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EPS – PROJECT 2022

Hydrophone Sound Level Meter
"Pontus"

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Abstract

The ocean is full of anthropogenic noise which can harm marine animals. The anthropogenic sounds can cause a threshold shift in their hearing sensibility, which can on its turn cause changes in their behavior. The aim of this project is to develop a portable hydrophone sound level meter that displays sound levels in real time. In addition, a warning signal will be displayed when a defined sound level is reached or surpassed. In order to achieve these goals, research was carried out. It was determined when sound levels and octaves become dangerous or deadly for the respective marine life. For the development process of the hydrophone sound level meter, it was important to determine requirements in order to make the device usable for this purpose. Based on the requirements, a selection of technical components and the design of the device was made. With the help of the necessary software, the measured values of a hydrophone can be displayed on the hydrophone sound level meter in an easily understandable way. In this report a final design of a hydrophone sound level meter is presented, which fulfils almost all requirements and objectives.

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1 Introduction

1.1 About the lab and the team

This project was requested by the Laboratory of Applied Bio-Acoustics (LAB) based in Vilanova y la Geltrú, Spain. The LAB aims to study and model the marine acoustic environment and develop technological solutions. These researches are done in order to limit and control the effects of marine noise pollution. This allows the sustainable development of human activities in the oceans. And by this way, to respond to the demands of local, national and international institutions, and those of society in general, in the face of one of the most recent degradation processes facing the marine environment.

The lab has worked with the EPS program many times but none of those projects are linked to ours. We can still mention the design of an autonomous acoustic buoy which had been done by three different EPS groups. Our student team is made up of Alloise Kleef (Biomedical sciences, Netherlands), Andrea Gordón Gaete (Design engineering, Spain), Jan-Erik Dotzler (Development and Management of Engineering and Automotive Construction, Germany) and Pierre Tarride (Mechanical engineering, France). We are supervised by Joan V. Castell (UPC teacher) and Mike van der Schaar (LAB researcher).

1.2 Project statement and brief

In modern days the ocean is not the quiet place it used to be. From every side there is a source of anthropogenic sound that is causing noise pollution. For example, the windmills that are spreaded over the coastlines or the oil drilling carried out around the ocean. These anthropogenic sounds can cause some problems for marine life. In normal circumstances a significant amount of marine animals are using sounds to communicate with each other or to detect danger. When there is a lot of noise pollution in the sea, animals could get confused and will change their behavior for the worse. For example, in 1996 exposure to military sonar during a NATO exercise was postulated as the cause of a mass stranding of 12 beaked whales in Greece [1]. The changing of behavior might not even be the biggest problem noise pollution causes. If the noise pollution exceeds certain thresholds it can actually damage some animals' hearing organs.

To get a better understanding of the noise pollution in the oceans, a monitoring system is used to record the sounds in the ocean. This monitoring system consists of a hydrophone and the device that displays the data recorded by the hydrophone. The difference between the current equipment and the equipment this project is focused on, is the user-friendliness. With the current equipment the user has to record the sounds and can only analyze the data when back on shore. This project will be focussing on developing a hand-held sound level meter that shows real time data. This enables the user to immediately see the sounds in the ocean when recording. This way the user can alter the place of interest according to the displayed data, It will save a lot of time and give the user a feeling of control.

1.3 Project Goal and Objectives

The purpose of this project is to design and develop a device which can show the sounds and noise pollution on a screen which are measured by a hydrophone in the ocean. The focus is on the device displaying the signals received from underwater in real time on a screen. For this, the prerequisite must be created so that the digital hydrophone can be connected to the receiver via a physical connection.

Furthermore, different filters of the received data are to be selectable so that different frequencies and octaves can be displayed. In addition, a warning signal is to be emitted when a threshold value is reached or exceeded that could be or is dangerous for an animal species in the sea. In addition, the unit must have an independent power supply. This power supply must also ensure the power supply of the hydrophone and the sound level meter for at least six hours of continuous running time.

The portable device should be suitable for both professional and non-professional users. So there are some additional requirements that need to be considered when designing the product. In order to address a large group of customers, the device should be user-friendly. Since the receiver is only used on boats, the device must be waterproof, sun-resistant and tough (durable) in order to be usable even in bad weather conditions. Furthermore, during design and development, care must be taken to ensure that the product is cost-effective and suitable for mass production.

All these functions and features make the portable device a unique product that is designed to stand out from all existing competitors with enthusiastic features, thereby exceeding the expectations of potential buyers.

1.4 Pontus

A product name is important because it reflects what a product is all about. In addition, a product should be easily recognised by a name and trigger a feeling or an image in people. As the existing hydrophone is called "porpoise", the first ideas were to name the product after a marine mammal. But this device is developed and designed to represent all kinds of sounds in the sea, including those of different marine species. That is why the name was chosen after the Greek god "Pontus". In Greek mythology, Pontus was an ancient, pre-Olympic sea god, one of the primordial Greek gods. This god's name embodies dominion over the seas, as the father of fish and other sea creatures.

1.5 Structure of the Report

To understand what a hydrophone is, the general principles of the hydrophone will be first explained. When this is clear, the principles of the hydrophone sound level meter will be explained. This is the final product that is developed in this project.

First the influence of anthropogenic sound on marine animals will be explained. In this section also the division of the marine animal groups will be discussed. After this the comparative and stakeholder research will be explained. Next, the requirements of the hydrophone will be disused.

Hereafter the general concepts will be presented. These are the first concepts developed with a pro and con list and an explanation why the final concept has been chosen. After presenting the final concept, the selection of the components for this concept will be presented. Every component will be shown step by step with an explanation of why the specific component is chosen and needed.

In the concept section, it is already shortly shown what eventually the final design will approximately look like. In the product design and layout design this will be shown with more detail. Both the case and the screen layout will be presented abundantly.

In the end of the developing section of the hydrophone sound level meter, the programming section will explain how the software is equipped. After this it will be shortly discussed how this product is developed with regard to ECO design.

At last a conclusion will be given. After this the bibliography with the consulted sources and the table of figures and tables will be provided.

2 General information

This section begins by explaining how a hydrophone works. The following describes how the measured values of the hydrophone are evaluated in a hydrophone sound level meter in order to show them legibly on a display.

2.1 What a hydrophone is and how it works

Hydrophones are essentially devices configured to pick up underwater sound and convert it into audio signals that can be converted into processable data (compare with Figure 1). This form of underwater microphone greatly facilitates the exploration of large bodies of water, even at depths and in circumstances that preclude diving as a means of exploration.

Figure 1: Hydrophone which is used in the UPC LAB.

Designed as a piezoelectric transducer, the hydrophone converts the pressure into an electrical signal. In modern hydrophone types, the amplifier and a digitizing chain is also integrated directly into the hydrophone housing. The Figure 2 below shows the direct piezoelectric effect in a very simplified way. [2] [3]

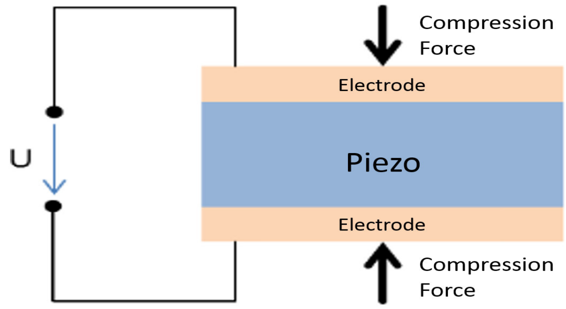

Figure 2: Direct piezolectrical effect

Industrial piezo elements are primarily made of ceramics. If several different ceramics are used, one speaks of a so-called material composite of the PZT ceramics. The mixed crystals consisting of PbZrO3 and PbTiO3 are excellent piezoelectric materials when doped precisely, for example with neodymium, manganese or nickel. Due to their ferroelectric soft materials, they can be polarized even at relatively weak field strengths and are therefore ideal for use in piezo actuators and sensors. [3]

2.2 Hydrophone Sound Level Meter

The hydrophone transforms the sound pressure into a voltage variation which is an analog signal. This analog signal must be transformed into digital information. The key parameters in this analog to digital transformation are Sampling Rate and Level precision.

Sampling in time and amplitude is the process of inspecting the value of an analog signal at regular time intervals. The time between two value captures is called the sample period (T, in second) and the number of value captures in one second is the sampling frequency (f, in Hz) [4]. Figure 3 simply explains the process of sampling.

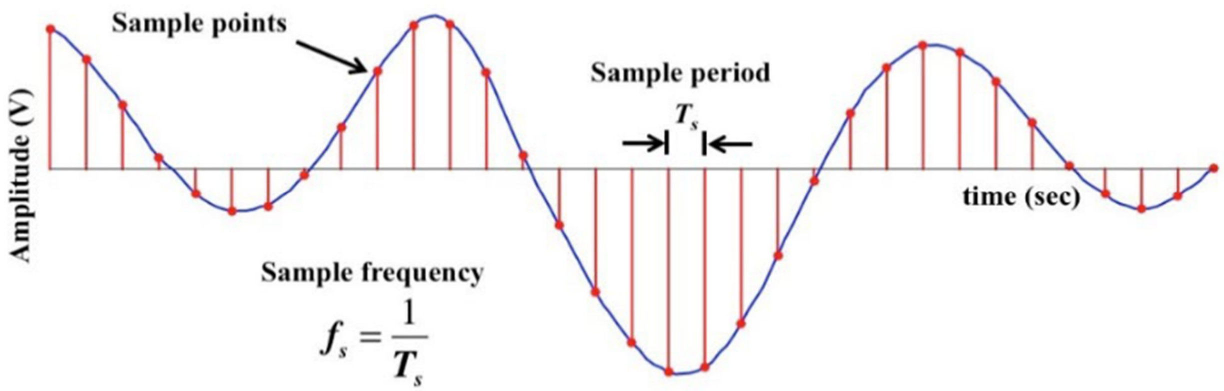

Figure 3: Sampling process [4]

The precision of this process is directly linked to the number of bits used. If you have more bits, you have more value than the signal can take and so the digitisation of the signal is more precise. But, you have to take care to not take a number of bits too high because the value could be too precise for his use and the final file could be too heavy and use a lot of space in the storage.

3 Background information about the noise in the sea

3.1 Noise pollution in the sea

As stated in the introduction, the ocean is not a quiet place anymore. Naturally the ocean is a relatively quiet place but it is not completely silent. The background sound of the ocean is well documenten and discussed for a long time. Even as far back as 1948 a paper reported the average sound levels for various frequencies as a function of wind speed and wave height. In 1962 a major review was published that examined many naturally occurring sounds in the ocean that result from rain, wind, marine life, ice and seismic activity like earthquakes and volcanic eruptions. [5]

However this is nothing compared to the anthropogenic (human-caused) noise pollution. Over the years this kind of noise pollution has radically increased. Informed estimates suggest that noise levels are at least 10 times higher today than they were a few decades ago. The largest contributor to anthropogenic noise pollution is commercial shipping. It generates noise of low frequencies between 5 to 500Hz. This is primarily created by the propeller action, propulsion machinery and hydraulic flow over the hull of the ship. This source of noise pollution is inescapable because it accounts for 90% of the international commerce. [1] [6]

Another source of noise pollution is the use of seismic exploration devices. It is a primary technique used by the energy industry in search of oil and natural gas reserves. It uses high-intensity sound to image the earth’s crust. Seismic exploration devices are also used for seismic reflection profiling. Which are used by academics and government groups to gather information on crustal structures, for the purpose of understanding the origin and tectonic history of the earth’s crust. The arrays of airguns used for the seismic reflection profiling, release a specified volume of air under high pressure, creating a sound pressure wave from the expansion and contraction of the released air bubble. [6]

Other noise pollution sources are sonar systems that seek information about objects in the ocean. The military uses sonars for target detection, localization and classification. Sonar systems produce a wide band of frequencies from low-frequency of less than 1000 Hz to high-frequency of over 20 kHz. At last industrial activities and construction contribute to underwater noise. Examples include coastal power plants, tunnel boring and wind turbines. The sources discussed here are only the major contributors. There are many minor sound sources that also cause noise pollution. [6]

3.2 How and why noise pollution influences animals in the sea

The anthropogenic sounds described above cause problems for marine life. Many marine animals are very acoustic, they use sound to perceive their environment, for mating, communication and for predator avoidance. When there is a considerate amount of anthropogenic sound in the ocean, these processes will be disturbed. Next to the behavioral problems anthropogenic sound causes, it also causes physical problems like hearing loss. [7]

Hearing loss discussed in literature is described in two different ways. First in a temporary hearing loss called temporary threshold shift (TTS). TTS is a relatively short-lived reduction in hearing sensitivity due to changes in the sensory cells of the ear. In general TTS results from exposure to intense sounds for short periods of time or somewhat longer exposures to lower sounds levels. Termination of the exposure eventually leads to the return of normal hearing ability. The second way of hearing loss is permanent, this is called the permanent threshold shift (PTS). PTS is a hearing loss that will never recover. PTS will result from intensive sound levels or longer periods of intensive sound levels. Also longer periods of lower sound levels could result in PTS. Both PTS and TTS influence processes which marine animals use for survival.

Other physical impacts of noise pollution include internal injuries, cellular damage to statocysts and neurons. Fish use statocysts for balance, orientation and body positional information. When this organ as well as ears or swim bladder are harmed, fish could get disorientated and die by stranding. Stress impacts from noise pollution also occur causing high levels of stress hormones, greater metabolic rate, oxygen uptake and overall worse body condition. This could include lower growth and weight, worsened immune response and lower reproductive rates. Even DNA integrity could be compromised by noise pollution. [7]

Noise pollution also causes behavioral problems. Animals exposed to noise pollution showed alarm responses, increased aggression, hiding, and flight reactions. It also decreases anti-predator defense, nest digging, nest care, mating calls and feeding. This could be a major problem for the ocean's ecosystem. Schooling also became uncoordinated due to noise pollution. This is not only a problem for the marine animals but also for commercial fishing. Some commercial catches dropped by up to 80% due to noise, and the bycatch rates could also be increased. [7]

3.3 Research into the animals in the sea

The research into the animals in the sea and how noise pollution is affecting them will be done by studying multiple papers on the subject. Because noise pollution in the sea is a well known subject under marine biologists, there are a considerable amount of papers on the subject. Despite the amount of papers published, it is still an ongoing research area and there are a great deal of gaps in the data.

In these papers the temporary threshold shift and the permanent threshold shift will be of most importance. The PTS and the TTS will be implemented in the device to give warning signals. In the current device only the TTS value will be the threshold for a warning signal. To establish PTS and TTS values, first the aquatic animals have to be divided into groups based on their hearing sensibility range.

The hearing groups are divided by means of phylogenetic[1] relationships, behavioural hearing studies and AEP measurements (based on electrophysiological response). When the groups are defined, the TTS and PTS values will be designated to each group. For invertebrate fish a danger value will be given since there is no TTS value available. Take into account that these values could be altered in the device when more information is available as it is an ongoing research field.

3.4 Marine animals hearing groups

As mentioned above, not all marine animals hear at the same frequency. This also means that not all marine animals will develop threshold shifts when exposed to the same amount of sound. Numerous authors have recognized that differences in frequency-specific hearing sensitivity among different animals influence how they are affected by noise exposure. [8] Experiments on goldfish indicated that the greatest level of TTS occurs when the noise source is at the frequency of best hearing [9].

In this report the marine mammals are divided into six mammal groups and two fish groups (see Table 2 and Table 3). These groups are based on their Phylogenetics relationships and a combination of auditory, physiological, and behavioural characteristics. The groups are generalised and individual animals within the groups could still have slightly different hearing sensitivity and thresholds. There may even be large overlap in frequency ranges between groups. The cetaceans are divided into 3

[1] Relating to the evolutionary development and diversification of a species or group of organisms or of a particular feature of an organism.

groups, low-frequency (LF), high-frequency (HF) and very high frequency cetaceans (VHF).

The low-frequency cetaceans (LF) group contains all of the mysticetes. The hearing sensibility of this group is calculated since there is no direct hearing data for this taxon. The audible frequency range relies on extensive assumptions and extrapolation, including mathematical modelling using anatomical parameters, characteristics of sound production and assumptions based on other species. These assumptions together with anecdotal observation of spontaneous responses to tonal signals in free-ranging animals and phylogenetic distinctions support the general designation of mysticetes as a low-frequency hearing group. The outer ear is absent in low-frequency cetaceans (a characteristic for all cetaceans), the external auditory canal is thin and partially blocked. The auditory pathway may involve some specialised fat [10]. Like humans the middle ear of mysticetes has an eardrum and ossicles to transfer the sound. For the mysticetes species that have been evaluated, it is observed that the cochlea is distinct in that the basilar membrane is exceptionally broad at the inner tip (an example of a cetaceans hearing organ is given in Figure 4). Within this group of whales there is evidence that some species are more specialised for the use of very low frequency (3 Hz to 30 Hz). This compared to species such as minke and humpback whales which generally use higher sound frequency for vocal communication. This suggests that this group may be divided in different categories.

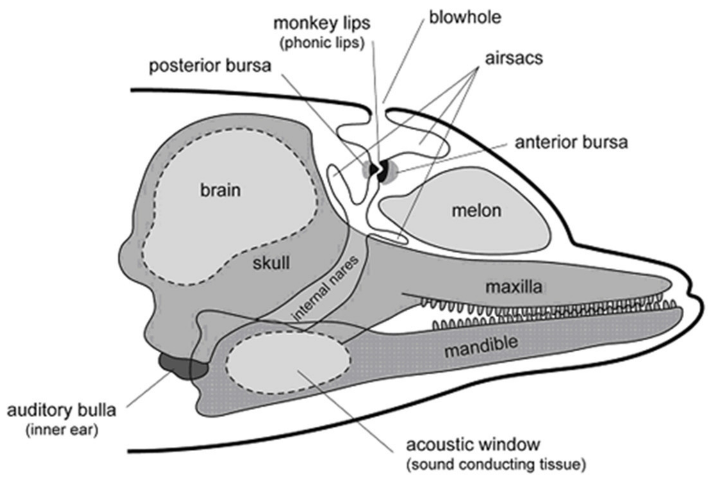

Figure 4: Cetaceans hearing organ [11].

The high-frequency hearing group (VHF) contains most of the dolphin species, beaked whales, sperm whales and killer whales. Other than for the low-frequency cetaceans group, the hearing sensitivity for this group is directly measured for approximately one-third of the species. This is done by either behavioural audiometry or neurophysiological, AEP measurements. Predictions about the hearing frequency ranges are also derived from anatomical modelling and sound production, although anatomical modelling this has only been done for relatively few species (e.g. the harbor porpoise and bottlenose dolphin). The odontocetes (a subdivision of cetaceans which are informally called toothed whales), which this hearing group contains, produce sounds in the form of clicks for social interaction and echolocating. Given that for most of the species within this group the optimal hearing sensitivity at frequencies of several tens of kHz or even higher, the group is described as high-frequency species. The high-frequency cetaceans also lack an outer ear. The odontocetes lack a functional internal auditory canal. Instead of using an internal auditory canal they uses a unique auditory pathway of acoustic fats aligned with the lower jaw to transfer the sound to the ear. Just as for the LF group, a further segregation into more specialised groups is proposed. More specifically a group of lower frequency is proposed for odontocetes such as sperm whales, killer whales and beaked whales. These odontocetes are generally larger than other odontocetes. A trend is documented that with increased body mass there is an increased sensibility for lower frequency [8]. This supports the hypotheses for a different category within the HF group. [8]

The last group of the cetacean is the very high-frequency cetacean (VHF). This group contains the true porpoises, most river dolphins, dwarf sperm whales and a number of oceanic dolphins. Within this group there is direct data available for three species. These are measurements of hearing using behavioural and/or AEP methods. These data indicate substantially higher upper-frequency hearing limits than the HF cetaceans. Predictions are also made by phylogenetics and sound production. Just as the HF cetaceans, cetaceans in the VHF group have a pathway of acoustic gats that transfer the sounds to the ear. The VHF cetaceans also differentiate themself by differences in the production of sound. The signals they produce exceed 100 kHz in almost all species and in some species even over 150 kHz. These values are the highest recorded in marine mammals, which support the distinction of VHF from the HF cetaceans. [8]

The next mammal hearing group is the Sirenian (SI) hearing group. The group contains manatees and dugongs, both are also known as sea-cows. There is some behavioural and electrophysiological hearing data of manatees available but a wide range of species specific data is not available yet. Hearing sensitivity data indicate some similarities to high-frequency cetaceans. Based on their taxonomic, auditory anatomical and sound production differences, the group is considered separately. Sirenian species lack an outer ear and their internal auditory canal is thin and partly blocked. The ossicles are massive and have an oil-filled bony structure, which makes the group unique. Because there is little data available for this group, the developed device will show a general hearing sensitivity range of 7 Hz to 160 kHz (This is the general hearing sensitivity range of all marine mammals [11]). [8]

The pinnipeds will be divided into two groups, the phocid pinnipeds (PW) and the Otariid pinnipeds (OW). Phocid pinnipeds have a broader frequency range of hearing sensibility. The ears of the two groups are anatomically different from one another. Both groups live in air as well as in water. The middle and inner ear of Otariid pinnipeds function the same in air and in water. In contrast to the ears of Phocid pinnipeds, which have adapted to a better hearing range underwater. This adaptation includes muscles that close the external ear canal when diving, an enlarged eardrum and massive middle ear ossicles that are ten times larger than in land animals with a similar skull size. These unique features expand their frequency range of hearing in water for a considering amount. [12]

A frequency range important to fish will also be included in the device. Fish will also be included in the device. Fish will account for two groups, the vertebrate fish (VF) and the invertebrate fish (IF). It is more difficult to determine a general hearing sensitivity range or a TTS/PTS for fish because not all fish have the ability to hear or produce sounds sound. At least 800 of the 33000 species of fish are able to produce sounds [13]. In regard to hearing capabilities, in general terms fishes can detect between 10 Hz to 500 Hz. Although some fishes have the capabilities to detect sounds to 3 kHz [14]. This depend on the type of fish and the way they detect sound. An overview of the different hearing capabilities are given in Table 1. The onset of TTS in fish are studied in a couple of fish, bluegill sunfish fathead minnow, goldfish and catfish. These studies have set the limit value of TTS onset at 170 dB. This is there for the value that will be used in the device. When more data is available the values set in the device can be altered.

For invertebrate fish (IF) there are no studies regarding TTS onset. Although a value for TTS is not available, a danger level can still be set. Several studies have analysed the physical effects in invertebrates after the exposure to specific sound pressure levels. For example, in a study performed in marine larvae, the SPL measurement of 165 dB cause body malformations and delay development (46% of malformations). [15]

Table 1: Hearing capabilities on different types of fish [13].

Group	Hearing characteristics	Examples
1	Fishes that do not possess a swim bladder, showing poor hearing abilities, and only have sensitivity to particle motion.	Sharks, mackerel, flatfish
2	Fishes with a swim bladder that is distant from the ear and does not contribute to sound pressure reception. These fishes are primarily particle motion detectors.	Salmon, Tuna, probably the majority of teleosts

3	Fishes where the swim bladder is close to the ear (but with no specialized physical connection), augmenting hearing sensitivity at some frequencies through the detection of sound pressure.	Atlantic cod, American and European eels
4	Fishes where the swim bladder or other gas volume is connected to the ear, enabling sound pressure to be detected, widening the frequency range of hearing and increasing hearing sensitivity to the extent that some species can detect sounds above 2 or 3 kHz, and some can even detect ultrasonic frequencies.	Herrings and relatives, otophysans (goldfish, catfish, etc.), some squirrelfishes, etc.

Table 2: Hearing groups and hearing sensibility range.

Marine mammal hearing group	**Genera (or species) included**	**Hearing range**
Low-frequency cetaceans (LF)	Baleen whales	7 Hz to 35kHz
High-frequency cetaceans (HF)	Dolphins, toothed whales, beaked whales, bottlenose whales	150 Hz to 160 kHz
Very high-frequency cetaceans (VHF)	True porpoises, Kogia, river dolphins, cephalorhynchid, *lagenorhynchus cruciger and L. Australia*	275 Hz to 160 kHz
Sirenians (SI)	Trichechidae, Dugongidae	7Hz to 160 kHz*
Phocid Pinnipeds (PP)	True seals	50 Hz to 86 kHz
Otariid Pinnipeds (OP)	Sea lions and fur seals	7 Hz to 160 kHz
Vertebrate fish (VF)	bluegill sunfish fathead minnow, goldfish, catfish	10 Hz to 3 kHz
Invertebrate fish (IF)	Marine larvae	10 Hz to 3 kHZ

*No exact data. Values are generalized hearing range for marine mammals

Table 3: TTS, PTS and general damaging values in dB.

Marine mammal hearing group	TTS onset:	PTS onset:	General damaging SPL value
LF	213	219	
HF	224	130	
VHF	196	202	
SI	220	226	
PCW	212	218	
OCW	226	232	
VF	170		
IV			165

4 Comparative and stakeholder analysis

In this chapter, a comparative analysis is used to determine which competing devices are already being sold on the market and what their specifications are. In the following, a stakeholder analysis is carried out to find out which interest groups are directly or indirectly involved in the development of a hydrophone sound level meter.

4.1 Comparative analysis

The comparative analysis is used to determine what competing devices already exist on the market. In addition, this analysis helps to determine which features or special specifications can be used to set a device apart from the competition.

There is currently no device specifically designed for this need and the task of displaying, recording and organising sound level data from a hydrophone for use at sea. Currently, the laboratory staff use a notebook to analyse the measurement data. But this is not a practical solution. This is because the notebook is neither waterproof nor suitable for use on a boat.

Below are some examples and comprehensive descriptions of existing products and the tasks that each device may or may not perform based on the criteria for a underwater acoustic level evaluator.

As can be seen Figure 5 below, none of these devices meet the essential requirements. As a result, if the product development of a new device is successful, there is an opportunity to stand out from the competition.

NEW DESIGN	Level	XL2 Audio and Acoustic Analyzer	Zoom H5	TASCAM DR-22WL	Sony PCM D-10	Zoom H8	Laptop/PC
Main function :							
Show measurements from a hydrophone	CR	No	Yes	Yes	Yes	Yes	Yes
Show instant sound level	Gr	Yes	Yes	Yes	Yes	Yes	Yes
Show spectrogram	Min	Yes	No	No	No	Yes	Yes
Derivate/ Powerfull function :							
Waterproof	CR	No	No	No	No	No	No
User-friendly	Gr	Yes	No	Yes	No	No	No
Hand-held	CR	Yes	Yes	Yes	Yes	Yes	No
Power all devices (include hydrophone)	CR	No	Yes	No	Yes	No	No
Different filters	Gr	No	No	No	No	Yes	Yes
Connectable to a hydrophone	CR	No	Yes	Yes	Yes	Yes	Yes
Touchscreen	Min	No	No	No	No	Yes	No
Usable with gloves	Min	Yes	Yes	Yes	Yes	No	No
Show a warning signal	CR	Yes	No	No	No	No	No
Sun resistant	Min	Yes	No	Yes	Yes	No	No
Adjustable background lighting	Min	No	No	Yes	Yes	Yes	No
6h hours continuous use	Gr	Typical battery lifetime > 4 hours	Yes, 16 hours	Yes, 12 hours	Yes, 32 hours	Yes, 10 hours	No
Extract the data from the device	Gr	Yes	Yes	Yes	Yes	Yes	Yes
Toughness	Gr	No	Yes	No	Yes	Yes	No

Min	(Minor)
Gr	(Great)
CR	(Critical)

Figure 5: Competitor Analysis Chart.

4.2 Stakeholder analysis

The aim of the stakeholder analysis is to identify which internal and external people could influence the project and work on it. Also in the development of a underwater acoustic level evaluator, there are different groups of people and stakeholders who are directly or indirectly involved in the project execution.

As shown in the Figure 6 below, a wide variety of stakeholders were identified. In addition, a distinction was made between internal and external stakeholders in the presentation. The following external stakeholders were identified for the hydrophone Sound level meter project:

- Suppliers: They are interested in selling goods and services,
- Government: Monitoring of regulations and limit values from the point of environmental protection
- Customers: They are interested in buying and using a product to display measurement data.

The following stakeholders were identified as internal interest groups:

- Developers: They are directly affected by the outcome of the product and they carry out the development and construction of the prototype,
- LAB: They have a direct influence on product development and they provide the project team with documents and information for conducting research,
- UPC: The university provides the resources for product development and supports the students in the project task.

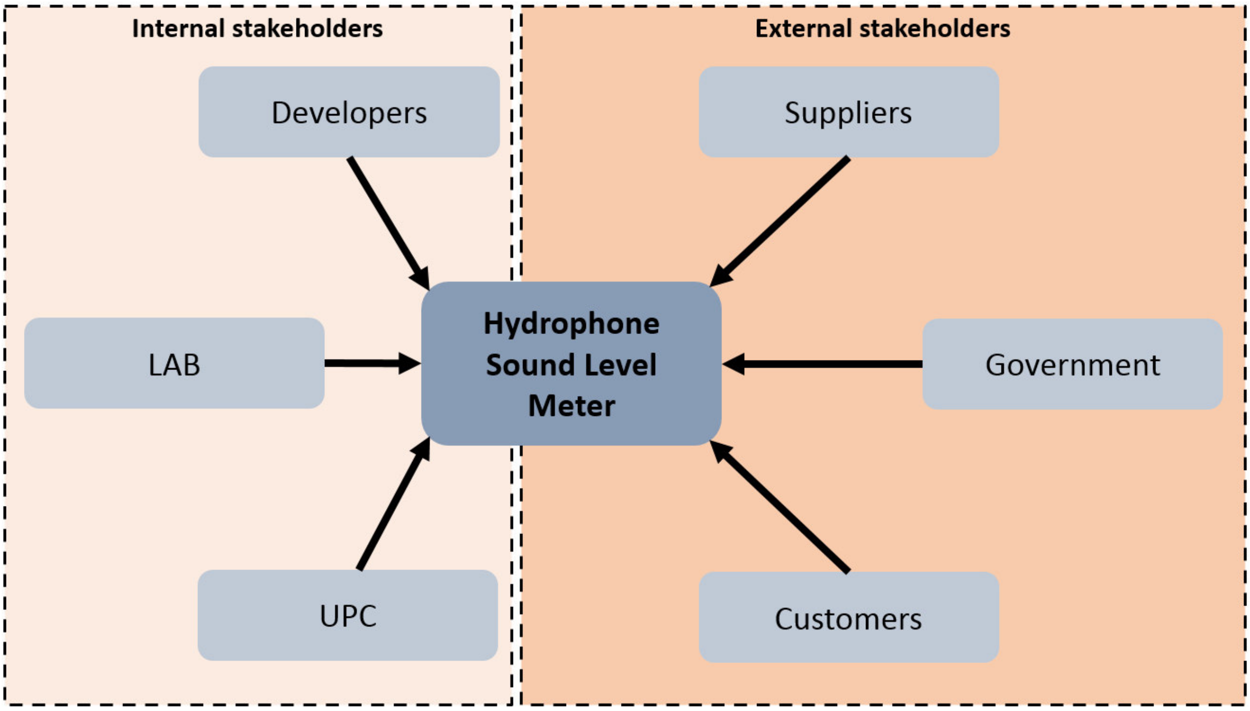

Figure 6: Stakeholder analysis for the hydrophone sound level meter.

