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Computer Systems / Rekenaarstelsels 245 - 2020

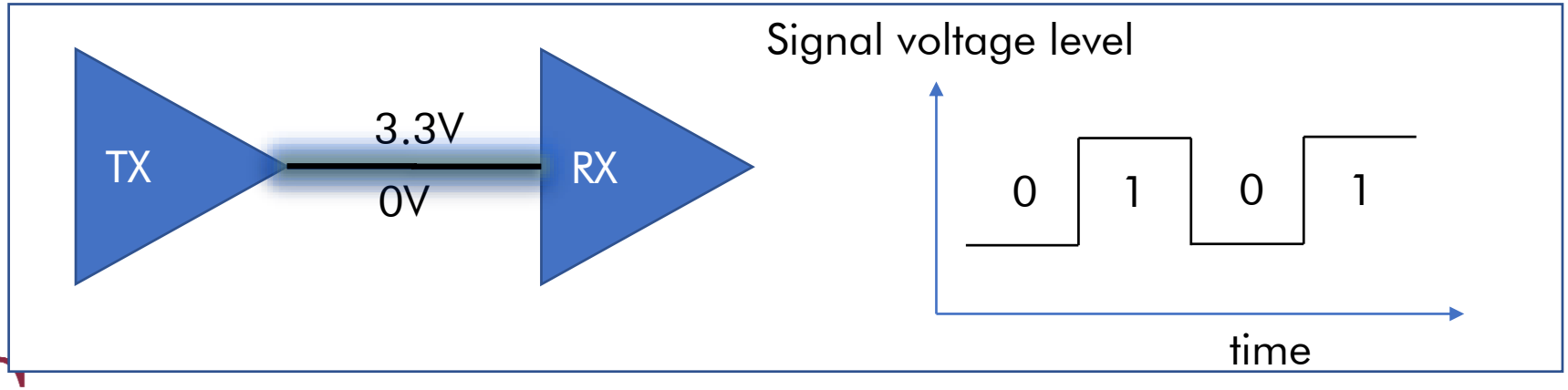
Lecture 15

Serial Communication Introduction/ Seriële Kommunikasie Inleiding

Dr Rensu Theart & Dr Lourens Visagie

What is serial communication?
Wat is seriële kommunikasie?

- **Serial communication**: Transmitting data one bit at a time (sequentially) over a communications channel.
- Voltage levels on a shared connection are varied over time to indicate binary information
- The connection is usually implemented as a physical wire, or a PCB track
- At the most basic:
  - Transmitter or sender (TX) sends the data
  - Receiver (RX) receives the data
  - Signaling all happens on a single connection



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- At the most basic:
  - Transmitter or sender (TX) sends the data
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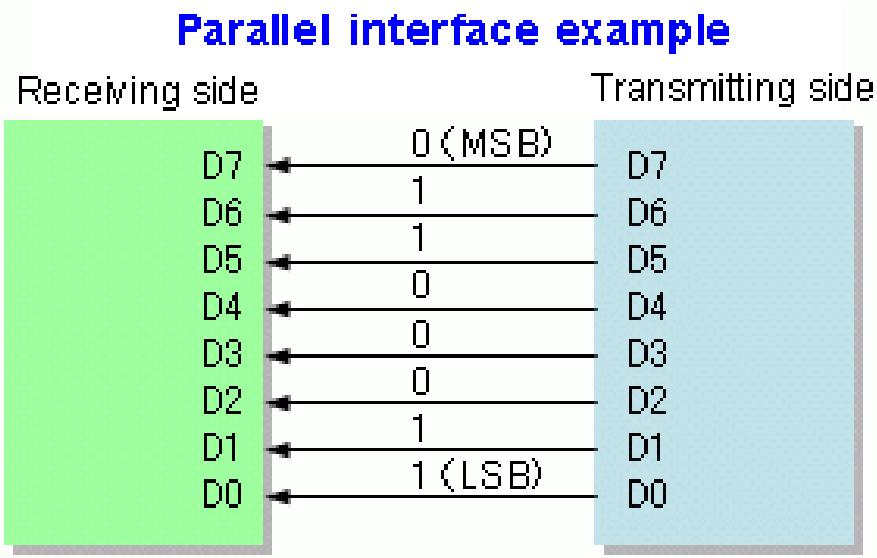
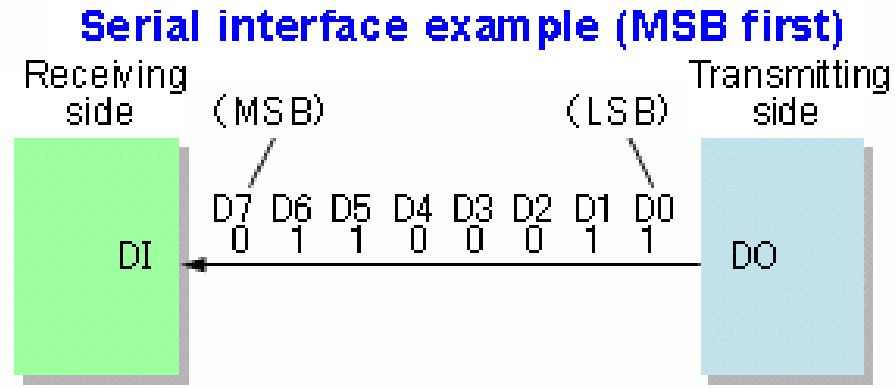
  - Signaling all happens on a single connection
- But it is usually a bit more complicated
  - Transmitter and receiver can swop roles
  - Some communication schemes allow multiple devices to use the same connection – then it becomes a communications bus
  - Some communication schemes have additional signals – improve speed and reliability

