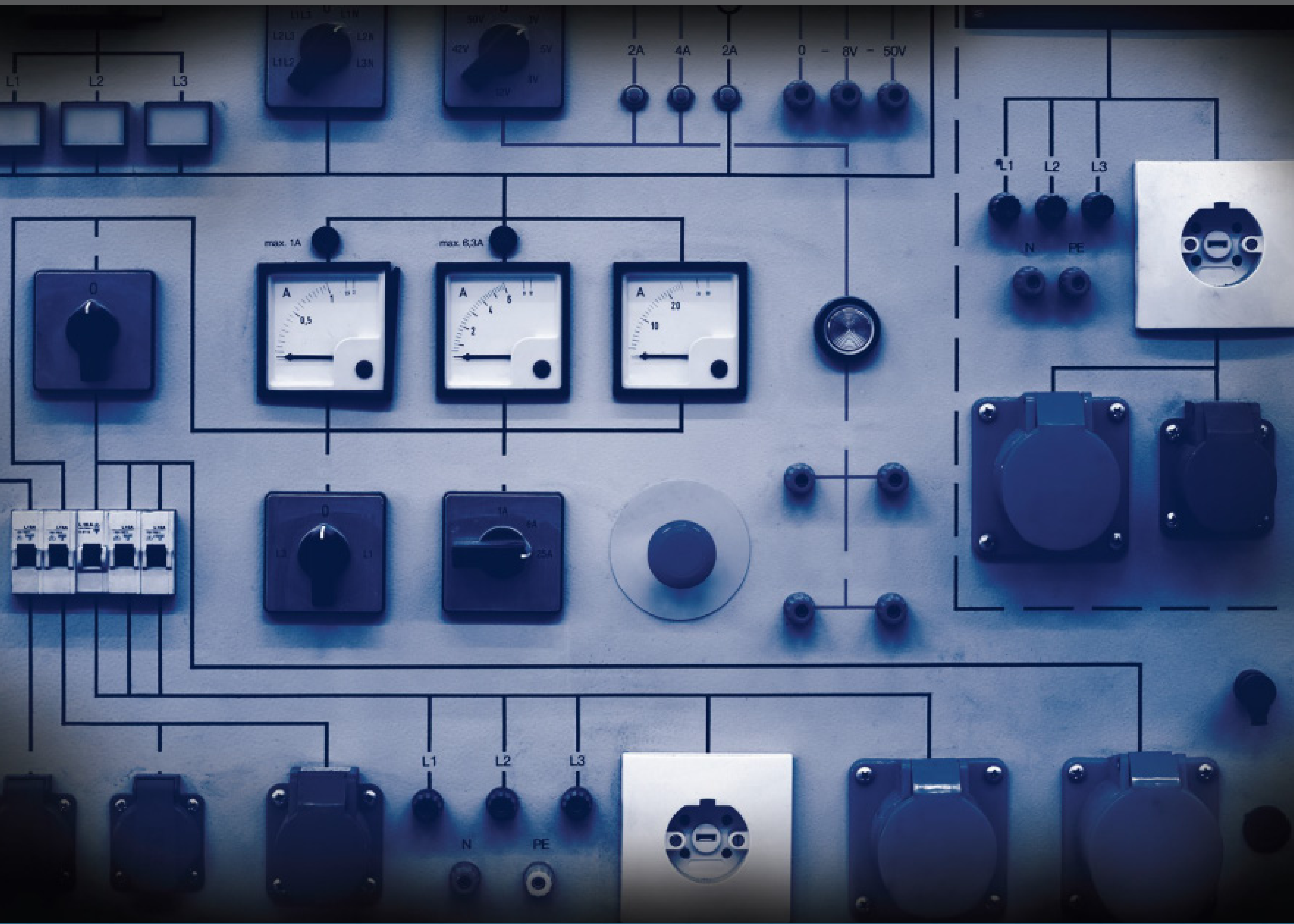

INDUSTRIAL SENSOR, ACTUATOR AND CONTROL APPLICATIONS

CP7718

Inspiring The Next Generation Of Engineers

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Contents

WORKSHEETS

WORKSHEETS

Worksheet 1 - Basic Outputs

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

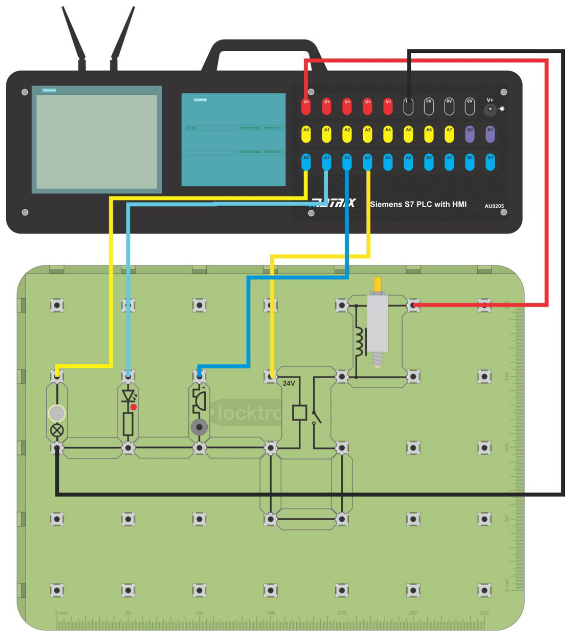
- Low current transistor outputs
- Higher current relay outputs

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

The photograph shows a simple warning beacon.

Over to you:

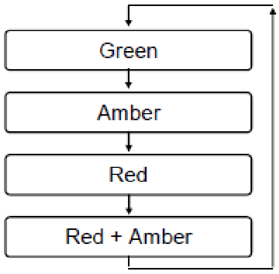
1. Build the Locktronics system shown opposite.
