Wireless Gateway Operational Manual

Version 2.8.4

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1. Introduction

Broadsens wireless gateways include GU200S, GU300 and GU300S. Broadsens wireless gateways connect and control Broadsens low-power wireless sensors such as SVT200-A, SVT300-A, SVT400-A, SVT200-V, SVT300-V, SVT400-V, SVT200-T SVT-C series sensors and SAG200. The control and analysis software BroadVibra™ is pre-installed inside the wireless gateway for easy configuration of the sensors.

One major advantage of Broadsens wireless gateways is the ability to divide the wireless sensors into multiple groups to monitor different parts of a machine or multiple machines. Each group can have its own monitoring schedule and controlled separately, as shown in Figure 1. The SVT-A series vibration sensors (including SVT200-A, SVT300-A & SVT400-A) in the same group can be synchronized to take data at the same time for advanced analysis.

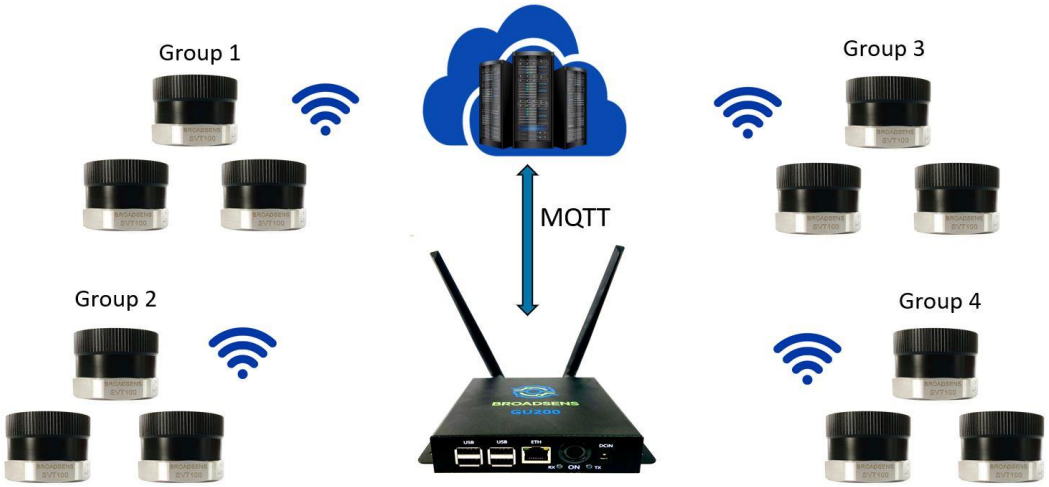


Figure 1 Group control of multiple wireless sensors

Another advantage of Broadsens's wireless gateways is the real-time data acquisition and visualization ability. Thanks to the ultra-low power design of sensors and the driver software from Broadsens wireless gateway, the sensors can take data continuously for a long time. The gateway integrates a time-series database (InfluxDB 64-bit version 1.8.10) for data review and analysis. InfluxDB is an ideal database for Industrial IOT (IIOT) applications. Data can be transferred to user's servers or clouds via MQTT protocol in real time. In default, wireless gateway stores data up to 6 months. Data will be automatically removed from the database once they exceed the specified dates to keep the gateway run smoothly.

Broadsens wireless gateways can be accessed from a web browser, so there is no software installation required. Broadsens wireless gateways do not need internet access to operate thanks to its integrated large data storage and database. The gateway can work standalone and the remote PC or server can be turned off. The architecture of the gateway allows the system to be integrated to large enterprise environment easily. At the same time, the gateway is also ideal for small to medium size companies, or R&D institutes.

1.1 Specifications

All gateways have fast four-core processor at 1.5GHz. GU200S has option of 32GB or 64GB storage, and GU300/GU300S have optional 64GB and 128GB storage. GU300/GU300S has additional RS485 Modbus RTU port, plus two GPIO ports.

The specifications of GU200S, GU300 and GU300S gateway are shown in Table 1. GU300/GU300S and GU200S use different BroadVibra software, since GU300/GU300S have faster internal speed than GU200S. GU200S, GU300/GU300S also use different firmware due to the different interface speed of internal Bluetooth Low Energy (BLE) chip. Both GU200S and GU300/GU300S's BLE chip have an integrated amplifier to boost their distance to the sensors.

Although the wireless gateways are equipped with 2.4GHz 802.11 b/g/n WiFi in default, it is recommended to use wired connection for the wireless gateways to ensure optimal operation. Since there could be lots of data coming in and out of the gateway, wired connection is preferred. **WiFi of the gateway is turned off in default. Please refer to Appendix 2 on how to turn on and configure WiFi.** The gateways come with 6dBi 2.4GHz antenna with SMA male connector.

Table 1 Specs of Broadsens gateways

Models	GU200S	GU300	GU300S
Processor	1.5GHz quad-core 64-bit ARM CPU		
Memory	2GB, 4GB or 8GB		
Data storage	32 GB or 64 GB	64GB or 128GB	
Communication with sensor	2.4GHz low power secure wireless, extended range, up to 20dBm		
Network interface	Fast Ethernet, dual-band 802.11ac wireless		
Sensor support	Up to 250 (60 SVT-A, 30 SVT-V, 60 SAG, and 100 SVT-T series sensors)		
Operating system	Linux Debian 64bit		
Software interface	BroadVibra software based on Node-RED		
Communication protocol	MQTT, TCP/IP, UDP, Modbus TCP, OPC UA	MQTT, TCP/IP, UDP, Modbus TCP & RTU, OPC UA	
Vibration analysis	Velocity, displacement, RMS, True peak, Peak-peak, STD, Crest factor, Kurtosis, trend analysis, FFT analysis, advanced filtering		
Database	InfluxDB for easy data review and export		
Power supply	9-18v DC isolated		
Power consumption	<15w		
Size	141x127x31mm (5.55x5x1.22 inch)	141x121x31mm (5.5x4.7x1.2 inch)	141x125x28mm (5.5x4.9x1.1 inch)
Weight	555 g (1.22 lb.)	490 g (1.08 lb.)	460g (1.02 lb.)
Working environment	-30 - 60 Celsius (-22 - 140 Fahrenheit), 10% ~ 90%RH		
GPIO	No	Yes	Yes
Cellular network	No	No	Yes
Additional features	Edge computing, real time clock, OTA upgrade, USB	Edge computing, real time clock, OTA upgrade, USB, RS485 RTU, 2nd power connector	Edge computing, real time clock, OTA upgrade, USB, RS485 RTU, 2nd power connector

GU300S supports global 4G LTE service and can be used worldwide. The cellular network specifications are as the following (Table 2):

Table 2 GU300S cellular network specs

Frequency Band	
LTE-FDD	B1, B2, B3, B4, B5, B7, B8, B12, B13, B18, B19, B20, B25, B26, B28, B66
LTE-TDD	B34, B38, B39, B40, B41
WCDMA	B1, B2, B4, B5, B6, B8, B19
GSM	850, 900, 1800, 1900MHz
GNSS	GPS, Beidou, GLONASS, GALILEO, QZSS
Data Transfer	
LTE	150 Mbps (DL) / 50 Mbps (UL)
HSPA+	42 Mbps (DL) / 5.76 Mbps (UL)
WCDMA	384 Kbps (DL) / 384 Kbps (UL)
EDGE	236.8 Kbps (DL) / 236.8 Kbps (UL)
GPRS	85.6 Kbps (DL) / 85.6 Kbps (UL)

Broadsens's wireless gateways support all popular web browsers, including Firefox, Google Chrome, Edge, Safari, Opera and Vivaldi. Please use provided user name and password to log in to the web interface of the wireless gateway.

1.2 Connectors

GU200S comes with Ethernet connector, four USB connectors, power switch and power supply input connector (Figure 2). The USB connector can be used to expand the gateway functions such as adding USB to RS232 interface by using a USB to RS232 adapter. An external USB WiFi adapter can also be plugged in to provide external WiFi (in case that the gateway does not come with WiFi adapter).

Note: GU200S is not recommended for new customers. Customers using GU200S are recommended to upgrade to GU300 or GU300S with additional features such as GPIOs and RS485 for future purchases.

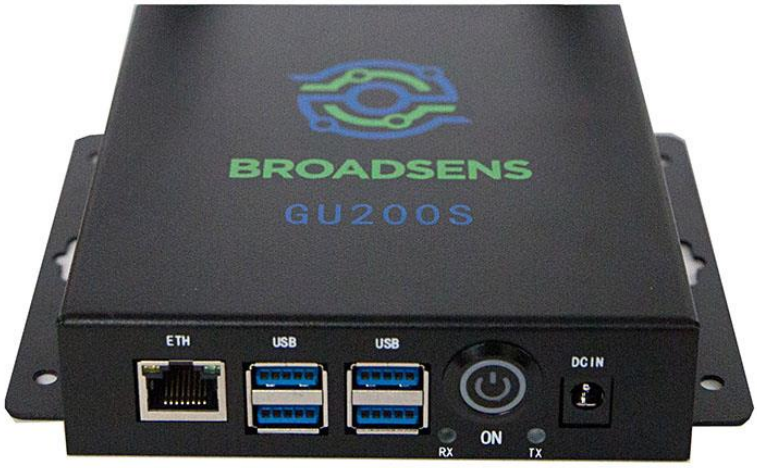


Figure 2 GU200S connectors

Besides USB and Ethernet interface, wireless gateway GU300 also has two GPIO connectors, RS485 RTU connector and additional power supply connector. The connectors are shown in Figure 3. The "DCIN" connector accepts 12V 2A (3A and up recommended) 2.1mm input. The additional power connector is located beside the "DCIN" connector, which can be used to provide power to the gateway in high vibration environments. This connector can also be used to power external sensors. RS485 connector is located beside the power connector. Two GPIO connectors are located between the RS485 connector and "DBG" (debug) connector. The debug connector is for internal usage only. GU300 is based on Raspberry Pi Compute Module 4 (CM4) industrial single board computer. The "IO1" connector correspond to CM4's GPIO port 26, and "IO2" connector corresponds to CM4's GPIO port 22. Each port can be configured as either input or output by software. Each IO port has a ground (GND) connector for easy connection. Please refer to section 12.1 GPIO ports for details on how to program them.

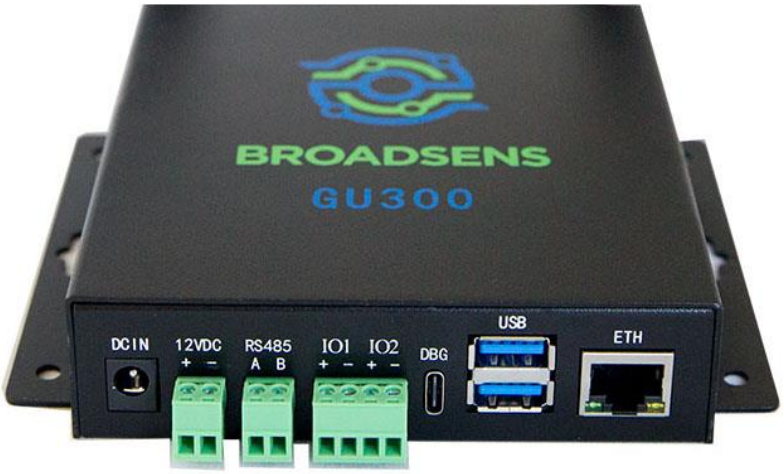


Figure 3 GU300 connectors

Attention: The GPIO ports use 3.3V voltage. Please do not connect the ports to high voltage such as 5V.

GU300S has the exact same connectors as GU300 in the back, minus the "DBG" connector (Figure 4).

Figure 4 GU300S connectors

In the front, GU300S also has an additional 4G LTE antenna, which is used for 4G LTE connection. GU300S also has a SIM card slot in the front, with which user can insert SIM card for 4G LTE service.

GU300S does not come with a power on/off button, since the gateway is supposed to be on all the time.

2. System setup

2.1 Gateway connection

To set up Broadsens wireless gateway and sensors, please prepare the following items:

- Broadsens wireless gateway with power adapter
- Ethernet cables
- A router, ideally with admin right. In case that user wants to use a PC to connect to the gateway directly, please refer to "Appendix 3. Direct connection to the gateway" of the manual.
- A fast PC or laptop that connects to the router (Intel i7/AMD Ryzen 7, minimum 8GB memory recommended)

2.1.1 Connection via Ethernet

A typical system connection diagram is shown in Figure 5. If local network is available, then the gateway can be connected to the local network directly. In case that a local network is not available, then 4G/5G router can be used to provide remote connection.

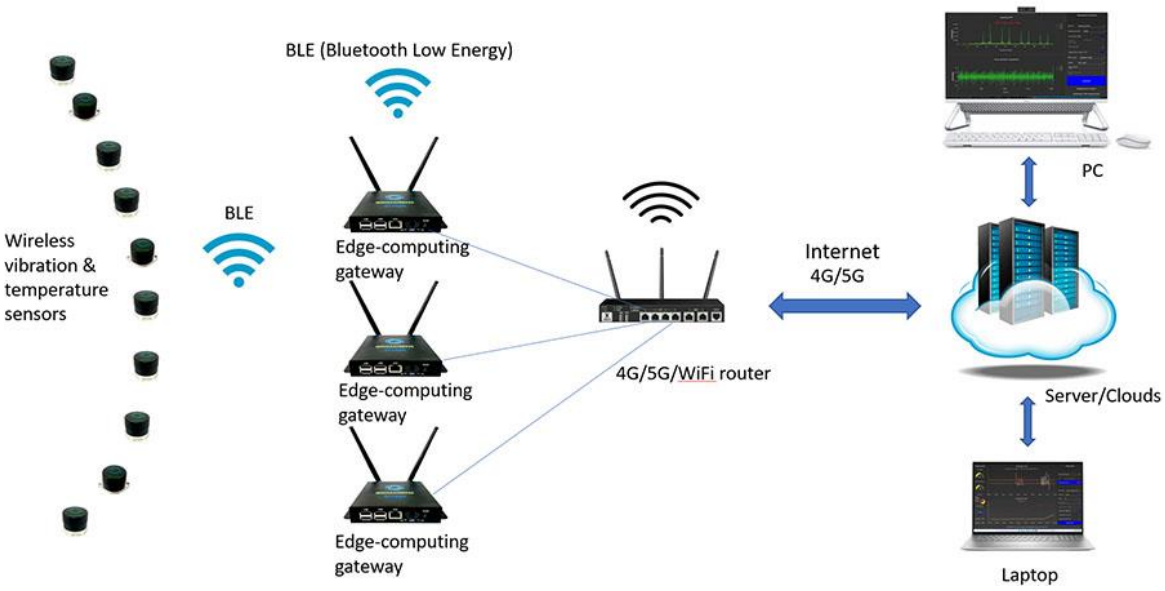


Figure 5 System connection

Please connect the power adapter to the wireless gateway, and plug an Ethernet cable to the Ethernet port of wireless gateway (Figure 5). The other end of the Ethernet cable should be plugged into the router's LAN port. Screw in one of the 2.4GHz antennas to the "BLE" port labeled at the gateway (Since the enclosure of the wireless gateway is made of metal, this external antenna ensures the gateway communicate with the sensors through the metal shielding). Please make sure that the BLE antenna is secured. Turn on the wireless gateway by pressing the power button. For GU300S, there is no power button, since the gateway is supposed to be "on" all the time.

If user has the admin right to the router, then please log in to the router and find out the IP address of wireless gateway by looking for the device name of "GU300-xxxxx", or ""GU300S-xxxxx", where "xxxxx" is the serial number of the gateway. It is recommended to use wired connection from the gateway to the router for the optimal performance.

In case that user does not have the admin right to a router, then please use software such as "Advanced IP Scanner" to find the IP address of the wireless gateway. The IP scan software can be downloaded here:

https://www.advanced-ip-scanner.com/

Advanced IP scanner has the option of running standalone without installation (Figure 6). Please make sure that the IP scanner software is running at the computer in the same network as the gateway.

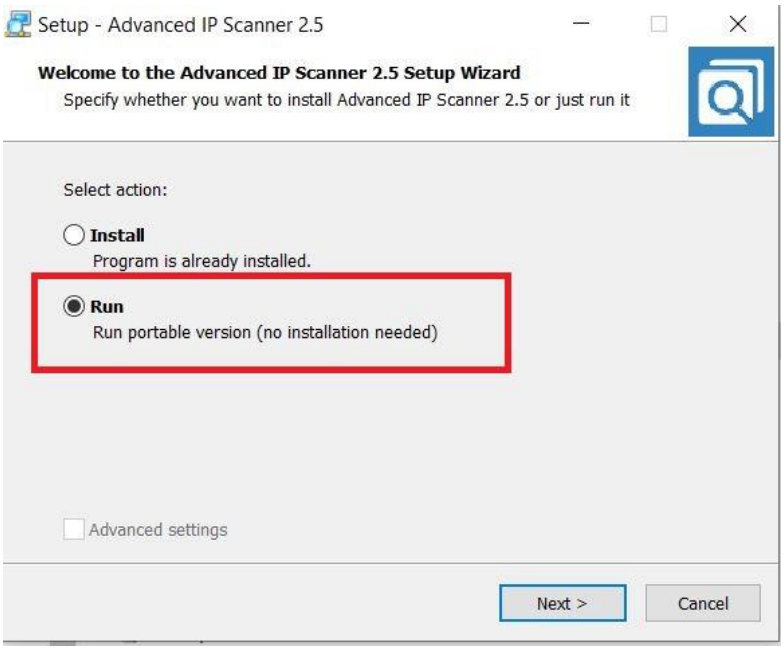


Figure 6 Advanced IP scanner running without installation

The name of the gateway may appear as the manufacturer of the microcomputer "Raspberry Pi Foundation" instead of "GU300-xxxxx" or "GU200S-xxxxx" or "GU300S-xxxxx" from the result of Advanced IP scanner. In rare cases, the name may be blank.

Note: Gateway serial number is unique for each customer, but not unique for different customers. The serial number have five digits and may contain letters. For example, the serial number can be GU300-00010, or GU300-A0755. Broadsens identifies its gateway by the combination of MAC address and serial number, which is unique for all customers. By doing this, a small serial number can be used for each customer.

Each gateway should be assigned a unique name by the customer in the MQTT configuration page. This enables tens of thousands of gateways to be deployed for each customer easily.

If the router has allocated many dynamic IPs in the past, then the router may not be able to assign an IP to the gateway. In this case, the router needs to be powered off, and powered on again to release the old IPs and assign a new IP to the gateway.

Assume that the dynamic IP of the gateway is 192.168.1.xxx (replace "xxx" with the real IP), then the link for the gateway dashboard web access is:

http://192.168.1.xxx:1880/ui

When a user logs in the for the first time, a pop-up window will appear asking for user name and password (Figure 7).

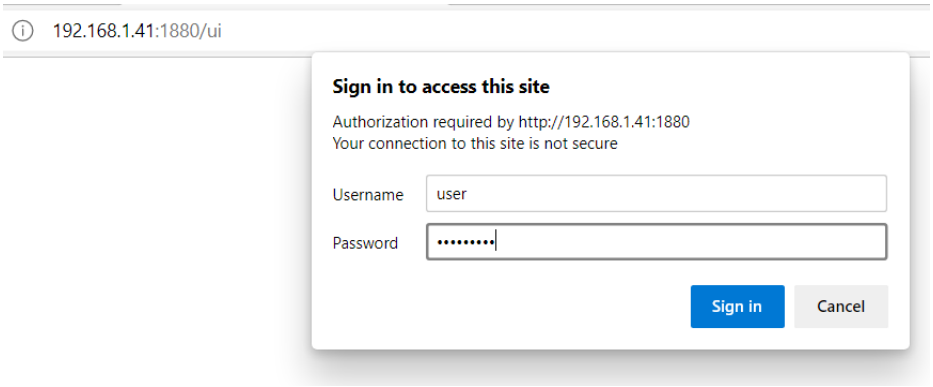


Figure 7 User name and password window

Please use the provided ID and password to log in to the web management page. Broadsens wireless gateway is designed to work in a secure enterprise network. **It is recommended to keep the gateway inside a secure sub network behind the firewall all the time.** For remote access, VPN or MQTT protocol is recommended. To send raw data or analysis result to clouds or a server, please refer to Broadsens wireless gateway communication guide, which provides detailed information and examples on how to send the information including raw data to servers at different networks or clouds.

2.1.2 GU300S 4G connection

This section shows how to setup GU300S's 4G LTE connection. Users can skip this section if gateway GU200S or GU300 is used. If an 4G or 5G router is available, then there is also no need to use GU300S. User can connect multiple gateways such as GU300 to the 4G/5G router and communicate remotely via the router. However, if user wants to use Broadsens's gateway GU300S cellular network ability, then GU300S can be set up to communicate via 4G LTE network globally (Figure 8).

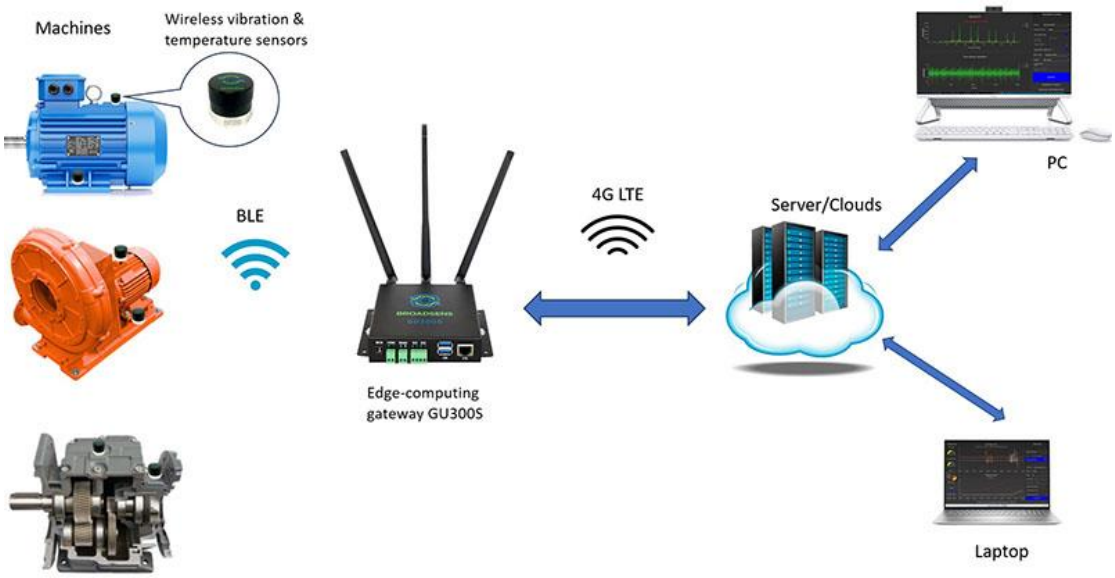


Figure 8 GU300S cellular connection

GU300S works with prepaid SIM cards or activated SIM cards that are not locked to specific devices globally. In USA, T-Mobile or AT&T network compatible SIM cards can be used directly. Some cellular providers (such as Verizon)'s SIM cards may need to be unlocked before usage.

Please follow steps below to insert the SIM card:

Step 1. In the gateway config page, click on "Shut down gateway", wait for 10 seconds, observe that the Ethernet port light is turned off, then unplug the power cable.

Step 2. Use a pin to push the SIM card eject button and pop up the SIM card tray (Figure 9). GU300S accepts mini size SIM card. Most SIM cards come with 3-cut option including mini size.

Figure 9 Eject SIM card tray from GU300S

Step 3. Insert the SIM card to the SIM card tray with contact pins facing up. Make sure that the card is firmly inside the tray (Figure 10).

Figure 10 Insert SIM card to the SIM card tray

Step 4. Push the SIM card tray back to GU300S (Figure 11), power on the gateway by plugging the cable, then the cellular network is ready to use automatically.

Figure 11 Insert SIM card tray to GU300S

Step 5. Verify the SIM card's cellular network connection. User still needs to SSH to the gateway through local Ethernet connection. GU300S's cellular network device is usb0. Use the following command to verify that a dynamic IP is assigned to GU300's 4G module (Figure 12):

ifconfig usb0

```
pi@GU300S-00009:~ $ ifconfig usb0
usb0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 192.168.225.26  netmask 255.255.255.0  broadcast 192.168.225.255
        inet6 fe80::d217:f704:bcfb:46c6  prefixlen 64  scopeid 0x20<link>
        ether 3a:26:f3:ce:bc:40  txqueuelen 1000  (Ethernet)
        RX packets 21  bytes 1604 (1.5 KiB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 47  bytes 7304 (7.1 KiB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```

Figure 12 GU300S cellular IP check

Please note that the above IP is not public IP. To access GU300S's dashboard, an VPN service is still needed. To verify that cellular network is accessible, please use the following command, where 8.8.8.8 is Google's server IP address (Figure 13):

ping -I usb0 8.8.8.8 -c 5

```
pi@GU300S-00009:~ $ ping -I usb0 8.8.8.8 -c 5
PING 8.8.8.8 (8.8.8.8) from 192.168.225.26 usb0: 56(84) bytes of data.
64 bytes from 8.8.8.8: icmp_seq=1 ttl=115 time=536 ms
64 bytes from 8.8.8.8: icmp_seq=2 ttl=115 time=685 ms
64 bytes from 8.8.8.8: icmp_seq=3 ttl=115 time=392 ms
64 bytes from 8.8.8.8: icmp_seq=4 ttl=115 time=391 ms
64 bytes from 8.8.8.8: icmp_seq=5 ttl=115 time=410 ms

--- 8.8.8.8 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4000ms
rtt min/avg/max/mdev = 391.191/482.778/684.790/114.440 ms
```

Figure 13 Verify cellular connection

Please replace 8.8.8.8 with an accessible server if Google is blocked in user's country. If "ping" shows 0% packet loss, then the cellular network is connected. Even when GU300S reboots, the cellular network will be automatically connected.

In case that user wants to check cellular signal strength, then please type in or copy & paste the following command:

minicom -D /dev/ttyUSB2

Then use the following command to check cellular signal strength (Figure 14):

AT+CSQ

And use the following command to check SIM card information (Figure 14):

AT+COPS?

