# MCP3008 ADC Setup Guide

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## 1 Overview

In this tutorial you will learn about the MCP3008 ADC and how to connect and use it with the Keysight Hacking Platform development kit.

## 2 What is an ADC and why do I need it?

An Analog to Digital Converter (ADC) is a device that can measure an analog voltage and covert the measurement to a digital code that can be used by a microcontroller such as a Raspberry Pi. We need an external ADC to measure analog voltages since the Raspberry Pi does not have its own ADC built-in.
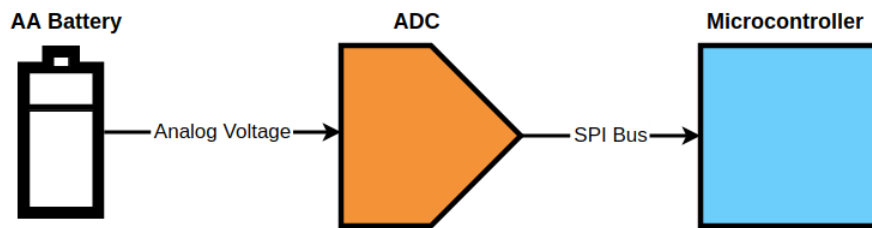


Figure 1: ADC Dataflow

There are several different types of ADCs from various manufacturers with varying degrees of precision. In this tutorial we will be using Microchip's MCP3008 8 channel 10-bit SPI ADC.

## 3 MCP3008 Data Interface

There are several different digital data buses that are commonly used by discrete ADCs to talk to microcontrollers (I2C, SPI, etc...). In our case the MCP3008 uses a Serial Peripheral Interface bus (SPI) for the digital data interface. An SPI bus consists of four discrete signals:

1.) **CLK or SCLK** - Serial clock signal generated by the master device

2.) **MOSI** - (Master Out Slave In) This is a serial data line for data from the master device to the slave device

3.) **MISO** - (Master In Slave Out) This is a serial data line for data from the slave device to the master device

4.) **SS or CS** - (Slave Select or Chip Select) This line is either pulled high or low (for the MCP3008 it is pulled low) by the master device to initiate communication with the slave device

# 4 Connecting the MCP3008 ADC to the Raspberry Pi

Before we can connect any device we need to know the device's pinout. Figure 2 is the pinout of the MCP3008 taken from its datasheet.
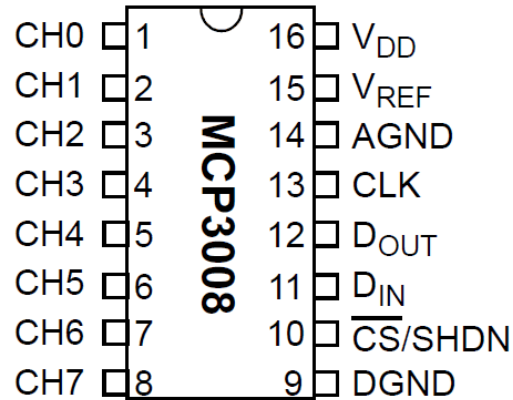


