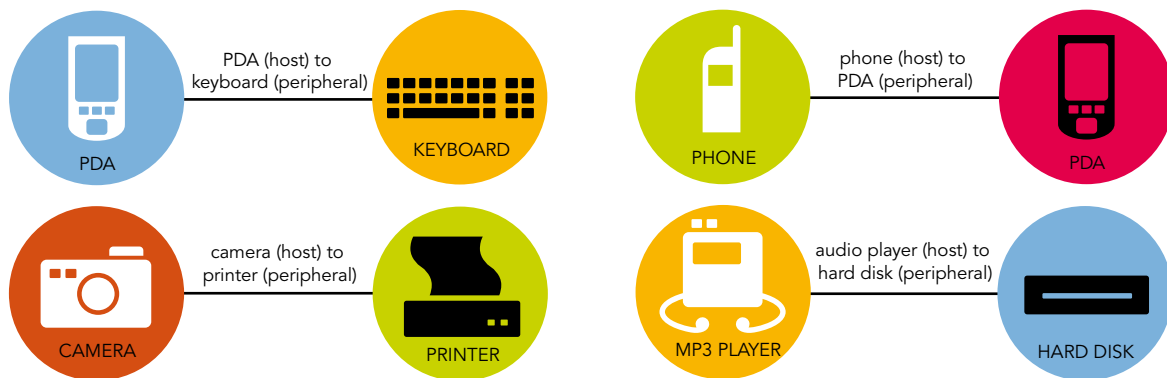

Figure 3: OTG enables point-to-point connectivity between peripherals without a traditional PC host.

To better understand how new OTG devices and features add to existing USB functionality, a quick review of USB device terminology follows.

‣ The *A-device* is the default host at the start of a session. It supplies power to V_{BUS}.
‣ The *B-device* is the default peripheral at the start of a session.

To these, the OTG Supplement adds the *OTG device* and defines two types: a dual-role device and a peripheral only device.

‣ An OTG *dual-role* device can act as either a host to select USB or OTG peripherals or as a peripheral to standard USB or OTG dual-role hosts. It can switch roles (with another OTG dual-role device) through the HNP. To facilitate power efficiency, a dual-role device can initiate (peripheral) or respond (host) to the Session Request Protocol (SRP) (discussed later). An OTG dual-role device can be identified by the presence of a Micro-AB receptacle, a new feature of the OTG Supplement.

In the context of this new OTG dual-role device, the definition of the A- and B-devices can now be expanded. If the A-device is dual-role, it may relinquish the role of host to a dual-role B-device through the HNP. If the Bdevice is dual role, it may be granted the role of host from the A-device through the HNP.

Unlike a traditional host, a dual-role device has limited host capability. It is not required to support some of the functions of a traditional USB PC/host and is not required to be capable of hosting all possible types of USB devices. The OTG dual-role device manufacturer may choose which devices or classes of devices the dual-role product will support when acting as the host. The details of these supported peripherals are maintained in the device's targeted *peripheral list*. As a limited host, the dual-role device must be capable of sourcing a Micromum of eight mA; as a peripheral it can sink up to eight mA.

