



Informatik der Systeme – Chapter 11: Computer Interfaces

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<https://kn.inf.uni-tuebingen.de>



- ▶ RS-232
- ▶ USB
- ▶ Thunderbolt
- ▶ RJ45
- ▶ Common Display Resolutions
- ▶ Analog vs. Digital
- ▶ VGA
- ▶ DVI
- ▶ HDMI
- ▶ DisplayPort
- ▶ HDCP

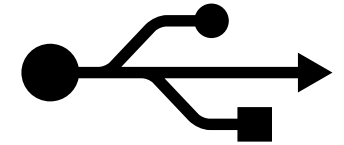


- ▶ **Recommended-Standard 232**
- ▶ Introduced in 1960
- ▶ Also called COM port
- ▶ Originally used to communicate between a computer and a modem
- ▶ Many types of computers had this connector
 - Devices like mice, mass storage, printers leveraged this port
- ▶ Port no longer used in consumer products
 - Still used in the industry



9-pin D-sub connector

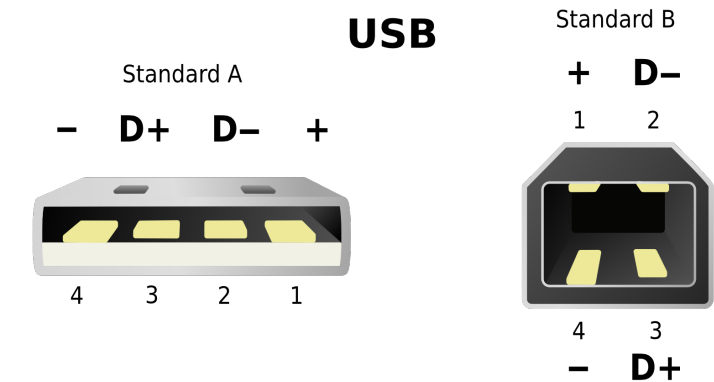
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- ▶ **Universal Serial Bus**
- ▶ Before USB there were many different connector types for devices
 - USB standard provides a universal connector
- ▶ Today, many devices use it
 - Mice, keyboards, mass storage, headsets, Wi-Fi antenna, webcams, Bluetooth adapter
- ▶ Replaced RS-232 because it provides advantages
 - Higher resistance to interference → longer cables
 - Higher bandwidth
 - Error correction
 - Hot-swappable (computer does not need to be rebooted)
 - Self-configuring (*Plug and Play*)



- ▶ Version 1.0 was introduced 1996
- ▶ Connects a host (A) to a device (B)
- ▶ Connector type (A, B) defines host or device
- ▶ Two transfer rates
 - Low-Speed: 1.5 Mbit/s
 - Full-Speed: 12 Mbit/s
- ▶ Was called „useless bus“ because Apple’s FireWire connector, which was introduced 1995, had a transfer rate of 400 Mbit/s



USB pins

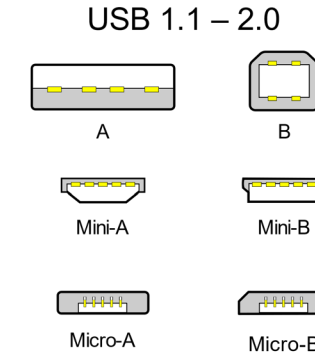
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- ▶ 4 contacts
 - Supply voltage (5 Volt)
 - Ground (0 Volt)
 - Data+
 - Data-



- ▶ USB 2.0 was introduced April 2000
- ▶ Transfer Rate of 480 Mbit/s
 - Led to a rapid adoption
- ▶ Next to the connector types A/B, Mini- and micro-connector types were added



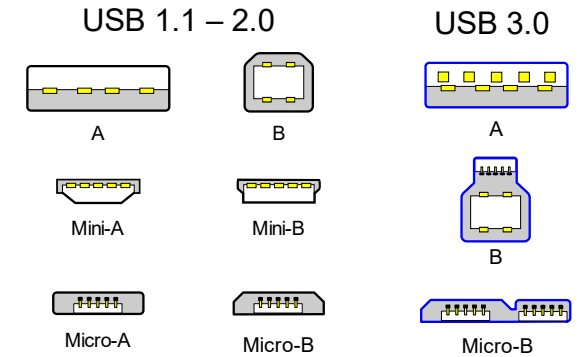
USB connector types

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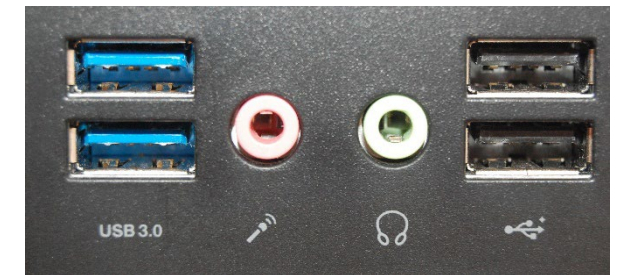
- ▶ USB 3.0 was introduced 2011
 - Transfer rate of 5 Gbit/s
- ▶ USB 3.1 was introduced 2014
 - Transfer rate of 10 Gbit/s
- ▶ USB 3.0/3.1 uses 5 additional contacts while being backwards compatible to USB 1.1 – 2.0
- ▶ USB 3.1 provides following transfer rates
 - **USB 3.1 Gen 1** same as USB 3.0
 - **USB 3.1 Gen 2:** 10 Gbit/s
- ▶ USB port colors carry information
 - USB 3.0/3.1 Gen 1 → blue
 - USB 3.1 Gen 2 → blue or red
 - Some manufacturers use other colors



