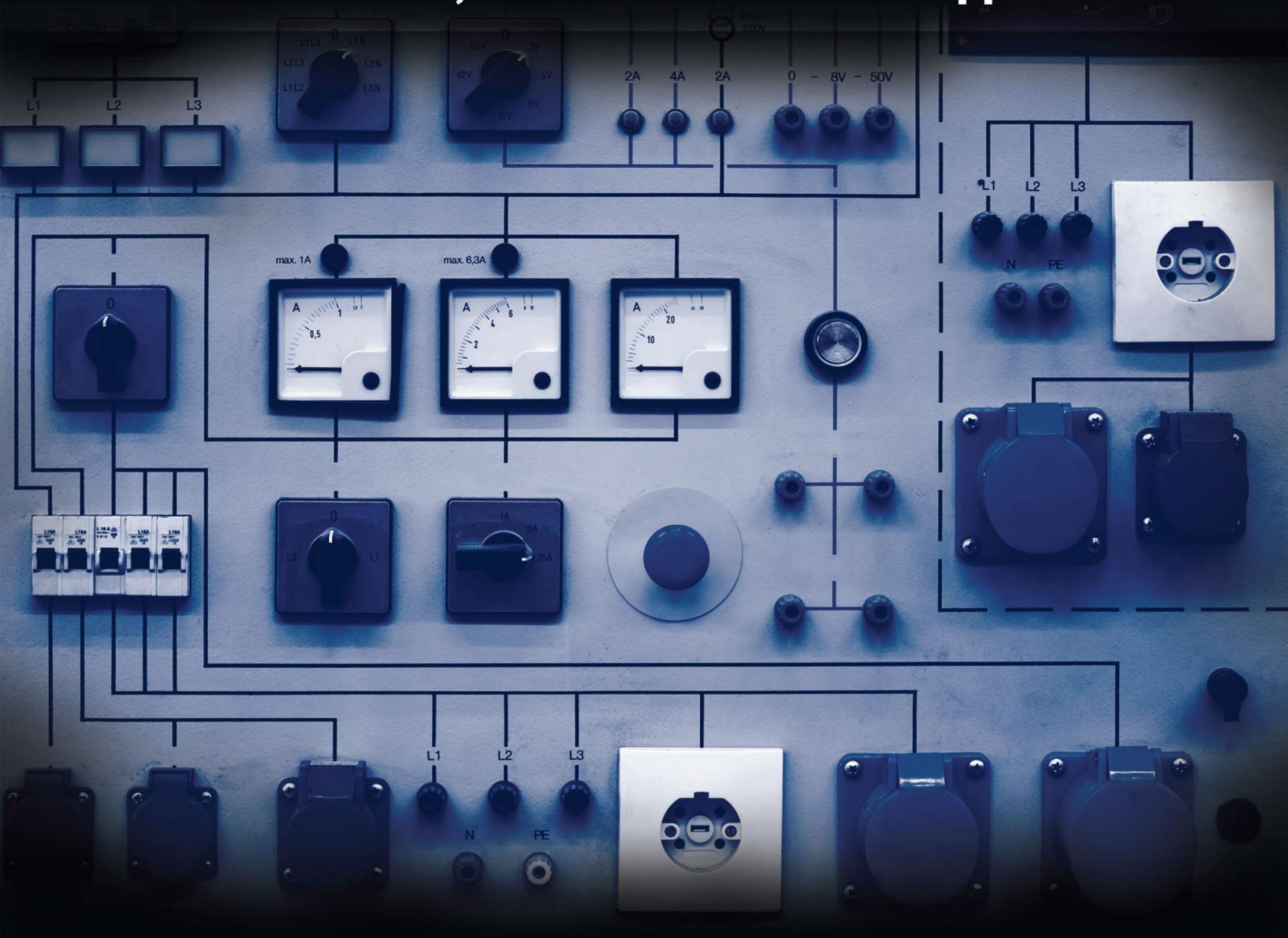
locktronics

Simplifying Electricity

Industrial sensor, actuator and control applications



CP7718

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Contents

Worksheet 1

Basic Outputs

Industrial sensor, actuator and control applications

Modern control systems - including PLCs - have two types of output:

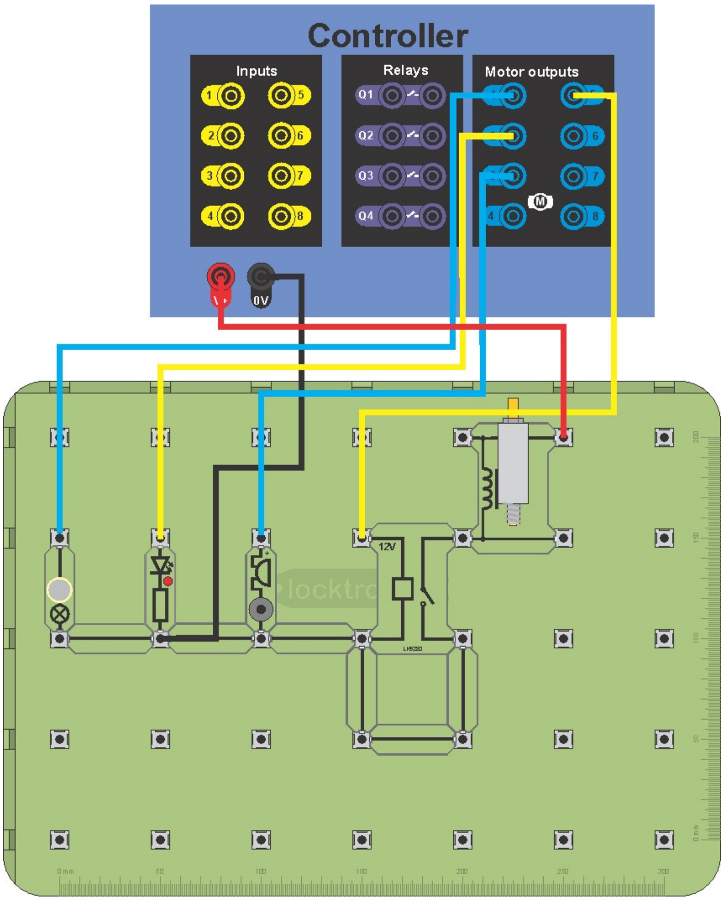
- Low current transistor outputs
- Higher current relay outputs

Transistor outputs can change very quickly but provide limited current. Relay outputs are relatively slow to change. However relays can switch a great deal more current than transistors due to their mechanical nature.

Photograph shows a simple warning beacon.

Over to you:

1. Build the Locktronics system shown opposite.
2. Create a simple program to go through each of the Motor outputs switching one on at a time.



So what?

- Motor output vary from one controller to the other. You will need to understand the capability of the outputs on your controller in terms of voltage and current.
- Where a controller is not able to supply enough voltage or current electricians make use of an external relay. Although the two circuits here have a common ground, relays are also good at isolating one circuit from another.
- Controllers vary in their internal circuitry - some do not have internal relays.

