

bDAS



Instrument's Manual

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INTRODUCTION

bDAS is a comprehensive and generic **digital acquisition system** or instrument. The instrument provides all the components and functionalities to perform measurements involving the use of radiotracers and radioactivity counting into industrial processes or environmental studies, such as study of water natural resources, etc.

bDAS instrument is a general-purpose counting system and therefore can be used in many fields and applications of radiotracers studies or measurements.

The bDAS instrument is compact and rugged allowing its fast and convenient transport as well as deployment, into difficult or harsh environments. bDAS is designed to be operated for long acquisition times (even weeks) in unattended mode and with minimum (battery-based) power supply. And yet, bDAS instrument implements latest digital counting and electronics technology.

This manual describes the instrument as a system and provides guidance to its operations. A separate and dedicated manual is provided for detailed description of the software and its algorithms and computational methods used in this program [1].

INTRODUCTION TO THIS MANUAL


This Manual describes the installation, setup, and use of bDAS instrument or system. It also describes in detail its features, capabilities and included components. We assume that you're familiar with the different terminology and technology of nuclear radiation detection and analysis, particularly of gamma-ray detection and analysis and the basic concepts of the radiometric counting techniques.

For clarity purposes, and when possible, we briefly explain the particularities of radioactivity counting and analysis. However, it should be understood that this is not the main objective of this document. References to appropriate academic and/or scientific publications are made throughout this Manual for further or complementary reading (see the "*Bibliography*" at the end of the document).

The following symbols and text formats were used throughout this document for emphasizing the terms and explanations:

This type face for examples or example descriptions and situations

➡ This format and text for emphasis of important statements or notifications

Icons (e.g. ) are also inserted within the text for quickly showing the corresponding Graphical User Interface (GUI) component or functional relationship being described.

Menu commands, key stroke commands or other software commands are shown in italics. E.g. "*File/Save As*" or *CTRL+P*.

Although the software can be installed and used under different operating systems (OS) and computer platforms, on this Manual we used *MS Windows 10 (English version)* for the screenshots and the software explanations.

Some more complementary descriptions on different aspects of the bDAS instrument are included as "*Appendixes*" to this Manual.

At the end of the Manual a detailed list of referred publications, textbooks or other reference materials are given for further or complementary reading, as well.

BRIEF INTRODUCTION TO BDAS

bDAS, or BrightSpec Digital Acquisition System, is a general purposes **digital acquisition system** or instrument for performing multiple radiation counting measurements in a synchronized and centralized management. bDAS is particularly suitable for performing accurate measurements of methods or studies involving the use of radiotracers in natural environments or industrial processes.

Radiotracers are widely used in many fields and applications [2] [3]:

- for the measurement of the flow rate of liquids, gases, and solids in many industrial systems.
- throughout oil refineries worldwide. Radioactive tracers have been used to a great extent in enhancing oil production in oil fields.
- for troubleshooting inspection and process analysis in chemical and petrochemical plants; where continuous operations and technical complexity make the use of radiotracer techniques very competitive and largely applied.
- in minerals processing plants
- in life-sciences, as nuclear medicine.
- for efficiency testing of wastewater treatment installations.

Just to site a few.

bDAS instrument is a general-purpose counting system and therefore can be used in many fields and applications of radiotracers measurements. The instrument provides all the components and functionalities to perform accurately and in synchronization such measurements and yet with minimum user or operator intervention. Once the instrument is properly setup, it can be left for long time unattended operations, provided the power supply is available. bDAS is designed to operate with minimum power supply requirements and to perform long period data acquisition. Additionally, bDAS instrument is compact and rugged allowing its fast and convenient transport as well as deployment, into difficult or harsh environments.

Yet, bDAS instrument implements latest digital counting and electronics technology, together with high quality materials and detection technology.

The bDAS system (see *Figure 1*) can be categorized into two main system components:

1. The detection probes
2. And the main control system

Where basically the detection probes are to perform the detection of gamma-ray events and the main control system is to supply the necessary power supply, counting memory and operation synchronization for all attached probes.



Figure 1: A BrightSpec bDAS system, shown with one set of probes

Subsequently each major component in bDAS is composed by other components.

Detection probes

Each detection probe is composed by:

- The probe itself

- A sub-sea grade and watertight cable.
- A cable drum or roller

Similarly, the probe is composed by:

- A watertight envelope or encapsulation with anti-shock protection
- A scintillator radiation detector
- A Single Channel Analyzer (SCA)

Main control system

Similarly, the control system is composed by a few components:

- The control case.
- The PC or notebook
- The bDAS and bDAS Analysis software

The control case is a rugged case which encapsulate:

- The DAS counters (two boards)
- The centralized power management and airflow.
- The data management
- And all possible (up-to 12) port connections to the probes.

The case allows the inclusion of a standard and generic PC or notebook. For this particular system, the notebook with the necessary software is included into the control system or case.

A detailed description and functions of each component is provided in the Chapter "System description" further in this Manual.

INSTALLATION AND SETUP

In this Chapter you will find the necessary information and minimum requirements for successfully installing and operating the bDAS instrument.

Unpack

Standardly, the bDAS system is transported or delivered with a protected, custom-made wooden crate.

The crate has a designed section for holding and fixing the bDAS probes for preventing any damage. See .



Figure 2: bDAS transport wooden container. The container has a custom-made frame holding the probes (no 1 on picture). The large carton boxes contain the probe's cable rolled into the cable drum.

When opening the crate, please verify that this is still the case, and each probe is correctly inserted in its frame in the transportation box.

The big carton boxes in the crate correspond to each probe cable rolled onto the cable drum.

Another small box should contain the bDAS case, power supplies and cables (data and power cables). Please notice that the notebook PC is shipped into the bDAS control box already fixed.

A flash memory key should be included with relevant documentation, certificates, manuals, and software installation. All documents are distributed in PDF format.