It is particularly important in product development to keep an eye on the interests and demands of potential customers. Because they are the ones who ultimately buy the product and thus generate sales. It should be noted that different customer groups have different ideas about the goods. Therefore we need to extract and define the user of our product as accurately as possible. The costumers determined are also sorted into the following three levels:

- Critical importance for our project
- Great importance for our project
- Minor importance for our project

The Table 4 below shows all identified customers for a hydrophone sound level meter, as well as their classification and why they are important for our project.

Table 4: Differentiation of customers.

User/Customer	Level	Why are they important for our project
Scientists	Critical	They measure the noise pollution so they can do research on what it does to curtain species in the sea
Students/Teachers	Minor	They only use it to get to know more about the noise pollution in the sea. Students learn how to use requisite measuring instruments
Environmentally concernced citizens	Minor	They only use it to get to know more about the noise pollution in the sea
NGO	Great	They measure noise pollution to put pressure on the government to limit or to stop the noise pollution
Industry	Critical	They measure the noise pollution they create to make sure they stay within the limited value of the law

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5 Requirements for the hydrophone sound level meter

Determining requirements is an elementary part of product development. This is the only way to ensure that the requirements of customers and internal and external stakeholders for the product to be manufactured are met.

But there are also different requirements to be considered when developing a hydrophone sound level meter. A distinction is made between two types of requirements:

- Main Requirements: These requirements are mandatory and essential for the product development
- Desirable Requirements: These requirements are important but not mandatory

As shown in the Table 5 below, the requirements were separated into main (M) and desirable (d) requirements.

Table 5: Requirements specification for the hydrophone sound level meter.

ID	Requirements	Specification	Type	Category
1	**General**		**Mandatory M / Desirable d**	
1.1	Measurements	The device must display measurements from the hydrophone	M	base factor
1.2	Warning signal	The device must be able to warn if levels exceed thresholds	M	base factor
1.3	Power all devices	All components of the device as well as the hydrophone should be powered	M	base factor
2	**Functional and Non-functional functions**			
2.1	Waterproof	The device should be waterproof so that it can be used on a boat	d	base factor
2.2	User-friendly	The device should be easy and simple to use for all customers	d	performance factor
2.3	Hand-held	The device should be small so that it can be used in the hand	d	base factor
2.4	Connectable	The device should be connectable to a digital hydrophone	d	base factor
2.5	Touchscreen	The device should be operated via a touchscreen	d	enthusiasm factor
2.6	Usable with gloves	The device should be able to be operated with gloves	d	base factor
2.7	Different	The device should be designed for	d	performance factor

	languages	several languages		
2.8	Sun resistant	The device should be resistant to UV radiation from the sun	d	base factor
2.9	Background lighting	The device should offer the possibility of a background lighting for the night	d	performance factor
2.10	Six hours running	The battery should be selected so that the device can be operated continuously for at least six hours	d	base factor
2.11	Extract Data	The device should offer the possibility that data can be exchanged with a computer	d	performance factor
2.12	Independent Power Supply	The device should be equipped with an independent power supply	d	base factor
2.13	Tough	The device should be robust against shocks and impacts	d	base factor
3	**Costs**			
3.1	Cost efficient	The device should have a good price-performance ratio.	d	base factor

6 General Concepts and Ideas

In this section, four different ideas for a hydrophone sound level meter are presented. It also describes the advantages and disadvantages of each concept and which is the final concept.

6.1 Concept 1

The first concept is a small portable device. Here, the cable of the hydrophone is physically connected directly to the portable device. This means that the data and measured values are transmitted via cable. Apart from that, there is another cable that attaches the hydrophone to the boat, so the device is safe and it doesn't drop accidentally in the water.

The device is characterised by the fact that it has a small screen for reading the measured values and sound levels. In addition, it offers navigation through the menu with buttons. The following Figure 7 shows a simplified representation of what an application with this concept might look like (without considering the second cable).

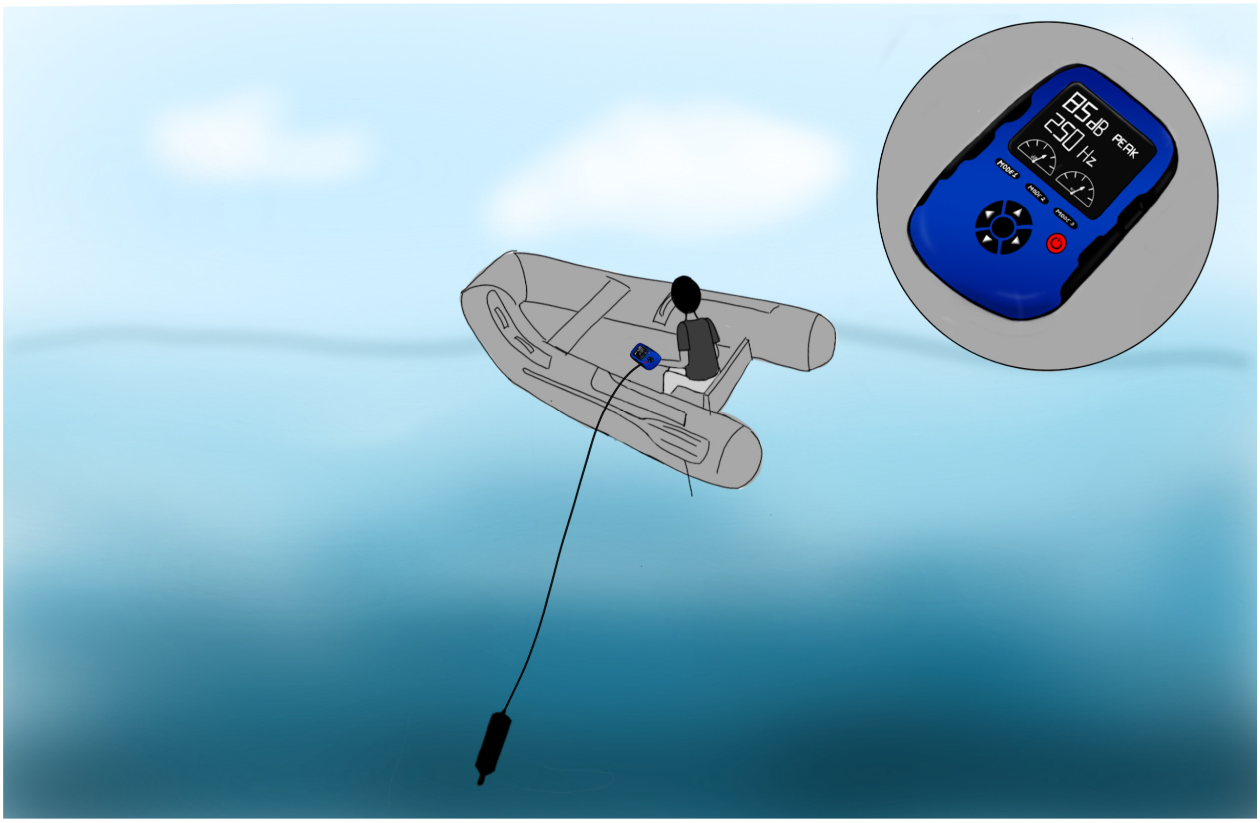


Figure 7: Concept 1

The Table 6 below represents the list of pros and cons of this first concept:

Table 6: Pros and Cons for Concept 1.

Pros	Cons
Hand-held	Only 1-3 people can see the screen at the same time
Only one device	Little installation space
No connection problems because all connections are with wires	Does not stand out from competing products
Suitable for professionals	Challenging to make waterproof
Plug and play	
Usable for professionals and amateurs	
Big market	

6.2 Concept 2

This concept is about a box that contains all the components and is connected to the hydrophone with a cable (see Figure 8). Then, in this case, the box is able to send the information to any kind of device that has a screen that can display the information. This would be possible with an app that runs on several devices and operative systems. The wireless transmission in this concept is via Bluetooth.

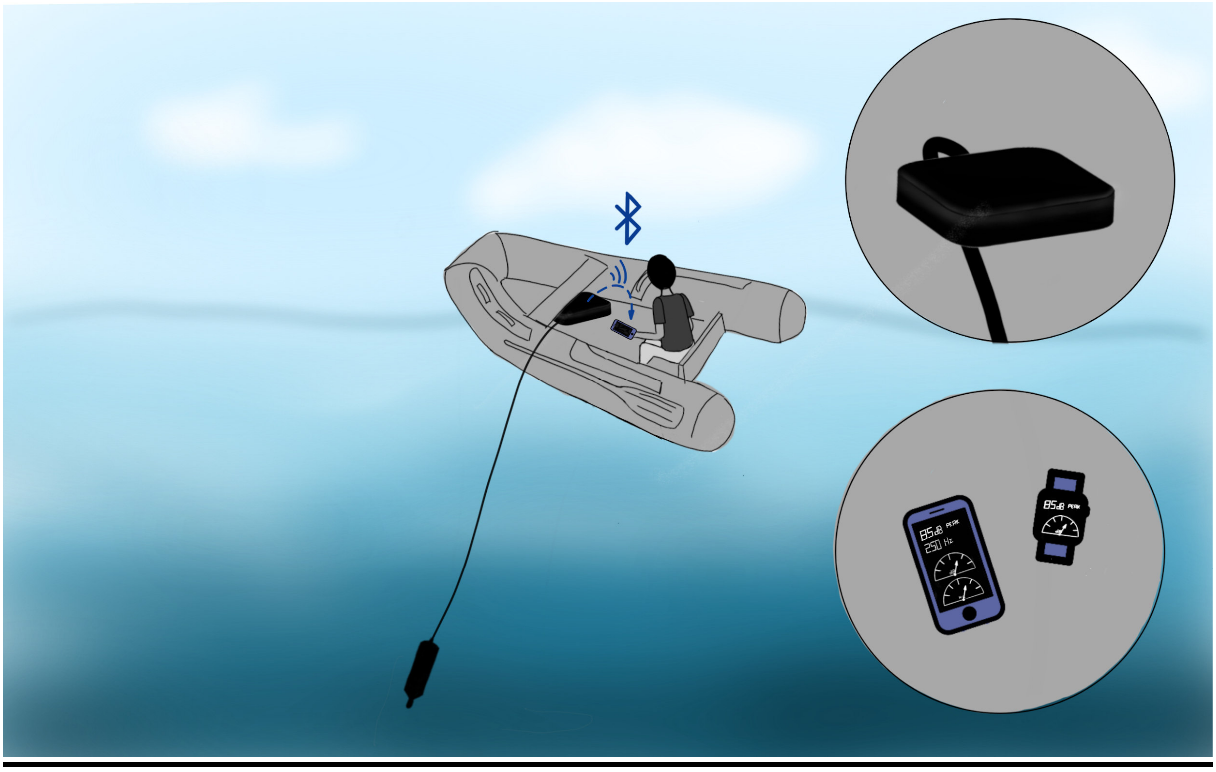


Figure 8: Concept 2

The Table 7 below represents the list of pros and cons of this second concept:

Table 7: Pros and Cons for Concept 2.

Pros	Cons
Connectable to mobile phones	An app is necessary
Connectable to digital watches	Different operating systems
A lot of people can see the measurements at the same time	Normal phones are not suitable to use on a boot (not waterproof, not robust)
Easy for manufacturing	Not every mobile phone can continuously run for at least 6 hours
Enough space for all components	

6.3 Concept 3

As shown in the Figure 9, here the device will be connected to a boat like a zodiac in which there is a screen already. Furthermore, apart from displaying the information on the boat's screen, it will also be able to share it via wifi and/or Bluetooth in other to connect with other devices too. For that option, we will also need an app that can be downloaded in several different operative systems.

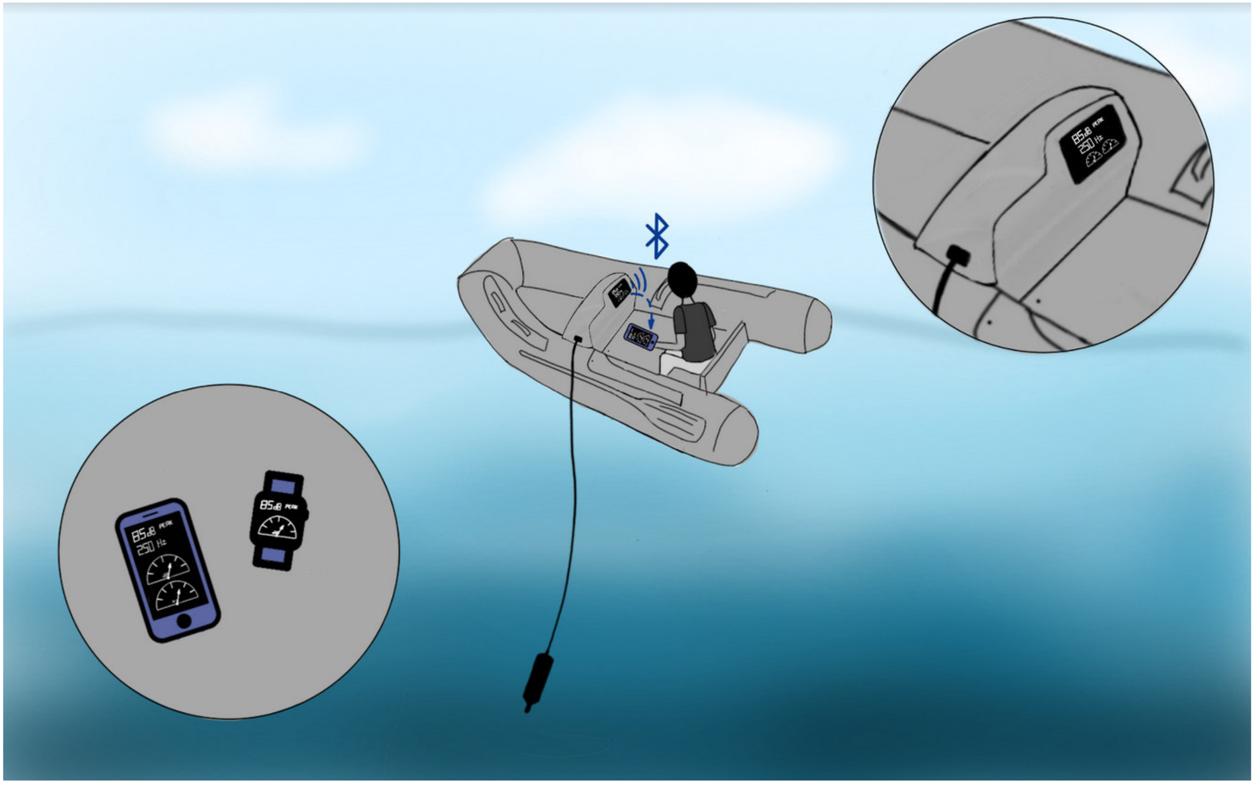


Figure 9: Concept 3

The Table 8 below represents the list of pros and cons of this third concept:

Table 8: Pros and Cons for Concept 3.

Pros	Cons
Only the receiver is necessary because the screen would already be present on the boot	The sonar must be compatible with the receiver
	Most sonar devices are not connectable
	The screen needs a lot of power

	This solution is not hand-held

6.4 Concept 4

In this last idea, as explained in Idea 2, there will be a receiver with a box shape. However, in this case, the receiver will be apart from the boat (see Figure 10). It will be placed in a buoy and will send signals to a device via Bluetooth. This one is overall thought for using it on the coast.

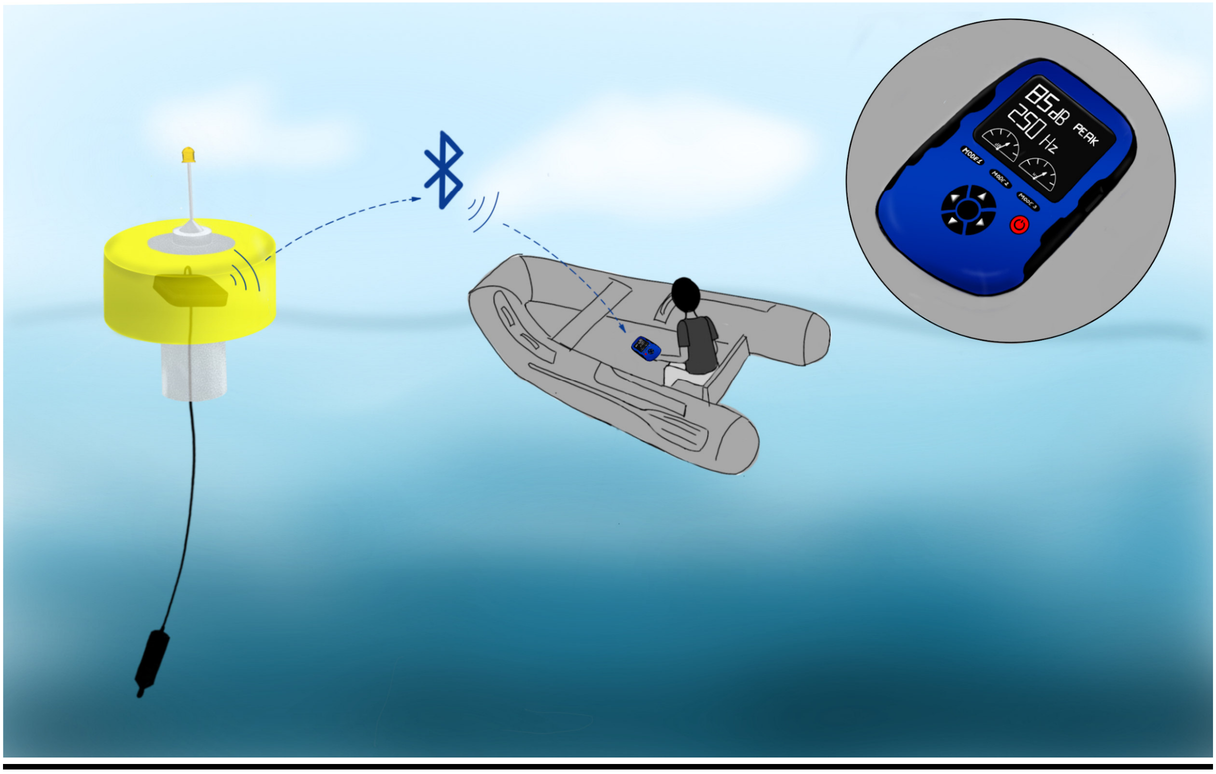


Figure 10: Concept 4.

The Table 9 below represents the list of pros and cons of this third concept:

Table 9: Pros and Conc for Concept 4.

Pros	Cons
The main structure of the buoy already exists	Not hand-held
Enough installation space	It is necessary to develop the device

Usable in dangerous positions or position where you can not stay with a boot	Small market
Device is independent of wires hence more user friendly	Might have connection problems
	It must be 100% waterproof for a long time
	Usable only for professionals

6.5 Final Concept

The final decision was made in favour of Concept 1 (see Figure 12). On the one hand, this is because all requirements can be met and implemented. And on the other hand, this concept guarantees high system stability. This is especially important for professional users. Even if a wireless concept seems more user-friendly at first glance, this final concept offers a simple plug and play solution.

To perform a sound measurement, the user must connect the hydrophone to the portable device. To do this, the male plug of the data cable is plugged into the female socket of the receiver and screwed tightly to make a waterproof connection. A waterproof connection is also made between the data cable and the hydrophone. As shown in the Figure 11 below, a cable with eight wires is to be used. Two of them are for power supply and the rest are for data transmission.

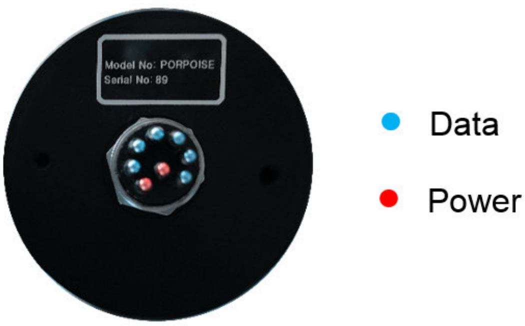


Figure 11: Rear view of the hydrophone with the data pins and power pins.

To relieve the data cable from the weight of the hydrophone during the measurement, the hydrophone is also attached to the boat with a safety line. This means that there is no tension on the data cable between the hydrophone and the acoustic level evaluator. To switch on the device, the on/off switch must be pressed once. During the measurement process, the user can read the measured values from the screen while standing or sitting. Using the various buttons, the user can navigate through the menu and select different settings. After the measurement process is finished, the measured data can be transferred to a computer. To prepare the portable acoustic evaluator for the next use, the integrated battery can be charged with the help of a charging cable.

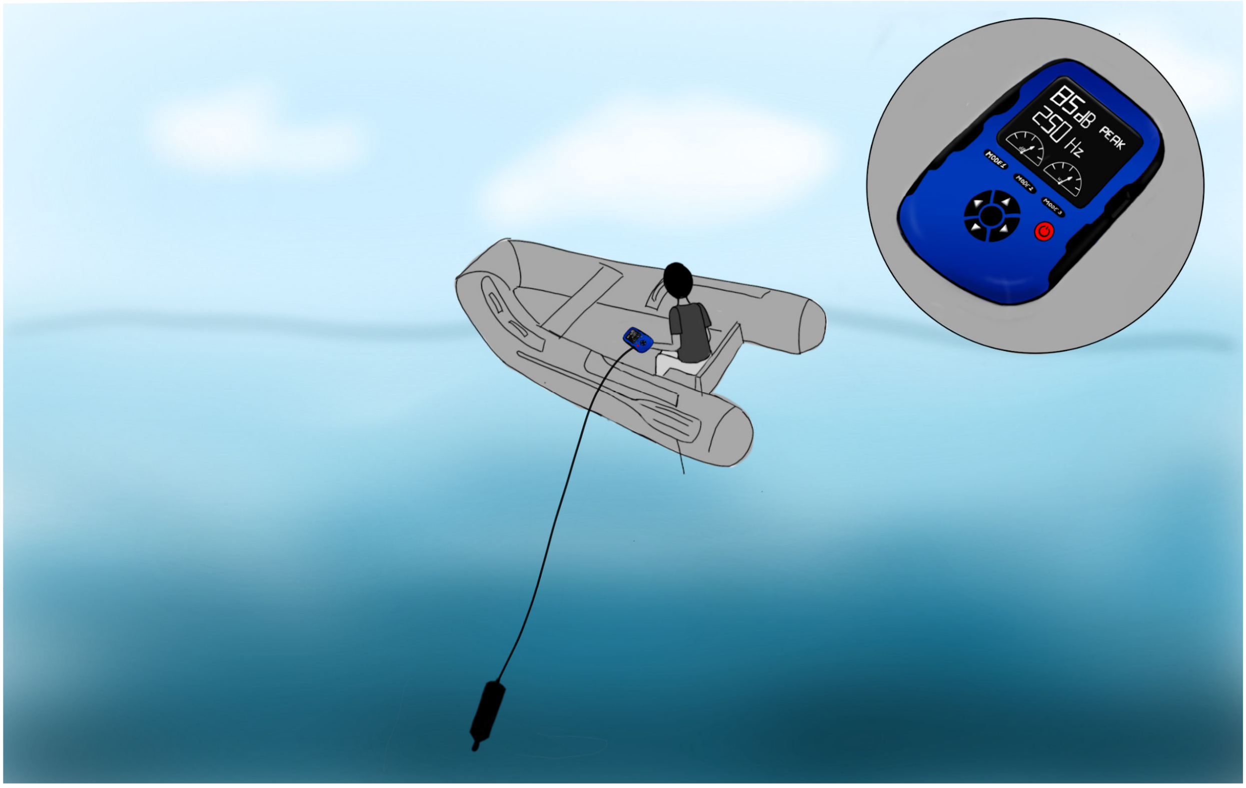


Figure 12: Final Concept is Concept 1.

7 Selection of components

This chapter describes the components that make up the Hydrophone Sound Level meter. A component diagram is also shown. This diagram helps to understand which components are wired together and how the current flow and data exchange takes place.

7.1 Components List

After selecting a concept, one of the next steps is to select the necessary components, because only with an exact and complete listing of all components is the basis for the subsequent product design phase. Therefore, a parts list was also created for this project in order to provide simplified information about which components and parts are required for the production of a hydrophone sound level meter.

The Table 10 below lists all components that are required for the production of a prototype according to the current project status. In addition, the parts list also describes the function of the individual components.

Table 10: Components List

Components	Description
Electrical components	
Raspberry Pi Zero 2 W	A small single-board computer as the central processing unit
2,7 inch E-ink Display	For displaying graphics and diagrams
Step Up DC-DC Converter (3,7 V to 12 V)	Steps up voltage from the input to its output
Step Down DC-DC Converter (12 V to 3,3 V)	Steps down voltage from the input to its output
ENC28J60 Ethernet SPI Module	This module converts Ethernet data signals to GPIO signals
Li-ion Battery	Is the power supply for all electrical components
Switches	
On/Off Switch	For switching the device on and off
Connectors	

Connector (Hydrophone)	Connector for connecting the hydrophone to the sound level meter
Connector (Charging supply)	Connector for connecting the external power charger to the sound level meter to charge the battery
Other components	
Wire	To connect the individual components
Shrink tubing	To protect the cables from short circuits

The Figure 13 below is a representation of all necessary components for the hydrophone sound level meter. The purpose of creating this overview is to show in a simplified way which components are to be interconnected.

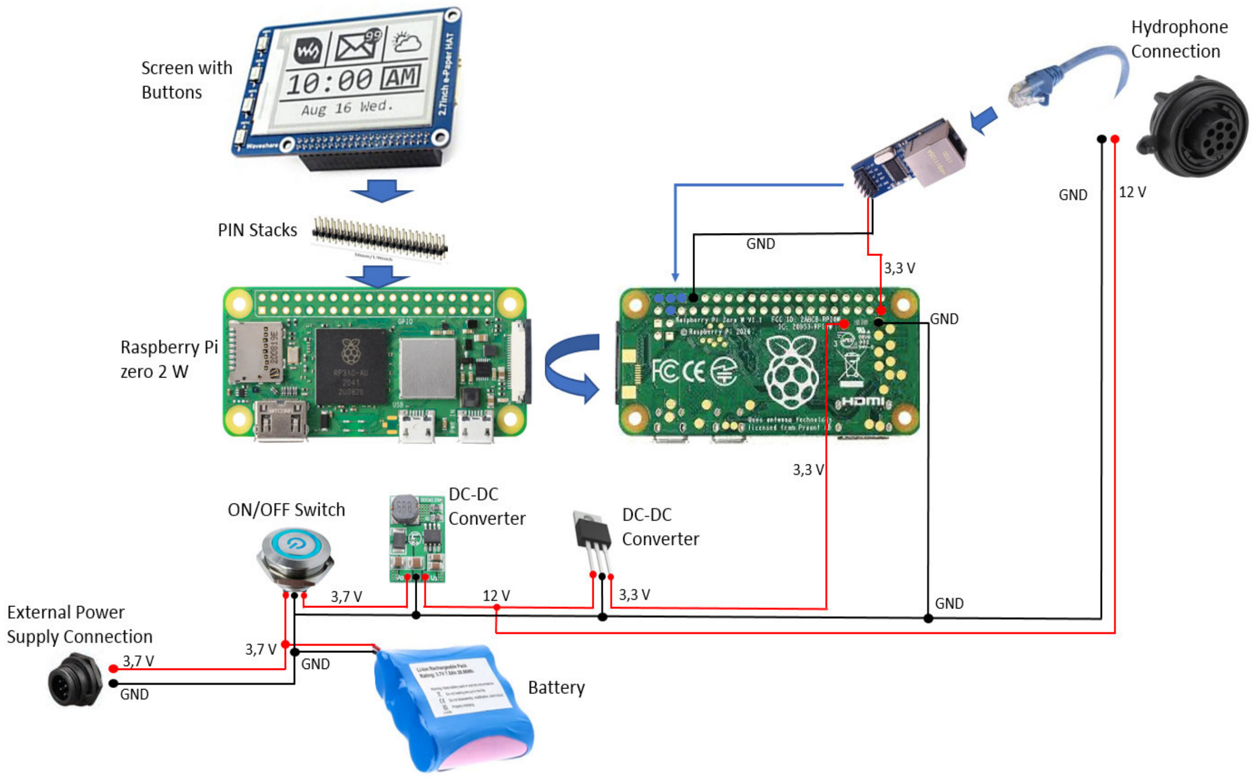


Figure 13: Components diagram.

With reference to Figure 13**Fehler! Verweisquelle konnte nicht gefunden werden.**, Figure 14 below again shows all the components within the system boundary of the Hydrophone sound level meter.

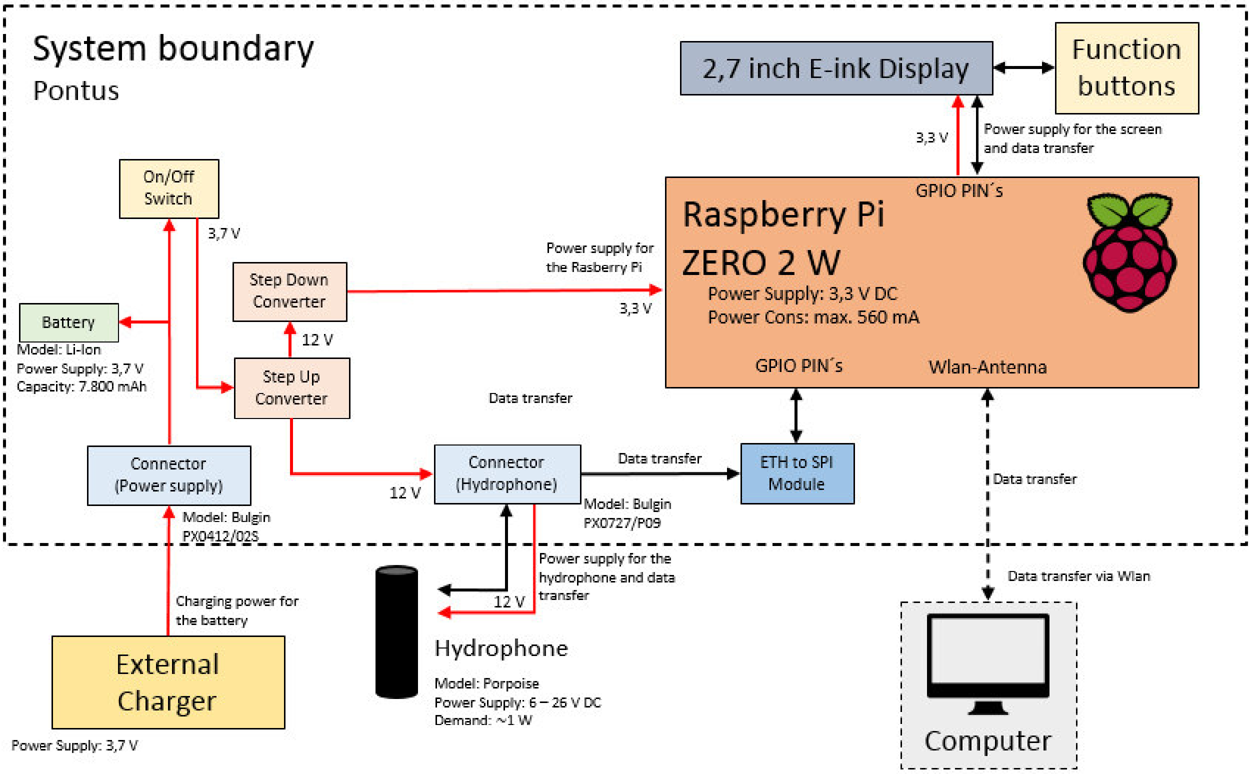


Figure 14: Components within the system boundary.

