Digital Signals

Control systems and Computer Networks

Dr Alun Moon

Lecture 1.2

Digital Signals

What is a digital signal?

A Digital Signal is:

Digital Signals

What is a digital signal?

A Digital Signal is:

True

Digital Signals

What is a digital signal?

A Digital Signal is:

True False

Digital Signals

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A Digital Signal is:

True	False
1	

Digital Signals

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Digital Signals

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Digital Signals

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Digital Signals

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Digital Signals

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Digital Signals

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5 V	

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  - Standards

Electrical Characteristics

Generally :

positive voltage logical 1

negative voltage logical 0

Electrical Characteristics

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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. . .

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- Traffic Lights

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  - Red $\rightarrow$ Red,Amber $\rightarrow$ Green $\rightarrow$ Amber $\rightarrow$ Red ...

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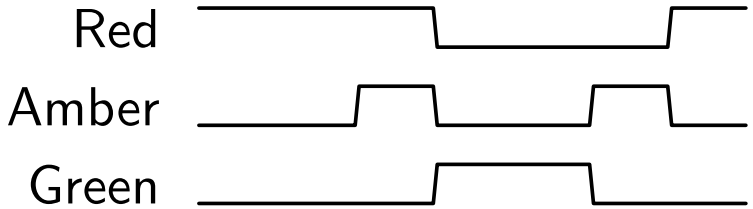

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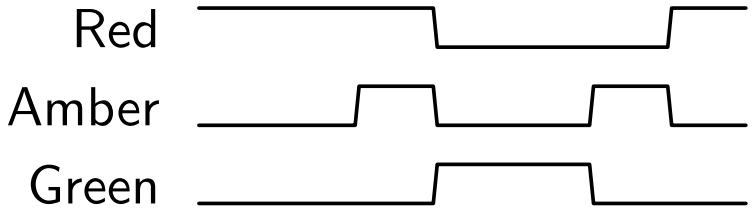

- Flashing

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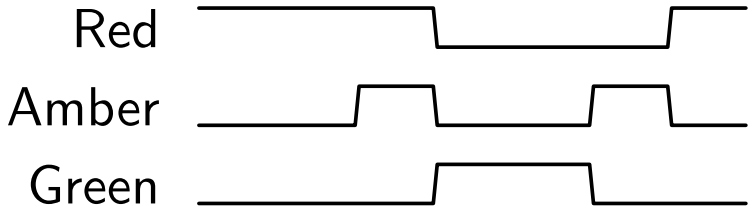

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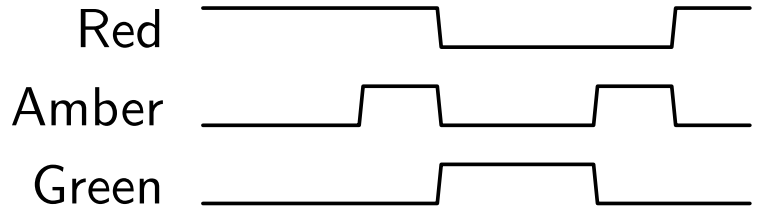

