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Escuela de Ingeniería Eléctrica

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Título: GPIO, ADC y comunicaciones

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1. Resumen

2. Nota teórica

En esta sección del laboratorio, se exponen los principales componentes que usarán para el proyecto a realizar: un voltímetro.

Arduino UNO

Se usará la placa de Arduino UNO que posee el microcontrolador ATmega328P.

Características generales

Sus detalles se describen a continuación:

- Es un MCU de 8 bits.
- Posee arquitectura RISC/Harvard.
- 4/8/16/64 kb memoria flash.
- 512b/1/2kb de memoria SRAM.
- 1/2kb de EEPROM.
- 23 GPIOs.
- Timer/Counters de 8 y 16 bits.
- Posee interrupciones.
- 8 canales PWM y comparador analógico.
- 6 canales 10-bit ADC.
- Posee protocolo SPI y USART (Universal Synchronous/Asynchronous Receiver/Transmitter) I2C.

Diagrama de bloques y pines

El diagrama de bloques de este MCU se muestra en la figura 1.

Fig. 1. Block Diagram

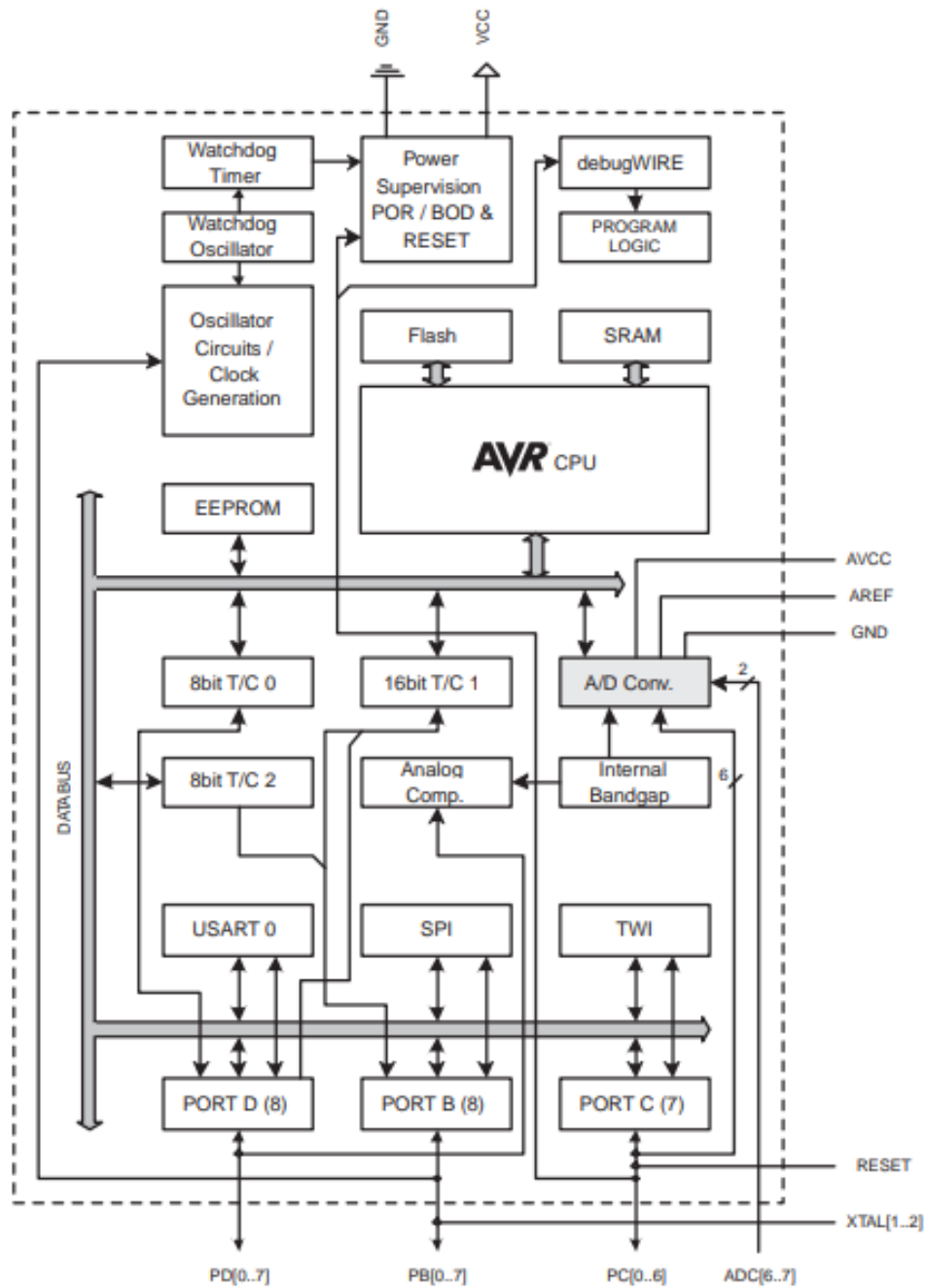


Figura 1: Diagrama de bloques de ATmega328P. Tomado de [1].

