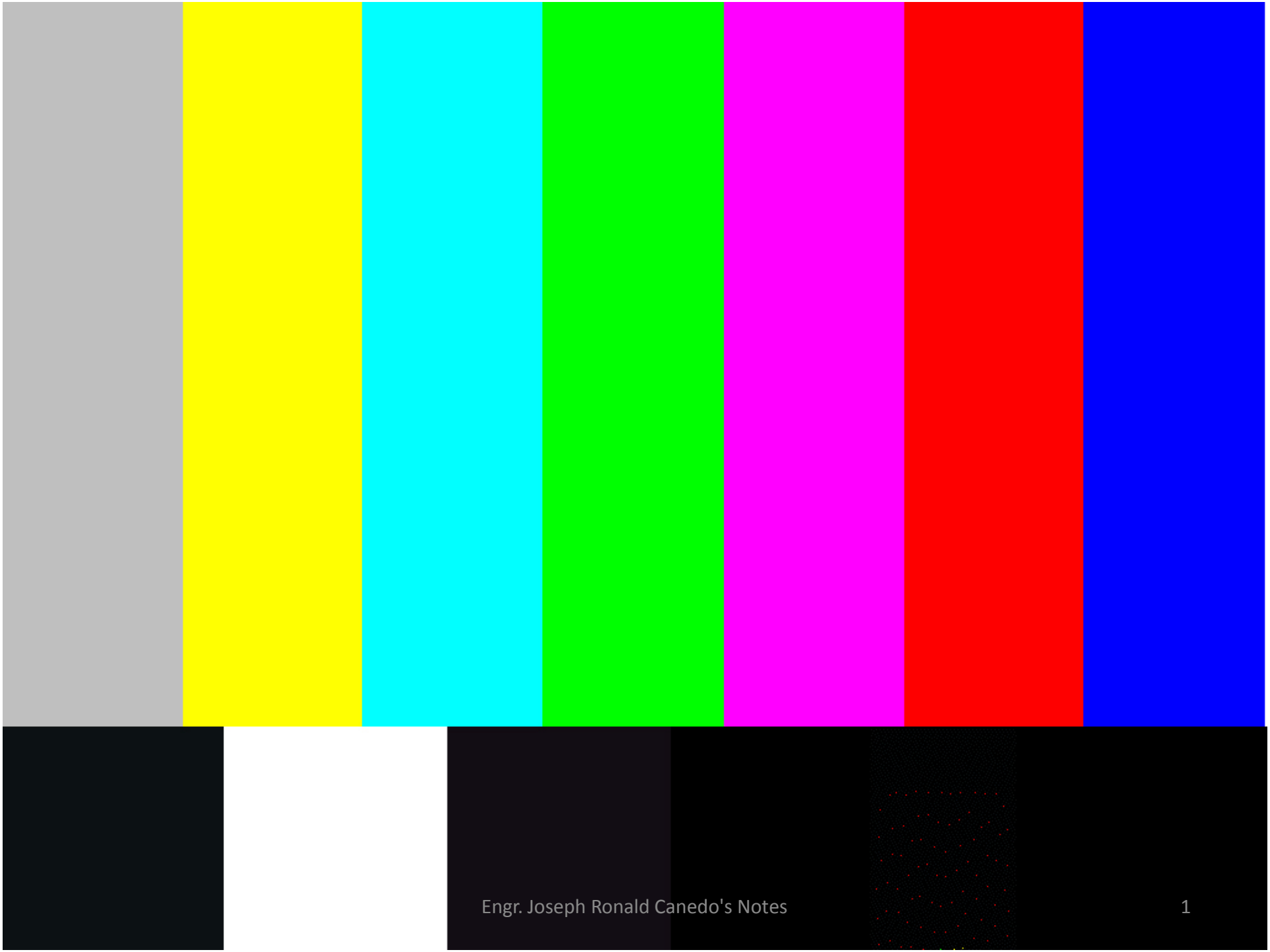


Analog

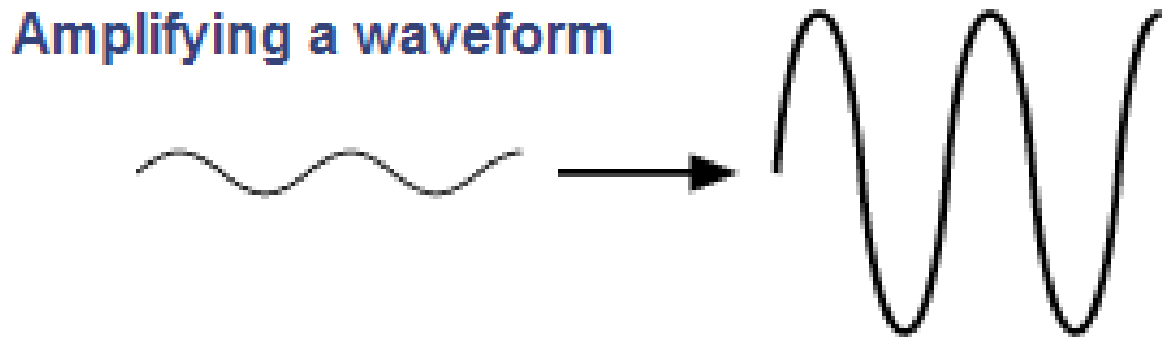
By:
Engr. Joseph Ronald Cañedo

Introduction

- In this chapter, we'll look at how you sample external voltages and convert these into digital values for processing by your embedded system. Such voltages may be generated by sensors and may represent light levels, temperature, or vibration.
- Or perhaps the voltages are the output of a microphone or audio system and need to be converted into digital data.
- Later, we'll take a look at how you turn digital data into an analog output voltage. We'll conclude the chapter with hardware to control electric motors.

Amplifiers

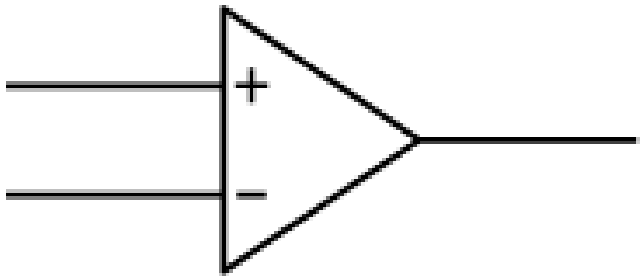
- Amplifiers are used to interface one analog circuit to another.
- An amplifier is a circuit that increases (or decreases) a given input voltage to produce an output voltage.



