Digital Signals
Control systems and Computer Networks

Dr Alun Moon

Lecture 1.3

Digital Signals
What is a digital signal?

A Digital Signal is:

Digital Signals
What is a digital signal?

A Digital Signal is:

True

A Digital Signal is:

   True   False

Digital Signals
What is a digital signal?

A Digital Signal is:

True	False
1	

Digital Signals
What is a digital signal?

A Digital Signal is:

True	False
1	0

Digital Signals
What is a digital signal?

A Digital Signal is:

True	False
1	0
on	

Digital Signals
What is a digital signal?

A Digital Signal is:

True	False
1	0
on	off

Digital Signals
What is a digital signal?

A Digital Signal is:

True	False
1	0
on	off
Pressed	

Digital Signals
What is a digital signal?

A Digital Signal is:

True	False
1	0
on	off
Pressed	Not-pressed

Digital Signals
What is a digital signal?

A Digital Signal is:

True	False
1	0
on	off
Pressed	Not-pressed
High	

Digital Signals
What is a digital signal?

A Digital Signal is:

True	False
1	0
on	off
Pressed	Not-pressed
High	Low

Digital Signals
What is a digital signal?

A Digital Signal is:

True	False
1	0
on	off
Pressed	Not-pressed
High	Low
5 V	

Digital Signals
What is a digital signal?

A Digital Signal is:

True	False
1	0
on	off
Pressed	Not-pressed
High	Low
5 V	0 V

Digital Signals
What is a digital signal?

A Digital Signal is:

True	False
1	0
on	off
Pressed	Not-pressed
High	Low
5 V	0 V
3.3 V	

Digital Signals
What is a digital signal?

A Digital Signal is:

True	False
1	0
on	off
Pressed	Not-pressed
High	Low
5 V	0 V
3.3 V	0 V

Digital Signals
What is a digital signal?

A Digital Signal is:

True	False
1	0
on	off
Pressed	Not-pressed
High	Low
5 V	0 V
3.3 V	0 V

▶ from a software perspective anything convenient for us to use

A Digital Signal is:

True	False
1	0
on	off
Pressed	Not-pressed
High	Low
5 V	0 V
3.3 V	0 V

- ▶ from a software perspective anything convenient for us to use
- ▶ there are external limitations and constraints,

Digital Signals
What is a digital signal?

A Digital Signal is:

True	False
1	0
on	off
Pressed	Not-pressed
High	Low
5 V	0 V
3.3 V	0 V

▶ from a software perspective anything convenient for us to use
▶ there are external limitations and constraints,
  • Physics

Digital Signals
What is a digital signal?

A Digital Signal is:

True	False
1	0
on	off
Pressed	Not-pressed
High	Low
5 V	0 V
3.3 V	0 V

▶ from a software perspective anything convenient for us to use
▶ there are external limitations and constraints,
  • Physics
  • Standards

Electrical Characteristics

Generally :

positive voltage logical 1

negative voltage logical 0

Electrical Characteristics

Generally :

positive voltage logical 1

negative voltage logical 0

Specific technologies have specific voltages for *on*

TTL Transistor Transistor Logic   5 V

CMOS Complementary Metal Oxide Semiconductor   3.3 V

Sequences

Digital signals exist in sequences. . .

Sequences

Digital signals exist in sequences. . .

- ▶ Traffic Lights

Sequences

Digital signals exist in sequences. . .

- ► Traffic Lights
  - • Red → Red,Amber → Green → Amber → Red . . .

Sequences

Digital signals exist in sequences...

- ▶ Traffic Lights
  - Red $\rightarrow$ Red,Amber $\rightarrow$ Green $\rightarrow$ Amber $\rightarrow$ Red ...
  - $\langle \{r\}, \{r, a\}, \{g\}, \{a\} \rangle$

Sequences

Digital signals exist in sequences...

- ▶ Traffic Lights
  - Red → Red,Amber → Green → Amber → Red ...
  - $\langle \{r\}, \{r, a\}, \{g\}, \{a\} \rangle$
  - Can be written as a Timing Diagram

  Red ⎍‾‾‾‾‾‾|_____|‾‾‾‾
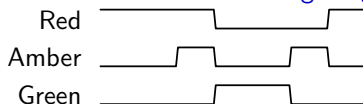
  Amber ____|‾|____|‾|____

  Green _____|‾‾‾|____

Sequences

Digital signals exist in sequences. . .

- ▶ Traffic Lights
    - Red $\rightarrow$ Red,Amber $\rightarrow$ Green $\rightarrow$ Amber $\rightarrow$ Red . . .
    - $\langle \{r\}, \{r, a\}, \{g\}, \{a\} \rangle$
    - Can be written as a Timing Diagram
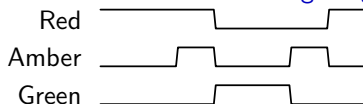
- ▶ Flashing

Sequences

Digital signals exist in sequences. . .

- ▶ Traffic Lights
  - Red → Red,Amber → Green → Amber → Red . . .
  - $\langle \{r\}, \{r, a\}, \{g\}, \{a\} \rangle$
  - Can be written as a Timing Diagram
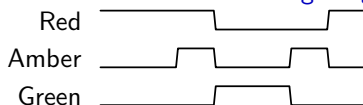
- ▶ Flashing
  - On → Off → On . . .

Sequences

Digital signals exist in sequences. . .

- ▶ Traffic Lights
  - Red → Red,Amber → Green → Amber → Red . . .
  - $\langle \{r\}, \{r, a\}, \{g\}, \{a\} \rangle$
  - Can be written as a Timing Diagram
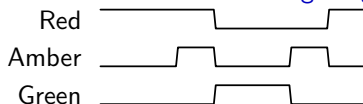
- ▶ Flashing
  - On → Off → On . . .
  -

Digital IO from the µC
Microcontrollers (µC) have dedicated hardware for digital IO.

