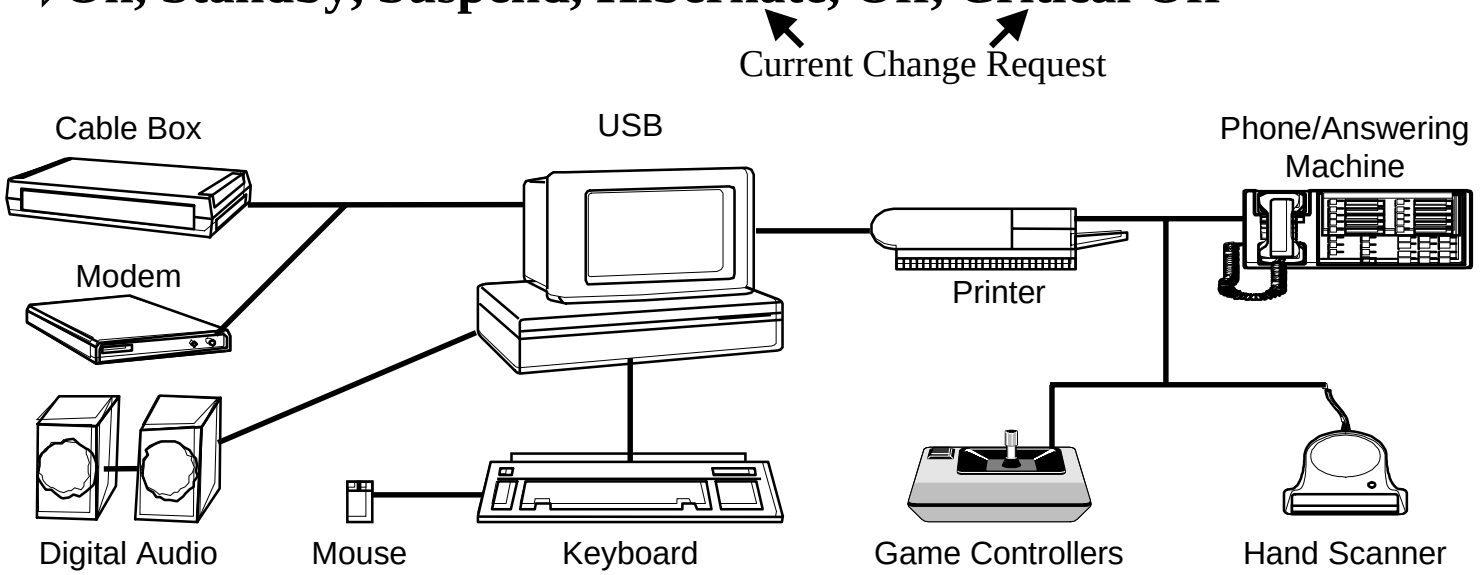

# Power Management

TEXAS
INSTRUMENTS

# What is Power Management

- **Power Budgeting**
  - **Evaluate Device Requirements**
- **Device Power States**
  - **On, Standby, Suspend, Off**
- **Global System Power States**
  - **On, Standby, Suspend, Hibernate, Off, Critical Off**




TEXAS INSTRUMENTS

UNIVERSAL SERIAL BUS

# Power Budget

- Unit Loads
  - Low & High Power Sources
  - Low & High Bus-Powered Devices
- Power sources
  - Bus powered
  - AC powered
  - Battery powered

# Device Power States

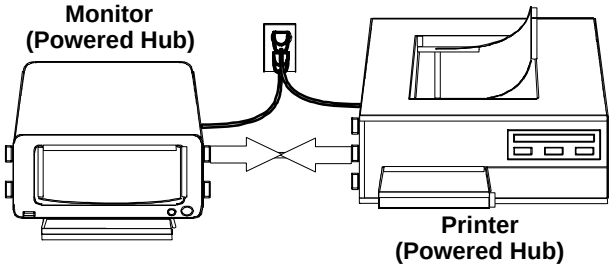
- Off, Low power, High power
- Standby - Reduced power
- Suspend - Lowest power state
  - Normal device operation ceases
  - Increased response time
- Device may wakeup the system
  - External event may restart system