7.2 Electrical Components

Different components are needed to produce the Hydrophone Sound level meter. One category is electrical components. These active components enable a circuit to output an electrical signal in some form with higher power than is provided to it by the source of the signal. Furthermore, active components allow control.

7.2.1 Single Computer Board

A Raspberry Pi Zero 2 W (see Figure 15) is used as the central processing unit. The choice for this small single computer board was not easy. In addition to several alternative manufacturers, one or two compromises had to be made in the selection of the Raspberry Pi Zero 2 W. However, the high performance, the small size and the low energy consumption were the key characteristics that led the project group to choose it. Basically, it has to be said that the single computer board is the most important main component of the hydrophone sound level meter. This is because the computer unit processes the measurement data received from the hydrophone and displays it in a way that is easy for the user to understand.

As already mentioned, one of the main reasons was the low energy requirements of the Raspberry Zero 2 W. Since the hydrophone sound level meter is designed for a continuous runtime of six hours, it is essential to choose components with low power requirements. The Raspberry Zero 2 W is rated at 0.5 to 0.7 watts at 3,3 volts. [16]

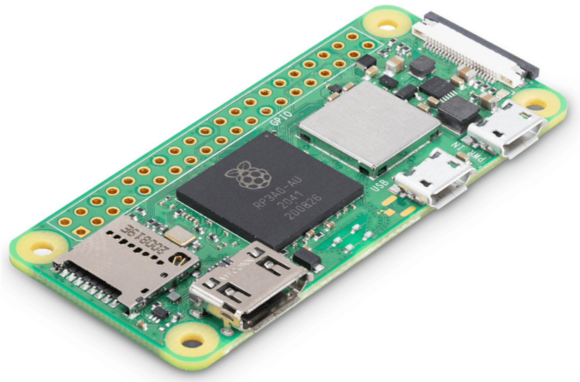


Figure 15: Raspberry Pi Zero 2 W [17].

The most important specifications of the Raspberry Pi Zero 2 W are listed below [17]:

- 1GHz quad-core 64-bit Arm Cortex-A53 CPU,
- 512MB SDRAM,
- 2.4GHz 802.11 b/g/n wireless LAN,
- Bluetooth 4.2, Bluetooth Low Energy (BLE), onboard antenna,
- Mini HDMI port and micro USB On-The-Go (OTG) port,
- microSD card slot,
- CSI-2 camera connector,
- HAT-compatible 40-pin header footprint (unpopulated),
- H.264, MPEG-4 decode (1080p30); H.264 encode (1080p30),
- OpenGL ES 1.1, 2.0 graphics,
- Micro USB power,
- Composite video and reset pins via solder test points,
- 65mm x 30mm.

There are several ways to supply the Raspberry Pi Zero 2 W with power. If there is a stable and clean voltage (low ripple) of 3,3 volts available from a stabilised or regulated power supply, then the Raspberry Pi Zero can also be supplied with power via the GPIO 3,3 V pin. It must be taken into account that no polyfuse is installed. This means that the applied voltage not only supplies the SoC, but also the USB devices. Under certain circumstances, not only the SoC will break, but also the USB devices. [16]

The project team has decided that the power supply should be provided via the 3,3 V interface. This is also recommended by the manufacturer and has the advantage of being very space saving.

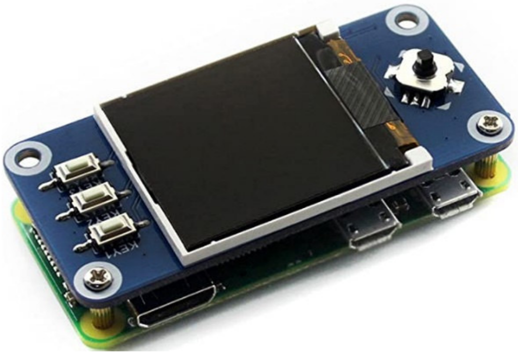
7.2.2 Display

In addition to the single computer board, the display is another very important component. It displays the measured values of the hydrophone in a way that is understandable to the user. In order to find a suitable variant for the hydrophone sound level meter, several display concepts were developed.

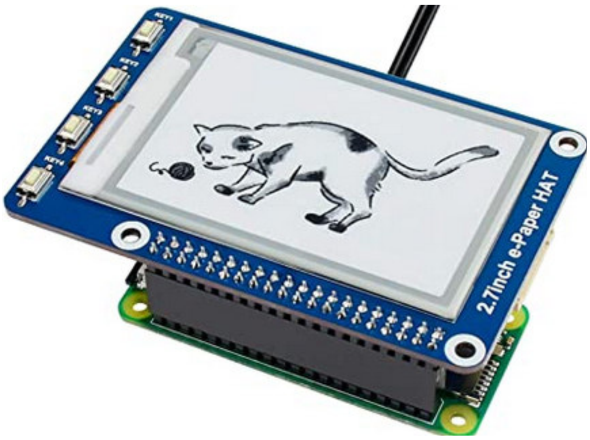
Attention was also paid to ensure that compatibility between the display and the small single computer board is possible without much effort. As shown in the Table 11 below, the following five display concepts were developed:

Table 11: Five concepts for the screen [18] [19] [20] [21] [22].

Concept 1	
	
Type of Screen:	Not specified
Power consumption:	Not specified
Power:	The screen is powered by the Raspberry Pi
Price:	30,86 €
Further information:	The screen is mounted on a board that can be connected directly to the Raspberry Pi. Thus plug and play. In addition, there are four buttons on the board

Concept 2	
	
Type of Screen:	1.44-inch LCD Display 128*128 Pixels 65K Display Color
Power consumption:	Not specified
Power:	The screen is powered by the Raspberry Pi
Price:	14,60 €
Further information:	The screen is mounted on a board that can be connected directly to the Raspberry Pi. Thus, plug and play. In addition, there are three buttons and a joystick on the board

Concept 3	
	
Type of Screen:	1.54 inch LCD Display Touch Screen
Power consumption:	Not specified
Power:	The screen is powered by the Raspberry Pi
Price:	21 €
Further information:	The screen is mounted on a board that can be connected directly to the Raspberry Pi. Thus, plug and play. In addition, there are six buttons and a joystick on the board

Concept 4	
	
Type of Screen:	2.7-inch E-ink Display 264*176 Pixel
Power consumption:	Not specified
Power:	Ultra low power consumption approx. 26,4 mW
Price:	20 €
Further information:	The screen is mounted on a board that can be connected directly to the Raspberry Pi. Thus, plug and play. In addition, there are four buttons on the board

Concept 5	
	
Type of Screen:	TFT Display ILI9341 1,44 inches 2,4 inches 3,2 inches
Power consumption:	Not specified
Power:	The screen is powered by the Raspberry Pi
Price:	5 – 10 €
Further information:	This screen must be wired to the Raspberry Pi

For a simplified decision-making process, all advantages and disadvantages of the respective concepts were listed in a pro-contra list. The pro-contra list is a simple way to decide for or against a specific project idea. The following Table 12 shows the respective advantages and disadvantages of the individual concepts:

Table 12: Pro-contra-list for the display concepts.

Concept	Pros	Cons	Priority
Concept 1	+ Plug and Play	- Expensive - No specifications given - Small screen - Design limited	5
Concept 2	+ Plug and Play + Joystick and buttons + Well-known manufacturer + 65K Colour Display	- Small screen - Design limited	4
Concept 3	+ Plug and Play + Joystick and many buttons	- Small screen - Design limited	3
Concept 4	+ Clear display easy to read + Low power consumption + Well-known manufacturer + Plug and play + Many positive reviews	- Black and white - Only four buttons	1
Concept 5	+ Very cheap + Many positive reviews + High design freedom	- Complex wiring	2

As shown in the Table 12, the decision was made in favour of the Concept 4 with the E-ink display. In addition to the 2.7 inch display, the low energy consumption is particularly convincing. The lower the energy consumption, the lower the necessary battery capacity and thus also a lower battery volume and less mass. Furthermore, the E-ink display convinces with a very good readability even in very strong sunshine. In contrast, other displays are often very difficult to read when they are dazzled by the sun. In addition, the screen is already mounted on a circuit board that can simply be connected to the Raspberry Pi Zero 2 W via the provided pin connections. Four buttons are also already mounted on the display board, which can be used to navigate through the menu structure. The price of about 20 euros per unit is an acceptable value for a brand product from Waveshare.

As a compromise for this selection, it has to be accepted that the display is only in black and white. This means that no coloured displays are possible. Even though four buttons are already mounted on the display board, two or three more buttons would facilitate navigation in the menu structure or the selection of various filter functions.

7.2.3 DC-DC Step Up Converter

The DC-DC step-up converter (compare withFigure 16: DC-DC Step-Up Converter Figure 16) is another important component in the hydrophone sound level meter. This is because this DC-DC step-up converter converts the battery voltage of 3.7 V to a voltage of 12 V. This allows the hydrophone to be supplied with the required current directly from this board [23].

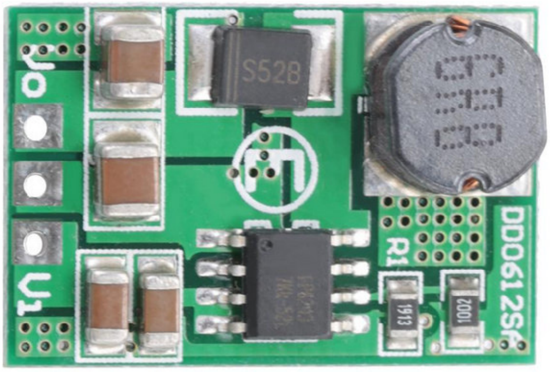


Figure 16: DC-DC Step-Up Converter [23].

The most important specifications of the DC-DC Step-Up Converter are shown below [23]:

- Input Voltage: DC 3,7 V,
- Output Voltage: DC 12 V,
- Output Power: 12 W,
- Average Output current: 0,63 A,
- Component Size: 24*16*6,2 mm.

7.2.4 DC-DC Step Down Converter

To operate Raspberry Pi Zero 2 W, a power supply is required. The input voltage can be 3.3 V or 5 V. Since both the screen and the ENC28J60 Ethernet SPI module require a working voltage of 3.3 V, the Raspberry Pi is supplied with an input voltage of 3.3 V. To provide this voltage, a step-down DC-DC converter (compare with Figure 17) is used. To provide this voltage, a step down DC-DC converter is used. This positive-voltage regulator with the model designation UA78M33CKCS converts the 12 V output voltage of the DC-DC step-up converter into an output voltage of 3.3 V. This component was chosen for this reason. The choice for this component is justified by the fact that it is very small, light and is used primarily in the industrial sector and thus meets all requirements.

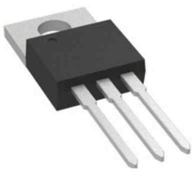


Figure 17: Step Down DC-DC Converter [18].

The most important specifications of the step down DC-DC converter are shown below [24]:

- Input Voltage: DC 5,3 – 25 V,
- Output Voltage: 3,3 V,
- Long Time Output Current: 0,5 A,
- Long Time Use Output Power: 1,65 W,
- Efficiency: 85 % for 3,3 V and 0,5 A,
- Operating Temperature Range: - 40°C to + 125°C,
- Input Connection: Solding,
- Output Connection: Solding.

7.2.5 ENC28J60 Ethernet SPI Module

In order to be able to evaluate the measurement information from the hydrophone, a physical connection must be established between the hydrophone and the small single computer board. There are two possibilities for this. One is to transfer the information via the USB micro port to the Raspberry Pi. The other option is to use the existing GPIO pins of the Raspberry Pi Zero 2W. As shown in the Figure 18 below, the data transfer between the Hydrophone and the single computer board is done via the GPIO pins. This requires an ENC28J60 Ethernet SPI module that converts the Ethernet data signals to GPIO signals. The connection between the ENC28J60 Ethernet SPI module and the Raspberry Pi is made with standard cables, which are soldered on both sides. A connection between the hydrophone connector and the ENC28J60 Ethernet SPI module is made using a network cable. The RJ45 plug is simply plugged into the RJ45 female socket provided on the ENC28J60 Ethernet SPI module. On the other side of the network cable, the individual wires are mechanically connected to the respective pin on the hydrophone connector.

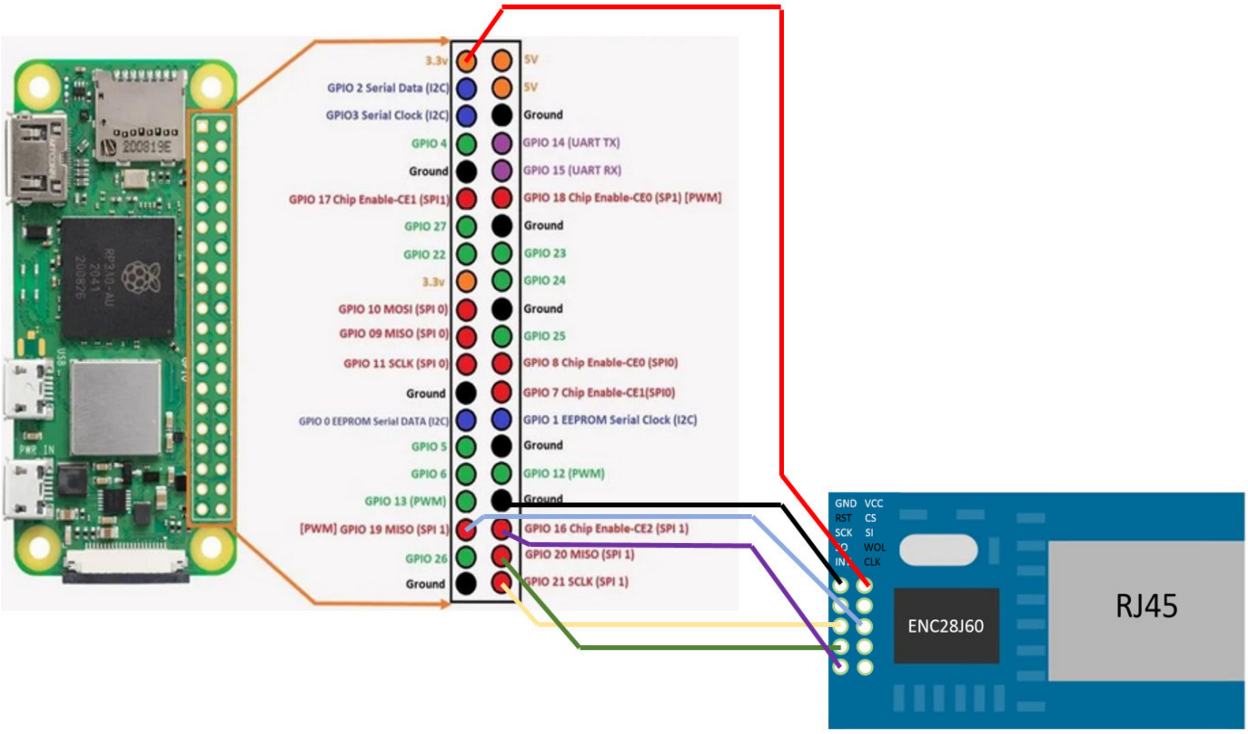


Figure 18: ENC28J60 Ethernet SPI Module connected to the Raspberry Pi Zero 2 W.

7.2.6 Battery

The battery is another central component. It provides the power supply for the Raspberry Pi Zero 2 W and the Hydrophone. A battery is an electrochemical energy storage device and a converter. When discharged, stored chemical energy is converted into electrical energy through the electrochemical redox reaction. The converted energy can be used by an electrical consumer independent of the power grid. [25]

In non-rechargeable primary batteries, the reactions during discharge are not or only partially reversible. In rechargeable secondary batteries (accumulators), on the other hand, the discharge reactions are largely reversible, so that multiple conversion from chemical to electrical energy and back is possible. The term "battery" refers to an interconnection of several galvanic cells. Colloquially, the term is also used for individual galvanic cells. Due to the many areas of application with very different requirements in terms of voltage, power and capacity, there are nowadays batteries in an almost unmanageable number of designs. [25]

The capacity of a battery is given as the theoretically charge capacity in ampere hours (unit: Ah). The removable capacity depends on the discharge current and the discharge voltage of the battery. Various discharge methods are common, including [25] :

- Constant current discharge,
- Constant resistance discharge,
- Constant power discharge.

Depending on the discharge method, the battery has a different capacity. A meaningful indication of the nominal capacity must therefore include the discharge current and the final discharge voltage. [25]

Since there are many different types of batteries. Therefore, a research was done to find out what the differences are between the different battery types. The following Table 13**Fehler! Verweisquelle konnte nicht gefunden werden.** shows a comparison of different battery types in terms of different specifications such as:

- Specific energy and specific density,
- Charge / Discharge efficiency,
- Cycle durability,
- Nominal cell voltage,
- Energy / Consumer price.

Table 13: Comparison of different battery types.

Battery Type	Specific energy	Specific density	Charge / discharge efficiency	Cycle durability	Nominal cell voltage	Energy / consumer price
Lead Acid	35 – 40 Wh/kg	80 – 90 Wh/L	50 – 95 %	350 cycles	2,1 V	0,01 €/Wh
NiCd	45 – 80 Wh/kg	70 – 100 Wh/L	70 – 90 %	1000 cycles	1,2 V	1 – 3 €/Wh
NiMH	60 – 120 Wh/kg	140 – 300 Wh/L	66 – 92 %	180 – 2000 cycles	1,2 V	2 – 4 €/Wh
Li-Ion Cobalt	150 – 250 Wh/kg	250 – 600 Wh/L	95 %	500 – 1000 cycles	3,6 V	0,15 €/Wh
Li-Ion Manga-nese	100 – 150 Wh/kg	250 – 600 Wh/L	95 %	500 – 1000 cycles	3,7 V	0,15 €/Wh
Li-Ion Iron Phospate	90 – 120 Wh/kg	300 – 500 Wh/L	> 85 %	1000 – 2000 cycles	3,2 – 3,7 V	0,6 €/Wh

After identifying the different battery types that could be used for the hydrophone sound level meter, a decision had to be made as to which battery should be used. To make the decision easier, another table was created with the advantages and disadvantages of each battery type. At the same time, this Table 14 shows which battery type was prioritised. It can be seen that the battery type "LI-Ion iron phosphate" is the favourite. This is mainly due to the fact that this battery type is very safe and guarantees a long runtime. It also scores with a high discharge rate and a low weight.

Table 14: Battery types comparison.

Battery Type	Pro´s	Con´s	Prio
Lead Acid	+ very cheap + Low self-discharge	- Really low energy density - Low cycle life - Not environmentally friendly	5
NiCd	+ Operating temperature in the low and high range + Simple storage and transportation	- High self discharge - Medium cycle life - Low cell voltage	5
NiMH	+ Reconditionable + Simple storage and transportation + Environmentally friendly	- High self discharge - High price - Low cell voltage	4
Li-Ion Cobalt	+ High energy density + Lower cost + Light-weight	- Risky specially when damaged - Low discharge rates - Poor cobalt resource	3
Li-Ion Manganese	+ High discharge rates + High Safety + Light-weight	- Lower energy density - Less volumetric capacity - Poor recycling performance	2
Li-Ion Iron Phospate	+ Long life and inherently safe + High discharge rates + Light-weight	- Less volumetric capacity - Medium energy density	1

In order to determine a suitable battery, a calculation must be made to know which capacity of the battery is required. For this purpose, the energy consumption of all components installed in the hydrophone sound level meter must be determined. In the following Table 15, all individual components are shown with their respective energy consumption.

Table 15: Power consumption calculation for the hydrophone sound level meter.

Component type	Details	Consumption
Raspberry Pi Zero 2 W	Max. power consumption: 3 W (0.6A) Average power Consumption:	600 mW
Screen	2,7 inch E-ink Display Average power consumption:	26,4 mW
Ethernet to GPIO Converter	ENC28J60 Ethernet SPI module Average power consumption:	594 mW
DC-DC Step Up Converter	Efficiency: 85 % for 12 V and 0,63 A, Average power consumption:	352 mW
DC-DC Step Down Converter	Efficiency: 90 % for 3,3 V and 0,5 A, Average power consumption:	123 mW
Hydrophone	PORPOISE TR-P-05-A-1-W-S-1 Average power consumption:	1.000 mW
Total power consumption for the hydrophone sound level meter:		**2.696 mW**

Now the following formula is used to calculate the required capacity of the battery. A safety margin of 20 per cent for the energy consumption is included in the calculation. In addition, a further safety factor of 40 percent is taken into account for the battery. This is because the battery must not be completely discharged and the capacity of the battery is reduced after several hundred charging and discharging processes. The calculated battery capacity is designed for a continuous running time of six hours.

$$\frac{P_{load}}{V_{Nominal}} * P_{safety} * hr * \ Battery_{safety} = minimum\ battery\ capacity$$

$$\frac{2{,}70\ W}{3{,}7\ V} * 1{,}2 * 6\ h * \ 1{,}4 = 7.356\ mAh$$

With:

$P_{load} = Load\ power,$

$V_{Nominal} = Nominal\ Battery\ Voltage,$

$P_{safety} = Power\ safety,$

$hr = running\ time\ in\ hours,$

$Battery_{safety} = Battery\ safety.$

To supply the hydrophone sound level meter with sufficient energy, a Li-Ion battery with a capacity of 7,800 mAh is used. The battery pack also includes charge and discharge protection. In addition to a cycle durability of up to 3,000 cycles, this battery model RS Pro 18650 26H Li-ion Battery (compare with Figure 19) convinces with further specifications, which are listed below [26]:

- Nominal Voltage: 3,7 V,
- Max. Discharge Current: 7 A
- Typical capacity: 7.800 mAh,
- Operating temperature: - 20°C to + 60°C,
- Shell material: PVC
- Weight 138 g,
- Size: 68*55*19 mm (L*W*H).

Figure 19: RS Pro 18650 26H Li-ion Battery Pack [26].

7.3 ON/OFF Switch

To switch the device on or off, an ON/OFF switch is required (see Figure 20). Although the Raspberry Pi Zero 2 W can also be shut down with the help of the operating software, it is then in a so-called sleep mode. This sleep mode has the disadvantage that although the device is switched off, it still consumes energy because the UPS uninterruptible supply control board is still in active mode. In order to avoid battery discharge, a waterproof ON/OFF switch with the model designation SV8FW3SS-3G1 is integrated between the battery and the DC-DC step up converter. At the same time, this switch is the on switch for the Hydrophone sound level meter. When the switch is pressed, power is supplied to the small single computer board and thus a boot process takes place.

Figure 20: SV8FW3SS-3G1 ON/OFF Switch [27].

7.4 Connectors

Different connectors are needed to mechanically connect external devices or components to the hydrophone sound level meter. These connectors are required for data transfer as well as for the transfer of electrical energy for charging the battery.

7.4.1 Bulgin PX0727/S09 as Hydrophone Connector

To transmit the measured values from the hydrophone, a connector is needed that connects the hydrophone with the hydrophone sound level meter. The connector should be waterproof and qualified for professional use. To connect the hydrophone, a Bulgin PX0727/S09 connector is used. This connector not only meets all the requirements, but is also already used in the marine sector for such applications. The following Figure 21 shows a picture of the Bulgin connector.

Figure 21: Bulgin PX0727/S09 Connector [28].

7.4.2 Bulgin Buccaneer PX0412/02P as External Power Supply Connector

To connect the external power supply to the hydrophone sound level meter, a connector is also required. This connector should also be waterproof and qualified for professional use. In addition, the connector is suitable for the transmission of current. This connector from Bulgin also fulfils all these requirements. The following Figure 22 shows a picture of the Bulgin connector.

Figure 22: Bulgin Buccaneer PX0412/02P Connector [29].

7.5 Other Components

In addition to the components described above, other components are required for the production of the hydrophone sound level meter. Cables are needed to wire the individual components together. The cables must meet the requirements of being certified for both data transfer and power transmission. Even if the currents involved are very small, the cables must be designed for this. To connect Bulgin's Hydrophone Connector to the

ENC28J60 Ethernet SPI Module, a standard network cable is used. Four wires are soldered to the hydrophone connector. The RJ 45 connector on the opposite side is plugged into the socket provided on the ENC28J60 Ethernet SPI module. Heat-shrink tubing is required to protect the soldered contacts from short-circuiting. This insulates all exposed contacts and prevents unwanted current flows.

8 Product design

8.1 Sketches

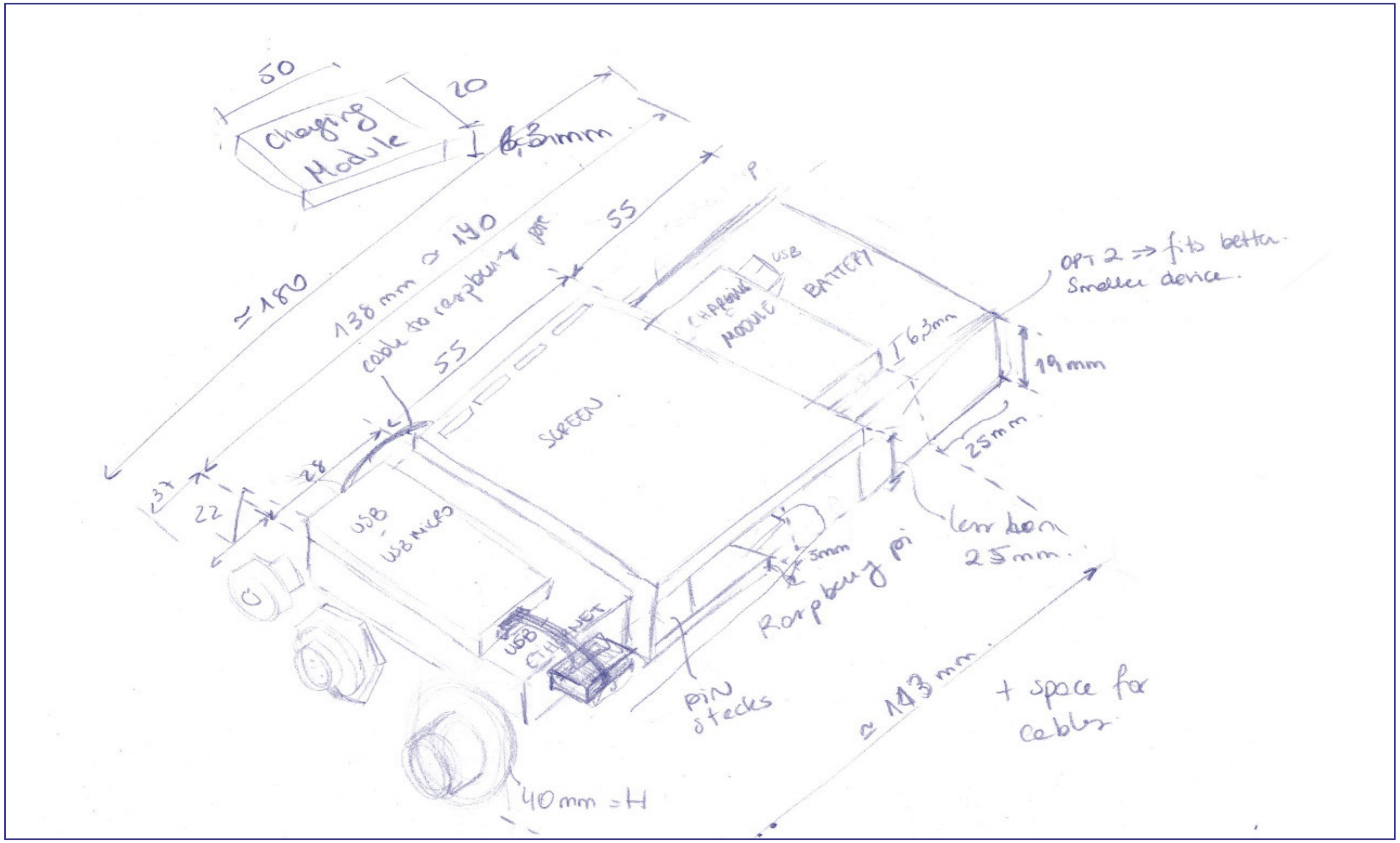


Figure 23: Components disposition.

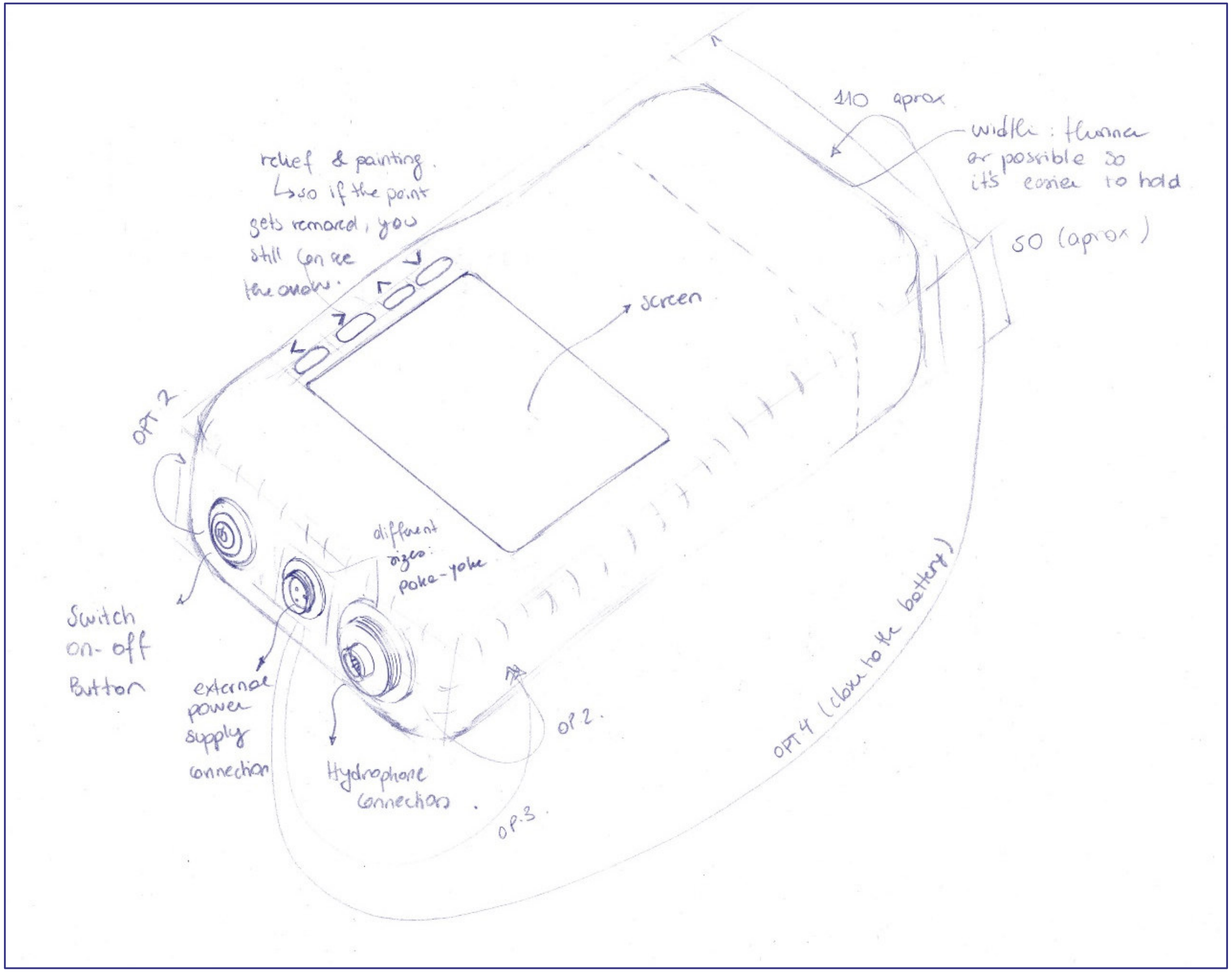


Figure 24: Device sketch.