2. Create a simple program to go through each of the outputs 1 to 4, switching on one at a time.



So What?

- Transistor outputs vary from one type of 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, engineers 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 - Sequence Outputs

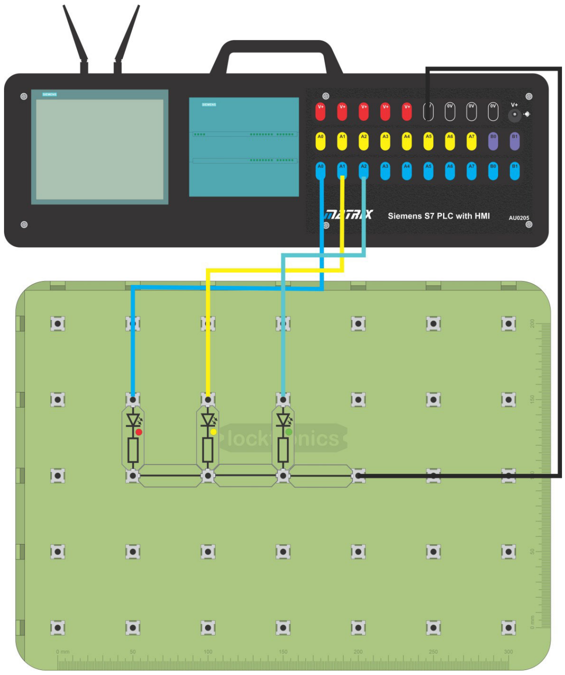


In a controller, it is useful to be able to switch from one system state to another. This is sometimes called a 'state machine'.

In the basic traffic light system shown here, there are four unique states for the lights. Therefore the system we design needs to switch between these four states, assigning different values to outputs as it does so.

