UNEXMIN DELIVERABLE D2.2

GENERAL INTERFACE SPECIFICATION REPORT UNEXMIN: AN AUTONOMOUS UNDERWATER EXPLORER FOR FLOODED MINES

Summary:

This is a summary documentation about the possible instrumentation that could provide meaningful geo-scientific data during underwater mine exploration missions.

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1 ACRONYMS

Acronym	Description
AC	Alternate current
AGC	Automatic Gain Control
ASCII	American Standard Code for Information Interchange
BLDC	Brushless Direct Current Motor
BNC	Bayonet Neill–Concelman
DAQ	Data Acquisition
DC	Direct Current
DIN	Deutsches Institut für Normung (English: German Institute for Standardization)
EC	Electrical Conductivity
FGM	Flux Gate sensor systeM
FPS	Frame per Second
GND	Ground
GRC	Gamma Ray Counter
IEC	International Electrotechnical Commission
IP	International Protection Marking
LED	Light-Emitting Diode
NPT	National Pipe Thread Taper
PC	Personal Computer
PCB	Printed Circuit Board
RMS	Root Mean Square
SBP	Sub-Bottom Profiler
SLS	Structured Light System
SNR	Signal to Noise Ratio
UV	Ultraviolet

2 PH MEASUREMENT

2.1. Glass pH probes

There are mainly two types of pH probes for high-pressure (138 bar or higher) applications. The ZrO2-based pH probes are rated for temperatures (t) between70 to 150 °C, 100 to 220 °C, or 180 to 350 °C, depending on the models; the glass-based pH probes are rated for t = 1 to 80 °C. So, the glass-based pH probe will work for this application.

2.2. pH probe specifications

Category	Description
Type	glass-based pH electrode
Description	high pressure and high temperature (HP/HT) glass based pH probe
Vendor	Corr Instruments LLC, 7112, Oaklawn Drive San Antonio, TX 78229
pH range	0 to 14 pH
Temperature range	1 to 80 °C
Pressure range	up to 138 bar
Process connection	Insertion tube output diameter: OD = 3/8” Minimum insertion length: b = 5” (custom) Mounting fitting: 1/4” NPT, male
Overall length	Minimum OL = 10” with 5” insertion length
Material	316 stainless steel
Electric connection	BNC connector, two-pole
Output level	±415 mV at 25 °C ±450 mV at 50 °C depending on measured pH value

Table 1. Glass-based pH electrode parameters

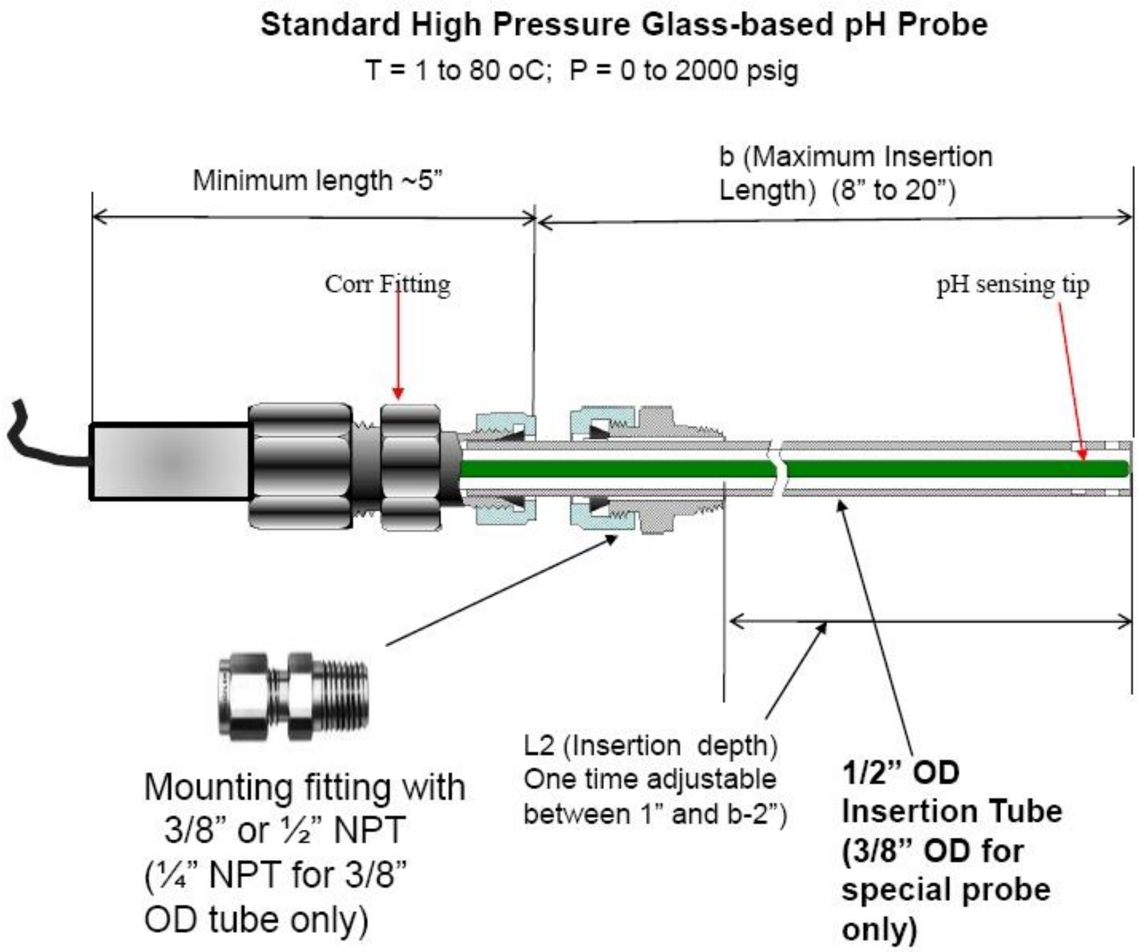


Figure 1. Standard glass-based pH probe dimensions

2.3. Reference probe for pH measurement

For high-pressure pH measurements, a separate reference electrode is required. Corr Instruments supplies a high-temperature and high-pressure Ag/AgCl reference electrode for this purpose, where t = 0 to 310 °C and the water saturation pressure (p) is rated up to 2000 psig.

2.4. Reference electrode specifications

Category	Description
Type	glass-based reference electrode for pH and other ISE measurement
Description	high pressure and high temperature (HP/HT) glass based probe
Vendor	Corr Instruments LLC, 7112, Oaklawn Drive San Antonio, TX 78229
Temperature range	1 to 310 °C
Pressure range	up to 2000 psig (137 bar)

Process connection	Insertion tube output diameter: OD = 3/8” Minimum insertion length: b = 5” (custom) Mounting fitting: 1/4” NPT, male
Overall length	Minimum OL = 10” with 5” insertion length
Material	316 stainless steel
Weight	dry: 0.3 kg wet: 0.2 kg
Electric connection	standard BNC connector, two-pole
Output type	mV

Table 2. Glass-based reference electrode parameters

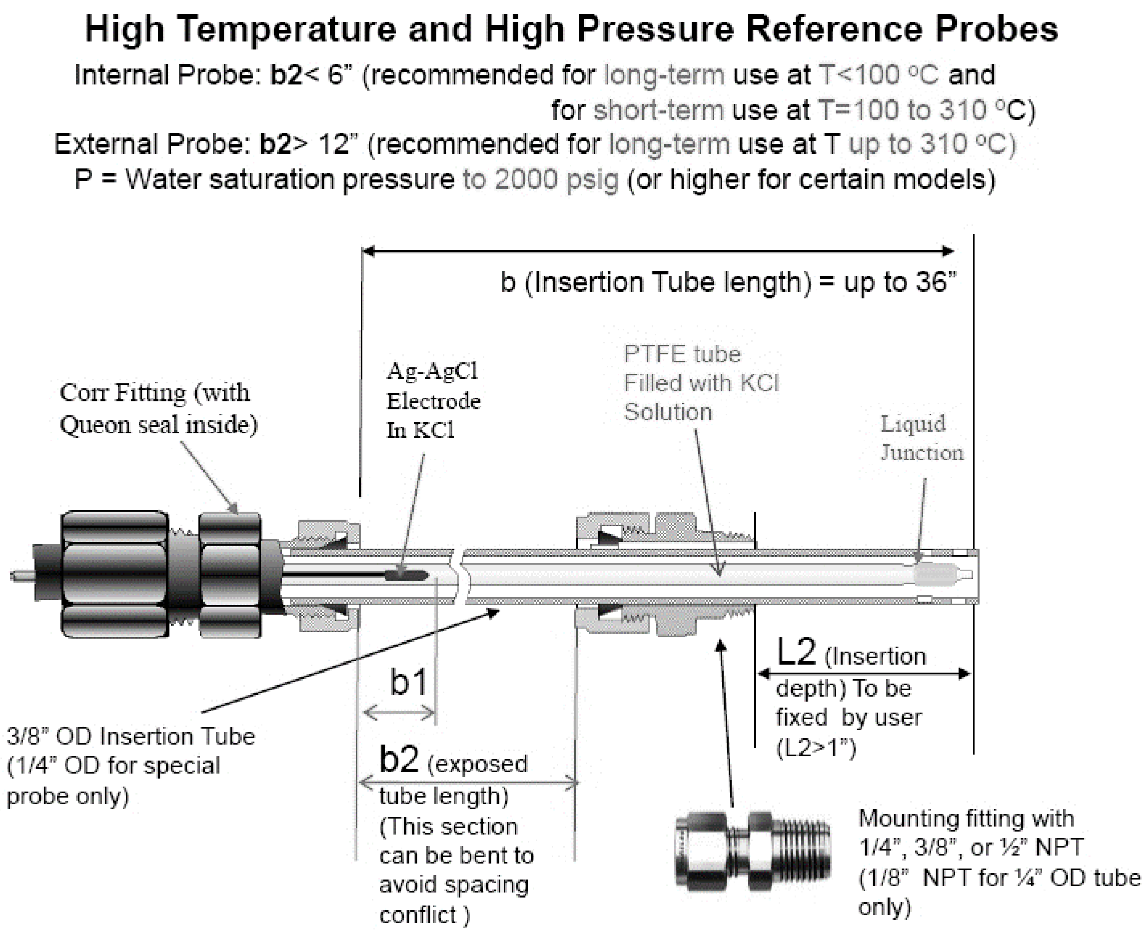


Figure 2. High pressure reference electrode

2.5. Signal conditioner for glass pH probe s

Strengthening of the pH electrode signal is doing by an operational amplifier-based signal conditioner. Its task of scaling ± 450 mV incoming DC voltage range (at 50 °C) to 0-5 V output signal. The output signal is proportional to the actual pH value. Actual scale values will be registered by periodic calibration.

Due to the large input impedance, the interface is ready to connect to the pH probe directly.
Since combined pH probe is not available for high pressure, a separated standard reference electrode is necessary to ensure reference level for the measurement.

2.6. pH signal conditioner specifications

Category	Description
Type	pH probe interface
Number and function of inputs	2 analog inputs: AI1: high impedance standard glass pH electrode; AI2: standard reference electrode; GND: signal ground (AGND, SGND);
Input impedance	1012 Ω, earth independent
Power consumption	±9 V DC; 12.7 mA at 25 °C
Operating environment	Storage temperature: -40 to 85 °C Operating temperature: 0 to 60 °C
Measuring range	pH = 0 to 14
Output data type	0 to 5V analog output
Input scale	pH= 0: Vin = +415 mV at 25 °C pH= 14: Vin = -415 mV at 25 °C Vin measured between AI1 and AI2
Output scale	pH= 0: Vout = +145 mV at 25 °C pH= 14: Vout = +4850 mV at 25 °C
Output protection	5.1 V DC, limited output voltage
Accuracy	±0.05 pH
Precision	±0.05 pH
Electrical connectors	PCB mounted terminal strips;
Housing, overall dimensions	IP55 ABS 153 x 110 x 66 mm ABB 1SL0852A00
Weight	150g

Table 3. pH signal conditioner specification data

2.7. Unit design block diagram

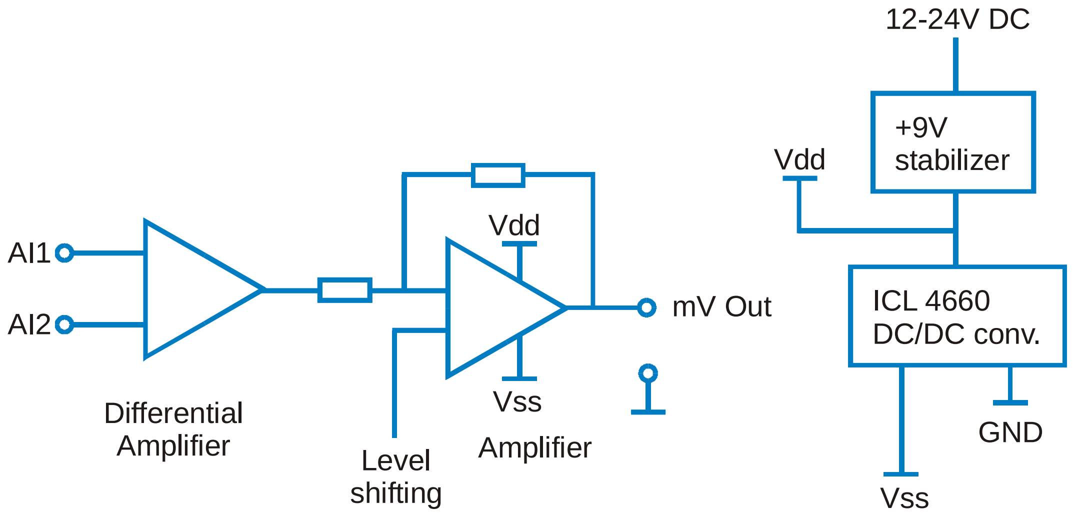


Figure 3. pH signal condition block diagram

2.8. Installation conditions

The pH signal conditioner is enclosed in a common housing with the signal conditioner of the EC meter with their common voltage booster and regulator.
Electronics of the pH signal conditioner does not require any electrical tuning.

The Figure 4 shows the location of pH and pH reference probes.

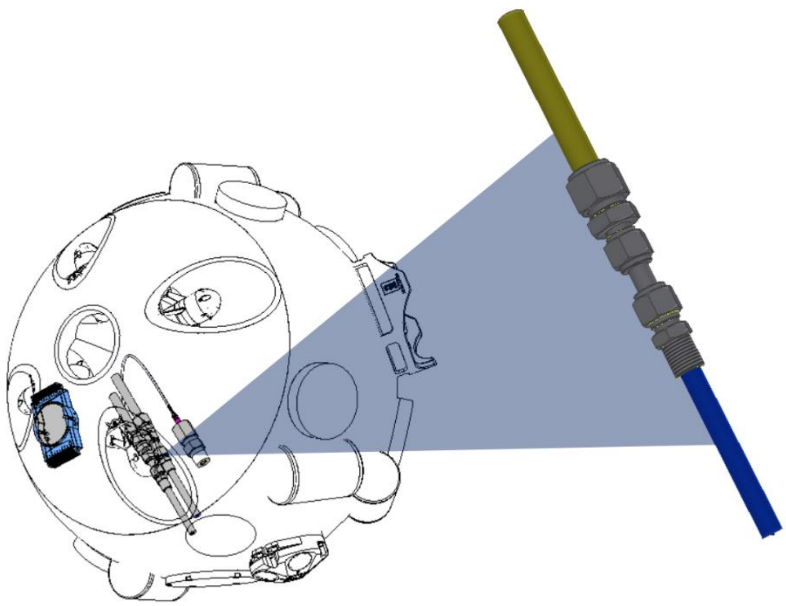


Figure 4. Location of pH and pH reference probes

2.9. Calibration

The pH interface requires periodic two-point calibration to be performed. Use standard pH = 4 and pH = 7 buffer solutions to perform calibration.

2.10.Mounting

The sensor interface electronics can be mounted by four locking tabs at its four corners by M4 x 25 mm screws. There is no preferred orientation vertical or horizontal mounting, both are allowed.

