Arduino Board and ATMega328 Architecture

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Outlines

- What is Arduino?
- Arduino Terminology
- Arduino Type
- Shield, Module, Sensor
- Arduino UNO R3
- Programming Language for Arduino UNO
- Serial Communication in Arduino UNO

What is Arduino?

- The Arduino is a programmable hardware board that runs an 8-bit /16 Mhz microcontroller with a special bootloader that allows users to upload programs to the microcontroller.
  - It has digital input pins for input from switches and output to Actuators (LEDS or electrical motors)
  - It also has analog pins to accept inputs from voltage based sensors.
- Arduino can be used to develop stand-alone interactive objects or can be connected to software on your computer.

What is Arduino? Open Source

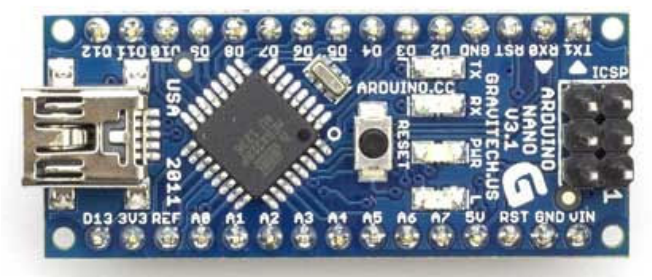
- Open Source Hardware
  - The Arduino system is open source - all hardware (made by Arduino distributors) has the schematics and PCB layouts available online.
- Open Source Bootloader
  - The bootloader is what runs on the chip before the program is run. It boots the chip and executes the program.
- Open Source Development Kit
  - The development kit - what you use to program an Arduino board - is also available online. It is free, open-source.

Arduino Terminology

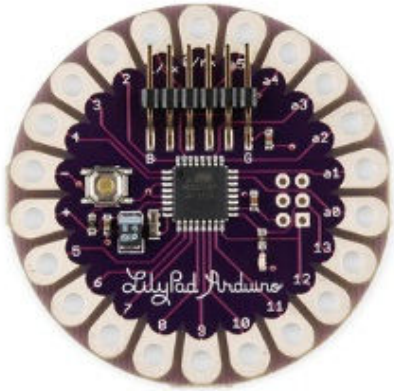
Terminology	Description
I/O Board	The I/O Board is the "brain" of the operation (main microcontroller you program it from your computer).
Shield	A Shield is a device that plugs into an I/O Board. These extend the capabilities of the I/O Board.
Sketch	A Sketch is a program written for the board and shields.
Sensor	components (Gas, etc.)
Module	serial data (GPS module, etc.).
Pin	an input or output connected to something.
Analog	values have the resolution of 0 to 1024, and in terms of voltage the 5 volts will be 1024.
Digital	value is either HIGH or LOW.

Arduino Type

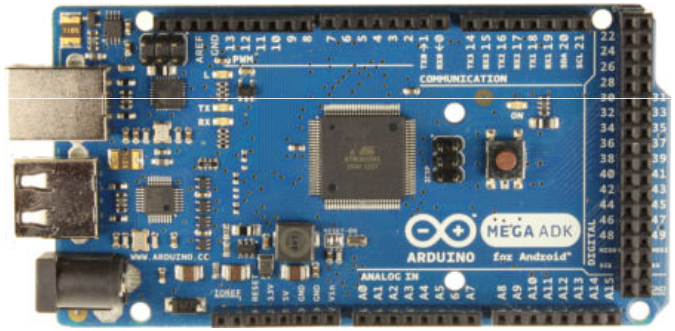
- Many different versions depend on the number of input/output pin or processor.



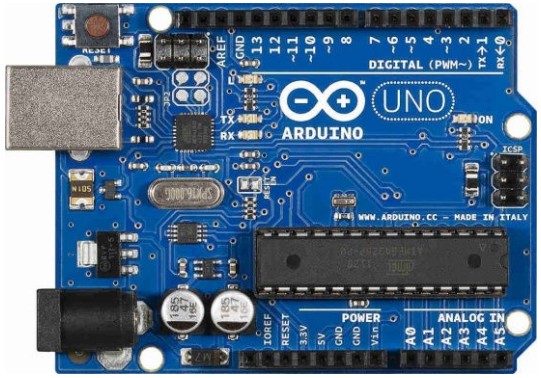
Arduino Nano



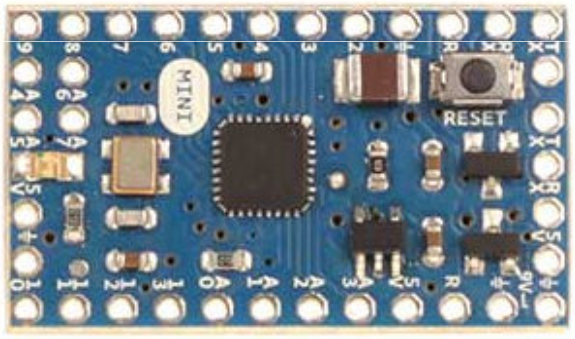
Arduino LilyPad



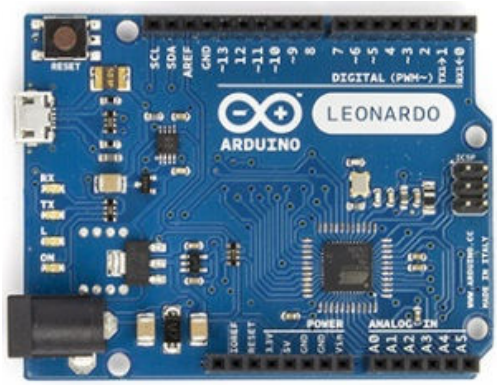
Arduino Mega



Arduino Uno

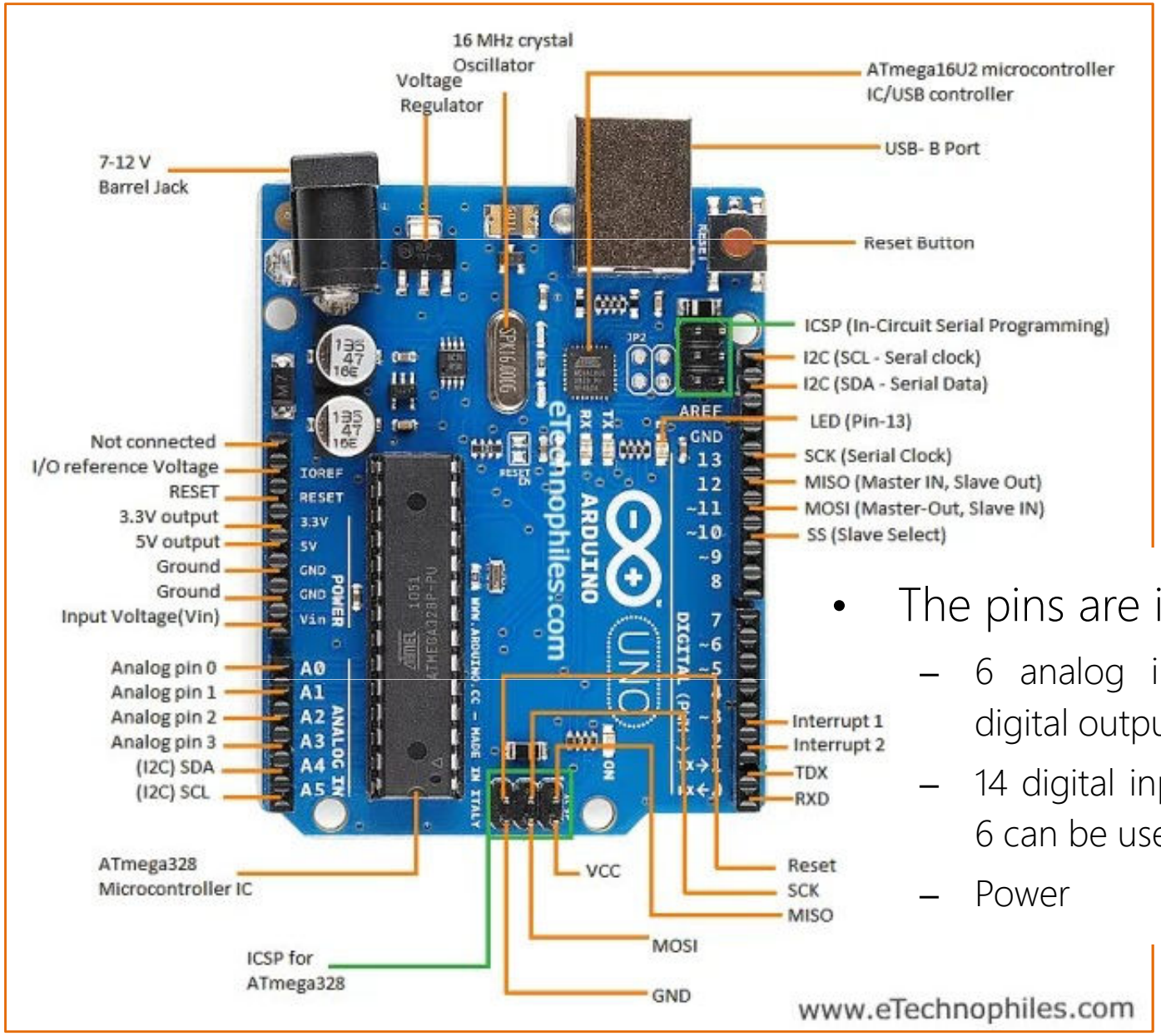


Arduino Mini



Arduino Leonardo

Arduino Uno

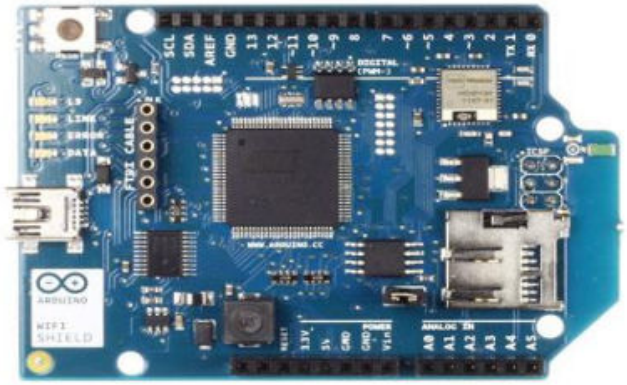


- The pins are in three groups:
  - 6 analog inputs (can be used as digital outputs).
  - 14 digital input/output pins (of which 6 can be used as PWM outputs).
  - Power

