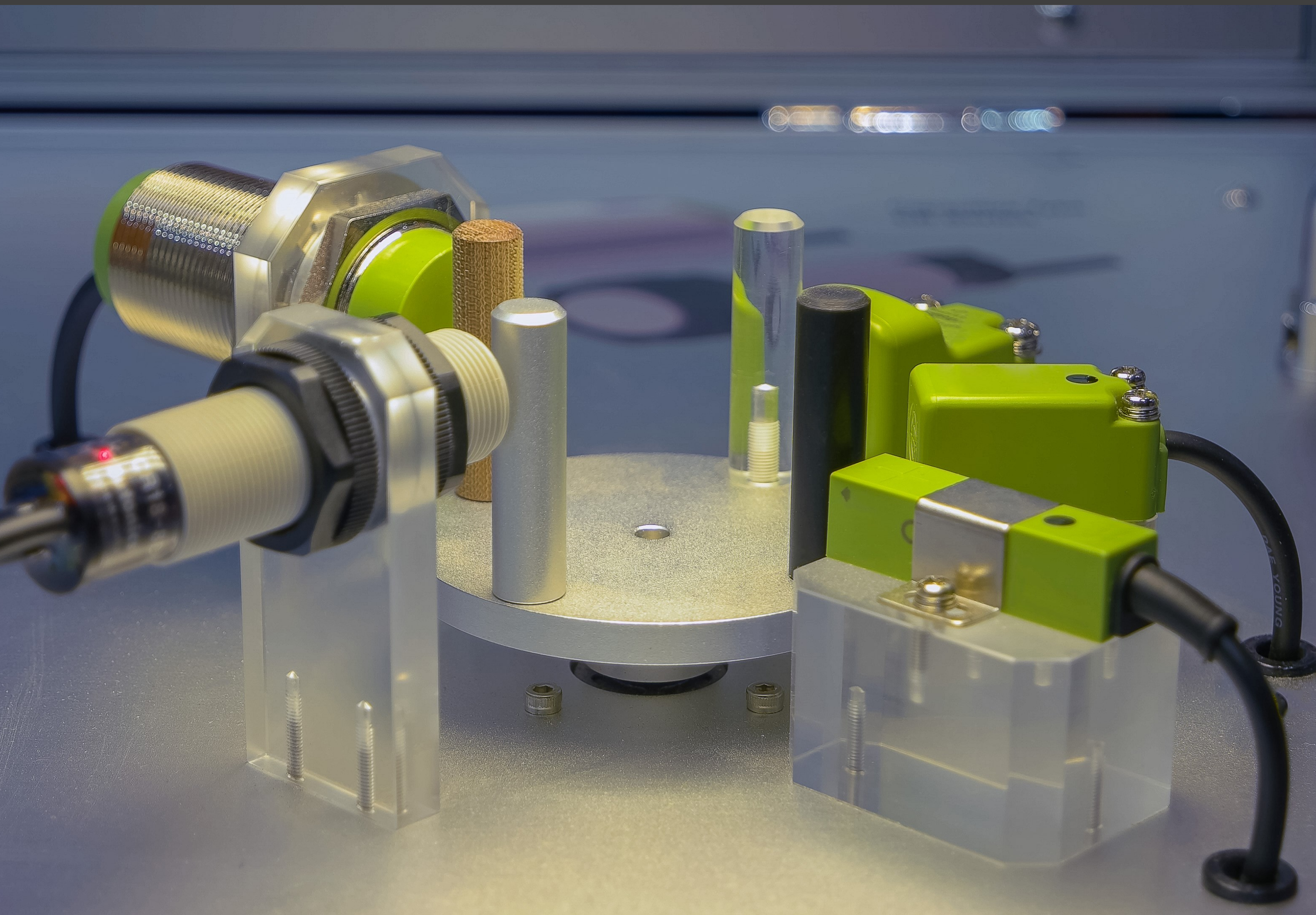
INDUSTRIAL MAINTENANCE

Industrial Maintenance - Sense and Control



CP6211

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Contents

Worksheet 1

Basic Outputs

Modern industrial control systems, including PLCs, typically provide two types of outputs:

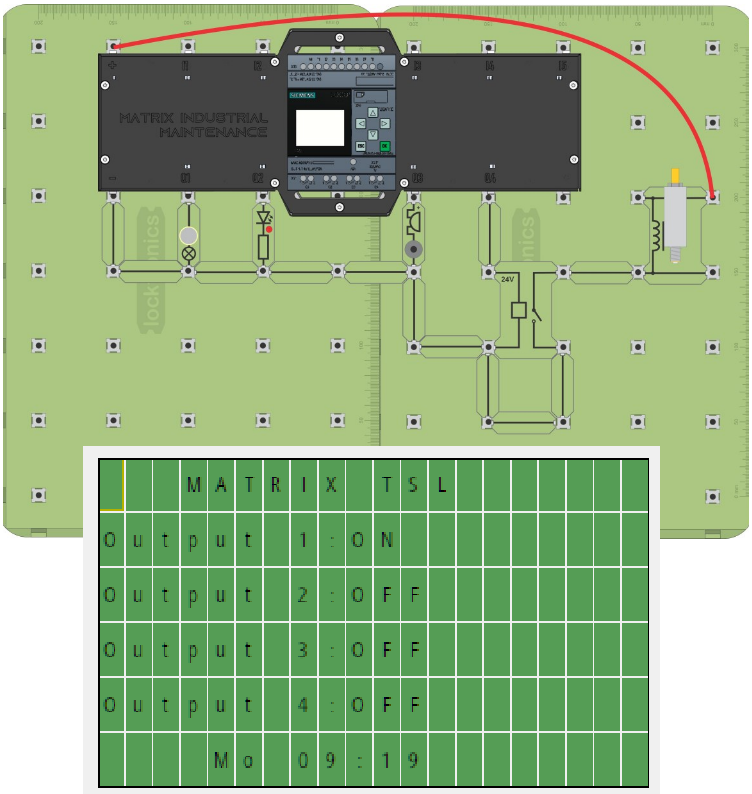
- Low-current transistor outputs
- High-current relay outputs

