Embedded System Design & Application

Inter Integrated Circuits bus

by Philips Semiconductors

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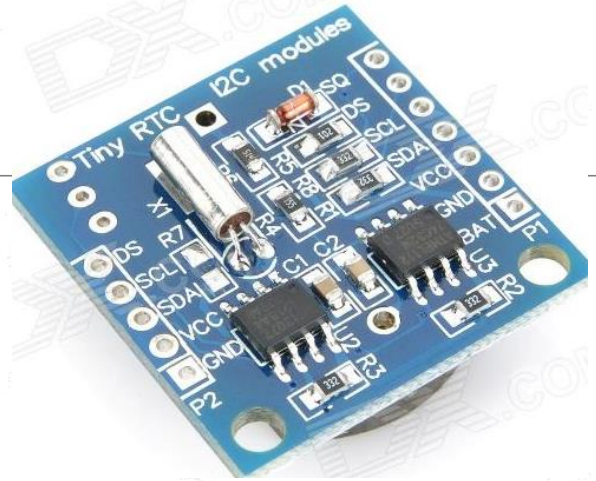
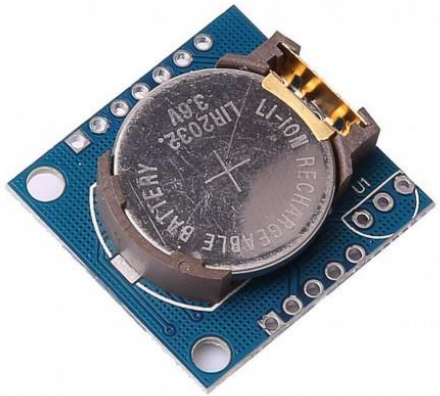
Agenda

- Introduction
- History
- Working
- Connecting multiple devices, LCD using I2C





I2C bus

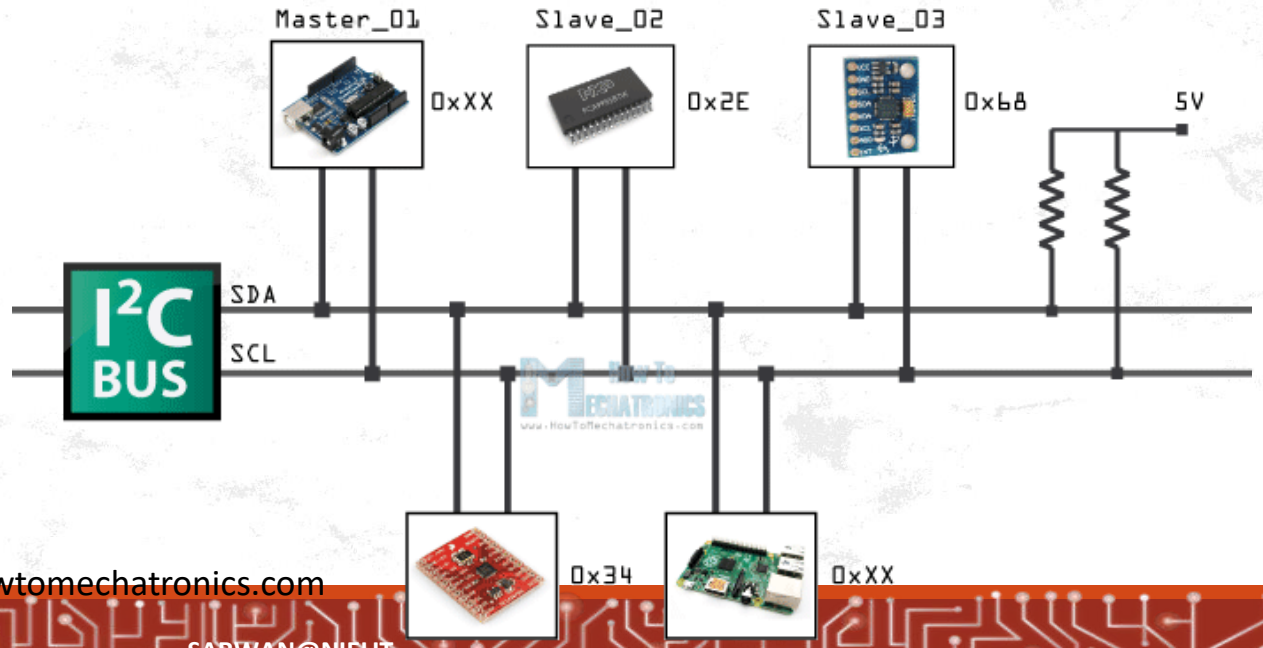
- **I²C (Inter-Integrated Circuit)**, pronounced *I-squared-C*, is a synchronous, multi-master, multi-slave, packet switched, single-ended, serial computer bus invented in 1982 by Philips Semiconductor (now NXP Semiconductors). It is widely used for attaching lower-speed peripheral ICs to processors and microcontrollers in short-distance, intra-board communication..
- Pronounced “eye-squared-see” or “eye-two-see”
- Two wire serial bus specification
- Invented by Philips in the early 1980s
  - The division is now NXP
  - Was a patented protocol, but patent has now expired