‣ An OTG *peripheral-only* device benefits from the smaller cabling/connectivity and power efficiency of OTG, but cannot assume the limited host role. It can consume a maximum of eight mA and can initiate SRP to wake up the host. It has a Micro-B receptacle or tethered Micro-A plug.
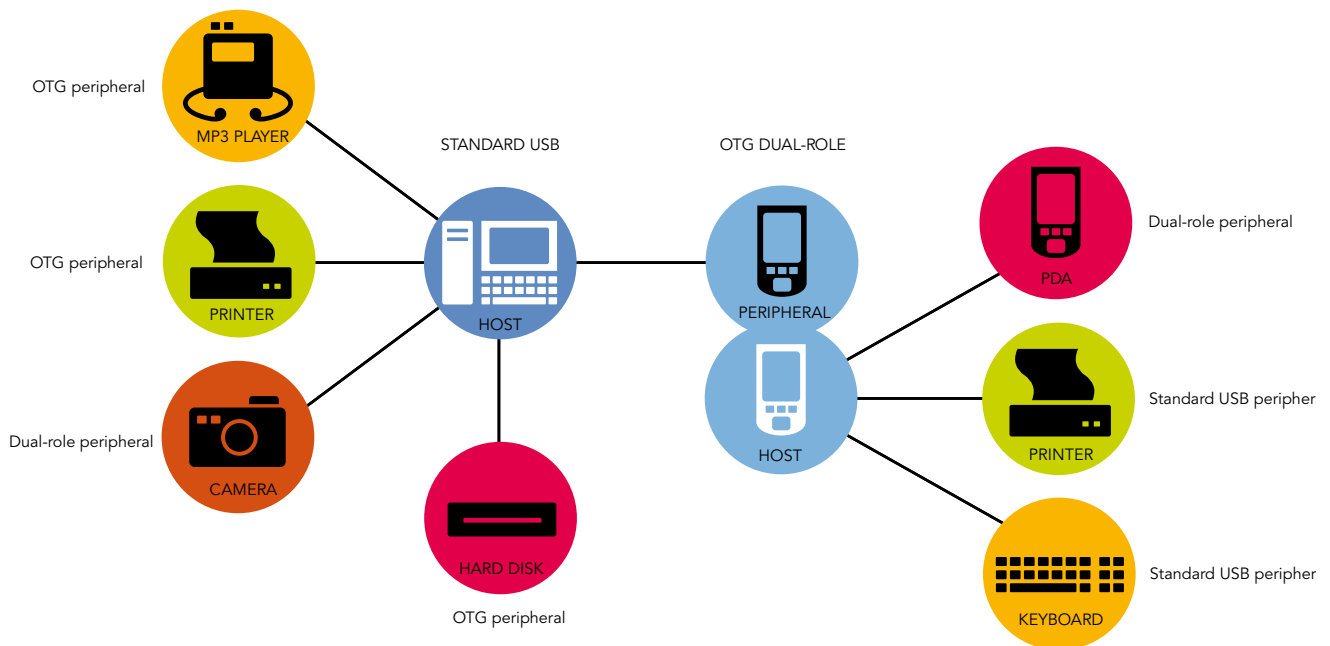

Figure 4: As a host, an OTG dual-role device can connect to standard USB peripherals or OTG peripherals. As a peripheral, a dual-role device can connect to standard USB or OTG dual-role hosts

Simplified Cabling, More Connectivity Options

USB has helped to simplify the cabling complexities of PC-centric peripherals, yet there are dozens of proprietary communications protocols, interfaces, even types of cables for small mobile/portable devices. Today the average consumer with a mobile phone, digital camera, and PDA needs at least four different cable types and a PC to interconnect these devices.

In addition to supporting the connectors and cable assemblies defined in the USB 2.0 Specification, the OTG Supplement defines new, smaller cables and connectors to better suit mobile form factors and adapters to enable use with traditional USB connectors and cables. Table 1 summarizes all plugs, receptacles, adapters, and cable combinations supported by both USB 2.0 and by the new OTG Supplement, Rev 1.0a.

	Cable assemblies	Connectors	Adapters	Compliant combinations
USB 2.0	► Standard-A plug to Standard-B plug ► Standard-A plug to Micro-B plug ► Captive cable with Standard-A plug	► Standard-A plug and receptacle (for the host) ► Standard-B plug and receptacle (for the peripheral) ► Micro-B plug and receptacle (alternative for peripheral)		
New in the Rev. 1.0a Supplement	► Micro-A plug to Micro-B plug ► Micro-A plug to Standard-B plug ► Captive cable with Micro-A plug	► Micro-A plug and receptacle ► Micro-AB receptacle (accepts Micro-A or Micro-B plug)	► Micro-A receptacle to Standard-A plug ► Standard-A receptacle to Micro-A plug	► Micro-A plug to Micro-B plug cable ► Micro-A plug to Standard-B plugcable ► Micro-A plug to captive cable ► Micro-A receptacle to Standard-A plug adapter ► Standard-A receptacle to Micro-A plug adapter

Table 1: USB 2.0 & OTG Compliant Connectors & Cabling Options

OTG introduces a new smaller Micro-AB receptacle that accepts both Micro-A and Micro-B plugs. Since a dual-role device must have only one Micro-AB receptacle, and this is the only approved use for this receptacle type, its presence serves to clearly identify a OTG dual-role device. Since each dual-role device maintains a unique targeted peripheral list for which it will act as host, the presence of a Micro-AB receptacle does not, however, imply 100% compatibility with all USB devices.

