v. 1, n. 1, 2021

Journal of
Engineering
Research

WATER QUALITY MONITORING THROUGH ARDUINO ROBOTIC SENSORS

Lorenzo Domarco Silva
FEIS-UNESP

Christiane M. Schweitzer
FEIS-UNESP

Elerson Gaetti Jardim Júnior
FOA-UNESP

Abstract: The number of applications aimed at the Internet of Things has increased significantly, and this approach is directly linked to the Fourth Industrial Revolution or at least we are on the verge of it, in which the "worlds of production and network connectivity are integrated through these technologies to become a reality"1. Combining Internet of Things (IoT) and cyber-physical systems, remote sensing has also been widely used and in different areas of monitoring, collecting and analyzing data from remote locations. The present work comes exactly at this point, developing national technology in IoT, aiming at the construction of an "Automated Mechatronicsystem with Own Generation of Energy for Real-Time Distance Water Quality Analysis". This system is a solution for various spheres besides providing care with water, the most important human benefit that exists on the planet, aims at the use of low-cost materials in the manufacturing process. This project aims to develop a low cost system for monitoring water quality in real time in an IoT environment. The developed system has a wide range of applications in the process of water quality analysis. In the areas of Aquaculture and Hydrology, monitoring of the environment and water resources, in obtaining data for Medicine, Environmental Management, among others.
Keywords: Water quality, robotics, IoT.

INTRODUCTION

We are living in the Fourth Industrial Revolution, or at the very least, we are on the verge of it, in which the "worlds of production and network connectivity are integrated through IoT ((Internet of Things, Internet of Things) and CPS (Cyber Physical Systems, Cyber Physical Systems)) to make Industry 4.0 a reality" according to GTAI 2014 (Germany Trade & Investis The economic development agency of the Federal Republic of Germany). During the first Industrial Revolution, mechanical production facilities were developed with the help of water and During the Second Industrial Revolution, mass production was carried out with the help of electricity. During the Third Industrial Revolution, electronic and information technologies were introduced to promote the automation of production. taking into account comparisons between other revolutions, there is no way to escape from means that improve both the well-being of humanity and efficiency of their productive means.

A term intrinsic to the Fourth Industrial Revolution and fundamental to guide this work is IoT, which can be defined as "a dynamic global network infrastructure, with self-configuration resources, based on standard and interoperable communication protocols, where physical and 'Things' virtual have identities, physical attributes and virtual personalities, use intelligent interfaces and are seamlessly integrated into the information network". (KRANENBURG, 2018).

In recent years, IoT has emerged as a promising technology framework used to integrate and extend manufacturing and automation processes like many others at the intra- and Inter-organizational levels. This emergence of IoT was fueled by the recent development in ICT (Information and Communications Technology). These technological developments will be and already are a way to provide a variety of solutions for the growing information needs in industries. This feasibility of implementation was evidenced by the sudden increase of companies around the world that exploit the benefits of digitization in horizontal and vertical chains of the same adopting Industry 4.0 in step of becoming leading digital companies in the complex industrial ecosystems of tomorrow. (Xu, et.al; ALVES & VENDRAMINI, 2016).

Using the '19th Annual Global CEO Survey' by the well-known PwC, or 'Pricewaterhouse Coopers', globally, companies plan to invest US$907 billion a year in the application of IoT in the industry. These investments are focused on digital technologies (such as sensors or connectivity devices), software and applications (manufacturing execution systems, for example), employee training, and driving organizational change. (ALVES & VENDRAMINI, 2016).

Brazilian companies currently invest little in IoT – only 1 in 10 invest more than 8% of their revenues – but this number is expected to double in the next five years. At the same time, 63% expect a return on their investment within two years. The present work comes exactly at this point, seeking to develop national technology in IoT, envisioning the impacts and projections already mentioned, but in line with sectors that are not yet so inserted in this digitalized medium. In this particular case, the investment in knowledge falls on the areas of Aquaculture and Hydrology, with consequent advances in obtaining data for Medicine, Environmental Management, among others. (ALVES & VENDRAMINI, 2016).

The project on which the report is being discussed deals with the construction of the rig or even the "Automated Mechatronic System with Own Power Generation for Remote Water Quality Analysis in Real Time", which is part of the use of technology as a tool for the development of science and monitoring. It would be a solution for several spheres, in addition to providing care with water, a very precious asset to our planet, aiming to take advantage of and minimize the release of resources for an action, whether research or manufacturing.

In addition, given the moment of pandemic, the importance of the probe is clear in view of its capacity for continuous monitoring and without human intervention (according to, better explained later), not by a global trend governed by Industry 4.0 and the expansion of the employment of the IoT, but to predict contagion and spread of diseases.

Reality shows how vulnerable society is to the spread of diseases, in this case COVID-19 is transmitted through the air, among other means. The monitoring of water parameters can represent a future safety and prevention of pathologies that are found in water environments and still do not have clear connections to its physical-chemical parameters.

FIELD OF USE

The present invention refers to an unmanned platform or probe that has a set of embedded electronic sensors in order to monitor physical-chemical parameters of an aqueous volume or region, being able to remotely send this collected data without the need for a source external electrical energy to power the device.

The fact that the rig can carry out its measurement activities for an uninterrupted long term of days, weeks or even months, as detailed in the relevant parts of this report, allows the continuous collection and sending of information in a sampling period never before carried out. Unlike current instruments that have the time bottleneck in operational load and management while the on-site manipulator provides punctual data, the then new system will bring the understanding of more complex phenomena linked to seasonality and non-immediate processes.

Its applications in the analysis of artificial reservoirs to natural hydrographic formations are numerous, including:

- Medicine, for example, checking the behavior of diseases linked to said parameters in the water in the reservoirs in real time;

• Environmental Management, for example checking changes caused by dumping of waste in water courses in real time;

• Aquaculture, for example monitoring and interfering in real time with the management of pH and oxygenation levels in the region raising fish, shellfish etc., and so on. for growing natural products. These data can be linked to studies that seek better efficiency and productivity.

• Hydrology, for example providing data for academic research directly linked to the area in real time and for long periods of measurement;

• Industry, monitoring of water resources admitted and discharged.

STATUS OF TECHNIQUE (WHAT IS KNOWN)

Devices consisting of electronic sensors for analyzing water quality require a specialized manipulator to move around the region every time a measurement is to be carried out, whether it is on the edge of a hydrographic formation or an artificial reservoir. Later, while the device has its battery banks at an operating charge level, the measurements are carried out and the data must still be recorded by the device handler, and following the generic procedure, we have a manual conversion to digital language for the purpose of manipulation demanded by academic studies and complex aquaculture management.

In the most modern devices, we have observed a trend towards adopting M2M (machine to machine, or machine to machine in Portuguese) technology for sending data from the sensor to a Web server and simplifying the process of annotating and subsequent sending . In these measuring devices there is a requirement that the user carry the sensor (reasons for charging the batteries, positioning and activating the sensor), and using this the activation of the commands is also carried out on the device itself. In other words, the decision of commands, including sending data over great distances, is done manually and in person, so not remotely.

The combination of 'communications' (M2M) and the use of low-cost sensors, internet connections and processors proves to be a promising and growing field. This 'machine to machine' link, linked to the composite architecture of sensors and triggers in 'Network' networks, form the philosophy of the IoT. Among many potential benefits, M2M and IoT technologies allow remote monitoring of people, assets or a location where manual monitoring is not economically viable, or costs can be significantly reduced using automated monitoring as opposed to manual techniques. Today, prominent examples include vending machines, automobiles, alarm systems and remote sensors. Today's fast-growing markets for M2M applications include tracking devices for containers or pallets, healthcare applications such as remote monitoring of a person's glucose levels or heart rate, monitoring of field-implanted industrial equipment and security systems.

