1. OBJECTIVE

The objective of this document is to describe the specifications for retrofit Wearable Component Analyzer product, a complete IoT (Internet of Things) based system from MachineSense^{TM} for continuous monitoring of operating condition and trend display of pumps based on vibration data in various industrial applications.

2. TARGET MARKET AND CUSTOMER REQUIREMENTS

The Wearable Component Analyzer is primarily intended to serve as a trending product which allows customers to continuously monitor vital variables of pumps and rotating machineries for any abnormalities.

3. PRODUCT FEATURES

The main features of Component Analyzer retrofit product are given below.

1) Trend graphs for:
    i) Vibration (with user-defined warning and alarm thresholds– have 3σ and 6σ limits).
    ii) Humidity
    iii) Ambient Temperature
    iv) Machine Temperature

3.1. **Product Part Numbers and Serial Numbers**

The product Part Number shall be in the following format:

WCA-	**X**	**R / O**	**- 64/65**	**-vv**

WCA	**Wearable Component Analyzer**
x	Number of Sensors in Kit (1, 3 or 5)
R / O	Retrofit or OEM
64 / 65	IP Rating
vv	RETROFIT - Input Voltage (24=24 vdc, 11=115 vac)
	OEM - seq number ## (blank = Novatec; 01 = future)

Example: Model #

WCA	**-**	**1R**	**-**	**64**	**-**	**24**

3.2. **Future Releases**

Release	**Description**	**Remarks**

Release 2	Wearable Component Analyzer with Smart Sensor	This will have Smart Sensor instead of SensorTag for vibration data collection at high sampling rates.

4. PRODUCT SCHEDULE

5. PRODUCT DESCRIPTION

5.1. **Product Architecture**

The block schematic of Wearable Component Analyzer product is shown in **Fig. 1**. The Component Analyzer sensor is essentially a multi-sensor from Texas Instruments called the SensorTag having IR MEMS temperature sensor, ambient temperature sensor, humidity sensor, pressure sensor, accelerometer, gyroscope and magnetometer. Of these, the accelerometer (vibration), ambient temperature, IR temperature and humidity data are used in the Wearable Component Analyzer product. The measurements can be communicated via the BLE (in-built in sensor tag) to the Raspberry Pi. This data can then be communicated to the cloud server through Wi-Fi. Additional analytics can be carried out at the server on the data to provide the trend displays. For Wearable Component Analyzer analytics, mainly the accelerometer data, which indicates vibration, is used.

The SensorTag requires 3.3V power supply which is derived from either 110-270V AC supply or 24V DC supply. This power conversion module shall be provided along with the Wearable Component Analyzer product. Thus, the Power Supply module will have two variants: 110-270V AC or 24V DC. The module will have the same form factor.

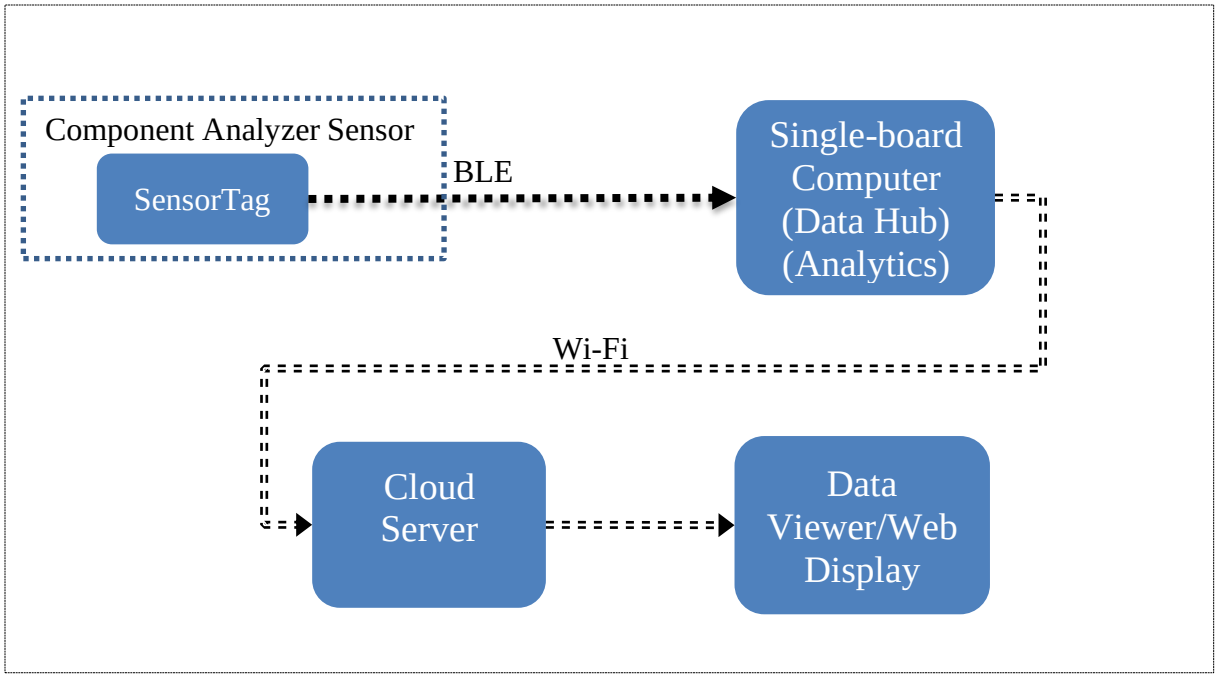


Fig. 1. Block schematic of the Component Analyzer product. Dashed arrows indicate data communication over a network.