# Hubs

- Power Type
  - Self Powered
  - Bus Powered
    - 4 external ports (max)
- HUB Types
  - Standalone
  - Compound
    - Embedded Device
    - External Ports

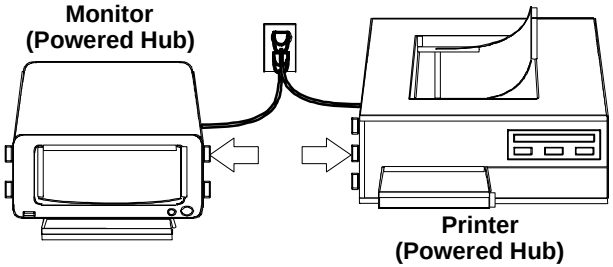
# Hot Attach

- Inrush limiting
- Attach detection
- System Notification
- Device Enumeration
- Device Configuration
- Power Allocation




# Device Removal

- Removal Detection
  - Transfer failure
  - Bus management
- Bandwidth Deallocation
- Power Deallocation
- Unloading Device Driver




TEXAS INSTRUMENTS

UNIVERSAL SERIAL BUS

# System Suspend

**DEVICE REQUIREMENTS:**

- All USB devices must support Suspend
- Max. suspend current <500ua
  - Bus termination ~320ua
- Device maintains state information
- Optional Remote wakeup

**DRIVER REQUIREMENTS**

- Connect to USB PM services
  - Suspend request
  - Suspend grant
  - Critical off
  - Resume notification
  - Optional
    - Save device specific info.
    - Selective suspend

**USB SERVICES:**

- Interface to O/S Power Management
- Notify Drivers of PM event
  - Responsible for sequencing
- Shutdown USB after all drivers suspend
- Restart activity on resume or wakeup
- Notify Drivers of Resume event
- Enumerate bus to detect device changes

# Suspend vs Hibernation

**SUSPEND**

- **System software suspends the device by turning off the device port in the upstream hub**
- **Device suspends when it detects lack of bus activity (3ms)**
- **Device wakeup request**
  - **Detected via USB bus poll**
- **Driver notified by bus enumerator**

**Current Change Request**

**HIBERNATION (Class Specific)**

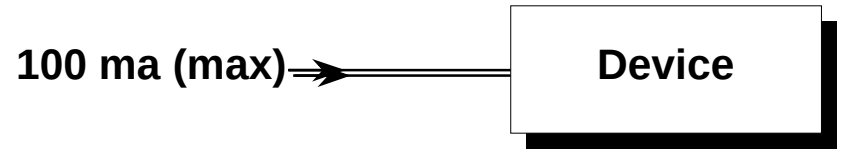
- **To USB device drivers, hibernation looks like suspend, except, device state is lost**
- **System may transition directly to hibernation from suspend**
- **Device driver responsible for saving device data needed to resume the device**

# Active Power Control

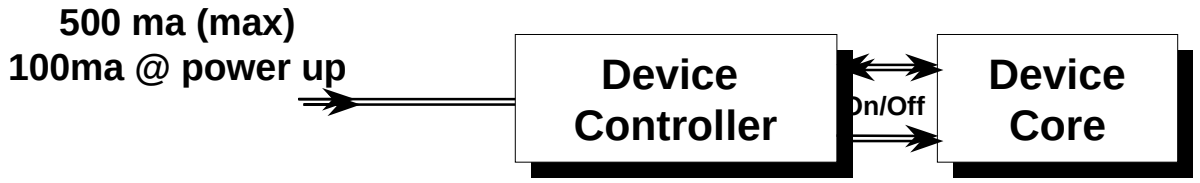
- Host sets device power policy
- Contract between driver and device
  - Minimize power consumption
- Device Design Guidelines
  - Stop clock idle detection
  - Idle time-outs
  - Multiple operational power levels
    - i.e.. disk rotational rates, TX power level
- Device Driver Guidelines
  - Suspend device during idle time
  - Device idle timers minimize bus traffic
  - Tradeoff performance vs. power
  - Comprehend latency of power level (i.e.. spin up time)