```
AT+CSQ
+CSQ: 18,99

OK
AT+COPS?
+COPS: 0,0,"AT&T EIOTCLUB",7

OK
```

Figure 14 GU300S AT command

Press “CTRL+A” followed by “Z” to bring up the help screen for minicom. Press “x” to exit minicom.

SIM card requiring manual APN

Generally, the APN (Access Point Name) can be obtained automatically by the SIM. In rare cases, SIM cards from some providers require obtaining APN manually. The APN can be set by the following procedures below manually.

a) SSH to the gateway, enter the following command:

sudo minicom -D /dev/ttyUSB2

to bring up the terminal program.

b) Then enter the following command:

AT+CGDCONT=1,"IP","APN"

where the “APN” of different provider is different, please change “APN” to the proper value. Please check with the SIM card provider for correct APN.

2.2 Sensor connection and battery

The wireless sensors are preconfigured with the gateway for the customers, so that the sensors are ready to use out of the box immediately. Please refer to the included system setup sheet for sensor ID and sensor group mapping. Fresh battery is typically installed 1-2 days before the shipment. No sensor activation is required.

Broadsens’s ultra-low power wireless sensors are ultra-compact and light weight (Figure 15 and Figure 16). The compact size makes them less intrusive and can be mounted on compact spaces. The light weight generates much more accurate vibration measurements especially for light machines and structures (heavy vibration sensors affect the vibration measurement negatively). Broadsens’s vibration sensors can be installed in tight spaces compared to other bulky wireless sensors.

Figure 15 Broadsens wireless vibration sensors compared to USA quarter coin

Figure 16 SAG200 wireless IMU sensor and long-range wireless vibration sensor

Broadsens's wireless vibration sensors have two options of case: single M6 screw hole case or double screw-hole case. Single M6 screw hole case allows the sensors to be mounted with pads, studs or magnet mounts easily. Double screw-hole case allows the sensors to be mounted with two screws, or wires. Both cases can also be mounted with epoxy directly.

Note: Each sensor type comes with a serial number that ranges from 0 to 65535. The sensor serial number is not unique. Broadsens identifies its sensors by serial number, sensor type and their MAC address. Users can treat the serial number similar to the IP addresses in a local network, and use gateway's name as the local network name. By combing the gateway name with the sensor serial number, user can have unlimited number of sensors.

Please find the sensor serial number (ID) from the sticker coming with the sensor. Each sensor can be assigned a unique description by the customer in the "sensor config" page.

Broadsens vibration sensors are based on the principle of a differential capacitance arising from acceleration-induced motion of the sense element, which further utilizes common mode cancellation to decrease errors from process variation, temperature, and environmental stress. The sensors include auto-calibration circuit integrated inside, which maintains the accuracy through years of field usage. Therefore, no recalibration is required in industrial applications.

Battery is preinstalled inside the sensor, unless the customer country's shipping carrier does not allow the battery included. In this case, one needs to install the battery to the sensor. Broadsens ultra-low power sensors use compact ½ AA size intrinsic safe battery 14250 for industrial applications. The recommended battery brands include Saft 14250 and EVE ER14250 (Figure 17). These batteries are hermetic sealed, using non-flammable electrolyte and not restricted for transportation. Broadsens obtained explosive environment certificate for SVT200, SVT300 and SVT400 wireless vibration sensors (both A and V series) with EVE ER14250. Please use recommended batteries from reliable sources for the optimal performance of the sensors. The connector of the battery is Molex 51021-0200 2P (Molex 51021-2P) with 1.25mm pitch.

Figure 17 14250 battery for Broadsens SVT-A & SVT-V wireless vibration sensors

Broadsens long-range wireless vibration sensors (SVT-L series) and wireless IMU sensor SAG200 use 18505 battery (Figure 18). SVT-L long-range sensors have integrated signal amplifier to boost both transmission and receive signal; Wireless IMU SAG200 does edge-computing inside the sensor. Therefore, both sensor types require longer battery for long-term usage. The 18505 battery capacity is 4000mAh. The connector of the battery is the same as the 14250 battery (Molex 51021-0200).

Figure 18 ER18505 battery for SAG200 wireless sensor

Please refer to the online guide on how to replace the sensor's battery.

Typically, sensor group is pre-configured based on customer's requirements. The default SVT-A series sensor group starting from "01", continuing in the pattern of "02", …, "0A", "0B", …, "0Z", "0a", "0b", …, "0z", "10", "11", …, and ending at "zz". There are 3,844 possible groups. When a customer plugs in the wireless gateway, the system is ready to use out of the box. The sensor group can be adjusted by the user at the "sensor config" page. **Please keep a record of gateway and sensor ID/group mapping.** If users change a sensor's group

number, then the sensor can only be accessed from the new group. The maximum number of SVT-A series sensors and SAG200 sensors in a group is 6.

2.3 Sensor mounting

One advantage of wireless sensors compared to wired sensors is the easy installation. No wiring is required on the sensors. Wireless temperature sensor SVT200-T uses epoxy mounting method. The temperature sensor measures the temperature on the surface of the machine/structure. Simply bond the sensor with epoxy to the spot where you want to monitor. If you just want to monitor the temperature temporarily, then a thermal conductive paste can be used. First apply some paste to the surface of the structure, then attach the temperature sensor to the paste gently.

SVT standard wireless vibration sensors (SVT200 to SVT400), SVT-L long-range wireless vibration sensors (SVT200-L to SVT400-L) and wireless IMU sensor SAG200 have four ways to mount: Epoxy mount, magnet mount, mounting pad or stud mount (Figure 19). The sensors have standard M6 size screw hole at the bottom, and can be fastened using magnet mount, mounting pad or M8 to M6 mounting stud. Broadsens magnet mount has M6 stud that can be screwed into the bottom of sensors directly. The magnet mount has H-shape legs, and can be installed on both flat or curved surfaces. Mounting pad ACE-PAD-01 has integrated M6 stud, and can be screwed into the sensor bottom, and mounted to structures with epoxy. Mounting pad ACE-PAD-02 has M8 screw hole in the middle, and should be used together with the mounting stud. The M8 end of the mounting stud can be screwed into the mounting pad ACE-PAD-02, and the M6 side of the mounting stud can be screwed into the sensor. The mounting stud is M8x10L(10mm length, 1.25mm thread pitch) at the bottom(to the structure), and M6*6L (6mm length, 1mm thread pitch) at the top(to the sensor). To measure a machine's status with strong vibration, it is recommended to use stud mount or mounting pads. Stud mount provides the best long-term monitoring consistency in a strong vibration environment.

Figure 19 Vibration sensor mounting

Real-time wireless vibration sensors SVT200-V, SVT300-V and SVT400-V in double-screw hole case support epoxy mount, screw mount and hanging wire mount. They can also come in standard single M6 screw hole case, which allow for magnet mount, stud mount and pad mount too. An SVT-T sensor is ideal for real-time monitoring of critical machines, such as motors, fans, high voltage power lines, train pantographs, water pumps, valves, engines, etc.

2.4 Front panel

When you log in for the first time, the sensors are preconfigured with the gateway and are ready to use out of the box. There are two types of layouts of the front panel. The standard version and the special edition. The standard version is for customers who purchased SVT-A series sensors, or both SVT-A and SVT-V series sensors. The special edition is for customers who only purchased SVT-V series sensors.

2.4.1 Standard front panel

Standard front panel is the commonly used version. It is for customers who have SVT-A series sensors, or both SVT-A and SVT-V series sensors. In the front page, the left side of the panel shows the gateway status, including gateway CPU usage, CPU temperature, memory usage, data usage and gateway clock and up time since its last reboot. The middle of the panel shows the acceleration and temperature information. The middle panel is blank when the gateway powers up for the first time (Figure 20). The right panel shows the DAQ control for SVT-A series sensors. The bottom of the panel shows the current BroadVibra software version number and copyright information.

Figure 20 Standard front panel

On top right corner, the dashboard shows the current computer time. Since version 2.8.1, the gateway clock time is added on the bottom left. User should pay attention to the gateway time and the computer time (Figure 21). If the date and time are different, then it is important to adjust the gateway's clock, make sure that the gateway clock and computer time are consistent. The gateway has integrated database, which uses UTC time. When the gateway saves data, retrieves data, plots data, or sends data via MQTT to the clouds, the gateway uses the gateway clock, instead of the clock from the local computer.

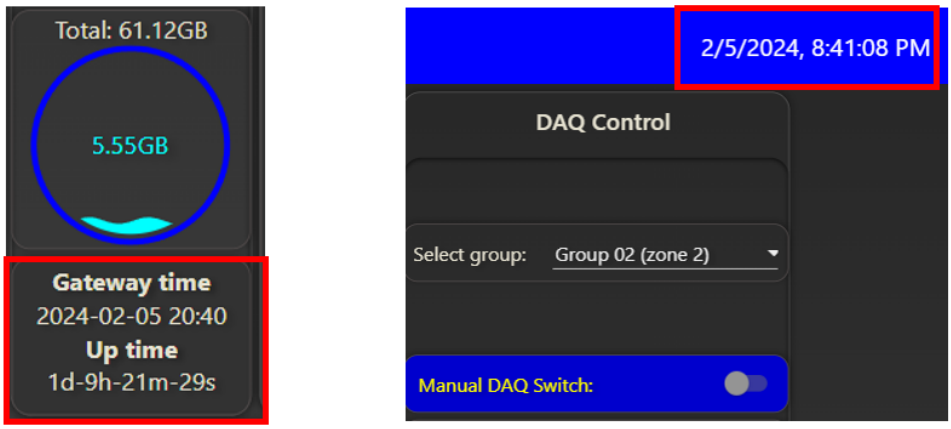


Figure 21 Gateway time vs computer time

User can update the gateway clock by SSH to the gateway (please refer to Appendix 1), and following standard Linux operation to change its time. If there is a time difference, then the gateway's time zone should be updated based on the gateway's location. This can insure that the sensors data are saved in correct time.

The gateway has internal precision hardware clock based on DS3231. When there is no internet connection and clock server, the gateway automatically switches to its own hardware clock to ensure proper time. There is a CR2032 cell battery to power the hardware clock. If the gateway cannot keep the correct time when it is powered off and powered on, then it is necessary to replace the CR2032 cell battery. After the battery replacement, please connect the gateway to internet to obtain the correct clock, and verify that the gateway can keep correct time.

2.4.2 Special edition front panels

If a customer only has SVT-V series sensors, then a special edition front panel is used. In this edition, the real-time vibration monitoring sensor SVT-V series chart is put in the first page. The SVT-A series sensor charts and DAQ control panel is moved to the second page and is called "SVT-A DAQ" (Figure 22).

In this front panel, the top chart shows the vibration velocity, the bottom two charts show acceleration RMS and temperature measurement. The side panel allows users to select SVT-V sensor group, and disable data saving, and refer to the ISO 10816 standard for vibration severity reference and alarms (please refer to chapter 3 for details).

The "Save data to database" switch is moved to the front page in the special edition version (since BroadVibra 2.8.2 SE). The switch should be turned off when users are installing the SVT-V sensors. Turning off data saving can avoid saving garbage data, since SVT-V sensors take data continuously non-stop. After user finishes SVT-V sensor installation, then user should turn on this switch, so that the vibration data can be saved to the database. User can review the

history data from “History data” page (please refer to chapter 4 for details).

Please note that “Save data to database” switch also controls data saving of all other sensor types including SVT-A sensor, SAG sensor and SVT-T sensor.

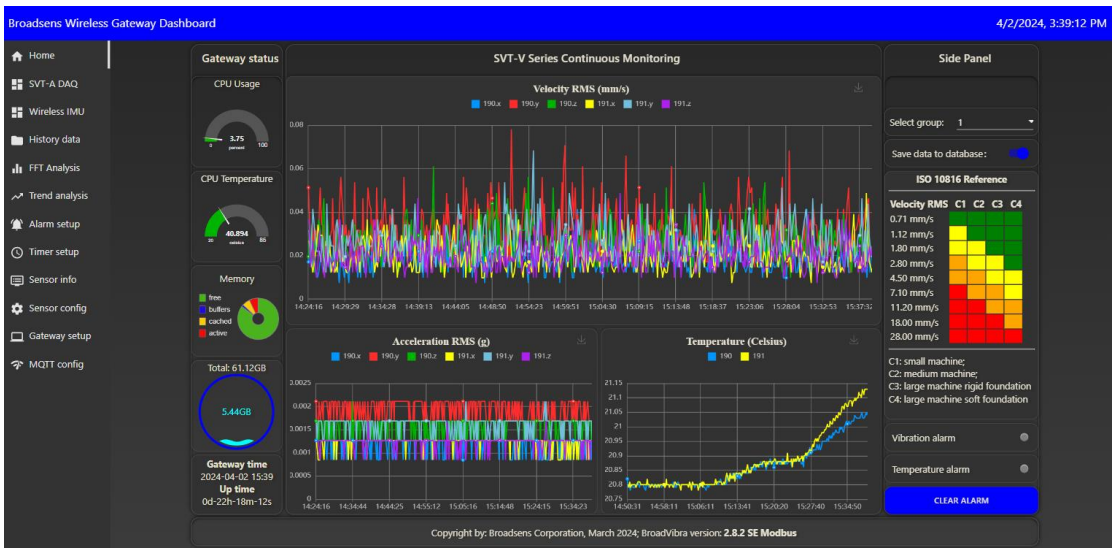


Figure 22 Special edition front panel with SVT-V sensors in homepage

If a customer only has SAG200 wireless IMU sensors, then the following special edition panel is used (Figure 23). Please note that users need to click on “Manual switch” to take data, so that the sensor signal can be shown in the charts.

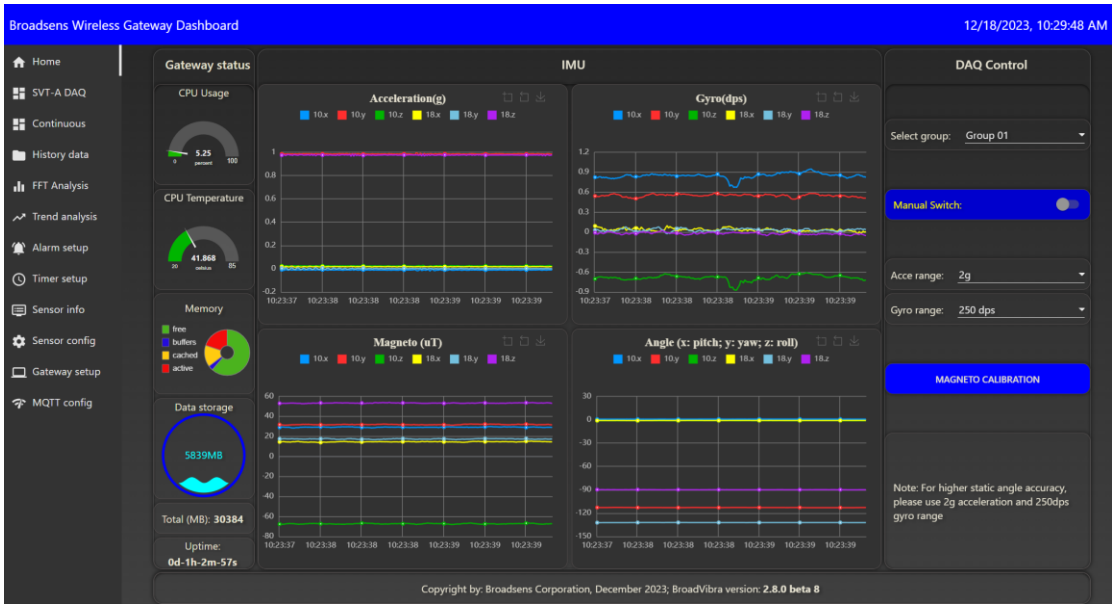


Figure 23 Special edition dashboard with SAG sensors in homepage

2.4.3 DAQ control

In the DAQ control panel (only applicable to SVT-A series sensors and SAG wireless IMU sensors), user can manually start the DAQ by pulling the “Manual DAQ switch” to the right. To do this, first select a “group/zone”, select “Real time” DAQ mode, and leave the rest at default selection, then turn on the DAQ switch, and the DAQ knob will turn into red color, showing that the gateway is connecting to the sensors in the selected “group/zone”. Depending on the distance from the gateway to the sensors, and number of sensors in the same group, it may take a few seconds or up to 30 seconds (if synchronization is used) for the gateway to receive data (Figure 24).

In the acceleration chart (Figure 24), the sensor ID is displayed for identification purpose. For example, if the ID of an SVT-A sensor is 8, then it will show 8.x, 8.y and 8.z in the chart, which correspond to x axis, y axis and z axis acceleration data. The live chart is very useful to visualize the acceleration status of a machine in operation.

Although Broadsens wireless sensors can continuously take data in real time mode, batch mode, multi DAQ mode and live FFT mode(synchronized or asynchronized), it is recommended to take data periodically with timers. This can prevent the gateway from being overloaded with large amount of data in a short period of time.

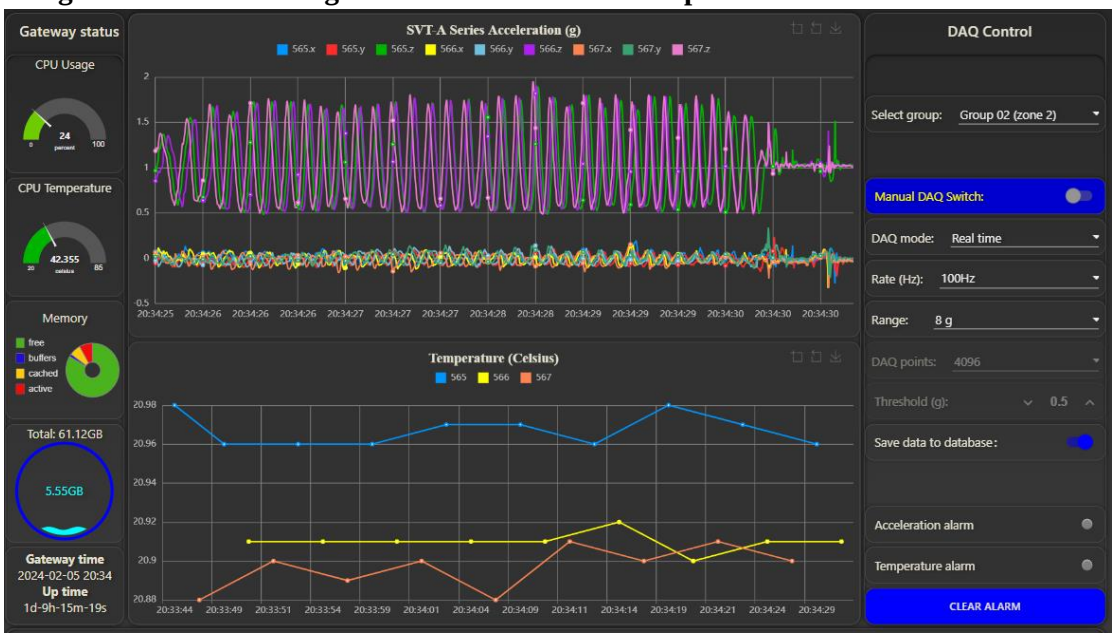


Figure 24 Dashboard with data acquisition

Broadsens ultra-low power wireless vibration sensors are optimized for acceleration data acquisition. This is the reason why Broadsens’s wireless vibration sensors can transmit raw data with extremely high battery efficiency. During the DAQ, emphasis is always given to the acceleration measurement, less data are taken for the temperature measurement, since the temperature changes slowly. In default, temperature is measured every 5s in real-time mode, or between each batch at batch mode and multi DAQ mode, and at the end of measurement in single DAQ and single FFT mode.

For fully automatically scheduled monitoring, please use timers (please refer to the "Timers setup" page). Acceleration alarms can also be set up at the "Alarm setup" page. When the acceleration exceeds a predefined threshold, then the "Acceleration alarm LED" will turn into red color.

In default, wireless gateway comes with 10 group/zones. Each group/zone can be configured and monitored separately. In each gateway, the zone number always starts from 1 and ends at 10. More zones can be added per user request. The group number can vary from "01" up to "zz" according to ASCII table order. Each zone is mapped to a unique group. The group/zone mapping can be set up at the "sensor configure" page (chapter 9. Sensor configuration of this manual). Multiple vibration sensors can be allocated to the same group/zone. The vibration sensors in the same group/zone can take data manually, or automatically by a timer. The timers can be set up at the "Timers setup" page. User can set up multiple times a day for the monitoring purpose. In case that users want to change a sensor's group, then it can be adjusted from the "Sensor config" page (chapter 9. Sensor configuration of this manual).

2.4.4 Acceleration range adjustment

For SVT-A series sensors, the adjustable g-range values are:

- 2g
- 4g
- 8g
- 16g*
- 32g*
- 64g*

Note: 1g=9.81 m/s^2

SVT200-A's range is user adjustable from 2g to 8g; SVT300-A's range is adjustable from 2g to 16g, and SVT400-A's range is adjustable from 8g to 64g.

The GUI allows you to setup an acceleration range outside the specified range of a sensor. This feature is useful if user wants to combine sensors of different range into the same group. If user sets an acceleration range outside the range of SVT200-A, SVT300-A or SVT400-A, then the sensor will ignore the new setting, and use the previous range.

For example,

. If user takes data at 16g for both 300-A and 400-A first, and user changes the range to 64g, then 300-A will stay at 16g, and 400-A will change to 64g.

. If user takes data at 8g for both 300-A and 400-A first, and users change the range to 64g, then 300-A will stay at 8g, and 400-A will change to 64g.

2.5 Data acquisition modes and sampling rate

Broadsens SVT-A series vibration sensor data acquisition supports adjustable sampling rate, adjustable DAQ (Data Acquisition) sampling modes, adjustable g range, adjustable DAQ points (in single DAQ, multi DAQ and single FFT mode), DAQ synchronization in the same group (Figure 25), and adjustable trigger threshold in trigger mode.

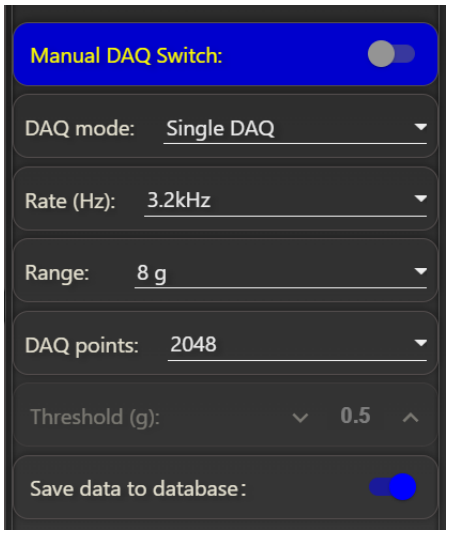


Figure 25 DAQ mode and options

The supported sampling modes of SVT-A sensors are:

- Real-time mode
- Synchronized real-time mode
- Batch mode
- Synchronized batch mode
- Single DAQ
- Synchronized DAQ
- Multi DAQ mode
- Synchronized multi DAQ mode
- Single FFT mode
- Live FFT mode
- Trigger mode (released in May, 2023)

Each mode has an identification number, as shown below. When the history data is exported or transferred via MQTT protocol, the data acquisition mode and the sampling rate are also included. The sampling mode and sampling rate can be used to re-construct the data.

Table 3 Data acquisition modes

Data acquisition modes	Identification code
Real-time	0
Synchronized real-time	1
Batch mode	2
Synchronized batch mode	3
Single DAQ	4
Synchronized single DAQ	5

Multi DAQ	6
Synchronized multi DAQ	7
Single FFT	8
Live FFT	9
Trigger mode	10

Currently, wireless IMU sensor SAG200 only has real time mode with fixed 50Hz sample rate.

2.5.1 Real-time mode and synchronized real-time mode

In real-time mode and synchronized real-time mode, vibration sensor takes data and sends out data continuously. There is no limit on how long the data acquisition lasts in these two modes, which allows the software to monitor down to 1 rpm rotating machines. The adjustable sampling rates at real-time and synchronized real-time mode are:

- 2Hz*
- 4Hz*
- 7Hz*
- 13Hz*
- 25Hz*
- 50 Hz
- 100 Hz
- 200 Hz

*: 2Hz, 4Hz, 7Hz, 13Hz and 25Hz require BroadVibra version 2.8.3 or higher, and SVT-A sensor firmware v2.9 or higher.

Since wireless network condition and the distance from the sensor to the gateway varies, there is slight variation on the arrival time of the sample data. Therefore, it is important to understand that the time stamp for the exported sensor data is only the time that the data arrives at the gateway. There is a buffer at the sensor, that ensures that the sensor takes data at the defined sampling rate (50Hz, 100Hz or 200Hz).

Real-time mode is great for live view of the machine vibration status and time domain analysis. When the sensor is far away from the gateway, the signal becomes weak and data could be lost during communication. In this case, the sensor will re-transmit the data, which can make the sampling rate lower than the given value. The longer the distance, the slower the transmission speed, and the lower the sampling rate.

For frequency domain analysis in an unstable network, it is recommended to use single DAQ mode, synchronized single DAQ mode, or single FFT mode to ensure the sample rate at the sensor.

Starting from BroadVibra version 2.4.1, the synchronization number is automatically calculated based on the number of sensors in a group. Please note that since all sensors share

the same bandwidth, it is recommended that the number of sensors in the same group is less than or equal to 4 (the maximum allowable number is 8).

When the sensors in the same group are synchronized to take data, they start taking data at the same time. It means that when a sensor connects to the gateway, the gateway will not release the "start DAQ" command unless one of the following two conditions are met:

1. The number of sensors connected to the gateway is equal to the synchronization number, or
2. The timer in the gateway reaches 30 seconds.

In the synchronization mode, the gateway will issue the "start DAQ" command immediately once the all the sensors in the current group connect to the gateway. The gateway will wait for the maximum of 30 seconds. Even if the number of sensors connected is less than the number of sensors in the current group, the data acquisition of connected sensors will start in 30 seconds after the "DAQ" command is issued to save energy. If all sensors have good RSSI (Received Signal Strength Indicator), the typical maximum connection time is less than 15 seconds. The 30 second limit guarantees that if there is a out of the range/faulty sensor in the same group, the system can still start and finish the DAQ without waiting and draining the connected sensors' battery indefinitely.

In real-time mode at 50Hz sampling rate, the power consumption of SVT-A series sensor is less than 200 μA in average (Figure 26), which is the best in the industry. When calculated with 1,000mA battery capacity, SVT-A sensor can take data continuously at 50Hz, 24 hours a day, 7 day a week for more than 6 months before replacing battery. The real battery capacity is 1,200 mA in room temperature. In harsh environments, the battery capacity will be reduced and that's why Broadsens uses 1,000mA capacity for the calculation to reflect more realistic battery life estimate.

[Tips]

Please note that the higher the sampling rate, the higher the noise. The higher the g range, the higher the noise too. SVT400-A will have slightly higher noise floor than SVT200-A and SVT300-A at the same g-range, since SVT400-A is designed for high g measurements. Therefore, user should choose proper g-range and the sampling rate based on the vibration level and bandwidth requirements to achieve the optimal signal to noise ratio.

Figure 26 Power consumption of SVT-A series sensor in real-time mode 50Hz

Please note that although the SVT-A series sensor and gateway can acquire raw acceleration data and temperature data continuously nonstop for months, the database coming with the gateway could be overloaded with such big amounts of data. A typical symptom of an overloaded system is the CPU usage spikes over 100% even if there is no active SVT-A series data acquisition going on. The active memory usage is also more than 50%. When this happens, it is required to delete the history from the database.

To take data continuously for a long time, it is recommended to use a more powerful dedicated server locally or on the clouds to handle such large amount of data. User can turn off "saving data to database" switch, and turn on the MQTT data output to send data to the data server. By doing this, the system can take data for many months non-stop.

Gateways with extended memory (4GB or 8GB version) also allow users to take raw data continuously for a much longer time than 2GB RAM memory.

It is safe for the SVT-V series sensor taking data continuously for years, since SVT-V sensors only send out computed results instead of raw data, hence much lower data volume.

2.5.2 Batch mode and synchronized batch mode

In batch mode and synchronized batch mode, the SVT-A series vibration sensors (SVT200-A, SVT300-A and SVT400-A) take a collection of data (320 samples) at the guaranteed given frequency, and send the data out wirelessly at the same time. The process repeats until the gateway's DAQ switch is turned off.

Batch mode timing chart is shown in Figure 27. In the following picture, the DAQ time is shown in blue arrowed line, and the data transmission time is shown in yellow arrowed line

(raw data transmission). At high sample rate, there could be a small-time gap between each batch, since the DAQ speed could be higher than the wireless transmission speed at high sample rate.

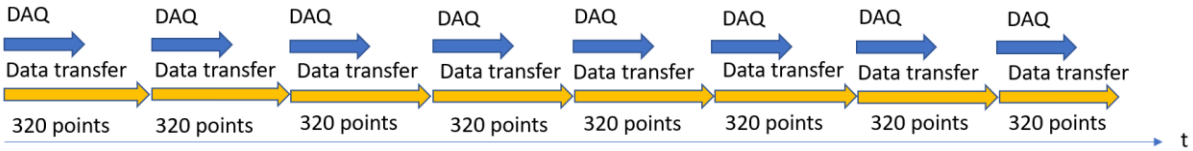


Figure 27 Batch mode timing chart

When the sampling rate is lower, and then the time gap between DAQ and data transfer is smaller. At 400Hz or 800Hz, there could be no time gap in between since the wireless transmission speed could be well above the DAQ speed if the gateway is close to the sensors. The time gap is affected by many factors such as the distance between the sensor and the gateway, interference and barriers in between.

The batch mode is very energy efficient. The latest testing data show that the batch mode power consumption is about 400µA in average. At 3.2kHz sampling rate batch mode, the power consumption is only 435µA (Figure 28). Please note that the new batch mode consumes slightly higher power than previous version, since 100ms break is removed in the new version. Moreover, the sensor sends out data in parallel with the data acquisition, instead of waiting for the end of data acquisition. This allows the throughput to be more than doubled.

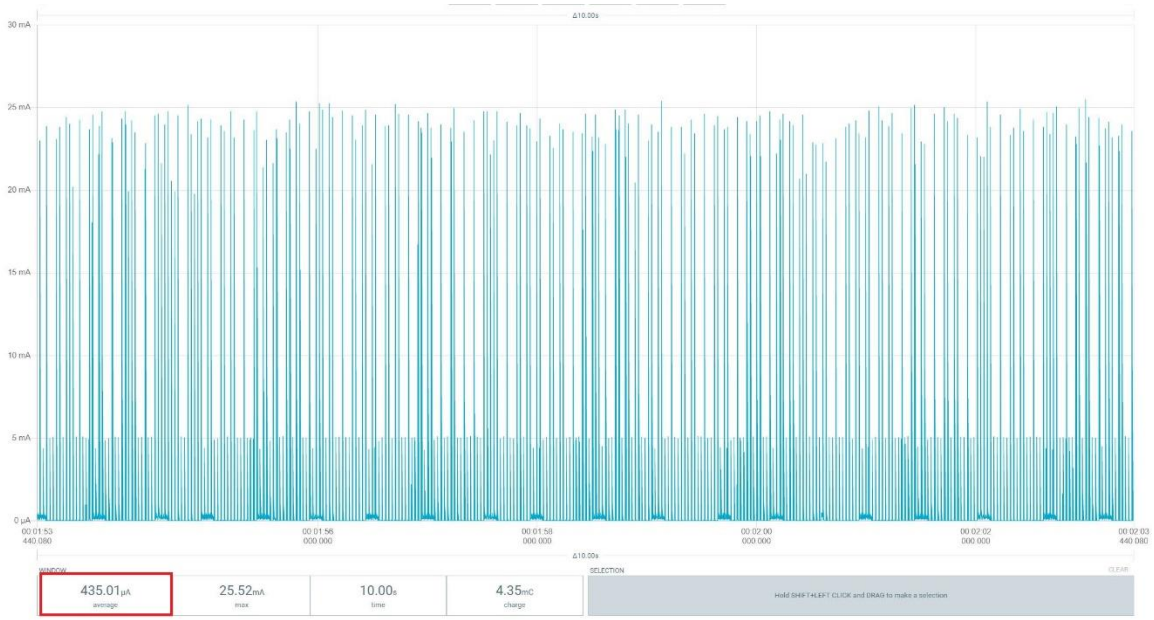


Figure 28 Power consumption of SVT-A series sensor at batch mode 3.2kHz

In batch mode, high frequency faults can be detected during data acquisition. Since in batch mode, the vibration sensor can continuously work for a long time with extreme high battery efficiency, the defects from machines can be completely covered.

The adjustable sampling rates at batch mode and synchronized batch mode are:

- 400 Hz
- 800 Hz
- 1600 Hz
- 3200 Hz
- 6400 Hz
- 12800 Hz
- 25600 Hz

2.5.3 Single DAQ mode and synchronized single DAQ mode

In single DAQ and synchronized single DAQ mode, the sampling frequency is guaranteed at the wireless sensor side. There is a circular buffer at the sensor that saves the data to insure the sampling rate. Therefore, even when the wireless transmission speed may vary from time to time, the sensor can guarantee the sampling rate.

Each sample is 6 bytes long, which contains x, y and z axes acceleration data in 16-bit format. The number of samples can be adjusted in single DAQ mode (Figure 29).

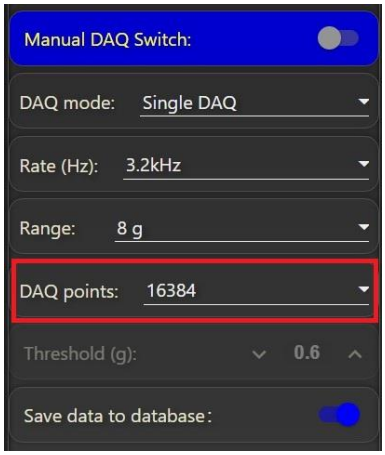


Figure 29 Single DAQ mode sample points adjustment

The adjustable sampling rates at single DAQ mode and synchronized DAQ mode are:

- 400 Hz
- 800 Hz
- 1,600 Hz
- 3,200 Hz
- 6,400 Hz
- 12,800 Hz
- 25,600 Hz

The adjustable number of samples in single DAQ mode is:

- 2,048

- 4,096
- 8,192
- 16,384

In the single DAQ mode, the vibration sensor takes the selected number of samples at the given frequency, and save the data at the sensor buffer, and starts transmitting at the same time. Typically, the data acquisition time could be much faster at high sampling rate. Therefore, it is normal that the sensor already finishes data acquisition, but the data transmission is still in progress. Single DAQ and synchronized DAQ mode are ideal for FFT analysis.

In the single DAQ mode, the gateway will check the number of sensors that finished data acquisition and transmission of data to the gateway. When all sensors in the same group finish data acquisition and transmission of data, the gateway will automatically turn off the DAQ switch. It is recommended to add a stop timer for single DAQ, in case that a sensor in the group is moved out of the range of the gateway, or damaged by accidents. Please refer to "Timer setup" section on how to set up a timer.