Source: wikipedia

I2C uses

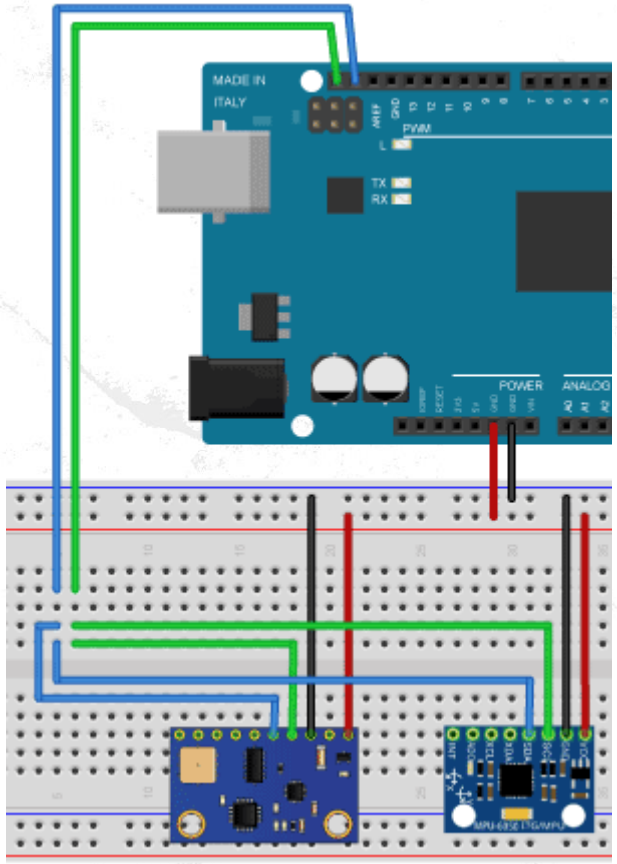
- Originally used by Philips inside television sets
- Now a very common peripheral bus standard
- Intended for use in embedded systems
  - Philips, National, Xicor, Siemens, … all use
- Also used in PCs
  - RTC, Temperature sensors, Variant is the SMBus (system management bus)
- Since October 10, 2006, no licensing fees are required to implement the I²C protocol. However, fees are required to obtain I²C slave addresses allocated by NXP

- The easy implementations comes with the fact that only two wires are required for communication between up to almost 128 (112) devices when using 7 bits addressing and up to almost 1024 (1008) devices when using 10 bits addressing.