Over to you:

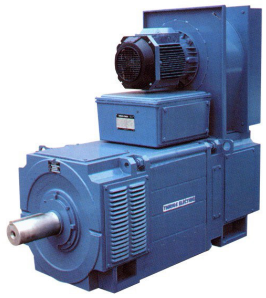
1. Build the system shown opposite.
2. Create a simple program to control the LEDs to simulate the behaviour of a set of traffic lights.
3. Start by assigning output values for each LED for a single state in the sequence.
4. Add a timer / counter to keep track of the current state and then add decisions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



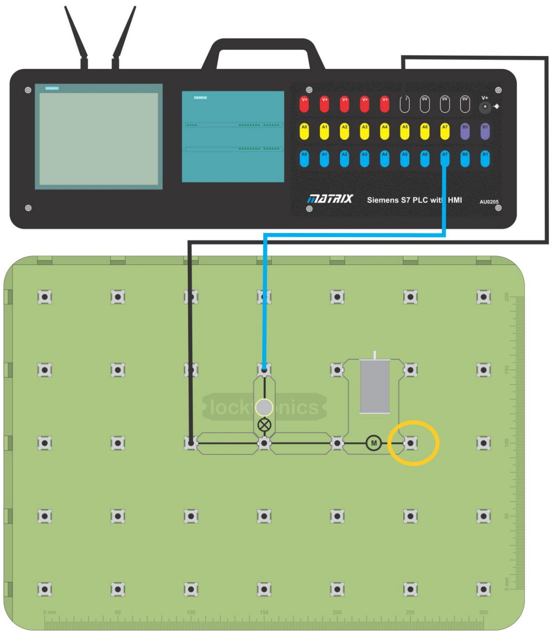
To vary the speed of a motor, you need to vary the **power** supplied to it.

Two of the easiest ways of doing this are:
- Vary the voltage applied to it;
- Use Pulse Width Modulation (or PWM) and vary the **duty cycle** (the ratio of 'on' time to 'off' time) of the motor supply.

Over to you:

1. Build the system shown opposite.
2. Create a simple program to enable PWM on output 7.
3. Ramp up the duty cycle from 'fully off' to 'fully on' in small steps over a 10 second period.
4. Move the wire for the output from the lamp to the motor

- The circle highlights where to move the output cable.

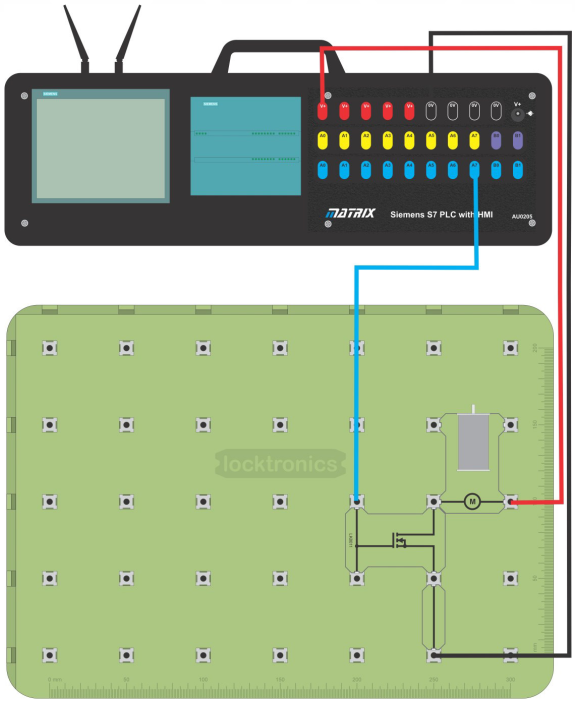


So What?

- We usually don't vary the motor supply voltage to control its speed, but vary the ratio of the 'on' time to 'off' time and pulse the output very quickly - thousands of times a second.

- This is a common requirement in control systems and so many industrial controllers will have inbuilt hardware and software functions to manage this. To find out, look at the datasheet for your controller.

Over to you:



1. Modify the circuit so that output 7 feeds a FET connected to a motor.

2. Is there any difference in the functionality of the program?

So What?

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

WORKSHEETS

Worksheet 4 - Basic Inputs

The sensors in any industrial system can be divided into two types: **analogue and digital.**

Some modern controllers have separate analogue and digital inputs. Some have inputs that can be configured as either analogue or digital.

