# System Design Considerations

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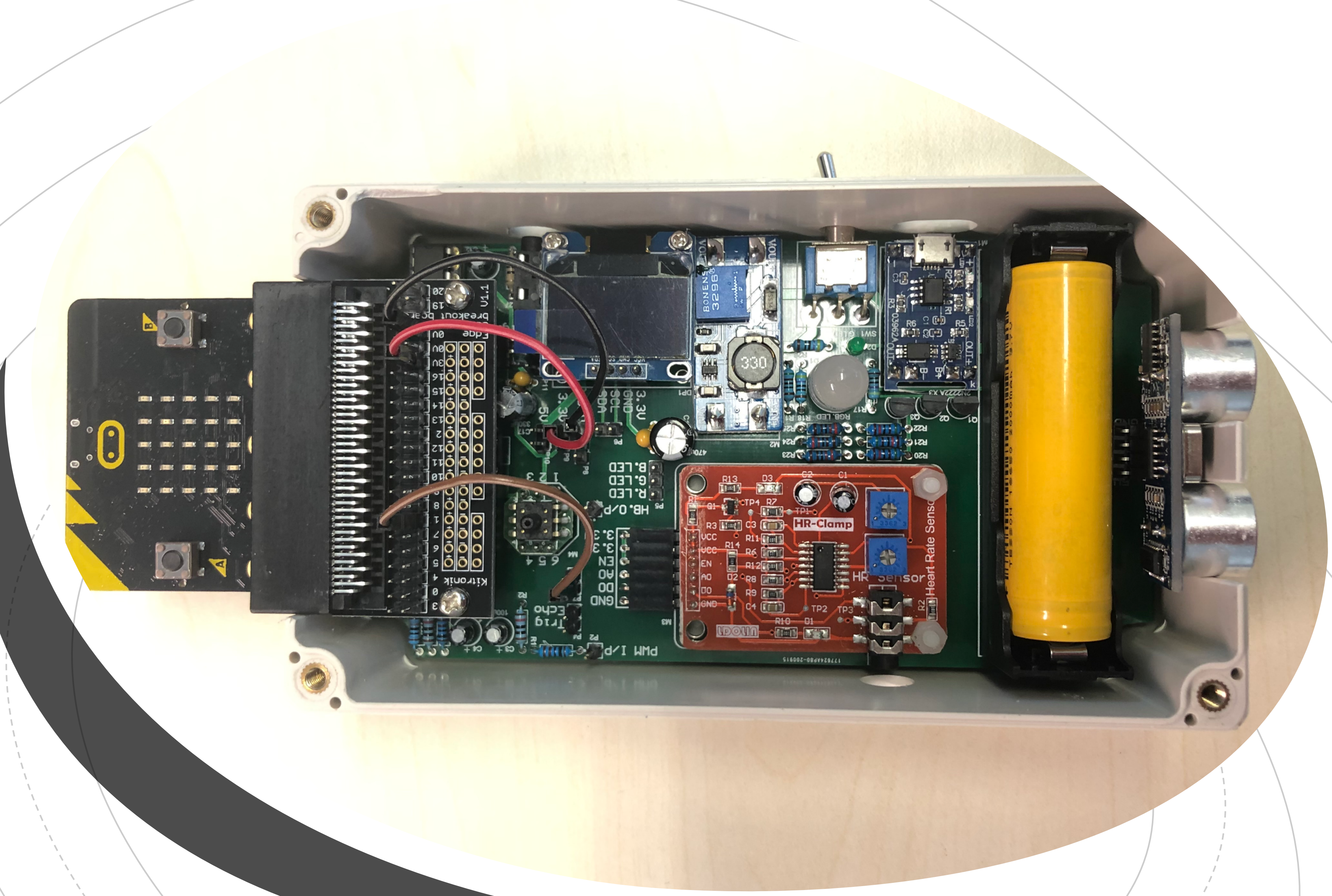
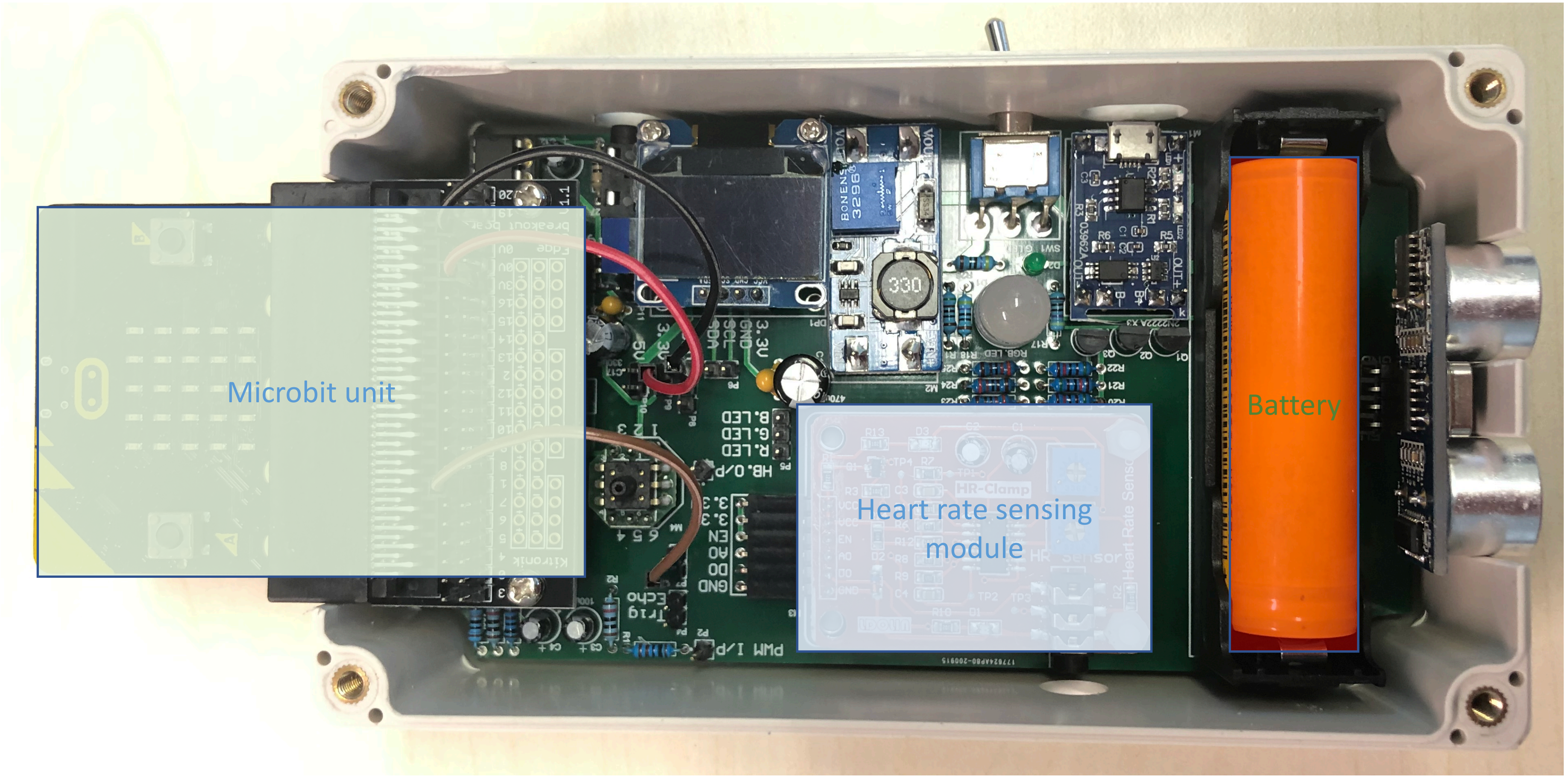
# Contents