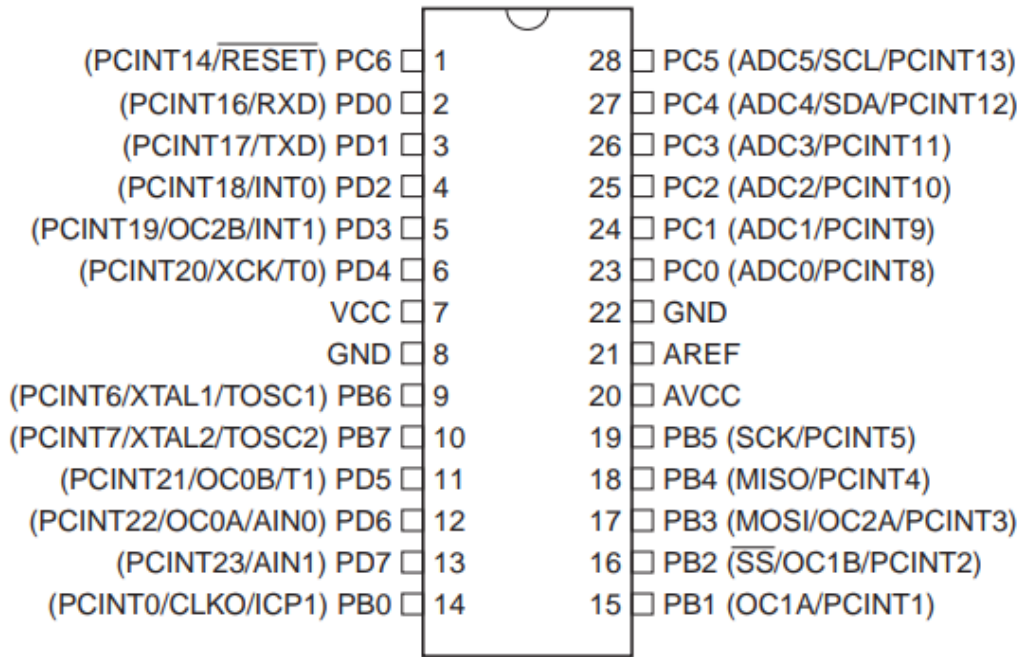


Figura 2: Diagrama de pines de ATmega328P. Tomado de [1].

Características eléctricas

La siguiente lista describe estos detalles.

- Voltaje: 1.8-5,5 V.
- Velocidad: 0-4 MHz, 1.8-5,5 V. 0-10 MHz, 2.7-5,5 V. 0-20 MHz, 4.5-5,5 V
- Modo activo: 0,3 mA
- Temperatura de funcionamiento: -55° a $+125^{\circ}$.
- Temperatura de almacenamiento: -65° a $+125^{\circ}$.
- Temperatura pin RESET y GND: -0,5 V a 13 V.
- Temperatura en los demás pines: -0,5 V a VCC0,5 V.
- Corriente por pin I/O: 40 mA.

Periféricos utilizados

Algunos periféricos usados del microcontrolador así como la pantalla PCD8544 fueron los siguientes:

- **pinMode:** esto se usó para cual pin era una entrada o salida, y esto ayuda para que el microcontrolador entienda todas las acciones que se desea realizar.
- **digitalWrite:** básicamente su función es para establecer el estado de una variable después de una acción, típicamente es para poner en alto o en bajo una señal.

- **analogRead:** esto devuelve el valor leído del pin de entrada analógico, el valor es proporcional a la entrada analógica tomando como base una tensión de referencia: 0-1023.
- **display.begin:** inicia/enciende la pantalla.
- **display.setContrast:** configuración del contraste de la pantalla.
- **display.clearDisplay:** limpia la pantalla.
- **display.setTextSize:** configura la posición del texto.
- **display.setTextColor:** establece el color de las letras.
- **display.setCursor:** este parámetro sirve para posicionar el texto en la pantalla.
- **display.println:** imprime el contenido deseado.
- **display.display:** imprime el logo de Adafruit y se coloca después de cada texto, de lo contrario no se mostrará el contenido.

Si bien, se debe mencionar que la pantalla PCD8544 desempeña un papel importante en este trabajo, porque permite mostrar las magnitudes de las tensiones eléctricas en las fuentes de alimentación, tanto para modo DC como AC. Por tanto, hay que conocer los pines que se usaron para darle sentido a los periféricos mencionados anteriormente. En el simulador se tienen 5 pines que se explican a continuación [2].

- **RST:** esta señal reiniciará el dispositivo y debe ser aplicado adecuadamente al chip. La señal activa está en bajo.
- **CS:** habilita la pantalla con el que se está comunicando en un bus SPI. Cuando esta señal está activa, el PCD8544 está habilitado y listo para recibir comandos o datos a través del bus SPI. Cuando la señal CS está inactiva, la pantalla no responde y no acepta datos.
- **D/C:** selecciona el modo de operación, alto o bajo.
- **DIN:** es una entrada para la línea de datos.
- **CLK:** es la señal de reloj que va de 0.0 a 4.0 Mbit/s.

