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SURVEILLANCE TECHNOLOGIES FOR THREE DIMENSIONAL NAVY

Technology Focus focuses on the technological achievements in the organization covering the products, processes and technologies.

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Integrated Sonobuoy Receiver System

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एवं
अध्यक्ष, डीआरडीओ
Secretary, Department of Defence R&D
&
Chairman, DRDO

MESSAGE

1. The research and development of naval sensors and weapons systems for Indian Navy assumes prime importance, with well-documented foray of our neighbours into waters of Indian Ocean Region (IOR). The three dimensional surveillance and Underwater Domain Awareness (UDA) holds the key to maintain our superiority in the IOR. In this regard, our DRDO laboratory, Naval Physical and Oceanographic Laboratory (NPOL) at Kochi has been at forefront in developing and delivering cutting-edge technologies for SONARs and other allied sensor systems to Indian Navy as well as to friendly navies.

2. As we march towards Amrit Kaal 2047, NPOL is developing technologies for design and development of futuristic SONARs that will counter silent and stealthy underwater platforms. This edition of Technology Focus will emphasise on the key enabling technologies developed in recent years by NPOL for indigenous SONARs. I am sure that this edition will serve as a reference for know-how of Indian SONAR technologies.

Skamat

(Dr. Samir V. Kamat)

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विशिष्ट वैज्ञानिक एवं
महानिदेशक (एनएस एवं एम)
Dr. Y. Sreenivas Rao
Distinguished Scientist &
Director General (NS & M)

सत्यमेव जयते

स्वच्छ भारत
एक कदम स्वच्छता की ओर

रक्षा मंत्रालय
MINISTRY OF DEFENCE
रक्षा अनुसंधान तथा विकास संगठन
DEFENCE RESEARCH & DEVELOPMENT ORGANISATION

Message

SONAR system design, development and delivery to an operational Navy is a capability that is possessed by a handful of nations, mostly from the developed world. NPOL, as a laboratory with a glorious legacy of providing SONARs to Indian Navy, is a gem in the arsenal of DRDO. For design and development of SONARs, NPOL has nurtured industrial partners of all sizes over the years to indigenise the complete ecosystem of Ship, Submarine and Torpedo-defence SONAR systems. The SONARs work in harsh ocean conditions and their performance is governed by these conditions. This has always pushed NPOL to keep developing reliable systems that are in sync with realities of the evolving ocean and technology scenario.

This edition of Technology Focus showcases the efforts undertaken in the recent years by NPOL to develop state-of-the-art technologies for the three dimensions of the Indian Navy. I am sure that readers will be happy to read about the new subsystems that will make the next-generation underwater surveillance, a reality.

Dr Y Sreenivas Rao

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उत्कृष्ट वैज्ञानिक
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Dr. K Ajith Kumar
Outstanding Scientist
Director

सत्यमेव जयते

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रक्षा अनुसंधान तथा विकास संगठन
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The Naval Physical and Oceanographic Laboratory (NPOL), Kochi was initially established as Indian Naval Physical Laboratory (INPL) in 1952 as a part of Indian Navy. With the formation of DRDO in 1958, INPL was absorbed and renamed as NPOL in 1968. NPOL evolved from a fleet support role and experimental studies in Acoustics, Transducer and Oceanography to a successful Sound Navigation and Ranging (SONAR) system laboratory. Today NPOL can boast of successful design and delivery of multiple Ship and Submarine SONARs along with underwater systems for Torpedo defence, to Indian Navy as well as to friendly navies in the neighbourhood.

The evolution of SONARs is countered by steady evolution of stealth and silent underwater platforms. Hence, a continuous and systematic Research and Development effort is required to keep up with "Passive/active limits of submarine detection". SONAR design and development effort is a multi-disciplinary area of work which consists of technology domain experts from Electro-acoustic transducers, Underwater Acoustics, Oceanography, Materials, Mechanical engineering and system engineering.

As NPOL starts to roll out towed array, airborne SONARs and other niche SONARs like buoy-based SONARs, imaging SONARs etc., a plethora of state-of-the-art technologies are being developed to achieve the goal of three-dimensional surveillance. This special issue of technology focus presents the new technologies under each technology domain, which have been developed and tested in last few years at NPOL. It is hoped that this issue will provide a cursory insight into the preparedness of NPOL to develop futuristic SONARs for Indian Navy up to 2047.

(Dr. K Ajith Kumar)
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SURVEILLANCE TECHNOLOGIES FOR THREE DIMENSIONAL NAVY

Sonar uses sound waves to detect, locate, and identify objects in water. The term Sonar is an acronym for sound navigation and ranging. Ships and submarines primarily use Sonars for underwater navigation and surveillance. The design of Sonar requires expertise in sensor technology, signal conditioning and processing, electronic packaging, materials technology, ocean acoustics, and mechanical engineering. Naval Physical and Oceanographic Laboratory (NPOL), a premier system laboratory of DRDO in Kochi, has proven the expertise required to develop various Sonar requirements for the Indian Navy. NPOL has been engaged in cutting-edge research in the area of underwater surveillance and communication systems for the past 70 years.

SONAR TRANSDUCER TECHNOLOGY

Free-Flooded Ring Transducer

The Free-Flooded Ring (FFR) transducer is one of the main stay underwater transmitters developed in NPOL for ASW Sonars. The high power-to-weight ratio and depth-independent acoustic characteristics make the FFR transducer more popular among other designs. FFR transducers are highly efficient compared to conventional Tonpilz transducers, which operate at the same frequency. The resonance frequency, or frequency band, of FFRs is governed by the dimensions of the FFR and the type of piezoelectric material used. The frequencies can be tuned by adding appropriate inactive materials between active piezoelectric segments that form the ring. FFR also uses multi-mode resonance to enhance its operating frequency band.

Features

- High power-to-weight ratio
- Depth-independent characteristics
- Unlimited depth of operation
- High source level and band width
- Omnidirectional in the azimuth plane

Specifications

Free-Flooded Ring

Capacitive Micro-machined Ultrasonic Transducers for Underwater Acoustic Imaging

Capacitive Micro-machined Ultrasonic Transducers (CMUT) transducers are Micro Electro Mechanical Systems (MEMS)-based structures that can be used to transmit and receive acoustic signals

Dimensions* (mm)	Frequency (kHz)	Power (KW)	Source Level (dB)	Weight-in-Air (kg)
200x160x120	4 to 6	8	201	10
380x320x120	1.5 to 2, 2.5 to 3.2	20	212	60

*ODxIDxHt

in the ultrasonic range. The basic building block of a CMUT is a capacitor cell consisting of a metalised membrane (top electrode) suspended above a heavily doped silicon substrate (bottom electrode). CMUTs achieve transduction electrostatically, unlike piezoelectric transducers. The merit of the CMUT derives from having a very large electric field in the cavity of the capacitor; a field of the order of 10^8 V/m or higher results in a very high electro-mechanical coupling coefficient. A 1x16-element CMUT sensor array for underwater acoustic imaging has been fabricated by MEMS technologies. The displacement characteristics of the devices have been measured by a Laser Doppler Vibrometer (LDV). All 16 elements of the array have a center frequency in the range of 1.29–133 MHz, which is expected to give a center frequency of 700 kHz, as designed for the underwater imaging application. The technology for the fabrication of multiple-element CMUT arrays has been established.

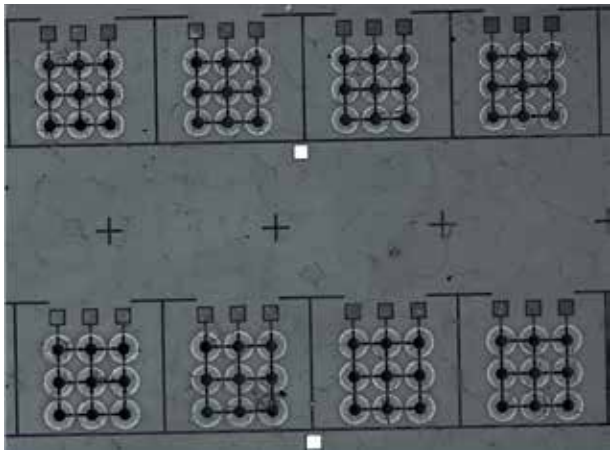
Features

- Fabricating ultrasonic sensors using micro-machining technology: a new technological approach
- Broad capacitance coverage and high electro-mechanical conversion efficiency
- Electrostatic transduction, in contrast with piezoelectric transducers
- The electro-mechanical coupling coefficient competes with the best piezoelectric materials
- Batch production of large arrays is feasible
- A better impedance match with media
- Can be directly integrated into electronic circuits such as the CMOS
- Superior bandwidth

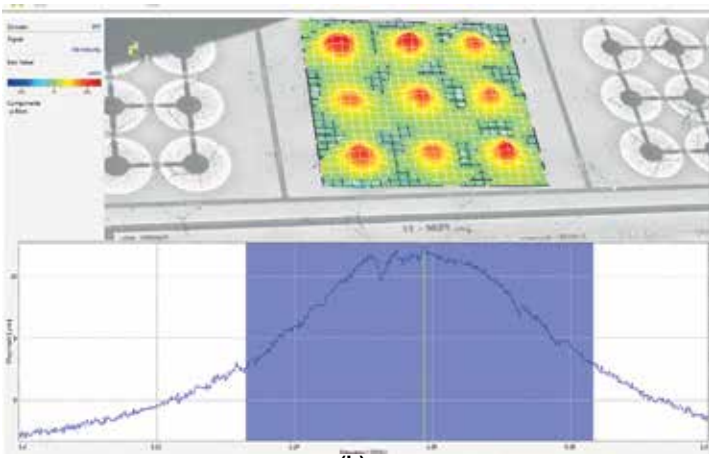
Specifications

Parameter	Value for 700 kHz	Values for 450 kHz
Type of substrate	SOI and Planar Si (375-450 μm thickness 3” dia)	
No. of elements	1 x 16	1 x 16
Pitch length	1.1 mm	1.71 mm
Kerf length	30 μm	30 μm
Dimension of the sensor array of 16 element	1.75 cm x 1.90 mm	2.74 cm x 2.3 mm
Receiving sensitivity	≥ -200 dB ref 1 V/μPa	

Designed and Developed by NPOL (with design consultancy from National Institute of Design, Ahmedabad)



(a)



(b)

(a) Micrograph Showing Four Elements (3x3 cells) of Two Different 1x16 Element CMUT Array (2x magnification) (b) Screenshot of the Deflection of Nine Cells in an Element of the 1x16 Array

Flexible Large Area PVDF Hydrophones

The flexible large area PVDF hydrophone is the latest addition to the family of underwater acoustic sensors. The PVDF hydrophone is designed and developed to meet specific requirements for low-frequency, large-aperture arrays like submarine flank arrays. The PVDF hydrophone is designed in a submarine flank array configuration with large area, flexible piezoelectric PVDF sheets to enhance the SNR through effective discrimination and significant cancellation of flow noise and hull/machinery noise through spatial area averaging techniques and the specific orientation of piezoelectric PVDF sheets in the sensor array. These state-of-the-art flank array hydrophones are made out of low-density, mechanically tough, and flexible materials and have excellent resistance to hydrodynamic stresses and impacts.