As much as we already have advanced water quality reading sensors with connectivity to send water quality data, these evolutions do not establish independence from the presence of the handler at the analysis site. The devices, however current they are, do not make use of the full capacity of M2M conversation. What we observe is a unilaterality in the flow of information in the instrument-to-server direction. After some evolutions, quality monitoring systems could enjoy the benefits of IoT.

Taking another perspective, current sensors also have a second impairment in the functionality of IoT implementation in the field, it is in the power system on which these devices are based. There is an indispensability of connecting to a strong external power source, either at the time of use (in order to meet the device's demand for electricity to perform its functions), or prior to use (so that when its batteries are charged and can be taken into the field). This is a bottleneck for carrying out activities in a continuous, automated and remote manner (actual use of the network control functionality - IoT).

Strictly, sending remote data from these sensors is already a reality, but remote use and management in the field for long periods does not: they do not have autonomy in power supply and consequent self-sustainability of their functions for a long period that allows for frequent measurements or sporadic without human intervention on site.

JUSTIFICATION AND OBJECTIVES

PROBLEM SOLVING (INVENTION)

In order to solve such inconveniences, the present invention was developed, through which electronic sensors for monitoring water quality have their independence from the connection of a strong external energy to the device to recharge its batteries or the device as a whole. With the energy self-sustainment managed by the power system combined with the IoT implementation in sending/receiving data remotely, we marked a sudden evolution in the efficiency of the sensors since with the invention there is no need for a manipulator, in person, for any intervention or recharge of the device.

Said device has a set of electronic sensors that capture the environment's analog signals, a data processor and microcontrollers to perform both tasks such as managing the power supply and self-support system in which they are inserted. The self-generated power supply system is powered by solar cells that convert sunlight into electrical charge used to charge the battery bank and all the hardware. Depending on the time, we have the use of solar energy and time from the battery bank as the main source, taking advantage of day and night seasonality in the production of light energy. Switching between these two load providers guarantees the product uninterrupted operation.

In short, the platform uses the most available resource in open fields such as rivers, oceans, lagoons and artificial reservoirs, which is solar light energy to be independent of human intervention in maintaining its load, together with all M2M remote connection technologies that enabled the adoption of the IoT, we have simplified the entire process of obtaining aqueous physicochemical data for future management and processing.

GOALS

In a timely manner, all the planning and methodology adopted in the development of this research aims to:

- Develop a project to monitor the physical and chemical parameters of water in an energy-sustainable way;

The project, in turn, must envision:

o Energy self-sustainment that allows for the need to dispense with human intervention, in person, in the food aspect;

o Data transmission remotely from the analysis site;

o Set of sensors, controllers and circuits capable of admitting physical and chemical quantities of water;

o Programming of systems in order to "talk" to all project devices;

o Development of a structure that supports the entire set of sensors and makes field use feasible;

- Build, in order to prove the theoretical concepts on which it is based, a prototype of the project in question;

The prototype in turn should envision:

o Choice of a set of controllers, sensors and data transmission modules;

o Choice of structural materials that meet the project requirements;

o Work on protecting electrical components from water and moisture.

MATERIALS AND METHODS

MATERIALS

Electrical components

The electrical components, before choice and comparison for adoption in the project, will be detailed in the part of this work given as E - Methodology. The sensors, modules, connectors, prototyping boards, microcontroller boards, wires, battery banks listed are those that ensured the fulfillment of the system's demands jointly, therefore, they are not exclusive that meet the needs. Parts are most viable within the context of cost feasibility and the scope of matching the required minimum quality or accuracy.

Sensors and modules

Shield transmitter TEL0078 WIFI V3 PCB (supports dual mode AP+STA, and connects to WiFi network of router). The module uses dynamic power management to achieve low power consumption (standby: <80uA; normal mode: medium: 8mA; peak: 200mA).

- Power: 5V DC
- Frequency range: 2.4 - 2.497GHz
- Output signal strength: 16dBm
- Transmission rate: 54Mbps - 1Mbps
- Transmission distance:<150M
- Supports IEEE 802.11b/g/n
- Supports AP, Client, Gateway and UART to WLAN mode and so on
- Supports DHCP, automatic access to IP; Support allocating IP to save device in AP mode [t]

Waterproof DS18B20 Temperature Sensor (very accurate, ±0.5°C accuracy, and provides temperature readings of up to 12-bits, configurable via a 1-wire data connection to the microcontroller)

- Power: 3~5V DC;
- Measuring range: -55°C to +125°C
- Accuracy: ±0.5°C between -10°C and +85°C
- Stainless steel tip[s]

PH sensor PH-4502C (set formed by a PH electrode and an electronic module that intermediates with the Arduino, for example, the electrode can be submerged in the container with water, leaving only the external cable exposed).

- Heating voltage: 5 ±0.2V (AC/DC);
- Working current: 5-10mA;
- Temperature range: 0-60˚C;
- Response time: 5S;
- Settling time: 60S;
- Power Component: 0.5W;
- Output: Analog;
- Measuring range: 0.00 ~ 14.00pH
- Zero points: 7+-0.5ph;
- Alkaline error: 0.2pH; [u]

Turbidity Sensor LGZD Sensor V1.1 (it emits an infrared light at its end, imperceptible to human vision, capable of detecting particles that are suspended in water, measuring the light transmittance and dispersion rate, which changes from according to the amount of TSS (Total Suspended Solids), increasing the turbidity of the liquid whenever the levels increase)

- Working voltage: 5V DC;
- Current: 30 mA(max)

- Response time: <500ms
- Output: Analog (0-4.5V) or digital (high 5V / low 0V)
- Operating temperature: -30°C to 80°C

Ultrasonic Distance Sensor HC-SR04 (composed of an emitter and a receiver, capable of measuring distances from ~2cm up to ~4m, with an accuracy of approximately 3mm)

- Power: 5V DC;
- Operating Current: 2mA;
- Sensor angle not greater than 15 degrees;
- Range: 2cm ~ 4m;
- High precision: ~3mm;
- Trigger input signal: 10us TTL pulse;
- Echo signal: TTL PWL signal output; [q]

Human interface outputs

4 RGB led; Buzzer 3.3V (audible alert output) and LCD display (generic but with 16*2 resolution layout)

Prototype plates

ARDUINO MEGA PROTO SHIELD REV3 prototyping board (plate with holes prepared to receive the construction and design of a welded circuit adjunct to the Arduino Mega 2560 Rev3 or even on the Arduino Uno Rev3 with minor adaptations explained further in E - Methodology).

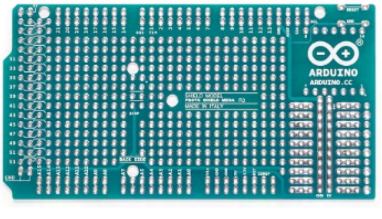


Figure 1 - Arduino Mega 2560 Rev3 micro controller

Source: Datasheet ARDUINO MEGA PROTO SHIELD REV3, 2020.

Microcontroller boards

ARDUINO MEGA 2560 REV3 microcontroller (8-bit board with 54 digital pins, 16 analog pins, 4 serial ports based on ATmega2560).

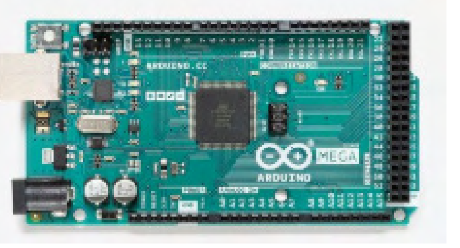


Figure 2 - Arduino Mega 2560 Rev3 micro controller

Source: Datasheet Microcontroller ARDUINO MEGA 2560 REV3, 2020

ARDUINO UNO REV3 microcontroller (8-bit board with 14 digital pins, 6 of which can be used as PWM outputs, 6 analog pins, based on ATmega328P).