[Separator data]

Starting from sensor firmware version 2.3, a separator/boundary is added at the end of each sensor's single DAQ points to make it easier for users to find the correct ending of each single DAQ. In previous sensor firmware version, users need to use timer marker to find the end of single DAQ samples. The separator data has all zero values at x, y and z-axes (Figure 30). Because in real world, it is impossible for the acceleration data to be all zero in three axes. The length of the separator is 40 data points.

Attention: In history data page, the exported CSV data file includes the data arrival time (transmission time) from the sensors to the gateway. The time stamp is not related to the sample rate. The time stamp is used to save the data and retrieve the data from the database.

For vibration analysis, after a user queries the data from the database, then the time stamp can be ignored, and the sampling rate should be used for FFT analysis.

[Data reconstruction]

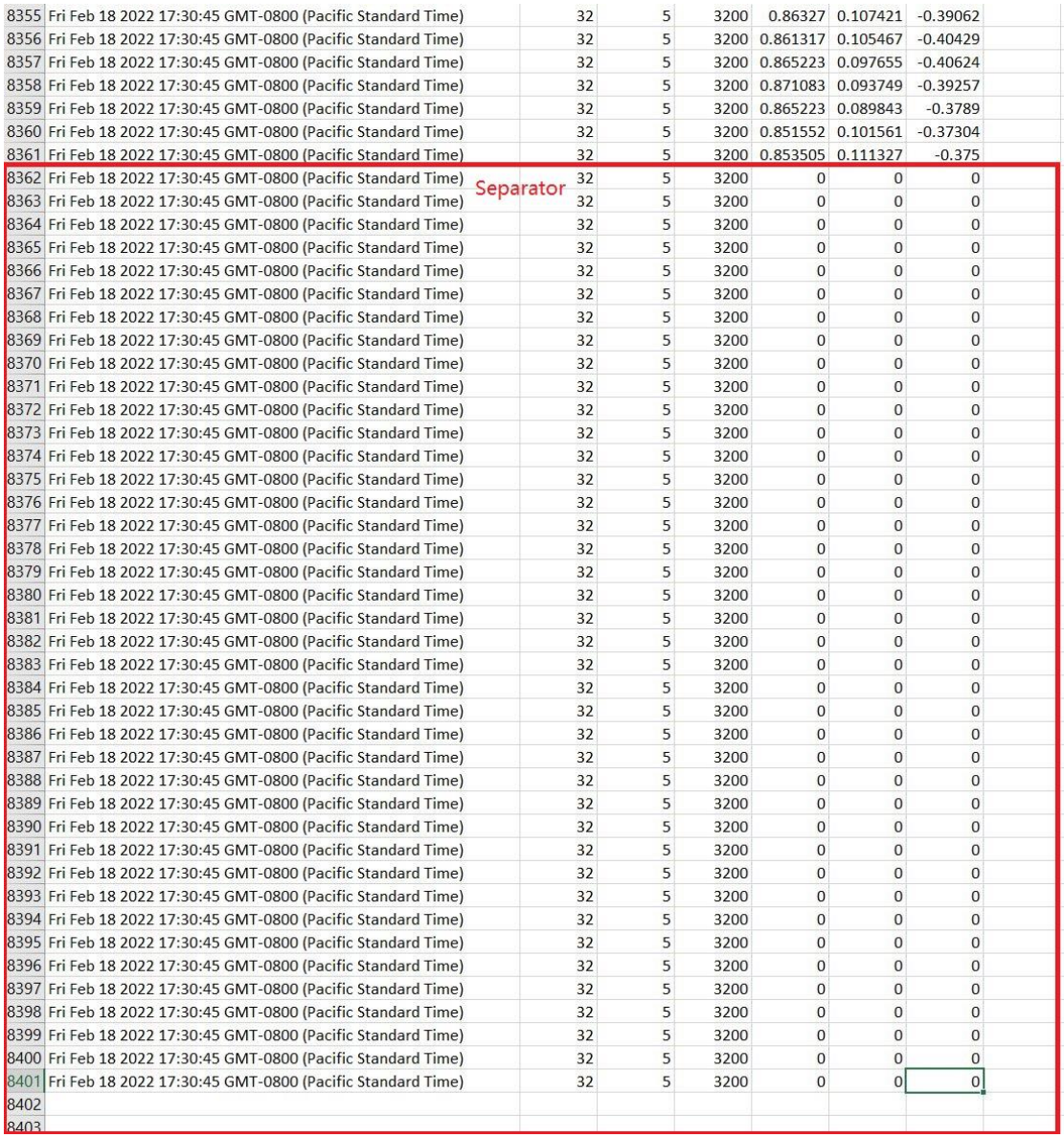
Data can be re-constructed as the following:

- Discard any separator data (x, y, z axes values are all equal to zero)
- The DAQ starting time can be set to the arrival time of the first data sample (x, y and z axis).
- The DAQ ending time= starting DAQ time + number of samples /sampling rate.

For example, if user takes 4,096 samples at 12.8kHz, and the first sample arrives at

11:09:08. Then the time stamp of each point is as follows:

Data arrival time stamp	Sample index
11:09:08	1
11:09:08+ 1/12800 s	2
11:09:08+2/12800 s	3
...	
11:09:08+ 4096/12800 s	4096



8355	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0.86327	0.107421	-0.39062
8356	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0.861317	0.105467	-0.40429
8357	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0.865223	0.097655	-0.40624
8358	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0.871083	0.093749	-0.39257
8359	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0.865223	0.089843	-0.3789
8360	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0.851552	0.101561	-0.37304
8361	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0.853505	0.111327	-0.375
8362	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8363	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8364	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8365	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8366	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8367	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8368	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8369	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8370	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8371	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8372	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8373	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8374	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8375	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8376	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8377	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8378	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8379	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8380	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8381	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8382	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8383	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8384	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8385	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8386	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8387	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8388	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8389	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8390	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8391	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8392	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8393	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8394	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8395	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8396	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8397	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8398	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8399	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8400	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8401	Fri Feb 18 2022 17:30:45 GMT-0800 (Pacific Standard Time)		32	5	3200	0	0	0
8402								
8403								

Figure 30 Separator data at the end of single DAQ

[Timing chart for synchronized single DAQ]

At synchronized single DAQ mode, sensors in the same group start taking data at the given

sample rate at the same time, and finish data acquisition at the same time. The sampling rate is guaranteed at the sensor side. A timing chart of the synchronized single DAQ mode is shown Figure 31. In the figure,

- "t_c" means sensor connection time (when sensor connects to the gateway), which can vary from sensor to sensor in the same group;
- "t_daq_s" means sensor data acquisition start time, which happens at the same time;
- "t_trans_s" means sensor data transmission time, which is typically the same time, but there could be slight variance;
- "t_daq_done" means sensor DAQ finishing time, which is the same
- "t_trans_done" is the sensor data transmission finishing time, which could vary a lot.

Figure 31 Synchronized single DAQ mode timing

In the synchronization mode, the gateway will issue the "start DAQ" command immediately once all the sensors in the current group connect to the gateway. The gateway will wait for the maximum of 30 seconds. Even if there are sensors not connected to the gateway, the data acquisition of connected sensors will start in 30 seconds after the "DAQ" command is issued to save energy. This is useful if one of the sensors is faulty (for example, run out of battery), then the other sensors can still take data without waiting indefinitely.

At single DAQ mode, the sensor takes data and transmit the data at the same time with the maximum capacity, so that the average power consumption is slightly higher in this mode. The average current can reach up to 428μA at peak usage when the sensor is taking data and also transmitting (Figure 32) at 12.8kHz. The current drops down to 338μA when data acquisition is finished and only data transmission is in progress (Figure 33).

After all data transmission is finished, then the sensor current drops down to around 130uA, since the sensor is still connected to the gateway. User should turn off the DAQ switch after

the single DAQ is done to save sensor power.

Since wireless network condition and the distance from the sensor to the gateway varies, there is variation on the arrival time of the sample data. If the sensor detects that a packet is lost, then the packet will be re-transferred to the gateway. Therefore, it is important to understand that the time stamp for the sensor data is only the time that the data arrives at the gateway.

There could be only a few hundred samples per second arrived at the gateway. To re-construct the data at the gateway, the sampling mode and the sampling rate used at the sensor side is also saved. To reconstruct the data, please use the sampling rate instead of the time stamp.

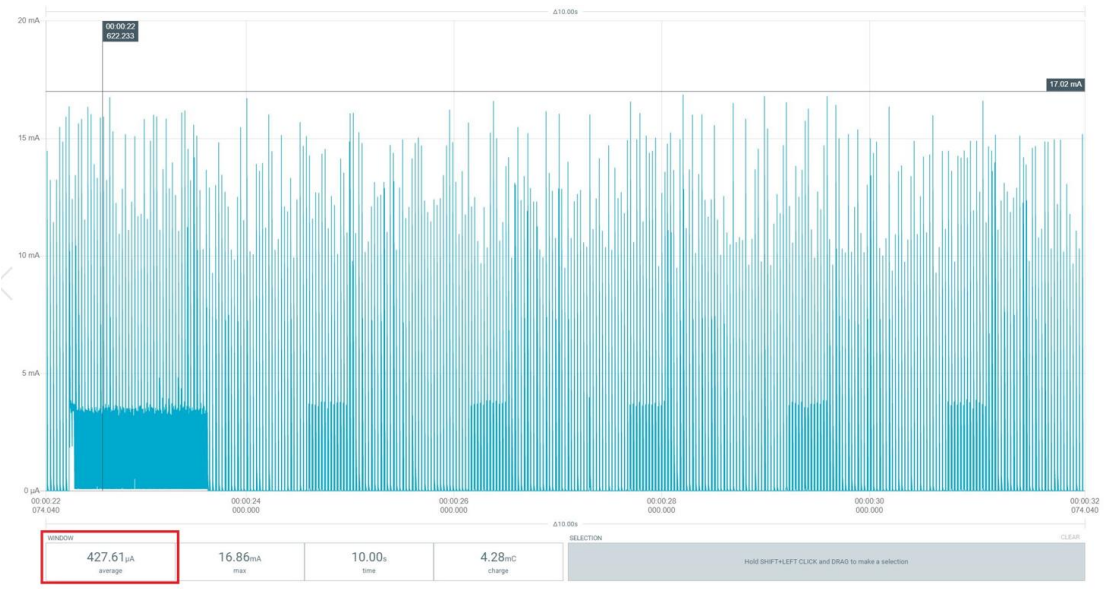


Figure 32 Single DAQ mode power consumption with both DAQ and transmission

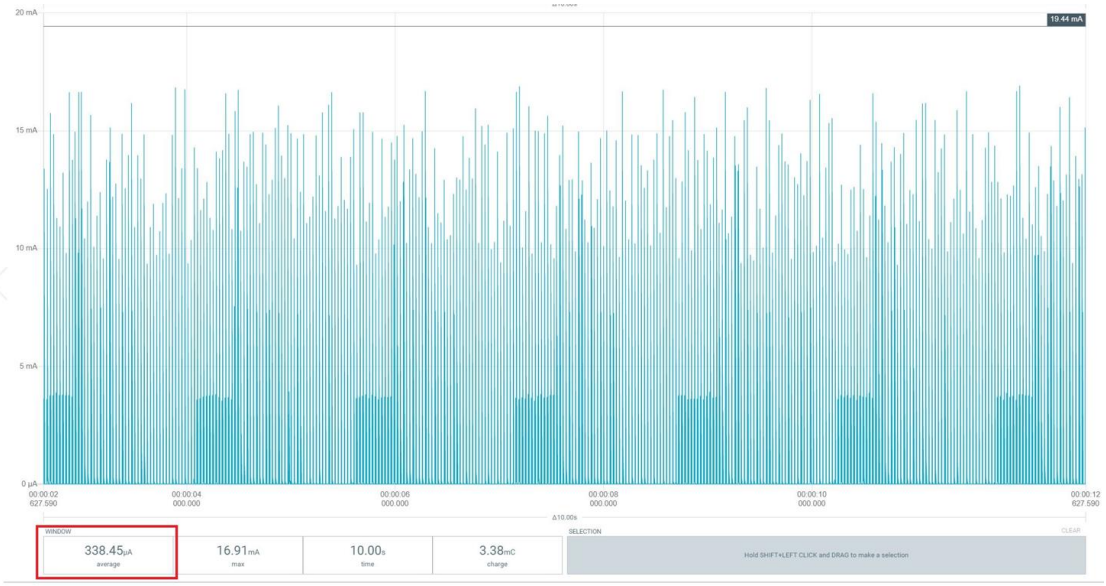


Figure 33 Single DAQ mode power consumption after DAQ, only transmission

2.5.4 Multi DAQ mode and synchronized multi DAQ mode

Since BroadVibra version 2.1.7 and SVT-A series sensor firmware version 2.2, the new multi DAQ mode is added. Multi DAQ mode is the continuous run of single DAQ mode. This mode allows almost continuous data acquisition at high sample rate, which is useful for long-time data acquisition and predictive maintenance.

The adjustable sampling rates at multi DAQ mode are:

- 400 Hz
- 800 Hz
- 1,600 Hz
- 3,200 Hz
- 6,400 Hz
- 12,800 Hz
- 25,600 Hz

The adjustable number of samples in multi DAQ mode is:

- 2,048
- 4,096
- 8,192
- 16,384

The timing chart of multi DAQ mode with a selection of 16,384 points and 2,048 points is shown in Figure 34. One can see that the DAQ typically finishes faster than the raw data transmission. When the circular buffer is filled up, then the sensor will wait for the data transmission to be finished before it starts the next DAQ. Therefore, 2,048 sample points has a smaller gap between each DAQ compared to 16,384 points. 16,384 sampling point gives a large number of continuous DAQ compared to 2,048 points. At low sample rate such as 400Hz, the time gap could be equal to 0.

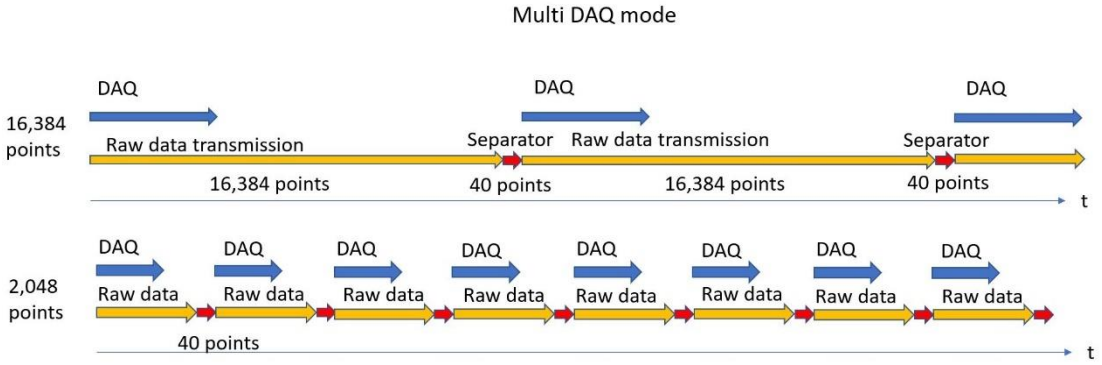


Figure 34 Multi DAQ mode timing chart comparison of 16,384 points to 2,048 points

At the gateway side, since data arrive continuously, a separator is used to tell the data belong to which DAQ. The separator data is all zero values at x, y and z-axes. Because in real

world, it is impossible for the acceleration data to be all zero in three axes. The length of the separator is 40 data points (Figure 35). From Figure 35, the time stamp is only used to save the data and retrieve the data from the database. For vibration analysis, after user queries the data from the database, then he should ignore the time stamp, and re-construct the data based on the sampling rate. In this example, we used 12800 Hz sampling rate.

User may also notice that the real data length is slightly longer than the specified data points. This design gives some extra data points and guarantees that the FFT analysis has enough points.

16718	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	-0.10156	-0.00928	-0.97705
16719	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	-0.10498	-0.01855	-0.98144
16720	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	-0.10352	-0.01953	-0.98926
16721	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	-0.10254	-0.01367	-0.98974
16722	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)	Separator	32	6	12800	0	0	0
16723	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16724	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16725	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16726	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16727	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16728	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16729	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16730	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16731	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16732	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16733	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16734	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16735	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16736	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16737	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16738	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16739	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16740	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16741	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16742	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16743	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16744	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16745	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16746	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16747	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16748	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16749	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16750	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16751	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16752	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16753	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16754	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16755	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16756	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16757	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16758	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16759	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16760	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16761	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	0	0	0
16762	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	-0.10791	-0.01709	-0.95801
16763	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	-0.08643	-0.01904	-0.95068
16764	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	-0.0708	-0.00439	-0.94775
16765	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	-0.09375	0.005371	-0.94629
16766	Fri Dec 10 2021 16:36:25 GMT-0800 (Pacific Standard Time)		32	6	12800	-0.12549	-0.01758	-0.97607

Figure 35 Separator data inside multi DAQ data

At synchronized multi DAQ mode, the data acquisition is synchronized for the sensors in the same group. The timing chart of synchronized single DAQ with 4 sensors is shown below (Figure 36). At synchronized DAQ mode, sensors in the same group start taking data and finish taking data at the same time. The data may arrive at the gateway at different time. When the

last set of data from the sensors arrive at the gateway, then the gateway issues a new synchronized starting DAQ command, and the sensors start taking data again immediately.

For each DAQ, the sensor data are separated by the separator again for easy data re-construction, as shown in Figure 35.

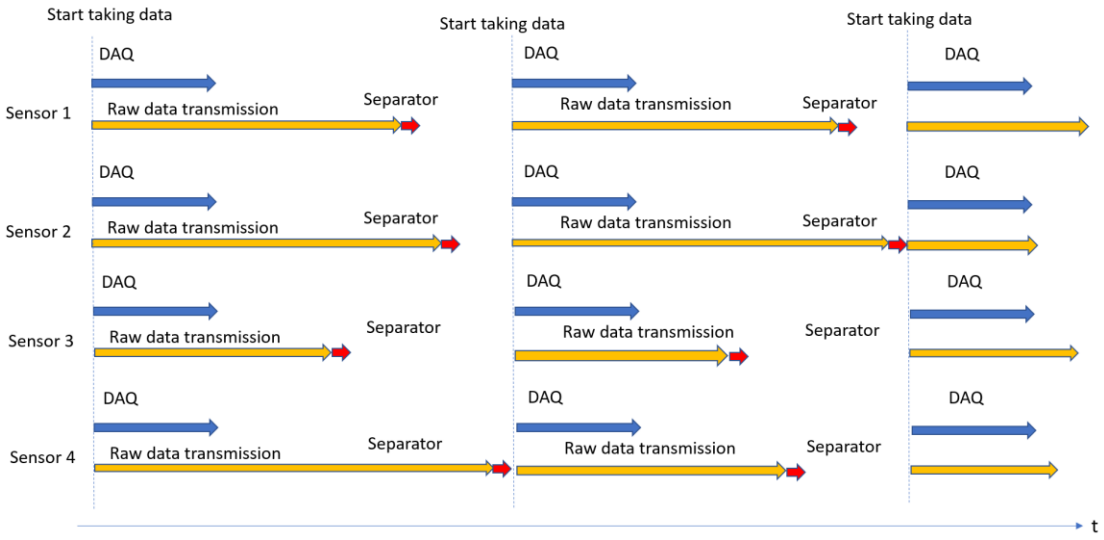


Figure 36 Synchronized multi DAQ mode timing chart

BroadVibra software automatically removes the separator during history data review, vibration trend analysis and FFT analysis. **If you want to use the multi DAQ mode data at another vibration analysis software, then it is important to remove the separator data before the analysis.**

2.5.5 Single FFT mode

In single FFT mode, all sensors in the same group are synchronized to take data one time, and the FFT analysis result is shown in the bottom chart (Figure 37). If there is single sensor in a group, then the sensor takes data immediately after it connects to the gateway. Temperature is still measured and saved in the database, but will not show up in the bottom chart.

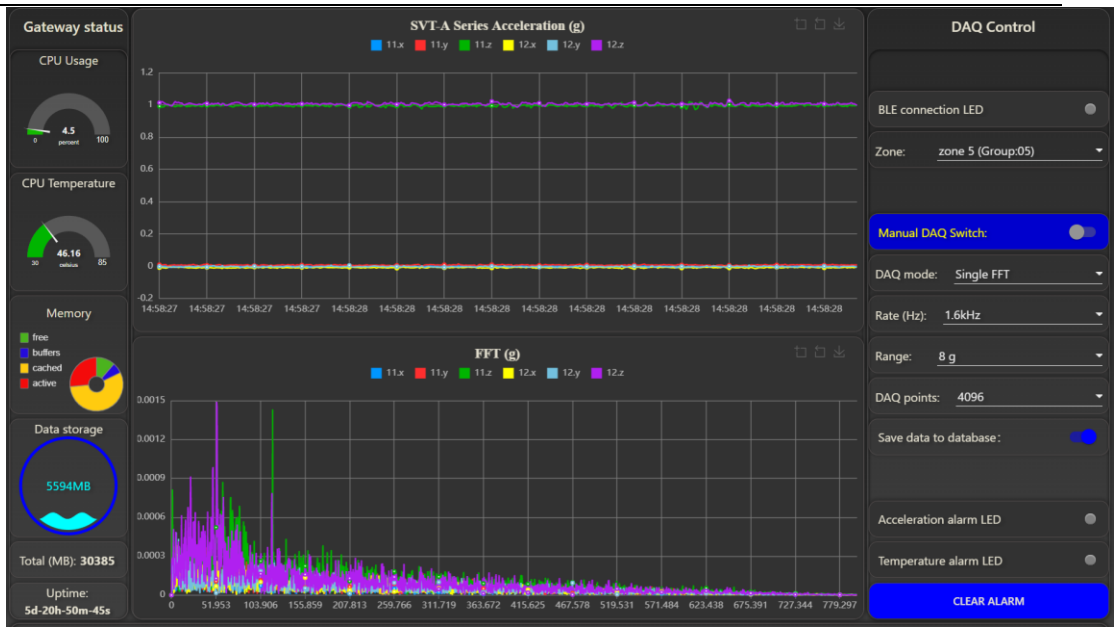


Figure 37 Single FFT mode

Similar to single DAQ mode, separator data is added at the end of each single FFT, so that the system knows when a sensor finishes taking data. Sampling rate, DAQ points and acceleration range can be adjusted at single FFT mode.

FFT result is saved under the following directory in the wireless gateway:

/home/pi/broadvibra/fft/sensorID/FFTPoints/sampleRate/fileName,

where "sensorID" is the sensor ID taking data in the current group, "FFTPoints" is the number of FFT points (1/2 of the DAQ points), "sampleRate" is the sampling rate used, "sampleRateScale" is the sample rate scale parameter, and "filename" is the FFT file name. For example, if sensor number 11 and 12 take single FFT data with a setup of 4096 points, 1600 sampling rate, then sensor 11's FFT result can be found at the directory:

/home/pi/broadvibra/fft/11/2048/1600

Sample rate scale is used to obtain the real sample rate of the sensor for accurate frequency domain analysis.

The corresponding file name is:

YearMonthDate_HHMMSS_sensorID.json

If in the "MQTT config" page, "single FFT" switch is enabled, then the FFT result is transmitted via the MQTT broker to a remote server. The MQTT FFT message is in JSON string format. Only acceleration FFT result is transmitted. To obtain velocity FFT MQTT message, or apply advanced filters, please enable "remote control" in the "MQTT config" page, and use remote FFT analysis feature. Please refer to chapter 7 of "Wireless gateway MQTT guide" for details.

Single FFT mode is to help user quickly look at the FFT result and checks out the machine condition. User can still go to "FFT analysis" page and perform the FFT analysis, and export

the FFT result and time-domain data into CSV file. There is no filter added in the single FFT mode. To apply a filter to the data, then it needs to be done at the “FFT analysis” page.

In the single FFT mode, the gateway will check the number of sensors that finished data acquisition and transmission of data to the gateway. When all sensors in the same group finish data acquisition and transmission of data, the gateway will automatically turn off the DAQ switch.

2.5.6 Live FFT mode

Live FFT mode is very useful for on-site testing and quickly find out the proper setup, including the acceleration range and the sampling rate for machine diagnosis. This mode can also be used to diagnose machine conditions quickly. In this mode, sensors will take data continuously. Time domain waveform is displayed in the top chart, and FFT result will be displayed in the bottom chart of the GUI (Figure 38).

In live FFT mode, all sensors in the same group are synchronized to take data repeatedly. Hence there will be a delay of data acquisition at the beginning. A message window will pop up at the top right corner of the browser to show the progress of the data acquisition and FFT. User can stop the data acquisition any time by turning off the “Manual DAQ switch” (Figure 38).

User can adjust the sampling rate and acceleration range in live FFT mode. The sampling points is fixed at 2048 points in the live FFT mode for quick response. Currently, live FFT analysis result is not saved, since this mode is designed for user to observe both the time domain and frequency domain waveform in real-time. If something interesting is observed, user can turn of the DAQ switch, and go to “FFT analysis” page to perform the FFT analysis with filters.

Live FFT mode’s FFT result will not be transferred via MQTT protocol. RAW data can be transferred in real time by enabling the “sensor data” option in “MQTT config” page.

Figure 38 Live FFT

2.5.7 Trigger mode

Trigger mode is especially useful to capture critical events that periodic data acquisition methods can not capture. This mode can also effectively reduce the number of data acquired and to be analyzed by users. Broadsens's trigger mode captures up to 520 pre-trigger samples by user-defined sample rate, which is very useful to find out what happens before and after the trigger event.

Trigger mode is also very effective to capture shock events with its generous pre-trigger buffer (Figure 39). In this example, a threshold level of 0.5g is defined. When the absolute value of the acceleration level at x, y or z axis of the sensor exceeds 0.5g, then the sensor will mark the vibration event, save up to 520 trigger samples, and capture the specified samples.

The trigger level can be adjusted from 0.1g to 25.5g. If the trigger level is out of range for a sensor, then the sensor will not be triggered. For example, if users set up the threshold level at 9g, and the maximum acceleration range of SVT200-A is 8g, then the sensor will never be triggered.

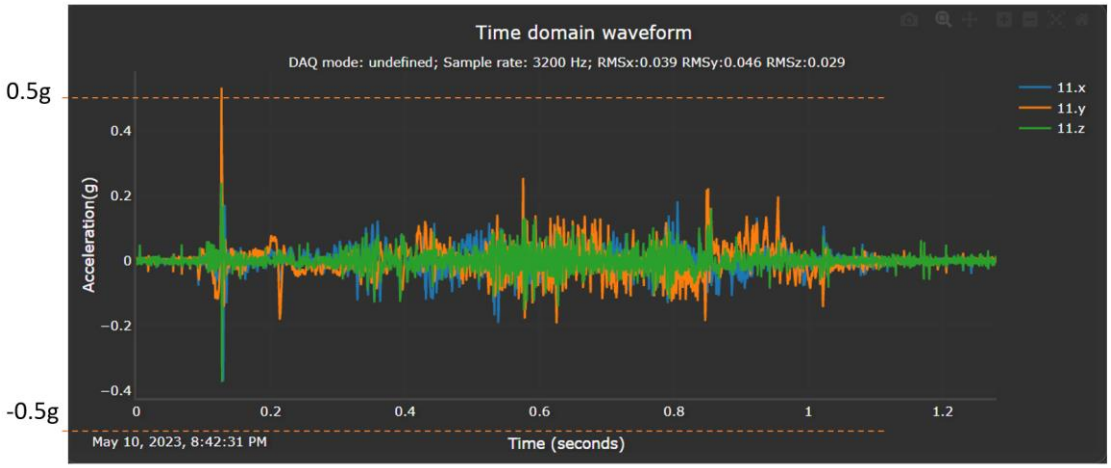


Figure 39 Shock event captured by defining a trigger threshold

Another useful application of the trigger mode is the conveyor system monitoring. In a conveyor system, the sensors are mounted at different motors, and each motor may turn on at different time, which requires that the sensors take data only when the motor rotates. If the sensors are arranged at the same group, then some sensors may take data when the motor is not on. If sensors are arranged at different group, then the sensor at different group may miss the vibration event. With trigger mode, sensors can be arranged in the same group with trigger mode, and the sensor only takes data when the vibration level exceeds the threshold, hence capturing the vibration event.

To capture the pre-trigger points, the SVT-A sensor needs to sample data at the user-selected rate, buffer the data, and compare the value against threshold. The higher the sampling rate, the more power it consumes to process and buffer the data. The current consumption in trigger mode (before the sensor is triggered) is shown in the following table (Table 4) based on the sample rate.

Table 4 Sample rate and power consumption at trigger mode

Sample rate (Hz)	400	800	1600	3200	6400	12800	25600
Current (uA)	267	280	307	360	469	679	1,060

To conserve battery power of the sensor, it is recommended to use trigger mode sample rate lower than 6400Hz, or higher sample rate for a short period of time. Alternatively, an SVT-V sensor can be used to trigger the DAQ of SVT-A sensors, which is very energy efficient (Requires BroadVibra version 2.7.7 and above).

Trigger mode is added to the SVT-A series sensors after BroadVibra version 2.7.2, gateway firmware version 2.7.0 and sensor firmware version 2.7.

2.6 Save data to database

In default, “Save data to database” switch is turned on, and sensor data is saved into the database coming with the wireless gateway (Figure 40). The database installed at the wireless gateway is InfluxDB, which is a time series database designed for IOT applications. The data can then be retrieved for review or downloaded later.

When installing SVT-V sensors, the “save data to database” switch can be turned off to avoid saving garbage data.

The database uses UTC time internally. When querying data from the database, BroadVibra software converts the UTC time to local time. If users change time zone, then the clock at the gateway should be updated to the local time for correct time display. The time zone can be adjusted by SSH to the gateway and change its time zone.

If user wants to take data continuously for many days non-stop, then it is also recommended to turn off “saving data to database” switch and use MQTT data transmission to send raw data to the server in real time instead.

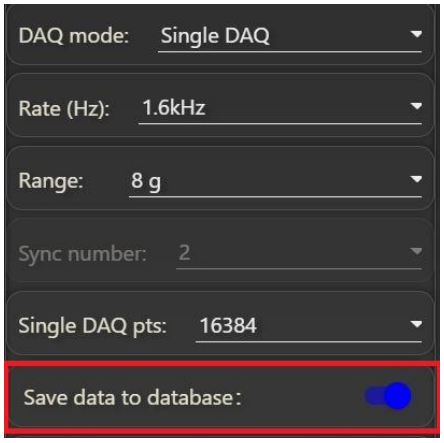


Figure 40 Data saving switch

2.7 Sampling rate

Broadsens wireless vibration sensors have internal clock that is used for data acquisition. Starting from BroadVibra version 2.7.5, the SVT-A series sensors’ sample rate can be fine-tuned for more accurate frequency analysis. The sensors have typically higher than specified clock rate. For example, SVT200-A sensor has typically 1-2% higher sample rate than specified, and SVT300-A and SVT400-A sensor have typically 2%-3% higher sample rate than specified.

For example, if the specified sample rate is 25.6kHz, and the sensor’s clock run 2% faster than specified, then the sensor is actually sampling at (25.6kHz x1.02)=26.11kHz. The sample rate scale parameter is applicable to all sample rates from 50Hz up to 25.6kHz.

The sample rate can be calibrated by giving the sensor proper sample rate scale parameter.

The default sample rate scale factor is 1.02. Please refer to the “FFT analysis” section (5.2.3) on how to fine-tune the sample rate scale factor (which is typically not needed for general applications). Each SVT-A sensor’s sample rate scale factor can be adjusted at the “Sensor Configuration” page.

3. Continuous Real-Time Vibration Monitoring

The second page of the dashboard (homepage in the special edition) shows the SVT-V series vibration sensors continuously monitor vibration in real time. SVT-V series wireless vibration sensors include SVT200-V, SVT300-V and SVT400-V, with acceleration range up to 8g, 16g and 64g respectively. They can monitor both low frequency and high frequency vibration events in real time 24/7 non-stop (Figure 41) and provide response within 0.5 second typically (Firmware version 2.1 or later is required for 0.5 second response time. The response time was about 1 second before firmware version 2.1). The 0.5s response time of SVT-V series sensors make them the fastest real-time low-power wireless vibration sensor in the industry (compared to fixed 90s or 3,600s response time from other similar products).

SVT-V sensors monitor the machine/structure vibration continuously without interruption. When they detect a vibration/impact/shock event, then they switch to 6.4kHz sample rate to acquire a fixed number (320 points) of samples for vibration analysis and sends the result to the wireless gateway.

Starting from BroadVibra version 2.7.2, an SVT-A sensor can be used to trigger SVT-A sensor’s DAQ. User can set up a threshold level on the velocity RMS, acceleration RMS or temperature of the SVT-V sensor, and when the threshold is exceeded, then a selected SVT-A group can be triggered to take data. Please refer to the alarm setup section of the manual for details.

The default trigger threshold is 0.1g in all x, y and z directions, so that an SVT-V sensor can capture even small vibration events. The vibration level should exceed 0.1g for a period of more than 330ms to trigger the high-speed mode. If the vibration level exceeds 0.1g in any axis (x, y, z), then the SVT-V sensor will switch to high-speed mode, calculate the vibration parameters, and send out the result. This can remove the environment noise interference.

If there is no vibration event detected, then the SVT-V sensor still toggles to 6.4kHz high-speed mode every 10s, acquire data, analyze data and send out the result.

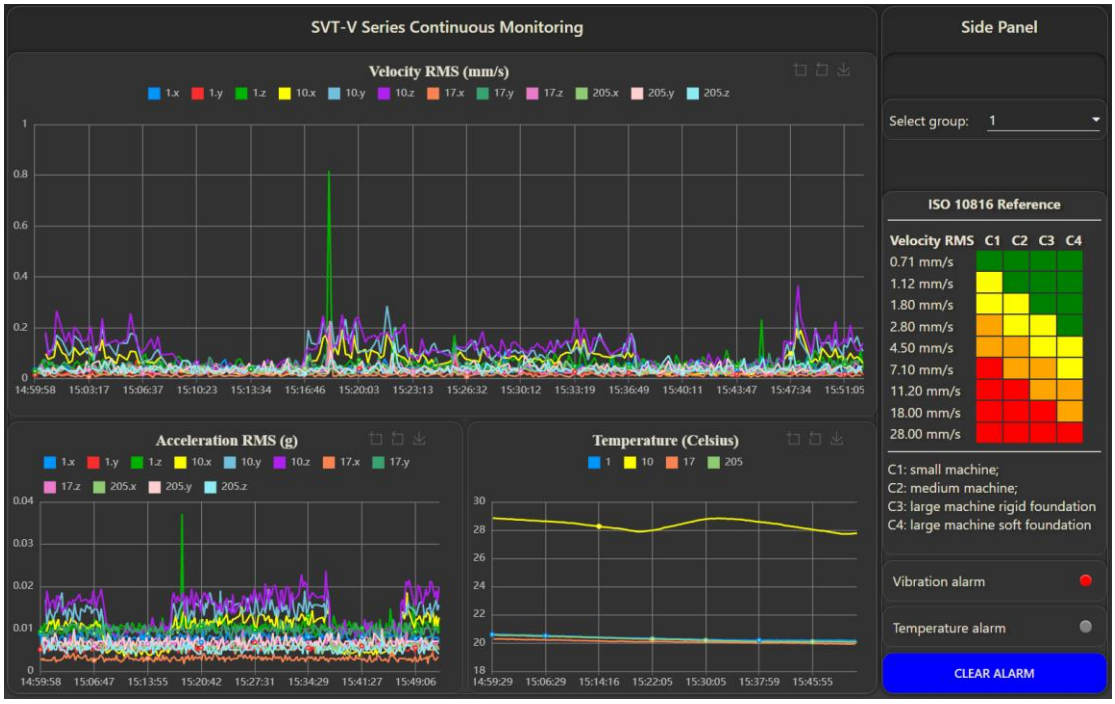


Figure 41 SVT-V sensors continuous real-time vibration monitoring

There are three curves in this page. The top curve shows vibration velocity RMS in mm/s or inch/s unit (the unit selection can be adjusted at the "Gateway setup" page). An SVT-V sensor measures the vibration velocity RMS value by integrating the acceleration values. The left curve in the bottom chart shows the acceleration RMS value. Any change of acceleration can be detected effectively by looking into this chart (Figure 42). The right curve in the bottom charts shows the structure/machine contact surface temperature.

The estimate of battery life of an SVT-V series sensor is as the following (Table 5):

Table 5 SVT-V sensor battery life estimate

Total triggered time (monitored machine vibration level>0.1g)	Battery life estimate in room temperature
24 hours a day, 7 days a week	19 months
12 hours a day, 7 days a week	3 years
8 hours a day	4 years
Not triggered (send out measurements every 10s)	More than 8 years

Since SVT-V sensors acquire acceleration data at high sampling rate of 6.4kHz, it can detect high frequency defects effectively. The sampling rate of an SVT-V sensor is fixed at 6.4kHz in default from the factory. It is possible to go up to 12.8kHz for SVT-V sensors. Please contact Broadsens to use other sampling rate in high frequency mode.

In default, the bandwidth of an SVT-V sensor is set at 0.1Hz to 3.2kHz, which covers

wider bandwidth than most other overall vibration sensors. This enables the SVT-V sensors to be used for both rotating machines and non-rotating machines. SVT-V sensors can also be used for civil structure monitoring due to its very low frequency monitoring ability.

Please note that even if the SVT-V sensor is not triggered, it still toggles to the high-speed mode, take data, and send out result every 10 seconds. Figure 42 shows an SVT-V sensor's data when a machine is turned on and off.