Proceed to unpack each component carefully. Use the included shipment list as reference to each included item.

BDAS INSTALLATION

The bDAS system is shipped ready to use. Therefore, its installation is straight forward:

- After each item has been unpacked and identified
- Verify, that the USB (type A) data cable between the bDAS case and PC is correctly and tightly connected
- Connect the probes into the bDAS control case. Use the ports on each side as conveniently the probes will be deployed.

- Although not strictly necessary, it's recommended that you use the same labeled connection port (A, B, C, D...) as the probe for better probe location and identification.
- When connecting the probe, hold firmly the probe-side matching connector and as straight as possible push it into case-side matching connection port.

➡ **Screw the connector's locking sleeve till the end for establishing sealed and secure probe connection.**

- Proceed to connect the bDAS case and notebook to the power main:
 - Switch ON the power, using the power switch on the bDAS case into the USB port.
 - Power On the notebook

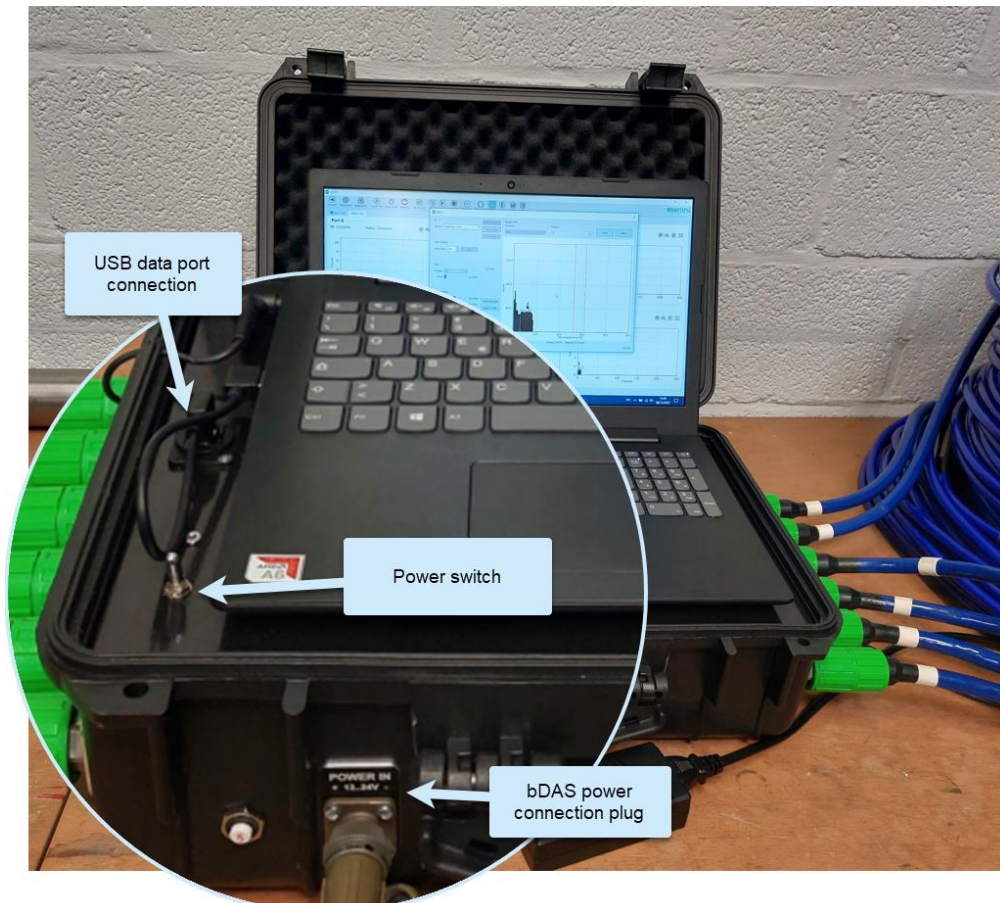





Figure 3 bDAS system case. Zoomed: Power switch and power DC connector, as well as USB data cable port.

- Locate the bDAS software icon  on the notebook and launch the software.
- On the main screen of the bDAS graphical user interface (GUI), click into the toolbar button “connect”  and verify that two bDAS boards are recognized. As a result, two TABs should appear on the program GUI, as shown in following screenshot (see Figure 4).
- Proceed to supply power to the connected probes. Click into the toolbar button “Power On” . After a few seconds all connected probes should be automatically identified and ready to be used. Their counting values would appear on the corresponding probe plotting graph.