Por lo que, los datos que se muestran en la pantalla PCD8544 es porque se usa el modelo de comunicaciones SPI: **Serial Peripheral Interface**, es un bus de interfaz comúnmente utilizado para enviar datos entre microcontroladores y pequeños periféricos como registros de desplazamiento, sensores y tarjetas SD [?].

Componentes electrónicos complementarios

Lista de componentes

Tabla 1: Lista de equipos

Componente	Cantidad	Precio
Arduino UNO	1	—
Kit de resistencias	1	—
Capacitancias	1	—
LEDs	4	—
Pantalla PCD8544	1	—
Botón	9	—
Amplificadores	4	—
RelaySPST	1	—
Fuentes de voltaje	8	—
Fuentes de senoidales	4	—
Capacitor	1	—
Total		

Diseño del circuito

El circuito que simula el voltímetro se muestra en la figura 3.

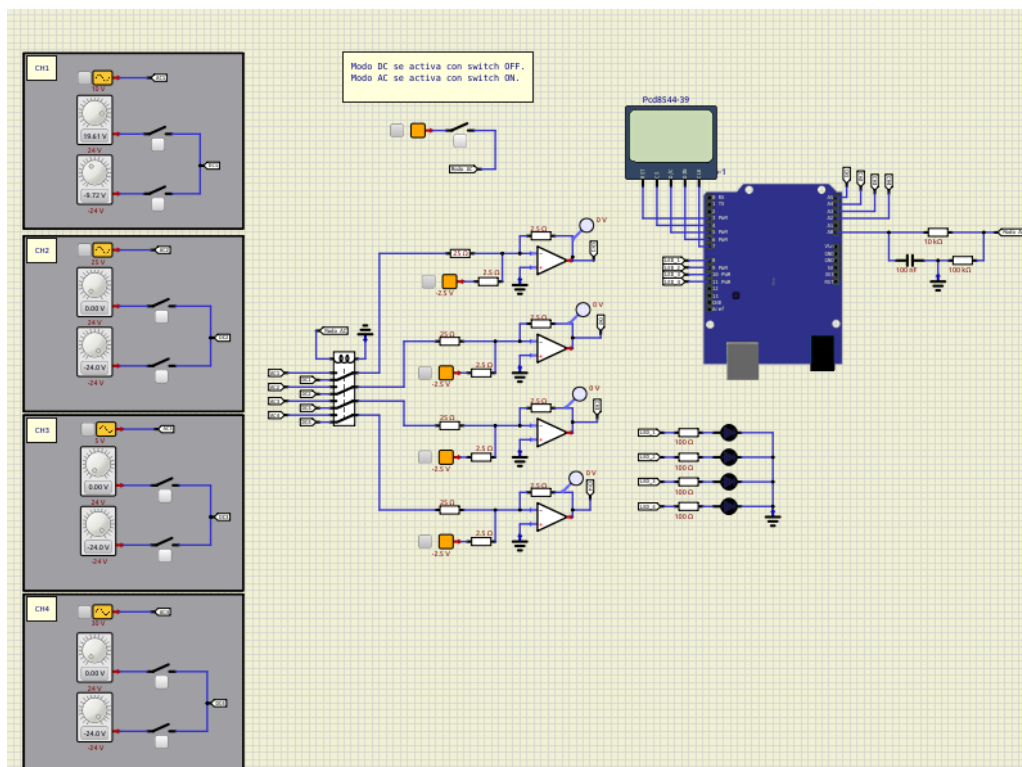


Figura 3: Circuito del voltímetro

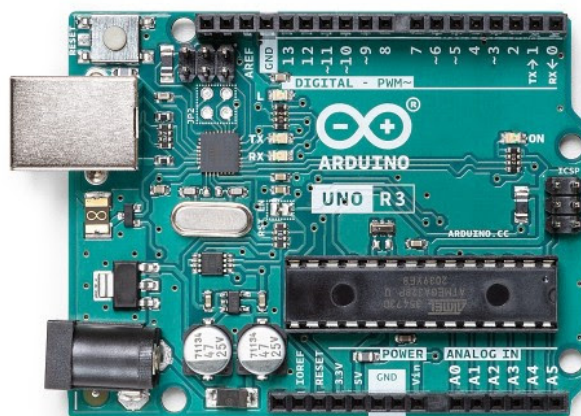
3. Desarrollo/Análisis
4. Conclusiones y recomendaciones

Referencias

- [1] Arduino UNO. Datasheet arduino uno. Arduino UNO, <https://docs.arduino.cc/resources/datasheets/A000066-datasheet.pdf>, julio 2014. Accedido en enero de 2024.
- [2] Sparkfun. Datasheet pcd8544. SparkfunO, <https://www.sparkfun.com/datasheets/LCD/Monochrome/Nokia5110.pdf>, noviembre 2008. Accedido en enero de 2024.

