Application Note 17

Universal Serial Bus Power Management

by Kevin Lynn

Introduction

Power management and distribution is a major factor in correctly designing USB (Universal Serial Bus) peripherals. Proper methods of designing USB peripheral power distribution are crucial to ensure full compliance with the USB specification, including compliance with electromagnetic interference (EMI) and voltage regulation requirements.

Device Classes

USB defines several device classes, differentiated by their power requirements or capabilities. The most important device classes are *hubs* and *functions*.

Hubs

Hubs provide for distribution of data and power to downstream (away from the host) devices and communicate with the host. Hubs may be either locally powered (self-powered), bus-powered from an upstream cable (toward the host), or a combination of the two.

Self-powered hubs have a local power supply. Examples are PCs (host), stand-alone hubs, monitors, printers, scanners, or docking stations, which may draw up to 100mA (one unit load) from an upstream port. Self-powered hubs are required to limit and report overcurrent conditions and may supply up to 500mA to each downstream port.

Bus-powered hubs obtain all power from the bus (a cable to an upstream self-powered hub) and may supply 100mA or more to each downstream port if the input power budget is not exceeded. Bus-powered hubs may draw 100mA at start-up from an upstream hub, increasing up to 500mA after enumeration, apportioning the power in increments of 100mA per downstream port plus 100mA internally. Bus-powered hubs must provide power switching for downstream ports on a per port basis or have a single switch for all of the ports (gang-mode power control).

Functions

Functions are endpoint low- or high-power devices and do not repeat data or provide downstream power.

High-power functions may initially draw 100mA at 4.4V from an upstream self-powered port, increasing after enumeration up to 500mA. If, during enumeration, there is insufficient power available from upstream, the remainder of the function is not powered and a power limit warning message is sent. Self-powered functions may draw 100mA from upstream with the remainder from a local power supply.

Low-power functions may draw up to 100mA from an upstream cable.

USB Power Distribution

Connection between devices are made using cables which are either detachable (such as a USB modem) or permanently attached (such as a keyboard). High speed (>1.5Mb/s) peripherals require shielded cable, while low-speed peripherals may operate with unshielded cable to minimize cost. The upstream port of a hub is, by definition, a high-speed port and requires a shielded cable. Figure 1 shows the voltage regulation requirements of a USB system based on current USB requirements.

Self-Powered Hub Requirements

USB self-powered hubs are required to provide a minimum of 4.75V at downstream ports under all legal load conditions. Self-powered hubs may draw up to 100mA operating current from an upstream hub.

To comply with UL defined safety requirements, current from any port must be limited to less than 25VA (5A for 5V ports). If such an overcurrent condition occurs, even if it is only momentary, it must be reported to the hub controller. Detection of overcurrent must disable all affected ports. If the

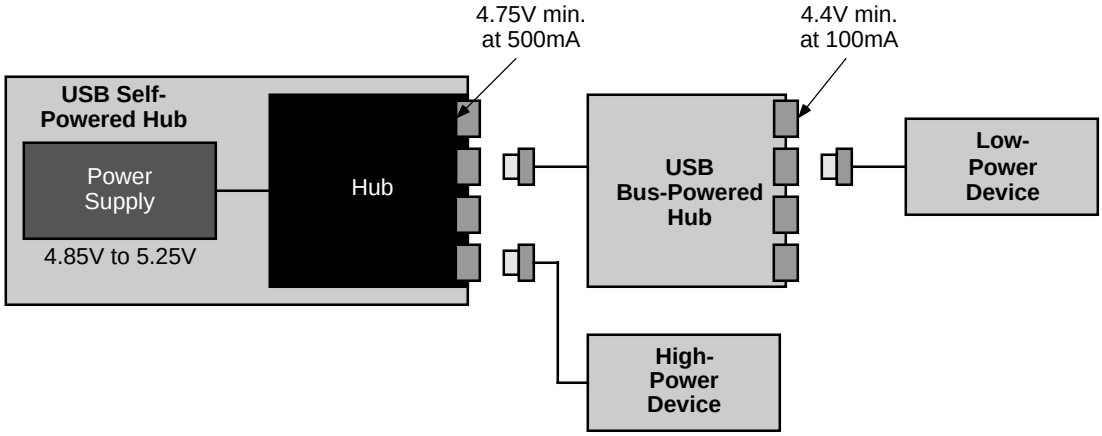

Figure 1. Typical USB Voltage Distribution System

overcurrent condition has caused a permanent disconnect (such as a blown fuse), the hub must report it upon completing its reset or power-up.

Overcurrent protection may be implemented on all downstream ports in aggregate (ganged), or on an individual (per port) basis. Overcurrent limiting devices may include polyfuses, standard fuses, or a solid-state switch. A practical limit is seven downstream ports per protection device.

Voltage Regulation Requirements

The dc output voltage, measured at the board side of the self-powered hub downstream connector, must remain below 5.25V and above 4.75V under all legal continuous load conditions.

The internal power supply tolerance dictates the allowable component voltage drops within a self-powered hub. Table 1 depicts the range of resistance of the overcurrent protection device, assuming a 30mV (or 60mΩ) drop across the PCB components. For example, Table 1 shows that using a 5V, 3% power supply allows a maximum resistance of 140mΩ for the overcurrent protection device. A 5.1V, 3% supply allows for a 340mΩ device. If it is expected that the PCB component voltage drops will be other than 30mV, then these values can be scaled appropriately.