# Device Powering

Low Power bus powered device




High power bus powered device



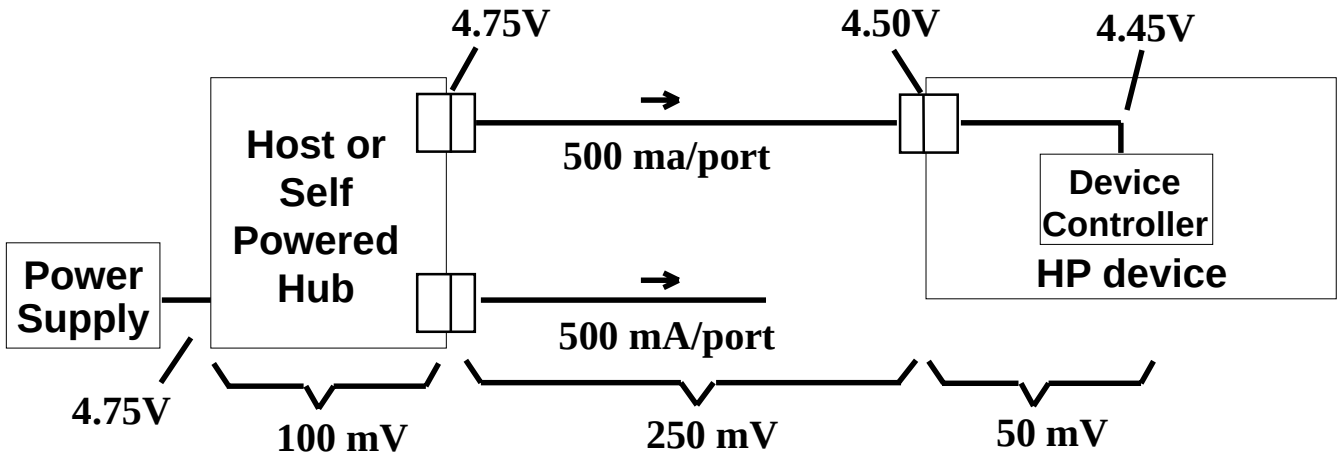

Locally powered device


- **Operating Power Levels**
  - **Low Power: 100mA or less**
  - **High Power: 500mA or less (Power up at 100mA or less)**
  - **Local Power: No power limit, may draw power from bus**

# Voltage Drop/Droop Requirements

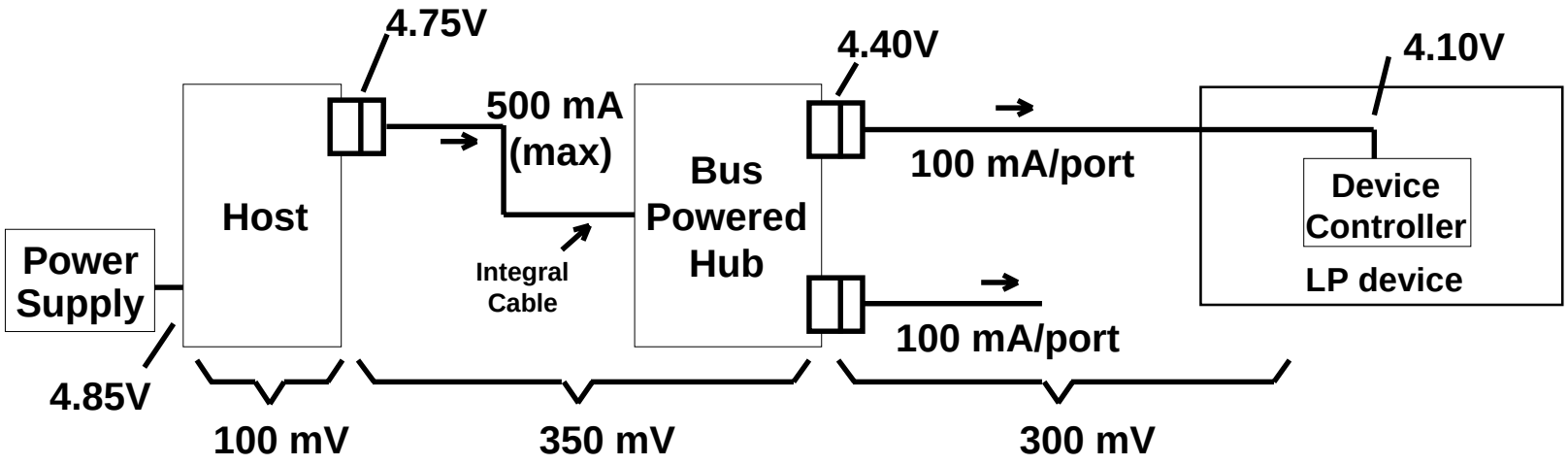
- **Must consider cumulative voltages drops in cables, connectors, pc board traces, current limit devices, etc.**
- **$V_{BUS(min)}$ determined by $V_{DROP}$ and $V_{DROOP}$**
  - **$V_{DROP}$ caused by IR drop in cables, connectors, etc**
  - **$V_{DROOP}$ caused by inrush current during hot plug**
- **$V_{BUS(min)}$ set by $V_{CC(in)}$ voltage regulator**
  - **Assumes a 500mv dropout for a 3.3V ± 5% regulator**
  - **$V_{BUS(min)}$ = 4.0V measured at regulator input**
- **Must consider different topologies**
  - **Host to high-power device or bus-powered hub**
  - **Host through bus-powered hub to low-power device**

