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USB On-The-Go Basics

USB On-The-Go (OTG) allows two USB devices to talk to each other without requiring the services of a personal computer. Although OTG appears to add "peer to peer" connections to USB, it does not. Instead, USB OTG retains the standard USB host/peripheral model, where a single host talks to USB peripherals. OTG introduces the dual-role device (DRD), capable of functioning as either host or peripheral. Part of the magic of OTG is that a host and peripheral can exchange roles if necessary.
Before OTG, the concept of an embedded host was already established in the USB world. Instead of duplicating the full UHCI/OHCI USB controllers and drivers built into personal computers, most embedded host chips provide limited hosting capabilities. This makes them better suited to the embedded environment than to the PC with its huge resources and infinite capacity for drivers and application software

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An OTG device may or may not be capable of functioning as a host, although it is likely that most OTG devices will be dual-role.

USB Peripherals

To help understand what OTG adds to a USB system, Figure 1 illustrates the basic USB peripheral circuitry on which OTG builds. These example peripherals operate at low or full speed, and are commonly known as "USB 1.1" devices, even though the USB 2.0 Specification includes the current USB 1.1 specification, while also introducing a third, higher speed.

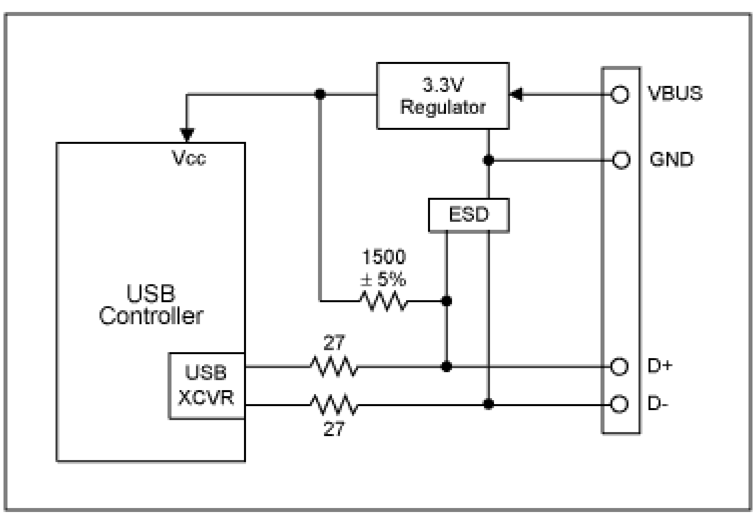

Figure 1. A USB peripheral controller and its associated circuitry.

The controller in Figure 1 might be a microprocessor plus USB SIE (Serial Interface Engine), an integrated µP/USB chip, or an ASIC connected to a USB transceiver. A bus-powered peripheral requires a 3.3V regulator, both to power the logic and to supply the proper voltage to a 1500Ω resistor connected to either the D+ or D- USB pins. This pullup resistor signals the host that a device is connected, and indicates the device's operating speed. A pullup to D+ indicates full speed, and a pullup to D- indicates low speed. The other end, ost or hub, contains 15kΩ pulldown resistors on D+ and D- to allow the pullup resistor to be detected. Finally, an ESD protection circuit is advisable on D+, D- and V_{BUS} pins because USB is designed to be hot-plugged.

How to be a Host

The Figure 1 circuit functions only as a USB peripheral device. To add OTG dual-role capability, the transceiver must be augmented to allow the OTG device to function as either host or peripheral. Adding the following to Figure 1 would allow the system also to function as a host:

- 15kΩ pulldown resistors on D+ and D-
- A means to supply, rather than draw, power on V_{BUS}

The ASIC or Controller must also contain logic to function as a USB host. Some of the host duties not present in a peripheral device are:

- Send SOF (Start of Frame) packets
- Send SETUP, IN, and OUT packets
- Schedule transfers within USB 1 msec frames
- Signal USB reset
- Provide USB power management

In addition to requiring a dual role peripheral/host USB controller, OTG requires additional circuitry to support two new protocols, called HNP and SRP.

Host Negotiation Protocol

An OTG dual-role device can operate either as a host or peripheral. In OTG nomenclature, the initial host is called the A-Device, and the initial peripheral is called the B-Device. The word *initial* is important. Once connected, OTG dual-role devices can exchange roles, host and peripheral, using the new Host Negotiation Protocol (HNP). HNP raises two obvious questions: (a) how are the initial roles determined, and (b) why is the role reversal necessary?