Figure 3 - Arduino Uno Rev3 microcontroller

Fonte: Source: Datasheet Microcontroller ARDUINO UNO REV3, 2020

Voltage regulators

Shield Voltage Regulator LM2596 Voltmeter BTE13-001A adjustable Step-Down type DC 4.5~40 to 1.25-37V with LED Display Voltmeter, USB port and easy connection terminals.

Figure 4 - Voltage Regulator LM2596 Voltmeter BTE13-001A

Source: Voltage Regulator Specification, 2020

- Wide Input Voltage range: 4.5-40V;
- Adjustable Voltage Output: 1.25-37V;
- Output current: 2A, 3A MAX (Recommended use of a heat sink, for power greater than 2A/10W);
- Conversion Efficiency: Up to 92% (The greater the output, the greater the efficiency);
- Switching Frequency: 150KHz;
- Rectifier: Non-Synchronous Rectification;
- Module Properties: Non-Isolated Step-Down Module (Buck);
- Short circuit protection: Current Limiter;
- Operating Temperature: -40 to +85 (output power 10W or less);
- Temperature at full load: 40.

Shield Voltage Regulator Step-Up XL6009E1 assuming current of 4A and efficiency can reach up to 94%. Ultra-high switching frequency up to 400KHz (400000 times per second).

Figure 5 - XL6009E1 Step-Up Voltage Regulator Shield

Source: Shield Voltage Regulator Specification, 2020.

- Input voltage range: 3V-32V
- Output voltage range: 5V-35V[a]

Cables

Furukawa network cable (model 120.0001.00001) category 5e, 4 pairs, 24 AWG, in yellow color. Dedicated to structured cabling systems for voice, data and image traffic, as per ANSI/TIA/EIA-568A standard requirements, including addendum 5 (Category 5e), for horizontal or secondary cabling between distribution panels (Patch Panels) and the connectors on the desktops.

Energy supply

Oksn solar panel model LL-2W (in addition to the solar cells, the solar panel comprises a polymer frame and two acrylic support surfaces).

Figure 6 - Oksn solar panel model LL-2W

Source: Oksn solar panel specification, 2020.

• Peak power generation: 2W

• Maximum current: 0.33A

• Maximum voltage: 6V

• Dimensions: 15x14x1.5cm [n]

Sealing components

OThe sealing components, upon choice and comparison for adoption in the project, will be detailed in the part of this work given as E - Methodology. Sealed boxes, sealing rings, cable glands are those that ensured the fulfillment of the system's demands together, therefore, they are not exclusive that meet the needs. Parts are most viable within the context of cost feasibility and the scope of matching the required minimum quality or accuracy.

Hermetic boxes

STECK model SEX171 hermetic passage box built according to Standard NBR IEC60670-1

Figure 7 - STECK model SEX171 hermetic passage box

Source: Passage Box Specification SEX171, 2020.

• Double insulation;

• 1/4" screw without metal elements;

• Resistance to mechanical shocks and impermeability;

• Raw Materials: Self-extinguishing Thermo-Plastic Material;

• Degree of Protection: IP 55;

• Mechanical Protection: IK08. [k]

STECK model SSX111 hermetic passage box built according to Standard NBR IEC60670-1

Figure 8 - STECK model SSX111 hermetic passage box

Source: SSX111 Junction Box Specification, 2020.

• 1/4" screw without metal elements;

• Resistance to mechanical shocks and impermeability;

• Raw Materials: Self-extinguishing Thermo-Plastic Material;

• Degree of Protection: IP 55;

• Mechanical Protection: IK08.

Sealing rings

General Seal silicone gasket (solve sealing problems due to chemical resistance along with elastic and low friction properties).

• Raw Materials: silicone with a seamless FEP jacket

• Thermal resistance: withstands temperatures between -70 and 160 °C.

Diameter: ISO 3601 standard 2.50cm. (Specification of O-rings, 2020

Cable press

Press S799CPTI and S801CPTI cables with threads, respectively, PG-7 and PG-11. They are built according to DIN 46320.

• Degree of Protection: IP 67;

• Colors: Black and Gray;

- Impact Resistance: High mechanical strength.

- Raw Materials: Self-extinguishing Thermo-Plastic Material (Polyamide 6.6)(Cable Press Specification, 2020)

Structural components

The structural components, before choice and comparison for adoption in the project, will be detailed in the part of this work given as E - Methodology. The metal profiles, screws, nuts, washers, crossmembers, supports and tripod are those that ensured the fulfillment of the system's demands together, therefore, they are not exclusive that meet the needs. Parts are most viable within the context of cost feasibility and the scope of matching the required minimum quality or accuracy.

METHODS

In order to carry out the activities, an orderly plan of steps was carried out that would provide for an organization and minimization of the release of resources, culminating in an efficient prototype in all aspects envisaged in chapter D - Objectives. For this, the order of the methods summarized in Table 1 was followed. The research procedures were carried out.

The main objectives to be met by the project were established in view of the budget and complexity.

Thus, the steps taken in prototyping were:

- Choice of devices that could meet the demands (number of ports, data processing, programming language, precision) of information admission or transmission;

- Choice of cables that support the power supply and also the exchange of information between the electronic parts;

- Configuration of a battery scheme that allows the system to work according to the seasonality of energy supply by solar panels

- Choice of available solar panels and enough number to fully recharge the battery bank during the period of sunlight

- Choice of enclosures to protect the circuit boards adjunct to the cable glands for the passage of wires

- A code was written to enable the "talk" of the sensors and the power system with the microcontrollers

- With all the electrical and sealing materials (intrinsic for the operation of the device) an architecture was designed to house them

- Both structural parts and airtight boxes were locked together by screws

- On the prototyping boards and protoboards, solders were applied after assembly according to the design of the power and information transmission circuits

- The electrical components in the hermetic boxes, the sensors in their built-in supports were added

- Cable glands were positioned in hermetic boxes according to the correspondence of inputs and outputs in each one. Afterwards passing the threads

- Codes referring to the power system were shipped

- Codes referring to the data admission system (sensors) were shipped

- In the voltage regulator circuits, the variable capacitors and resistors were adjusted in order to charge the battery bank and/or supply the circuits with the correct voltage

- Reinforcements were performed by adding forces (addition of electrical parts) requesting weight or torsion (still taking concepts of bending moment, CG, etc.)

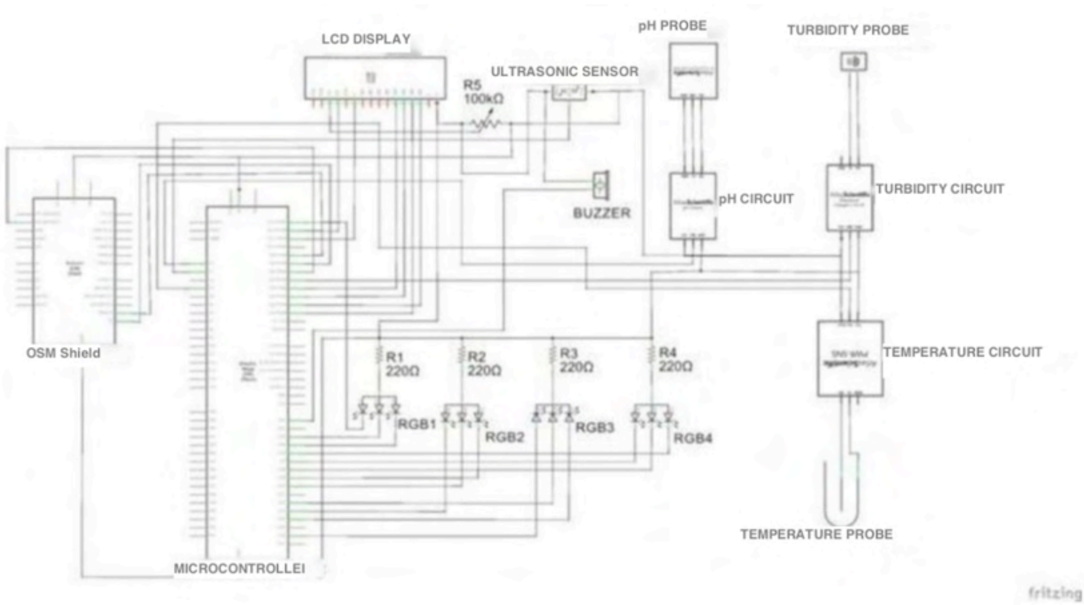
The present project and consequent prototyping consisted of a probe for reading the physical-chemical parameters of the water, equipped with an energy self-sustainment system and remotely exchanging data. To