8.2 Renders

Figure 25: Pontus from the front side.

Figure 26: Pontus from the turned side.

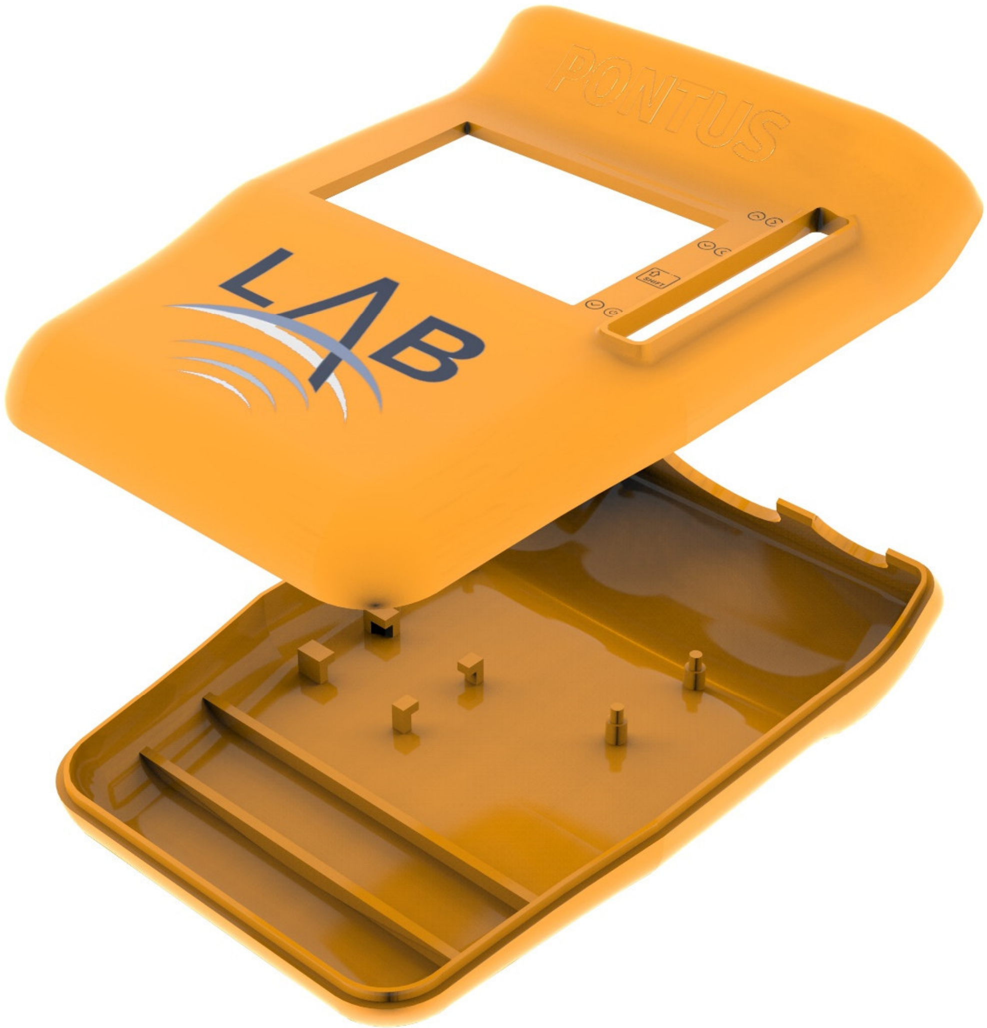


Figure 27: Eploded view of the case.

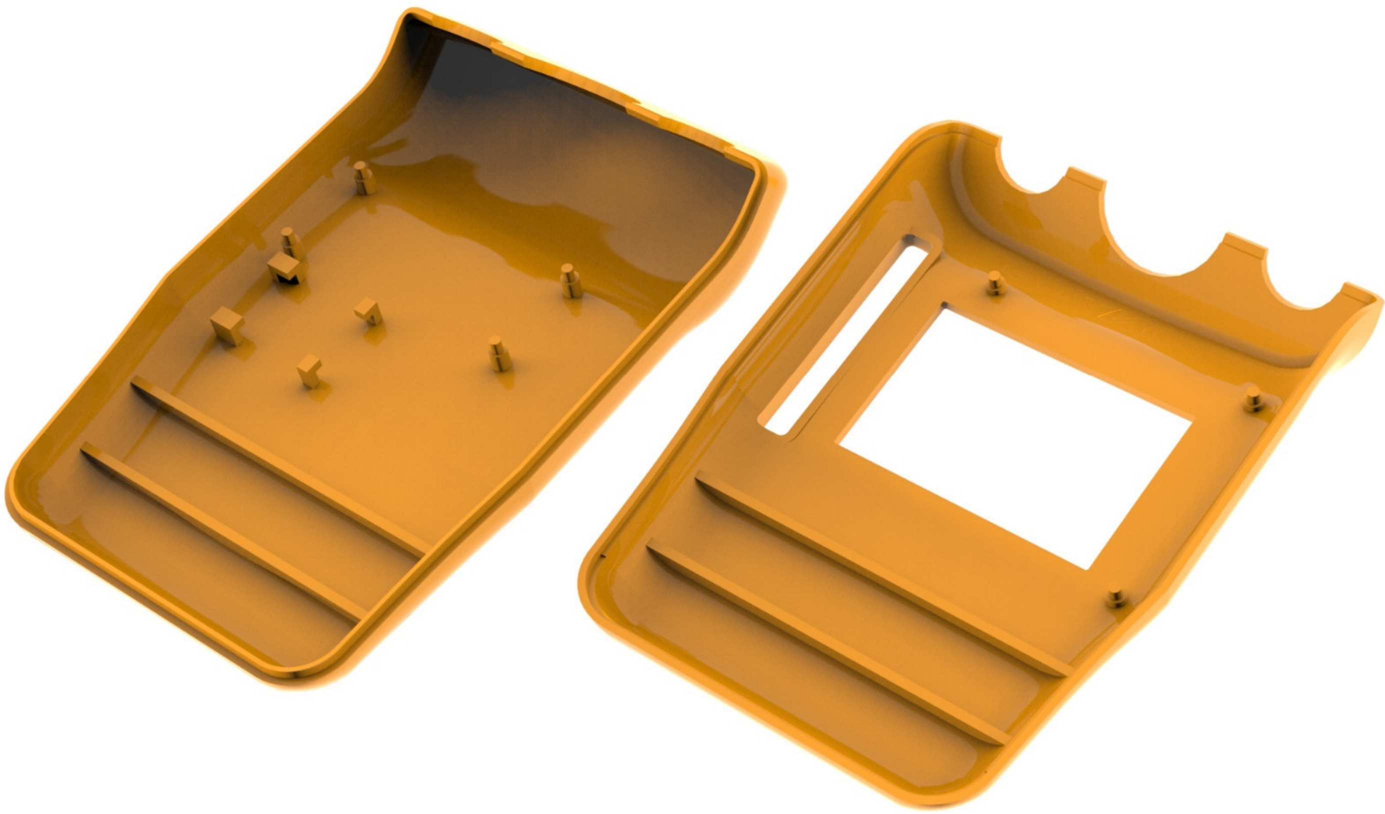


Figure 28: Interior details of the case.

9 Layout desing

9.1 First Ideas

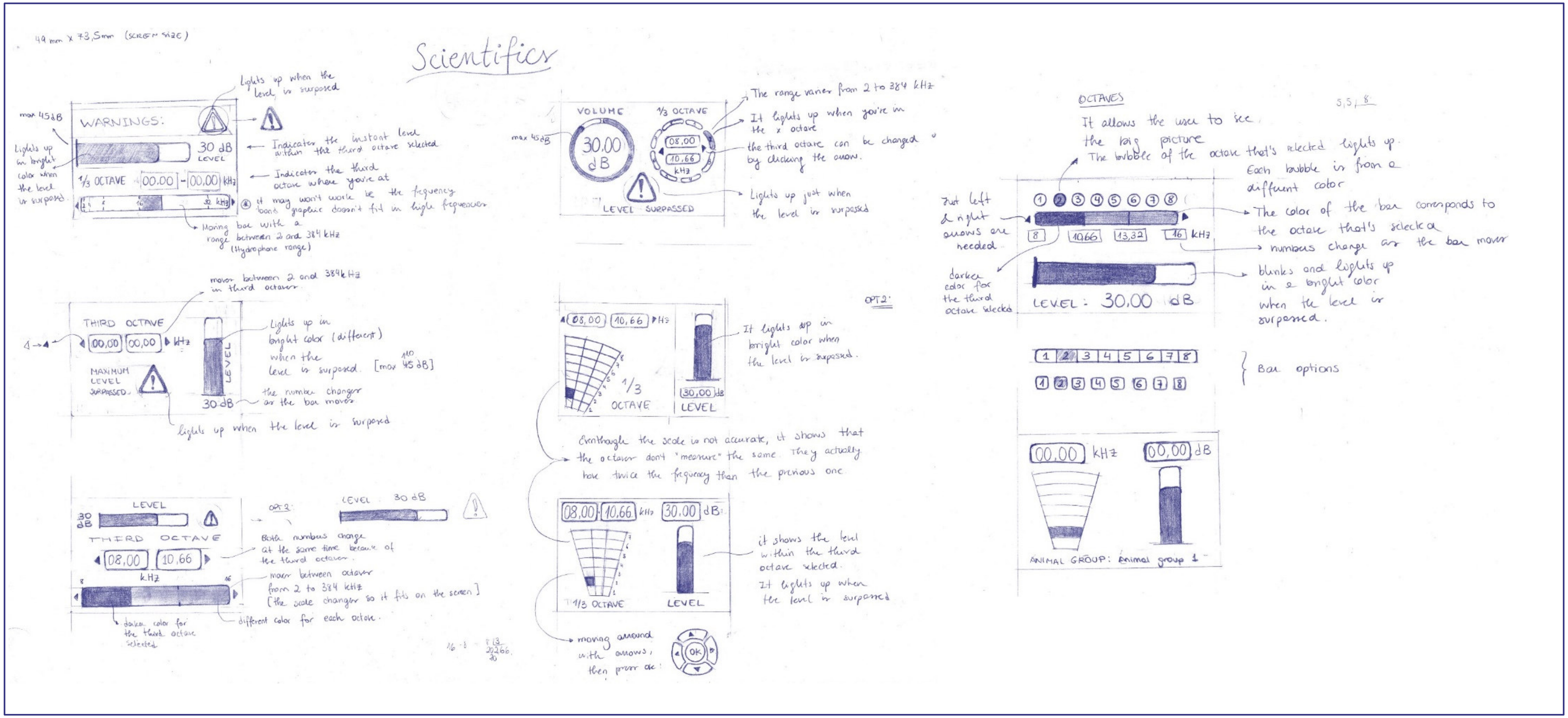


Figure 29: Layout ideas for advanced users.

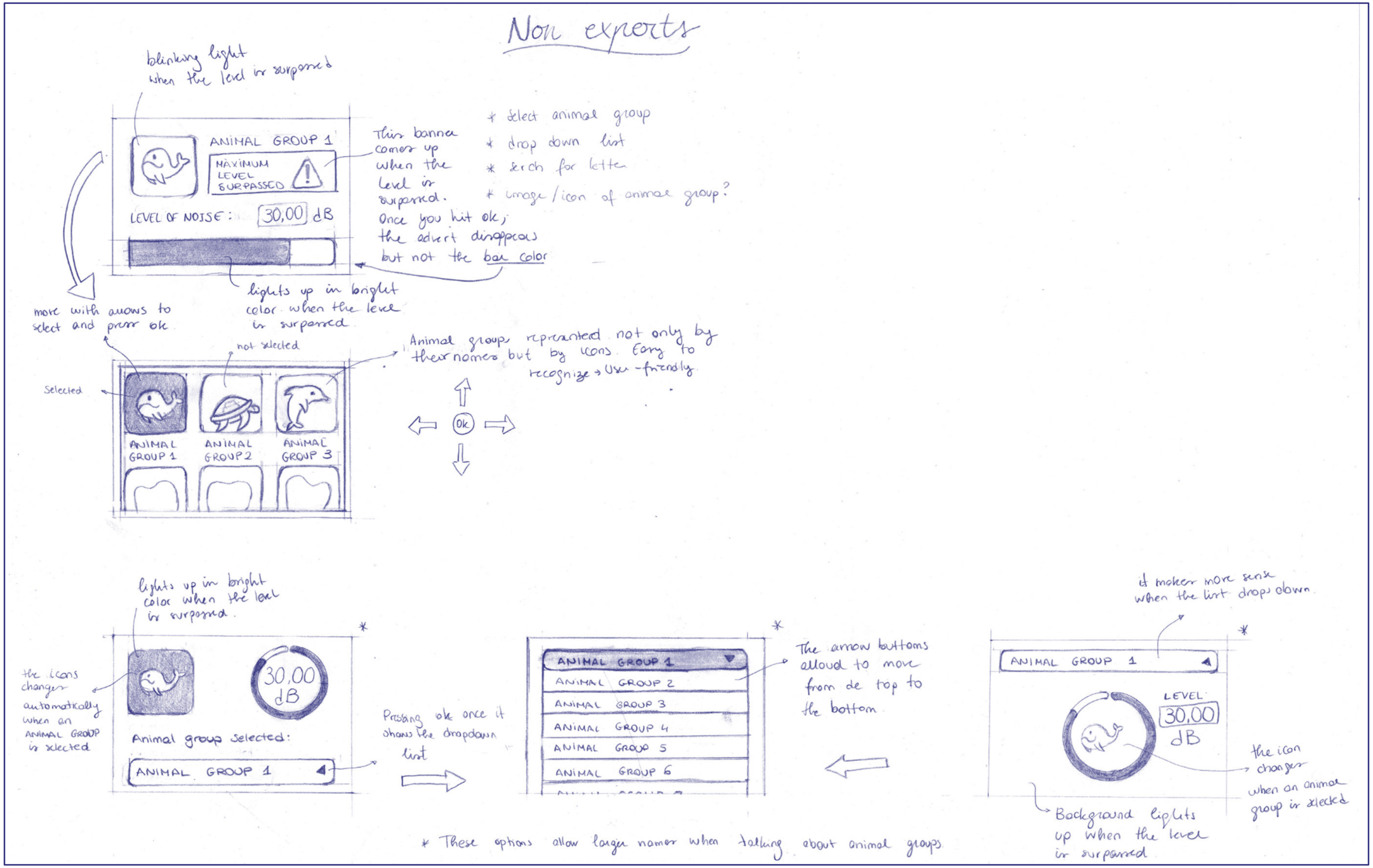


Figure 30: Layout ideas for group users.

9.2 Final layout

For the final layout design, the ideas of Scientifics, professionals and non-experts roles had been merged to simplify the programming. They both will be sharing the circle section grid adapted to their needs.

For changing between modes, the user will select with the right and left arrows that which are shown below the grid. The name of *1/3 OCTAVE* will change to the first animal group, *VHF*.

<u>Advanced mode</u>

For the advanced mode, the grid will show the octaves and their thirds. By pressing the right-left and up-down buttons, the user will be able to navigate throughout the panel quite easily. At the same time, the numbers on the top will change automatically when the user selects different divisions. This numbers show the bandwidth in kHz. The first number will be the minimum and the second one will show the maximum.

Also, the level bar will show the level of the sound that is recorded by the bandwidth that the user previously selected. To show the level more precisely, there is an upper box that shows the level in decibels. The following Figure 31 show the different positions of the squares that the user can select:

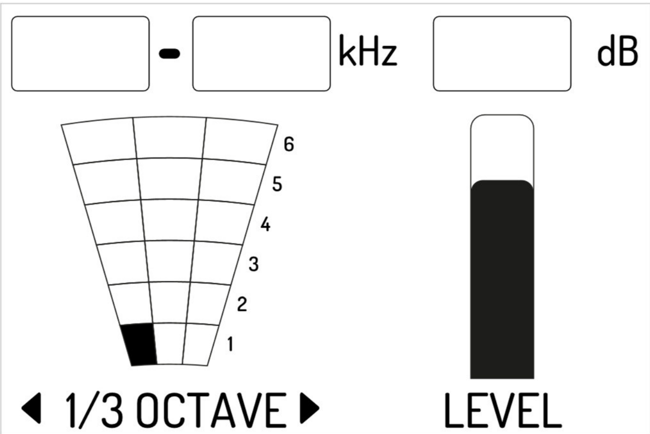


Figure 31: Example of advanced mode layout.

For changing between modes, the user will select with the right and left arrows which are shown in the grid above. The name of *1/3 OCTAVE* will change to the first animal group, *LF*.

Group mode

For the group mode, the usability will be the same one, but the grid will be divided in the eight groups of animals mentioned before in this article. The navigation this time will be just selecting the groups up and down. The level bar will act just like on the mode before (see Figure 32).

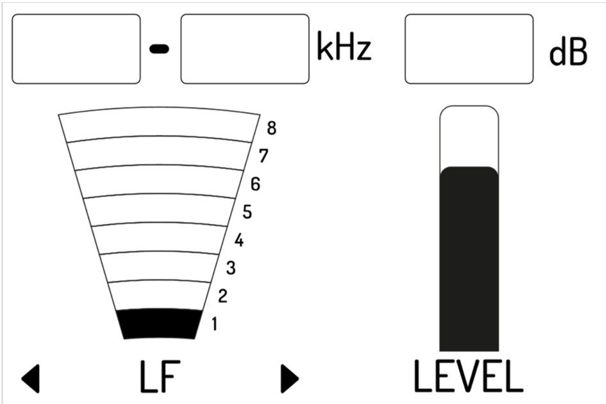


Figure 32: Example of group mode layout.

In both modes (see Figure 33), if the level surpasses the threshold for that bandwidth, the screen will show an alert just by blinking. This will be made by inverting the colors of the screen, so the background turns black:

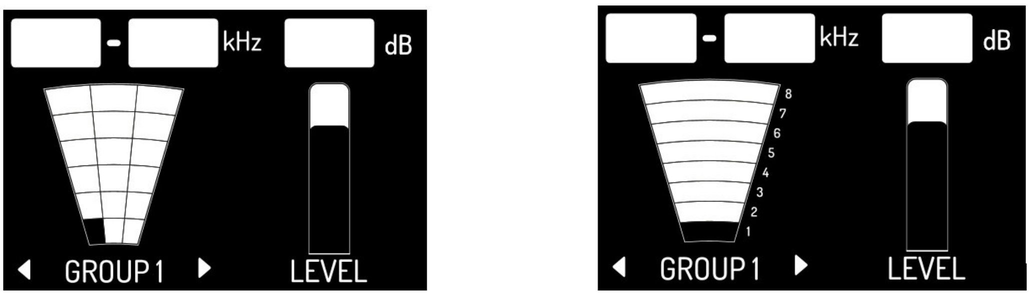


Figure 33: Alert in the advanced mode (left side) and alert in the group mode (right side).

10 Programming of Pontus

For this project, the language of programming is Python.

This program is separated into four parts which have four different functions:

- To read the data from the hydrophone
- To analyse this data in order to transform them into relevant information
- To display this information in the most user-friendly way
- To alert the customers when a peak level is higher than a predefined level

Other features can be added to this list in order to make the device more user-friendly.

10.1 Reading of information

The hydrophone sends data to our device by the ethernet port. Those data are sent in a wave file. This type of file is a no-compress file, and this prevents the loss of data. To extract the values, we use the library scipy and most specifically the module called “wavfile”. The function to read the file gives us the sample rate, in samples per second, and the value of each point of measurement. Those values are stored in a long list, called an array, that allows us to modify them and extract them in an efficient way. Because the wave file is in a 16 bits format, the values are between -32768 and 32767.

We can’t use those values directly; we must convert them and give them real meaning.

10.2 Analysation of information

The first step of the analysis is to convert the value from the number of bits to pressure. To do that, first, we must divide by the maximum value possible, then multiply by the voltage to convert to the ADC range, then divide by the gain of the hydrophone and finally, divide by the coefficient links to the sensibility of the hydrophone.

$$Pressure\ Value = \frac{Bit\ Value}{Max\ Value} * Voltage * \frac{1}{gain} * \frac{1}{coefficient\ sensibility}$$

With this equation, we obtain pressure values in pascal (Pa). In our case, the maximum value is 32768 because we work with a 16-bit file, the voltage is 3V, there isn't gain, so it's equal to 1 and the sensibility coefficient is 10-8.5V/µPa. The three last values are imposed by the hydrophone.

The second step is to convert the pressure values into a spectrogram. A spectrogram is a visual representation of the spectrum of frequencies of a signal as it varies with time (see Figure 34). So, when you look at a spectrogram, you must consider three parameters. The two firsts are common to other diagrams and are the x-axis and the y-axis. The third one is a specification of a spectrogram, and it is the colour of the point. Two points with different colours have different values.

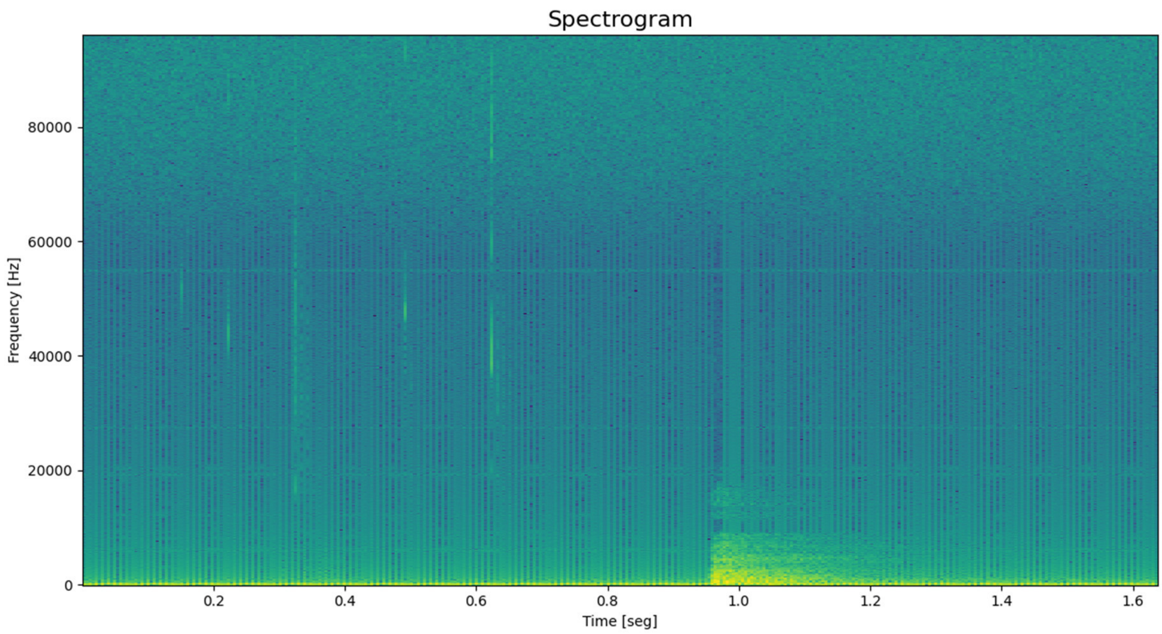


Figure 34: Example of spectrogram.

Then, we calculate the root mean square of the pressure values between two chosen frequencies and for a period of one second.

$$x_{rms} = \sqrt{\frac{1}{n}\ (x1 + x2^2 + \ldots + xn^2)}$$

Finally, we divide the value by the pressure of reference in the water, which is equal to 1µPa. Then apply the logarithmic function at the square of the previous result and multiply it by 10. With this, we obtain the sound level in decibels, and now, we can display them to the user.

10.3 Displaying of information

In order to display the information on the screen, we use the library called pygame. This library allows us to create an image by addition different images on different layers (see Figure 35). With this method, it is very easy to create all the variation.

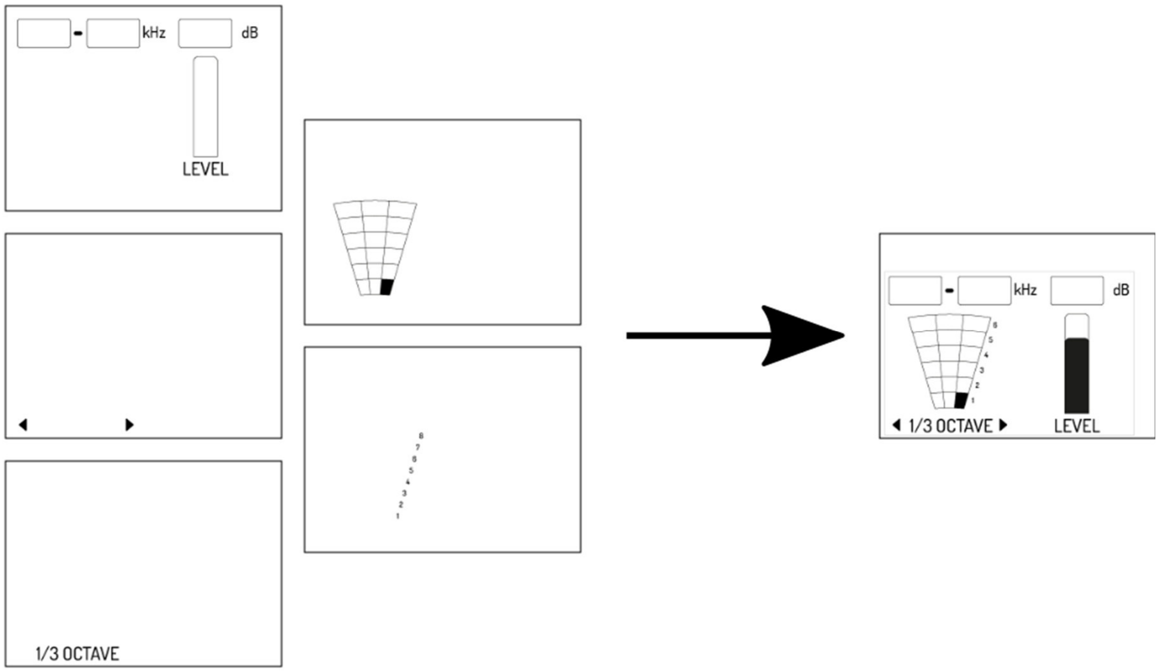


Figure 35: Construction of the image we want to display.

Our image is composed of five layers of image, a rectangle to draw the bar level and three texts in order to indicate the current value of the sound and the range of the studied sound.

10.4 Alerting the user

When the sound level is higher than the limit set by a database, the screen has to display an alert signal (see Figure 36). With this, the user can see instantly that the limit is over the value fixed. In order to alert the user, an alert sign blinks on the level intensity bar. The sign that blinks 10 times each second allows the user to see quickly that the limit is higher than the limit.

Figure 36: The two states of the blinking alert sign.

This way of alerting the user is different from what was initially designed. Reversing the colour of the screen was impossible with the library used and the only way to reverse it was too energy-intensive:

11 Cost calculation

The cost of the device is calculated by adding all the prices from the individual component (see Table 16). However this will only be a rough estimation. Components can become cheaper over time. It can also become more expensive over time, for example the raspberry pi can be more expensive because of the chip shortage. Also in this cost calculation the labour of assembling the device is not taken into account. Another thing to keep in mind is that when the device will be produce in bigger quantities the price will also lower.

When the device will be brought to the market the price will be much higher. There are many factors to take into account to set a price. The patenting, the supply and demand, the needed profit margin. At this moment a rough calculation of the selling price cannot be made yet.

Table 16: Cost calculation.

Component	Price
Raspberry Pi Zero 2 W	20,39 €
2,7 inch E-ink Display	24,04 €
DC-DC Step-Up Converter (3,7 V to 12 V)	5,00 €
Step Down DC-DC Converter (12 V to 3,3 V)	2,20 €
ENC28J60 Ethernet SPI Module	4,86 €
Li-ion Battery	34,11 €
On/Off Switch	21 €
Hydrophone Connector PX0727/S09	15,42 €
Power supply Connector PX0412/02P	9,93
Housing	6 € per piece (for a production volume of about 100 pieces)
Manufacturing	27 €
Extra materials	3 €
Total Costs	**172,95 €**

12 ECO Design

Eco-design is becoming increasingly important in design, as man-made changes to our environment can no longer be denied. Eco-design not only refers to energy-efficient and recycling-friendly products, but also takes into account the entire life cycle of a product, as well as upstream and downstream processes such as raw material extraction, production conditions, use and disposal. Eco-design as a design philosophy also addresses aspects such as user behaviour, the possibility of replacing or repairing defective parts and the durability and longevity of the product itself.

Eco-design was also taken into account in the development and product design of the hydrophone sound level meter in order to avoid negative effects on the environment. The following aspects were mainly taken into account during product development:

- Longevity,
- Sustainable Design.

12.1 Longevity

The durability of a product is one of the most important points in eco-design. Because if a product offers a long usability over the entire life cycle, both the total material consumption and the energy input can be reduced. It should be mentioned that it is not the consumption or expenditure for a device that is reduced, but that fewer products have to be produced over a longer period of time.

Among other things, longevity was taken into account in the selection of the rechargeable battery. Even though there are much cheaper variants besides the Li-ion iron phosphate battery, the Li-ion battery is known for its particularly long service life. In addition, the hydrophone sound level meter uses a Li-ion iron phosphate battery, which is much easier to recycle than other Li-ion batteries.

But also in the selection of materials, care was taken to ensure that the plastics are durable and long-lasting. Particular attention should be paid to the choice of materials to ensure that they are resistant to salt water and strong sunlight. However, consideration is also given to using recycled plastic in order to reduce the general consumption of raw materials.

Another focus during the development process was to ensure that durable components are used. Because the device is supposed to be waterproof, individual components cannot simply be replaced. As a result, the failure of one component would render the entire product unusable. This is because opening the unit to replace components can damage the housing or seals. Such damage would lead to permanent leakage of the unit.

