## **Lesson Plan**

| **Lesson 4 - Potentiometer** | | | | | |
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| **Learning Aims:** In this lesson students will be introduced to analogue input/output pins on the Pico. They will learn that analogue pins allow a much wider range of values to be handled than via digital pins.**Learning Objectives:**  * How to utilise the Pico analogue to digital convertor pins to allow analogue input * That analogue input allows a wider range of values to be represented compared to digital input * How to use analogue signals to control the brightness of an LED | | | | | |
| **Key Words** | | ADC, analogue, PWM, Duty Cycle, Frequency, Potentiometer | | | |
| **Preparation before the lesson:**  Print required handouts 2 x Pots for each Pico  6 x M2M jumper wires per Pico  In addition it's **highly recommended** that teachers undertake these activities prior to the lessons.   * **Slides contain speaker notes where applicable** | | | | | |
| **Assessment opportunities** | | Correct implementation of coding tasks Completion of Challenges activities Correct answers to plenary questions  PRIMM activity and discussions | | | |
| **Lesson Resources** | | [Potentiometer wiring diagram](https://docs.google.com/document/d/1MJja1EoB6RUisKhjL3eSE7SzrsLnbFOA/edit?usp=drive_link&ouid=114120863087517164066&rtpof=true&sd=true)  [Dimmer Switch Activity Worksheet](https://docs.google.com/document/d/1aJtp8BvW8QDJ77_O_zv2HKO0oJG4-EV5/edit?usp=drive_link&ouid=114120863087517164066&rtpof=true&sd=true)  [Lesson 4 ppt](https://docs.google.com/presentation/d/1B4y3l_x7vKd8TaAKG4A8s9bz7fw5n9l6/edit?usp=drive_link&ouid=114120863087517164066&rtpof=true&sd=true) | | | |
| **Teachers Guides:** | | | [Analogue V Digital Teacher Lesson Guide](https://docs.google.com/document/d/1x-R3mQiFFpoM99kFBEk4FsarYF5hqHg0/edit?usp=sharing&ouid=114120863087517164066&rtpof=true&sd=true)  [Guide to Potentiometers](https://docs.google.com/document/d/12MgfZACZntzwIHQ7qYMa1R6dvdRHLzDd/edit?usp=sharing&ouid=114120863087517164066&rtpof=true&sd=true) | | |
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| **NC Links** | | | * design, use and evaluate computational abstractions that model the state and behaviour of real-world problems and physical systems. * understand the hardware and software components that make up computer systems, and how they communicate with one another and with other systems * use two or more programming languages, at least one of which is textual, to solve a variety of computational problems; | | |

| Starter activity (Slide 2)  5 mins | Students will begin by thinking about analogue versus digital sound and decide if one is better quality than the other.  Feedback on the starter briefly discussing pros and cons surrounding quality. Students often believe digital is “better quality” not really understanding how analogue data has to be converted to be stored digitally and that precision can be lost during the process; this loss of precision can have a detrimental effect on sound accuracy meaning it is less true to life. This in turn may result in quality issues.  Lead into digital v analogue on the Pico explaining that the Pico has built on board analogue to digital convertor. Recap on how digital pins can only represent a maximum of two values and how data such as sound needs to be converted to allow a computer to interpret or store the analogue values as digital data. This is the focus of today's lesson | |
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| Slide 3 | Lesson aims are outlined present these to students | |
| Slide 4 & 5 | **Analogue pins on the pico** Definition of an Analogue-to-Digital Converter (ADC) **Analogue-to-Digital Converter (ADC)**: A device or circuit that converts continuous analogue signals into discrete digital values, allowing analogue input data, such as voltage, temperature, or sound, to be processed by digital systems, such as microcontrollers and computers.  The Pico has 3 ADC pins which allows for analogue data to be input via multiple analogue input devices. An additional analogue pin is attached to an internal temperature (thermometer)sensor. As digital data has only two states one and off. Analogue data via the Pico has over 65,000 states which allows us to represent or read real life states such as sound.  **slide 5 use the analogy**  Imagine you have a bucket of water and you're slowly pouring water into it. The water level in the bucket represents an analogue signal. It's a continuous value that can take on any value between the minimum (empty bucket) and the maximum (full bucket).  Analogue signals are everywhere in the world around us. They represent changes in physical quantities like temperature, pressure, light intensity, and even sound waves. Unlike digital signals, which can only have two values (0 or 1), analogue signals can take on an infinite number of values. ADC lets us take these signals and convert them into digital values. | |
| **Activity 1**  (Slides 6)  10 mins | Introduction of POTs (potentiometers) as a form of analogue input. POTs are common in everyday life, often for volume control, dimmer switches and temperature controls.  These are used when more control is required than simply turning on and off a device. **The teacher guide handout provides guidance on these devices allowing teachers to decide how much information will be useful to their students.**  A basic understanding will suffice for the majority of students. A potentiometeris a three-terminal resistor with a sliding or rotating contact that forms a variable voltage divider. Allowing the voltage to be measured as the dail turns the voltages is whether increased or decreased. The Pico ADC work with the 3v current  The resistance of the potentiometer between the rotating contact and one terminal is proportional to the distance the dial has moved from that terminal. | |