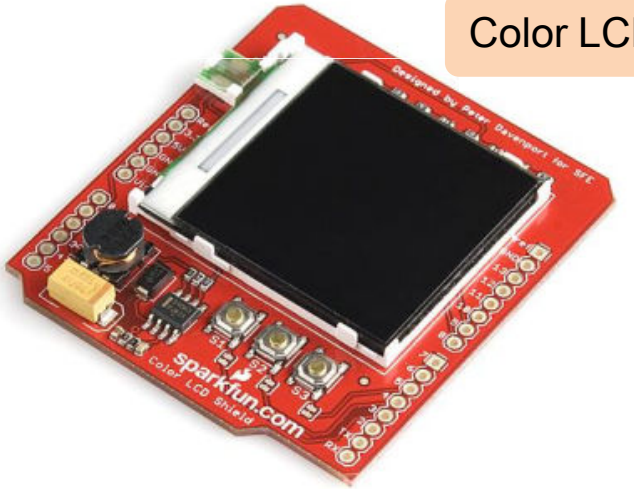
Arduino Uno – Shields

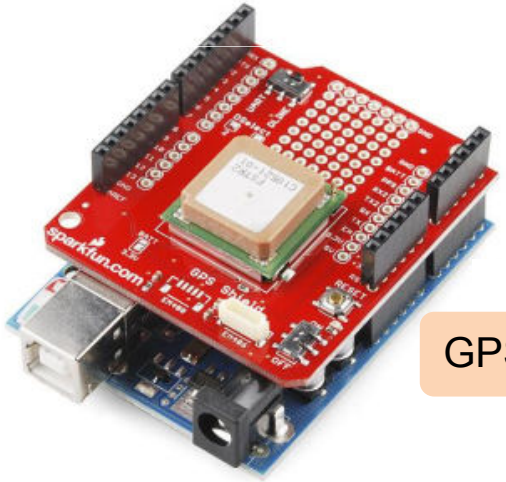
- **Arduino Shields** are add-on boards than can be plugged on top of an Arduino board and provided additional capabilities and functionalities to an Arduino Board.

Wireless Network Shield

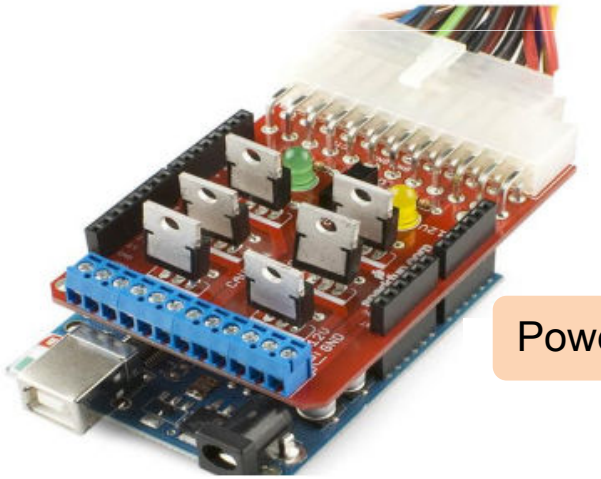


Color LCD Shield





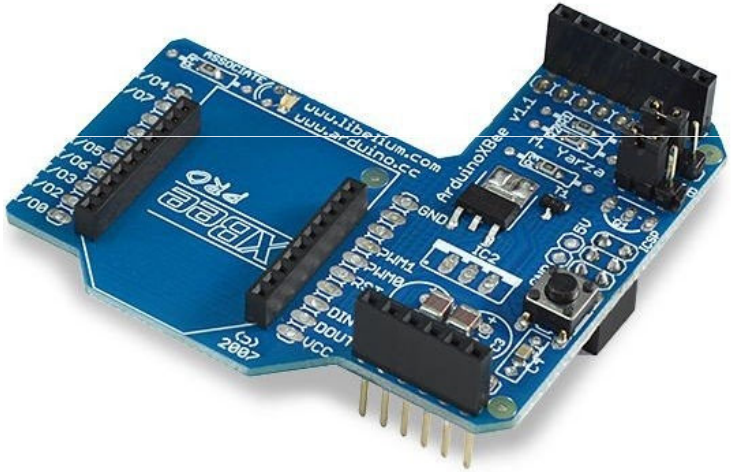
GPS Shield



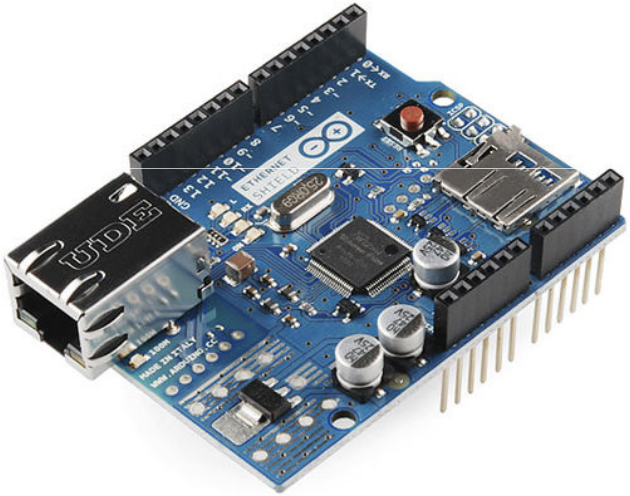
Power Driver Shield

Arduino Uno – More Shields

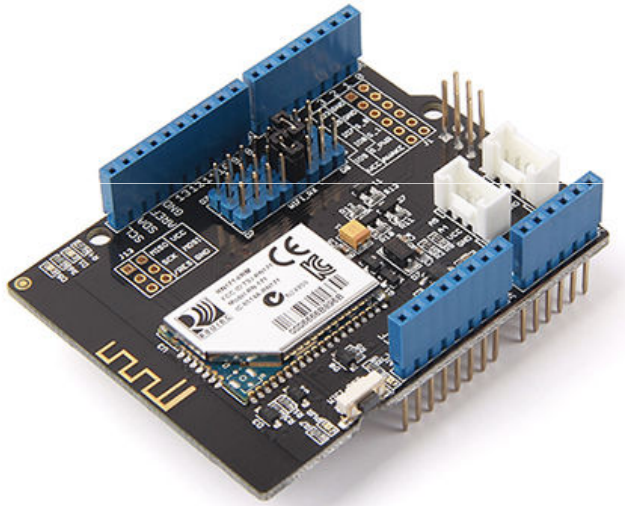
- Communication shields: XBee, Ethernet, and Wifi.



XBee Shield



Ethernet Shield



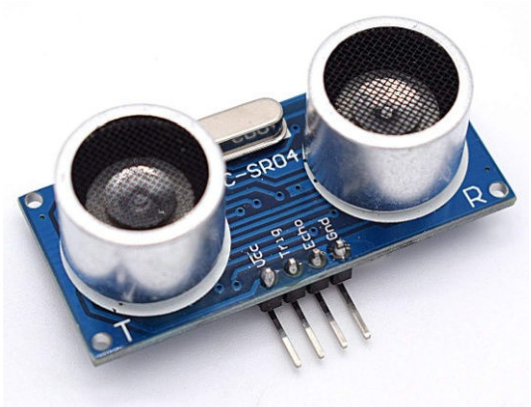
WiFi Shield

Arduino Uno – Modules

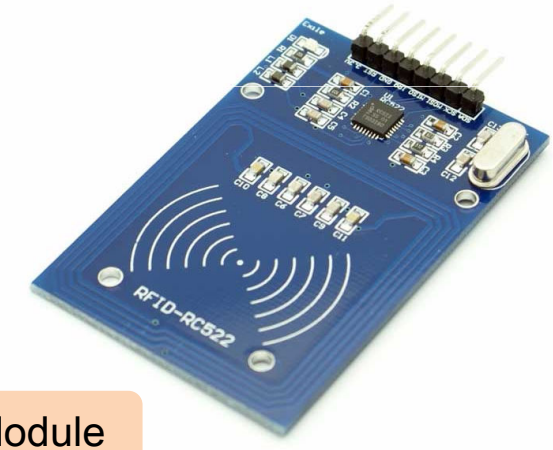
- **Module** is a ready-to-use board with a Sensor or an IO device on it. Modules send serial data strings to the Arduino.

