

# lab 07

# UART

Digital design – laboratory exercises

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# UART

- Universal asynchronous receiver/transmitter
- Serial protocol for communication between devices
- Enables communication between Nexys board and:
  - PC (over serial port)
  - [expansion modules](#) (PMOD interface)
  - other devices
    - protocols RS-232, RS-422, RS-485
    - Bluetooth modules, ZigBee etc.

# UART (cont.)

- Data transmission over two wires
  - RX – receiver
  - TX – transmitter
- High voltage (logical 1) on a wire when idle
- The two communicating devices do not share a clock – that's why we call the protocol asynchronous. However, they must have the same sending frequency, the baud rate:
  - baud rate is a number of pulses/symbols per second
  - when a symbol is a bit: baud rate = bit rate

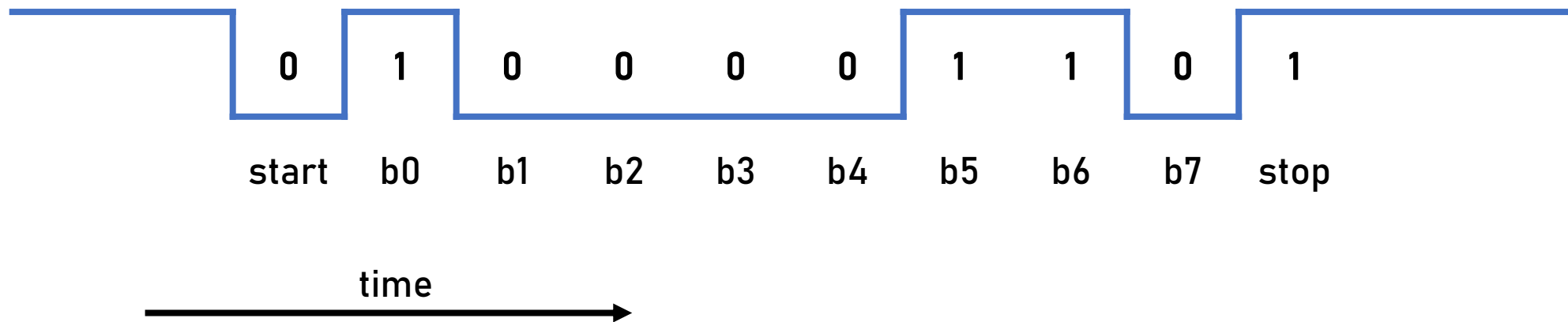
# UART packet

start bit 1 bit	data 5 to 9 bits	parity 0 or 1 bit	stop bits 1 or 2 bits
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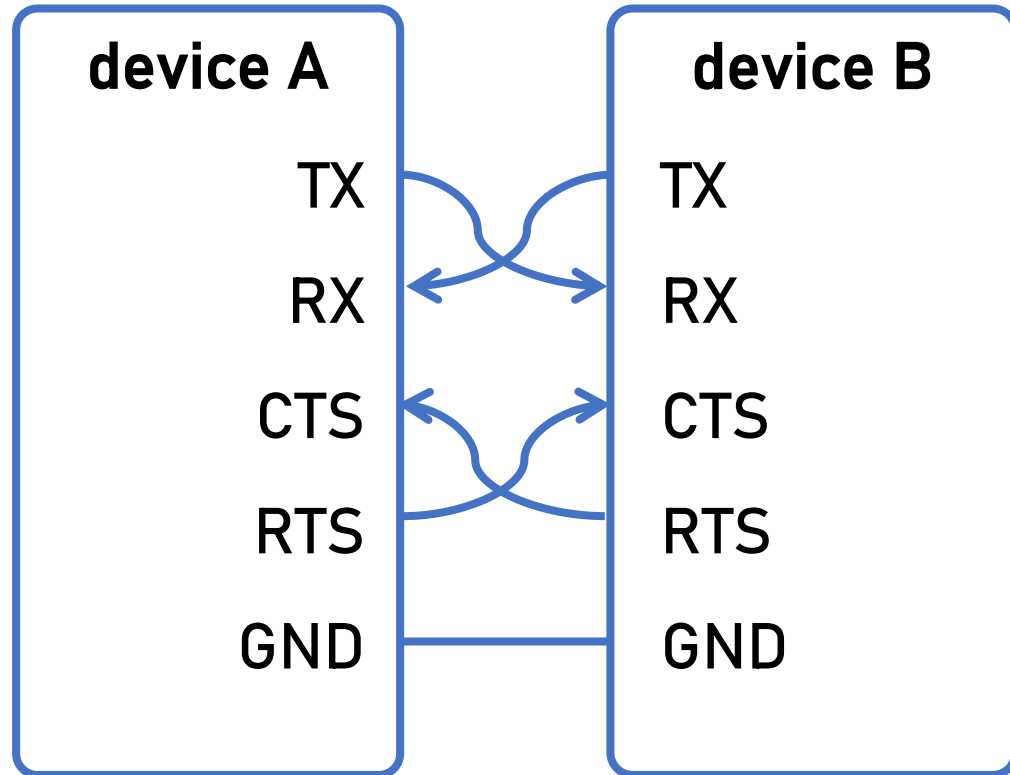
- **start bit:** always 0, announces the start of transmission
- **data:** if no parity bit is used, up to 9 bits can be packed into this part, otherwise up to 8. The least significant bit (LSB) is sent first;
- **parity:** optional; odd or even parity check
- **stop bits:** signal the end of the transmission by establishing a high voltage (logical 1) on the wire