The components that make up the voltage drop include the circuit trace, overcurrent protection device, and output filter ferrite beads. The printed circuit board power and ground traces, solder connections, and ferrite beads on both power and ground output lines may total 60mΩ, dropping a total of 30mV at 0.5A. Additional traces, ferrite beads, and protection devices are needed for each output port. Figure 2 represents the component voltage drops of a typical self-powered hub.

Transient Droop Requirements

USB supports dynamic attachment (hot plug-in) of peripherals. A current surge is caused by the input capacitance of the downstream device. Ferrite beads are recommended in series with all power and ground connector pins. Ferrite beads reduce EMI and limit the inrush current during hot-attachment by attenuating high-frequency signals while dc current passes freely. The simplest ferrite beads consist of a small ferrite tube on a tinned solid copper wire. The resistance of the ferrite bead wire should be as low as possible, with a large solder-pad to minimize connection resistance. USB requires that momentary droop of the 4.75V at a bus-powered hub's upstream cable connector never goes below 4.42V.

Nominal Voltage	Supply Tolerance	Minimum Voltage	Maximum Voltage	Maximum R_{ON}
4.85V	1%	4.8V	4.9V	40mΩ
	2%	4.75V	4.95V	0mΩ
	3%	4.7V	5V	—
	4%	4.66V	5.04V	—
	5%	4.61V	5.09V	—
4.90V	1%	4.85V	4.95V	140mΩ
	2%	4.8V	5V	40mΩ
	3%	4.75V	5.05V	0mΩ
	4%	4.7V	5.1V	—
	5%	4.66V	5.15V	—
4.95V	1%	4.9V	5V	240mΩ
	2%	4.85V	5.05V	140mΩ
	3%	4.8V	5.1V	40mΩ
	4%	4.75V	5.15V	0mΩ
	5%	4.7V	5.2V	—
5.00V	1%	4.95V	5.05V	340mΩ
	2%	4.9V	5.1V	240mΩ
	3%	4.85V	5.15V	140mΩ
	4%	4.8V	5.2V	40mΩ
	5%	4.75V	5.25V	0mΩ
5.05V	1%	5V	5.1V	440mΩ
	2%	4.95V	5.15V	340mΩ
	3%	4.9V	5.2V	240mΩ
	4%	4.85V	5.25V	140mΩ
	5%	4.8V	5.3V	—
5.10V	1%	5.05V	5.15V	540mΩ
	2%	5V	5.2V	440mΩ
	3%	**4.95V**	**5.25V**	340mΩ
	4%	4.9V	5.3V	—
	5%	4.85V	5.36V	—
5.15V	1%	5.1V	5.2V	640mΩ
	2%	5.05V	5.25V	540mΩ
	3%	5V	5.3V	—
	4%	4.94V	5.36V	—
	5%	4.89V	5.41V	—

Table 1. Maximum Allowed On-Resistance with 30mV PCB Voltage Drop*

* Shading represents USB-compliant conditions.

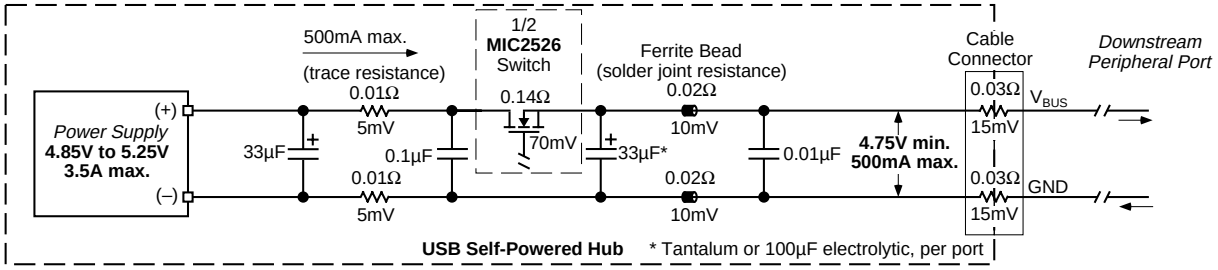

Figure 2. Self-Powered Hub Per-Port Voltage Drop

Bulk capacitance of at least 120µF per hub is required. This bulk capacitance provides the short-term transient current needed during a hot-attachment event. A four-port hub with a 33µF, 16V tantalum capacitor mounted close to each downstream connector (see Figures 5, 6, 7, and 8) should have hot-plug droop much less than 330mV. If electrolytic capacitors are substituted, 100µF, 10V units should provide similar transient droop protection.

Figure 3 shows the waveforms for a typical hot-plug event using the circuit of Figure 6. The hub output capacitor supplies the bulk of the inrush current to the downstream unit load (44Ω, 10µF). This current exceeds 2A for less than 10µs. The adjacent port voltage droop of 142mV is well within the 330mV specification limit.

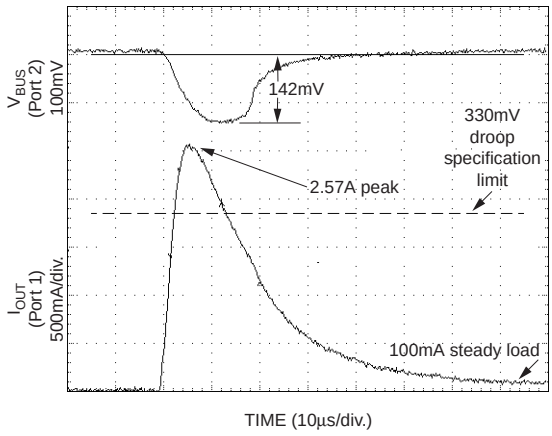

Figure 3. Typical Hot-Plug Event

Detach Transient Surge

When current in a wire is interrupted, the inductance of the wire may cause a voltage spike as the magnetic field collapses. To reduce these spikes, which generate EMI, and to prevent damage to components, 0.01µF, 25V ceramic bypass capacitors should be installed directly from V_{BUS} pin to the ground pin at each port.