Transistor outputs are fast and ideal for driving signals to other control devices. But they can’t handle much current directly. Relay outputs, while slower due to their mechanical switching, are robust and better suited to driving loads like pumps, solenoids, or indicator beacons found in maintenance systems.

The photograph shows a simple industrial warning beacon used in equipment status indication.

Over to you:

1. Assemble the Locktronics system shown.
2. Load Program 1.
3. It will cycle through outputs 1 to 4, turning each one on in sequence.
4. The LOGO! PLC's screen displays the status of each output during operation.



So what?

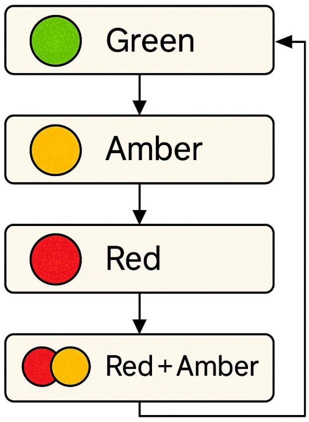
- In industrial maintenance, understanding the output capabilities of your PLC is essential. Transistor outputs vary between models, so always check the voltage and current ratings before connecting equipment.
- When a controller can't drive a load directly such as a motor, solenoid, or warning light external relays are used to handle the higher current.
- Even with a common ground, relays provide electrical isolation between the control and power circuits, which is critical during fault-finding or system upgrades.
- Some PLCs lack internal relays, so maintenance teams must account for this when

Worksheet 2

Sequenced Outputs

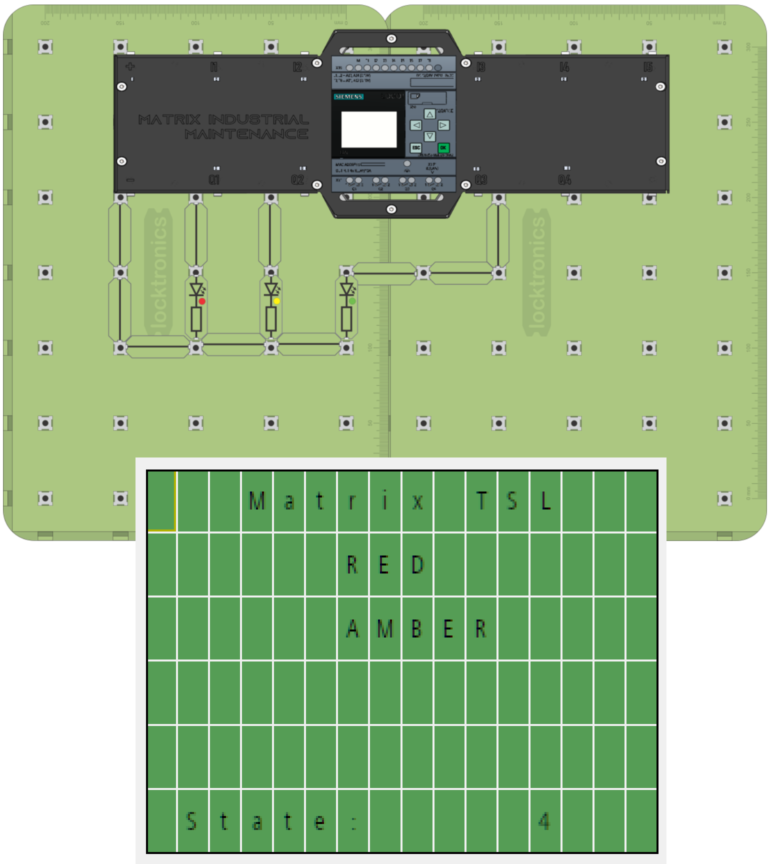
Switching between system states is a key part of many control programs. This method is often called a 'state machine'.

In the basic traffic light example shown here, there are four distinct states. The system must step through these states, assigning specific output values to control the lights.



Over to you:

1. Build the system shown opposite.
2. Load Program 2, it will control the LEDs to simulate the behaviour of a set of traffic lights.
3. It assigns output values for each LED for a single state in the sequence.
4. It uses a timer / counter to keep track of the current state and then add decisions into the program based on that state.
5. It modifies the output values, depending on the current state.



So what?