5.2. **Detailed Specifications**

Hardware Requirements

COMPONENT ANALYZER SENSOR	
Mechanical	
Weight	7.0 oz (0.2 kg)
Dimensions length x width x depth	2.6 in x 1.7 in x 1.1 in (66.7 mm x 42.7 mm x 27.6 mm)
Sensor housing material	Metal plastic hybrid
Enclosure rating	IP64, IP65 optional
Environmental	
Operating temperature	
Ambient temperature	14°F (-10°C) to 149°F (65°C)
Surface temperature	up to 185°F (85° C)

Hazardous condition	Class-1 Div-2
Acceleration	
Range	- 16g to + 16g
Resolution	2%
Accuracy	10 mg
Sampling rate (configurable)	300/3000 per minute
Power	
Power supply (built in)	3.3 volt DC adapter
Bluetooth Communication	
Bluetooth Low Energy (BLE)Range	15 ft
Bluetooth Low Energy (BLE)Tx power	-5.8 dBm
Bluetooth Low Energy (BLE)Standard	4.1

Environmental	
Operating temperature range	14°F (-10°C) to 149°F (65°C)
Power	
Power in	24VDC or 110 - 270VAC
Power out	3.3 volt
Bluetooth Communication	
Bluetooth Low Energy (BLE) Range	15 ft
Bluetooth Low Energy (BLE) Tx Power	-7.5 dBm

Bluetooth Low Energy (BLE) Standard	4.1

DATA HUB	
Functional	
Connect to sensors via Bluetooth Low Energy (BLE)	
Two days of storage data for disconnected applications (1 data set/second rate)	
Maximum of 3 years if 1 data set/ 10 minute rate	
Smart-phone/tablet-based WiFi connect app (WiFigurator)	
Auto-upgrade over Internet	
Mechanical	
Mounting	Rail/wall mount
Enclosure rating	IP50
Dimensions length x width x depth	4.8 in x 3.0 in x 1.3 in (121 mm x 76 mm x 33 mm)
Weight	2.3 oz (0.06 kg)
Environmental	23°F (-5°C) to 150°F (65°C)
Power	5 volt DC adapter from 110 - 270VAC

ELECTRONICS	
Processor	Quad core 1.2G Hz broadcom BCM2837 64-bit CPU
Memory	Micro SD card
Storage	16 GB
RAM	1 GB
I/O	40-pin extended GPIO and 4 USB Ports, full size HDMI,

	LAN
Radio	BCM43438 WiFi and Bluetooth Low Energy (BLE) on board
OS	Linux
Certification	CE/IEC/FCC

Firmware Requirements

1. Data-rate(Samples/Sec):
   AC
   X - 40
   Y - 40
   Z – 40
   BP - 1
   GY – 1, 1, 1
   HY - 1
   IR – 1, 1
   MG – 1, 1, 1
2. Sensor Auto-setup: No manual intervention on the field shall be required for adding sensors and modifying sensor configuration, apart from the physical connections.
3. OTA (Over-the-air) Firmware Upgrade: Modify the sensor firmware from any location.
4. Remote Diagnostic and Alarm System: Monitor the sensor health remotely and take action.

Software, Analytics and Data Visualization Requirements

There are two visualization interfaces. A web interface named Crystalball and a mobile (android/iOS) app named Data Viewer. The Data Viewer display is available on the Crystalball under 'Data Monitor' tab.

1. Credentials: Three types of users- Admin, Asset manager and Data viewer. The privileges of these roles are given below:

Serial No.	Role Name	Privileges
1	Admin	Manage Users: Create, Edit, Disable/Enable, Delete
		Manage Assets, Manage Assets, Enable/Disable MRO for 3

		types of users
		Hide Gauges
2	Asset Manager	Manage Assets, Hide Gauges
3	Data Viewer	Can view data viewer

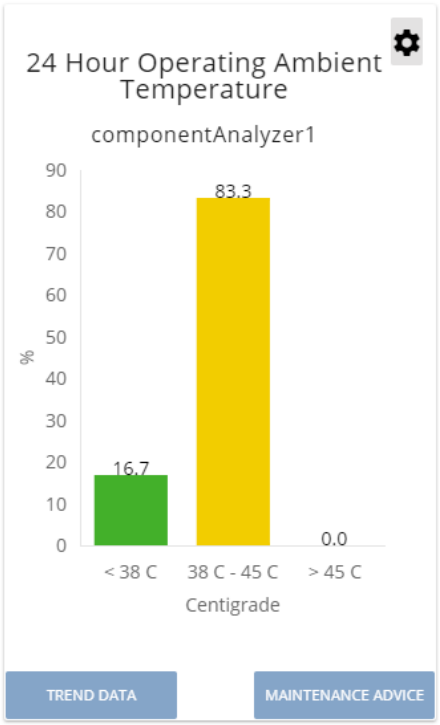
2. The user shall be guided to the documentation in the main web page. Notifications shall be sent to users when changes are made to the software, with appropriate documentation.
3. The Crystalball will have sensor on-boarding and off-boarding features.
4. Sensor On-boarding (for Retrofit): Feature in Crystal Ball, transferring a product package (kit), containing one or more sensors to a machine of the retrofit customer by entering the package serial number. It should provide option for creating a new machine if needed.
5. During on-boarding the user should be able to add machine model (optional). This information will be needed for feedback.
6. Sensor Off-boarding (for Retrofit): Un-assigning a sensor package from a particular machine, so that it is available for adding to another machine within the same company on CB.
7. Each machine can have one or more subassembly instances. Each subassembly instance can have multiple sensors associated with it.
8. Ambient Temperature and Humidity shall be displayed on the top right corner of the data monitor display, in small icons and values.
9. The default view for machines on the 'Data Monitor' will be 'TREND DATA'. Trend graphs on this view provide visualization of historic data in graphs.
10. In addition to the trends two gauges shall also be displayed under a separate tab. These gauges and their subassembly names are given in the following table.

