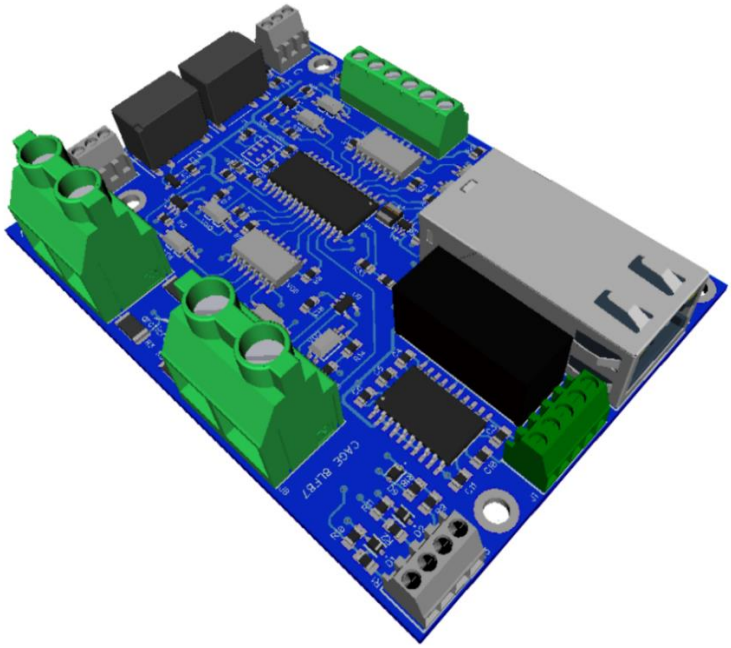
arctic rays

Submersible Monitoring System

(High Voltage Version)