Figure 5. pH signal conditioner enclosure

3 CONDUCTIVITY MEASUREMENT

3.1. Measured parameter

Measured parameter is the electrical conductivity (G or EC), the inverse of the resistance (R). Since the object of the measurement is any (liquid) material, the measured value is a specific value, with respect to unit length of the particular material.

3.2. EC sensor

The EC sensor is a high-pressure metal pipe with an insulated central electrode. The Figure 6 shows the location of the EC sensor in the UX1.

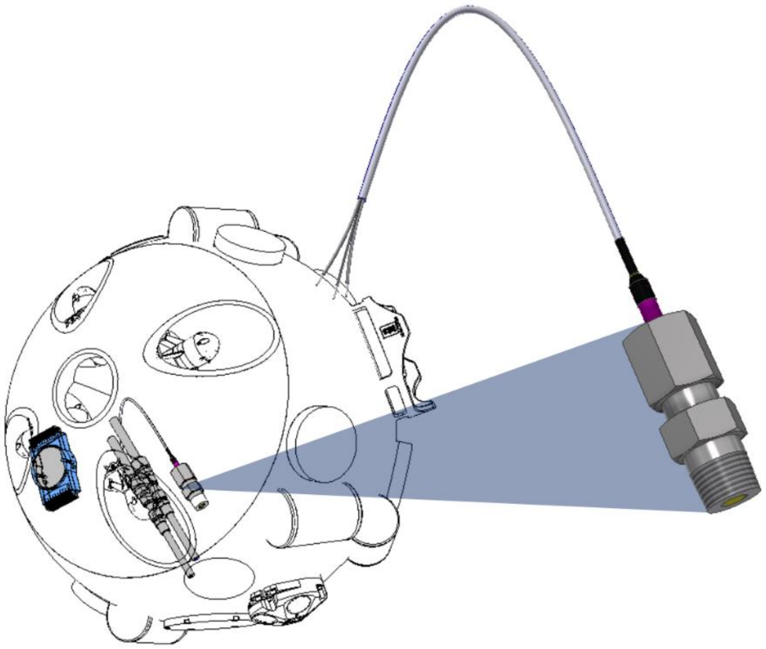


Figure 6. Location of the EC sensor

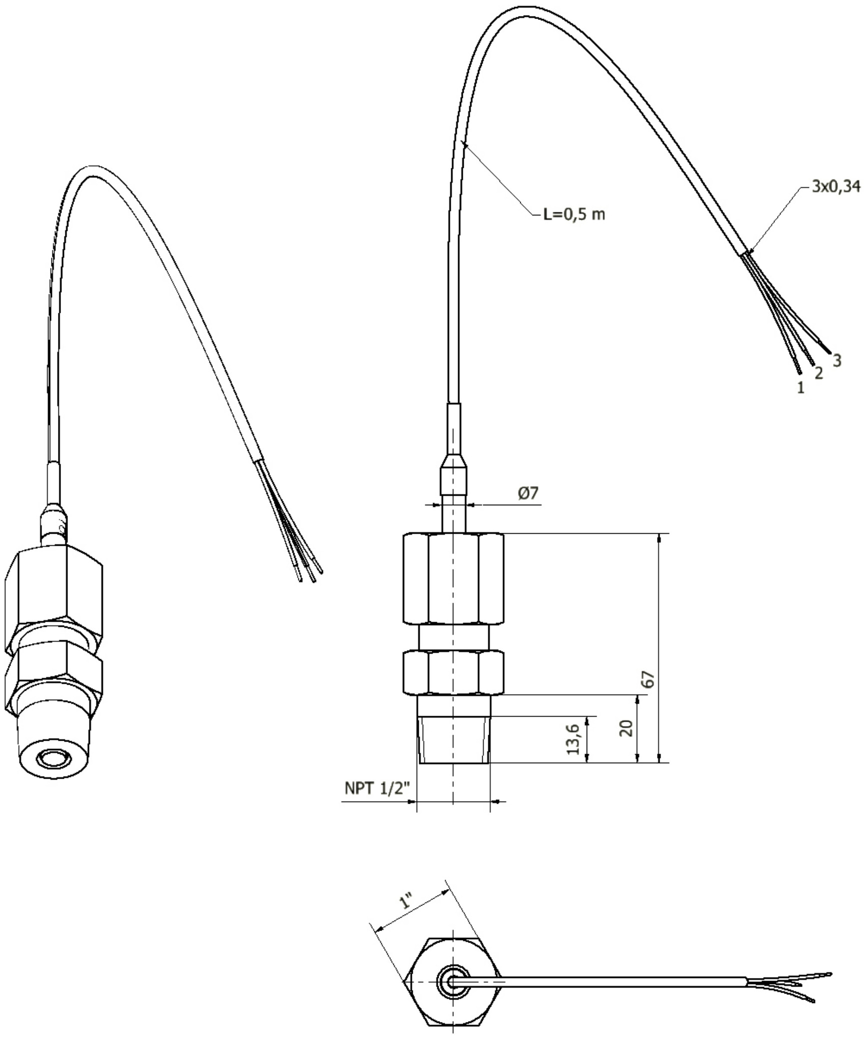
3.3. Specifications

Category	Description
Type	High pressure Electric Conductivity sensor
Vendor	UNIM, Research Institute of Applied Earth Sciences
Temperature range	1 to 80 °C
Pressure range	1 to 60 bar
Cell constant	K > 1 cm-1
Process connection	Mounting fitting: 1/2” NPT, male
Overall length	Minimum OL = 67 mm

Material	316 stainless steel
Weight	dry: 0.3 kg wet: 0.2 kg
Electric connection	Vinyl-insulated round cable with three 0.34 mm2 copper cores; 500 mm standard length
Output type	resistance

Table 4. Electric Conductivity electrode parameters

3.4. Dimensions



Cable type: LIYCY 3 x 0.34 mm2 shielded copper signal cable		
Wire ID	**Colour**	**Connection**
1	Brown	EC sensor out 1
2	White	EC sensor out 2
3	Green	GND

Figure 7. High Pressure EC probe

3.5. Electronic interface

The conductivity is calculated by the measuring electronics. The measured sample is listed as a determining factor for the gain of the signal-processing instrument. Therefore, the electronics converts the conductivity into millivolt readings.

The conversion between conductance and voltage output requires special interface electronics, which is based on quite simple measuring method.

Since the measured sample becomes a passive electrical component of the interface it needs small amounts of electrical power.

On the front of the interface there is an AC sine (or square) wave generator – sine oscillator - as measuring signal source, which connecting to an amplitude stabilizer.

The sine or square signal – after permanent attenuation - gets on the second stage, which is a simple amplifier. Its gain is varied by the measured conductivity. The output is a different amplitude AC wave proportional with the conductivity and therefore resistivity according to Ohm's law.

The third stage of the circuit is a precision rectifier, which forms a constant DC level from the rectified AC wave and feed that to the DAQ system.

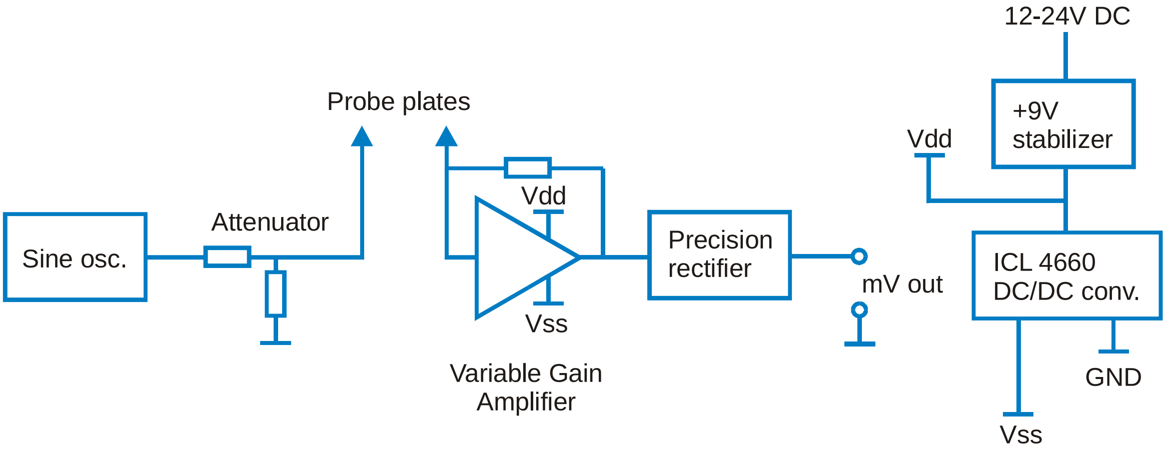


Figure 8. Analog Electrical Conductivity Meter block scheme

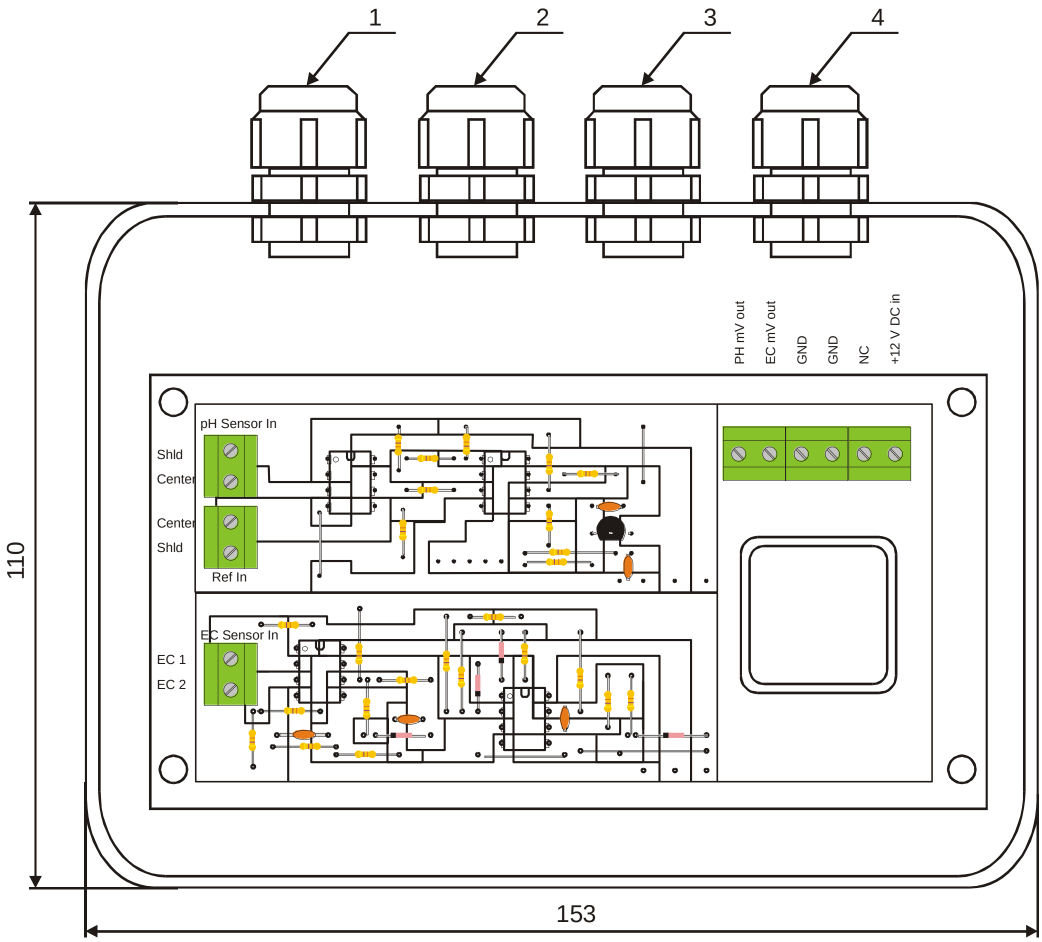
3.6. Specification

Category	Description
Type	EC probe interface
Number and function of inputs	1 analog input AI1: analog input for standard EC probes with K ≥ 1 cm-1 cell constant; GND: signal ground (AGND, SGND);
Input impedance	1012 Ω, earth independent
Power consumption	±9 V DC; 15 mA at 25 °C
Operating environment	Storage temperature: -40 to 85 °C Operating temperature: 0 to 60 °C
Measuring range	EC = 0 to 4 mS/cm
Input variable type	resistance
Input scale	EC= 0: Rin = ∞ at 25 °C EC= 10 mS/cm: Rin = 100 Ω at 25 °C Vin measured between AI1 and AI2
Output data type	0 to 5V analog output
Output scale	EC = 0 mS/cm: Vout = +110 mV EC = 10 mS/cm: Vout = +4950 mV at 25 °C
Output protection	5.1 V DC, limited output voltage
Accuracy	±0.200 μS/cm (±2%)
Precision	±0.200 μS/cm
Electric connectors	PCB mounted terminal strips;
Cable	Vinyl-insulated round cables with three 0.34 mm2 copper cores; 1000 mm standard length
Housing, overall dimensions	IP55 ABS 153 x 110 x 66 mm ABB 1SL0852A00
Weight	150g

Table 5. EC signal conditioner specification data

We cannot determine the exact K (Cell Constant) value now; it can only be known after the factory have made the probe. It will be larger than 1 cm-1. It should be good for solutions with average up to EC = 10 mS/cm.

3.7. Common housing for pH and EC electronics



Connection	Cable gland	Cable	Signal
1	PG-7	Coaxial	BNC center: pH sensor input Shield: GND
2	PG-7	Coaxial	BNC center: reference sensor input Shield: GND
3	PG-7	LIYCY 3 x 0.34 mm2 shielded copper signal cable	Brown: EC sensor 1 White: EC sensor 2 (unipolar inputs) Green: GND
4	PG-7	LIYCY 3 x 0.34 mm2 shielded copper signal cable	Brown: +12 V / 100 mA DC input White: pH mV output Yelow: EC mV output Green: GND

Figure 9. Common housing for pH and Electrical Conductivity electronics

3.8. Sending analog output on serial bus

The analog outputs, provided by pH and EC signal conditioners must be converted to any digital format and send by serial bus. The device, which can do this, is called as ADAM 4117, an 8 channel analog input module with RS485 and Modbus communication.