# $V_{DROP}$ : Host to Self-powered Hub




- Power Supply 5.00v +/- 5%
- Host can drop 100mV
  - traces, ferrite beads, connector, current limit device
- Detachable cable can drop 250mV max @ 500mA
- Bus-powered device may drop 50mV max
  - traces, connectors, etc

# $V_{DROP}$ : Host to Low-powered Device

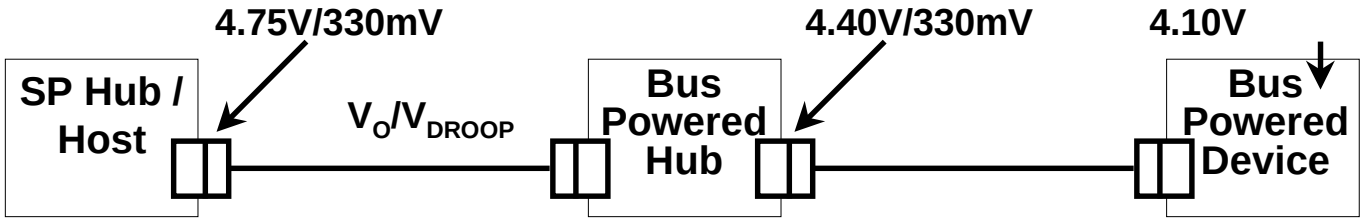



- **Bus-powered hub with integral cable can drop 250mV max.**
  - **connector, traces, power distribution switch, ferrite beads, etc**
- **To meet system power distribution requirements the Bus-powered Hub may require an integral cable.**

# $V_{DROOP}$ & Inrush Current Limiting

**DESIGN REQUIREMENTS:**

- **330mV max. $V_{DROOP}$ when hot-plugging to SP Hub**
- **Maximum load at downstream cable end is 10μF in parallel with 44Ω**
- **Output port power lines must be bypassed with no less than a 120μF tantalum capacitor**
- **Bus-powered Hubs must provide surge limiting**
  - **Soft start when enabling downstream ports**