GPS Module

Bluetooth Module

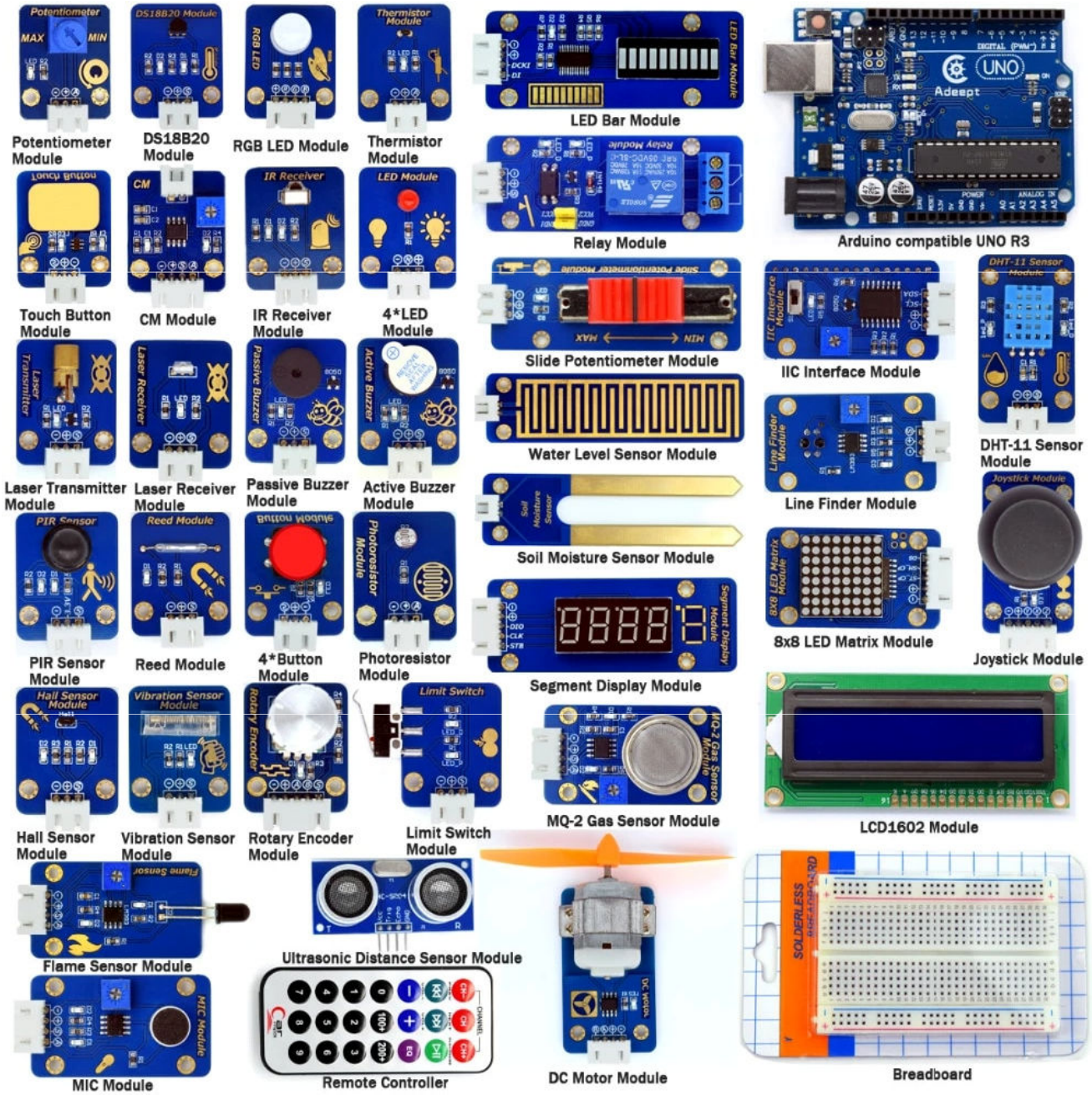


Ultrasonic Module



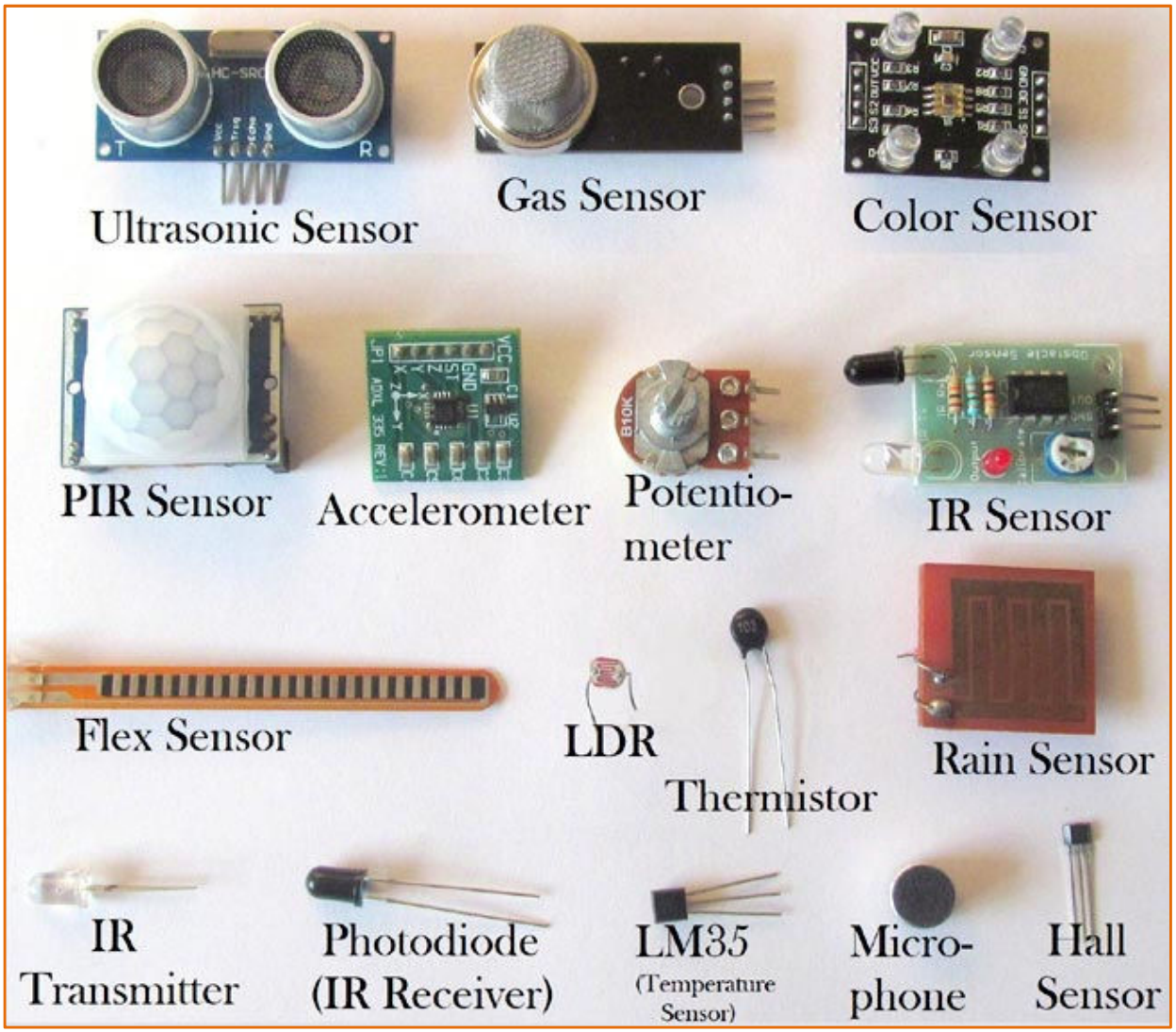
RFID Module

Arduino Uno – More Modules



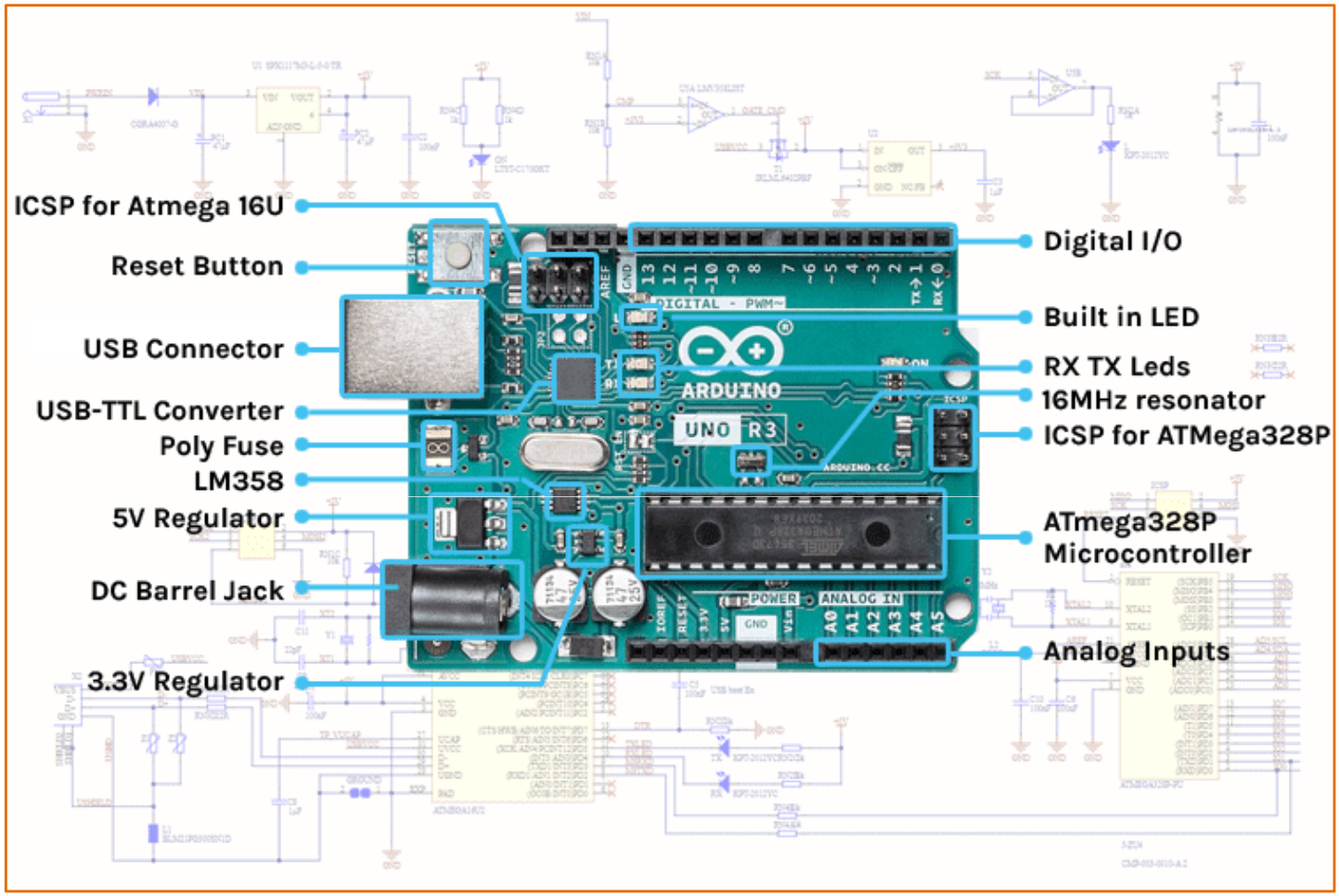
Arduino Uno – Sensors

- A **sensor** is a device that detects and responds to some type of input from the physical environment.



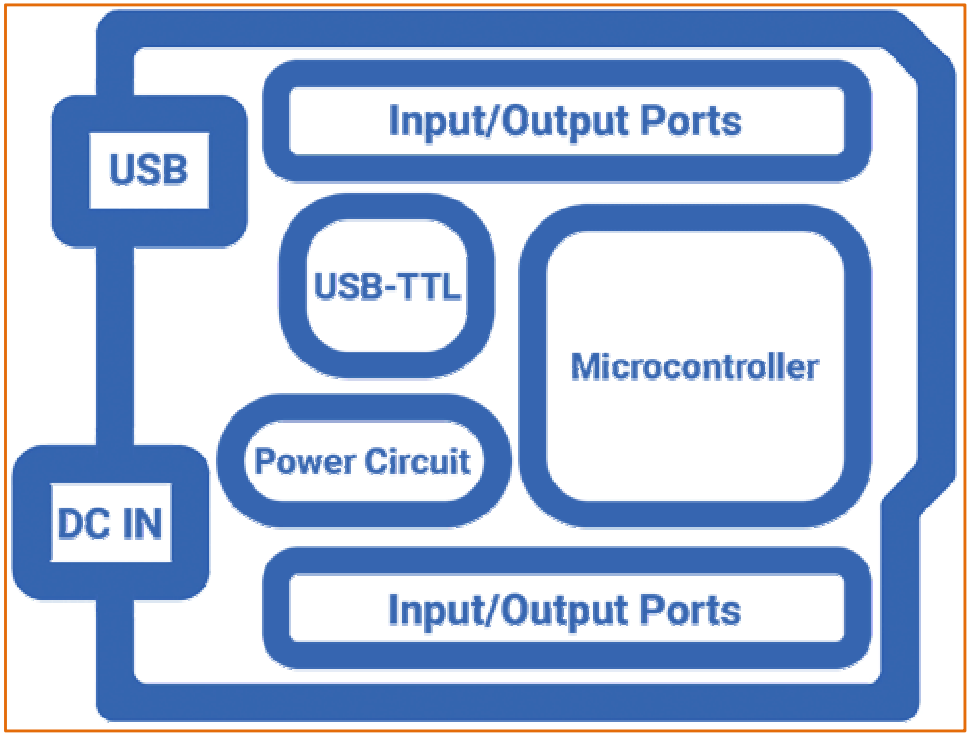
Arduino Uno R3 - Hardware

- Arduino hardware is a PCB-mounted microcontroller that you can program and use for simple daily tasks, mathematical computations, and prototyping and testing.