3.9. Specifications

Category	Description
Type	ADAM 4117
Function	8 channel AI with Modbus output
Analog Input types	0 - 15V; 0 - 10V; 0 - 5V; 0 - 1V; 0 - 500mV; 0 - 150mV; ± 15V; ± 10V; ± 5V; ± 1V; ± 500mV; ± 150mV; ±20 mA 0; 20 mA; 4-20 mA Support Uni-polar and Bi-polar input Channel Independent Configuration
Resolution	16 bit
Input impedance	Voltage: 800 kΩ Current: 120 Ω
Power input	10 - 48 V DC
Power consumption	1.2 W at 24 V DC input; 25 °C
Operating environment	Operating temperature: -40 to 85 °C
Output data type	EIA RS-485 ASCII command & Modbus/RTU
Communication speed	1200 – 115.2 kbps
Accuracy	Voltage mode: ±0.1 % Current mode: ±0.2 %
Noise immunity	1KV Surge Input, 3KV EFT and 8KV ESD Protection
CMR @ 50/60 Hz	92 dB min.
Electric connectors	2 x plug-in terminal block (#14~22 AWG)
Housing, overall dimensions	112 x 70 x 25 mm
Mounting	DIN rail, panel mounting or Piggyback Stack, raster 56 mm
Weight	150g

Table 6. ADAM 4117 8 CH AI to RS-485 converter

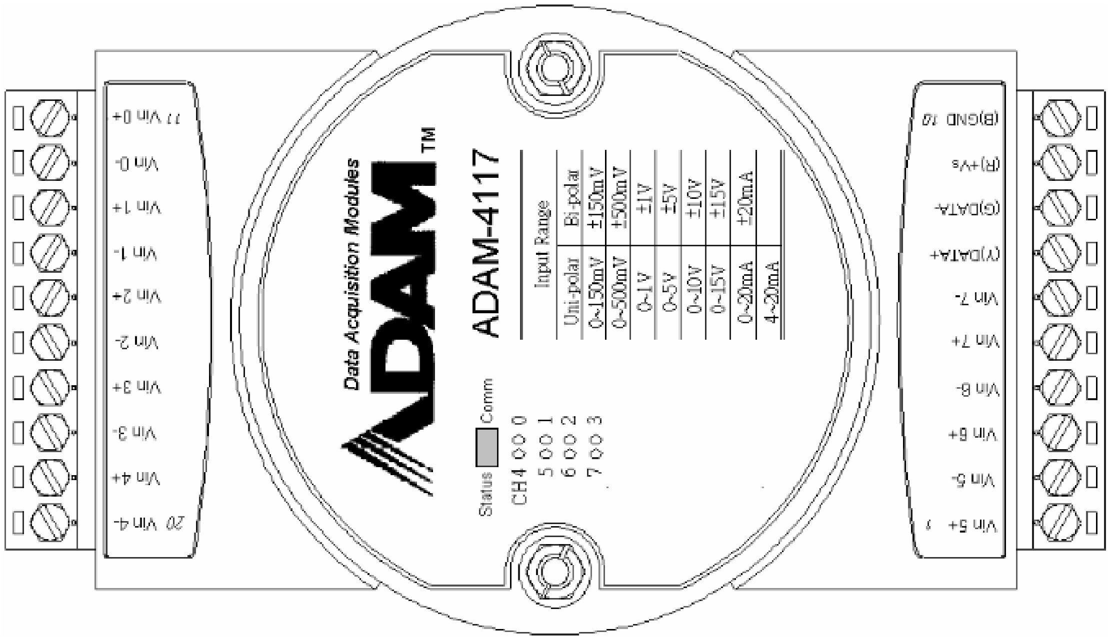


Figure 10. ADAM 4117 front panel

3.10.Configuration

Channel	Configuration	Description
1	± 500 mV	Spare (for other instrument or case of any malfunction)
2	± 1 V	Spare (for other instrument or case of any malfunction)
3	0 – 5 V	pH input
4	0 – 5 V	EC input
5 - 7	0 – 5 V	Spare

Table 7. ADAM 4117 channel configuration

3.11.Mounting

ADAM modules can be mounted on any panel, on provided brackets, on DIN rails or may be stacked together. The RS-485 network, together with screw-terminal plug connectors, allows for system expansion, reconfiguration and repair without disturbing field wiring. The analog converter should be as close as possible to the sensors in order to reduce the noise effect in the analog signals.
The Figure 11 shows the location of the ADAM module.

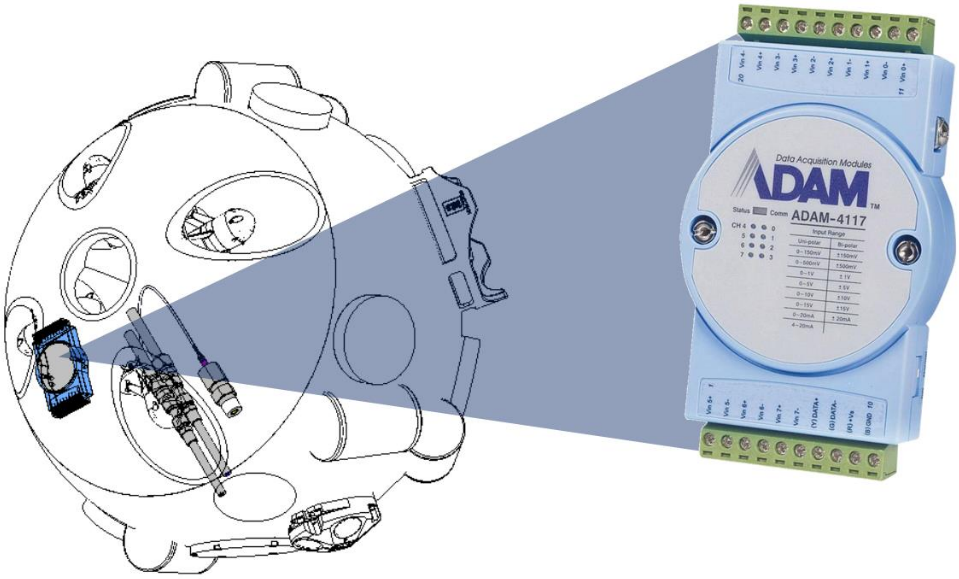


Figure 11. Location of the ADAM 4117 module

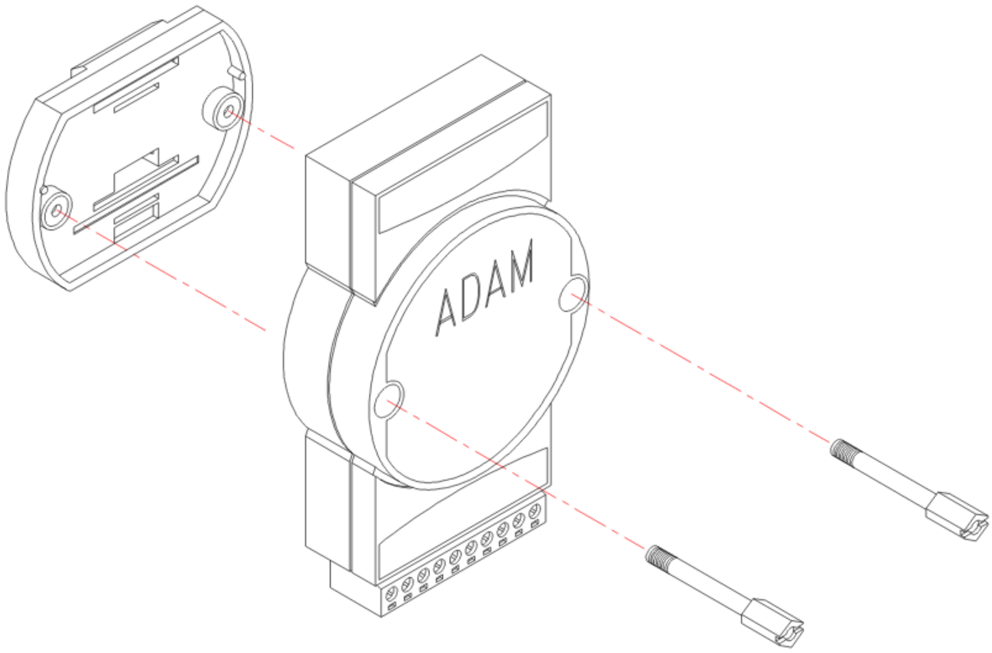


Figure 12. ADAM DIN-Rail Adapter

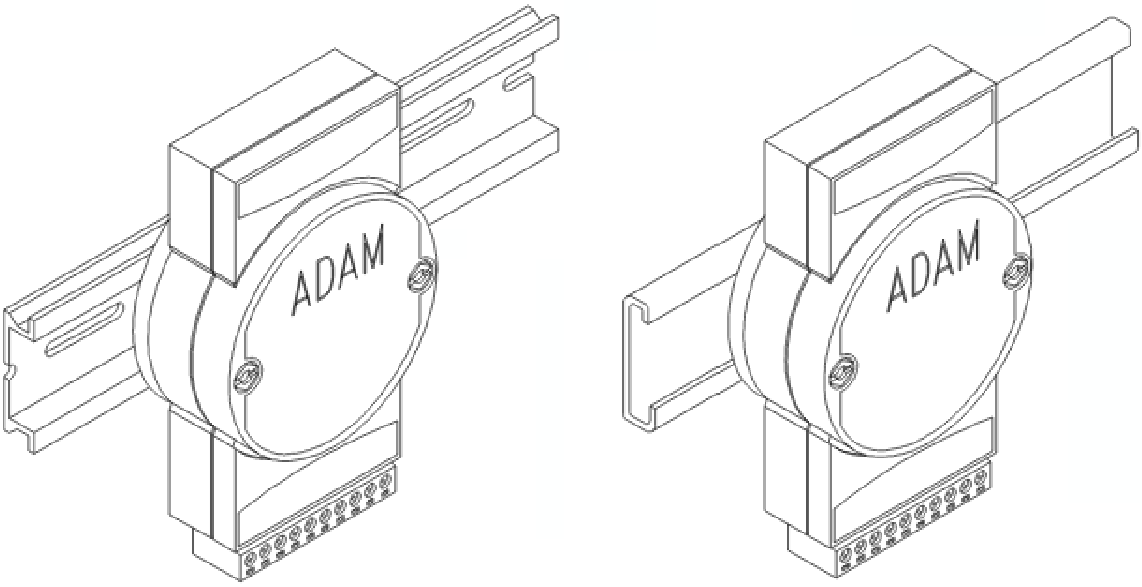


Figure 13. ADAM DIN-Rail Mounting

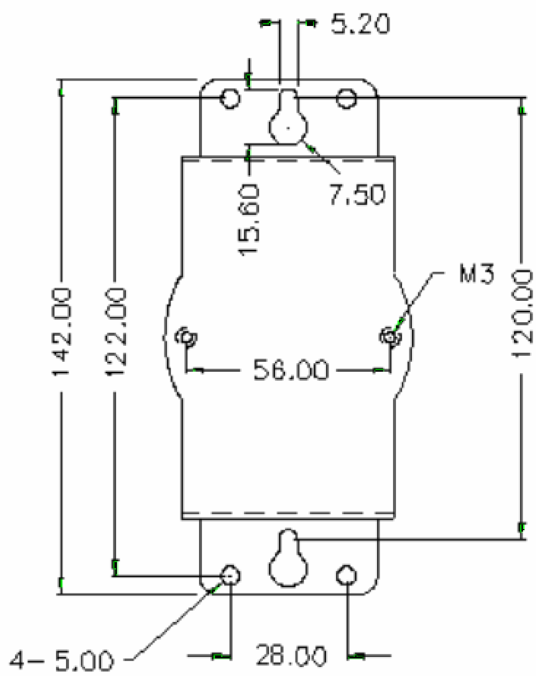


Figure 14. Panel Mounting Bracket

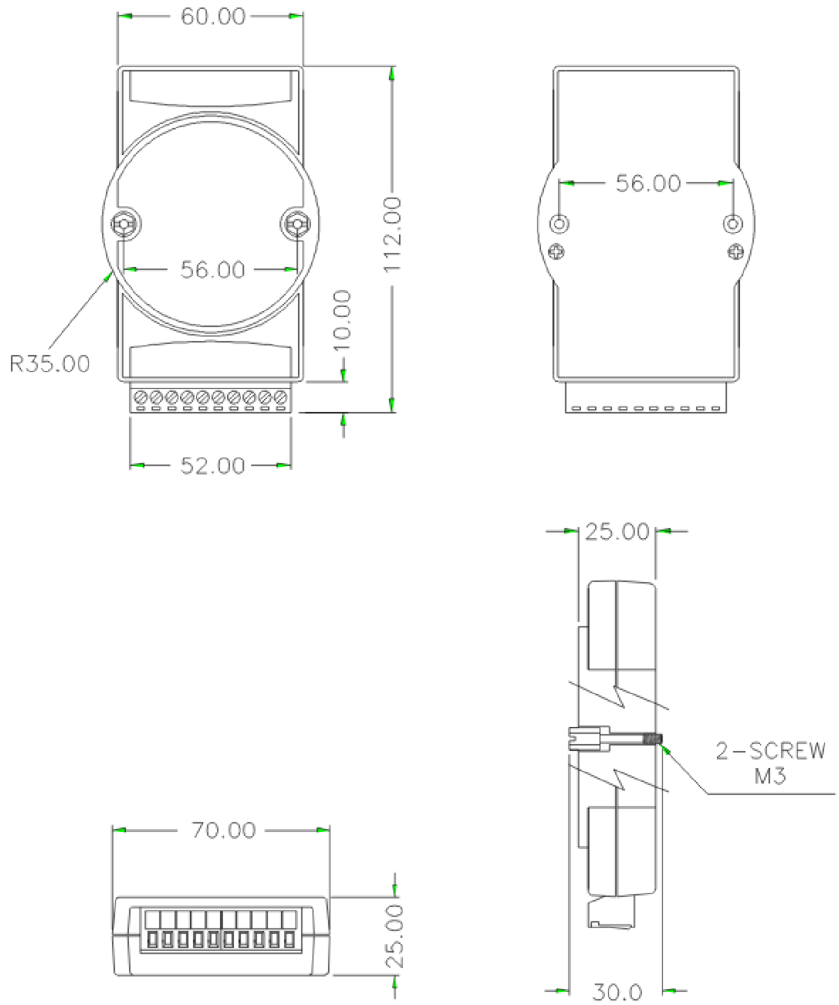


Figure 15. ADAM 4117 dimensions

4 WATER SAMPLER UNIT

4.1. Overall dimensions

The whole water sampler unit is in one storage tank. The outer dimensions of the storage tank is shown in Figure 16. The thickness of the tank is 5 mm.

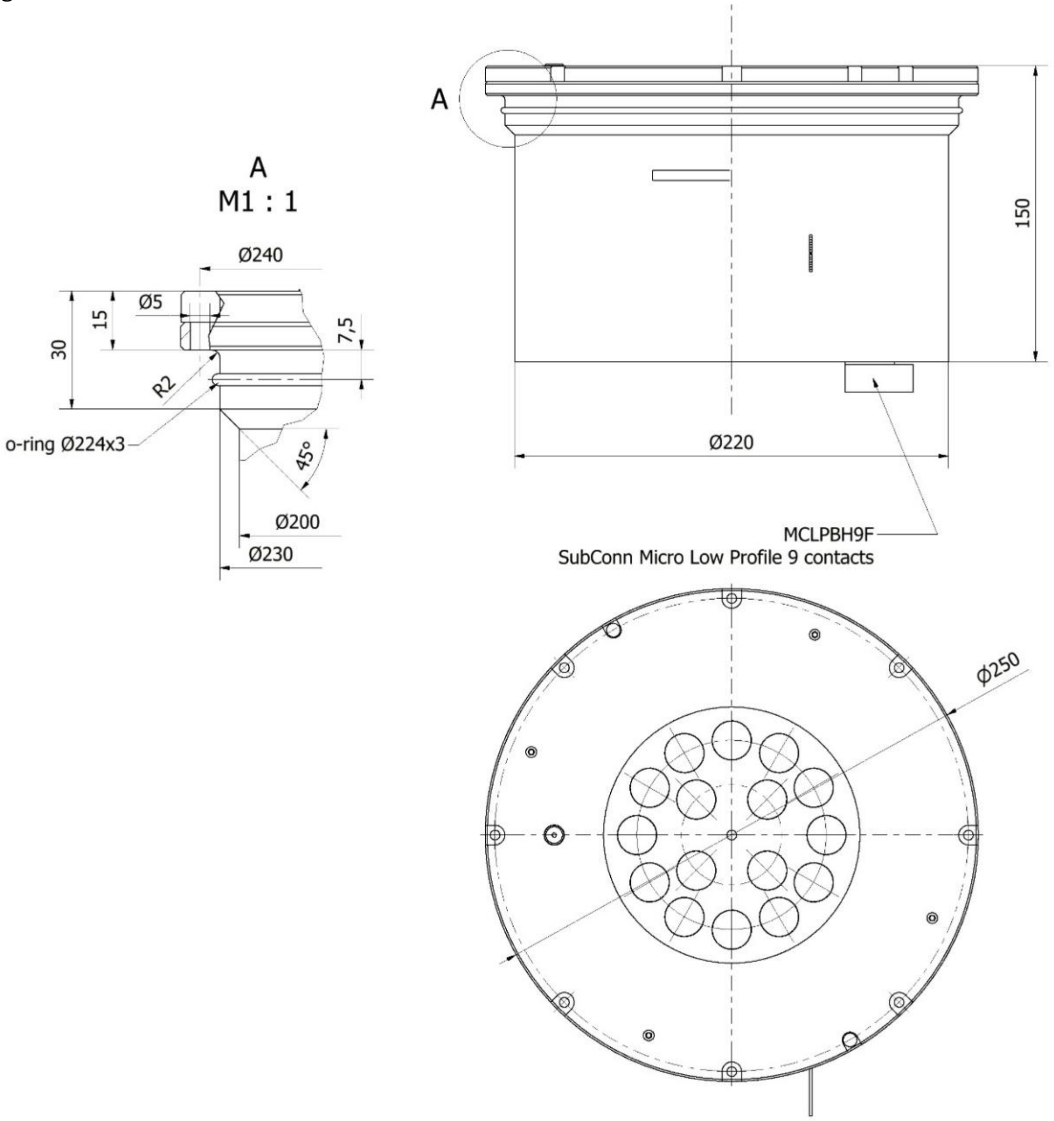


Figure 16. The dimensions of the storage tank

A block diagram of the unit is shown in Figure 17 where internal connections and communication can be seen as a schematic.
The water sampler unit receives a trigger signal to start the sampling process.