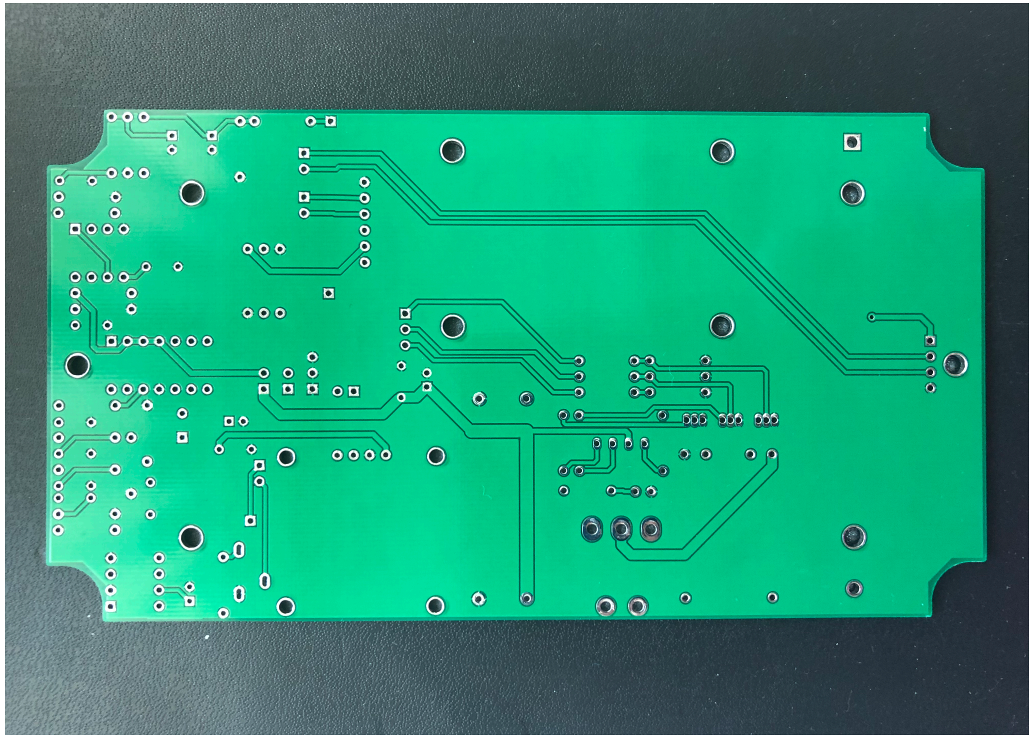

# Simple Electronic systems [Your lab kit]

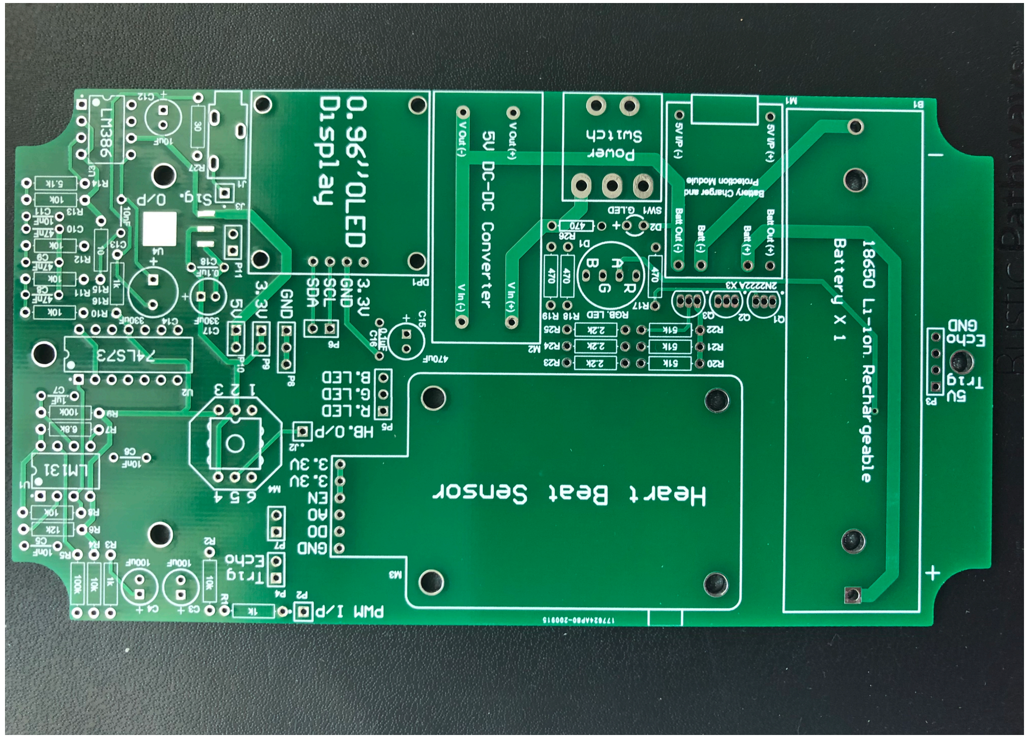
# There are many modules inside.



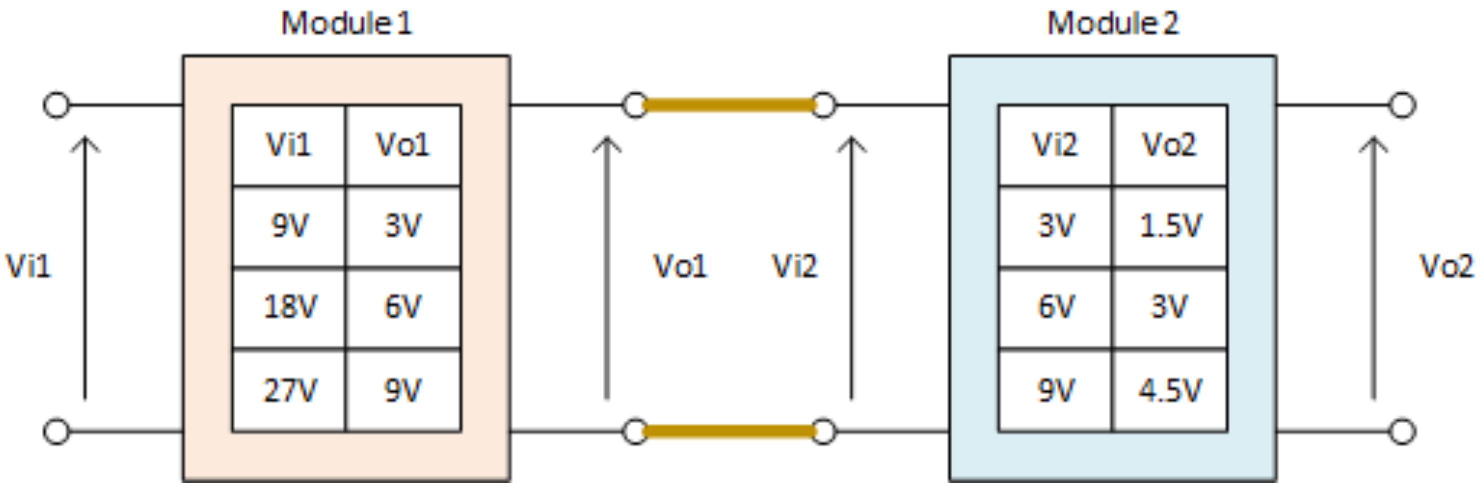
# How are the modules connected?

- External wires, but not for complicated circuits
- A **printed circuit board** (PCB) mechanically supports and electrically connects electrical or electronic components using conductive tracks, pads and other features etched from one or more sheet layers of copper laminated onto and/or between sheet layers of a non-conductive substrate. Components are generally soldered onto the PCB to both electrically connect and mechanically fasten them to it. [Wikipedia]





## What do we need to consider before connecting two modules?




Issues – The automatic watering system consists of many modules. We have to connect those modules together, like playing LEGO blocks, to realize the system. However, apart from functionalities, what do we need to consider before connecting them? Let's see an example. If Modules 1 and 2 have the above input-to-output characteristics, what are Vo1 and Vo2 if Vi1 = 9V?