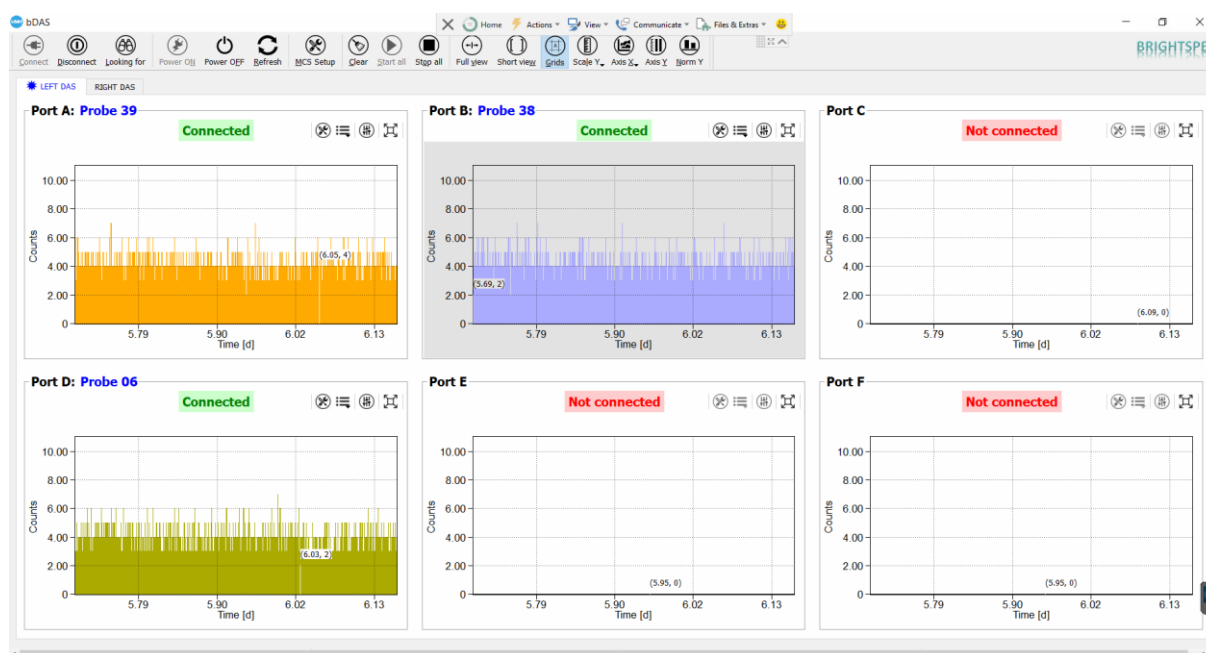



Figure 4: Main window of the bDAS acquisition software.

BDAS SETUP

Standardly, every delivery probe for each shipped bDAS system is already setup using its individual detector operational parameters (such as High voltage and/or amplification, etc). The probes are set up for detection of gamma-rays in an energy range approximately between 40 keV and 2 000 keV.

However, the Single Channel Analyzer window or counting region-of-interest (counting ROI) is not set for any specific energy region.

Please proceed to setup this ROI for each probe in correspondence of the gamma-ray emission from the radiotracers being used or of your interest.

To setup each individual probe for a specific ROI in the SCA, use the icon  on the specific data plot of the recognized probe.

➡ Please notice that data plots on the GUI with not recognized probe connection are not available (grayed out)

When clicking into tools button the probe's setup dialog will show up, as shown in Figure 5. This dialog shows the hardware acquisition parameters corresponding to the SCA being used on that particular probe.

Since the probe's SCA is an advanced digital device, there is an excellent and convenient method to setup the probe counting ROI for a specific energy region. Click on the PHA option. Using this option, the bPAD device is turned into "pseudo spectrum" or "pseudo PHA" mode. In this mode the input voltage pulses range is divided into several channels and the bPAD device starts to acquire counts sliding each SCA ROI over all the channels in the input range. In such a way a "pseudo energy spectrum" is re-assembled or acquired.

Using this mode, it's very easy and convenient to correctly setup the SCA counting ROI. If the probe is turned into that mode and a reference radioactive source is used. The gamma-ray emissions are easily detected into the "pseudo spectrum" and therefore the device counting ROI can be accurately set by just setting the ROI boundary setting controls or by just dragging the mouse pointer over the peak's region.

An example of such, "pseudo spectrum" obtained and counting ROI setup for ^{60}Co gamma-rays emission is shown on Figure 5.

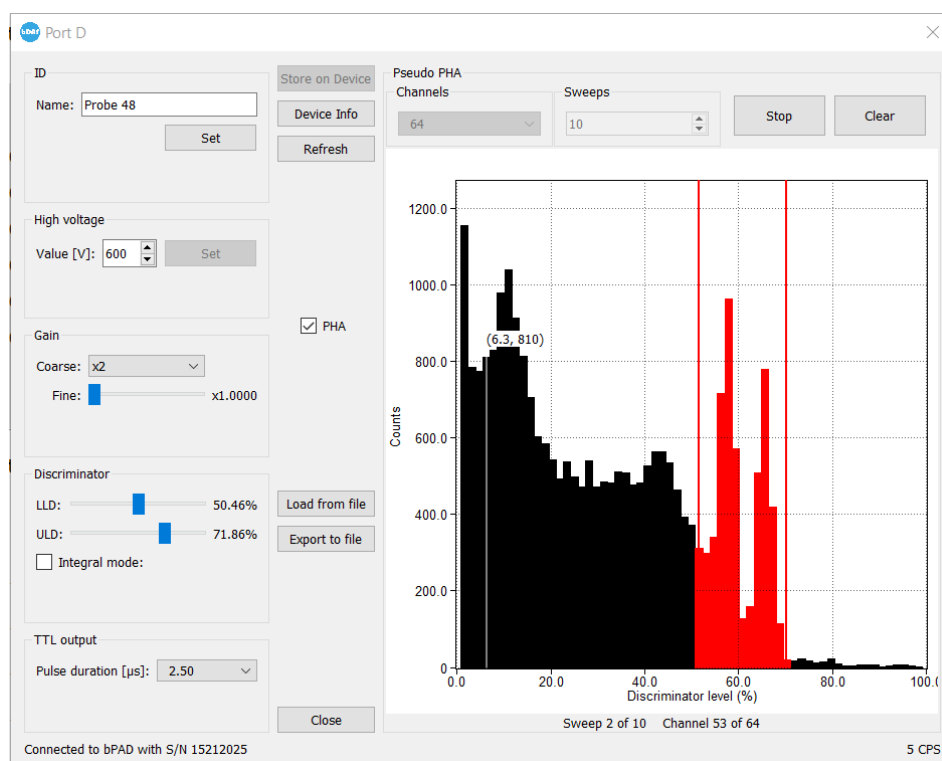


Figure 5: bDAS individual probe setup dialog

You can as well set the ID for each probe for easy identification, using a text generic string of 20 characters

Finally, don't forget to save the new hardware parameters into the device itself by selecting the button "Store on Device" on this dialog.

For more details on this setup, please refer to bDAS software manual [4] or further into this document as well.

BDAS DESCRIPTION

This chapter describes, in detail, the different components and items that compose the BrightSpec bDAS instrument. It also provides some description to their functionalities and inter-relation with other components in the instrument.