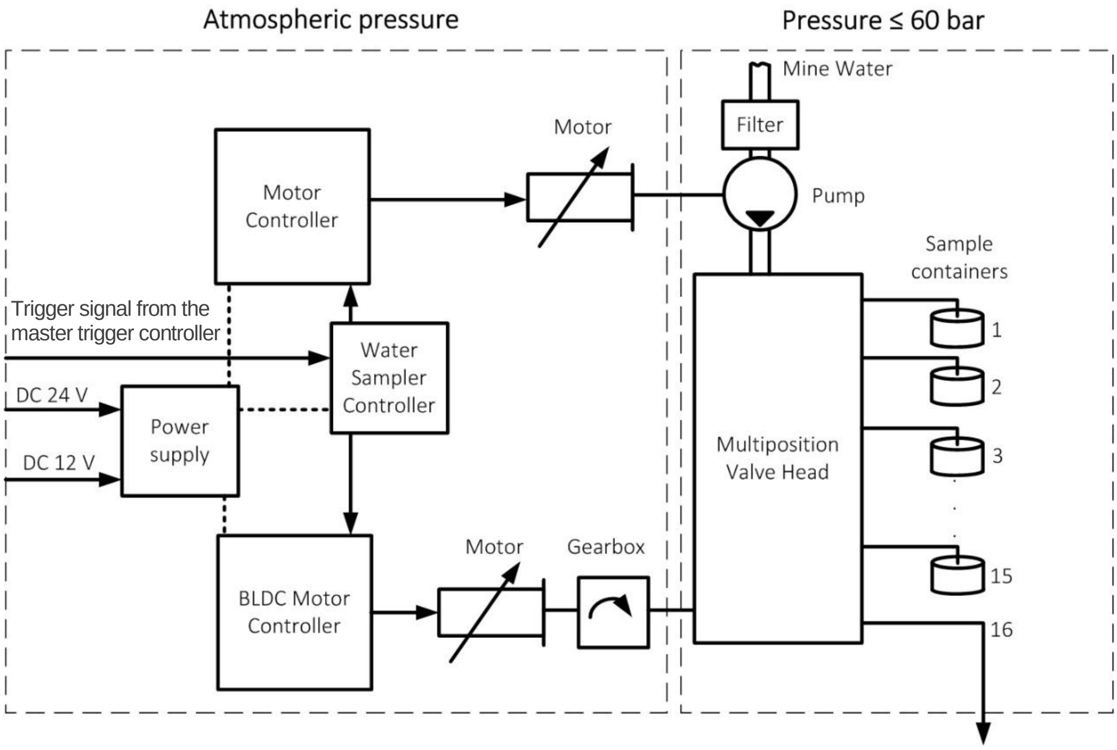


Figure 17. Block diagram of the water sampler unit

The 3D model of the sampler module is shown in Figure 18.

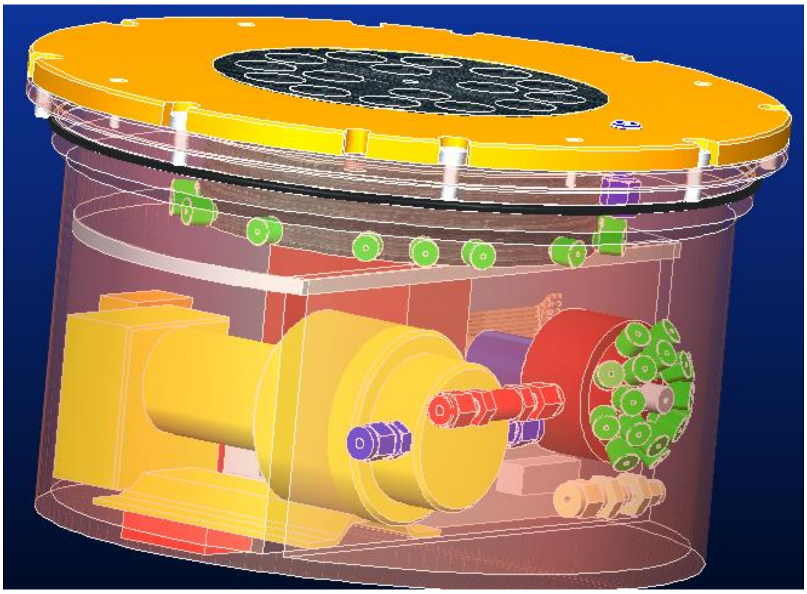


Figure 18. 3D model of the water sampler unit

Two independent chambers will be set up. One of these chambers is the sampling section and is filled with water. The other chamber is at atmospheric pressure and contain mainly electrical elements and other parts, which do not have adequate internal pressure and pressure protection.

4.2. Communication and output data

The unit has one I^2C communication interface. The water sampler controller gets a trigger signal over the I^2C bus. Thereafter the controller runs the water sampling method, which consist in 10 steps:

- Water sampler controller is sending a signal to the pump motor controller.
- Pump is working (Flushing state through one chamber of the valve head).
- Pump is turned off.
- Water sampler controller is sending an instruction to the valve motor controller.
- Motor is rotating the head of the multi-position valve to a discrete position.
- Pump is working.
- The sampling process is in progress.
- Pump is turned off.
- Water sampler controller is sending an instruction to the valve motor controller.
- Motor is rotating the head of the multi-position valve to a discrete position.

The timing diagram of the sampling is shown in Figure 19.

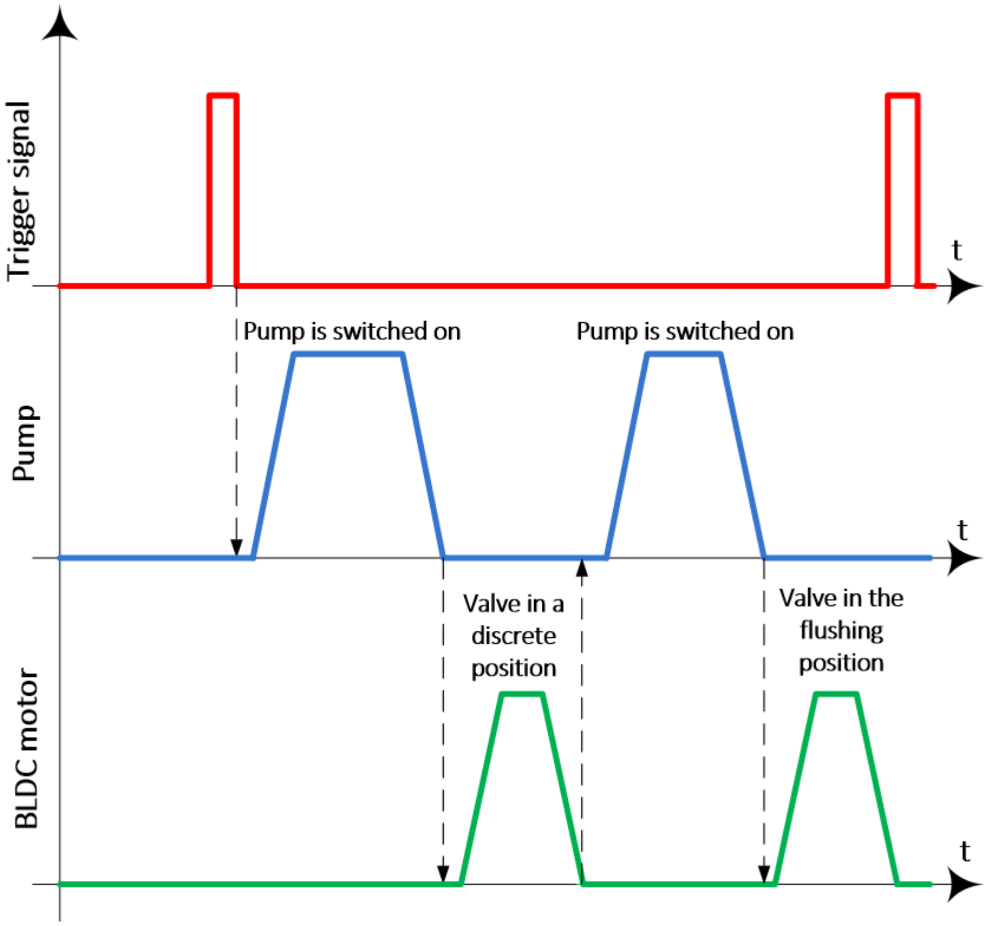


Figure 19. Timing diagram of the water sampler

The unit will not provide output data. After the arrival of the robot, the sampler holder can be taken out to do laboratory measurements.

4.3. Mounting

The water sampling module will be mounted on the top of the robot, the location of the unit is shown in Figure 20. The storage tank can be fastened with eight M5 hexagon socket screws and sealed with O rings. O rings are used to prevent the robot from the water.

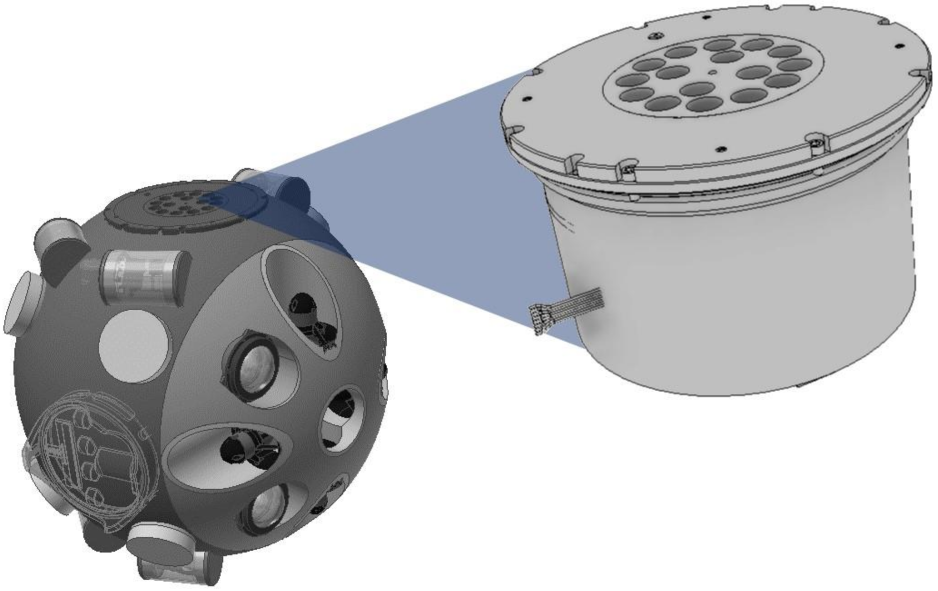


Figure 20. Location of the sampler unit

4.4. Installation conditions

The sampler unit is connected to the robot over SubConn micro low profile 9 pin connectors (MCLPBH9F). The connector will handle up to 700 bar pressure. The connector would serve two purposes. Some pins are used as a power connector, the others will be reserved for the I^2C bus. The I^2C communication would be between the on-board computer of the robot and the water sampler controller.

4.5. Power consumption and input voltage

The sampler system requires at least three voltage levels to work correctly. These discrete voltage levels are 5 V, 12 V and 24 V. The power requirements of the electrical parts are written in Table 8.

Name of the unit	Voltage	Current
Micro annular gear pump	24 V	max. 3 A
Motor of the valve	12 V	max. 7 A
EPOS 4 digital positioning controller	min. 10 V	100 mA
S-G05 pump controller	12-28 V	100 mA
Water sampler controller	5 V	20 mA

Table 8. Power consumption of the electrical elements

Referring to the timing diagram of the system, the sampling process power consumption can be divided to two states:

- Only the pump and their electrical components work.
- Only motor of the valve and their electrical components work.

Therefore, the power of the two states are different as shown in Table 9.

State	Power
Pump	44-60 W
Motor of the multi-position valve head	60-80 W

Table 9. The operating states

4.6. Parts of the system

The pre-defined components are listed in Table 10. Quantity and dimension are also written. The main components are the pump, the storage tank, sampler holder, multi-position valve head, BLDC motor with planetary gearhead and the controllers of the system/submodules.

Number	Elements of the sampling unit	Dimension	Quantity
1	Micro annular gear pump MZR-6355	146 (L) x 70 (W) x 72 (H)	1
2	BLDC motor EC 16	Ø16	1
3	EPOS 4 digital positioning controller	59.5 (L)x58.5 (W)x33 (H)	1
4	Planetary Gearhead GP 22 C	Ø22	1
5	O-ring	3x228	1
6	Storage tank	Ø220x142, edge Ø250	1
7	Screw cap	Ø270x8	1
8	Multi-position valve head	Ø47.5	1
9	Valve connectors	1/16"	33
10	Hexagon socket screw	M5x12	6
11	PIC controller	59.5 (L)x30 (W)x15 (H)	8
12	Micro Low Profile connector	34.5x15.5	1
13	Roto Variseal	-	1
14	Gear pump seal	-	1
15	Male NPT Connector	1/8"	3
16	Reducer	1/8" to 1/16"	1
17	SS-2F Filter	1/8"	1
18	Sampler Holder	Ø130x40	1
19	Piston with O-rings	Ø19.5x15	15
20	S-G05 pump controller	100x92x35	1
21	Hexagon socket screw	M3x12	10
22	Separator element	Ø220x5	1
23	Separator element	92 mm height	1

Table 10. The components of the water sampler

4.7. Wet and dry weights

The water sampler unit consists in two chambers. One chamber will be filled with water of the mine and the other will be at atmospheric pressure. The calculated wet and dry weights are listed in Table 11.

Wet weight	Dry Weight
~ 5 kg	~ 7 kg

Table 11. The wet and dry weights of the sampler unit

4.8. Capacity of the water sampler

The sampler holder can store 15 independent sample. The dimension of one container is shown in Figure 21. The dead volume is planned, because of the precipitation of the gases. The total sampler capacity is ~ 7,85 cm^3.

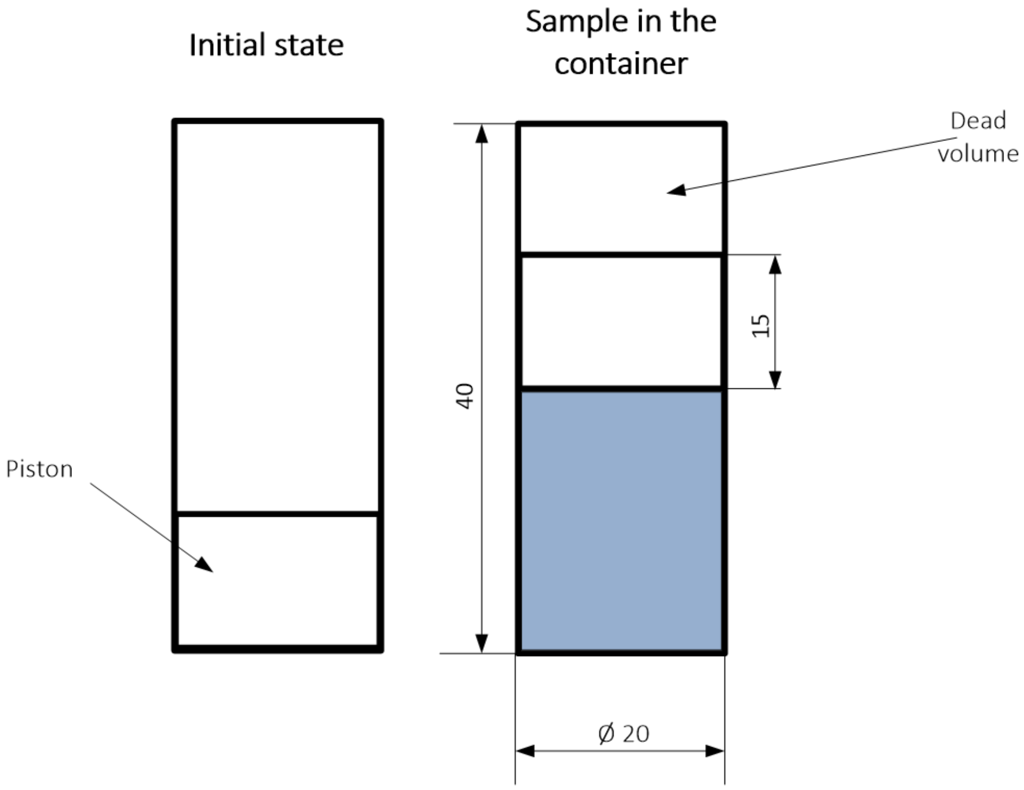


Figure 21. The dimension of one sampler storage

The total amount of the taken sample for one container is 5 cm^3. The containers are placed in cylindrical in the sampler holder part.

