USB hub for device testing

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USB hub for device testing

how I build a special purpose USB hub
in the beginning

I was developing for the sysmoQMOD quad modem board
development target

the debug interfaces are on the back
development target

3 sub-targets
development target

multiple debug interface
testing target

SIM card
power ctrl
QMOD hub
USB to serial
SWD prog.
JTAG prog.
USB to serial

7-port hub required
the USB devices do not appear when plugging the hub in
4.1.1 Bus Topology

The USB connects USB devices with the USB host. The USB physical interconnect is a tiered star topology. A hub is at the center of each star. Each wire segment is a point-to-point connection between the host and a hub or function, or a hub connected to another hub or function. Figure 4-1 illustrates the topology of the USB.

Due to timing constraints allowed for hub and cable propagation times, the maximum number of tiers allowed is seven (including the root tier). Note that in seven tiers, five non-root hubs maximum can be supported in a communication path between the host and any device. A compound device (see Figure 4-1) occupies two tiers; therefore, it cannot be enabled if attached at tier level seven. Only functions can be enabled in tier seven.

![Diagram of USB hierarchy](image)
USB hierarchy

my setup has only 3 hubs
USB tree

disconnect everything and go step per step
USB tree

use `lsusb -t` to show the tree

```
/: Bus 04.Port 1: Dev 1, Class=root_hub, Driver=xhci_hcd/1p, 10000M
/: Bus 03.Port 1: Dev 1, Class=root_hub, Driver=xhci_hcd/2p, 480M
|  Port 1: Dev 2, If 0, Class=Wireless, Driver=btusb, 12M
|  Port 1: Dev 2, If 1, Class=Wireless, Driver=btusb, 12M
|  Port 2: Dev 3, If 0, Class=Video, Driver=uvcvideo, 480M
|  Port 2: Dev 3, If 1, Class=Video, Driver=uvcvideo, 480M
/: Bus 02.Port 1: Dev 1, Class=root_hub, Driver=xhci_hcd/4p, 10000M
/: Bus 01.Port 1: Dev 1, Class=root_hub, Driver=xhci_hcd/4p, 480M
```

`root_hub` does not count as hub
USB tree

plug the first hub

```
/:
Bus 04.Port 1: Dev 1, Class=root_hub, Driver=xhci_hcd/1p, 10000M
/:
Bus 03.Port 1: Dev 1, Class=root_hub, Driver=xhci_hcd/2p, 480M
  |__ Port 1: Dev 2, If 0, Class=Wireless, Driver=btusb, 12M
  |__ Port 1: Dev 2, If 1, Class=Wireless, Driver=btusb, 12M
  |__ Port 2: Dev 3, If 0, Class=Video, Driver=uvcvideo, 480M
  |__ Port 2: Dev 3, If 1, Class=Video, Driver=uvcvideo, 480M
/:
Bus 02.Port 1: Dev 1, Class=root_hub, Driver=xhci_hcd/4p, 10000M
/:
Bus 01.Port 1: Dev 1, Class=root_hub, Driver=xhci_hcd/4p, 480M
  |__ Port 3: Dev 99, If 0, Class=Hub, Driver=hub/4p, 480M
  |__ Port 4: Dev 100, If 0, Class=Hub, Driver=hub/4p, 480M
```
USB tree

plug the second hub
USB tree

plug the second hub

we actually have already 4 hubs
USB tree

mark the port numbers
most 7-port USB hub are actually 2 4-port hubs chained
hub requirements

testing hub requirements:

- 7-port flat
hub internals
bad routing and bad cables can lead to bad signal quality and unstable communication

```
kernel: usb 1-1.4.6: clear tt 1 (9102) error -71
kernel: usb 1-1.4.6: clear tt 1 (90b2) error -71
kernel: usb 1-1.4-port5: disabled by hub (EMI?), re-enabling...
kernel: usb 1-1.4.5: USB disconnect, device number 26
kernel: usb 1-1.4.5: cannot submit urb (err = -19)
kernel: usb 1-1.4.6: clear tt 1 (9102) error -71
kernel: usb 1-1.4.6: clear tt 1 (90b2) error -71
```
hub requirements

testing hub requirements:

- 7-port flat
- proper routing (impedance controlled differential signals)
hub internals

devices can be powered individually
hub requirements

testing hub requirements:

- 7-port flat
- proper routing (impedance controlled differential signals)
- switched power outputs (with indication)
USB 2.0 should draw max. 500 mA from the upstream port. This is not enough to power 7x500 mA downstream ports. An external power supply will help.
hub requirements

testing hub requirements:

- 7-port flat
- proper routing (impedance controlled differential signals)
- switched power outputs (with indication)
- external power supply
to power cycle (12V) the sysmoQMOD, I used a serial controlled relay
hub requirements