As briefly described in the Introduction to this manual. The BrightSpec bDAS instrument is composed by two main components:

1. The detection probes
2. And the main control system

The *Figure 1* shows a picture of a central control system with one probe and its connection cable.

We will now describe in detail the sub-components of each main system element.

THE BDAS PROBES

The detection probes in the bDAS instrument lays a crucial part as they are the radiation detection sensors. These sensors are built in such a way that they are capable of deployment on harsh environment (even under water) and for handling them under such circumstances as well.

Probe envelope

Each probe is encapsulated into a rugged, stainless-steel, watertight enclosure. This enclosure provides watertightness (even sub-sea level) and anti-shock protection to the delicate instruments and electronics placed inside.

The probe envelope is made of high-quality stainless steel (SS-316) and sealed for working under the sea for at least 30 meters depth.

Additional anti-shock protection is placed into the envelope in order to prove shock protection for its resident components and electronic circuitries.

The mechanical diagram of the stainless-steel envelope is shown below:

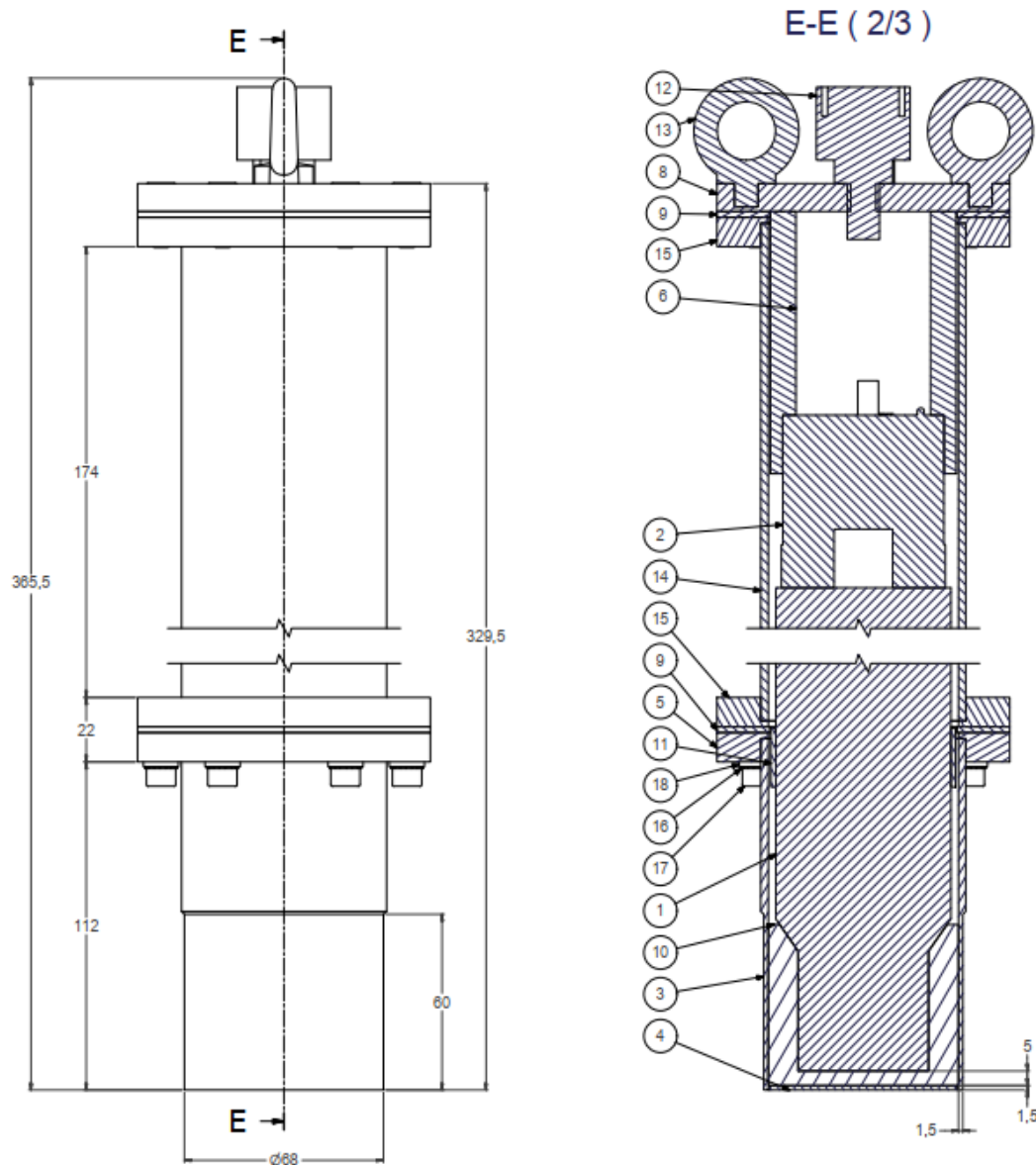


Figure 6: Mechanical drawing of the stainless-steel probe envelope used in bDAS

A thinner (1.5 mm steel) stainless-steel wall is provided around the scintillator detector crystal for maximizing its detection sensitivity without reducing its anti-shock protection.

There are two detachable rings. See Figure 8, 1 and 2 markings. The ring on top (1 on Figure 8 below and mechanical drawings on Figure 7), includes also two (2) eyebolt holders (3 on Figure 8) for fixing a transportation or holding cable which provides better fixing, transportation or lifting of the probe. The top plate includes a watertight, subsea level cable connector (Figure 7 and 4 on Figure 8), as well.