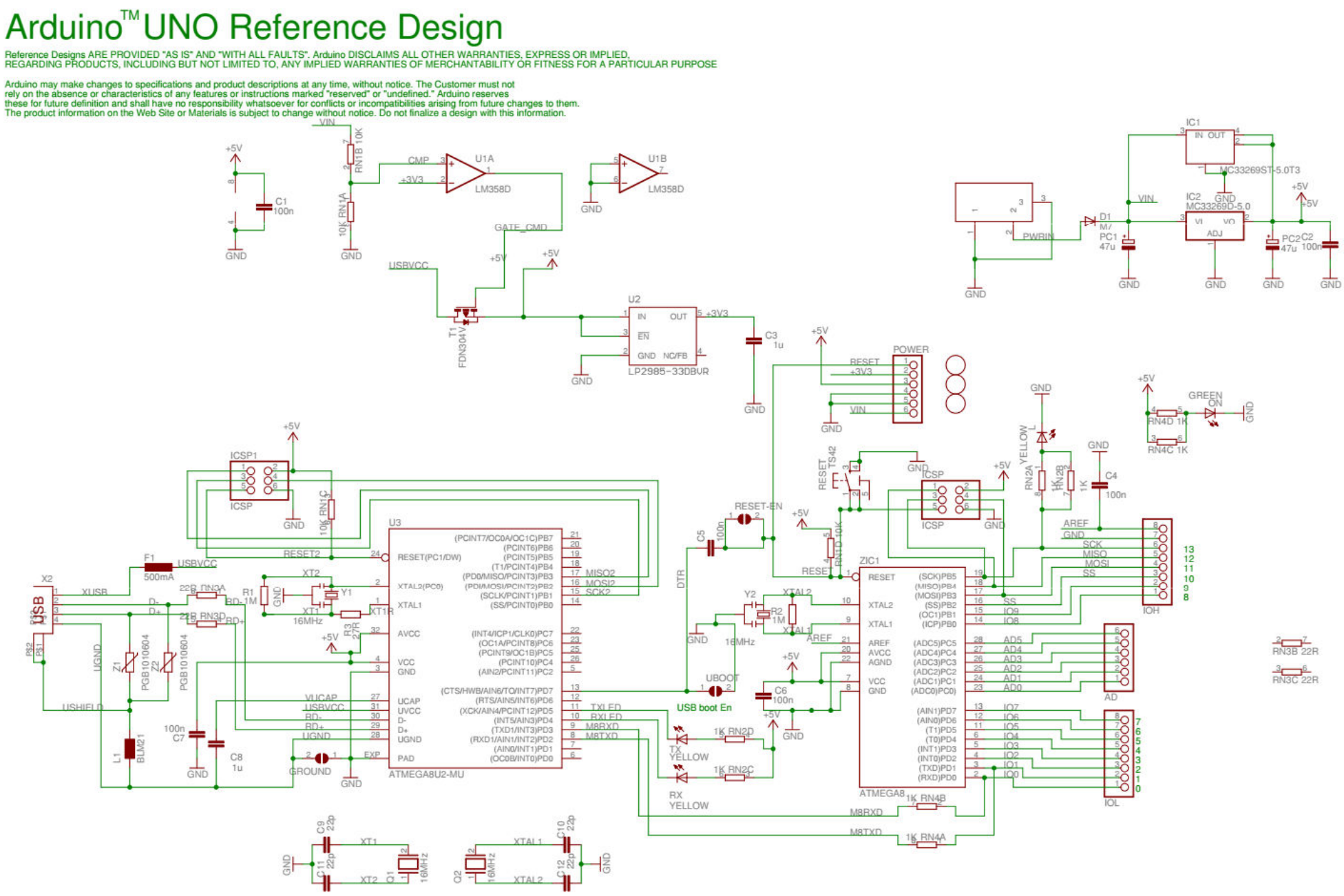
Arduino Uno R3 – Hardware (cont')

- An **Arduino development board** consists of the core microcontroller with its supplementary components and the necessary circuitry to communicate with the PC which we will be using for both communications as well as programming the microcontroller.



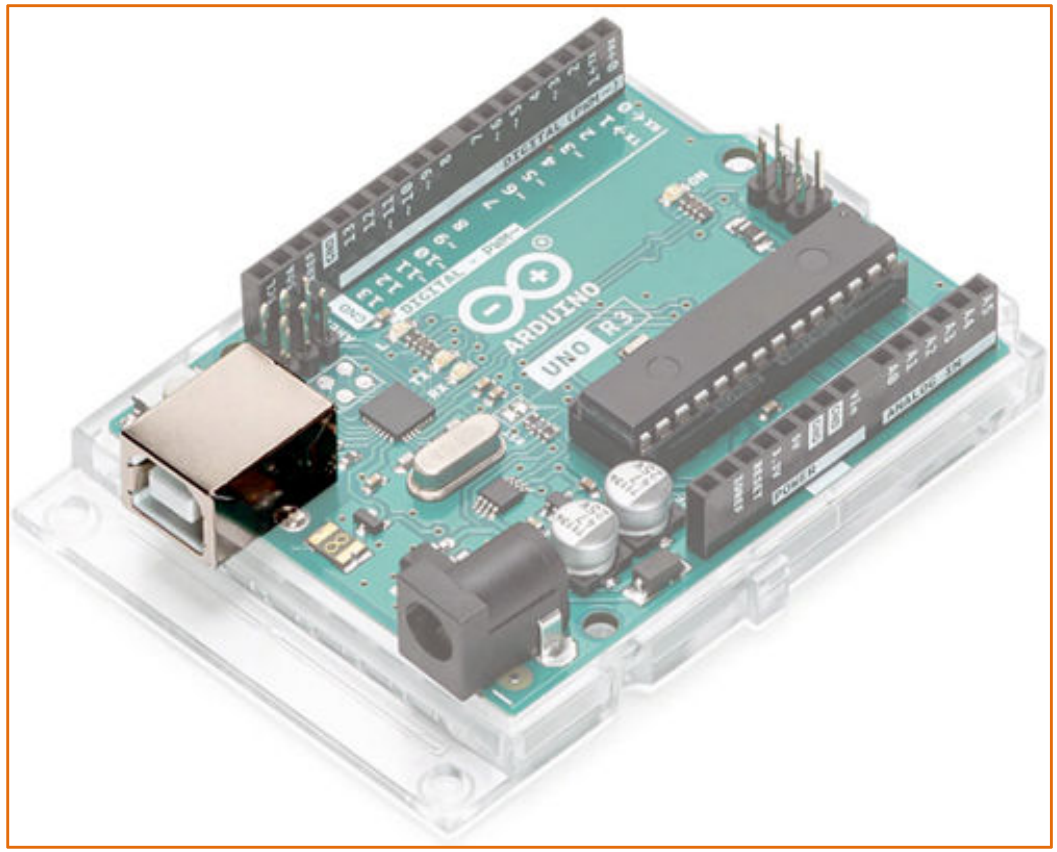
- For communication or programming purposes, we will be using a **USB-to-TTL** converter, which will be embedded within the Arduino board.
- The Arduino is NOT limited to the capabilities of an **ATMEGA328 chip**. There are plenty of board variants available, with an entirely different set of features like different microcontrollers, layout, number of I/O ports, etc.

Arduino Uno R3 - Schematic



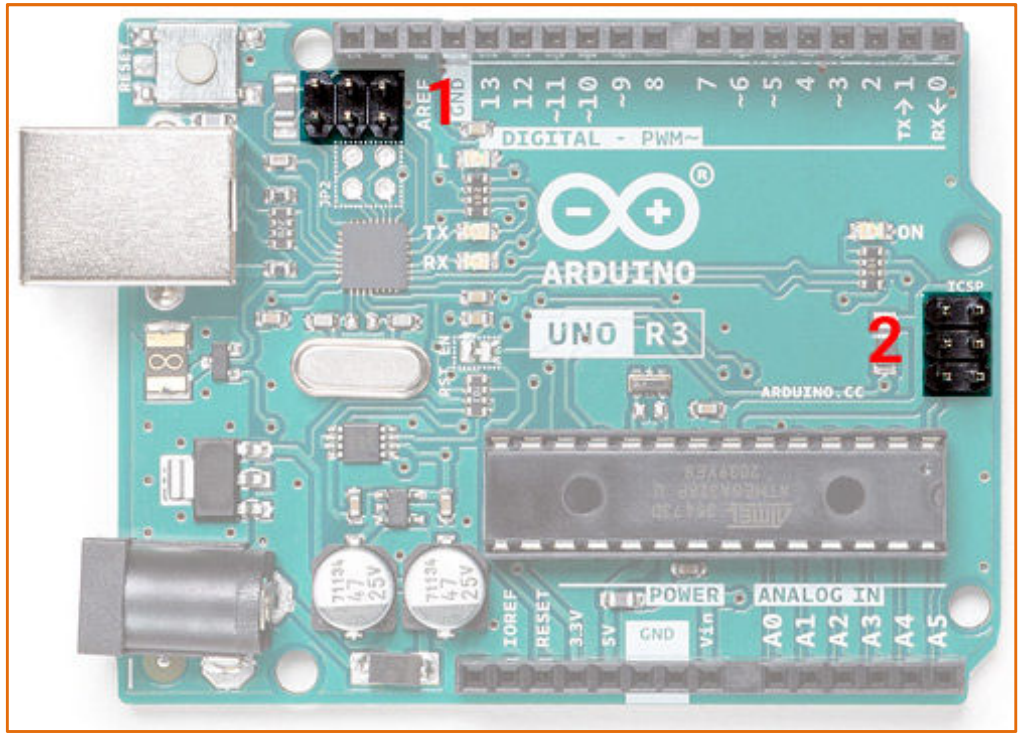
Arduino Uno R3 – USB-B Socket

- The USB socket on the UNO has two functions. One is for communication, to connect with the computer through a USB port, and also to load the firmware into the Arduino with the help of the bootloader. The second is to power the Arduino. You can use the USB port to power the Uno directly from any USB port.