- 7-port flat
- proper routing (impedance controlled differential signals)
- switched 5V power outputs (with indication)
- external power supply
- switched high voltage (6-40V) power outputs
CuVoodoo USB hub

12V 2A power supplies are a lot more common than 5V 3A
hub requirements

- 7-port flat
- proper routing (impedance controlled differential signals)
- switched 5V power outputs (with indication)
- external power supply
- switched high voltage (6-40V) power outputs
- embedded 5V 3A regulator
hub power control

```
[diode slides]$ uhubctl
Current status for hub 1-1.4 [1d50:617a CuVoodoo power USB hub 2022092002, USB 2.00, 7 ports, ppss]
  Port 1: 0100 power
  Port 2: 0503 power highspeed enable connect [174c:55aa Intenso USB 3.0 Device 9020000000000001308]
  Port 3: 0100 power
  Port 4: 0100 power
  Port 5: 0100 power
  Port 6: 0100 power
  Port 7: 0303 power lows speed enable connect [15d9:0a4d]
[diode slides]$ uhubctl --location 1-1.4 --ports 1 --action off
Current status for hub 1-1.4 [1d50:617a CuVoodoo power USB hub 2022092002, USB 2.00, 7 ports, ppss]
  Port 1: 0100 power
Sent power off request
New status for hub 1-1.4 [1d50:617a CuVoodoo power USB hub 2022092002, USB 2.00, 7 ports, ppss]
  Port 1: 0000 off
[diode slides]$ uhubctl
Current status for hub 1-1.4 [1d50:617a CuVoodoo power USB hub 2022092002, USB 2.00, 7 ports, ppss]
  Port 1: 0000 off
  Port 2: 0503 power highspeed enable connect [174c:55aa Intenso USB 3.0 Device 9020000000000001308]
  Port 3: 0100 power
  Port 4: 0100 power
  Port 5: 0100 power
  Port 6: 0100 power
  Port 7: 0303 power lows speed enable connect [15d9:0a4d USB OPTICAL MOUSE]
```

**uhubctl** allows to remotely switch power on the power
hub requirements

- 7-port flat
- proper routing (impedance controlled differential signals)
- switched 5V power outputs (with indication)
- external power supply
- switched high voltage (6-40V) power outputs
- embedded 5V 3A regulator
- (individual) remotely controlled power outputs (hub feature)
CuVoodoo USB hub

my own USB hub
CuVoodoo USB hub
speed indication

- red + blue: high speed
- blue: low speed
- red: full speed
- green: power on
power input protection

feedback protection

current limit

EMI protection variable values

470uF needed, else when powering up > 5 ports simultaneously cause 5V dip and hub reset

only enable when VBUS is present

470uF/50V

C4

R5

10k

C5

1uf/50V

VTRG

VTRG SW

C7

1uf

470uF

XL25965

XL25965-5.0

U4

SW

SW

EN

GND

C6

1uf

33uf

D534

L1

33uf

D534

C8

470uF

only enable when VBUS is present

R3

10k

D2

Q2

Q3

Q4

R3

10k

Q1

100k

R4

470uF

R8521530

Q5

10k

3A

R2

10k

D1

Q2

Q3

Q4

R3

10k

Q1

100k

Feedback protection

disable 5V external power when 6-40V external power is provided

pull VTRG_SW low also when 5V and 6-40V plugged, but VBUS unplugged

prevent feedback when external power is provided

local power

BUS passed through until lack plugged

prevent feedback

0.3A

F1

R3

S3

R8521530

RS3

10k

Q1

100k

R4

470uF

R8521530

0.3A

F1

R3

S3

R8521530

RS3

10k

Q1

100k

R4

470uF

R8521530

0.3A

F1

R3

S3

R8521530

RS3

10k

Q1

100k

R4

470uF

R8521530

0.3A

F1

power output protection

**current limit (500 mA)**

+ over-current sensing
ESD protection

USB hub - DFP1

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hub features

- 7-port flat
- proper routing (impedance controlled differential signals)
- switched 5V power outputs (with indication)
- external power supply (5V, 6-40V)
- switched high voltage (6-40V) power outputs
- embedded 5V 3A regulator
- (individual) remotely controlled power outputs (hub feature)
- speed indication
- power input protection (over-current and feedback)
- (individual) power output protection (over-current and sensing)
- ESD protection (on UFP and all DFP)
CuVoodoo USB hub
limitations

- not very compact
- USB 2.0 only (I did not need more)
- not USB-C
- over-current not reported (hub chip bug)
- not available in shops

but it’s open source, and you can build your own: https://git.cuvoodoo.info/usb_hub
(check for releases to get the fabrication files)