# Example

- Example of sending ASCII character 'a' (0x61) without parity bit and with one stop bit.



# Connecting devices



**TX** - transmit

**RX** - receive

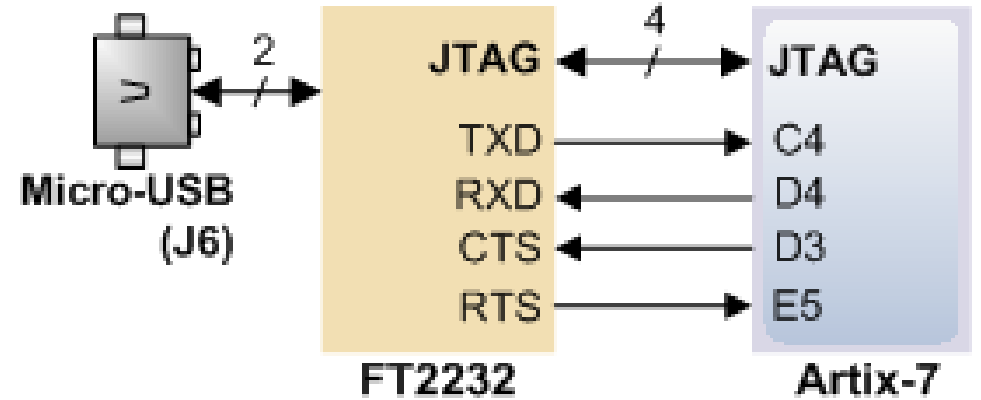
**Optional pins for flow control:**

**CTS** - clear to send

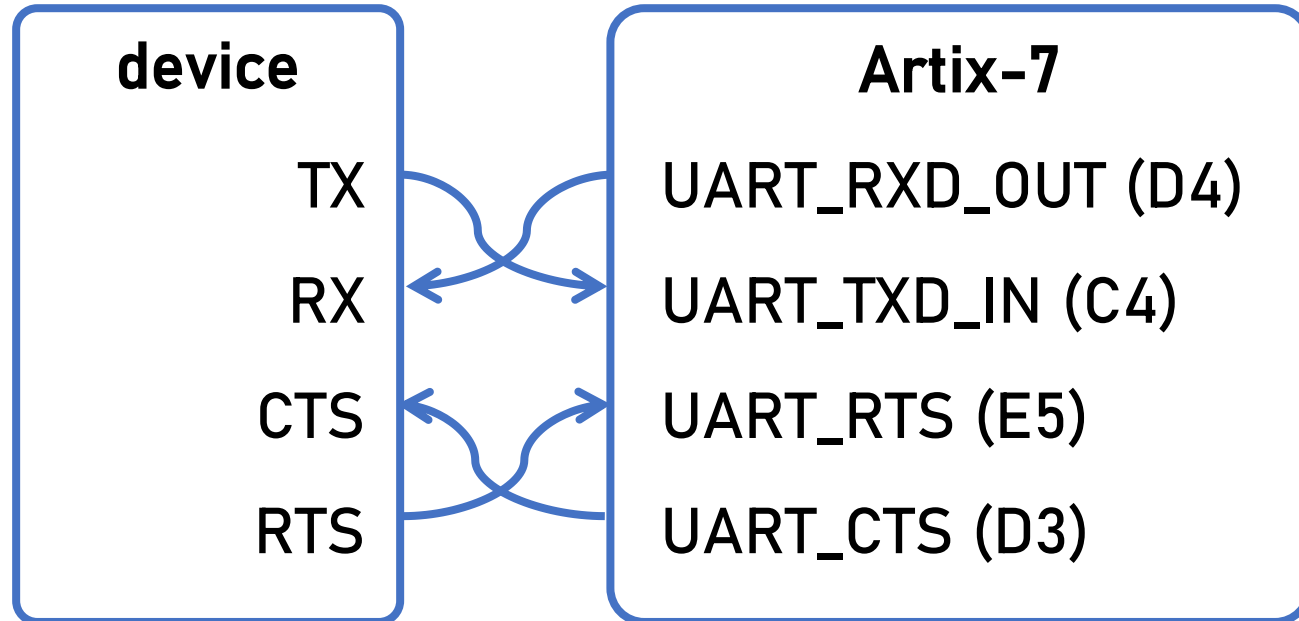
**RTS** - request to send

Device can transmit data when its CTS input is low.