USB connectors are keyed to ensure correct topologies and are differentiated through the shape of the plug overmold and color coding for plugs and receptacles. The USB 2.0 Specification limits the maximum size of the overmold for the Micro-B plug on the Standard-A to Micro-B cable, but it does not define the shape of the overmold. The OTG Supplement constrains the size and the shape of the overmold for the Micro-A plug. The Supplement also constrains the size and shape of the Micro-B plug overmold if used on new OTG cables.

For detailed technical drawings of plugs, receptacles, overmolds, adapters and cabling options, refer to the OTG Rev 1.0a Supplement.

Limited Power Sourcing Requirements

A traditional USB host must be capable of sourcing up to 500 mA of current to traditional USB peripherals. Since a dual role device can act in a limited-host capacity, it must be able to source power on the V_{BUS} as well. But supplying the power requirements of some traditional peripherals is not practical for many battery-powered products. Thus the OTG Supplement allows dual-role devices to supply as little as eight mA to meet the needs of peripherals supported by the dual-role device. Note, too, that the maximum current an OTG device (whether dual-role or peripheral-only) can consume from the USB cable is a corresponding eight mA.

Session Request Protocol

Portable USB devices normally power down their USB bus and transceivers when not in use to conserve battery charge.
The OTG Supplement defines a Session Request Protocol (SRP) enabling the A-device (initial host) to do the same when there is no bus activity. SRP enables the B-device (initial peripheral) to then initiate bus activity by prompting the host to power up the V_{BUS} when it is ready to begin a session.

Any A-device, whether a traditional USB host (PC, laptop) or OTG host can respond to SRP. Any B-device, whether a standard USB or OTG peripheral can be designed such that it can initiate SRP. A dual-role device must be capable of initiating and responding to SRP.

The OTG Supplement defines two SRP signaling methods (data-line pulsing and V_{BUS} pulsing) for use by the B-device to allow maximum latitude in the design of A-devices. Each A-device is only required to respond to one of the two signaling methods. A B-device initiates SRP using both methods to ensure that the A-device responds.

Supported Operation Speeds

OTG dual-role devices must support both limited-host and peripheral modes. For peripheral mode, full-speed operation is required, high speed is optional. In limited host mode, full speed operation is required, low and high speeds are optional.

Targeted Peripheral List

When acting as host, a dual-role device is not required to support operation with all other types of USB peripherals. The peripherals supported by the device are determined by its manufacturer and identified in its '*targeted peripheral list*.' This may be as simple as the name, manufacturer, device type, and model number of supported peripherals, or it may contain OTG peripheral 'types,' such as 'OTG keyboard' or 'OTG camera', etc. A device manufacturer may choose, for example, to support only devices running a specific OS or peripherals compliant with a particular device-class specification. OTG peripheral types must conform to specific characteristics currently being defined by the OTG Device Working Group.

Host Negotiation Protocol (HNP)

By definition, the role of host is assumed by the A-device at the beginning of a session. The HNP allows the role of host be transferred back and forth between dual-role devices any number of times during a connectivity session. This eliminates the need for the user to manually switch the cable connections to accomplish this role reversal. HNP will typically be initiated in response to user input or by an application on the dual-role B-device.

No Silent Failures

On occasion, USB products can be connected yet do not support the type of communication requested by the user. The OTG Supplement now requires that the dual-role device involved in such a situation send understandable and, if possible, self-explanatory messages to inform the user of the problem and guide them to corrective action without the need a reference manual or similar support materials.

Hub Support

Today many USB peripherals share USB host ports through use of USB hubs. While OTG dual-role devices support USB hubs, standard USB hubs do not support the signaling methods used for the SRP and HNP. Thus, when an OTG dual-role A-device is directly connected to a standard USB hub, it cannot issue a command that would enable a downstream B-device to expect or initiate HNP.

Target OTG applications

OTG simplifies data exchange in a variety of applications by allowing direct communication between two devices when a PC is not available. By enabling point-to-point connectivity between and formerly peripheral-only devices, OTG opens up a range of new applications in the mobile/portable space from battery-powered handheld products to non-portable peripherals. See Table 2 for a list of some of the many data exchange tasks made possible by OTG capabilities.