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  -

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

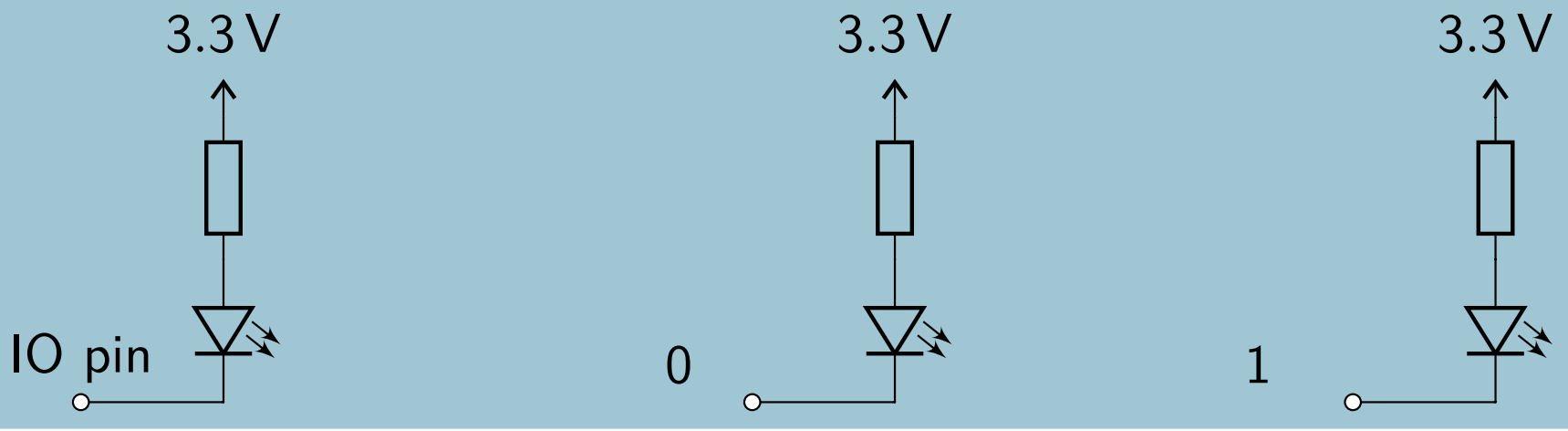
0. GPIO pin set as input
1. GPIO pin set as output

IO Circuits

Output

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

The LED



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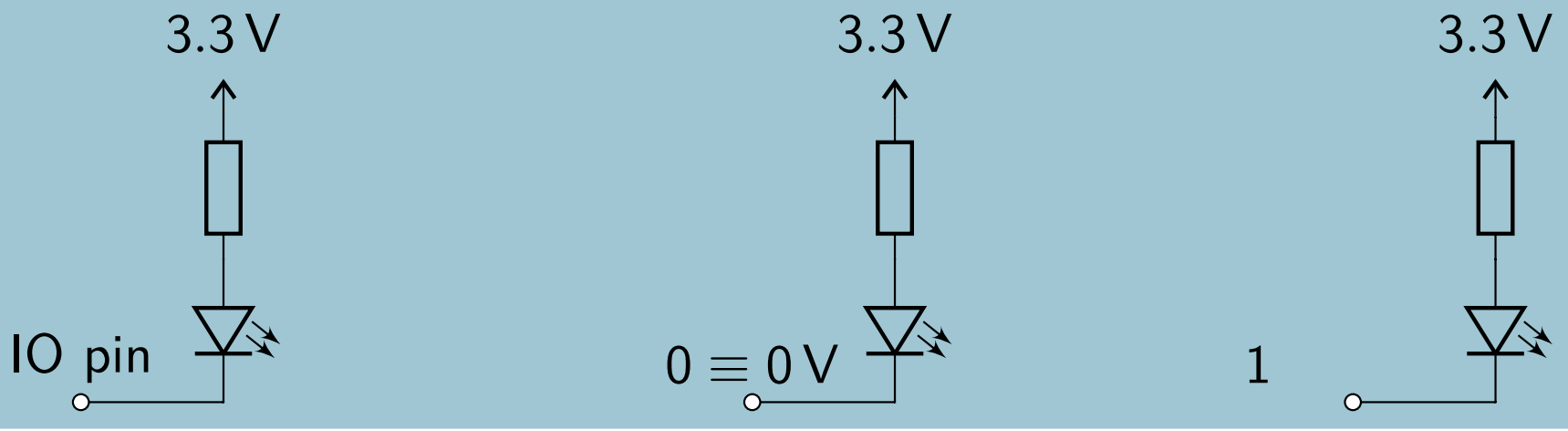