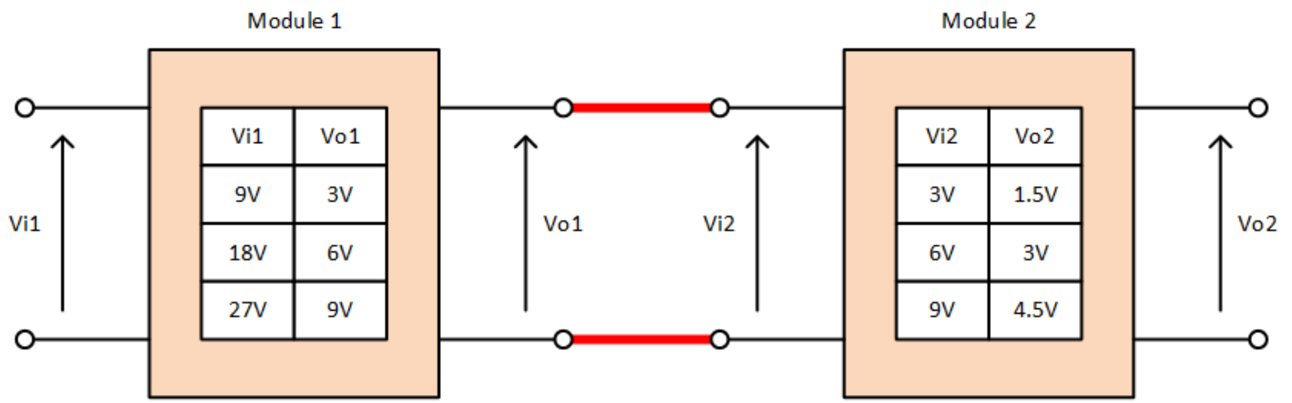
Answer: Vo1 = 3V and Vo2 = 1.5V ? Is it really the case?

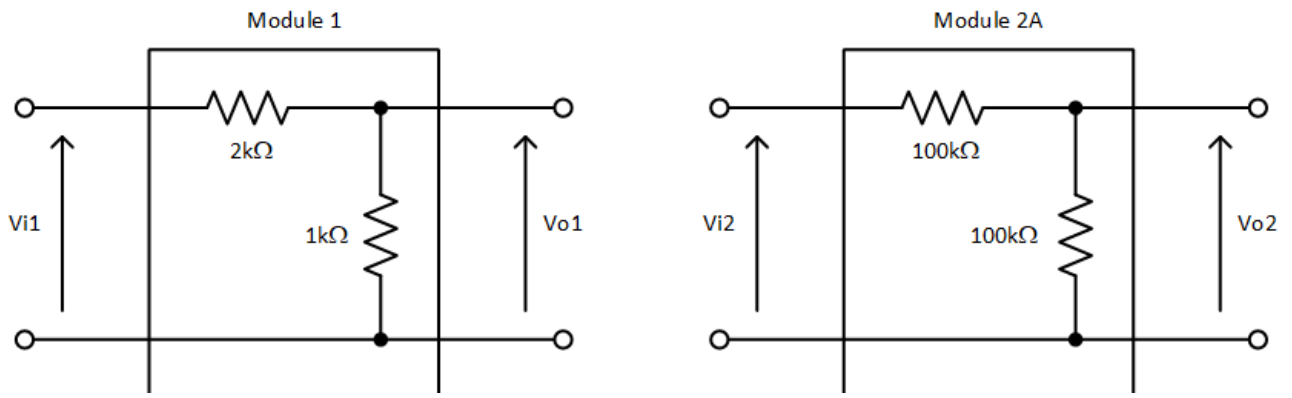
# See two examples

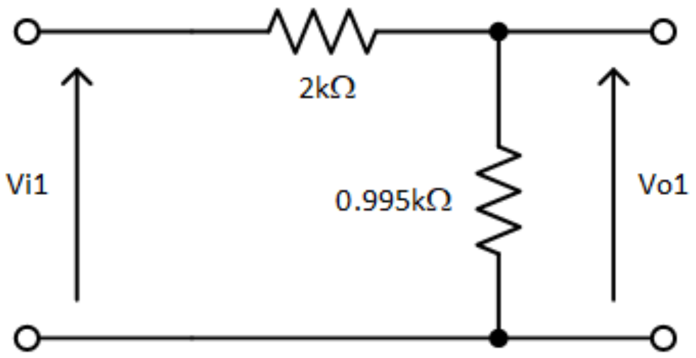
Case 1

If we consider Modules 1 and 2 individually without considering the two modules, the given circuits can fulfil the input-output voltage relationships. That is, Vo1 = Vi1 / 3 and Vo2 = Vi2 / 2.

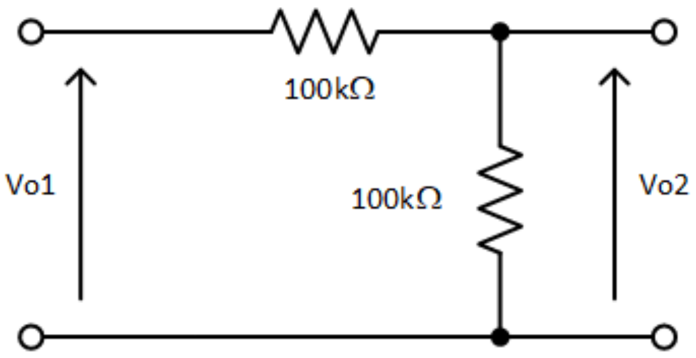
However, what are Vo1 and Vo2 if the two modules are connected? Let's do an analysis.



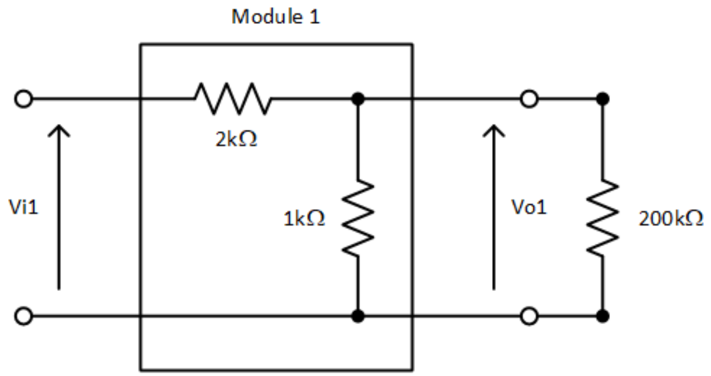






The value of Vo1 is Vo1 = 0.995 / (0.995 + 2) Vi1 = 0.332 Vi1 (close to Vi1 / 3)




The value of Vo2 is Vo2 = 100 / (100 + 100) Vo1 = 0.5 Vo1 (equal to Vo1 / 2)




Use an equivalent resistor to represent the two parallel-connected resistors. The value of the equivalent resistor is (1) (200) / (1 + 200) = 0.995kΩ

If Vi1 = 9V, Vo1 = 2.988V, Vo2 = 1.494V (-0.4% from 1.5V).

# Keep something in mind

- The value of Vo2 is 1.494V, which is not EXACTLY equal to 1.5V, deviation = (1.494 – 1.5) x 100% / 1.5* = -0.4%.
- The overall input-to-output voltage relationship is not equal to the resultant effect of the two individual modules.
- We have to think about the root cause.