Figure 2: MCP3008 ADC Pinout

Notice the half-circle notch on the top of the part. This mark will help you determine where pin 1 is on the MCP3008. Figure 3 labels the MCP3008's pins based on their functions.
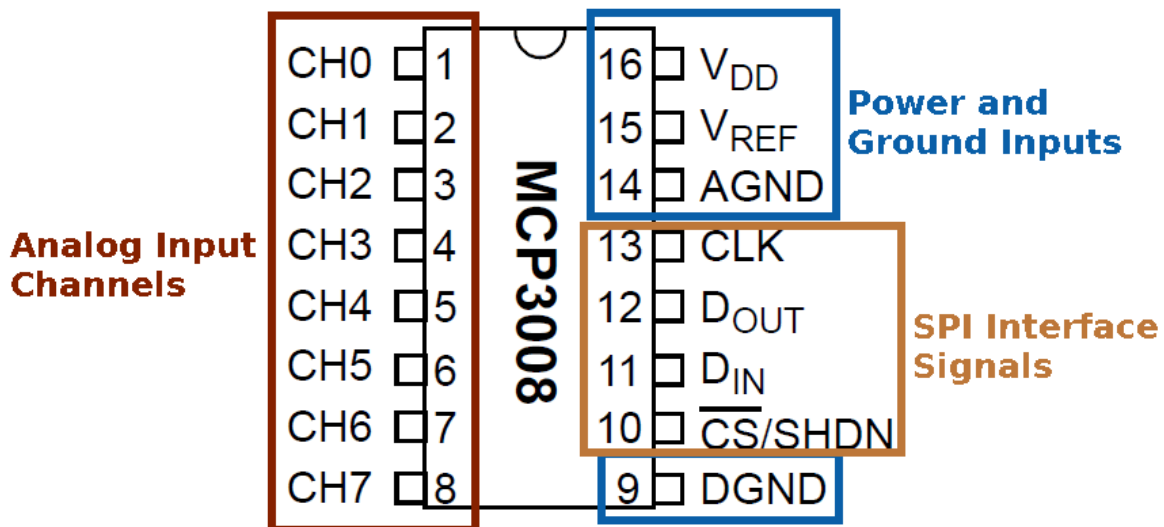


Figure 3: MCP3008 ADC Pinout Labeled

Now that we understand the pinout of the MCP3008, the next thing we need to figure out is which pins we need to connect to on the Raspberry Pi. The Raspberry Pi 3 has two SPI buses available on its GPIO header. If you refer to the Keysight Hacking Platform hardware guide you know that SPI bus 0 is already in use by the touchscreen. Therefore, we will use SPI bus 1 to connect to the MCP3008. The GPIO lines that are used for SPI bus 1 are show in Figure .
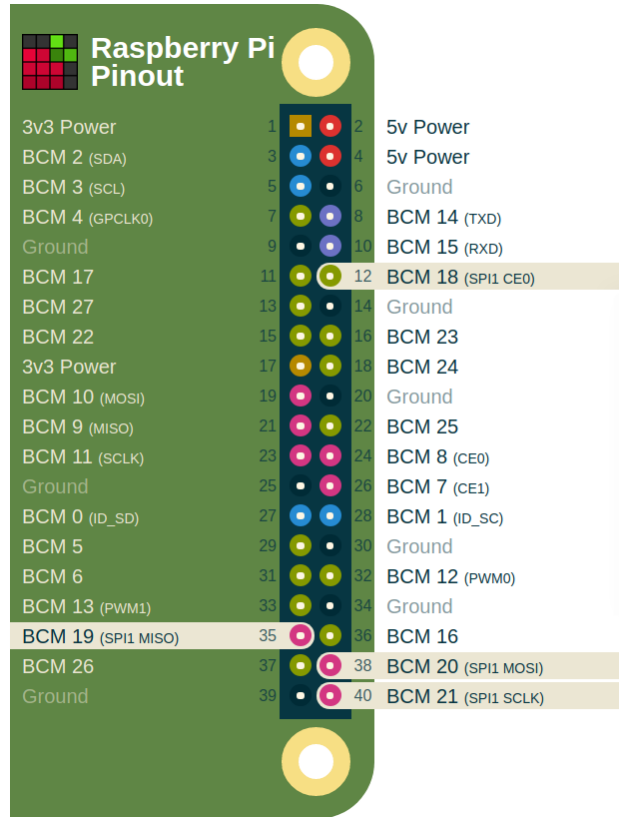
Figure 4: Raspberry Pi 3, SPI Bus 1

The last bit of information we need to know is that the Raspberry Pi 3's GPIO lines operate at 3.3V. Therefore, we will run the MCP3008 off of the 3.3V rail (the MCP3008 can run off of 3.3V or 5V).