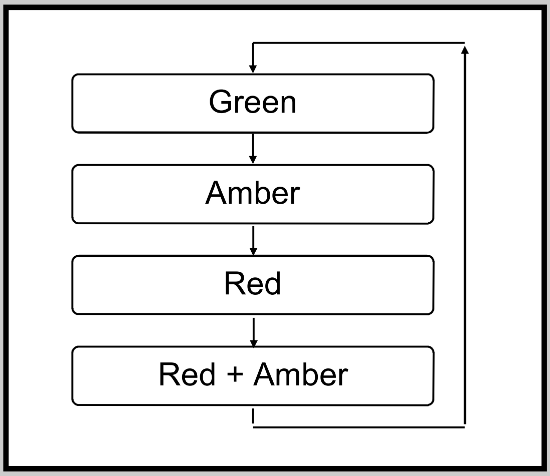
Worksheet 2

Sequenced Outputs

Industrial sensor, actuator and control applications

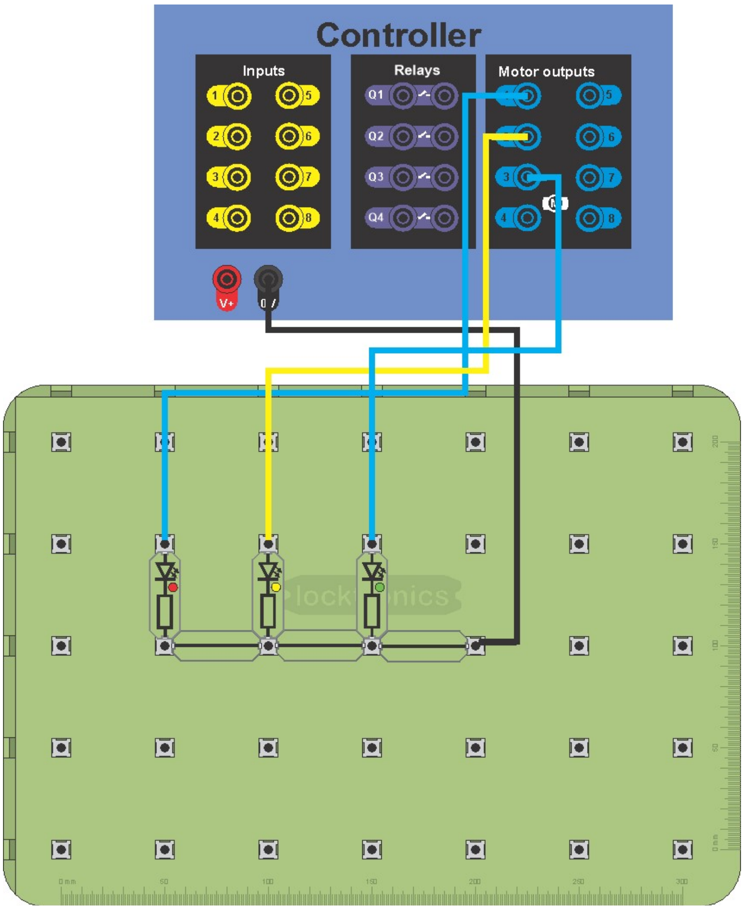
In a controller it is useful to be able to switch from one state to another. This is sometimes called a 'state machine'.

In the basic traffic light system shown there are four unique states that the lights can be in. Therefore the system we will design will need to be able to switch between these four states assigning different values to the outputs depending on the state they are in.



Over to you:

1. Build the system shown opposite.
2. Create a simple program to control the LEDs to simulate a set of traffic signals.
3. Start by assigning output values for each LED for a single state.
4. Add a timer / counter to keep track of your current state and then start adding decisions into your program based on the state.
5. Modify your output values depending on the current state.



So what?

- Changing a basic output is the simplest of programs. In the next few worksheets you will use this routine many times.

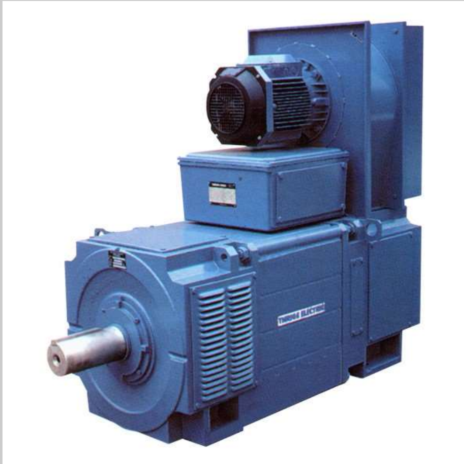
Worksheet 3

Pulse Width Modulation

Industrial sensor, actuator and control applications

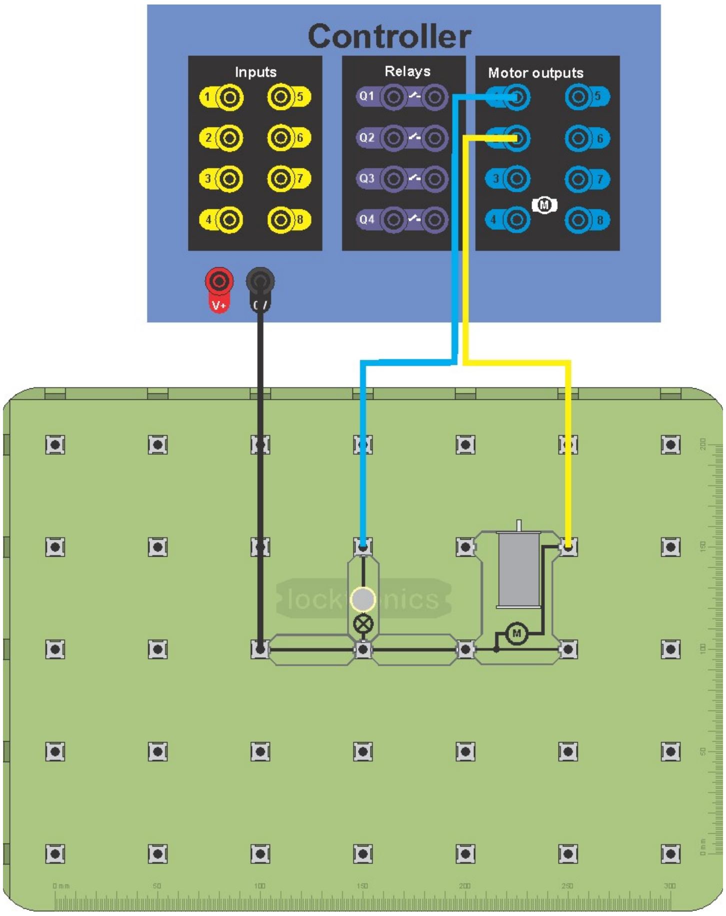
To vary the speed of a motor you need to vary the **power** supplied to it. The two easiest ways of doing this are to vary the voltage, or vary the **duty cycle** (the ratio of on time to off time) of the motor supply. This is called Pulse Width Modulation or PWM.

Photograph shows a 12V DC motor with gearbox.



Over to you:

1. Build the system shown opposite.
2. Create a simple program to enable PWM on output 1.
3. Ramp up the duty from fully off to fully on in small steps over a 10 second period.
4. Repeat this exercise for PWM output channel 2.
5. Take the 0V wire, disconnect it from the 0V terminal and connect it to output terminal 3.
6. Modify your program so that output 3 switches on and off at regular intervals. Monitor what happens to the bulb and the motor as the PWM ramps up.



So what?

- Using output 3 we now have control of both the speed direction of the motor.
- When output 3 is low the current is supplied from the PWM channel and exits via output 3.
- When output 3 is high the current is supplied from the output and exits via the PWM.
- Motor outputs can SINK or SOURCE current.

Worksheet 3

Pulse Width Modulation

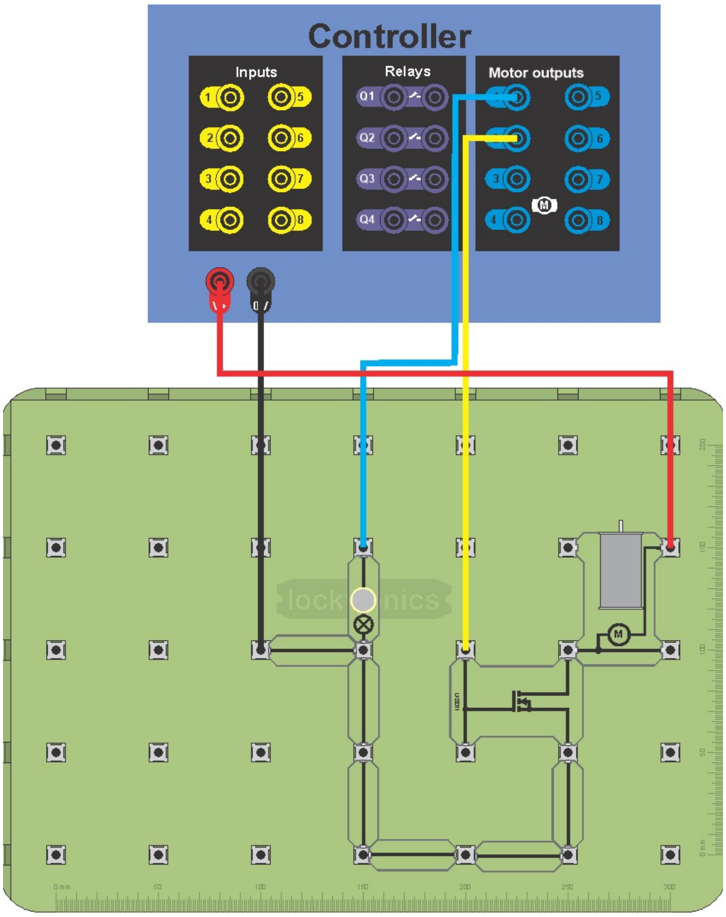
Industrial sensor, actuator and control applications

Over to you:

1. Modify the circuit so that the output 2 feeds a FET connected to a motor.
2. Is there any difference in the functionality of the program?

So what?

- FETs are useful as current amplifiers and where a controller needs to switch larger currents fast then external transistor drivers may be necessary.
- Transistors switch much faster than relays.
- The motor outputs of your controller will either be simple FETs or will be a grid of FETS that can both sink and source current. You will need to understand the internal circuitry of your controller to understand its capabilities.