*% deviation = difference / reference value

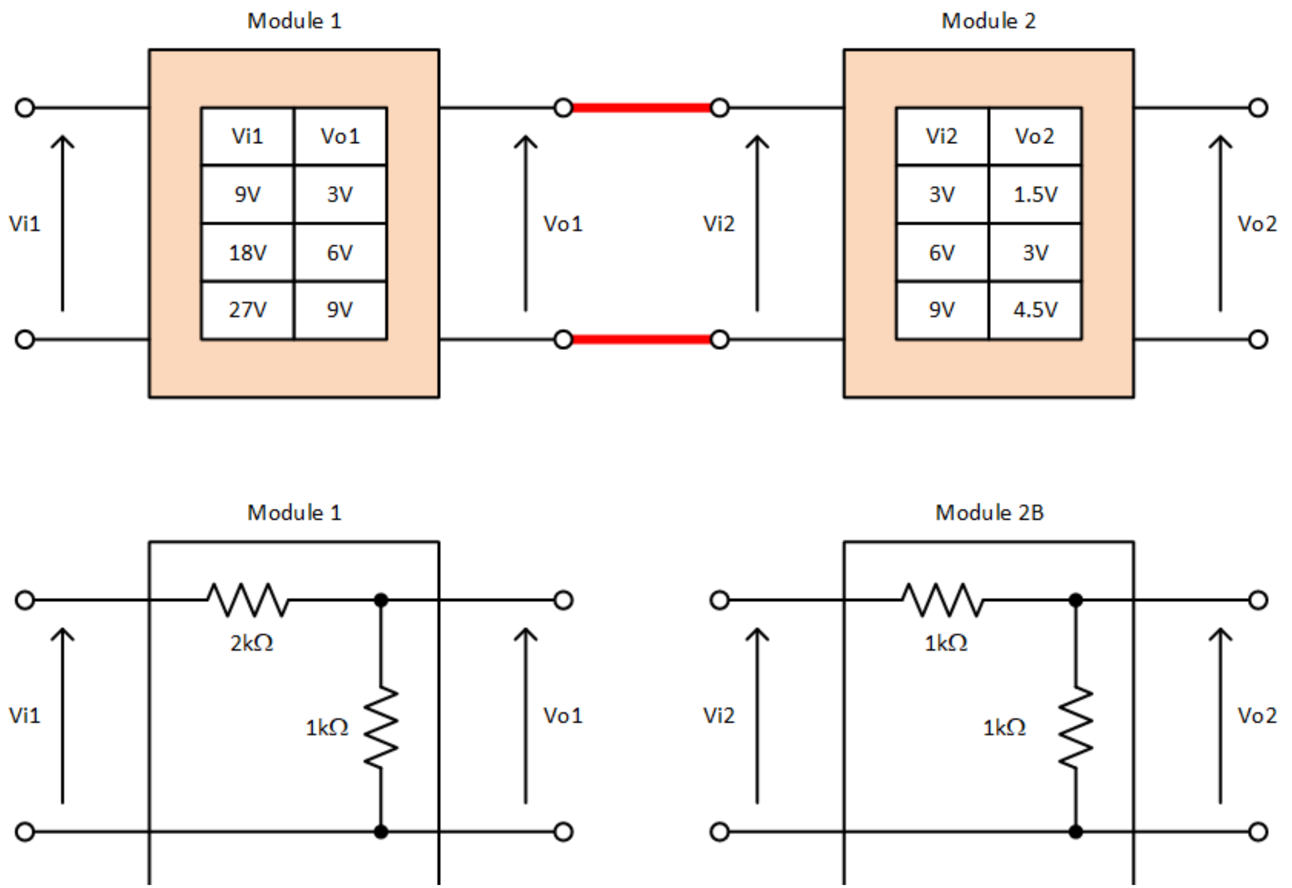
= (actual value – reference value) / reference value

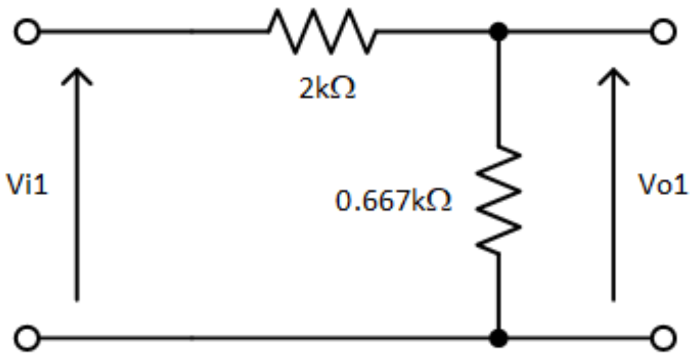
# See two examples

Case 2

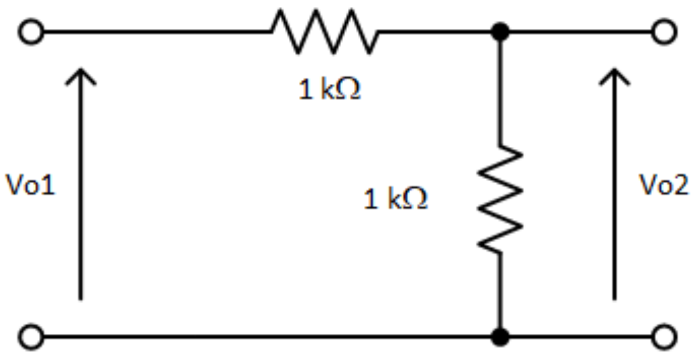
If we consider Modules 1 and 2 individually without considering the two modules, the given circuits can fulfil the input-output voltage relationships. That is, Vo1 = Vi1 / 3 and Vo2 = Vi2 / 2.

However, what are Vo1 and Vo2 if the two modules are connected? Let's do an analysis.

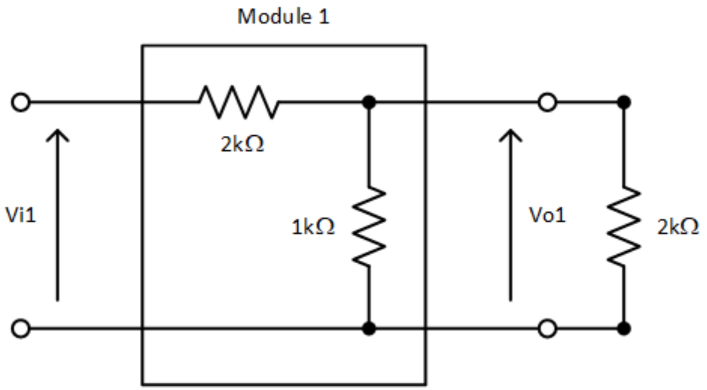





The value of Vo1 is Vo1 = 0.667 / (0.667 + 2) Vi1 = 0.25 Vi1 (much different from Vi1 / 3)




The value of Vo2 is Vo2 = 1 / (1 + 1) Vo1 = 0.5 Vo1 (equal to Vo1 / 2)




Use an equivalent resistor to represent the two parallel-connected resistors. The value of the equivalent resistor is (1) (2) / (1 + 2) = 0.667kΩ.

If Vi1 = 9V, Vo1 = 2.25V, Vo2 = 1.125V (25% deviation from 1.5V).

# Observations

- The value of Vo2 is 1.125V, which is significantly different from the reference value - 1.5V, 25% deviation - calculated by (1.125 – 1.5) x 100% / 1.5 = -25%.
- The overall input-to-output voltage relationship is not equal to the expected one.
- What are the reasons?