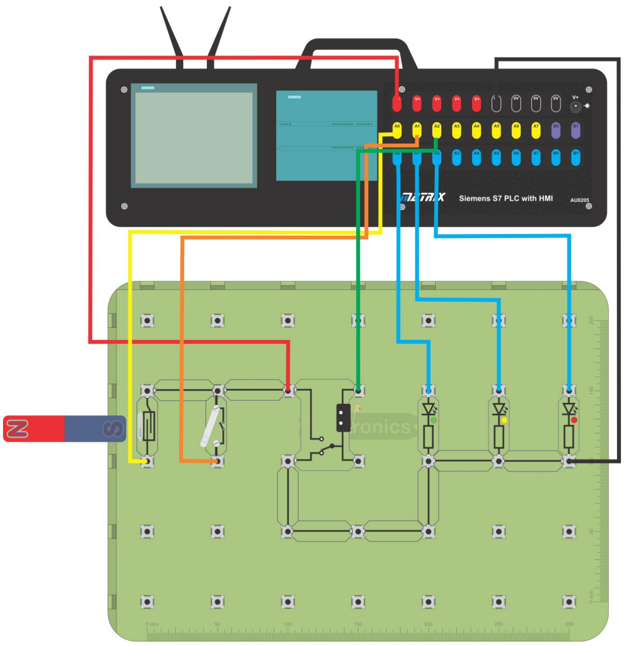
Digital sensors have a two-state output, usually known as either 'on' or 'off', determined by the power supply voltage - often 24V (on) and 0V(off).

Analogue sensors have a continuous range of output voltages, normally between 10V and 0V. Analogue sensors are covered later in the course.

The photograph shows a pressure switch.

Over to you:

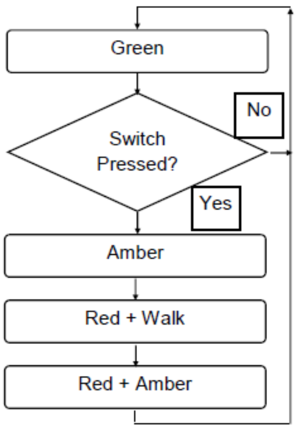
1. Build the system shown opposite.
2. Create a simple program to read the digital state of the switches, where 'pressed' or 'activated' = 'ON'
3. Display the state of the switches on the corresponding outputs.



So What?

- The three switches work in different ways.
- Input circuits inside controllers vary. Some have simple interfaces to microcontrollers which allow a single input to be either analogue or digital. Others have opto-isolated inputs which define them as digital only.

Worksheet 5 - Pedestrian Crossing



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

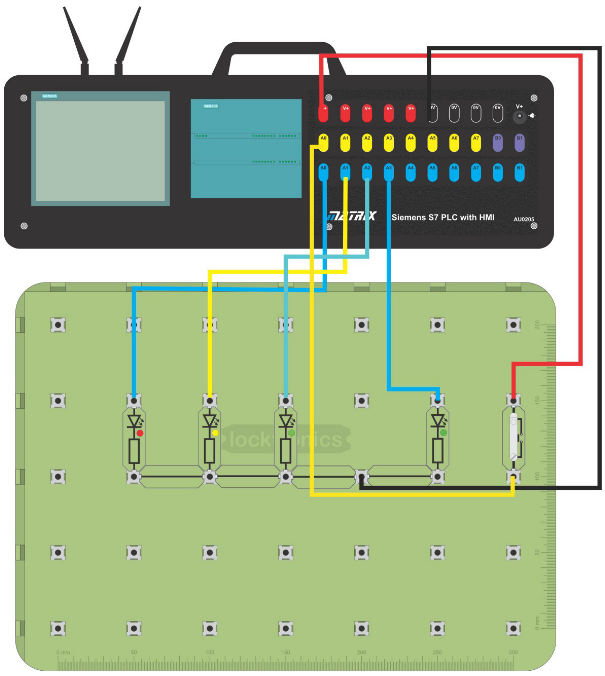
In this, the green light is on and traffic flows, until a pedestrian presses a switch to request to cross. The controller then turns the light from green to amber for 5 seconds, to warn motorists that a red light is coming, and then to red to stop the traffic.

At that point, a second green light, facing the pedestrian, flashes to show 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 so that traffic can flow again.