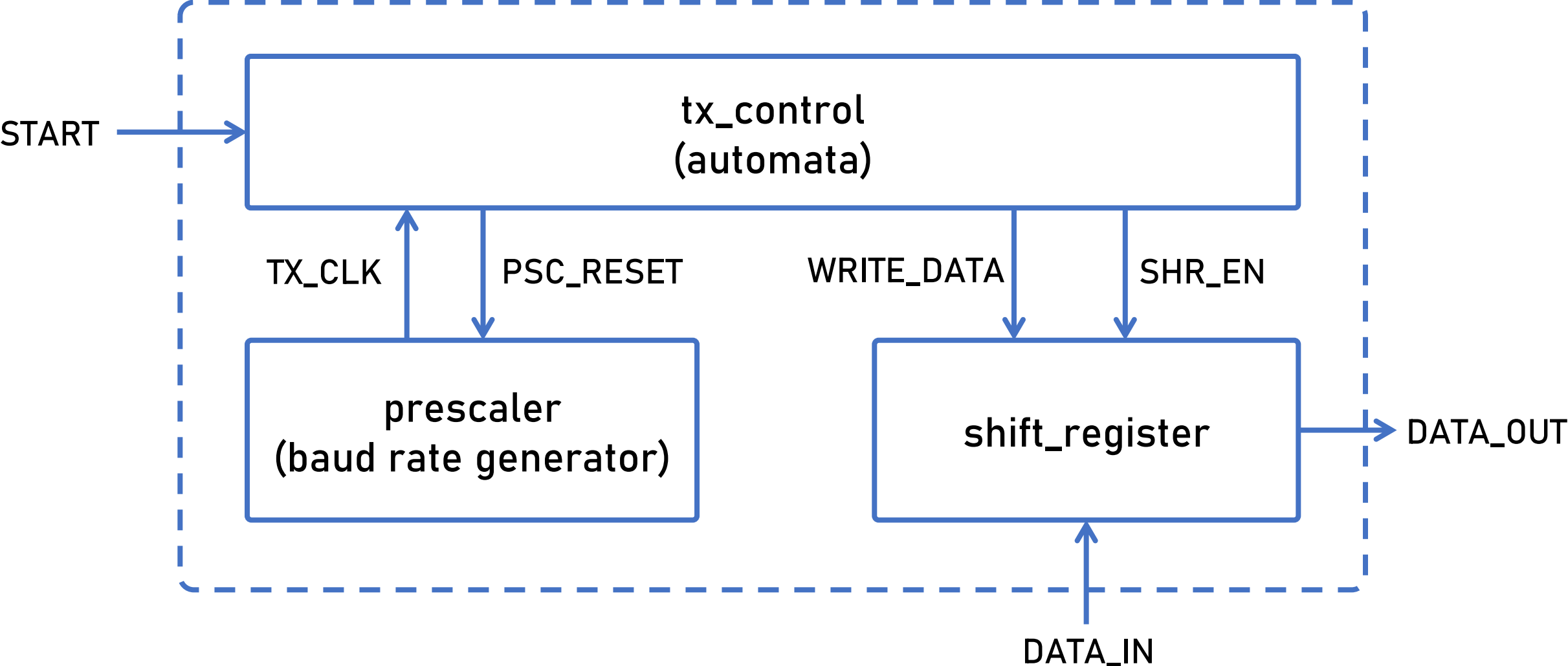
# I/O pins



USB-to-UART converter

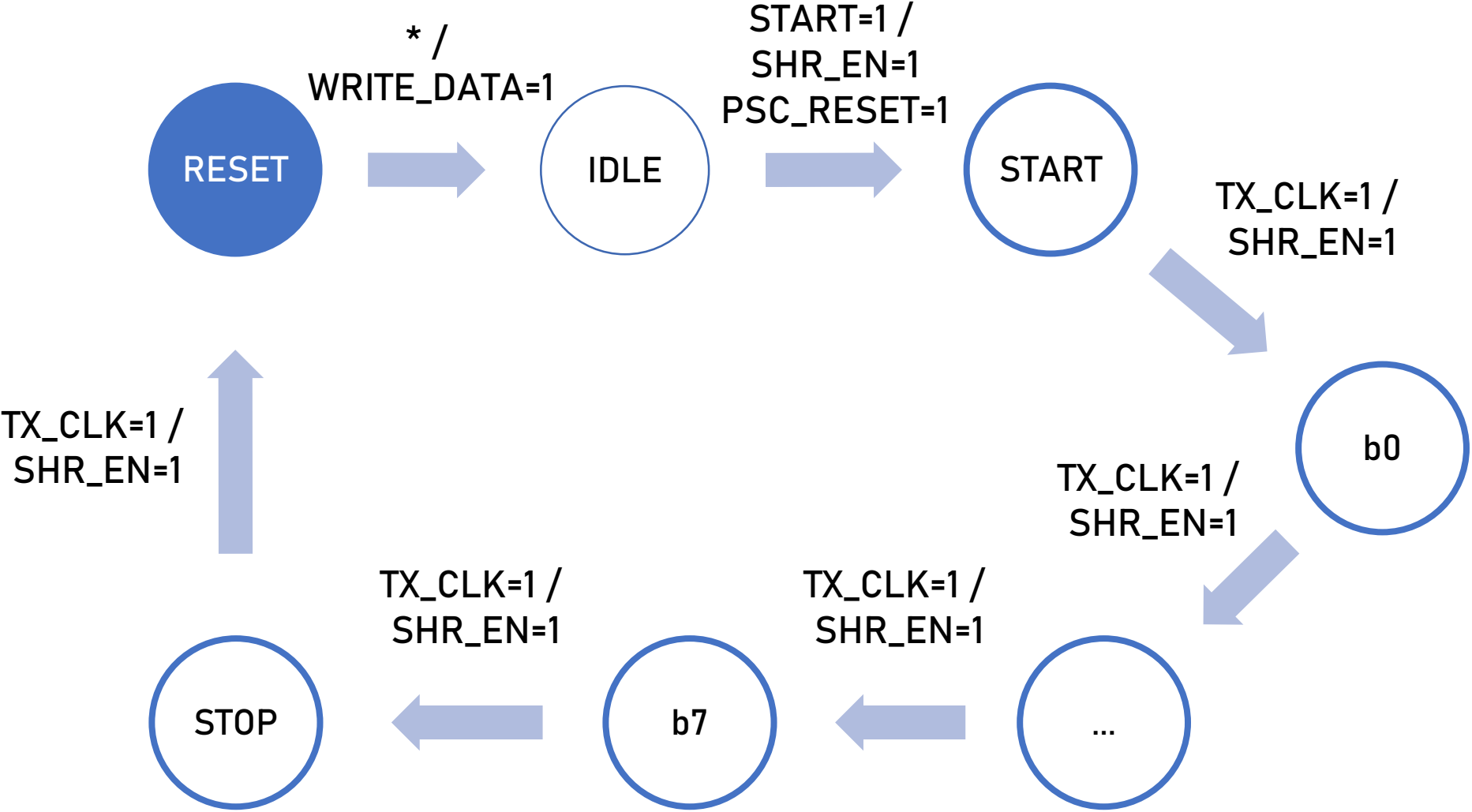


# Transmitter module





# Transmitter: a diagram



# Tools

- Windows

- a driver for virtual COM (USB packets converter):  
<https://ftdichip.com/drivers/vcp-drivers/>
- communication:
  - Hercules: <https://www.hw-group.com/software/hercules-setup-utility>
  - Free Serial Port Terminal: <https://freeseportterminal.com>

- Linux

- Nexys is seen as an USB device, usually ttyUSB0 and ttyUSB1 (JTAG and UART)  
`dmesg | egrep -i --color 'serial|ttyUSB'`
- communication tools: cu or screen or putty
- Example using screen:  
`screen /dev/ttyUSB1 9600`
- Serial port setup (8 data bits, no parity, one stop bit)  
`stty -F /dev/ttyUSB1 cs8 -parenb -cstopb -crtcts`

# Challenge

- We have devised an UART controller, which can send one byte.  
Use it to send a string of bytes, i.e. "Done!"
  - Hint: use finite state machine