Worksheet 4

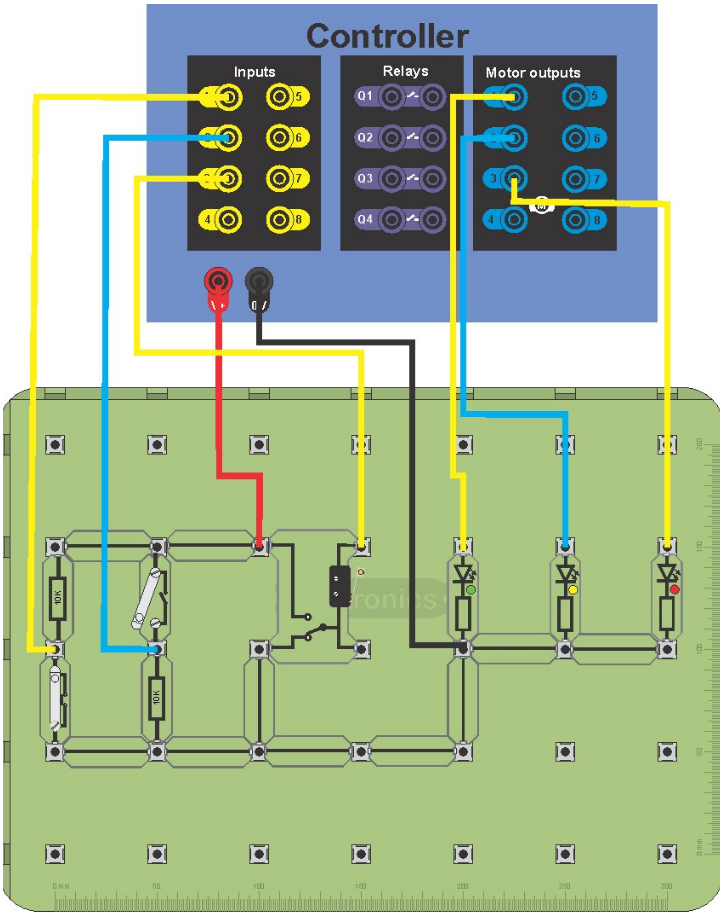
Basic Inputs

Industrial sensor, actuator and control applications

The sensors in any industrial system can be divided into two types: **analogue** and **digital.** The inputs on most modern controllers are compatible with both analogue and digital signals. **Digital** sensors have a two state output, usually either 'on' or 'off'. The power supply used determines the voltages corresponding to these two states - often 10V (on) and 0V(off). **Analogue** sensors have a continuous output normally ranging between the supply voltage and 0V. Analogue sensors will be covered later in the course.
Photograph shows a pressure switch.

Over to you:

1. Build the system shown opposite.
2. Create a simple program to read the digital state of the switches where pressed or activated = 'ON'
3. Display the state of the switches on the corresponding outputs.



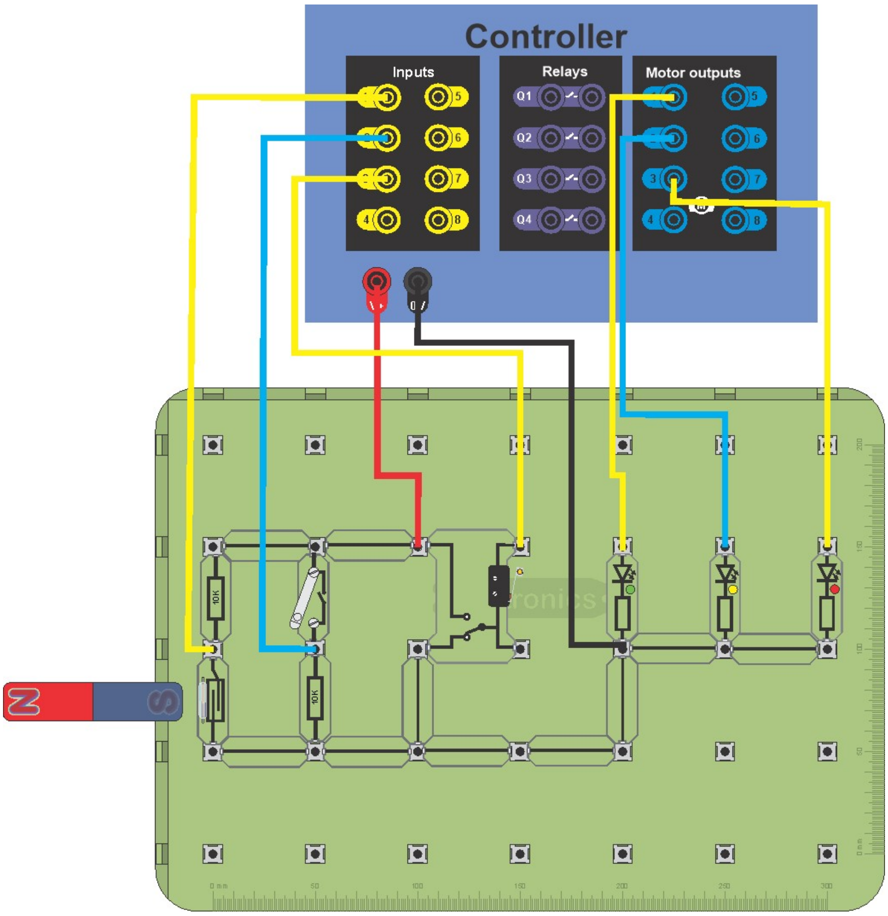
So what?

- The two switches work in different ways. The push to make switch switches a low voltage to the input, the slide switch switches a high voltage to the input.
- The voltage on the input pin may not be as simple as V+ or 0V on the input. The actual voltage will depend on the input resistance inside your controller. Most often controllers have interna pull down resistors which will affect the voltage on the input when you attach a resistor.

Worksheet 4

Basic Inputs

Industrial sensor, actuator and control applications



Over to you:

1. Change the left hand switch for a reed relay and use a magnet to activate it.

So what?

- The reed relay is a good example of a digital sensor.
- Digital sensors behave just like digital switches.

Worksheet 5

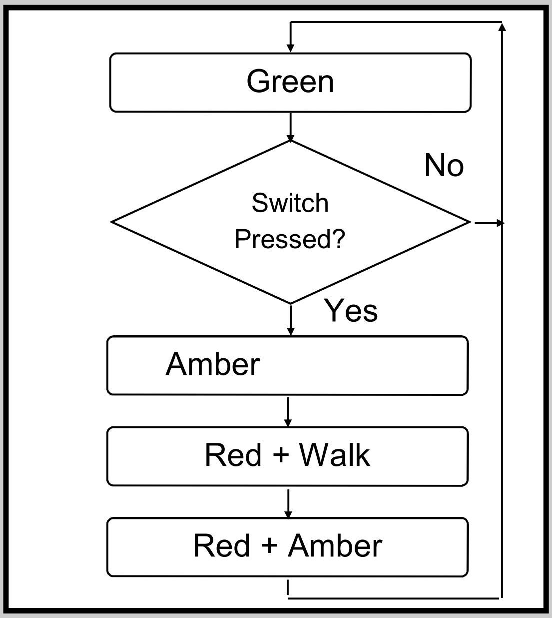
Pedestrian Crossing

Industrial sensor, actuator and control applications

By combining the previous worksheets we can now create a fully functional road crossing system.

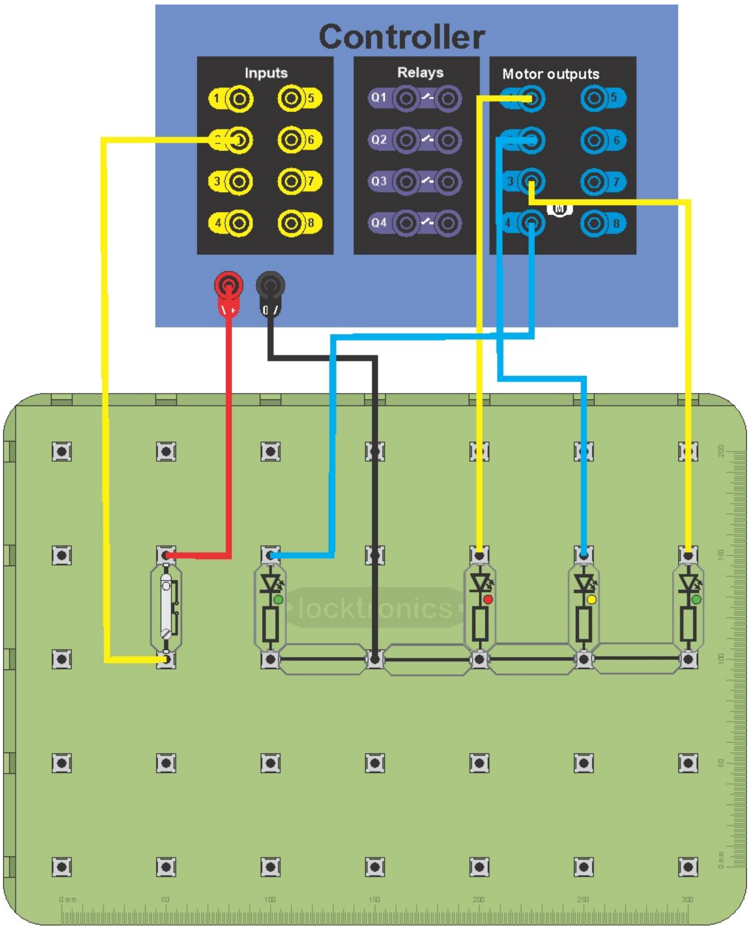
In this system under normal conditions the green light is on and traffic flows. A pedestrian presses a switch to request to cross. The controller then turns the green light to amber for 5 seconds - to warn motorists that a red light is coming - then to red to stop the traffic light.