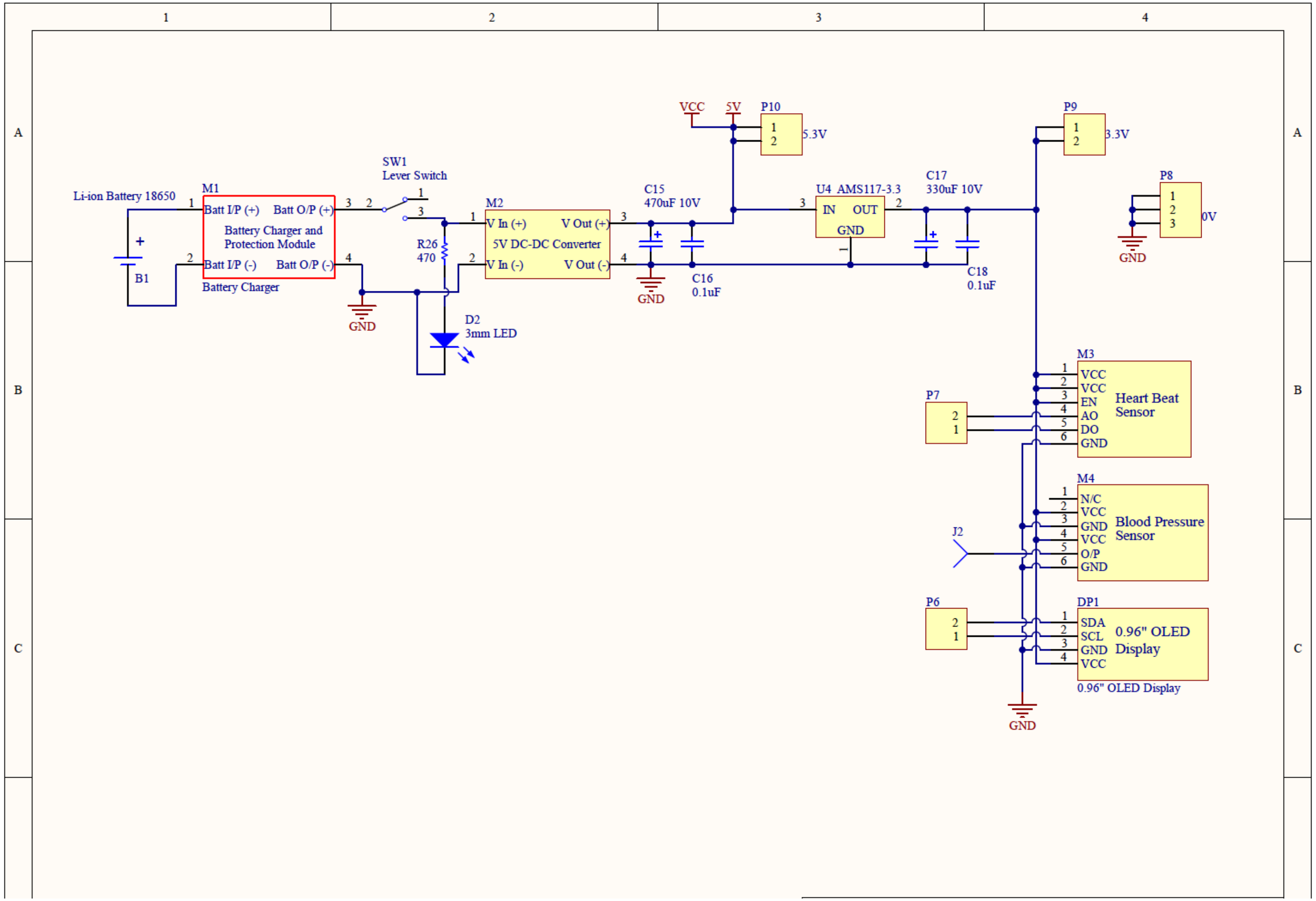
# Loading effect

- Comparing Cases 1 and 2, the difference is the values of the resistors in Modules 2.
- The deviation of Vo2 from the “theoretical” one, i.e., 1.5V, increases as the values of the resistors in Module 2 reduce.
- As the values of the resistors in Module 2 reduce, the input current of Module 2, or equivalently the output current of Module 1, increases.

How to interpret this effect?

In electrical engineering, this effect is called “loading effect”. Module 2 is considered as an external load on Module 1. As the output current of the module, i.e., “Module 1”, increases, its output voltage will be reduced.

What is the implication?

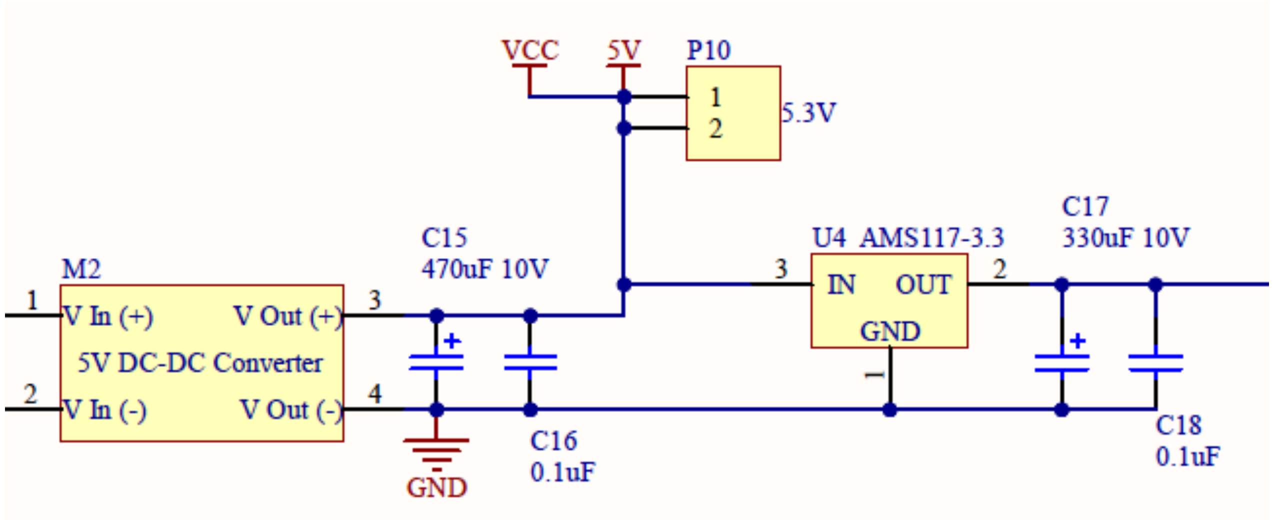



# Circuit diagram of the heartbeat monitoring system

# What shall you achieve ?

# Considerations when using a module

- First, understand the functionality of the module. It is important to understand how the module converts from one physical quantity into an electrical signal [sensor], or from an electrical signal into a physical quantity [actuator], or from an electrical signal into another electrical signal, etc?
- The examples are listed:



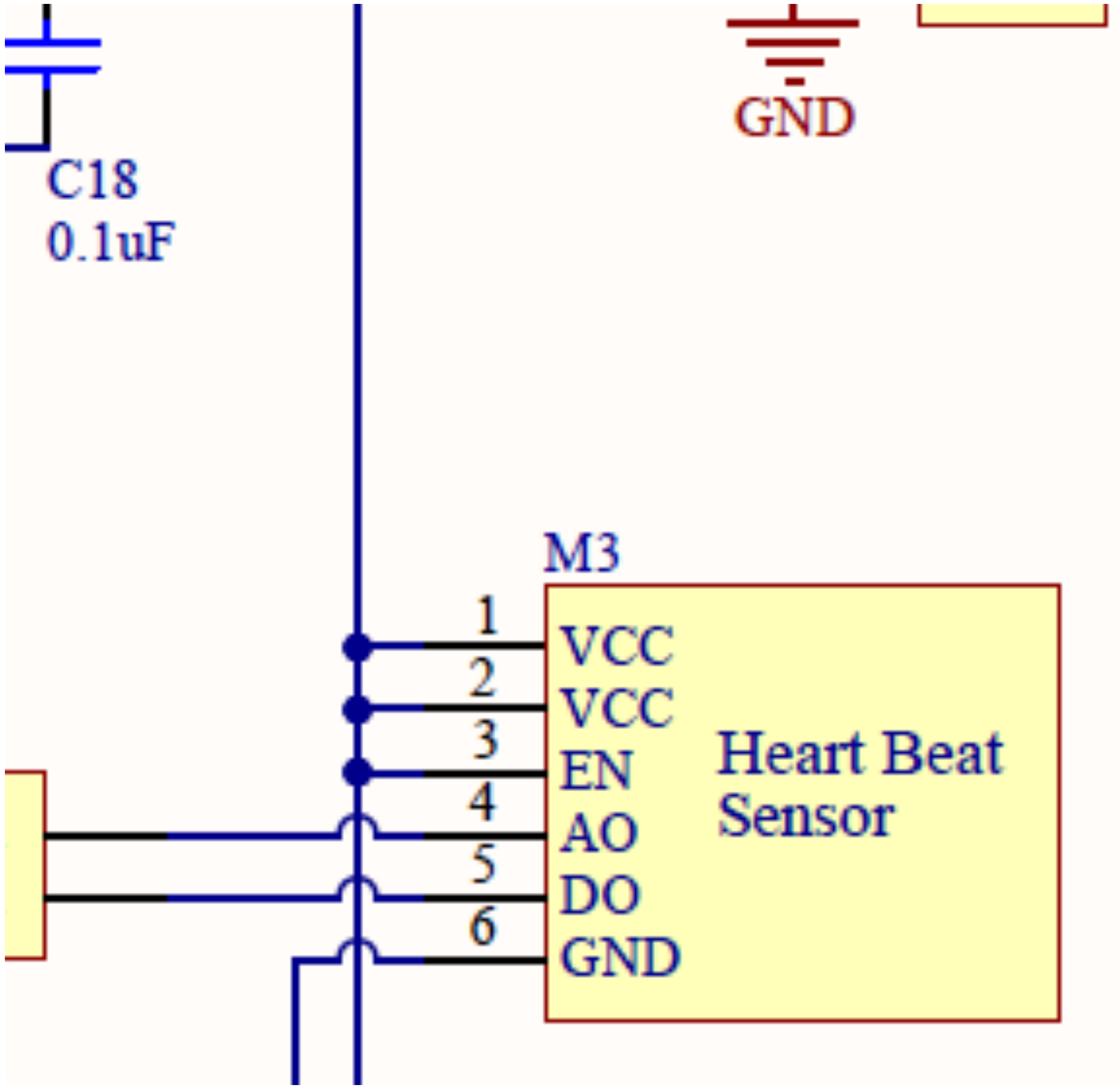

This is a simple power processing arrangement, going through different stages. Why?