Features

- Made out of un-axially drawn piezoelectric PVDF sheets
- Can be made into two-dimensional surface sensors
- Has high hydrostatic sensitivity
- Less sensitivity for in-plane vibrations, such as hull vibrations
- Integrated baffle structure with specially formulated rubber and PU
- Easily curved to follow the shape of the hull
- Does not disturb the hydrodynamic behaviour of the submarine
- Low-weight characteristics and matching acoustic impedance

Specifications

Dimension	: 200 mm x 180 mm x 63 mm
Weight of hydrophone	: 3.2 kg
Frequency of operation	: 10 Hz - 10 kHz
Active material	: PVDF sheet
Capacitance	: 2 nF - 3.3 nF
Receiving sensitivity	: -201 ± 1.5 / -196 ± 1.5 dB ref 1 V/µPa
Acceleration sensitivity	
(Z axis)	: -10 to -80 dB for 10 Hz - 3 kHz
(X Axis)	: -18 to -90 dB for 10 Hz - 3 kHz
(Y Axis)	: -30 to -90 dB for 10 Hz - 3 kHz
Directionality	: Omni directional (up to 4 kHz)
Integrated baffle	: Specially formulated rubber and PU

PVDF Hydrophone

Fibre-optic Hydrophone Array with Hybrid DWDM-TDM Architecture

One of the major advantages of Fibre-optic hydrophone is their capability of multiplexing many sensors by utilising the concept of combining Dense Wavelength Division Multiplexing (DWDM) and Time Division Multiplexing (TDM) techniques. Fibre-optic hydrophone arrays with hybrid DWDM-TDM multiplexing are state-of-the-art technology suitable for realising advanced compact passive Sonar systems for any kind of platform. Interferometric fiber mandrel-type hydrophones are chosen for the array development. In this case, a single-mode fiber wound on a compliant metallic shell will be used as the transduction mechanism in an optical interferometer configuration. The interferometric phase modulations corresponding to the acoustic

signature can be demodulated using an electronic demodulator known as an interrogator. The three major subsystems of the fibre-optic hydrophone array are: (i) the laser source; (ii) the interferometric mandrel sensing element; and (iii) the interrogator. The array and associated subsystems are designed in a modular concept, such that a large array can be realised with the addition of modules and operated through a synchronization system. The sensors and subsystems are environmental-cleared under stringent conditions suitable for even in submarine operation.

Features

- Totally electrically passive at the wet end
- Minimum cabling
- No EMI interactions
- High-sensitivity interferometric sensors
- Minimum detectable pressure close to DSSO level
- Reliable and long life

Specifications

Considering 32 sensor module with one laser and interrogator

Sensor Array

- Acoustic sensitivity : Better than -135 dB. ref. 1V/µPa
- Acoustic bandwidth : Up to 10 kHz
- Depth of operation : Up to 600 m, Can be designed for 1000 m also
- Sensor dimensions : Φ - 30 mm to 60 mm & Length: 50 to 100 mm (variable based on bandwidth)
- Encapsulation : Polyurethane moulding
- Directivity : Omni-directional (in azimuthal plane)
- Array format : Various form factors possible (Planar, Linear, Conformal, Cylindrical, etc.)
- Sensor separation in array : Based on maximum acoustic frequency aimed

Laser Source

ESS-qualified integrated laser system card with pulsed output for TDM applications, with VME backplane for a standard 19" rack, and an extreme low-noise master laser mounted in a noise isolation chamber with MIL standard fibre-optic connectors.

- Dimension : 220 mm (L) X 260 mm (H) X 40 mm (W)
- Power input to cabinet : 230V 50 Hz AC
- Power consumption : < 60W
- Switching speed of laser pulse : < 5ns
- Pulse duration : Variable from 10 ns – few 100 µs
- Pulse repetition rate : Variable from 1 Hz to few 1000 kHz
- Maximum optical power output : ~150 mW

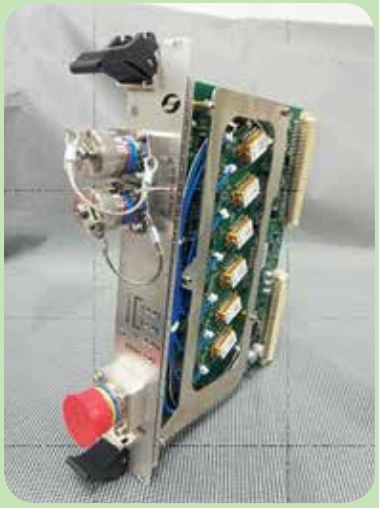
Interrogator System

FPGA-based system architecture; ESS-qualified interrogator system with VME backplane for standard 19" rack.

- Minimum Phase Noise : 30 µrad/rt. Hz in band > 1 kHz
- No of DWDM channels : 4
- No. of TDM channels : 8 (in each DWDM channel)
- Dimension : 160 mm (L) X 233 mm (H) X 40 mm (W)
- Power input to cabinet : 230V 50 Hz AC
- Power consumption : < 40W
- Output : Gigabit Ethernet

32 Mandrel Hydrophones Arrayed in a Planar Form

Master Laser Assembly in Noise Isolation Chamber



Integrated Laser System

Interrogator Card

Acoustic Vector Sensor for Directional Sonobuoys

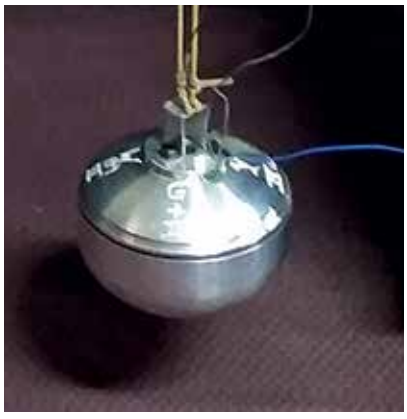
An acoustic vector sensor is a compact sensor developed for expendable directional sonobuoys. This sensor is developed for very low-frequency applications for airborne ASW operations. The sensor comprises two orthogonal dipoles in the azimuth plane and one collocated omni-hydrophone. The dipoles measure the acoustic vector variables, and the omnidirectional hydrophone measures the acoustic pressure. From this information, acoustic intensity is computed, and the direction of arrival of the incident sound is estimated. Using multiple acoustic vector sensors, the range and position of the target are accurately estimated.

Features

- Compact sensor suitable for 'A' size sonobuoy
- Low frequency band
- Spheroid geometry

Specifications

Parameters	Values
Resonance frequency	500 Hz (Nominal)
Frequency band	5 Hz – 2.5 kHz
RS (dB// V/µPa)	≥ -205 @ 1 kHz
Capacitance at 1 kHz	12 nF (dipole)
Directivity	Figure-of-eight
Dimensions	Φ 100 mm
Operating depth (max)	300 m
Weight in air	1.2 kg
Cable connector	Two 2-core telemetry cable



Standalone Acoustic Vector Sensor

Unlike scalar pressure sensors, acoustic vector sensors measure the amplitude and phase of acoustic particle motion in a dedicated direction using an

omni-directional sensor and three orthogonally co-located directional sensors. The amplitude of the signal output of each directional channel of a vector sensor is proportional to the orientation relative to the direction of acoustic pressure propagation. The ratio of the signal amplitudes between two directional channels and the cross-spectra between the vector sensor omni and directional channels enable one to estimate the bearing to the source from a single point measurement.

Features

- Offers significant operational advantages over traditional hydrophones by providing both amplitude and phase of the acoustic signals
- Improved performance with a smaller array aperture as compared to the conventional scalar hydrophone array

Specifications

Specifications	Value
Sensing element	Omni-directional hydrophone and tri-axial accelerometer
Buoyancy	Neutral
Hydrophone sensitivity	-196 dB (ref. 1 V/uPa)
Accelerometer sensitivity	500 mV/g
Operation frequency	Up to 6 kHz

Acoustic Vector Sensor

SONAR POWER AMPLIFIERS

GaN-based 4-Channel HF Class-S SMPA Card

The GaN-Based 4-Channel HF Class-S SMPA card is a state-of-the-art Sonar power amplifier designed to convert the DC power into high-frequency AC for underwater acoustic transducers efficiently and effectively. This PA is using Class-S amplification topology, and it is incorporating GaN-based devices taking efficiency considerations into account. With insanely fast advancements in technology, the rate of improvement in silicon power MOSFETs has decelerated, nearing their theoretical bounds. Gallium nitride is a better trade-off for Si-based devices due to its superiority in high-temperature operation, high switching frequencies, and efficiency. This system is designed to generate high-frequency square-wave signals from a battery power source. Power amplifiers are assembled in a 6U PCB plug-in card, which features four GaN-based class-S PA channels, each capable of delivering 150W of power at a frequency of 500 kHz. The output of each channel is connected to a transformer and filter assembly, which boosts the voltage and filters the harmonics present in the output. The power density of this amplifier reaches an impressive 10 W/inch^2, demonstrating its high performance. A Multiple Input, Multiple Output (MIMO)-based transmission scheme for enhancing the resolution of the side scan image is planned on the same hardware unit as part of the futuristic studies.

Features

- Compact and stackable PCB
- Supports standard 6U VME form factor with plug-in configuration
- Rugged design to meet MIL standard 461E, ESS
- Compact dimensions to suit space-constrained platforms
- Inbuilt FPGA-based signal generator
- Waveform generation supports up to 1 MHz (CW, LFM)
- Supports transmission parameter configuration via debug PC
- Supports FPGA configuration updates using JTAG
- Inbuilt continuous digital health monitoring module for PA card

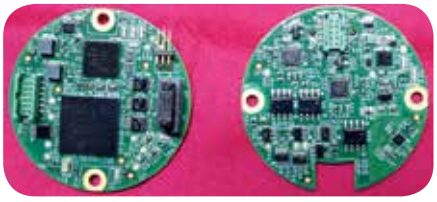
Specifications

Dimensions	: 233 mm (W) x 15mm (H) x 160 mm (D) [Plug mate]
Number of PA channels	: 4
Operating frequency	: upto 1MHz (Fundamental switching)
Maximum pulse length	: 10 ms
Input Power supply	: 150 - 200V DC
Output power/channel	: 150 VA
Protections	: Over current, Over voltage, Safety fuses
Waveform generation	: Artix 7.0 FPGA-based inbuilt waveform generator
Health monitoring	: Temperature, power rails
Communication	: Digital I/O with optical isolation

Designed and Developed by NPOL (with design consultancy from the industry partner M/s Mistral Solutions, Bangalore)

Wideband Feedback Controlled Power Amplifier

The wideband feedback controlled power amplifier is a complete DAQ on a coin-sized PCB. The unit has an extremely low-noise pre-amplifier, analog gain circuits, a digitally controlled variable gain amplifier, a programmable anti-aliasing filter, an analog-to-digital converter, and a command and data RS 485 4-wire link. The complete system consumes a power of approximately 0.25 W during operation. The command and data interface is implemented over a custom interface over 4-wire RS 485 that enables up to 14 such units to be bussed together over a single 4-wire link.



S. No.	Parameters	Value
1	Sampling frequency	Programmable to > 100 kHz
2	Data resolution	16 bit
3	Self-noise level	< 5 nV/√Hz
4	Power consumption	< 0.25 W
5	Dimensions	Ø25 mm
6	Weight	< 10 g
7	Interface	RS485
8	Gain	Programmable -20 dB to +40 dB
9	Cutoff	Programmable 1 KHz to 10 KHz
10	External synchronization	Supported
11	Bus-able	Yes
12	Single supply	Yes
13	Supply voltage	6-9 V DC
14	Pressure tolerant	Yes

The PCB has both analog and digital circuits along with high-speed interfaces in the same small area. Hence, the design has been done extremely carefully to minimise artifacts and preserve the signal quality of the sensitive analog inputs.