What is serial communication?
Wat is seriële kommunikasie?

Serial vs. Parallel communication

- **Serial** communications: Single line/signal/wire/channel that is varied over time to transfer multiple bits of information
- **Parallel** communications: Multiple lines/signals/wires/channels (also varying over time) that can transfer multiple bits of information at a single time instant
- Serial communication takes longer to send the same data, but parallel communications have more signals/cables





What is serial communication?
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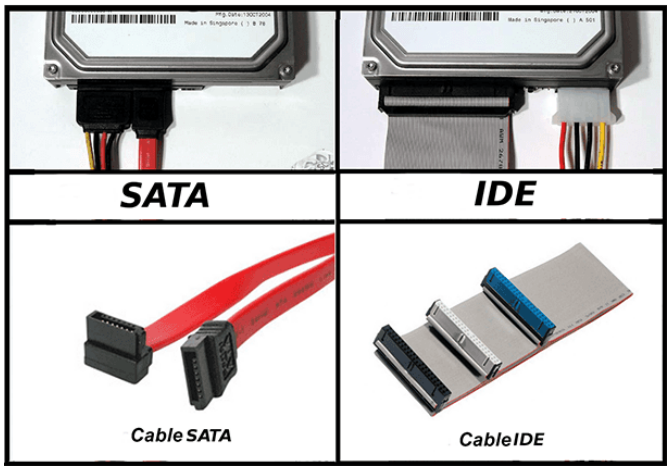
Serial vs. Parallel communication

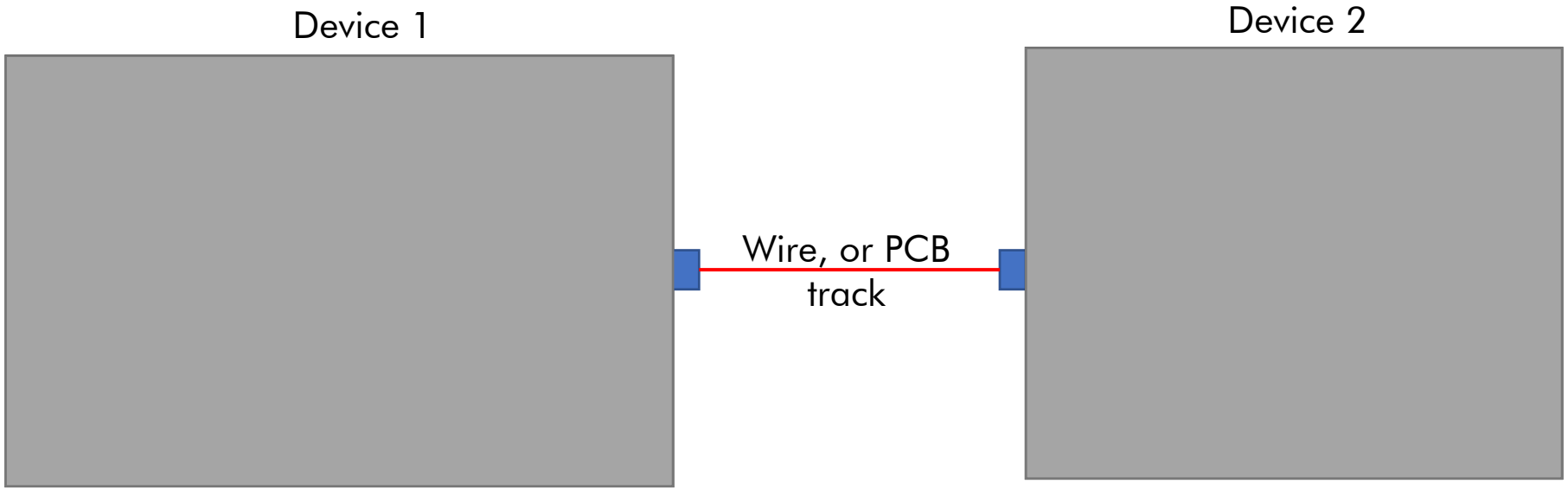
- Example: Hard drives – IDE (parallel) vs. SATA (serial)