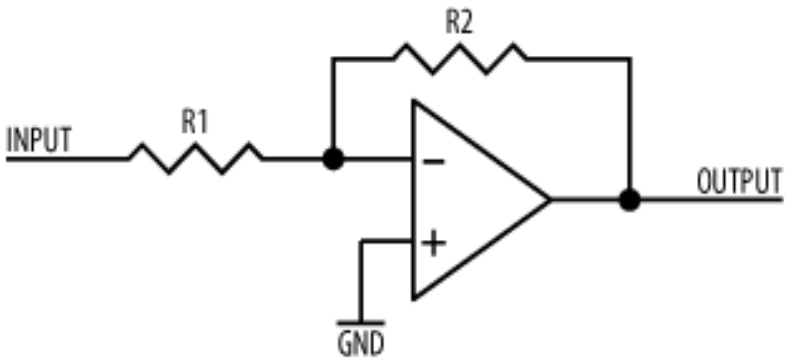
$$\text{Gain} = V_{OUT} / V_{IN}$$

Amplifiers

Schematic symbol for an op amp

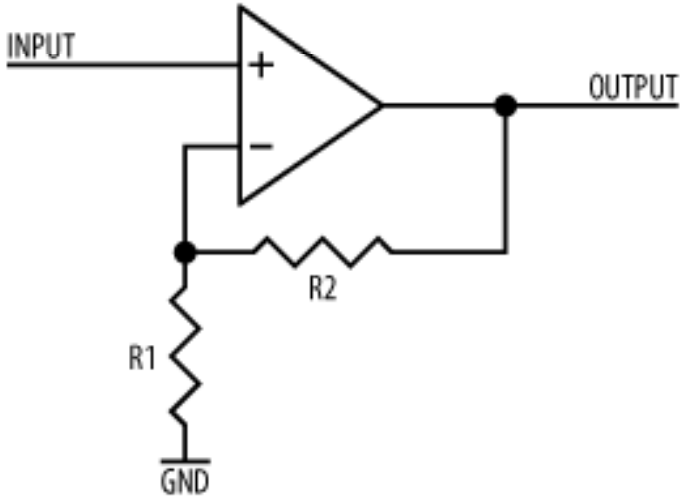


Inverting amplifier



Gain = − R2 / R1

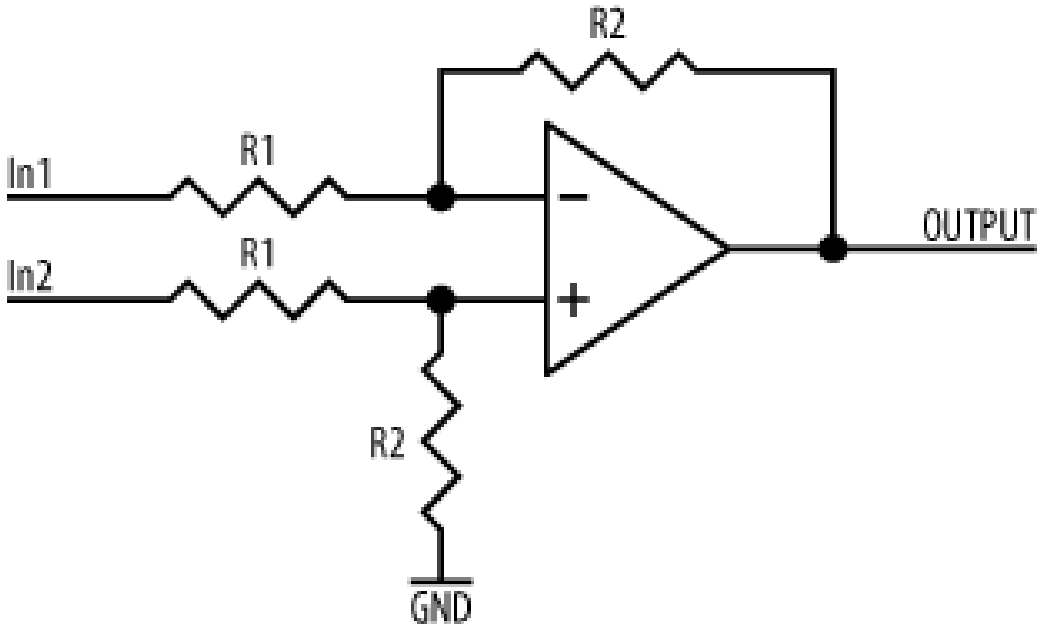
Noninverting amplifier



Gain = 1 + R2 / R1

Amplifiers

Differential amplifier



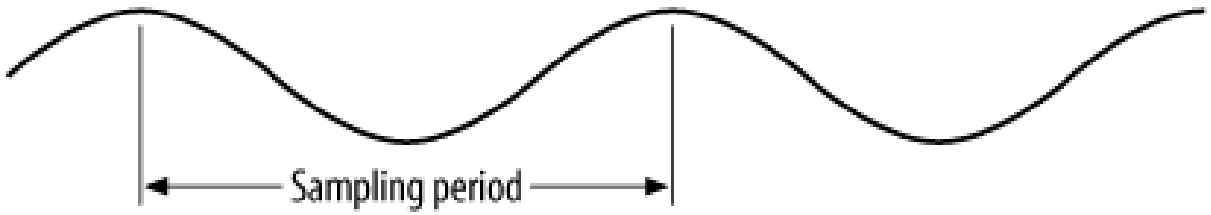
$$V_{OUT} = (In2 - In1) * (R2 / R1)$$

Analog to Digital Conversion

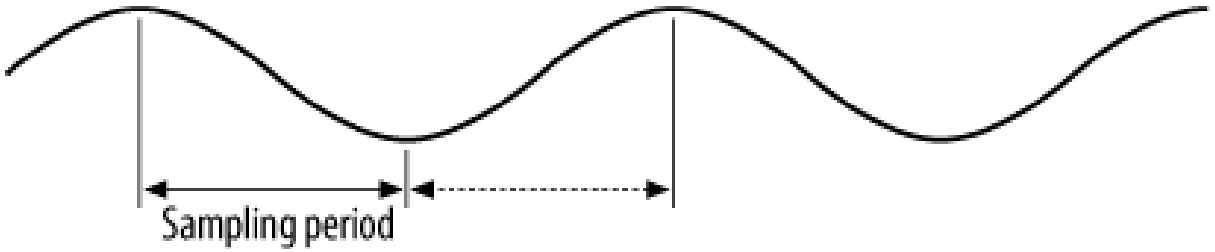
- A device that converts an analog input voltage to a digital number is known as an Analog to Digital Converter.
- A codec (COder DECoder) is an ADC combined with a Digital to Analog Converter (DAC), providing both analog input and analog output in one chip.
- There are several different types of ADC.
  - Integrating ADCs
  - successive approximation ADC
  - Flash ADCs (also known as parallel ADCs)
- The process of converting an analog signal to digital is known as **sampling** or **quantization**. ADCs have two principle characteristics: **sample rate** and **resolution**. Sample rate is expressed as samples per second (SPS) and refers to how frequently an analog input signal is converted into a digital code.

Analog to Digital Conversion

- Sample Rates



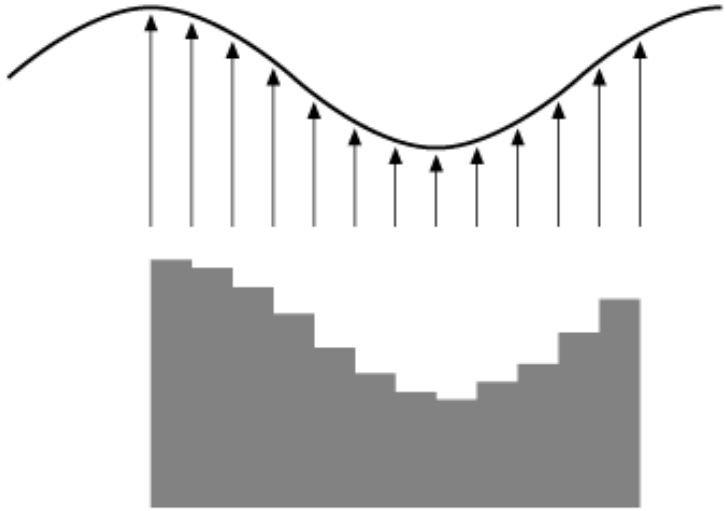
Poorly chosen sample rate gives inaccurate signal reading