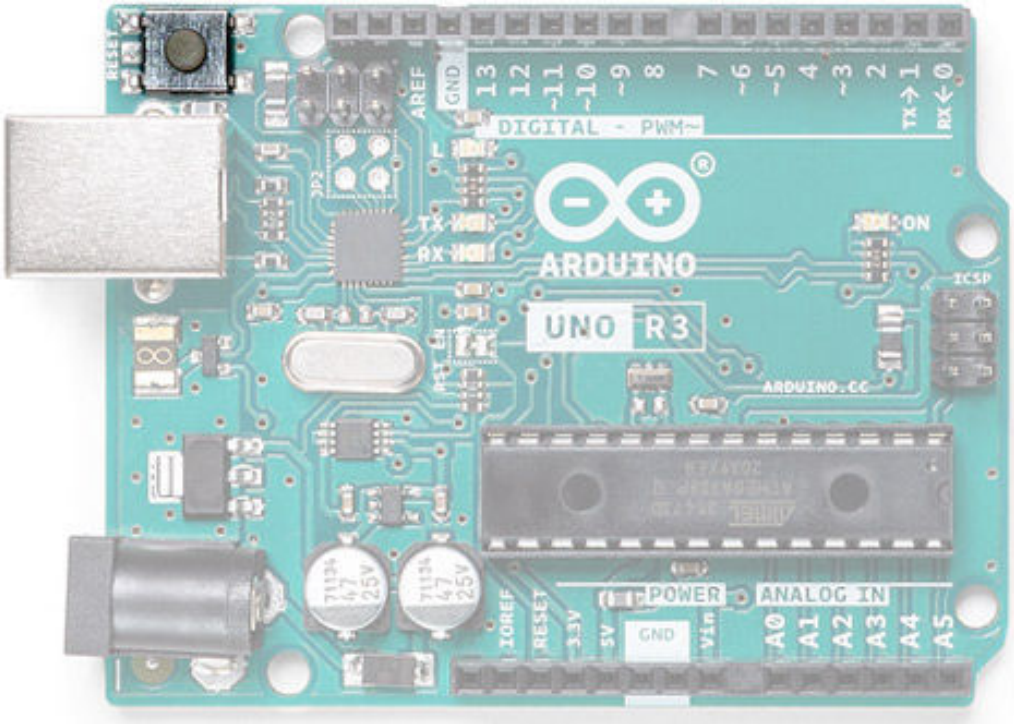
Arduino Uno R3 – ISCP Pins

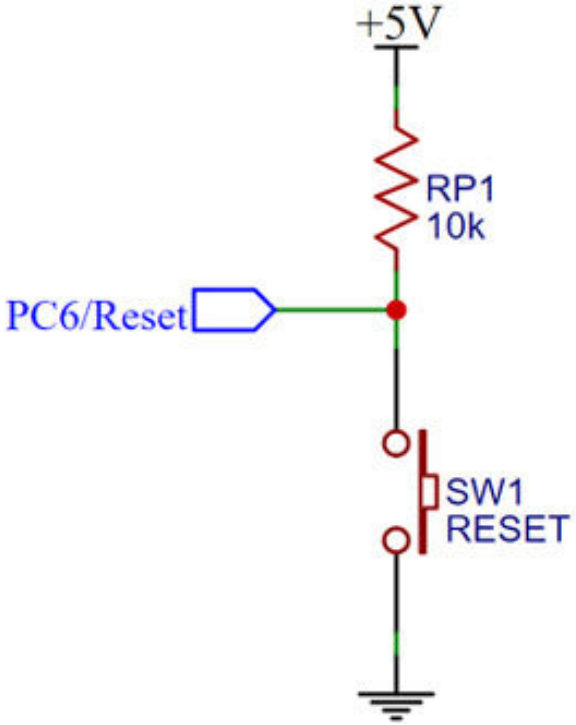
- In the UNO you can find two 6 pin connectors. One is **near the USB – TTL Chip** and the other one is **at the end of the board**. These pins are used to program those two microcontrollers. The USB – TTL chip on this board is an ATMgega16U. The connector marked as 1 is used to program the USB-TTL firmware into this chip. And the connector marked as 2 is used to burn the bootloader into the ATMega328 microcontroller.



Arduino Uno R3 – Reset Button

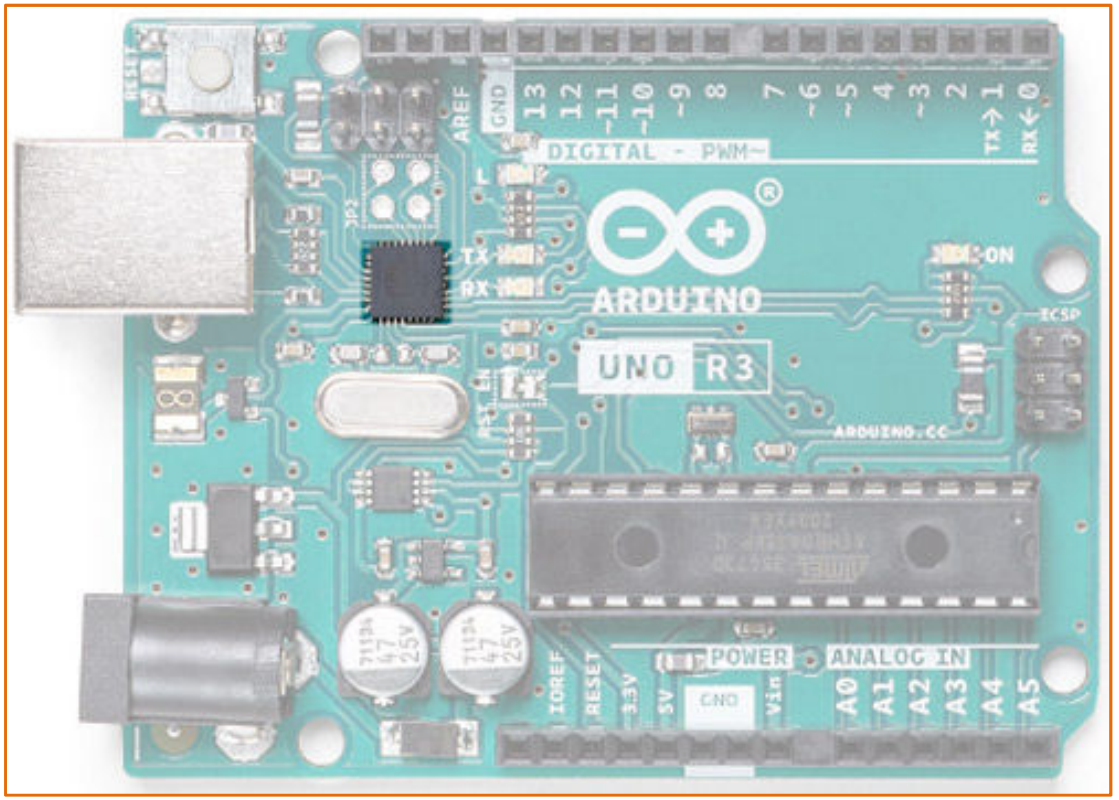
- As the name indicates this tactile switch is used to reset the ATMega328 microcontroller. It's connected to the PC6/Reset pin, which is pulled up through a 10K. When the switch is pressed the pin is pulled to the ground and the chip will reset.





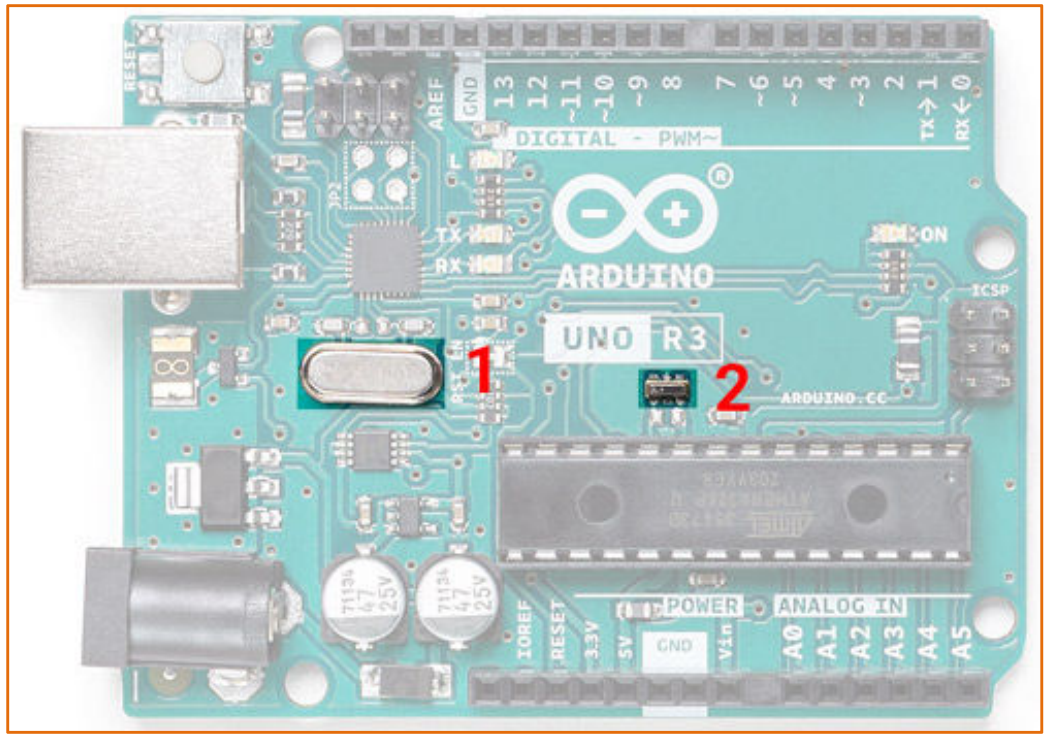
Arduino Uno R3 – USB-TTL Interface Chip

- To communicate with the computer, the Arduino relies on a USB-TTL interface. In UNO, ATMega16U with custom firmware act as a USB – TTL interface chip.