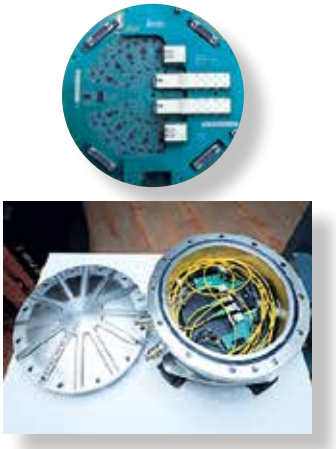
SONAR SIGNAL CONDITIONING SYSTEMS

32-channel Data Acquisition system

The 32-channel data acquisition system is a Sonar front-end analog processing system. It provides 32 channels of acoustic data acquisition and processing. It is designed for front-end systems co-located with sensors in the wet end. It addresses the requirement for data acquisition from a large number of sensors distributed over a wide area. The system is capable of synchronising multiple units with a master sync signal. The system sends the conditioned, digitized data to the remote system for further processing through the Gigabit Passive Optical Network (GPON) interfaces. It also receives the commands from the remote system through the same interface, thus ensuring secure, faster, and flexible data transfer without EMI interference.

Features

- Distributed front-end with minimum cabling
- Ethernet telemetry over Fibre-optic cable
- Supports Gigabit Ethernet (GbE) as well as fibre-optic-based telemetry
- GPON-based telemetry and synchronization scheme
- Simultaneous sampling of a large number of channels
- Remote programming in an inaccessible area
- Provision to modify the application program and location ID remotely
- Provision to monitor the health status of the system
- Data and control data interface through a single SFP module
- Dual data/management port and power supply port for hot redundancy
- Compact dimensions to suit space-constrained platforms
- Designed to support systems with a built-in pre-amplifier



32-channel Data Acquisition system

Specifications

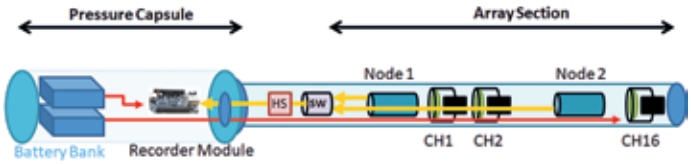
Physical dimension	: Circular with diameter of 190 mm and height 60 mm
Thermal cooling	: Conduction cooled operating temperature range: -20°C to +70°C
Power input	: 200V DC
Signal input	: Differential analog input
Signal output	: Digitized data in GbE or GPON format
Gain control	: Digital Potentiometer with individual/simultaneous channel gain adjustment control
Synchronisation scheme	: 1Hz pulse with 50 % duty cycle from GPON ONT
Connectivity	: MIL 38999 underwater connectors for signal and power input, Gigabit rate RJ45 or SFP for data in/out.
Pressure test	: Can withstand pressure up to 60 bar
Thermal test	: Stable at less than 70˚C
Signal Conditioning unit	: Circular with diameter of 340 mm and height of 200 mm

Designed by NPOL, Development Partner: Ms. Mistral Solutions Pvt. Ltd, Bangalore

BaLRAM

BaLRAM is a 16-channel autonomous data recording linear acoustic receiver array that is intended for lake or sea acoustic signal recording. BaLRAM has 16 uniformly spaced hydrophones, and the data from these hydrophones is digitised and recorded inside the module itself. The module also has an inbuilt power source that supports operation for more than 8 hours. BaLRAM can also be optionally fitted with an Attitude and Heading Reference System (AHRS) and depth sensor module so as to log its own orientation and depth during deployment. The system is completely untethered, and only mechanical tethering is required for its operation.

The electronics are based on low-data acquisition systems that have already been developed for various projects and are proven to be part of systems already inducted by the Navy. It has been deployed and operated successfully at sea and freshwater lakes as part of various experiments.



BaLRAM

Features

- Battery operated
- Commercial 5V battery bank is used
- COTS ARM based board used to store data on USB drive
- Gain can be set in beagle bone
- Uniform linear spacing for 16 channel
- MEMS-based AHRS sensor (Optional)
- Depth sensor (Optional)
- Power consumption < 7 W
- Internal battery banks supports operation of more than 8 hours
- Can operate up to depth of 450 m
- NPOL developed electronics, housings, and pressure chambers
- Manufactured in-house

Specifications

S. No.	Parameter	Value
1	Power source	Battery bank, 5V, 20000 mAh
2	Operation	Autonomous, Untethered
3	Data storage	USB drive, 64 GB+ (expandable as required)
4	Element spacing	4 KHz
5	Sampling frequency	25600 Hz
6	Endurance	12 hours (Using internal batteries alone)
7	Power consumption	< 7 W
8	Pressure rating	300 m
9	Manufacturer	NPOL
10	Equivalent noise pressure	< SS1
11	Simultaneous sampling	Yes
12	Data interface	Ethernet for real time monitoring and USB storage
13	Environment	Underwater (fresh water and marine)
14	Data storage	Generic binary file
15	Dimensions	Ø110 mm x 3000 mm
16	Weight	~ 40 kg

BaLRAM is expected to be useful for all kinds of acoustic, oceanographic, and commercial applications. The power and storage section is easily expandable, which will help tailor the system to specific applications. All major vendors are indigenous, including the vendor for the hydrophones. Presently, there are no indigenous vendors who provide equipment for underwater measurements or applications. The major players are all based in the US and Europe. The availability and cost-effectiveness of imported equipment are major risks associated with indigenous underwater activities.

Integrated Ethernet Node PCB

The Integrated Ethernet Node (IEN) is a mixed-signal data acquisition cum telemetry module used in towed arrays that converts analog sensor data to ethernet packets. The PCB also includes a heading and roll sensor, an Ethernet switch for Daisy Chaining, programmable gain stages for amplification or attenuation, and depth conditioning circuitry. Data from nine hydrophone channels is acquired simultaneously, digitized, and converted to UDP over IP over Ethernet. The engineer sensor data is also embedded in the same Ethernet packet.

The design was implemented in 2 PCBs (signal conditioning PCB and controller PCB), as shown in Fig. The PCBs should be sandwiched one above the other using connectors. Combined the features of multiple PCBs in a conventional towed array into a single design, thereby reducing the wiring complexity. Reduced wiring between PCBs reduces signal integrity issues, overall weight, cost, development, and testing time compared to individual PCBs. The use of connectors aided in wiring ease as opposed to conventional pigtail soldering.

IEN PCB

Features

- Ethernet conversion of 9 analog channels
- Accelerometer cum magnetometer sensor for roll, heading-and-pitch measurement.
- Interface for depth sensor
- Fine steps of Gain/Attenuation
- 3 port ethernet switch for multiplexing ethernet data in an array
- Switched capacitor anti-aliasing filter-cut off programmable in fractions
- External interface through connector

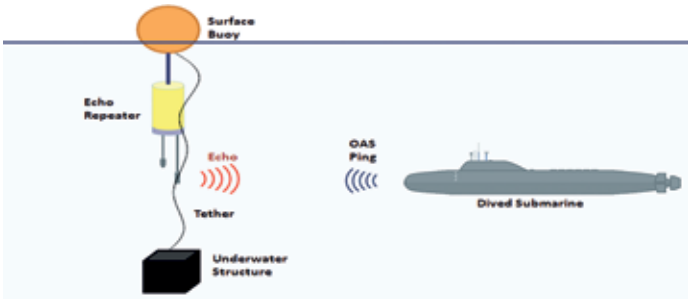
Specifications

- Dimension - 78 mm x 28 mm
- Current from 8V -170 mA
- Data rate- 1.9 Mbps
- Ethernet Switch-managed 3 port Layer 2
- 255 gain/ attenuation steps using Digipot

Application: Towed Array Ethernet Node

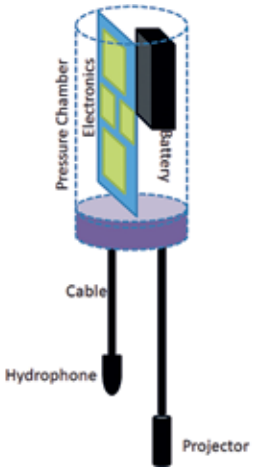
Echo Repeater

An echo repeater is required for underwater trials for the dived submarine, AUV, or ROV to safely locate a submerged underwater structure. The portable miniature echo repeater will be attached to the underwater structure, which will reply to the echo from the Sonar array onboard submarine and thus help navigate it safely around the structure. The system operates from a battery, draws low power, and generates sufficient SL so that the submarine might reliably detect it.



Operation Scenario

The system consists of a hydrophone and a projector connected to a pressure chamber, which houses the electronics and the power supply (batteries). The system is expected to operate at a depth of around 50 meters. The unit uses the transducer elements already being used on various platforms.

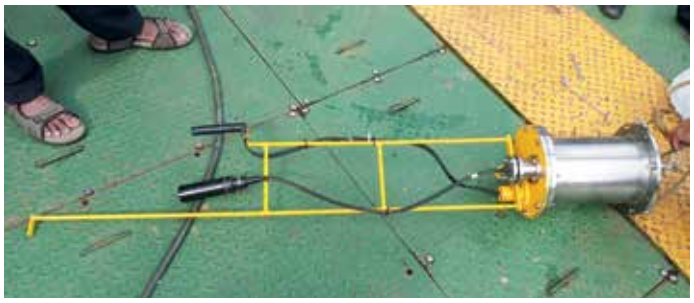


Echo Repeater

The system developed can be programmed for various sound detection levels and can be turned up to some level for a particular frequency of operation.

Specifications

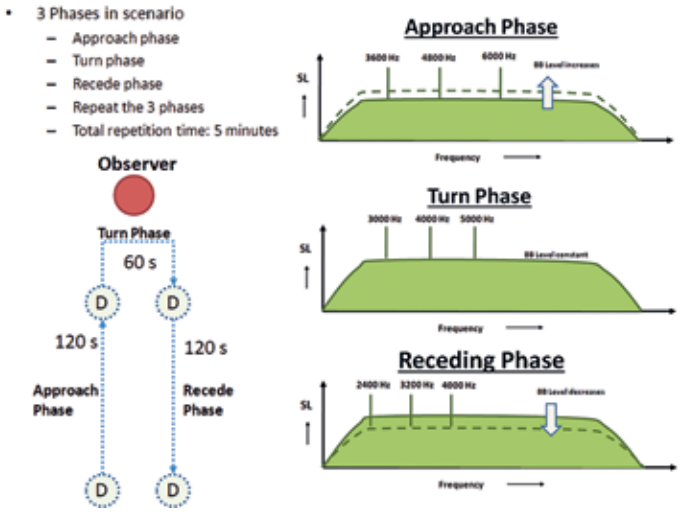
S. No.	Parameters	Value
	Transmission Parameters	
1	Transmitted frequency	Programmable
2	Transmitted pulse width	Programmable
3	Transmitted SL	Programmable
	Reception Parameters	
1	Receiver MDL (SL)	Programmable
2	Received pulse width (at MDL)	Programmable
	Mechanical Parameters	
1	Weight	< 25 kg
2	Dimensions	Ø40 mm x 40 mm height
	Power	
1	Power consumption	< 1.5 W
2	Endurance	72 hours
	Transducers	
3	Hydrophone	Proven transducers
4	Projector	Proven transducers



Acoustic Spoofer

It is a programmable sound source that can be configured to mimic the exact actions of a ship or a submarine according to very elaborate scenarios. The system is designed to be cost-effective and high-endurance. The depth of deployment can be programmed at launch. It can be used as a decoy as well as a target for Sonar exercises.