- Nowadays, the tendency is to use serial communication across physical cables (USB, HDMI)
- Parallel communication is found inside the microcontroller (system bus), or as copper tracks on a PC mainboard or other PCBs – typical for external memory interfaces, or camera interfaces

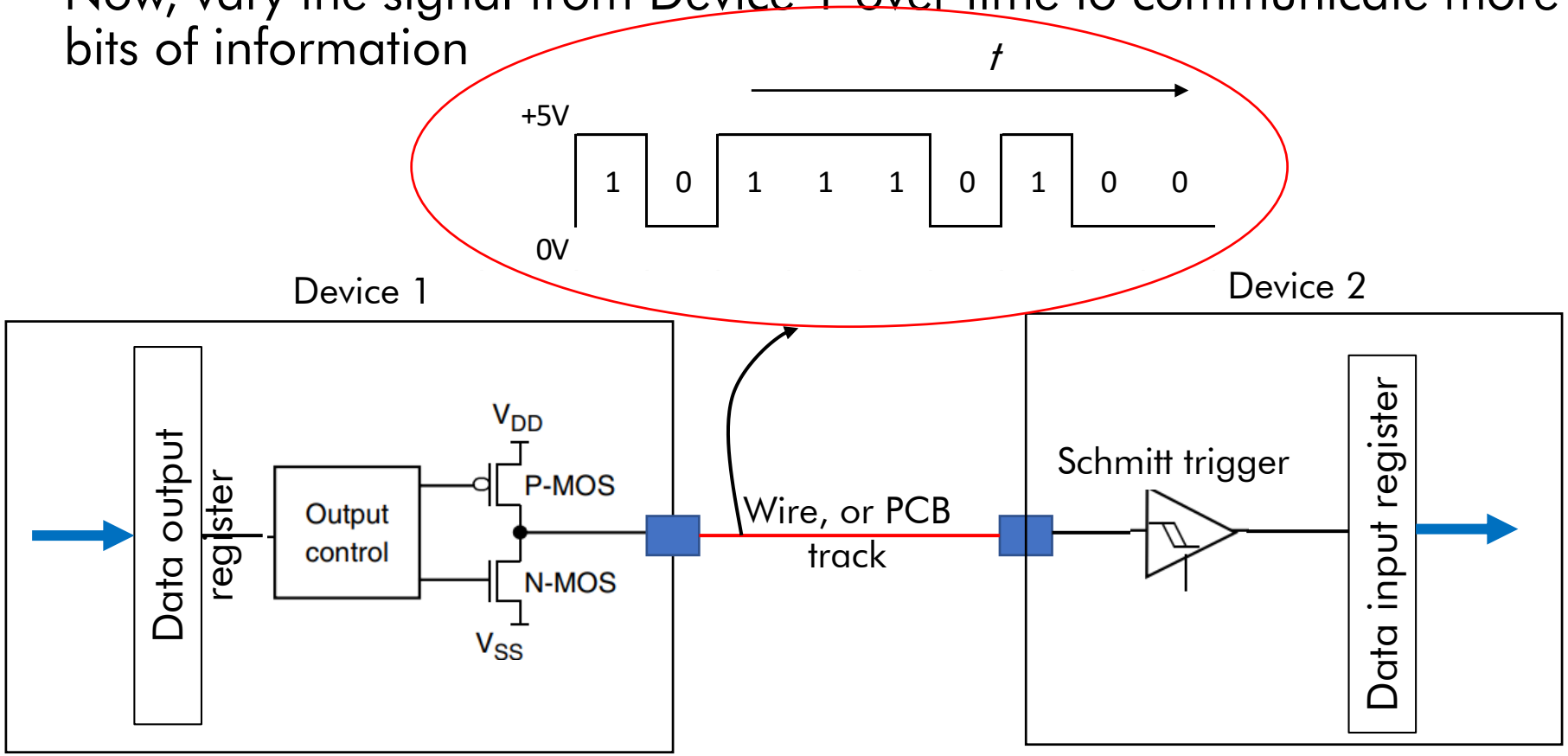
From GPIO to inter-device communication
Vanaf basiese intree/uittree na kommunikasie