12.2 Sustainable Design

As the hydrophone sound level meter is to be available for both the business to business and business to customer market, sustainable design is not to be neglected. In today´s society, responsible use of natural resources is assumed. As already described in the previous point, recycled raw materials are used as far as possible. Likewise, care is taken to ensure that the materials and components used can also be recycled or disposed of easily and as environmentally friendly as possible.

In addition to the points mentioned above, minimising the use of harmful substances is also of great importance. After all, when users hold the device in their hands for many hours, there should be no side effects from plastic incompatibilities. When selecting materials, it is therefore important to ensure that plastics or materials with a high level of toxicity are used.

13 Prototype

A prototype was built because the laboratory provided components (see Figure 37). This prototype is only used for demonstrations and presentations to show what possibilities the developed device offers. For the prototype, mainly two electronic components and two different battery types were used. The central component for processing the measurement data of the hydrophone is a Raspberry Pi 3 B. With the help of the touch screen, the user can control the hydrophone. With the help of the touch screen, the user can set or select different filters or settings. To transfer the measurement data from the hydrophone to the single computer board, an Ethernet to Ethernet converter is used, which is connected to the Rasberry Pi via a LAN cable. On the other side of the converter is an RJ45 socket to connect the hydrophone to it. As the hydrophone requires an external power supply, two 9 V batteries are connected in series to provide a stable and sufficient power supply of 18 V to the hydrophone. The Raspberry Pi 3 B, on the other hand, is powered by a 20,000 mAh power bank. The power supply is provided via a commercially available USB to USB micro cable. All components are fixed firmly and securely on a transparent polymethyl methacrylate plate.

Figure 37: Prototype.

14 Conclusion

The objective of the project was to develop a device that show instant sound levels recorded by the hydrophone that is connected to it. The main requirements of this device are that is has to be hand-held, that this device must show instant sound levels recorded by the hydrophone and give an alert when measurements surpass a certain defined value. Other desirable requirements are making the device waterproof. Also the device preferable need to have filters to focus on one specific group of marine animals.

The concept that is proposed in this project satisfy all of the requirements. The device is connectable to a digital hydrophone, it can show instant sound levels, it has different filters and it will give a warning signal when sound levels surpass a threshold value and it will be waterproof. At this moment a prototype is developed with a 3D printer and with alternative components such as a raspberry pi 3B instead of a raspberry pi zero 2W. These components are fixed on a polycarbonate plate to show the functionality of the device. When the intended concept will be produced the device will be hand-held and is able to connect to a digital hydrophone. The software is programmed. The sound level values that are dangerous for marine animals are established. Also the groups in which the marine animals are divided. These date are implemented in the prototype. The device is able to give a warning signal when these values are surpassed per specific animal group. All the components needed to make this device are divined and can be used when the device is going to be produced. The case and the layout of the screen are designed. All the components that are selected and the case that is designed will be waterproof. This makes the developed concept a success.

Although the sound level values that are dangerous for the animals are divined and implemented in the device, these values should be able to change because it is an ongoing research field. The PTS values are it this moment not yet implemented as another warning signal, this could in the future also be improved. Also some smaller improvements could be made, for example, the on and off switch is unnecessarily expensive. For the price efficiency it would be better to look for an inexpensive one. In addition, the power efficiency of the device can be increased if the DC-DC step down converter is connected directly to the battery instead of being connected behind the DC-DC step up converter. Due to a design freeze and too little time, a change in the wiring of the components was no longer possible.

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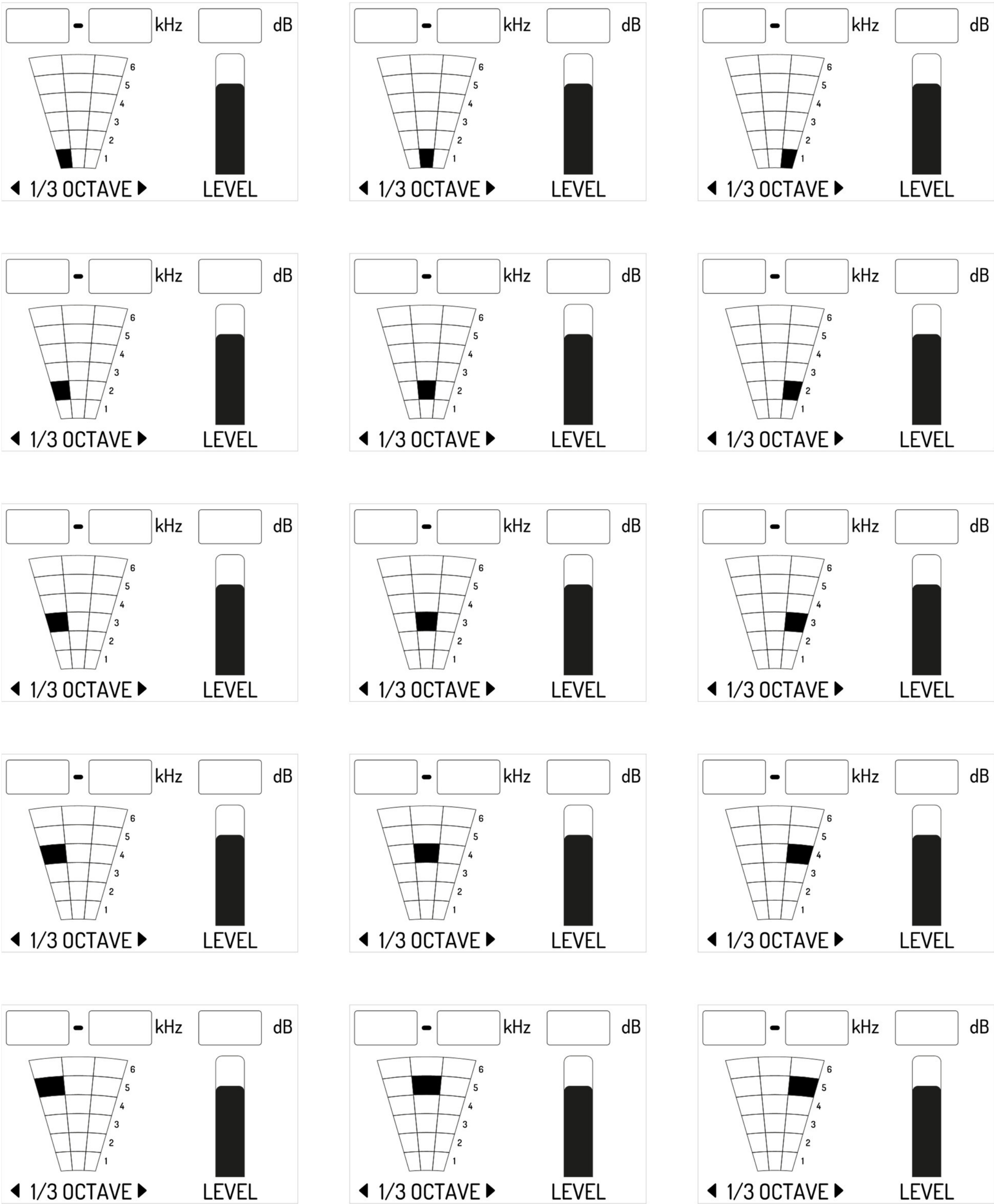
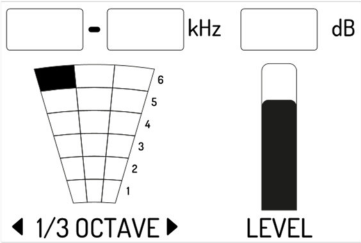
Table of figures

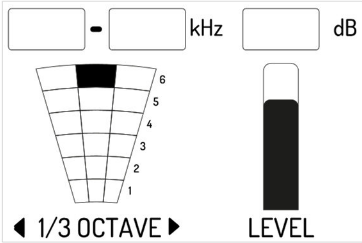
Table of tables

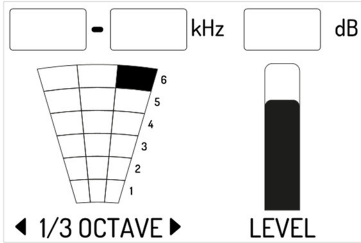
Appendix A: Layout screens

Advanced mode

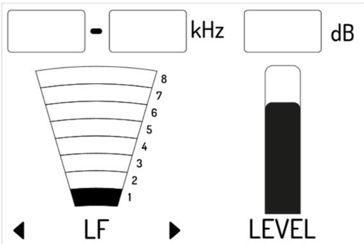


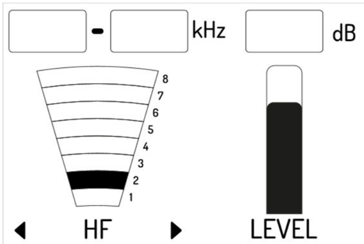

kHz
dB
1/3 OCTAVE
LEVEL

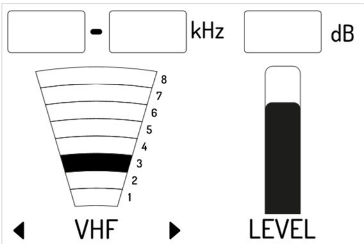

kHz
dB
1/3 OCTAVE
LEVEL

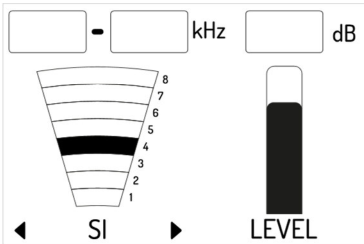

kHz
dB
1/3 OCTAVE
LEVEL

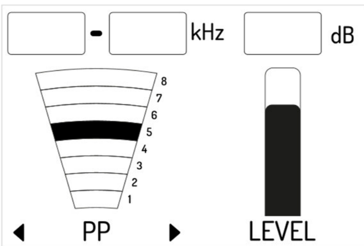
Group mode

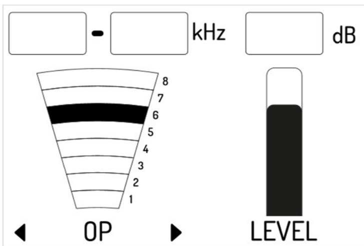

kHz
dB
LF
LEVEL

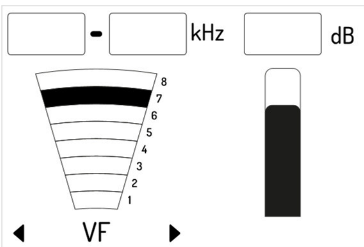

kHz
dB
HF
LEVEL

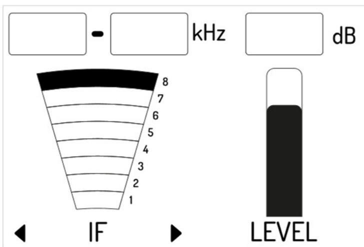

kHz
dB
VHF
LEVEL


kHz
dB
SI
LEVEL


kHz
dB
PP
LEVEL


kHz
dB
OP
LEVEL


kHz
dB
VF


kHz
dB
IF
LEVEL

Appendix B: Program / Source Code

```
#import all the librairies needed
from numpy import around
from function import *
from display import *

#open the file with data from different animals and extract the data for this file
data_animals_list = extract_group("group_data.txt")

#open the file with octave data and extract the data for this file
data_octave_list = extract_group("octave.txt")

#open the wave file wanted
frequence_array, time_array, value_array = extract_wave_file("test.wav")

while True:
    #get the time from the begin of the program in second
    current_time = (pygame.time.get_ticks()//1000)%60

    #if the second has changed
    if current_time != previous_time:
        previous_time = current_time
        #ask for update the isplay on th screen
        update_screen = True

    #if the screen must be updated
    if update_screen:
        #extract the lower, upper and limit value in function of the configuration
        lower_value,upper_value,limit_value=extrat_limits(data_animals_list,data_octave_list

        #get the time since the begin of the program in second
        current_time = (pygame.time.get_ticks()//1000)%60

        #display of all the information
displaying(arrow_configuration,group_configuration,grid_location,grid_selected,around(conver
/1000,3),limit_value)

        #force the screen to do not updated
        update_screen=False

    #check if there is an event
    for event in pygame.event.get():

        #if the cross is pressed
        if event.type == pygame.QUIT:
            #close the program
            pygame.quit()
            quit()

        # when the user make a right click
        if event.type == MOUSEBUTTONDOWN and event.button == 1:
            #udpate all the parameters for the display of the informations
            group_configuration,arrow_selected,arrow_configuration,grid_selected,grid_locat

    #update of the display
    pygame.display.flip()
```

```
#import all the librairies needed
from scipy.io import wavfile
import numpy as np
import matplotlib.pyplot as plt
from scipy import signal

#Draw the spectrogram in function of the input values
def draw_spectrogram(t,f,data):
    plt.figure()
    plt.pcolormesh(t, f,data) # Lineal spectrogram
    plt.ylabel('Frequency [Hz]')
    plt.xlabel('Time [seg]')
    plt.title('Spectrogram',size=16)
    plt.show()

    return

#Convert value
def convert_data_dB(data):
    nbr_bit = 32768
    voltage = 3
    gain = 1
    coef_pressure = 1 * 10**(-170/20)            #given by the builder of the hydrophone (
V/Pa)
    pressure_ref_water = 1


    #transformation the data express in V to a data express in Pa
    data_change = data / nbr_bit * voltage / gain / coef_pressure
    #divide this new value by the pressure if reference in the water
    data_change = data_change / pressure_ref_water
    #square this number
    data_change = np.square(data_change)
    #express the dat in dB
    data_change = 10 * np.log10(data_change)
    #return the data express in dB
    return data_change

#Search the closet value indice of one numbers
def search_closest_nbr (array,nbr_wanted):
    #loop to travel all the array
    for i in range(0,array.shape[0]):
        #if the number of the array is highter than the number wanted
        if array[i]>nbr_wanted:
            #if this indicator is not 0
            if i != 0:
                #get the value of the previous number in the array
                nbr_before = array[i-1]
                #get the current value of the number in the array
                nbr_now = array[i]
                #if the difference between the number wanted and the previous number is le
the different between the current number and the number wanted
                if nbr_wanted - nbr_before < nbr_now - nbr_wanted:
                    #decrease the value of the indicator by 1
                    i = i-1
                #break the loop
                break
    #return the value of the indicator
    return i
```

```

#search the closets values indices of two numbers
def search_interval (array,first_nbr,second_nbr):
    return search_closest_nbr(array,first_nbr),search_closest_nbr(array,second_nbr)

#extract the data from an hydrophone and convert them
def extract_wave_file(audioName):
    #opening of the file
    fs, audiodata = wavfile.read(audioName)

    nbr_point_fft = 1024

    #Creation of the spectrogram

    f, t, Sxx = signal.spectrogram(audiodata, fs,window = signal.hamming(nbr_point_fft),)

    #Modification of the values due to the caracteristics of the hydrophone
    data_change = convert_data_dB(Sxx)

    return f,t,data_change

#extract the criticals values from a txt file for each animal families and return a list wi name, the lower value and the higher value
def extract_group(text_file):
    #open the file
    data_file = open(text_file,"r")
    content = data_file.readlines()
    #creation of an empty list
    liste = []
    #travel all the content of the file
    for line in content:
        #split the line with the /
        middle_list = line.strip().split("/")
        #the first term of the new list is the name of the family
        new_list=[middle_list[0]]
        #travel the rest of the list
        for i in range(1,len(middle_list)):
            #put the value in the new list
            new_list.append(float(middle_list[i]))
        #put the new list in the general list
        liste.append(new_list)
    #return the general list
    return liste

#extract the values from a first matrix to another smaller in function of parameters give b user
def extract_value(time_matrix, frequency_matrix, value_matrix,first_f,second_f,time,duratio
    #search the value of the indicator for the two marker than are given for the frequency
    position_first_f,position_second_f = search_interval(frequency_matrix,first_f,second_f)
    #search the value of the indicator for the two marker than are given for the time
    position_first_timer, position_second_timer = search_interval(time_matrix,time,time+dur
    #split the value matrix to just have the value between the given marker
    new_matrix = value_matrix[position_first_f:position_second_f+1,position_first_timer:position_second_time
    #return this new matrix
    return new_matrix

#do the root means square of the values of a select windows
def root_mean_square(time_matrix,frequency_matrix,value_matrix,first_f,second_f,time):
```

```
    #take the square of select windows (frenquency and a time period)
    value = np.square(extract_value(time_matrix, frequency_matrix,
value_matrix,first_f,second_f,time,1))
    #do the square root of the sum of the all values divide by the number of values
    rms = np.sqrt((value/value.size).sum())
    #return the root mean square
    return rms

#funtion to extract the limits in fonction of the mod/group selectionned by the user
def
extrat_limits(data_animals_list,data_octave_list,group_configuration,grid_selected,grid_lo
    #reset values
    lower_value= 0
    upper_value = 0
    limit_value = 220

    #if we are not in the scientific mod
    if  group_configuration != 0:
        lower_value = data_animals_list[group_configuration-1][1]
        upper_value = data_animals_list[group_configuration-1][2]
        limit_value = data_animals_list[group_configuration-1][3]
    #if we are in the scientific mod
    elif grid_selected:
        #extract the value in fonction of the octave selected by the user
        if grid_location == [1,1]:
            lower_value = data_octave_list[0][1]
            upper_value = data_octave_list[0][2]
        elif grid_location == [1,2]:
            lower_value = data_octave_list[1][1]
            upper_value = data_octave_list[1][2]
        elif grid_location == [1,3]:
            lower_value = data_octave_list[2][1]
            upper_value = data_octave_list[2][2]
        elif grid_location == [2,1]:
            lower_value = data_octave_list[3][1]
            upper_value = data_octave_list[3][2]
        elif grid_location == [2,2]:
            lower_value = data_octave_list[4][1]
            upper_value = data_octave_list[4][2]
        elif grid_location == [2,3]:
            lower_value = data_octave_list[5][1]
            upper_value = data_octave_list[5][2]
        elif grid_location == [3,1]:
            lower_value = data_octave_list[6][1]
            upper_value = data_octave_list[6][2]
        elif grid_location == [3,2]:
            lower_value = data_octave_list[7][1]
            upper_value = data_octave_list[7][2]
        elif grid_location == [3,3]:
            lower_value = data_octave_list[8][1]
            upper_value = data_octave_list[8][2]
        elif grid_location == [4,1]:
            lower_value = data_octave_list[9][1]
            upper_value = data_octave_list[9][2]
        elif grid_location == [4,2]:
            lower_value = data_octave_list[10][1]
            upper_value = data_octave_list[10][2]
        elif grid_location == [4,3]:
            lower_value = data_octave_list[11][1]
```

```
            upper_value = data_octave_list[11][2]
        elif grid_location == [5,1]:
            lower_value = data_octave_list[12][1]
            upper_value = data_octave_list[12][2]
        elif grid_location == [5,2]:
            lower_value = data_octave_list[13][1]
            upper_value = data_octave_list[13][2]
        elif grid_location == [5,3]:
            lower_value = data_octave_list[14][1]
            upper_value = data_octave_list[14][2]
        elif grid_location == [6,1]:
            lower_value = data_octave_list[15][1]
            upper_value = data_octave_list[15][2]
        elif grid_location == [6,2]:
            lower_value = data_octave_list[16][1]
            upper_value = data_octave_list[16][2]
        elif grid_location == [6,3]:
            lower_value = data_octave_list[17][1]
            upper_value = data_octave_list[17][2]
        #convert the values from kHz to Hz
        lower_value = lower_value*1000
        upper_value = upper_value *1000
    #if we are not in this two mods
    else:
        #put defaults values
        lower_value = 0
        upper_value = 96000
    #return all the limits values
    return lower_value,upper_value,limit_value
```

```
#import all the librairies needed
import pygame
from pygame.locals import *

#start pygame
pygame.init()

#function of the display of information
def displaying(arrow,group,grid_location,grid_selected,instant_value,lower_limit,upper_lim

    #fill the window in white
    display_surface.fill((255,255,255))
    #display of the background
    display_surface.blit(im_background,(0,0))

    #display of the arrows
    if arrow == 0:
        display_surface.blit(im_arrow_b,(0,0))
    elif arrow == 1:
        display_surface.blit(im_arrow_l,(0,0))
    elif arrow == 2:
        display_surface.blit(im_arrow_r,(0,0))

    #if we are in the scientific mode
    if group == 0:
        #display all the images needed
        display_surface.blit(im_octave_nbr,(0,0))
        display_surface.blit(im_octave_mode_name,(0,0))
        #if we are on the grid
        if grid_selected:
            #display the image in function of the location of the cursor
            if grid_location == [1,1]:
                display_surface.blit(im_octave_1_1,(0,0))
            elif grid_location == [1,2]:
                display_surface.blit(im_octave_1_2,(0,0))
            elif grid_location == [1,3]:
                display_surface.blit(im_octave_1_3,(0,0))
            elif grid_location == [2,1]:
                display_surface.blit(im_octave_2_1,(0,0))
            elif grid_location == [2,2]:
                display_surface.blit(im_octave_2_2,(0,0))
            elif grid_location == [2,3]:
                display_surface.blit(im_octave_2_3,(0,0))
            elif grid_location == [3,1]:
                display_surface.blit(im_octave_3_1,(0,0))
            elif grid_location == [3,2]:
                display_surface.blit(im_octave_3_2,(0,0))
            elif grid_location == [3,3]:
                display_surface.blit(im_octave_3_3,(0,0))
            elif grid_location == [4,1]:
                display_surface.blit(im_octave_4_1,(0,0))
            elif grid_location == [4,2]:
                display_surface.blit(im_octave_4_2,(0,0))
            elif grid_location == [4,3]:
                display_surface.blit(im_octave_4_3,(0,0))
            elif grid_location == [5,1]:
                display_surface.blit(im_octave_5_1,(0,0))
            elif grid_location == [5,2]:
```

```
            display_surface.blit(im_octave_5_2,(0,0))
        elif grid_location == [5,3]:
            display_surface.blit(im_octave_5_3,(0,0))
        elif grid_location == [6,1]:
            display_surface.blit(im_octave_6_1,(0,0))
        elif grid_location == [6,2]:
            display_surface.blit(im_octave_6_2,(0,0))
        elif grid_location == [6,3]:
            display_surface.blit(im_octave_6_3,(0,0))
    display_surface.blit(im_octave_grid,(0,0))

#if we are in the casual mode
else:
    #display all the images needed
    display_surface.blit(im_group_nbr,(0,0))
    #if the group 1 is selected
    if group == 1:
        display_surface.blit(im_group_1_bandwidth,(0,0))
        display_surface.blit(im_group_1_name,(0,0))
    #if the group 2 is selected
    elif group == 2:
        display_surface.blit(im_group_2_bandwidth,(0,0))
        display_surface.blit(im_group_2_name,(0,0))
    #if the group 3 is selected
    elif group == 3:
        display_surface.blit(im_group_3_bandwidth,(0,0))
        display_surface.blit(im_group_3_name,(0,0))
    #if the group 4 is selected
    elif group == 4:
        display_surface.blit(im_group_4_bandwidth,(0,0))
        display_surface.blit(im_group_4_name,(0,0))
    #if the group 5 is selected
    elif group == 5:
        display_surface.blit(im_group_5_bandwidth,(0,0))
        display_surface.blit(im_group_5_name,(0,0))
    #if the group 6 is selected
    elif group == 6:
        display_surface.blit(im_group_6_bandwidth,(0,0))
        display_surface.blit(im_group_6_name,(0,0))
    #if the group 7 is selected
    elif group == 7:
        display_surface.blit(im_group_7_bandwidth,(0,0))
        display_surface.blit(im_group_7_name,(0,0))
    #if the group 8 is selected
    elif group == 8:
        display_surface.blit(im_group_8_bandwidth,(0,0))
        display_surface.blit(im_group_8_name,(0,0))

#constant for the display of numbers
x_middle_firt_nbr = 53
x_middle_second_nbr = 158
x_middle_third_nbr = 297
y_middle_nbr = 86

#creation of a fond for the text
font = pygame.font.Font(None, 42)

#display of the lower limit
first_nbr = str(lower_limit)
```

```
    text_first_nbr = font.render(first_nbr, True, (0,0,0))
    size_x_nbr,size_y_nbr = font.size(first_nbr)
    display_surface.blit(text_first_nbr,(x_middle_firt_nbr-size_x_nbr//2,y_middle_nbr-size_

    #display of the upper limit
    second_nbr = str(upper_limit)
    text_second_nbr = font.render(second_nbr, True, (0,0,0))
    size_x_nbr,size_y_nbr = font.size(second_nbr)
    display_surface.blit(text_second_nbr,(x_middle_second_nbr-size_x_nbr//2,y_middle_nbr-s

    #display of the real time value
    third_nbr = str(instant_value)
    text_third_nbr = font.render(third_nbr, True, (0,0,0))
    size_x_nbr,size_y_nbr = font.size(third_nbr)
    display_surface.blit(text_third_nbr,(x_middle_third_nbr-size_x_nbr//2,y_middle_nbr-size

    #variable for the display of the bar
    x_bar = 279
    y_bar = 121
    width_bar = 35
    radius_border_bar = 5
    maximum_length_bar = 151

    #variable of the real time value
    real_time_value = instant_value
    maximum_value = value_limit
    if real_time_value > maximum_value:
        real_time_value = maximum_value

    #calculation of the lenght of the real time bar
    lenght_bar = int(real_time_value/maximum_value*maximum_length_bar)
    #display of the bar
    pygame.draw.rect(display_surface, (0,0,0), (x_bar, y_bar+maximum_length_bar-lenght_bar-
lenght_bar-radius_border_bar), 0)
    pygame.draw.circle(display_surface,(0,0,0),(x_bar+radius_border_bar,y_bar-
lenght_bar+maximum_length_bar+radius_border_bar),radius_border_bar)
    pygame.draw.circle(display_surface,(0,0,0),(x_bar+width_bar-radius_border_bar,y_bar-
lenght_bar+maximum_length_bar+radius_border_bar),radius_border_bar)
    pygame.draw.rect(display_surface,(0,0,0),(x_bar+radius_border_bar,y_bar-lenght_bar+max
2*radius_border_bar,radius_border_bar),0)
    pygame.draw.rect(display_surface,(255,255,255),(x_bar,y_bar + 1 + maximum_length_bar,w

    #if the real time value is highter than the max value, a exclamation sign is blinking
    if real_time_value == maximum_value:
        if (pygame.time.get_ticks()*10//1000)%2==1:
            display_surface.blit(im_warning,(232,130))
        else :
            display_surface.blit(im_warning_n,(232,130))

    #variable for the display of buttons
    coord_x_button = 400
    coord_y_button = 70
    spacing_x_button = 40
    spacing_y_button = 55

    #display of the up arrow button
    display_surface.blit(im_arrow_up_button,(coord_x_button,coord_y_button))
    #display of the right arrow button
    display_surface.blit(im_arrow_right_button,(coord_x_button + spacing_x_button,coord_y_b
```

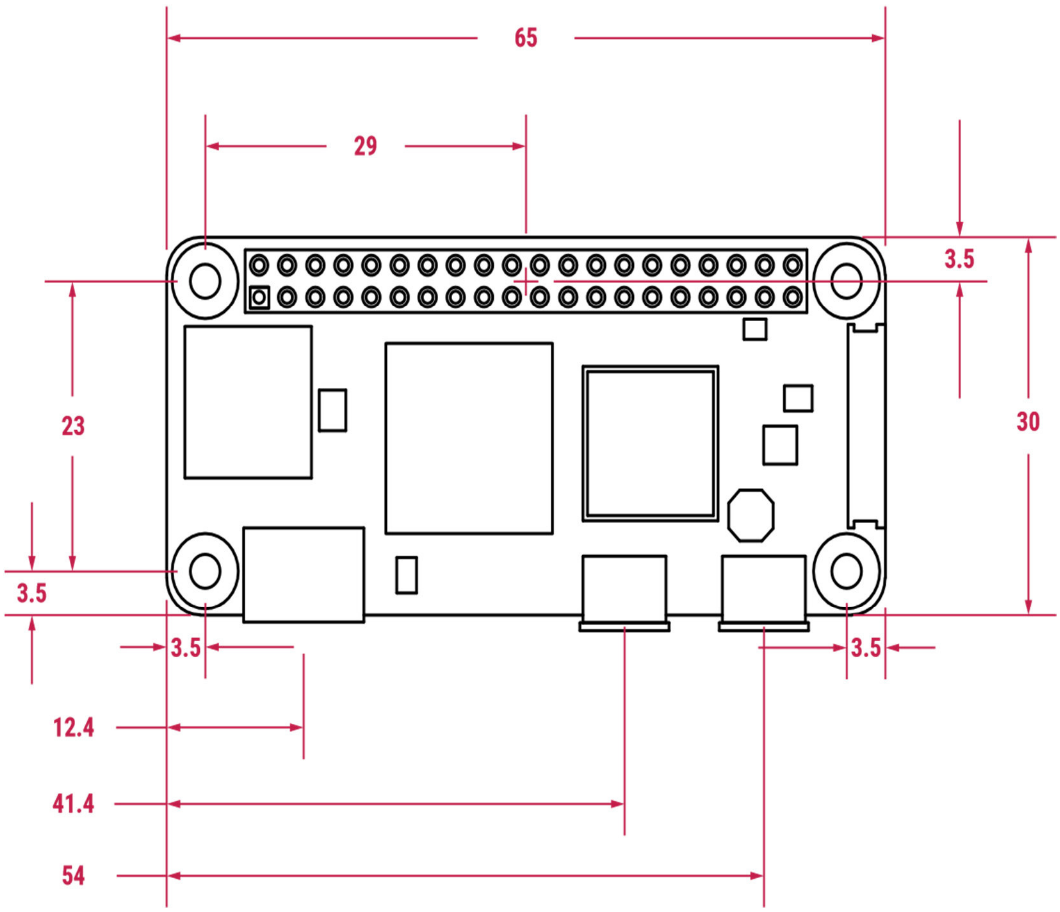
```
    #display of the down arrow
    display_surface.blit(im_arrow_down_button,(coord_x_button,coord_y_button + 1 * spacing_
    #display of the left arrow
    display_surface.blit(im_arrow_left_button,(coord_x_button + spacing_x_button,coord_y_bu
    #display of the shift button
    display_surface.blit(im_shift_button,(coord_x_button,coord_y_button + 2 * spacing_y_but
    #display of the check button
    display_surface.blit(im_ok_button,(coord_x_button,coord_y_button + 3 * spacing_y_butto
    #display of the shut down button
    display_surface.blit(im_off_button,(coord_x_button + spacing_x_button,coord_y_button +

    return #with this function we don't need to return something

#function used when a mouse click happends
def
event_mouse(coord_click_x,coord_click_y,arrow_selected,arrow_configuration,group_configurat

    #constant for the hitbox of the buttons
    coord_x_button = 400
    coord_y_button = 70
    spacing_x_button = 40
    spacing_y_button = 55
    size_button = 32

    #if the click is on the shutdown button
    if coord_click_x in range(coord_x_button + spacing_x_button,coord_x_button + spacing_x_
in range(coord_y_button + 3 * spacing_y_button,coord_y_button + 3 * spacing_y_button + size
        pygame.quit()
        quit()

    #if the arrow for selectionning the group is selected
    elif arrow_selected:

        #if we want to enter in the grid of the scientific mod
        if group_configuration == 0 and coord_click_x in range(coord_x_button ,coord_x_butt
range(coord_y_button + 0 * spacing_y_button,coord_y_button + 0 * spacing_y_button + size_bu
            arrow_selected = False
            grid_selected = True
            arrow_configuration = 0

        #if it's the right arrow that is pressed
        elif arrow_configuration == 2:

            #if the button of selection was clicked
            if coord_click_x in range(coord_x_button,coord_x_button + size_button) and coo
spacing_y_button,coord_y_button + 3 * spacing_y_button + size_button):
                group_configuration = group_configuration + 1
                #security for not getting to hight in the increment
                if group_configuration == 9:
                    group_configuration = 0

            #if the left arrow image is pressed
            if coord_click_x in range(coord_x_button + spacing_x_button,coord_x_button + sp
coord_click_y in range(coord_y_button + 1 * spacing_y_button,coord_y_button + 1 * spacing_y
                arrow_configuration = 1

        #if it's the left arrow that is pressed
        elif arrow_configuration == 1:

            #if the image of selection was clicked
```

```
            if coord_click_x in range(coord_x_button,coord_x_button + size_button) and coor
spacing_y_button,coord_y_button + 3 * spacing_y_button + size_button):
                group_configuration = group_configuration - 1
                #security for not getting to low in the increment
                if group_configuration == -1:
                    group_configuration = 8
            #if the right arrow image is pressed
            if coord_click_x in range(coord_x_button + spacing_x_button,coord_x_button + sp
coord_click_y in range(coord_y_button + 0 * spacing_y_button,coord_y_button + 0 * spacing_y
                arrow_configuration = 2

        #if we want to enter the grid of the scientific mod
        if group_configuration == 0 and coord_click_x in range(coord_x_button ,coord_x_butt
range(coord_y_button + 0 * spacing_y_button,coord_y_button + 0 * spacing_y_button + size_bu
            arrow_selected = False
            grid_selected = True
            arrow_configuration = 0

    #if the grid is selected
    elif grid_selected:

        #if the cursor is in the bottom line and the user go down
        if grid_location[0] == 1 and coord_click_x in range(coord_x_button ,coord_x_button
range(coord_y_button + 1 * spacing_y_button,coord_y_button + 1 * spacing_y_button + size_bu
            #pass in arrow mode and disable the grid mode, and the arrow is the right one
            arrow_selected = True
            grid_selected = False
            arrow_configuration = 2

        #if the up button is pressed
        elif coord_click_x in range(coord_x_button ,coord_x_button + size_button) and coor
spacing_y_button,coord_y_button + 0 * spacing_y_button + size_button):
            new_nbr = grid_location[0] + 1
            #security to do not go outside of the grid
            if new_nbr < 7 :
                grid_location = [new_nbr,grid_location[1]]

        #if the down button is pressed
        elif coord_click_x in range(coord_x_button ,coord_x_button + size_button) and coor
spacing_y_button,coord_y_button + 1 * spacing_y_button + size_button):
            new_nbr = grid_location[0] - 1
            #security to do not go outside of the grid
            if new_nbr > 0 :
                grid_location = [new_nbr ,grid_location[1]]
        #if the right button is pressed
        elif coord_click_x in range(coord_x_button + spacing_x_button,coord_x_button + spac
coord_click_y in range(coord_y_button + 0 * spacing_y_button,coord_y_button + 0 * spacing_y
            new_nbr = grid_location[1] + 1
            #security to do not go outside of the grid
            if new_nbr < 4 :
                grid_location = [grid_location[0],new_nbr]

        #if the left button is pressed
        elif coord_click_x in range(coord_x_button + spacing_x_button,coord_x_button + spac
coord_click_y in range(coord_y_button + 1 * spacing_y_button,coord_y_button + 1 * spacing_y
            new_nbr = grid_location[1] - 1
            #security to do not go outside of the grid
            if new_nbr > 0 :
                grid_location = [grid_location[0],new_nbr]
```