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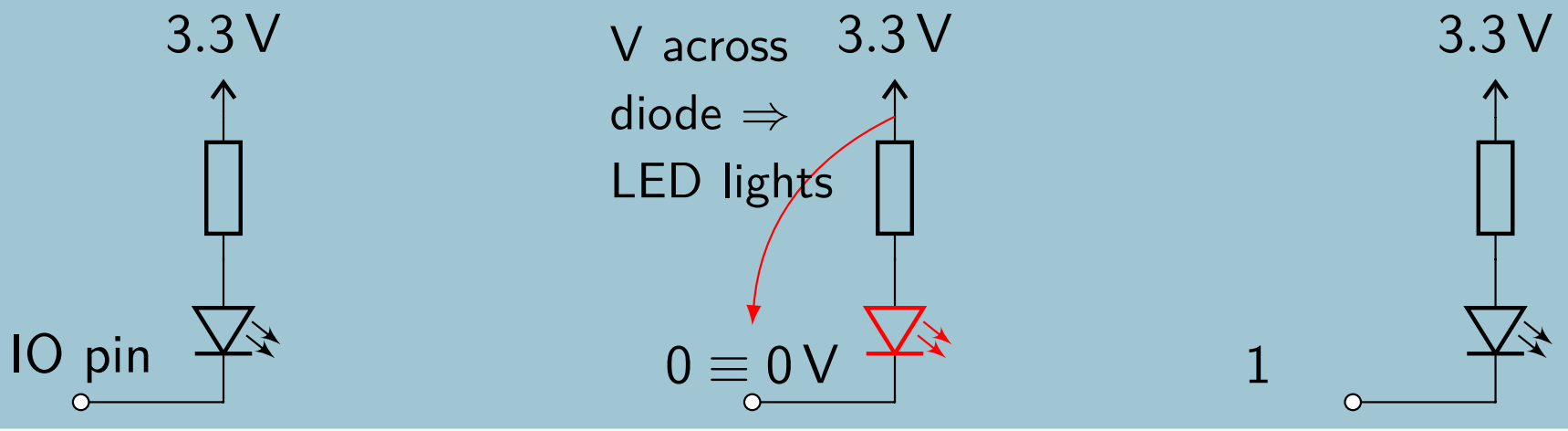

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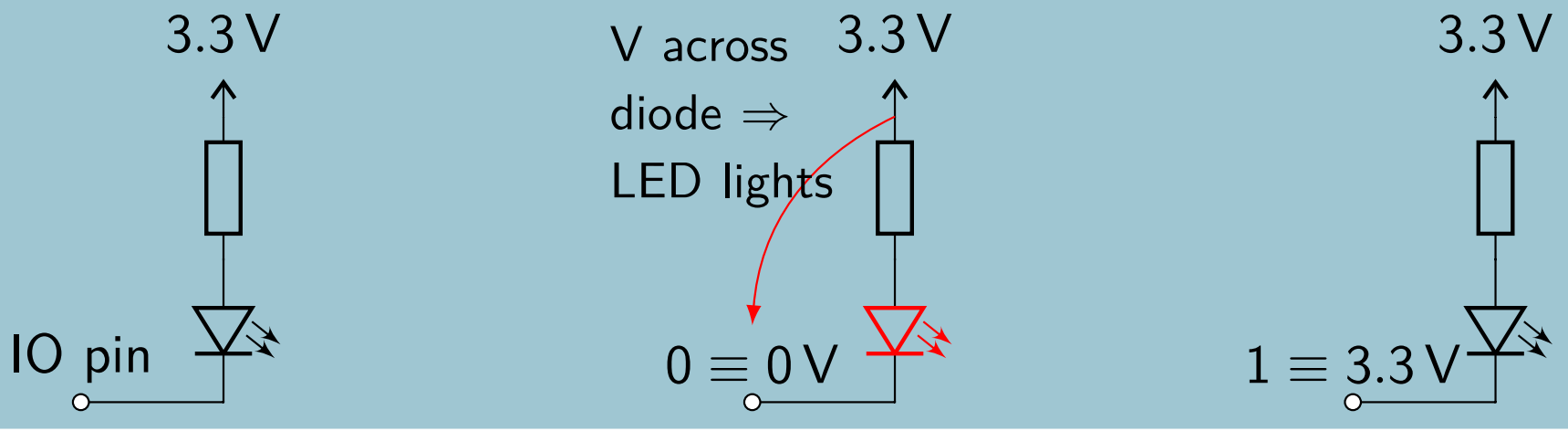