USB connector types

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USB 3.0 (left) und 2.0 (right)

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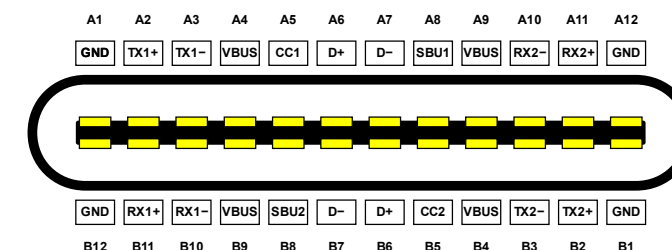


- ▶ New connector type Type-C was introduced 2014
- ▶ Connector is point symmetrical for both sides (host and device)
 - Host/device assignment via communication
- ▶ Type-C only defines the connector type and the pins
 - The protocol and transfer rate is defined by the USB version
 - USB 2.0 – 4.0 is supported
- ▶ Charging up to 100 W possible (20 V, 5 A)
 - Every cable must support 3 A → 60 W
 - Special cables are capable of carrying 5 A



USB Type-C cable

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USB Type-C pins

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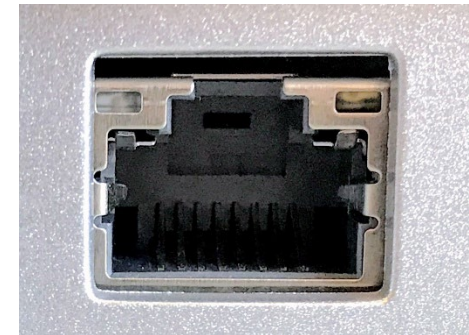
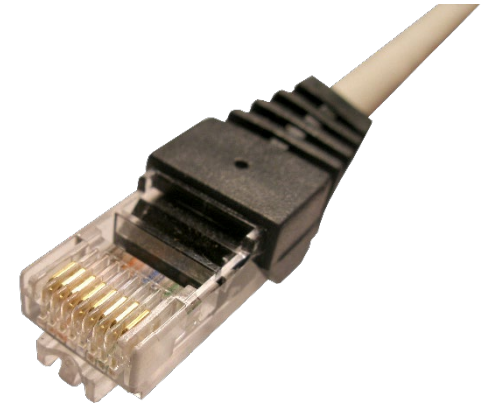
- ▶ USB 3.2 was introduced 2017
- ▶ Supported transfer rates
 - **USB 3.2 Gen 1(x1)** same as USB 3.0 (5 Gbit/s)
 - **USB 3.2 Gen 2(x1)** same as USB 3.1 Gen 2 (10 Gbit/s)
 - **USB 3.2 Gen 2x2:** 20 Gbit/s
 - Type-C connector type is mandatory
 - Type-A/B is not capable of such transfer rates



- ▶ Developed by Intel in cooperation with Apple
- ▶ Uses USB Type-C connector type
- ▶ Transfer rate of 40 Gbit/s
- ▶ Supports multiple tunneled protocols
 - USB 3.1 Gen 2 (10 Gbit/s)
 - 8x DisplayPort 1.2 lanes
 - Capable of 2x 4K (60 Hz) displays
 - Charging up to 100 W
 - 4x PCIe 3.0 lanes
 - An external graphics card can be connected
- ▶ Thunderbolt 4 is built on top of Thunderbolt 3
 - Some features are no longer optional, but mandatory
 - Capable of 1x 8K (60 Hz) display



- ▶ RJ45 (Registered Jack 45) first defined by Bell Labs in 1970s
- ▶ Used in telecommunication sector
- ▶ Now, it is “the Ethernet port” in consumer electronics
- ▶ Contains twisted pair cables
- ▶ Cables support different speeds
 - Cat 3 up to 100 Mbit/s
 - Cat 5 up to 1 Gbit/s
 - Cat 5e up to 2.5 Gbit/s
 - Cat 6 up to 10 Gbit/s (max. 55 meters)
 - Cat 6A up to 10 Gbit/s (max. 100 meters)
 - Cat 8.1/8.2 up to 40 Gbit/s