| **Activity 2** (Slide 7)  10 mins | Distribute the resources and the circuit diagram.  Show the wiring circuit on the slide.  Explain wiring up the circuit, the POTs have 3 pins, the important one is the **middle pin which is used for receiving the signal**, this is attached to the ADC 0 10th Pin from the top right side. The remaining POT pins are attached to ground and 3v rail. Have students annotate the diagram to identify the Pin numbers on the diagram  Students should be a little more confident now with wiring the circuits and should find this circuit simple. There should now be many connections and students should be encouraged to check connections from previous lessons are still in place. For this lesson only 1 POT is needed for the activities and challenges but two POTs are shown on the wiring diagram to allow students to prepare for the next and final lesson when students will utilise two POTs. | |
| **Activity 3**  Slide 9-10 | PRIMM activity worksheet where students Identify what will happen when the code is executed. They should be able to annotate and discuss many aspects of the code based on prior learning.  Demonstrate live how the POT input can be displayed using the console plotter in Thonny. The code of this is included in the code folder in addition a video is included if required.  Then walk through the code with the students  **Import Statements**  from machine import Pin, ADC  from time import sleep  **2. ADC Initialization**    adc = ADC(0)   * This initialises an ADC object on ADC channel 0. The argument 0 is the ADC pin. note how no GPIO is used here   **3. Infinite Loop**      while True:  print(adc.read\_u16())  sleep(0.5)   * while True: * print(adc.read\_u16()): Reads the ADC value and prints it.   + adc.read\_u16(): Reads a 16-bit (unsigned) analogue value from the ADC pin. The u16 means "unsigned 16-bit". The ADC converts the analogue signal into a value ranging from 0 to 65535, corresponding to the voltage level on the pin. * sleep(0.5): Pauses the program for 0.5 seconds before the next iteration of the loop. This adds a delay between consecutive readings, making it easier to observe changes over time. * The code continuously reads analogue input from an ADC channel. * Every 0.5 seconds, it prints the current ADC value, which represents the analogue signal's voltage on the specified pin. Using the plotter in Thonny allows you to also view the changes in the values | |
| **Activity 4**  Slide 11  25 mins | Real life application of a dimmer switch is introduced to students on this slide. It is likely but not certain that students will have experiences of a dimmer switch. Explain to students that the brightness of a light is determined by the amount of current flowing through it at any given time. A pot switch can control that current to dim a light. We can simulate this using the PICO  When you apply a PWM Pulse width modulation signal to a pin you are turning on and off the pin in extremely quick succession this results in less voltage travelling through the pin resulting in a dimming effect to the LED. This same principle can be applied to other hardware such as a motor to control its speed. It is the way in which you can create an analogue output.  **What is PWM?**  **PWM** stands for **P**ulse **W**idth **M**odulation. It's a type of digital signal where, over a set period of time, the signal can be turned on and off incredibly fast.  This *very* *fast* ON/OFF signal can create a dimming effect for LEDs.  **What is PWM Duty Cycle?**  We can decide how long we keep our LEDs ON/HIGH by changing the **Duty Cycle**. The duty cycle is the percentage of the time that our LED will be ON. The higher the duty cycle, the longer the LED will be ON, and the brighter our LED will appear.  Duty cycle for the Pico in MicroPython can range from **0 to 65535**, which is handy as this matches the output of our potentiometer (**0-65535**) so we can use this value directly without having to manipulate it.  **What is PWM Frequency?**  Our PWM code also needs a frequency value, which is the number of times per second that we will repeat the ON/OFF cycle.  **Show students the changes required to the code shown on slide 12**  Note how lines 7 & 8 creates a PWM object and passes in the led\_onboard from the earlier activity and sets the frequency the duty cycle is set during the infinite loop to continually adjust the brightness  Students then work through the **activities on the worksheet** to create a dimmer switch making use of the onboard LED on the PICO.  Working in buddy groups of 3 or 4 as in previous lessons to check each other's wiring and code.  The dimmer switch is the main activity for the lesson. Students should be given time to prepare for the final lesson by adding a second potentiometer.  Slides are also provided if teachers want to give explicit instruction on the circuit for two pot’s this is also in the handout for students and students should at this stage be confident to follow this independently.  Finally if any time is remaining the flashing light activity can be completed.  Students should be gaining confidence now and may be happy to code from scratch. The code in these activities are fairly short, but this is due to the volume of concepts covered with ADC and PWM. However as in the previous lessons the starter code may be supplied to students from the 1st activity.  For students who finish early they can code the 2nd POT or complete a game challenge activity. | |
| **Plenary**  (Slides  5 mins | Questions on slides. Answers can be written in books or on an exit ticket | |
| **Homework** | Research how analogue to digital convertors can be used in medicine.  **Answer key**  **Medical devices** use ADCs to convert various physiological signals into digital form for diagnosis, monitoring, and treatment.   * **Sensors**: Capture biological signals like heart rate, blood pressure, and brain activity and many more * **ADCs**: Digitise these signals for medical analysis and storage. **Examples**:   + Electrocardiograms (ECGs) for heart monitoring.   + MRI and CT scanners for imaging.   + Blood glucose meters for diabetes management. |  |