At that point a second green light facing the pedestrian flashes showing that it is clear to cross. After 30 seconds this turns off, the red and amber lights come on for 5 seconds and then the lights turn green and traffic can flow again.



Over to you:

1. Build the system shown opposite.
2. Sketch a full flow chart for your program.
3. Create a simple program to control the state of the three main signal lights according to the description of the system above.



So what?

- This program has to make extensive use of timers which are a staple of industrial control programs.

Worksheet 6

Stepper motors

Industrial sensor, actuator and control applications

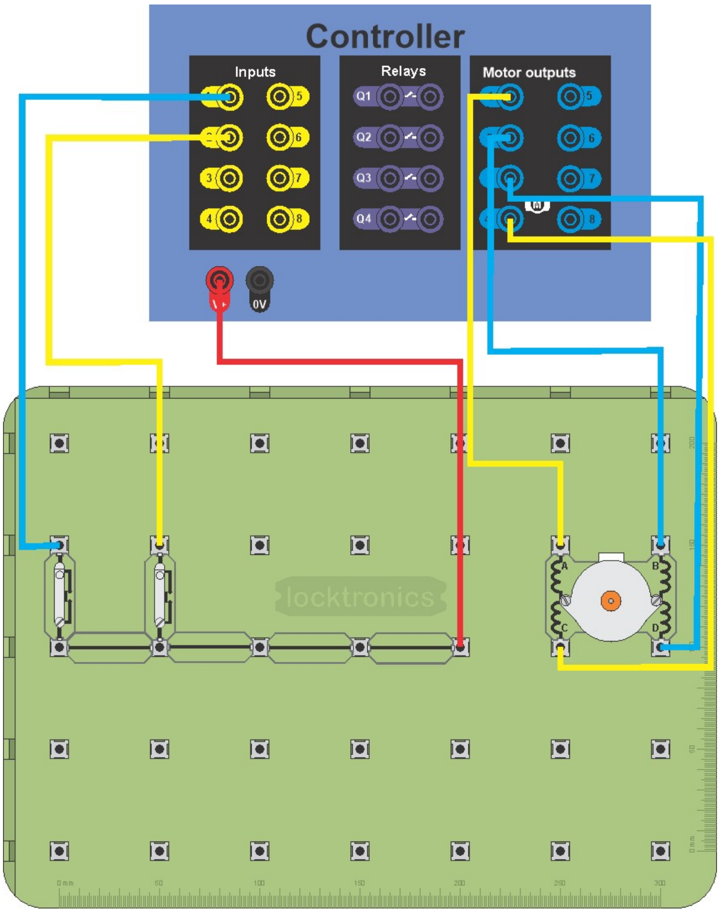
Stepper motors use four internal coils to allow the rotor to be moved in small steps - forwards or backwards. Stepper motors vary in the number of steps they provide in one rotation. The stepper motor we use takes 48 separate steps per revolution; a positional accuracy of 7.5 degrees. The four coils must be energised in the correct sequence to allow the motor to rotate correctly.

	A	B	C	D
Step 1	0	0	0	1
Step 2	0	1	0	0
Step 3	0	0	1	0
Step 4	1	0	0	0

Stepper Motor Full Step Profile

Over to you:

1. Build the system shown opposite.
2. Create a simple program that will rotate a stepper motor.
3. Next modify your program so that the motor only rotates when the first switch is pressed, switch off all four outputs when the switch is not pressed.
4. Next modify your program so that when the second switch is pressed the motor will rotate in the opposite direction - just reverse the sequence of outputs.



So what?

- Reversing the sequence allows the motor to turn in the opposite direction.

Worksheet 6

Stepper motors

Industrial sensor, actuator and control applications

Stepper Motor Half Step Profile

	A	B	C	D
Step 1	1	0	0	1
Step 2	0	0	0	1
Step 3	0	1	0	1
Step 4	0	1	0	0
Step 5	0	1	1	0
Step 6	0	0	1	0
Step 7	1	0	1	0
Step 8	1	0	0	0

Over to you:

1. Use the half step profile in the table above to increase the accuracy of the system.

So what?

Half stepping effectively doubles the resolution of the stepper motor by alternating between one and two active coils. Using half stepping the stepper motor we use takes 96 separate steps per revolution, giving it a positional accuracy of 3.75 degrees.

Worksheet 7

Potentiometers

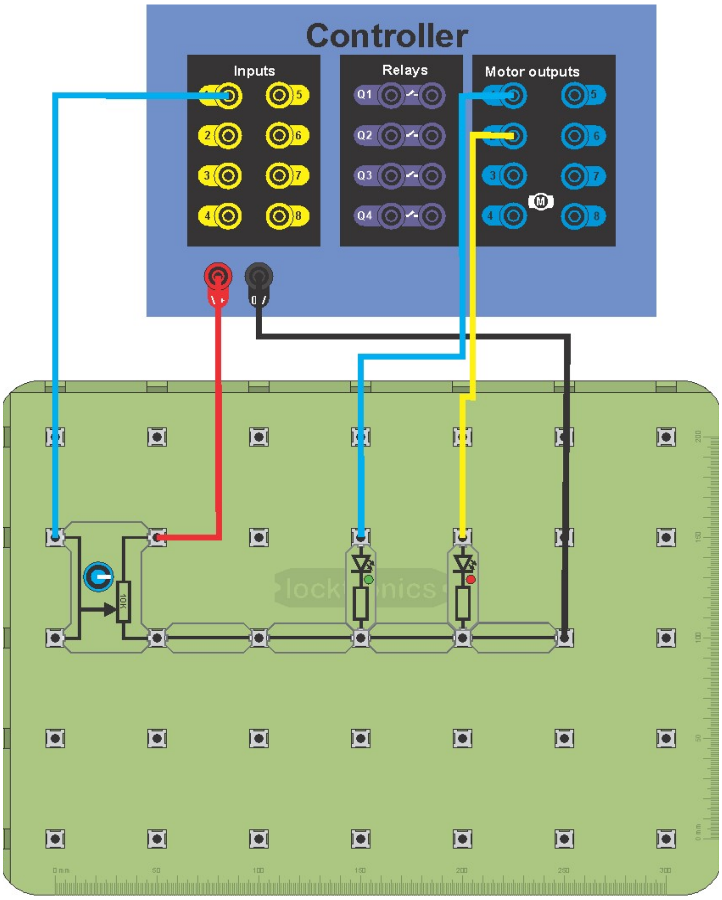
Industrial sensor, actuator and control applications

Switches apply a 12V or 0V signal to a controller input. Potentiometers apply a voltage somewhere between 12V and 0V. It is useful to use potentiometers when a quantity between on and off is needed - to set the level of a light, the speed of a conveyor belt, or the temperature in a room.

Photograph shows a heater control panel with potentiometers to control temperature.

Over to you:

1. Build the system shown opposite.
2. Measure the voltage range provided by the potentiometer at the input to the controller.
3. Imagine that this is a heater control. Decide on a voltage range that is acceptable - say below 5V. In this range the green LED should be on. For all voltages above 5V the green LED should be off and the red LED should be on
4. Develop a program for the controller to give the required functionality.



So what?

- In some situations purely digital inputs are enough to control a system. However there are many situations where we need to input a variable value into a system - such as setting a temperature, setting a speed etc. and the easiest way for humans to do this is to use a dial control of some kind.
- In this case we often use a potentiometer to effectively input a variable value to a controller.