The image shows a partial flow chart for the system.

Over to you:

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



So What?

- This program makes extensive use of timers - the staple of industrial control programs.

WORKSHEETS

Worksheet 6 - Potentiometers

A switch usually apply either a 24V or 0V signal to a controller input.

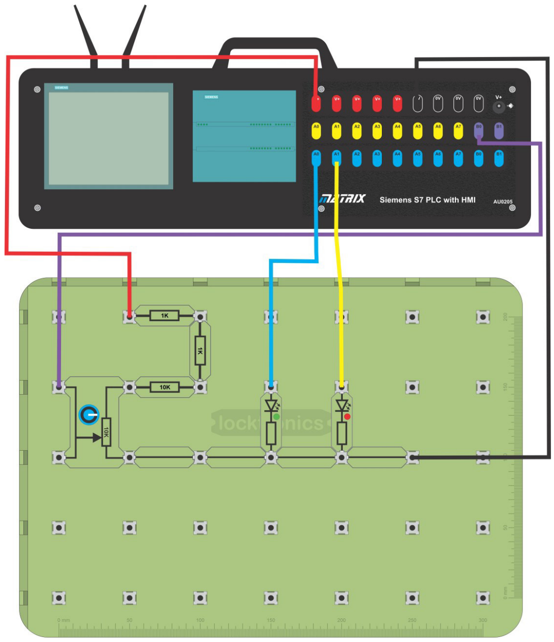
A potentiometers applies a signal somewhere between 24V and 0V.

It is useful to use potentiometers to set the level of a light, the speed of a conveyor belt, or the temperature in a room, for example.

The photograph shows a heater control panel using potentiometers to control temperature.

Over to you:

1. Build the system shown opposite.
2. Measure the range of voltages provided by the potentiometer at the controller input.
3. Suppose that this is a heater control. Decide on an acceptable voltage range, say 0V to 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 to give the controller this functionality.



So What?

- In some situations, purely digital inputs are enough to control a system. However there are 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 us to do this is to use a dial control of some kind.
- In this case, we often use a potentiometer to input a variable value to a controller.

Worksheet 7 - Using Sensors

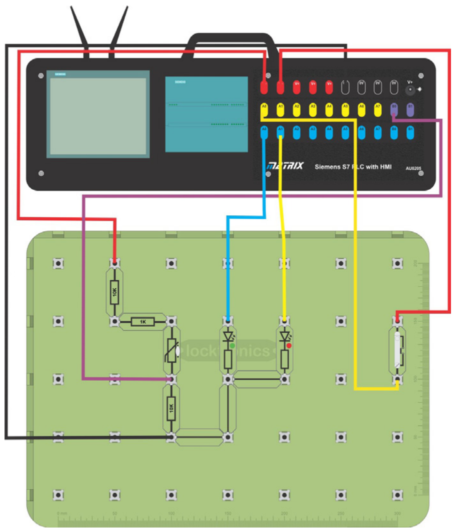
Some sensors are digital, such as the reed relay you saw earlier, Hall effect sensors, simple level sensors etc.

However most are analogue - their output signal varies between 0 and 10V usually, representing a varying quantity, light level, temperature, voltage, or current, for example.

We can use signals from these to measure these quantities and make control decisions.

The photograph shows a heater control panel.

Over to you:



1. Build the system shown opposite. The thermistor is an analogue sensor. Touching it simulates increasing the temperature inside the appliance.

2. Create an application to sample the temperature sensor and trigger an alarm when the sensor increases by 1%.

3. Use the switch on input 1 to take a temperature reading.

4. Then use your fingers on the thermistor to apply some heat. After a 1% change, the green status LED should turn off and the red error LED should turn on.

So What?

- You often need to calibrate the sensors used in a control system.