Given below is a scenario with three phases and the corresponding pressure levels generated during each phase plotted versus frequency on the horizontal axis. Here, the spoofer mimics a submarine that initially approaches the observer (due to increasing signal levels and Doppler shift), then stops and then moves away.



Specifications

S. No.	Parameters	Value
1	Acoustic frequency	Programmable 1 KHz-9 KHz
2	Source level	Programmable
3	Transmitted SL	Programmable
4	Tonals	4 No's, Programmable
5	Modulation	Possible
6	Shaft and Blade modulation	Possible
7	Time varying amplitude	Possible
8	Broadband shape	Programmable
9	Power consumption	< 3 W
10	Power source	Batteries (COTS)
11	Electrical tether	Not required
12	Weight	< 8 kg
13	Dimensions	1000 mm x 140 mm x 140 mm
14	Pressure rating	35 m (can be increased)

The entire system has been made so as to enable ease of deployment and operation at sea. Since the device can operate untethered, it can also be deployed from a small buoy.

All the items used are indigenously developed with local vendors.

Autonomous Recorder

The autonomous recorder is indigenously developed measurement equipment to record very feeble underwater acoustic signals. It is being developed and tested using indigenous vendors. The system is a small, cost-effective replacement for imported systems presently being used in the country. The system consists of a low-noise hydrophone and data acquisition system, battery-powered power conditioning circuits, a remote activation mechanism, and a protective housing. Presently, the system is being developed with a comparatively low-pressure housing based on acrylic, but it can be easily modified for higher depths.

Specifications

S. No.	Parameters	Value
1	Sampling frequency	Programmable to >100 KHz
2	Data resolution	24 bit
3	Self noise level	< SS0
4	Endurance	> 48 hrs
5	Internal battery	Yes
6	Internal depth sensor	Yes
7	Real Time Clock	Yes
8	Configurable sampling	Yes
9	Remote ON/OFF	Yes
10	Weight	< 2 kg
11	Electrical tether	Not required
12	Protective cage	Yes
13	Dimensions	600 mm x 100 mm x 100 mm
14	Pressure rating	35 m (can be increased)

9-Channel Analog-To-Ethernet Node

The Analog-To-Ethernet (ATE) converts analog signals given to the inputs into digitised data packed into UDP/ IP/ Ethernet packets. The board operates from a single DC supply. It is well suited for battery power applications as it features low noise and low power circuits. The board is realised as two PCBs stacked on top of each other to reduce real-estate requirements. The board has been extensively used in various naval systems and has been in production. The ADC inputs also support synchronised sampling and an external trigger for sampling. There is an

inbuilt synchronisation mechanism that allows multiple such units to be synchronised. There is also a pressure capsule with o-ring sealing available for the DAQ, if required.

Specifications

S. No.	Parameters	Value
1	Sampling frequency	Programmable to >100 KHz
2	ADC resolution	16 bit
3	No. of channels	9
4	Power consumption	< 2 W
5	Dimensions	75 mm x 32 mm
6	Connectors	Micro-connectors x 2
7	Interface	Ethernet, RS485
8	Gain	Programmable -20 dB to +40 dB
9	Cutoff	Programmable 1 KHz to 10 KHz
10	External synchronization	Supported
11	Sensors	Voltage, Temperature
12	Single supply	Yes
13	Supply voltage	6-9V DC
14	Pressure tolerant	Yes

The unit has been widely used and is in production for more than 8 years and updated versions are being regularly developed. It is made to be easily scalable.

Indigenous Ultra-Compact DC-DC converter

The indigenous ultra-compact DC-DC converter is used in space-constrained applications requiring conversion of 240–310 V DC to a lower voltage, like 8 V. The output is also trimmable. The unit has been custom-made for NPOL specifications by an indigenous vendor.

Specifications

S. No.	Parameters	Value
1	Dimensions	65 mm x 22 mm x 15 mm
2	Weight	< 65 g
3	Input voltage	270 V DC nominal (240-320 V DC)
4	Output voltage	8 V (Trimmable)
5	Output Power (max)	30 W
6	Cooling method	Conduction
7	MTBF (hours)	150000 hours
8	Enclosure finish	Yellow Chromate
9	Input /Output Connectors	Pin Ø1 mm
10	Over voltage protection	Yes
11	Overload protection	Yes
12	Over temperature protection	Yes
13	Reverse polarity protection	Yes
14	EMI Filtering	As per MIL-STD-461E
15	Efficiency (at Full Load)	> 82 %
16	MIL-STD-810F Compliant	Yes

The unit also has very low ripple at the output. There is also an input over-voltage protection for 450 V (50 ms). The output is isolated, with an isolation rating of 500 volts. There is also a pressure capsule available for the module, if required.

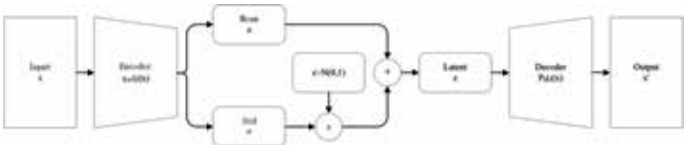
SONAR DISPLAY AND INFORMATION AND PROCESSING TECHNOLOGIES

Ultra High Resolution Human Machine Interface

The main function of the Sonar display is to present Sonar data to the operator on various information pages. To reduce the operator's memory load and to provide a high level of situational awareness in a multi-sensor environment, a 4K resolution HMI is introduced. The display resolution is Ultra High Definition (3840x2160). Compared to conventional Sonar displays (resolution 1600x1200), the 4K display contains about 4 times more information. It is currently used in the latest integrated Sonar suite for strategic platforms.

AI-based Underwater Passive Target Classification System

Underwater passive target classification is a challenging task due to the intrinsic complexity of the radiated noise from the target. It is treated as an open-set classification problem, where quite often test data of those classes that were not present during the training phase is encountered. Variational Auto Encoder (VAE), being a generative model, can perform the above task with less amount of data. Its beta version, having a hyper-parameter beta on the VAE, produces better output even in complex data sets. Mel-frequency Cepstral Coefficients (MFCCs) form the feature set.



As the availability of sufficient and quality data is a real concern for testing defence applications, a model that can generalise effectively with less amount of data, such as this, is an ideal choice for classification tasks and is presently being tried out with recorded sea trial data from Sonars.

Generic Fault Detection System

A Fault Detection System (FDS) is used to detect and localize faults in a Sonar system. The FDS receives health parameter information from different SONAR subsystems, analyses it, and determines the health of each subsystem.

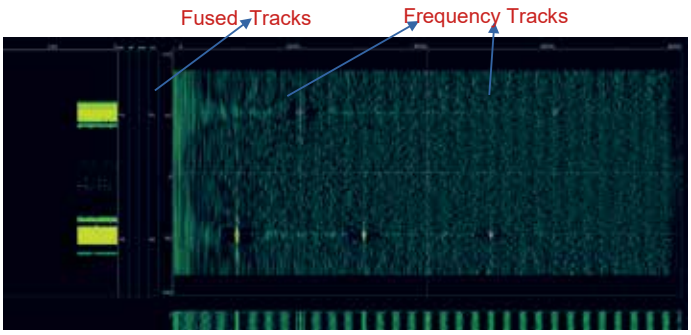
Sample Key Value Pair Code

FDS-GUI – Detailed Health Information

A generic interface is defined between FDS and subsystems. Health parameters of subsystems are defined in a generic way using key-value pairs. The key-value pair format is common for all subsystems. Each key-value pair contains a key, parameter description, data type of parameter, unit of parameter, value of parameter, health status of parameter, and criticality status of parameter. The key must be unique within a subsystem to identify a specific health parameter of that subsystem. The scheme is used in the latest Sonar projects.

Multi-frequency Line Tracking

Multi-Frequency Line Tracking (MFLT) is a system developed to track multiple frequencies of the same target. Once Low Frequency Analyser and Recorder (LOFAR) or Detection of Envelope Modulation on Noise (DEMON) processing of the signal has been performed, frequency vs. azimuth information will be obtained. The method can be applied to the above information to obtain bearing-frequency tracking, which can accommodate multiple frequencies from the same target. The method comprises Kalman filter-based tracking on the frequency and a bearing-based model. MFLT has been successfully tested in submarine Sonar projects.



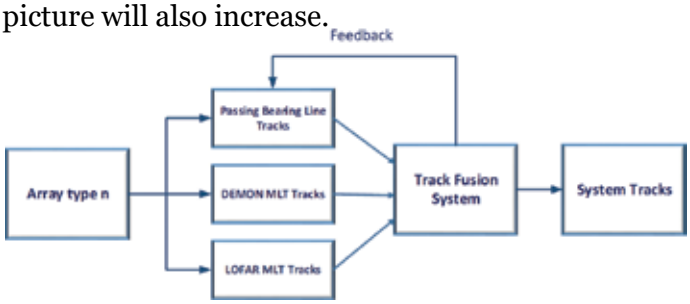
eXpress Data Path-based Generic Digital Data Recorder

Digital Data Recording (DDR) of sensor data during sea trials of Sonars is essential for system analysis, enhancement, and training. A generic DDR software solution is designed by deriving the timing information of Ethernet frames through independent timestamps, thus providing a single solution for all Ethernet-based Sonar systems. The recording solution is realised on high-end servers running Linux with the eXpress Data Path (XDP) library for achieving high throughput data rates in the order of 10 GB/s. Path XDP is a new in-kernel programmable layer that operates at the L2-L3 layers. It is not a fully kernel bypass solution like DPDK and Netmap but an in-kernel fast path. The integration of XDP with the kernel makes it unique and powerful.

Compared to user space driver kernel bypass solutions like DPDK, XDP has many features, like providing kernel stack features and kernel security, and it does not require specialized hardware or resources exclusive to packet processing. So, for Sonar applications that require handling high data rates, XDP-based DDR is employed.

Underwater Passive Multi-sensor Multi-track Fusion System

In a distributed multi-sensor underwater Sonar system, individual sensor processing systems will produce sensor-level tracks, and they will send their tracks to a central system for fusing the information to produce system-level tracks. The Sonar operator requires only a concise view of the tactical scenario, which can be provided by the system-level tracks. The track fusion system is a central entity that fuses the sensor-level tracks produced by the passive multi-sensory system to form system tracks. When the sensor-level information is diverse, the challenge of fusing the information to provide the target-level picture will also increase.



EMBEDDED SYSTEMS

Intel Xeon-D 1559-based Signal Processing 6U VPX SBC

NPOL's Single Board Computer (SBC) 'NPOL-XEON1559-V1-2022' is a 6U VPX SBC-based on the Intel Xeon-D 1559 embedded server-class chip that delivers high performance. The SBC is designed for use in defence applications where High-Performance Computing (HPC) requirements with high reliability are expected. The Xeon-D 1559 SBC offers 12 dual-threaded CPU cores that can go up to 2.1 GHz max frequency with an integrated AVX512 advanced SIMD engine, graphics chip, PCIe 4.0, USB 3.0, SATA, 1/10G Ethernet, etc. The board also has a Xilinx Kintex-7 FPGA. The board is supplied with dual redundant SPI

boot Flash and Red Hat Enterprise Linux (RHEL). Other supported operating systems are VxWorks, LynxOS, and Microsoft Windows.