The cable orientation determines the initial roles (Figure 2). Dual-role devices use a new receptacle called the mini-AB. The mini-A plug, the mini-B plug and the mini-AB receptacle add a fifth pin (ID) to give different electrical identities to the cable ends. This ID pin is connected to ground inside the mini-A plug and left floating in the mini-B plug. The OTG device receiving the grounded ID pin is the default A-device (host), and the device with the floating ID pin is the default B-Device (peripheral).

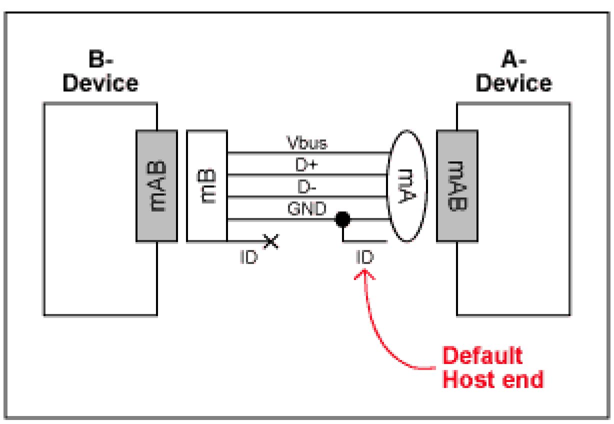

Figure 2. Fifth ID pin determines default host.

To understand the need for HNP and host/peripheral role reversal, the Figure 3 example shows two dual-role devices, a PDA and a printer. The PDA has a printer driver inside. The two devices are connected with the new OTG cable as shown, making the printer the default host (A-Device) and the PDA the default peripheral (B-Device). But this is backwards. The PDA, which has the printer driver, needs to act as USB host to the printer, which contains no driver. Rather than bothering the user by asking for the cable to be reversed, HNP allows the roles to be reversed automatically and silently.

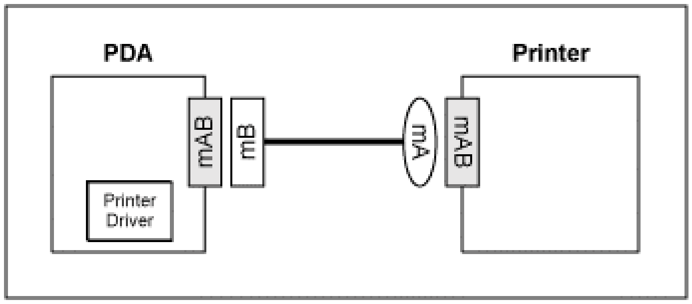

Figure 3. OTG cable is inserted "backwards".

Session Request Protocol

The OTG specification adds a second new protocol to USB, called session request protocol (SRP). SRP allows a B-Device to request an A-Device to turn on V_{BUS} power and start a session.

An OTG *session* is defined as the time that the A-Device is furnishing V_{BUS} power. (Note: the A-Device always supplies V_{BUS} power, even if it is functioning as a peripheral due to HNP.) The A-Device can end a session by turning off V_{BUS} to conserver power, a very important requirement in a battery powered device such as a cell phone.

Figure 4 shows a common OGT application, two cell phones connected together to exchange information. The right phone received the mini-A end of the cable, making it the A-Device and defaulting to the host role. The left phone is the B-Device, defaulting to peripheral. If there is no need to communicate over USB, the A-Device can power down the V_{BUS} wire, which the B-Device can detect so that it too can enter a low power state.

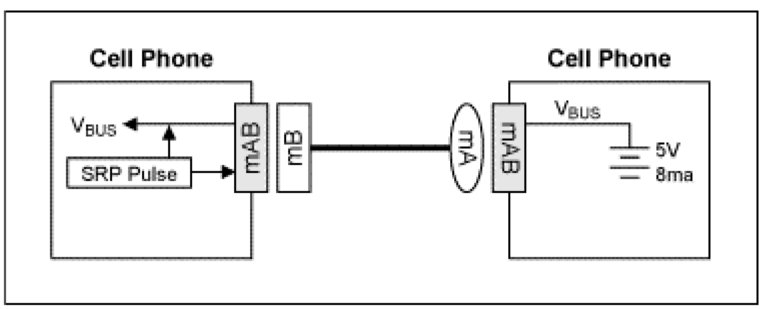

Figure 4. OTG Session Request Protocol (SRP).