Each wireless gateway is configured to monitor a fixed group of SVT-V series sensors before BroadVibra version 2.7.0. For BroadVibra version 2.7.0 and higher, each gateway can monitor multiple groups of SVT-V series sensors. It is recommended to monitor up to 6 SVT-V sensors in each group, and up to 30 SVT-V sensors at each gateway. The SVT-V sensor ID and group number are fixed at the factory.

SVT-V sensors with double-screw mount enclosure has high precision temperature sensor integrated at the bottom of the sensor, so that it can measure the structure/machine surface temperature effectively.

An SVT-V sensor has self-calibration ability for the acceleration and temperature measurement, so that there is no calibration required in field usage. Each time when the SVT-V sensor takes data, it automatically performs the self-calibration. This can save labor costs and ensure the quality of data in the long term.

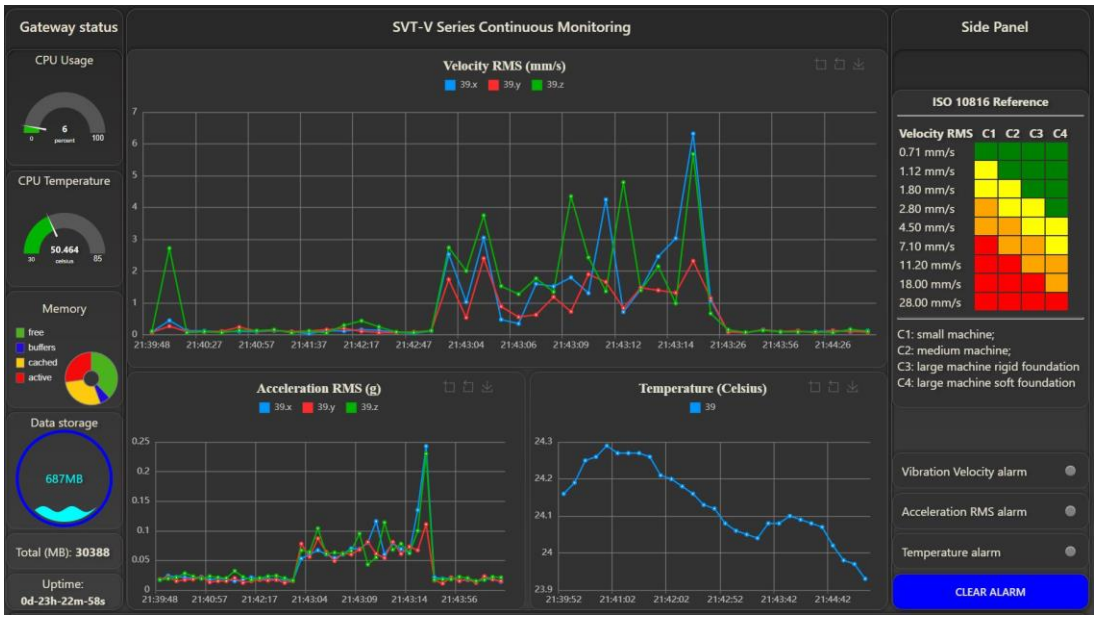


Figure 42 True real-time vibration monitoring by SVT-V sensors

In the side panel of continuous monitoring, the ISO 10816 standard table can be referred to check the machine conditions. The green color means normal condition, yellow color means "need attention", orange color means "problematic", and red color means "need maintenance".

User may also refer to Figure 43 for motors status. Please note that the values in the figure is for reference only. The threshold value may need to be adjusted for each case.

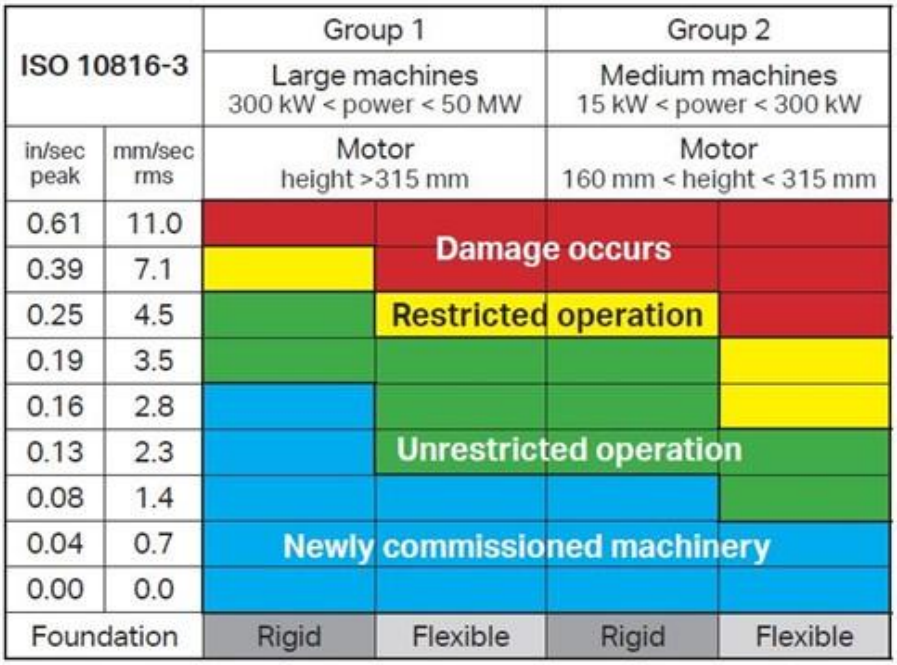


Figure 43 ISO 10816 table for motors

Before BroadVibra version 2.6.0, user needs to manually adjust the acceleration RMS offset. Starting from BroadVibra version 2.6.0, the SVT-V sensors automatically remove the acceleration RMS offset at the sensor side.

Vibration velocity RMS, acceleration RMS and temperature alarm can be set up for continuous real-time vibration monitoring. The alarm threshold can be adjusted at the "Alarm setup" page. In Figure 41, vibration velocity exceeds a pre-defined alarm level and the LED turn into red color. Click on "Clear alarm" button to reset the alarm LED and alarm notification.

4. History data review and export

Thanks to its integrated time series database, Broadsens's wireless gateway offers the ability to review history data easily (Figure 44). There are three types of vibration and temperature sensors, and sensor type can be selected to review the corresponding history data. The supported sensor types include SVT200-A, SVT300-A, SVT400-A, SVT-200V, SVT300-V, SVT400-V, SVT200-T and SAG200. In Figure 44, SVT-A series sensor is selected. When for the first time a user logs in, the data review history panel is empty, which is normal. User needs to select sensor type, sensor group, database query method, and click on "Confirm" button to show the data.

Figure 44 SVT-A series sensor history data review

4.1 History data query

There are two ways of history data query: By "relative time" or by "start time". "Query by relative time" selects the latest data relative to the current time. For example, a duration of 5 minutes will only show the data in the last 5 minutes. "Query by start time" method selects data starting from the provided date and time. Each method has its pros and cons. It is faster to use "Query by relative time" after a manual DAQ to check out the new data. This way, user does not need to enter the data and time information. "Query by start time" allows a user to check any data at any time by selecting the "start date and time" information. If data were taken a few days ago and new data were taken after that, then "Query by start time" method should be used.

4.1.1 Query by relative time

To use "Query by relative time", turn on the switch of "Query by relative time" (the switch knob color turns into blue). In this mode, start time selection are disabled. A user first selects number of points (for example 2000 points), then chooses the relative time (for example, 5 minutes). If there are data collected in the past relative time, then it will return the data curve. User can zoom in the data curve and review the details. To save system resource, the acceleration curve only shows the maximum number of 60,000 points from version 2.8.4 and above, or 10,000 points before version 2.8.4 for acceleration, and only 500 points for temperature. If there are more than the maximum number of points, then only selected points are shown. For example, if user chooses 20,000 points, then all points will be shown after version 2.8.4, and only 1 of every two points is shown in the figure. User can click on the

"Download acceleration data" button to download the RAW data, which is a complete set of the real data. The options of relative time query are:

5 minutes, 10 minutes, 30 minutes, 1 hour, 4 hours, 8 hours, 24 hours, 3 days, 7 days, 14 days and 30 days.

To quickly test the data review function, user can go to "Zone I" page, choose "manual start" to acquire some data. Stop the data acquisition. Then come to the "History data" page, click on the "Zone 1" button, select "2000" points, and then select "5 minutes". The system will show the latest data.

4.1.2 Query by start time

To query by "start time", turn off the switch of "Query by relative time", and click on the small calendar sign on the right of the "start time" (Figure 46). This will bring up the calendar selection.

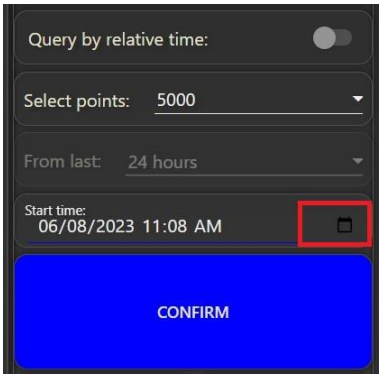


Figure 45 Click calendar sign to select start time

Please note that different browser may show the "start time" differently. Figure 46 shows the display from Google Chrome. Some browser such as Firefox may only show the date selection (Figure 47).

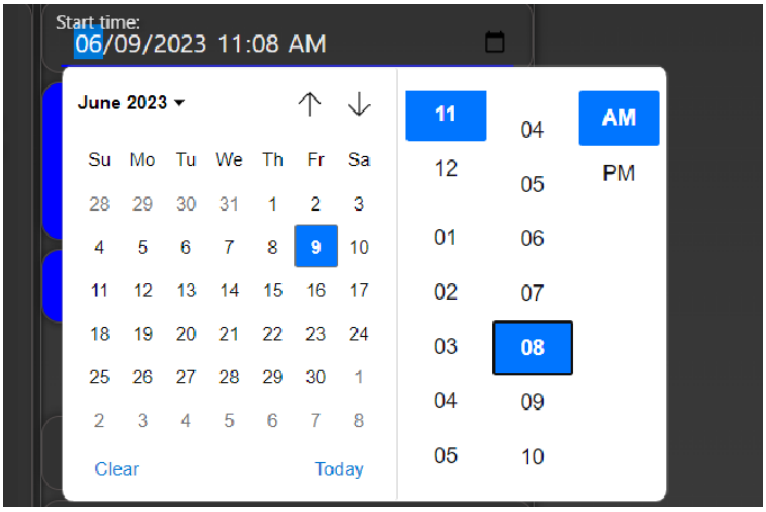


Figure 46 Start time selection with Chrome browser

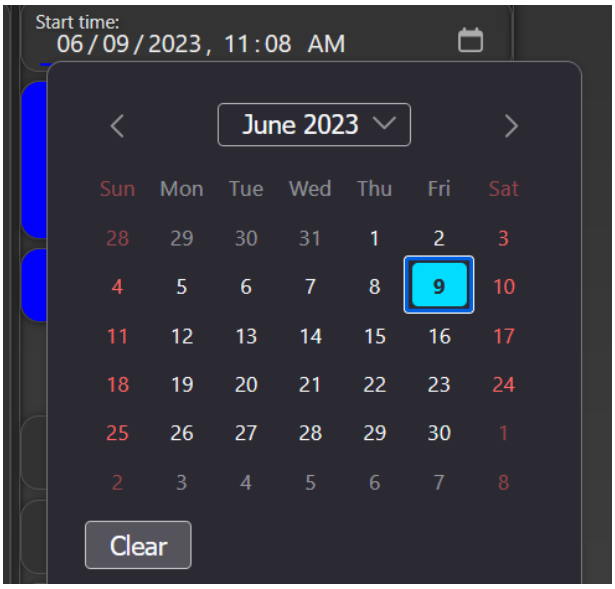


Figure 47 Start time selection with Firefox browser

In this case, user needs to type in the time section manually. First click on the hour or minute, then use keyboard to enter the desired value (Figure 48).

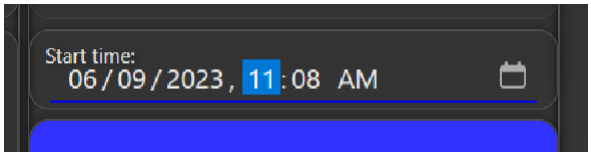


Figure 48 Manually enter time with Firefox browser

After selecting the start time, click on the "Confirm" button to show the data starting from the selected data and time (Figure 49). Query by "start time" is useful to review data when "Query by relative time" does not work.

The query result is limited by both the query period and query "Points". The maximum number of sample points that can be queried is 160,000 points. If user takes lots of data in a short period of time, and want to display more data, then user can increase the number of points from "select points" dropdown menu. For example, if the "select points" option is 5,000 points, and the query period is from last three days, and the gateway takes more than 5,000 samples, then only 5,000 sample points will be shown. Increasing the "select points" option to 20,000 will show longer period time of data.

Figure 49 Query by start time

Since database query of a large amount of data could take a long time, it is always a good practice to only query the data that one needs. The options of maximum number of query points are: 1,000, 2,000, 5,000, 10,000, 20,000, 40,000, 80,000 and 160,000. **Please note that it could take several minutes or longer to query 160,000 points of data.** This limit of the number of maximum points also applies to "Query by date/time" option.

During database query, a popup message will show that query is in progress. When the query is finished, the chart will update, and another popup message shows that the query is finished. In case that the database query returns 0 data, a popup message will remind that user should take data, or change query condition.

For SVT-A series sensor, user can select all the sensors in the same group/zone to review their data, or select a single sensor from the sensor list in the selected group. For SVT-V series sensor (Figure 50) and SVT-T series temperature sensor (Figure 51), user can select a sensor group, and choose "select all" to review all the sensor's data in the same group, or select a particular sensor from the selected group to review its data. SAG wireless IMU sensor history data review is similar to SVT-A series sensor. From the "sensor type" dropdown menu, select "SAG IMU" sensor, then query the database to show the history data (Figure 52).

Figure 50 SVT-V series sensor history data review

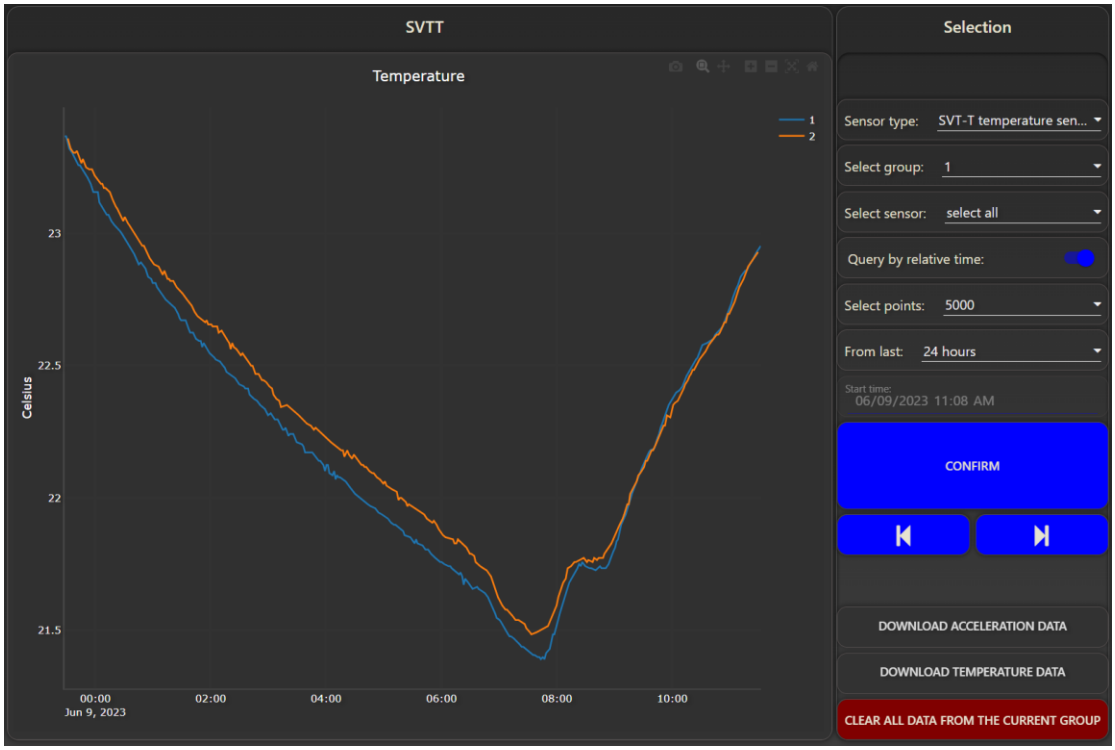


Figure 51 SVT-T temperature sensor data review

Figure 52 SAG wireless IMU sensor data review

In the data review chart, user can take a snap shot of the current curve and save it as "png" format (Figure 53). In the review of SVT-A series data, the DAQ modes used and sample rate will be shown. When there are multiple DAQ modes or sample rates, the software will show all the DAQ modes and sample rates in the data shown.

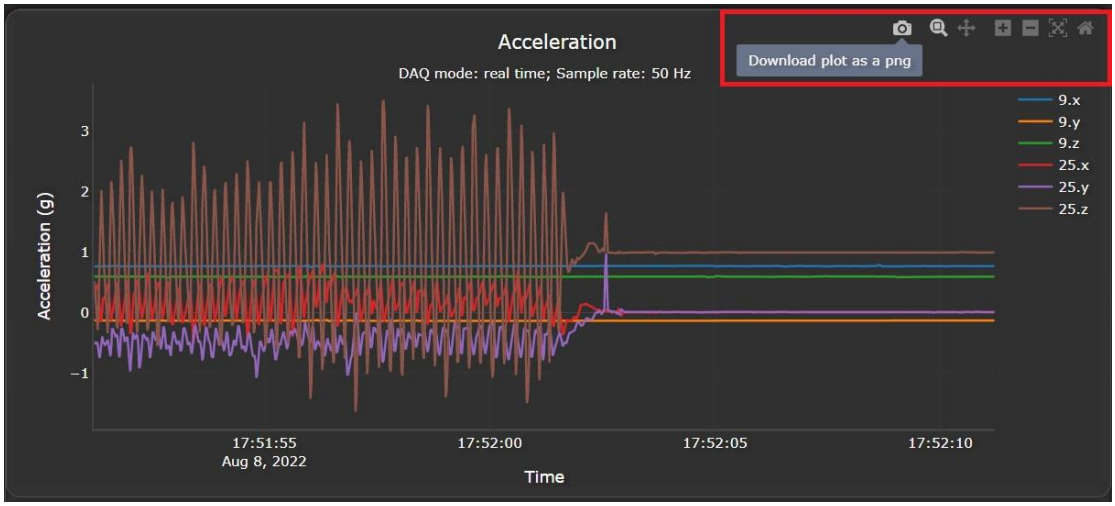


Figure 53 Figure operation

User can also zoom in/out the data easily by using the mouse to select an area (Figure 54). Click the "home" sign in the icons to return to the default zoom. Another useful tip is to click on the legend of a curve will hide the curve; click it again will show the curve. This feature is useful to hide some curves and focus on the interested curve.

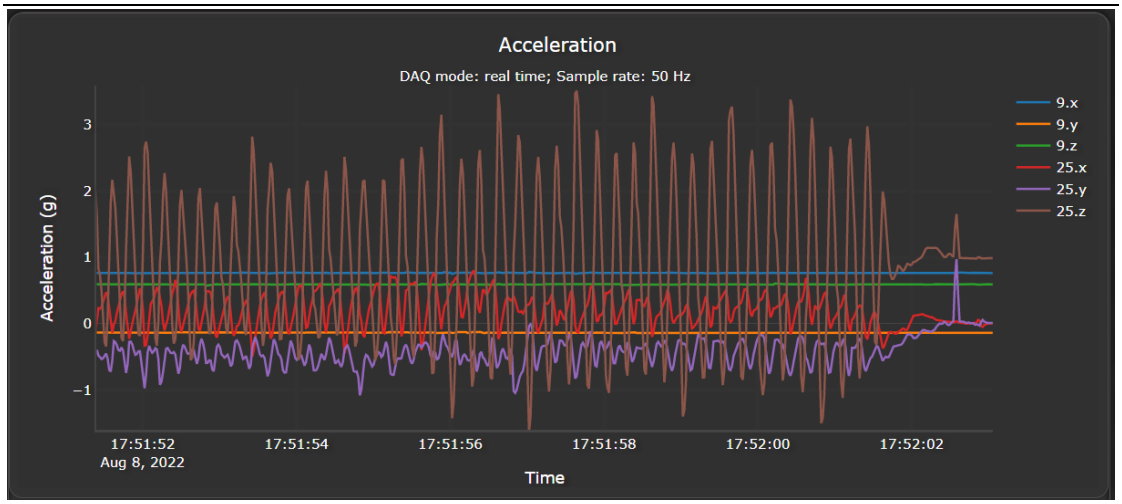


Figure 54 Zoomed in view of the curves

4.1.3 Step forward and step backward

Step forward and step backward buttons can be used to moved conveniently to the previous data set or a later data set. They are located below the "confirm" button. Click on the "|◀" button to move to a previous data set (step backward); click on "▶|"button to move to a later data set (step forward).

If there is no data returned, then the system will pop up a message window showing that "no data returned".

When user takes lots of data in a short time, and "Query by relative time" method can only return the maximum number of 160,000 points relative to the current time, to check more data, user can use the step backward button to view data before the current data set. User can also use "Query by start time" method by toggle off the "Query by relative time" switch (the switch knob turns into grey color in this case), and then use the "step forward" or "step backward" button the view data at different time.

For SVT-A series sensor and SAG IMU sensor, the step size is defined by the points, and upper bounded by 16,384 samples. For SVT-V series sensor and SVT-T temperature sensor, the step size is fixed at 5,000 points (2,000 points before version 2.8.0).

4.2 RAW data export and data reconstruct

RAW data can also be downloaded from the history data page (Figure 55). The data format is in CSV format. In default, the database saves history data for half a year. Data older than half a year will be automatically deleted. This prevents the data from taking up the whole storage space. Therefore, it is recommended to upload the data to user's private server or cloud for backup via the MQTT upload option. Broadsens provides standard server and software to save

the history data up to five years. Broadsens also provides documents on how to transfer data to the server or clouds via MQTT protocol in real time. If a customer's needs help to set up their private server or cloud, then please do not hesitate to contact Broadsens.

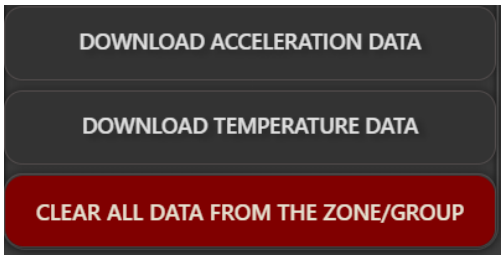


Figure 55 Download or delete history data

4.2.1 Raw data export

To download raw data from an SVT-A series sensor, in "History data" page→ in "sensor type" dropdown menu, select "SVT-A series"→ in "select zone" dropdown menu, select the zone that the sensor belongs to→ in "select sensor" dropdown menu, select the sensor interested in, or keep the default option of "select all" to download all sensor data from the zone. Select the date/time when the DAQ happens and the number of points. Click confirm button to query the data from the database. Then click on "download acceleration data" to download the raw data. SVT-A sensor's raw data can also be downloaded from the FFT analysis page.

User can also download the temperature data by clicking on the "download temperature data" button. The RAW data file is in "CSV" format and can be imported to an analysis software for analysis (Figure 56).

	Data arrival time	Sensor	Mode	Rate	X_axis	Y_axis	Z_axis
2	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	-0.00073	0.006348	0.995847
3	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	-0.00586	-0.00049	0.987546
4	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	0	0.003418	0.989011
5	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	0.000977	0.000732	0.989744
6	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	0.000244	-0.00244	0.995847
7	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	0.001709	0.005615	0.999021
8	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	-0.00342	0.001709	0.981199
9	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	-0.00488	0.009277	0.998288
10	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	0.001953	0.009033	0.99072
11	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	0.002197	0.004395	0.985105
12	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	0.000488	0.004395	0.988279
13	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	0	0.003418	0.995115
14	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	0.000977	0.001709	1.004392
15	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	0.001953	0.003662	0.997312
16	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	-0.00195	0.004639	0.992185
17	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	-0.00171	-0.00098	0.991697
18	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	-0.00439	0.00293	0.99365
19	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	-0.00269	0.000244	0.996335
20	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	-0.00122	-0.00024	0.990476
21	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	0.004395	0	0.982175
22	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	-0.00024	-0.00269	0.98779
23	Thu Feb 23 2023 22:10:04 GMT-0800 (Pacific Standard Time)	11	4	1600	-0.00122	0.005127	0.992917

Figure 56 RAW data export

Data of SVT-A series sensors can also be downloaded from the FFT analysis page. It is recommended to use the data export at the FFT analysis page if single DAQ, single FFT, live FFT or multi DAQ mode is used.

To download data from SVT-V series sensor, in "History data" page→ in "sensor type" dropdown menu, select "SVT-V series". Select the date/time and the number of points. Click confirm button to query the data from the database. Then click on "download acceleration data" to download the overall vibration data. You can also download the matching temperature data by clicking on the "download temperature data" button.

To download data from SVT-T series sensor, in "History data" page→ in "sensor type" dropdown menu, select "SVT-T series". Select the date/time and the number of points. Click confirm button to query the data from the database. Then click on "download temperature data" to download the temperature data. Please ignore the "download acceleration data" for SVT-T sensors.

To download data from SAG IMU sensor, in "History data" page→ in "sensor type" dropdown menu, select "SAG IMU". Select the date/time and the number of points. Click confirm button to query the data from the database. Then click on "download acceleration data" to download the IMU sensor data.

4.2.2 Data reconstruct

For SVT-A series sensor, data reconstruct is required to obtain the exact DAQ time. For example, the time stamp in column A of Figure 56 can be deleted safely, since the time stamp shows the data arrival time to the database through wireless transmission. The time stamp is used to save the data to the database and retrieve the data from the database and should not be used for data analysis. The time stamp shows the time that the data arrives at the gateway, not the data acquisition. For example, there could be only about 500 points per second for 3,200Hz sampling rate per the time stamp. The data should be reconstructed based on the sampling rate in data analysis. Column B, C and D can also be deleted safely. The sampling rate used in the DAQ is shown in Column D. This sampling rate should be used for the data analysis such as FFT analysis.

If you use single DAQ mode or multi-DAQ mode, then the separator data (all zeros on x, y and z axes) must be deleted too for the data analysis.

Data can be reconstructed as the following:

- Discard any separator data (x, y, z axes values are all equal to zero)
- The DAQ starting time can be set to the arrival time of the first data sample (x, y and z axis).
- The DAQ ending time= starting DAQ time + number of samples /sampling rate.

For example, if you take 4,096 samples at 12.8kHz, and the first sample arrives at 11:09:08. Then the time stamp of each point is as the follow:

Time stamp	Sample index
11:09:08	1
11:09:08+ 1/12800 s	2
11:09:08+2/12800 s	3
...	...
11:09:08+ 4096/12800 s	4096

4.3 Delete data from the database

SVT-A series sensor data in the current group selection can be deleted completely to save drive space and speed up the database query. Click on the "Clear all data from the group" button, then a pop-up window will warn user that all data in the current zone will be deleted from the database. Choose "Cancel" to cancel the option, or choose "OK" to delete all data. Please proceed with caution.

SAG IMU sensor data can be deleted similar to SVT-A series sensors.

SVT-V series sensor and SVT-T series sensor data can also be deleted by selecting the corresponding sensor type, then click on the "Clear all data from the group" button. All history data of the selected sensor type will be removed after clicking the "OK" button from the pop-up window.

If user wants to quickly delete all history data, then this can be done at the "Gateway setup" page, using "Reset database" feature. "Reset database" will clean up all history data including trend analysis.

5. Vibration data analysis

There are two useful tools inside Broadsens's wireless gateways for vibration data analysis: vibration trend analysis and FFT analysis. More advanced analysis can be done using the raw data. Vibration FFT analysis applies to SVT-A series sensors only.

5.1 Vibration trend analysis

Vibration trend analysis is very intuitive and useful to help users identify machine problems quickly when time goes by. This is especially useful for applications where the sensors are permanently mounted in a hazardous location. Currently, there are seven parameters

provided in vibration trend analysis:

- Acceleration rms (root mean square)
- Velocity rms
- True peak (maximum absolute value of both positive and negative acceleration)
- Peak to peak
- Crest factor
- Kurtosis
- Skewness
- Mean
- Standard deviation

Acceleration rms (root mean square) and velocity rms indicate the energy of the acceleration and velocity respectively. They have a positive effect on wear fault and a weak sensitivity to early fault. They are calculated by the following formula, where xi is either acceleration or velocity.

$$X_{\mathrm{RMS}} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} x_i^2}.$$

The bandwidth of acceleration rms is from DC to R/2, where R is the sample rate. The bandwidth of velocity rms is from 10Hz to 1kHz. If the sample rate is lower than 2kHz, then the bandwidth of velocity rms is from 10Hz to R/2.

True peak, the maximum amplitude from the data, is always used to detect breakdown accompanied by instantaneous impact. The true peak is the maximum absolute value of both positive and negative acceleration in the given period. Because the SVT-A series sensors can measure DC offset, the true peak value contains earth gravity. For example, if the sensor is mounted on a flat surface, then x, y axis true peak value will be close to 0g, and z axis true peak value will be about 1g (slightly larger than 1g due to nose.). 1g is from earth gravity.

Peak to peak is the maximum value of the acceleration minus the minimum value of the acceleration in the period. Peak to peak value is added starting from BroadVibra version 2.7.5. Peak to peak value removes the earth gravity, and can be used to tell the vibration level more intuitively.

Crest factor is defined as the ratio of peak value and RMS. Crest factor can be used to as a reference to judge bearing condition directly. The threshold value to judge physical condition of bearing is approximately 1.5. Generally speaking, there could be local defect if the crest factor value exceeds 1.5.

The mean value of a set of numbers, xn, n = 1, …, N, is given by the following equation:

$$\bar{x} = \frac{1}{N}\sum_{n=1}^{N} x_n$$

In the following, we use symbol μ for the mean value.

The variance of a set of numbers, x_n, n = 1, …, N, with a known mean value of μ, is given by the following equation:

$$\sigma^2 = \frac{1}{N}\sum_{n=1}^{N}(x_n - \mu)^2$$

The standard deviation σ is a measure of the variability of a signal about its mean value. For a vibration signal with a mean value of zero, the standard deviation is equal to the RMS (root-mean-square) value of the signal.

The kurtosis of a set of numbers, x_n, n = 1, …, N, is given by:

$$\kappa = \frac{1}{N\sigma^2}\sum_{n=1}^{N}(x_n - \mu)^4$$

where σ is the standard deviation of the signal, μ is the mean of the signal.

The skewness of a set of numbers, x_n, n = 1, …, N, is given by the following equation:

$$\gamma = \frac{1}{N\sigma^3}\sum_{n=1}^{N}(x_n - \mu)^3$$

The skewness is a measure of the asymmetrical spread of a signal about its mean value. It is the ratio of the average cubed deviation from the mean divided by the cube of the standard deviation. Therefore, it is dimensionless. For a random variable with normal distribution, the skewness is zero.

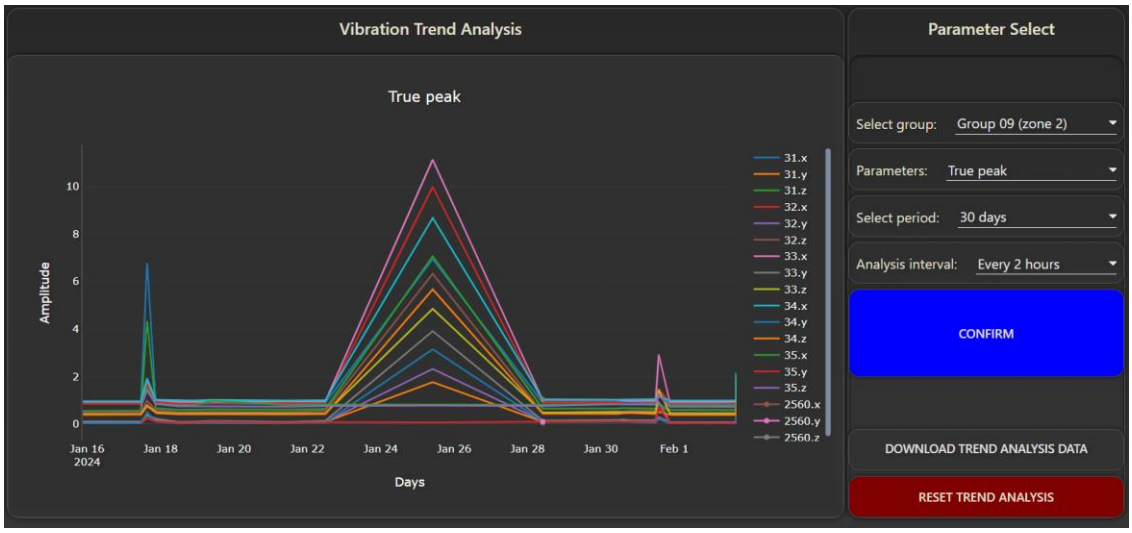


Figure 57 Vibration trend analysis

Vibration trend is calculated by group. To view the vibration trend, first select a group, then select the analysis parameter, finally select the analysis days, then click the "CONFIRM" button to load the analysis result from the database. The available analysis days are:
7 days, 14 days, 30 days, 60 days, 90 days, 180 days and 365 days

Vibration trend analysis is performed automatically to reduce the workload for users. User can select the trend analysis interval from the dropdown menu (Figure 58).

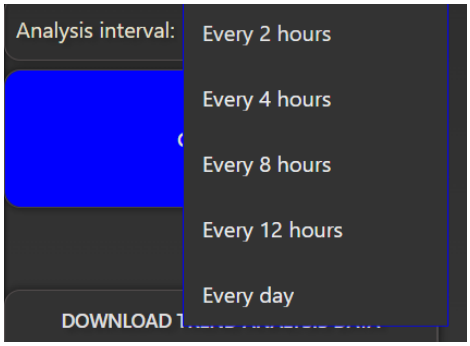


Figure 58 Trend analysis interval

Note:

- If there is no data taken in the defined interval, then the trend analysis database will not be updated to save system resource.
- The gateway will use up to 50,000 points in the defined interval for the analysis. If there are more data taken during the interval, then the data will be ignored to reduce the system load.

Uses can add sensors at any time, or remove any sensors at any time. When a new sensor is added, the software will start calculating its vibration trend. When a sensor is removed, then the vibration trend from the sensor will not be updated.

Analysis result data can be downloaded by clicking on the "Download analysis data". The data is in CSV format for compatibility with most analysis software such as MATLAB.

Vibration trend analysis data can be cleared by clicking on the "Reset trend database" button. A popup warning message will ask user to confirm. Click on "OK" button to delete all the trend analysis result from the database.

5.2 FFT analysis and filtering

FFT analysis and advanced filtering function are included with the BroadVibra software installed at Broadsens wireless gateway. This is very useful to identify machine issues such as bearing fault, or imbalance. FFT analysis can be performed at each vibration sensor.

5.2.1 FFT analysis

In Figure 59, the top chart is the FFT waveform, and the bottom chart is the corresponding time-domain waveform. The filtering is disabled in this figure ("No filter" in the filter type selection). The waveforms can be zoomed in easily for detailed view. FFT result and time-

domain data can be downloaded from the interface. There are two options to select the analysis data: Use the latest data; or use the data at a specified date/time. This feature is similar to “query by relative time”, or “query by start time” in the history data review.

Hanning window is added to the FFT analysis since version 2.8.2 to better handle spectral leakage. Spectral leakage is the result of an assumption in the FFT algorithm that the time record is exactly repeated throughout all time and that signals contained in a time record are thus periodic at intervals that correspond to the length of the time record. If the time record has a nonintegral number of cycles, this assumption is violated and spectral leakage occurs. Hanning window has smaller error when spectral leakage happens. In general, the Hann window is satisfactory in 95% of cases. It has good frequency resolution and reduced spectral leakage.

To test the FFT function, user can choose “single DAQ” mode in the front page, select a sampling frequency, for example 3.2kHz. Then select a group to take data. Click on “Manual start” to start the DAQ. After a sensor in the selected group finishes taking data, the software will show the message that the sensor finishes taking data. Once all sensors in the same group finish DAQ, the software automatically stops DAQ. User can also click on the “stop” button to turn off the DAQ any time. Then at the FFT analysis page, select a sensor that just finishes taking data, choose analysis points (1,024, 2,048, 4,096, 8,192 or 16,384 for single DAQ mode), choose “Use latest data” option, and then click on “CONFIRM” button. The FFT analysis will be performed. The more points user selects for the analysis, the more time it takes for the gateway to calculate the FFT.

Figure 59 FFT analysis

The FFT plot shows the peak band frequency for the sensor at x, y and z axes, and the associated peak values. The default unit is acceleration in g. The time domain waveform shows the current DAQ mode, sampling rate, and RMS values in x, y and z axis. When there are multiple sampling rates used in the selected data set, then the FFT analysis will show a popup message warning the user that multiple sampling rate detected. The system will use the first sampling rate for the FFT calculation. But user should avoid using data of multiple sampling rates for the FFT analysis, which can produce incorrect result.

If an SVT-A sensor's RPM information is provided, then the RPM is displaced at the FFT plot (BroadVibra version 2.7.6 above required). User can click on the dropdown button in the FFT plot, and select "RPM" to show the corresponding 1x, 2x, …, 10x lines with respect to the RPM. The default state of the dropdown button is "None", which hides the 1x, 2x, … lines. The x-axis unit is frequency in Hz, and 1Hz=60 RPM.

The number of points for FFT analysis can be selected from the drop-down menu. Moreover, since Broadsens vibration sensor sampling rate can be adjusted with multiple options, which means that user can have adjustable Fmax for vibration analysis. The maximum Fmax value is 10kHz for all SVT-A series sensors.