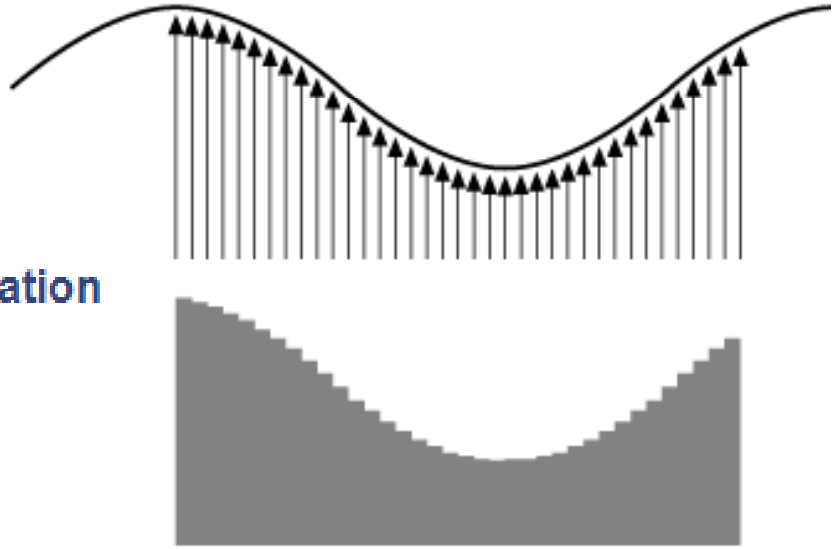
Shorter sampling period

Analog to Digital Conversion

- Sample Rates

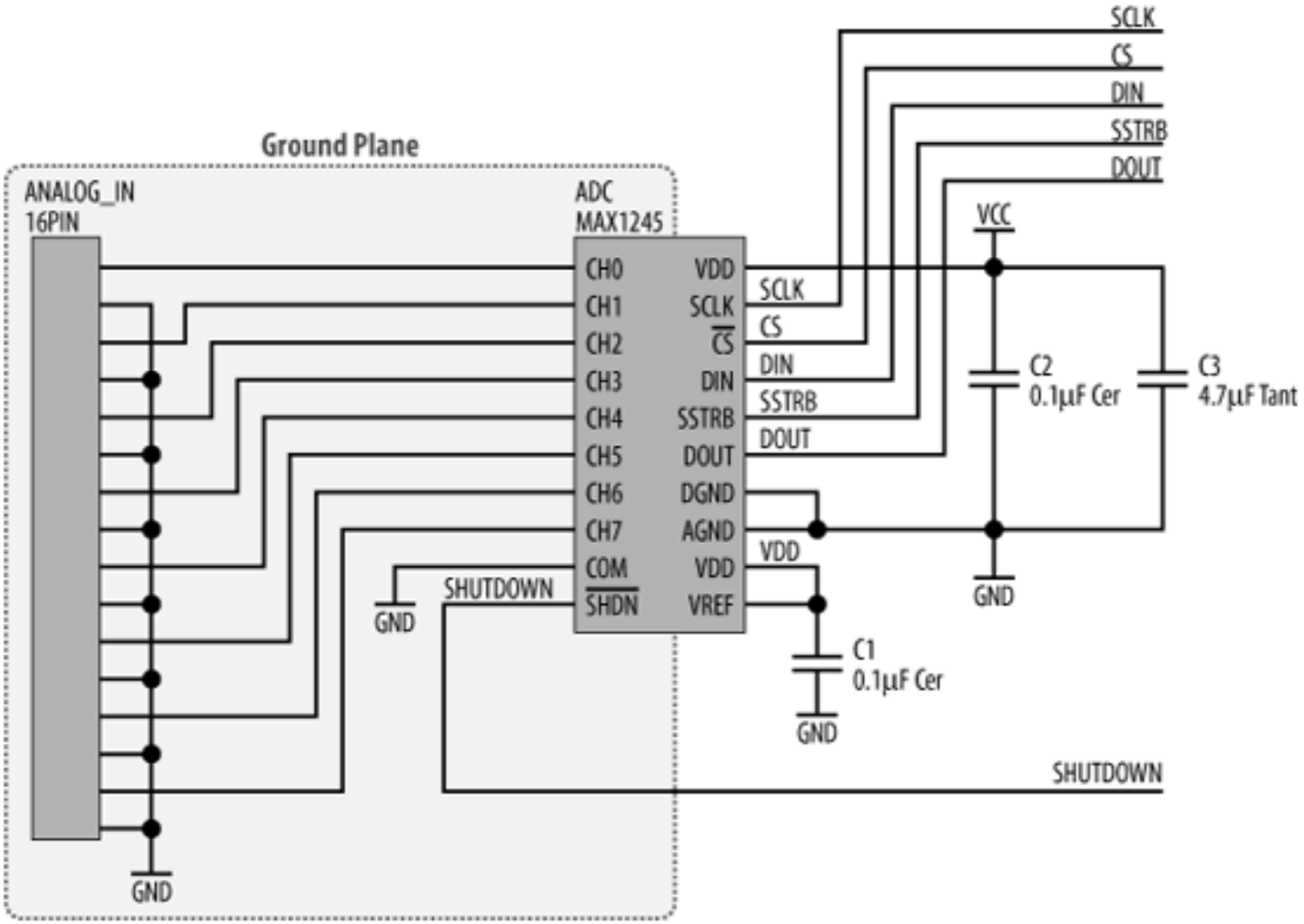


Sampling period and corresponding quantization



Fast sample period results in less quantization

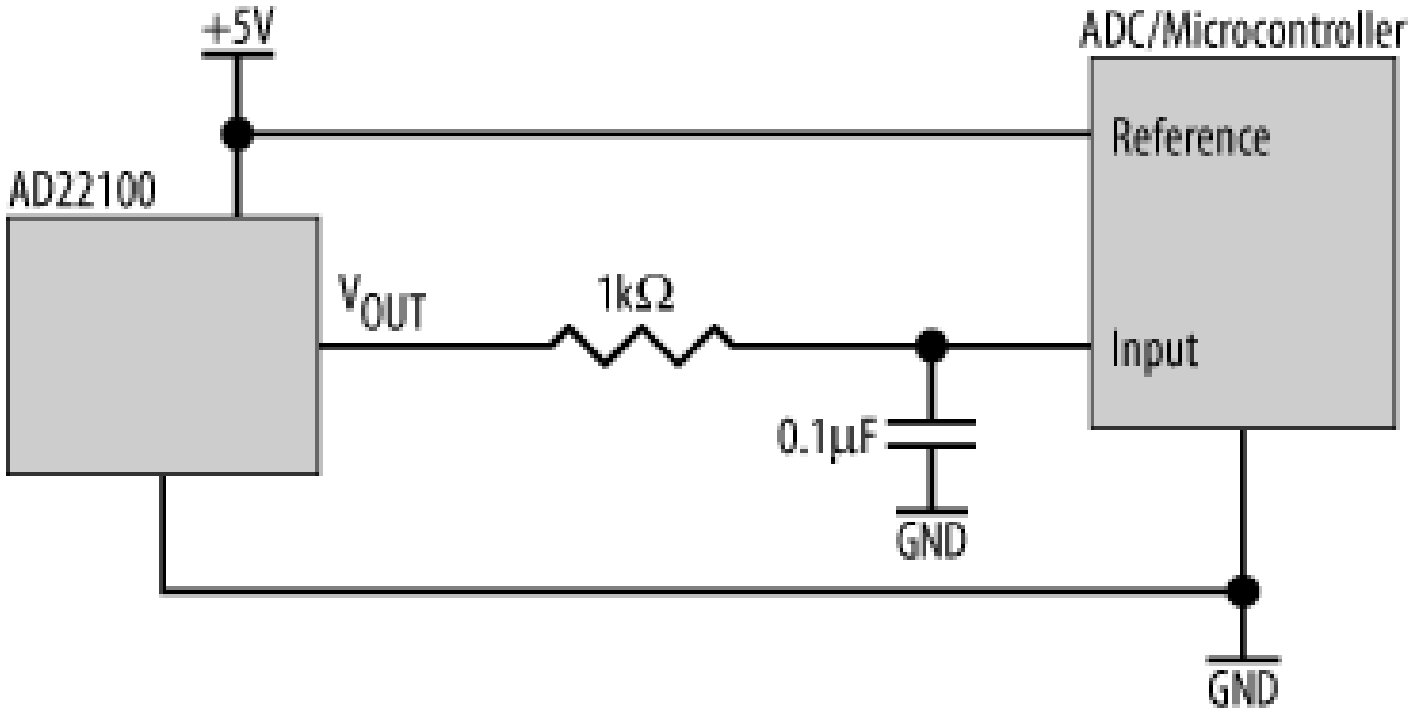
Interfacing an External ADC

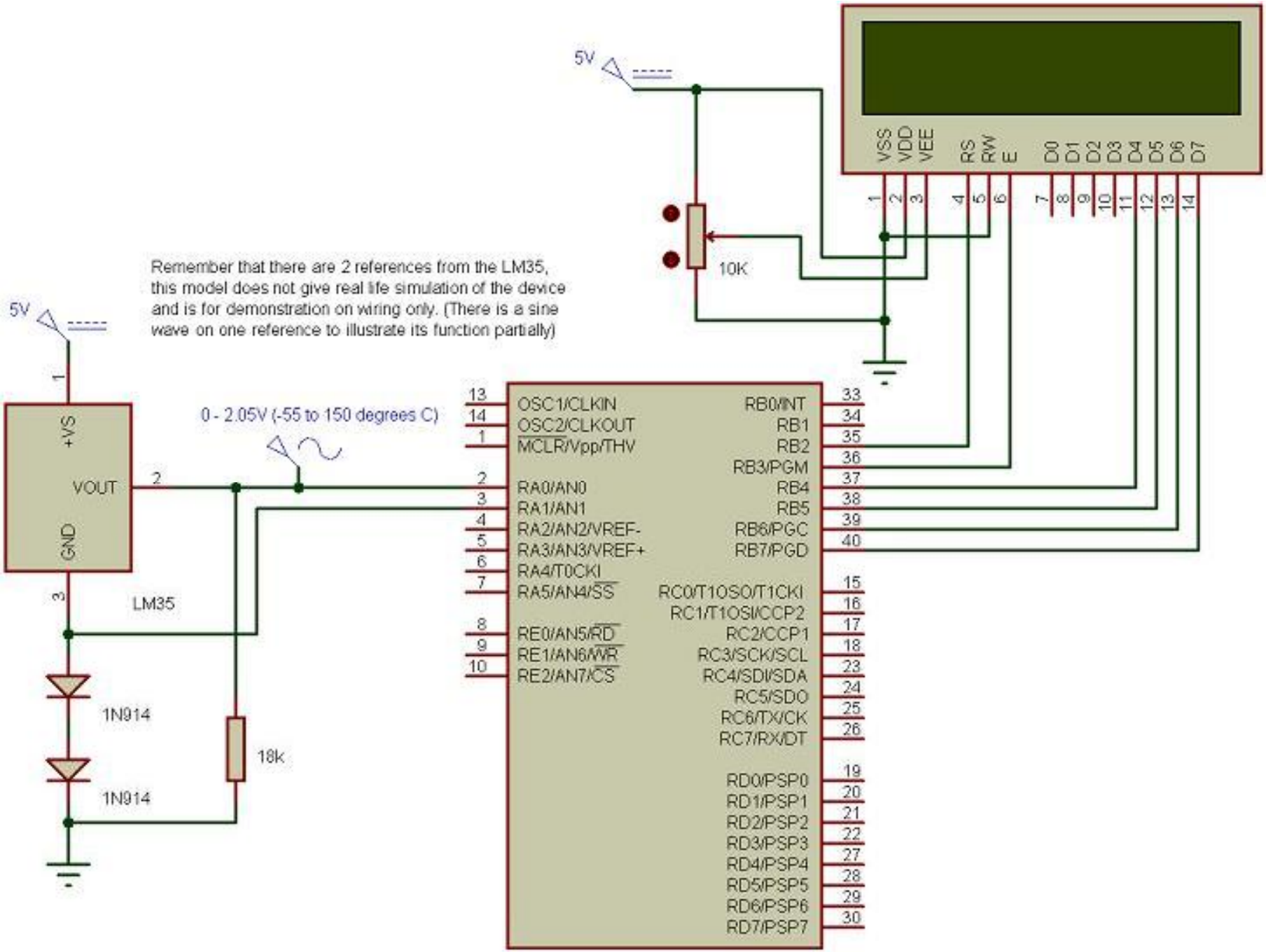


Temperature Sensor

- The LM35DZ is an accurate temperature sensor that will provide an analogue output of 10mV per degree C within 0.01% Its not hard to interface one with a PIC, and the following example allows for a temperature range of -55 to 150 deg C.

ADD22100/AD22103 with an RC filter

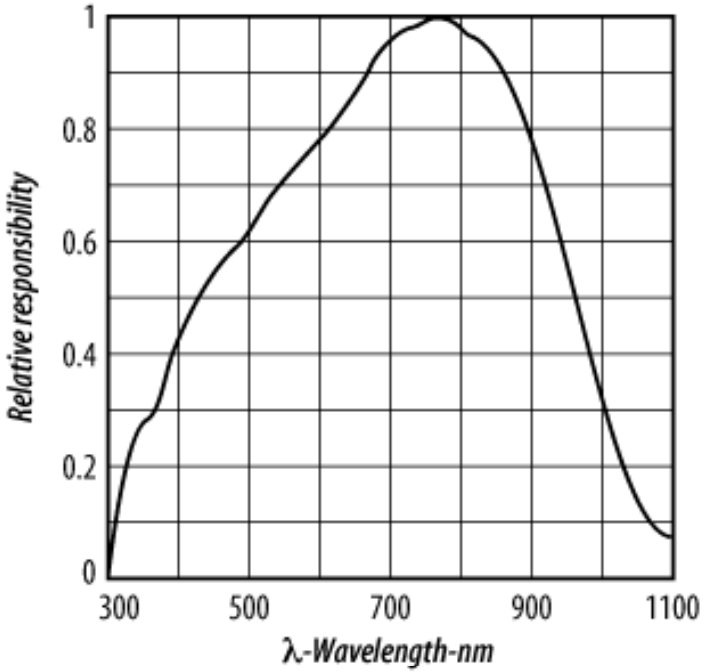



5V
VSS
VDD
VEE
RS
RW
E
D0
D1
D2
D3
D4
D5
D6
D7
10K
Remember that there are 2 references from the LM35, this model does not give real life simulation of the device and is for demonstration on wiring only. (There is a sine wave on one reference to illustrate its function partially)
5V
+VS
VOUT
GND
LM35
0 - 2.05V (-55 to 150 degrees C)
1N914
1N914
18k
OSC1/CLKIN
OSC2/CLKOUT
MCLR/Vpp/THV
RA0/AN0
RA1/AN1
RA2/AN2/VREF-
RA3/AN3/VREF+
RA4/T0CKI
RA5/AN4/SS
RE0/AN5/RD
RE1/AN6/WR
RE2/AN7/CS
RB0/INT
RB1
RB2
RB3/PGM
RB4
RB5
RB6/PGC
RB7/PGD
RC0/T1OSO/T1CKI
RC1/T1OSI/CCP2
RC2/CCP1
RC3/SCK/SCL
RC4/SDI/SDA
RC5/SDO
RC6/TX/CK
RC7/RX/DT
RD0/PSP0
RD1/PSP1
RD2/PSP2
RD3/PSP3
RD4/PSP4
RD5/PSP5
RD6/PSP6
RD7/PSP7