5. Anexos

Aquí van las hojas del fabricante de los componentes usados para este laboratorio.



Description

The Arduino UNO R3 is the perfect board to get familiar with electronics and coding. This versatile development board is equipped with the well-known ATmega328P and the ATmega 16U2 Processor. This board will give you a great first experience within the world of Arduino.

Target areas:

Maker, introduction, industries

Features

- **ATMega328P Processor**
 - **Memory**
 - AVR CPU at up to 16 MHz
 - 32KB Flash
 - 2KB SRAM
 - 1KB EEPROM
 - **Security**
 - Power On Reset (POR)
 - Brown Out Detection (BOD)
 - **Peripherals**
 - 2x 8-bit Timer/Counter with a dedicated period register and compare channels
 - 1x 16-bit Timer/Counter with a dedicated period register, input capture and compare channels
 - 1x USART with fractional baud rate generator and start-of-frame detection
 - 1x controller/peripheral Serial Peripheral Interface (SPI)
 - 1x Dual mode controller/peripheral I2C
 - 1x Analog Comparator (AC) with a scalable reference input
 - Watchdog Timer with separate on-chip oscillator
 - Six PWM channels
 - Interrupt and wake-up on pin change
- **ATMega16U2 Processor**
 - 8-bit AVR® RISC-based microcontroller
- **Memory**
 - 16 KB ISP Flash
 - 512B EEPROM
 - 512B SRAM
 - debugWIRE interface for on-chip debugging and programming
- **Power**
 - 2.7-5.5 volts



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1 The Board

1.1 Application Examples

The UNO board is the flagship product of Arduino. Regardless if you are new to the world of electronics or will use the UNO as a tool for education purposes or industry-related tasks, the UNO is likely to meet your needs.

First entry to electronics: If this is your first project within coding and electronics, get started with our most used and documented board; Arduino UNO. It is equipped with the well-known ATmega328P processor, 14 digital input/output pins, 6 analog inputs, USB connections, ICSP header and reset button. This board includes everything you will need for a great first experience with Arduino.

Industry-standard development board: Using the Arduino UNO R3 board in industries, there are a range of companies using the UNO board as the brain for their PLC's.

Education purposes: Although the UNO R3 board has been with us for about ten years, it is still widely used for various education purposes and scientific projects. The board's high standard and top quality performance makes it a great resource to capture real time from sensors and to trigger complex laboratory equipment to mention a few examples.

1.2 Related Products

- Starter Kit
- Arduino UNO R4 Minima
- Arduino UNO R4 WiFi
- Tinkerkit Braccio Robot



2 Ratings

2.1 Recommended Operating Conditions

Symbol	Description	Min	Max
	Conservative thermal limits for the whole board:	-40 °C (-40°F)	85 °C (185°F)

NOTE: In extreme temperatures, EEPROM, voltage regulator, and the crystal oscillator, might not work as expected.

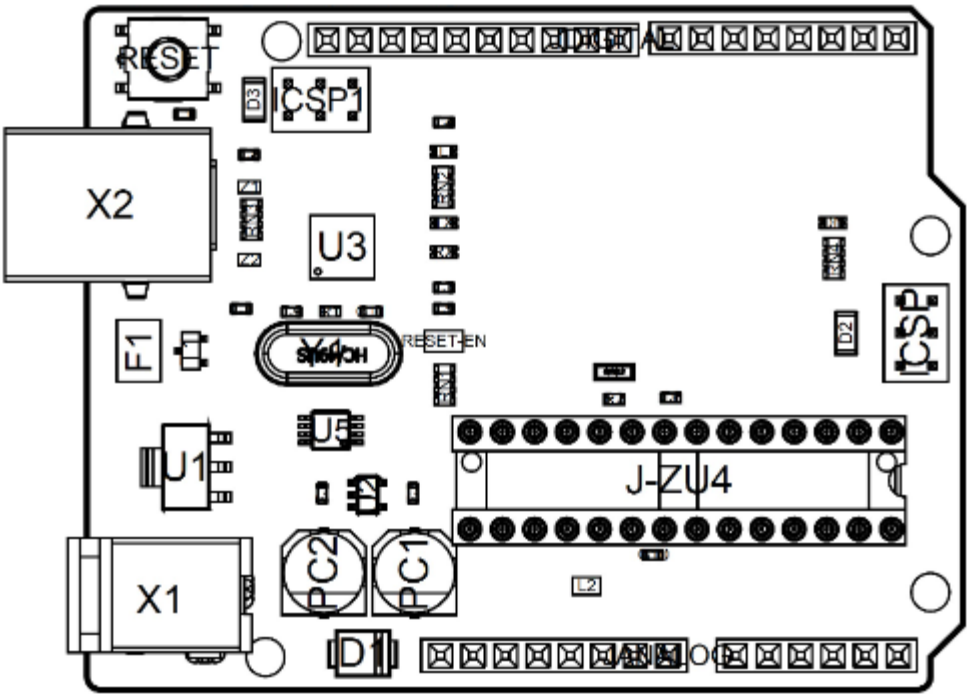
2.2 Power Consumption

Symbol	Description	Min	Typ	Max	Unit
VINMax	Maximum input voltage from VIN pad	6	-	20	V
VUSBMax	Maximum input voltage from USB connector		-	5.5	V
PMax	Maximum Power Consumption	-	-	xx	mA