- On device 1, use a pin configured as an output – this device (microcontroller) will drive the signal level on the output to a zero or one, depending on what the program for that microcontroller does
- On device 2, use a pin configured as input – this microcontroller will not try to control the signal level, but sense the signal level
- Connect the two pins together. Now device 2 can sense the signal that device 1 is outputting. (Device 1 is transferring information to device 2)



From GPIO to inter-device communication
Vanaf basiese intree/uittree na kommunikasie

- Using this strategy, we can convey 1-bit of information at one instant in time
- Now, vary the signal from Device 1 over time to communicate more bits of information



From GPIO to inter-device communication
Vanaf basiese intree/uittree na kommunikasie

Questions…

1.

How does device 2 know when the next bit of information is going to be valid? (this is called **synchronization**)

2.

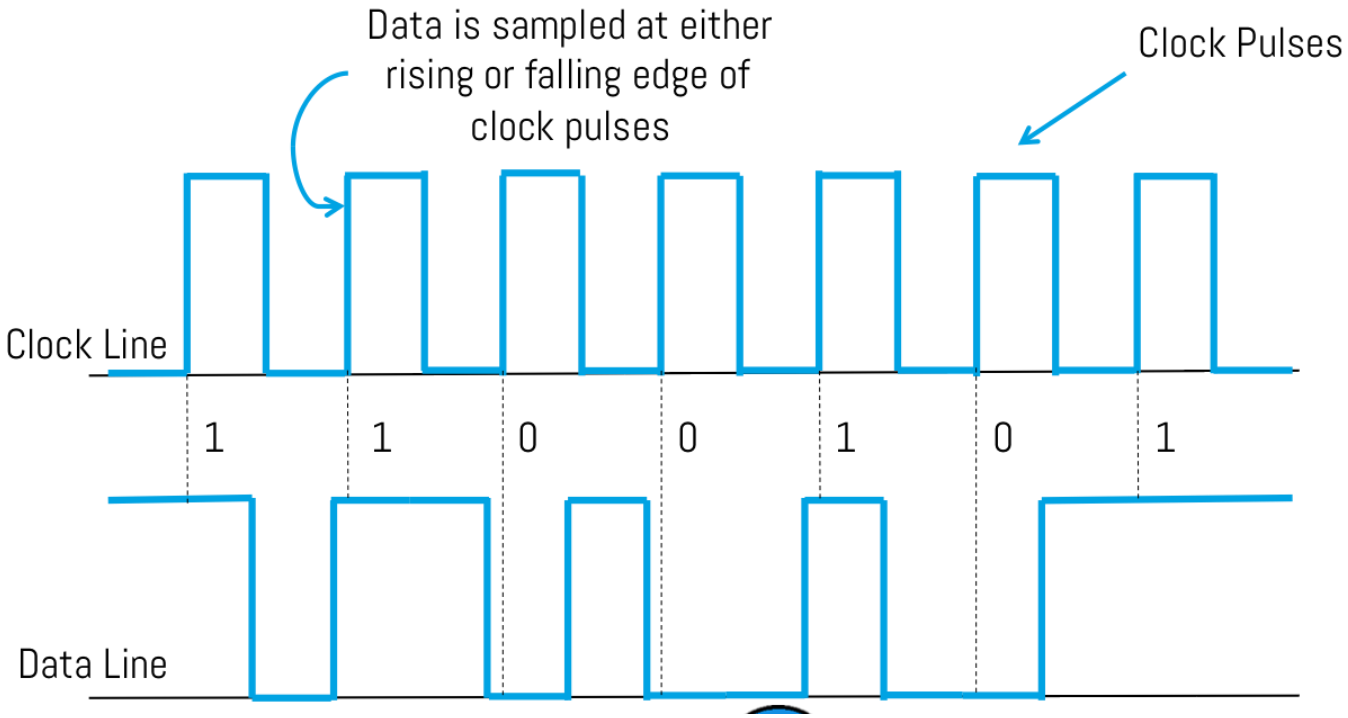
So far this is only one-way communication. How does device 2 reply information to device 1 (**unidirectional** vs. **bi-directional** communication)?