[Step forward and step backward]

"Step forward" and "step backward" buttons can be used to moved conveniently to the previous data set or a later data set. They are located below the "confirm" button. Click on the "|◄" button to perform FFT analysis on previous data set (step backward); click on "►|"button to perform FFT analysis on a later data set (step forward). The step size is defined by the sample points in FFT analysis.

5.2.2 Advanced filtering

BroadVibra software has advanced filtering function, in which the cutoff frequency can be adjusted continuously (compared to limited options from other vibration analysis software). Moreover, the filtering order can be adjusted too. The optional filtering orders are 4^{th} order, 8^{th} order and 12^{th} order. If a filtering option is selected, then the original raw data is filtered before the FFT analysis. Filtering is very useful to detect early-stage defects, since the small defects can be covered by other characters of the machines.

If a filter is applied, then the RMS value is calculated after the filter. The FFT analysis is also performed after the filtering.

For example, user can apply an 4^{th} order high-pass filter with cutoff frequency of 1Hz to remove the DC offset.

The following are some reference cutoff frequency parameters for machine condition

monitoring and predictive maintenance:

High-Pass filters

- 200Hz: middle and high leak frequency for water, oil
- 500Hz: Low speed machinery having <125hz. Bearing & gearing problems
- 1000Hz: Intermediate speed machinery (<2000 rpm) with gear mesh <300hz
- 2000Hz: Medium speed machinery (<4000rpm) with gear mesh <600hz
- 5000Hz: High speed machinery

Lowpass filters

- 40Hz: Machine structure balance
- 40Hz: Oil, water pipeline ultra-low frequency leakage

Bandpass filters

- 60Hz-90Hz: Oil, water pipeline low-frequency leakage
- 20Hz–150Hz: Felt problems on paper machines
- 50Hz–300Hz: Certain structural resonance excitation, modulation of gear mesh in low-speed machinery
- 100Hz–600Hz: Gear mesh modulation in intermediate speed machinery.
- 500Hz–1kHz: Gear mesh modulation

In Figure 60, a 4th order high-pass filter with cutoff frequency of 300Hz is applied to the signal shown in Figure 59. One can see that all the frequency components below 300Hz are attenuated from the FFT, and the high frequency responses appear clearly in the figure.

Figure 60 4th order High pass filter applied to signal

5.2.3 Velocity measurements

At the dropdown menu for the "Measurements" selection, user can select "velocity" to obtain velocity measurements. When velocity is selected, then time domain waveform, FFT plot and the RMS values will switch to velocity (Figure 61). After selecting "velocity", please click on the "Confirm" button to apply the change. After clicking on the "confirm" button, please wait for the gateway to finish calculation.

In default, only 2Hz high pass filter is applied for velocity measurement for better low-frequency monitoring. Filters can be applied to vibration velocity to get the desired frequency response and RMS values. For example, a bandpass filter of cutoff frequency at 10Hz, and a 2nd cutoff frequency at 1kHz will return velocity measurements from 10Hz to 1kHz based on ISO 10816 standard.

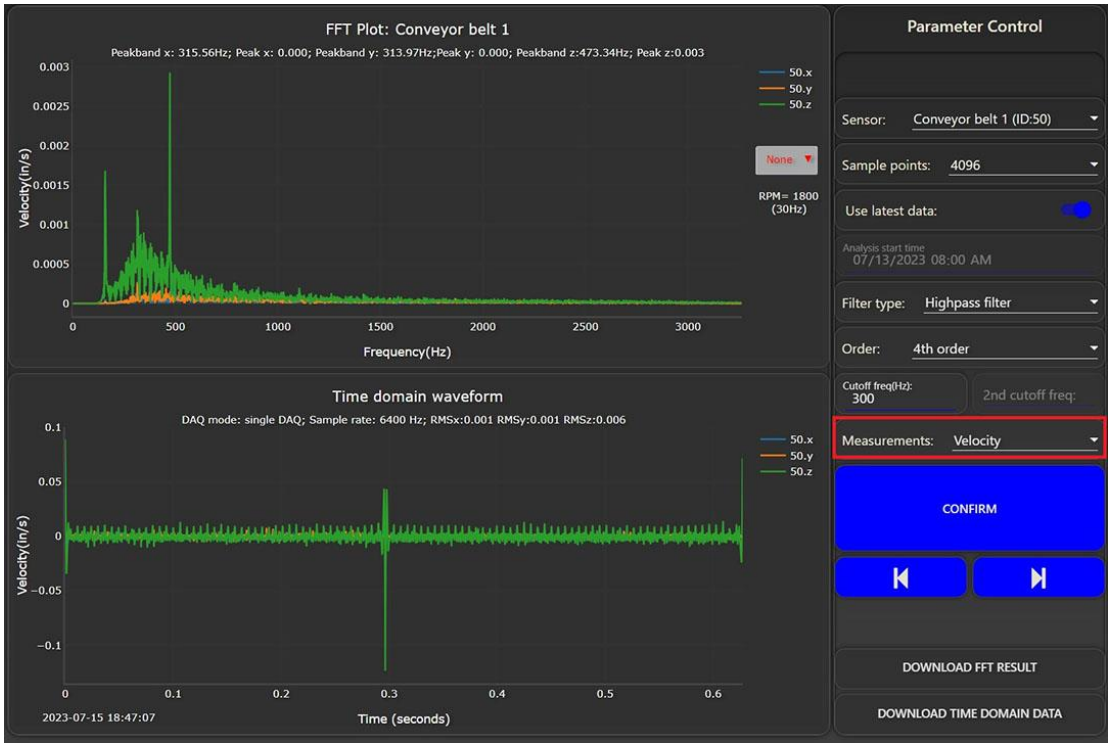


Figure 61 Velocity measurements

5.2.4 Displacement measurements

At the dropdown menu for the "Measurements" selection, user can select "displacement" to measure the displacements. When "displacement" is selected, then time domain waveform, FFT plot and the peak-peak values calculated will change to displacement (Figure 62). After changing the measurements, please click on the "Confirm" button to apply the change. Please wait for the gateway to finish calculation.

In default, only 10Hz high pass filter is applied for displacement measurement when the sample rate is lower or equal to 3.2kHz. When the sample rate is higher or equal to 6.4kHz, a bandpass filter of 10Hz to 1kHz is applied, since displacement is mainly in low frequency range. Filters can be applied to vibration velocity to get the desired frequency response and RMS values. For example, a bandpass filter of cutoff frequency at 10Hz, and a 2nd cutoff frequency at 500Hz will return displacement measurements from 10Hz to 500Hz.

Figure 62 Displacement measurements

5.2.5 Sample rate calibration (sample rate scale)

Each SVT-A series vibration sensor's clock rate can be calibrated for accurate frequency analysis. The accuracy can reach <0.2% at room temperature. To perform the sample rate calibration, a vibration calibrator with high frequency accuracy is required. The sample rate scale can be calculated according to the following steps:

Step 1. Use single DAQ mode to take 2,048 or 4,096 samples with the sensor mounted to the vibration calibrator. Then at the FFT analysis page, select "acceleration" measurements, and click the "Confirm" button.

Step 2. Check the peak band frequency, and compare to the correct peak band frequency. Then the correct scale rate can be calculated by the following formula:

Rate scale =current rate scale+(vibration calibrator frequency- measured frequency)/measured frequency

For example, if the vibration calibrator frequency output is 159Hz, the measured frequency is 157Hz, and the current rate scale is 1.01, then the correct rate scale is:

$$1.01+(159-157)/157=1.02$$

This means that the sensor's actual sample rate is equal to the specified sample rate x1.02. For example, if the sensor samples at 25.6kHz at the DAQ setup page, then the real sample rate is: 25600x1.02=26,112 Hz.

Step 3. Update the sensor's rate scale. Record the current sensor's id, group number and description. Delete the sensor from the sensor configuration page. Re-enter the sensor's id, group number, description and new scale rate.

Step 4. Retake data and verify that the sensor's FFT frequency matches the vibration

calibrator's frequency.

The default value of rate scale is 1.02, which has typically 1% frequency accuracy.

5.2.6 Different DAQ modes for FFT analysis

For accurate FFT analysis, it is recommended to choose "Single DAQ" mode, "Single FFT mode", "Multi-DAQ mode" , "live FFT mode" or "trigger mode". In these modes, the vibration sensor will perform data acquisition in the specified frequency. The data are buffered at the vibration sensor and transmitted to the wireless gateway at the same time. The specified sampling frequency is guaranteed at the sensor side. It may take longer time for the gateway to receive all the data depending on the wireless interference and signal quality. During FFT analysis, the software will use the true sampling rate at the sensor side for accurate FFT analysis. "Multi-DAQ mode" offers sudo-continuous data acquisition with guaranteed sample rate at the sensor.

A timer can be set up to let the gateway take data automatically between a given time period with a fixed interval. For example, you can set up a timer to let a sensor take data from 8am to 8pm, with a period of every 30 minutes, and a DAQ time of 2 minutes. Please refer to "Timers Setup" section for details.

"Batch mode" data acquisition also offers excellent FFT analysis result (Figure 63). One can see that batch mode FFT peaks match the single DAQ mode FFT peaks very well. However, there are some side band signals from the batch mode. The reason is that in batch mode, the data are collected at the sensor side at a given frequency accurately, and the data are transmitted to the wireless gateway. Different from the "single DAQ", in batch mode, sensor takes much less samples (320 samples in each batch; also, wireless sensor takes data continuously, which means that after the transmission is finished, wireless sensor goes back to data acquisition and transmission cycle again. There could be a lot more data available at batch mode.

Figure 63 Single DAQ FFT vs batch mode FFT

Data taken at the real-time mode could be used for FFT analysis too. Since the sampling frequency is not 100% accurate for low lower wireless data transmission (the data transmission rate may fluctuate depending on the environment wireless noise, there could be some error. If user can ensure that the sensor's RSSI is large than -65dBm, then the real time mode can provide continuous DAQ and good frequency accuracy too.

6. Alarm setup and notification

User can set up alarms for SVT-A series sensors and SVT-V series sensors. For SVT-A series sensors, alarm threshold can be set up for each group/zone differently. For SVT-V series sensors, each sensor can have different threshold level (Figure 64). Moreover, when the threshold level of an SVT-V sensor is exceeded, an SVT-A group can be assigned to trigger its data acquisition.

6.1 Alarm thresholds

For SVT-A series, the following threshold level can be set up:

- x-axis upper bound
- x-axis lower bound
- y-axis upper bound
- y-axis lower bound
- z-axis upper bound
- z-axis lower bound
- temperature upper bound
- temperature lower bound

For SVT-V series sensors, the following threshold level can be set up:

- x-axis velocity rms
- y-axis velocity rms
- z-axis velocity rms
- x-axis acceleration rms
- y-axis acceleration rms
- z-axis acceleration rms
- temperature upper bound
- temperature lower bound

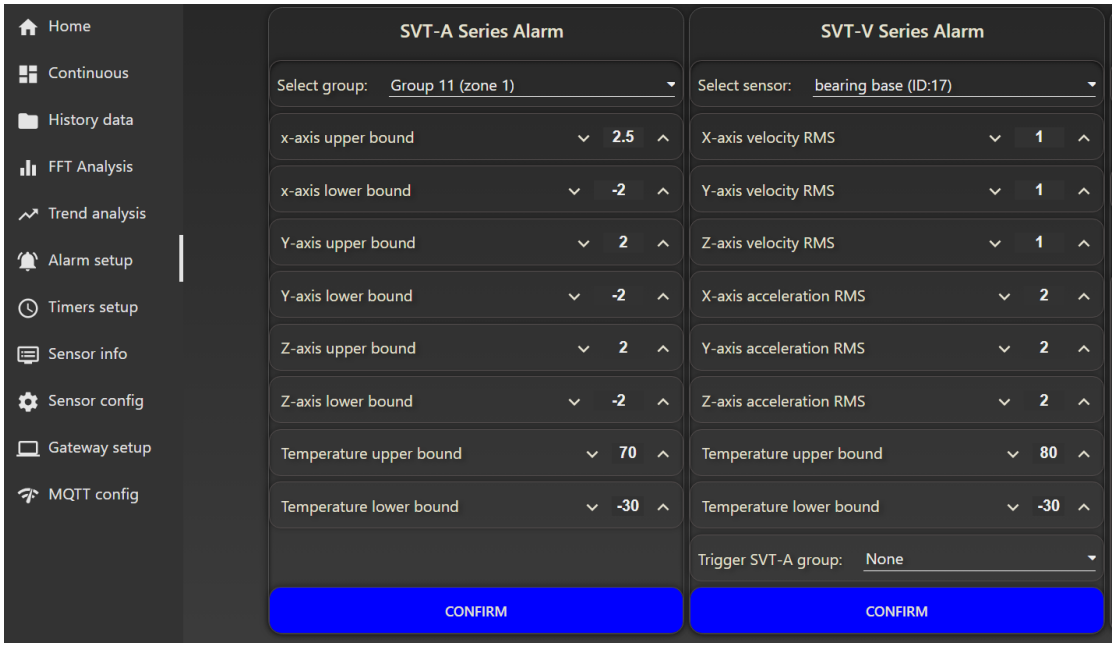


Figure 64 Alarm setup

When the given threshold is exceeded at a given group/zone, the alarm LED will turn into red color. User can refer to ISO 10816 and the machine type to setup the vibration velocity RMS threshold.

For example, to set up an alarm threshold for SVT-A sensor in zone 2, select “zone 2” from the drop-down menu, set up threshold values for x, y, z axes and temperature bound, then click on “Confirm” button. The threshold is set up for the zone. To verify the function, user can set a low threshold value for a sensor, then shake the sensor. When the threshold is exceeded, the LED light will turn into red color.

6.2 SVT-V sensor triggered SVT-A DAQ

Starting from BroadVibra 2.7.7, an SVT-V sensor can be used to trigger an SVT-A group’s DAQ. The trigger threshold level is the same as the SVT-V sensor’s alarm threshold level. To set up the trigger, in the “Trigger SVT-A group” dropdown menu, select a group, and click the “Confirm” button.

For example, in Figure 65, if the velocity RMS exceeds 1 mm/s (if the current unit system is metric), or 1 inch/s (if the current unit system is Imperial unit), or acceleration RMS exceeds 2g, then group 12 of SVT-A sensor will start its DAQ. If temperature threshold is exceeded, it will not trigger SVT-A sensor’s DAQ. The DAQ mode and sample rate are configured at the SVT-A sensor’s DAQ control panel. The allowable DAQ mode is single DAQ, synchronized single DAQ and single FFT mode to prevent the system from running indefinitely.

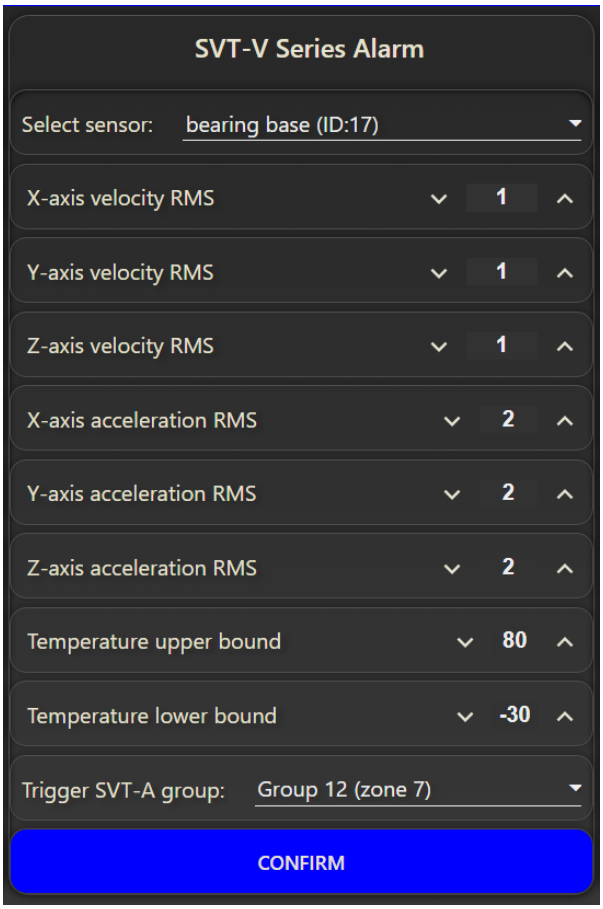


Figure 65 SVT-V sensor triggered SVT-A group DAQ

Note:

1. **If there is DAQ in progress, then DAQ request from the SVT-V trigger event will be ignored.**
2. **If an SVT-A trigger group is selected, then the SVT-A sensor group can be triggered repeatedly by the SVT-V sensor, as long as the vibration level exceeds the SVT-V sensor's alarm threshold.**
3. **If the SVT-A sensor's DAQ mode is in one of the continuous modes such as real time, batch, multi-DAQ or live FFT, then the system automatically toggles the DAQ mode to single DAQ with sample rate of 3200Hz, so that the sensor battery won't be drained by continuous DAQ. Please contact Broadsens to enable continuous DAQ from SVT-V sensor trigger.**

To disable triggering an SVT-A sensor group's DAQ, in the "Trigger SVT-A group" dropdown list, select "None", and click confirm button (Figure 66).

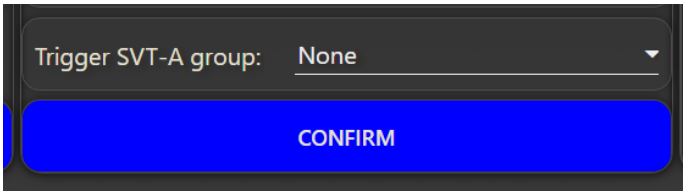


Figure 66 Disable SVT-V sensor triggered SVT-A DAQ

There are many advantages of using an SVT-V sensor to trigger SVT-A group DAQ:

1. Save power of SVT-A sensors in trigger mode. With proper trigger threshold level by an SVT-V sensor, a vibration event can be captured, and analyzed with SVT-A sensor's FFT and advanced filtering ability.
2. A synchronized DAQ mode can be set up at the SVT-A sensor group, so that a vibration event can trigger synchronized DAQ of SVT-A sensors in the same group.
3. Instead of fixed interval DAQ, which can miss many important vibration events or machine defects, an SVT-V sensor triggered DAQ can trigger SVT-A sensor's DAQ only necessary.

For example, an SVT-V sensor can be used along with 2 or 4 SVT-A sensors for rail track monitoring. The SVT-V sensor can be used to trigger the SVT-A sensor's synchronized DAQ when a train passes by. The SVT-A sensor can be used to track the vibration level, velocity and displacement.

6.3 Alarm email and text notification

Alarm notification can be sent via emails. *Figure 67* shows an example on how to set up the alarm email notification. To enable this function, first push the switch of "Email alarm notification" to the right. Then enter the SMTP server address of your current email provider. Please also provide a port number for the SMTP server. If the port number uses secure connection mode, then please turn it on (switch to the right). Typical SMTP secure ports are 465 and 587. Then enter user name and password to log in to the SMTP server. User name and

password will be changed into "……." sign and encrypted with AES 128-bit algorithm Then enter the target email address where the alarm will be sent to. For multiple targe email address, one should separate them with "," sign. Click on "Submit" button to apply the change, or click on the "cancel" button to cancel the setup.

Some email providers such as Google may require extra step to setup the email service. For example, Google SMTP requires to generate an APP password. In this case, please check with the particular email provider for support.

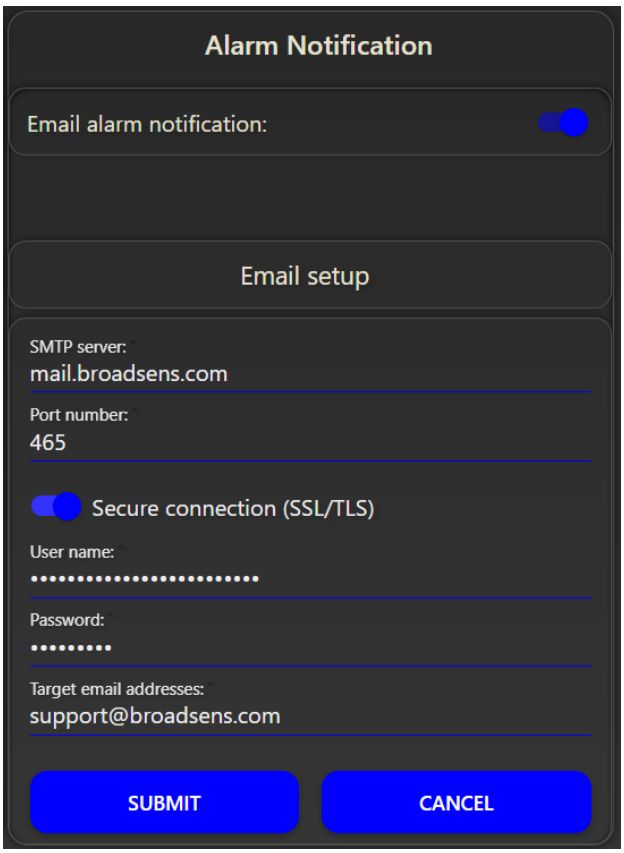


Figure 67 Email setup for alarm notification

Text notification can also be setup by using email to SMS service or email to text service. Please check corresponding cellular service provider in user's country for details.

7. Timer setup

BroadVibra software allows users to set up timers for automatic DAQ of SVT-A series sensors and SAG IMU sensors. Since SVT-V and SVT-T series sensors take data continuously non-stop, there is no need to set up timers for SVT-V and SVT-T series sensors.

A new simplified timer is used to replace the original complicated timer starting version 2.8.0. The new timer greatly simplifies the process to set up periodic DAQ for multiple sensor groups (Figure 68).

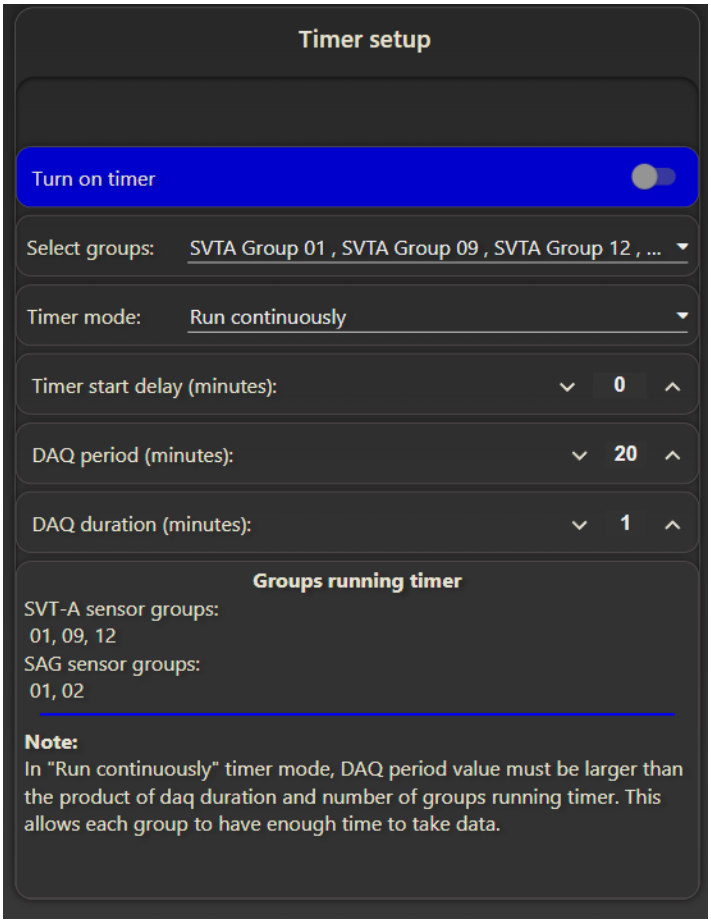


Figure 68 Timer setup

To set up a timer for multiple groups, in "Timer setup" page, click on "select group", where user can add multiple groups of SVT-A series sensors and SAG sensors to the timer (Figure 69).

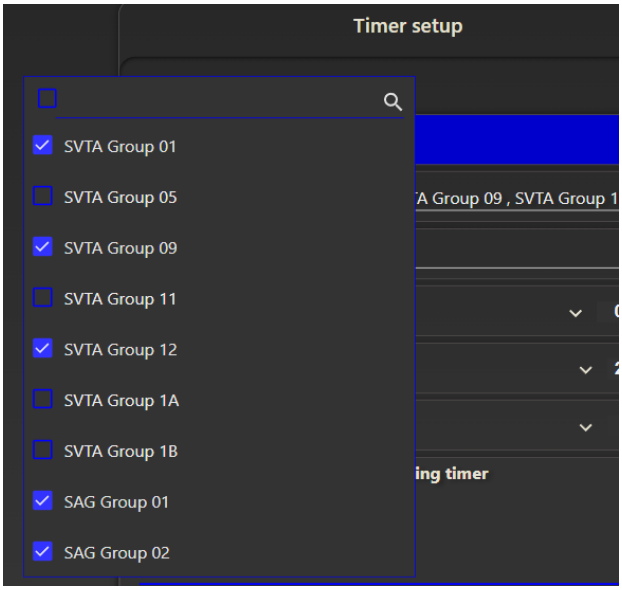


Figure 69 Multiple sensor group selection

The groups running timer table shows the selected groups that are running the timer. When

multiple groups are selected, then the group will run based on the order provided in the table Figure 70.

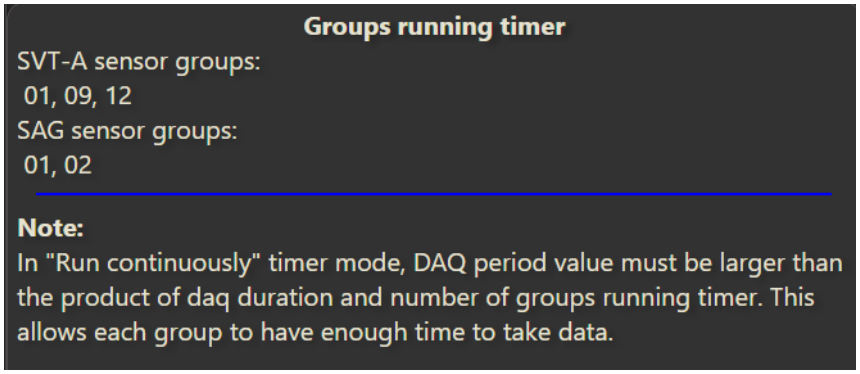


Figure 70 Groups using the timer

There are two timer modes: "run once" or "run continuously". In "run once" mode, all sensor groups only take data once, then stop taking data. In "run continuously" mode, selected sensor groups will take data based on the provided "DAQ period" and "DAQ duration".

User can enter a "Timer start delay" value. The default value is 0, which means that the timer will start run immediately. The unit is in minutes. If user wants to start taking data at desired time, for example, 8am in the morning. The current time is 6:15am, then user should enter value 105 minutes (8am-6:15am) for the "timer start delay" value. If the current time is 2pm, and user wants to take data at 8am next day, then user should enter 1080 minutes (12pm-2pm+8am).

"DAQ period" is the period that the sensor groups take data, and "DAQ duration" is the duration of each group taking data. This is explained in Figure 71. In this figure, there are three sensor groups. The first sensor group in the "groups running timer" table, will take data, followed by the second group, and then the third group. There is two seconds gap between each group, so that the database has enough time to save data. After all groups finish taking data, then the gateway will wait until the next DAQ period starts.

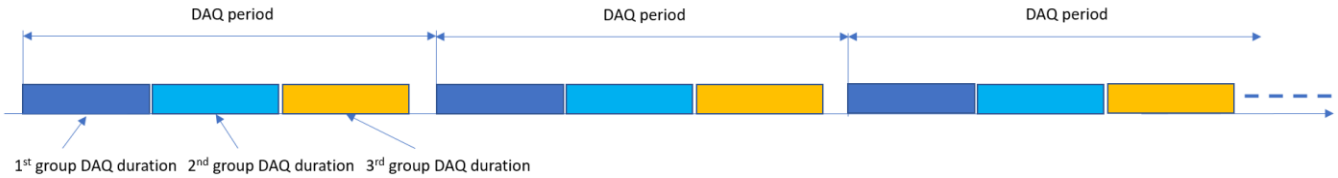


Figure 71 DAQ period and duration

In "run continuously" timer mode, the DAQ period value must be larger than the product of DAQ duration and number of groups running timer. This allows each group to have chance taking data. If the DAQ period value is smaller than the product of DAQ duration and number of groups, then the system automatically increases the DAQ period, or reduces the DAQ duration to meet the condition.

8. Sensor information table

The sensor information table (Figure 72) shows detailed information about each sensor, including row number, sensor ID, sensor name (user defined), group number, serial number, MAC address, RSSI (Received Signal Strength Indicator), battery level, firmware version and the last time sensor information is updated.

The first table shows SVT-A series sensor information, the second table shows the SVT-V series sensor information, and the 3rd table shows SVT200-T temperature sensors information. SVT-A sensor information table also shows the sample rate scale parameter “Rate scale”. The rate scale is used to reflect the real sample rate. For example, if the specified sample rate is 3.2kHz, and the rate scale is equal to 1.02, then the real sample rate is 3.2kHz x 1.02=3.26kHz. The default value of the rate scale is equal to 1.

SVT-A sensor information also shows the RPM of the machine (since BroadVibra version 2.7.6). The RPM is optional and only for rotation machines. If the RPM is not provided, then this field is empty.

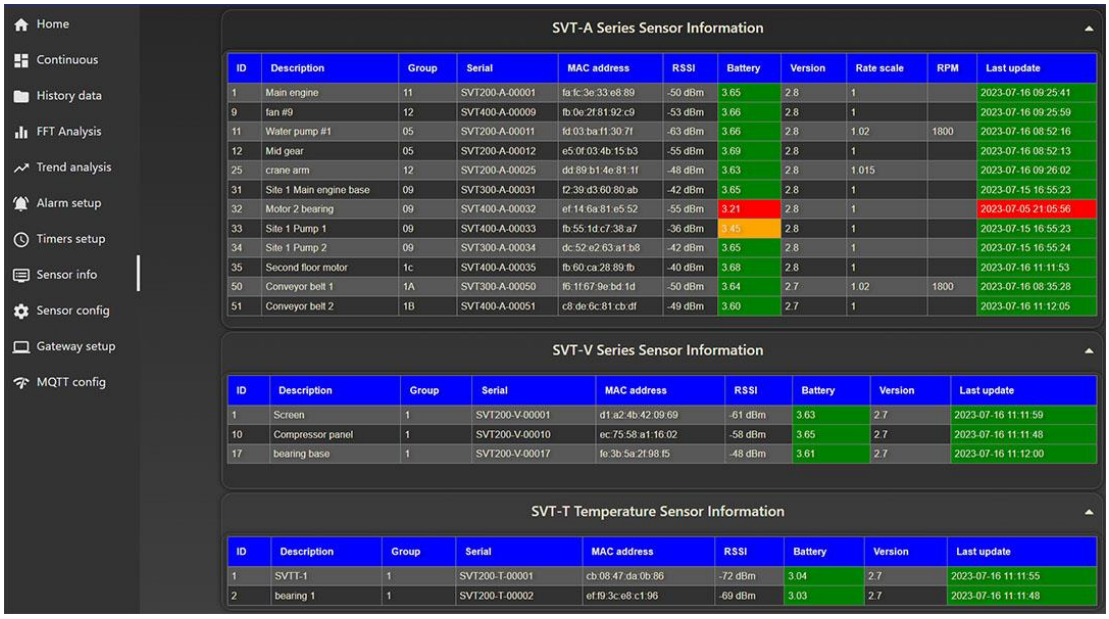


Figure 72 Sensor information table

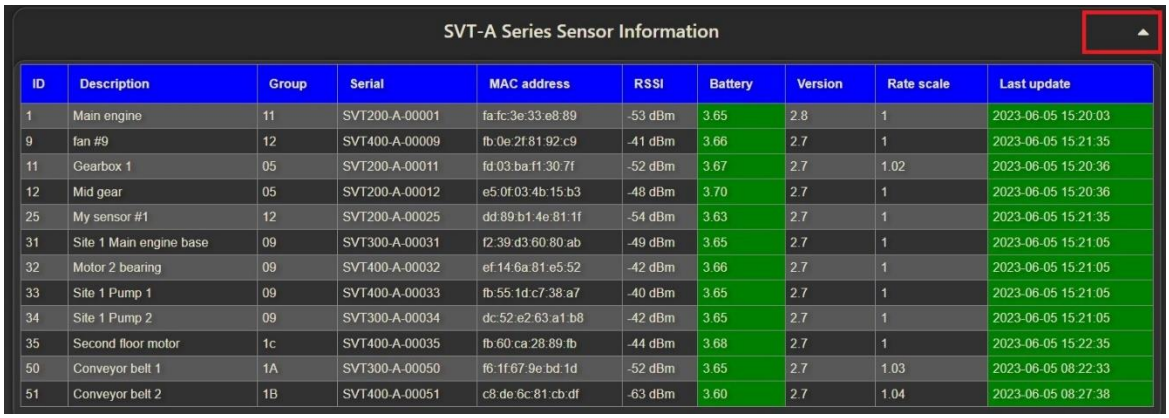
The RSSI is an indicator of the sensor signal strength. As a rule of thumb, the RSSI of SVT-A and SAG sensors should be more than -70 dBm in average for stable and fast data transmission; and the RSSI of SVT-V and SVT-T sensors should be more than -80 dBm in average. The SVT-A and SAG sensors transmit large amount of raw data that requires higher bandwidth, therefore the RSSI requirement is higher than SVT-V and SVT-T sensors. The RSSI can be affected by interference from other wireless devices, so that it is normal to see a variation of RSSI value from a sensor.

The battery level background has three color displays. When the sensor battery level is

normal (more than 3.50v), the display background is green. When the battery level is in medium-low (between 3.42v to 3.50v), then the display background changes into orange color. When the battery level is low (less than or equal to 3.42v), the background becomes red color to remind user to replace the battery in time. When the battery level is low, the sensor can still work for a period of time (1-6 months typically). However, since the OTA firmware upgrade requires high current, the OTA firmware upgrade will have issue.

The "update time" is also useful to see when the sensor data is acquired. If the update time does not change over the past few days and the automatic DAQ timer is set up for a given sensor, then one should check out the sensor condition.

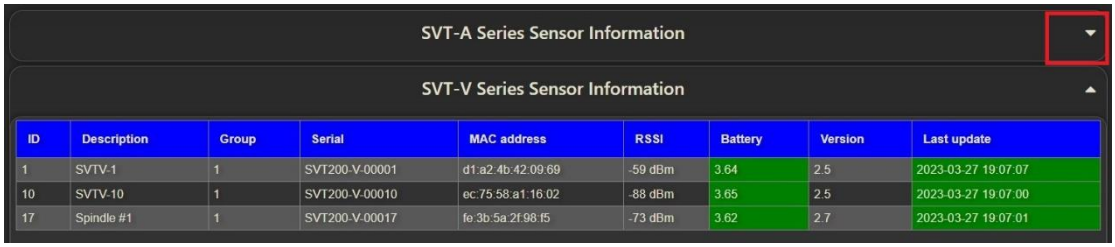
Each table can be collapsed to hide the table. This can be done by clicking on the top right corner "triangle" button of the table (Figure 73).



ID	Description	Group	Serial	MAC address	RSSI	Battery	Version	Rate scale	Last update
1	Main engine	11	SVT200-A-00001	fa:fc:3e:33:e8:89	-53 dBm	3.65	2.8	1	2023-06-05 15:20:03
9	fan #9	12	SVT400-A-00009	fb:0e:2f:81:92:c9	-41 dBm	3.66	2.7	1	2023-06-05 15:21:35
11	Gearbox 1	05	SVT200-A-00011	fd:03:ba:f1:30:7f	-52 dBm	3.67	2.7	1.02	2023-06-05 15:20:36
12	Mid gear	05	SVT200-A-00012	e5:0f:03:4b:15:b3	-48 dBm	3.70	2.7	1	2023-06-05 15:20:36
25	My sensor #1	12	SVT200-A-00025	dd:89:b1:4e:81:1f	-54 dBm	3.63	2.7	1	2023-06-05 15:21:35
31	Site 1 Main engine base	09	SVT300-A-00031	f2:39:d3:60:80:ab	-49 dBm	3.65	2.7	1	2023-06-05 15:21:05
32	Motor 2 bearing	09	SVT400-A-00032	ef:14:6a:81:e5:52	-42 dBm	3.66	2.7	1	2023-06-05 15:21:05
33	Site 1 Pump 1	09	SVT400-A-00033	fb:55:1d:c7:38:a7	-40 dBm	3.65	2.7	1	2023-06-05 15:21:05
34	Site 1 Pump 2	09	SVT300-A-00034	dc:52:e2:63:a1:b8	-42 dBm	3.65	2.7	1	2023-06-05 15:21:05
35	Second floor motor	1c	SVT400-A-00035	fb:60:ca:28:89:fb	-44 dBm	3.68	2.7	1	2023-06-05 15:22:35
50	Conveyor belt 1	1A	SVT300-A-00050	f6:1f:67:9e:bd:1d	-52 dBm	3.65	2.7	1.03	2023-06-05 08:22:33
51	Conveyor belt 2	1B	SVT400-A-00051	c8:de:6c:81:cb:df	-63 dBm	3.60	2.7	1.04	2023-06-05 08:27:38

Figure 73 Collapse table to hide the table

After the table is collapsed, the "triangle" button will turn upside down. Click the "triangle" button again to expand the table to the original full display state (Figure 74). (Note: in certain cases, the table may not go back to full display due to browser cache memory; You can simply select another page such as front page, and then go back to the "sensor information" page, the table should go back to full display).



ID	Description	Group	Serial	MAC address	RSSI	Battery	Version	Last update
1	SVTV-1	1	SVT200-V-00001	d1:a2:4b:42:09:69	-59 dBm	3.64	2.5	2023-03-27 19:07:07
10	SVTV-10	1	SVT200-V-00010	ec:75:58:a1:16:02	-88 dBm	3.65	2.5	2023-03-27 19:07:00
17	Spindle #1	1	SVT200-V-00017	fe:3b:5a:2f:98:f5	-73 dBm	3.62	2.7	2023-03-27 19:07:01

Figure 74 Expand the table back to full display

When user adds a new sensor or delete a sensor, the sensor information table is automatically updated. When a new sensor is added to the gateway, the sensor's MAC address, RSSI, battery level and software version is in red color. For SVT-A and SAG sensors, user needs to use the "manual DAQ switch" to take data to show the sensor information. The software can automatically tell SVT-A series' type. For SVT-V and SVT-T series sensors, the data will come in automatically (no need to take data manually). If a sensor's information such

as ID or group number is entered incorrectly, then the corresponding sensor's information won't be updated in the table.

Starting from BroadVibra version 2.7.1, when a sensor is not connected to the gateway for more than 24 hours, then the corresponding "Last update" row will become orange color; when a sensor is not connected to the gateway for more than 48 hours, then the "Last update" row will become red color. This feature helps user to identify problematic sensor immediately.

9. Sensor configuration

Sensor setup can be adjusted in "Sensor config" page (Figure 75). The sensor configuration includes SVT-A series sensor setup, SVT-V series sensor setup, SVT200-T temperature sensor setup, SAG IMU sensor setup and Sensor configuration export and import.

9.1 SVT-A series sensor configuration

SVT-A series sensors can be added, deleted, change description, RPM, change group and upgrade the firmware at "Sensor config" page.

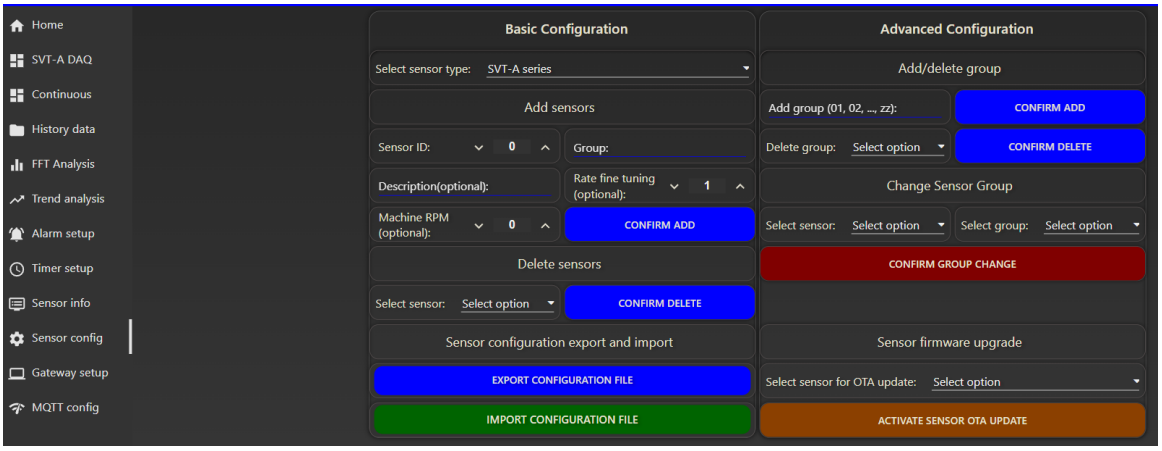


Figure 75 Sensor configuration

9.1.1 Add or delete a sensor

Each SVT-A sensor's ID and group number are saved at the sensor's flash memory, so that even if the battery is replaced, the sensor still remembers its ID and group assignment. **Therefore, SVT-A sensor's group number must be adjusted by first adding the sensor to the assigned group.** Then the sensor's group number can be changed using "change sensor group" function (please refer to chapter 9.1.3 for details).

a) Add a sensor

To add an SVT-A sensor, in the “Basic configuration” section, from “Select sensor type” dropdown menu, select “SVT-A series” sensor type (Figure 76), and enter the sensor ID. User only needs to enter the numeric numbers of the sensor ID. For example, if the sensor’s ID is SVT300-A-00235, then user only needs to enter the nonzero numeric value 235.

In the group area, enter the assigned sensor group number. Please do not use other group number at this time. The sensor group can only be adjusted after it is added to the gateway.

User can give a description to the sensor (optional) at this time. If the sensor description is not provided, then a default description of “SVTA-” +sensor ID will be used. Enter the group number of the sensor provided by the factory. The “Rate fine-tuning” and “Machine RPM” are also optional. Press “confirm add” button to add the sensor, or click on “cancel” button the cancel the operation.

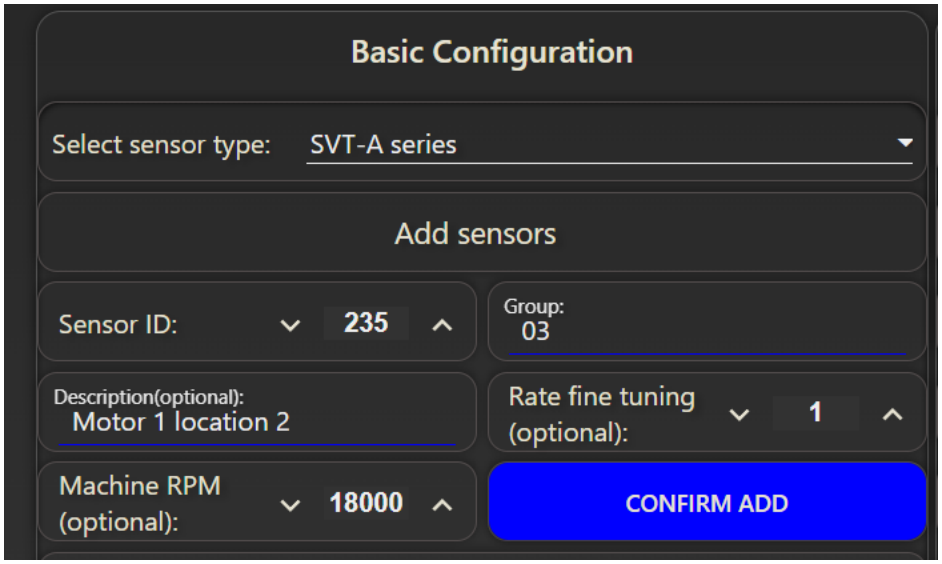


Figure 76 Add an SVT-A sensor

[Rate fine tuning]

If there is no value provided, the sample rate fine-tuning parameter default value 1.02 is used, which matches the most of Broadsens sensor’s true sample rate. The rate scale allows for more accurate frequency domain analysis. The real sample rate of the sensor is equal to product of the specified sample rate in the DAQ and the rate scale. For example, if the sample rate is 6.4kHz and the rate scale is 1.02, then the real sample rate is 6.528kHz. Since the wireless vibration sensors always have a sample rate higher than specified value, the allowable rate scale range is from 1 to 1.04.

[RPM]

RPM is added since version 2.7.6. This field is optional For an AC motor, the number of poles and the frequency determine the no-load RPM. For a 60 Hz system with four poles, the RPM equation would be:

(Hz x 60 x 2) / number of poles = no-load RPM

For a 60Hz four-pole AC motor, the RPM is 60x60x2/4=1800 RPM

For a 50Hz four-pole AC motor, the RPM is 50x60x2/4=1500 RPM

When there is a load, the motor could run slower. For example, at 60 Hz, a motor with six poles would run at 1,200 RPM under no load and at approximately 1,175 RPM loaded.

[Tips] Because SVT-A sensors in the same group share the same bandwidth, it is recommended to allocate no more than 6 SVT-A sensors in the same group. The maximum allowable number of SVT-A sensors in the same group is 6. Same sensor type such as SVT300-A should be assigned to the same group.

33	Site 1 Pump 1	09	SVT400-A-00033	fb:55:1d:c7:38:a7	-40 dBm	3.65	2.7	1	2023-06-05 15:21:05
34	Site 1 Pump 2	09	SVT300-A-00034	dc:52:e2:63:a1:b8	-42 dBm	3.65	2.7	1	2023-06-05 15:21:05
35	Second floor motor	1c	SVT400-A-00035	fb:60:ca:28:89:fb	-44 dBm	3.68	2.7	1	2023-06-05 15:22:35
50	Conveyor belt 1	1A	SVT300-A-00050	f6:1f:67:9e:bd:1d	-52 dBm	3.65	2.7	1.03	2023-06-05 08:22:33
51	Conveyor belt 2	1B	SVT400-A-00051	c8:de:6c:81:cb:df	-63 dBm	3.60	2.7	1.04	2023-06-05 08:27:38
1028	Site 2 shaft	11	SVTx00-A-01028					1.02	

Figure 77 Sensor information table

b) Add a sensor to a new group

To add a sensor to a new group that does not exist at the wireless gateway, users need to add the group first.

For example, if we want to add sensor SVT200-A-00108 with preassigned group “2B” to a gateway (**please use the preassigned group number only. The group number can be adjusted later on**). But group “2B” does not exist at the gateway. Then please follow the steps below:

1. We add the sensor first:

At “sensor config” page→ Select “SVT-A series” sensor type → type in sensor ID: 108, sensor name (optional), and group: 2B → Press “confirm add” button. Then the sensor SVT200-A-00108 is added to group “2B”.

2. Since the group does not exist on the gateway, we also need to add the group.

At the “Sensor Config” page→ “Advanced configuration”, “Add/delete” group section, enter the new group. In this example: group “2B”. Click on “confirm add” button, then group 2B is added to the gateway (Figure 78).

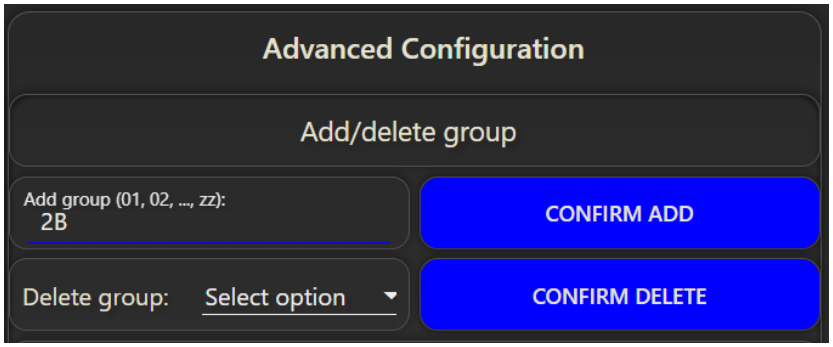


Figure 78 Add new group

3. Now user can go to home page → DAQ control → Group selection, select “Group 2B”, then the sensor 108 will show up. Turn on the “Manual DAQ switch” to take some data. If the sensor is added successfully, then the data curve will show up. The corresponding sensor information will be updated at the “Sensor Info” page.

c) Duplicate sensor ID

Since each sensor should have a unique ID, when the software detects that a duplicate ID is entered, then it will give an error message at the top right corner of the screen (Figure 79). One should double-check the sensor ID and group.

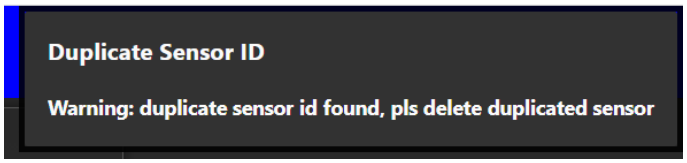


Figure 79 Duplicate sensor ID

d) Delete a sensor

An existing sensor can be deleted from the gateway. The sensor can be selected from the drop-down menu and press “confirm delete” button (Figure 80). A pop-up window will ask the user to continue or cancel. Press “OK” to delete the sensor, or “Cancel” to cancel the action. When one wants to change the sensor row number in the sensor information table, one may delete the sensor first, and then add the sensor back to the desired location.

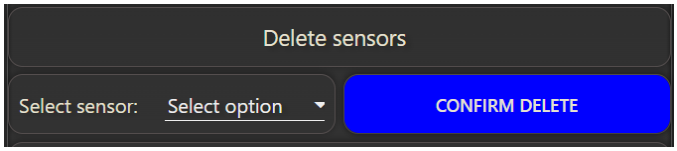


Figure 80 Delete a sensor

e) Change sensor setup

To change a sensor’s setup such as RPM or description, please delete the sensor first, then add back the sensor with the same ID (serial), current group number and a new description. The sensor’s other information such as RPM can be adjusted by deleting the sensor, and adding back the sensor with new RPM too.

9.1.2 Group management

User can add group or delete a group at the “Advanced configuration” -> “Add/delete” group section, section (Figure 78). Enter a group number, click on “Confirm Add” button to add a group. Each gateway allows to have up to 10 groups of SVT-A sensors.

To delete an existing group, select the groups from the dropdown list, and click on "Confirm delete" button. Then the group is deleted.

There are up to 3,844 groups (expandable to 238,328 groups) can be selected. The available groups are from 00,01, …,09, 0A, 0B, …, 0Z, 0a, 0b, …, 0z, 1A, 1B, …, 1Z, 1a, …, 1z, ,…, to zz. Each SVT-A sensor is pre-assigned a group number. The group number of the SVT-A sensor can be adjusted by the user.

When there are multiple gateways, it is recommended that each gateway has different groups. That is, the group number should not overlap for the gateways in the same factory. For a company, each SVT-A vibration sensor has a unique ID. The server identifies the sensor by its ID, not the group number. The group number is only designed for gateway control purpose.

9.1.3 Adjust sensor group

An SVT-A sensor's group number is saved at both the sensor's flash memory and the gateway. Even if the sensor runs out of battery, its ID and group number will remain unchanged. Therefore, to adjust the sensor's group number, please make sure use the sensor's current group number and the "change sensor group" option in the "Advanced Configuration" section. To do this, select the sensor ID that user wants to adjust, then select a new group number from the dropdown menu.

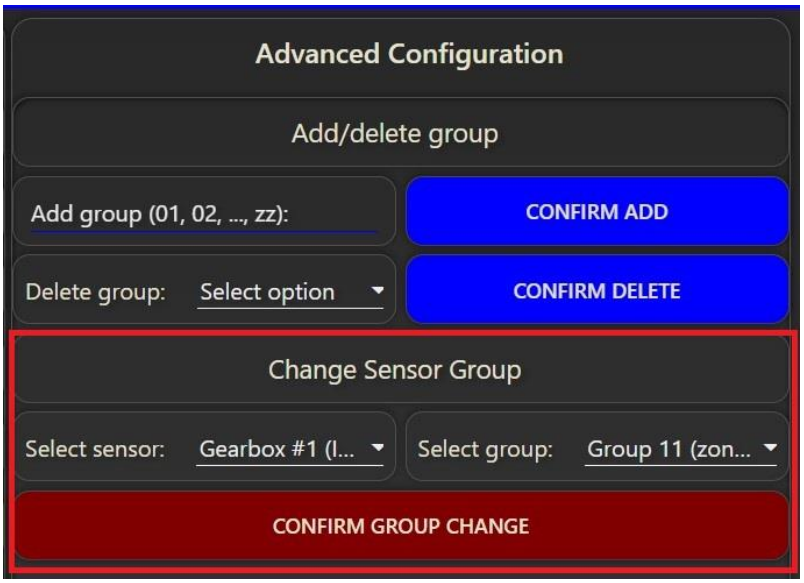


Figure 81 Adjust sensor group

If the group number does not exist, then please add a group first. Then the group number will show up in the "Select group" dropdown menu.

Pressing "Confirm Group Change" button, a pop-up window will ask the user to confirm. Press "start" to continue. Then the gateway will wake up the particular sensor to change its group number. In the mean time, a message will show up in the top right corner, telling user that the sensor group change is in progress (Figure 82).

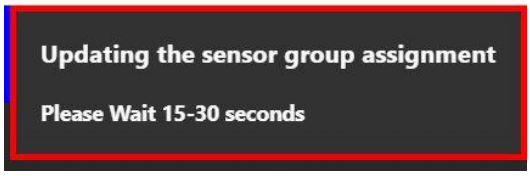


Figure 82 Sensor group adjustment

If the group change is successful, then another message will show up in the top right corner, telling user that the group change is successful (Figure 83). If there is no message coming up, then it means that the sensor connection times out due to network congestion. In this case, please try again. When there are multiple sensors in the same group, a gateway needs to check each sensor's ID, to make sure that the correct sensor changes the group. Therefore, it is possible for the group change to time out. You can simply retry. When the group is changed successfully, the sensor information table is also updated with the newly assigned group number.

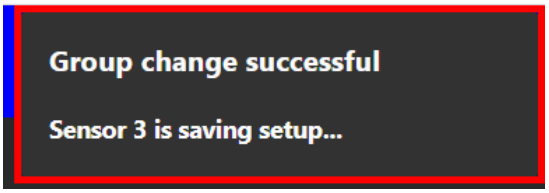


Figure 83 Group change successful

9.1.4 Sensor firmware update

SVT-A series sensor's firmware can be updated Over The Air (OTA) by using the "Activate sensor OTA" option (Figure 84). Broadsens wireless vibration sensors supports the highly secure firmware upgrade with AES 128-bit protection. This high security measure protects the sensors from hacker's attack. The firmware and boot loader are encrypted with highly complicated algorithm.

To update a sensor's firmware, first select the sensor from the list, then press the "Active sensor OTA) button, then a pop-up window will ask the user to confirm. Press "Start" to start the OTA process, press "cancel" to cancel the action. To update the sensor firmware, a zipped new sensor firmware will be provided to the user. When the process starts, the gateway will wake up the sensor ID provided, and send out the "OTA" command.

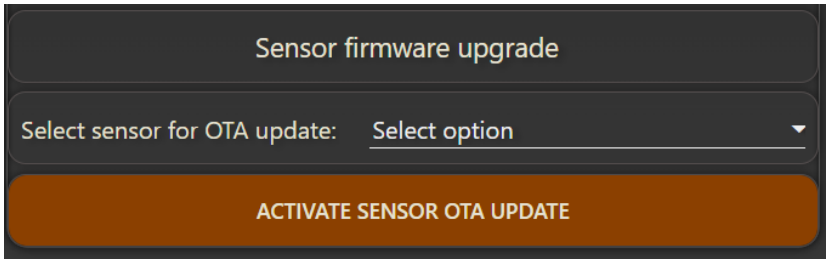


Figure 84 Activate sensor OTA

The OTA process can be performed by using a smart phone. An application program needs to be installed to perform the OTA process. Depending on user's smart phone model (Apple or Android), the operation detail can be obtained from Broadsens.

9.2 SVT-V series sensor configuration

SVT-V series sensor can be configured at the "sensor config" page (Figure 85). In the "select sensor type" dropdown menu, select "SVT-V series", then user can add or delete an SVT-V sensor from the gateway.

The group number for each SVT-V sensor is fixed at the factory and can only be adjusted by the factory. This is to maximize the battery efficiency of the SVT-V sensor to allow the sensor for real-time monitoring with multiple years of battery life. Therefore, the "Advanced configuration" section is greyed out. Please enter the group number provided by the factory. The valid group number of SVT-V sensors is from 1 to 256. Group 0 is reserved for factory internal testing.

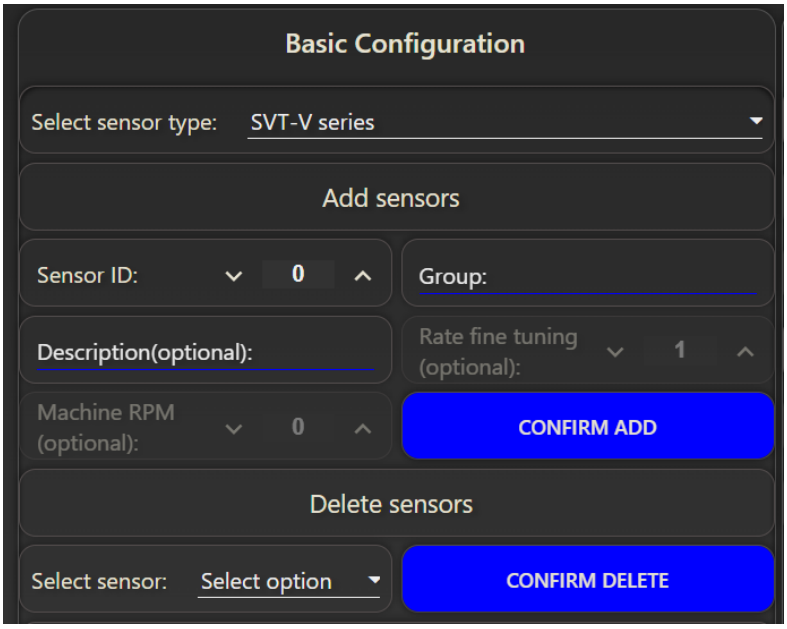


Figure 85 SVT-V series sensor configuration

To add an SVT-V sensor, enter sensor ID (labeled on the sensor), sensor description and group number. Press "Confirm" to apply the change, and press "cancel" button to cancel the change. The new sensor information is automatically updated in the sensor information table.

Example of adding an SVT-V sensor

In this example, we will add a sensor SVT200-V-01058, with group number 5 to the gateway.

Step 1. Enter sensor ID 1058 (only need to enter the non-zero numeric numbers of the serial number), and provide the sensor description (optional), and the provided group number "5".

Step 2. Press "confirm" button. The sensor is ready to use.

To delete an SVT-V sensor, simply select the sensor in the "Delete sensors" section, and click on "Confirm delete" to delete the sensor.

The default group number for the SVT-V series sensor is 1. There are 256 groups allowed for the SVT-V sensor. Different from SVT-A series sensors, adjacent gateways can have the same group number for SVT-V sensors. So in a large factory, it is common to have thousands of SVT-V series sensors, but only up to five group numbers used.

Each gateway can support multiple SVT-V groups. The recommended number of V-series sensors in each group is up to 5, and the number of groups is up to 10.

It is possible for two gateways to have the same SVT-V sensor. In this case, both gateways will collect data for the same sensor. This feature could be useful for redundancy design and critical structures/machines.

To adjust the description of an SVT-V sensor, please first delete the sensor, and then enter the new sensor description. The sensor information table will be updated automatically with the sensor configuration. User can always refer to the sensor information table for the latest sensor configuration information.

9.3 SVT-T series sensor configuration

SVT-T series sensor includes SVT200-T ultra-low power wireless temperature sensor, whose battery can last more than 10 years working continuously (measuring temperature and sending out result every 15 seconds).

The process of adding an SVT-T series sensor is the same as adding an SVT-V series sensor. Select "SVT-T temperature" from the "select sensor type" dropdown menu. Enter the sensor ID, description (optional) and group number to add the sensor (Figure 86). Please use the group number provided by the factory. The valid group number of SVT-T sensors is from 1 to 256. Group 0 is reserved for factory internal testing.

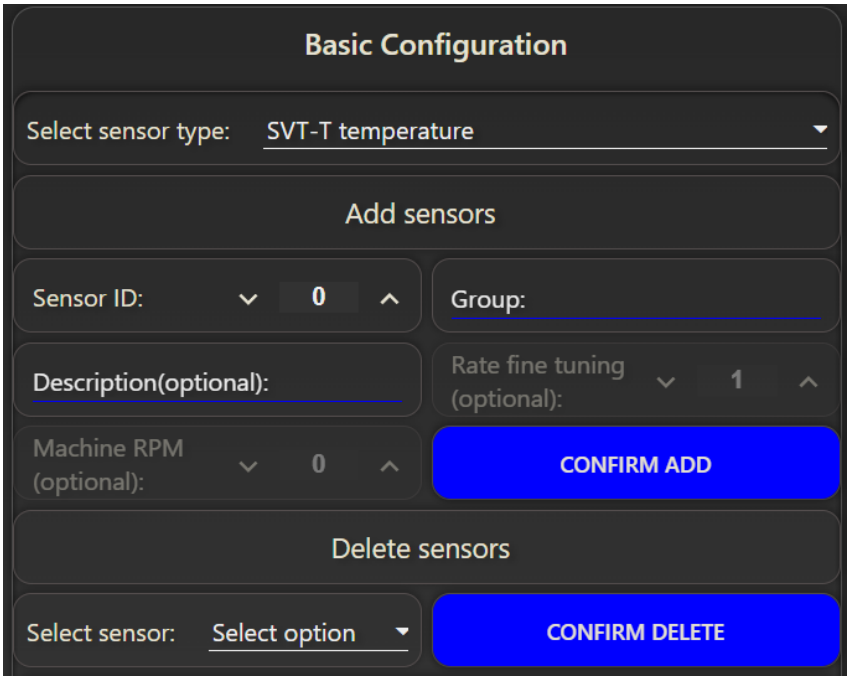


Figure 86 SVT-T series sensor configuration

Similarly, an SVT-T sensor can be deleted by selecting the particular sensor, and click on "Confirm delete" button. The SVT-T sensor information table in the "sensor information" page will be updated accordingly.

It is possible for two gateways to have the same SVT-T sensor. In this case, both gateways will collect data for the same sensor. This feature could be useful for redundancy design and critical structures/machines.

9.4 SAG IMU sensor configuration

SAG IMU sensor configuration is the same as SVT-A series sensors. In the "Basic Configuration" section, select "SAG IMU" from the "select sensor type" dropdown menu. Then user can add, delete an SAG IMU sensor (Figure 87). The "select sensor" list will be automatically updated to the SAG IMU sensors.

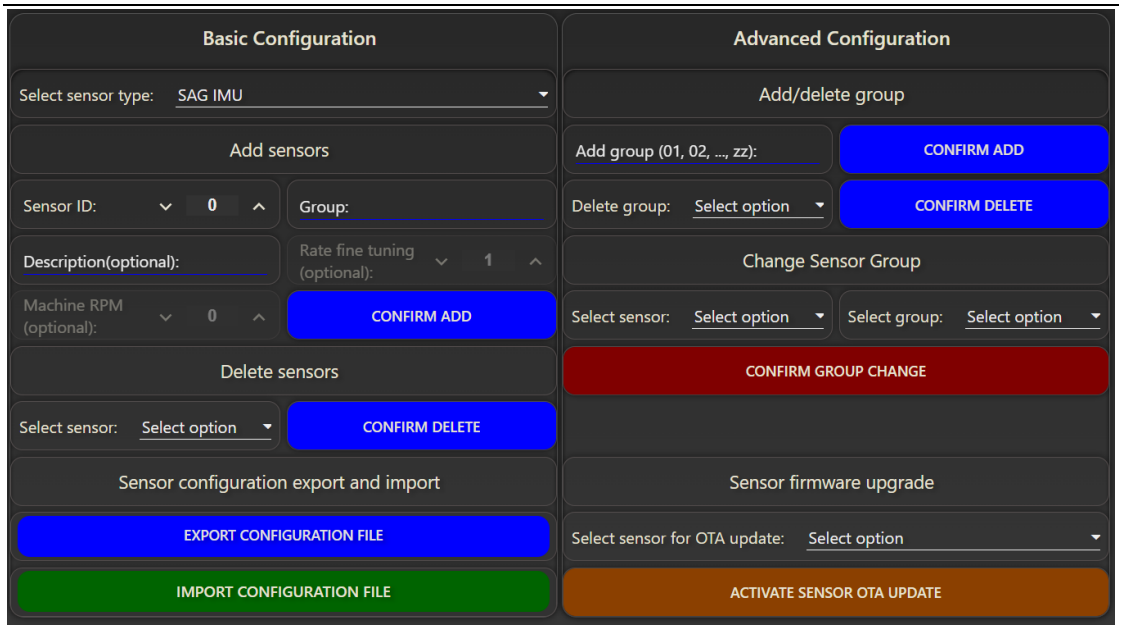


Figure 87 SAG IMU sensor configuration

SAG IMU sensor's group can also be adjusted following the same process as the SVT-A sensor. Please refer to section 9.1 for details**. It is important to add the sensor with the provided ID and current group number, then use the "change sensor group" function to change the sensor to a new group.**

SAG IMU sensor's firmware can also be updated using the "sensor firmware upgrade".

9.5 Sensor configuration export and import

Current sensor configuration can be exported by clicking on "Export configuration file" to export the current sensor configuration (Figure 88). Gateway name, location and alarm thresholds are also exported to the file. The default export file name is gateway name + "config" + current year, month and date. For example, an exported sensor configuration file is called "GW2021_config_20230528.sse". The file is encrypted to protect the sensor information. This feature is useful when a user wants to back up the current sensor and gateway system setting.

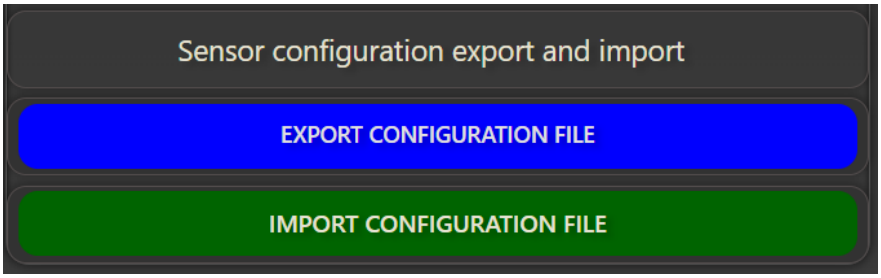


Figure 88 Sensor configuration export and import

Note: When using the latest Chrome browser, the browser will ask the user if want to keep the download file. Please click on “keep” (Figure 89) button to save the file with correct file name. Otherwise, the file name will become “Unconfirmed xxxx.crdownload”.

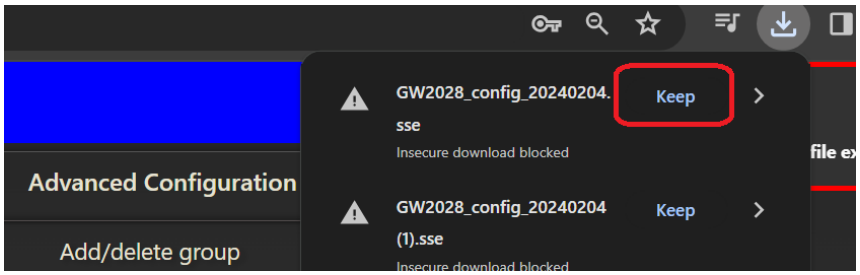


Figure 89 Save the configuration file with Chrome browser

To import a sensor configuration file, click on “Import configuration file”, select the correct file and upload the sensor configuration file. If an incorrect file is selected, the system will show a message that the file format is incorrect. **After sensor configuration is updated, the BroadVibra will automatically reload in 5 seconds.** A pop-up window will remind user that the software will reload. It takes 10-15 seconds for the software to reload.

10. Gateway setup

Gateway setup page has two functions: gateway configuration and gateway update (Figure 90). Gateway configuration allows user to restart the gateway, shutdown the gateway, show its current MAC address and select the unit system. Gateway update allows user to update the gateway software, firmware, and reset internal database to factory default.

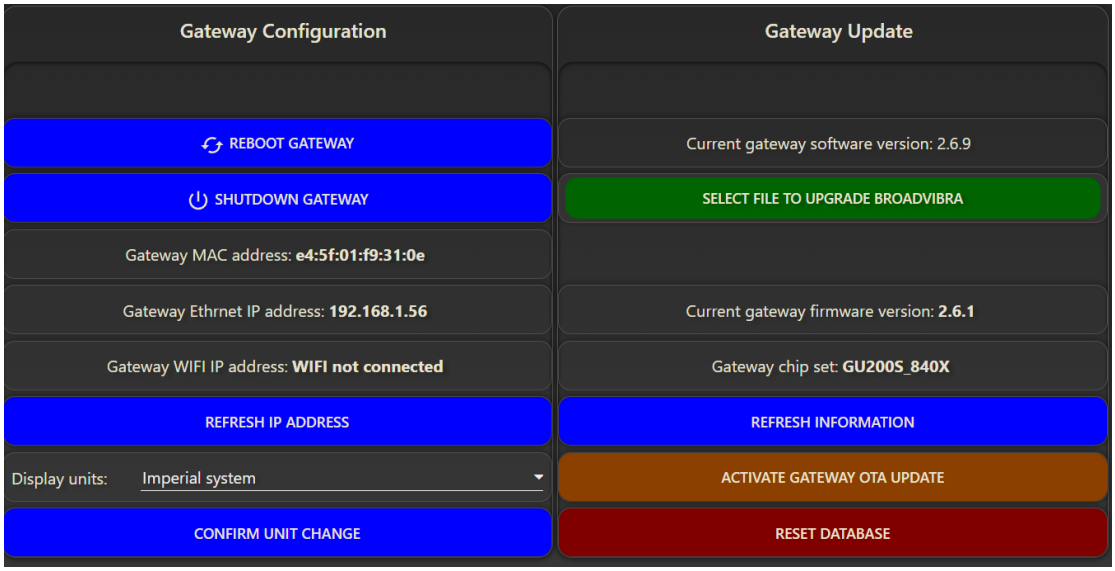


Figure 90 Gateway setup

10.1 Gateway Configuration

When the gateway memory is running low, user can restart the gateway to release the memory used by the database. This is done by clicking on the “restart gateway” button (Figure 91). It is also advised to clean the database when the database takes up too much memory of the gateway. When the gateway needs to be shut down, press the “Shutdown gateway” button to shut down the gateway gracefully to maximize its life.

Gateway MAC address of the Ethernet port interface is shown as the unique identifier of the gateway. Gateway’s Ethernet current IP address and WiFi’s IP address are also shown. When the network is not connected, then the IP is shown “not connected”. Sometime, the software loads faster than network connection, and the IP address is not shown when system starts for the first time. Click the “refresh IP address” button to show the latest IP address information.

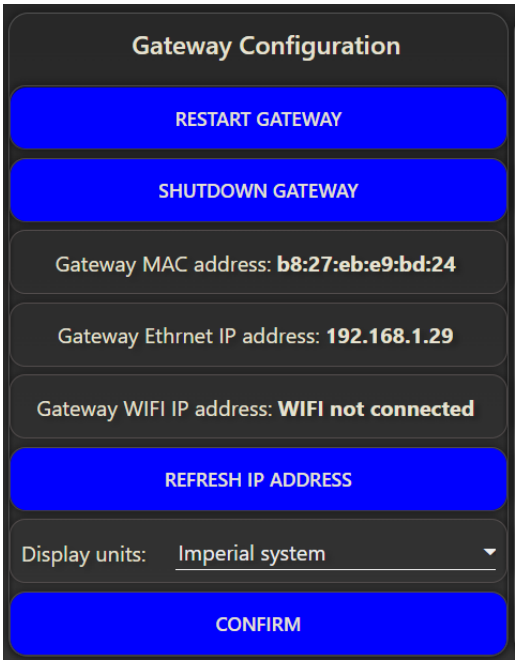


Figure 91 Gateway configuration

Unit system selection

Measurement unit can be adjusted by selecting either "Imperial system" (English system) or "Metric system" (International system) in the dropdown menu, and click on "Confirm" button. A popup window will ask user to confirm the change. Click on "OK" to implement the change.

Please note that to make the systems consistent, the MQTT outputs including raw data, alarm and trend analysis are based on metric system. Users need to add unit conversion if they plan to use Imperial units at the server side.

10.2 Gateway update

The current gateway software (BroadVibra) version, firmware version and chip set are displayed (Figure 92). Please note that gateway software version, gateway firmware version and sensor firmware version can be totally different, since they are developed and maintained by different R&D teams of Broadsens.

10.2.1 Gateway software update

BroadVibra software is updated regularly by Broadsens regularly to bring the new features to users. This can be done easily by clicking on the "select file to upgrade BoradVibra" button. Click the button and open a file upload window. Select the update file and press "open" to upload the new software. The default update file name is called "BroadVibra_ver_x.x.x.bef",

where ".bef" is the file type, "x.x.x" is the version number. In this example, the file name is called "BroadVibra_ver_2.1.4.bef".

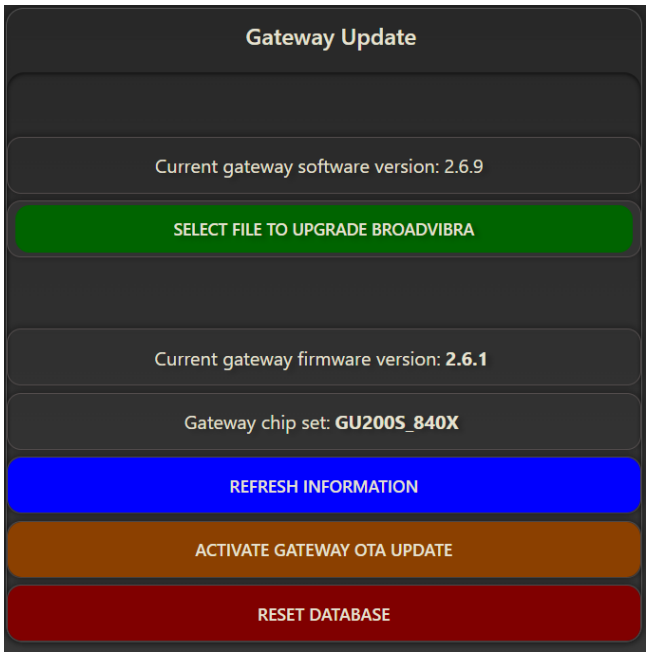


Figure 92 Gateway update

If a wrong file is selected, then a message window will show up in the top-right corner of the browser, telling user that a wrong file is chosen.

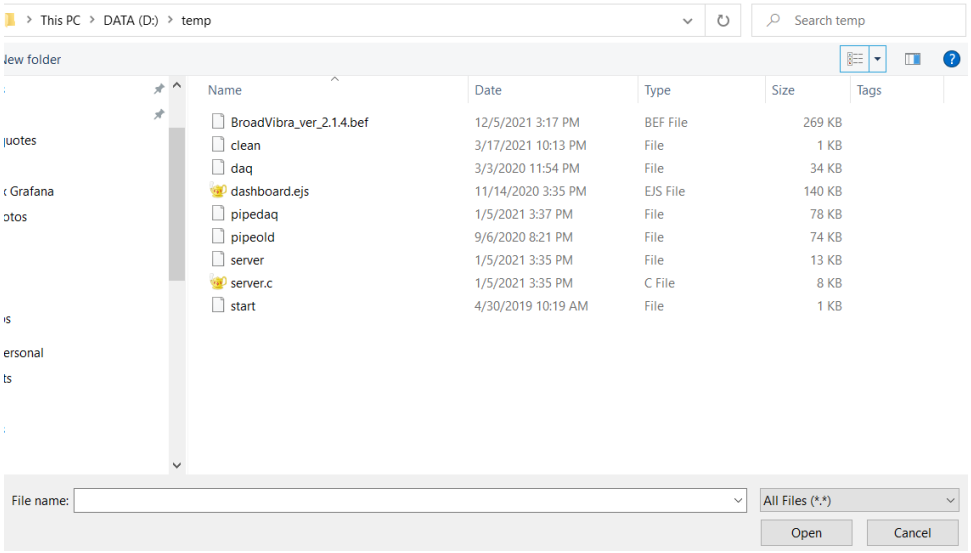


Figure 93 Select BroadVibra update file

The update file is encrypted with advanced algorithm. If the update software is loaded successfully, then a pop-up window will ask user to restart the gateway (Figure 94). User can

still click the “cancel” button to finish the job before re-start the gateway to apply changes. Click on the “OK” button to restart the gateway and apply the update.

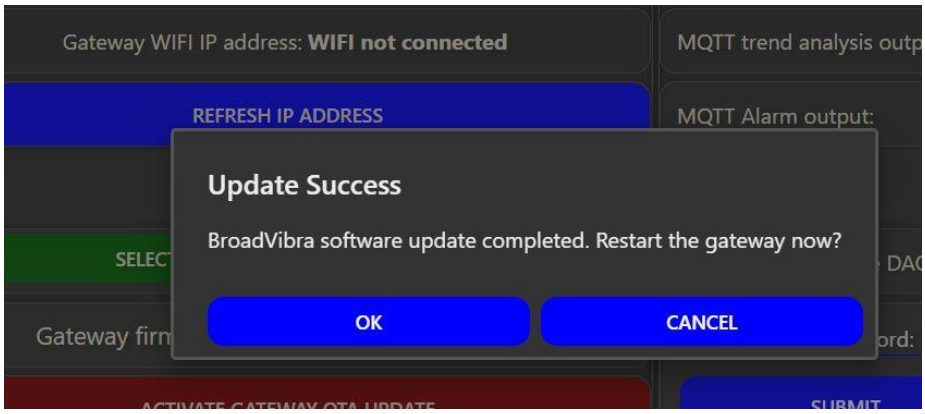


Figure 94 BroadVibra software update success

It takes about 1 minute for the gateway to restart. After the gateway restarts, user may need to refresh the browser page (press F5 key) to see the updated web page.

[Remote software update]

Starting from software version 2.7.8, gateway software can be updated remotely. The remote software update requires internet access. For details, please refer to the MQTT communication guide.

10.2.2 Gateway firmware upgrade

Broadsens gateway has a dedicated high performance low-power wireless IC to handle the communication with sensors exclusively. The gateway firmware runs inside the wireless IC. The current firmware version can be seen from the gateway information. In Figure 92, the software shows the current firmware version is 2.6.1 and the gateway wireless IC chip set is “GU200S_840X”. Press the “refresh firmware version” button to update the current firmware version information. If the gateway firmware is outdated, then the gateway chip set may show “please update firmware” information. In this case, please contact Broadsens and update gateway firmware first. The current wireless IC chip set includes:

- GU200S_840X
- GU200S_833E (Japanese version for local radio law compliance)
- GU300_840X
- GU300_840E (Japanese version for local radio law compliance)

The gateway firmware can be updated via the secure OTA process. The whole process is highly secure to ensure the integrity of the system. To activate the gateway OTA update, press the “activate gateway OTA update” button. There will be a pop-up window to ask if the user

wants to continue. Press “cancel” button to cancel the process, and press “start” to start the process (Figure 95).

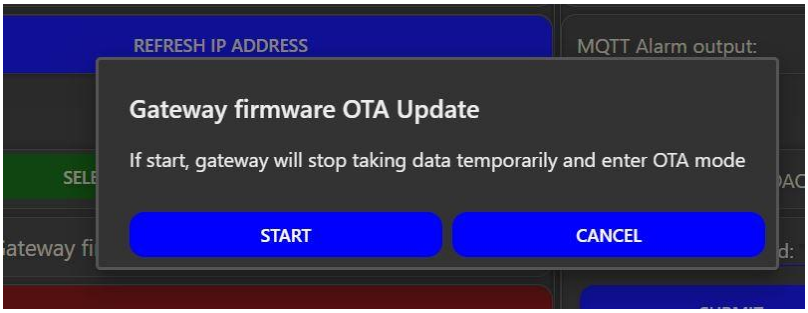


Figure 95 Gateway firmware update

When the gateway OTA process is activated, the gateway will stop functioning temporarily. When there is no activity, the gateway will go back to the working state after about 2 minutes. Please follow the firmware upgrade guide on how to update the firmware. A smart phone is required to perform the gateway firmware upgrade.

After the gateway firmware is updated, press the “refresh firmware version” button to update the current firmware version information. It is worth mentioning that pressing the “refresh firmware version” button can also be used to check the communication between the gateway controller and low-power wireless IC. If the communication is normal, then a message window will show up in the top right corner of the browser showing “Received reply from wireless chip”.

10.2.3 Database reset

Gateway’s database can be reset to factory default setting. To do this, click on “Reset database” button. A popup window will ask user to confirm the operation. Press “OK” to reset the database. This feature should be used with caution, since it will erase all data collected, including trend analysis.

11. MQTT Configuration

MQTT configuration page allows user to change the gateway’s name for MQTT data transmission, adjust gateway’s location (latitude and longitude), turn on/off MQTT gateway information, sensor information, sensor live data transmission, alarm output, single JSON data, single FFT, trend analysis result of the gateway, and allows remote DAQ control of the gateway from a remote server or clouds (Figure 96). Starting from BroadVibra version 2.6.1, external MQTT broker can be used. When an external MQTT broker is used, then the internal MQTT

broker is bypassed automatically.

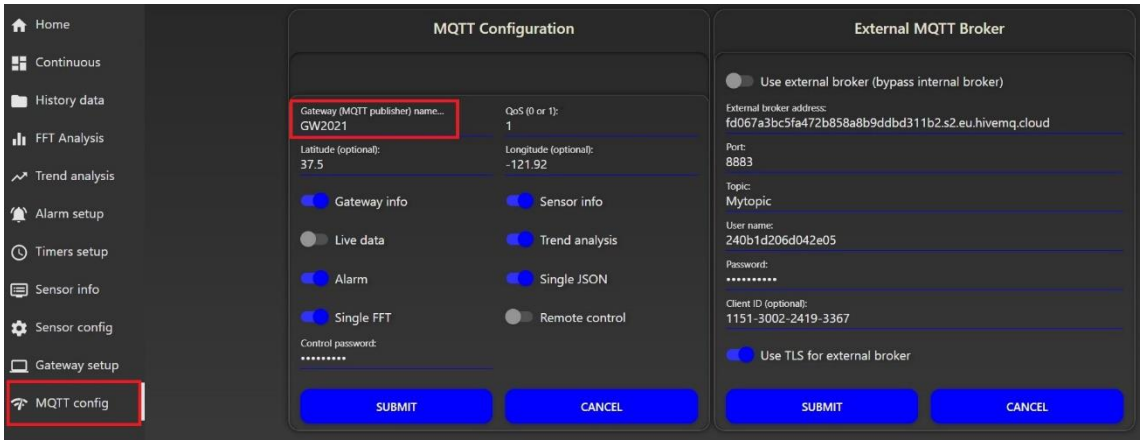


Figure 96 MQTT configuration

11.1 MQTT configuration

Broadsens's wireless gateway comes with MQTT broker (publisher) installed. The MQTT broker is Mosquitto version 2.0.11 stable release (some old gateways use Mosquitto version 1.5.7 stable release). Each gateway should be assigned a unique name. For example, the gateway in Figure 97 is assigned a name "GW2058". There is no limit on how many gateways a company uses, so that tens of thousands of gateways can be used.

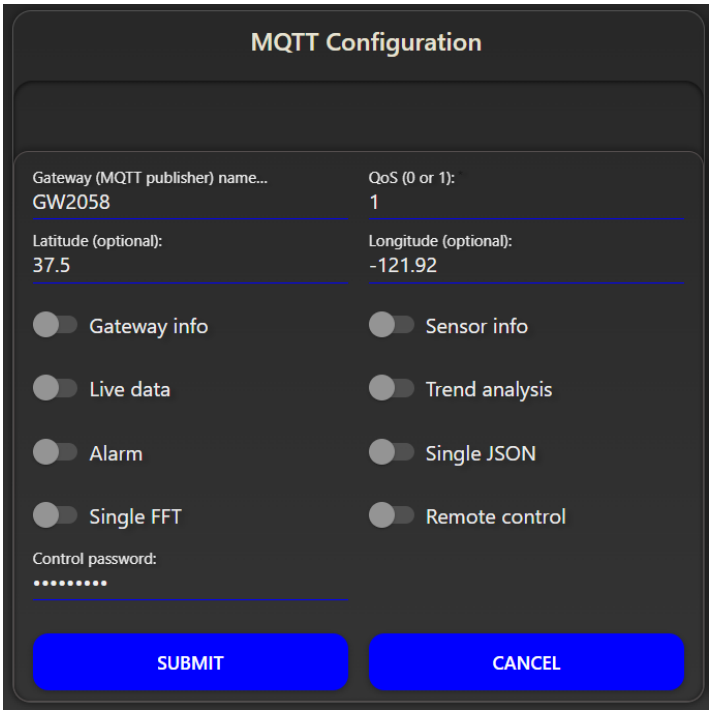


Figure 97 Gateway MQTT configuration

QoS stands for "Quality of Service". The QoS option controls the quality of service for both the internal broker and external MQTT broker. Select "1" for better quality of service, or

"0" to save network bandwidth. Each gateway has an optional location information (latitude and longitude). The default GPS location of the gateway is Broadsens's headquarter in California, USA.

Gateway information and sensor information MQTT output can be turned on or off. Live binary sensor data can be sent to servers or clouds in real time. Toggle the "Live data" switch to the "on" position, and click "Submit" button to allow the MQTT raw acceleration data to be sent out in real time. Switch on the "MQTT Alarm output", and click "Submit" button to enable the alarm message sent to the server/cloud.

Switch on the "MQTT trend analysis output", and click "Submit" button to enable the trend analysis result sent to the server/cloud. **The gateway only sends out the latest trend analysis result to save bandwidth.** Therefore, if there are no new data taken in the defined trend analysis interval, then the gateway will not send out the trend analysis message. The topic of the vibration trend analysis message is "trend".

"Single JSON" option is added since BroadVibra version 2.7.4. When this option is turned on, single DAQ, synchronized single DAQ and trigger mode data will be sent out in JSON string format at the end of each sensor's data acquisition.

Switch on the "MQTT FFT", and click "Submit" button to enable the single FFT result to be sent to the server/cloud (This switch is only useful when using single FFT mode. Other DAQ modes will not have effect when this switch is on). Since SVT-V series sensor's temperature measurement is sent with V-series sensor information, turning off "Sensor data" switch will still have the temperature information transmitted. You can simply ignore the temperature data if you don't need it.

For help to set up the MQTT subscription on the server side, please refer to "Wireless gateway MQTT guide". In the guide, Broadsens provides the MQTT protocol and data parsing examples, so that user can send the real time data quickly to their server or cloud.

Tips: Please turn off all MQTT switches including "Gateway info", "Sensor info", "Sensor data" …, if there is no server or cloud upload available to save the gateway system resource.

Data acquisition of SVT-A series sensors can be triggered remotely via MQTT control. DAQ mode, DAQ sample rate, acceleration range and DAQ points (DAQ points will be ignored in unlimited data modes such as real time or batch mode) can be controlled remotely via MQTT.

To turn on the remote MQTT DAQ control, turn on the switch of “Remote control”, enter a control password, and click “Submit” button. Password is required for remote MQTT control. The MQTT control password can be updated by entering a new password and click the “submit” button. In default, the password is hidden from users.

FFT analysis, filtering and measurements (acceleration or velocity) can also be controlled remotely. This allows the remote sever to fully use the gateway’s edge-computing ability. The FFT result, along with time-domain data will be transferred in JSON string format for easy parsing.

Please refer to “Wireless gateway MQTT guide” on how to control DAQ of the wireless gateway remotely, or perform FFT analysis for a given sensor with optional filtering with MQTT protocol.

Please note that to make the systems consistent, the MQTT outputs including raw data, alarm and trend analysis are based on metric system. Users need to add unit conversion if they plan to use Imperial units at the server side.

11.2 Use external MQTT broker

Starting from version 2.6.1, BroadVibra software allows user to set up external MQTT broker from the front panel (Figure 98). To use an external MQTT broker, turn on the “use external broker” switch and click on “submit” button. Click “cancel’ button to cancel the action. If an external MQTT broker is used, then the internal MQTT broker of the wireless gateway is turned off automatically to save system resource.

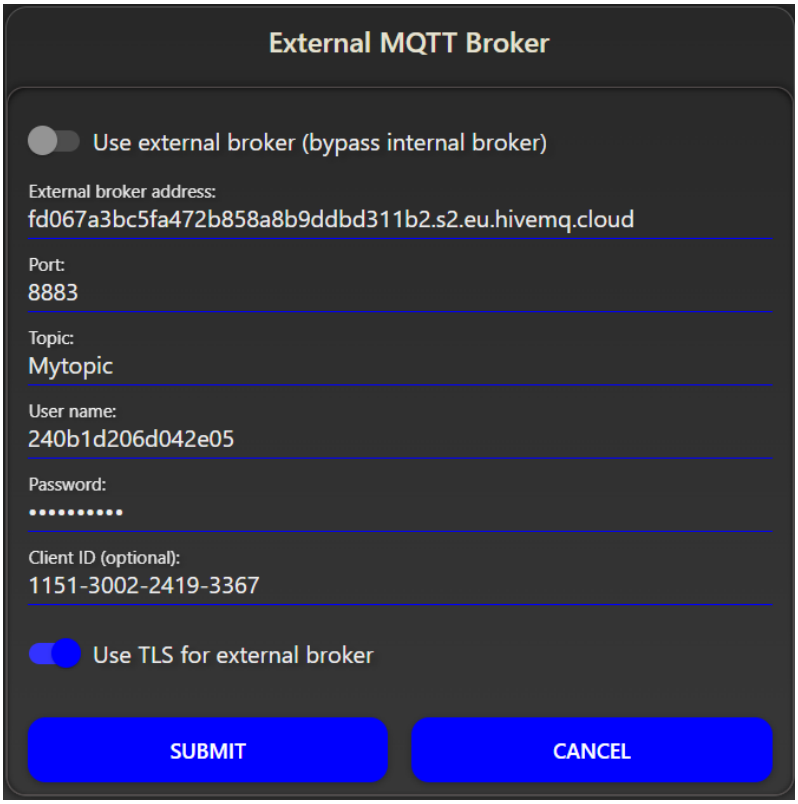


Figure 98 Use external MQTT broker

Please enter the external MQTT broker address, port number (default port is 1883 for non-TLS broker, and 8883 for TLS-enabled broker), topic (optional), user name and password and client ID (optional). Since BroadVibra version 2.7.4, both internal and external MQTT broker's QoS is controlled in the "MQTT configuration" option (Figure 97). Client ID is added in BroadVibra version 2.7.5 for brokers that require client ID information.

If the external MQTT broker requires TLS connection, then please turn on "Use TLS for external broker" switch and click on "Submit" button.

12. Hardware interfaces

12.1 GPIO ports

Edge-computing gateway GU300 series added two GPIO ports, which can be used as either inputs or outputs. In default, the two ports are used as inputs. When user measure the voltage levels at these two ports, the voltage is 0v. When GPIO is at “high” state, the voltage level is 3.3v.

Note: Although GU300 comes with GPIO protection circuit, it is important to have the external input voltage at 3.3V at high state, and 0v at low state.

The controller board of GU300 gateway uses Raspberry PI CM4. The GPIO port mapping is as the following:

- GPIO1: GPIO channel 26 in Raspberry Pi CM4 board
- GPIO2: GPIO channel 22 in Raspberry Pi CM4 board

There are multiple ways to configure the GPIO. Since users have complete control of the gateway, users can decide to program the GPIO with Python, C/C++, JavaScript, or any other preferred programming languages.

An easy way to configure the GPIO is to use Python. Broadsens gateway has Python 3 and RPi.GPIO module preinstalled. The available commands are:

import RPi.GPIO as GPIO

This way user can refer to all functions in the module using the shorter name "GPIO".

RPi.GPIO supports referring to GPIO pins using either the physical pin numbers on the GPIO connector or using the BCM channel names from the Broadcom SOC that the pins are connected to. It is recommended to use BCM channel names:

GPIO.setmode(GPIO.BCM)

To set up a channel as an input:

GPIO.setup(channel, GPIO.IN)

Or as an output:

GPIO.setup(channel, GPIO.OUT)

Where channel is the channel number. In our case it is either 26 (GPIO1) or 22 (GPIO2)

To read the value of an input channel, call:

GPIO.input(channel)

where channel is the channel number (26 or 22) as used in setup. It will return a value of 0, GPIO.LOW, or False (all are equivalent) if it is low and 1, GPIO.HIGH, or True if it was at a high level.

To set the output state of a GPIO pin, call:

GPIO.output(channel, state)

where channel is the channel number and state is the desired output level: either 0, GPIO.LOW, or False for a low value or 1, GPIO.HIGH, or True for a high level.

When you are done with the library, it is good practice to free up any resources used and return all channels back to the safe default of being inputs. This is done by calling:

GPIO.cleanup()

It is possible that user does not want to clean up every channel leaving some set up. Then user can clean up individual channels:

GPIO.cleanup(channel)

The following example shows to how to output 3.3V from the GPIO1 on the gateway.

[Example]