Worksheet 8

Using sensors

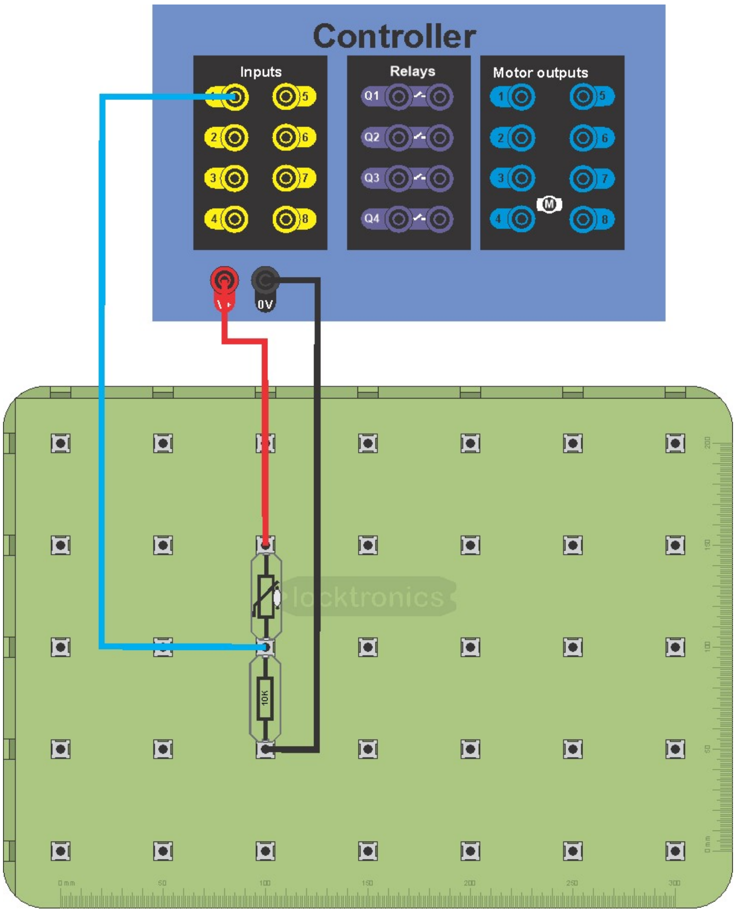
Industrial sensor, actuator and control applications

Some sensors are digital: the reed relay you saw earlier, Hall effect sensors, simple level sensors etc.
However most sensors are analogue - their output varies between 0 and 12V representing a varying quantity. For example: light level sensors, temperature sensors, voltage sensors, current sensors etc. We can use the voltage from these sensors to measure quantities and make control decisions on them.

Photograph shows a remote heater control panel.

Over to you:

1. Build the system shown opposite. The thermistor carrier is an analogue sensor. Touching the temperature sensor is like increasing the heat inside the appliance. Assuming you are in room temperature at 20 C then heating the sensor to 24C with your fingers should not be a problem.
2. Create an application to sample the analogue sensor and trigger an alarm when the sensor reaches 24C.
3. Use the calculation shown above to convert the analogue voltage reading into a temperature reading.



So what?

- You will often need to calibrate any sensor used in a control system.

Worksheet 9

Detecting Faults 1

Industrial sensor, actuator and control applications

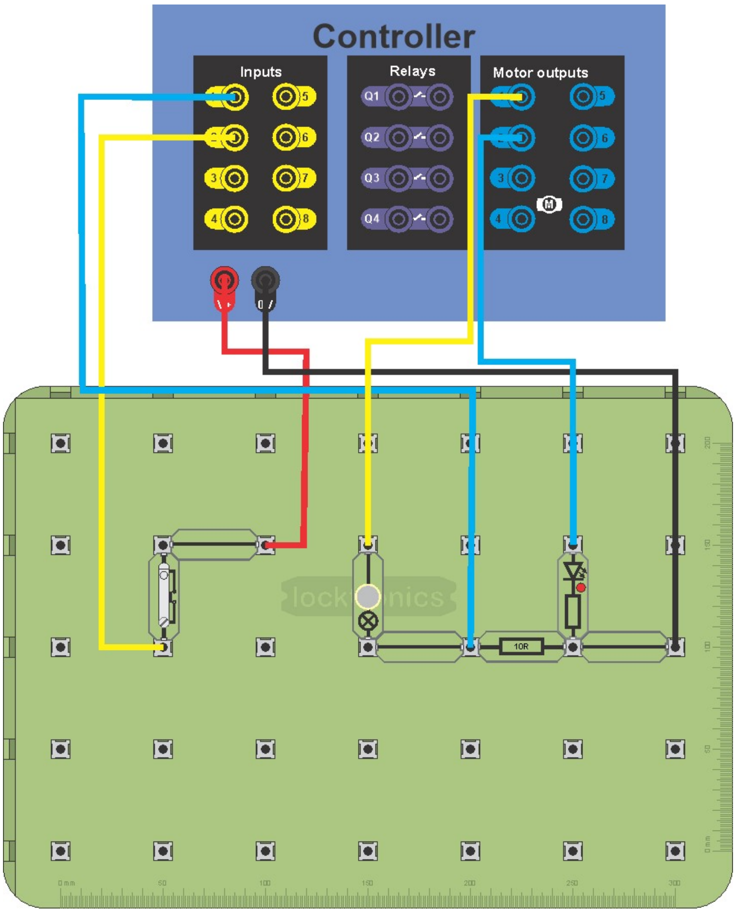
In modern industrial systems, controllers also report on the status of the system and many of its components.

In this landing gear system, the controller can detect if the main landing gear is not fully engaged and therefore inform the pilot and flight control so that they can both react accordingly.

Photograph shows landing gear on an aircraft.

Over to you:

1. Build the system shown opposite. It contains a resistor that allows the current in an incandescent warning bulb to be monitored.
2. Create a program that allows you to switch the bulb on and off using the switch connected to I1.
3. Add an analogue sample function to your program for I2 and detect the voltage change across the 10ohm resistor as current flows through it.
4. Switch on the red LED if the analogue signal does not respond when the lamp is switched on. Remove the bulb and test to ensure your broken bulb detector is working correctly.



So what?

- In safety critical systems it is possible to use additional circuitry to verify that systems are working correctly.
- The use of a small resistor in the path of an actuator is effectively a current sensor.

Worksheet 10

Detecting Faults 2

Industrial sensor, actuator and control applications

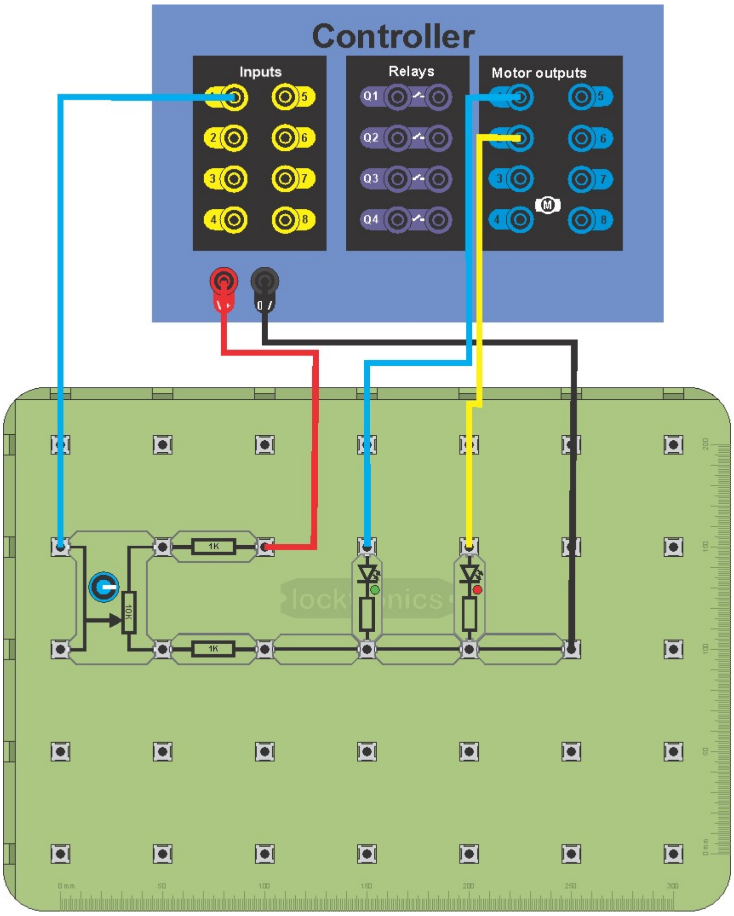
In fault critical systems such as rockets and industrial processes where a fault could have catastrophic consequences it is important to track and keep on top of all problems as they develop.

It is often difficult to detect a faulty reading when using analogue sensors. If a sensor is shorted to one of the power supply rails then the input into the controller would still resemble a valid signal.