- Control systems writing to outputs and turning them on is a basic and very important function in control systems. This action is used often to operate equipment such as indicator lamps, relays, or valves.
- Manually switching outputs through the control system is a practical method for testing and fault-finding. It allows you to confirm whether devices are wired correctly and responding as expected, without relying on full system operation.
- This is also useful when commissioning new panels or replacing components. Always verify what each output controls, check terminal labels, and be cautious of load conditions before activating any output.

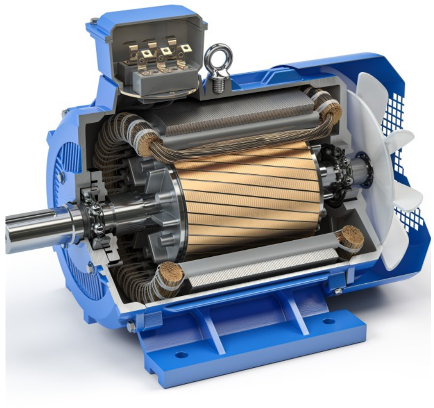
Worksheet 3

Pulse Width Modulation

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

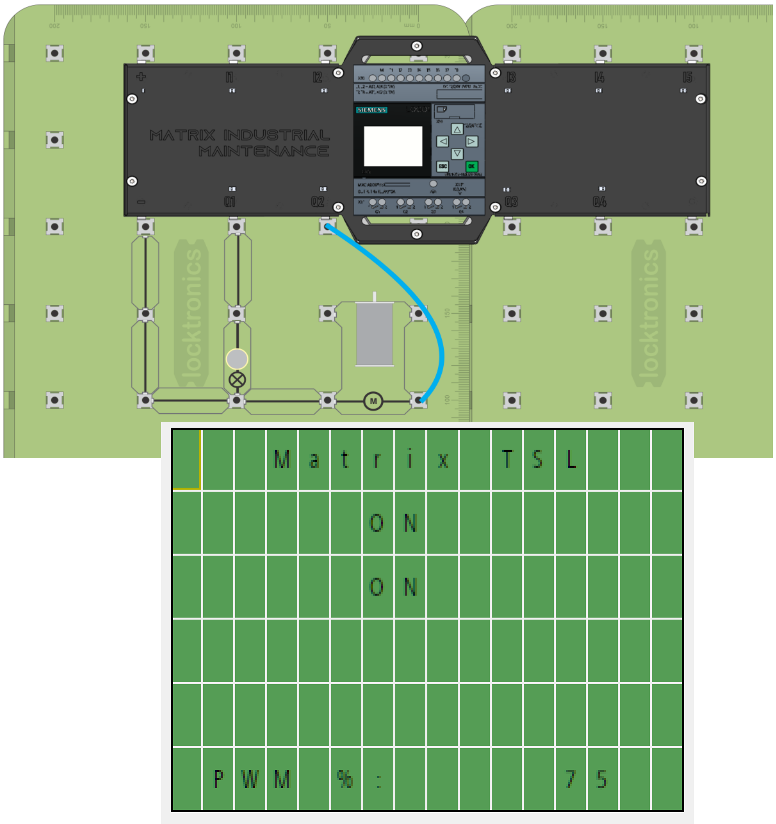
Two of the easiest ways of doing this are:

- 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:

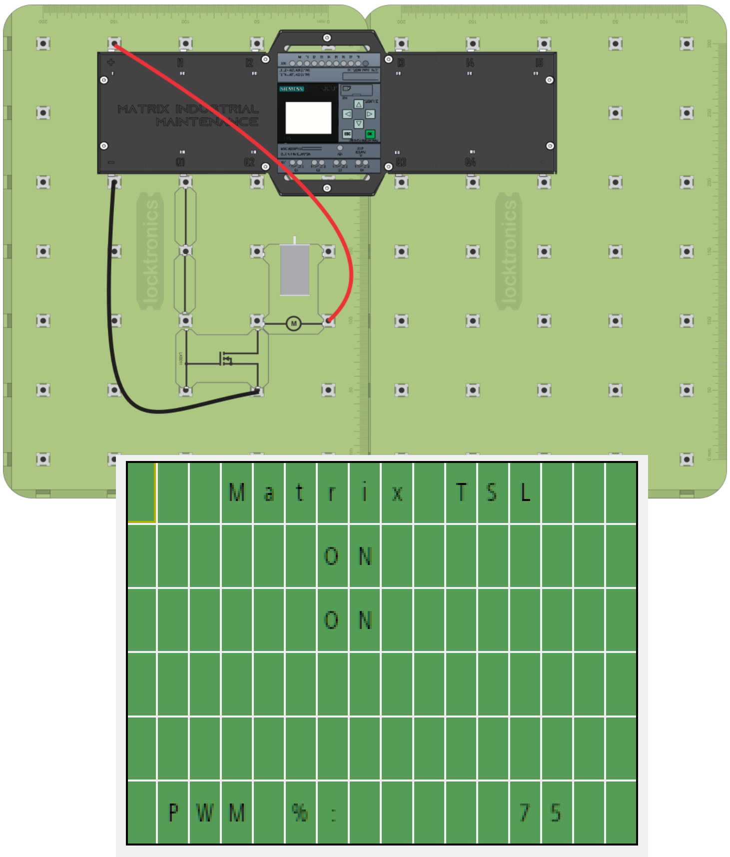
1. Build the system shown opposite.
2. Load Program 3, to enable PWM on Output 1.
3. Ramp up the duty cycle from ‘fully off’ to ‘fully on’ in small steps over a 10 second period.
4. Do the same for Output 2.
5. The LOGO! PLCs screen shows the status of each of the outputs and also the current PWM percent-age.