# Other Examples

- This module is used to measure heart beats. What questions we need to ask?

- What is its operating principle?
- How is it powered?
- How to ask the module to start operating?
- What information does the module provide?

[We shall get the answers in the lab session.]

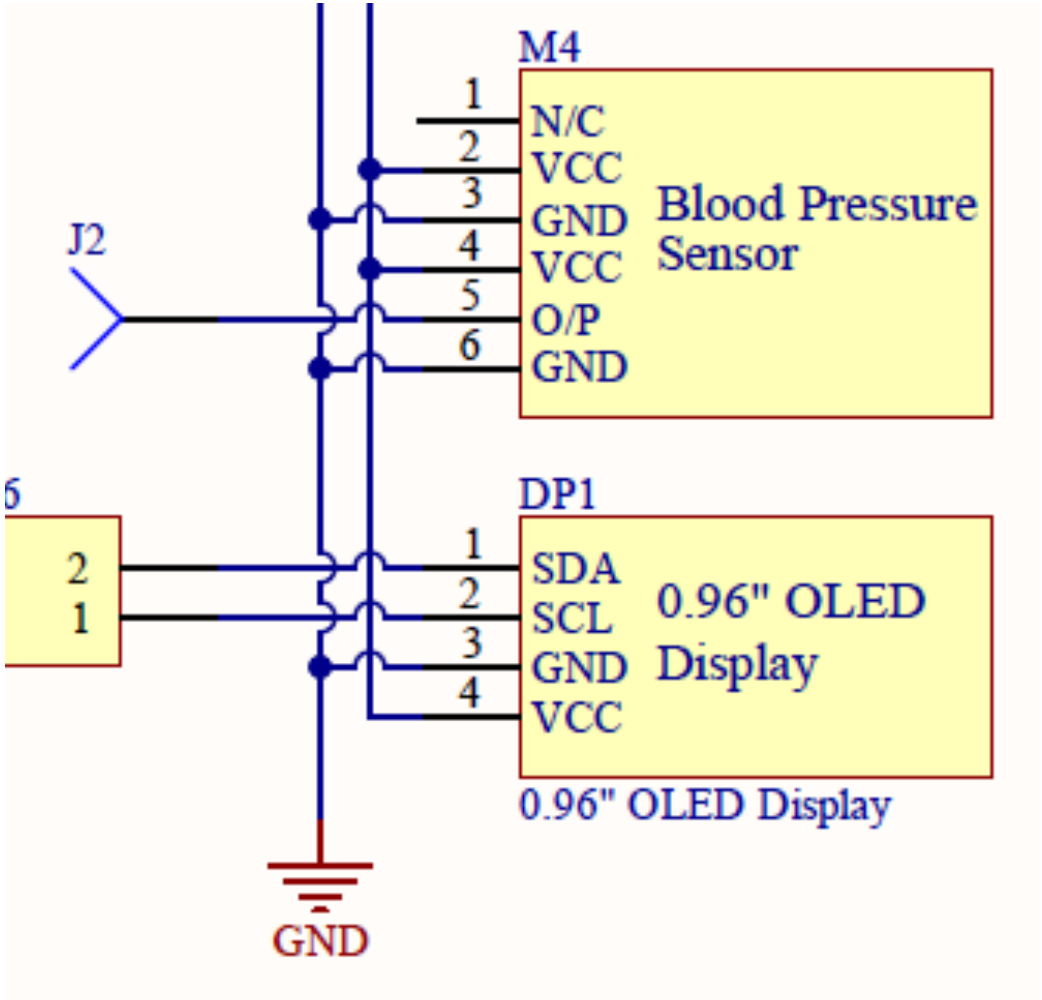


# Other Examples

There are two modules – blood pressure sensor and OLED Display. What questions we need to ask?

- What are their operating principles?
- How are they powered?
- How to ask the modules to start operating?
- What information do the modules provide?

* The blood pressure will not be used in this project



# About OLED

OLED is an abbreviation of Organic Light Emitting Diode

-A flat light emitting technology

-Use organic materials that emit light when electric current is applied

Introduction to OLED

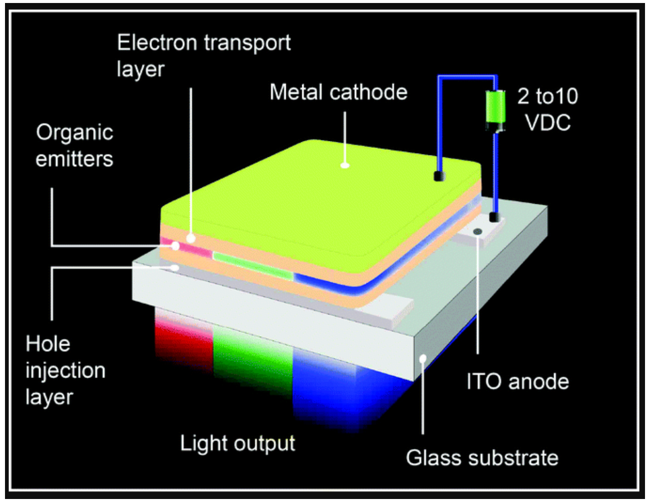
https://www.youtube.com/watch?time_continue=201&v=ZcTxI4QoGAo

and

https://www.oled-info.com/introduction

# Basic Design of OLED

- Like a sandwich
- Place a series of organic thin films between two conductors.
- When electrical current is applied, a bright light is emitted.

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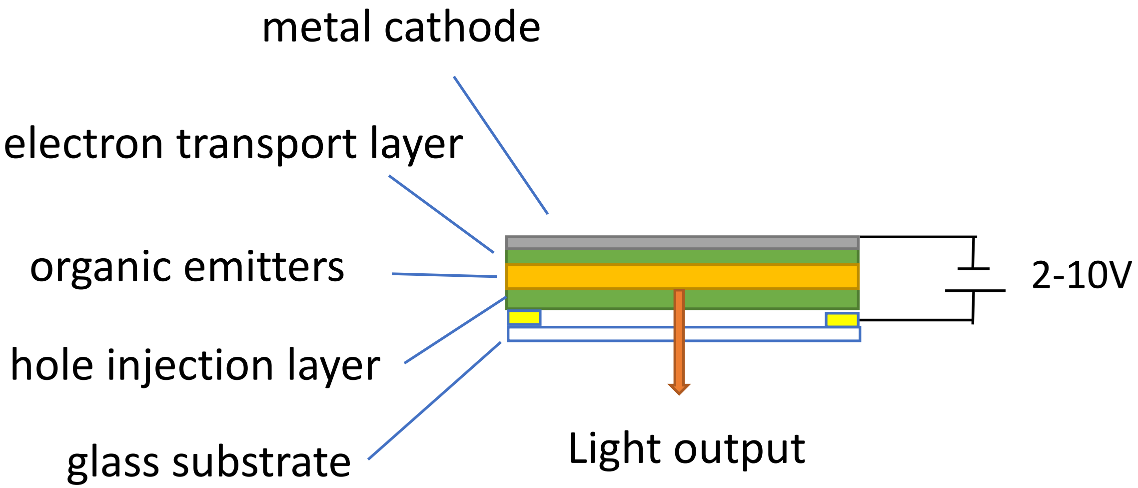