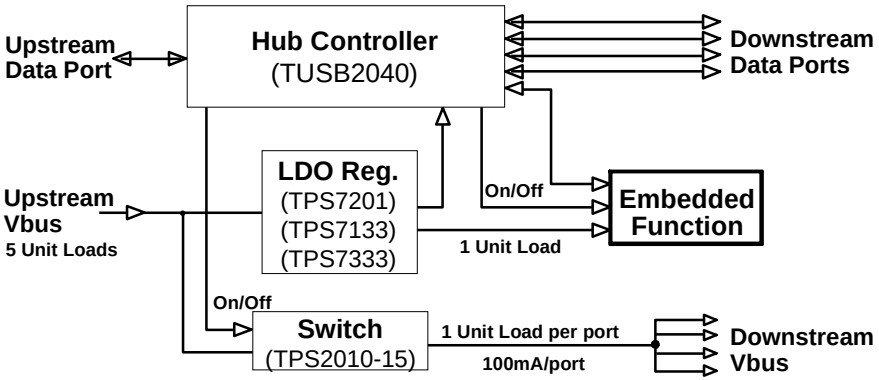



TEXAS INSTRUMENTS

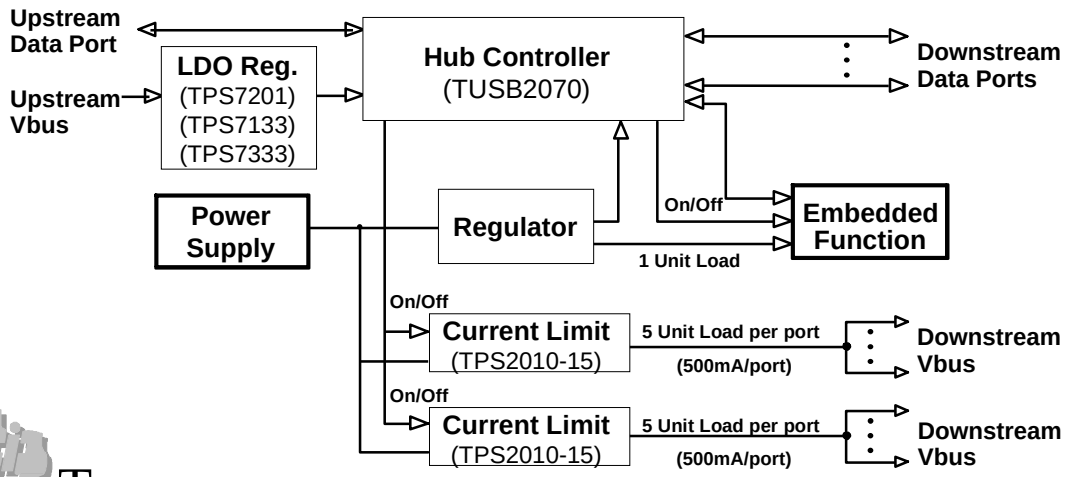
UNIVERSAL SERIAL BUS

# Hub Power Dist. Requirements

## USB Bus-Powered Hub




## USB Self-Powered Hub




**Bus-Powered Hubs:**
Draws all power from USB connector power pins
**Self-Powered Hubs:**
Internal function and downstream port power does not come from USB.

**Low Powered Function:**
1 Unit Load = 100mA
**High Powered Function:**
5 Unit Loads = 500mA

**USB Switch Application:**
The Host and all Self-powered hubs must implement over-current protection. They must detect the overcurrent condition and report it to the USB Host Controller. The controller will then remove power to that port.

**LDO Regulator:**
Each hub must run on 3.3V. The Vbus supplies 5V nom and inputs may be as low as 4.40V. A 500mV max dropout voltage is recommended.

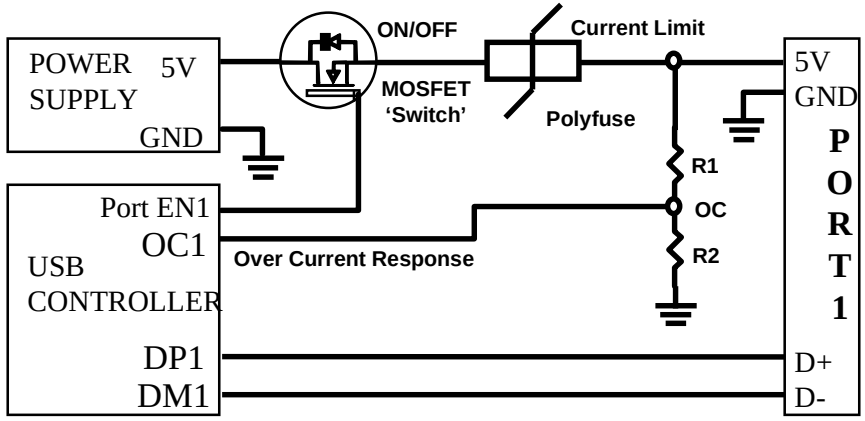
TEXAS INSTRUMENTS

# Polyfuses vs MOSFET Switches

| | Polyfuse | MOSFET |
|---|---|---|
| Report Overcurrent Condition | NO | YES |
| Fast Response Time | NO (150ms) | YES (45µs) |
| Limit Output Current < 5A | YES | YES |
| Meets $V_{DROP}$ Requirements (90mV) | 2.5A Device | YES |
| Meets $V_{DROOP}$ Requirements (330mV) | NO | YES |
| Enabled/Disabled by Controller | NO | YES |