Printed Circuit Layout

The power circuitry of USB printed circuit boards requires a customized layout to maximize thermal dissipation and to minimize voltage drop and EMI.

Printed circuit power and ground traces should be wider than traces used in a normal digital layout to reduce their in-circuit resistance. Each solder or header connection may be expected to contribute up to 10mΩ, emphasizing the importance of trace resistance reduction. Table 2 shows typical resistance in mΩ/inch for standard conductor widths and thickness.

Through-hole *via* connections may each have 15mΩ resistance. If a power trace traverses through a board, use multiple vias to reduce the interconnect resistance. Placing traces on both sides of the board, connected with multiple vias, can cut the trace resistance in half. Solder plating on the solder-side also reduces trace resistance.

Short and wide same-side traces generally reduce voltage drop. Ground planes should have a separation line between output ports to isolate transient droop during hot-attachment. Ground planes are good thermal radiators and provide EMI suppression.

Conductor Thickness	Conductor Width (inches)	Resistance (mΩ/inch)
½ oz/ft^2	0.025	39.3
	0.050	19.7
	0.100	9.8
	0.200	4.9
1 oz/ft^2	0.025	19.7
	0.050	9.8
	0.100	4.9
	0.200	2.5
2 oz/ft^2	0.025	9.8
	0.050	4.9
	0.100	2.5
	0.200	1.2
3 oz/ft^2	0.025	6.5
	0.050	3.2
	0.100	1.6

Table 2. Trace Resistance

Figure 2 shows the various voltage drops for a self-powered hub caused by printed circuit trace resistance, solder joints, power switches, and ferrite beads on power and ground leads. Traces which carry the combined current from the input should be made heavier to minimize voltage drops, or separate wide traces should be laid out directly from the input filter capacitor to each switch input pin.

Voltage Drop Analysis

Adding the drops to the minimum output voltage of 4.75V shows that a minimum input of 4.85V is needed to ensure adequate output. The overall voltage drop to each port, caused by the printed circuit board and overcurrent protection device, is recommended to be less than 100mV. Ground traces are as important as power traces, as all voltage drops are in series. The voltage drop across a self-powered hub board has three components: board (V_{PC}), protection (V_P), and output filter (V_{FB}).

V_{PC} is the trace resistance of the power and ground paths, approximately 15mΩ each, times 0.5A.

$$V_{PC} = 2 \times 0.015\Omega \times 0.5A = 15mV$$

V_{FB} is the resistance of two ferrite beads and their solder joints, approximately 15mΩ each × 0.5A

$$V_{FB} = 2 \times 0.015\Omega \times 0.5A = 15mV$$

$$V_{PC} + V_{FB} = 15mV + 15mV = 30mV$$

The maximum voltage drop recommended across a self-powered hub is 100mV, so the loss in the protection device (V_P) should not exceed 70mV:

$$V_P = 100mV - 30mV = 70mV$$

At an output port current of 500mA, the per-port protection device's resistance may be up to 140mΩ:

$$V_P = 140m\Omega \times 0.5A = 70mV$$

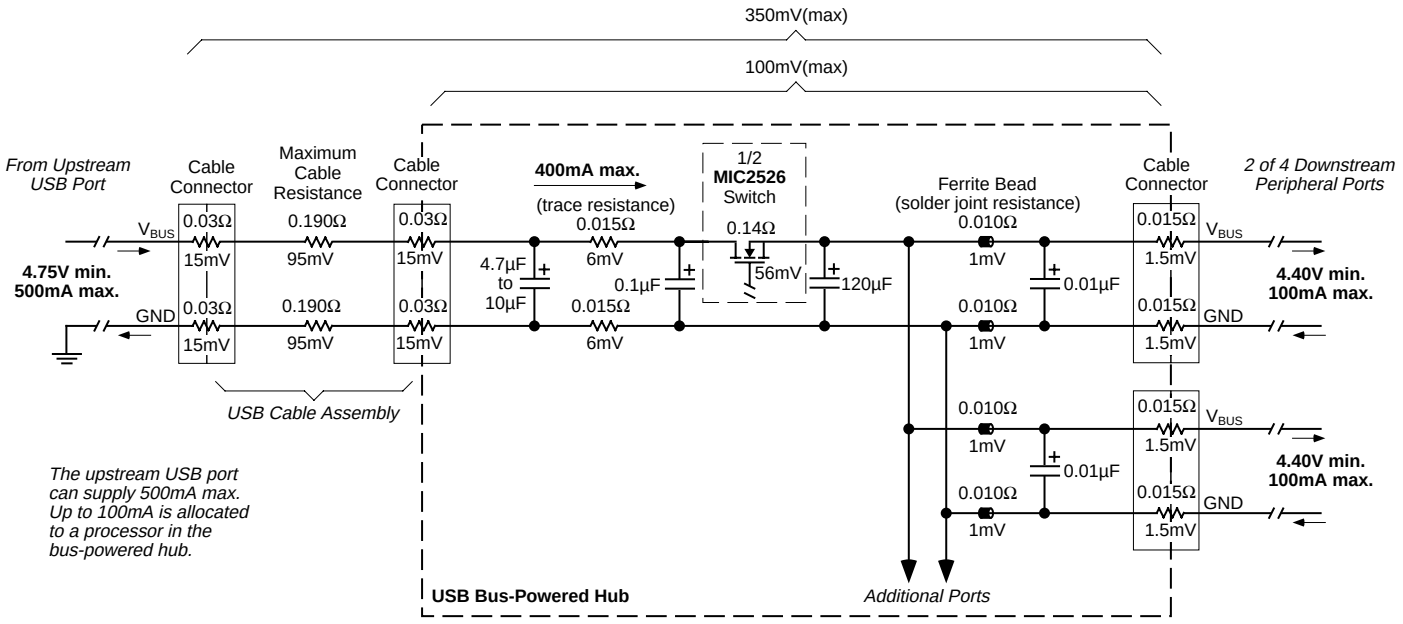

Figure 4. Bus-Powered Hub Voltage-Drop Analysis

Component Selection

Due to the limited voltage drop budget allowed for self-powered hubs, each component must be evaluated for its contribution to voltage drop.

