

## Port Overview

PORT Name	Port Description
PORTB	<ul style="list-style-type: none"><li>• Microcontroller Pins: PB0-PB7</li><li>• 8 pins total, only PB0-PB5 are connected to Uno R3 header pins</li><li>• PB6 and PB7 are dedicated to the external clock crystal</li><li>• Functions: digital I/O, SPI interface, timer PWM (Pulse Width Modulation) outputs</li></ul>
PORTC	<ul style="list-style-type: none"><li>• Microcontroller Pins: PC0-PC6</li><li>• 7 pins, only PC0-PC5 are exposed</li><li>• PC6 is a RESET pin (used to restart the chip)</li><li>• Functions: ADC inputs, I2C communication, digital I/O</li></ul>
PORTD	<ul style="list-style-type: none"><li>• Microcontroller Pins: PD0-PD7</li><li>• Functions: UART (serial communication), external interrupts, timer PWM (Pulse Width Modulation), digital I/O</li></ul>

## Pin Overview

### Port B Pins

MCU Pin Name	Arduino Function	Arduino Header Pin
PB0	Digital 8	D8
PB1	Digital 9 (PWM)	D9
PB2	Digital 10 (PWM,SS)	D10
PB3	Digital 11 (PWM, MOSI)	D11
PB4	Digital 12 (MISO)	D12
PB5	Digital 13 (SCK / onboard LED)	D13
PB6	XTAL1 (Crystal input)	Not exposed to headers
PB7	XTAL2 (Crystal output)	Not exposed to headers

## Port C Pins

MCU Pin Name	Arduino Function	Arduino Header Pin
PC0	Analog 0	A0
PC1	Analog 1	A1
PC2	Analog 2	A1
PC3	Analog 3	A2
PC4	Analog 4 (A4 / SDA)	A3
PC5	Analog 5 (A5 / SCL)	A4
PC6	RESET	RESET

## Port D Pins

MCU Pin Name	Arduino Function	Arduino Header Pin
PD0	Digital 0 (RX)	D0
PD1	Digital 1 (TX)	D1
PD2	Digital 2	D2
PD3	Digital 3 (PWM)	D3
PD4	Digital 4	D4
PD5	Digital 5 (PWM)	D5
PD6	Digital 6 (PWM)	D6
PD7	ADC Power	D7

## Other pins

MCU Pin Name	Arduino Function	Arduino Header Pin
AVCC	ADC Power	+5V
AREF	Analog Reference	AREF
GND	Ground	GND
VCC	Power +5V	+5V

## Function Description

- PWM (Pulse Width Modulation) - A technique where a digital pin switches rapidly between HIGH and LOW to simulate an analog output
  - The pin is always either 5V (HIGH) or 0V (LOW), but the ratio of high time to low time changes
  - The ratio between HIGH time and LOW time is called duty cycle
  - Duty Cycle (%) =  $\frac{\text{Time HIGH}}{\text{Total period}} \times 100$

Duty Cycle	What it does	Average Voltage (5V system)
0%	Always LOW	0V
25%	High $\frac{1}{4}$ of the time	1.25V
50%	High $\frac{1}{2}$ of the time	2.5V
75%	High $\frac{3}{4}$ of the time	3.75V
100%	Always high	5V

- What is PWM used for
  - LED brightness control - Dim an LED smoothly by changing duty cycle
  - Motor speed control - More high time > motor pins faster
  - Analog-like voltage output - Can be filtered to make a steady voltage for circuits
  - Audio / tone generation - Rapid PWM can generate sound frequencies for buzzers for speakers
- SS (Slave Select) - A digital control line used in SPI communications. This pin is used by the master to tell a specific slave that the master wants to communicate with them

- MOSI (Master Out, Slave In)
  - Used in SPI Communication
  - This is the line where the master sends data to the slave
  - Example: Master sends a byte to an SPI sensor
- MISO (Master In, Slave Out)
  - Used in SPI communication
  - This is the line where the slaves sends data back to the master
  - Example: Sensor sends a reading back to Arduino
- SCK (Serial Clock)
  - Clock line for SPI
  - The master generates this clock to synchronize data transfer on MOSI and MISO
  - Data is only valid on clock edges, so timing is controlled by SCK
- Crystal Input
  - Pins for the external crystal oscillator
  - Provide the microcontroller with a stable clock
  - Not exposed as headers - used internally to run the MCU at precise timing
- SDA (Serial Data)
  - Used in I2C communication
  - Carries the data line for all I2C devices on the bus
  - Can be used to talk to sensors, displays, or other microcontrollers over I2C
- SCL (Serial Clock)
  - Clock line for I2C
  - Master generates this clock to synchronize data on SDA
- RX (Receive)
  - Serial UART receive pin
  - Reads incoming data from another device over UART/Serial
  - Example: Receiving data from a computer or GPS module
- TX (Transmit)
  - Serial UART transmit pin
  - Sends data to another device over UART/Serial
  - Example: Sending sensor readings to a computer
- ADC (Analog-to-Digital Converter)
  - Converts an analog voltage into a digital number
  - ATmega328P has 10-bit ADC, so 0-1023 values correspond to 0-5V
  - Example: Reading a potentiometer