Synchronous vs. Asynchronous communication
Sinkrone en asinkrone kommunikasie

- **Communication synchronisation** – means with which the receiving device can determine when, in the time-varying data stream, one bit of information begins and the other ends
- Serial communication can be classified as synchronous or asynchronous

Synchronous vs. Asynchronous communication
Sinkrone en asinkrone kommunikasie

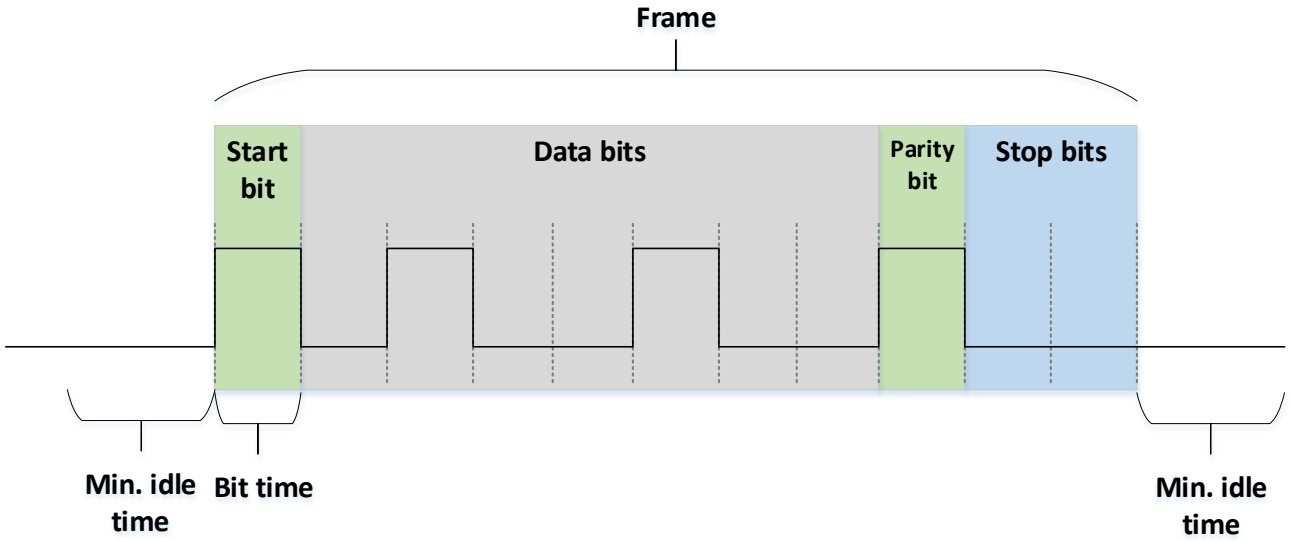
- **Synchronous** communication – separate clock signal is used to notify receiver when the next bit can be read



- **Pros**: Simple implementation. Allows for fast data transfer
- **Cons**: One more signal or wire is needed

Synchronous vs. Asynchronous communication
Sinkrone en asinkrone kommunikasie

- **Asynchronous** communication – the receiver figures it out on its own, based on
  - A known (expected signal rate)
  - The transitions in the data stream (when 0 changes to 1, or 1 to 0)
  - Special markers in the signal (Start bit, stop bit)