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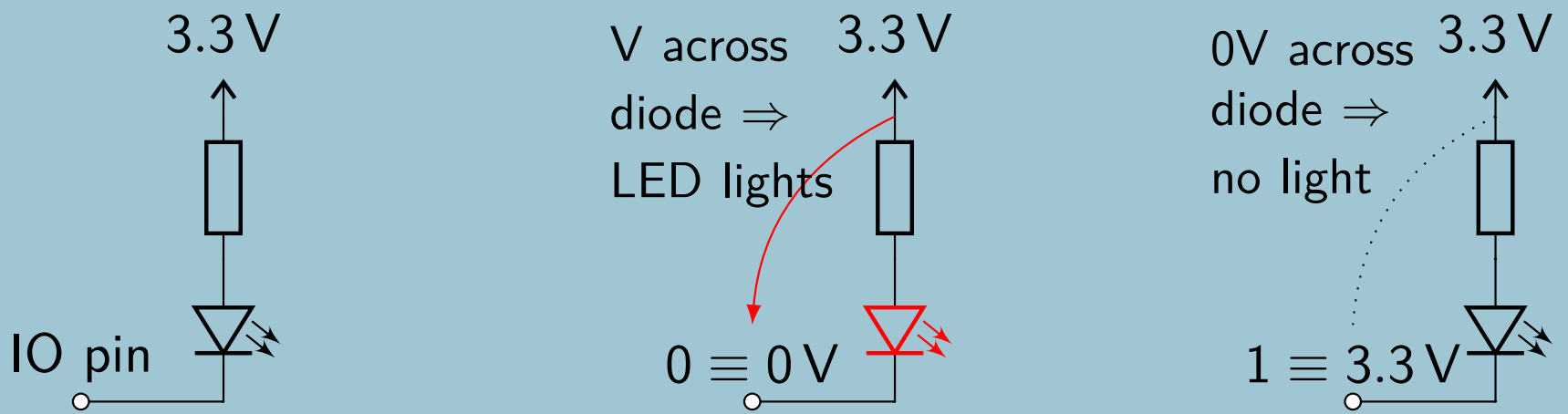

IO Circuits

Input

- The µC pin is set to 0 or 1 by the external circuit
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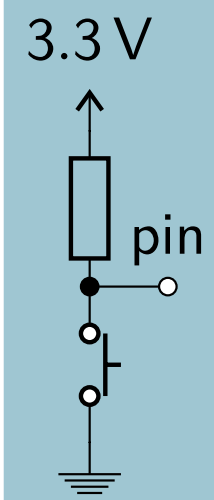
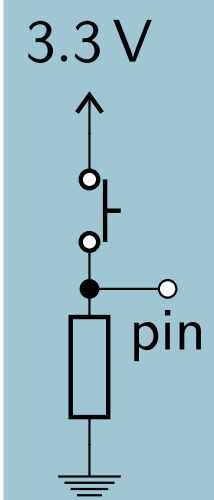
Base Shield Push Buttons



- Not Pressed pin is connected to 3.3 V (logic 1) through *pull-up* resistor

Upper Shield 5-way switch



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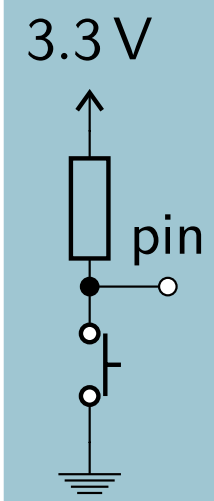

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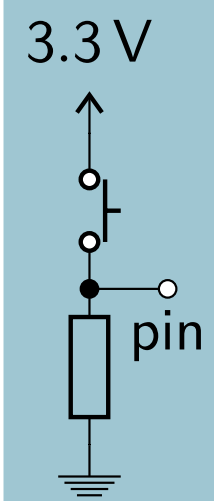

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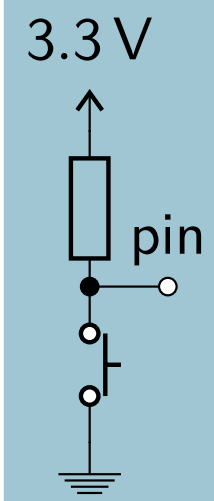