Light Sensor

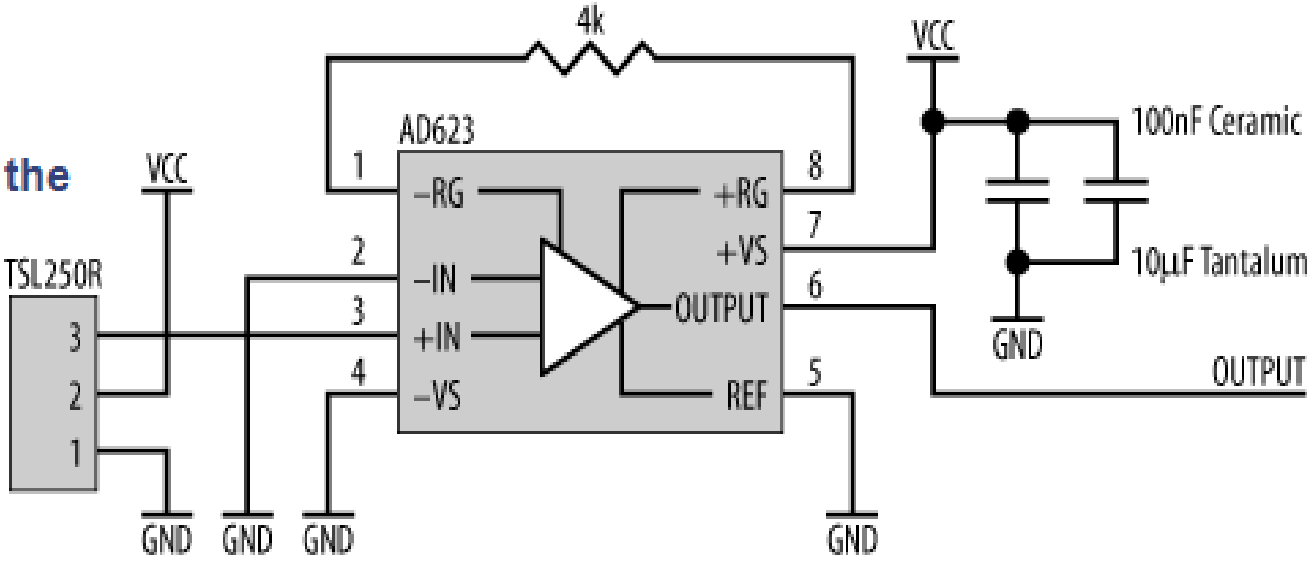
- The obvious use of a light sensor is to monitor natural light levels, and perhaps use the results to control artificial-lighting systems. But combine this sensor with a directional light source (such as a bright LED enclosed in a baffle), and you have a security detector.

light sensor



Spectral response

Amplifying the output of the light sensor



Accelerometer

- Analog Devices makes some really nice accelerometers, and we'll learn how to interface an ADXL150 (http://www.analog.com/library/analogDialogue/archives/30-4/acccel.html) to an embedded system.
- You can use an accelerometer for a number of applications, not just for measuring linear acceleration of vehicles.
- The ADXL150 is a single-axis (one- dimensional) accelerometer with a resolution of 10 m g and a full-scale range of ±50 g.
- For dual-axis (two-dimensional) sensing, choose the ADXL250.

Accelerometer

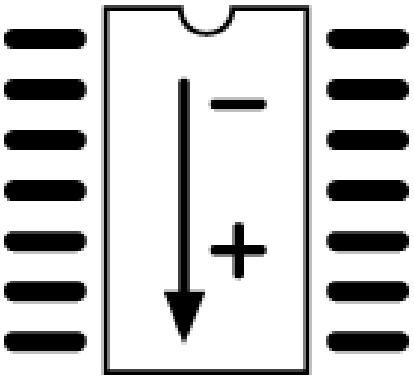
- g is the unit of acceleration. One g is approximately equal to 9.8 m/sec^2 (32.2 $feet/sec^2$). As a passenger in a commercial jet aircraft, you'll experience a force of about 2 g when the aircraft turns. A fighter aircraft will experience a force of around 8 g when turning sharply. Without a special suit, the jet fighter pilot would black out under a force of 8 g. So the ADXL150, with a range of ± 50 g, can measure a significant amount of force!

Accelerometer

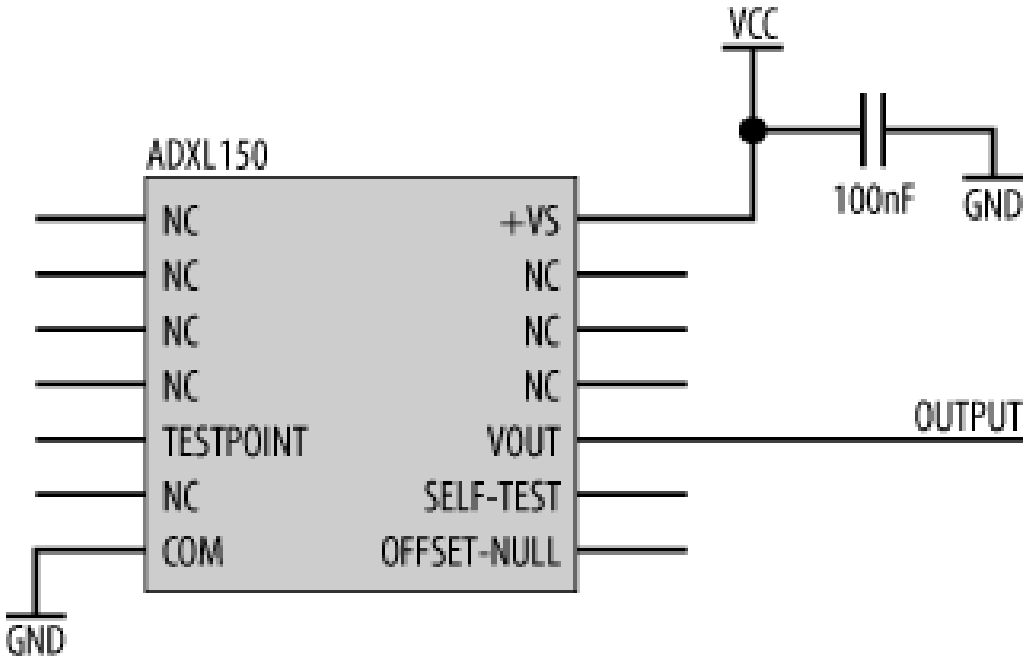
- Applications
  - Seismometer for geophysical applications or to measure vibrations or ground shift in mines, tunnels, or at building sites.
  - You could use it to monitor motion and, by placing three accelerometers orthogonally, get an accurate 3-D motion recorder.
  - The same setup could also be used as a digital carpenter's spirit level by sensing the direction of the Earth's gravitational field.
  - Perhaps you might use it to monitor violent physical shock, such as crash-test measurements.

