# Peripheral Expansion

**General-purpose Expansion**

**Wireless Expansion**

**Display Technologies**

**Display Connections**

# General purpose expansion

Peripheral device transfer rates outstripped the abilities of legacy parallel ports and RS-232 serial ports, leading to new peripheral expansion standards

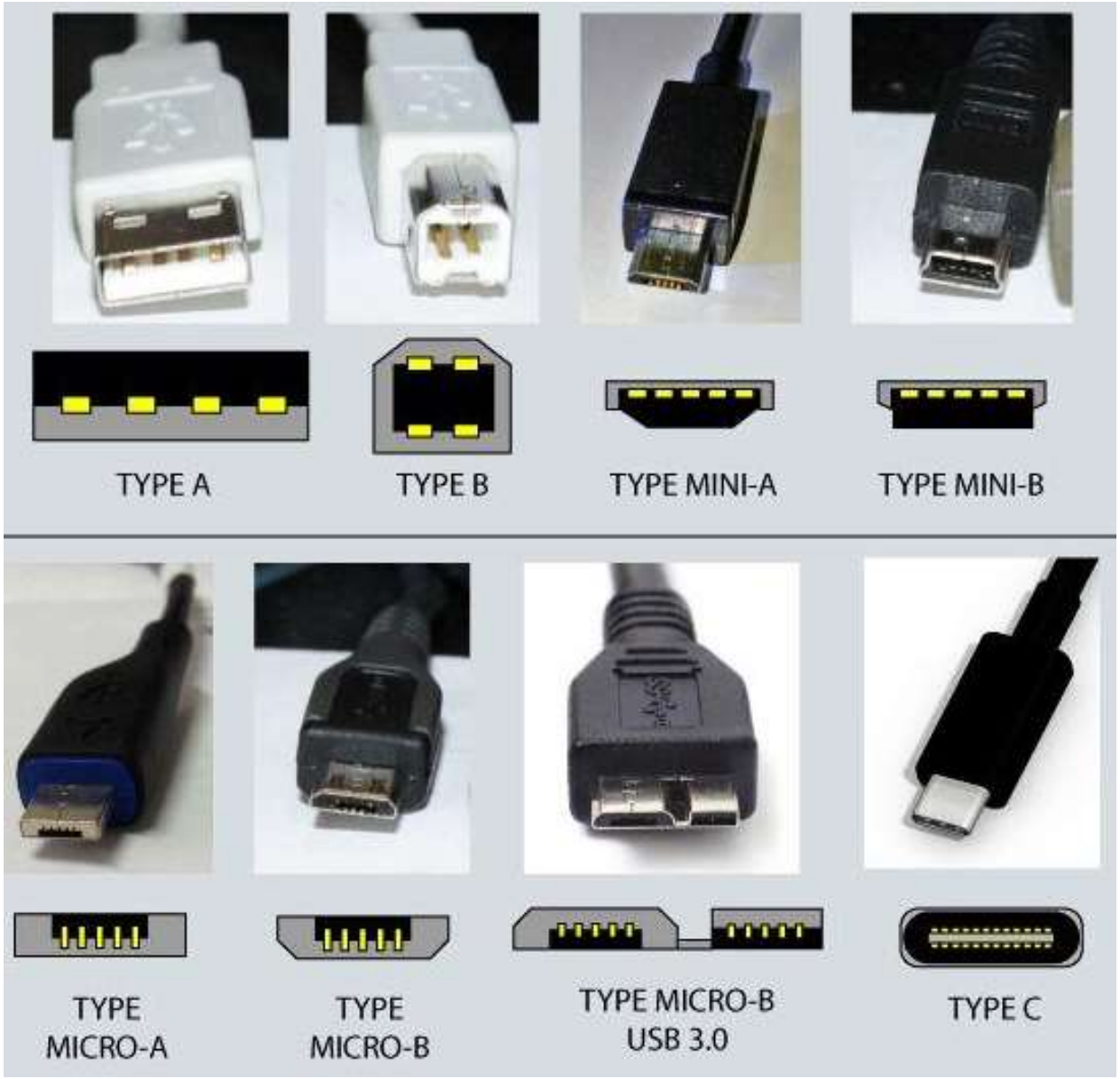
- USB (Universal Serial Bus)
  - developed by Intel
  - serial
  - *hot swappable*
  - high speed: USB 3.0 5 Gbit/s (moving towards 10)
  - can supply power (2.5 to 4.5 Watts)