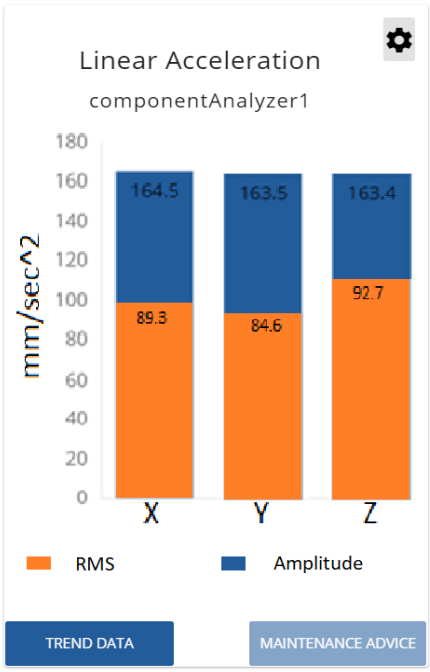
Assembly	**Sub Assembly**	**Colour and Value Gauges**
MachineSense (Component Analyzer)	**MachineSense**	**1)** Machine On-Time 2) Sensor Installation

The gauges and their description are provided in the table below:

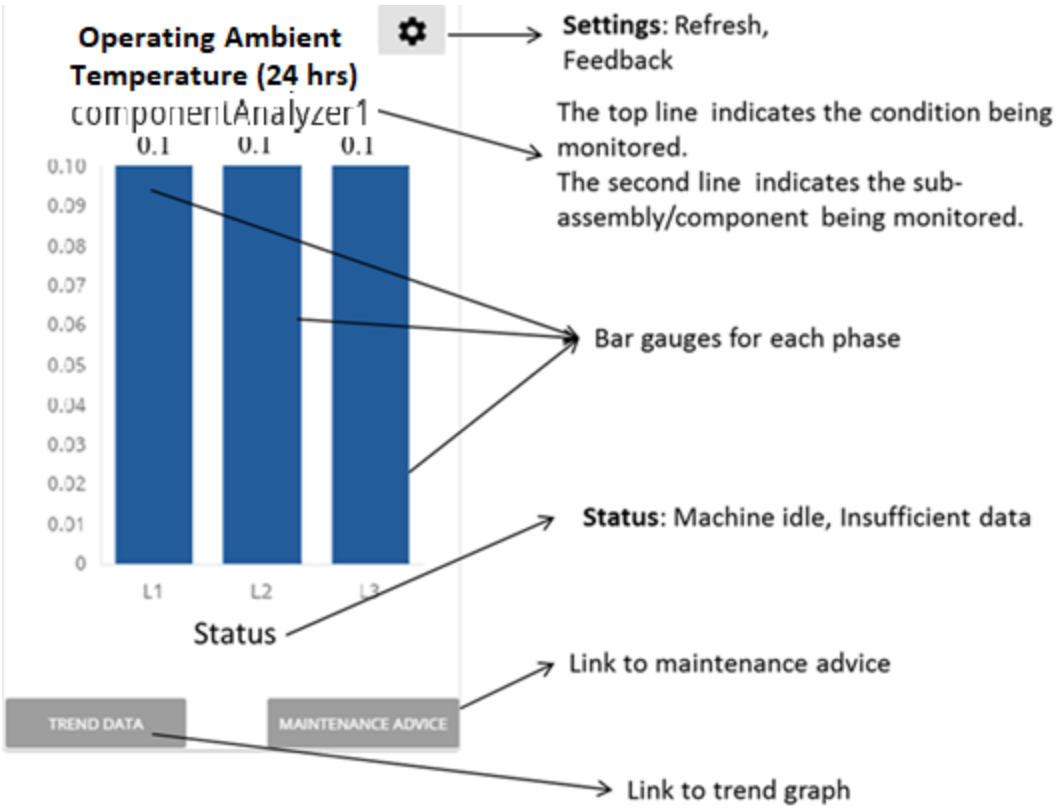
Gauge Name	**Gauge Icon**	**Description**

Machine Utilization (24 hrs) (Initializing / Insufficient Data status for almost 24 hour with machine off and on condition) *If not 24 hours of data, display note "Last x Hrs Data"*		Machine Utilization gauge shows the utilization of a machine over 24 hours. A utilization of 80% implies that the machine was being utilized for 80% of the time over 24 hrs, i.e., for 19.2 hrs; for the remaining 4.8 hrs, the machine was idle.
Sensor Installation (Initializing / Insufficient Data status after 1 hours of Machine Utilization gauge activation)		Indicates whether the Wearable Component Analyzer sensor is mounted properly on the machine or not. GREEN indicates correct sensor placement and RED indicates wrong placement.
Vibration (Amplitude) (Initializing / Insufficient Data status after 1 hour without data)		Shows the machine condition (Amplitude of vibration)based on the statistical distribution of vibration data. GREEN indicates normal or healthy condition, YELLOW indicates warning condition and RED indicates alarm condition.
Vibration (Asymmetry) (Initializing status after 1 hour without data)		Gives the machine condition (Asymmetry of vibration) based on the statistical distribution of vibration data. GREEN indicates normal or healthy condition, YELLOW indicates warning condition and RED indicates alarm condition.

Rotor Status (Initializing status after 1 hour without data)		It shows the operating condition of the rotor and bearing condition of the machine. GREEN indicates normal or healthy condition, YELLOW indicates warning condition and RED indicates alarm condition.
Operating Ambient Temperature (24 hrs) (Initializing status after 1 hour without data)		Indicates the duration(in percentage) of operational ambient temperature during the last 24 hours in three bins; GREEN (<38°C), YELLOW (38°-45°C) and RED (>45°C).

Linear Acceleration		Indicates the RMS(Orange bar) and Amplitude(Blue bar) values of Linear acceleration in all 3 axes.

11. The bar gauges should be auto-scaled according to the value of the variable. The following bar gauge shall be displayed:
    1. Operating Ambient Temperature (24 hrs)
12. The stacked bar gauges should be auto-scaled according to the value of the variable. The following bar gauge shall be displayed:
    1. Linear Acceleration
13. The general format for the bar gauges is provided in Fig. 2. The descriptions for each of the gauges are given in the Table below.