So what?

- Motor speed is rarely adjusted by changing the supply voltage directly. Instead, control is achieved by pulsing the output rapidly and adjusting the ratio of 'on' time to 'off' time.
- This technique, known as Pulse Width Modulation (PWM), is efficient and widely used for controlling motors, lighting, and other variable loads. In many systems, PWM signals are also used as control inputs to variable frequency drives (VFDs), which then regulate motor speed more precisely.

Worksheet 3
Pulse Width Modulation



Over to you:

1. Modify the circuit so that 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 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.

Worksheet 4

Basic Inputs

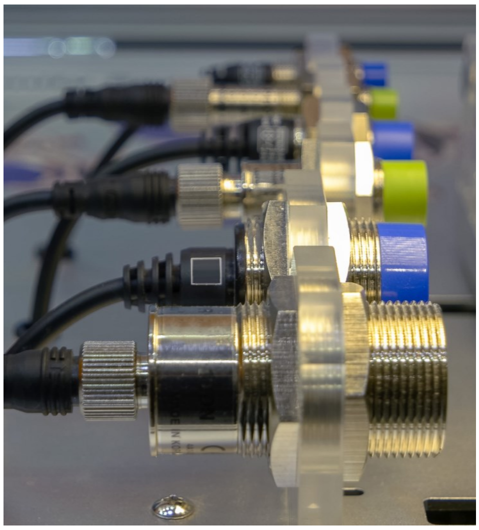
The sensors in any industrial system can be divided into two types: **analogue** and **digital.**

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).

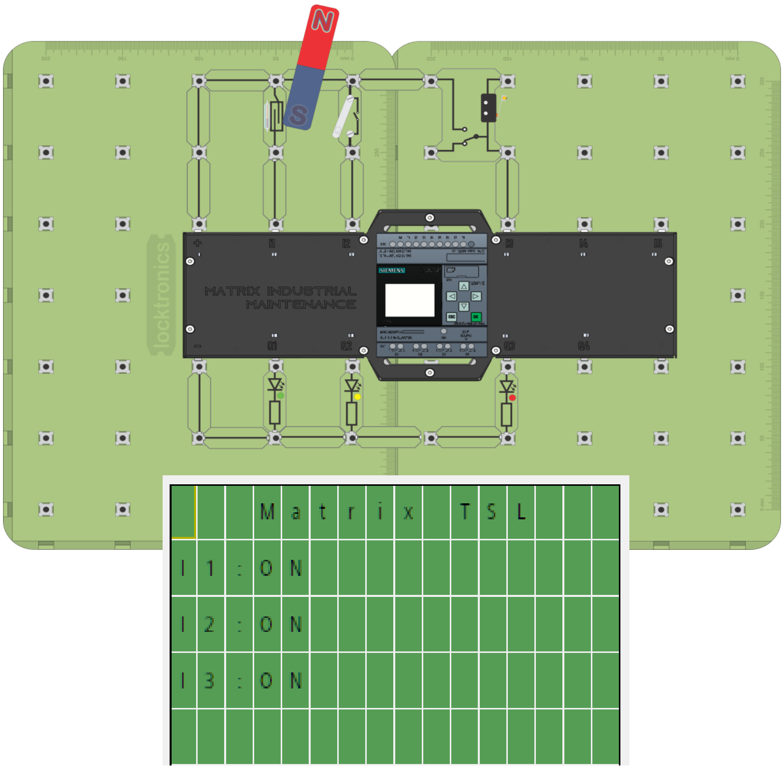
Analogue sensors have a continuous range of output voltages, normally between 10V and 0V. Analogue sensors are covered later in the course.

The photograph shows some industrial metal proximity sensors.



Over to you:

1. Build the system shown opposite.
2. Load Program 4 to read the digital state of the switches, where ‘pressed’ or ‘activated’ = ‘ON’
3. Display the state of the switches on the corresponding outputs.
4. The LOGO! PLCs screen shows the status of each of the inputs this time, not the outputs.



So what?

- The three switches operate differently, which is important to understand during maintenance.
- Some controllers accept both analogue and digital signals on the same input. Others use opto-isolated inputs that only accept digital signals.
- Always check the input type before connecting or replacing a sensor to avoid signal errors.

Worksheet 5

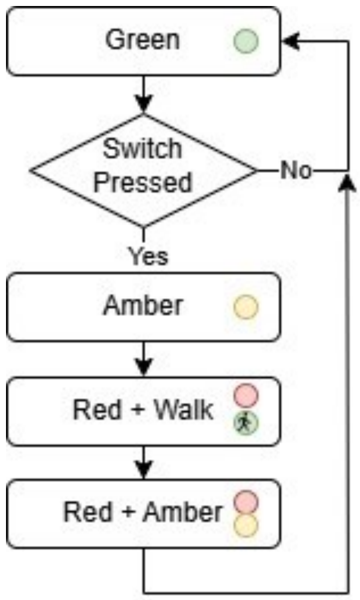
Pedestrian Crossing

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.