NPOL-XEON1559-V1-2022 SBC

PCB-Assembly

Specifications

- Intel Xeon-D 1559 processor 12 core, Dual Thread 64-bit, 18 MB Cache with turbo boost up to 2.1 GHz
- 64 GB DDR4 SDRAM with ECC, soldered
- 256MB NOR Flash, dual redundant BIOS
- Ethernet – 6 x 1 GigE, 2 x 10G
- Multiple USB 3/2, SATA 3.0 ports, 128 GB SSD NAND, NVME SSD 1TB
- Audio, video, on-board RTC, temperature and power monitoring sensors
- Kintex-7 FPGA – Multiple differential and single ended IO lines
- +12V operation
- Dimension: 233 mm x 160 mm, 1.0 in (5HP) pitch
- Operating Temperature: -20°C to +55°C

Targeted Applications

- Sonar and Radar signal processing
- Display, audio and image processing
- Sensor data recording
- Node for high performance, multicore, and distributed computing

Low Power Zynq Ultrascale+ MPSoC-based 3U VPX SBC

NPOL's Zynq Ultrascale+ MPSoC-based SBC 'NPOL-EP-ZYNQSBC3CC-V1-2022' is a 3U VPX conduction cooled SBC-based on Xilinx Zynq Ultrascale+ MPSoC FPGA, intended to provide high-end computational capability for projects which are constrained by Size, Weight and Power (SWaP). SBC is engineered for Defence markets to cater for high performance computing requirements for high endurance stand-alone systems powered from batteries like AUVs and wide area sensor networks as well as for sheltered systems like ship/submarine/airborne SONARS. Zynq Ultrascale+ MPSoC architecture offers two ARM A53 cores along with two real-time R5 cores in the processing system (PS) and a wide range of configurable blocks like logic cells, CLBs, Block RAMs, Ultra RAMs, DSP Slices, high speed transceivers, DLLs, etc. As part of the Programmable Logic (PL) section. This board is highly recommended for realising highly parallel time-sensitive array signal processing applications. The board has high speed interfaces like four 1G BaseT, PCIe and USB 3.0.

SBC Solder Side

PCB Top Assembly

Specifications

- Zynq Ultrascale+ MPSoC FPGA XCZU9CG
- Two A53 cores and two R5 cores
- 8 GB of high speed DDR4x SDRAM for PS and 1GB for PL
- 128 MB serial NOR Flash
- 32 GB NAND Flash
- 1 TB NVME 2280 SSD
- Four 1G BaseT Ethernet
- GPIO, temperature, current and voltage sensors
- 6K logic Cells, 2K DSP Slices, 40 MB RAM in the PL section
- Dimensions: 100 mm x 160 mm, 1.0 in. (5HP) pitch
- Ambient operating temperature: -20 °C to + 55 °C

Targeted Applications

- Sonar and Radar signal processing
- Signal processing in SWaP constrained applications like AUV.

NXP QorIQ T4241-based Signal Processing SBC

NPOL's T4241 SBC is a 6U VPX SBC-based on NXP

Multicore QorIQ T-series SoC-based on 64bit Power architecture e6500 cores. This SBC is designed for use in NPOL SONAR projects aiming software portability and scalability. T4241 SoC enables this SBC with high performance computing capability along with power efficiency (performance per watt), which is the main strength of PowerPC series processors. Power efficiency coupled with scalable cores makes this SBC an ideal choice for high performance multicore rugged computing applications. The T4241 SBC offers 12 dual threaded CPU cores which can go up to 1.8GHz max frequency integrated with 12 Altivec advanced SIMD engine, PCIe, USB, SATA, 1/10G Ethernet, etc. The board is supplied with boot loader and embedded Linux on a reliable NOR boot Flash. Both air-cooled (NPOL-ES-T4241-V1-XX, 2018) and conduction cooled (NPOL-236-T4241CC-V1-2020) versions are available.

Conduction Cooled T4241 6U VPX SBC

Air Cooled T4241 6U VPX SBC

Conduction Cooled T4241 SBCs in Signal Processing ATR

Specifications

- CPU:- NXP T4241, 12 Dual threaded 64bit Cores, 128bit Altivec SIMD per core
- 6MB shared L2Cache
- RAM:- 12GB DDR3L (three independent memory controllers)
- Flash:- 256MB NOR, 64GB SSD, SDCARD slot
- Buit-in RTC, Watchdog Timer, XMC slot - PCIex8
- Temperature, Current & Voltage sensors
- Kintex-7 FPGA :– with 2GB DDR & BOOT Flash
- Dimension:- 6U VPX
- Operating Temperature:- -20°C to +55°C
- OS: - Embedded Linux with Xorg server for graphics
- Signal Processing libraries:- NPOL SSPL, FFTw, BLAS,MEPL

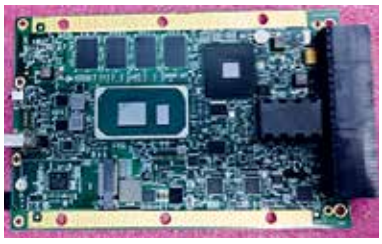
Targeted Applications

- Sonar and Radar Signal processing

Next Gen Unified Signal, Information and Display Processing 3U VPX SBC

NPOL's SBC 'NPOL-EP-I71185SBC3CC-V1-2022' is a 3U VPX SBC based on an Intel 11th Gen (Tiger Lake UP3) processor that is built on Intel 10 nm process technology and delivers high performance and responsiveness at low power. SBC is engineered for defence markets to cater for high-performance computing requirements, with a peak computational power of ~ 740 GFLOPS. It supports time-sensitive applications and has the capability to run multiple workloads, including AI and deep learning applications. The i7-1185GRE processor offers four dual-threaded CPU cores that can go up to 4.4 GHz max frequency with an integrated Platform Controller Hub (PCH), integrated Intel® Iris® Xe Graphics with up to 96 EUs, PCIe 4.0, and a USB C-type port. The board has four Time Sensitive Networking (TSN) capable 1G BaseT and one 10 G Ethernet interface. The board is supplied with Intel Slim Boot Loader (SBL) and Red Hat Enterprise Linux (RHEL). Other supported operating systems are VxWorks, LynxOS, and Microsoft Windows.

Conduction Cooled SBC



PCB Assembly

Specifications

- Intel Core i7-1185GRE, 1.8GHz with turbo Boost upto 4.4GHz, AVX 512
- 16 GB of high speed LPDDR4x SDRAM
- Multiple USB 3.2 ports
- Stereo audio
- 64 GB SLC SATA NAND Flash
- 1TB NVME 2280 SSD
- Dual redundant BIOS
- Support up to 3 Displays with resolution up to 4096 x 2304 @ 60Hz
- TSN capable four 1G BaseT Ethernet and Single 10 G (KR)
- On-board Watch dog timer, GPIO, Temperature, current and voltage sensors
- Dimensions: 100 mm x 160 mm, 1.0 in (5HP) pitch
- Ambient operating temperature: -20 °C to + 55 °C

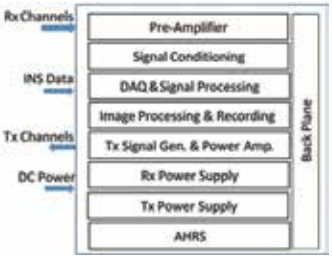
Targeted Applications

- Sonar and Radar Signal processing
- Display and image processing
- AI Inference processor
- Node for high performance computing
- Signal processing in SWaP constrained applications like AUV

Integrated Electronics for Next Generation Side Scan SONAR

NPOL has developed integrated electronics for next-generation Side Scan Sonars (SSS). The modular architecture is designed for use in multi-beam SSS, MIMO SSS, and Synthetic Aperture Sonar (SAS). Integrated electronics includes receiver array pre-amplifiers, signal conditioning electronics, data acquisition and signal processing electronics, image processing and recording electronics, transmit signal generators and power amplifiers, transmit and receive power supplies, an Attitude and Heading Reference System (AHRS), and an underwater enclosure. The system can support up to 80 receive channels with a 40 MHz sampling frequency. It also supports four independent high-power, high-frequency transmit channels with precise synchronisation capability for MIMO operation. The system uses a Xilinx Kintex UltraScale FPGA KU060 for signal processing and a low-power Intel Core-i7 processor for image processing.

Integrated Electronics



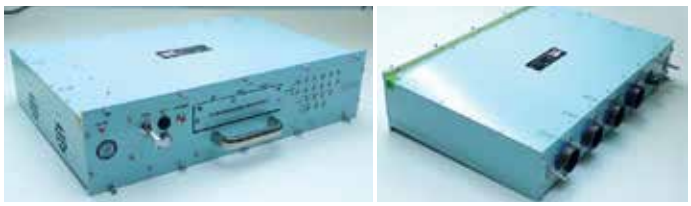
Block Diagram of the Integrated Electronics

Specifications

- Number of receive channels - 80
- Receive blocks - LNA, PGA, LPF, ADC
- Receive sampling frequency up to 40MHz
- Number of transmit channels - 4
- Transmit frequency - up to 2MHz
- Transmit power per channel - 150W
- Signal processor - Xilinx Kintex UltraScale FPGA KU060
- Image processor - Intel Core-i7
- Power consumption - 150W
- Operating temperature - -10 °C to +55 °C
- Overall dimensions - 320 mm x 300 mm x 280 mm
- External interface - GigEth
- INS interface - Eth/RS 485

Generic and Scalable PWM Transmit Signal Generator

NPOL's Transmit Signal Generator NP-TSG-1.X is a 2U rack-mountable Line Replaceable Unit (LRU) designed for generating various signals for transmission during active mode of SONAR operation. The unit is based on a QorIQ T2080 quad-core processor and a PWM generator module based on an Xilinx Artix 7 FPGA. The unit is designed to interface signals with class D and class S switched-mode power amplifiers. 160 differential discrete IOs generate signals for driving and controlling power amplifiers.



