Thunderbolt™ Technology Reference Guide

What is Thunderbolt™ technology

Thunderbolt™ Technology is a new high-speed I/O technology developed by Intel Corporation. Each Thunderbolt™ technology interface consists of two 10.3 Gbps full-duplex data paths. The interface takes existing PCI-Express and DisplayPort and joins them together into a single data signal. This is accomplished by the Intel developed controller. In the host PC, the controller takes in the PCI-Express from the I/O controller hub and the DisplayPort from either the native signal in the I/O controller or from a discrete graphics controller. This combined signal is sent via a full-duplex pair of differential signals. Each controller has two ports available to enable daisy chaining.

The specification has chosen the mini-DisplayPort connector, which has been repurposed for the Thunderbolt™ technology signaling. However, the specification does enable backwards compatibility and is capable of accepting a standard DisplayPort connection as well.

The cables can be either electrical or optical, but must be active in either case to insure appropriate signal integrity at the receiving end. For an active copper-based cable, 3 meters is the approximate length limit; however, using an optical cable enables distances in the tens of meters range. The peripheral system will receive the signal in a controller that will extract the PCI express and DisplayPort signals.

How does Thunderbolt™ technology change the PC industry?

Thunderbolt™ technology enables transmission of both data (PCI-Express) and video (DisplayPort) over a single small form-factor cable. This enables extending the “internal” PC data bus into the peripheral. This enables designers to create innovative new PC products and configurations, no longer constrained to the boundaries of the chassis walls. This enables very small form factor host systems that utilize only the Thunderbolt™ technology connector and new “docking” environments that enable the full PC I/O experience such as USB 3.0, eSATA, flash card, Ethernet in addition to the video.

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TPS22980/1 3V to 19.8V Power Mux with Overcurrent Limiting

Description
The TPS22980/1 is a current-limited power mux providing downstream power to a cable and peripheral device from either a low voltage supply (3V to 3.6V) or a high voltage supply (4.5V up to 19.8V). The desired output voltage is selected by digital control signals. Switching from a low voltage supply to a high voltage supply enables downstream peripherals to increase the available power delivered from a host.

The high voltage (VHV) and low voltage (V3P3) switch current limits are set with external resistors. Once the current limit is reached, the TPS22980/1 will control the switch to maintain the current at this limit.

When the high voltage supply is not present, the TPS22980/1 will maintain the connection to the output from the low voltage supply. Upon the presence of a high voltage power supply and the high voltage enable signal, the high voltage switch will close in conjunction with the low voltage switch until a reverse current is detected on the low voltage switch, allowing a seamless transition from low voltage to the high voltage supply with minimal output droop and shoot-through current.

The TPS22980/1 is the ideal solution for switching power from a Thunderbolt™ host to downstream peripherals.

Features and benefits
• Provides a 3V to 3.6V low voltage power switch to support Thunderbolt™ technology applications
• Provides a 4.5V to 19.8V high voltage power switch to support Thunderbolt™ technology higher power applications
• Adjustable current limits in each switch enable protection from over current conditions.
• Thermal shutdown adds added protection to the host system from overcurrent events.
• Reverse current blocking prevents back-powering the host from powered peripheral systems.

TPS22986 3V to 3.6V Automatic Power Mux

Description
The TPS22986 is a supply selection device selecting an available 3.3V from two supply inputs and connects this to the outputs. If 3.3V is not present, the outputs are high impedance.

The TPS22986 has two modes. In Normal Mode, the two outputs are independent with 10mA capability and 500mA capability. One output is automatic and one is controlled by a digital input control signal.

In Control Mode, the low current output behaves the same as Normal Mode and the high current output is controlled by a combination of monitored digital input signals and valid voltages on the two supply inputs. In this mode, the TPS22986 monitors slow speed UART traffic and automatically enables the switches.

In either mode, when a valid supply is not available, the TPS22986 will open all switches and the outputs become high impedance. If the connected supply exceeds 3.6V maximum, it is disconnected from the outputs to protect the powered active circuitry.

The TPS22986 is the ideal solution for switching power inside a Thunderbolt cable to its active circuitry.