Worksheet 8 - Detecting Faults 1

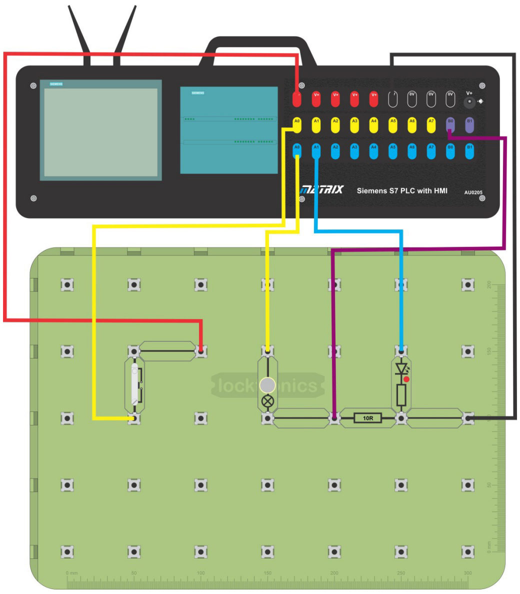
In modern industrial systems, controllers also report on the status of the system and many of its components.

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

The photograph shows aircraft landing gear.

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 the program for I7 to detect the voltage change across the 10Ω resistor as current flows through it.
4. Switch on the red LED if this signal is zero when the lamp is switched on.
5. Test this 'broken bulb detector' by removing the bulb.



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.

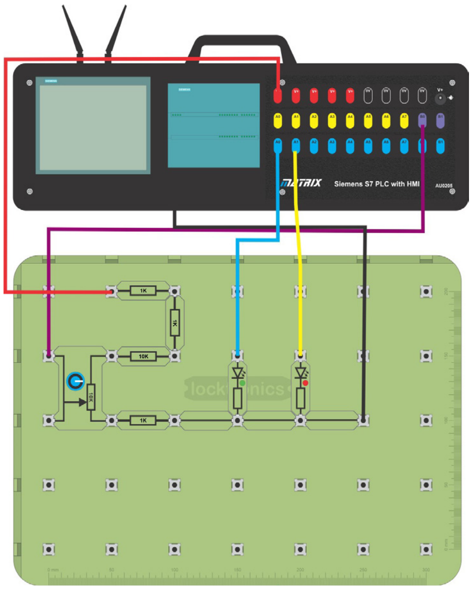
Worksheet 9 - Detecting Faults 2

In fault critical systems, such as industrial processes where a fault could have catastrophic consequences, it is important to track all problems as they develop.

When using analogue sensors, it can be difficult to detect a faulty reading. If a sensor is short-circuited to one of the power supply rails, for example, the input signal into the controller would still resemble a valid signal.

The photograph shows a stamping press.

Over to you:



1. Build the system shown opposite. It contains a potentiometer which is supplying the analogue sensor signal.

2. Create a program to:
- Read the potentiometer signal;
- Light the green LED if the signal has a value between 5% and 95%.
- Light the red LED if the signal is outside of these values.

3. Short-circuit the analogue input B0 to +V and 0V, in turn and check that the system is detecting the fault correctly.

So What?

- In safety critical systems, additional circuitry can be used to verify that systems are working correctly.

- Intelligent circuit design and programming can considerably enhance the functionality of a system.

WORKSHEETS

Worksheet 10 - Open-Loop Control

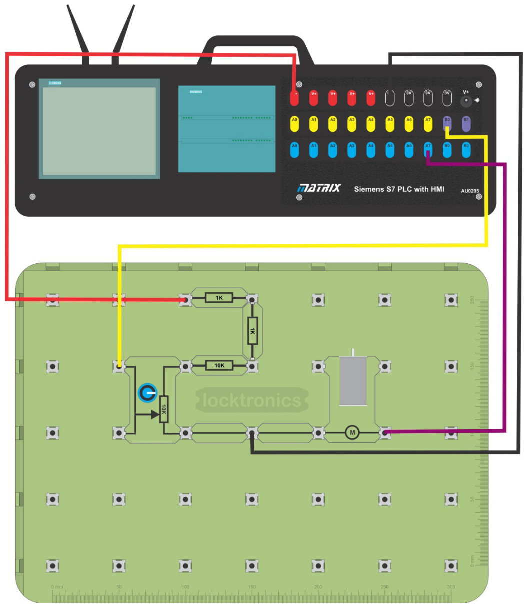
There are two principal types of control system: open loop and closed loop. Closed loop systems have some kind of feedback which allows for system regulation. Open loop systems have no feedback and engineers rely on an understanding of the components in the system to provide the required functionality.