# USB Standards

| Variant | Speed (peak) | Typical use |
|---|---|---|
| USB 1.1 Low Speed | 1 Mbit/s | keyboards, mice |
| USB 1.1 Full Speed | 11 Mbit/s | printers, scanners |
| USB 2.0 High Speed | 480 Mbit/s | hard disks, digital cameras |
| USB 3.0 Superspeed | 5 Gbit/s | new portable mass storage |
| USB 3.1 Superspeed+ | 10 Gbit/s | new portable mass storage |

- USB 4 is under development, using usb C connectors, with
- speeds of 40Gbit

# USB Connectors



# General purpose expansion

- FireWire
  - aka. i.Link and IEEE 1394
  - developed by Apple
  - can supply up to 45 Watts
  - largely replaced SCSI on cheaper systems
  - used for disk storage and video transfer

- Thunderbolt
  - developed by Intel
  - can supply 10 Watts
  - high speed: 10 Gbit/s

# Wireless expansion

- Bluetooth
  - short-distance wireless peripheral connection
  - version 4.0 at ~26 Mbit/s (theoretical peak rate)
  - different standards for different peripheral ‘classes’
    - so peripheral can save power by using smallest appropriate transmitter

| Class | Transmit power | Approx. range |
|---|---|---|
| 1 | 100 mW | 100 m |
| 2 | 2.5 mW | 10 m |
| 3 | 1 mW | 1 m |

# Wireless expansion

- Bluetooth Profiles
  - protocols tailored for particular communication needs
  - device supports protocol subset required for it to do its job
  - large range of profiles, some examples are:

- **Advanced Audio Distribution Profile (A2DP):** high quality audio, for wireless headphones
  **Cordless Telephony Profile (CTP):** for connecting to cordless phone base stations
- **Dial-up Networking (DUN):** to make a mobile phone act as a modem
- **File Transfer Profile (FTP):** to browse and transfer files
  **Hands-Free Profile (HFP):** to let car entertainment systems control a phone
  **Human Interface Device (HID):** for keyboards, mice, game pads, etc.
  **Headset (HSP):** to let headsets pass phone audio, and control basic phone features
- **LAN Access (LSP):** to tether an Internet-connected mobile phone to a tablet or laptop