NP-TSG-1.1 Front and Rear View

Specifications

- High resolution PWM signal generation on 144 differential lines
- Scalable with multiple units (sub-micro second synchronization between multiple units achieved using dedicated sync lines)
- Support for various waveforms viz. CW, FM (stepped, Linear, Hyperbolic, and Sinusoidal), combination of these and pulse trains
- PWM signal generation for UCS viz. voice, telegraphy, message and data
- Precise transmit beamforming (using delays at 12.5 ns resolution)
- Support for various array geometries (linear, cylindrical, planar or any arbitrary geometry)

Hardware

- CPU: NXP QorIQ T2080 , FPGA: Xilinx Artix 7
- Memory: DDR3 (4 GB with CPU, 4 GB with FPGA) NOR Flash: 512 MB
- Dimension (NP-TSG-1.1) : 433 mm (Width) x 292 mm (Depth)
- Operating temperature: -20 °C to +55 °C
- Environmental : JSS 55555 Category N1, MIL-STD-461E

Targeted Applications

- Active Sonar, Mine and obstacle avoidance Sonar
- Underwater communication system

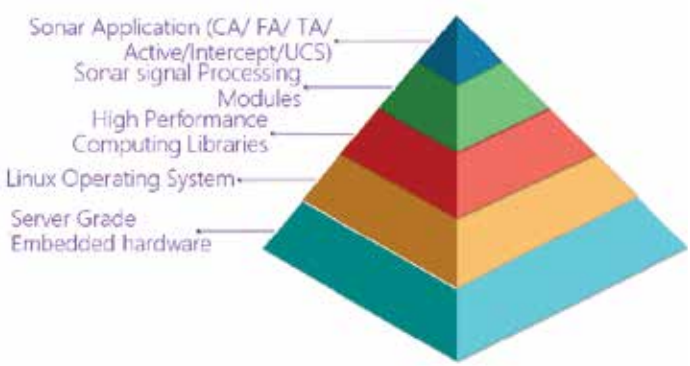
Signal Processing Systems on General Purpose Multi-core Processors

Hitherto, the signal processing sub-systems performing the signal processing of the Sonar signals from the transducer arrays were implemented in specialised hardware with specific computing resources or dedicated circuits. A reconfigurable, modular, and scalable computing technology for Sonar signal processing has been developed, which enables the signal processing subsystems to be developed without any fixed assumptions regarding how they are going to be integrated or run in final hardware.

Features

- A new, scalable architecture for signal processing systems
- Reusable system software across similar projects
- Distributed and easily reconfigurable at the system and application level
- Capability to handle high data rates from multiple types of arrays, even with different sampling domains
- Parallelism is achieved using multi-threading and threaded library functions like SSPL, Intel MKL, or the Intel IPP

Scalable applications for Sonar signal processing



Scalable Application Architecture

Sonar Signal Processing Library

Sonar Signal Processing Library (SSPL) is developed using a generic approach to support various Sonar architectures such as hull-mounted, towed array, submarine Sonar, DDS, etc. using an object-oriented design methodology. These libraries are developed with features to incorporate reusability, configurability, support for evolution, scalability, and platform dependence.

The Laboratory have developed a common framework to identify and develop library components for various Sonar signal processing systems. Sonar Signal Processing (SP) systems developed using configurable and well-tested signal processing libraries achieve significant improvements in terms of development time, testability, portability, maintainability, upgradability, and quality.

Library Modules Developed in SSPL Ver 1.0

Beamformer	Time domain, Frequency domain, conventional and adaptive
Detector	Replica correlator, Energy detector, Heterodyne correlator, Segmented RC
Tracking	Data associator, Kalman filter, PDA filter, Multiple/single measurement track
Post processor	Cubic interpolator, Quantiser (exponential, linear), Normalizer (2 pass, OTA, SAXA, TPM, split three pass mean)
Waveforms	Standard waveforms –CW, LFM, HFM, Pulse trains, Custom waveform
Transform	FFT, FFT_IP, FFTW
Windows	Rectangular, Chebyshev, Bartlett, Blackman....
Utility fns	Peakpick, beat, downsampler, etc.

AIRBORNE TECHNOLOGIES

Sonobuoy Receiver System for Airborne Sonar

A Software-defined Radio (SDR)-based multi-channel Very High Frequency (VHF) sonobuoy receiver system to receive signals from sonobuoy transmitters and link with the onboard processor in Anti-Submarine Warfare (ASW) aircraft was developed by NPOL in collaboration with Data Patterns India Pvt. Ltd., Chennai. It consists of a receiver unit, a preamplifier, and a receiver status indicator, as shown in Figure.

Sonobuoy Receiver System

The sonobuoy receiver is designed to receive the signals from Sonobuoys simultaneously and demodulate the wide-band signal. It also filters the demodulated signals using appropriate filters and feeds them to the on-board signal processor and display systems. The receiver system generates audio signals, Low-Frequency Analysis and Recording (LOFAR) signals, and demonstration of envelope Modulation on Noise (DEMON) signals for the eight channels. The data is fed to the signal processor for LOFAR and DEMON processing and display. The channel selections, self-tests, and system health monitoring are undertaken from the display console and GUI through an RS422 or Ethernet link.

This newly developed multi-channel sonobuoy receiver system is capable of receiving eight passive sonobuoy channels simultaneously. The frequency of the signals shall be in the 40 MHz bandwidth in the VHF range and be split into 99 sonobuoy channels. This has the ability to receive the RF signal spectrum dynamically, amplify the signals of interest, and remove interference.

Sonobuoy Homing System for Airborne Sonar

The Sonobuoy Homing System is designed primarily for operation in helicopters for homing

on to sonobuoys deployed at sea. Radio direction finding systems help the pilot navigate the aircraft towards distant beacon transmitters by monitoring the sense of direction towards the beacon, i.e., left/right and fore/aft. Such systems are commonly called homing systems. The position of the sonobuoy as 'Left' or 'Right' of the aircraft is derived from a phase comparison of the signals received from a two-antenna array designed to operate in the VHF range through the left/right switching unit. Similarly, the position of the buoy as 'Fore' or 'Aft' of the aircraft is derived from a two-antenna array by comparing the outputs from the fore/aft switching unit. The system provides a continuous indication of whether the buoy is ahead or astern of its relative bearing, as well as the bearing angle read out through the display processor of the SONAR. When the aircraft comes exactly on top of the sonobuoy, the system shows the 'ON TOP' indication.

NPOL has developed a SDR-based sonobuoy receiver system for the homing of sonobuoys deployed at sea in collaboration with Data Patterns India Pvt. Ltd., Chennai. It consists of a receiver unit, dual-channel left/right and fore/aft front-end switching units, and a control unit, as shown in Figure.

Sonobuoy Homing System

Frequency of the signals shall be in 40 MHz bandwidth in VHF range and is split into 99 sonobuoy channels. The signals are digitally down converted, filtered based on signal bandwidth and synchronously demodulated to obtain the homing information and shall be displayed in the homing indicators (GARMIN meters), which are fitted in the cockpit of the aircraft and operator console. The homing receiver system is interfaced with Display Processor ATR, to send and receive commands/status through RS422 as well as Ethernet interface.

Integrated Sonobuoy Receiver System for Airborne Sonar

A SDR-based multi-channel integrated sonobuoy receiver system to receive signals from sonobuoy transmitters and link with the onboard processor in ASW aircraft has been developed by NPOL in collaboration with Data Patterns India Pvt. Ltd., Chennai. It consists of a receiver unit and a UHF transmitter unit, as shown in Figure.

Integrated Sonobuoy Receiver System

The system is an integrated version of the VHF sonobuoy receiver with direction finding and UHF Sonobuoy command activation functionalities. The VHF receiver is used in aircraft for locating the deployed sonobuoys to detect underwater submarines, decoding the data from the sonobuoys, and command activation done through the UHF high-power transmitter, which is interfaced with the VHF receiver unit. This VHF receiver system will receive signals through predefined VHF band channels from the stationed sonobuoys and will report to the aircraft about the position data through a user-friendly GUI using a map overlay technique. The selected channel-decoded data is also available in audio output (I/Q) and can be used for recording purposes. The unit is realised in a highly integrated configuration as a single (full ATR, short form factor) unit with an

integrated RF preamplifier section, which is easy to install on various types of platforms without separate LRUs and its additional cabling interfaces.

The receiver is a 5-channel VHF receiver covering an overall bandwidth of around 40 MHz, which is divided into 99 sonobuoy channels. The 5-channel phase-coherent front-end section has the necessary filtering and amplification circuits to achieve the required sensitivity and dynamic range. For direction finding, the phase-coherent five RF channels that receive the signals from antennas will have a phase difference due to the spatial separation of the antennas installed in the aircraft. The final direction finding is accurately calculated using signal processing, and the same is displayed in the GUI.

Features

- 99 Frequency channels for sonobuoys
- Simultaneous processing of 32 sonobuoys
- Simultaneous direction finding of 32 sonobuoys
- UHF command activation of sonobuoys

TOWED ARRAY TECHNOLOGIES

Containerised Electrical Winch System

The containerised electrical-driven winch system developed is a robust and advanced winch system designed for the safe deployment and recovery of a passive twin-line towed array SONAR and its associated tow cable. The winch is engineered to be dependable, deliver high performance, and be user-friendly.

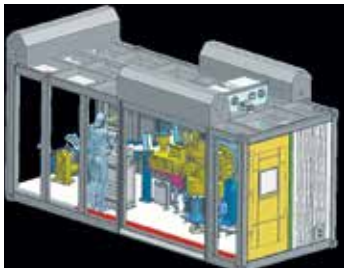
Both the twin-line towed arrays and cable can be wound on a single winch drum, offering compactness and enhanced reliability compared to a system with two drums. The system is designed to withstand all the acceleration and shock loads that it may encounter. The fitting of the entire winch subsystem into a 20 feet container provides ease of installation and dismantling onboard naval platforms and ensures compactness for the entire system.

Features and Benefits

- Compact and modular design using standardised and exchangeable components.
- Containerised design for easy integration with naval platforms
- Structure made of duplex stainless steel for higher and superior corrosion resistance
- Torque sensors for line pull monitoring
- A hybrid (optical and electrical) slip ring enhances the reliability of the system by eliminating intermediate electronics for data conversion
- An electrically driven level wind enables adaptability for tow cables of different diameters
- Dual electric motors and a drive-combining gearbox simultaneously cater to redundancy and compactness requirements
- Ensures low-noise operation
- The ergonomically designed operator console with advanced HMI, displaying operating parameters, enhances system and operator safety
- Incorporates sensors for safety interlocks, enabling automated and foolproof system operation

Specifications

- Dimension: 6.125 m (L) x 2.572 m (W) x 3.175m (H)
- Operational cable tension: 20 kN
- Survival sea state: 6
- Operational Power: 45 kW
- Winch Speed: 18 RPM



Optimum Decision-based Left-Right Ambiguity Resolution

Towed arrays suffer from the inherent property of being unable to distinguish targets from the left and right sides. The capability to resolve the left-right ambiguity is necessary for accurate target localization. Left-right (LR) ambiguity of the target is associated with any linear array of sensors with an omni-directional response. This limits the capability of discriminating between a detected target on the left or right side of the array. This problem arises from the fact that linear arrays with omni-directional sensors cannot distinguish between signals coming from any direction `θ' and their complementary angle (360 – θ). Therefore, the beam patterns also look similar (both on the left and right sides of the array), as shown below.

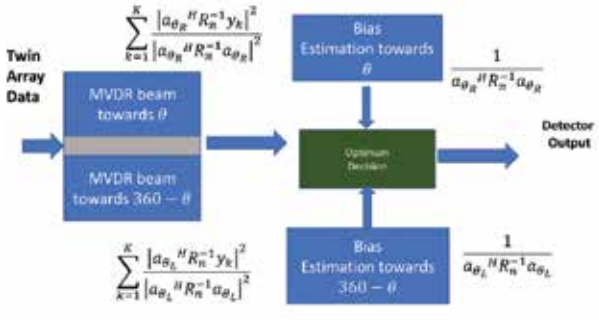
Left-Right Ambiguity in Linear Arrays

Cardioid-based L/R Ambiguity Resolution

Cardioid processing is a commonly used algorithm to resolve the left-right ambiguity of a towed array Sonar using triplet array. When the inter element spacing between left and right array is small, severe signal-to-noise-ratio (SNR) degradation occurs at the output of detector after cardioid processing.