AR402HV-03 REV.A - Firmware v1.0



USER MANUAL

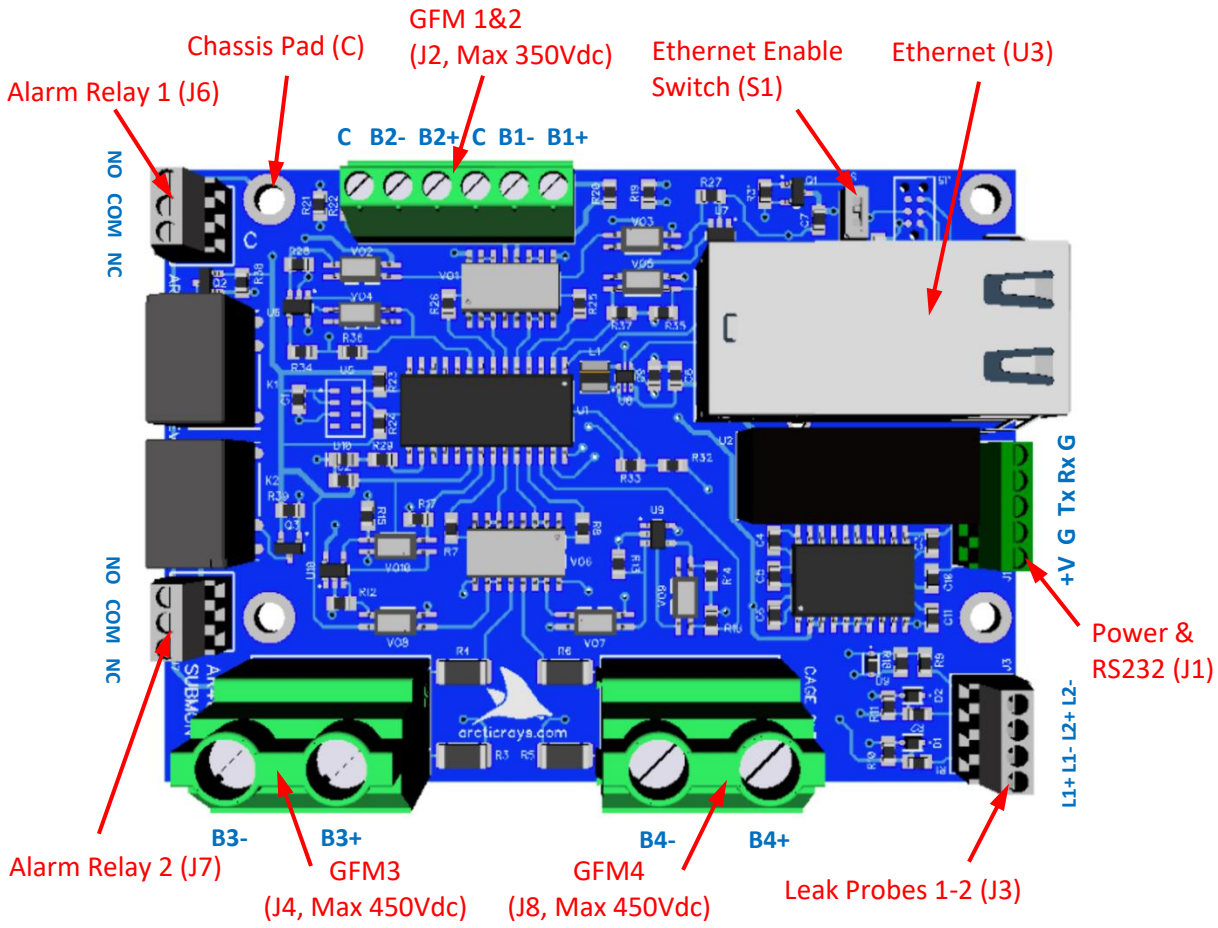
20 May, 2021

I. INTRODUCTION:

The Arctic Rays Submersible Monitoring System (SUBMON) provides ground fault monitoring, leak detection, and environmental sensing in a compact single PCB. The ground fault circuit automatically monitors both poles of 4 independent DC busses: Two up to 350V, and two up to 450V. The leak detection circuit is self-checking, fail-safe, and monitors 2 independent remote water detection probes. The SUBMON board also contains barometric pressure, temperature, and humidity sensors which can be used to monitor the internal environment of any subsea housing. With a wide input supply range, small form-factor, and onboard Ethernet and RS232 serial communications, the SUBMON system is a full-featured, versatile electrical system monitoring solution designed specifically for underwater vehicles and subsea systems.

II. SETUP

The SUBMON system consists of a main printed circuit board (3.56”L x 2.56”W x 0.75”H), and 2x leak probes. Connections and pinouts are shown below.



***NOTE:** All Ground Fault connections should be properly fused. The SUBMON board does not provide short-circuit protection.*

***NOTE:** Always use wire ferrules when making connections to screw-terminals, in order to ensure good electrical contact and avoid short circuits and wire fatigue.*

CONNECTOR PINOUTS

J1 (Power & Serial):

1. +Vin (5-32Vdc)
2. GND
3. RS232 TX Out (19200 bps, 8-N-1-N)
4. RS232 RX In (19200 bps, 8-N-1-N)
5. GND

J2 (Ground Fault Monitors)

1. Bus1 + (350Vdc max)
2. Bus1 -
3. Chassis (Hull/Seawater Connection. Also connected to mounting pad "C")
4. Bus2 + (350Vdc max)
5. Bus2 -
6. Chassis (Hull/Seawater Connection. Also connected to mounting pad "C")

J4 (Ground Fault Monitors)

1. Bus3 + (450Vdc max)
2. Bus3 -

J8 (Ground Fault Monitors)

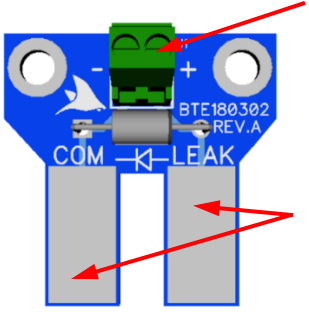
1. Bus4 + (450Vdc max)
2. Bus4 -

***NOTE:** Mounting pad "C" is connected to the chassis line in the ground fault monitoring circuit. This can be used as a convenient connection to seawater if the board is mounted using metal hardware. If you do not wish to tie this pad to chassis, use plastic mounting hardware to ensure it is isolated. Alternatively, pins J2-3 or J2-6 can be used to tie to a more suitable chassis point elsewhere.*

J3 (Leak Probes):

1. L1+
2. L1-
3. L2+
4. L2-

SUBMON Leak Probe



Connection to SubMon main board. Observe polarity when connecting probe to channels on J3 or J4. Probes connected backwards will show a leak (fail safe).