Features and benefits
• Provides a 3V to 3.6V low voltage power switch to support Thunderbolt™ technology applications
• Automatically detects an available power supply from each end of the Thunderbolt™ cable to provide power to the active cable.
• UART signal monitoring provides automatic supply switching to power the active Thunderbolt cable.
• Provides switching between supplies while maintaining necessary power supply conditions to prevent brownout.
• UART signal buffering prevents back-powering and loading of other UART devices on the bus.
**TPS55340 Boost converter with integrated MOSFET**

**Description**
The TPS55340 is a boost converter with integrated 5-A (peak), 40-V power switch. It is ideal for size constrained applications, yet delivers high output currents from a small 3x3mm 16 pin QFN package. The input voltage range is 2.9V to 38V to accommodate single-cell and multiple-cell lithium ion batteries, as well as standard bus voltages. The maximum output voltage can be programmed up to 38V. The switching frequency is set by an external resistor from 100kHz to 1.2MHz to allow optimization for size or efficiency, and can also be synchronized to an external clock signal.

**Features and benefits**
- Integrated 60mΩ Low-Side MOSFET Delivers High Output Power & Efficiency
- High Light-Load Efficiency with Pulse-Skipping and 500μA Quiescent current Saves Energy
- 3x3mm QFN Supports High Power-Density Designs.
- Meets Thunderbolt Host Power Specification to provide 30W

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**DS100TB211 Low Power, Dual Lane Signal Conditioning Retimer**

**Description**
The DS100TB211 is a dual lane bi-directional signal conditioning retimer with an input Continuous Time Linear Equalizer (CTLE), clock and data recovery (CDR), and an output driver for Thunderbolt cable and peripheral applications. Each channel of the DS100TB211 independently locks to serial data at a nominal 10.3 Gbps rate without the need for any external reference clock reducing system BOM cost and board space. The fully adaptive receive equalization with a powerful 36 dB gain stage enables 3m+ of thin, inexpensive 40-AWG copper cable with multiple connectors. The CDR function resets the jitter budget to ensure an error free operation. Advanced cable diagnostic features such as on-chip receiver eye processing on each of the input channel reduce manufacturing cost and time. Offered in a tiny 5mm x 5mm QFN package and powered using a single 2.5v power supply, the DS100TB211 consumes less than 250 mW per bi-directional lane and can be implemented on a 4-layer printed circuit board.

**Features and benefits**
- Dual-lane CDR with fully adaptive 4-stage equalization enables thin, inexpensive 40-AWG cable
- Integrated clock synthesis & power filtering reduces BOM cost, PCB layers
- On-chip cable diagnostics lowers assembly time, cost
- Less than 250mW of power per lane, Single power supply simplifies system design
HD3SS0001 Data Source Selection Switch

Description
The HD3SS0001 is a high-speed passive switch designed to support low speed and high speed signals required for Thunderbolt™ applications using the mDP connector. The HD3SS0001 switches between DDC, AUX, and the 10Gbps TB signal in order to support DisplayPort, Dual Mode DisplayPort, and Thunderbolt. The HD3SS0001 also switches between the Thunderbolt Low Speed UART transmit/receive pair and DisplayPort Main Link 1 (ML1) pair. The device supports 5.4Gbps for DisplayPort and 10.3Gbps for Thunderbolt. Switch control is determined by three control pins and the mDP connector pin used for cable detect. Advanced cable diagnostic features such as on-chip receiver eye processing on each of the input channel reduce manufacturing cost and time. Offered in a tiny 5mm x 5mm QFN package and powered using a single 2.5v power supply, the DS100TB211 consumes less than 250 mW per bi-directional lane and can be implemented on a 4-layer printed circuit board.

Features and benefits
• Compatible with DisplayPort 1.2 and Thunderbolt Electrical Standard
  — Supports DP and DP++ Configurations
  — Handles HPD (5V tolerant) and CA_DET
  — Supports AUX and DDC MUX
• -3dB Differential bandwidth of over 10GHz
• Excellent Dynamic Characteristics (at 5GHz)
  — Crosstalk = -30dB
  — Isolation = -20dB
  — Insertion Loss = -1.5dB
  — Return Loss = -16dB
  — Max Bit-Bit Skew = 4 ps

LM3017 High Efficiency Boost with True Shutdown for Battery Disconnect

Description
The LM3017 is a versatile low-side NFET controller incorporating load disconnect and input side current limiting. It is designed for simple implementation of boost conversions in Thunderbolt Technology. The input voltage range of 5V to 18V accommodates a two or three cell lithium ion battery or a 12V rail. The enable pin accepts a single input to drive three different modes of operation: boost, pass through, or shutdown mode. In shutdown mode, the LM3017 draws less than 40nA from the input supply.