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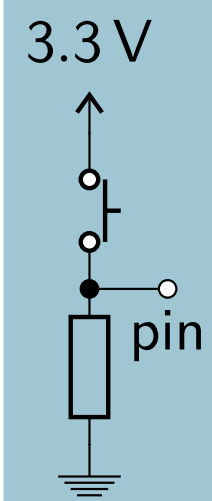

- Not Pressed pin is connected to 0 V (logic 0) through *pull-down* resistor

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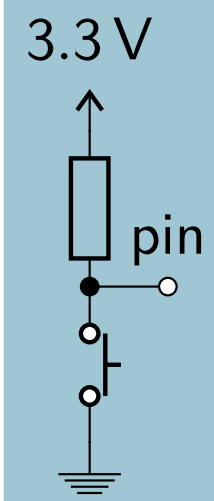

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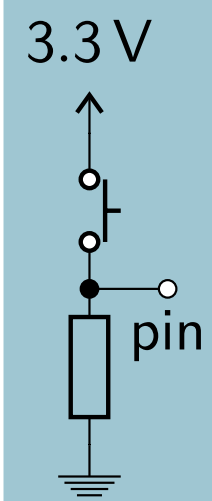

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Some Mathematics

- Digital signals are logic values
- Can be modelled using discrete maths and Boolean Algebra.
- We need a new notation to indicate the change in state

Definition (Change in state)

The new state is indicated by the use of a prime.

$$a' = a \oplus 1$$

The digital signal a has a new value a', the XOR of the current state and 1

What does this do?

Sequences

- A sequence can be written in a manner similar to a set:

$$\langle \{r\}, \{r, a\}, \{g\}, \{a\}, \{r\} \rangle$$

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- Iteratively:

$$b_n = n \in \mathbb{Z}_{\text{primes}}$$

$$g_{n+1} = B_1 \Rightarrow g_n \oplus 1$$

Constraints from Standards

Now we have an understanding of:

- What a digital signal is
- How to manipulate them

We have a question:

What should the signal be? How should it behave?

This is where constraints from the application domain, and any applicable standards, dictate the operation.

Traffic lights

we can substitute blue for amber

For a 2-way junction we have 2 sets of Lights.

$$r_n, a_n, g_n, r_w, a_w, g_w$$

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- What combinations are allowed?
- What are the allowed transitions?

Morse Code

- Morse code is a Digital signal (on and off)
- The sequence of states and their timing is defined by standards International Morse code Recommendation ITU-R M.1677-1

Timing

1. short mark, dot or "dit" : "dot duration" is one time unit long
2. longer mark, dash or "dah": three time units long
3. inter-element gap between the dots and dashes within a character: one dot duration or one unit long
4. short gap (between letters): three time units long
5. medium gap (between words): seven time units long

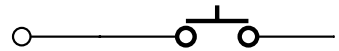
Two Handed start

- In many industrial automation environments "two-handed" start is used as a safety feature
- to start a machine, two start switches, **must** be pressed together, in order to start.

Logic

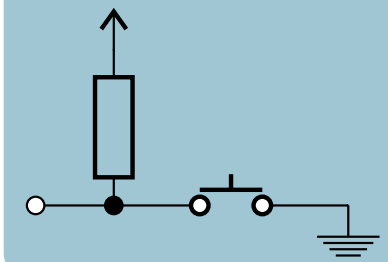
m	state of motor
b_1	one start switch
b_2	second start switch
Constraint	$b_1 \wedge b_2 \Rightarrow m$
Action	$m' = m \vee (b_1 \wedge b_2)$

Pullup and pulldown resistors

- In a number of places pull-up and pull-down resistors are mentioned.
- The problem occurs when a wire/pin has no input driving it, what logic value does it have? 

Pull-up resistor

Pull-up resistor connects the pin to the supply (logic 1) ensuring a 1 when there is no other signal.



Pull-down resistor

Pull-down resistor connects the pin to the ground (logic 0) ensuring a 0 when there is no other signal.