Leak Probe Terminals. Ensure that these pads are located at the lowest point in the housing to be monitored. Bridging them with water will result in a leak detection.

J6 & J7 (Alarm Relays 1 & 2):

1. Normally Open Contact
2. Common
3. Normally Closed Contact

III. COMMS CONFIGURATION:

There are two simultaneously active options for communicating with the SUBMON board: RS232 Serial and 10/100 Base-T Ethernet (TCP or UDP). Serial communications are handled by an isolated RS232 port at connector J1, set to 19200bps, 8-N-1-N.

Ethernet communications are handled by a Lantronix XPort serial-to-ethernet converter module (U3). Power for this module is controlled via the Ethernet Enable DIP-switch (S1). ***Ensure that this switch is ON when using Ethernet communications (default).*** In applications where Ethernet is not needed, S1 can be switched OFF to minimize power draw.

XPort Modules are configured by Arctic Rays with a **dynamic IP address (DHCP)** and a serial port configuration of 19200bps, 8-N-1-N. Communications with the XPort's serial channel (i.e. the SUBMON board) can be handled directly via **TCP on port 10001**, or using the Lantronix virtual COM port (VCP) drivers.

Modification of XPort settings, including changing IP address, UDP/TCP transport protocol, security settings, etc … is provided via the XPort's webpage. Login using the device's IP address and the default ***BLANK*** username/password.

For more information on configuring the XPort module for your particular network requirements, consult the XPort User Guide: http://www.lantronix.com/wp-content/uploads/pdf/XPort_UG.pdf

IV. THEORY OF OPERATION

First, it is important to emphasize that the SUBMON system is an automated measurement and reporting device for ground faults, leaks, and housing environmental parameters, NOT a circuit protection or control system. It is up to the host system to interpret the data sent by the SUBMON board, display it to the vehicle operator, and trigger any alarms or circuit interruption devices based on this data. The SUBMON system does include two alarm relays which can be used to trigger other fault suppression systems automatically, but this is to be used with caution, as the trip time cannot be guaranteed, and is subject to the GFM mode and cycle settings.

INITIALIZATION: Upon power-up, the SUBMON board loads saved settings, initializes RS232 serial and Ethernet communications, and sends out a welcome message containing version information:

#V Submersible Monitor AR401-03A FW: v1.4 May 20 2021 15:01:17 L.Frey.<CRLF>

It then starts transmitting data via both RS232 and Ethernet ports at a rate of 5Hz. The RED diagnostic LED will flash every time data is output, to serve as a visual "heartbeat" that the board is working. If the onboard CPU should lock-up for any reason, an onboard watchdog timer will reset it in 2 seconds. This will be seen by the re-sending of the welcome message which indicated re-initialization.

LEAK DETECTION: The leak/water detection circuits are used to alert the user to the presence of liquid water in a pressure housing or oil-filled electrical junction box. Each leak detect channel (L1-L2) connects to a remote probe, which should be located at the lowest point in the housing to be monitored. All probes are checked 5 times per second for both continuity and water detection. If a

probe becomes disconnected, its "PROBE FAIL" flag is raised. If its two detection pads are bridged by water, its "LEAK" flag is raised. When connecting the probes, polarity should be observed. If a probe is connected backwards, it will FAIL SAFE (i.e. will indicate a leak detection).

ENVIRONMENTAL SENSING: The SUBMON board is typically located in a dry electrical pressure housing. The environmental sensors on the board allow the user to monitor the barometric pressure, temperature, and humidity inside that housing.

- ***VACUUM:*** Use this reading to indicate vacuum during a housing leak check, or in the case of a housing which is normally operated under vacuum, loss of vacuum is a good indication of a compromised seal. Check this value prior to putting the vehicle in the water to avoid potential water ingress.
- ***HUMIDITY:*** The humidity sensor can also serve as an early warning of leak, or excessive condensation which could drip onto an electrical component from above, while not registering on a leak probe. **NOTE: Some boards may not be equipped with this feature.*
- ***TEMPERATURE:*** The temperature sensor can alert the user to excessive heating of the housing on-deck. Keep any heat emitters away from the sensor (U5), to avoid inaccurate measurements.