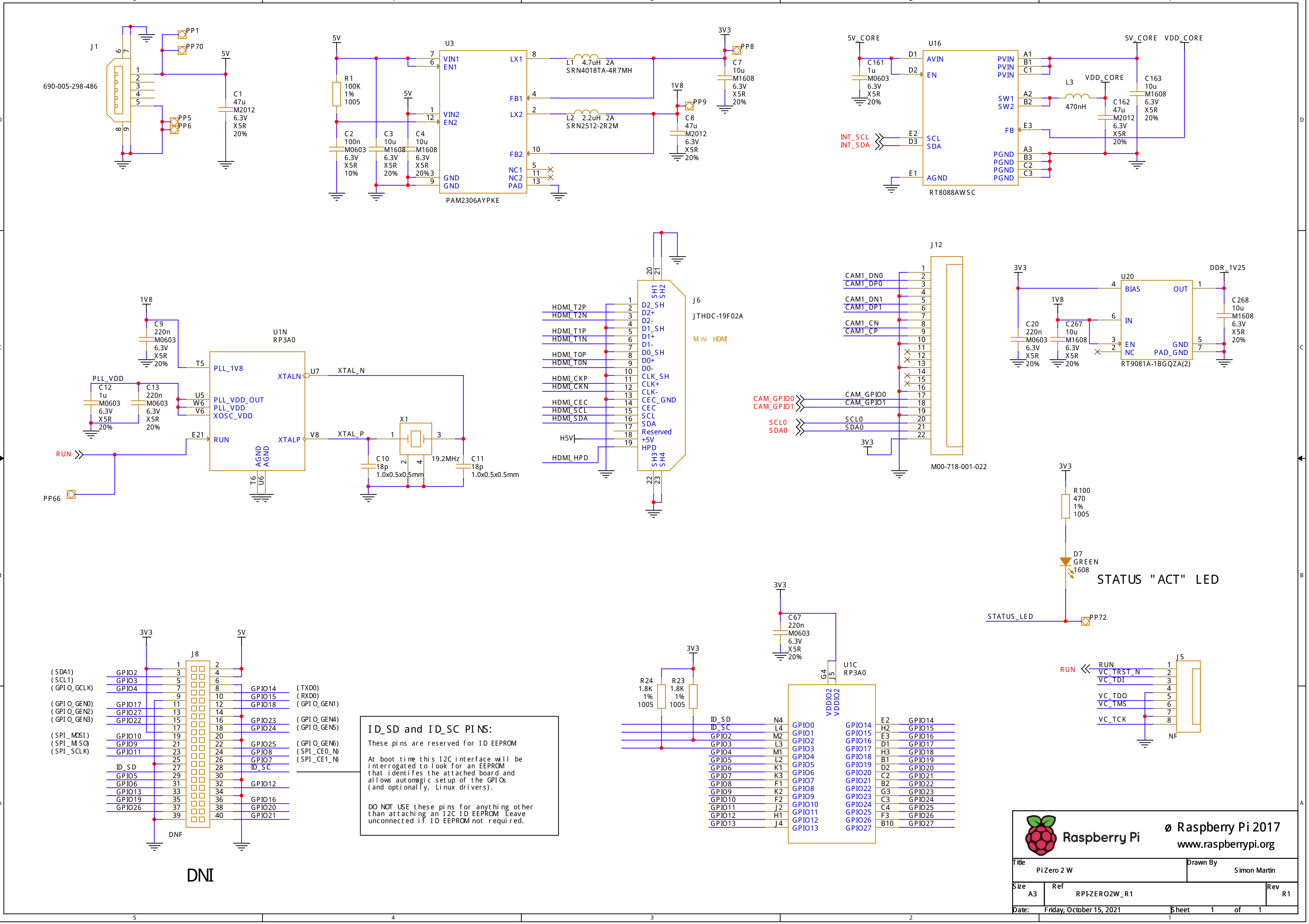
```
    #force the screen to be updated
    update = True

    #return all the variable needed for the display of informations
    return group_configuration,arrow_selected,arrow_configuration,grid_selected,grid_locat

#importation of all the picture
im_background = pygame.image.load("./image/General Background.png")

im_arrow_b = pygame.image.load("./image/Arrow.png")
im_arrow_r = pygame.image.load("./image/Selected Arrow Right.png")
im_arrow_l = pygame.image.load("./image/Selected Arrow Left.png")

im_group_nbr = pygame.image.load("./image/Groups Numbers.png")
im_octave_nbr = pygame.image.load("./image/Octaves Numbers.png")

im_group_1_bandwidth = pygame.image.load("./image/Group bandwidth 1.png")
im_group_1_name = pygame.image.load("./image/Group Name 1 - LF.png")

im_group_2_bandwidth = pygame.image.load("./image/Group bandwidth 2.png")
im_group_2_name = pygame.image.load("./image/Group Name 2 - HF.png")

im_group_3_bandwidth = pygame.image.load("./image/Group bandwidth 3.png")
im_group_3_name = pygame.image.load("./image/Group Name 3 - VHF.png")

im_group_4_bandwidth = pygame.image.load("./image/Group bandwidth 4.png")
im_group_4_name = pygame.image.load("./image/Group Name 4 - SI.png")

im_group_5_bandwidth = pygame.image.load("./image/Group bandwidth 5.png")
im_group_5_name = pygame.image.load("./image/Group Name 5 - PP.png")

im_group_6_bandwidth = pygame.image.load("./image/Group bandwidth 6.png")
im_group_6_name = pygame.image.load("./image/Group Name 6 - OP.png")

im_group_7_bandwidth = pygame.image.load("./image/Group bandwidth 7.png")
im_group_7_name = pygame.image.load("./image/Group Name 7 - VF.png")

im_group_8_bandwidth = pygame.image.load("./image/Group bandwidth 8.png")
im_group_8_name = pygame.image.load("./image/Group Name 8 - IF.png")

im_octave_mode_name = pygame.image.load("./image/1-3 Octave.png")

im_octave_grid = pygame.image.load("./image/Octave background grid.png")
im_octave_grid_grey = pygame.image.load("./image/Grey_Octave background grid.png")

im_octave_1_1 = pygame.image.load("./image/Octave 1.1.png")
im_octave_1_2 = pygame.image.load("./image/Octave 1.2.png")
im_octave_1_3 = pygame.image.load("./image/Octave 1.3.png")

im_octave_2_1 = pygame.image.load("./image/Octave 2.1.png")
im_octave_2_2 = pygame.image.load("./image/Octave 2.2.png")
im_octave_2_3 = pygame.image.load("./image/Octave 2.3.png")

im_octave_3_1 = pygame.image.load("./image/Octave 3.1.png")
im_octave_3_2 = pygame.image.load("./image/Octave 3.2.png")
im_octave_3_3 = pygame.image.load("./image/Octave 3.3.png")

im_octave_4_1 = pygame.image.load("./image/Octave 4.1.png")
im_octave_4_2 = pygame.image.load("./image/Octave 4.2.png")
```

```
im_octave_4_3 = pygame.image.load("./image/Octave 4.3.png")

im_octave_5_1 = pygame.image.load("./image/Octave 5.1.png")
im_octave_5_2 = pygame.image.load("./image/Octave 5.2.png")
im_octave_5_3 = pygame.image.load("./image/Octave 5.3.png")

im_octave_6_1 = pygame.image.load("./image/Octave 6.1.png")
im_octave_6_2 = pygame.image.load("./image/Octave 6.2.png")
im_octave_6_3 = pygame.image.load("./image/Octave 6.3.png")

im_arrow_left_button = pygame.image.load("./image/left-arrow.png")
im_arrow_right_button = pygame.image.load("./image/right-arrow.png")
im_arrow_up_button = pygame.image.load("./image/up-arrow.png")
im_arrow_down_button = pygame.image.load("./image/down-arrow.png")
im_shift_button = pygame.image.load("./image/shift.png")
im_ok_button = pygame.image.load("./image/check.png")
im_off_button = pygame.image.load("./image/power-button.png")
im_warning = pygame.image.load("./image/warning.png")
im_warning_n = pygame.image.load("./image/warning_n.png")


#constant for the display surface
size_x_display_surface = 480
size_y_display_surface = 320

#start of the window
display_surface = pygame.display.set_mode((size_x_display_surface,size_y_display_surface))

#default value for the configuration of the start
arrow_configuration = 2
group_configuration = 1
arrow_selected = True
grid_selected = False
grid_location = [1,1]
update_screen = True
previous_time = 0
```

Appendix C: Datasheets



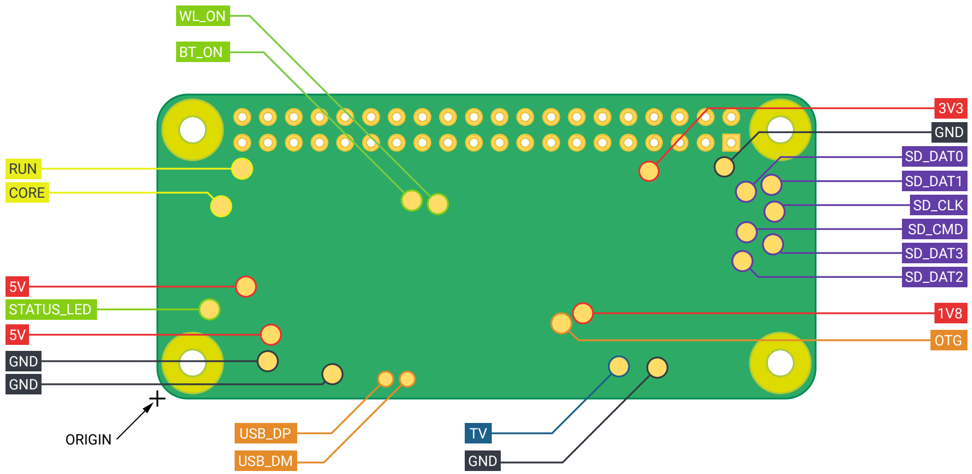
Note: all dimensions in mm


J1
690-005-298-486
PP1
PP70
PP5
PP6
C1 47u M2012 6.3V X5R 20%
5V
U3
PAM2306AYPKE
VIN1 EN1 VIN2 EN2 GND GND LX1 FB1 LX2 FB2 NC1 NC2 PAD
R1 100K 1% 1005
C2 100n M0603 6.3V X5R 10%
C3 10u M1608 6.3V X5R 20%
C4 10u M1608 6.3V X5R 20%
L1 4.7uH 2A SRN4018TA-4R7MH
L2 2.2uH 2A SRN2512-2R2M
3V3
PP8
C7 10u M1608 6.3V X5R 20%
1V8
PP9
C8 47u M2012 6.3V X5R 20%
5V_CORE
U16
RT8088AWSC
AVIN EN SCL SDA AGND PVIN PVIN PVIN SW1 SW2 FB PGND PGND PGND PGND
C161 1u M0603 6.3V X5R 20%
INT_SCL
INT_SDA
L3 470nH
VDD_CORE
C162 47u M2012 6.3V X5R 20%
C163 10u M1608 6.3V X5R 20%
U1N
RP3A0
PLL_1V8 PLL_VDD_OUT PLL_VDD XOSC_VDD RUN XTALN XTALP AGND AGND
C9 220n M0603 6.3V X5R 20%
PLL_VDD
C12 1u M0603 6.3V X5R 20%
C13 220n M0603 6.3V X5R 20%
RUN
PP66
XTAL_N
XTAL_P
X1 19.2MHz
C10 18p 1.0x0.5x0.5mm
C11 18p 1.0x0.5x0.5mm
J6
JTHDC-19F02A
Mini HDMI
HDMI_T2P HDMI_T2N HDMI_T1P HDMI_T1N HDMI_T0P HDMI_T0N HDMI_CKP HDMI_CKN HDMI_CEC HDMI_SCL HDMI_SDA H5V HDMI_HPD
D2_SH D2+ D2- D1_SH D1+ D1- D0_SH D0+ D0- CLK_SH CLK+ CLK- CEC_GND CEC SCL SDA Reserved +5V HPD
J12
M00-718-001-022
CAM1_DN0 CAM1_DP0 CAM1_DN1 CAM1_DP1 CAM1_CN CAM1_CP CAM_GPIO0 CAM_GPIO1 SCL0 SDA0
U20
RT9081A-1BGQZA(2)
BIAS IN EN NC OUT GND PAD_GND
DDR_1V25
C20 220n M0603 6.3V X5R 20%
C267 10u M1608 6.3V X5R 20%
C268 10u M1608 6.3V X5R 20%
R100 470 1% 1005
D7 GREEN 1608
STATUS "ACT" LED
STATUS_LED
PP72
J8
DNF
(SDA1) (SCL1) (GPIO_GCLK) (GPIO_GEN0) (GPIO_GEN2) (GPIO_GEN3) (SPI_MOSI) (SPI_MISO) (SPI_SCLK)
(TXD0) (RXD0) (GPIO_GEN1) (GPIO_GEN4) (GPIO_GEN5) (GPIO_GEN6) (SPI_CE0_N) (SPI_CE1_N)
DNI
ID_SD and ID_SC PINS:
These pins are reserved for ID EEPROM
At boot time this I2C interface will be interrogated to look for an EEPROM that identifes the attached board and allows automagic setup of the GPIOs (and optionally, Linux drivers).
DO NOT USE these pins for anything other than attaching an I2C ID EEPROM. Leave unconnected if ID EEPROM not required.
C67 220n M0603 6.3V X5R 20%
R24 1.8K 1% 1005
R23 1.8K 1% 1005
U1C
RP3A0
VDDIO2 VDDIO2
J5
NF
RUN VC_TRST_N VC_TDI VC_TDO VC_TMS VC_TCK
Raspberry Pi
© Raspberry Pi 2017
www.raspberrypi.org
Title Pi Zero 2 W
Drawn By Simon Martin
Size A3
Ref RPI-ZERO2W_R1
Rev R1
Date: Friday, October 15, 2021
Sheet 1 of 1

Raspberry Pi Zero 2 W

Test Pad locations

Label	Function	X (mm from origin)	Y (mm from origin)
STATUS_LED	Power state of LED (LOW = ON)	5.15	8.8
CORE	Processor power	6.3	18.98
RUN	Connect to GND to reset	8.37	22.69
5V	5V Input	8.75	11.05
5V	5V Input	11.21	6.3
GND	Ground pin	10.9	3.69
GND	Ground pin	17.29	2.41
USB_DP	USB port	22.55	1.92
USB_DM	USB port	24.68	1.92
OTG	On-the-go ID pin	39.9	7.42
1V8	1.8V analog supply	42.03	8.42
TV	Composite TV out	45.58	3.17
GND	Ground pin	49.38	3.05
GND	Ground pin	55.99	22.87
3V3	3.3V I/O supply	48.55	22.44
SD_CLK	SD Card clock pin	60.95	18.45
SD_CMD	SD Card command pin	58.2	16.42
SD_DAT0	SD data pin	58.13	20.42
SD_DAT1	SD data pin	60.65	21.1
SD_DAT2	SD data pin	57.78	13.57
SD_DAT3	SD data pin	60.8	15.22
BT_ON	Bluetooth power status	25.13	19.55
WL_ON	Wireless LAN power status	27.7	19.2

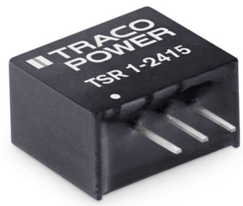


TRACO POWER

Non-Isolated DC/DC Converter (POL)

TSR 1 Series, 1 A

- **Up to 96% efficiency – No heat-sink required**
- **Pin compatible with LMxx linear regulators**
- **SIP-package fits existing TO-220 footprint**
- **Built in filter capacitors**
- **Operation temp. range –40°C to +85°C**
- **Short circuit protection**
- **Wide input operating range**
- **Excellent line / load regulation**
- **Low standby current**
- **3-year product warranty**



The TSR 1 series step-down switching regulators are drop-in replacement for inefficient 78xx linear regulators. A high efficiency up to 96% allows full load operation up to +60°C ambient temperature without the need of any heat-sink or forced cooling. The TSR 1 switching regulators provide other significant features over linear regulators, i.e. better output accuracy (±2%), lower standby current of 2 mA and no requirement of external capacitors. The high efficiency and low standby power consumption makes these regulators an ideal solution for many battery powered applications.

Models

Order Code	Output Current max.	Input Voltage Range	Output Voltage nom.	Efficiency typ.
TSR 1-2412	1'000 mA	4.6 - 36 VDC (9 VDC nom.)	1.2 VDC	74 % (at Vin min.)
TSR 1-2415			1.5 VDC	78 % (at Vin min.)
TSR 1-2418			1.8 VDC	82 % (at Vin min.)
TSR 1-2425			2.5 VDC	87 % (at Vin min.)
TSR 1-2433		4.75 - 36 VDC (9 VDC nom.)	3.3 VDC	91 % (at Vin min.)
TSR 1-2450		6.5 - 36 VDC (12 VDC nom.)	5 VDC	94 % (at Vin min.)
TSR 1-2465		9 - 36 VDC (12 VDC nom.)	6.5 VDC	93 % (at Vin min.)
TSR 1-2490		12 - 36 VDC (24 VDC nom.)	9 VDC	95 % (at Vin min.)
TSR 1-24120		15 - 36 VDC (24 VDC nom.)	12 VDC	95 % (at Vin min.)
TSR 1-24150		18 - 36 VDC (24 VDC nom.)	15 VDC	96 % (at Vin min.)

Note - For input voltage higher than 32 VDC an external input capacitor (22 µF) is required.

Input Specifications

Input Current	- At no load	9 Vin models:	1 mA typ.
		12 Vin models:	1 mA typ.
		24 Vin models:	1 mA typ.
	- At full load	9 Vin models:	1'000 mA max.
		12 Vin models:	1'000 mA max.
		24 Vin models:	1'000 mA max. (at Vin min.)
Reflected Ripple Current		9 Vin models:	150 mAp-p typ.
		12 Vin models:	150 mAp-p typ.
		24 Vin models:	150 mAp-p typ.
Recommended Input Fuse	- 9 Vin input	1.2 Vout models:	630 mA (slow blow)
		1.5 Vout models:	800 mA (slow blow)
		1.8 Vout models:	800 mA (slow blow)
		2.5 Vout models:	1'250 mA (slow blow)
		3.3 Vout models:	1'250 mA (slow blow)
	- 12 Vin input	5 Vout models:	1'600 mA (slow blow)
		6.5 Vout models:	1'250 mA (slow blow)
	- 24 Vin input	9 Vout models:	1'250 mA (slow blow)
		12 Vout models:	1'600 mA (slow blow)
		15 Vout models:	1'600 mA (slow blow)
Input Filter			Internal Capacitor

Output Specifications

Voltage Set Accuracy			±2% max.
Regulation	- Input Variation (Vmin - Vmax)		0.2% max.
	- Load Variation (10 - 100%)		0.6% max. (1.2 & 1.5 Vout models)
			0.4% max. (other models)
Ripple and Noise (20 MHz Bandwidth)		1.2 Vout models:	50 mVp-p typ.
		1.5 Vout models:	50 mVp-p typ.
		1.8 Vout models:	50 mVp-p typ.
		2.5 Vout models:	50 mVp-p typ.
		3.3 Vout models:	50 mVp-p typ.
		5 Vout models:	50 mVp-p typ.
		6.5 Vout models:	50 mVp-p typ.
		9 Vout models:	75 mVp-p typ.
		12 Vout models:	75 mVp-p typ.
		15 Vout models:	75 mVp-p typ.
Capacitive Load			470 µF max.
Minimum Load			Not required
Temperature Coefficient			±0.015 %/K max.
Start-up Overshoot Voltage			1% max.
Short Circuit Protection			Continuous, Automatic recovery
Output Current Limitation			250% typ. of Iout max.
Transient Response	- Peak Variation		150 mV typ. / 200 mV max. (50% Load Step)
	- Response Time		250 µs typ. / 350 µs max. (50% Load Step)

EMC Specifications

EMI Emissions	- Conducted Emissions		EN 55032 class A (with external filter)
	- Radiated Emissions		EN 55032 class A (with external filter)
		External filter proposal:	www.tracopower.com/overview/tsr1

General Specifications

Relative Humidity	95% max. (non condensing)

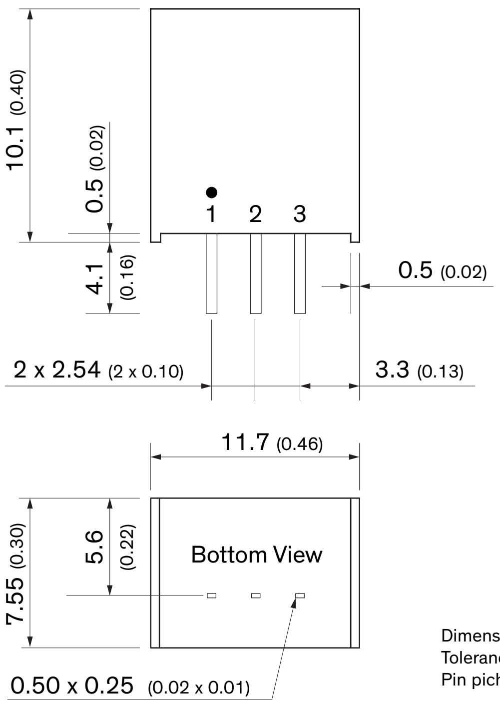
All specifications valid at nominal voltage, full load and +25°C after warm-up time unless otherwise stated.

Temperature Ranges	- Operating Temperature - Storage Temperature	–40°C to +85°C –55°C to +125°C
Power Derating	- High Temperature	2.4 %/K above 60°C
Over Temperature Protection Switch Off	- Protection Mode - Measurement Point	150°C typ. (Automatic recovery) Internal IC temperature
Cooling System		Natural convection (20 LFM)
Switching Frequency		400 - 600 kHz (PWM) 500 kHz typ. (PWM)
Insulation System		Non-isolated
Reliability	- Calculated MTBF	25'710'000 h (MIL-HDBK-217F, ground benign)
Environment	- Vibration - Thermal Shock	MIL-STD-810F MIL-STD-810F
Housing Material		Non-conductive Plastic (UL94 V-0 rated)
Potting Material		Silicone (UL 94 V-0 rated)
Soldering Profile		265°C / 10 s max.
Connection Type		THD (Through-Hole Device)
Weight		1.9 g
Environmental Compliance	- Reach - RoHS	www.tracopower.com/info/reach-declaration.pdf www.tracopower.com/info/rohs-declaration.pdf

Supporting Documents

Overview Link (for additional Documents)	www.tracopower.com/overview/tsr1

Outline Dimensions



Dimensions in mm (inch)
Tolerances: ±0.5 (±0.02)
Pin pich tolerances: ±0.25 (±0.01)

Pinout	
Pin	**Function**
1	+Vin
2	GND
3	+Vout

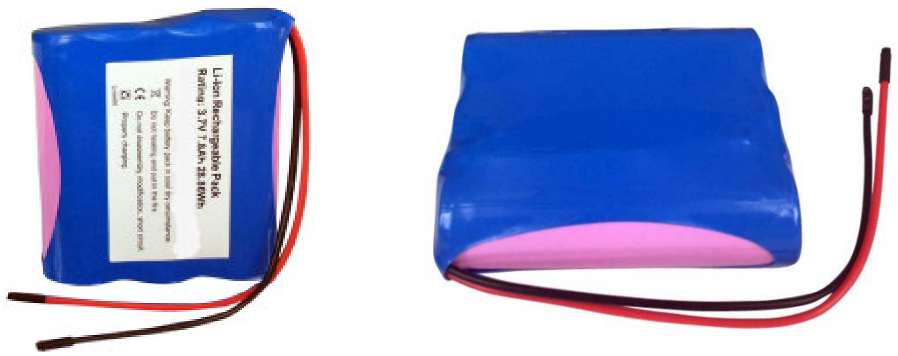
ENGLISH

Datasheet

RS Pro Article: 1449408

RS Pro 18650 26H Li-ion Battery Pack

Tested and approved to UN38.3



1 Preface

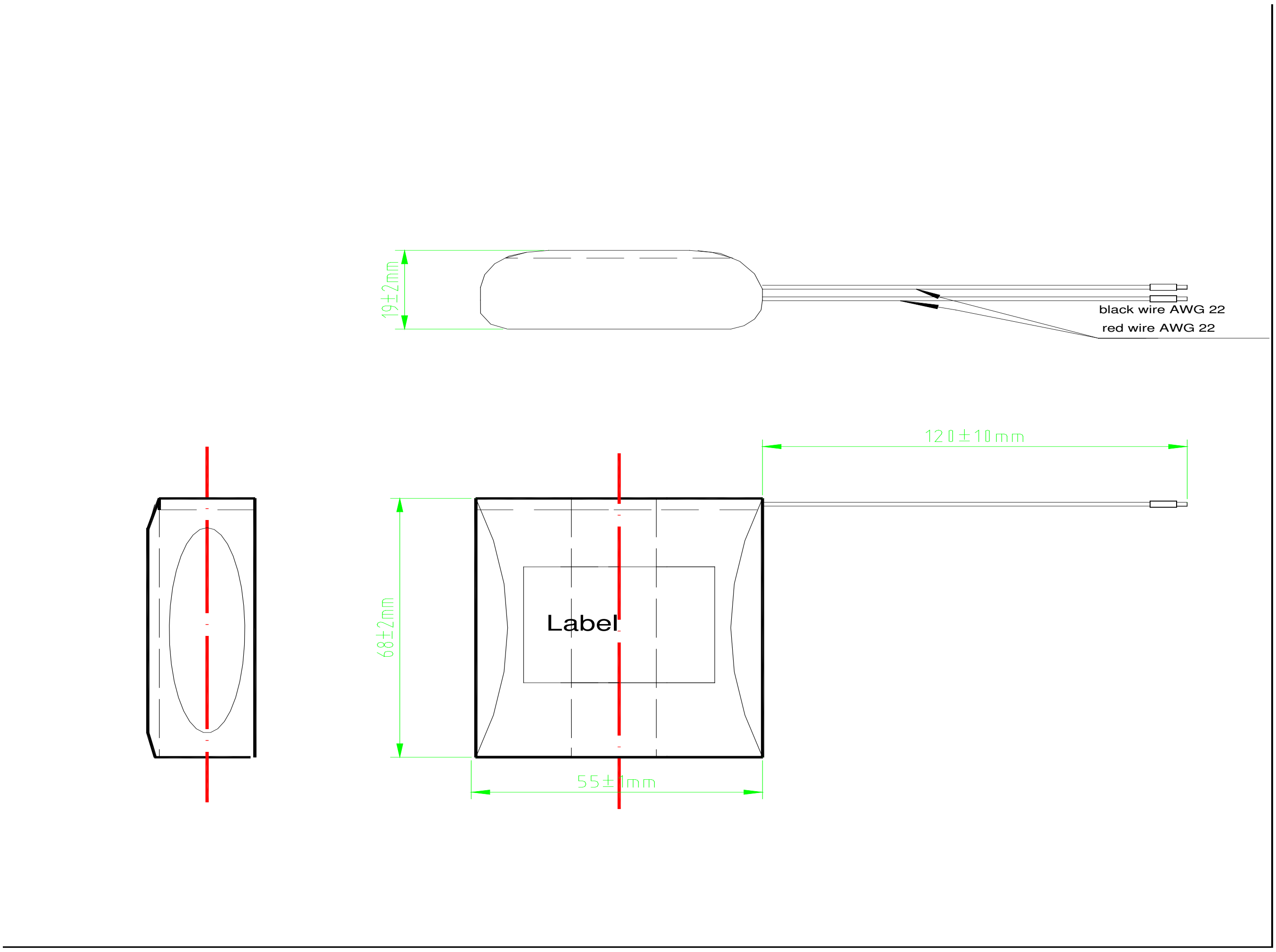
This manual describes the type and size, performance, technical characteristics, warning and caution.