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.3172115109

Steps	Process	Steps	Description of procedure
1	Pre-project	Goals	The main objectives to be met by the project were established in view of the budget and complexity
2	Pre-project	Electric materials	Choice of devices that could meet the demands (number of ports, data processing, programming language, accuracy) of information admission or transmission
3	Pre-project	Electric materials	Choice of cables that support power and also exchange information between electronic parts
4	Pre-project	Electric materials	Configuration of a battery scheme that allows the system to work according to the seasonality of energy supply by solar panels
5	Pre-project	Electric materials	Choice of available solar panels and enough number to fully recharge the battery bank during the period of sunlight
6	Pre-project	Sealing materials	Choice of enclosures to protect the circuit boards adjunct to the cable glands for the passage of wires
7	Project	Code	A code was written to enable the "conversation" of the sensors and the power system with the microcontrollers
8	Project	Format	With all the electrical and sealing materials (intrinsic for the operation of the device) an architecture was designed to house them
9	Project	Structure	Given the layout of the parts and layout of the device, a structure was designed that would support the efforts and house the architecture
10	Project	Structural materials	Materials were chosen according to the distribution of efforts and purpose (their choices were in the design phase due to their dependence on the layout)
11	Execution	Mounting	With all the materials necessary for the operation, the assembly of the molding and machining the structural parts was started.
12	Execution	Junctions	Both structural parts and boxes were locked together by screws
13	Execution	Welds and construction of circuits	On the prototyping boards and prototype boards, solders were applied according to the design of the power and information transmission circuits
14	Execution	Addition of Electrical Materials	The electrical components in the hermetic boxes were added, the sensors in their built-in supports
15	Execution	wiring	The cable glands were positioned in the hermetic boxes according to the correspondence of inputs and outputs in each one.
16	Execution	Code shipment	Codes referring to the power system were shipped
17	Execution	Code shipment	Codes referring to the data admission system (sensors) were shipped
18	Settings	Energy Supply	In the voltage regulator circuits, the variable capacitors and resistors were adjusted in order to charge the battery bank and/or supply the circuits with voltage;
19	Settings	Structure	Reinforcements were carried out by adding forces (addition of electrical parts) requesting weight or torsion (still taking concepts of bending moment, CG etc.)

Table 1 - Step Sequence Planning Summary

Source: author's own elaboration



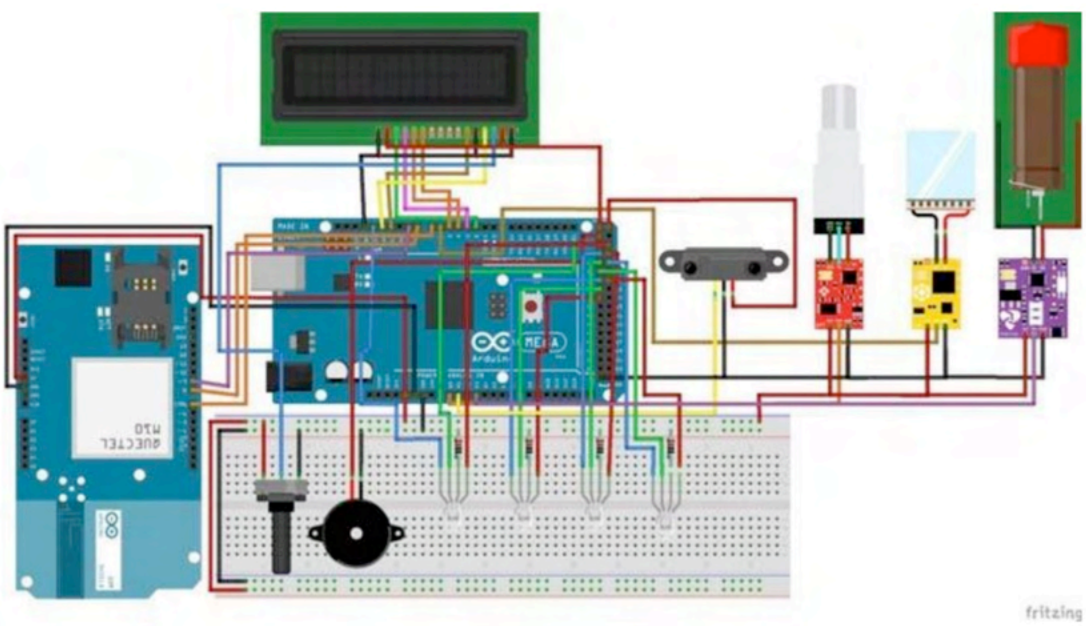


Figure 9 – Arduino Project – Concept Prototype

Source: Arduino Project, 2018.

operate according to the device, it comprises an architecture that unites in a single structure (point 1a and 1b shown in Figure 10), the power plant used (point 2 shown in Figure 10), an energy store (point 3 shown in Figure 10), processors and microcontrollers (point 4 indicated in Figure 10), hermetic box(es) (points 5a 5b indicated in Figure 10) and the sensors (points 6a, 6b, 6c and 6d indicated in Figure 10) properly sayings which give meaning to the device and fit the function in a probe field.

The structure (point 1 indicated in Figure 10) is made of a resistant material that, in addition to uniting all the parts, providing a fixing base for the components, is responsible for keeping the probe in the established position. The housing is dimensioned to the point of withstanding the efforts of weight, wind, durability to solar decay, chemical debilitation of the water due to submersivity, ability to crimp the components and the probe as a whole in support of the location to be analyzed.

The material adopted, according to the requirements, was Naval Aluminum Alloy 5052-H34 (naval) which composes the 0.1mm sheets (folded in a W Profile for greater rigidity) indicated in the Figure by 1a; for regions of the structure where we have places of stress and a tendency to bend more, structural reinforcements were added in machined aluminum alloy 6351-T6 (naval) and part connections in stainless steel Austenitic Alloy AISI 304 indicated in the Figure by 1b. The profiles and structural assemblies were not entirely made of stainless steel because despite their durability characteristics, both corrosion and mechanical resistance, the aspect of economic viability was evaluated through the resource limit for project development and subsequent adoption on an industrial scale. The methodology applied for choosing and positioning materials was better explained in this work in Methodology.

And also in the structure, however, detailing the joints between machined parts and profiles, hexagonal screws of class 5.8mm (DIN 933) were adopted, M8 nuts (DIN 934 of DIN 13 threads), self-locking nuts (Nylon Insert Hex Lock Nut) hexagonal Ma 8mm (DIN 985 of DIN 13 threads) and threaded bars of size M8 (DIN 975 DIN 13 thread). The constituent materials of the screws, nuts and threaded bars vary between Austenitic Stainless Steel Alloy AISI 304, zinc plated steel and carbon steel. The criterion used for the adoption of the different materials, at each specific point, was again the exposure to the environment, resistance to mechanical efforts and salinity in view of the economic viability

The Arduino MEGA2560 microcontroller from ATMEL Corporation was adopted. This component is capable of processing the data obtained by the sensors for readings of physicochemical water parameters compatible with the Arduino platform.