GROUND FAULT MONITORING: The SUBMON system monitors both poles of four (4) independent, isolated DC power busses for insulation resistance to seawater (aka chassis, hull, or earth ground). Busses 1&2 can be configured to support any voltage up to 350V max. Busses 3&4 can be configured to support any voltage up to 450V max. ****IMPORTANT: The nominal voltages of these busses ARE SET AT THE FACTORY, and will be labeled on the SubMon board. Busses should be isolated from one another, or false readings will occur. IMPROPER CONNECTION CAN RESULT IN PERMANENT DAMAGE TO THE SUBMON CIRCUITRY. If unsure, contact Arctic Rays for assistance.***

In order to measure the insulation resistance between a bus and the hull, the SUBMON circuit temporarily connects one leg of the bus to the hull, and looks for current flow on the other leg (limited to 1mA max). In a properly isolated system, there should be no connection between any of the power busses and seawater, and thus, no current flow.

A current leakage value from 0-1000 µA (0-1ma) is reported for each channel, where 0 is an open-circuit (full isolation), and 1000 is a dead-short (full connection), between the bus being measured and the hull. Translating these values to other real-world units, such as insulation resistance (ohms), is up to the destination system software, and should be calibrated appropriately. In general practice, any system with a current leakage of >500 µA should be secured and corrected.

The ground fault monitor can operate in one of 10 modes:

- 0 = OFF
- 1 = Continuous, BUS1+ only
- 2 = Continuous, BUS1- only
- 3 = Continuous, BUS2+ only
- 4 = Continuous, BUS2- only
- 5 = Continuous, BUS3+ only
- 6 = Continuous, BUS3- only
- 7 = Continuous, BUS4+ only
- 8 = Continuous, BUS4- only
- 9 = Cycle all channels automatically

Mode 9 (cycle all) should be used during normal operation. In this mode, the "SAMPLE TIME" parameter (0-3600 sec) defines how often the system should measure the ground fault on all poles, the default being continuous cycling (0 sec). The DWELL TIME parameter (0-60 sec) defines how long to hold at each pole before measurement. This allows any stray capacitance to bleed-off, and the channel to settle before taking a reading. The default dwell time is 5 seconds.

EXAMPLE: Operating in Mode 9 with sample time = 300, and dwell time = 3. The SUBMON ground fault monitor circuit will take a measurement once every 5 minutes. It will take a total of 24 seconds to cycle through all 8 poles (dwelling for 3 seconds at each one), and then return to an idle state. ****NOTE: Channels will continue to show the last measured value until they are updated in the next cycle.***

If, during normal operation, a ground fault is seen, the user can select any one of the 8 poles (BUS1+, BUS1-, BUS2+, BUS2-, BUS3+, BUS3-, BUS4+, BUS4-) for continuous monitoring by switching to modes 1-8. In these modes, one pole is connected for measurement and the value is updated 5 times per second. This continuous, fast-response mode allows troubleshooting of ground faults in the field. When desired, the user can switch back to Mode 9 for normal automatic cycling. ****NOTE: If in continuous mode, only the channel being measured will be updated. All other channels will continue to show their last measured values.***

The sample time can also be reduced to speed up the frequency of fault-checking. Just be aware that this will increase the percentage of time that one of the busses is connected to the hull as part of the measurement process.

ALARM RELAYS: The SUBMON system offers two SPDT, 1A signal relays, which can be used for instantaneous alarm notification, independent of serial/Ethernet communications and graphical user interface software. Each relay can be configured to switch on a GFM level threshold or on either one of the 2 leak detectors by changing the "r1source" and "r2source" settings. ****NOTE: The default configuration is for both relays to NOT respond to any alarms.***

V. COMMUNICATIONS PROTOCOL:

When using either RS232 or Ethernet (Virtual COM Port) communications, the SUBMON board connects at ***19200bps, 8-N-1-N***. Output is ASCII text, terminated by a carriage-return, line-feed sequence (0x0D0A). Both methods are fully isolated from the SUBMON circuitry and leak probes.