The second ring (2 on Figure 8) is provided mainly for better or easier servicing of the probe. It's better to inspect or troubleshooting the radiation

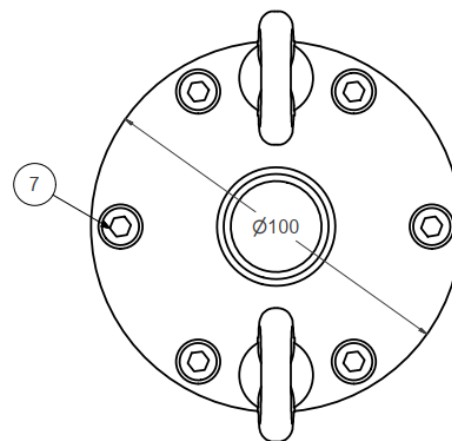


Figure 7: Mechanical drawing of the probe envelope top plate



Figure 8: Photograph showing the probe's watertight, stainless-steel envelope connected to corresponding cable. The different parts are numbered for reference.

THE RADIATION DETECTOR

Each probe's envelope houses a radiation detector. bDAS uses a scintillator type radiation detector with NaI(Tl) crystal of 38 mm (1.5 inches) diameter and 51 mm (2 inches) depth. The detector crystal is optically coupled to a standard, 10 stages, photomultiplier (PMT) with 14 pin JEDEC socket connector output.

The detector encapsulation is made of Aluminum (Al) of 1.25 mm thick corpus. Around the scintillator crystal the Al wall is only 0.5 mm thick.

This particular scintillator detector model¹ has been designed to stand mild shocks by using an extended anti-shock protection around the PMT and scintillator crystal.

The operational gain stability is better than 1.5% over 24 hours of continuous operations at 20 °C room temperature.

The PMT has a mu-material shielding around of 0.65 mm thick for making it less sensitive to magnetic fields.

The next figure (Figure 10) shows the exact mechanical drawing for this detector and its photomultiplier.

This part of the probe is where the photons or gamma-rays emitting from the sample or media are detected and converted into current [4], which in turn is converted into voltage electronic pulses with voltage amplitude proportional to the energy deposited by the photon in the scintillator crystal (see more on [4], [5] and [6]).

Standardly, the detector would have an energy resolution of better than 7.8 % on the ^{137}Cs gamma-ray emission of 661.7 keV [7]. For each distributed probe of a bDAS system we carefully measure the spectroscopy performance of each detector before its inclusion into the probe. These tests are done with a Multi-channel Analyzer, usually a bMCA [8], and radioactive reference sources placed at approximately 5 cm in front of the detector entrance. The recorded energy spectrum is then analyzed by our gamma-ray spectrum analysis software – bGamma [9] and the energy resolution and other spectroscopy-related parameters reported.

Each specific result and the MCA acquisition parameters are reported on the certificate of performance accompanying each bDAS probe.

An example of such spectrometry verification is shown here, just for reference.

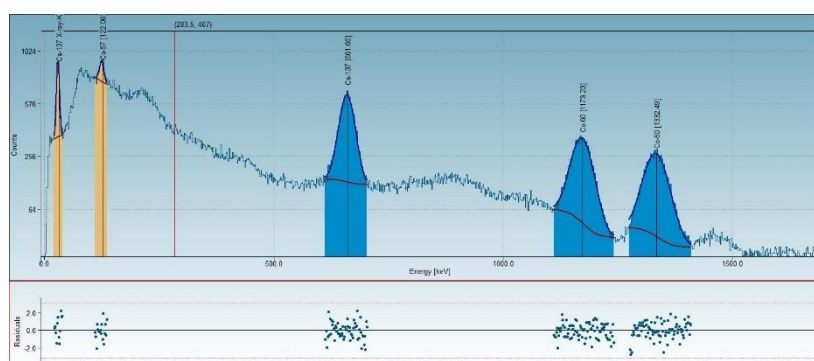


Figure 9 A typical energy spectrum recorded with bDAS scintillator detector using a multichannel analyzer, bMCA. The acquired spectrum is analyzed with bGamma, spectrum analysis and quantification software