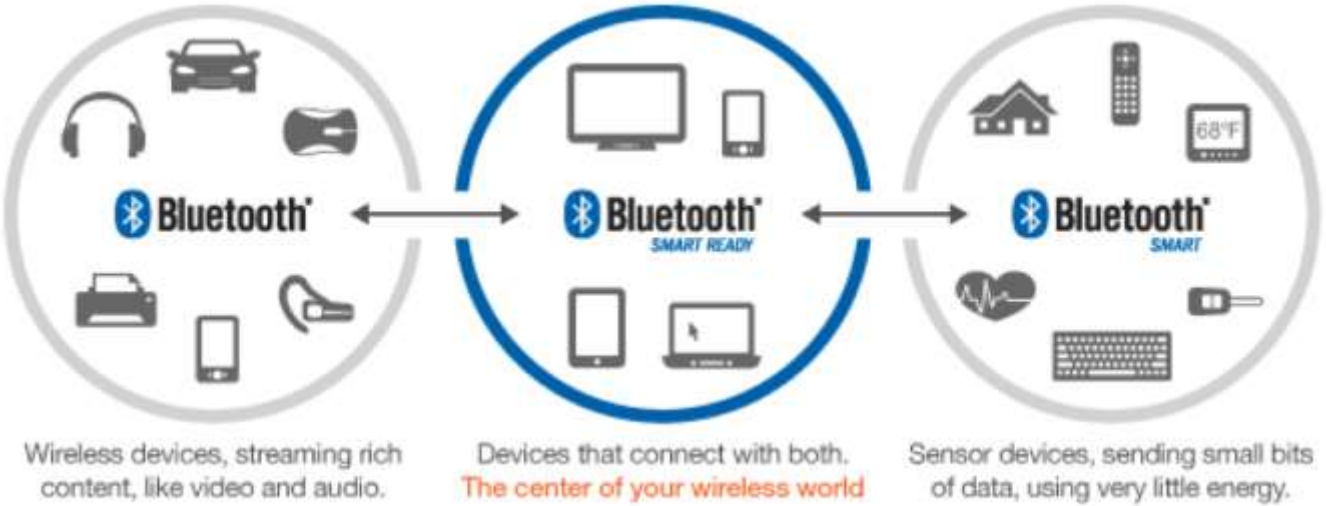
# Wireless expansion

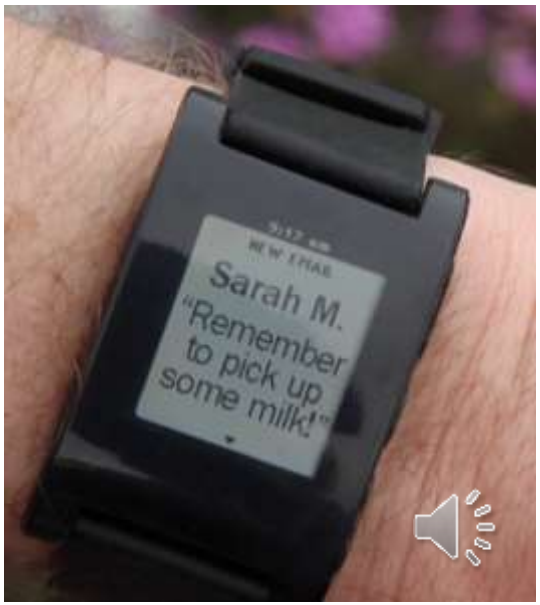
- Example: car entertainment system that supports Bluetooth Hands-Free Profile, Dial-up Networking and Advanced Audio Distribution Profile, protocols, amongst others


- Bluetooth devices connect via *pairing*
  - *discoverable* party transmits its name, class, profiles etc
  - other party shares link
  - both devices authenticate to each other
  - initiate supported profiles

# Personal Area Networks

- Personal area networks are networked devices on or around a person
  - Bluetooth 4.0 introduced lower power classes to support it
  - other competing protocols are in the market