DATA OUTPUT:
Upon startup, the SUBMON board will transmit a startup message with version and calibration values, then begin streaming data at ~5Hz, as comma-delimited messages, in the following format:

"#baro,temp,hum,channel,GF1+,GF1-,GF2+,GF2-, GF3+,GF3-,GF4+,GF4-,probes,leaks<CRLF>"

Where the fields are…
"#": Signifier that this is the start of a status message.
"baro": Barometric pressure in mBar
"temp": Temperature in °C
"hum": Relative Humidity in % (if not equipped, will show "-1")

"channel": Current ground fault channel (i.e. pole) being measured (0=OFF, 1=BUS1+, 2=BUS1-, 3=BUS2+, 4=BUS2-, 5=BUS3+, 6=BUS3-, 7=BUS4+, 8=BUS4-)
"GFx": Ground fault level (i.e. current leakage to seawater) for the indicated pole in µA (0-1000)
"probes": Leak probe failure flags (hexadecimal, 0=OK, 1= PROBE FAIL)
"leaks": Leak detect status flags (hexadecimal, 0=OK, 1=LEAK)
"<CRLF>": End of line sequence (0x0D0A)

EXAMPLE: *"#1022,22.7,52,0,0000,0000,0992,0000,03,A0<CRLF>"*

In this example, the SUBMON board is saying the following to the host:

1. This is a status message ("#")
2. Barometric pressure in the housing is 1022 mBar
3. Temperature in the housing is 22.7 °C
4. Relative Humidity in the housing is 52%
5. The ground fault monitor is currently IDLE (all channels OFF, none actively being read)
6. The high voltage bus (e.g. 120V) has no ground faults on either pole.
7. The last reading of the positive leg of the low voltage bus (e.g. +24V) showed a near dead-short to chassis. The negative leg (e.g. 24V RTN) is isolated.
8. Leak probes L1 & L2 are disconnected. All others are OK.
9. Leak probes L5 & L8 are showing a water detection. All others are DRY.

COMMAND SET:
All commands are ASCII text, NOT case-sensitive, and should be terminated with either a carriage return (0x0D) or a line-feed (0x0A). Replies begin with a "#" character, followed by the command and message, and are terminated with <CRLF> (0x0D0A). ****NOTE:*** ***All settings changes are stored in non-volatile memory and will be retained after a power cycle.***

"?": SETTINGS. The settings command returns all current settings in the following format:

"#?gfmode,dwell,sample,g1alarm,g2alarm,r1source,r2source<CRLF>"

Where the fields are…
"#?": Signifier that this is the start of a settings message.
"gfmode": Ground Fault Monitor Mode
0 = GF monitor OFF
1 = Continuous monitoring of CH1 only (BUS1+)
2 = Continuous monitoring of CH2 only (BUS1-)
3 = Continuous monitoring of CH3 only (BUS2+)
4 = Continuous monitoring of CH4 only (BUS2-)
5 = Continuous monitoring of CH5 only (BUS3+)
6 = Continuous monitoring of CH6 only (BUS3-)
7 = Continuous monitoring of CH7 only (BUS4+)
8 = Continuous monitoring of CH8 only (BUS4-)
9 = Cycle all channels automatically (DEFAULT)
"dwell": Ground fault channel dwell time in seconds (0-60, DEFAULT = 5)
"sample": Ground fault sampling time in seconds (0-3600, DEFAULT = 0)
"g1alarm": Ground Fault BUS1 alarm threshold (0-1000 µA, DEFAULT = 500)
"g2alarm": Ground Fault BUS2 alarm threshold (0-1000 µA, DEFAULT = 500)

"r1source": Alarm relay #1 source (0=OFF, 1-8=Leak detect 1-8, 9-12=GFM BUS1-4)
"r2source": Alarm relay #2 source (0=OFF, 1-8=Leak detect 1-8, 9-12=GFM BUS1-4)
"<CRLF>": End of line sequence (0x0D0A)

EXAMPLE REPLY: *"#?9,03,0900,0425,0500,0450,0600,9,1<CRLF>"*
In this example, the SUBMON board is saying the following to the host:

1. This is a settings message ("#?")
2. Ground fault monitoring mode is 9 (CYCLE ALL)
3. Ground fault channel dwell time is set to 3 seconds
4. Ground fault sample interval is set to 900 seconds (cycle once every 15 minutes)
5. Ground fault BUS1-4 alarm thresholds are set to 425,500,450,600 µA, respectively
6. Alarm Relay #1 source is set to GFM BUS1 (Relay1 closes if Bus1+/- ground fault > 425 µA)
7. Alarm Relay #2 source is set to Leak 1 (Relay2 closes if leak probe #1 detects water)

