· Communication tech · wire   wireless
                        USB, HDMI   Wifi, ✳

· UI devices
   ↳ keyboard, capacitive touch, camera, mic, display, speaker

USB
- universal serial bus
- UART protocol
- standard connection to most UI
- 4 pins : power, gnd, data +,-   (can be self powered)
- USB 1.0 → 12 Mbps
  USB 3.2 → 20 Gbps
- tiered star topology
   ↳ USB Host
      · initiates transfer   USB HOST ── USB Hub
      · all transfer is relative to it

for connection:
step 1 : ennumeration (device —info→ host)
step 2 : host checks if it can drive the device

classes of USB devices
- HID : human interface
- communication device class (CDC) implement virtual com
   ↳ Arduino etc.
- Mass storage class
- Audio class

HDMI

- High-definition multimedia interface
- transfers audio-visual data, allows control info to pass enabling remote control : CEC

- HDMI v1 :   3·96 Gbps   : 1080 p 60fps
- HDMI v2 :   12·6 Gbps   : 8K res.

- **Industrial scientific & Medical (ISM) Radio freq (RF) Band**
- 2·4 GHz , 5·8 GHz   are popular
- these are royality free , also used for wifi + bluetooth

- **Wifi**
- 2 topologies → 1nfrastructure   Adhoc
                        ↓   ↓
                   ☆ , center of network   peer to peer
                   is access pt /router

- transmission range is affected by freq $^{1/\alpha}$, power $^{\alpha}$, interferrence $^{1/\alpha}$
- ~ 10 Gbps , 20 - 150 m . wifi 6

- **Bluetooth**
- Low rate , low power , 10-m20m , rate : Kbps
- 2·4 GHz range
- star topology
- 2 protocols → BT classic ←—— not comp. —— BLE (low energy)

- but most hosts are dual mode, can connect to both
- uses frequency hopping

Capacitive touch

- capacitance ↑ on touch
  - ↳ ∝ dielectric constant
- processor used to figure out pt of contact.

Camera

- lens
- sensors (CMOS, + Analog-to-Digital)
- Image Signal Processor (ISP)
- Interface I/O

microphone   (charge needed is found on electret

- MEMS & ECM ← 2 kind
- both use capacitor, transduced signal is analog

charge by pump

MEMs > ECM   ← smaller, better signal to noise ratio

speaker

- electric → mechanical → sound energy

Pipeline

- dont use common
- work best when full
- pipleline conflict → halt to pipleim, feush instruc.

① insufficient resource
  same resource, write mem. & read mem
  have suff resources, processing units to allow simultaneous
  action

② data dependency conflict
  using old value
  source operand of cur = dest op of prior
  → solve by detecting dependeney and stalling cur op
  before ex stage (ie Decode stage)
  → insert nops

③ branch inst
  · 2 cycles wasted as decision to branch is in Ex stage
  ① decision made earlier in decode stage (add a adder)
    delay = 1 cycle
  ② delayed bracnluing
    (2) instructions after loop is always executed.
      ↳ must be independent → affecting flags !!!
      ↳ or nop

  ③ dynamic branch prediction
    hw to predict outcome of branch inst: T/F
    according lines up next inst.
    can be correct or wrongs

Arm cortex Processor : 3 stage pipeline (F, D, Ex)

↓

has branch speculation

↓

fetches inst of both T & F situation during D,
Decodes the correct one when in Ex