Flexible display


Transparent display

# Advanced Applications

# OLED in the project

Passive OLED

Key features

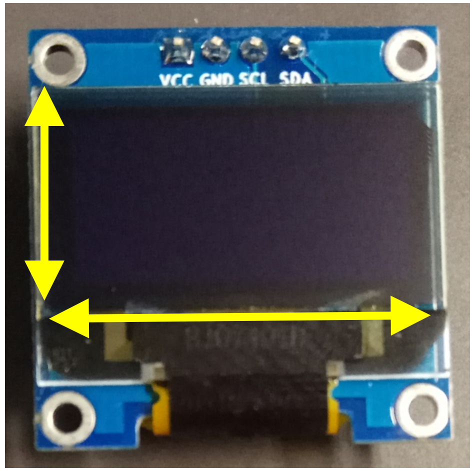
- Dimension: 0.96 inch
- Resolution: 128 x 64 (dots)

Location specified by (x,y) co-ordinates

Text and simple shape can be made by dots

Control via I2C bus

64 dots




128 dots

# What is I2C (I Square C)?

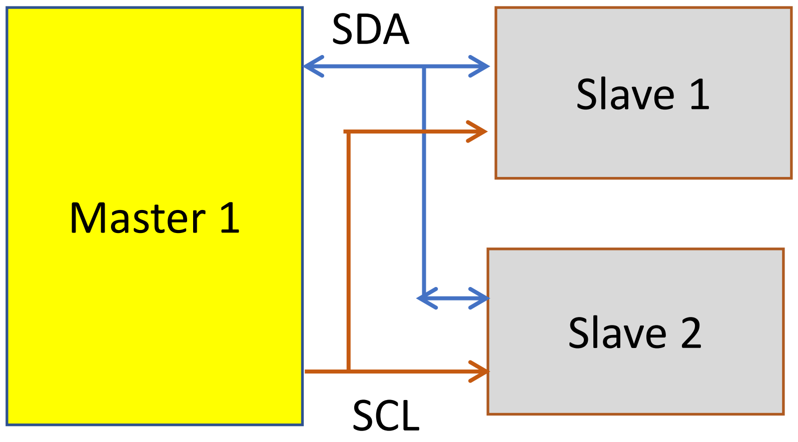
- I2C : Inter-Integrated Circuit
- A synchronous serial communication, multi-master, multi-slave, wired communications
- Only required two signal wires: SCL (Serial Clock) and SDA (Serial Data)
  - SCL is the clock signal, and SDA is the data signal.

Introduction of I2C :
https://learn.sparkfun.com/tutorials/i2c

# Master and Slave in I2C

- The device that initiates a transaction on the $I^2C$ bus is called the master. The master controls the clock signal. A device being addressed by the master is called a slave.
- Using just 2 lines (SDA and SCL), a master can connect to multiple slaves (up to 1008)
- We can also have multiple masters / multiple slaves.

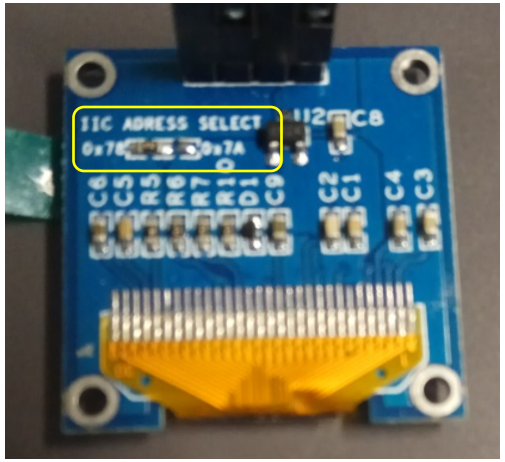
Example of 1 master and 2 slaves



# Address of Slave Devices

- How to differentiate different devices if they are connected to the same master?
  - Each I$^2$C-compatible hardware slave device comes with a predefined device address. Eg. our OLED is 60d
  - To allow multiple identical devices connecting to one I2C bus, user can alter some lower bits of the address.
  - For example, our OLED's address can be modified by re-soldering a resistor at the back.

    (Address will then be changed to 61d)

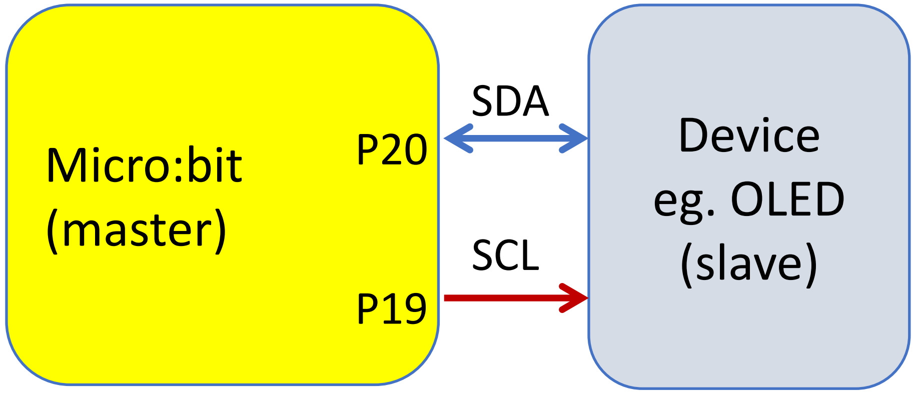


# How I2C Works?

- The master transmits the device address of the intended slave at the beginning of every transaction.
- Each slave is responsible for monitoring the bus, but only the slave with that address will respond.

# Connecting OLED to Micro:bit

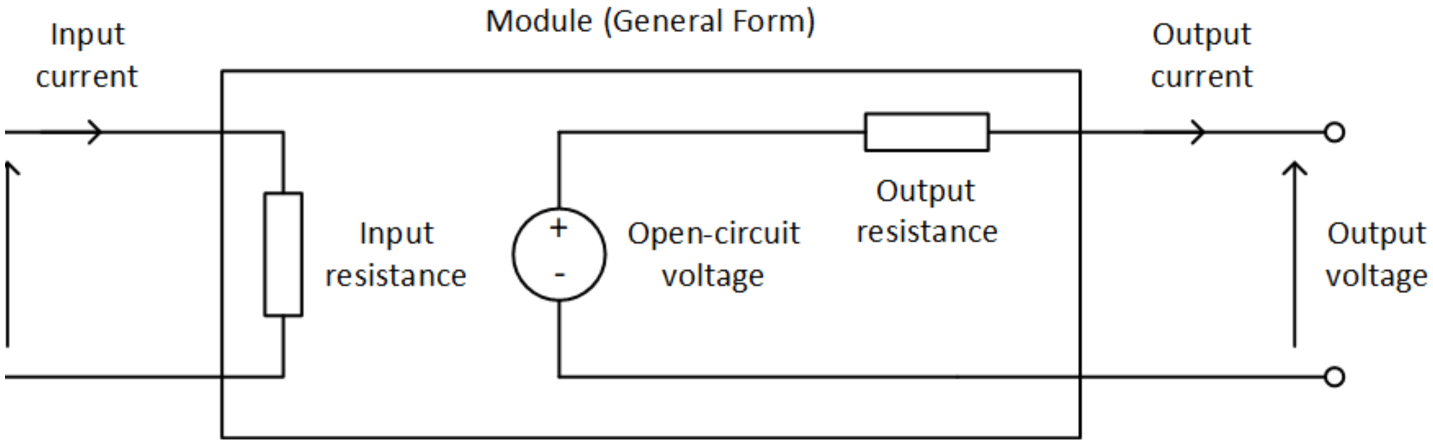
- $I^2C$ requires two wires
  - SCL: clock signal
  - SDA: data signal




- Micro:bit uses P19 and P20 for I2C
- Connections
  - 3V for supply
  - Pin 19 of micro:bit → Slave device’s SCL
  - Pin 20 of micro:bit → Slave device’s SDA
  - Common ground

# Considerations when using modules

Second, study the electrical specification.  Typically, the electrical port on the module has several parameters need to be considered.  They are input/output voltage, input/output current, and input/output resistance.