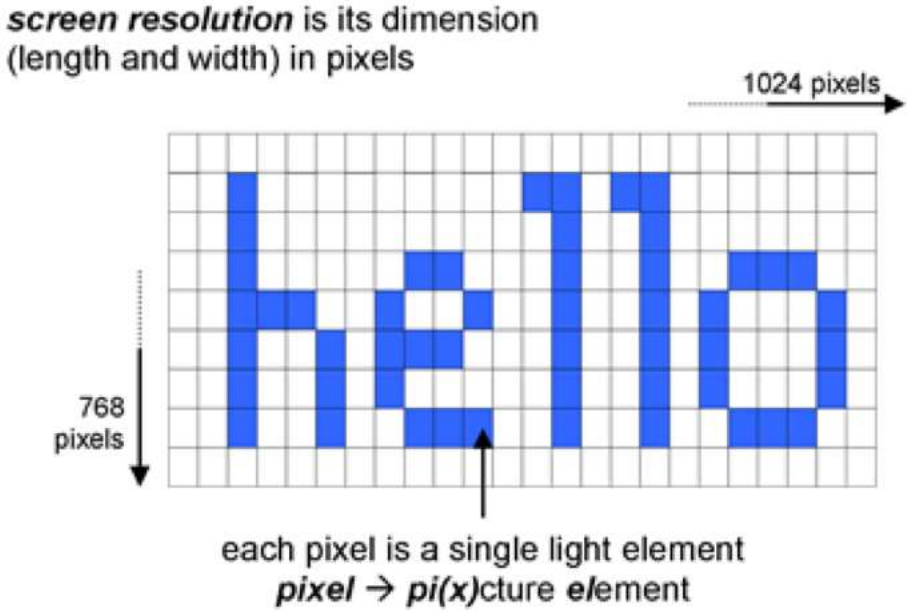
# Personal Area Networks

- ANT
  - open standard
  - competitor to Bluetooth in PAN market
  - popular in health & fitness sector (heart rate monitors, GPS tracker etc. that transmits to a wearable display)


- Proprietary PAN protocols exist too

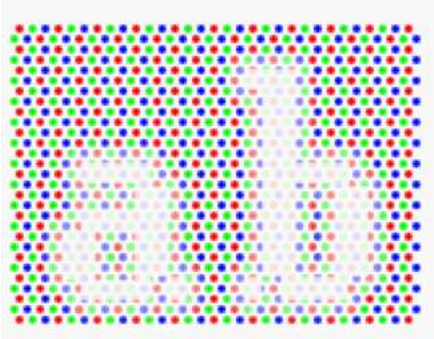
# Display technologies

- Display resolution is length and width in pixels
  - *pi(x)*cture *el*ement
  - pixel composed of subpixels (red, green, blue: RGB)



# Display technologies

- Legacy display: CRT Monitors
  - Cathode Ray Tube
  - analogue video standard (e.g. VGA)
  - junk!



Electron beam aimed at phosphor dots
No fixed relationship between dots and pixel

LCD (liquid crystal display) has set pattern of subpixels in each pixel

# Display technologies

- LCD panel
  - crystals twist under current to block or pass light from a backlight

TN – Twisted Nematic
•cheap
•quick response time
•restrictive viewing angle

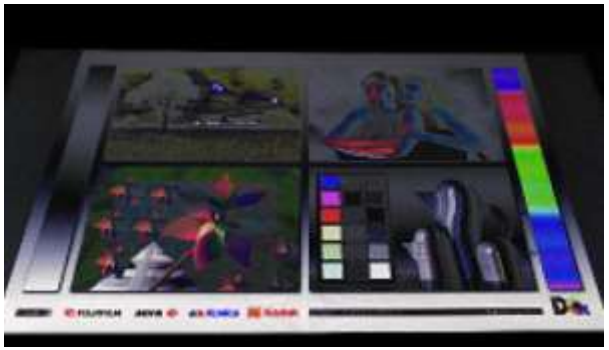
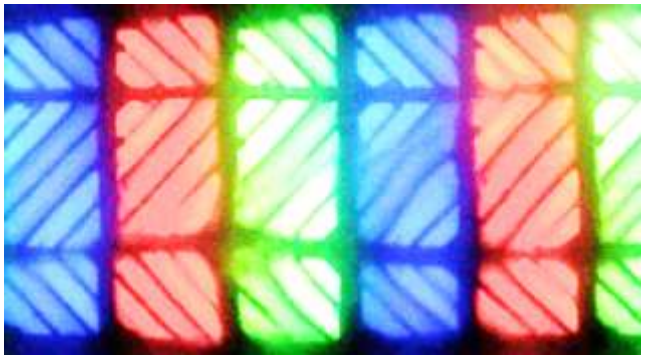


photo: notebookcheck.de



Vertical Alignment
- pieces of subpixels orient in different directions
- better viewing angle range
- slower response time