2 Product and Model

2.1 Products: Lithium-ion Battery Pack

2.2 Model: RS Pro 18650-26H M(18650 7800 mAh 3.7 1S3P) 2.3

Picture and output wire (To prevail in kind)



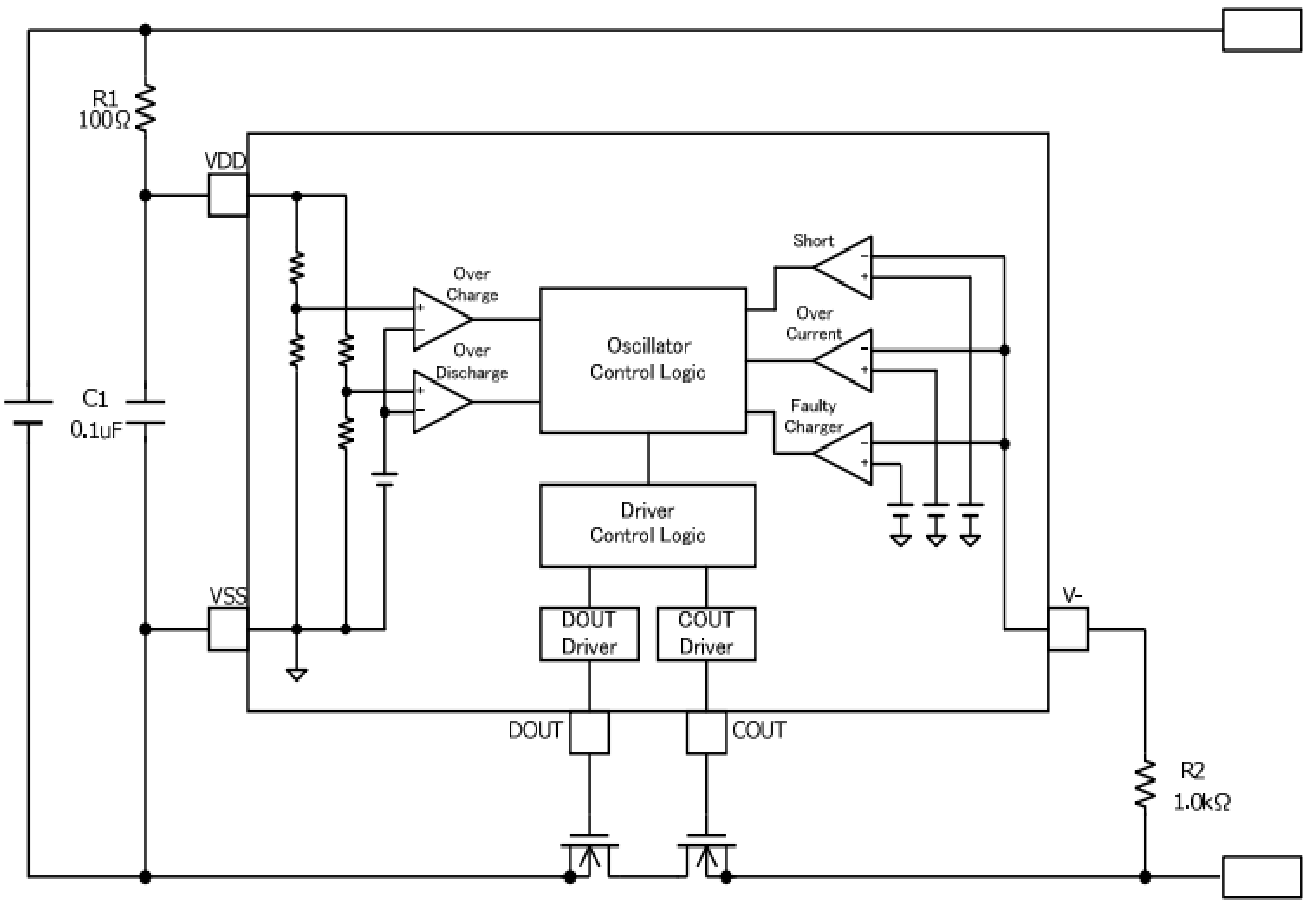
1.	Positive	Red one wire with 22 AWG	Length: 120 ±10 mm	Molex 39-01-4021
2.	Negative	Black one wire with 22 AWG	Length: 120 ±10 mm	

Battery Pack Specifications

Item		Parameters
Nominal Voltage		3.7 V
Typical capacity		7.8 Ah (At 0.2C, 2.75 V discharge)
Discharge	Max. Discharge Current	> 7 A (ambient temperature 25°C)
	Cut-off voltage	2.75 V
Charge	Voltage	4.2 ±0.05 V
	Current	Standard Charge: 0.5°C Rapid Charge: 1°C
	Max. Current	1C (ambient temperature 25°C)
	Charge mode	CC/CV, use special lithium charger
Inner resistance	Discharging Inner resistance	≤ 100 mΩ
Operation temperature / humidity range	Charge	0℃ to +52℃
	Discharge	-20℃ to +60℃
		When the environment temperature is higher than 45℃, pay attention to ventilation and heat rejection.
Storage temperature/ humidity range	Temperature	1 year: -20 to 20°C 3 months: -20 to 45°C 1 month: -20 to 60°C
Protection function	Over charge protection, Over discharge protection	
Shell material	PVC	
Weight	138 g	
Size (L x W x H) mm	68 x 55 x 19 ± (2-1-2 mm)	

4. Protective circuits (CL-R01-097-A01-MIST)

Item	Min.	Typical.	Max.	Unit.
Over-Charge detect voltage	4.225	4.25	4.275	V
Over-Charge recovery voltage	4.00	4.050	4.10	V
Over-Discharge detect voltage	2.58	2.50	2.58	V
Over-Discharge recovery voltage	2.90	3.00	3.10	V
Overcurrent protection	4		7	A
Idle mode		7		μA
Operating Temperature	-20	25	60	℃
Main loops electrify resistance			60	mΩ



LITHIUM CELLS OR BATTERIES TEST SUMMARY IN ACCORDANCE WITH SUB-SECTION 38.3 OF MANUAL OF TESTS AND CRITERIA FOR THE FOLLOWING RS PRO PRODUCTS

BATTERY TRANSPORTION INFORMATION

Name of cell, battery or product manufacturer, as applicable:	Cell, battery or product manufacturer's contact information to include address, phone number, email address and website for more information:
Item Number : 1449408 Item Name : RS PRO 3.7V Lithium ion Rechargeable pack Item Description :	RS Components Ltd Birchington Road Corby Northants NN17 9RS United Kingdom Tel: +44 (0) 845 850 9900 RSWWW.COM Email: RCustomerServicesUK@rs-components.com

Name of the test laboratory to include address, phone number, email address and website for more information:	A unique test report identification number:	Date of the test report:

List of tests conducted and results (i.e., pass/fail):

- Test T.1: Altitude Simulation :
- Test T.2: Thermal Test :
- Test T.3: Vibration :
- Test T.4: Shock :
- Test T.5: External short circuit :
- Test T.6: Impact/Crush :
- Test T.7: Overcharge :
- Test T.8: Forced discharge :

Testing additional comments:

Description of cell or battery to include at a minimum: Lithium ion or Lithium metal cell or battery; Mass; Watt-hour rating, or lithium content; Physical description of the cell/battery; and Model numbers:

- Cell/battery Type :
- Cell or Battery :
- LC or W/h rating :
- Cell or Battery Weight :

Reference to assembled battery testing requirements, if applicable (i.e., 38.3.3(f) and 38.3.3;(g)):	Reference to the revised edition of the Manual of Tests and Criteria used and to amendments thereto, if any:	For air transport only: Does the cell or battery comply with the 30% State of Charge?

PRODUCT CLASSIFICATION FOR TRANSPORT (According to UN - DGP)

UN Classification:	Proper Shipping Name:

Signature with name and title of signatory as an indication of the validity of information provided:

Andrew Shorley
RS Pro Engineering Manager

Date document was generated:

This document remains valid as long as no changes, modifications, or additions are made to the model(s) described in this document, after being transported from a Manufacturer XYZ facility.
The model(s) has (have) been classified according to the applicable transport regulations and the UN Manual of Tests and Criteria as of the date of the certification. The model(s) must be packaged, labeled, and documented according to country and other international regulations for transportation.

SV8 Series Anti-vandal Switch

Applications / Markets


Audio / Visual


Security Devices


Industrial Controls


Kiosks


Electrical Housewares


Medical Equipment

Specifications

Electrical Rating: 2A, 36VDC
Electrical Life: 200,000 Cycles
Contact Resistance: 50mΩ Max. at 1A 12VDC
Dielectric Strength: 2,000V RMS at sea level
Operating/Storage Temperature: -20°C to 70°C
Travel: 1.80mm
Moisture Protection: IP67
Contact Arrangement: SPST
Actuation Force: 4.5 N
Panel Thickness: 1-6mm
Mounting Nut Torque: 1-3Nm

Features & Benefits

- **Short body design**
- **25mm diameter panel cutout**
- **Multiple LED options**
- **Ring or Ring/Power symbol illumination available**
- **IP67 rated**
- **SPST**
- **Soldered wire leads (500mm long) optional**

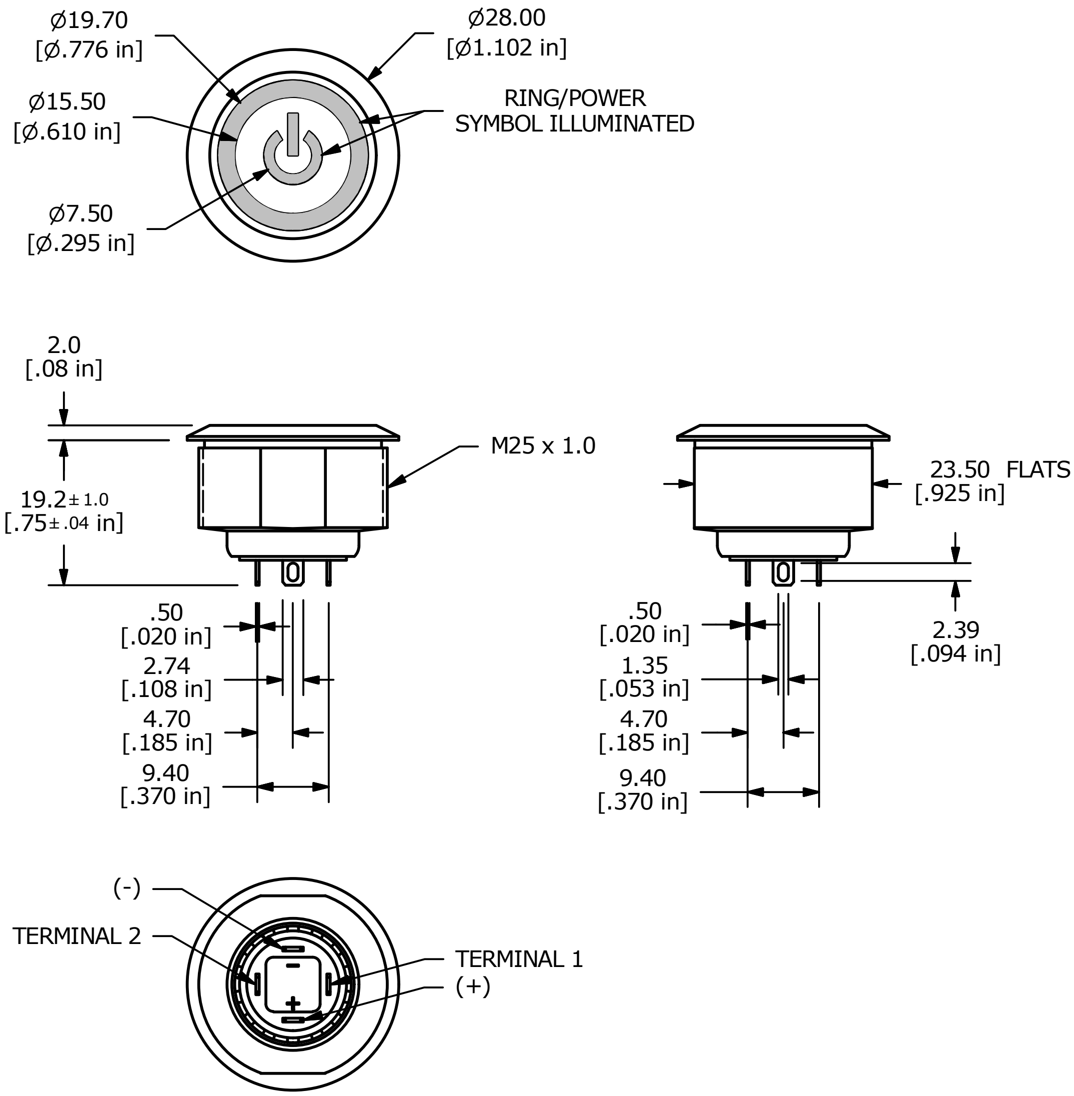
Part Number Configurator

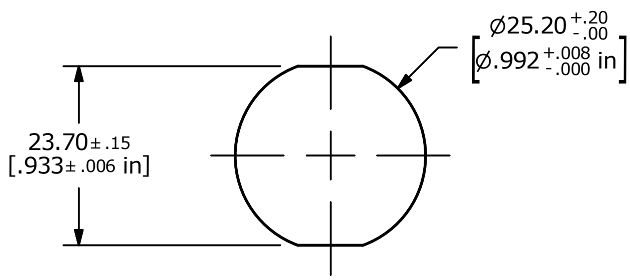
Series	Actuator Options	Terminal Options	Function Options	Body Finish Options	Actuator Finish Options	Lens Style Options	LED-Color Options	Illumination Voltage Options
SV8	**F** - Flat	**2** - Solder **W** - Wire Leads 500mm long	**3** - 1 Pole Off - (On)*	**S** - Stainless Steel	**S** - Stainless Steel	**3** - Ring moveable with Actuator **6** - Ring /Power moveable with Actuator	**0** - White **1** - Red **3** - Green **4** - Blue **5** - Yellow **G** - Red/Green **H** - Red/Blue	**1** - Base Voltage

NOTES:
*( ) denotes function is momentary

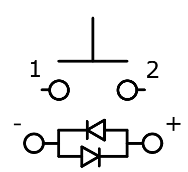
Specifications subject to change without notice 3.5.2020

BODY DIMENSIONS



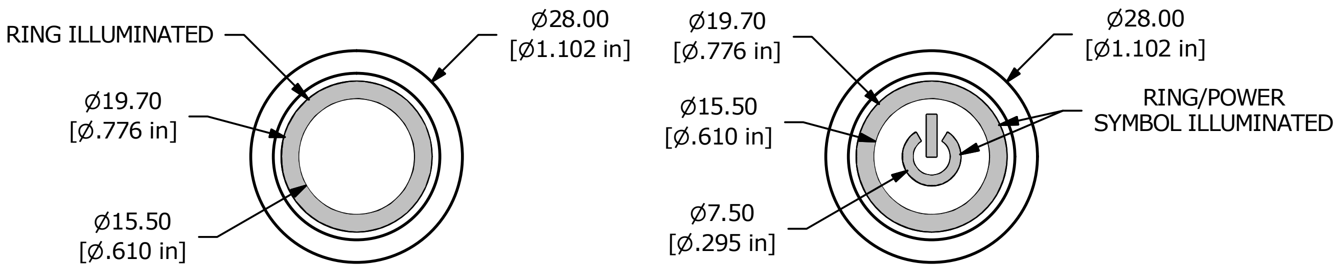


RECOMMENDED PANEL CUTOUT



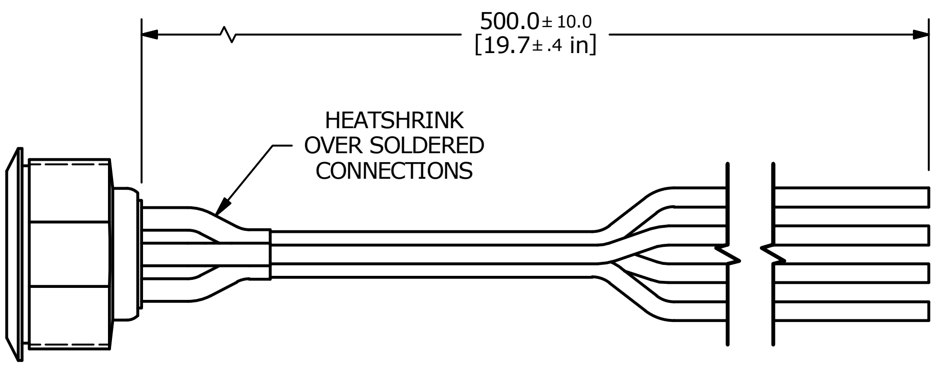
SCHEMATIC

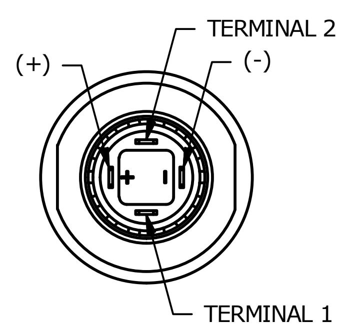
Acuator Options



Wire Lead Option

SWITCH	WIRE	LENGTH
SW1-1	WIRE, 20AWG AWM UL3385, BLACK	500.0 [19.7 in]
SW1-2	WIRE, 20AWG AWM UL3385, BLACK	500.0 [19.7 in]
SW1- (-)	WIRE, 20AWG AWM UL3385, GREEN	500.0 [19.7 in]
SW1- (+)	WIRE, 20AWG AWM UL3385, RED	500.0 [19.7 in]





BOTTOM VIEW
SHOWN WITHOUT
WIRING

Standard Buccaneer

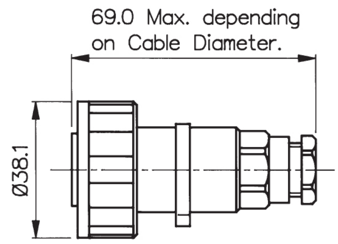
- IP68 rating tested at 1.054kg/sq cm (15lb/sq in) 10m depth for 2 weeks and 9.84kg/sq cm (140lb/sq in) 100m depth for 12 hours
- IP69K, Tested in accordance with DIN 40050/Part 9 IP6k9k
- Water and dustproof to IP68 when mated
- 2, 3, 4, 6, 7, 9, 12 and 25 Contact
- 12A, 277V AC/DC 2 Contact screw terminal, 3 Contact screw terminal and crimp contacts
- 10A, 277V AC/DC 4 Contact screw terminal
- 5A, 277V AC/DC6 and 7 Contact screw terminal
- 5A, 150V AC/DC 9 Contact crimp contacts
- 5A, 50V AC/DC 12 Contact crimp and solder contacts
- 1A, 50V AC/DC 25 Contact crimp and solder contacts
- Plug or socket connection in each body style
- Compact design
- Diameter over coupling ring 38mm
- Sealing caps available to maintain IP68 rating of unmated connectors
- 7 body styles - flex cable, Inline cable, panel mount (front), panel mount (rear), PCB mount, bulkhead and flange mount
- Leading earth contact for 3 Contact socket version
- Positive locating keyways - cannot be mis-connected
- Easy assembly - no special tools required on screw terminal versions
- Cable range from 3.5mm - 9mm
- Colour coded identification variants
- Pre-wired, overmoulded cable assemblies
- UL, CSA and VDE approvals
- EN60068-2-52 Test Kb Salt Mist (Cyclic) Marine Severity Level 1

Standard Buccaneer

Flex Cable Connector

PX0731/P

- Mates with Inline or Panel Mounting Versions
- Screw Locking Ring
- Plug or Socket Versions
- Leading Earth on 3 Contact connectors
- Contacts 2, 3, 4, 6, 7, 9, 12, 25
- Standard Cable Acceptance (2 to 9 Contact) 6-8mm, 3.5-9mm with alternative glands - See page 25

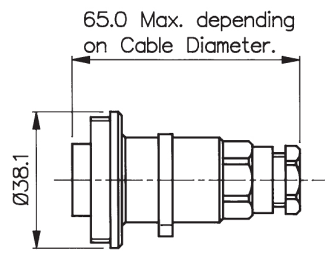


Contacts	Termination	Plug Contacts	Socket Contact	Contacts
2	Screw	PX0736/P	PX0736/S	Supplied Fitted
3	Screw	PX0731/P	PX0731/S	Supplied Fitted
3	Crimp	PX0776/P	PX0776/S	Supplied Loose
4	Screw	PX0748/P	PX0748/S	Supplied Fitted
6	Screw	PX0739/P	PX0739/S	Supplied Fitted
7	Screw	PX0745/P	PX0745/S	Supplied Fitted
9	Crimp	PX0728/P	PX0728/S	Supplied Loose
12	Crimp/Solder	PX0794/P	PX0794/S	Order Separately (SA3348/SA3347)
25	Crimp/Solder	PX0820/P	PX0820/S	Order Separately (SA3180/SA3179)

Inline Cable Connector

PX0732/S

- Mates with Flex or Panel Mounting Versions
- Screw Locking Ring
- Plug or Socket Versions
- Leading Earth on 3 Contact connectors
- Contacts 2, 3, 4, 6, 7, 9, 12, 25
- Standard Cable Acceptance (2 to 9 Contact) 6-8mm, 3.5-9mm with alternative glands - See page 25

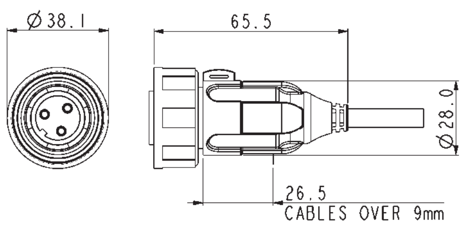


Contacts	Termination	Plug Contacts	Socket Contact	Contacts
2	Screw	PX0737/P	PX0737/S	Supplied Fitted
3	Screw	PX0732/P	PX0732/S	Supplied Fitted
3	Crimp	PX0778/P	PX0778/S	Supplied Loose
4	Screw	PX0749/P	PX0749/S	Supplied Fitted
6	Screw	PX0740/P	PX0740/S	Supplied Fitted
7	Screw	PX0746/P	PX0746/S	Supplied Fitted
9	Crimp	PX0729/P	PX0729/S	Supplied Loose
12	Crimp/Solder	PX0795/P	PX0795/S	Order Separately (SA3348/SA3347)
25	Crimp/Solder	PX0821/P	PX0821/S	Order Separately (SA3180/SA3179)

Pre Wired Flex Cable Connector

PX0700

- Overmoulded cable assemblies
- Up to 14mm dia cable with PVC or PU jackets
- Mates with Inline connector and all panel connectors



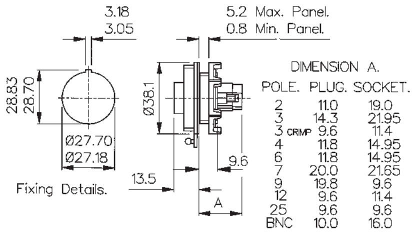
Standard Buccaneer

bulgin

Front Panel Mounting Connector

PX0730/P

- Mates with Flex Cable Connector
- Single Hole Fixing
- Plug or Socket Versions
- Contacts 2, 3, 4, 6, 7, 9, 12, 25

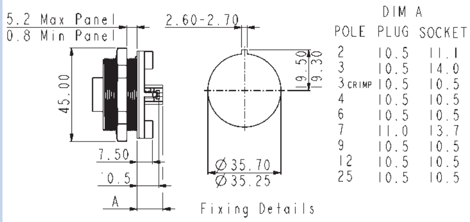


Contacts	Termination	Plug Contacts	Socket Contact	Contacts
2	Screw	PX0735/P	PX0735/S	Supplied Fitted
3	Screw	PX0730/P	PX0730/S	Supplied Fitted
3	Crimp	PX0779/P	PX0779/S	Supplied Loose
4	Screw	PX0747/P	PX0747/S	Supplied Fitted
6	Screw	PX0738/P	PX0738/S	Supplied Fitted
7	Screw	PX0744/P	PX0744/S	Supplied Fitted
9	Crimp	PX0727/P	PX0727/S	Supplied Loose
12	Crimp/Solder	PX0796/P	PX0796/S	Order Separately
25	Crimp/Solder	PX0822/P	PX0822/S	Order Separately

Rear Panel Mounting Connector

PX0709/P/03

- Mates with Flex Cable Connector
- Single Hole Fixing
- Plug or Socket Versions
- Contacts 2, 3, 4, 6, 7, 9, 12 or 25

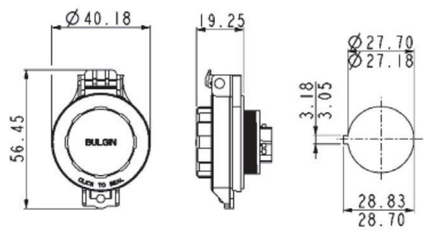


Contacts	Termination	Plug Contacts	Socket Contact	Contacts
2	Screw	PX0709/P/02	PX0709/S/02	Supplied Fitted
3	Screw	PX0709/P/03	PX0709/S/03	Supplied Fitted
3	Crimp	PX0708/P/03	PX0708/S/03	Supplied Loose
4	Screw	PX0709/P/04	PX0709/S/04	Supplied Fitted
6	Screw	PX0709/P/06	PX0709/S/06	Supplied Fitted
7	Screw	PX0709/P/07	PX0709/S/07	Supplied Fitted
9	Crimp	PX0708/P/09	PX0708/S/09	Supplied Loose
12	Crimp/Solder	PX0708/P/12	PX0708/S/12	Order Separately (SA3348/SA3347)
25	Crimp/Solder	PX0708/P/25	PX0708/S/25	Order Separately (SA3180/SA3179)

Sprung Loaded Sealing Cap

PX0713

- IP54 rated
- Spring loaded
- Clip shut to seal
- For use with front of panel mounting connector types

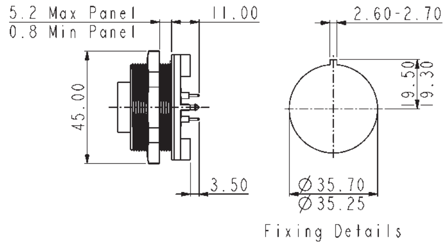


Standard Buccaneer

Rear PCB Mounting Connector

PX0707/P/12

- Mates with Flex Cable connector
- No. Contacts: 3, 4, 6, 9, 12 or 25
- Plug or socket versions
- Pre-loaded Gold Plated contacts

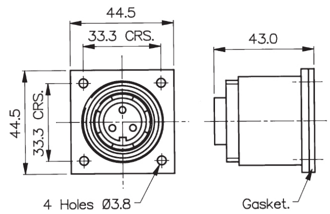


Contacts	Termination	Plug Contacts	Socket Contact	Contacts
3	PCB	PX0707/P/03	PX0707/S/03	Supplied Fitted
4	PCB	PX0707/P/04	PX0707/S/04	Supplied Fitted
6	PCB	PX0707/P/06	PX0707/S/06	Supplied Fitted
9	PCB	PX0707/P/09	PX0707/S/09	Supplied Fitted
12	PCB	PX0707/P/12	PX0707/S/12	Supplied Fitted
25	PCB	PX0707/P/25	PX0707/S/25	Supplied Fitted

Bulkhead Flange Mounting Connector

PX0756/S

- Mates with Flex Cable Connector
- Plug or Socket Versions
- Contacts 2, 3, 4, 6, 7, 9, 12, 25
- Supplied with sealing gasket and screw sealing grommets

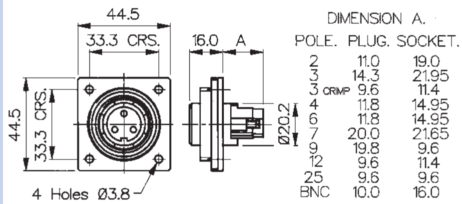


Contacts	Termination	Plug Contacts	Socket Contact	Contacts
2	Screw	PX0757/P	PX0757/S	Supplied Fitted
3	Screw	PX0756/P	PX0756/S	Supplied Fitted
3	Crimp	PX0787/P	PX0787/S	Supplied Loose
4	Screw	PX0761/P	PX0761/S	Supplied Fitted
6	Screw	PX0758/P	PX0758/S	Supplied Fitted
7	Screw	PX0760/P	PX0760/S	Supplied Fitted
9	Crimp	PX0762/P	PX0762/S	Supplied Loose
12	Crimp/Solder	PX0798/P	PX0798/S	Order Separately (SA3348/SA3347)
25	Crimp/Solder	PX0823/P	PX0823/S	Order Separately (SA3180/SA3179)

Low Profile Flange Mounting Connector

PX0765/S

- Screw Flange Fixing
- Plug or Socket Versions
- Contacts 2, 3, 4, 6, 7, 9, 12, 25
- Mates with Flex Cable Connector
- Supplied with sealing gasket and screw sealing grommets



Contacts	Termination	Plug Contacts	Socket Contact	Contacts
2	Screw	PX0764/P	PX0764/S	Supplied Fitted
3	Screw	PX0765/P	PX0765/S	Supplied Fitted
3	Crimp	PX0781/P	PX0781/S	Supplied Loose
4	Screw	PX0766/P	PX0766/S	Supplied Fitted
6	Screw	PX0767/P	PX0767/S	Supplied Fitted
7	Screw	PX0768/P	PX0768/S	Supplied Fitted
9	Crimp	PX0769/P	PX0769/S	Supplied Loose
12	Crimp/Solder	PX0797/P	PX0797/S	Order Separately (SA3348/SA3347)
25	Crimp/Solder	PX0824/P	PX0824/S	Order Separately (SA3180/SA3179)

Coloured Contact Inserts

Coloured Inserts

- With or without matching gland nut
- Positive visual identification
- Available in; Black, Blue, Green, Grey, Light Grey, Red, White and Yellow

Contact Inserts Colour Options

Part No	Suffix Colour
Blank	Black
BL	Blue
GN	Green
GY	Grey
LG	Light Grey
RD	Red
WH	White
YL	Yellow

Insert/Gland Nut Combinations

1	Insert and Gland Nut Coloured
2	Insert Only Coloured

E.g. PX0731/P/YL1 = Yellow insert and gland nut

Contacts for 12 and 25 Contact Inserts

12 and 25 way contacts

- Crimp or Solder Plugs and Sockets
- Gold Plated
- Current ratings:
  12 way: 5A, 50V
  25 way: 1A, 50V

Contacts - Solder & Crimp for 12 and 25 Contact

Contacts (for 12 Contact) (Supplied in packs of 10)	Solder	Crimp
Plugs	SA3348/1	SA3348
Sockets	SA3347/1	SA3347

Contacts (for 25 Contact) (Supplied in packs of 10)	Solder	Crimp
Plugs	SA3180/1	SA3180
Sockets	SA 3179/1	SA3179

Assembly Tools

PNo 14025 and 13027

- Crimp Tools for 3, 9,12 and 25 Contact crimp contacts
- Insertion/Extraction Tool for 25 Contact contacts

Tools

Crimp Tool (25 Contact)	PNo. 14025/1AMP
Crimp Tool (12 Contact)	PNo. 14025
Positioner (12 Contact)	PNo. 14025/5AMP
Crimp Tool (9 Contact)	PNo. 13826
Crimp Tool (3 Contact)	PNo. 14232
3 Contact positioner	PNo. 14232/1
Insertion/Extraction Tool (25 Contact)	PNo. 13027
Insertion/Extraction Tool (12 Contact)	PNo. 13027/1
Insertion/Extraction Tool (3 Contact)	PNo. 13027/3

Cable Glands

12023/1, 12023/2 & SA3253

- Pack of alternative cable glands to suit cables from 3.5 to 9mm dia.