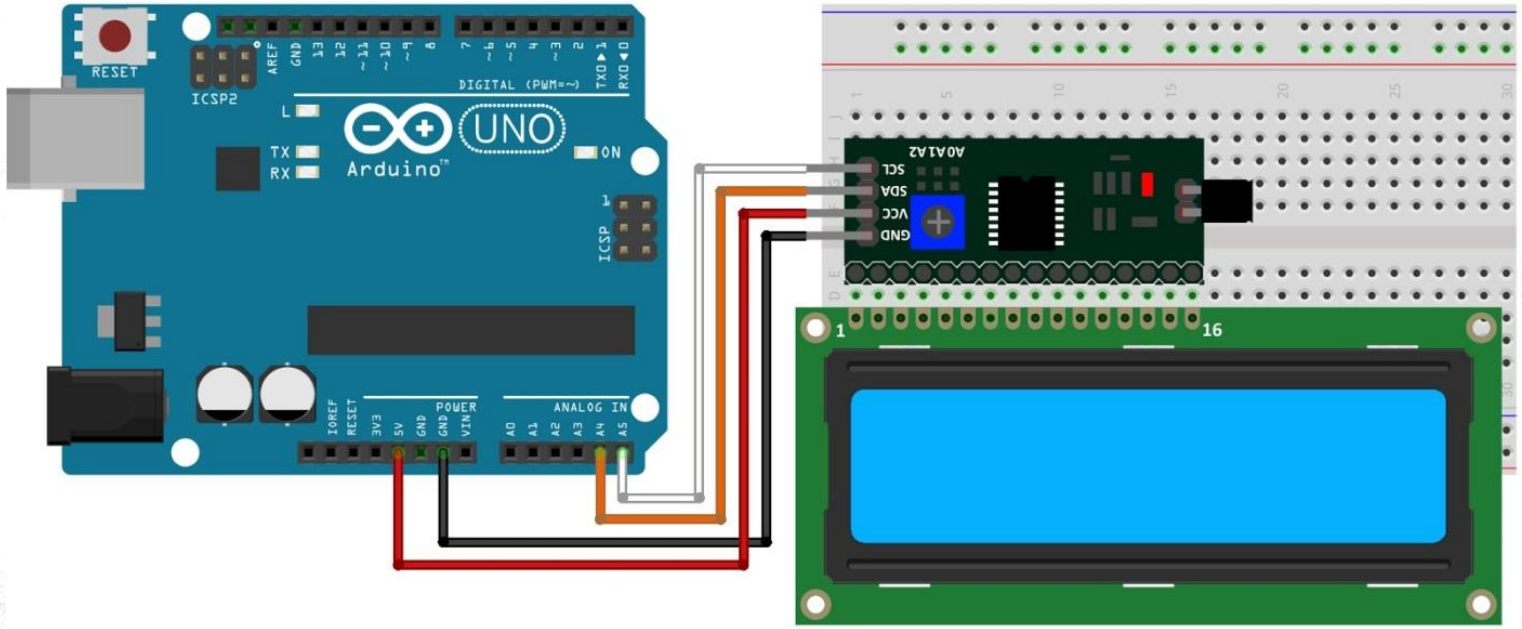


Source:howtomechatronics.com

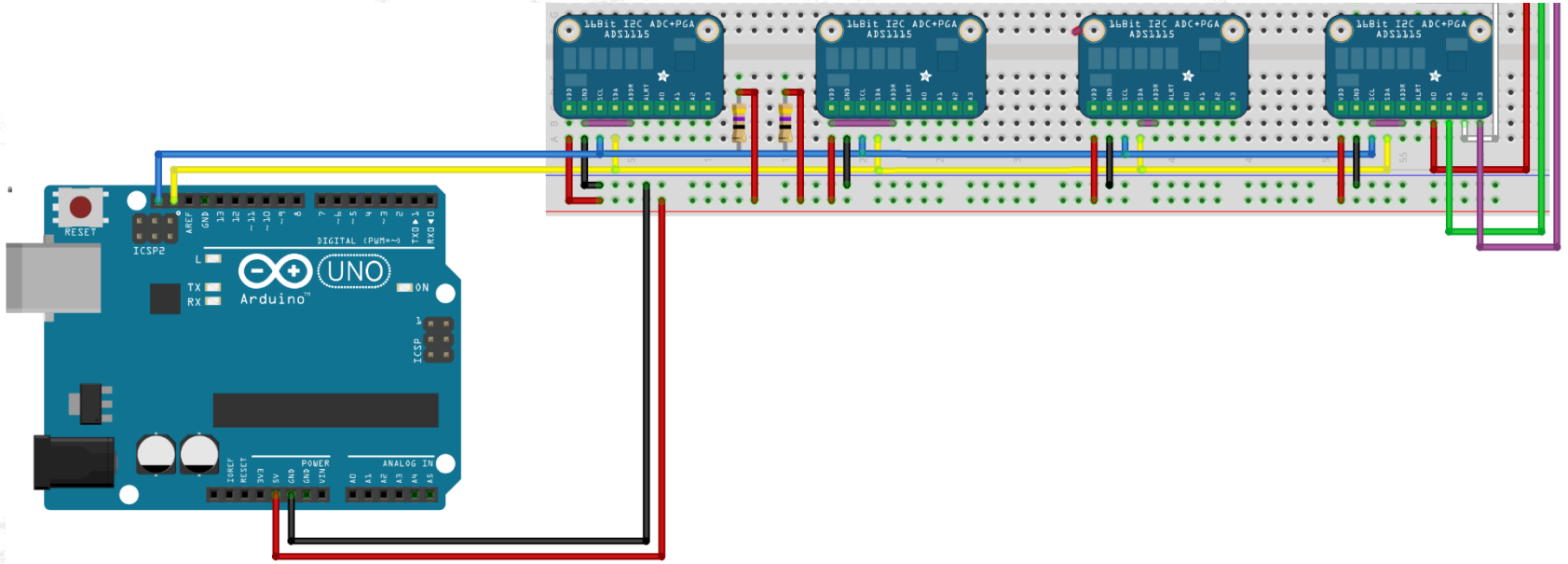
- The two wires, or lines are called Serial Clock (or SCL) and Serial Data (or SDA). The SCL line is the clock signal which synchronize the data transfer between the devices on the I2C bus and it's generated by the master device. The other line is the SDA line which carries the data.
- The two lines are "open-drain" which means that pull up resistors needs to be attached to them so that the lines are high because the devices on the I2C bus are active low. Commonly used values for the resistors are from 2K for higher speeds at about 400 kbps, to 10K for lower speed at about 100 kbps.