Photograph shows variable speed motors in a pumping station

Over to you:

1. Build the system shown opposite.

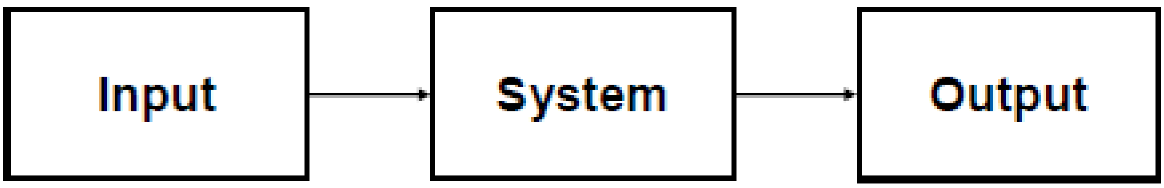
2. Create a program to read the signal from the potentiometer and use it to vary the speed of the motor, using Pulse Width Modulation.



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.



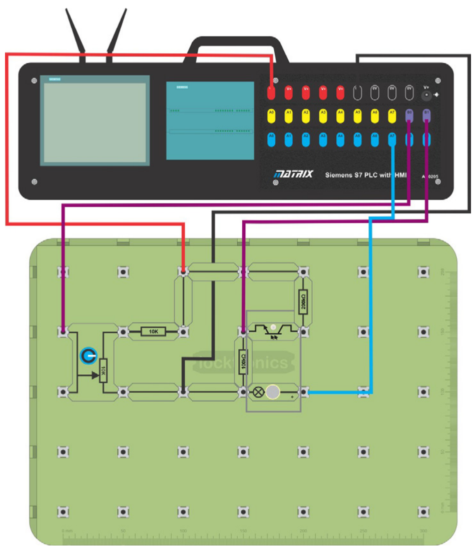
The light level sensor circuit shown below, is an example of a closed-loop control system.

The lamp lights up its surroundings. A signal from the light sensor indicating light level, is fed back and compared to the desired light level, set by the potentiometer.

The system knows when the desired light level has been reached and can compensate for background lighting .

The photograph shows a lamp with a built-in sensor.

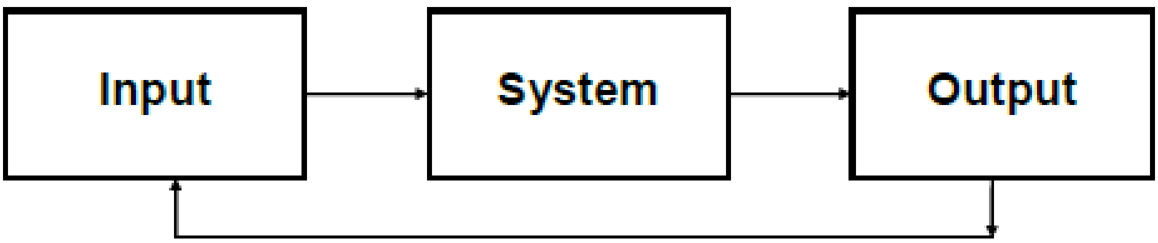
Over to you:



1. Build the system shown opposite.
2. Use a sheet of A4 to create a 'room' around the light source and sensor and shield the system from ambient light.
3. Characterise the voltage reading from the light sensor for 100% bulb on to 0% LED bulb on and the stages in between.
4. Change the program so that the potentiometer is used to adjust the system for a light level - not a PWM output value. The program should constantly check light level and adjust output accordingly.
5. Use your mobile phone torch to adjust ambient light level - when you shine the torch on the sensor - the output to the LED lamp should decrease.

So What?

- This is a closed-loop system. The potentiometer sets the required light level and then the controller measures and adjusts the light level to achieve that.
- Closed loop systems are more effective at achieving a required result.



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