3 Functional Overview

3.1 Board Topology

Top view



Board topology

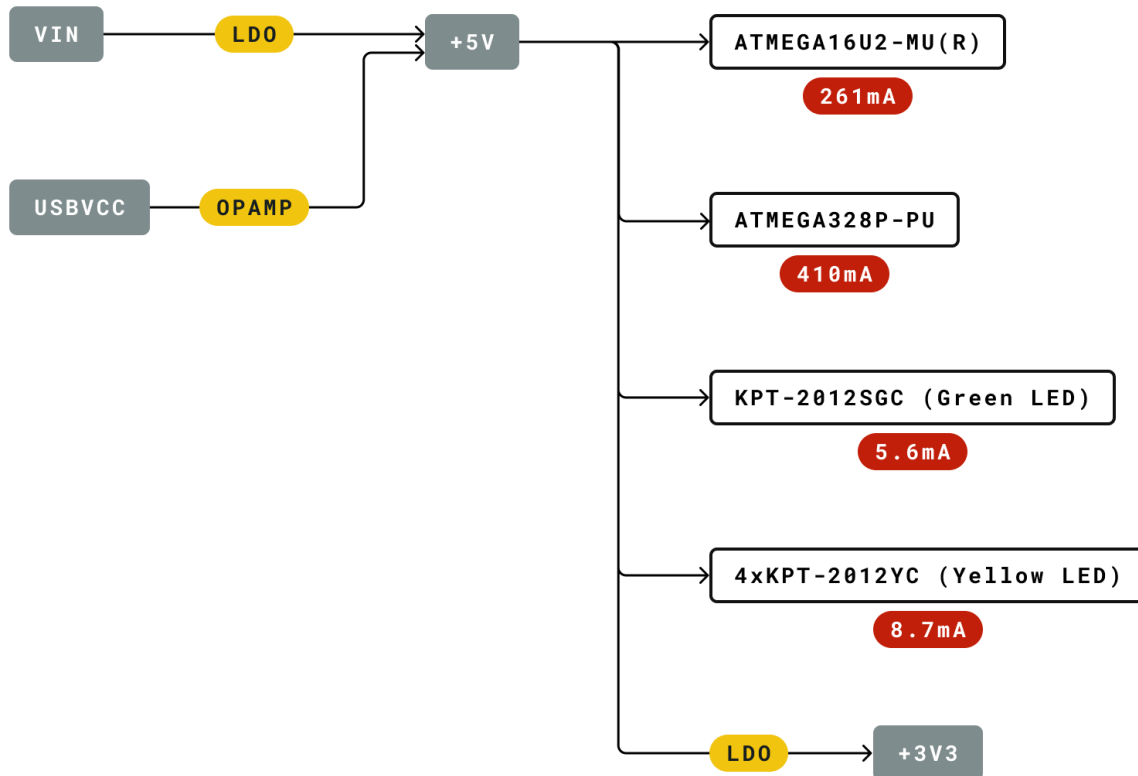


Ref.	Description	Ref.	Description
X1	Power jack 2.1x5.5mm	U1	SPX1117M3-L-5 Regulator
X2	USB B Connector	U3	ATMEGA16U2 Module
PC1	EEE-1EA470WP 25V SMD Capacitor	U5	LMV358LIST-A.9 IC
PC2	EEE-1EA470WP 25V SMD Capacitor	F1	Chip Capacitor, High Density
D1	CGRA4007-G Rectifier	ICSP	Pin header connector (through hole 6)
J-ZU4	ATMEGA328P Module	ICSP1	Pin header connector (through hole 6)
Y1	ECS-160-20-4X-DU Oscillator		

3.2 Processor

The Main Processor is a ATmega328P running at up to 20 MHz. Most of its pins are connected to the external headers, however some are reserved for internal communication with the USB Bridge coprocessor.

3.3 Power Tree



Legend:

Component

Power I/O

Conversion Type

Max Current

Voltage Range

Power tree



4 Board Operation

4.1 Getting Started - IDE

If you want to program your Arduino UNO R3 while offline you need to install the Arduino Desktop IDE [1] To connect the Arduino UNO to your computer, you'll need a USB-B cable. This also provides power to the board, as indicated by the LED.

4.2 Getting Started - Arduino Web Editor

All Arduino boards, including this one, work out-of-the-box on the Arduino Web Editor [2], by just installing a simple plugin.

The Arduino Web Editor is hosted online, therefore it will always be up-to-date with the latest features and support for all boards. Follow [3] to start coding on the browser and upload your sketches onto your board.