- **Pros**: Still only a single signal
- **Cons**: Implementation is more complex, slower data speeds (compared to synchronous)

Bi-directional communication
Bi-direksionele kommunikasie

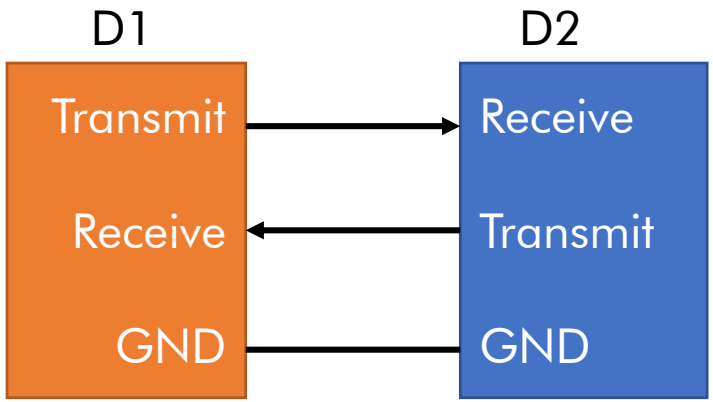
- Communication in one direction only has limited use
- **Bi-directional communication**: information can flow in both directions
- Some definitions:

Simplex	Half-duplex	Full-duplex
Communication in one direction only	Bi-directional communication, but only in one direction at a time	Simultaneous bi-directional communication

Point-to-point	Bus
Only two devices with dedicated communications channel between them	The same communication channel is shared by multiple devices

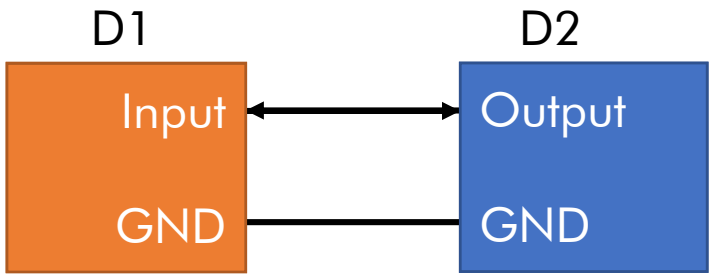
Bi-directional communication
Bi-direksionele kommunikasie

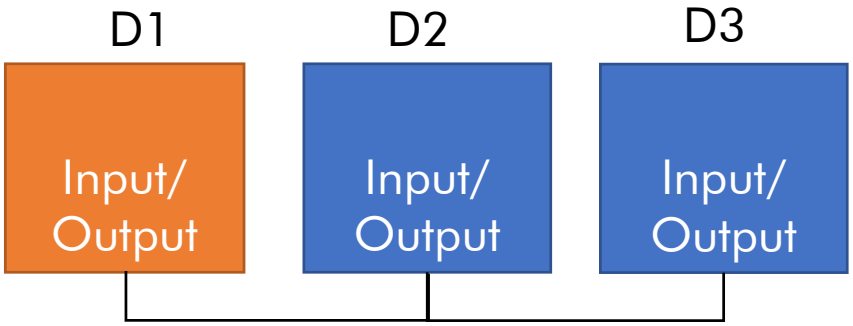
- How then do we achieve bi-directional communication?
- Option 1: Use 2 signals – one for sending data from Device 1 to Device 2, and another one to send from D2 to D1
- This scheme is a full-duplex, point-to-point communications link
- Make sure about signal direction: Signals are usually labelled Transmit (TX) or Receive (RX), but relative to which device? – check the data sheet!
- (Need a common reference voltage for the signals - connect GND as well)