5 MULTISPECTRAL UNIT

5.1. Overall dimensions

The multispectral unit consists of two modules:

- The lighting module with the LEDs and the controller unit,
- The camera module.

The outer dimensions and shaping are the same on both modules (Figure 22).

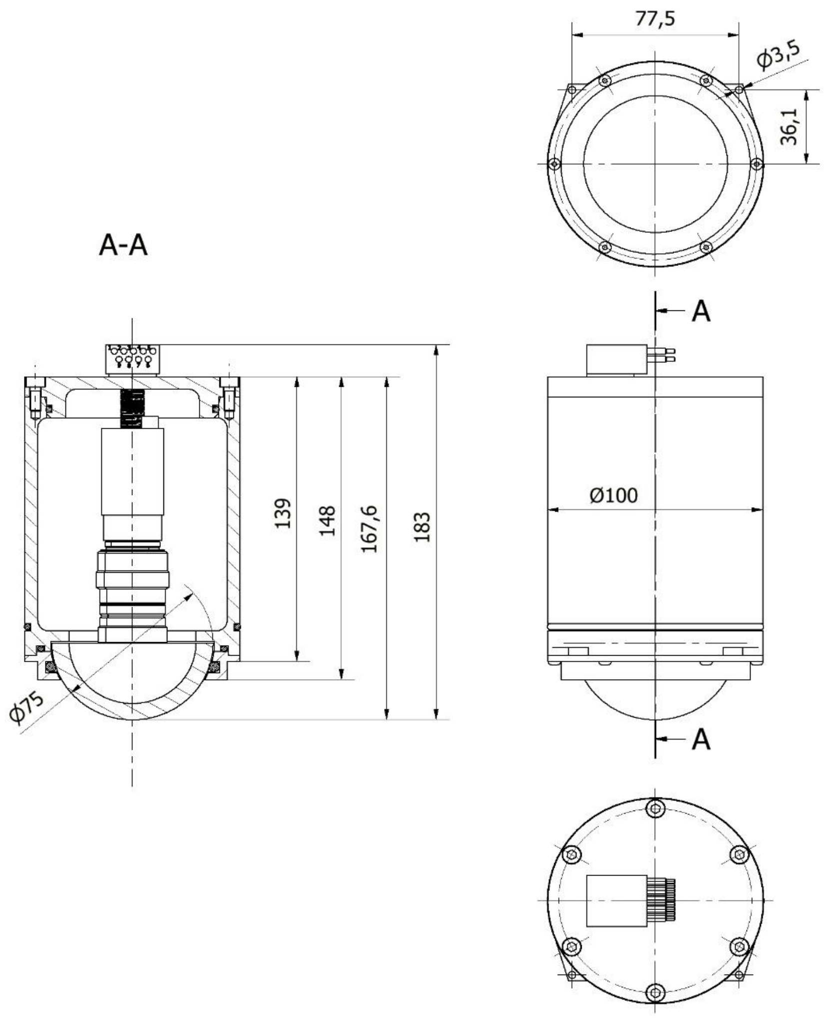


Figure 22. Dimensions of the unit

Block diagram on Figure 23 shows the internal connection and communication schematic. As shown, the outer communication interfaces are;

- Trigger signal
- Gigabit Ethernet (GigE Vision) to the camera

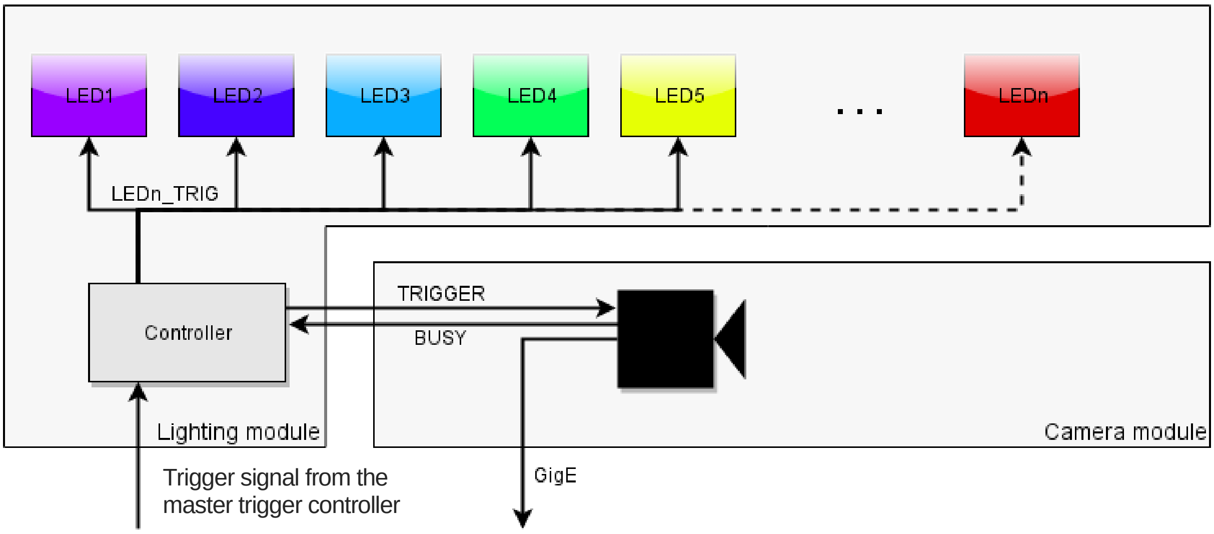


Figure 23. Block diagram of the multispectral unit

5.2. Communication and output data

The unit has 2 communication interfaces, I^2C/RS485 for sequence configuration and Ethernet GigE for image storing in the main computer. The controller also receives a trigger signal from the master trigger controller in order to be synchronized with the other sensors. After receive this trigger the controller runs the multispectral imaging sequence that was configured previously:

- Switch on the first LED light (the lowest wavelength)
- When the light is on, trigger the camera
- If the camera is not busy takes a picture and transfers over Ethernet
- Switch off the light
- After the transfer is done switch on the next light, trigger the camera and so on until the last wavelength

The output data of the unit is 14 image per sample in raw or jpeg compressed format and 1600*1200 pixels resolution.

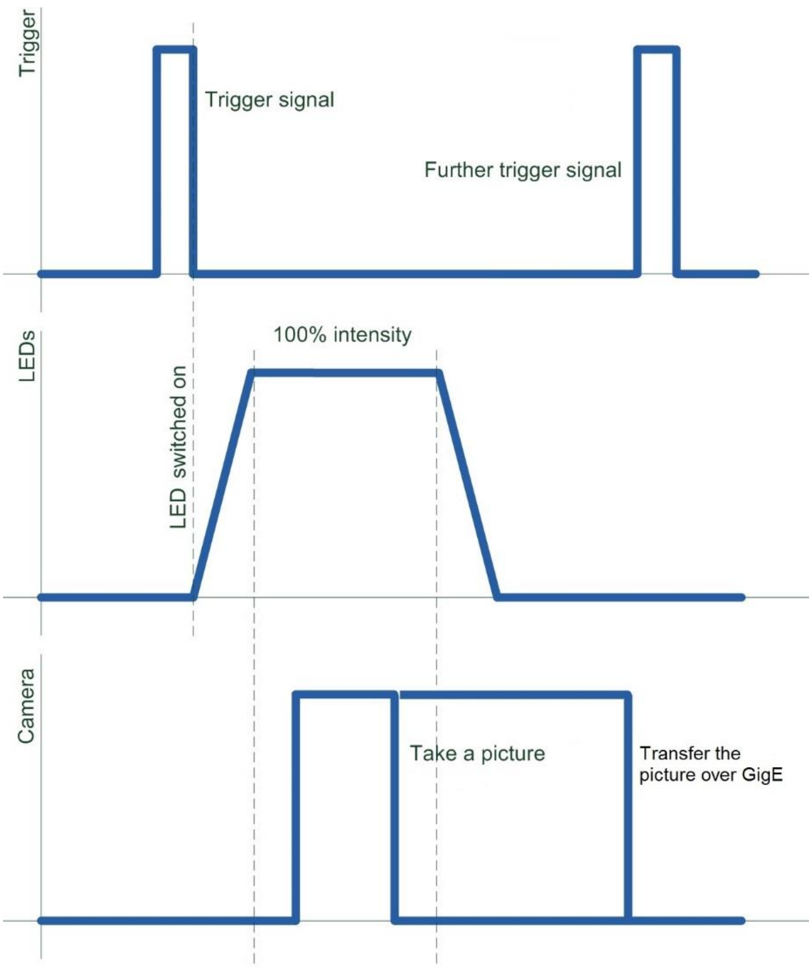


Figure 24. Timing diagram

5.3. Mounting

The lighting module and the camera module will be mounted on the side panel of the robot inside two holes between the thrusters manifold as shown on Figure 25. Each unit can be fastened with two M3 hex socket screws and sealed with O rings.

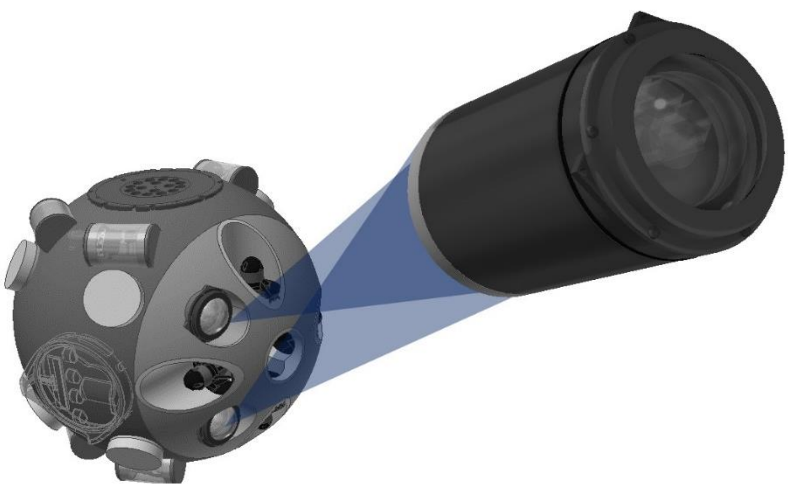


Figure 25. Location of the multispectral unit (upper: lighting module, lower: camera module)

5.4. Installation conditions

The lighting and camera modules are connected to each other inside the robot over SubConn micro low profile 9 pin connectors (MCLPBH9F). This connector serves as a power connector and an input of the I^2C bus from the robot's on-board computer to the multispectral unit's controller board. Another purpose of the connector is to connect the signals between the lighting and the camera module (trigger and busy signals between the camera and the controller). The camera module has an additional SubConn Ethernet connector (DLPBH13F) to connect the camera to the robot's on-board computer.

5.5. Specifications of the camera

Type	Allied Vision Mako 192B/C
Resolution	1600*1200 pixels
Frame rate	60 fps
Sensor type	CMOS (e2V EV76C570)
A/D bits	10
Shutter type	global
Shutter speed	14 - 1870000 µs
Interface	GigE
Voltage	12 V DC
Power	2.1 W
Weight	80 g
External trigger	yes
Dimensions	60.5*29*29 mm

Table 12. Specifications of the camera

5.6. General parameters of the unit

- Wavelength range: 400 nm – 850 nm.
- Number of wavelength regions: 14.
- In the range 400 – 850 nm to get almost equal dispersion, the difference between wavelength regions must be 25 to 42 nanometres. Maximum two-two deviations allowed upwards and downwards. The sum of the two downward deviations should be less than 15 nm, both of them should be less than 10 nm. The sum of the two-upward deviation should be less than 45 nm, both of them should be less than 40 nm.
- The different wavelength light units can be operated individually in pulse mode and can be switched on or off in a millisecond precision time-based.
- Working distance: 0.5 ± 0.25m in water.
- Lighting/viewing angle: 90° vertically, 30° horizontally.
- Resolution: 1 mm on the work plane (with 0.5 m working distance).
- Camera: at least 1500*1200 pixels, with adjustable integration time. At least a 1500 by 500 pixels region should be used to record the spectrum from the wall and the rest is used to record the water absorption on the reference light path simultaneously.
- The unit has a reference light path (at least 10 centimetres long and at least 200 by 200 pixels on the sensor) to measure the spectral absorption of the water and record it simultaneously on the same sensor as the wall spectrum (Figure 26).
- Minimal measurable reflexion: 1% (in case of: surface with Lambert dispersion directional pattern, 0.5 m working distance, clear water, signal to noise ratio (SNR): 2.
- Reproducibility: 5% relative (in case of: 20% reflection, surface with Lambert dispersion directional pattern, 0.5 m working distance, clear water).
- Connection with the mine's water: optical window dome (meniscus) on the robot's spherical surface with constant thickness, internal radius: at least 50 mm, material: glass (possibly plexi or polycarbonate). The distance between the rotational axis of the two multispectral modules (the lighting module and the camera module) is at most 0.21 m.
- Power supply: 12V DC. Power consumption: on average, less than 25 W (can be even 40-50 W for short periods).
- Dry weight: 1.6 kg, wet weight: 0.4 kg.

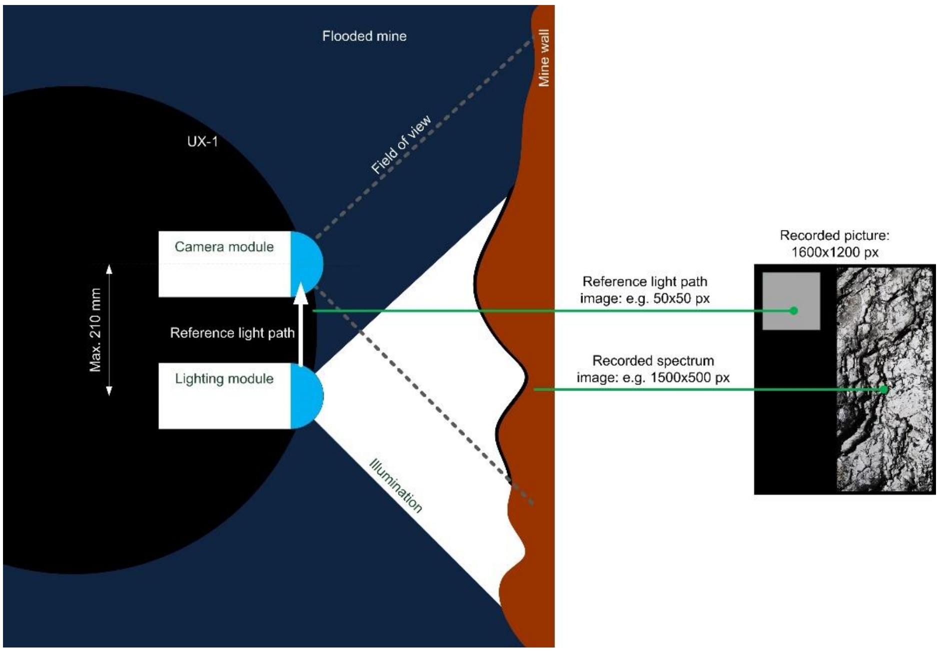


Figure 26. Details of the multispectral imaging

6 UV FLUORESCENCE IMAGING UNIT

6.1. Installation condition

The UV LEDs in selected wavelengths are built into the structured light system (SLS). The complete SLS has been designed by INESC-TEC, therefore this documentation not contains the whole unit specification.
The Figure 27 shows the position of the SLS lighting units in the UX1. There are four pieces lighting units on the front side. All units contain 10 individual 3W UV LEDs for the fluorescent imaging in pair with white LEDs for the electro optical image gathering.
It is suggested to use the UV LED block in all SLS ligthing unit's, thus causes the UX1 capable of record fluorescent images from the front facing direction of the surrounding environment at once, and there will be a possibility to compare the real coloured pictures with the fluorescent ones.