Photograph shows a stamping press

Over to you:

1. Build the system shown opposite. It contains a potentiometer which we can assume is supplying our analogue sensor signal.
2. Create a program to read in the signal from the potentiometer.
3. Light up the green LED if the analogue signal is between the values 50 and 200.
4. Light up the red LED if the analogue signal is outside of the values mentioned above.
5. Short input I1 to +V and 0V and make sure that the system is detecting the fault correctly.



So what?

- In safety critical systems it is possible to use additional circuitry to verify that systems are working correctly.
- Intelligent circuit design and programming can considerably enhance the functionality of a system.

Worksheet 11

Open Loop Control

Industrial sensor, actuator and control applications

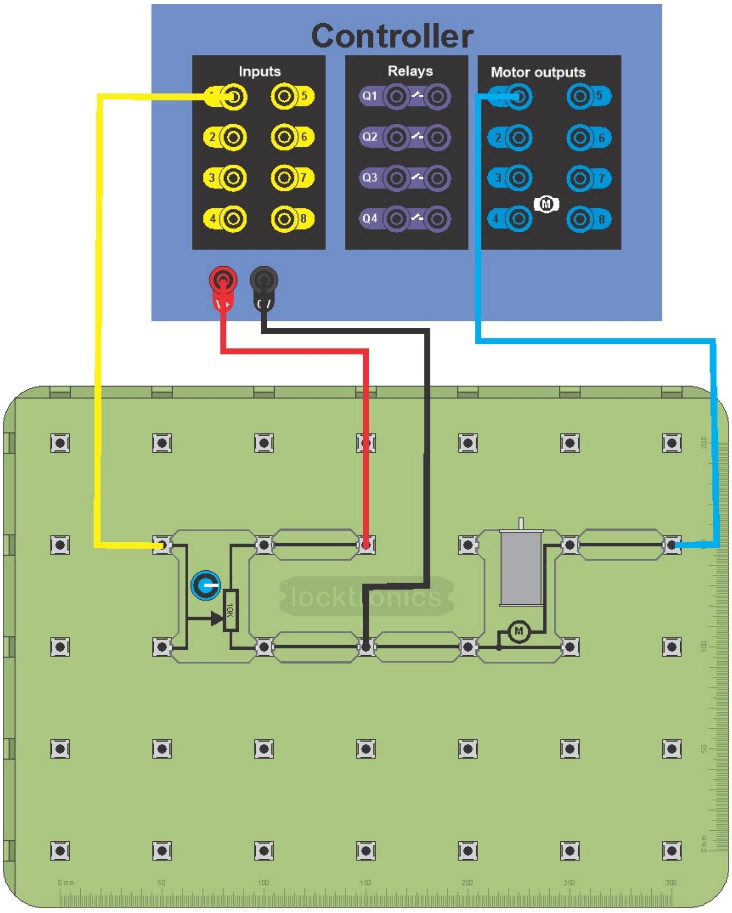
In fault critical systems such as rockets and industrial processes where a fault could have catastrophic consequences it is important to track and keep on top of all problems as they develop.

It is often difficult to detect a faulty reading when using analogue sensors. If a sensor is shorted to one of the power supply rails then the input into the controller would still resemble a valid signal.

Photograph shows a stamping press

Over to you:

1. Build the system shown opposite.
2. Create a program to read in the signal from the potentiometer and vary the speed of the motor using variable Pulse Width Modulation.



So what?

- This is an example of an Open Loop control system.
- In a open loop system, the output state of the system is being controlled but is never monitored to make sure it is correct.

Input → **System** → **Output**

Worksheet 12

Closed Loop Control

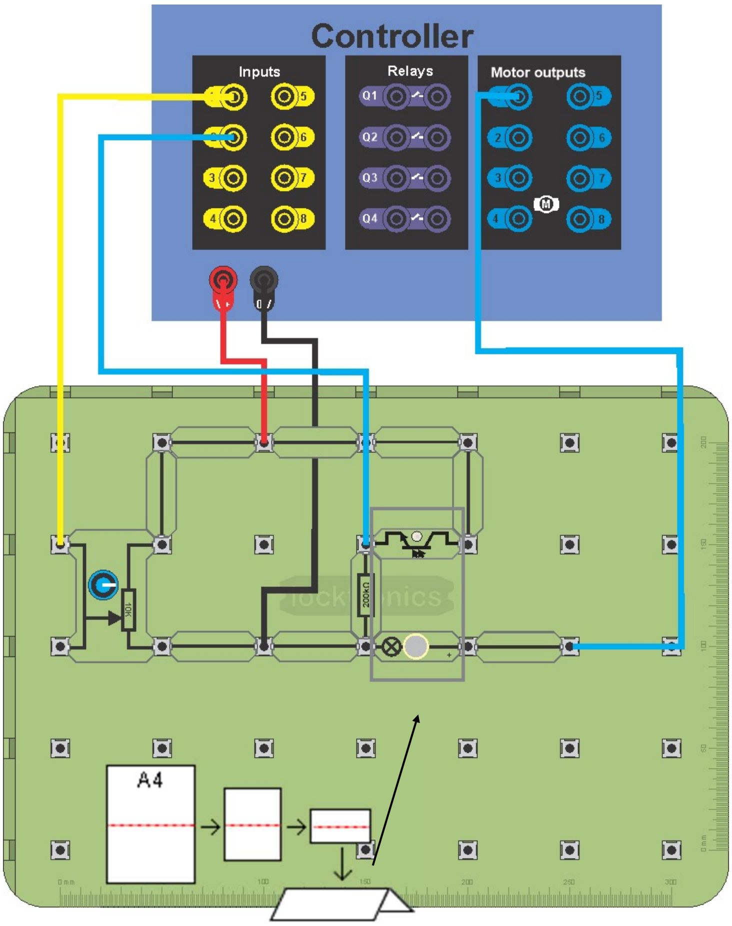
Industrial sensor, actuator and control applications

The light level sensor circuit shown below is a closed loop. The lamp lights up the area. A signal from the light sensor (phototransistor), indicating the light level, is fed back to the system and compared with the desired light level, set by the potentiometer signal. The system can then know if and when the desired light level has been reached and can adjust for an background light that filters in.

Photograph shows a lamp with built in light sensor.

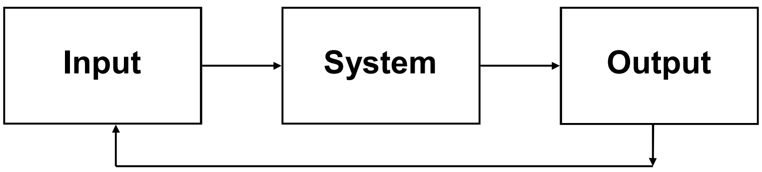
Over to you:

1. Build the system shown opposite.
2. Use a sheet of A4 to create a 'room' around the light sensor and bright LED lamp.
3. Characterise the voltage reading from the light sensor for 100% bulb on to 0% LED bulb on and the stages in between.
4. Create a program to read in the signal from the potentiometer to select a light level and then alter the PWM drive on the LED bulb to achieve that light level.
5. Use your mobile phone torch to adjust ambient light level - when you shine the torch on the 'room' the output to the LED lamp should decrease.



So what?

- This is a closed loop system: the potentiometer dictates the required light level and then the controller measures the light level achieved.
- Closed loop systems are more effective at achieving a required result.



About this course

Introduction

The course provides a framework for learning to program and use industrial components with electronics controllers - especially PLCs. Locktronics equipment makes it both quick and simple to construct and investigate the electrical circuits used by industrial controllers. The end result can look exactly like the circuit diagram, thanks to the symbols printed on each component carrier. With the Locktronics circuit assembled students are free to use their programming knowledge to create programs to drive various aspects of industrial machinery and processes. The course is controller and programming language agnostic - you can use it with any combination. The course is designed to work with a 12V power supply.

Aim

The course aims to introduce students to programming industrial controller units to allow them to interact with the types of sensing and control circuits used in industrial machinery.

Prior Knowledge

It is recommended that pupils have some prior knowledge in the programming languages chosen to complete the course. It is also recommended that the course is completed in a single language and then maybe repeated with an alternative programming language to reinforce learning.