**Complete Polyfuse Solution with Enable and Over Current Response**

**Polyfuses do <u>NOT</u> meet all of the requirements of the USB specification**




**Intelligent MOSFET switches do meet all of the requirements of the USB specification**

TEXAS INSTRUMENTS

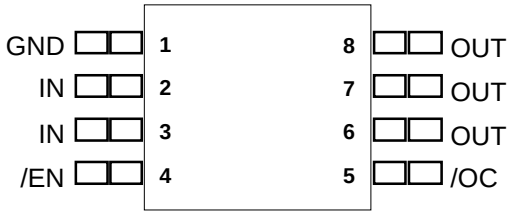
# TPS2014/15 Power Dist. Switches

**TPS2014/15**

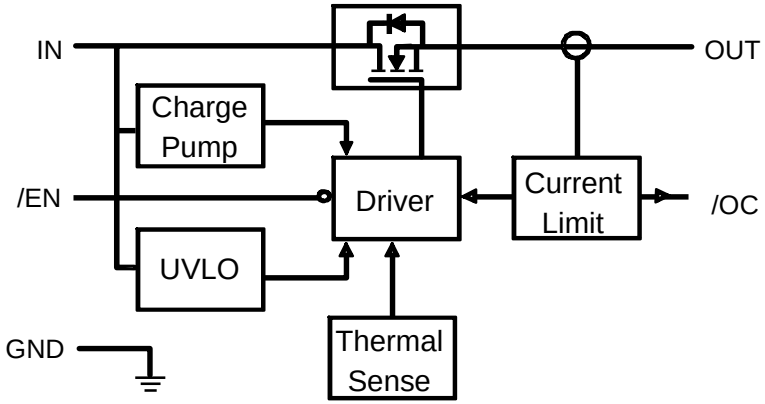
- High-Side MOSFET Switch
  - 95 m Ω max $r_{DS(on)}$ (5.5-V input)
  - TPS2014: 0.6A continuous, 1.2A current limit
  - TPS2015: 1.0A continuous, 2.0A current limit
- 2V Logic Compatible Enable Input
- **Overcurrent and Thermal Protection**
  **With Overcurrent logic output**
- 4.0V to 5.5V Operating Range (7V max)
  (Due to UVLO)
- Controlled Rise and Fall Times limits
  Current Surges and minimizes EMI.
- **Undervoltage Lock-Out Guarantees the Switch is Off at Power Up**
- Thermal Protection
- 10µ A Maximum Standby Current

- Applications
  - **USB** Bus-Powered and Self-Powered Hubs
  - Hot insertion applications
  - Power Distribution

**D PACKAGE**




**(TOP VIEW)**




**Maintenance Free Over-Current and Thermal Protection**

TEXAS INSTRUMENTS

UNIVERSAL SERIAL BUS

# Non-Ganged Hub Power Dist.

BOM for Non-Ganged Configuration:

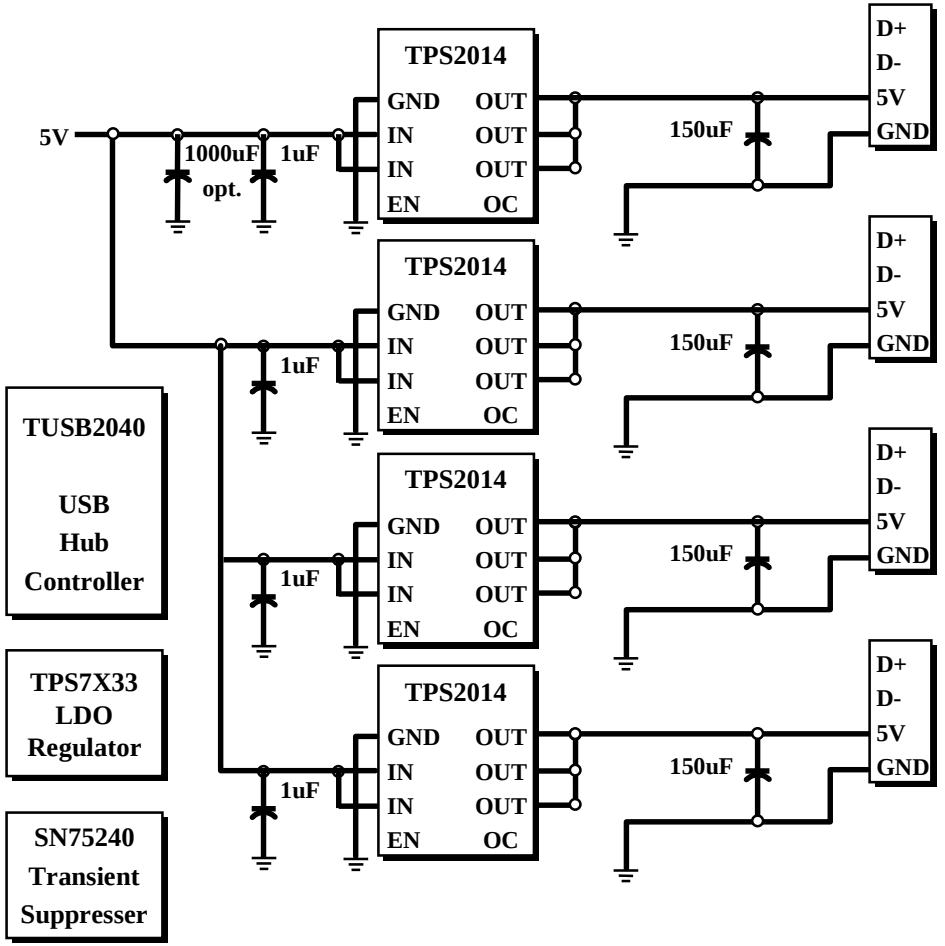
| | |
|---|---|
| **TUSB2040** | **QTY 1** |
| **TPS75240** | **QTY 2** |
| **TPS7133** | **QTY 1** |
| **TPS2014** | **QTY 4** |
| **Ferrite Beads** | **None** |
| **Cap, 150uF (USB req.)** | **QTY 4** |
| **Cap, 1000uF (option)** | **QTY 1** |
| **Cap, 1uF** | **QTY 4** |

PROS:

**Lower Current Devices**
**No Ferrite Beads Required**
**Good Voltage Droop Response**
**Faults only shut down the Port affected (most user friendly)**

CONS:

**Highest Cost solution**



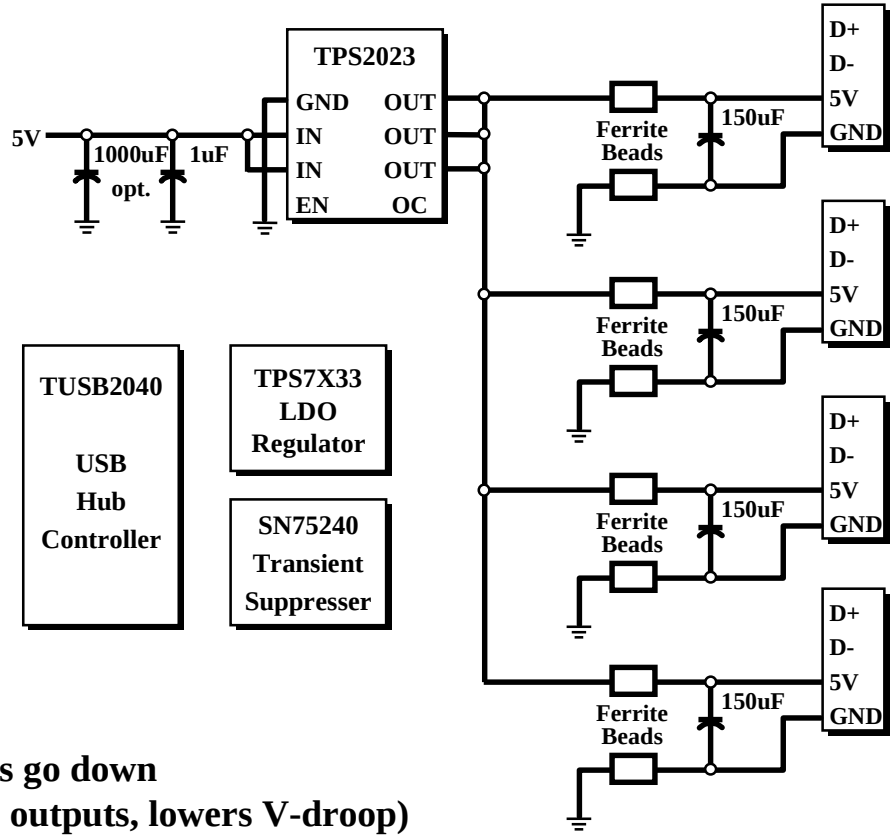

TEXAS INSTRUMENTS

UNIVERSAL SERIAL BUS

# Ganged Hub Power Distribution

BOM for Ganged Configuration:

| | |
|---|---|
| **TUSB2040** | **QTY 1** |
| **SN75240** | **QTY 2** |
| **TPS7133** | **QTY 1** |
| **TPS2023** | **QTY 1** |
| **Ferrite Beads** | **QTY 8** |
| **Cap, 150uF (USB req.)** | **QTY 4** |
| **Cap, 1000uF (option)** | **QTY 1** |
| **Cap, 1uF** | **QTY 1** |




PROS:

**Most Cost Effective**
**Lowest IC Count**

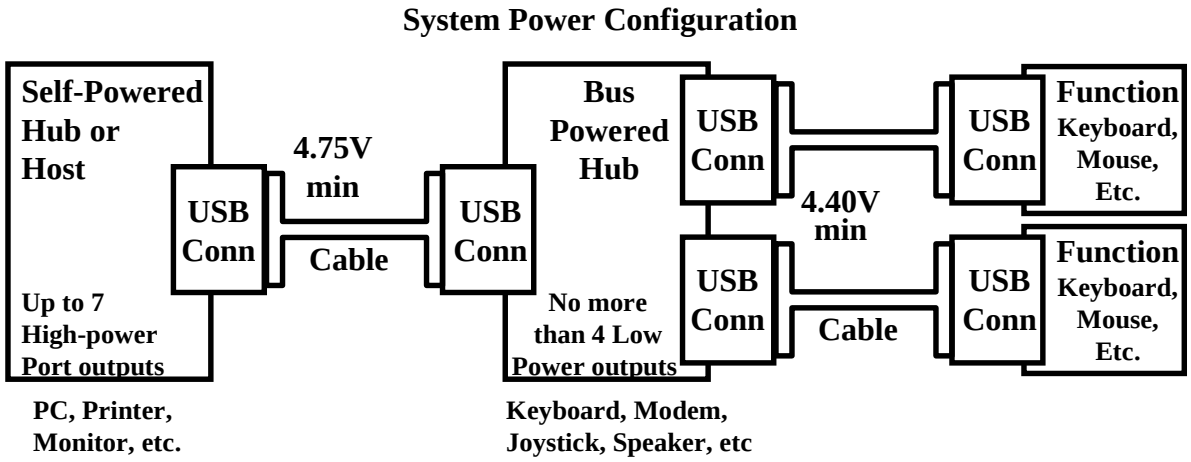
CONS:

**Fault on one port shuts down switch, and all ports go down**
**Ferrite Beads required (adds impedance between outputs, lowers V-droop)**
**Higher current devices required (4 X 500mA = 2A min, with 5A UL max)**

TEXAS INSTRUMENTS

# Summary

- **USB power management was designed in from the start**
- **Well suited for power managed desktop & laptop computers**
- **Illegal topologies gracefully rejected**
- **Designs must pay strict attention to $V_{DROP}$ and $V_{DROOP}$ req.**
- **Current limit devices, power switches, and LDO regulators are required by the USB spec.**
- **Polyfuse, in general, are not an adequate current limit device for power management**




TEXAS INSTRUMENTS