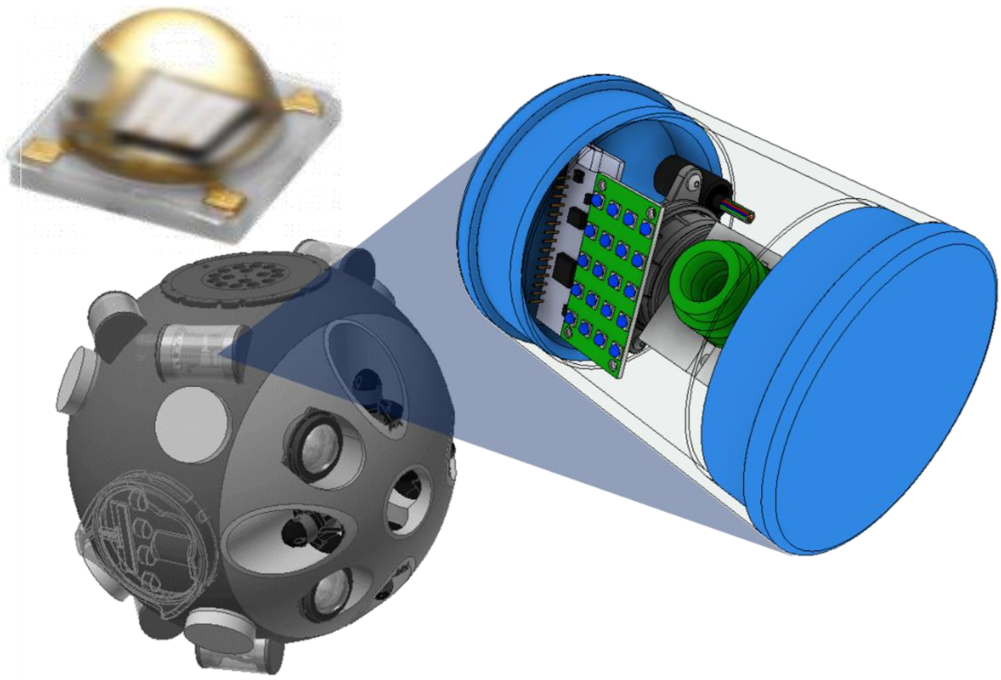


Figure 27. Position of the lighting units in the UX1

6.2. Operation of the UV LEDs

All SLS units are synchronized by the main trigger generator in order to have the same time reference. Each SLS is pre-configured through RS485, with the desired time common action behaviour, that, at the same way the other's SLS also know. This makes possible to never collide in time the light emissions from different light sources and thus the image acquisition.

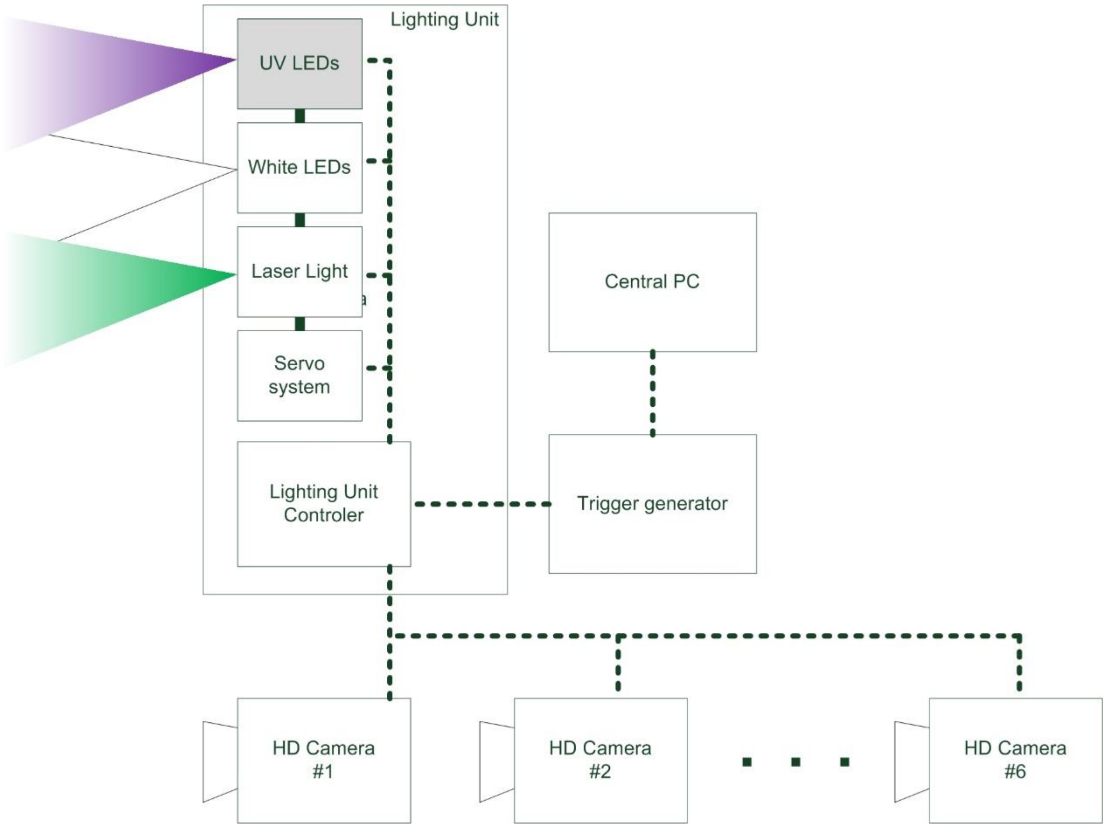


Figure 28. Connection and communication line between the computer and the UV LEDs

After the incoming trigger signal the selected and addressed wavelength UV LEDs will be switched on. When the whole intensity illumination formed the HD cameras could take one shot from the investigated parts of the tunnel or shaft. After turn off the UV LEDs it is possible to start a new trigger signal and switch on another illumination light source (white or UV). The Figure 28. shows the schedules of the UV imaging.

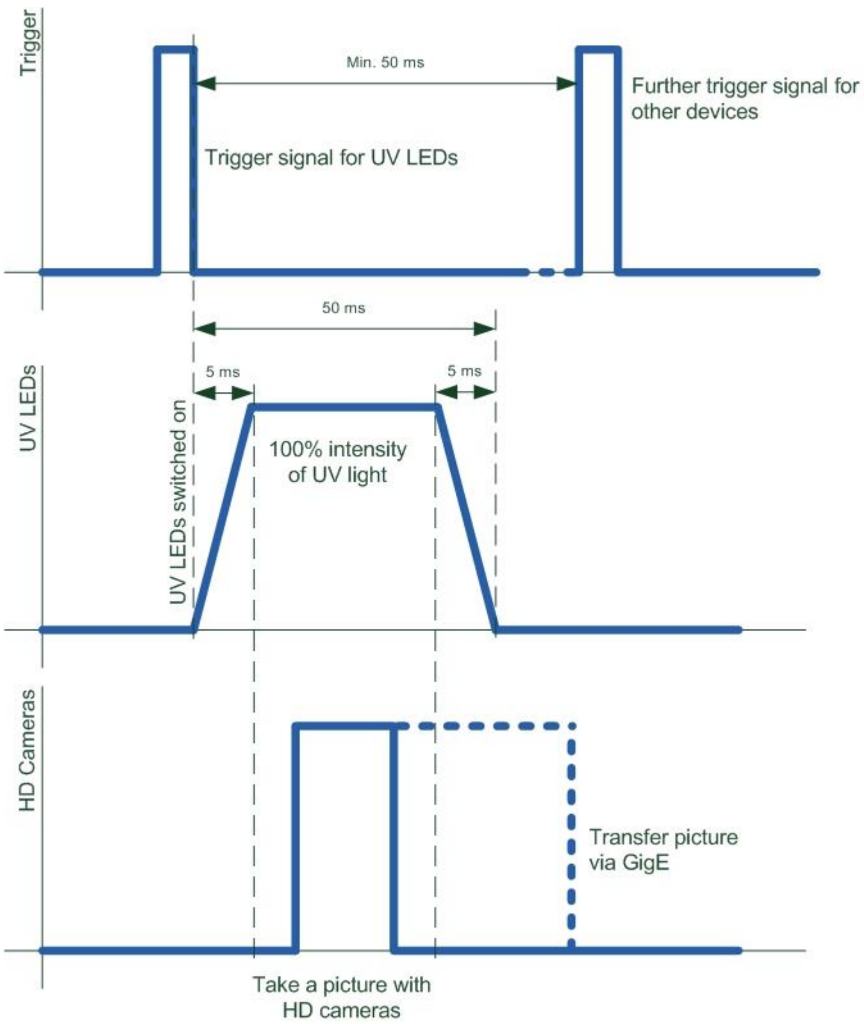


Figure 28. Scheduling tasks of UV imaging

6.3. Dimensions and specification

The following table (Table 13) and figures (Figure 29 - Figure 31) shows the most important properties of the selected UV LEDs.The technical data presented (such as forward current) refers only to one LED, but for the efficient illumination 10 UV LEDs are needed.

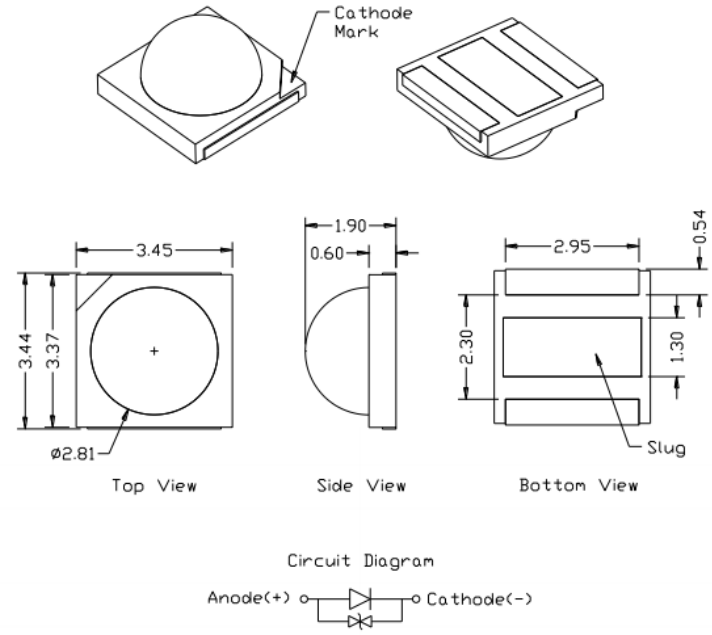


Figure 29: Emitter Mechanical Dimensions

(Source: ProLight PK2N-3LLE-SD 3W UV Power LED Technical Datasheet Version: 1.5)

Radiometric Power	350 mA	Minimum	335 mW
		Typical	510 mW
	700 mA	Minimum	650 mW
		Typical	950 mW
Forward voltage	350 mA	Minimum	2.85 V
		Typical	3.2 V
		Maximum	3.85 V
	700 mA	Typical	3.6 V
Operating Board Temperature *at Maximum DC Forward Current*	-40°C … 90°C		
Average DC Forward Current	700 mA		
Peak Pulsed Forward Current	1000 mA less than 1/10 duty cycle@1KHz		

Table 13. Technical specification of the applied UV LEDs

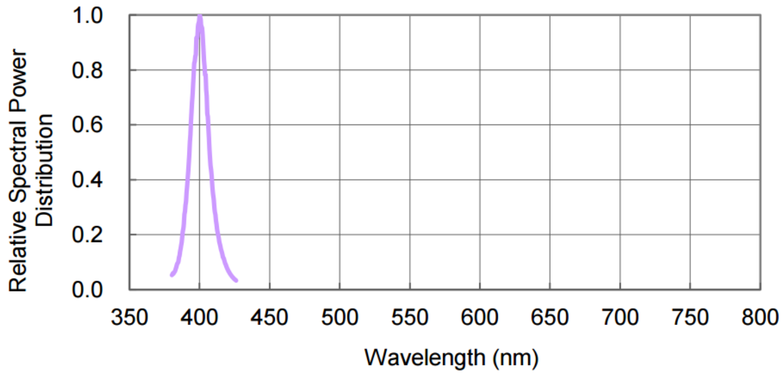


Figure 30: Color Spectrum, TJ = 25°C

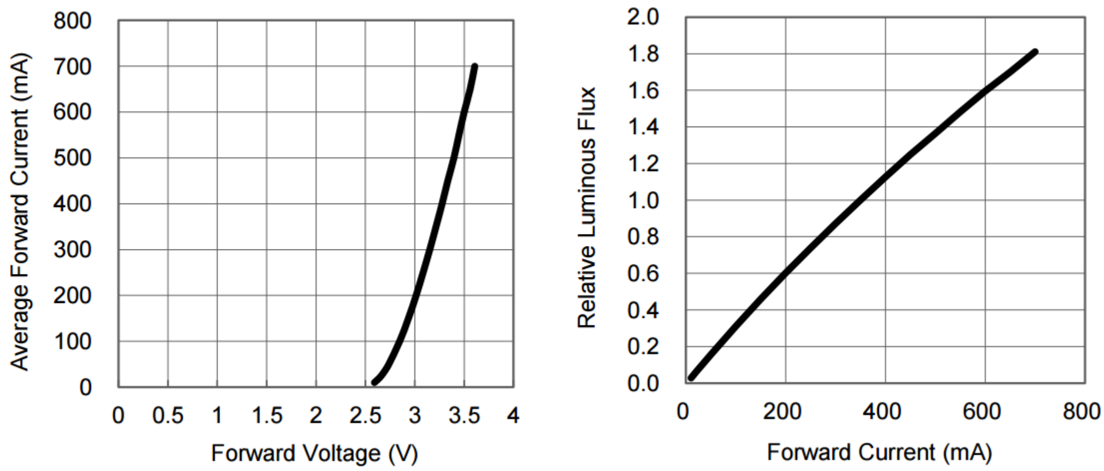


Figure 31: Forward Current Characteristics, TJ = 25°C

For decreasing or eliminate the intensity of the UV light under approximately 400 nm wavelength which comes back to the camera it must be used an edge filter. The filter will be placed in front of the HD cameras. The Table 14 and Figure 32 shows the technical data (dimmensions and the transmission curve) of a typical edge filter: Semrock BLP01-405R-25 (Table 14). The edge filter removes the unwished UV lights and the recorded picture will shows the fluorescent colors only.

Semrock BLP01-405R-25 edge filter	
Diameter	25 mm
Thickness	3.5 mm

Table 14. Important properties of the edge filter

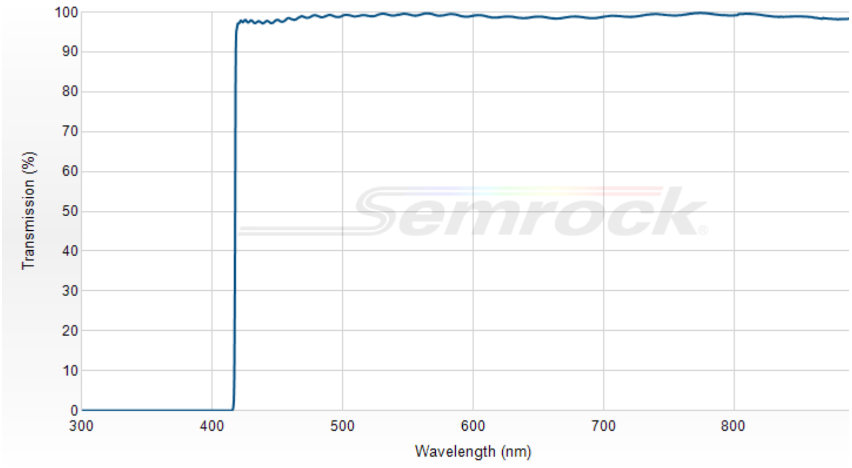


Figure 32. Transmission curve of the Semrock BLP01-405R-25 edge filter

7 MAGNETIC FIELD MEASURING

7.1. General description

The flux gate sensor system (FGM) measures the magnetic field strength and collects data that will be stored by the main computer for post processing. Connection between the FGM and the central processing unit runs on RS-485.