Instructor Guide

Industrial sensor, actuator and control applications

Learning Objectives

On successful completion of this course the pupil will have learned:

- to distinguish between analogue and digital sensors;
- that simple digital sensors have a two-state output - either open (off) or closed (on);
- that digital sensors have a high resistance when open, and a small resistance when closed;
- that simple digital sensors output a signal either at 0V or at the full power supply voltage;
- the circuit symbols for a range of switches, bulbs and sensors;
- that some components are polarised, so that they work properly only when connected the right way round;
- that a controller can be programmed to recognise a high input voltage as the switch being either 'on' or 'off';
- that output devices require a variety of current levels to make them operate;
- that relays can be used to deliver higher currents
- that transistors are much faster then relays in switching on and off;
- how to connect a control unit to deliver current through its transistor output terminals;
- how to connect a control unit to deliver current through its relay output terminals;
- that systems typically consist of three basic elements, input, process and output subsystems;
- that analogue sensors output a continuous range of voltages;
- that a potentiometer can set a reference voltage to determine quantities such as temperature;
- that there are two commonly used types of control system, open-loop and closed-loop;
- that an analogue voltage can be produced by varying the duty cycle of a digital square wave signal;
- the advantages of a stepper motor over a simple DC motor;
- that analogue sensors may require a complex calculation to yield a useful value;
- that control units can be programmed or controlled using a variety of different languages;

Instructor Guide

Industrial sensor, actuator and control applications

What the student will need:

To complete this course the pupil will need the following equipment:

Power source:
The mains-powered 'plug-top' power supply can be adjusted to output voltages of either 3V, 4.5V, 6V, 7.5V, 9V or 12V, with currents typically up to 0.5A. The voltage is changed by turning the selector dial just above the earth pin until the arrow points to the required voltage. The course uses the 12V setting exclusively. However any power supply can be used. If you prefer your students to work from exactly 12V then please use a bench top power supply.

Qty	Code	Description
1	HP2045	Shallow plastic tray
2	HP4039	Lid for plastic trays
1	HP5540	Deep tray
2	HP7750	Locktronics daughter tray foam insert
1	HP9564	62mm daughter tray
1	LK0123	Magnet
1	LK2363	MES bulb, 12V, 0.2A
1	LK3246	Buzzer (12V)
1	LK4025	Resistor - 10 ohm, 1W 5% (DIN)
1	LK4322	Stepper Motor
2	LK5202	Resistor - 1K, 1/4W, 5% (DIN)
1	LK5203	Resistor - 10K, 1/4W, 5% (DIN)
1	LKxxxx	Resistor - 200K, 1/4W, 5% (DIN)
1	LK5214	Potentiometer, 10K (DIN)
1	LK8011	Power FET
14	LK5250	Connecting Link
1	LK5280	Relay 12V 10A (tranparent case)
2	LK5291	Lampholder carrier
1	LK5402	4.7K thermistor, NTC (DIN)
1	LK5404	Switch, reed
2	LK5603	Lead - red - 500mm, 4mm to 4mm stackable
2	LK5604	Lead - black - 500mm, 4mm to 4mm stackable
4	LK5607	Lead - yellow - 500mm, 4mm to 4mm stackable
4	LK5609	Lead - blue - 500mm, 4mm to 4mm stackable
1	LK6207	Switch Press (morse key-type strip, push to make)
1	LK6209	Switch on/off (stay put, sideways swivel strip)
2	LK6430	LED, red, 12V (DIN)
1	LK6431	LED, yellow, 12V (DIN)
1	LK6432	LED, green, 12V (DIN)
1	LK6634	Microswitch
1	LK6706	Motor 3/12V D.C. 0.7A
1	LK7290	Phototransistor
1	LK6838	Solenoid
1	LK6841	MES bulb, 12V, LED, white
1	LK8275	Power supply carrier with battery symbol
1	LK8900	7 x 5 baseboard with 4mm pillars
1	HP2666	Power supply

Using this course:

Our goal is to help students understand sensors and control systems in the context of industrial systems - to understand the components, the circuit diagrams, and the role of the Programmable Logic Controller (PLC).

We do this by asking students, working individually or in pairs, to build a number of circuits typically found in an industrial system that uses an industrial controller. Students generate or select an existing program that makes the circuit work in the desired way, and then take measurements, make drawings, or describe what is happening in the circuits, to reinforce learning.

Worksheets:
It is expected that the worksheets are printed / photocopied, preferably in colour, for the students' use. Students will need their own permanent copy, as a record of what they have learned.

Each worksheet has:

- an introduction to the topic under investigation;
- step-by-step instructions for the investigation that follows;
- a summary of the important points of learning

Types of controller
The worksheets are kept very generic. This allows almost any controller to be used. We do specify that the circuits are limited to 12V as the rating of many of the electronics components is 12V max.

Programming using Flowcode:
This is best carried out with the MIAC NXT. The MI3728 datasheet gives a brief introduction on this.

Programming using Labview, Matlab or other PC based language:
This is best carried out with the MIAC NXT controller. An API for the MIAC NXT is available which allows students to easily control the inputs and outputs.

Programming using Siemens S7 or other PLC
The course is compatible with any PLC and any PLC programming software.

Time:
It will take students between six and ten hours to complete the worksheets. It is expected that a similar length of time will be needed to support the learning that takes place as a result.

Instructor Guide

Scheme of Work

Industrial sensor, actuator and control applications

Worksheet	Notes for the Teacher	Timing
1	**Basic Outputs:** The first worksheet is designed to guide students into using controller outputs. To do this they will be asked to create a small program to switch the Motor or transistor outputs on and off one at a time.	**40 - 60 minutes**
2	**Sequenced Outputs:** This worksheet takes the output control one step further by explaining the fundamentals of a finite state machine. This is then reinforced with the practical exercise of writing a simple traffic light controller program. The program has four unique states which represent the different combinations of lights that can be active on the signal. The movement between the preset states is also another key aspect.	**40 - 60 minutes**
3	**Pulse Width Modulation:** Worksheet three starts to look at slightly more advanced outputs by using Pulse Width Modulation. This can be achieved by use of timers for pulsing an output, or by programming a controller's PWM internal PWM peripheral if one is included in the controller you use. As a reinforcement to this you could place a capacitor between the PWM output and ground and use a voltmeter to measure the analogue output as you change the PWM mark/space parameter. Whilst controllers make use of a internal transistors it is useful to understand the role of the FET as a power amplifier.	**40 - 60 minutes**
4	**Basic Inputs:** This example tackles the problem of polling digital switches. The students will learn that they will have to write a loop into their program so the switch values can be checked continuously. This example also gets the student up to speed with storing values into variables to represent the digital input voltage.	**40 - 60 minutes**

Worksheet	Notes for the Teacher	Timing
5	**Pedestrian Crossing:** This worksheet combines outputs, and inputs to create a fully operational pelican crossing system. The worksheet does not recommend a method here: You might want to introduce the concept of using state machines to manage programme flow.	**40 - 60 minutes**
6	**Stepper motors** This worksheet introduces students to stepper motors to teach the main differences between analogue DC Motors and Digital Stepper motors. The program is created in two stages, the first being a full stepping approach and the second (optional) using half stepping techniques to effectively double the resolution of the motor.	**40 - 60 minutes**
7	**Potentiometers** This worksheet introduces students the use of potentiometers as analogue controls in electronic systems. Students need to set up a variable for the input voltage and make decisions as to go/no go values.	
8	**Using sensors** This worksheet introduces students to analogue sensors and also to the data manipulation or maths often required to obtain a meaningful result from an analogue input. The NTC thermistor characteristics are given in the reference section on Using thermistors. Students will need to understand how thermistor resistance temperature changes and what the voltage at the input pin will be for a given temperature. If the controller you are using has a low input resistance then it will affect the circuit - you may need to leave out the balancing resistor in the potential divider chain and recalculate. The thermistor used is an EPCOS B57164K0472J000. Students will probably want to use a look up table in their program.	**40 - 60 minutes**

Worksheet	Notes for the Teacher	Timing
9	**Detecting Faults 1:** This worksheet introduces automatic fault sensing to the industrial controller. By detecting if an output has switched on as expected the students programs can determine if an output such as a bulb has become damaged or missing. This allows students to see for themselves how to design and create a fault tolerant system.	**40 - 60 minutes**
10	**Detecting Faults 2:** This worksheet moves on from the first fault finding worksheet to include analogue sensors and how to make these tolerant to faults such as electrical breaks or shorts. The users programs can then detect these faults and inform the user of the problem.	**40 - 60 minutes**
11	**Open Loop Control:** This worksheet details the basics of an open loop control system. An analogue voltage created from a potentiometer is used as the input to a DC motor speed controller. Students should note here that the motor is simply being told what to do and has no control over any aspect of the system.	**40 - 60 minutes**
12	**Closed Loop Control:** This worksheet details the basic of an closed loop control system. A bulb is driven directly from an input analogue voltage provided by a potentiom-eter. The light level from the bulb is then fed back into the system to create a error or difference between what is expected and what is sensed. This error is then used to adjust the control signal to allow the bulb to behave as expected. The changing output can be seen by removing and replacing the paper roof that sits over the bulb and sensor circuitry. When the paper is present the light from the bulb will be fairly dim as the sensor is detecting the correct amount of light. When the paper is removed the bulb will become brighter to try and raise the amount of light sensed by the sensor.	**40 - 60 minutes**

Using MIAC

Industrial sensor, actuator and control applications

MIAC NXT (product code MI5550) is a general purpose industrial control unit fitted with 4mm sockets. A full description and reference document for MIAC is available on the Matrix web site.