# Considerations in different kinds of modules

- Different types of modules require different input and/or output requirements.  The following is the considerations that need to be considered.

| Type | Input voltage | Input current | Input resistance | Output voltage | Output current | Output resistance |
|---|---|---|---|---|---|---|
| Sensor | N/A | N/A | N/A | Yes | Yes | Yes |
| Actuator | Yes | Yes | Yes | N/A | N/A | N/A |
| Others | Yes | Yes | Yes | Yes | Yes | Yes |

# About Microbit Power Pins

**Power (3V)**

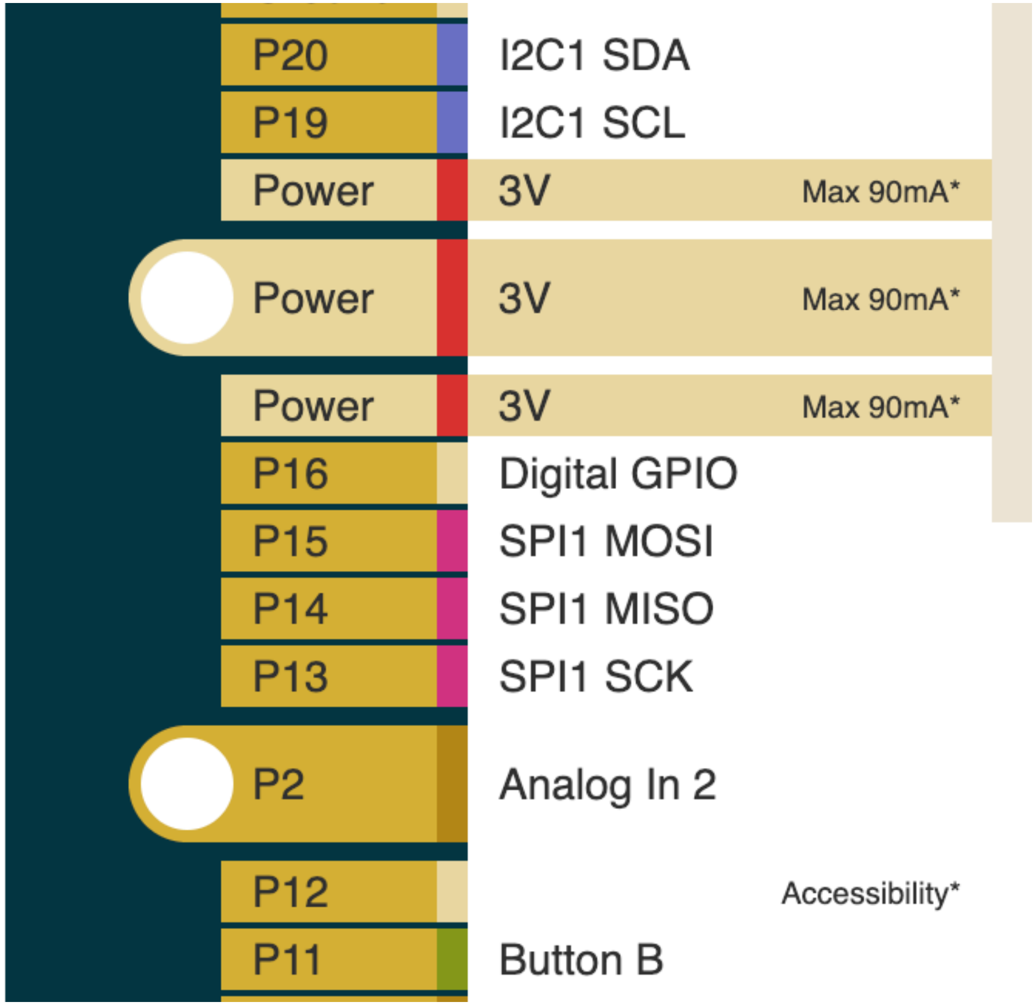
The micro:bit is capable of supplying 3V power but only up to a maximum current of 90mA. Exceeding this threshold will cause excessive heating of and potentially damage to the onboard voltage regulator.

The onboard KL26 regulator is rated at a maximum of 120mA when powered from USB and a budget of 30mA is allowed for the nRF51822 and peripherals that make up the micro:bit itself.

The onboard KL26 regulator is not used when powered from battery.

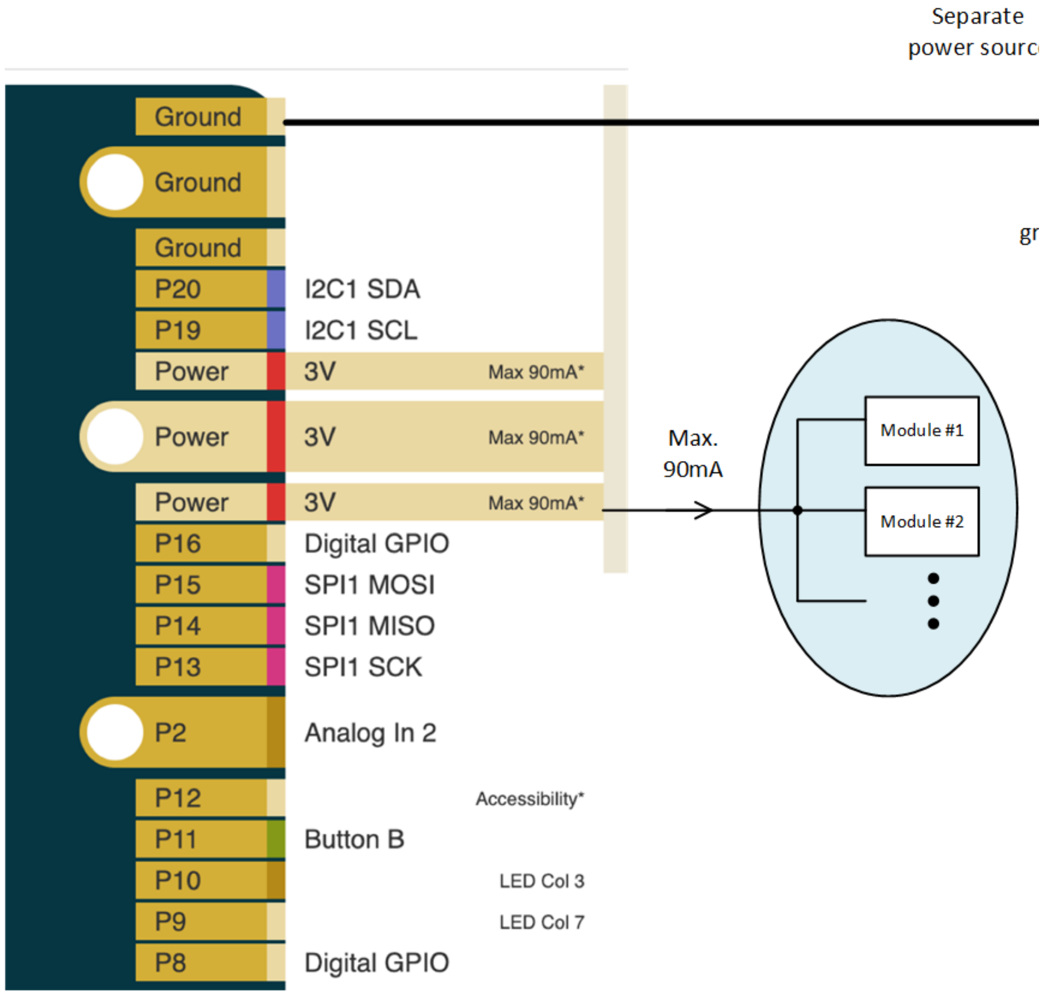
For more information see:
http://tech.microbit.org/hardware/powersupply/

Source: [https://microbit.pinout.xyz/pin-3v-power.html](https://microbit.pinout.xyz/pin-3v-power.html)



# Way to increase the no. of modules

If there are many modules connected to the system, we can use a separate power supply for modules and the grounds of the module and Microbit are common.



# Conclusions

- Instead of knowing the application of the modules or integrated circuits (ICs) only, it is equally important to understand the input and output characteristics of those modules.
- In order to use those modules or ICs in an effective way, it is important to understand if the output characteristic of the front-end modules or ICs can match with the input characteristics of the loading module or ICs.
- Studying the datasheets of the modules and ICs are important, as they will give designers the requirements and specifications of the modules and ICs.
- The datasheets contain a lot of useful information to assist designers with some recommended circuits and architecture for enriching the functionality and meeting the needs of designers.