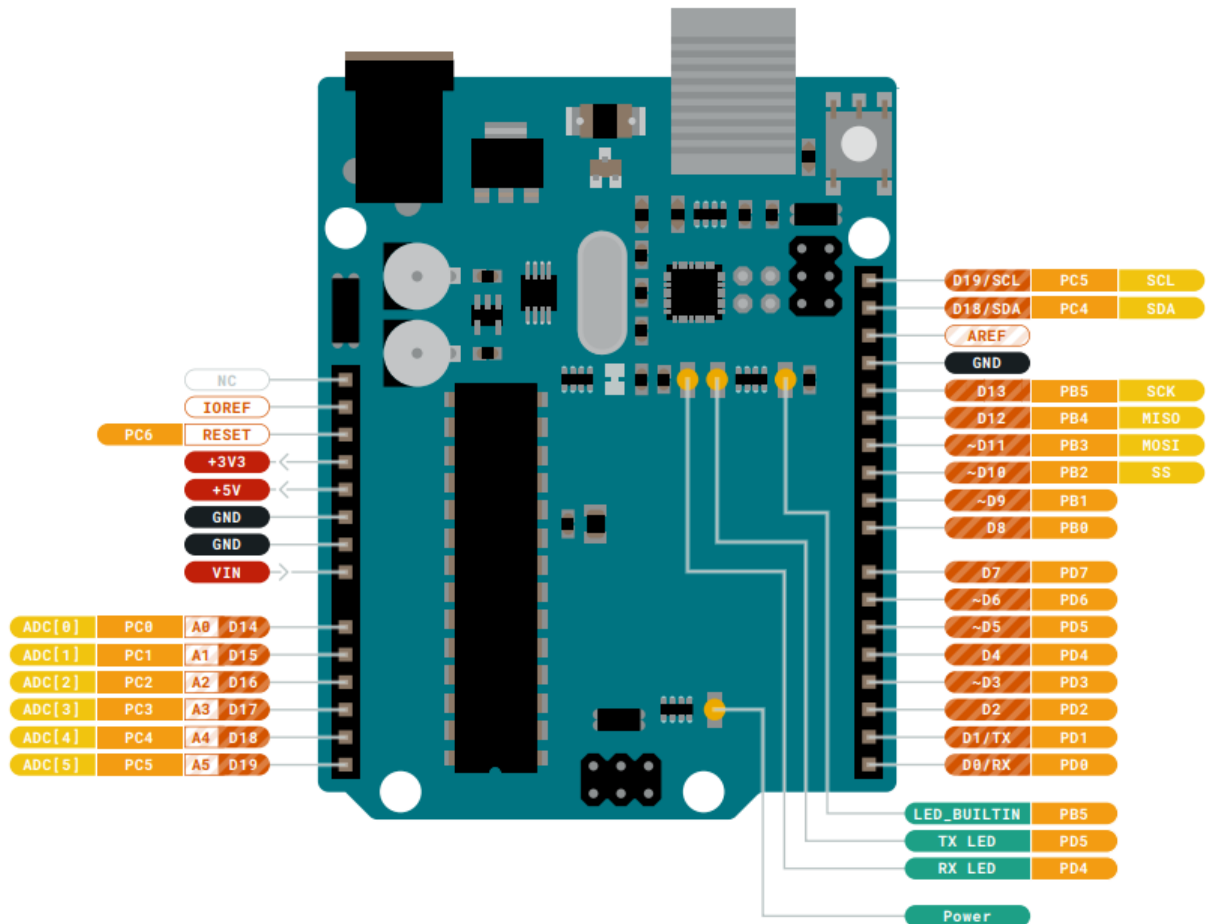
4.3 Sample Sketches

Sample sketches for the Arduino UNO R3 can be found either in the "Examples" menu in the Arduino IDE or in the "Documentation" section of the Arduino website [4]

4.4 Online Resources

Now that you have gone through the basics of what you can do with the board you can explore the endless possibilities it provides by checking exciting projects on Arduino Project Hub [5], the Arduino Library Reference [6] and the online Arduino store [7] where you will be able to complement your board with sensors, actuators and more.