Polyfuse Protection Limitations

Most resettable Polymer Positive Temperature Coefficient Fuses (PPTC—polyfuse) are not suitable as the sole over-current protection in USB self-powered hubs. A self-resetting 2.5A PPTC may take up to 100 seconds to trip at 5A. The voltage drop due to the higher on-resistance of lower current-rated polyfuses placed on individual ports may exceed the 100mV self-powered hub drop budget.

Polyfuse Resistance Increases

Polyfuses may permanently increase resistance after a trip event or exposure to high temperature, such as wave-soldering. A typical 0.11A polyfuse specified to pass 0.67A at 70°C, requires 5 seconds to trip with a 5A load. Its pretripped on-resistance ranges from 50mΩ to 100mΩ at 25°C ambient, rising permanently to approximately 170mΩ after an initial trip. This exceeds the 140mΩ resistance recommended by USB. Polyfuses require additional components to be switched off or reliably report overcurrent.

Power Regulators

Linear regulators may be used to provide cost-effective closely-regulated standard voltages from unregulated power supplies. Low-dropout (LDO) regulators provide current-limited, ±2% regulated output over a wide range of input voltage and output loads. LDO regulators have a logic enable pin and an error flag output that indicates current limiting or undervoltage.

5V LDO regulators can provide regulated voltage output with as little as 5.35V input under full load. Micrel's MIC29301 LDO regulator is rated for continuous 3A output with a typical 3.8A current limit and short-circuit limit of less than 5A. MIC29301 has a logic-level, noninverting, output-enable pin that allows the output to be turned on or off, and an open-drain error flag that conducts to ground if the device is in current limit or undervoltage lockout (low input—excessive dropout). Figure 5 shows a stand-alone self-powered hub using an MIC29301-5.0.

Integrated High-Side Power Switches

For hubs with a regulated power supply, integrated power switches provide an economical, robust power management solution. Micrel's MIC2505/25 single and MIC2506/26 dual switches react quickly to overloads, providing safety margin and overall power control and have an error flag output. The enable feature is available as inverting or noninverting logic, allowing flexibility in choice of hub controllers. All integrated switches are guaranteed to survive an output short circuit with a 5.25V input. Table 3 shows the characteristics of Micrel's USB power switches.

Part Number	Switches	Logic	I_{OUT}	R_{ON}
MIC2505-1	single	noninverting	2.0A	35mΩ
MIC2505-2	single	inverting	2.0A	35mΩ
MIC2506	single	noninverting	1.0A	70mΩ
MIC2525-1	single	noninverting	0.5A	140mΩ
MIC2525-2	single	inverting	0.5A	140mΩ
MIC2526-1	dual	noninverting	0.5A	140mΩ
MIC2526-2	dual	inverting	0.5A	140mΩ

Table 3. Micrel Switches

Individual- and Ganged-Port Switching

Individual-port switching offers several advantages over ganged-port switching. If a fault should occur on one port, the other ports remain unaffected, while a ganged-port switch would disable all ports. Individual-port control also offers superior transient droop performance since ports have isolation from each other. Individual-port control advantages apply to both self-powered and bus-powered hubs.

Individual Port Control

Figure 6 in the circuit examples section shows a self-powered hub using two MIC2526 dual 500mA switches to control four individual ports. If the USB controller has a single output enable or overcurrent detection pin, the respective inputs or outputs may have a common connection. An external digital latch on each enable pin could be used to disable individual ports during an overcurrent condition, allowing the other ports to continue to operate.