RESULTS AND DISCUSSIONS

Due to this year's pandemic situation, the probe was developed and implemented in its entirety. Functional and performance tests were carried out in a domestic environment, limited to ambient conditions. Power and energy autonomy tests and only two sensors (temperature and turbidity) were tested, as shown below. However, other tests of resilience, sealing, connectivity, and with other sensors, as well as the detailing of its structure, physical and electrical design will be complemented, as soon as the permissions for access to laboratory and external environments are authorized.

TEMPERATURE

For its study and functional tests, the use of the FLUKE-59MAX Thermometer was adopted as a parameter, since it performs

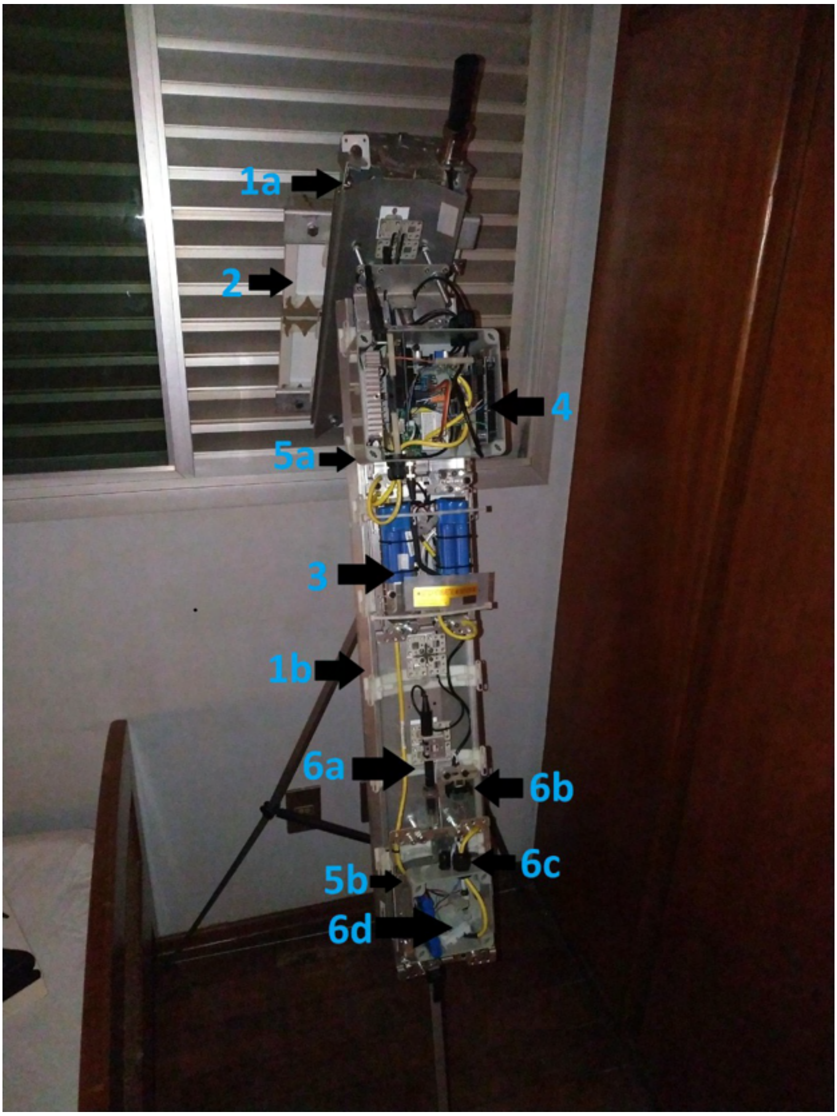


Figure 10 - simplified diagram for better understanding of the probe

Source: author's own elaboration

the measurement at a distance by Infrared and has, even working without contact, a considerable precision (see Table). The non-contact measurement in the middle in which the DS18B20 Sensor is inserted provides greater accuracy to the sampled values since there is no probe insertion interfering with the temperature of the liquid analyzed by the sensor and therefore the need to wait for heat exchanges until the thermal equilibrium of the system.

TURBIDITY SENSOR

Turbidity Sensor detects water quality by measuring turbidity / opacity levels and uses an analysis system to detect particles suspended in water. The increase in turbidity, in turn, is caused by solid particles such as organic materials and clay, which consequently interfere with the propagation of light, associated with the sensor through the Tyndall effect, which describes the dispersion of projected light in a liquid, that is, the greater

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.3172115109

Specifications		
temperature range	-30 °C a 350 °C (-22 °F at 662 °F)	
Accuracy (Calibration geometry with an ambient temperature of 23 °C ±2 °C)		
	≥ 0 ˚C:	±2.0 °C or ±2.0% of reading, whichever is greater
	≥ -10°Ca<0 °C:	±2,0 °C
	< -10 °C:	± 3,0 =C
	≥ 32 T:	±4.0 °F or ±2.0% of reading, whichever is greater
	≥ 14 °F a <32 'F:	± 4,0 T
	< 14 °F	± 6,0 °F

Figure 11: Specifications: 59 MAX Infrared Thermometer

Source: https://www.fluke.com/pt-br/produto/medicao-de-temperature/termometers-ir/fluke-59-max

Temperature: FLUKE-59MAX (°C)	Temperature sensor DS18B20 (°C)
32,7	29,8125
33,7	32,5625
34,2	32,8125
36,1	34,3125
38,3	34,75
38,6	34,8125
39,6	36,9125
39,6	37,8125
40,1	38,125
41,1	40,25
43,4	42,18
43,9	42,37

Table 2: Collected values

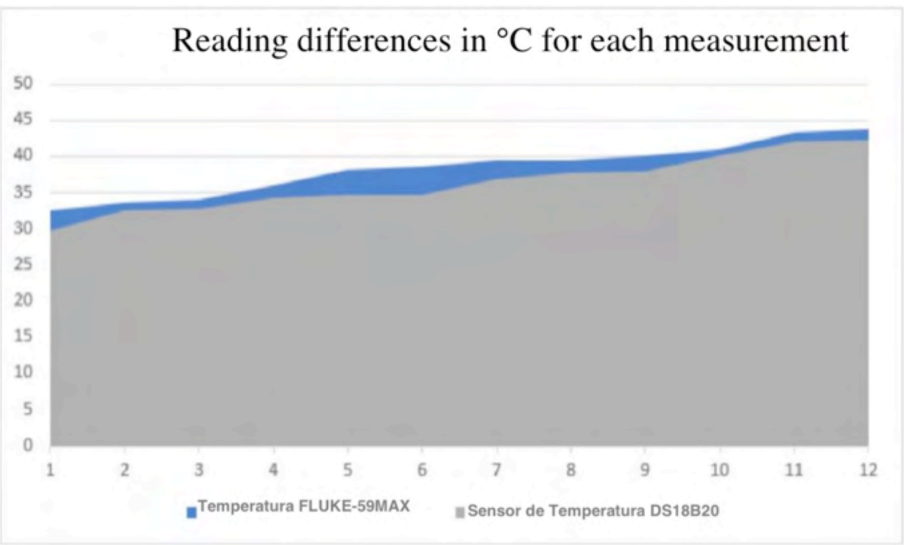


Figure 12: Reading comparison graph between measurements by the FLUKE 59-MAX Thermometer and the DS18B20 Sensor