For measuring the magnetic field vector in three orthogonal directions, three direction-sensitive sensors would be sufficient (in principle, the perpendicularity is not completely necessary). The perpendicular system has best conditions for this measurement. Applying six piece of sensors we can measure local changes also, since the entire magnetic field will be changing in time.

7.2. Overall dimensions

7.2.1. Sensors

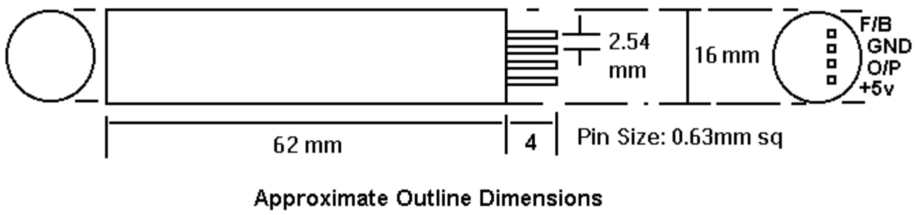


Figure 33. The dimensions of the FGM3 sensor

There are 3 pair of FGM3 sensors (Figure 34) needed for the proper determination of the current magnetic field. The position of sensor pairs need to be perpendicular compared to each other. The 3 pair of FGM sensors generate an arbitrary position Cartesian coordinate system (Figure 34).

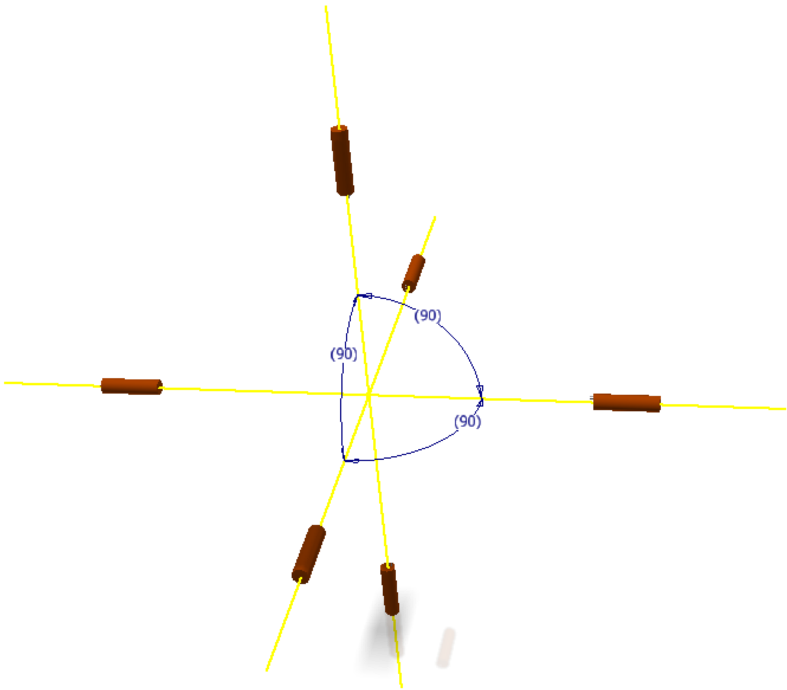


Figure 34. Position of the 3 pairs FGM3 sensors

7.2.2. Electronics

The Figure 35 shows the electronic blocks and the structure of the three FGM3 magnetic field sensors pairs, which contains the power module, the sensor interface modules with temperature compensation, the microcontroller module and the RS485 communication module. The Table 13 shows the input port configuration of the junction box.

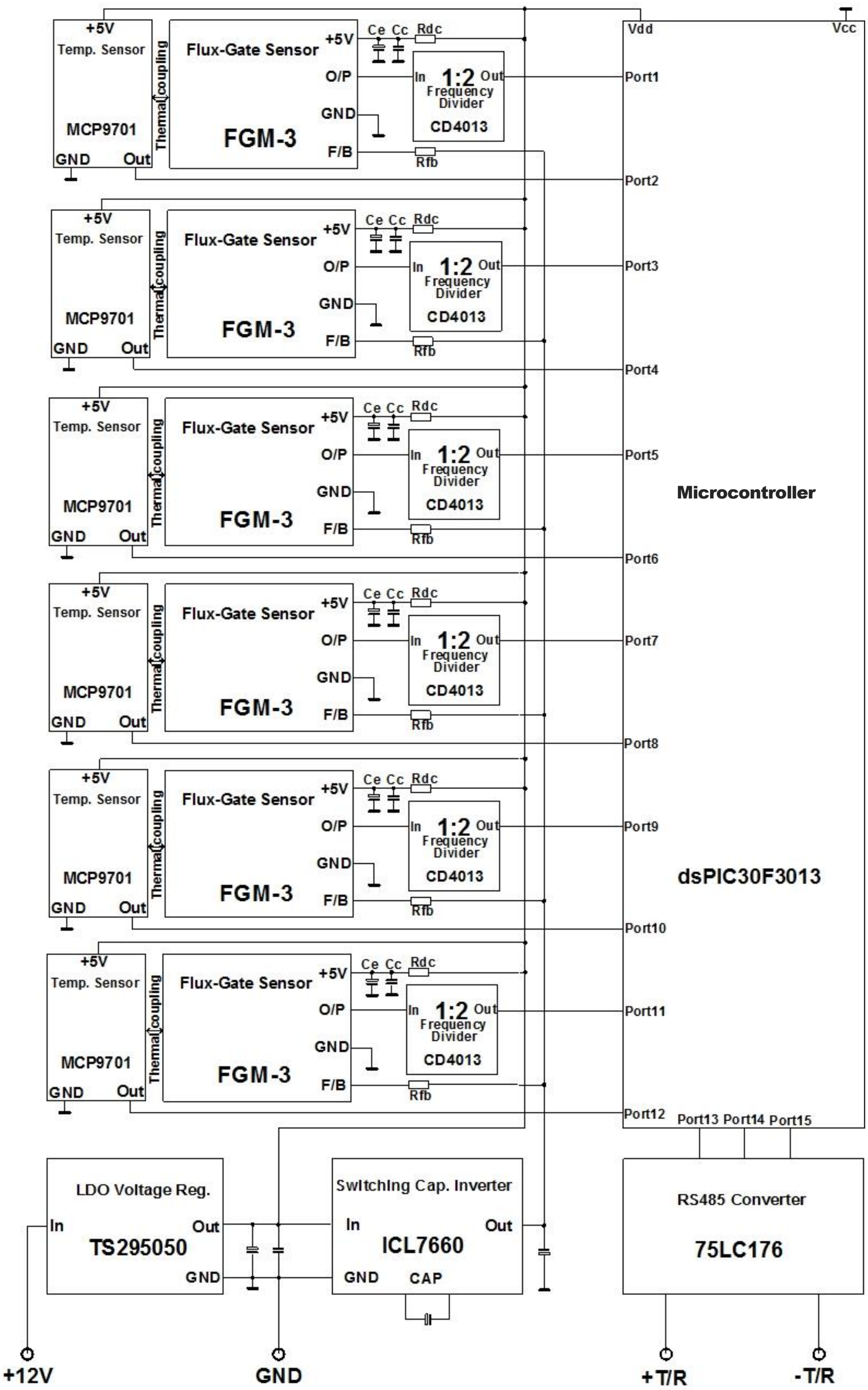
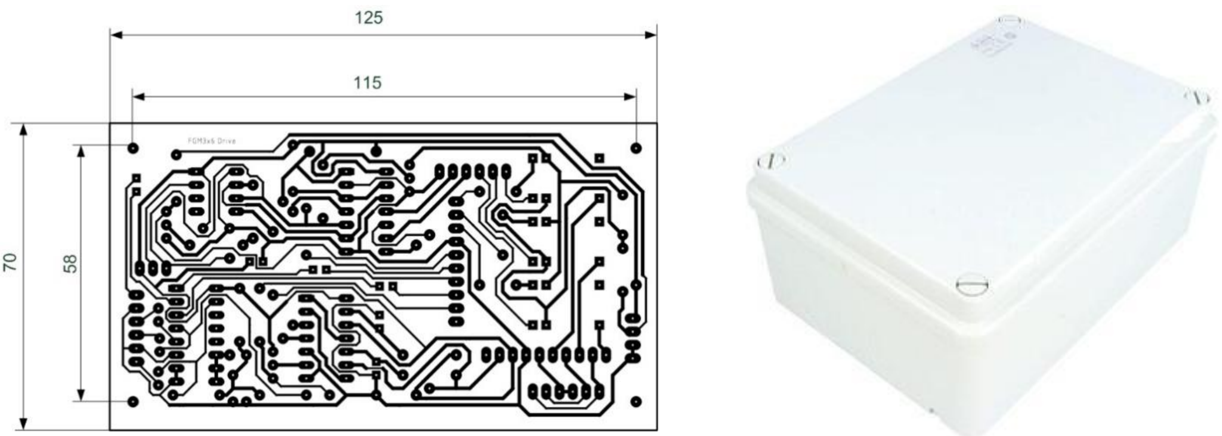


Figure 35. FGM driver electronic blocks

Input channel	FGM-3 sensor position	Description
Port 1	Top	Upper FGM-3 out
Port 2		Temperature of upper FGM-3
Port 3	Bottom	Lower FGM-3 out
Port 4		Temperature of lower FGM-3
Port 5	Front	Front FGM-3 out
Port 6		Temperature of front FGM-3
Port 7	Rear	Rear FGM-3 out
Port 8		Temperature of rear FGM-3
Port 9	Left	Left FGM-3 out
Port 10		Temperature of left FGM-3
Port 11	Right	Right FGM-3 out
Port 12		Temperature of right FGM-3

Table 13. Flux gate sensor positions

The Figure 36 shows the printed electronic board (PCB) with the mounting holes and sows the suggested/possible junction box. It is possible to directly mount the PCB into the UX1 hanged by four screws. In this case the PCB needs to be protected by waterproof resin coating.



Junction box: 153x110x66 mm

Figure 36. Electronic PCB board and the housing of the electronic parts

7.3. Installation conditions and mounting

The FGM3 sensors don’t need to be in contact with the ambient mine water, therefore the 6 sensor pieces can be placedinside the pressure hull. The interior of the pressure hull is not pressurized and not wetted, thus there is no need to apply any additional waterproof or pressure protection solutions. The FGM3 sensors will be fitted into the inner side of the hull, using pre-mounted sockets.

The distance between the centre point of the robot and each sensors must be equal and as much as possible for each ones. The distance between the back side of the FGM3 sensors and the centre of volume of the UX1 is 220 mm in case of all FGM sensors. The Figure 37 shows the positions of the FGM3 sensors.

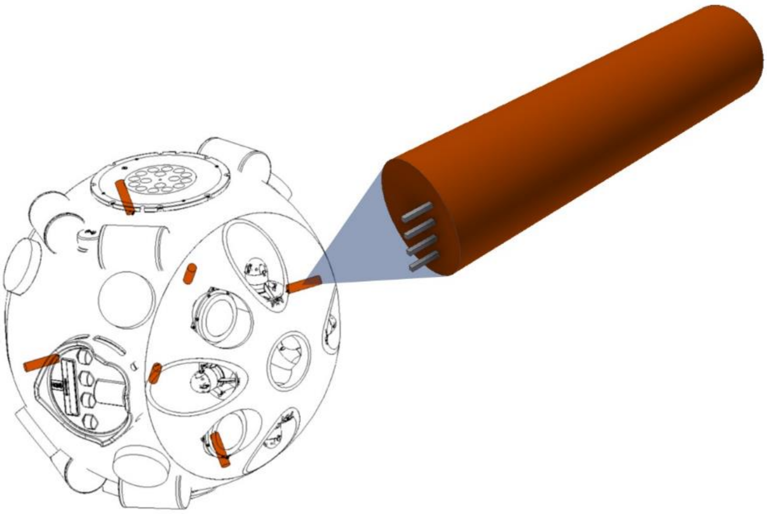


Figure 37. Orientation and position of FGM3 sensors in the UX1

The Table 14 contains the important technical information of the Magnetic Field Measure Unit.

Sensitivity	1 nT
Measuring range	+/-50000 nT
Accuracy	min. 1%*
Operational temperature range	-15 - 70°C
Electrical PCB size	125 x 75 mm (with 4 pcs dia 3.3 mm mounting screw hole)
Housing, overall dimensions	IP55 ABB junction box 1SL0852A00, 153x110x66
Sensor arrangement	3 pair of sensors on XYZ axes
Sensor case	Plastic
Measuring frequency	1 Hz
Output data type	ASCII sequence (position, 6 pcs. component)
Data connection	RS485 DSUB9 (female)
Output data type	16 bit signed integer; six pieces, comma delimited + <CR>+<LF>
Electric connectors	Vinyl-insulated round cable with four 0.34 mm2 copper cores; 1500 mm standard length
Power	2 wire (0,5 mm length; 0.34 mm^2) 12VDC@500mA
Sensors weight	dry 0,1 kg
	wet 0.06 kg
Electronic weight	dry 0,3 kg
	wet -0.8 kg

**Temperature compensation needed in the operation temperature range*

Table 14. Specification of Magnetic Field Measure Unit

7.4. Output data

The Table 15 shows the communication between the Magnetic Field Unit and the central computer. The suggested frequency of the data update is 1 Hz considering the possibilities of the whole measuring environments.

PC	"?FG"+<CR>+<LF>
FG	"48123,48456,23123,23456,-10123,-10456"+<CR>+<LF>

Table 15. Output communication of FGM sensors

The simple query command start with string "?FG" and closed by a Carriage Return + Line Feed always. The question includes the name of the sensor type as address. The response message start with the current six directional magnetic field measured values. The values unit is nT and has already temperature compensated. The 6 measured values are separated by "," (comma) and the response message closed by Carriage Return + Line Feed as well.
The scheduling query, identification of the place (position) of each sensors and insertion of the proper timestamp will be done by the central computer.

8 SUB-BOTTOM PROFILER UNIT

8.1. General description

The sub-bottom profiler (SBP) sensor is going to investigate the bottom of a desired tunnel, therefore the unit is should be positioned at the bottom of the UX1 and with an orientation near vertical. The Figure 38 shows the possible and preferable location of the sub-bottom profiler.

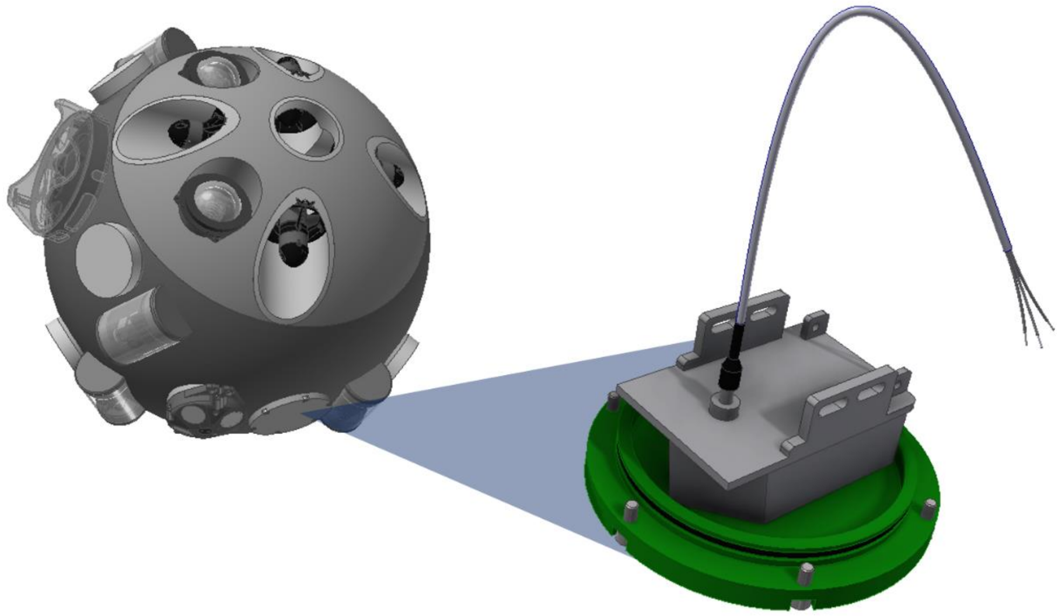


Figure 38. Location of the sub-bottom profiler

The ultrasonic sub-bottom profiler (SBP) maps the mine wall (or floor layer) material and collects data to a SEG-Y type database. This method and data format allows to post processing data. The SEG-Y data format is the output of the central computer only; connection between the sub-bottom profiler and the central processing unit runs on RS-485.