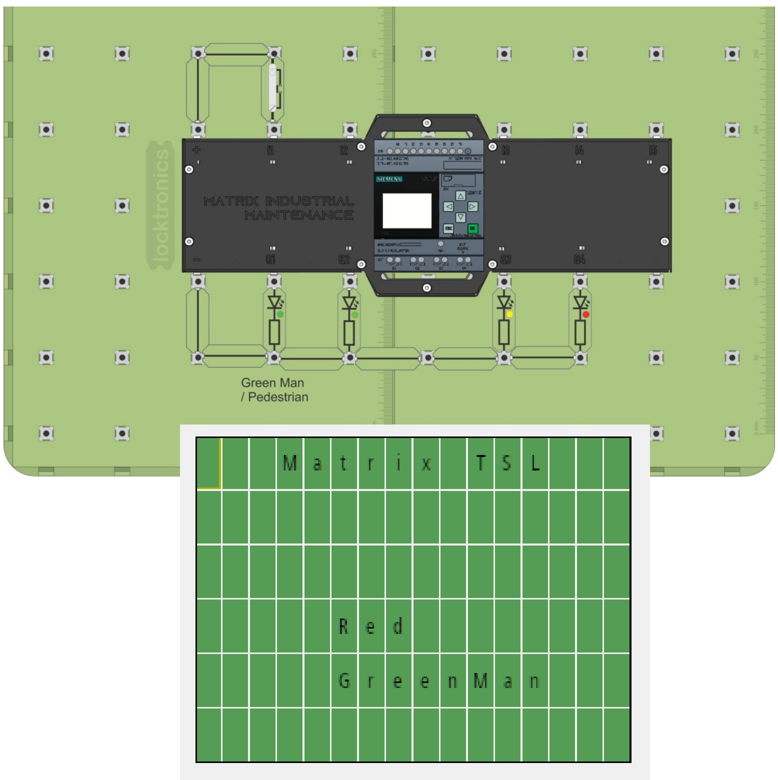
At that point, a second green light, facing the pedestrian, flashes to show that it is clear to cross. After 30 seconds, this turns off, the red and amber lights come on for 5 seconds and then the lights turn green so that traffic can flow again.

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. Load program 5 to control the state of the three main signal lights according to the description given above.
4. The LOGO! PLCs screen shows the status of each of the lights, including the pedestrian walk green man.



So what?

- This system relies heavily on timers, which are a core element in industrial control. Timers are used to manage delays, enforce safety pauses, and coordinate the sequence of events.
- Whether you're handling traffic lights or machine operations, understanding how to timers operate on a basic level is essential for reliable and safe system behaviour during maintenance.

Worksheet 6

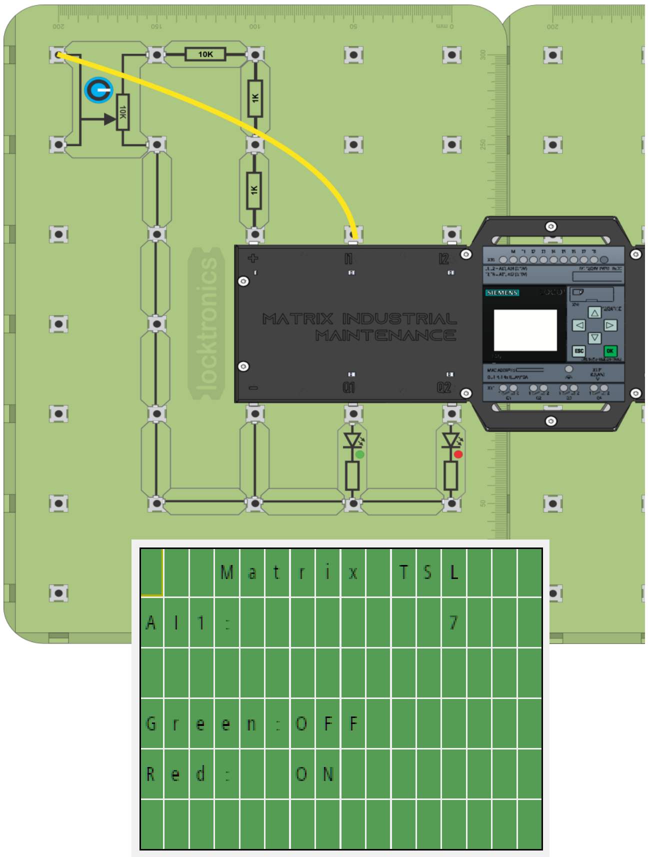
Potentiometers

A switch typically sends either a 24V or 0V signal to a controller input.
A potentiometer, on the other hand, provides a variable voltage between 0V and 24V.

Potentiometers are useful for setting values like light level, conveyor speed, or room temperature.
The photograph shows an electrical control panel where potentiometers are used to set current limits.

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. Load program 6 to give the controller this functionality.
5. The LOGO! PLCs screen shows the status of the lights and the analogue input value.



So what?

- In industrial maintenance, digital inputs are often enough for basic control tasks like detecting switches or sensors. But when setting values such as motor speed, pressure limits, or temperature targets, a variable input is required.
- A common and simple method is to use a dial, typically a potentiometer, which allows maintenance teams to adjust settings directly on the panel without needing to access the software.