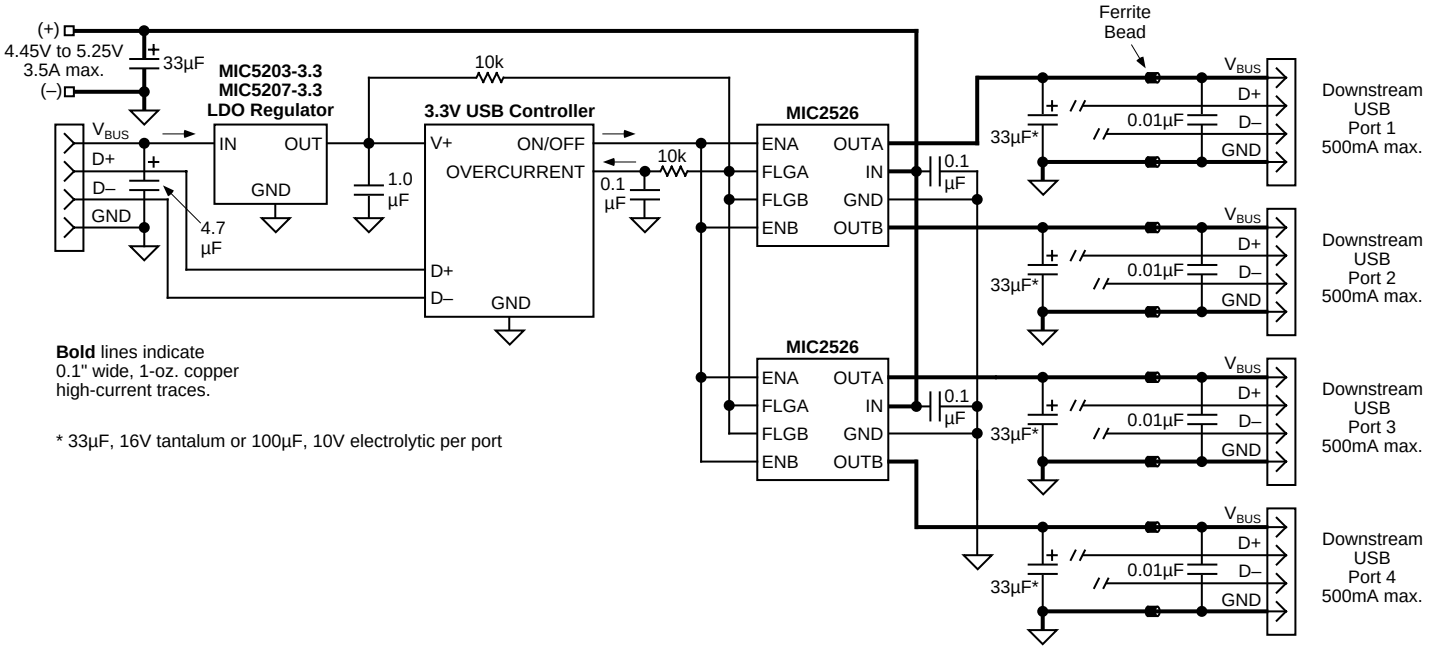

Figure 6. Regulated-Input Self-Powered Hub

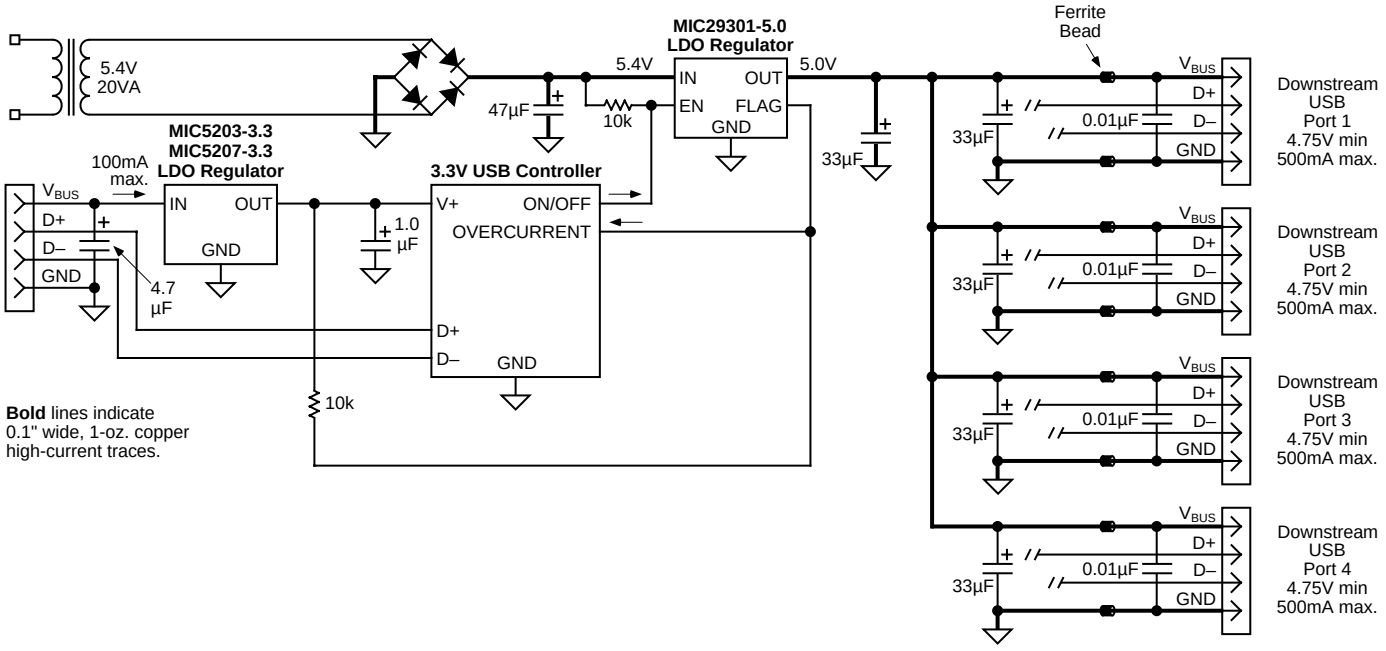

Figure 5. Simple Stand-Alone Self-Powered Hub

Ganged Overcurrent Limiting

Figure 7 shows a ganged-output, self-powered hub using a single MIC2505 2A switch to protect up to four outputs. Output filters with two ferrite beads per port satisfy USB requirements by preventing hot-attach transients at one port from causing transient voltage droop of more than 330mV on adjacent ports.

Bus-Powered Hub Requirements

USB specifies that bus-powered hubs have power switching for their downstream ports, so that downstream current may be enumerated and controlled. Port power is switched under host software control on an individual port basis or by a single switch for all ports (gang-mode power control). Port power is not switched off during a reset, so that attached devices may be monitored. The upstream cable connector must receive a minimum of 4.75V, while each downstream port provides a minimum of 4.40V at 100mA. Bus-powered hubs obtain all power from an upstream self-powered hub. They may draw up to 100mA upon power up. After configuration of internal functions and downstream ports, a maximum of 400mA is allocated up to a maximum of four downstream ports. Each port must be capable of supplying a minimum of 100mA.