Source: own elaboration

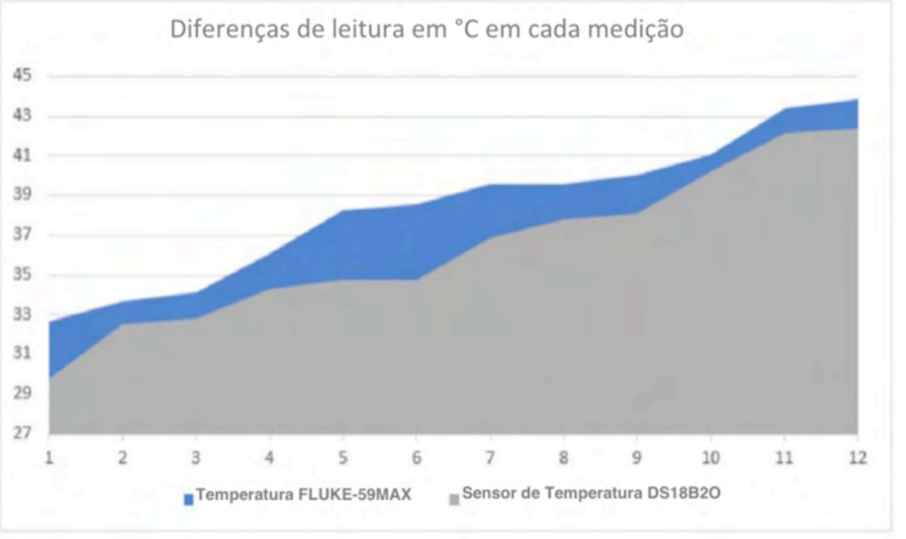


Figure 13: Graph focusing on Area of difference:

Source: own elaboration

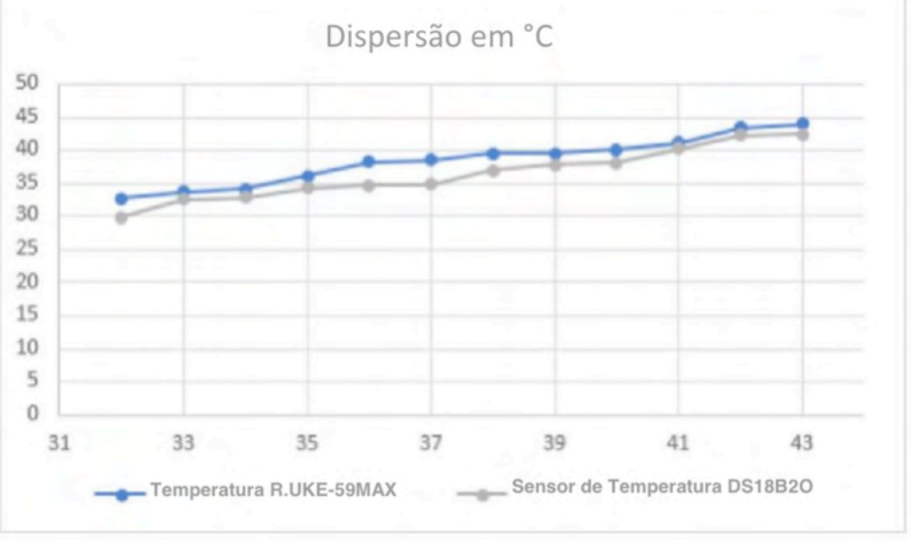


Figure 14: Value scatter plot:

Source: own elaboration

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.3172115109

the number of particles, the more the light will be scattered. The mathematical unit used to measure Turbidity is the NTU, which comes from the English language, Nephelometric Turbidity Unit, which means Nephelometric Turbidity Unit. Relationship between NTU and reading in volts is established through the second degree equation:

$$f(x)\ [NTU] = -1120.4x^2+5742.3x-4352.9\ [V].$$

His deduction started in an experimental way, studying with samples of more and less turbid waters and thus used as parameters for the first correspondences between V and NTU. Note that the voltage values in the Table below are accurate, however the Turbidity values are measured roughly by sample type and hence the large distance between each water quality in NTU.

With table 3 in hand, the graph of the behavior of the output volts corresponding to the turbidity of each sample was plotted.

Since the behavior resembles a parabolic curvature, it was decided to determine an equation of the second degree that would meet the silhouette. See a generic quadratic equation:

$$f(x) = ax2 + bx + c$$

To form it completely it is necessary to obtain the constants a, b and c. The reasoning starts from the correspondence of Turbidity values (f(x)) to output voltage values in the ST100 Sensor (x). It was performed by adopting a system of 3 equations, ignoring the units, evaluating only the numerical correspondence:

$$F(x) = 3000 \text{ for } x = 2.59;\ F(x) = 2000 \text{ for } x = 3.49;\ F(x) = 100 \text{ to } x = 4.16$$

So you can determine the values of a, b and c:

F(x) = ({57423} {x})/{10} - ({5602} {x}^{2})/{5} - {43529}/{10}

From the mathematical function that governs the behavior, it was possible to draw a curve that operates in its functioning, as shown in the graph in Figure 16.

Internally, the Turbidity Sensor has an exclusive trimpot for reading adjustment, normally this device is designed to meet the maximum voltage of 4.2V, but it is possible to use it to adjust this output voltage. The lower limit set was 2.6V, corresponding to 3000 NTU. To better understand it, a bar was placed next to the graph in Figure 17 in order to identify how turbid the water analyzed would be, with dark being the turbidity and gradually lighter to translucent.

Type of sample	Voltage at ST100 Turbidity Sensor (v)	Sample turbidity (NTU)
very cloudy water - opaque	2,59	3000
partially cloudy water - opaque	3,3	2500
very cloudy water - translucent	3,49	2000
partially cloudy water - translucent	3,78	1500
slightly cloudy water - translucent	3,9	1000
slightly cloudy water - transparent	4,1	500
slightly cloudy water - transparent	4,16	100

Table 3 - Turbidity Sensor performance curve determination experiment

Source: author's own elaboration

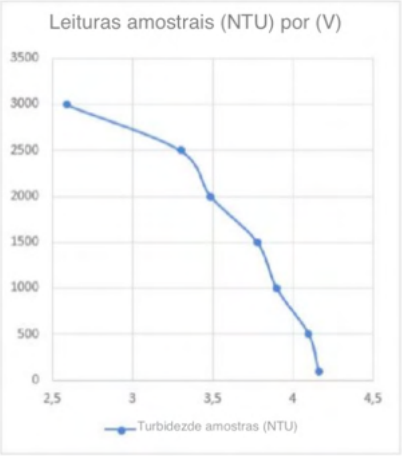


Figure 15: ST100 sensor reading graph for each sample.

Source: author's own elaboration

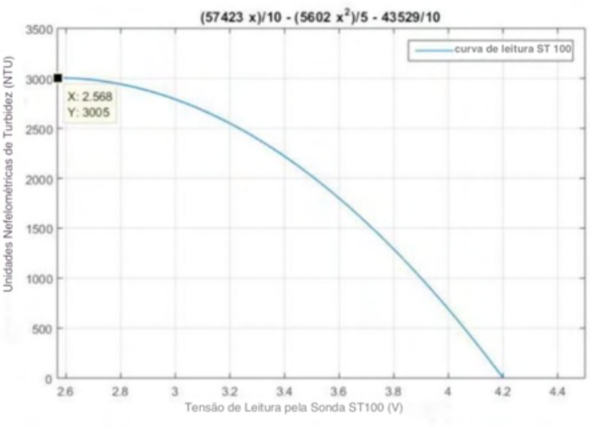


Figure 16: Function curve determined for the relationship between Output voltage in the ST100 sensor signal and water turbidity

Source: author's own elaboration

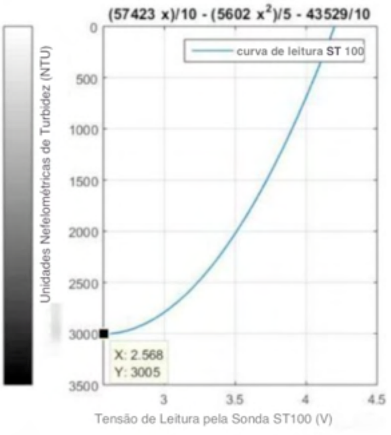


Figure 17: Function curve determined for the relationship between Output voltage in the sensor signal and water turbidity with illustrative bar

Source: author's own elaboration

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.3172115109

CONCLUSIONS

As initially proposed in the research project, the planned activities were carried out almost entirely. Due to the pandemic, some tests and implementations could not be carried out and will be complemented in future work.