Optimum Decision-based L/R Ambiguity Resolution

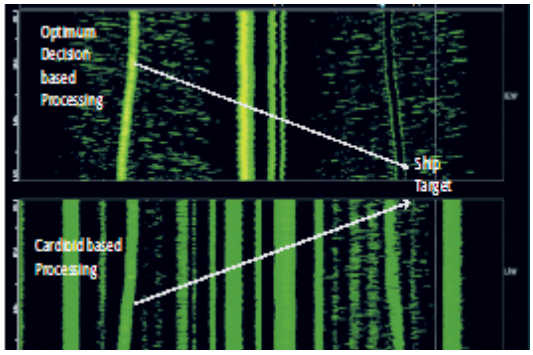
The NPOL introduced a new detector which minimizes the average probability of error. In this approach, the L/R ambiguity problem is formulated as a hypothesis testing problem. Let hypothesis H_0 denotes the hypothesis where target is in the left side. Similarly, H_1 denotes the hypothesis where target is present in the right side. A decision rule is taken which minimizes the average decision error. The beam-former output of left array and right array towards the direction θ are combined in an optimum way to decide the target side. There will not be any SNR degradation in decision-based L/R ambiguity resolution. The block diagram of the new LR processing is shown below.



Block Diagram of the Optimum Decision-based LR Processing

Comparison on Trial Data

The new LR processing is compared with the cardioid-based processing using sea trial data, as shown in Figure. The left-right ambiguity of the consort ship around the broadside is resolved properly in the new LR processing. Comparing with new processing, spurious peaks are visible in exiting LR processing, and the degradation in SNR is also visible in the waterfall display.



Comparison of Algorithms

Seamless Twin Array Connector

Twin arrays are a proven technology worldwide to address the LR ambiguity problem faced in towed SONAR systems. A twin array is a linear sensor array with two towed arrays towed alongside. Each sensor array consists of acoustic and engineering sensors and their conditioning electronics, which are mechanically packaged in housings and jacketed inside a flexible polyurethane tube filled with oil. The total length of each leg of the towed array is 30 m.

The twin array has to be towed horizontally, and both arrays should maintain constant array separation from the fore-end to the aft-end of the twin array. This is possible with the introduction of a seamless twin-array connector with a streamlined shape to minimize disturbances to the flow. The electrical connections between the tow cable and sensor array are achieved by a cable harness with a set of electro-mechanical connectors.

Seamless Twin Array Connector

Twin array integrated with seamless twin array connector

Twin Array During Deployment and Towing on-board MV Kurathi

Features

- Enables parallel towing of two towed arrays
- Easy assembly and removal of Seamless twin array connector (line replaceable)
- Accommodates inherent twist in tow cable by ± 450
- Compact and low weight for easy handling onboard ship
- Pressure tight configuration upto 45 bar

Specifications

- Connector diameter: 57 mm
- Array separation: 300 mm
- Tow load: 2000 kgf
- Electrically and mechanically mate-able with cable interface module and towed arrays
- Operating pressure: 30 bar

Application: Twin line towed arrays

TOWED BUOYS

Underwater Towed Body

An underwater towed body has been developed that can operate up to 50 meters in depth and at 2-4 knots of speed and is deployable from a surface platform using a towed cable and winch. The towed body can carry a payload up to 75 kg. Sensor arrays mounted on the towed body include side scan SONAR, forward and bottom-looking SONARS, and an underwater communication transducer array. Auxiliary sensors mounted on the platform are INS, DVL, heading/roll sensors, and depth sensors. During operation, the body is towed behind a ship using an armored tow cable. The hydrodynamic stability of the towed body was established through extensive towing experiments conducted at the High Speed Towing Tank facility at NSTL, Visakhapatnam. Hydrodynamic parameters like pitch and roll were measured using underwater motion measurement sensors.

Underwater Towed Body

Specifications

- Dimensions (Overall) : 2.80 m (L) x 0.6 m (B) x 0.5 m (H)
- Weight : 250 kg (in air)
- Buoyancy : Free flooded
- Control surfaces : Passive

Sub-surface Mooring Buoy

A sub-surface mooring buoy is a state-of-the-art mooring buoy to position an acoustic sensor array or payload under water at sea. The buoy is designed for an underwater depth of 300 m and provides a

net buoyancy of 1.5 tons. The buoy is designed as per ASME BPVC Section VIII and is manufactured using duplex stainless steel. In addition, the buoy is also designed as a modular concept, and multiple buoys are assembled to achieve higher net buoyancy.

Specifications

Depth rating	: ≥ 300 m in seawater
Maximum Weight	: ≤ 1050 kg
Net Buoyancy	: ≥ 1500 kg
Dimensions	: 1.3 m x 1.3 m x 2.2 m
Material of buoy	: Duplex stainless steel (UNS: S 32205)

Pressure-balanced Enclosure for Forward Looking Sonar

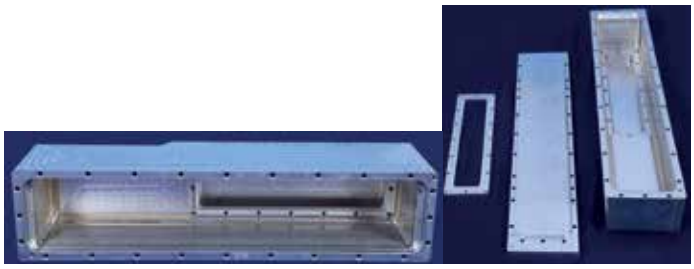
For forward-looking Sonar, a pressure-balanced enclosure is developed that is intended to house the transmitter and receiver and the associated electronics, including PCB cards, power amplifiers, power supplies, etc., without water ingress. It consists of two compartments, which are separated by a flexible diaphragm. On one side of the diaphragm, the electronic components are housed in an oil-filled environment, and the other side of the diaphragm is open to the hydrostatic pressure, maintaining the depth-independent capability depending on the strength of the material of the diaphragm selected. In comparison to the conventional design, the depth-independent design is more compact and weight-efficient. This sleek and rugged design meets the stringent environmental requirements specified for naval systems.

Features

- Depth-independent design
- Compact dimensions to suit space constrained platforms
- Rugged design to meeting JSS 55555 environmental specifications
- Aesthetic and ergonomic design
- Less weight and suitable for submersible applications.
- Corrosion resistant

Specifications

- Dimensions (Overall) : 460 mm (L) x103 mm (B) x 122 mm (D)
- Weight : 12 kg
- Surface treatment : Hard anodised
- Diaphragm : Neoprene



Pressure-balanced Enclosure

SONAR MATERIALS

Acoustic Baffles for Conformal Array Sonars

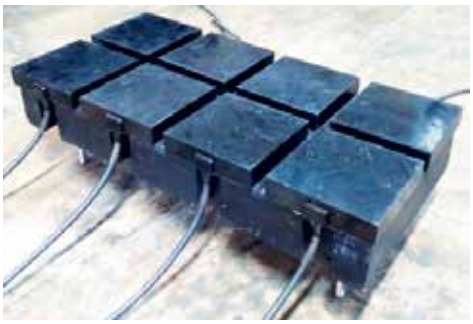
Acoustic baffles are used for the purpose of providing discrimination against vibration and noise sources in certain directions as well as to alter the shape of the array's directivity pattern. Any type of Sonar, especially the submarine Sonars of conformal or flank type, requires baffles to house its sensors. The baffles are designed to meet many conflicting requirements, such as the need to be lightweight while providing high acoustic and vibration isolation. Nitrile-rubber-based nanocomposite materials were used to fabricate acoustic baffles with better acoustic performance and vibration isolation. The baffle is designed with a multilayer structure with perforated rubber layers interspaced with thin composite layers. The particular design of vibro-acoustic baffles is most efficient at low frequencies, has improved RS of its sensors, and consequently has better performance and a longer range.

Features

- Made out of specially formulated Nitrile rubber composite
- Passed shock test (K 200) and temperature cycling (-10 ° to 50 °C)
- Improved vibration isolation at very low frequency
- Lightweight, pressure insensitive and long life

Specifications

Total weight/m²	<125 kg/m²
Vibration isolation	from 50 Hz
Acoustic attenuation	from 100 Hz to 20 kHz
Compressive strength	> 10 MPa
Pressure cycling	> 300 cycles upto 70
Thermal cycling	>100 cycles from -10 °C to +50 °C



Prototype Baffle

Conformal Array Prototype

CFRP Structure for Bow Mounted Sonar

Sonar sensors are conventionally mounted on metallic structures. For the first time in NPOL, a CFRP structure was fabricated using autoclave molding for the fitment sensors, signal conditioning electronics, and junction boxes of the bow-mounted conformal array Sonar.

Salient Features

- Lightweight structure, around 3 times weight reduction compared to metallic structure
- High strength-to-weight ratio
- Composites then have excellent fatigue resistance.
- Low chance of Magnetic Anomaly Detection (MAD)
- Isolation of noise from the hull due to the low sound speed of composites
- Self-damping

Specifications

- Tensile modulus: 120 GPa
- Tensile strength: 1.5 GPa
- Density: 1.58 g/cc
- Moulding: autoclave processing
- Dimensions: 1.3m x 0.9m x 3.5m

Flexible Indium Gallium Zinc Oxide-based amplifier circuits

Indium Gallium Zinc Oxide-based (IGZO) transistors and their integrated circuits have attributes that complement silicon-based large-scale integrations, devices that are high-performing but expensive. In the application of transistors as amplifiers, the amount of amplification depends on the characteristics of the transistor, the input bias voltage, and the amplifier circuit of which the transistor is a part. Circuits made with typical MOSFETs are replicated using IGZO TFTs with similar operation characteristics. NPOL developed IGZO-based flexible amplification circuits for acoustic sensors as part of its activity at the MEMS Regional Centre. Piezoelectric films such as poly vinyledene Difluoride (PVDF), PZT, and 1-3 piezo composites are the acoustic sensing elements in these sensors. Flexible IGZO-based amplifier circuits are fabricated with transistors in top-contact configuration employing micro-fabrication techniques.