Accelerometer

Axis of sensitivity



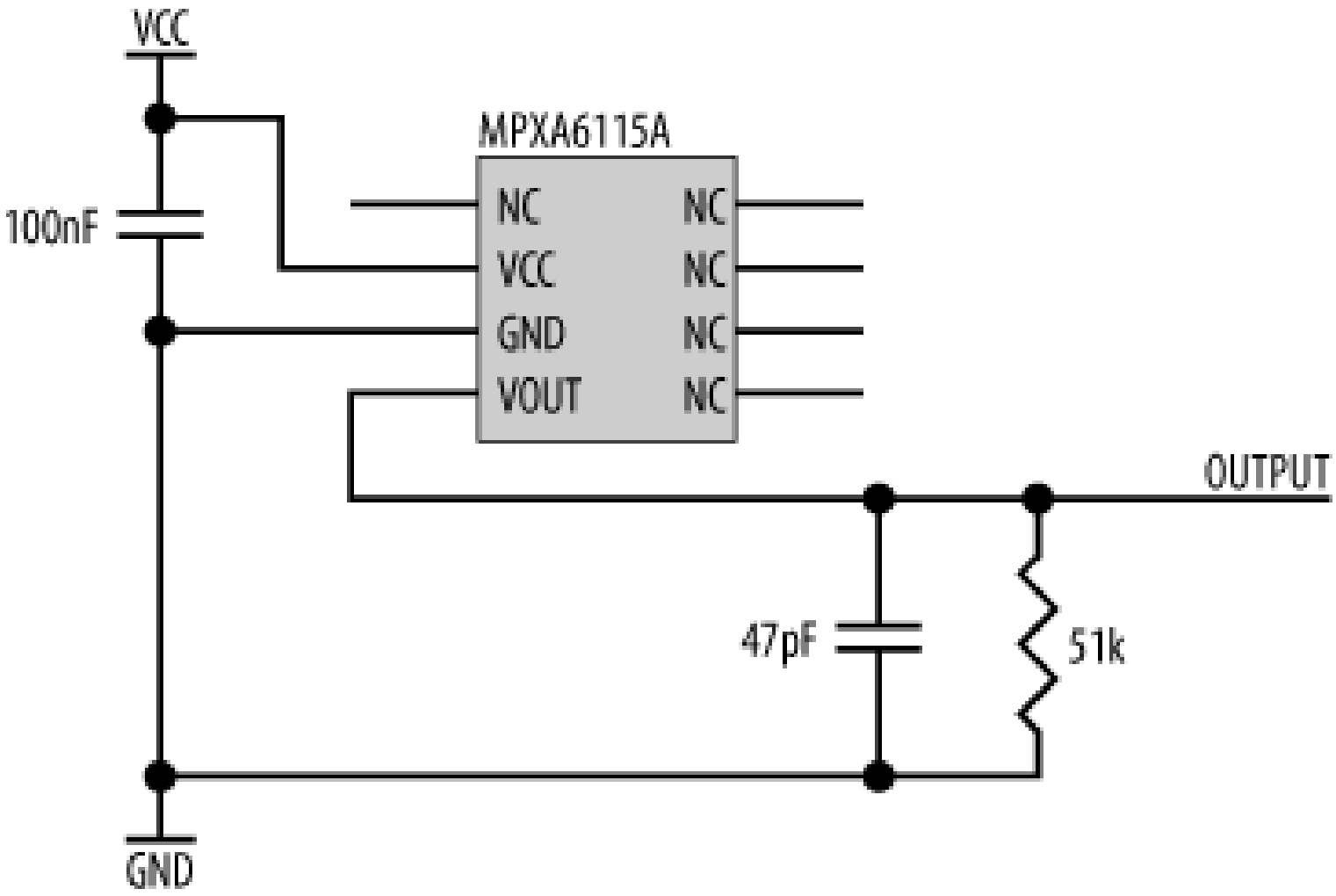
Using the ADXL150



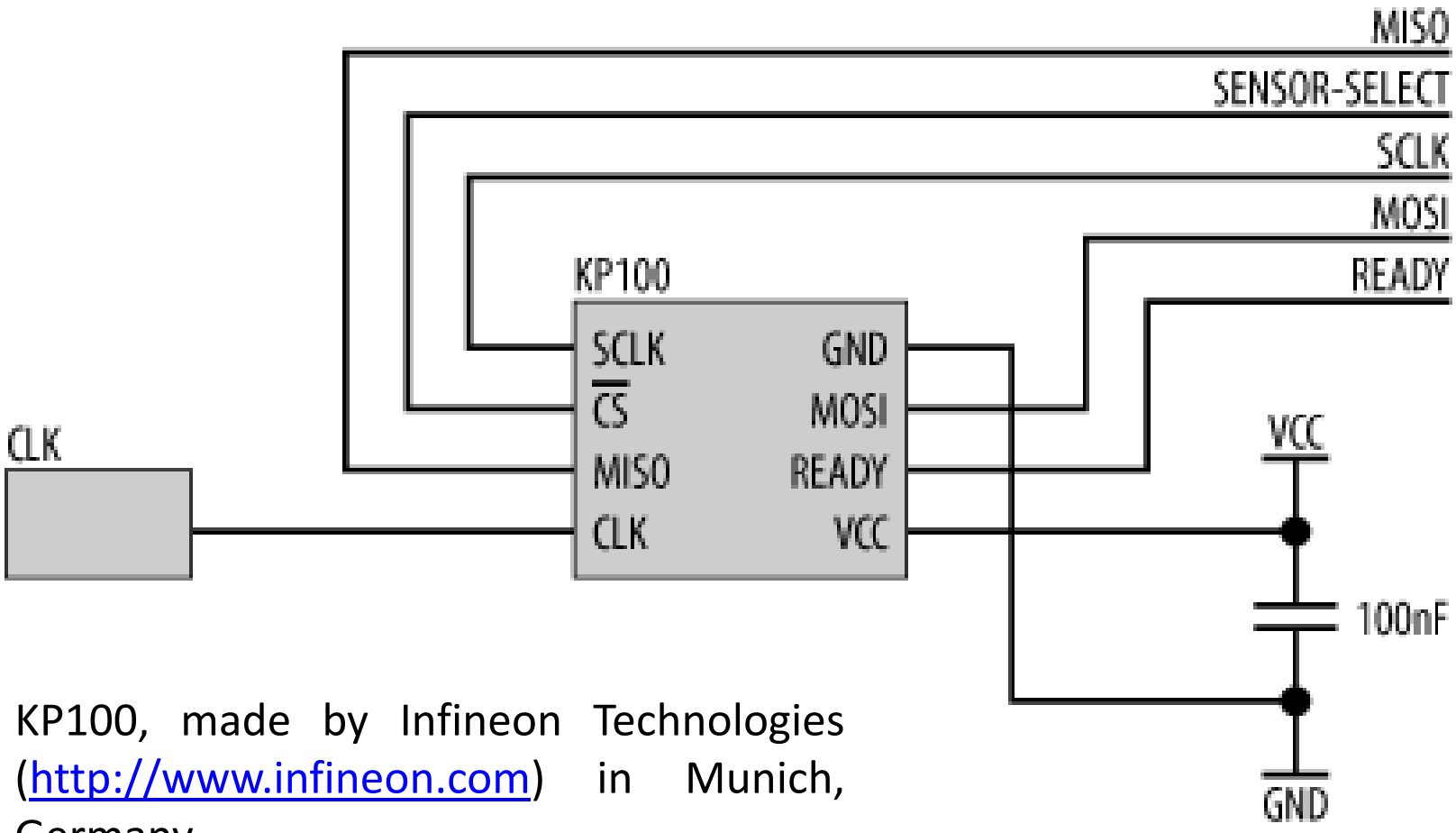
Pressure Sensors

- The most obvious use of these sensors is in measuring air pressure for weather monitoring and prediction.
- But pressure sensors are also used in cars to measure manifold pressure, in washing machines to measure water levels, and in biomedical applications such as measuring blood pressure.
- Another application of pressure sensors is to measure altitude, since air pressure changes with height above sea level.
- Ocean depth can similarly be measured.
- Pressure sensors come in three types: *absolute, differential, and gauge.*