14. There will be greyed out gauges for Vibration (Amplitude), Vibration (Asymmetry) and Rotor Status. These gauges will have user feedback option to suggest the colors based on known status.
15. There will be 24hrs temperature gauge (bar gauge) for ambient temperature. 'Ambient Temperature (24 hrs)' will show the ambient temperature for past 24 hrs in a bar plot with three bins.
16. Colour gauge icons display: GREEN indicates normal or healthy condition, YELLOW indicates warning condition and RED indicates alarm conditions. The gauge name shall be displayed on the top line (centred) and the subassembly of the gauge shall be displayed on the next line (centred, in smaller font than gauge name). See the example below (Fig.2).
    a. The gauge settings on the top right provide refresh, feedback and input features. The *Refresh* pulls the latest gauge status from the server. The *Feedback* feature allows the user to provide manually the present status of the gauge; this could help in making the algorithms better. The *Input* feature can be used to manually enter the yellow and red threshold levels to be used instead of the default values. Heading - "Enter Threshold Inputs"
    b. Gauges and Trends can be refreshed by pulling the screen with mouse.
    c. The links to trend graph and maintenance advice are also indicated in the figure.

d. The gauge icons should also indicate when a machine is idle (‘Machine idle’) and when there is insufficient data for correct gauge display (‘Insufficient data’), below the icon.
e. When the sensor installation is faulty the status shall be displayed as ‘Senor Installation Faulty’.
f. When sensor is newly installed for the first ten minutes when no data is available at the Crystalball, display a rotating hour glass with ‘Initializing Data’ message.
g. If a gauge has been offline due to machine idle or insufficient data, it requires 10 minutes to be restored after data transfer happens or correct data is sent. During these 10 minutes display ‘Initializing Data’.

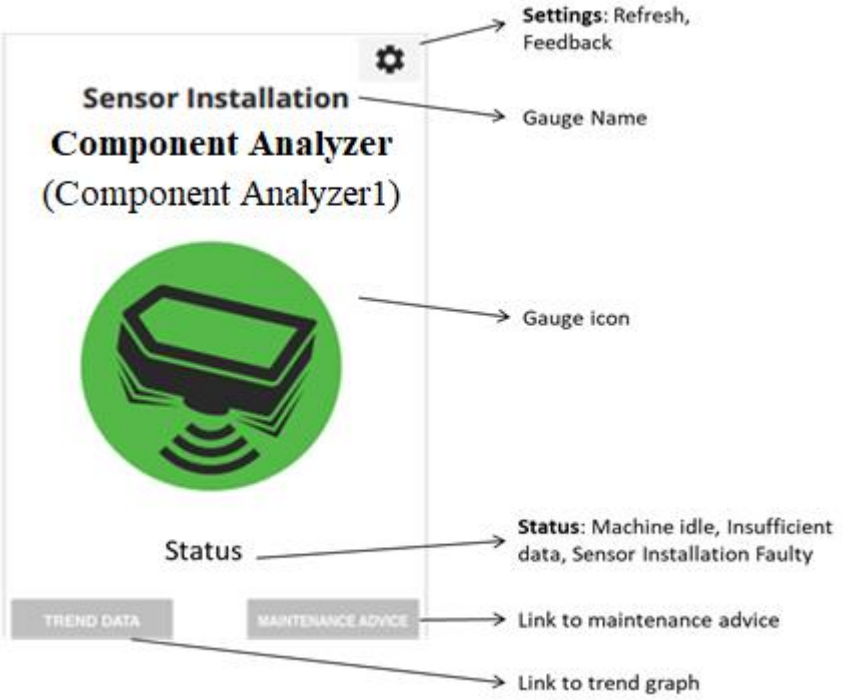


Fig. 2: Format for colour gauges when active.

17. **Trend graphs** should provide the trend data for
    - Last 30 minutes
    - Last hour
    - Last 4 hours
    - Last 8 hours
    - Last 24 hours
    - Last 7 days
    - Last 30 days

- Day so far
- Week so far
- Month so far
- Year so far

Default trend view is of **Last 4 hours.**

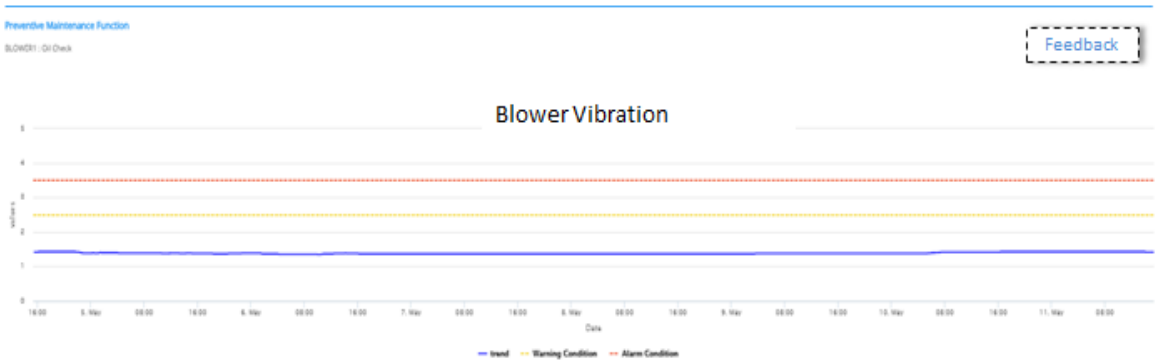
18. The following **trend graphs** shall be prepared for display (in order):

MachineSense

19. Vibration (Amplitude)
    This trend will have warning (yellow) and alarm (red) conditions based on the crest factor from vibration data.
20. Vibration (Asymmetry)
    In this trend instead of the warning and alarm thresholds, the 3σ (dashed yellow lines) and 6σ (dashed red lines) limits of the vibration data shall be shown. The legends shall mention '3σ' and '6σ', and not warning and alarm conditions.
21. Rotor Status
    This is based on the skewness of vibration data. The 3σ (dashed yellow lines) and 6σ (dashed red lines) limits of the vibration data shall be shown. The legends shall mention '3σ' and '6σ'.
22. Humidity (10 min)
    The unit shall be '%'.
23. Ambient Temperature (10 min)
    The unit shall be '^{o}C'.