"mode" SET GFM MODE. The mode command sets the ground fault monitoring circuit's operating mode. Follow the command with one of the following values to set the mode:

0 = OFF
1 = Continuous, BUS1+ only
2 = Continuous, BUS1- only
3 = Continuous, BUS2+ only
4 = Continuous, BUS2- only
5 = Continuous, BUS3+ only
6 = Continuous, BUS3- only
7 = Continuous, BUS4+ only
8 = Continuous, BUS4- only
9 = Cycle all channels automatically

"dwl" SET DWELL TIME. The dwell time command sets the ground fault monitoring circuit's channel dwell time in seconds. Follow the command with a numerical value from 0-60 (measure immediately, up to maximum dwell of 1 minute before measurement). Once set, the dwell time is stored in non-volatile memory and will be retained after power cycle.

"samp" SET SAMPLE TIME. The sample time command sets the ground fault monitoring circuit's sampling time (time between updates) in seconds. Follow the command with a numerical value from 0-3600 (i.e: cycle all channels continuously, to maximum of 1 hour between updates). Once set, the sample time is stored in non-volatile memory and will be retained after power cycle.

"r1": SET RELAY1 SOURCE. This command sets the source for Alarm Relay #1. Follow the command with a numerical value from 0-12 to select the desired source as follows:

0 = OFF
1-8 = Leak detector 1-8 (leak detectors 3-8 are not implemented on this board)
9 = GFM BUS1
10 = GFM BUS2
11 = GFM BUS3
12 = GFM BUS4

****NOTE:** There is 50 µA of hysteresis needed to reset the relay when sourced to a GFM channel.*

"r2": SET RELAY2 SOURCE. This command sets the source for Alarm Relay #2. The command parameter is the same as shown for RELAY1 above.

"ax": SET GFM BUS ALARM THRESHOLD. This command sets the ground fault alarm level for GFMx (where x=1-4). This level is only used to trip the alarm relay when its source is set to GFMx. Follow the command with a numerical value from 0-1000 µA. **Example: "a1 500" would set the alarm level for GFM BUS1 to 500µA. If one of the relays had its source set to 9 (GFM1), it would close when the GF level on that bus met or exceeded 500µA.*

"cal": CALIBRATE GFM CIRCUIT. This command sets the calibration coefficients for the GFM circuit. Each of the 8 poles has two coefficients, such that the output is given by the linear equation:

y = mx + b , where…
"y" is the output in µA (0-1000)
"x" is the raw ADC measurement in counts (0-1023)
"m" is the gain coefficient
"b" is the offset coefficient

To change the coefficients, issue the command, followed by a space, then a space-delimited string of coefficients (maximum 3 digits of precision) in the form:

"cal m1 b1 m2 b2 m3 b3 m4 b4 m5 b5 m6 b6 m7 b7 m8 b8".

The values will be saved in non-volatile memory, and will be retained on power-cycle. If the command has been executed correctly, the reply values should match the command.

EXAMPLE COMMAND: *"CAL 0.859 -9.344 0.954 -17.067 0.906 -0.812 1.033 -3.487 0.859 -9.344 0.954 -17.067 0.906 -0.812 1.033 -3.487<LF>"*

EXAMPLE REPLY: *"#CAL 0.859 -9.344 0.954 -17.067 0.906 -0.812 1.033 -3.487 0.859 -9.344 0.954 -17.067 0.906 -0.812 1.033 -3.487<CRLF>"*

****NOTE: The GFM is calibrated at the factory for the nominal bus voltages. It is not recommended to use this command unless absolutely necessary. In order to display raw ADC counts, set all values to m=1, b=0.***

"run": OUTPUT RUN/STOP. The output command toggles run/stop of data streaming. To stop, follow the command with a "0". To run, follow it with a "1". Streaming will automatically re-start when power to the SUBMON board is cycled.

"help": HELP. The help command prints out a user-readable list of supported commands.

"ver": VERSION. The version command prints out board revision and firmware version information, followed by GFM and PTH sensor calibration coefficients.

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