Interfacing the Freescale MPXA6115A pressure sensor



KP100 pressure sensor circuit

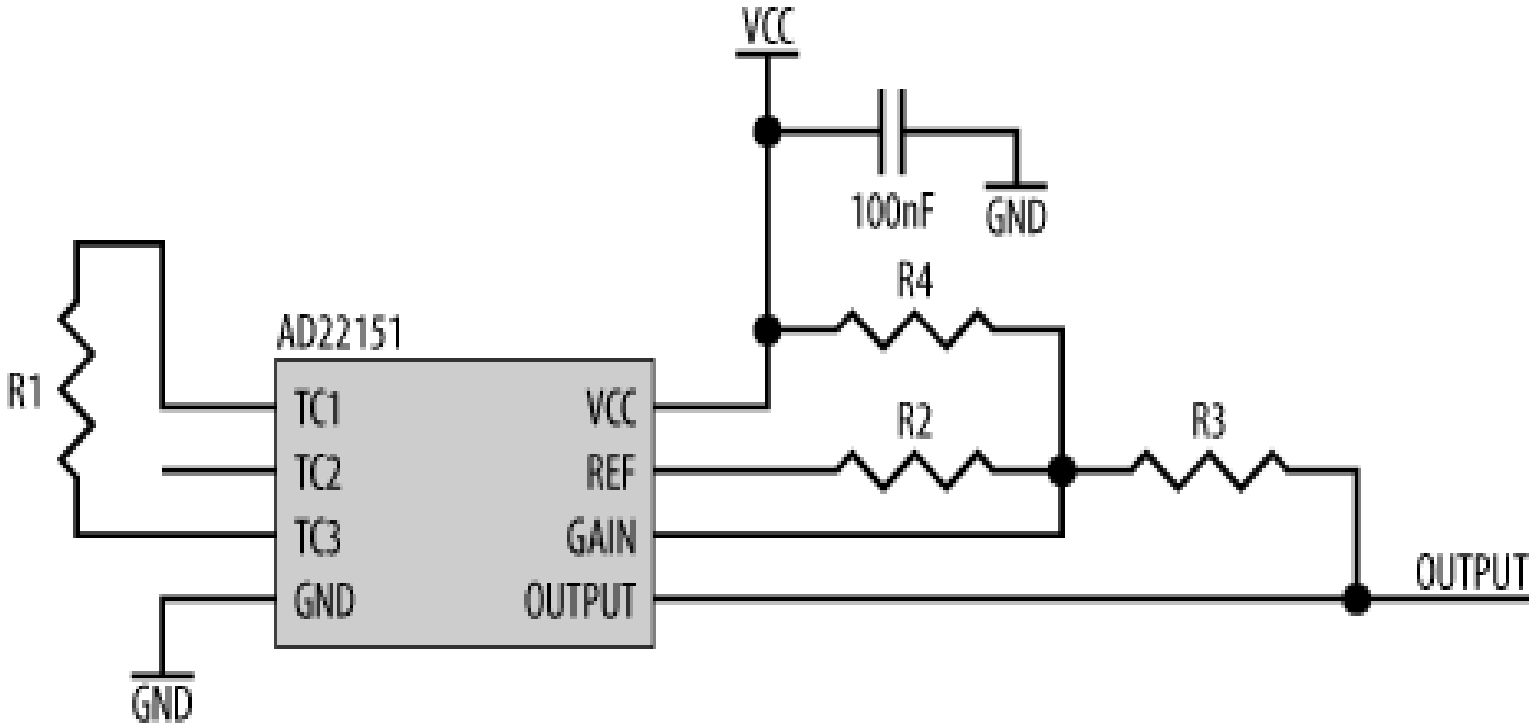


KP100, made by Infineon Technologies (http://www.infineon.com) in Munich, Germany

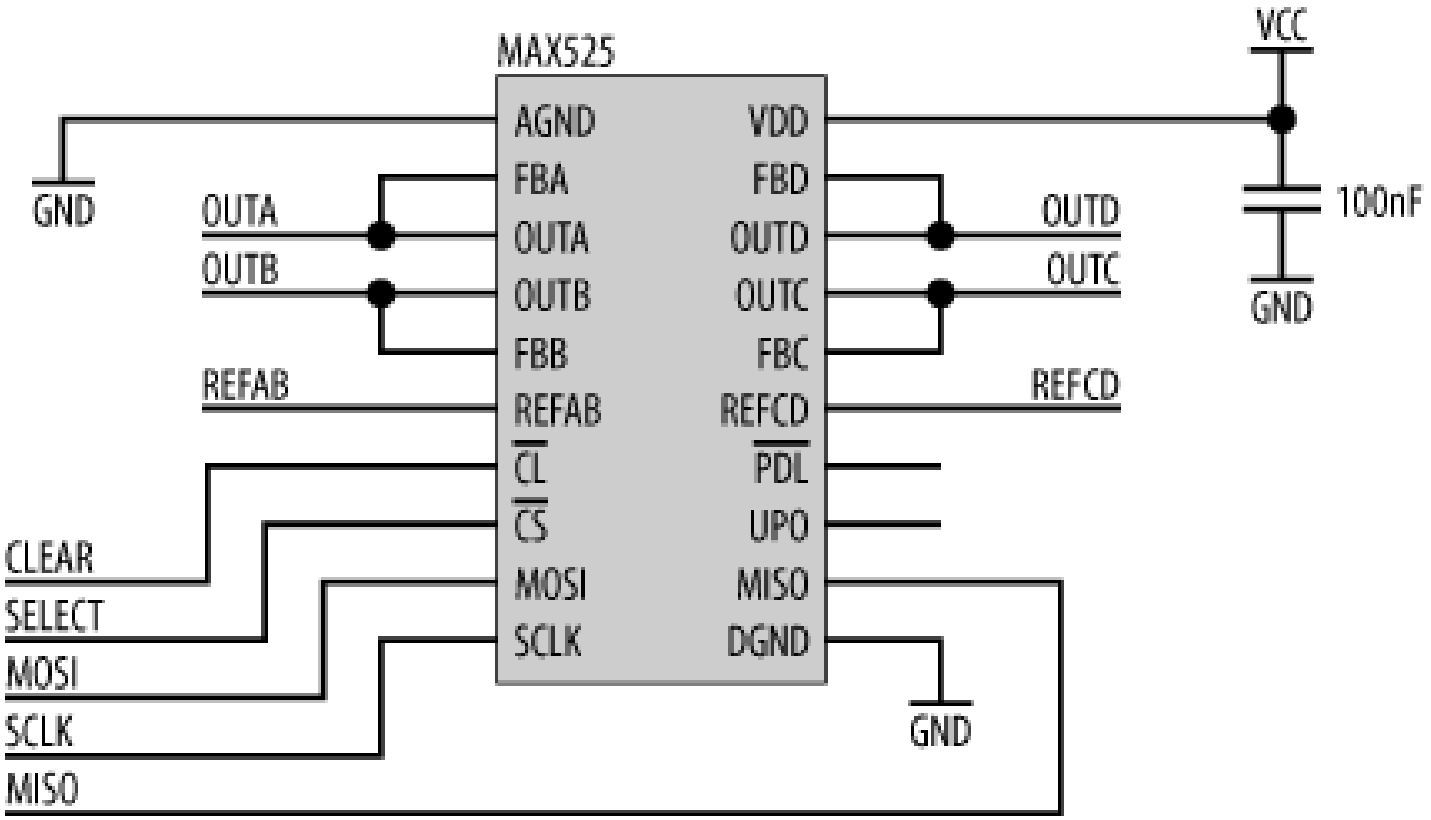
Magnetic-Field Sensor

- The AD22151 magnetic-field sensor by Analog Devices.
- Its primary use is for position and proximity sensing.
- A magnetic source is used as a reference point, and the sensor's distance from that source may be easily determined by the measured field strength.
- The sensor has inbuilt temperature compensation and amplification.