MIAC NXT datasheet

A full technical datasheet on the MIAC NXT is available. This is product code MI3728. This includes guides on programming using Flowcode App Developer, MATLAB and Lab View.

Using MIAC NXT as a Personal Computer Windows interface

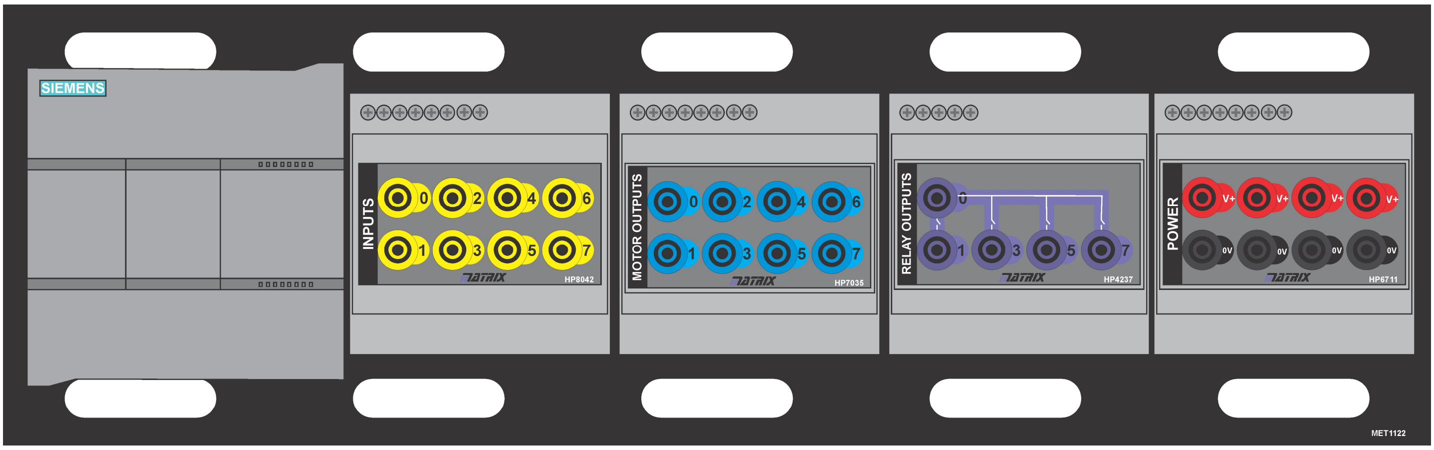
An Application Programming Interface for the MIAC is available free of charge. This is product code MI8975. This can be downloaded from the Matrix web site and sent to the MIAC NXT using the Mloader application. The Mloader application can also be downloaded from the Matrix web site free of charge. When the API is downloaded to the MIAC NXT the MIAC becomes a general purpose Personal Computer input output controller. The API allows the MIAC to be programmed using any third party software such as Matlab, LabView, C for Personal computers etc. The API is documented in the MIAC datasheet MI3728.

Using MIAC NXT in an embedded context

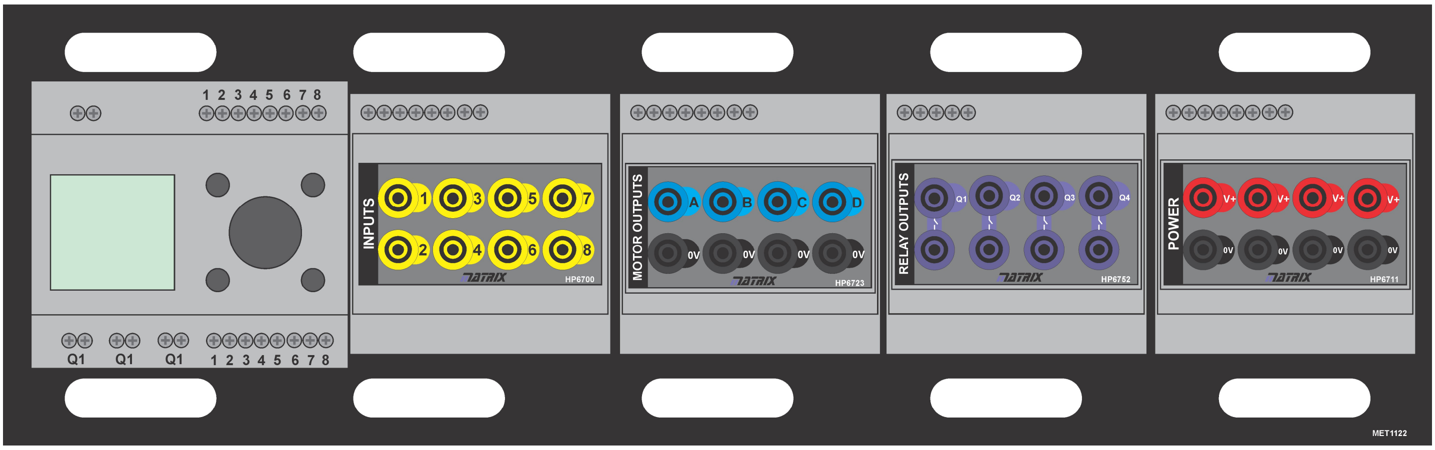
The MIAC NXT is based on a 24 series PICmicro microcontroller from Microchip. It can be programmed using C or Flowcode which make hex code for the MIAC NXT. A full simulation component for MIAC NXT is available in Flowcode 10. Hex code for the MIAC can be downloaded to the MIAC NXT using the Mloader utility.

Using PLCs

Industrial sensor, actuator and control applications



Typical Siemens PLC configuration



Other PLC configuration

If you are using a PLC for this course then there are several options:

Siemens S7

Siemens S7 is a popular choice for industrial control. 4mm connector add-ons for Siemens PLCs are available from Matrix as shown in the diagram. Siemens input outputs start numbering at 0. Not all S7s have relays - make sure you choose the correct model.
Input module: HP8042, Motor module: HP7035, Relay module: HP4237, Power module: HP6711

Other PLCs

There are many other PLCs with input output numbering starting at 0 or 1, with different numbers of onboard motor outputs, relays etc. Make sure that you have the correct input output modules for your PLC. 4mm interfaces for these PLCs are also available from Matrix. 4mm interfaces that may be of interest from Matrix are: Input module: HP6700, Motor module: HP6723, Relay module: HP6752, Power module: HP6711

Using thermistors

Industrial sensor, actuator and control applications

The thermistor is a EPCOS B57164K0472J000 4k7 NTC thermistor.

The characteristics are shown in the table here.

This should enable you to calculate the output voltage from a potential divider chain using the NTC thermistor and a 10K resistor from a given supply voltage.

R/T No.	4001	
T (°C)	$B_{25/100}$ = 3950 K	
	R_T/R_{25}	α (%/K)
−55.0	88.052	7.3
−50.0	61.65	7.0
−45.0	43.727	6.8
−40.0	31.395	6.5
−35.0	22.802	6.3
−30.0	16.742	6.2
−25.0	12.367	6.0
−20.0	9.2353	5.6
−15.0	7.0079	5.4
−10.0	5.3654	5.4
−5.0	4.126	5.2
0.0	3.2	5.0
5.0	2.4986	4.9
10.0	1.9662	4.7
15.0	1.5596	4.6
20.0	1.2457	4.5
25.0	1.0000	4.4
30.0	0.80355	4.2
35.0	0.65346	4.1
40.0	0.53456	4.0
45.0	0.43966	3.9
50.0	0.36357	3.8
55.0	0.30183	3.7
60.0	0.25189	3.6
65.0	0.21136	3.5
70.0	0.17819	3.4
75.0	0.15089	3.3
80.0	0.12833	3.2
85.0	0.10948	3.1
90.0	0.093748	3.0
95.0	0.080764	2.9
100.0	0.069842	2.9
105.0	0.060455	2.9
110.0	0.052498	2.8
115.0	0.04574	2.7
120.0	0.039972	2.7
125.0	0.034984	2.6
130.0	–	–
135.0	–	–
140.0	–	–
145.0	–	–
150.0	–	–
155.0	–	–

Version control

Industrial sensor, actuator and control applications

Date	Release notes	Release version
16 12 2014	Updated for RoHS compliance	LK8739-80-3
01 12 2016	Changed references from CD to website	LK8739-80-5
21 04 21	Version 2 released	
18 05 22	Version 3 released	