The LM3017 provides an output from Vin to 20V in order to drive the Power Load Switch or Mux for the host Thunderbolt port. The ability to drive an external high-side NMOS provides for true isolation of the load from the input. Current limiting on the input ensures that inrush and short-circuit currents are always under control.

Features and benefits
• True load disconnect works with input side current limiting to protect the switch, boost inductor, and battery from excessive current draw in a short circuit condition
• Meets both broadband output noise requirements and output ripple spec with less than 50mV pk-pk
• Output power capability delivers up to 30W for driving two Thunderbolt ports at 15W each
• ±1% reference voltage provides accurate output to power load switch
• Enforced start up time allows output to charge up to input voltage in less than 20 milliseconds, per Thunderbolt specifications
• 430kHz fixed switching frequency provides low ripple and high efficiency at 93%

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LMZ10501 1A SIMPLE SWITCHER® Nano Module with Integrated Inductor

Description
The LMZ10501 SIMPLE SWITCHER® nano module is an easy-to-use step-down DC-DC solution capable of driving up to 1A load in space-constrained applications. Only an input capacitor, an output capacitor, a small filter capacitor, and two resistors are required for basic operation. The nano module comes in an 8-pin LLP footprint package with an integrated inductor. The LMZ10501 operates in fixed 2.0MHz PWM (Pulse Width Modulation) mode, and is designed to deliver power at maximum efficiency. Ideal for use in Thunderbolt™ Technology, the LMZ10501 supplies the high efficiency step down conversion needed in the active cable. It accepts a 2.7V to 5.5V input from the power load switch and provides an adjustable output to drive the clock and data recovery retimer. As a synchronous, DC-DC solutions, the LMZ10501 saves power and reduces heat generation compared to an LDO. With the integrated inductor, it still maintains the extremely small solution size that is necessary in the active cable head for Thunderbolt™ Technology.

Features and benefits
• Integrated inductor for maximum space savings and ease of use
• Miniature form factor (3.0 mm x 2.5 mm x 1.2 mm)
• High efficiency up to 97% reduces system heat generation
• Adjustable output voltage for flexibility
• Easy component selection and simple PCB layout
• Low output voltage ripple less than 10mV peak-peak

TPS55340 or LM3017
TPS22980/1
TPS2296
TPS22986
Thermoelectric
Controller
Retimer
Power Load Switch
PWR & GND
DC-DC Step Down
Active Cable
DATA
Retimer
DC-DC Step Down
Intel Thunderbolt
Controller
PCIe Display Port

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## Devices Description Features

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<th>Devices</th>
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| TPS22980/1 | 3.3V or 18V power MUX w/ selectable overcurrent limits | • Single integrated solution saves board space and simplifies system design  
• Integrated switches provide either low voltage (3.3V) or high voltage (18V) to attached peripheral  
• Adjustable current limit allows customized protection (4.5V to 19.8V, 3.0V to 3.6V) |
| DS100TB211 | Signal conditioning retimer with CDR | • Dual-lane CDR with fully adaptive 4-stage equalization enables thin, inexpensive 40-AWG cable  
• Less than 250 mW of power per lane, single power supply |
| TPS22986 | Power supply selector | • Instead of through cable circuitry, optimized to use with any Thunderbolt technology cable, simplifying cable designs  
• Automatically selects appropriate supply |
| HD3550001 | Data source selection switch | • Single solution integrates a multiple discrete components saving board space  
• Optimized pinout for routing from signals sources to connector |
| TPS5340 | Boost converter with integrated MOSFET | • Internal 5-A MOSFET Switch delivers 30W  
• 2.9-V to 32-V Input Voltage  
• Light-load efficiency |
| LM3017 | Boost controller with true shutdown | • Output power capability delivers up to 30W for driving two Thunderbolt ports at 15W each ±1% reference voltage provides accurate output to power load switch  
• Enforced start up time allows output to charge up to input voltage in less than 20 milliseconds, per Thunderbolt specifications  
• 430kHz fixed switching frequency provides low ripple and high efficiency at 93% |
| LMZ10501 | 1A SIMPLE SWITCHER® Nano Module with integrated inductor | • Integrated inductor for maximum space savings and ease of use  
• Miniature form factor (3.0 mm x 2.5 mm x 1.2 mm)  
• High efficiency up to 97% reduces system heat generation |

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