AD22151 magnetic-field sensor circuit

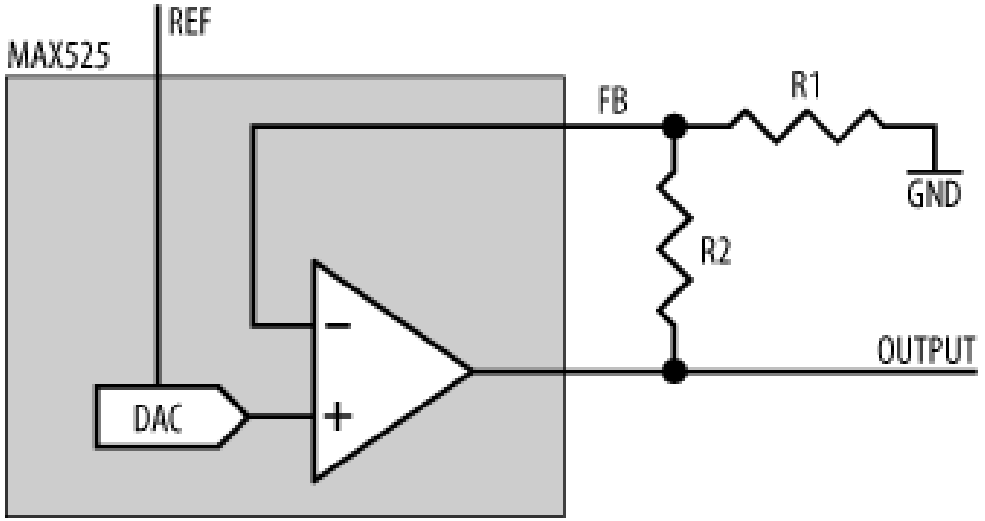


Digital to Analog Conversion

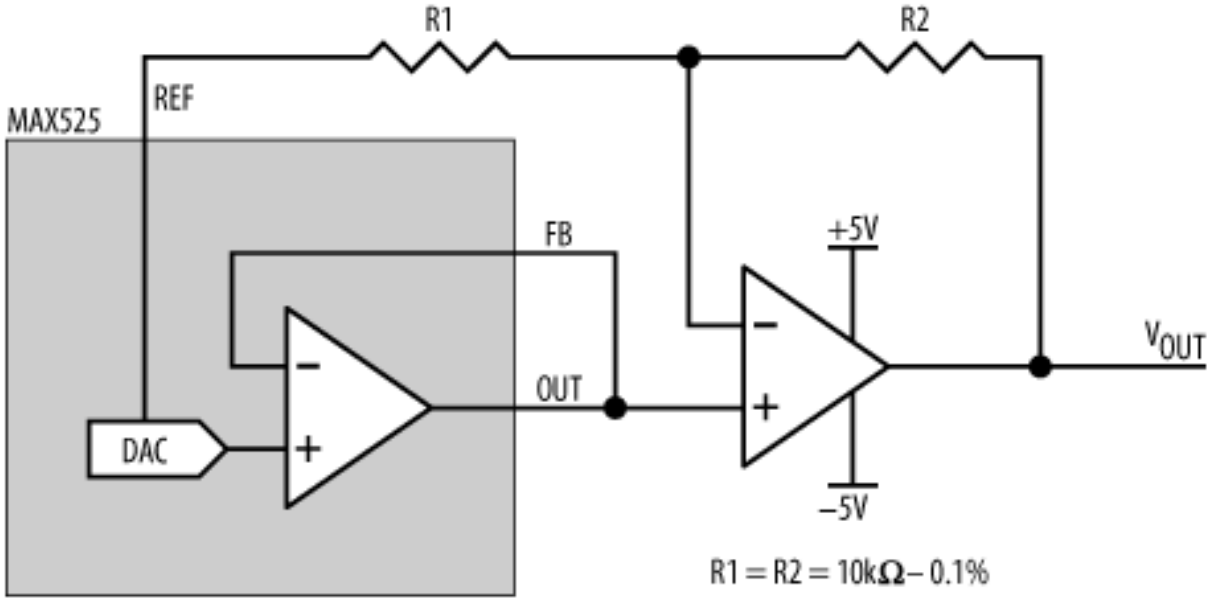


MAX525 circuit

Feedback resistors for non-unity gain



Bipolar output

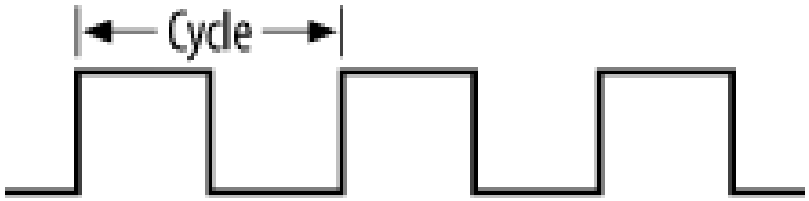


R1 = R2 = 10kΩ – 0.1%

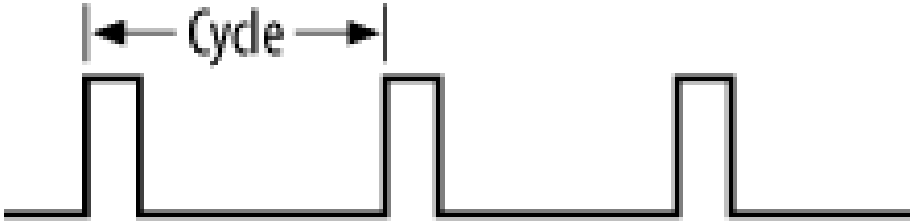
PWM

- Using a DAC may seem the obvious way to generate an analog output voltage, but there is another way that uses nothing more than a digital I/O line configured as an output.
- This technique is known as Pulse Width Modulation (PWM).
- A low-pass (averaging) filter on the PWM output will convert the pulses to an analog voltage, proportional to the duty cycle of the PWM signal.
- By varying the duty cycle, we can vary the analog voltage.

A ubiquitous square wave

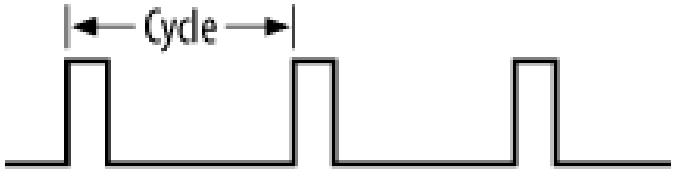


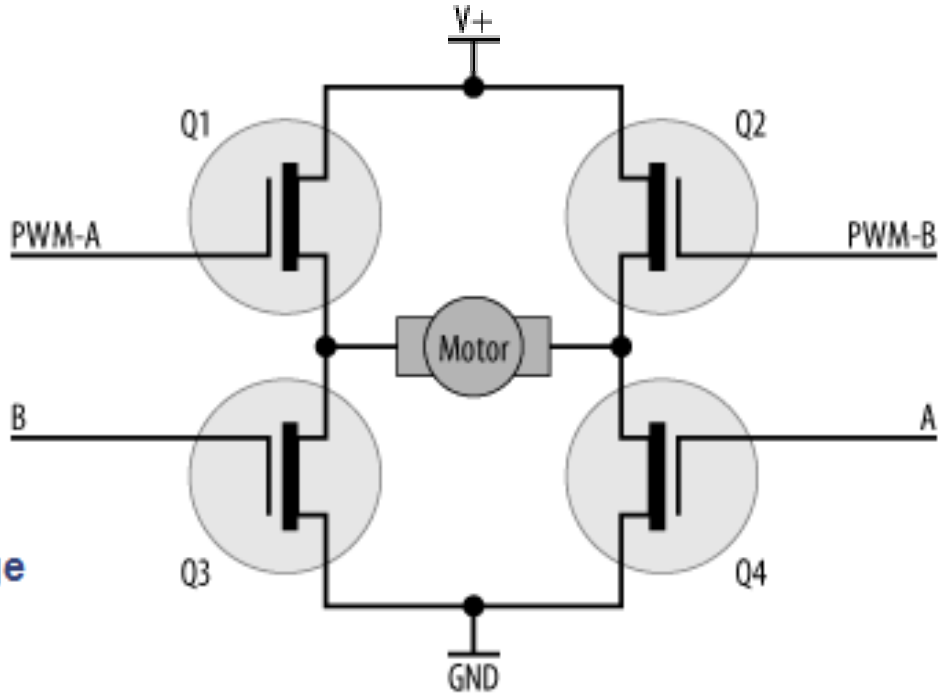
10% duty cycle



Motor Control

- A better way is to use PWM.





Motor drive circuit using an H-bridge

Switching Big Loads

- H-bridge chip to switch relatively large voltages (and the corresponding big currents) needed to drive electric motors.