Transient Regulation

Bus-powered hubs have similar requirements to that of self-powered hubs. USB requires that voltage transients at a 4.4V peripheral port must never go below 4.07V. Layout, ferrite beads, and both capacitor value and type affect transient regulation.

Inrush Current

When power switches are energized, output capacitors may draw high inrush current causing an upstream voltage droop which could affect other circuits. USB requires that hot-attach or switched events present one unit load maximum (44Ω min. with 10µF max.). High inrush current may also cause EMI or damage tantalum capacitors. Micrel's power switch products eliminate these problems by providing soft start which limits inrush current. Micrel's MIC2526 high-side switches have a charge pump which slows turn-on time between 1 and 2ms.

Suspend Power

When a hub is suspended, downstream ports are still powered. When downstream devices are suspended, the maximum allowed average current per port is 500µA including the data line pull-up resistors and power switch operating current.

Voltage-Drop Regulation

A 350mV maximum total drop is allowed from an upstream self-powered hub connector to bus-powered hub downstream socket connector, as shown in Figure 4. This drop includes the cable, connectors, switch, and board. An *attached* cable may have 20mΩ per IDC header, or soldered connection, instead of 30mΩ per USB cable connector contact, providing a larger voltage margin for the hub components. Standard length cables have a wire size chosen to produce a voltage drop of less than 190mV for two conductors at 500mA current. Shorter cables, using the same gauge wire, produce a smaller voltage drop. Figure 4 shows the component voltage drops for a typical bus-powered hub.

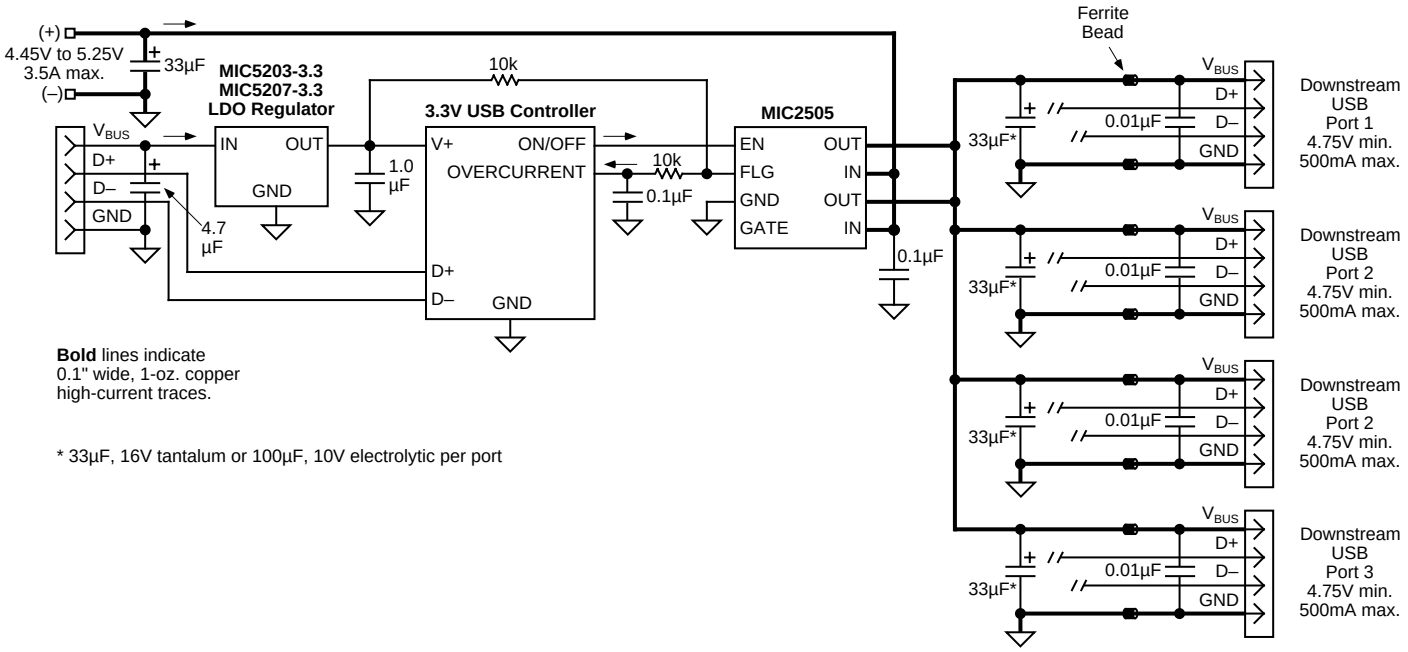

Figure 7. Ganged-Switch Self-Powered Hub

USB Cables

USB specifies the construction and wire gauge of cables used to connect host to hub to peripherals. USB also specifies a maximum cable power wire resistance of 190mΩ and a maximum cable length of 5m (3m for a low-speed attached subchannel cable) to minimize voltage drop and transmission time.

Connector Resistance

The standard mated USB connector is assumed to have 30mΩ maximum contact resistance per pin after 1500 insertions, including the solder connections to the PC board and cable wires. Since the voltage cannot be measured at the contact point, USB voltages are usually measured at the circuit board side of a connector, between the power pin and ground pin (not power supply ground).

Detachable Cables

Detachable cables have different style connectors on each end to prevent incorrect connections (for example: the downstream port of one hub to the downstream port of a second hub).