Bi-directional communication
Bi-direksionele kommunikasie

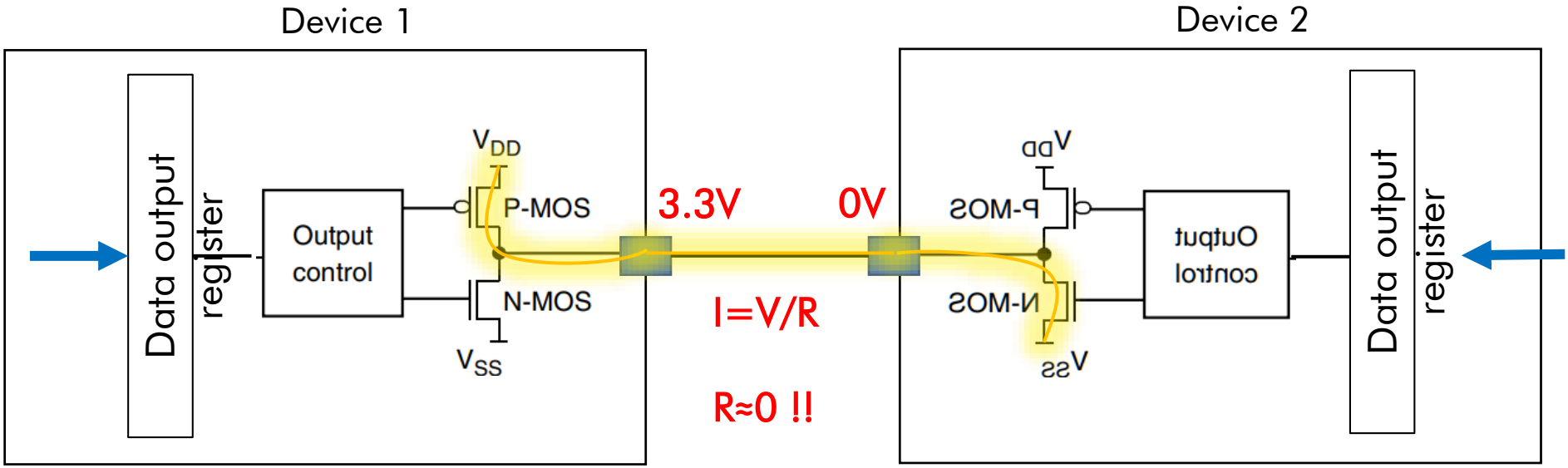
- <u>Option 2</u>: Another way – use the same physical wire/track/signal, but set device 1 as input/output, and device 2 as output/input whenever communication direction has to change
- Now we need a way to synchronise which device is allowed to control the signal
- This idea can be extended to a **communications bus** – more than two devices can use the same "line" to communicate.
- Usually in a bus communication architecture, one device will control the synchronization (the **master** device) and other devices (**slave** devices) will only communicate when allowed by the master





Bi-directional communication
Bi-direksionele kommunikasie

- Bus Contention: General term for two devices trying to use the bus at the same time
- At hardware level, this can be a problem: Let's say both devices are configured as output, device one outputs a logical 1, and device 2 outputs a logical 0



- This will cause a short-circuit! There is a limit to how much current the MOSFETs can supply and sink. The GPIO port of the microcontroller will get damaged
- The bus communication scheme has to prevent such a situation from occuring

Dedicated Serial Communication Hardware
Toegewyde seriële kommunikasie hardeware

- How would the program look that communicates using GPIO? -> LOTS of writing to memory mapped port registers. Timers. Interrupts
- At communication rate of 1 Mbps (1,000,000 bits per second), you will get 1 million interrupts per second! With a 10MHz clock and 1 machine instruction per clock cycle, you can only execute 10 machine instructions in the ISR
- The answer is to use special hardware that takes care of lower-level communications (synchronization, timing, data formatting and signal levels) – frees up the CPU so that it can perform other higher-level tasks
- Only interrupt processor for higher-level interaction, i.e. interrupt after transmission ended, or when data is arriving
- Sometimes removes the need for CPU interaction during the transfer altogether (Direct Memory Access – DMA)

- Communication will only work if both sets of specialised hardware follow the same rules for synchronisation, bi-directional transfers and signal levels. This leads to standardisation of a communications interface
- Standard serial communications interfaces: UART, I^2C, SPI, CAN, Ethernet, Serial ATA, USB, etc.
- Some of these are so common, most microcontrollers have such hardware embedded (UART, I^2C, SPI)

Standard Serial Communication
Standaard Seriële Kommunikasie

	Half/Full-duplex	Bus/point-to-point	Synchronous/ Asynchronous
UART (Universal Asynchronous Receiver/Transmitter	Full	Point-to-point	Asynchronous
I^2C (Inter-Integrated Circuit)	Half	Bus	Synchronous
SPI (Serial Peripheral Interface)	Full	Bus	Synchronous