Thus, the initially planned model will be completed, so that tests of resilience, sealing, connectivity, and with other sensors, as well as the detailing of its structure, physical and electrical design will be complemented, as soon as the access permissions to the environments laboratory and external services are authorized.

Some corrections will also be made, such as corrections arising from the tests performed, adding reinforcements to the structure with ABS parts and heat sinks to the voltage rectifier. Corrections to the power system, adjustment of the Step UP amplifier at 7.2v in order to provide the battery charge at its nominal voltage, since the output of the solar panels is in the range of 6.0v.

Although there is much to be done, this work has shown promise, with great interest from researchers in the application areas, for future tests and potential implementation in environments. From these additional tests, it will be possible to statistically analyze the results, to proactively identify degrading elements of the observed water quality, and correlation with microbiology, as these variables can impact the occurrence of pathogenic and multiresistant microorganisms to antibiotics, in particular of the genus Enterococcus and from the order Enterobacterales. This analysis and correlation will be performed by the team of the Laboratory of Microbiology and Immunology FOA/UNESP.

It is interesting to note that this work was presented at the 32nd. UNESP CIC and with approval for the 2nd. Phase. The full details will be submitted to the AUIN (UNESP Innovation Agency), for analysis and potential registration of innovation.

REFERENCES

Alves, F. Vendramini, E. Indústria 4.0: Digitalização como vantagem competitiva no Brasil. Disponível em: https://www.pwc.com.br/pt/publicacoes/servicos/assets/consultoria-negocios/2016/pwc-industry-4-survey-16.pdf , 2016.

Cabo de rede Furukawa (modelo 120.0001.00001) categoria 5e, disponível em: https://www.atera.com.br/produto/cabocat5yel/Cabo+UTP+Furukawa+CAT.5e+4+pares+amarelo+p-+metro.

Datasheet ARDUINO MEGA PROTO SHIELD REV3, Placa de prototipação disponível em: https://store.arduino.cc/usa/arduino-mega-proto-shield-rev3-pcb, 2020.

Datasheet Microcontrolador ARDUINO MEGA 2560 REV3, disponível em: https://store.arduino.cc/usa/mega-2560-r3., 2020.

Datasheet Microcontrolador ARDUINO UNO VER3, disponível em: https://store.arduino.cc/usa/arduino-uno-rev3, 2020.

Especificação transmissor TEL0078 WIFI V3 PCB, disponível em: https://wiki.dfrobot.com/WIFI_Shield_V3_PCB_Antenna_SKU_TEL0078

Especificação Anel de vedação silicone General Seal, disponível em: https://www.generalseal.com.br/anel-vedacao-silicone., 2020.

Especificação Caixa de passagem hermética STECK modelo SEX171, disponível em: https://www.steck.com.br/produtos/caixas-de-passagem-e-distribuicao/caixas-light/caixa-light-170-x-145-x-845., 2020.

Especificação Caixa de passagem hermética STECK modelo SSX111, disponível em: https://www.steck.com.br/produtos/caixas-de-passagem-e-distribuicao/caixas-light/caixa-light-102-x-102-x-55., 2020.

Especificação Painel solar Oksn modelo LL-2W, disponível em: https://oksnbrasil.com/utilidades/painel-solar-1.html., 2020.

Especificação Regulador de Tensão LM2596 Voltímetro BTE13-001A, disponível em: https://www.saravati.com.br/srvt000138.

Especificação Regulador de Tensão Step-Up XL6009E1, disponível em: https://www.baudaeletronica.com.br/modulo-regulador-de-tensao-step-up-xl6009e1.html

Especificação Sensor de PH PH-4502C, disponível em: https://www.eletrogate.com/sensor-de-ph-arduino-modulo-de-leitura?utm_source=Site&utm_medium=GoogleMerchant&utm_campaign=GoogleMerchant&gclid=Cj0KCQjwlvT8BRDeARIsAACRFiXwpqBvTXQWjqAd3GaeiX3FNZyZk1JhBfLUvSlGCm7kuCfhRxvAfq8aAp8_EALw_wcB

Especificação Sensor de Temperatura DS18B20 a Prova D'água, disponível em: https://www.eletrogate.com/sensor-de-temperatura-ds18b20-a-prova-dagua?utm_source=Site&utm_medium=GoogleMerchant&utm_campaign=GoogleMerchant&gclid=CjwKCAjw8-78BRA0EiwAFUw8LMcaxjb93Cu1FNNvNpfGRI91xG1mCyTAzUTYs2sbtWR54KMIAkefVRoCWGEQAvD_BwE

Especificação Sensor de Turbidez LGZD Sensor V1.1, disponível em: https://www.baudaeletronica.com.br/sensor-de-turbidez-para-monitoramento-de-agua.html

Especificação Sensor Ultrassônico de Distância HC-SR04, disponível em: https://www.usinainfo.com.br/sensor-ultrassonico-arduino/sensor-ultrassonico-de-distancia-hc-sr04-2295.html

Germany Trade & Investis. **The economic development agency of the Federal Republic of Germany**. Disponível em: https://www.gtai.de/gtai-en

Kranenburg, R.V. The Internet of Things: A Critique of Ambient Technology and the All-Seeing Network of RFID, Institute of Network Cultures, 2018.

Li Da Xu, Eric L. Xu & Ling Li (2018) Indústria 4.0: estado da arte e tendências futuras, International Journal of Production Research, 56: 8, 2941-2962, DOI: 10.1080 / 00207543.2018.1444806

Projeto Arduino. Water Quality Monitoring and Notification System. In: https://create.arduino.cc/projecthub/eani/water-quality-monitoring-and-notification-system-f85d23., 2018.

Ray, P.P. A survey on Internet of Things architectures. **Journal of King Saud University,** 2016. Disponível em: http://dx.doi.org/10.1016/j.jksuci.2016.10.003

ATTACHMENTS - TECHNICAL SPECIFICATIONS

Special Steels and Alloys - table b.12.2 page 487

Brands		chemical compositions					Specific applications
electrometal	Equivalent	%C	%Cr	%NI	%Mo	Outros	
E303	AISI 303	0,15 máx	18,0	0,60 máx	0,60 máx	S - Ü.1S m*x	Turned parts for the food and dairy industries. Parts produced on automatic lathes : screws, pins, nuts, etc. Part for the automobile and aeronautics industries.
EMU	AI$1 304	0,08 máx l	19,0	10,0	-	-	Valve and piping parts ; hospital equipment, heat exchangers, equipment for chemical, petrochemical, pharmaceutical, food and cellulose industries. Metal frames parts for mechanical construction, screws, rivets, tie rods, spring wire etc.
tMUL	A1S1 MUL	0,03 máx	19,0	10,0	-	-	Same applications as E304 steel, for welded parts that cannot be later solubilized. It is also applied in the aeronautical and electrical industries.
E316	AJSI 316	0,08 máx	17,0	12,0	2,50	-	Same applications as E304 steel, plus shipbuilding parts. It has better resistance to corrosion and oxidation than E304 steel, in addition to superior mechanical properties. It is widely used in the paper industry.
UL6L	A13I 316L	0,3 máx	17,0	11,0	2,50		Same applications as E316 steel, for welded parts

Extrusion Alloys Specific Characteristics

Depending on the application, we show the specific characteristics for each alloy.