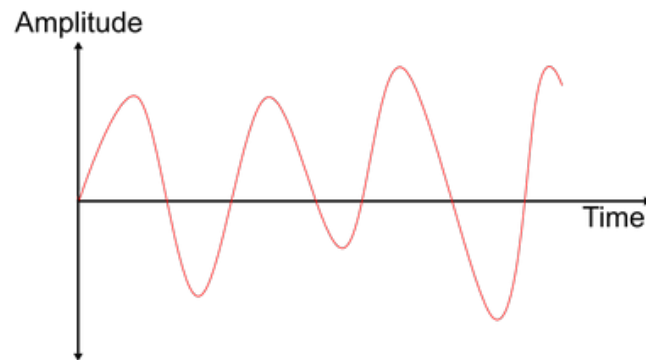




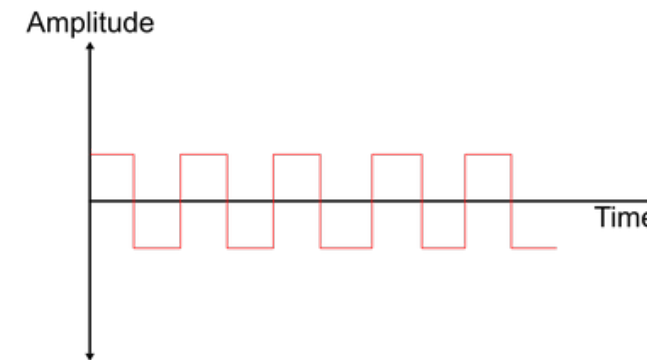
- ▶ Display resolutions are denoted by *width x height*
- ▶ Common display resolutions are
 - VGA: 640 x 480
 - HD: 1280 x 720
 - HD+: 1600 x 900
 - Full HD: 1920 x 1080
 - WQHD: 2560 x 1440
 - 4K: 4096 x 2160
 - 5K: 5120 x 2880
 - 8K: 8192 x 4320



- ▶ Electrical signals can be sent and interpreted in different ways
- ▶ Analog signals can have a continuous value along the amplitude
- ▶ Digital signals can only be discrete values (e.g., 0 and 1)



Analog Signal



Digital Signal



- ▶ Introduced 1987 by IBM
- ▶ Transmission of an analog signal to carry video information
- ▶ Dedicated pins for red/green/blue
- ▶ Resolutions up to 1920x1080 supported
- ▶ No longer in use
 - In 2010 Intel and AMD decided not to support VGA anymore



Intel und AMD besiegeln das Ende der VGA-Schnittstelle, <https://www.golem.de/1012/80023.html>



- ▶ **Digital Video Interface** was introduced in 1999 by the Digital Display Working Group
- ▶ Different modes were supported
 - DVI-D: digital signal
 - DVI-A: analog signal
 - DVI-I: digital and analog signal
 - Any signal type could be connected
- ▶ Single and dual link possible
 - Dual link uses 6 additional pins in the center
 - Bandwidth increase
- ▶ Biggest resolutions
 - Single link: 1920x1080 (60 Hz)
 - Dual link: 2560x1600 (60 Hz)

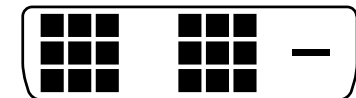
FEMALE LAYOUT



DVI-I (Single Link)



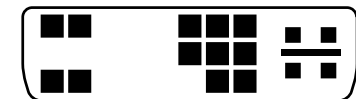
DVI-I (Dual Link)



DVI-D (Single Link)



DVI-D (Dual Link)



DVI-A



DVI-D connector

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- ▶ **H**igh-**D**efinition **M**ultimedia **I**nterface was introduced 2002
- ▶ Digital video signal
- ▶ Current version 2.1 supports displays up to 5K (60 Hz)
 - With display stream compression, which must be supported by the display, even higher resolutions are possible
- ▶ A *royalty fee* will be charged for the implementation of a HDMI connector
 - 0.15 \$ per sold product
 - Only 0.05 \$ if the HDMI logo is used (a certification is required)
 - Only 0.04 \$ if HDCP is additionally implemented



HDMI Type D (micro),
C (mini) and A

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DisplayPort

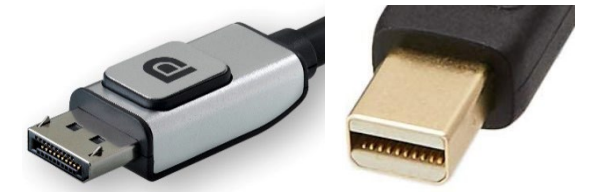
- ▶ Introduced 2006 by the Video Electronics Standards Association
- ▶ Current version 2.0 supports displays up to 8K (60 Hz)
- ▶ In contrast to HDMI, no *royalty fee* is being charged



Graphics card with 3x
DisplayPort, 1x HDMI and 1x DVI

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DisplayPort (left)

Mini-DisplayPort (right)

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- ▶ **H**igh-bandwidth **D**igital **C**ontent **P**rotection was introduced 2003 by Intel
- ▶ Transmission of video and audio is encrypted and protected against recording
- ▶ Use case
 - Online Streaming (Netflix, Amazon Prime, etc.)
 - DVD and Blu-ray
 - TV
- ▶ Every HDCP certified device contains keys which are used in the encryption step
 - Keys that have become public will be locked via a revocation list
- ▶ HDCP prevents playback on devices that do not implement HDCP