Worksheet 7

Using sensors

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

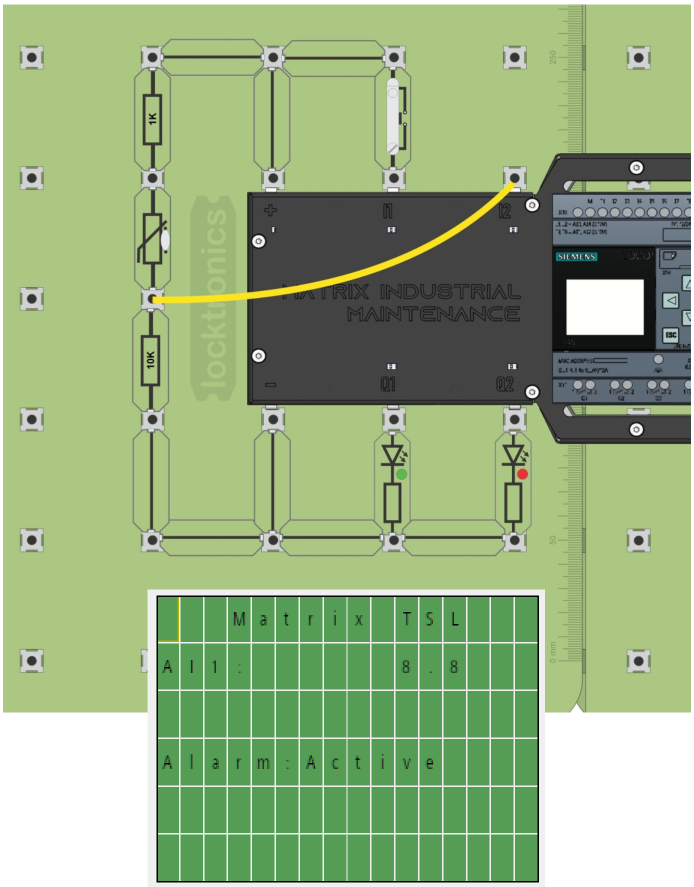
However most are analogue, their output signal varies between 0 and 10V usually, representing a varying quantity, light level, temperature or voltage, for example.

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

The photograph shows a temperature 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. Load Program 7 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.
5. The LOGO! PLCs screen shows the analogue input value and the alarm status.



So what?

- Being able to read and interpret analogue signals is essential in industrial maintenance. Most real-world values like temperature, pressure, and flow vary continuously.
- Analogue sensors provide this information, allowing systems to respond with greater accuracy. Understanding how these signals work helps maintenance teams troubleshoot faults, calibrate equipment, and ensure systems operate within safe and efficient limits.

Worksheet 8

Detecting Faults 1

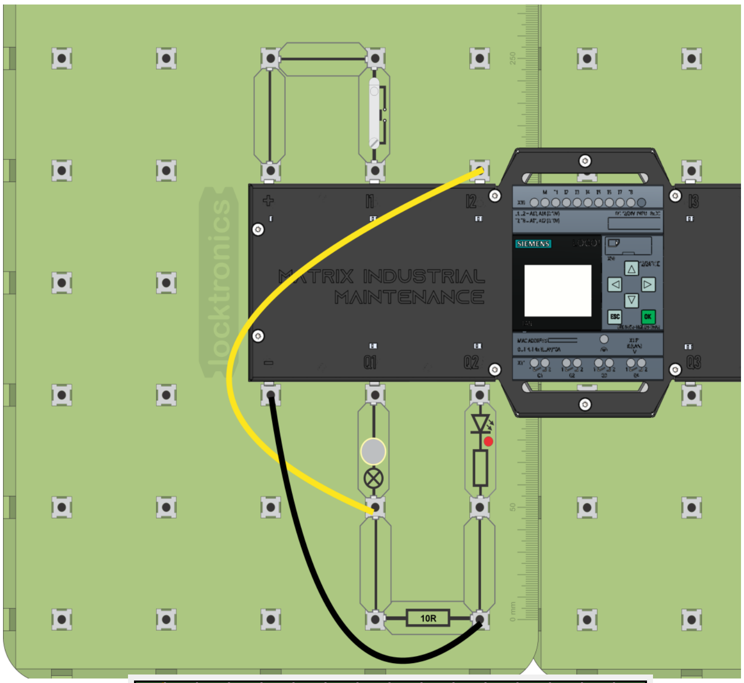
In modern industrial systems, controllers also report on the status of the system and many of its components.

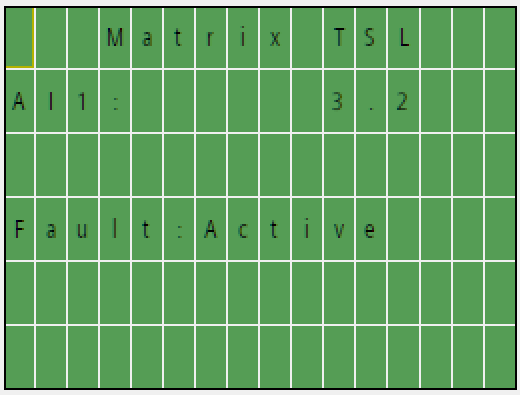
In this landing gear system, the controller can detect when the main landing gear is not fully engaged and inform the pilot and flight control so that they can react accordingly.