¹ Scionix, model 38B51/2M-X2. Produced by Scionix Holland B.V. The Netherlands

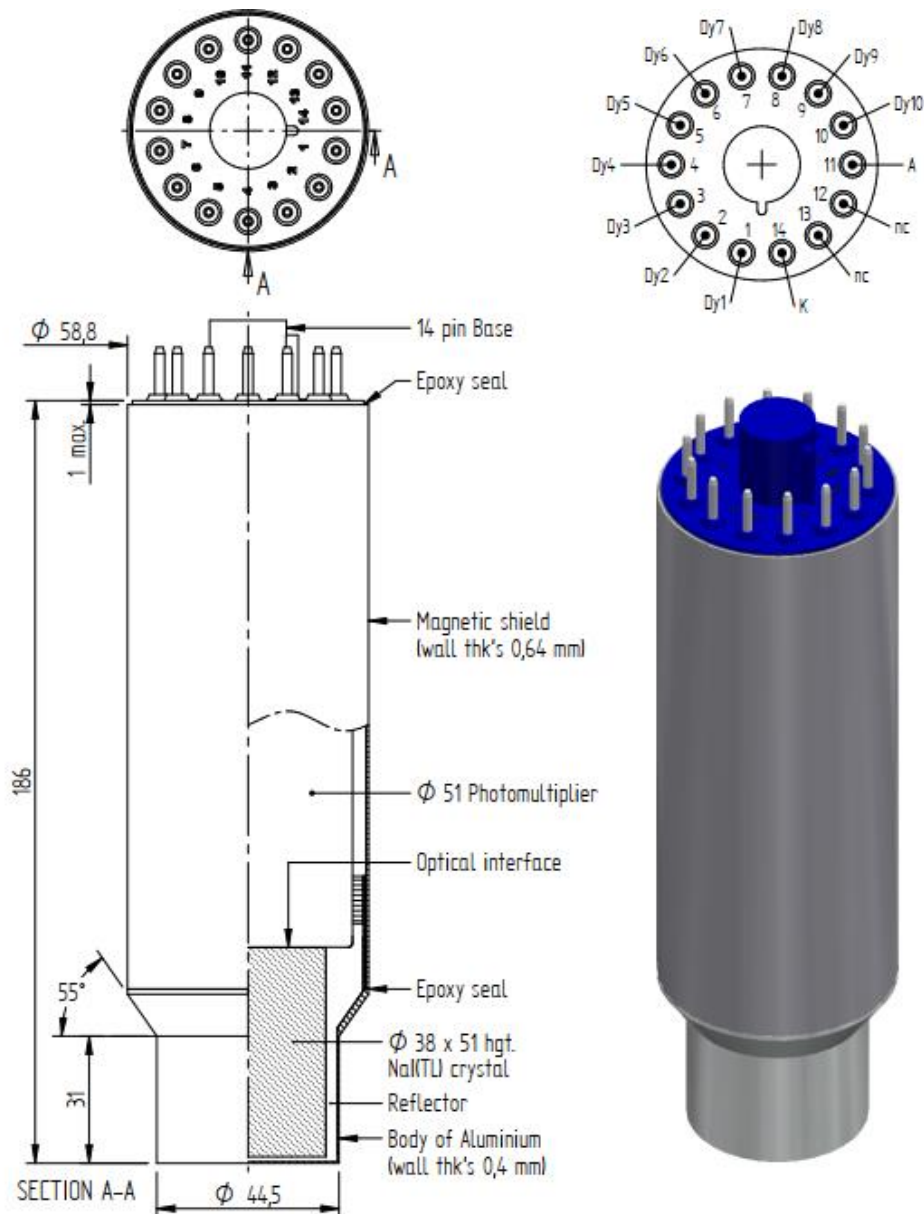


Figure 10: Technical drawing for the scintillator detector and photomultiplier used in the bDAS probe

SINGLE CHANNEL ANALYZER

A very important part of the probe is the electronic module which analyzes the pulses coming from the scintillator detector and convert it into counts. In the probes we use a very compact, fully digital single channel analyzer (SCA) module: BrightSpec, bPAD-422 [10].

This electronic module is directly hooked into the 14-pin tube-base connector of the detector's PMT. The bPAD provides the following functionalities:

- Amplifies the pulses coming from the scintillator PMT.
- Provides amplification gains for user's setup: Coarse and fine settings of amplification
- Reduces electronic noises
- Counts the pulse events that fall into the SCA window
- Reports/transmit the SCA count rate to the bDAS control system.
- Implements RS-422/RS-485 data communication with main bDAS control unit.
- Provides detector's High Voltage BIAS (up-to + 1 500 Volts).

The bPAD itself is powered by +6 DVC from the bDAS module located in the bDAS system or case.



Figure 11: Probe's compact electronic module and digital single channel analyzer (SCA), model bPAD-422.

PROBE'S CABLES AND CONNECTORS

Finally, each probe is connected to the central control system via a 50-meters long cable. The cable is a multi-core cable with certified sub-sea operational conditions. A diagram of the cable core is presented here.

Each cable and probe are connected to the bDAS control unit via a connection probe, using watertight and sub-sea proof high-quality cable connectors. All connectors; on the probe side and/or the bDAS side; are matching to each one of the cables. In such a way, cables can be interchanged, or different probes can be exchanged. Additionally cables can be chained to create larger cable length (larger than 50 meters).

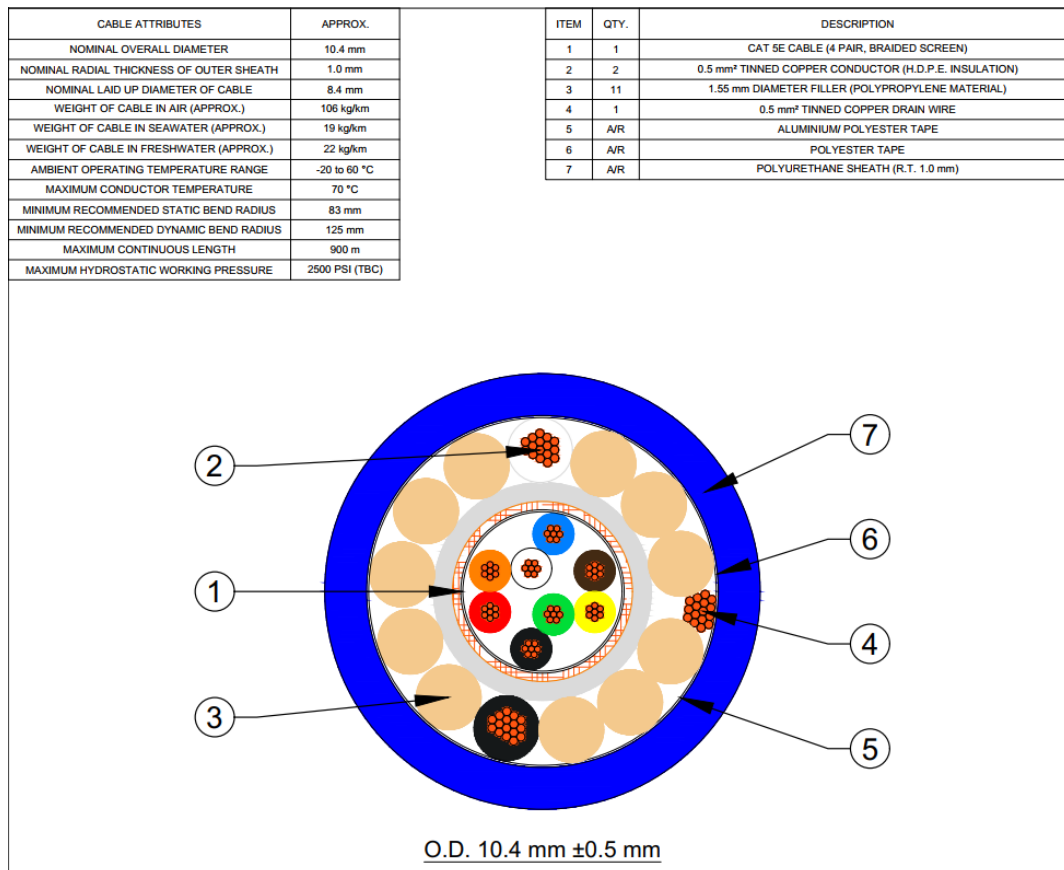


Figure 12: Diagram of the cable core for the Sub- Sea, watertight bDAS cable

Each probe's cable is provided with an industrial-standard cable drum or roller. The cable drum makes the transportation and deployment of the cable and therefore of the bDAS probe more convenient.