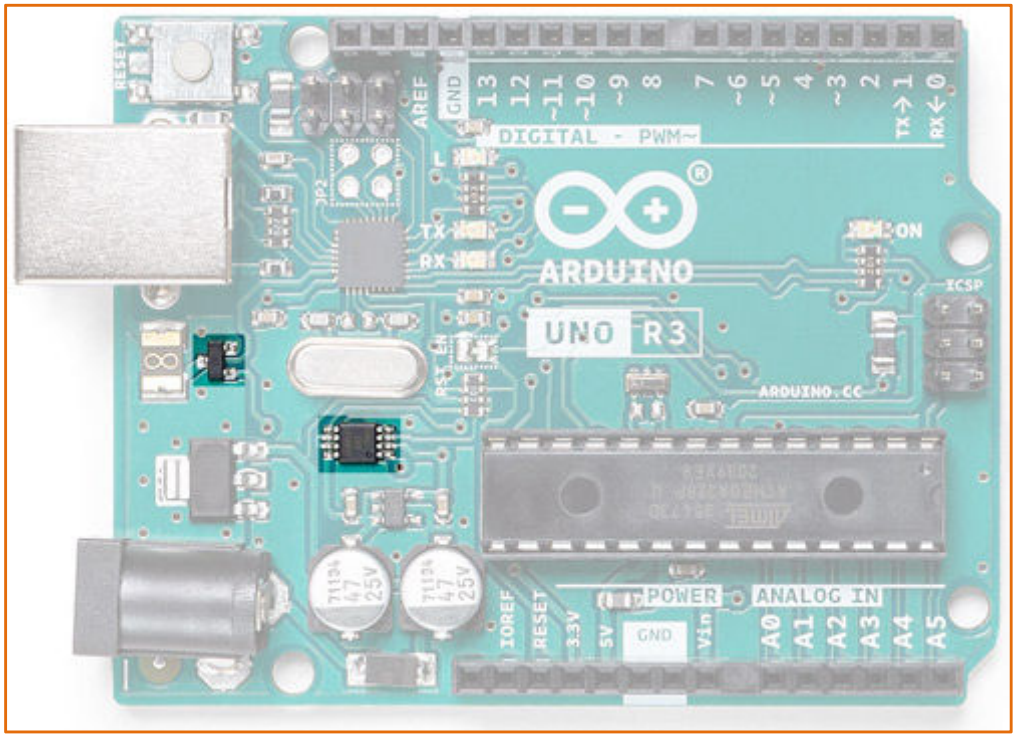
Arduino Uno R3 – Crystal Oscillator

- For a microcontroller to work it needs a clock source. The clock circuit determines the speed with which the microcontroller operates.
- The ATMega series microcontrollers can use two types of clock sources.
  - Internal RC oscillator: built into the microcontroller, but its maximum frequency is limited and it is not that accurate.
  - External clock generator: a Quartz crystal oscillator or a ceramic resonator.



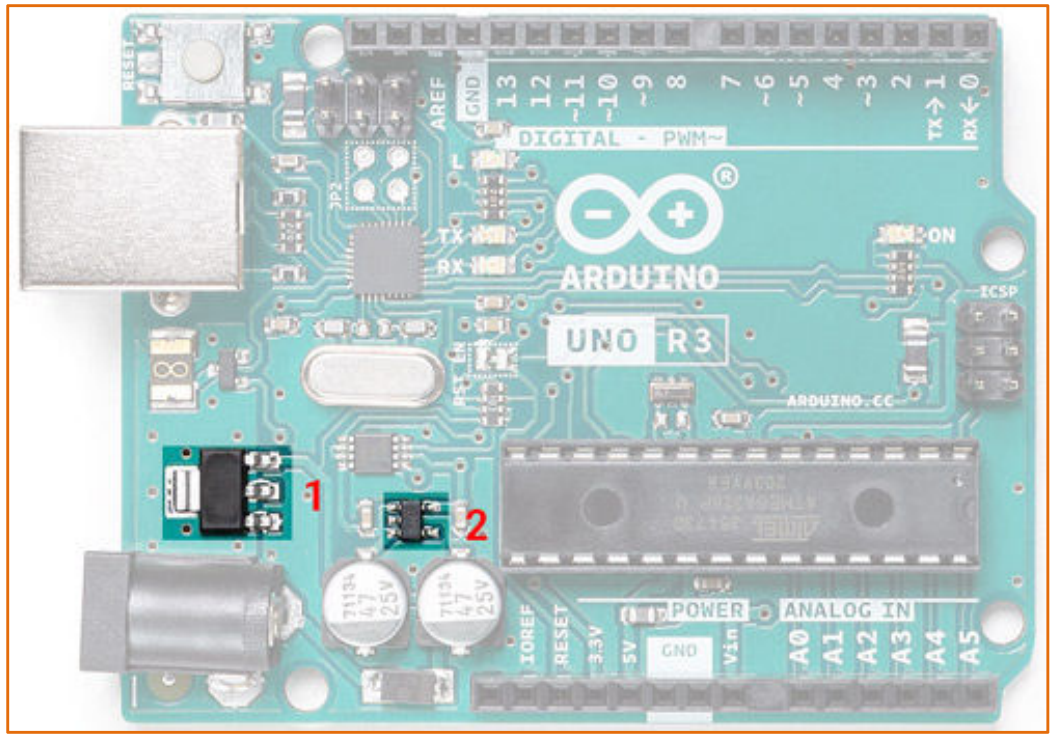
Arduino Uno R3 – Power Path Control

- If you inspect a UNO, you can find an LM358. It's used as a comparator to control the input power path.
  - When the input power is provided through the barrel jack or Vin pin, the power path control circuit will cut off the USB power pin from the circuit which in fact will protect the USB port.



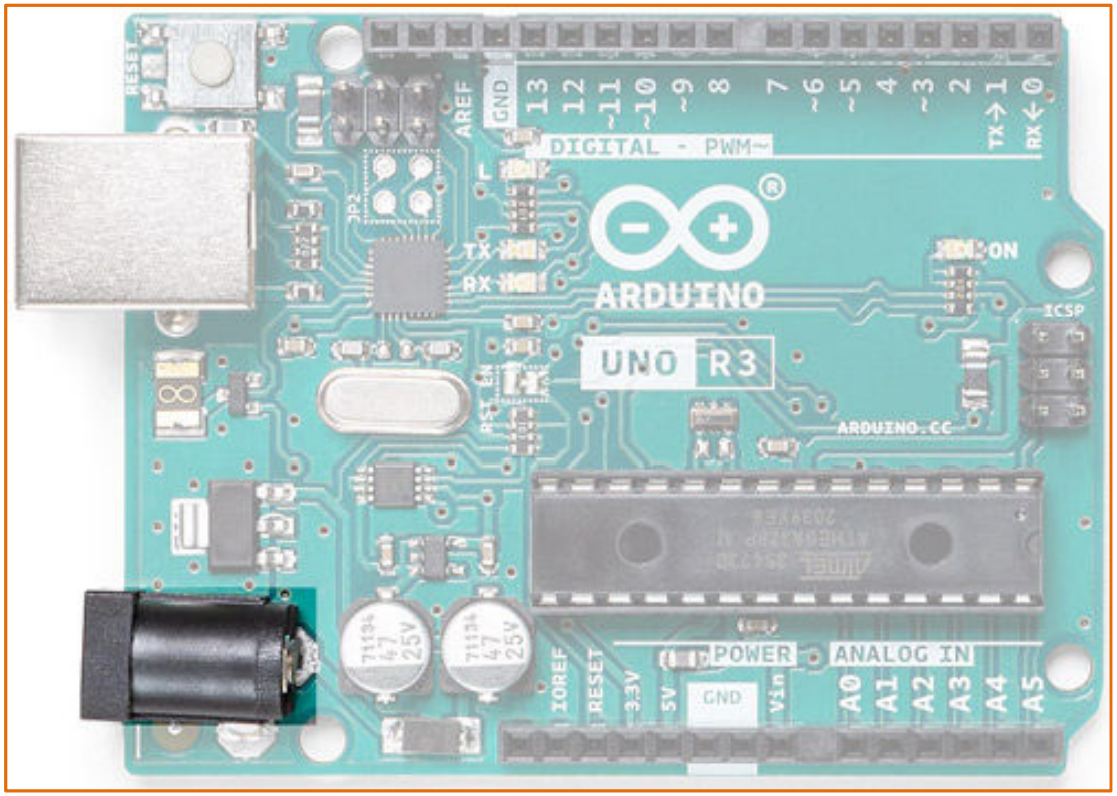
Arduino Uno R3 – Voltage Regulator

- The ATMega328 and ATmega16U2 have a maximum input voltage of around 5V and most modules or accessories work on either 5V or 3.3V. The Arduino can accept 7-12V through the Vin pin or the DC barrel jack. So, to step it down, there are **two regulators** onboard. One is a **5V regulator** (marked as 1) for the microcontrollers and the other one is a **3.3V regulator** which is used to provide 3.3V through 3.3V pin.



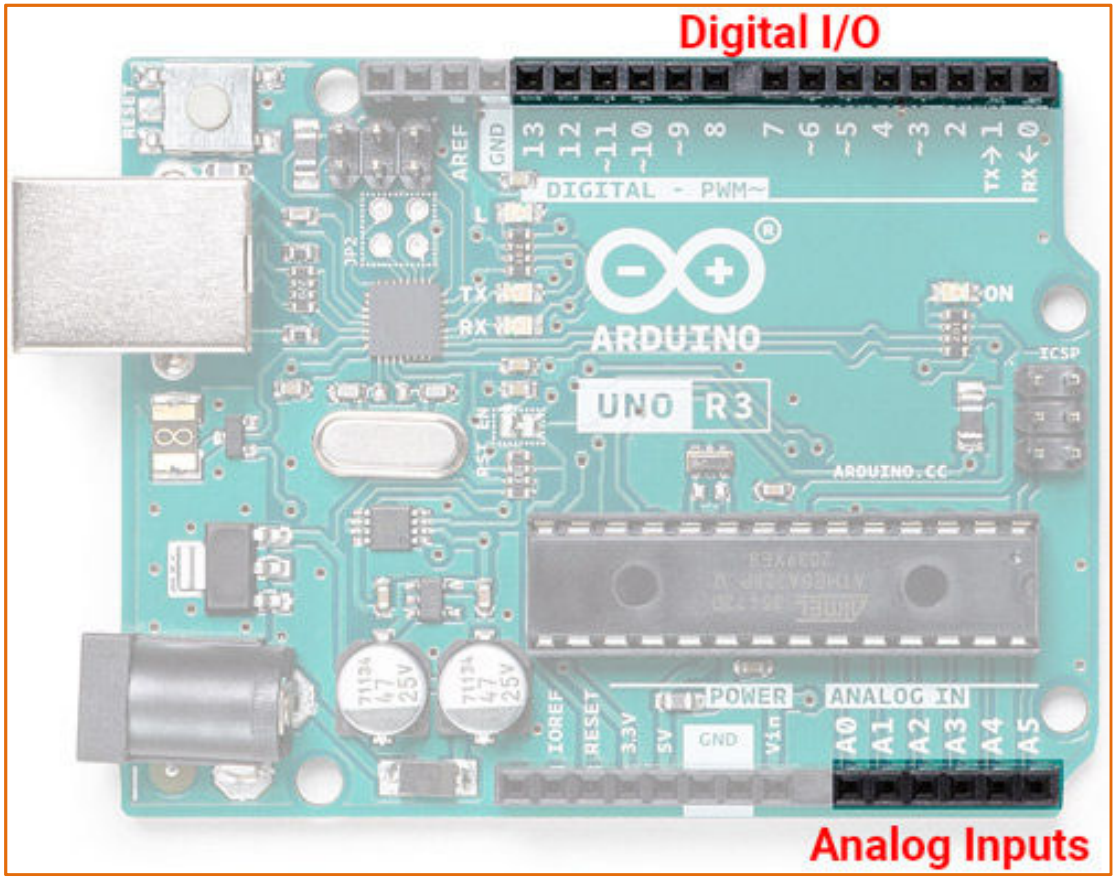
Arduino Uno R3 – DC Barrel Jack

- The DC barrel jack is used to supply power to the UNO. We can supply 7-12V through it and hence we can use a 12V DC adapter or 9V DC adapter on this Jack to power the Arduino board.