A standard USB cable has a Series A connector on the upstream end and a Series B connector on the downstream end, with 28AWG data wires and 90Ω ±15% impedance. Cables are not allowed to have the same series (A or B) connector on both ends to ensure proper data and power flow.

The maximum voltage drop allowed across a bus-powered hub and its cable is 350mV. A bus-powered hub may draw 500mA, producing a 250mV drop in a standard 190mΩ maximum cable and its connectors, leaving 100mV margin for a bus-powered hub circuit board, switch, and connectors.

Specifying an attached bus-powered hub cable simplifies the voltage drop equation by reducing cable length and the downstream connector resistance. A keyboard with a 1m cable would be a typical example of an attached cable bus-powered hub. Since the keyboard would plug into the monitor or self-powered hub near the user, it does not need a longer cable.

Lower Cable Resistance

Table 6.2 in the USB specification shows resistance per meter for various AWG wire sizes. A keyboard-based bus-powered hub, with a short 2m, 22AWG attached cable, as opposed to the standard 3.1m, 22AWG detachable cable, has a cable resistance of 114mΩ per conductor.

Four-Port Bus-Powered Hub Voltage Drop

See Figure 4 for the various voltage drops for a bus-powered hub. There are two components of voltage drop:

High Current in Upstream Cable

Use the 500mA maximum to compute the voltage drops in the upstream cable connector, cable wires, and downstream cable connector. Good layout should produce less than 35mV drop in the 500mA section of the hub printed circuit board. A ganged-output (MIC2526) has a typical on-resistance of 145mΩ, including lead solder joints, for a 400mA voltage drop of 58mV. Subtracting the above voltage drop (93mV) from the 100mV maximum, leaves 7mV for each 100mV output filter and connector.

$$V_{CON} = 0.5A \times 30m\Omega \times 4 \text{ pins} = 60mV$$

$$V_{WIRE} = 0.5A \times R_{WIRE} \times 2 \times \text{wire length}$$

$$V_{0.5} = V_{CON} + V_{WIRE} = 50mV + V_{WIRE}$$

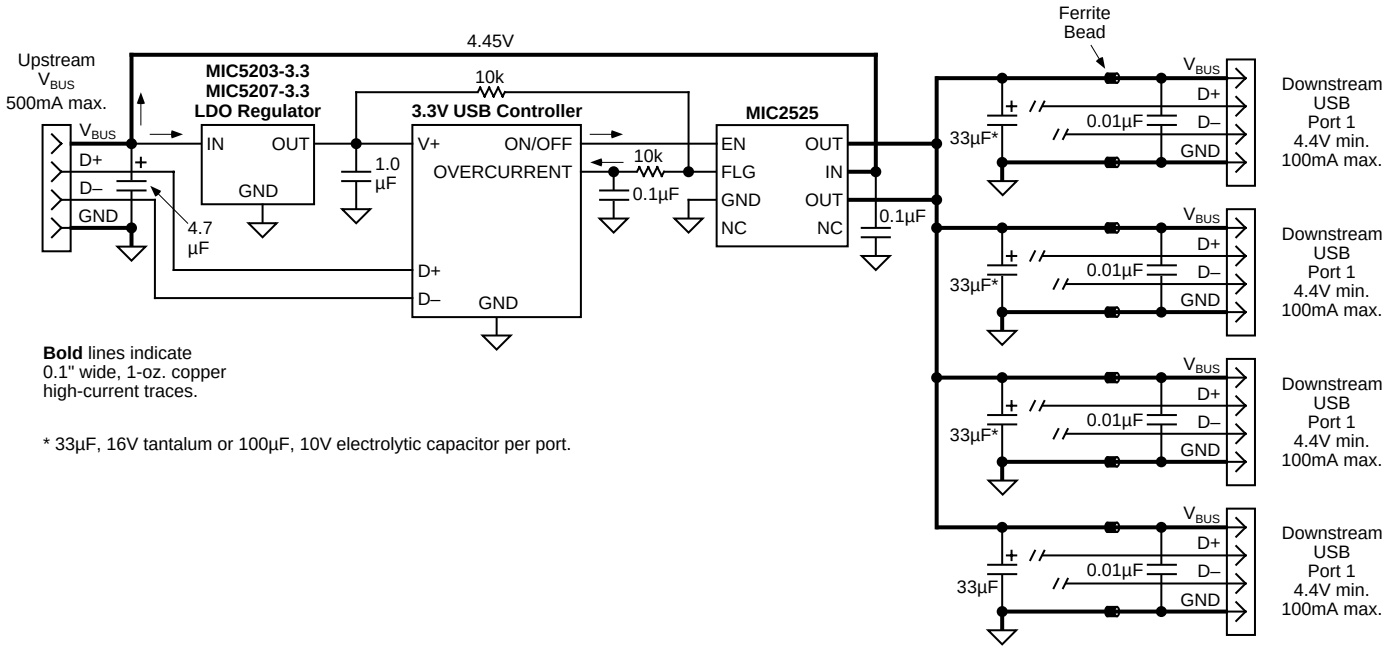

Figure 8. Ganged-Output Bus-Powered Hub

Circuit Examples

Figure 5 shows a minimal self-powered hub, using Micrel's MIC29301-5.0 3A LDO linear regulator to provide 5.0V ±2% (4.9V to 5.1V) from an *unregulated* >5.35V, 3.5A transformer-rectifier-capacitor input. The MIC29301-5.0BT has an enable pin to control ganged power, up to 3.5A, to seven downstream ports each drawing up to 500mA. The MIC29301 limits current to less than 4A with less than 5A short-circuit current. An error flag goes low if the device is in current limit, thermal shutdown, or has an excessive output voltage drop. If heavy loads cause the thermal shutdown to activate, a slow thermal oscillation may occur as the regulator heats up under load and cools down when shut-off. The hub controller may be programmed to shut down the LDO regulator after the error flag has been low for a preset time and then to periodically reenergizing the LDO regulator enable to determine if the excessive load has been removed.