The sub-assemblies for these trend graphs shall be 'ComponentAnalyzer'.

24. **Text Feedback**: The feedback could be either one of the pre-defined text templates or a custom text. The text format could be '[Text Template] From [Date- Optional] [Time- Optional] To [Date- Optional] [Time- Optional]'. The time and date information is optional, and a pull down menu shall be provided to the user to choose the time and date from. The current date and time shall be default (in case no date or time is provided). The issue is supposed to persist till the current time if no 'To' field is provided.
    E.g.: 'Abnormal Vibration Observed From 15/05/2017 14:01 To 16/05/2017 4:01'.



Trend	Text Template	Description
Vibration (Amplitude)	1. Abnormal Vibration Observed	If the user observes abnormal vibration, he/she can provide the information using this feedback message.
	2. Custom	Any additional information that user wants to provide can be put here.
Vibration (Asymmetry)	3. Abnormal Vibration Observed	If the user observes abnormal vibration, he/she can provide the information using this feedback message.
	4. Custom	Any additional information that user wants to provide can be put here.
Rotor Status	1. Bearing Fault Detected	If a bearing fault has been manually detected, the information can be communicated here.
	2. Custom	Any additional information that user wants to provide can be put here.

25. **CSV Download**: The trends should have options to download the data in csv format, for the selected time duration. This allows the user to use the data for further processing or visualization.
26. Trends can be refreshed by pulling the screen with mouse.
27. The following table provides the list of issues descriptions and corrective actions by their preventive maintenance (PM) functions.

PM Function	Issue Description	Corrective Action

Humidity (10 Min)	Humidity in the machine vicinity is high.	Check if the HVAC is working properly.
Ambient Temperature	Temperature of the atmosphere around the machine is high.	Check if the HVAC is working properly.
Sensor Installation	Sensor is not correctly installed.	Reinstall the sensor properly
Vibration Amplitude	Amplitude of vibration is high.	Check the operating condition of the machine I.e. machine health, lubrication and input power supply condition.
Vibration Asymmetry	High asymmetry is observed in the machine.	Check the alignment of the rotor and shaft.
Rotor Status	Anomalies has been detected in the rotor.	Check the condition of the rotor.

5.3. **Quality Requirements**

5.4. **Performance Requirements**

5.5. **Safety, Standards and Compliance Requirements**

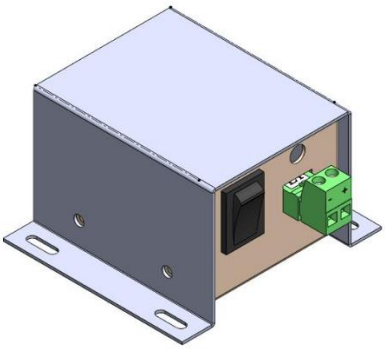
IEC Standards to be followed for Safety and EMI/EMC Compliance

a) IEC/EN 61508: Functional safety of electrical, electronic and programmable electronic control systems.
b) IEC 60695: Fire hazard testing.
c) IEC 61326-1: Requirements for immunity and emissions regarding EMC for electrical equipment.
d) IEC 60950-1: Standard for safety.

6. SUPPORTING DATA

6.1. **Mechanical Design**

The mechanical housings for the Wearable Component Analyzer sensor and power supply are shown below. The Wearable Component Analyzer sensor will have a hole at the bottom to ensure that the IR radiation for measuring object (machine) temperature passes through.



b) Wearable Component Analyzer sensor

b) Power supply

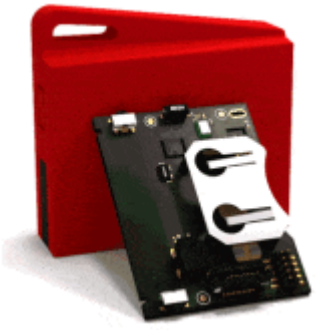
6.2. **Functional Specifications**

6.3. **Component Specifications**

- *Wearable Component Analyzer Sensor*

  CC2650 SensorTag™

  - CC2650 SimpleLink™ Multistandard Wireless MCU
    - ARM® Cortex®-M3
    - Up to 48-MHz Clock Speed
    - 128KB of In-System Programmable Flash
    - 8KB of SRAM for Cache
    - Supports Over-The-Air Upgrade (OTA)

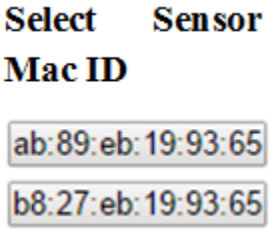


  - 10 sensors including support for light, digital microphone, magnetic sensor, humidity, pressure, accelerometer, gyroscope, magnetometer, object temperature, ambient temperature

7. VERIFICATION AND TESTING

8. QUALITY CHECK AND CALIBRATION

1. The Wearable Component Analyzer product has only one sensor, namely the **CC2650** SensorTag. The variables to be checked for data connection to the server are Ambient Temperature, IR Temperature, Humidity and Motion (3-axis vibration) Data.
2. GUI: The QC process shall have a local GUI to the data hub. The landing view will ask user to select one of the connected sensors to the data hub by the mac IDs (as shown below).