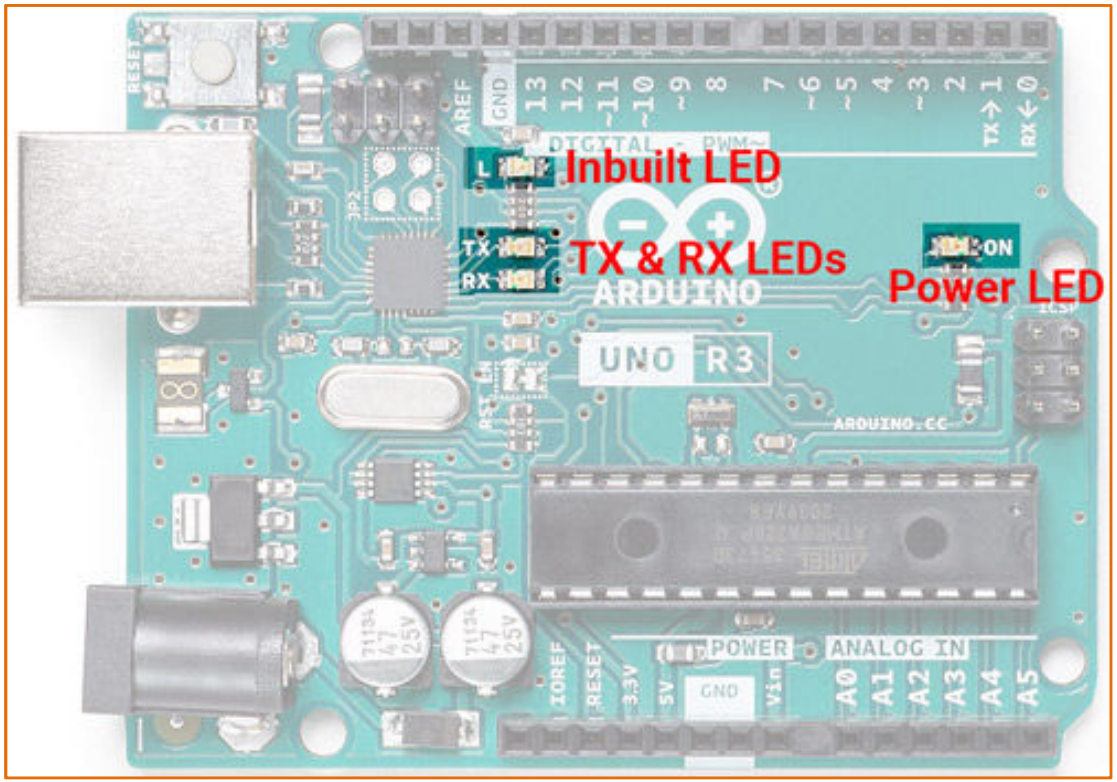
Arduino Uno R3 – Digital and Analog I/O

- The Arduino UNO has **14 digital I/O pins** and **6 Analog inputs**. The digital I/O pins are 5V logic level and you can also use the Analog pins as digital I/O too. Arduino UNO supports 6 channel 10 bit ADC inputs through A0-A5, which can be sampled and analyzed using UNO.



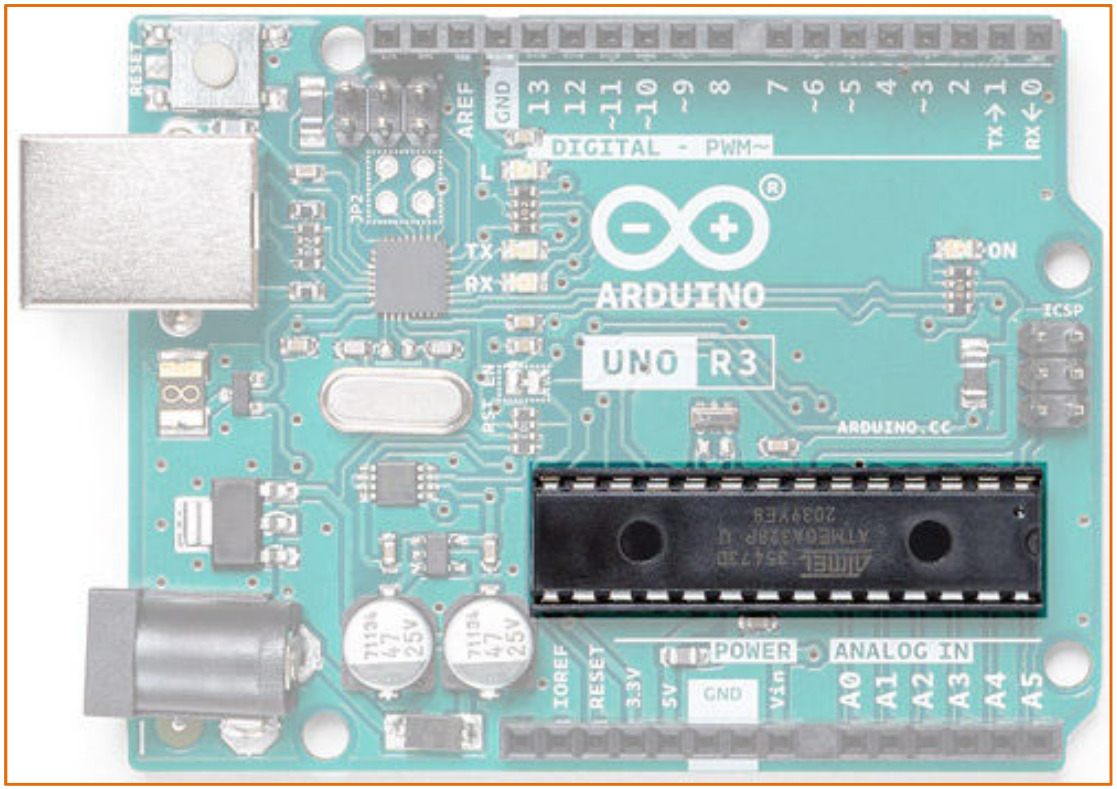
Arduino Uno R3 – Status LEDs and Inbuilt LED

- Uno has **4 LEDs** onboard. One is used as a power indicator and two are used to show the activity of the Rx and Tx pin. The other one is tied to the Digital pin 13, which can be used to test the Arduino board or simply as an indicator.



Arduino Uno R3 – ATMega328P - The Brain

- The main component on the Arduino board – the **ATMega328P Microcontroller**. UNO uses a **28Pin DIP version** of ATMega328P. Atmega328P is **pre-programmed with a bootloader** that allows you to directly upload the program to Arduino through USB without the need for an external programmer.



Arduino Uno R3 – Technical Specifications

Component	Specification
Microcontroller	ATmega328P
Operating voltage	5 V
Input voltage (recommended)	7 – 12 V
Input voltage (limits)	6 – 20 V
Digital I/O pins	14 (of which 6 provide PWM output)
Analog input pins	6
DC current per I/O pin	20 mA
Flash memory	32 KB
SRAM	2 KB
EEPROM	1 KB
Clock speed	16 MHz
Weight	25 g

Arduino Uno – Programming Language

- Arduino programming language can be divided in **three main parts**: functions, values (variables and constants), and structure.

Functions (for controlling the Arduino board and performing computations)		
Advanced I/O	noTone() pulseInLong() shiftOut()	pulseIn() shiftIn() tone()
Analog I/O	analogRead() analogWrite()	analogReference()
Bits and Bytes	bit() bitRead() bitWrite() lowByte()	bitClear() bitSet highByte()
Characters	isAlpha() isAscii() isDigit() isHexadecimalDigit() isPrintable() isSpace() isLowerCase()	isAlphaNumeric() isControl() isGraph() isLowerCase() isPunct() isUpperCase()

Arduino Uno – Programming Language

Functions (for controlling the Arduino board and performing computations)		
Communication	Serial Stream	SPI Wire
Digital I/O	digitalRead() pinMode()	digitalWrite()
External Interrupts	attachInterrupt()	detachInterrupt()
Math	abs() map() min() sq()	constrain() max() pow() sqrt()
Random Numbers	random()	randomSeed()
Trigonometry	cos() tan()	sin()
USB	Keyboard	Mouse
Zero, Due & MKR Family	analogReadResolution()	analogWriteResolution()

Arduino Uno – Programming Language

Variables (Arduino data types and constants)		
Constants	HIGH | LOW LED_BUILTIN Floating Point Constants	INPUT | OUTPUT | INPUT_PULLUP true | false Integer Constants
Conversion	(unsigned int) byte() float() long()	(unsigned long) char() int() word()
Data Types	array boolean char float long size_t String() unsigned long word	bool byte double int short string unsigned int void
Variable Scope & Qualifiers	const static	scope volatile
Utilities	PROGMEM	sizeof()

Arduino Uno – Programming Language

Structure (The elements of Arduino (C++) code)		
Arithmetic Operators	% (remainder) + (addition) / (division)	* (multiplication) - (subtraction) = (assignment operator)
Bitwise Operators	& (bitwise and) >> (bitshift right) | (bitwise or)	<< (bitshift left) ^ (bitwise xor) ~ (bitwise not)
Boolean Operators	! (logical not) || (logical or)	&& (logical and)
Comparison Operators	!= (not equal to) <= (less than or equal to) > (greater than)	< (less than) == (equal to) > = (greater than or equal to)
Compound Operators	%= (compound remainder) *= (compound multiplication) += (compound addition) -= (compound subtraction) ^= (compound bitwise xor)	&= (compound bitwise and) ++ (increment) -- (decrement) /= (compound division) |= (compound bitwise or)