LCD connection using I2C



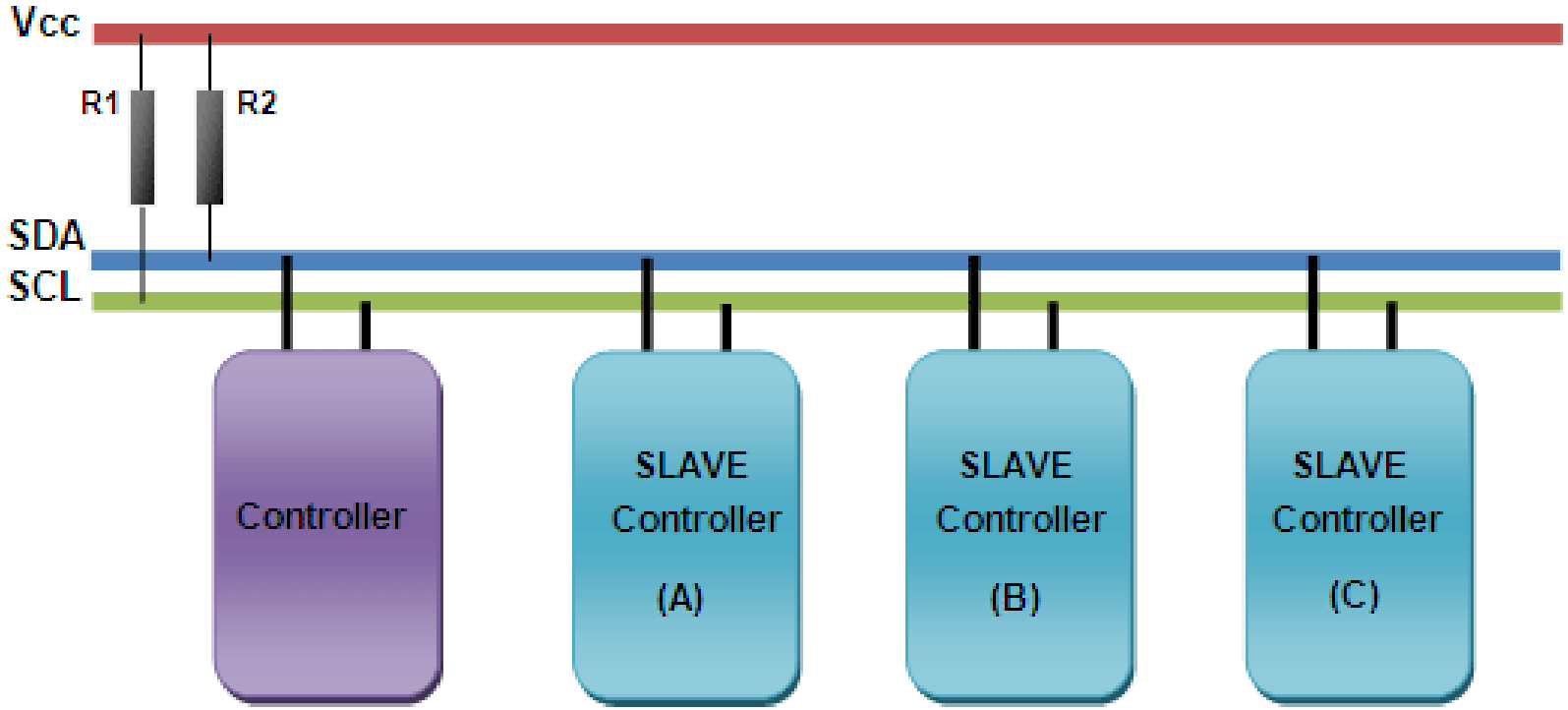
Connecting multiple devices using I2C



TWI / I²C (I-two-C)

- In TWI the serial data transmission is done in asynchronous mode.
- This protocol uses only two wires for communicating between two or more ICs.
- The two bidirectional open drain lines named SDA (Serial Data) and SCL (Serial Clock) with pull up resistors are used for data transfer between devices.

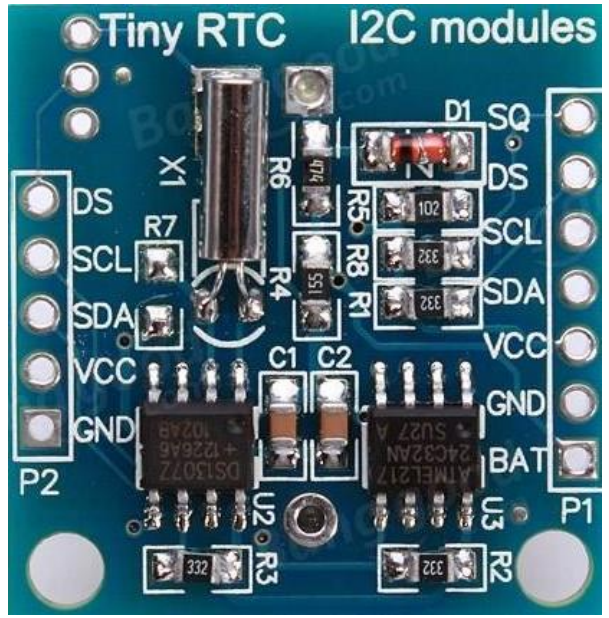
- One of the two devices, which controls the whole process, is known as Master
- the other which responds to the queries of master is known as Slave device.
- The ACK (acknowledgement) signal is sent/received from both the sides after every transfer and hence reduces the error.
- SCL is the clock line bus used for synchronization and is controlled by the master.
- SDA is known as the data transfer bus.