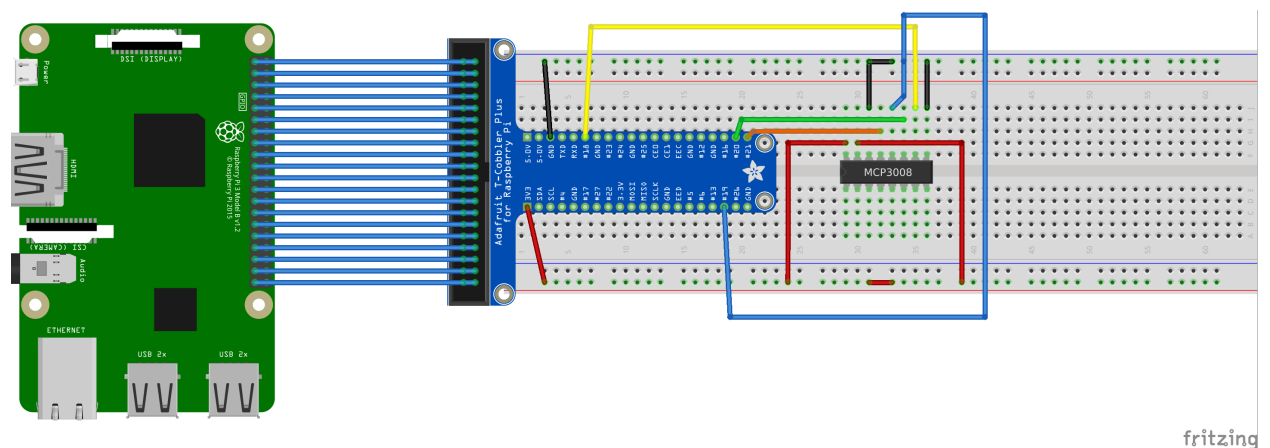After putting all this information together, we can hook the up MCP3008 to the Raspberry Pi as shown in Figure 5.



Figure 5: MCP3008 ADC connection to the Raspberry Pi

# 5 Converting a Voltage to an ADC Code

The MCP3008 is a 10-bit ADC. This means that the ADC will convert the voltage that it measures to a number that is between 0 and 1023. The maximum voltage the MCP3008 can measure is $V_{ref}$ which in our case is 3.3V and that can be measured is 0V. Therefore, the formula for converting the measured voltage to an ADC code is as follows:

$$ADC\ Code = \frac{V_{in}}{V_{ref}} * 1023 = \frac{V_{in}}{3.3V} * 1023$$

# 6 Notes About Input Voltage

Since we configured the MCP3008 to be powered from a 3.3V rail, the highest voltage we can measure is 3.3V. If you decide to use 5V devices we need to make a simple voltage divider to limit the max voltage that the ADC will see to 3.3V. This can easily be accomplished with a pair of resistors as shown in Figure 6.
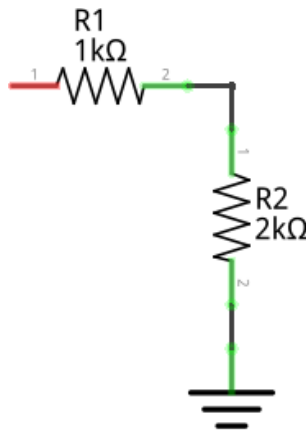


Figure 6: 2/3's Voltage Divider

The 5V device will be connected to pin 1 of R1 and the ADC input channel will be connected to the junction between R1 and R2. The equation for a two resistor voltage divider is as follows:

$$V_{out} = V_{in} * \frac{R2}{R1+R2} = V_{in} * \frac{2k}{1k+2k} = V_{in} * \frac{2}{3}$$

# 7 Software to use the MCP3008

**Add the name of the folder where the ADC examples are located after creating the folder structure!**