The drum has a handle for transportation and a level-crank for easy rolling of the cable. It also includes strong industrial-grade Velcro for fixation of the cables ends to the plates of the roller.



Figure 13 Photograph showing six sets of bDAS probe's watertight cables with corresponding cable drum.

THE BDAS CONTROL UNIT

The bDAS instrument has a device that centralizes and concentrates all the necessary electronics and elements to provide power to the connected probes, as well as to perform independently and asynchronously all the data acquisition and data collection. This device is realized into a rugged plastic case for easy transportation and deployment.

The bDAS control unit or also referred as the "bDAS control case" is made of hard plastic (industrial grade Polypropylene plastic or PP), specially designed for transportation of delicate equipment, tools, and electronics under harsh environments, including humidity.

The case has been engineered to include:

- Air ventilation system
- bDAS electronic modules
- power adaptors, connectors, and electronics necessary to provide power to the whole system
- frame plates for secure and strong fixation of all components inside the case, as well as inclusion of a working plate for operation of a notebook onto the case.
- Data splitters and connectors for data interconnection between probes-bDAS boards-PC.
- Switches and indicators

Connection ports

The bDAS case has embedded 12 connection ports. Six on each side. See *Figure 14*.



Figure 14: bDAS control case, showing a side face with six labeled ports for probes connections.

Each connection port is labelled, as seen in *Figure 14*. The probe's envelopes also have a matching marking (A, B, C, etc).

➡ Although it is not compulsory to match probe to the corresponding labeled port, doing so might provide better visualization and visual recognition of the given deployed probe in the field.

The connection ports are made with the same watertight, sub-sea class cable connectors. Hence, full watertightness is kept as well as the possibility to freely interchange cables and probes.

Therefore up-to 12 probes can be connected, powered, and operated from a single bDAS control case.

The case control unit is shipped with dust protection cups. If certain ports are not being used, we recommend to protect those port connections by using the dust protection cup, as shown in the picture below.



Figure 15: Use of dust protection cups

Air ventilation

Each control case has built-in several DCV air ventilators and the necessary electronics for powering and controlling them. Holes and air paths are made in such a way that together with the air ventilators they create a steady air flow, keeping the temperature inside the case acceptable for its fine operations even when kept completely closed.



Figure 16: Control case air ventilators and air paths. Back side of the case and top plate.

The back air ventilators are protected with anti-dust filters.

Closing mechanisms

The control case can be secured against unauthorized opening by using the lugs on the case and the locking port. See *Figure 17*. The locking port facilitates the use of a U-lock mechanism. The case can be safely operated in a complete closed state.

There is an engraving on the side case shell for passing over the power cable of the notebook. Make sure the cable is correctly placed into that area before closing the case lid.

The bDAS control case can be safely operated completely closed and locked.



Figure 17: Locking provisions on the bDAS control case

- ➡ **When closing the case, make sure no objects or cables are jammed between the halves of the case shell. When the PC is kept inside the closed case, use the cable path engraving on the side case shell for the power adaptor cable of the PC.**

Case power

The bDAS control case provides a centralized way of powering all the electronics circuits and devices attached to it. That includes powering of the probes.

There is a single power connector on the front side of the case. See *Figure 18*. The connector is a military grade multipin Amphenol-type DCV power connector with protection cup. The case also incorporates circuitries for voltage surges and over-current protection.

The AC/DC adaptor for the connection to the main is provided as well.

For powering the bDAS control case, and therefore the complete system; connect the AC/DC adaptor to the main and its output to this connector.



Figure 18: Power connector on the front side of the bDAS control case.

The system can be operated by external power supplies, such as battery packs. This can be done using the same power connector.

➡ **The power consumption for a system with all 12 probes powered and connected is to be of approximately 2 Amps.**

bDAS controllers

The core of the system are the DAS controllers. These are electronic boards that:

- Allow remote setup of each individual probe (bPAD)
- Provide power to connected probes
- Perform unattended and asynchronous data (counts) gathering and memory from each probe.

Each DAS board hosts six probes connections. DAS controllers can be chained. There is no limit on the number of controllers to be chained, rather it is limited by the total power consumption.



Figure 19: DAS controller board. Each board can power and connect to up-to six probes. Two of these controllers are built into a bDAS control case

Each bDAS control case has two DAS boards for connecting and managing up-to 12 individual probes, as can be seen on below figure.