The communication protocol between the sub-bottom profiler sensor and the central computer is looking like the FG sensor's format: conversation starts with the question of the PC. The question includes the name of the sensor type as address (Table 16):

PC	"?SB"+<CR>+<LF>
Sub-bottom Profiler	"0, -123.4567, ... 0.0" + <CR> + <LF>

Table 16. Output communication of Sub-bottom sensors

The SBP data as 12-bit floating point, signed amplitude data for a particular point "shooting" time series. The length of the series, and time division are programmable (later determined). The central computer is responsible for SBP "operation, ie the individual" shots, the computer must be post an SEG-Y format "and start receiving the data. The individual "shot list" sections: header into data line of position or UTC data.

8.2. Specifications

Category	Description
Type	Ultrasonic sub-bottom profiler sonar
Powering	Input: 10 to 18 VDC with High Voltage Protection Nominal: 12VDC at 0.28 A Usage: 7 W maximum
Operating environment	Operating temperature: -15°C to 70°C Pressure: 60 bar
Measuring range	0.5 - 40 m
Accuracy	±0.01 m
Dead band	0 - 0.5 m from the sensor surface
Angle of wiew	10° - 40°
Penetration depth	0.1 m
Bandwidth	10 Hz
Sampling rate	1 Hz
Sonar power output	300 W (RMS), 2400 W (peak to peak)
Frequency	200/50 kHz
Output type	RS-485; 12-bit fixed-point, signed
Electric connectors	Vinyl-insulated round cable with four 0.34 mm2 copper cores; 1500 mm standard length
Sensor case	Fully gasketed, high-impact plastic alloy
Waterproof	IEC 529, level IPX-7 (submerged to 1 meter for 30 minutes)
Overall dimensions	Sensor: 100x65x56 mm Electronics: 100 x 100 x 25 mm
Weight	370g

Table 19. Sub-bottom profiler specifications

The Figure 39 shows the Sub-bottom sensor with the mounting possibilities and the important overall dimensions.

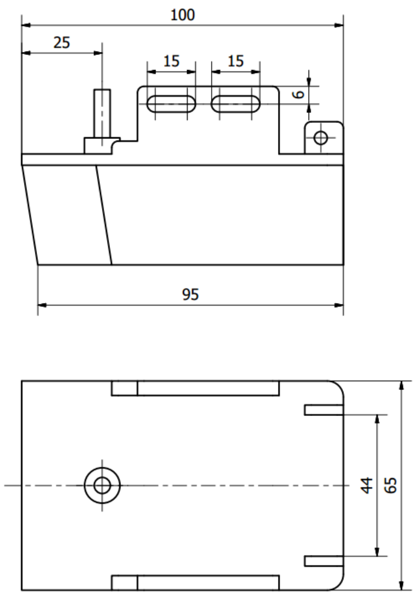


Figure 39. Overall dimensions of the Sub-bottom sensor

8.3. Unit design block diagram

Sub-bottom profiler consists of six parts (Figure 40)

- The microcontroller unit, that schedules and controls the sending and receiving pulse packages. Furthermore, it measures the package traveling time and builds an image map of the bottom.
- DC/DC converter, that interfaces the signal levels between the microcontroller and the transmitter driver.
- Driver unit, that ensures output power for transducer.
- Preamplifier with automatic gain control (AGC), that amplifies the incoming signal.
- LDO voltage regulator, will act as power supply for the entire sub-bottom profiler electronics.
- RS-485 converter, interfaces the microcontroller output to the standard serial bus.

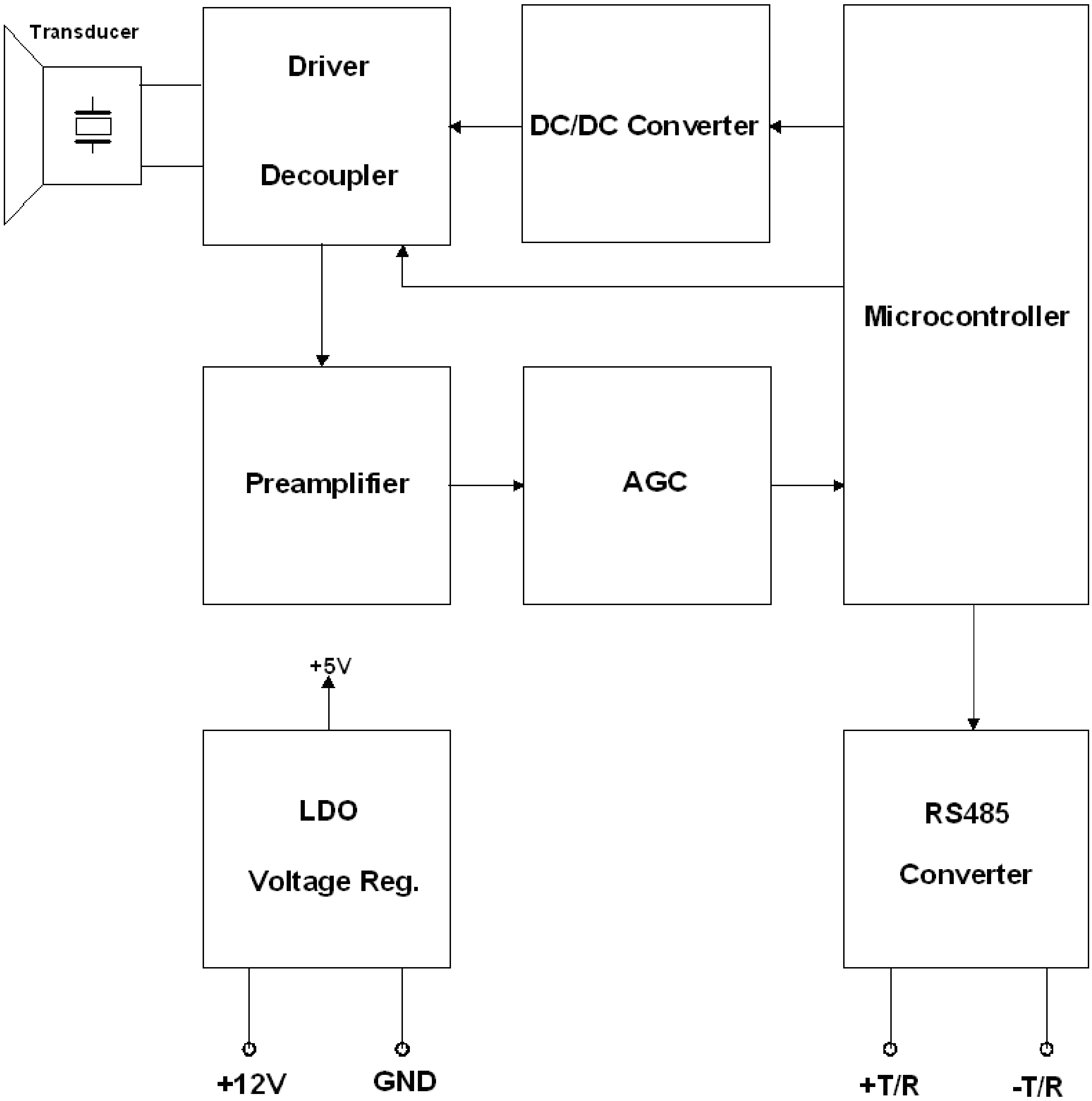


Figure 40. Sub-bottom profiler block diagram

9 GAMMA RAY COUNTER UNIT

9.1. Overall dimensions

The gamma ray counter (GRC) unit can be assembled in the same hull as the water sampler unit. Thus, the adaptor parameters/dimensions of the unit are the same as it was in the case of the water sampler. The Figure 41 illustrates the main dimensions of the equipment. For sealing, a double o-ring system is used. The electrical connection of the unit is solved with a MCLPBH9F waterproof connector to the robot.

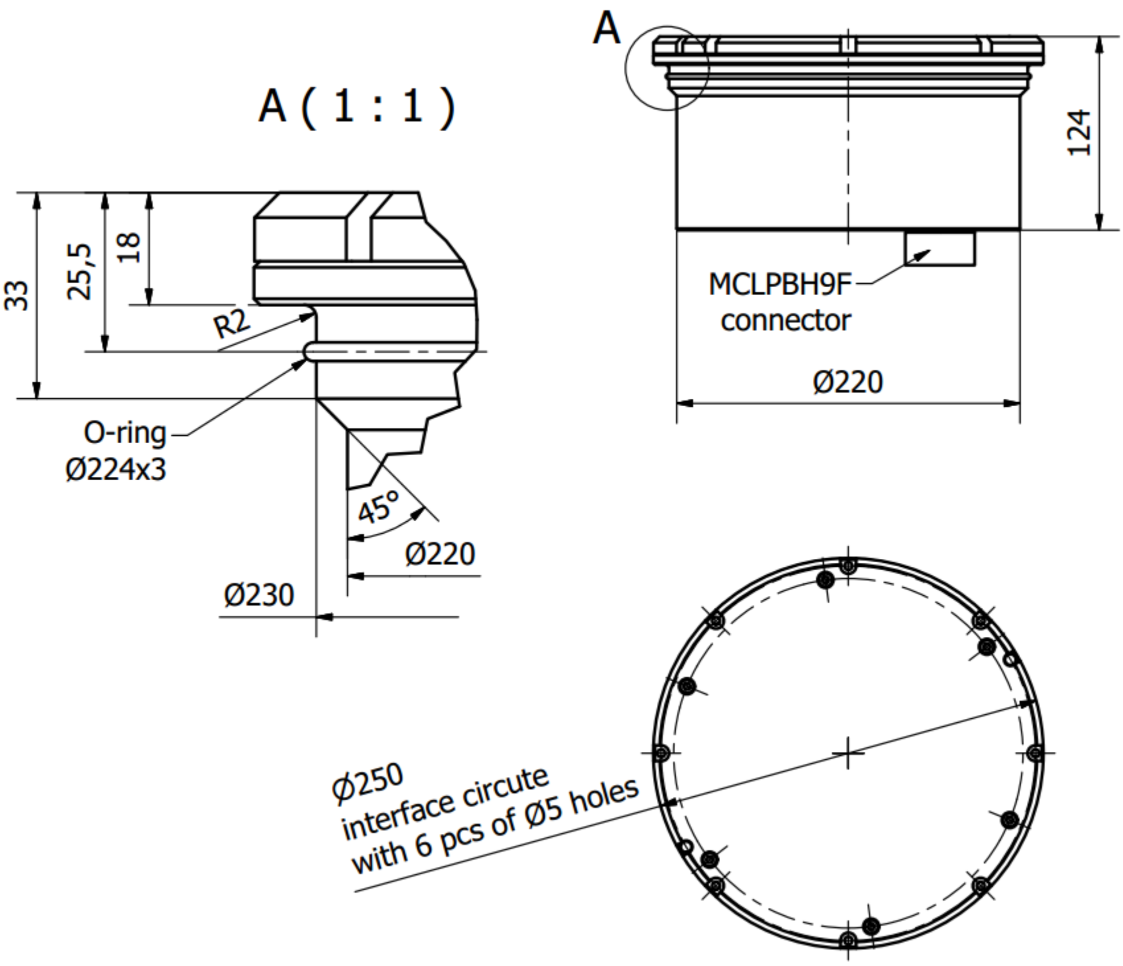


Figure 41. The dimensions of the gamma ray counter unit

The Figure 42. shows the location of the unit on 3D picture. The unit requires a bigger hull, which is the same used with the water sampler unit.

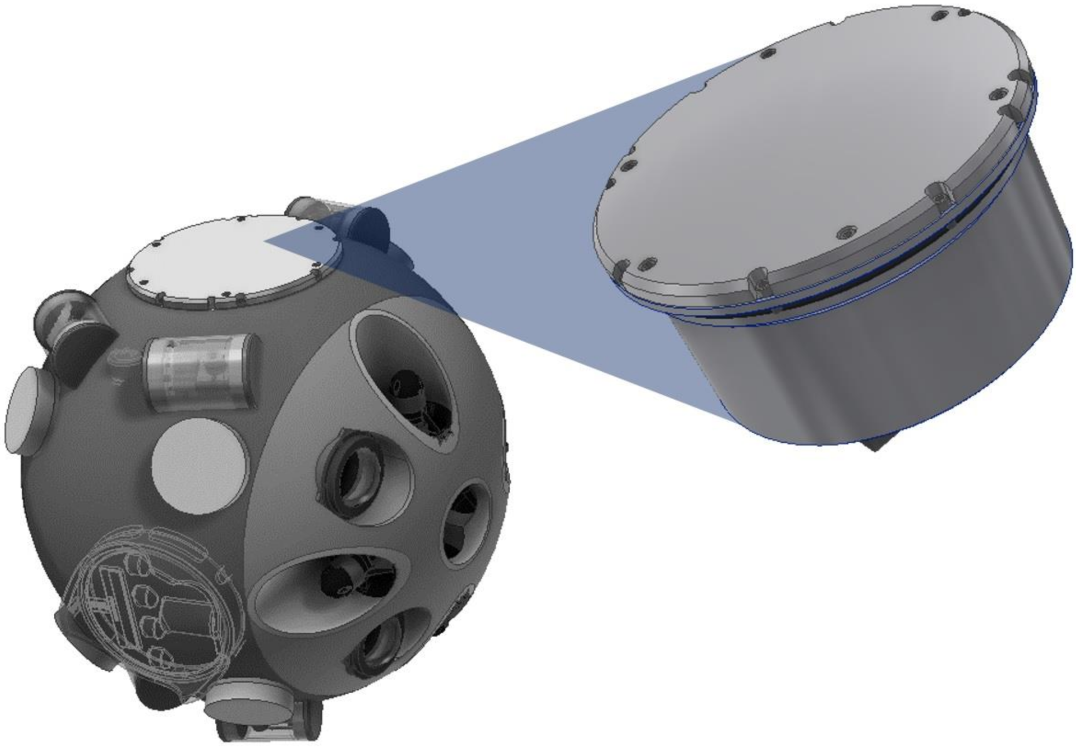


Figure 42. Location of the gamma ray counter unit in the robot

9.2. Specification

The detector essentially provides the air dose rate of X-ray or gamma radiation in Gy / h units based on the IEC 1017-1: 1995 Hungarian standard regulations. The main parameters of the equipment can be found in the Table 20.

Parameter	Value
Nuclear parameters	
Type of detector	energy compensated GM tube
Indication range	20 ... 100 W nGy
Measuring range	1 µGy / h ... 1 Gy / h (Above the measuring range of 100 Gy / h the transmission monotonically increasing)
Energy range	60 keV ... 1.5 MeV
Averaging time	2 s ... 4 min, auto
Relative basic error using Cs-137 as reference	± 15%
Statistical volatility (Standard deviation)	10%
Overload	The instrument will not be damaged under 100 Gy / h

Energy dependence (relative to Cs-137)	± 20%
Beta radiation sensitivity	0.3%
Warm-up timemax.	30 sec
Power parameters	
Supply voltage	12 V
Current consumption	max. 25 mA
Communication parameters	
Communication type	RS-485
Communication speed	2400 baud
Electrical connector	MCLPBH9F: 1: GND 3: Trigger input 4: Trigger GND 5: 12 V DC in 7: Data + 8: Data -

Table 17. Specification of the gamma ray counter unit

The communication requirements of the unit are a 12V power supply and maximal 20mA current consumption. RS485 communication is used on 2400 baud.
The electronics of the unit does not disturb the operation of other equipment. The unit fulfils the interference protection in relation to the requirements of IEC 801.