QC Setup

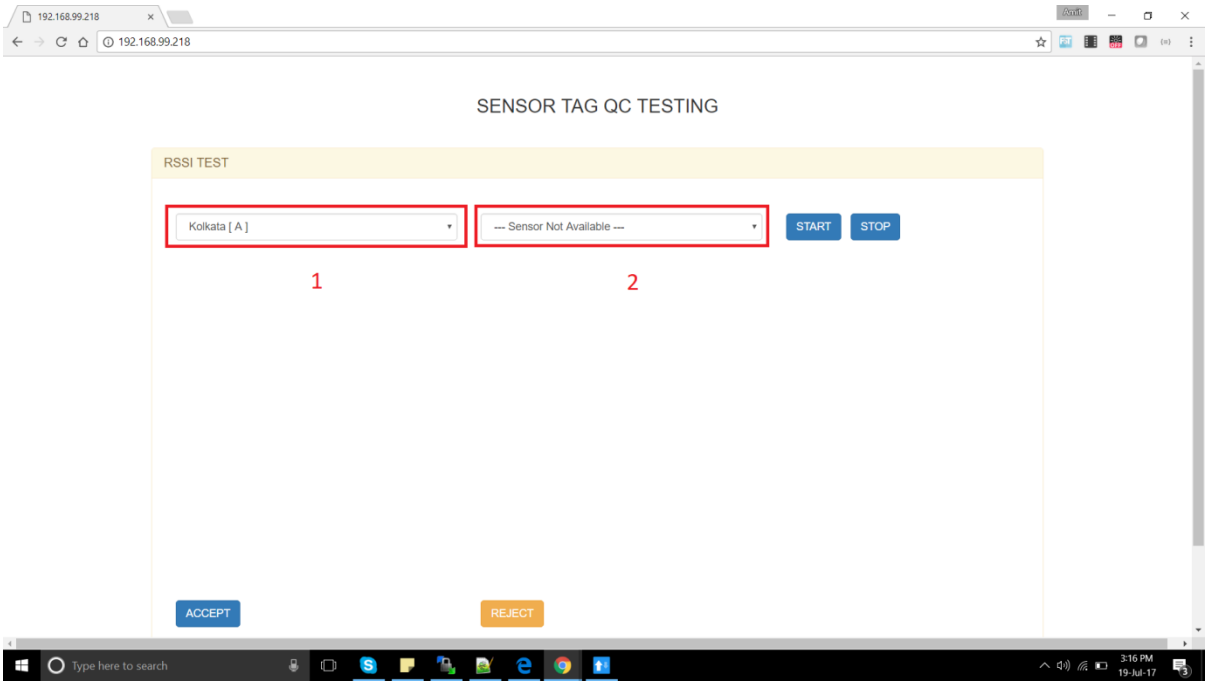
The following components are required for SensorTag QC.

1. Raspberry Pi 3 Data Hub.
2. MMC card with latest "SensorTag QC" Image installed.
3. SensorTag (for QC), placed within 10 ft from the Data Hub.

The MMC card is inserted in the Raspberry Pi 3.

Accessing the QC GUI

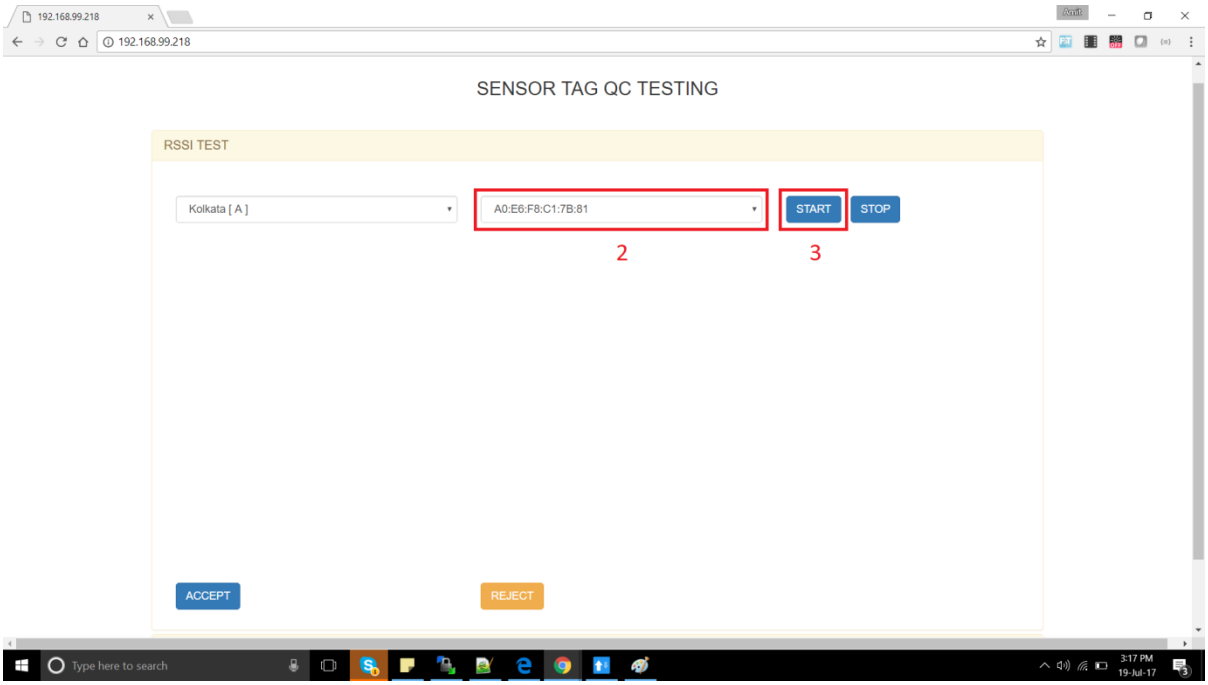
The DataHub QC page is accessed by typing the QC RPI s' IP address:



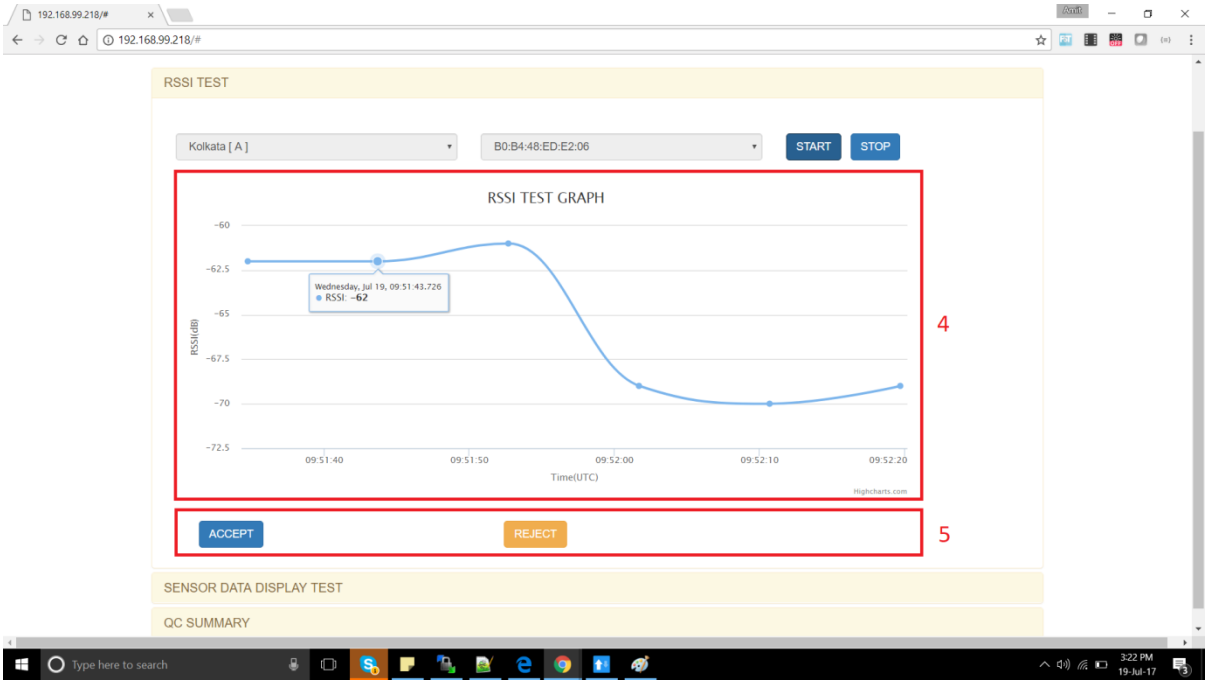
RSSI Test:

In RSSI TEST tab there is two dropdown list:

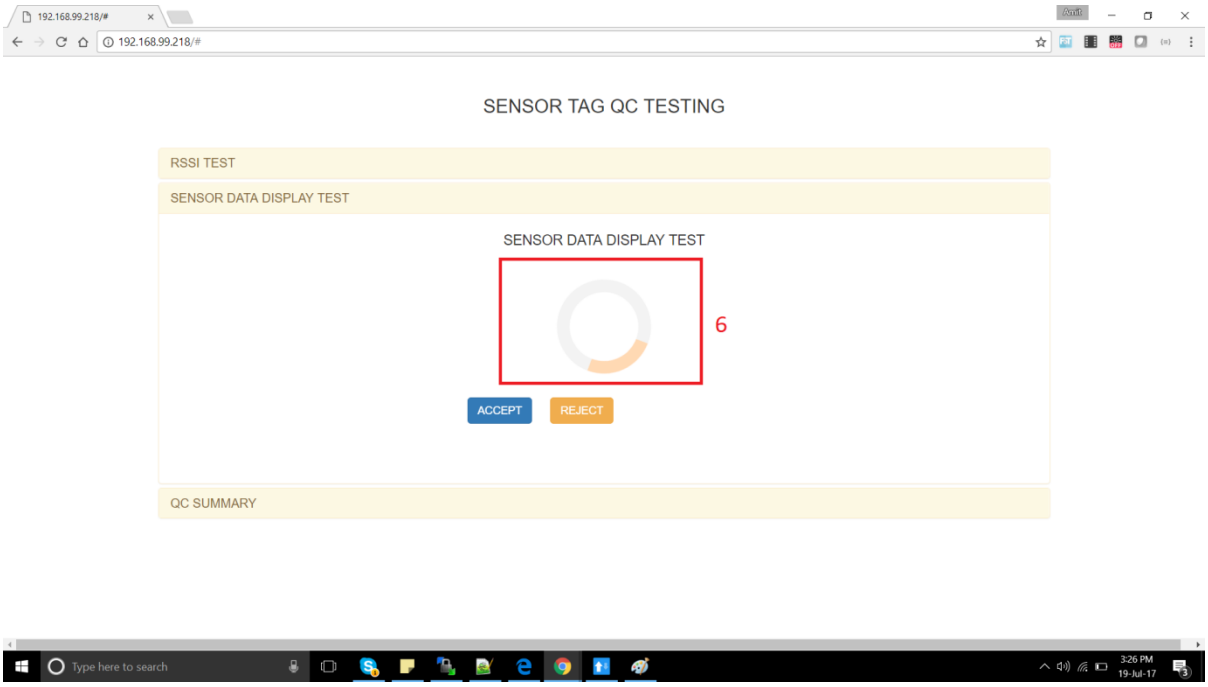
1. QC Station Code: This is used to choose the station code.
2. Sensor tag mac id: To do the SensorTag QC, select the MAC Id of the sensortag from the dropdown list.



