How to Develop Hardware to Perform USB Device Switching

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Abstract

This document is intended for undergraduate level electrical engineering students or electronic hobby enthusiasts, who wish to create a device to enable or disable USB devices. The document includes a brief introduction into USB communication, and then goes in depth into what components can be used to provide proper switching for USB. The use of an oscilloscope to measure signals is described, as well as a description of how to create a prototype for a USB switch box.
Introduction

USB devices have been becoming more universal for devices like mice and keyboards for computers, as the older PS/2 connectors slowly phase out. Having a USB connection has provided a more general connector that can be used for almost any device now that a user may want to use. Such devices may include a digital camera, ipod, printer, or an external audio card. The beauty of USB is not only in its universality, but that it allows for users to plug or unplug its devices whenever they want while the computer is running. Powering down the computer and restarting is not necessary if one wishes to plug or unplug USB devices.

Objective

By the end of this document, the reader should have enough understanding of USB communication to be able to choose components, design, and implement a device to enable, disable or effectively just switch USB devices on or off. This can be helpful if a user does not have easy access to their USB inputs, or if there are multiple USB devices they would like to switch between. For example, this could be useful if someone had a scanner linked to multiple computers. One could then switch between which computers to send the signal to. Also, it is possible that a user may simply just want to disable a device when they do not wish to use it and then enable it later.
USB Communication

If one were to cut a USB cable, they would find four different colored wires hidden beneath the insulation.

Red   +5 V  
Green  Data +  
White  Data –  
Black  Ground

The red wire is what gives the device power, and is always 5V, while the black wire is a ground wire. The actual data travels along the green and white wires. It is important to note here that USB communication is bidirectional, in that communication between the computer and the device travels to and from one another. This piece of information will be prevalent later when switching components are discussed.

Now that it is understood what the wires physically represent, it is intuitive to then next understand what the signals across the data wires look like on an oscilloscope. If one were to attach the leads of an oscilloscope across the green data line and ground, a stream of bits would appear on the scope. It is recommended to press the auto set button on the scope here in order to see the bits clearly. What appears on the screen will be a set of bits in a header, followed by multiple zeros. The header is being sent periodically from the device to the computer, essentially communicating that it is still plugged in. The period can be calculated by allowing for more milliseconds per division. If one allows for a large enough range of time, they will be able to see multiple spikes on the
screen that are actually the header being resent. For multiple USB mice and keyboards measured during an experiment specifically, a period of approximately 8 milliseconds was found.

Continuing with a USB mouse as an example, if one were to press the auto set button again in order to only view one period, they can view the bit patterns of data being sent by the movement of the mouse. In order to visualize this better, imagine half of the oscilloscope screen from left to right being filled with the reoccurring header, and then when the mouse is moved, its directional data is then sent as bits of data filling the second half of the screen with a signal immediately following the header. Once the mouse stops moving, only the header data is sent again until the mouse is moved or a button is clicked. It is also important to note here that although the USB device is powered from 5V, the signals are being sent at 3.3V, which can be measured on the oscilloscope along with the period.

If you were to unplug the device and then plug it back in while having this same oscilloscope configuration, you would see very briefly a stream of data being sent to the computer. This data essentially is giving the computer its information. This way the computer can recognize what it is and be able to interpret its bit streams later. When you see the icon on your monitor display “Found new hardware….IBM Keyboard”, this is a result of this data being sent. This is a great attribute of USB that allows it be versatile, and also allow for devices to be unplugged and plugged in repeatedly. The computer will always receive the information it needs to understand the input of the device.
Switching Implementation

In my particular case, I wanted to be able to enable and disable a USB mouse when needed. The first idea I had was to use a transistor as a switch that could be biased from a 5V source. It was thought that if the transistor were biased or unbiased, then I could control the connection or disconnection of the USB data lines. It turns out that this can control the connection of the data lines, but fails to ever enable the device due to the fact that a USB is a bidirectional form of communication and a transistor only allows for a one way signal.

For USB switching I recommend the use of relays or an analog mux. These devices can operate from a 5V source, and provide a connection that allows for bidirectional communication. The relays will close when 5V are applied across them, and the mux has input pins on the IC which allow connections to open and close based upon the high or low voltages across those input pins.

For USB devices, only one data line needs to be disrupted in order to disable the device, however if only one wire is going to be disabled this must be the white wire. If both wires (green and white), are opened and closed simultaneously through a relay or analog mux, there are no problems with the computer recognizing the device, but if only the green wire is disconnected and then reconnected the computer does not always recognize the device again. This is why it is smart to only enable or disable the white wire (Data -) across the relay or analog mux.
Prototype Construction

To create the prototype for a switch box one will need a switch, a protoboard, a relay, two female USB connectors to pins, a USB cable, and finally the USB device that is to be enabled or disabled. Connect the USB cable from the computer to the first female connector on the protoboard. On the other side of the protoboard connect the other female connector to the USB device. Wire the red 5V, green data +, and black ground wires together. Next, place the relay on the center of the board. Wire the power pin to the switch, and the other pin on the switch to the 5V wire, and the ground pin to the ground wire. There are now 6 pins left on the relay (Refer to the data sheet in the reference section for wiring purposes). This particular relay allows for two different states. When the relay does not have 5V across its terminals, a connection is made between a common pin and one adjacent to it. When the voltage is applied via a switch from the user, the common pin is then disconnected from that pin and then connected to the other pin next to it. This can be helpful if two devices are being switched between each other. Also, just leaving one of the pins connected to nothing allows for 1 device to be either enabled or disabled by connecting and disconnecting its white data line. When the computer is turned on, the prototype switch board is powered and ready for operation.

Results and Conclusions

Although the primary focus of my research and experimentation has been through mice and keyboards, my new found understanding of USB devices has led me to believe that it is very likely that this switching implementation can be used for most, if not all USB devices. A switch box of the sort that was described during the prototype
construction section of this document is a very inexpensive alternative to purchasing commercial switch boxes. It is recommended that if a switch box is to be constructed, that a proper enclosure be purchased, and have this enclosure grounded for safety reasons. Also, having traces designed on a PCB, or at least soldering all pins and wire connections securely is a must in order to prevent any malfunctions through the life of the switch box.

References

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