Vcc
R1
R2
SDA
SCL
Controller
SLAVE
Controller
(A)
SLAVE
Controller
(B)
SLAVE
Controller
(C)

- I^2C/TWI is a half duplex serial transmission and hence the data flow can be in a direction at a time.
- The data transfer rate depends on crystal frequency of slave controller. The rate of data transfer refers to clock frequency on SCL bus which must be $1/16^{th}$ of slave frequency.

Basic Characteristics

- two-wired bus : originally to interact within small num. of devices (radio/TV tuning, ...)
- speeds:
  - 100 kbps (standard mode)
  - 400 kbps (fast mode)
  - 3.4 Mbps (high-speed mode)
- data transfers: serial, 8-bit oriented, bi-directional
- master/slave relationships with multi-master option (arbitration)
- master can operate as transmitter or receiver
- addressing: 7bit or 10bit unique addresses
- device count limit: max. capacitance 400 pF



RTC – Real Time Clock

Initializing RTC


```
#include <Wire.h>
#include "RTClib.h"

RTC_DS1307 rtc;

char daysOfTheWeek[7][12] = {"Sunday", "Monday", "Tuesday", "Wednesday", "Thursday", "Friday", "Saturday"};

void setup () {
   Serial.begin(9600);
  if (! rtc.begin()) {
   Serial.println("Couldn't find RTC");
   while (1);
  }
}
```

```
void loop () {
  DateTime now = rtc.now();
  Serial.print(now.year(), DEC);
  Serial.print('/');
  Serial.print(now.month(), DEC);
  Serial.print('/');
  Serial.print(now.day(), DEC);
  Serial.print(" (");
  Serial.print(daysOfTheWeek[now.dayOfTheWeek()]);
  Serial.print(") ");
  Serial.print(now.hour(), DEC);
  Serial.print(':');
  Serial.print(now.minute(), DEC);
  Serial.print(':');
  Serial.print(now.second(), DEC);
  Serial.println(); delay(3000);
}
```

EEPROM

Writing 1 at 0^{th} address location

```
#include <EEPROM.h>

void setup() {
        // write  ( address, value)
  EEPROM.write(0, 1);
}

void loop() { }
```

Read status from EEPROM on startup

```
#include <EEPROM.h>
int address = 0;
byte value;
void setup() {
  Serial.begin(9600);
  pinMode(13,OUTPUT);  pinMode(2,INPUT);
  value = EEPROM.read(0);
  Serial.print("value in EEPROM  : ");
  Serial.println (value) ;
  if (value ==1)// switch on LED else off
    digitalWrite(13,HIGH);
  else
    digitalWrite(13,LOW);
}
```

Write status of button in EEPROM

```
void loop() {
  if (digitalRead(2) ==HIGH) {
   if (value==1) value=0;
   else value=1;
   while (digitalRead(2) ==HIGH) ;
   EEPROM.write(0, value);
   Serial.print(" value Updated in EEPROM  : ");
   Serial.println (value) ;
  }
  if (value ==1)// switch on LED else off
   digitalWrite(13,HIGH);
  else
   digitalWrite(13,LOW);
}
```

- Github Repo

https://github.com/sarwansingh/IoT/tree/master/ClassExamples/CEPTAM_ESDA_Sept24

Project Code @ Github :

- Timer controlled LED