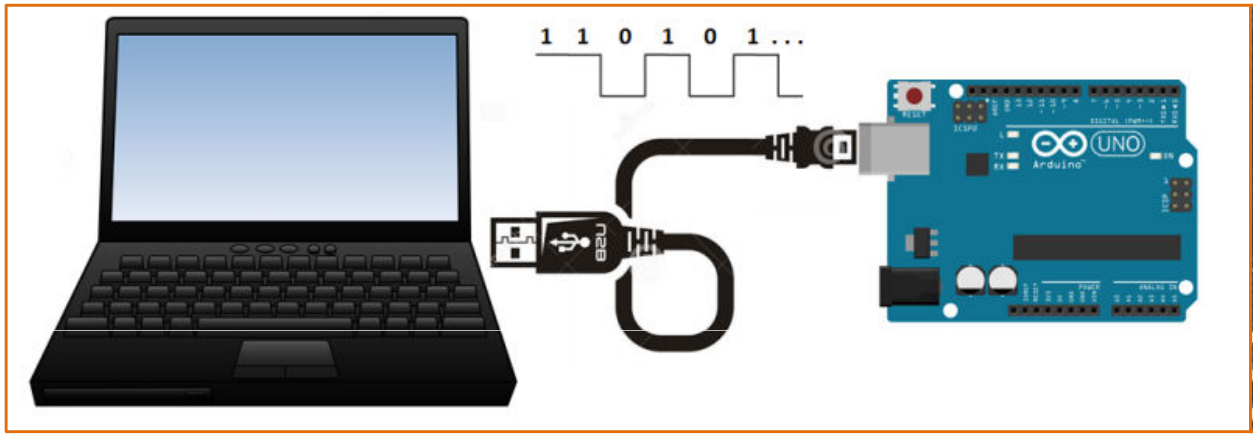
Arduino Uno – Programming Language

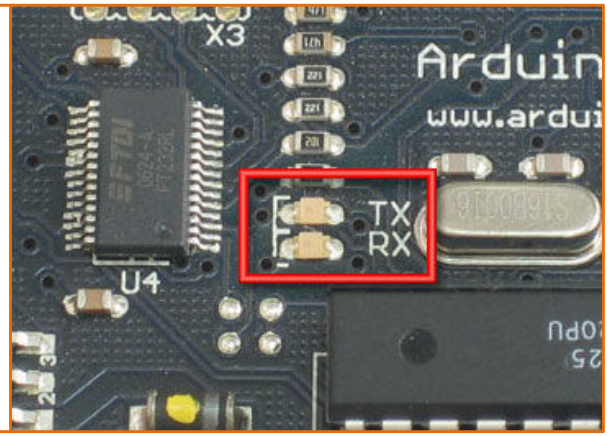
Structure (The elements of Arduino (C++) code)		
Control Structure	break do …while for if switch…case	continue else goto return while
Further Syntax	#define (define) /* */ (block comment) ; (semicolon)	#include (include) // (single line comment) {curly braces}
Pointer Access Operators	& (reference operator)	* (dereference operator)
Sketch	loop()	setup()

- Refer to https://www.arduino.cc/reference/en for detailed information.

Arduino Uno – Serial Communication

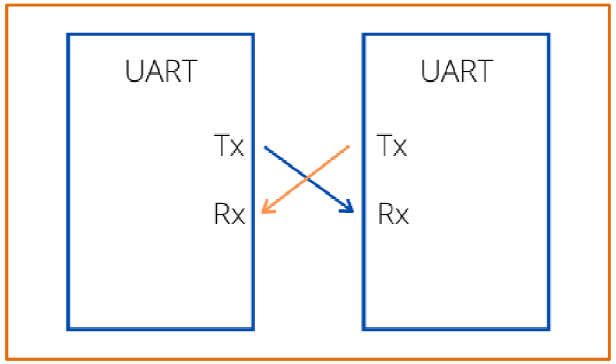
- RX LED blinks when the Arduino is receiving data.
- TX LED blinks when the Arduino is transmitting data.



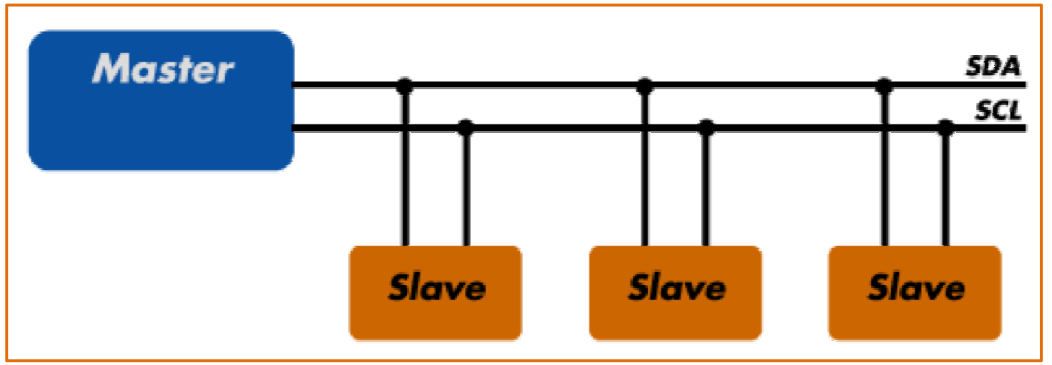


Arduino Uno – Serial Data Transfer

- Universal asynchronous receiver/transmitter (UART) is a hardware communication protocol that uses asynchronous serial communication with configurable speed.
- Serial Peripheral Interface (SPI) is a synchronous serial data protocol used by microcontrollers for communicating with one or more peripheral devices quickly over short distances. It can also be used for communication between two microcontrollers.
- Inter-integrated Circuit (I2C) or Two-Wire Interface (TWI) is a two-wire serial communication protocol for connecting low speed peripherals to a microcontroller or computer motherboard.



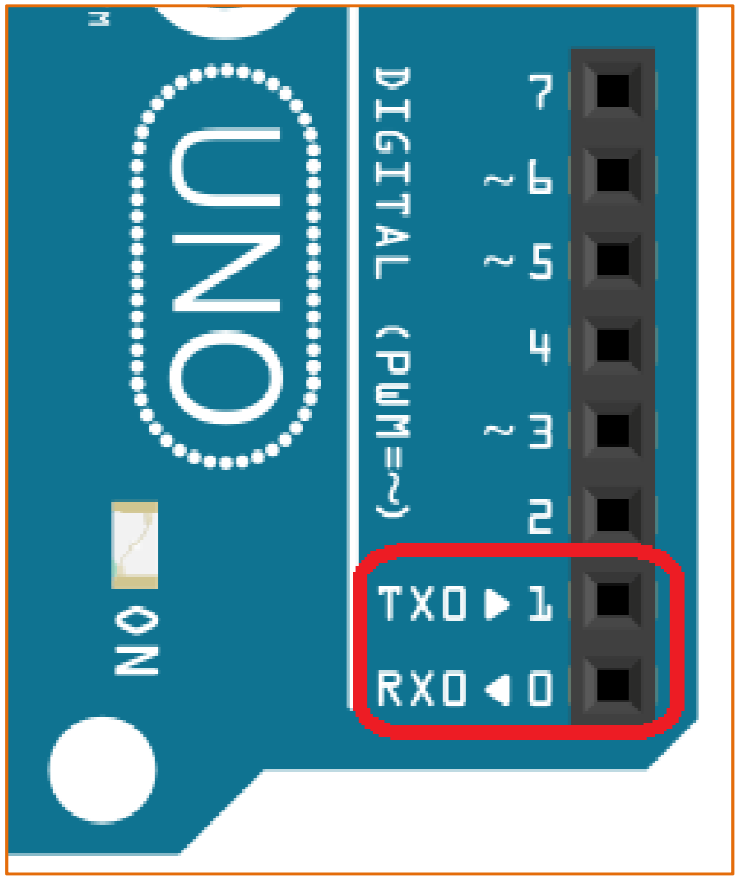
[UART device communication diagram]

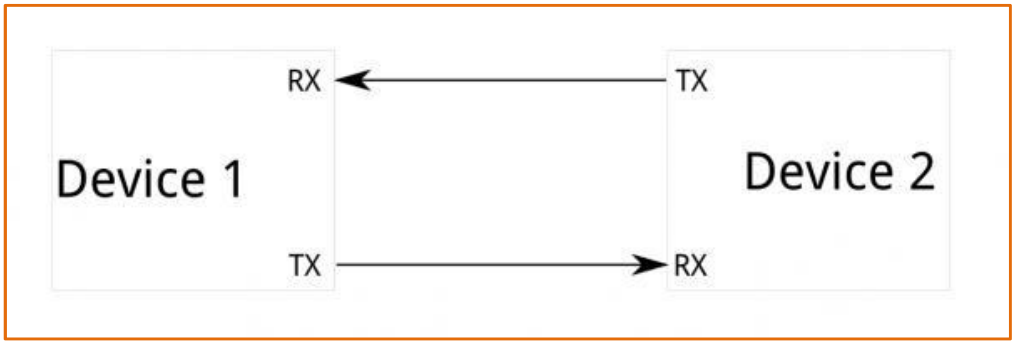


[I2C two wire bus layout]

Arduino Uno – UART

- All Arduino boards have **at least one serial port** (also known as a UART). It communicates on **digital pins 0 (RX) and 1 (TX)** between the Arduino board or other devices, as well as with the computer via **USB**.





Arduino Uno – SoftwareSerial Library

- The SoftwareSerial library allows serial communication on other digital pins of an Arduino board, using software to replicate the functionality (hence the name "SoftwareSerial").
- It is possible to have multiple software serial ports with speeds up to 115200 bps.
- To use this library: **`#include <SoftwareSerial.h>`**
- SoftwareSerial library has the following known limitations:
  - It cannot transmit and receive data at the same time.
  - If using multiple software serial ports, only one can receive data at a time.
  - Not all pins on the Mega and Mega 2560, the Leonardo and Micro boards support change interrupts
  - On Arduino or Genuino 101 boards the current maximum RX speed is 57600bps.
  - On Arduino or Genuino 101 boards RX doesn't work on digital pin 13.

THANK YOU ALL FOR LISTENING

QUESTIONS AND ANSWERS