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. Load Program 8 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 **I2** 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.
6. The LOGO! PLCs screen shows the analogue input value and the fault status.





So what?

- In safety-critical systems, extra circuitry is often used to confirm that devices are operating as expected.
- One common method is placing a small resistor in line with an actuator. By measuring the voltage across the resistor, the system can detect if current is flowing. This helps verify that the actuator is not just being commanded, but is actually drawing power and likely operating correctly.

Worksheet 9

Detecting Faults 2

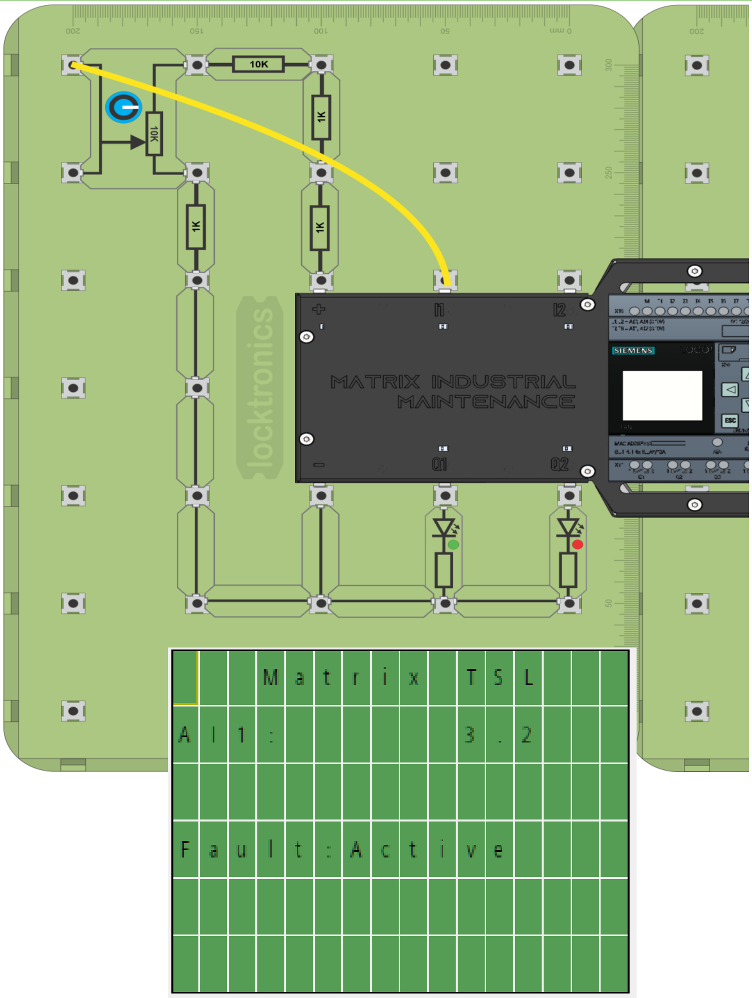
In fault critical systems, such as industrial processes where a fault could have catastrophic consequences, it is important to track all problems as they develop.

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 sheet steel machine.

Over to you:

1. Build the system shown opposite. It contains a potentiometer which is supplying the analogue sensor signal.
2. Load Program 9 to:
   - read the potentiometer signal;
   - light the green LED if the signal has a value between 50 and 200.
   - light the red LED if the signal is outside of these values.
3. Short-circuit input **I1** to +V and 0V, in turn and check that the system is detecting the fault correctly.
4. The LOGO! PLCs screen shows the analogue input value and the fault status.



So what?

- Well-designed circuits and control logic play a key role in ensuring equipment operates safely and reliably. Intelligent use of inputs and monitoring can help detect faults early, confirm devices are responding correctly, and reduce unplanned downtime. This approach is especially important when maintaining systems that must meet strict safety or operational standards.