Cable Acceptance - Alternatives

Gland Diameter	Gland Part No.	Gland Colour	Additional Suffix
6-8mm	12023	Black	Standard for 2-12 Contact
3.5-5mm	SA3426	Grey	Suffix /04†
5-7mm	12023/1	White	Suffix /05
7-9mm	12023/2	Yellow	Suffix /07*
Gland Pack	SA3253	Pack of 3 glands to suit cables 3.5-5mm, 5-7mm & 7-9mm dia†	

*Note: 7-9mm gland standard for 25 way, no suffix required.
†Includes additional black gland cage for 3.5-5mm dia. cable range.
To order connector with alternative cable gland add suffix to part no. e.g. PX0731/P/07 = PX0731 3 Plug connector with cable gland to suit 7-9mm dia. cable.

Cable Acceptance - Standard as supplied

No. Contacts	Cable Diameter or Type
2-12 Contact	6-8mm
25 Contact	7-9mm

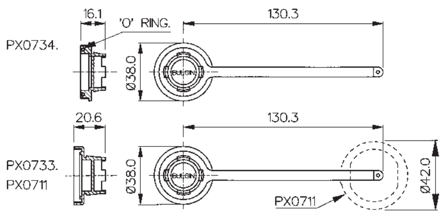
Standard Buccaneer

Accessories

Sealing Cap and Assembling Tool

PX0734 & PX0733

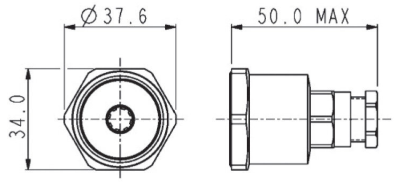
- Maintains IP68 Rating of Unmated Connectors
- Can be used to remove Inserts
- PX0734 for Flex Cable Connector
- PX0733 for Inline, Front Panel, Bulkhead and Flange mount connectors
- PX0711 for PCB and Rear Panel Mount connectors



Rear of Panel Back Shell

PX0799

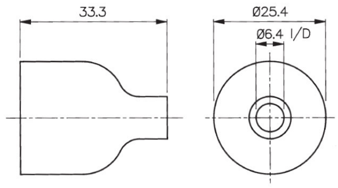
- Provides environmental seal to rear of panel
- Standard cable acceptance 6-8mm, 3.5 to 9mm with alternative glands
- For use on front panel mounting connectors
- Replaces mounting nut in panel connector



PVC Insulation Boot

PNo. 12855

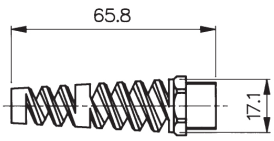
- Shock protection for rear of connector
- Flammability Rating UL94V-0
- Fits Front Panel Mount Versions only



Cable Support Accessory

PNo. 12237

- Gives Extra Support to the Cable
- Suitable for 5-7mm and 7-9mm Cable Diameters



Part No System

bulgin

PX07XX / X / XX / XX X

Body Styles

PX0736
PX0731
PX0776
PX0748
PX0739
PX0745
PX0728
PX0794
PX0820
PX0737
PX0732
PX0778
PX0749
PX0740
PX0746
PX0729
PX0795
PX0821
PX0735
PX0730
PX0779
PX0747
PX0738
PX0744
PX0727
PX0796
PX0822
PX0709
PX0708
PX0707
PX0757
PX0756
PX0787
PX0761
PX0758
PX0760
PX0762
PX0798
PX0823
PX0764
PX0765
PX0781
PX0766
PX0767
PX0768
PX0769
PX0797
PX0824

Contacts Type

P = Plug
S = Socket

Cable Acceptance or PCB/Rear Panel Mounting

Flex Cable and Inline Connectors cable acceptance use:
Blank = 6-8mm (Black) standard for 2-12 Contact

04 = 3.5-5mm (Grey)
05 = 5-7mm (White)
07 = 7-9mm (Yellow)
(standard for 25 way, no suffix required)

PCB (PX0707) and Rear Panel Mount connectors (PX0708 and PX0709) use:

02 = 2 Contact	03 = 3 Contact
04 = 4 Contact	06 = 6 Contact
07 = 7 Contact	09 = 9 Contact
12 = 12 Contact	25 = 25 Contact

Front Panel, Bulkhead and Flange Mount - not required:

Insert/Gland Nut Colour

Blank = Black
BL = Blue
GN = Green
GY = Grey

LG = Light Grey
RD = Red
WH = White
YL = Yellow

Insert/Gland Nut Colour Combination

1 = Insert and Gland Nut Coloured
2 = Insert only Coloured

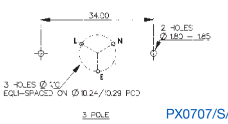
Examples:

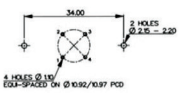
PX0707/P/06= PCB Panel connector, Plug contacts, 6 Contact
PX0731/S = Flex Cable connector, socket contacts, 3 Contact
PX0732/P/07/BL2 = Inline Cable connector, Plug contacts, 3 Contact, 7-9mm cable acceptance, blue insert

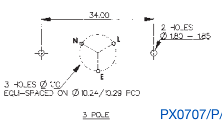
PCB Layouts

Sockets
Contact Nos viewed from rear of panel

Plugs
Contact Nos viewed from rear panel rear of panel


PX0707/S/03


PX0707/S/04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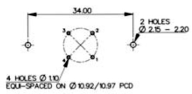
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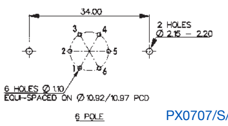
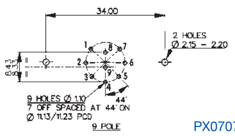
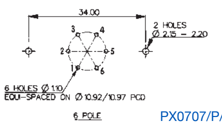
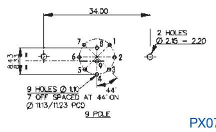

PX0707/S/06


PX0707/S/09


PX0707/P/06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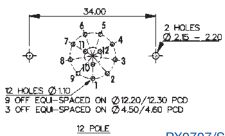
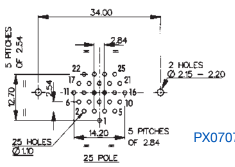

PX0707/S/12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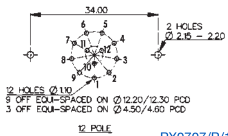
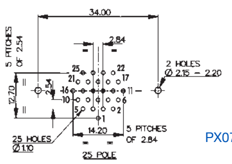

PX0707/P/12


PX0707/P/25

Specifications

Electrical:

No. Contacts:	2, 3	4	6, 7	9	12	25
Current Rating:						
VDE	12A	10A	5A	5A	5A	1A
UL, CSA	12A	10A	5A	5A	5A	1A
Voltage Rating (AC/DC):	277V	277V	277V	150V	50V	50V

Contact Resistance:	<10mΩ (2-9 Contact) <5mΩ (12 Contact) <5mΩ (25 Contact)
Insulation Resistance:	>10^4MΩ @ 500V DC (2-9 Contact)
AC Breakdown voltage:	4kV Contact - Contact (2-9 Contact) 6kV Contacts - Panel (Low Profile Flange and Panel Types – 2-9 Contact) 7.5kV Contacts - Panel (Other Types – 2-9 Contact)
Operating Temp. Range:	–20°C to +70°C

Approvals:

UL (Underwriters Laboratory)	E93288 and E337507
CSA (Canadian Standards Associations)	LR80968-30
VDE (Verband der Elektrotechnik)	40023148

Overmoulded cable assemblies approvals to customer requirements.

Material:

Body Mouldings:	Glass Filled Polyamide UL94HB
Inserts (2-25 Contact):	Polyamide UL94V-0
PX0707	Polyamide UL94V-0
PX0708	Polyamide UL94V-0
PX0709	Polyamide UL94V-0
Overmoulded types:	
Body Mouldings:	Polyurethane
Flammability Rating:	UL94V-HB
Contacts:	
Screw Terminal:	Brass, Nickel Plated
Crimp (9 Contact):	Copper Alloy, Tin Plated
Crimp/Solder (12+25 Contact):	Copper Alloy, Gold Plated (0.1µm on Nickel)
BNC inserts:	Brass, Nickel Plated
BNC contacts:	Brass, Silver Plated
RoHS	Compliant

Mechanical:

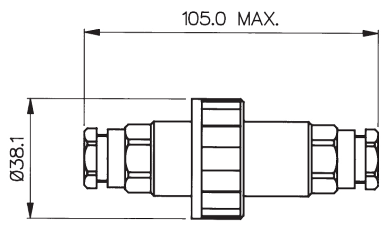
Sealing:	IP69K, Tested in accordance with DIN 40050/Part 9 IP6k9k IP68, EN 60529:1992+A2:2013 Tested @ 1.054kg/sq.cm. (15lb/sq.in.) 10m depth for 2 weeks. EN 60529:1992 +A2:2013 Tested @ 9.84kg/sq.cm. (140lb/sq.in.) 100m depth for 12 hours.
Salt Mist:	EN60068-2-52 Test Kb Salt Mist (Cyclic) Marine Severity Level 1
Cable Acceptance:	
2-12 Contact - standard gland:	6-8mm dia
2-12 Contact - alternative glands:	3.5-9mm dia
25 Contact - standard gland:	7-9mm dim
25 Contact - alternative glands:	3.5-7mm dim
Contact Accommodation:	
2 and 3 Contact screw terminals:	2.5-4mm2 (12-14AWG)
3 Contact crimp:	1-1.5mm2 (16-17AWG)
4, 6 and 7 Contact:	1-1.5mm2 (17-16AWG)
9 Contact:	0.14-0.25mm2 (24-26AWG)
12 Contact:	0.25-0.34mm2 (22-24AWG)
25 Contact:	0.14-0.25mm2 (24-26AWG)
Terminations:	
2-7 Contact:	Screw Terminals
3 Contact:	Screw Terminals & Crimp
9 Contact:	Crimp Contacts
12 Contact:	Crimp & Solder Contacts
25 Contact:	Crimp & Solder Contacts
Tightening Torques:	
Flex Mounting/Inline:	Gland Nut: 1.13Nm (10lbf.in.)
Panel Mounting:	Rear Fixing Nut: 1.7Nm (15lbf.in.) Front Fixing Nut: 1.4Nm (12.4lbf.in.)
Surface/Bulkhead and Low Profile Flange Mounting:	4 Fixing Screws (using washers supplied) 0.34Nm (3lbf.in.)
Sealings Caps/Locking Ring:	1.13Nm (10lbf.in.)
Rear thread, Front Panel Connector:	M27 x 1.0-6H
Thread, Front Panel Connector:	M35 x 1.0-6H

Sealed Cable Joiner

Cable Joiner

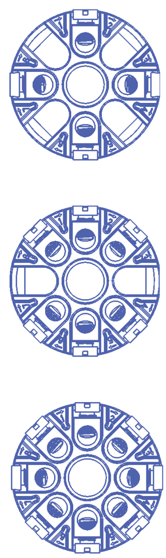
PX0777

- IP68 & IP69k Rating
- For Sealed Inline Connections
- Standard Cable Acceptance 6-8mm
- Cable Range 3.5-9mm (using alternative glands)
- Supplied with 4, 6 or 8 way
- Terminal Block
- Available Moulded in Black or Orange



Specifications	PX0777	PX0777/4POLE, 6POLE, 8POLE
Rating:	16A, 250V AC	10A, 250V AC
Wire Termination:	3 way Terminal Block	4, 6, 8 way Terminal Block
Conductor Accommodation:	2.5mm² max (14AWG)	1.5mm² max (16AWG)
Cable Acceptance:	6-8mm dia alternative glands available on request	6-8mm dia alternative glands available on request
Material:	Glass Filled Polyamide UL94-HB	Glass Filled Polyamide UL94-V0
Sealing:	IP68 to BSEN 60529 : 1992 1.054kg/sq.cm. (15lbs/sq.in.) 10m depth for 2 weeks IP69k to DIN 40050-9	IP68 to BSEN 60529 : 1992 1.054kg/sq.cm. (15lbs/sq.in.) 10m depth for 2 weeks IP69k to DIN 40050-9
Salt Mist	EN60068-2-52 Test Kb Salt Mist (Cyclic) Marine Severity Level 1	EN60068-2-52 Test Kb Salt Mist (Cyclic) Marine Severity Level 1
Operating Temp. Range:	–20°C to +70°C	–20°C to +70°C
Colour:	Black Orange (Add /OR to PNo.)	Black Orange (Add /OR to PNo.)
RoHS	Compliant	Compliant

POLE Configurations



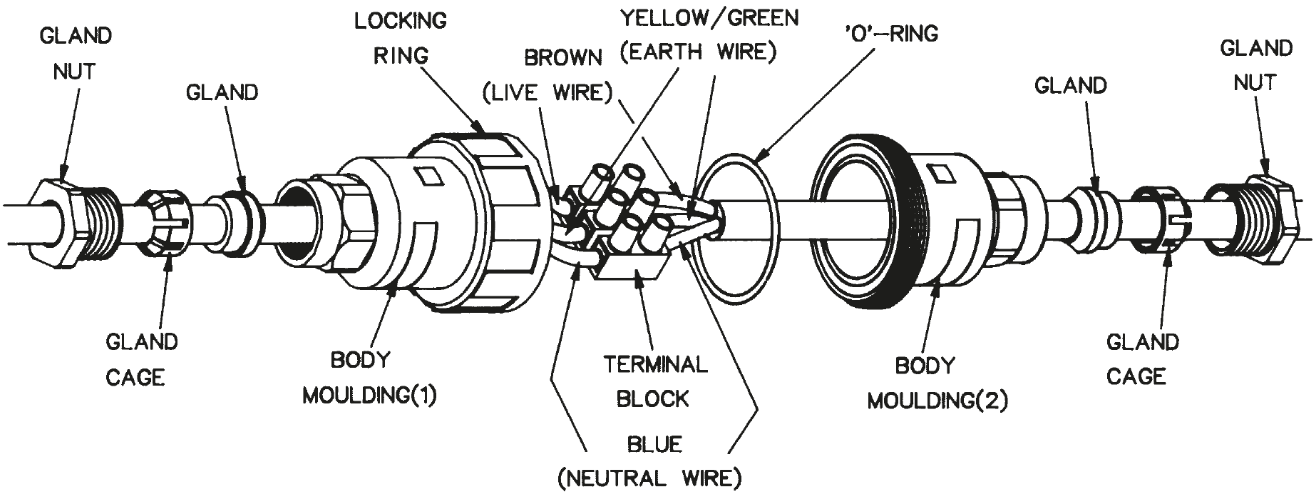
Examples

PX0777 – 3 Contact 6-8mm Black.
PX0777/04 – 3 Contact 3.5-5.0mm Black.
PX0777/04/OR –3 Contact 3.5-5.0mm Orange.

PX0777/4POLE – 4 Contact 6-8mm Black.
PX0777/6POLE/04 – 6 Contact 3.5-5.0mm Black.
PX0777/8POLE/04/OR – 8 Contact 3.5-5.0mm Orange.

PX0777 /	XPOLE /	XX /	XX
Part No	Blank = 3 Contact 4POLE = 4 Contact 6POLE = 6 Contact 8POLE = 8 Contact	Blank = 6-8mm 04 = 3.5-5mm 05 = 5-7mm 07 = 7-9mm	Blank = Black OR = Orange

PX0777 WIRING AND ASSEMBLY INSTRUCTIONS

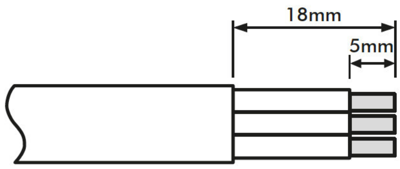


1. Strip wires to dimensions shown.

2. Assemble components parts onto cable as shown, then connect wires to terminal block.

   ENSURING WIRES CONNECTED INTO ONE SIDE OF TERMINAL BLOCK MATCH WIRES CONNECTED INTO THE OTHER SIDE.

   i.e. Brown to Brown (Live)
   Blue to Blue (Neutral)
   Green/Yellow to Green/Yellow (Earth)



Wire stripping details

3. Bring the two body mouldings together ensuring the ‘O’ ring is correctly located in groove then lock together with locking ring, ensure ring is fully tightened.

   Put gland cage over gland and push fully home into its appropriate body then fully tighten gland nuts.

4. To ensure a good seal, all surfaces must be completely free of dust, grease or any other contamination.

THIS CABLE CONNECTOR IS SUITABLE FOR USE WITH LOADS NOTEXCEEDING 16 AMPS USING 1.5mm2 CABLE

ALWAYS USE WITH SUPPLY PROTECTED BY AN RCD (RESIDUAL CABLE DEVICE), IF IN DOUBT CONSULT A QUALIFIED ELECTRICIAN.

DANGER

DISCONNECT MAINS SUPPLY BEFORE DISMANTLING CONNECTOR

400 Series Buccaneer

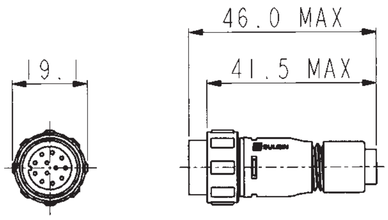
- Sealed to IP68 when mated
- IP68 rating tested at 1.054kg/sq cm (15lb/sq in) 10m depth for 2 weeks
- 2 and 3 pole - 8A, 250V rating
- 4, 6 and 8 pole - 5A, 125V rating
- 10 and 12 pole - 1A, 50V rating
- 2.5mm contact engagement for electrical integrity 'Scoop proof' contacts
- Contact inserts are part of body moulding
- Cable range from 3 to 7mm
- Overall length (flex + flex in-line) 80mm
- Gold plated contacts
- Diameter over coupling ring 19.1mm
- Pre-wired, overmoulded cable assemblies
- Flex, Flex In-Line, Front Panel, Rear Panel and PCB mounting body styles
- Plug and Socket versions in all body styles
- Flame Retardant moulding material - Polyamide UL94-V0
- Contacts supplied separately (except PCB versions)
- Sealing caps available to maintain IP68 rating
- Secure sealing system
- Crimp and solder contacts
- PCB mounting connector supplied with contacts pre-loaded
- Front and rear panel mounting panel connectors
- CCC, UL, CSA and VDE approvals
- EN60068-2-52 Test Kb Salt Mist (Cyclic) Marine Severity Level 1

400 Series Buccaneer

Flex Cable Connector

PX0410

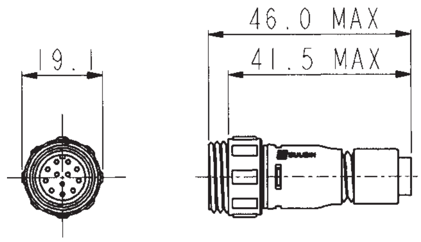
- Mates with Flex In-line or Panel mounting versions PX0401, PX0411, PX0412 & PX0413
- Pin or socket
- 2, 3, 4, 6, 8, 10 or 12 pole
- Screw locking ring
- Contacts supplied separately



Inline Flex Cable Connector

PX0411

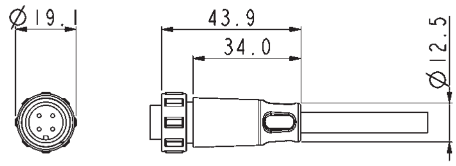
- Mates with Flex Cable connectors PX0400, PX0402 & PX0410
- Pin or socket
- 2, 3, 4, 6, 8, 10 or 12 pole
- For in-line cable connection
- Contacts supplied separately



Pre Wired Flex Cable Connector

PX0400

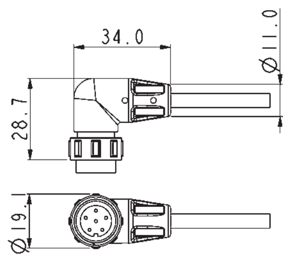
- Overmoulded Flex connector for pre-wired cable assemblies
- Pin or socket
- Cable range 2.5 -9.0mm o/d
- 2, 3, 4, 6, 8, 10 or 12 pole
- Mates with PX0401 & PX0411 Flex In-Line connectors and PX0412 & PX0413 panel mounting connectors



Pre Wired Flex Cable Connector

PX0402

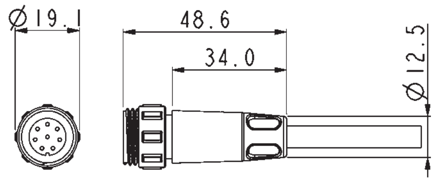
- Right-angled overmoulded
- Flex connector for pre-wired cable assemblies
- Pin or socket
- Cable range 2.5 -9.0mm o/d
- 2, 3, 4, 6, 8, 10 or 12 pole
- Mates with PX0401 & PX0411 Flex In-Line connectors and PX0412 & PX0413 panel mounting connectors



Pre Wired Inline Flex Connector

PX0401

- Overmoulded Flex connector for pre-wired cable assemblies
- Pin or socket
- Cable range 2.5 -9.0mm o/d
- 2, 3, 4, 6, 8, 10 or 12 pole
- Mates with PX0400, PX0402 &
- PX0410 Flex connectors

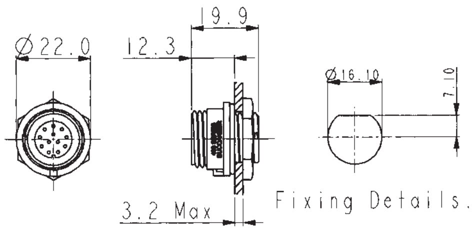


400 Series Buccaneer

Front Panel Mounting Connector

PX0412

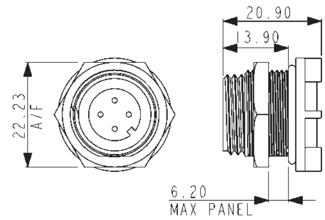
- Mates with Flex Cable connectors PX0410, PX0400 & PX0402
- Front Panel mounting
- Single hole fixing
- Contacts supplied separately
- 2, 3, 4, 6, 8, 10 or 12 pole



Rear Panel Mounting Connector

PX0413

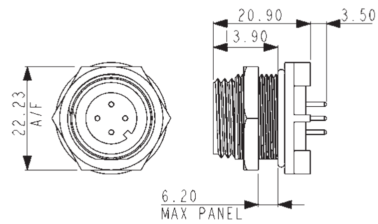
- Mates with Flex Cable connector PX0410, PX0400 & PX0402
- Rear Panel mounting
- Single hole fixing
- Contacts supplied separately
- 2, 3, 4, 6, 8, 10 or 12 pole



PCB Mounting Connector

PX0413

- Mates with Flex Cable connector PX0410, PX0400 & PX0402
- PCB Rear Panel mounting
- Straight PC spills
- Supplied with pre-loaded gold plated contacts
- 2, 3, 4, 6, 8, 10 or 12 pole



Sealing Caps and Accessories

PX0480 PX0480/1 PX0481 PX0484

- Maintains IP68 Rating of Unmated Connectors
- PX0480: Fits PX0412 (panel mounting)
- PX0480/1: Fits PX0401 & PX0411 (flex in-line)
- PX0481: Fits PX0400, PX0402 & PX0410 (flex connector)
- PX0484: Fits PX0413 (PCB and rear panel mount)

Gland Packs

Part No	Description
PX0482	Pack of 4 pairs cable glands and collets to suit cables from 3.0 to 5.0mm diameter.
PX0483	Pack of 4 pairs cable glands and collets to suit cables from 5.0 to 7.0mm diameter.

400 Series Buccaneer

Specifications

Crimp Contacts

Pole	Current Rating	Pin	Socket	Pack Qty	Cable Acceptance (dia)
2, 3	8A	SA3350	SA3349	10	20 - 24 AWG
4, 6, 8	5A	SA3348	SA3347	10	22 - 26 AWG
10, 12	1A	SA3180	SA3179	10	24 - 28 AWG

Solder Contacts

Pole	Current Rating	Pin	Socket	Pack Qty	Cable Acceptance (dia)
2, 3	8A	SA3350/1	SA3349/1	10	20 - 24 AWG
4, 6, 8	5A	SA3348/1	SA3347/1	10	22 - 26 AWG
10, 12	1A	SA3180/1	SA3179/1	10	24 - 28 AWG

Insertion / Extraction

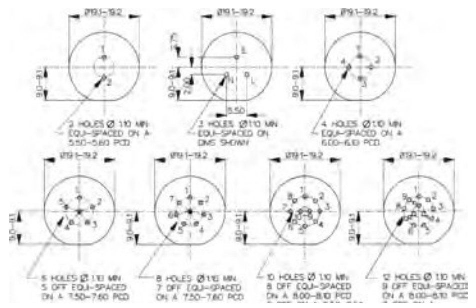
	Poles	Contact Rating	Colour	Part No
Insertion/Extraction Tool	2,3	8A	Blue	13027/2
Insertion/Extraction Tool	4,6,8	5A	Red	13027/1
Insertion/Extraction Tool	10,12	1A	Green	13027

Crimp tools

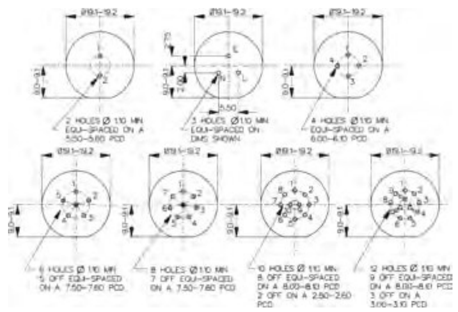
	Poles	Contact Rating	Colour	Part No
Positioner	2,3	8A	Blue	14025/8AMP
Positioner	4,6,8	5A	Red	14025/5AMP
Positioner	10,12	1A	Green	14025/1AMP
8 Indent Crimp Tool for use with positioners				14025

PX0413 PCB Contact Layout

Sockets
Contact numbers viewed from rear of panel



Plugs
Contact numbers viewed from rear of panel



2 pole (8 Amp) | 3 pole (8 Amp) | 4 pole (5 Amp) | 6 pole (5 Amp) | 8 pole (5 Amp) | 10 pole (1 Amp) | 12 pole (1 Amp)

400 Series Buccaneer

Specifications

Electrical:

No. Poles:	2, 3	4, 6, 8	10, 12
Current Rating:	8A	5A	1A
Voltage Rating (ac/dc):	250Vac/dc	125Vac/dc	50Vacdc
Contact Resistance:	<5mΩ		
Insulation Resistance:	>10^6MΩ (@ 500V d.c.)		
AC Breakdown voltage:	2.5kV		

Operating Temperature:

Flex and panel types	–40°C to +80°C
Overmoulded	–20°C to +60°C

Approvals:

UL	E214972
CSA	1273303
VDE	40002226
CCC	2011010203500398 – 1 Amp Rated 2011010203500399 – 5 Amp Rated 2011010203500400 – 8 Amp Rated

Overmoulded cable assemblies approvals to customer requirements.

Material:

Flex and panel types:

Body Mouldings:	Polyamide
Flammability Rating:	UL94V-0
UV Resistance:	To EN 50021:1999

Overmoulded types:

Body Mouldings:	Polyurethane
Flammability Rating:	UL94V-HB
Contacts:	Copper alloy, Gold plated
O Rings:	Nitrile
Panel Sealing O Ring:	Nitrile
RoHS	Compliant

Mechanical:

Sealing:	IP68, EN60529:1992+A2:2013 tested @ 1.054kg/sq cm (15lb/sq in) 10m depth for 2 weeks
Salt Mist:	EN60068-2-52 Test Kb Salt Mist (Cyclic) Marine Severity Level 1
Cable Acceptance:	3.0 - 7.0mm
Contact Accommodation:	2, 3 pole, 20 - 24 AWG 4, 6, 8 pole, 22 - 26 AWG 10, 12 pole, 24 - 28 AWG
Termination:	Crimp, solder and PCB

Insertion/Withdrawal Force:

No. poles:	2	3	4	6	8	10	12
Insertion Force (typ):	19N	25N	27N	27N	28N	55N	62N
Withdrawal Force (typ):	12N	17N	17N	21N	22N	25N	29N

Tightening Torques:

Panel mount (PX0412)	
Rear fixing nut:	1.0-1.1Nm (9lbf.in.)
Panel mount (PX0413)	
Front fixing nut:	1.0-1.1Nm (9lbf.in.)

Cable Retention force:

3.0mm dia	60N
4.0 to 7.0mm dia	80N
Rear panel thread PX0412:	M16x1.5
Panel thread PX0413:	18.97x26TPI Whitworth form to BS84 med fit

Dimensions:

Overall dimensions of connectors when mated together

Flex + Flex In-Line	80mm
Dia. over coupling ring	19.1mm

PX04 xx	/	XX	X	/	XXXX

Body Styles

PX0410 = Flex body
PX0411 = Flex in-line body
PX0412 = Front panel mounting body
PX0413 = Rear panel/PCB mounting body

Number Contacts

02 = 2 pole,
03 = 3 pole,
04 = 4 pole,
06 = 6 pole
08 = 8 pole,
10 = 10 pole,
12 = 12 pole

Contact Type

P = Pin,
S = Socket

For PX0410 and PX0411 cable connectors - Cable Entry Size:

3035 = 3.0 - 3.5mm (Light Grey)
3540 = 3.5 - 4.0mm (Grey)
4045 = 4.0 - 4.5mm (Green)
4550 = 4.5 - 5.0mm (Red)

5055 = 5.0 - 5.5mm (Yellow)
5560 = 5.5 - 6.0mm (Blue)
6065 = 6.0 - 6.5mm (White)
6570 = 6.5 - 7.0mm (Black)

Cable gland and collet supplied in colour coded pairs.

For PX0413 PCB/Rear Panel Mount:
PC = Pre-loaded PC pins
Blank = no pins supplied

For PX0412 Front Panel Mount:
Suffix not required - leave blank

Examples:

PX0410/10S/4045 = Flex cable connector, 10 socket contacts with gland and collet for cables between 4.0 and 4.5mm diameter (supplied less contacts).
PX0412/08P = Front panel mounting connector, 8 pin contacts (supplied less contacts.)
PX0413/06P = Rear panel mounting connector, for 6 pin contacts (supplied less contacts).
PX0413/04P/PC = Rear panel/PCB connector, 4 pin contacts, PCB mounting (supplied with contacts loaded).