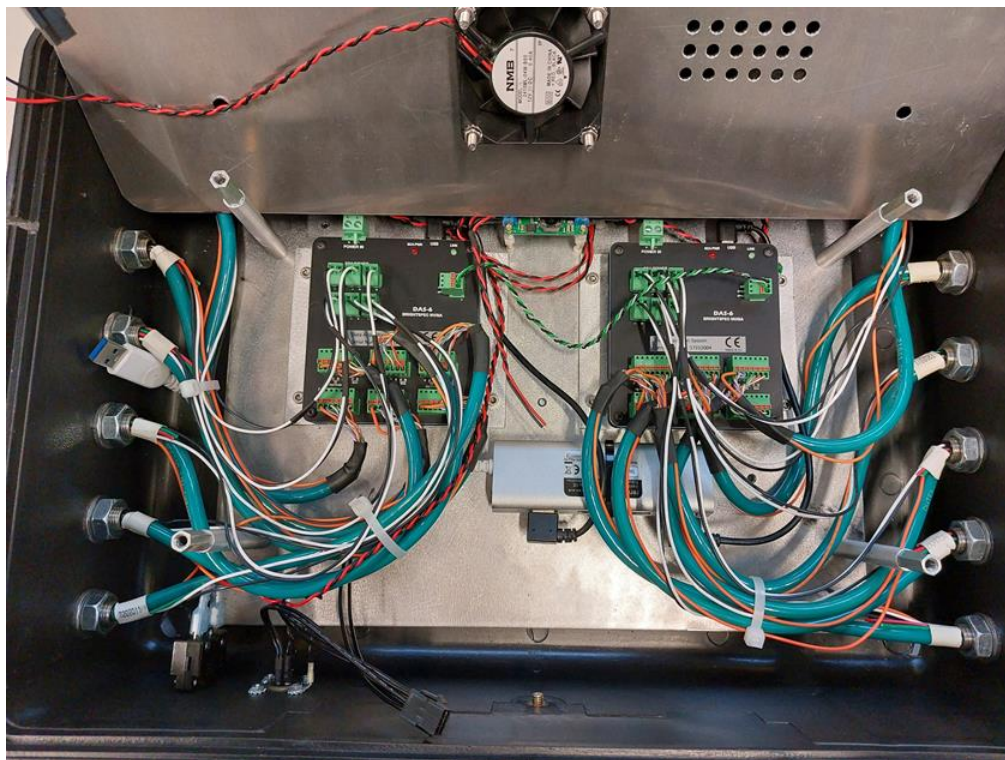


Figure 20: Two Das controllers inside a bDAS case

CONTROL PC OR NOTEBOOK

Standardly, each bDAS system is supplied with a PC for performing the data acquisition and analysis.

The PC (notebook type) is placed inside the bDAS case and fixed on top of a plate by use of industrial-grade Velcro® strips. This allows to operate the case with a detached PC or the PC simply outside the case.

The notebook is a standard, modern PC with MS Windows Pro (64-bits) as Operating System. Standardly the selected OS language is English, but it can be chosen differently as well.

The driver of the PC has been updated to be able to operate it with the lid completely closed.

Just connect one of the USB ports of the notebook to the USB port connection (type-A) on the top plate of the bDAS control case unit.

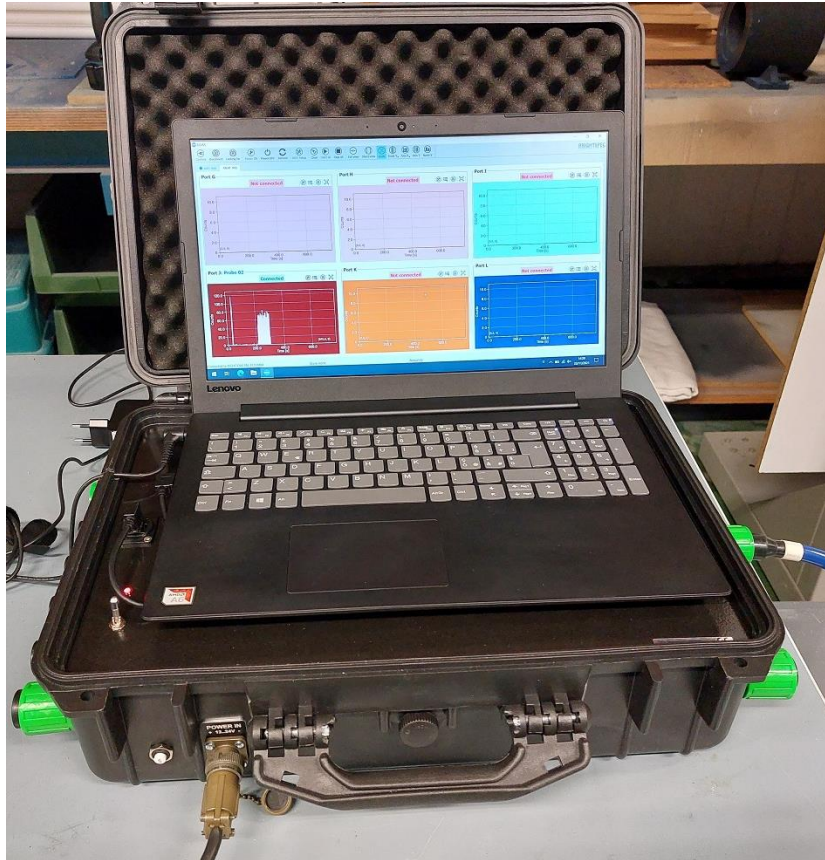


Figure 21: A bDAS system operated with a notebook onto its controller case.

BDAS SOFTWARE

bDAS instrument have been designed to operate using its software. Two main programs are provided:

1. bDAS and
2. bDAS Analysis:

bDAS software: Is the main software to control and interact with bDAS instrument. This program provides the following main functionalities:

- Initializes all the DAS boards on the bDAS
- Connects to the DAS controllers
- Provides GUI for individual setup of each connected probe
- Power to each DAS controller and probes
- Setup and performs data acquisition
- Visualizes data acquisition from each probe
- Provides basic data manipulation on acquired data
- Performs calibration for each channel of probe
- Saves acquired data automatically or intentionally on external files.

Among others.

The second software, bDAS Analyze, is provided for analyzing the data recorded into files by bDAS software.

Due to the extension of the description for the operation of these software we recommend that you follow their instructions and descriptions on the dedicated User's Manual for the bDAS software.

Since this software is recently finished, make sure you download the latest version of it and its User's Manual. This can be done from BightSpec WEB site (www.brightspec.be) Section "Downloads" or contact us for receiving it.

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