5 Connector Pinouts



Pinout

5.1 JANALOG

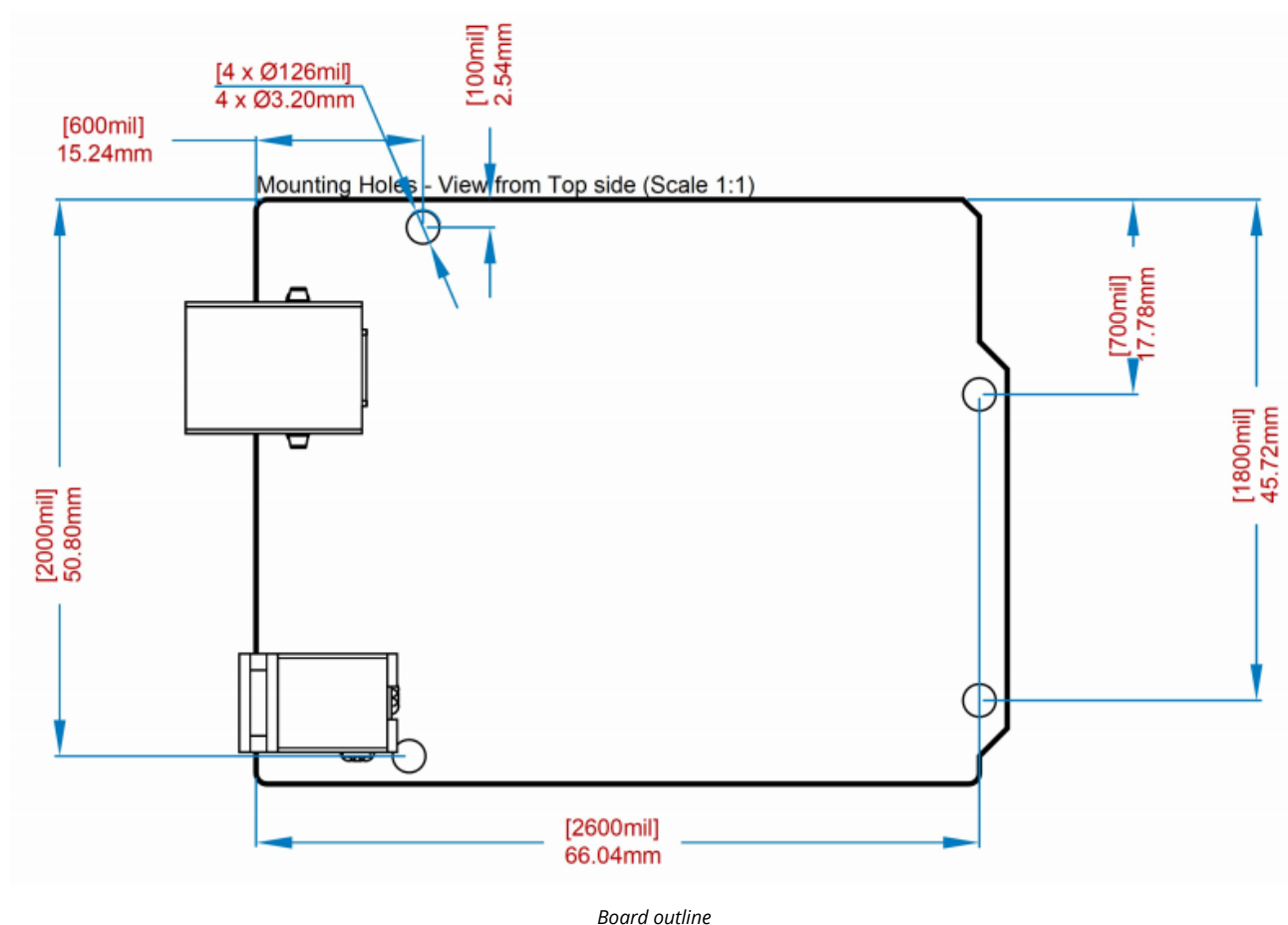
Pin	Function	Type	Description
1	NC	NC	Not connected
2	IOREF	IOREF	Reference for digital logic V - connected to 5V
3	Reset	Reset	Reset
4	+3V3	Power	+3V3 Power Rail
5	+5V	Power	+5V Power Rail
6	GND	Power	Ground
7	GND	Power	Ground
8	VIN	Power	Voltage Input
9	A0	Analog/GPIO	Analog input 0 /GPIO
10	A1	Analog/GPIO	Analog input 1 /GPIO
11	A2	Analog/GPIO	Analog input 2 /GPIO
12	A3	Analog/GPIO	Analog input 3 /GPIO
13	A4/SDA	Analog input/I2C	Analog input 4/I2C Data line
14	A5/SCL	Analog input/I2C	Analog input 5/I2C Clock line

5.2 JDIGITAL

Pin	Function	Type	Description
1	D0	Digital/GPIO	Digital pin 0/GPIO
2	D1	Digital/GPIO	Digital pin 1/GPIO
3	D2	Digital/GPIO	Digital pin 2/GPIO
4	D3	Digital/GPIO	Digital pin 3/GPIO
5	D4	Digital/GPIO	Digital pin 4/GPIO
6	D5	Digital/GPIO	Digital pin 5/GPIO
7	D6	Digital/GPIO	Digital pin 6/GPIO
8	D7	Digital/GPIO	Digital pin 7/GPIO
9	D8	Digital/GPIO	Digital pin 8/GPIO
10	D9	Digital/GPIO	Digital pin 9/GPIO
11	SS	Digital	SPI Chip Select
12	MOSI	Digital	SPI1 Main Out Secondary In
13	MISO	Digital	SPI Main In Secondary Out
14	SCK	Digital	SPI serial clock output
15	GND	Power	Ground
16	AREF	Digital	Analog reference voltage
17	A4/SD4	Digital	Analog input 4/I2C Data line (duplicated)
18	A5/SD5	Digital	Analog input 5/I2C Clock line (duplicated)

5.3 Mechanical Information

5.4 Board Outline & Mounting Holes



6 Certifications

6.1 Declaration of Conformity CE DoC (EU)

We declare under our sole responsibility that the products above are in conformity with the essential requirements of the following EU Directives and therefore qualify for free movement within markets comprising the European Union (EU) and European Economic Area (EEA).