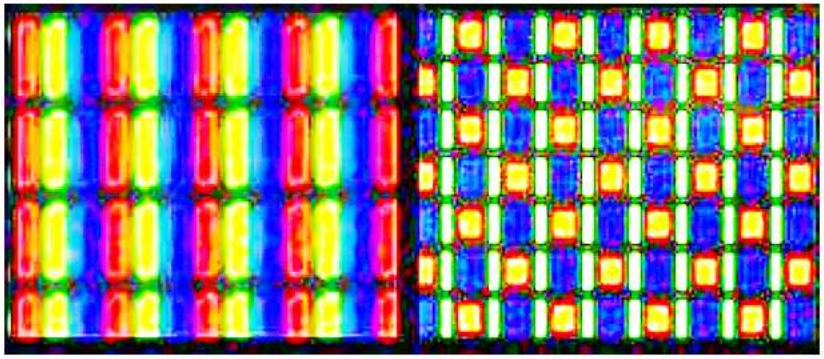
photo: digitalversus.com

In Plane Switching (IPS, Super TFT)
- wide viewing range, good colour
- slower response time than TN

# Display technologies

- Organic LED
  - pixels emit light
  - popular on mobile phones

- PenTile Matrix
  - a way of arranging pixels, especially in OLED
  - human eye is sensitive to green, so green subpixel is smaller than red or blue and may be shared with neighboring pixels



# Display Connections

- Legacy data transmission to display standard
  - VGA (Video Graphics Array)
  - analogue standard. Many variants of standard
  - wave contains timing and red/blue/green intensity information
  - timing information used by display to figure out which part of the screen the colour information should be applied too
  - prone to interference (e.g. ghosting)

# Display Connections

- DVI (Digital Visual Interface)
  - connector supports analogue & digital, but usually used for digital

- HDMI (High Definition Multimedia Interface)
  - digital video & audio
  - supports HighBandwidth Digital Copy Protection (HDCP)

- DisplayPort
  - digital video & audio

# Display Resolution Acronyms

| | Standard | | Wide | |
|---|---|---|---|---|
| Standard | QQVGA | (160x120) | | |
| | HQVGA | (240x160) | | |
| | QVGA | (320x240) | | |
| | WQVGA | (400x240) | | |
| | HVGA | (480x320) | | |
| | VGA / SD | (640x480) | | |
| Extended | XGA | (1024x768) | WXGA | (1280x800) |
| | XGA+ | (1152x864) | WXGA+ | (1440x900) |
| | SXGA | (1280x1024) | | |
| | SXGA+ | (1400x1050) | WSXGA+ | (1680x1050) |
| | UXGA | (1600x1200) | WUXGA | (1920x1200) |
| Quad Extended | QWXGA | (2048x1152) | | |
| | QXGA | (2048x1536) | WQXGA | (2560x1600) |
| | QSXGA | (2560x2048) | WQSXGA | (3200x2048) |
| | QUXGA | (3200x2400) | WQUXGA | (3840x2400) |
| Hyper Extended | HXGA | (4096x3072) | WHXGA | (5120x3200) |
| | HSXGA | (5120x4096) | WHSXGA | (6400x4096) |
| | HUXGA | (6400x4800) | WHUXGA | (7680x4800) |

# Display Resolution Acronyms (HD)

| | | |
|---|---|---|
| HD | nHD | (640x360) |
| | qHD | (960x540) |
| | HD | (1280x720) |
| | FHD | (1920x1080) |
| | QHD | (2560x1440) |
| | WQXGA+ | (3200x1800) |
| | UHD 4K | (3840x2160) |
| | DCI 4K | (4096x2160) |
| | UHD+ 5K | (5120x2880) |
| | FUHD 8K | (7680x4320) |
| | QUHD 16K | (15360x8640) |

# Summary

- General-purpose Expansion
  - USB
- Wireless Expansion
  - Bluetooth, ANT (PAN)
- Display Technologies
  - Legacy, CRT, LCD, OLED, PenTile
- Display Connections
  - CVI, HDMI, Display Port