Output Filter

Output ports must have a 120µF bulk capacitance per hub. Tantalum capacitors across the power and ground lines, near each downstream connector, reduce EMI and decouple voltage droop caused when downstream cables are hot-attached. Ferrite beads in series with V_{bus}, the ground line and the 0.01µF bypass capacitors at the power connector pins are recommended for EMI and ESD protection.

Flag Transient Filtering

The transient in-rush current to downstream capacitance may cause a short-duration (10µs to 20µs) error flag, which may cause erroneous overcurrent reporting. A simple 1ms RC low-pass filter (10kΩ and 0.1µF) in the flag line (see Figures 5, 6, and 7) eliminates short-duration transients.

Electrostatic Discharge Protection

Flyback transients and electrostatic discharge (ESD) may exceed the maximum operating voltage ratings of ICs. Micrel's MIC2526 has been tested and certified to exceed the requirements of IEC 1000-4-2 (EN 50082-1) for 15kV air-discharge and 8kV contact discharge with the output filters shown in the circuit examples (120µF, 0.01µF, and ferrite beads).

Although Micrel's USB switches are compliant to IEC standards for ESD protection, USB controllers may need additional ESD protection to assure a robust design. For USB controller data lines, ESD protection should also be provided protection that can be added inexpensively with external transient protection devices such as the SurgeX™ protector from Cooper/Bussman, telephone (314) 394-2877.

Self-Powered Hub with Individual Power Switches

When a local 5V $^{+5}/_{-3}$% power supply, such as a standard personal computer, provides operating voltage from 4.85 to 5.25V, protection devices with less voltage drop than a polyfuse or LDO regulator are needed. Micrel's integrated high-side power switches have low on-resistance, built-in current limiting, thermal shutdown, and logic-level enable. The worst-case voltage drop recommended across the self-powered hub board, MIC2526, and ferrite beads is 100mV, guaranteeing 4.75V at the downstream output port.

Figure 6 illustrates a self-powered hub with up to four downstream 500mA switched ports, using two MIC2526 dual 0.5A power switches.

Figure 7 shows a four-port self-powered hub, using a single MIC2505 2A power switch to provide ganged power from a 5V $^{+5}/_{-3}$% regulated local supply.

Ganged-Output Bus-Powered Hub

Figure 8 shows a single MIC2525 140mΩ switch providing ganged power switching to four downstream ports. The single power switch controls all downstream ports, with soft start limiting the inrush current to the four downstream 33µF capacitors when the switch is enabled. A low-cost MIC5203 (SOT-143) or MIC5207 (TO-92) 3.3V low-dropout (LDO) regulator provides power from the bus to the USB controller.

Summary

Micrel's logic-controlled high-side power switch integrated circuits are ideal for USB power switching applications. Each offer superior protection and performance relative to polyfuses. In addition, proper PCB layout techniques are highly recommended to ensure that both USB voltage regulation and transient regulation specifications are satisfied.

Printed Circuit Layout Hints

- Power Traces
  - wide, heavy copper
  - short, straight traces
  - “star” from input filter capacitor
  - same side, no vias
- Ground
  - wide ground plane
  - same side, no vias
- Switches
  - wide power input traces
  - 0.1µF ceramic input bypass close to IC
  - wide power output traces
  - IC placed near output port
  - “star” power traces from input capacitor
  - power traces on same side, no vias
- Output Filter
  - close to output port
  - 120 µF tantalum, 10V
  - 0.01µF ceramic 25V bypass
  - ferrite bead on power lead
  - ferrite bead on ground lead
  - connector shield to ground plane
- Thermal Management
  - ground plane under switch
  - wide traces to all IC pins
  - thermal paste or adhesive under IC
  - maximum copper area, both sides
  - air circulation inside and outside

Definitions

Controller

A microprocessor which implements the Universal Serial Bus protocols.

Host

The root hub host computer system where the Universal Serial Bus host controller is installed. This includes the host hardware platform (CPU, bus, etc.) and the operating system in use.

Host Controller

The host’s Universal Serial Bus interface.

Hub

A Universal Serial Bus device which repeats data and provides additional connections to the Universal Serial Bus.

Bus-Powered Hub

Receives operating power from the upstream port, up to 500mA.

Root Hub

A Universal Serial Bus hub directly attached to the host controller. This hub is attached to the host; tier 0.

Self-Powered Hub

Draws less than 100mA from upstream port, provides downstream power from 5V +5/–3% internal power supply and up to 500mA per port, 3.5A per protection device.

Port

Point of access to or from a system or circuit. For Universal Serial Bus, the point where a Universal Serial Bus is attached.

Downstream Port

The direction of data flow away from the host. A downstream port is the port on a device electrically farthest from the host that generates downstream data traffic from the hub. Downstream ports receive upstream data traffic.

Root Port

The upstream port on a hub.

Upstream Port

The direction of data flow toward the host. An upstream port is the port on a device electrically closest to the host that generates upstream data traffic from the hub. Upstream ports receive downstream data traffic.

Unit Load

Not more than 100mA power drain under normal operating conditions, with a 4.4V bus.

Universal Serial Bus (USB)

A collection of Universal Serial Bus devices, software, and hardware that allows them to connect the capabilities provided by functions to the host.

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