Alloy	Corrosion Resistance	Decorative Anodizing	Protective anodizing	Welding	Welding CTIG}	Machining	Deformability i Frio	Brasagem	Others
1050	A	A	A	A	A	E	A	A	
1350	A	A	A	A	A.	E	A	A	
2011	C	E	B	N	N	A	G	N	resistance welding
2014	C	E	B	c	N	B	D	N	resistance welding
2017	c	E	B	N	N	B	C	N	resistance welding
2024	c	E	B	N	N	B	C	N	resistance welding
3003	A	D	B	A	A	D	A	A	
5052	A	A	A	A	A	C	A	B	
53%	A	A	A	A	A	C	C	N	
6060 6063 e X6463	A	A	A	A	A	D	B	A	
6061	A	D	A	A	A	C	C	B	
6101	A	A	A	A	A	D	B	A	
6261	A	C	A	A	A	C	C	B	
6262	B	C	A	A	A	A	c	A	
6351	A	D	A	A	A	C	c	C	
7075	C	E	B	N	H	B	D	N	resistance welding
7104	B	N	A	A	A	C	B	N	Excellent for porcelain enamel.

Extrusion Alloys Characteristics and Applications

	FEATURE / APPLICATIONS	
liga	**Características**	**Typical Applications**
1050	Lower mechanical strength high corrosion resistance good formability, easy to weld, suitable for decorative anodizing	Industrie chemical pharmaceutical and household utensils Refrigeration (heat exchangers in general)
1350	High electrical conductivity good formability Excellent machinability	Special alloy for electrical conductors
2011	high mechanical strength medium resistance to corrosion	Parts machined in toto automabco Excellent alternative to cutting brass
2014	High mechanical strength and high ductmity, medium corrosion resistance	aeronautical industry transport, machinery and equipment
2017	Good machinability, high mechanical strength and high ductility. Medium mechanical resistance to corrosion, good conformability	Machined parts for the aeronautical industry, transport, machinery and equipments
2024	High mechanical strength and high ductness medium resistance to corrosion medium conformance	Machined and forged parts Aeronautical industry transport machinery and equipment
3003	Medium mechanical strength high corrosion resistance good formability	Tubes for heat exchangers «automotive radiators) Antennas
4043 4047	salon leagues on soida sticks	Welding of alloy groups 1000 3000 and 6000
5052	Good mechanical strength with corrosion resistance, good conformability	Strands for reluctant transport and equipment
5356	Mechanical resistance to 5052 high corrosion resistance good contourability	Welding Rivets especially 5052 and 5083 with each other and with Hgas from the groups 1000, 3000 and 6000
6060 • 6063	Medium mechanical strength, high corrosion resistance Suitable conformability for matte decorative anodizing	Profiles for civil construction, caiximana in general, mobile irrigation pipes and lighting
6061	Good mechanical strength, good corrosion resistance	Structures, shipbuilding vehicles and rivets Industna furniture
6101	High electrical conductivity measures mechanical strength good corrosion resistance	Special alloy for electrical fWts and busbars (structures;
6261	Good mechanical strength, good corrosion resistance,	Vehicle bodies, structures and equipment
6262	Excellent machinability, high mechanical strength, resistant to corrosion suitable for decorative anodizing	Parts used automatically. Excellent alternative to cutting brass
6351	Good mechanical strength to corrosion resistance, good conformability, medium machinability	Structural engineering construction of ships, vehicles and equipment Parts used in non-automatic lathes
X6463	Medium mechanical strength good corrosion resistance	Panels and panels for automotive appliances and cabinets
7075	The highest values of mechanical strength, average resistance to corrosion,	Parts subject to more than years mechanical efforts in the aeronautical industry, modifying machines and equipment Plastic ejection molds
7104	High mechanical strength, good corrosion resistance, good conformability, suitable for decorative anodizing	Welded Structures

Extrusion Alloys Mechanical Properties

Alloy	Temper	Tensile Strength limit (MPa)		Conventional Flow Limit (MPa)		Shear Strength limit (MPA)	% of Elongation in 50 mm	Brinell hardness 2,5-62.5
	0	95	(80)	-	(30)	(62)	25	•
1050	H14	85	(100)	70	(80)	(72)	•	•
	H18	110	(130)	90	(100)	(76)	-	•
1350	0	-	(95)	-	(30)	(55)	-	•
2011	T3	310	(363)	260	(328)	(206)	10	(113)
	T6	•	(340)	•	(230)	•	10	(90)
2014	T4	345	430)	240	(290)	•	12	(105)
	T6	415	(500)	365	(440)	(310)	-	(135)
2017	T4	380	(448)	220	(290)	(310)	12	(104)
2024	0	240	▪	130	•	•	10	•
	T4	395	(510)	260	(380)	(282)	-	(126)
	0	130	(120)			(76)	25	
	H12	115	(140)			•	•	

3003	H14	140	(151)			(97)	-	
	H16	165	•			(103)	•	
	H18	185	-			(110)	-	
	0	220	(209)			(123)	25	
	H32	215	(227)	160	(183)	•	•	
5052	H34	233	(260)	180	(235)	(144)	-	
	H36	255	•	200	250	(165)	•	
	H38	270	-	-	-	(165)	-	
	0	130	(125)	•	-	(76)	18	
5050	T4A	110	(145)	60	(79)	(98)	•	
6063	T5	150	(219)	110	(189)	(118)	8	66
X6463	T6C	180	(226)	150	(197)	(135)	-	
	T*	205	(235)	170	(213)	*	8	
	0	150	-	110	-	(82)	18	
	T4	180	(211)	110	(129)	(165)	16	
5061	T6	260	(309)	240	(280)	(206)	8	(102)
	T6”	290	(351)	240	(332)	•	10	(106)
	T8	-	(368)	-	(348)	(100)	•	•
	T89	370	-	325	-	-	•	-
	T4A	157	(186)	83	(108)		•	•
5261	T4	181	(199)	98	(123)	-	-	-
	T6C	229	(280)	199	(248)	-	10	(90)
	T6	260	(309)	240	(280)	•	8	(102)
6351	T4	220	(227)	130	(121)	(152)	16	(64)
	T6	290	(315)	255	(288)	(201)	8	(106)
6101	0	-	(137)	▪	(82)		•	•
	T6	200	(230)	172	(213)		-	•
6262	T6	260	-	-	-		10	-
	T9	360	(390)	330	(370)		5	(111)
7075	0	275		165	•			•
	T6	560	(630)	495	(608)	(329)	-	(150)
7104	T4A	204	(229)	128	(158)		•	-

Data o» voltage and «pressed in the MEGAPASCAL unit (MPa), equivalent to IN/mntf The measurement of humidity kgtmm2 « oOtida divxwxjo-s» o <alue m<*cated by 9 807

For the conversion of MPa to KSI dnnde by 6 894

Values without parentheses are the specified minimums with the exception of temper O (annealed) where the maximum resistant properties are dull.

Values in parentheses are typical expected.

All alloys can be turned in F temper without guaranteeing mechanical properties

The minimum and typical values shown refer to the products most used in the indicated Temperas

Different wall thicknesses or diameters can lead to changes in the specified and typical expected minimums.

T6 temper for drawn material with caliper step

Arduino Mega 2560 Rev3 microcontroller technical specifications

Microcontroller	ATmega2S60
Operating Voltage	5V
Input Voltage (recornmended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	S4 (of which IS provide PWM output
Analog Input Pins	16
DC Current per 1/0 Pin	20 mA
DC Current for 3.3V Pin	SO mA
Flash Memory	2S6 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz
LED_BUILTIN	13
Length	101.52 mm
Width	53.3 mm
Weight	37 g

Arduino Uno Rev3 microcontroller technical specifications

Microcontroller	ATrnega328P
Operating Voltage	5V
Input Voltage (recornmended)	7-12V
Input Voltage (limit)	6-20V
Digital 1/0 Pins	14 (of which 6 provide PWM output)
PWM Digital 1/0 Pins	6
Analog Input Pins	6
DC Current per 1/0 Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATrnega328P) of which O.S KB used by bootloader
SRAM	2 KB (ATrnega328P)
EEPROM	1 KB (ATrnega328P)
Clock Speed	16 MHz
LED-BUILTIN	13
Length	68.6 mm
Width	53.4 rrirn
Weight	25 g