```
# Import Python GPIO library
import RPi.GPIO as GPIO
GPIO.setmode(GPIO.BCM)

# Set GPIO1 as output
GPIO.setup(26,GPIO.OUT)
# Output high (3.3V)
GPIO.output(26,GPIO.HIGH)
# release the library
GPIO.cleanup(26)
```

To run the example, copy and save the above code into a file, for example, a file named "test.py". Then use an FTP software such as WinSCP to transfer the file into the gateway. To run the code, SSH to the gateway, and type in the following command:

python test.py

A multimeter can be used to measure the voltage level at GPIO1 to verify the voltage change.

When gateway reboots, the GPIO ports will reset to default state (input).

If user wants to configure the GPIO automatically each time when gateway boots up, then the file “rc.loal” can be edited. Use the following command “sudo nano /etc/rc.local” to edit the “rc.local” file, and add the python file to the bottom of the file. For example, if the Python program file name is “test.py”, then the following line should be added at the bottom of the “rc.local” file:

python test.py &

Save the “rc.local” file, then the program is executed each time when the gateway boots up.

For more accurate timing of the GPIO port, C/C++ can be used to program the GPIO ports. “pigpio” library is recommended for C/C++ support. Please refer to the “pigpio” website for details and examples.

It is also possible to use the Node-RED GPIO node (node-red-node-pi-gpio). The node also uses the Python GPIO library. The “node-red-node-pi-gpio” node is not installed in the gateway in default. To add this node and use the node, user needs to gain access to the control panel (Please refer to Appendix 4 on how to gain access to the control panel). Then the node can be added in the control panel.

Gateway GU300 series also has a network reset function, which is implemented with Python GPIO routine. The gateway reset button uses Raspberry Pi CM4 GPIO channel 23. Please do not modify GPIO channel to ensure that the “reset” function works properly.

12.2 RS485

Gateway GU300 series support RS485 interface. GU300 integrates isolated MAX13487E half-duplex, ±15kV ESD-protected RS-485/RS-422-compatible transceiver.

MAX13488E has auto direction control, so that it is easy to program the RS485 and eliminates the codes to toggle read/write directions. The auto direction control circuitry consists of a state machine and an additional receive comparator that determines whether this device is trying to drive the bus, or another node on the network is driving the bus.

MAX13487E features reduced slew-rate drivers that minimize EMI and reduce reflections caused by improperly terminated cables, allowing error-free transmission up to 500kbps.

GU300's RS485 interface port is "/dev/ttyAMA1". RS485 sensors can connect to GU300 series gateways quickly. There are multiple ways to program the RS485 interface. Modbus RTU protocol is typically used for data communication. GU300 series gateway comes with Modbus node preinstalled, which supports both Modbus RTU and Modbus TCP function.

[Example]

In this example, a Modbus RTU test flow (Figure 101) is provided by Broadsens (please contact Broadsens for the test flow) that communicates with a Modbus RTU temperature and humidity sensor (Figure 99). The test flow can be imported by the user from control panel (please refer to Appendix 4 on how to gain access to the control panel). The gateway functions as a Modbus RTU master, and the sensor functions as a slave.

Figure 99 Modbus RTU temperature & humidity sensor

The default address of the Modbus temperature and humidity sensor is 1 (the address can be modified at the "Modbus query" function node). To connect the sensor to the gateway, please follow Figure 100, where the sensor is powered by the gateway's 12v power supply, which . User can also use an external power supply for the sensor.

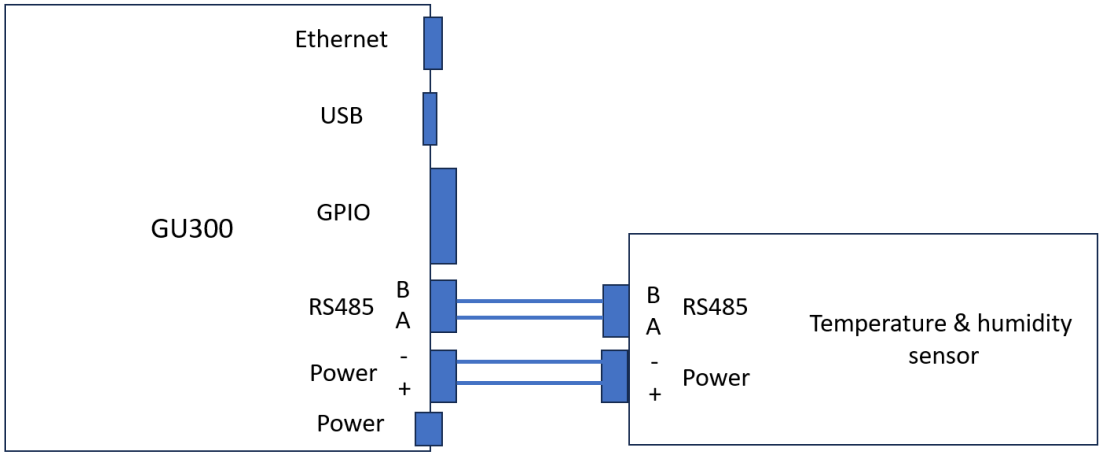


Figure 100 Modbus RTU sensor connection with gateway

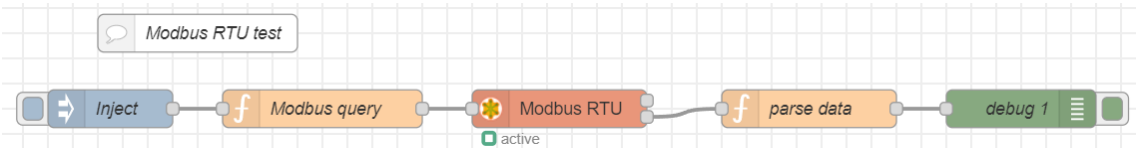


Figure 101 Modbus RTU test flow

If the sensor is connected correctly, then the temperature & humidity reading can be obtained by clicking on the "inject" node. The debug window of the control panel will show the sensor reading (Figure 102).

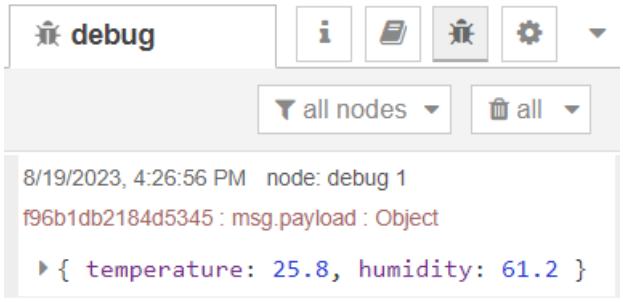


Figure 102 Modbus RTU reading

The sensor reading can be further transferred by the gateway to user's clouds or sever through network protocol such as Modbus TCP, MQTT, UDP or HTTP, etc.

To use the gateway as a Modbus RTU slave, BroadVibra Modbus RTU software is required. Modbus RTU Slave Node is required to use the software. Please refer to the Modbus guide section 3.3 and section 4 for details.

Modbus TCP can be implemented by connecting to the gateway's Ethernet port, and use the internal Modbus TCP node. For details, please refer to Broadsens's Modbus guide.

12.3 USB

The gateway's USB interface has multiple functions. User can connect an external flash drive to the USB to copy files directly to the flash drive. An external SSD could be used for extended storage. Or user can connect an USB to RS232 adapter, so that RS232 interface can be used. An external WiFi antenna can also be connected to the USB interface. Please refer to Raspberry Pi's official website for USB functions and usage. Each USB port's current is limited up to 600mA.

13. SAG IMU Sensor

Broadsens's SAG IMU sensor include SAG200, which is a 9-degree IMU sensor. SAG200

also outputs pitch, yaw, roll Euler angles besides acceleration, gyro and compass data. The pitch, yaw and roll angles range from -180 to 180 degree.

SAG200 is one of the IMU sensors with the longest lasting battery life in the industry. The current consumption including data collection, Euler angle edge computation and data transmission is less than 5mA in average. The battery capacity of SAG200 is 4,000mAh. When calculated with 80% battery capacity (considering environment effect on the battery capacity), the sensor can continuously work for 640 hours. If the sensor takes data for less than 8 minutes a day, then the sensor's battery can last 10 years.

Different from SVT sensors, the y axis of the SAG sensor points upwards (Figure 103). The size of the sensor is 37x71 mm (DxH). The weight of the sensor is 117 g (4.1oz). The sensor is rated IP68 and built for tough industrial environments.

Figure 103 SAG IMU sensor x, y, z axis

To take data, from the "DAQ control" panel, select SAG sensor group, click on "Manual switch" to turn on the sensors (Figure 104). Each group can support up to 6 SAG200 sensors. It is recommended to keep the number of sensors in each group small for quick response of the curves.

The acceleration range and gyro range can be adjusted from the dropdown menu. The sensor's acceleration range has the following options:

2g, 4g, 8g and 16g.

The sensor's gyro range has the following options:

250 dps, 500 dps, 1,000 dps and 2,000 dps

SAG200 can be used for both dynamic and static angle measurements. Therefore, it is possible to use the sensor for applications such as bolt loosening. For better static angle accuracy, please use 2g acceleration range and 250 dps gyro range.

The gyroscope inside SAG200 is calibrated automatically each time when user takes data. SAG200 will check the sensor's movement. When the sensor is static, then the gyroscope's offset is adjusted automatically at the beginning. When the sensor detects that the sensor is moving, then the gyroscope offset won't be updated.

Figure 104 SAG IMU sensor DAQ

The compass (magnetometer) needs to be calibrated for better yaw accuracy. Otherwise, there could be large error for yaw direction measurement. Magnetic objects such as magnets will have strong effect on the compass. Large metal will have effect on the accuracy of compass too.

To calibrate the compass, click on "magneto calibration" button, A pop up window will show up reminding user that DAQ of SAG IMU or SVG-A sensors should be stopped before going to the next step (Figure 105).

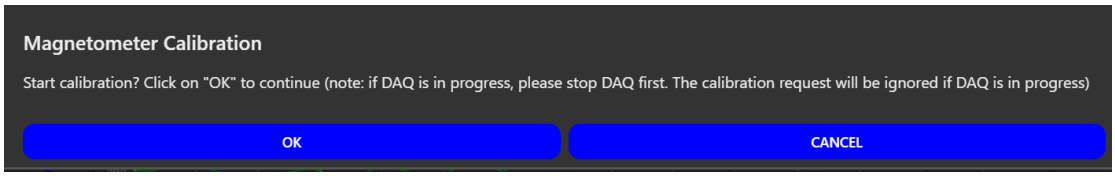


Figure 105 Magnetometer calibration popup window

Click "OK" button to start the calibration process. The DAQ switch will be turned on automatically, and another window will pop up describing how to calibrate the sensor (Figure

106). The SAG IMU sensors will start taking data of acceleration, gyro and magnetos. When user rotates the sensor, the acceleration, gyro and magneto curve will show the corresponding change in the background. The Euler angle will not be calculated during the calibration process, so the pitch, yaw and roll will show as flat lines in the background. The intermediate calibration data will not be saved to the database.

Please rotate the sensor in x, y and z axis for three times. Ideally, the sensor should also be rotated in a sphere shape. When there are multiple SAG200 sensors in the same group, please calibrate the sensor one by one.

Figure 106 Magnetometer calibration in progress

After finish rotating all the sensors, click on “Done” button. Then the calibration result will be saved to the sensor automatically.

Since -180 and 180 degree are the same value, user may notice that pitch, yaw and roll angle toggle from -180 to 180 degree or vice versa in dynamic angle measurements.

SAG IMU sensor’s data can be reviewed in the history data review page. The data can also be exported into CSV file by clicking on the “download acceleration data” button.

Appendix 1. Static IP & SSH

When there are multiple gateways, it is recommended to use static IP for each gateway for easy management. **The easiest way to set up the static IP for the gateway is to use the router management page.** Different router has different management page and method. The following shows the management page for ASUS router (Figure 107). At the menu, select "LAN" in the advanced setting, then click on the "DHCP" server tab. At the "manually assign IP" section select the gateway, click on "+" sign to add the gateway as the static IP.

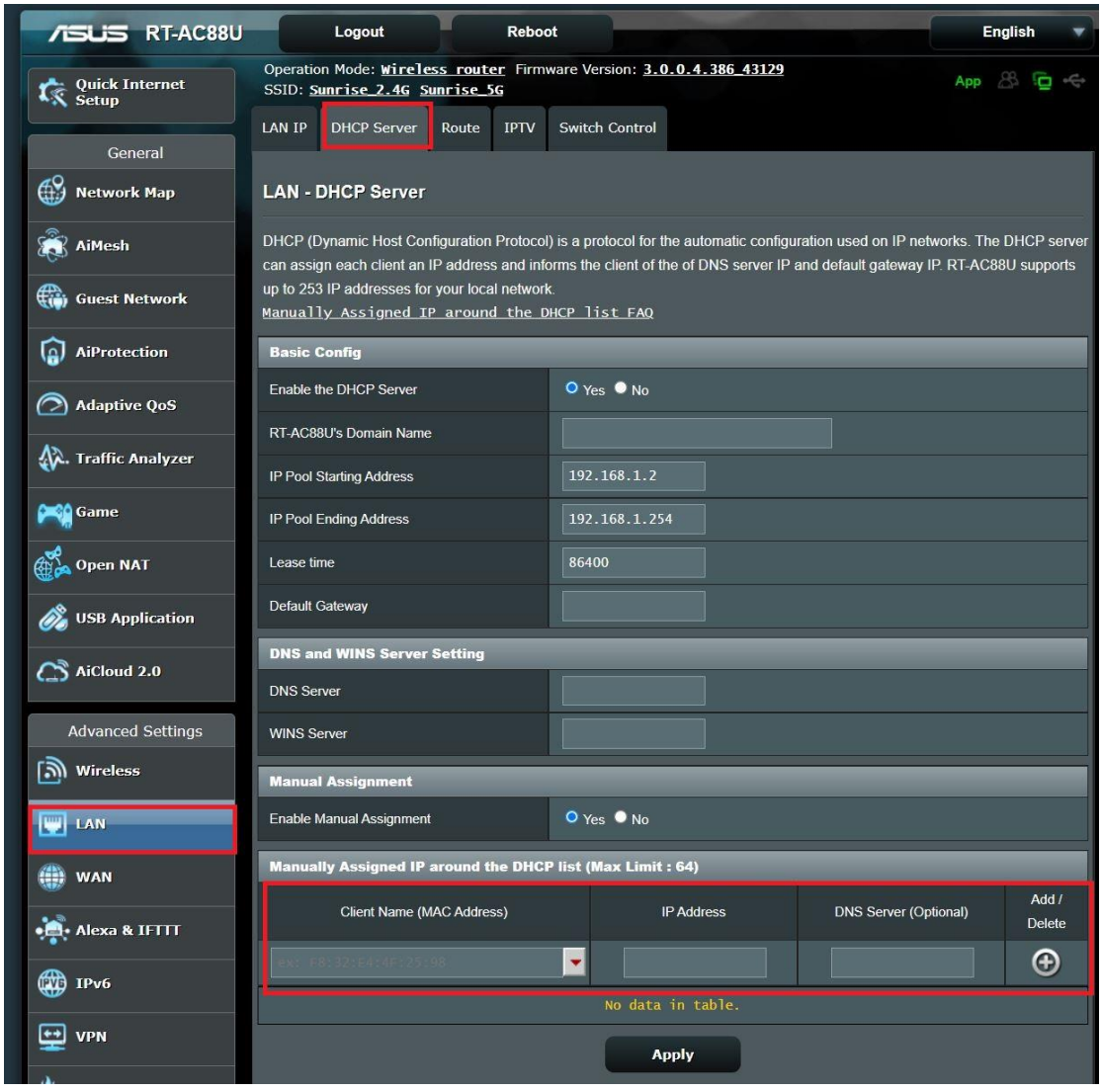


Figure 107 Set static IP at ASUS router

This method allows the gateway to change to a different router easily without modifying the set up inside the gateway.

Alternatively, user can log in to the gateway and assign a static IP (**This method is not recommended, since if the gateway changes network, then the static IP should be modified beforehand**). SSH software is needed to log in to the gateway. The recommended software is "Putty". Putty can be downloaded from the official website: https://www.putty.org/.

Open Putty, enter the IP address of the gateway to access, choose "SSH" option, click on "Open" (Figure 108). Then a terminal window will pop up. Enter the provided SSH username and password to log into the gateway. **Please note that in Linux OS, when user types in the password, the password is hidden (no display). After typing in the password, just press "enter" key to continue.**

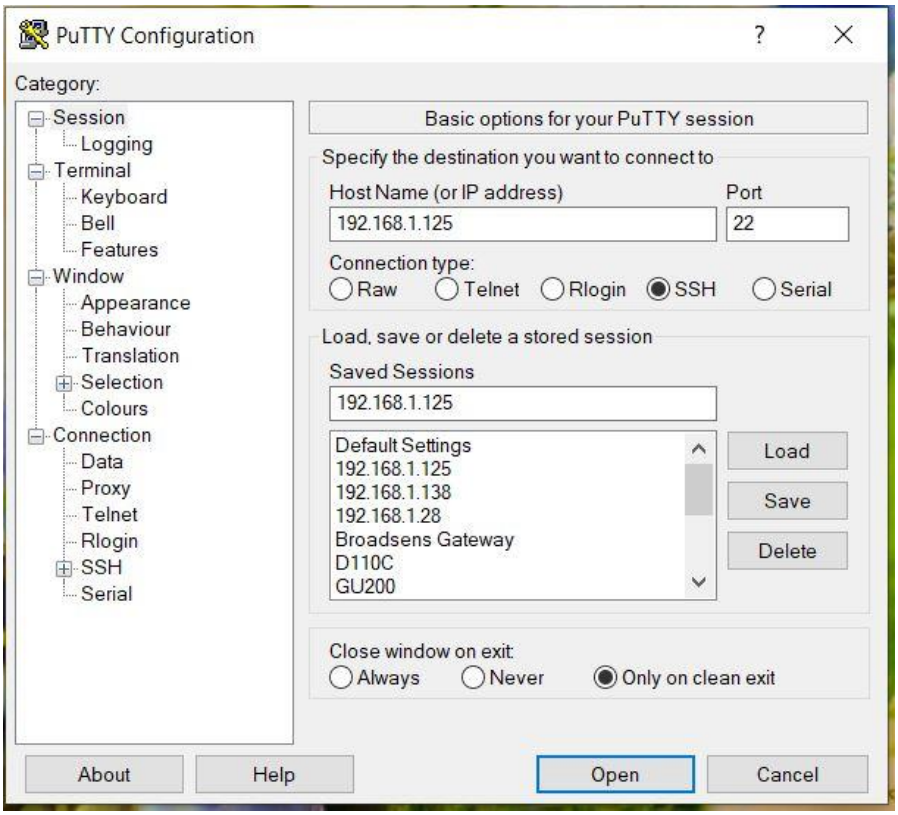


Figure 108 Putty window

In command window, enter the following command to edit the "dhcpcd.conf" file:

sudo nano /etc/dhcpcd.conf

Assume that we want to use static ip "192.168.1.128" for the wired connection, then add the following lines to the end of "dhcpcd.conf" file:

interface eth0

static ip_address=192.168.1.128/24

static routers=192.168.1.1

static domain_name_servers=192.168.1.1

Please double-check and make sure that you enter the correct IP address.

Enter the following command to reboot the gateway：

sudo reboot

Then the static IP for Ethernet is ready to use.

Attention: Don't use static IP for wired connection and wireless connection at the same time. It is recommended to use wired Ethernet connection for the gateway. Only use WiFi for backup usage when a wired connection is not possible.

[Recover from a wrong static IP entry]

In case that a wrong IP address is entered, and you can't access the wireless gateway via the network connection. Then user can reset the gateway's network setting to DHCP by using a tooth stick, and press the "reset" button at GU300/GU300S gateway for 10 seconds. Then the gateway will reset to DHCP.

For gateways GU200/GU200S, user may follow the steps below to recover from the problem:

Please open the wireless gateway case by removing four black screws on both sides of the wireless gateway, remove the micro-SD card from gateway, and put the card into a card reader. Connect the card reader to a Windows or Linux machine. For Windows machines, it is important to ignore the Windows message asking to format the card. Open the folder and edit "cmdline.txt" file. You will need to add the correct IP address to the end of the file. The format is as the following:

ip=x.x.x.x

Make sure you do not add any extra lines. For example, if the correct IP address is 192.168.0.2, then enter "ip=192.168.0.2" at the end of the file. Put the card back to the gateway and boot up again to access gateway with the assigned new IP.

Correct the error at "dhcpcd.conf" file after logging in.

Appendix 2. Change password and use WiFi

Appendix 2.1 Change SSH password

To change the current SSH password, use Putty to log in, and enter the following command:

sudo passwd pi

You will be prompted to enter the new password. Make sure you use a strong password. The password you enter is hidden.

The system will ask you to retype the password to make sure that you provide the new password correctly.

Appendix 2.2 Set up WiFi

WiFi can be set up for the gateway in case that wired connection is not possible. Wired connection to a router is always recommended whenever possible. For certain GU200S models, WiFi module is not integrated. In this case, an external WiFi USB adapter should be used.

WiFi of GU200S is FCC certified. A wireless USB adapter is recommended for the legacy gateway GU200 if the customer wants to use the external WiFi in areas where FCC certificate is required. A Linux Debian system compatible USB WiFi adapter is recommended. Sometimes, USB WiFi adapter driver should be installed to make the WiFi work.

For the latest 64-bit Debian OS, WiFi is disabled in default because of different WiFi regulations in different countries. WiFi is also forbidden in certain applications that require high security.

You must select a country before you can use WiFi. Please follow the steps below to enable WiFi.

Step 1. Use SSH to log in the gateway. In command window, type in the following commands:

sudo raspi-config

Then it brings up the following window (Figure 109).

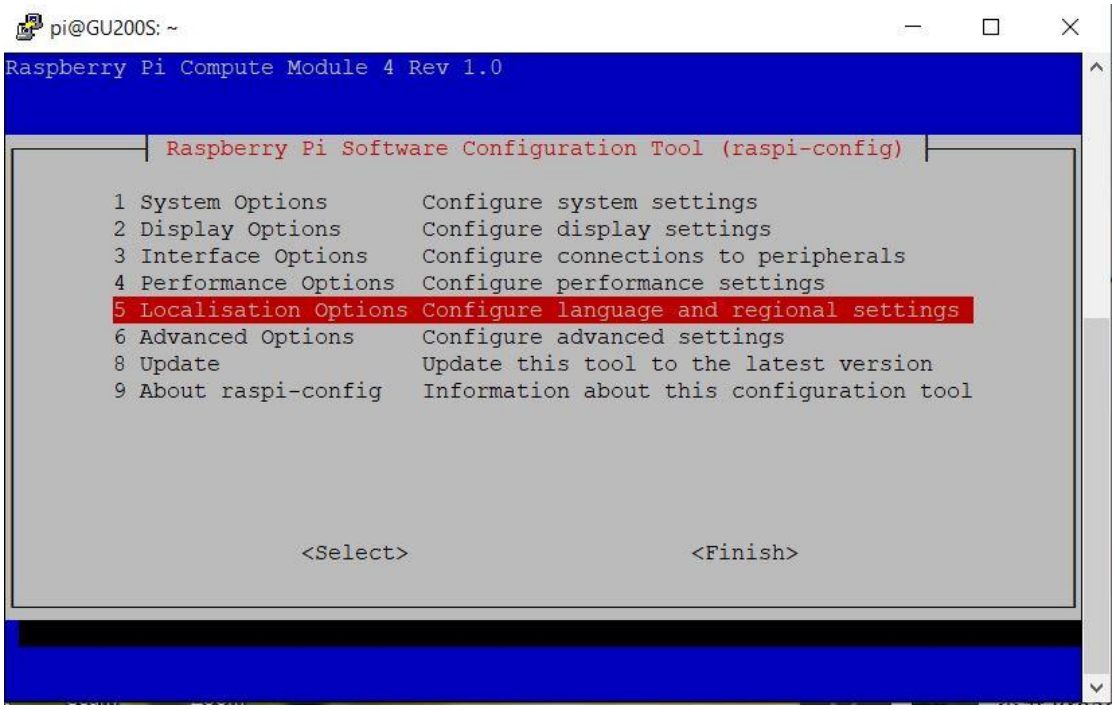


Figure 109 Configuration window

Choose item 5 “Localization Options”. Use “Tab” key to choose “Select”. Press “enter” key to go to the next screen.

Step 2. Choose item L4 to select WiFi country (Figure 110). Select “OK”.

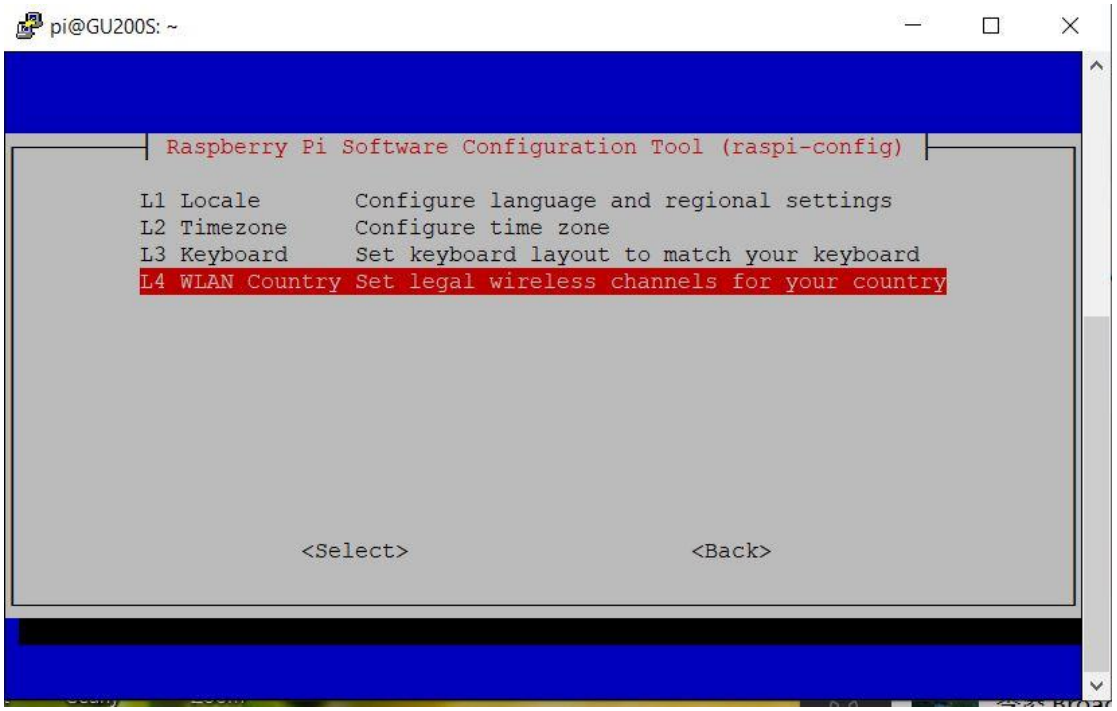


Figure 110 Choose WiFi country

Step 3. WiFi SSID and password can be entered with this interface too. Select item 1 “System options”, then select “S1 Wireless LAN” to enter the WiFi’s SSID and password (Figure 111). Reboot the gateway to apply the changes.

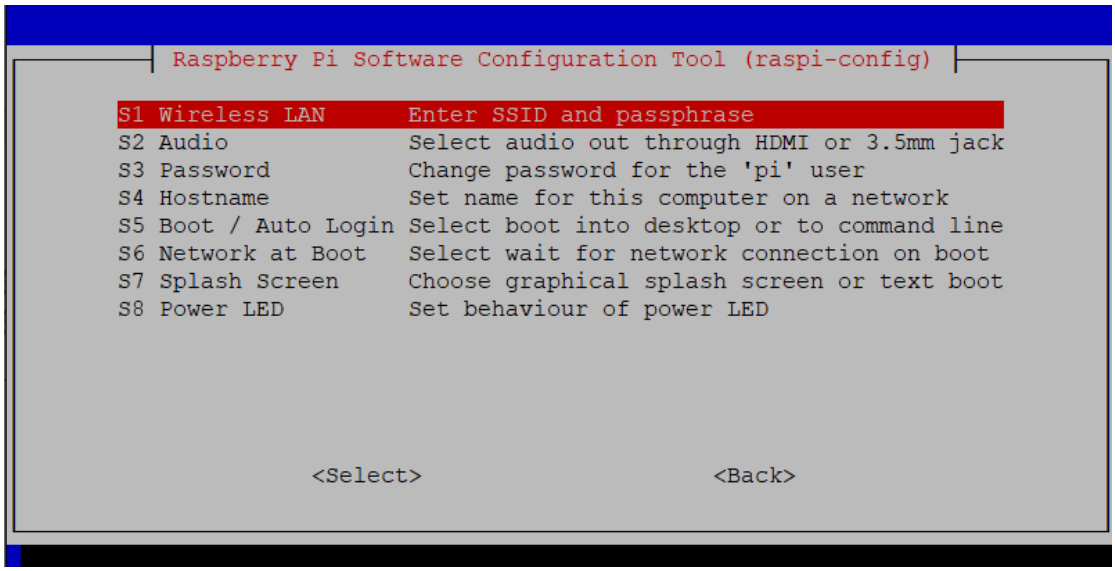


Figure 111 Enter WiFi SSID and password

Alternatively, you can edit the WiFi configuration directly. Exit Raspi-configuration too. In the terminal window, open the wpa-supplicant configuration file in “nano” editor with the following command:

```
sudo nano /etc/wpa_supplicant/wpa_supplicant.conf
```

Go to the bottom of the file and add the following lines:

```
network={
    ssid="your WiFi ssid"
    psk="your password"
}
```

In the above lines, replace “your WiFi ssid" and "your password" with your own ssid and WiFi password in your wireless network.

Save the file and reboot the gateway. The WiFi is set up and ready to use.

Appendix 2.3 Turn on/off WiFi

WiFi can be turned off after it is enabled. Although BLE has auto frequency hop integrated, disabling WiFi can improve the BLE signal strength. User can SSH to the gateway, and turn off WiFi easily by entering the following command:

sudo rfkill block wifi

WiFi can be turned on again by entering the following command:

sudo rfkill unblock wifi

Appendix 2.4 Change Time zone

Time zone should be updated for the history data review and data export to show correct local time.

When the gateway is moved to a new location, time zone can be changed by selecting "L2 Timezone" in Figure 110, and select the corresponding city in user's time zone. Then use "Tab" key to jump to "OK', and select "finish" to update the time zone.

Appendix 3. Direct connection to the gateway

Sometimes, it is desirable to connect a laptop directly to the gateway. There are multiple ways to implement this function. Broadsens recommends using the following method, which is easy to use and the gateway can be connected to any network without modification easily. Please note that the gateway should not be assigned a static IP from the "dhcpcd.conf" file. The following method assumes that the gateway uses dynamic IP.

Step 1. Install "tftpd" DHCP server software. First download the DHCP server software "tftpd64.exe" (Please contact Broadsens if you want to use 32-bit OS) from the following link:

https://broadsens.com/download/software/Tftpd64-4.64-setup.exe

During the software installation, or when the software opens for the first time, if Windows firewall asks for the permission for the "tftpd64" software, then please allow the software to work for both private and public networks.

Step 2. Set up static IP for the Ethernet adapter of the laptop. In the Windows search function, search for "network connections", or use "control panel->Network and Internet->Network connections" to find Ethernet adapter.

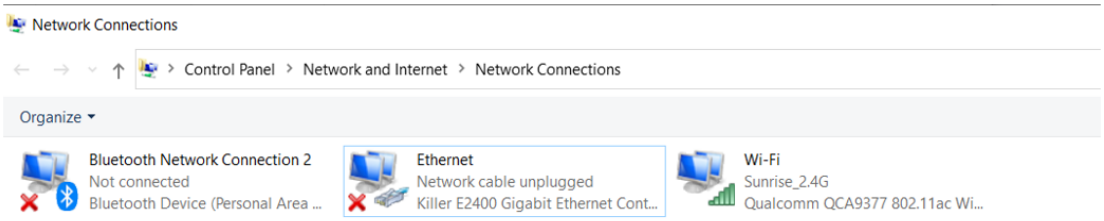


Figure 112 Ethernet adapter

Right click on the “Ethernet” icon, select “properties”, then the following properties window pop up (Figure 113).

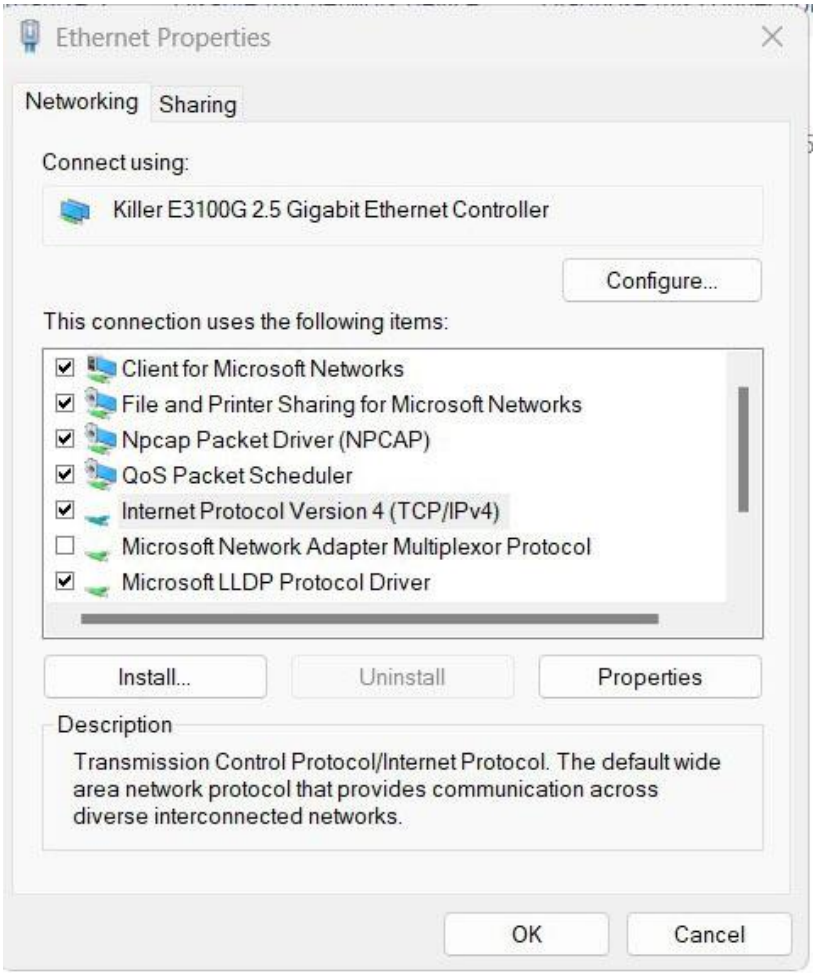


Figure 113 Ethernet properties window

Select "Internet Protocol Version 4(TCP/IPv4)", then click on "Properties" button to bring up the IPv4 configuration window (Figure 114).

Enter a static IP address for the Ethernet adapter of the laptop. Here we use “192.168.5.1”. You may use other available IPs too.

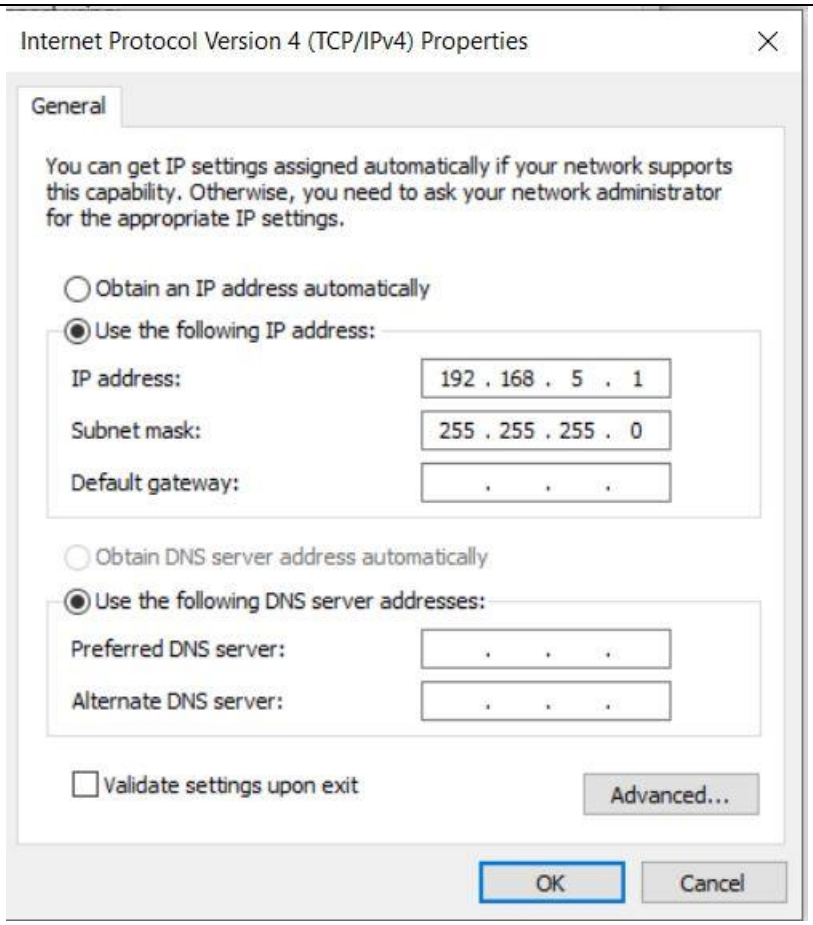


Figure 114 Static IP for Ethernet adapter

Step 3. Set up DHCP server for the Ethernet adapter of the laptop. Open tftpd, click on "settings" in the bottom of the software.

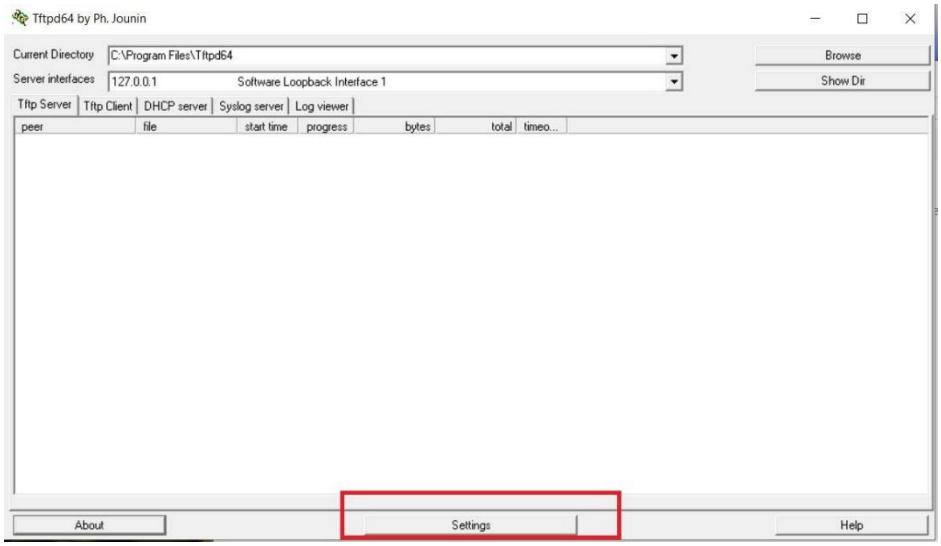


Figure 115 tftpd settings

Follow Figure 116 to enter the corresponding set up information. Please note that the router IP should be the static IP of the Ethernet adapter in Step 2. The "IP pool start" address should

start from “xxx.xxx.xxx.10” to avoid conflict.

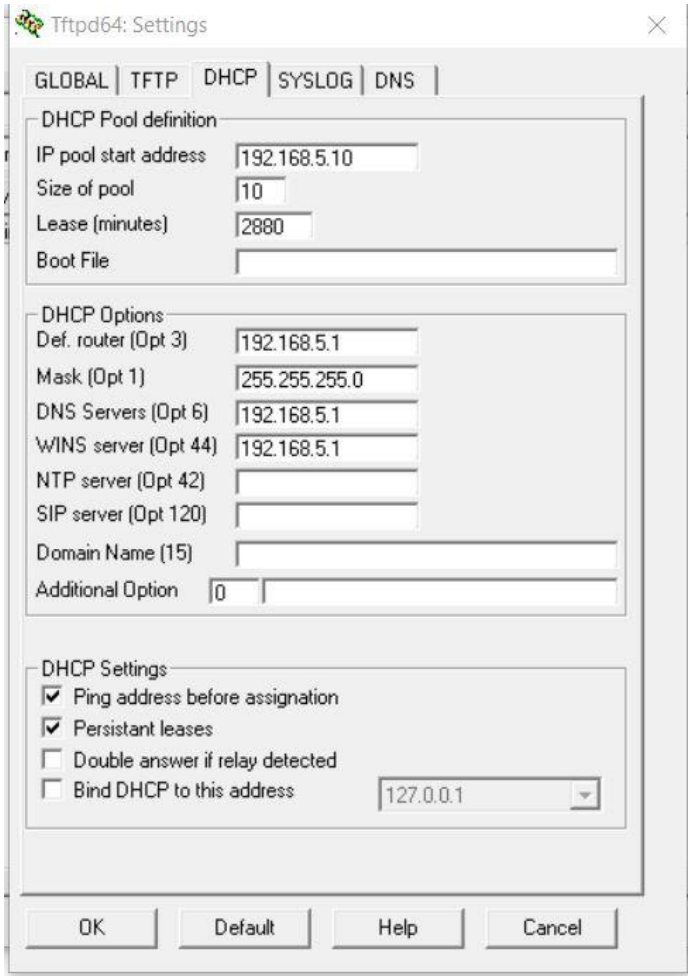


Figure 116 Set up DHCP for Ethernet adapter

Step 4. Connect the gateway to the laptop and enjoy the direct connection. Power up gateway, connect Ethernet cable from the gateway to the Ethernet port of the laptop. Click on the “DHCP server” tab, gateway IP should appear in the DHCP panel. In the following example, the new IP is “192.168.5.10”.

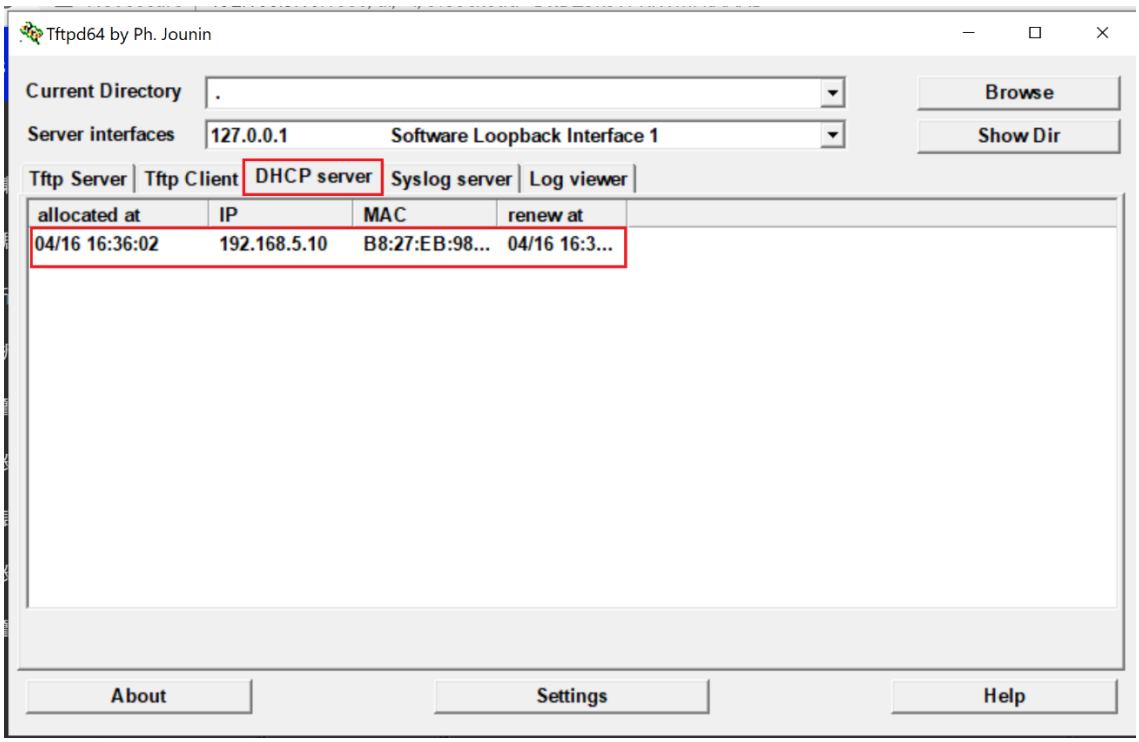


Figure 117 Find new IP for gateway

Now the gateway can be accessed from the new IP address given by step 3. In this example, the new IP address is 192.168.5.10. From the laptop browser, enter the following link to access the gateway dashboard "192.168.5.10:1880/ui".

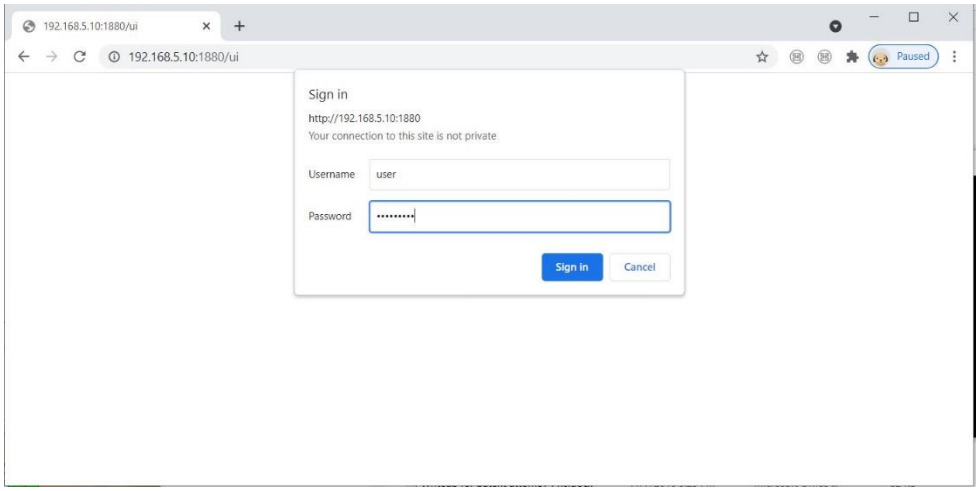


Figure 118 Access the gateway from a web browser

Appendix 4. Access the Control Panel

For advanced users, you can modify the front panel user name and password, control panel admin password, access the control panel, and add more features Node-RED nodes such as machine learning, audio and video ability. **Attention: Modifying the flows of the gateway will void the warranty so please proceed with caution.**

To do this, use SSH software such as Putty to log in to the gateway, then go to the hidden directory by typing in the command:

cd .node-red

For maximum security, the password in the software setting is hash protected. User needs to generate a hashed password by typing in the following command:

node-red admin hash-pw

Enter a new password such as “hello123”, then a hashed password is generated. Please copy the hashed password by pressing down left mouse key and select the hashed password.

[Change front panel user name and password]

User can modify front panel’s user name and password. Type in the following command to modify the setup file “settings.js”:

nano settings.js

Scroll down and modify the user name and password(Figure 119) .

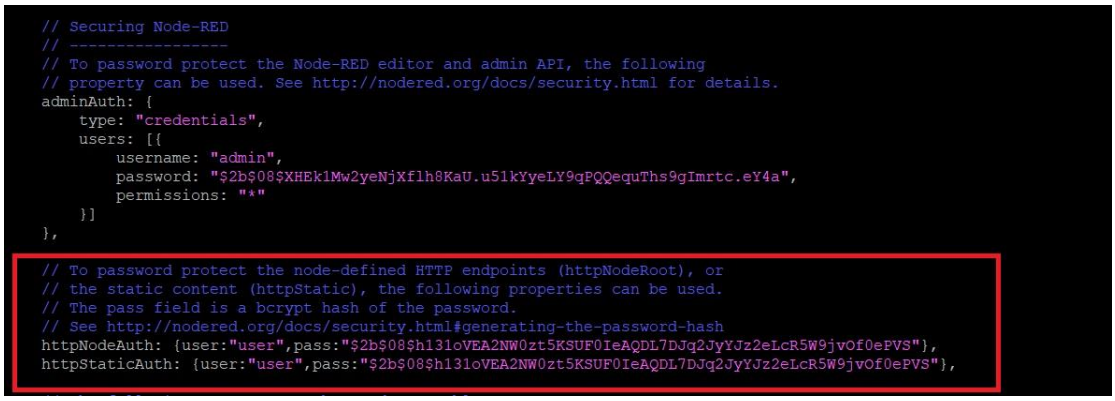


Figure 119 Change front panel's user name and password

Please paste the hashed password by right clicking the mouse key in Putty for user. Then in the front panel, please use the new password “hello123” to log in.

[Change control panel admin's password]

The admin's name and password for the backend control panel can also be modified. You can modify the admin's password similar to modifying front panel's user password (Figure 120).

First create a new admin password such as "hello123", then generate a hashed password.

```
// Securing Node-RED
// -----------------
// To password protect the Node-RED editor and admin API, the following
// property can be used. See http://nodered.org/docs/security.html for details.
adminAuth: {
    type: "credentials",
    users: [{
        username: "admin",
        password: "$2b$08$XHEk1Mw2yeNjXflh8KaU.u51kYyeLY9qPQQequThs9gImrtc.eY4a",
        permissions: "*"
    }]
},

// To password protect the node-defined HTTP endpoints (httpNodeRoot), or
// the static content (httpStatic), the following properties can be used.
// The pass field is a bcrypt hash of the password.
// See http://nodered.org/docs/security.html#generating-the-password-hash
httpNodeAuth: {user:"user",pass:"$2b$08$h131oVEA2NW0zt5KSUF0IeAQDL7DJq2JyYJz2eLcR5W9jvOf0ePVS"},
httpStaticAuth: {user:"user",pass:"$2b$08$h131oVEA2NW0zt5KSUF0IeAQDL7DJq2JyYJz2eLcR5W9jvOf0ePVS"},
```

Figure 120 Modify admin user name and password

Next, paste the hashed password (right click the mouse key) for user admin to the "settings.js" file. Save the file. Restart the gateway.

Then user can log in to the control panel of the gateway from the link with the new password "hello123":

192.168.xxx.xxx:1880/admin

Please note that there is no warranty on the system if the flows are changed. So please make a backup of the whole ".node-red" directory. In case that something goes wrong, user can always copy back the whole setup.

[Node update]

It is possible to update the nodes from the control panel. It is strongly recommended not to update the nodes unless the update is required by Broadsens. Broadsens tests each node thoroughly before the deployments. **It is crucial that the "node-red-node-serialport" must not be updated**, since this node is customized by Broadsens. If user wants to update this node, then please contact Broadsens for details.

Appendix 5. Gateway Software Update History

Version 2.8.4

- Add velocity RMS to trend analysis. Change acceleration RMS name from "RMS" to "Acceleration RMS"
- Increase history data review plot resolution for SVT-T sensors

Version 2.8.3

- Allows to delete multiple sensors at a time. Makes it faster to adjust system setting.
- When user clears history data, the buffered data file is also cleaned
- Increase history data display resolution for SVT-V sensors

Version 2.8.2

- Add Hanning window for FFT analysis for better spectrum leakage handing
- Add MQTT message for SAG200 (wireless IMU)
- Fix a bug that when user refreshes new timer setup page, the display shows previous setup instead of the current one
- Fix a bug that when user sets up new timer, the timer needs to be turned on once to see available groups.

Version 2.8.1

- Added gateway clock display. When there is discrepancy between gateway clock and computer time, the gateway clock should be adjusted for correct data time
- Update trend analysis MQTT message format, add sensor description and gateway name to trend analysis message
- In timer setup, change minimum DAQ period from 5 minutes to 3 minutes, which allows for more frequent data acquisition
- Use the latest data for trend analysis, instead of using the earliest data from user-defined time. This allows trend analysis to be updated even when user takes lots of data in the analysis interval
- Fix a bug that sensor info table is not updated when importing sensor config file (introduced in version 2.8.0)

Version 2.8.0

- Added SAG200 wireless IMU sensor support
- Simplified timer setup. Make it easy to set up periodic DAQ for multiple groups
- Fix sensor information update time bug at the end of each month
- Auto clear alarms every 2 hours
- Chang SVT-A sensor default RPM from 0 to 18000

Version 2.7.9

- Added displacement measurements for SVT-A sensors

Version 2.7.8

- Added MQTT remote gateway software update ability
- Added MQTT remote DAQ SVT-A trigger mode support

Version 2.7.7

- Added the feature of SVT-V sensor triggered SVT-A sensor group scan. When an SVT-V sensor's velocity or acceleration RMS level exceeds threshold, an SVT-A sensor group can be selected to take data in predefined DAQ mode.

Version 2.7.6

- Added machine RPM (optional) for SVT-A sensor
- Added RPM 1x, 2x, ... for FFT analysis
- When add a SVT-A sensor group, zone mapping is created automatically
- Timer zone/group mapping is displayed at the timer page
- Added MQTT control remote alarm clear ability

Version 2.7.5

- Added client id support for external MQTT broker.
- Simplified gateway configuration export. One click to download current gateway and sensor configuration with gateway name
- Added sample rate fine tuning for each sensor for accurate frequency analysis purpose
- Added peak-peak parameter for trend analysis
- FFT plot added peak bands and peak values for x, y, z axes
- Change default SVT-A sensor trigger threshold from 0.1g to 0.5g
- Fixed daylight-saving bug (when querying database with "start date and time", there could be time shift due to daylight saving)
- MQTT Remote FFT message added peak-peak values

Version 2.7.4

- Added single JSON mode that sends out single DAQ and trigger mode data in JSON string at the end of DAQ
- MQTT trend analysis message added group number
- In FFT analysis and history data review, added trigger mode display (undefined before)
- Optimized FFT export CSV file (use DAQ start time, removed data arrival time to avoid confusion), added DAQ information to header

Version 2.7.3

- Optimized periodic DAQ with timers. Periodic DAQ allows multiple timers from different groups/zones to overlap each other. Added "apply changes" button to start periodic DAQ immediately with new DAQ period and duration.

Version 2.7.2

- Added SVT-A sensor trigger ability (needs gateway firmware 2.7 or above, sensor firmware 2.7 or above)
- Added SVT200-T MQTT output

- For external MQTT broker, remote control requires to add gateway name before control message now

Version 2.7.1

- When a sensor is not connected to gateway for 1 day, “sensor last update” info will become orange color; if not connected for 2 days, it will become red color
- Fix single FFT bug when there are multiple sensors, the sensor ID only shows the same id and same temperature. The bug was introduced at version 2.5.5

Version 2.7.0

- Allow to have multiple groups of SVT-V sensors. This increases the number of SVT-V sensors supported in a gateway dramatically
- Change "zone/group" wording to "group/zone". This makes it easier to select a group among dozens of gateways in the same factory
- Added new SVT200-T sensor support. Allows multiple groups of SVT-T sensors
- Fixed a bug that the external MQTT broker control may not work for certain MQTT brokers.
- Removed "reset" button on "sensor info" table. Added the ability to hide individual information table

Version 2.6.9

- Added the feature to reset the database to factory default. This allows to quickly clean all data.
- Allow user to type in values for alarm setup besides using cursors
- If "save to database" switch is turned off, then SVT-V sensors data won't be saved

Version 2.6.8

- Separated sensor information and sensor data in MQTT output. User can select and send out only sensor info now
- When a sensor is not added in the gateway, then the sensor data and info will not be sent out with MQTT from the gateway
- Added remote MQTT sensor list feature to obtain complete sensor information
- In single DAQ mode, if a sensor is not added in the gateway, but the sensor is in the same group as other sensors in the gateway, then there will be "Invalid sensor" message to remind user to change the sensor's group.

Version 2.6.7

- Added step forward and step backward button for FFT analysis, which makes it easy to change data set
- Added step forward and step backward button for history data review
- Added waiting message information during history data review & FFT analysis

Version 2.6.4-2.6.6

- Added gateway info, trend analysis, alarm, topic to external MQTT broker
- Added remote MQTT FFT analysis support. User can fetch time domain data and its FFT analysis via MQTT. The data is in JSON string format for easy parsing
- Added switch to turn on/off MQTT gateway information

Version 2.6.2-2.6.3

- Added external MQTT broker TLS support (on/off)
- In history data review, added individual selection of SVT-V sensors.

Version 2.6.1

- Added MQTT reset function. The gateway can be remotely reset with MQTT command
- Added external MQTT broker setup in the front panel. When external MQTT broker is used, internal MQTT broker will be disabled

Version 2.6.0

- Added vibration velocity calculation at FFT analysis page
- Automatically calculates acceleration offset at SVT-V sensors. No need to manually adjusts now
- Changed SVT-V sensor velocity output to velocity RMS output. Added ISO 10816 reference table for easy comparison

Version 2.5.9

- In FFT analysis, added RMS calculation at time waveform display

Version 2.5.8

- Added support for SVT300-V and SVT400-V real-time wireless vibration sensors
- Removed edge effect when filtering is enabled at FFT analysis
- At FFT analysis, if filter is enabled, then the time-domain data output is filtered data, instead of raw data

Version 2.5.7

- Added the feature that when restarting gateway, the BLE chip resets automatically

Version 2.5.3-2.5.6

- Improved history data review for SVT-A series sensors. Removed "playback" selection. Automatically calculates elapsed time with sample rate.
- FFT analysis x-axis changed to time (seconds). In the time domain data display, it shows data acquisition mode and sampling rate information.
- Gateway firmware version shows more detail (one more digit)
- Fixed a bug of trend analysis file data index not-aligned well with values

Version 2.5.2

- Fixed a bug that in single FFT mode, only the last sensor data is sent to MQTT
- Added temperature MQTT upload in single FFT mode

Version 2.5.0

- Added Live FFT and single FFT data acquisition modes in the front page
- Added automatic FFT result transfer of single FFT result to remote servers using MQTT protocol

Version 2.4.0-2.4.1

- Removed synchronization number entry. Gateway automatically calculates synchronization numbers
- Improved live data display by upgrading the plotting plug in.
- Reduced data saving volume to micro SD to prolong its life

Version 2.3.5

- Optimized sensor info table date & time display
- Added color display for battery level

- Added screen auto scale ability for small screens

Version 2.3.1

- Improved SMTP email setup compatibility with certain email servers

Version 2.3.0

- Added Imperial unit option
- Added sensor configuration export and import function
- Added gateway chipset information

Version 2.2.0-2.2.2

- Added sync-Multi DAQ mode
- Added periodic DAQ function to the timer
- Added gateway location information (latitude & longitude)
- Send gateway information in one MQTT message now (more efficient)

Version 2.1.9:

- Added gateway firmware version
- Automatic update sensor list in the DAQ interface when sensor is adjusted
- Always show Alarm email setup information now
- Updated gateway MQTT info, added "up time".
- Make SVT-V sensors velocity and acceleration display color consistent

Version 2.1.8:

- Fix GU200 occasional manual start fail issue. Need gateway firmware version 2.2 and above

Version 2.1.7:

- Added multi DAQ function. Continuous run of single DAQs
- Removed 100ms rest time for batch mode. Allows more data to be acquired and transferred at batch mode.

Version 2.1.6:

- Added automatic single DAQ turn off function when number of finished sensors reach the total sensors in the group.
- After switching zone, first-time DAQ curve does not flash to give user better experience.

Version 2.1.5:

- Automatically adjust zone order after user enters a new zone

Version 2.1.4:

- Fixed an acceleration range bug that is introduced at version 2.1.0 (individual setup adjustment was not applied to range in certain cases)
- Disable range adjustment during single DAQ

Version 2.1.3:

- Added software update ability in the dashboard (easier to update software)
- Added hover color effect for all buttons

Version 2.1.2:

- Added MQTT remote control ability

Version 2.1.1:

- Improved alarm info. Now email shows detailed alarm information

- Optimized sensor configuration. Added "cancel" buttons;
- Added SVT-V sensor current group number display
- Removed sensor No. Only use sensor ID from now on. It is easier to input sensor info
- Improved sensor info table display speed. Automatically adjust sensor orders

Version 2.1.0:

- Added individual group/zone sampling rate, range and mode adjustment ability
- Increased automatic timer clock accuracy from 60s to 1s

Version 2.0.9:

- Added single sensor selection for data review and increased data download limit to 160,000
- Added gateway MQTT alarm output and trend analysis output options
- Improved sensor adjustment and added auto detection of duplicate sensor id entered by a user

Version 2.0.8:

- Added emailing alarm function to dashboard

Version 2.0.7:

- Updated SVT200-V voltage display to show correct value
- Fixed the sensor delete bug that after system reboot, the deleted sensor may re-appear

Version 2.0.6:

- Always use Eth0 for the MAC address now. Also show both Ethernet and WiFi IP
- Updated SVT200-A voltage display to show correct voltage level

Version 2.0.5:

- Sensor firmware 2.1 fixed SVT200-A current leak introduced from firmware v2.0
- Added highlighted power switch. Makes it look nicer
- Added highpass, lowpass filter options for FFT analysis

Version 2.0:

- Added adjustable sampling points function for single DAQ mode.
- Maximum number of single DAQ points increased to 16384
- Added Kurtois, skewness and crest factor for trend analysis
- Added group/zone mapping, plus group/zone delete function
- Added sensor delete function
- Added alarm set up for different group/zones
- Added alarm for SVT200-V sensor

Version 1.8:

- Added the option of 100Hz and 200Hz sampling rate at real-time mode.
- Improved batch-mode transmission speed.
- Slightly improved single DAQ speed by ~10%.

Version 1.7:

- Add single DAQ mode and synchronized single DAQ mode (true sampling rate guaranteed at the sensor side).
- JavaScript timing library accuracy increased from milli seconds to microseconds

Version 1.6:

- Added OTA function for both GU200 and SVT100-A sensor

- Added group adjustment ability for SVT100-A sensor
- Added firmware version number information on sensors and gateway

Version 1.1-1.5:

- Added true vibration sampling rate option (batch mode) for FFT analysis. In batch mode, true sampling rate is ensured at each batch.
- Added synchronized sampling option. All devices in the same group are synchronized to start DAQ in milliseconds level.
- Added FFT analysis ability in the gateway.
- Added sensor information in the gateway, including serial number, MAC address, RSSI & battery power.

Version 1.0:

- Initial release

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