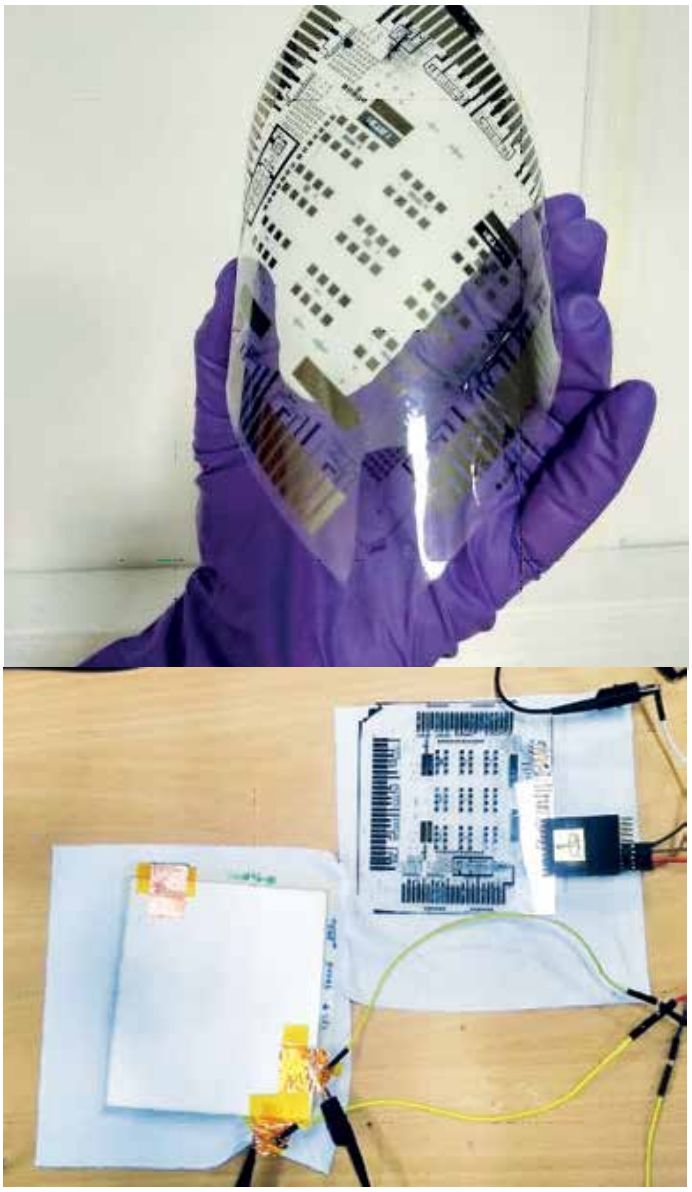
Features

- Feasibility of fabrication on flexible substrate
- Sensors can be positioned as close as possible to the amplifier circuit
- Low temperature processing
- High large area uniformity
- Printing techniques can be employed for large area flexible circuits
- Advantages of conformability

Specifications

Parameter	Values
Substrate	Polyimide/PEN
Channel	IGZO
Dielectric	ALD Al2O3
S & D material	Mo
Patterning method	Lift-off and etching
Passivating layer	Si3N4
On-Off ratio	10^6
Mobility	20 cm²/Vs
Voltage gain and 3 dB bandwidth	18 dB, 11 kHz

Designed and Developed by NPOL (Consultancy in design and fabrication from National Centre for Flexible Electronics, IIT Kanpur)



(a) IGZO TFT Amplifiers on PEN (b) Measurement of Amplifier Response with PVDF Sensor

Polymer-based Acoustic Isolator for UWACS Triton Dunking Unit

NPOL developed an Underwater Communication System (UCS) receiver array for Indian naval ships. The present receiver needs suitable isolation materials to improve the directivity of the system. The development of such isolator materials should have high hardness, pressure-resistant up to 20 bar, and have acoustic and vibration absorption characteristics. Two variants of isolators are designed and developed based on blend of FRP and reinforced SBR composite. Both isolators were tested for directivity measurement, and an improvement in hystrostatic performance was obtained for the rubber isolator compared to the blend of FRP composite. Communication trials were conducted on an isolator-fitted system for a various of ranges and depths. By introducing this particular rubber isolator as an acoustic shield over the top of system, it reduces own ship noise and is found to be very effective in system performance. This isolator was tested with the current Under Water Acoustic Communication System (UWACS) system fitted onboard.

Features

- Made out of specially formulated SBR composite
- Designed perforated rubber with sandwich construction
- Moulded without bubbles and protrusion on the surface
- Passed hydrostatic pressure up to 20 bar
- Improved acoustic and vibration isolation characteristics
- Archieved improved directivity of receiver systems

Rubber Isolator

Isolator Fitted System

Rubber Anti Vibration Mounts Equivalent to AKCC

Elastomeric mounts are extensively used on naval platforms. The primary functions of these mounts are (i) insulating machinery onboard against the effects of underwater explosions and (ii) minimizing machinery vibrations from transmitting to the hull of the platform. The importance of anti-vibration

treatments has increased manyfold recently on account of the initiatives for stealth.

NPOL has developed a mount equivalent to AKCC in physical dimensions with superior shock and vibration isolation capability. After extensive onboard evaluation, the Indian Navy accepted the Rubber Anti Vibration Mounts (RAVMs) for fitment on onboard machinery and equipment for all their commands.

Salient Features

- Vibration damping upto 60dB
- Shock Isolation 60 % upto 220 g
- Shelf life > 5 years
- Service life > 15 Years
- Deflection @ rated load 0.6±0.3 mm
- Capacities 15, 25, 85, 120 and 220 kg
- RAVMs qualified as per Standard QAP of IN
- RAVM 120 field trials completed RAVM 120 accepted by Indian Navy for onboard machinery
- ToT under progress
- Industrial Partners M/s Keltron & Vajra

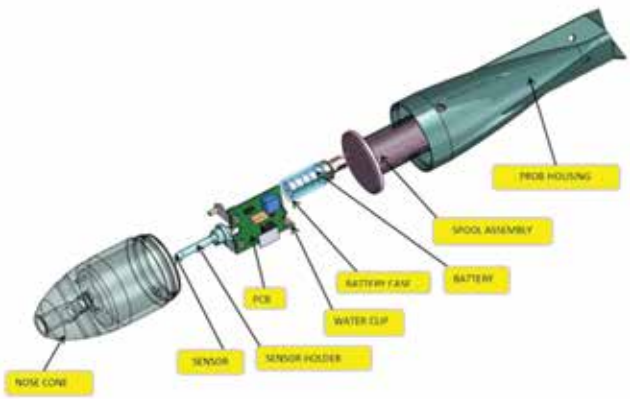
Type	RAVM15	RAVM25	RAVM85	RAVM120	RAVM220
Capacity (kg)	15	25	85	120	220
Deflection (mm)	0.6±0.25	0.6±0.25	0.5±0.25	0.6±0.3	0.6±0.3
Resonance (Hz)	28	28	25	27	27

ASW OCEANOGRAPHY

Expendable Bathy Thermograph-NG

The study of oceans is an essential aspect from strategic, economic, and ocean engineering points of view. In any given situation, the detection and discrimination of an underwater target are highly dependent on the propagation characteristics of the medium, which depend on the *in-situ* data. Expendable Bathy Thermographs (XBT) are designed for rapid mapping of upper layer temperature, which is a cost-effective, robust, and easy-to-use instrument to estimate the sound speed profile for military applications.

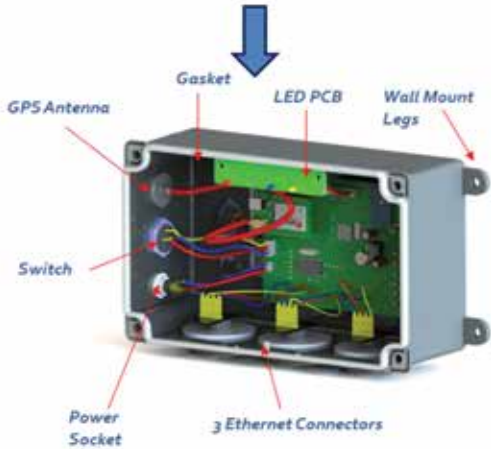
The newly developed XBT-NG system consists of a probe with an integrated sensor, probe electronics, and battery, which are used to collect temperature data and send it onboard using single-wire telemetry. The probe will be launched from an aesthetically designed hand-held launcher with an Ethernet and Wi-Fi interface. The data will be transferred to the laptop or deck unit using Wi-Fi or Ethernet. The Deck unit will send the data to a PC or laptop via Ethernet communication. The Human Machine Interface (HMI) on the PC or laptop presents the temperature profile received and also has command control as well as algorithms for Quality Check (QC), data blending (up to station depth), and sound velocity estimation. XBT-NG is intended to replace all the existing systems onboard Indian naval ships.



XBT-NG Probe

Hand-held Launcher

HMI



Deck Unit

Sound Velocity Recorder

The Sound Velocity Recorder (SVR) is the pinnacle of precision for measuring the speed of sound in the vast depths of the ocean. Unleash the power of accurate underwater SONAR systems with our state-of-the-art instrument. The SVR is a marvel of technology, seamlessly integrating a conductivity sensor, a thermistor, and a pressure sensor. This dynamic trio works in harmony to measure seawater conductivity, temperature, and depth, providing essential data to calculate the speed of sound. Utilising internationally accepted algorithms, our SVR ensures unparalleled accuracy in sound speed measurements. Stay ahead with our SVR's innovative Ethernet communication protocol, which enables seamless online monitoring of sound speed. Dive into the future of underwater exploration, where precision meets connectivity.

Explore the depths with confidence as our SVR empowers your Sonar system with the optimum range prediction capability, setting a new standard for excellence in underwater acoustics.

Features

- State-of-the-art sensor technology Toroidal conductivity sensor, precision thermistor, and MEMS pressure sensor
- Dedicated GUI for programming the instrument
- Rugged design to meet JSS 55555 environmental specifications
- Ethernet communication protocol for online monitoring
- SS-316/Titanium/Super Duplex Probe for Submarine Integration
- Probe can withstand 50 bar hydrostatic pressure

Specifications

- Dimensions: 227 mm (length) x 80 mm (diameter)
- Resolution: 1cm/s
- Accuracy: +/- 5 cm/s

Sound Velocity Recorder

TECHNOLOGIES FOR COMPACT HULL MOUNTED SONAR FOR SHALLOW WATER CRAFTS

Technologies were developed for a state-of-the-art compact SONAR system suitable for installation onboard Anti-Submarine Warfare (ASW) ships. The hardware comprises a compact staggered transducer array, a sleek and rugged display cum processing console, modular front-end signal conditioning hardware, and high-efficiency switched-mode power amplifiers.

Transducer Array **Front-end Electronics** **Power Amplifier** **Multifunction Console**

Features

- Compact dimensions to suit space-constrained platforms
- Optimized for shallow-water operations
- Automatic target designation and tracking of multiple targets
- Reverberation suppression capability
- Provision for self-noise cancellation
- Beam stabilization to overcome own-ship platform dynamics
- Automatic LRU-level fault detection and fault localization
- Integrated SONAR performance prediction

Transducer Array

- Staggered Cylindrical Transducer Array
- More staves in less space
- Higher source levels
- Better radiation characteristics

Front-end Electronics

- Modular design
- Conforms to the VME form factor
- Wide dynamic range
- Programmable Gain Control
- Supports remote configuration via Ethernet interface

Power Amplifier

- Class D switched-mode power amplifier
- IGBT full bridge configuration
- Employs pulse width modulation
- High efficiency (> 85 %)
- Low distortion (< 5 %)
- 3U form factor
- Power level control in steps of 1 dB

Multi-function Console

- High-resolution (1600 x 1200) display monitors, Touch Input Display (TID)
- COTS General Purpose Processor (Intel Core i7/XXeon)
- A software framework based on the Qt4 toolkit for HMI software
- Seamless cursor and support for streaming audio/video
- Rugged servers for signal processing
- Software developed in MATLAB, C++, and Qt in a Linux environment

Subsequent to the development of these technologies, they were integrated, installed onboard, and successfully demonstrated to the User. The production version of the demonstrated equipment technology is being considered for installation on shallow water crafts. To facilitate this, NPOL transferred equipment technology to M/s Bharat Electronics Limited (BEL).

Editors are thankful to the laboratory correspondent of NPOL, Smt Letha MM, Sc 'F' and Shri Raju RP, Sc 'E', for preparing this issue of *Technology Focus*.