Worksheet 10

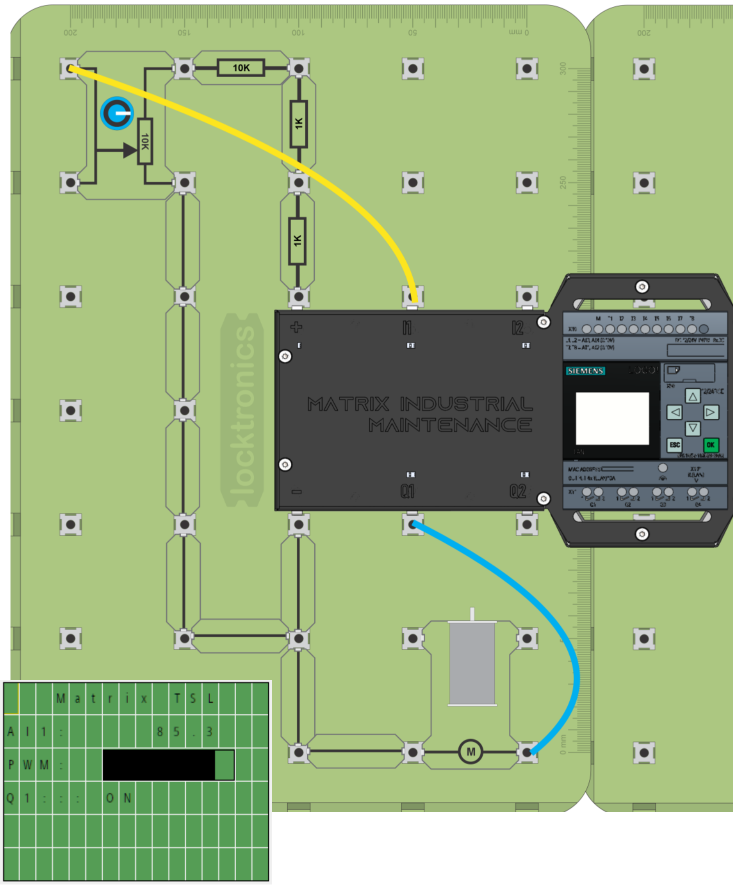
Open-Loop Control

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. Load Program 10 to read the signal from the potentiometer and use it to vary the speed of the motor, using Pulse Width Modulation.
3. The LOGO! PLCs screen shows the analogue input value, the PWM value and the output value.



So what?

- This is an example of an open-loop control system.
- Open-loop systems control outputs without feedback. They are simple but won't detect faults like a stuck valve or failed actuator. Knowing where these are used helps identify issues during inspections and repairs.

Input → **System** → **Output**

Worksheet 11

Closed-Loop Control

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

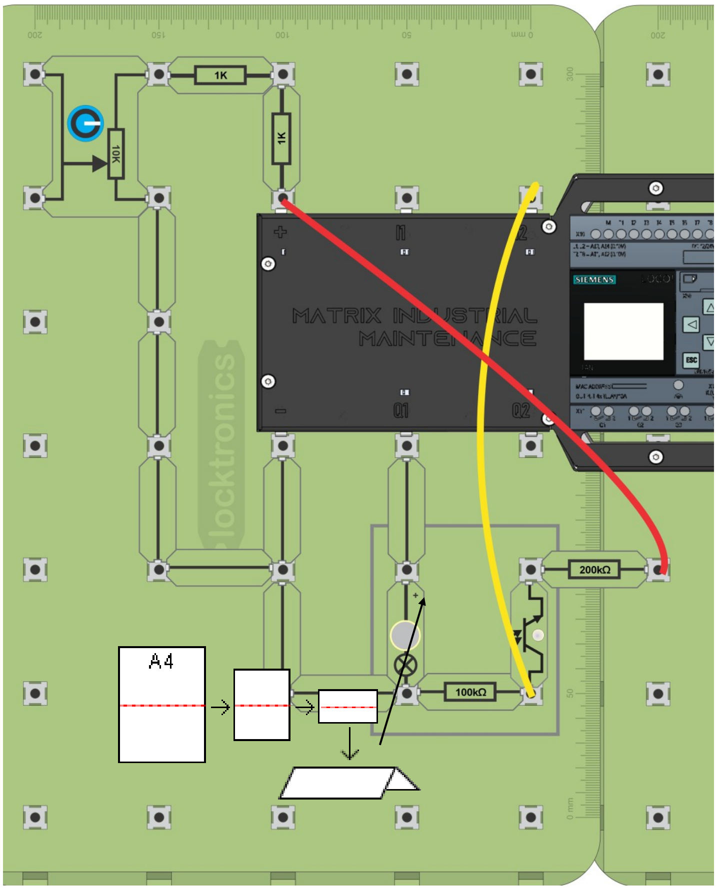
The lamp lights up its surroundings. A signal from the light sensor indicating light level, is fed back and compared to the desired light level, set by the potentiometer.

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.

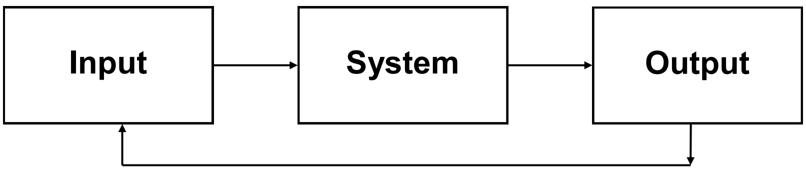
Over to you:

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. Load Program 11 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.



Maintenance Tips

Everyday Maintenance Tips for Industrial Sensors & Control Systems

In industrial systems, always keep an eye on output devices like lamps, relays, and solenoids check for heat damage, wear, and loose wiring. If a sequence isn't behaving as expected, timers or relay contacts might be at fault. PWM-controlled devices like motors should be monitored for overheating, and it's good practice to shield signal cables to avoid interference.

Inputs can fail from something as simple as a broken wire or a faulty switch, so it's worth simulating inputs during troubleshooting. Safety systems, like those in pedestrian crossings, need to be checked regularly especially to ensure they fail to a safe state. Potentiometers are prone to wear and can give jumpy readings, so test them with a known resistance or replace if readings are inconsistent.

Sensors should be kept clean and aligned, with all connectors checked for damage or looseness. Fault detection is more reliable when you simulate issues intentionally disconnect wires or short outputs to see if alarms or indicators trigger as expected. This helps validate both hardware and software responses.

Open-loop systems can drift over time if load conditions change or actuators begin to stick, so regular recalibration is important. Closed-loop systems offer better stability but depend heavily on accurate sensors and well-tuned PID settings. If the system starts to oscillate or misses its setpoint, check calibration and adjust PID values as needed.

Version control

04 04 25	New curriculum created from CP7718