OTG HOST	PERIPHERAL (traditional & OTG)	TASK
PDA	PDA	Exchange files
	Mobile phone	Surf web, send e-mail, load files/contact information
	Digital camera	Exchange pictures
	Keyboard, Mouse	User interface
	Printer	Print files, pictures
	Portable storage	Store/retrieve data files
	Portable audio player	Load/store music files
	Scanner	Scan pictures
	GPS	Get directions, maps
Mobile phone	Mobile phone	Exchange directories, contact info, messages, songs
	PDA	Exchange files, surf web
	Digital camera	Upload pictures to web
	Digital audio player	Exchange songs
	MP3 player	Upload/download music files
	Card scanner	Scan business cards
Digital camera	Digital camera	Exchange pictures
	Mobile phone	Upload pictures to web, e-mail
	Printer	Print pictures
	Mass storage	Store/archive pictures
Digital audio player	Digital audio player	Exchange songs
	CD player	Upload songs
	Speakers	Play songs
	Storage	Retrieve/store songs
Portable storage	Digital audio player	Store songs
	Digital camera	Store pictures
	Digital video camera	Store video clips
Printer	Digital camera	Print pictures
	Scanner	Print scanned pictures
	Mass storage	Print stored/archived files

Table 2: USB On-The-Go Applications

USB OTG supplement status

The OTG Supplement to the USB 2.0 Specification Rev. 1.0a was formally released on December 18, 2001 by the USB Implementers Forum (USB-IF), a non-profit corporation founded by the group of companies that developed the USB Specification. Developed by the USB On-The-Go Committee working under the auspices of the USB 2.0 Promoter Group, the OTG Supplement details the functional, mechanical, electrical, software specifications, and goals for OTG devices. Contributors to the Supplement's development include companies that build consumer and business products and manufacturers of connectors, cables, embedded controllers, and software. They include Advanced-Connectek (ACON), Cypress, Ericsson, Hewlett-Packard, InSilicon, Intel, MCCI, Microsoft, Motorola, Molex, Inc., NEC, Nokia, Onspec, Palm, NXP, SoftConnex, Texas Instruments, and TransDimension.[2]

To download a copy of the complete USB OTG Supplement, visit: www.usb.org/developers/onthego/.

USB OTG and NXP Semiconductors

NXP Semiconductors has a long history of involvement with the USB-IF. Its USB ICs have been proven in a wide range of computer-related products including PCs, keyboards, printers, monitors, and scanners and are popular in consumer audio/video products such as MP3 players, digital cameras, set-top boxes, mobile phones, and PDAs. In addition to marketing a growing range of ICs and systems with embedded USB functionality, NXP Semiconductors provides extensive design-in support and a large portfolio of reference designs and kits for companies developing USB-based consumer and computing products.

As a core member of USB-IF and an active member of the OTG working group, NXP Semiconductors spearheaded the new initiative for point-to-point connectivity within the USB community now known as OTG. In 2001, NXP released the ISP1161 – the first single-chip, integrated host and peripheral controller conforming to the USB Specification Revision 1.1. Before the OTG Supplement could be formally announced, the USB-IF required proof of a working prototype board. NXP was the first to demonstrate this with a working ISP1161-based prototype.

First in a complete roadmap of NXP On-The-Go solutions, the NXP ISP1362 is a single-chip USB OTG controller based on its proven ISP1161 predecessor. Announced in January 2002, the ISP1362 integrates an advanced host controller, a peripheral controller and an OTG transceiver. It is optimized for embedded systems and incorporates many innovative patent-pending architectural enhancements that reduce processor overhead and maximize utilization of the USB 2.0 12 Mb/s full-speed bandwidth. The ISP1362 is targeted for development of OTG products that are fully compliant with USB Specification Rev. 2.0 and the OTG Supplement Rev. 1.0a.

Conclusion

USB is one of the most successful technologies introduced in recent years with over a billion units shipped to date. Sales of new USB products leveraging enhanced OTG functionality have the potential to dwarf even those numbers very quickly. Increased consumer product functionality and convenience made possible by OTG should only improve consumer acceptance of USB products. Semiconductor and consumer electronics manufacturers alike can benefit from this opportunity to deliver fresh, useful features in their next generation products.

[2] Source: OTG Supplement, Rev. 1.0a.

Sources / References

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