- ▶ The K64F has 5 ports with 32 IO pins which can be used as GPIO pins (General Purpose Input Output)
- ▶ The IO circuit has a number of configureable options for each pin, accessed through several registers
- ▶ **ALL** the appropriate bits need to be set or it doesn't work.

GPIO Hardware Registers
Sequence and purpose of bits to set

There are several bits to set to configure the pin

1. System Clock Gating Control Register SCGC
   Enables the clock signal for the port, making it function

2. Pin Control Register PORTx_PCRn
   a 32bit register for each pin setting several options
     - IRQC – Interrupt configuration (what causes an interrupt to occur)
     - MUX – Pins have multiple functions, this selects the function to use.
     - DSE – Drive Strength, the electrical characteristics of the output
     - ODE – Open Drain, elctrical connections of the Output
     - PFE – Passive Filter for inputs (debounce and glitch rejection)
     - SLE – Slew Rate, how fast the output switches between high and Low
     - PE – enable pull up or down resistor for inputs
     - PS – selects the pull-up or pull-down resistor.

GPIO Hardware Registers
Port Registers

Each Port has several registers to use for the actual IO operations. Each bit in the register corresponds to an external pin.

GPIOx_PDOR Port Data Output Register

      0. Set the output to logic 0

      1. Set the output to logic 1

GPIOx_PSOR Port Set Output Register

      0. output does not change

      1. Set the output to logic 1

GPIOx_PCOR Port Clear Output Register

      0. output does not change

      1. Set the output to logic 0

GPIOx_PTOR Port Toggle Output Register

      0. Output does not change

      1. Change the logic state of the output

GPIO Hardware Registers
Port Registers

GPIOx_PDIR Port Data Input Register
   0. Pin is set to input logic 0 (or is not configured)
   1. Pin is set ti input logic 1

GPIOx_PDDR Port Data Direction Register
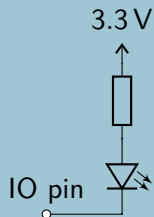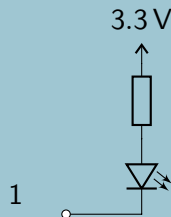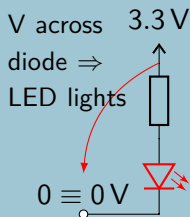   0. GPIO pin set as input
   1. GPIO pin set as output

IO Circuits
Output
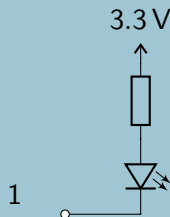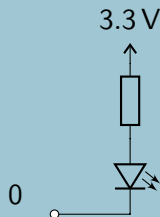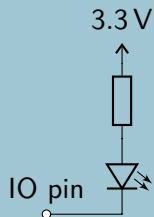
- The μC pin is set to 0 or 1
- in the case of the K64F $1 \equiv 3.3\,\text{V}$
- But what does that do?
- It depends on the external circuit.

The LED

IO Circuits
Output

- ▶ The µC pin is set to 0 or 1
- ▶ in the case of the K64F $1 \equiv 3.3\,\text{V}$
- ▶ But what does that do?
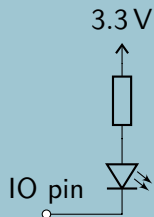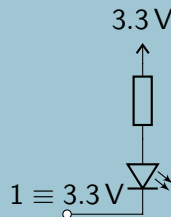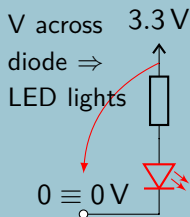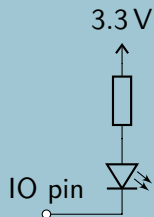- ▶ It depends on the external circuit.

The LED

- The μC pin is set to 0 or 1
- in the case of the K64F $1 \equiv 3.3\,\text{V}$
- But what does that do?
- It depends on the external circuit.

The LED

3.3 V

IO pin

V across
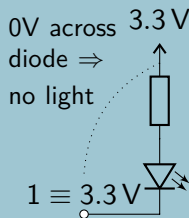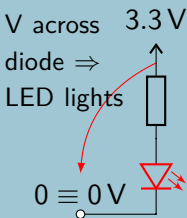diode ⇒
LED lights   3.3 V

$0 \equiv 0\,\text{V}$

3.3 V

1

IO Circuits
Output

- The μC pin is set to 0 or 1
- in the case of the K64F $1 \equiv 3.3\,\text{V}$
- But what does that do?
- It depends on the external circuit.

The LED

3.3 V

IO pin

V across diode ⇒ LED lights   3.3 V

$0 \equiv 0\,\text{V}$

3.3 V

$1 \equiv 3.3\,\text{V}$

IO Circuits
Output

- The µC pin is set to 0 or 1
- in the case of the K64F $1 \equiv 3.3\,\text{V}$
- But what does that do?
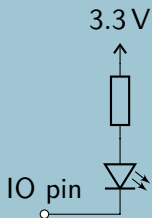- It depends on the external circuit.

The LED

3.3 V

IO pin

V across diode ⇒ LED lights   3.3 V

$0 \equiv 0\,\text{V}$

0V across diode ⇒ no light   3.3 V

$1 \equiv 3.3\,\text{V}$

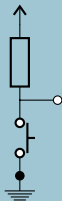# IO Circuits
Input

- The μC pin is set to 0 or 1 by the external circuit
- But what does that mean?
- It depends on the external circuit.

Base Shield Push Buttons

Upper Shield 5-way switch