ROHS 2 Directive 2011/65/EU	
Conforms to:	EN50581:2012
Directive 2014/35/EU. (LVD)	
Conforms to:	EN 60950-1:2006/A11:2009/A1:2010/A12:2011/AC:2011
Directive 2004/40/EC & 2008/46/EC & 2013/35/EU, EMF	
Conforms to:	EN 62311:2008

6.2 Declaration of Conformity to EU RoHS & REACH 211 01/19/2021

Arduino boards are in compliance with RoHS 2 Directive 2011/65/EU of the European Parliament and RoHS 3 Directive 2015/863/EU of the Council of 4 June 2015 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

Substance	Maximum limit (ppm)
Lead (Pb)	1000
Cadmium (Cd)	100
Mercury (Hg)	1000
Hexavalent Chromium (Cr6+)	1000
Poly Brominated Biphenyls (PBB)	1000
Poly Brominated Diphenyl ethers (PBDE)	1000
Bis(2-Ethylhexyl} phthalate (DEHP)	1000
Benzyl butyl phthalate (BBP)	1000
Dibutyl phthalate (DBP)	1000
Diisobutyl phthalate (DIBP)	1000

Exemptions: No exemptions are claimed.

Arduino Boards are fully compliant with the related requirements of European Union Regulation (EC) 1907 /2006 concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH). We declare none of the SVHCs (<https://echa.europa.eu/web/guest/candidate-list-table>), the Candidate List of Substances of Very High Concern for authorization currently released by ECHA, is present in all products (and also package) in quantities totaling in a concentration equal or above 0.1%. To the best of our knowledge, we also declare that our products do not contain any of the substances listed on the "Authorization List" (Annex XIV of the REACH regulations) and Substances of Very High Concern (SVHC) in any significant amounts as specified by the Annex XVII of Candidate list published by ECHA (European Chemical Agency) 1907 /2006/EC.

6.3 Conflict Minerals Declaration

As a global supplier of electronic and electrical components, Arduino is aware of our obligations with regards to laws and regulations regarding Conflict Minerals, specifically the Dodd-Frank Wall Street Reform and Consumer Protection Act, Section 1502. Arduino does not directly source or process conflict minerals such as Tin, Tantalum, Tungsten, or Gold. Conflict minerals are contained in our products in the form of solder, or as a component in metal alloys. As part of our reasonable due diligence Arduino has contacted component suppliers within our supply chain to verify their continued compliance with the regulations. Based on the information received thus far we declare that our products contain Conflict Minerals sourced from conflict-free areas.

7 FCC Caution

Any Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

- (1) This device may not cause harmful interference
- (2) this device must accept any interference received, including interference that may cause undesired operation.

FCC RF Radiation Exposure Statement:

1. This Transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.
2. This equipment complies with RF radiation exposure limits set forth for an uncontrolled environment.
3. This equipment should be installed and operated with minimum distance 20cm between the radiator & your body.

English: User manuals for license-exempt radio apparatus shall contain the following or equivalent notice in a conspicuous location in the user manual or alternatively on the device or both. This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions:

- (1) this device may not cause interference
- (2) this device must accept any interference, including interference that may cause undesired operation of the device.

French: Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes :

- (1) l'appareil ne doit pas produire de brouillage
- (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

IC SAR Warning:

English This equipment should be installed and operated with minimum distance 20 cm between the radiator and your body.



French: Lors de l'installation et de l'exploitation de ce dispositif, la distance entre le radiateur et le corps est d'au moins 20 cm.

Important: The operating temperature of the EUT can't exceed 85°C and shouldn't be lower than -40°C.

Hereby, Arduino S.r.l. declares that this product is in compliance with essential requirements and other relevant provisions of Directive 2014/53/EU. This product is allowed to be used in all EU member states.

8 Company Information

Company name	Arduino S.r.l
Company Address	Via Andrea Appiani 25 20900 MONZA Italy

9 Reference Documentation

Reference	Link
Arduino IDE (Desktop)	https://www.arduino.cc/en/Main/Software
Arduino IDE (Cloud)	https://create.arduino.cc/editor
Cloud IDE Getting Started	https://create.arduino.cc/projecthub/Arduino_Genuino/getting-started-with-arduino-web-editor-4b3e4a
Arduino Website	https://www.arduino.cc/
Project Hub	https://create.arduino.cc/projecthub?by=part&part_id=11332&sort=trending
Library Reference	https://www.arduino.cc/reference/en/
Online Store	https://store.arduino.cc/

10 Revision History

Date	Revision	Changes
26/07/2023	2	General Update
06/2021	1	Datasheet release