Now suppose the user of the left phone presses a button to synchronize address books, or any other action that requires a USB session. The "SRP Pulse" block in the left phone pulses first the D+ wire, and then the V_{BUS} wire to wake up the A-Device (the A-Device may respond either to D+ or V_{BUS} pulsing.) The A-Device detects the pulse, causing it to switch on V_{BUS} and start a session.

There's a bit more complexity to SRP (that's why it's called a protocol). For example: the B-Device must first insure that a session is not in progress by measuring V_{BUS}. It must also carefully control the V_{BUS} pulse to allow for the possibility that it might be connected to a traditional USB host, such as a PC through a mini-B to A cable adapter.

Once a session is underway, the devices may or may not use HNP.

OTG Transceiver

We're now ready to look at the requirements for an OTG transceiver in Figure 5.

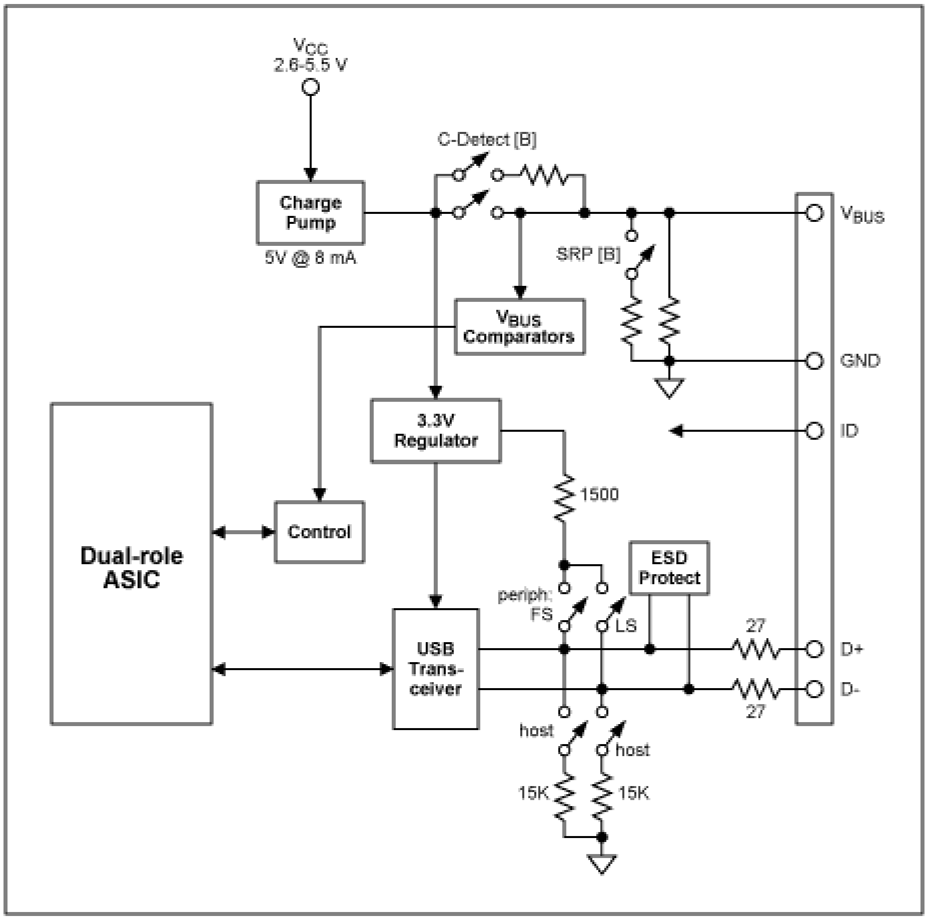

Figure 5. An OTG Transceiver.

The Figure 5 system builds on the in Figure 1 example circuit. The ASIC block could also be a microprocessor or DSP with USB capability. Three additions make the transceiver OTG compatible:

1. Switchable pull-up and pull-down resistors on D+/D- to allow peripheral or host functionality.
2. Circuitry to monitor and supply 5V power on V_{BUS} as an A-Device, and to monitor and pulse V_{BUS} as a B-Device initiating SRP.
3. An ID input pin, which is made available as an output to the ASIC.

For this system to operate as a dual-role OTG device, the ASIC or DSP or whatever is connected to the transceiver must be capable of functioning as a peripheral or host, and switching roles on the fly as a result of HNP.

Most of the added transceiver circuitry manages the V_{BUS} pin, which now must also supply 5V power at 8mA as a host, and perform V_{BUS} pulsing as a peripheral. Analog switches configure the transceiver for the various roles it must play.

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