3. The **Start** button will display the RSSI level.
4. This is the RSSI test graph of the selected sensor.



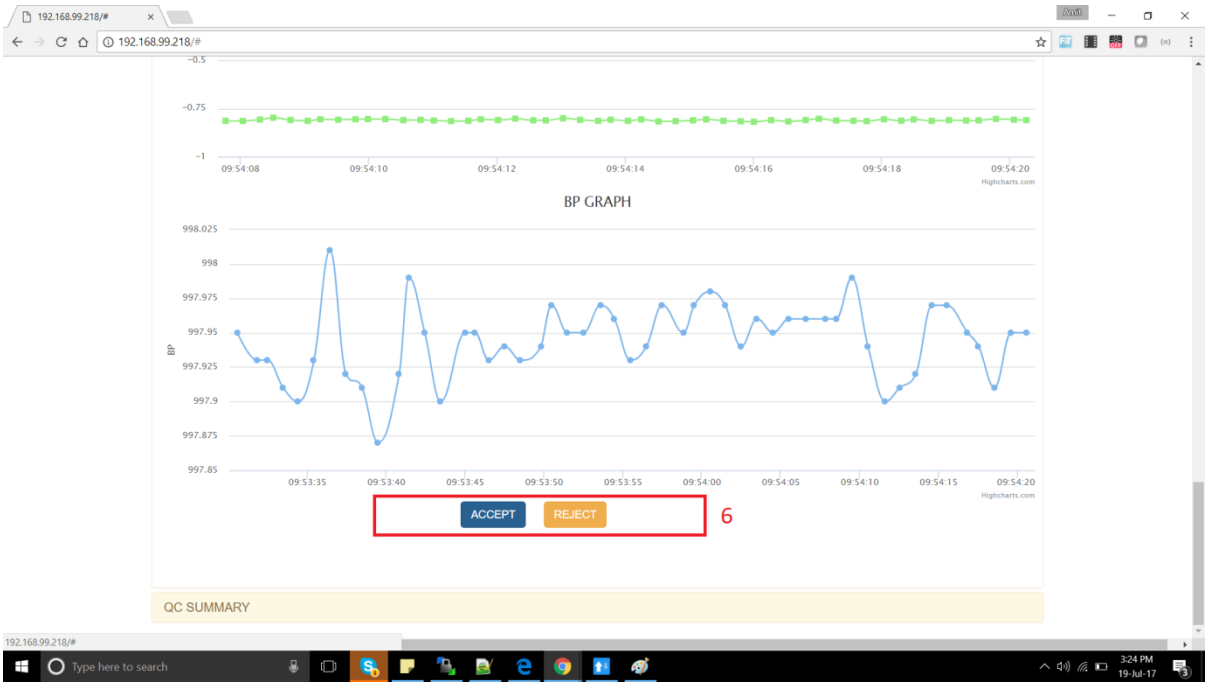
5. In 5th section we have two buttons:
    a. **REJECT:** If we have to reject the sensor on the basis of RSSI level then user can reject it by clicking on this button.
    b. **ACCEPT:** If the RSSI level is above threshold value (-80dB), indicated by a dashed red line, the user has to click on the button. then the sensor will start connecting and this process will take approx. 10 sec.



Sensor Data Display Test:

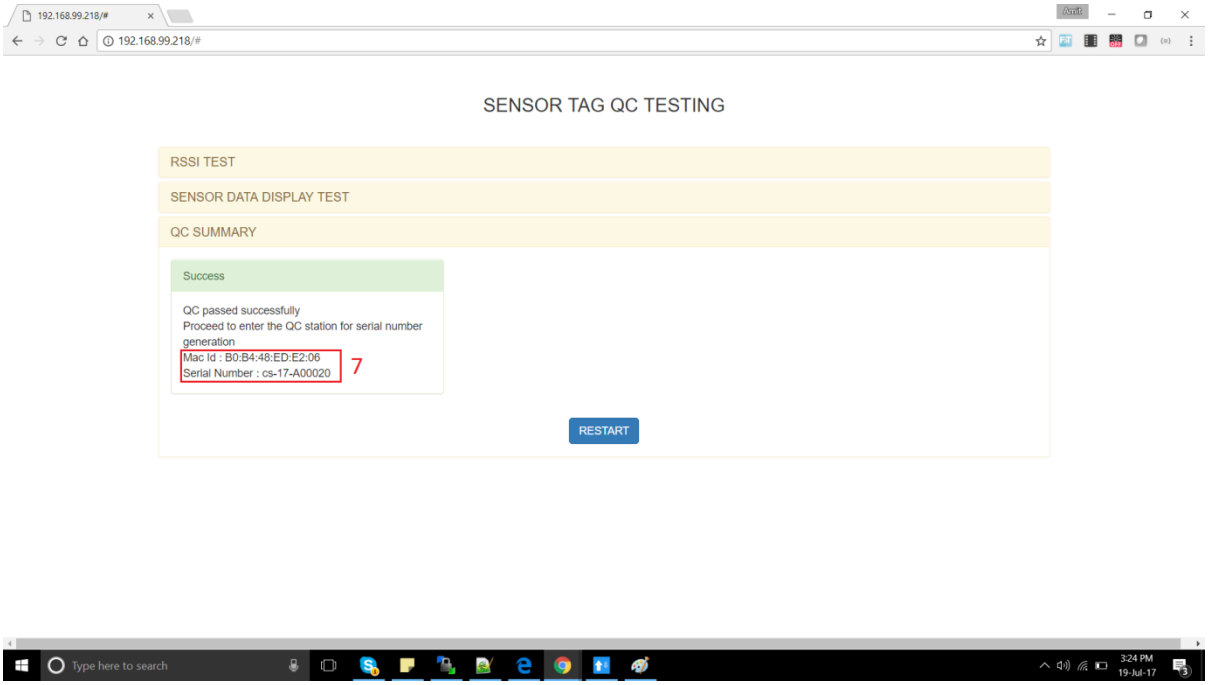
If the sensor gets connected the data flow will be started. And we can check all the sensor data one by one.


192.168.99.218/#
GY
AC GRAPH
AC
BP GRAPH
09:53:22
09:53:24
09:53:26
09:53:28
09:53:30
09:53:32
09:53:20
Highcharts.com
Type here to search
3:23 PM
19-Jul-17


192.168.99.218/#
BP GRAPH
BP
ACCEPT
REJECT
6
QC SUMMARY
09:54:08
09:54:10
09:54:12
09:54:14
09:54:16
09:54:18
09:54:20
09:53:35
09:53:40
09:53:45
09:53:50
09:53:55
09:54:00
09:54:05
09:54:10
09:54:15
Highcharts.com
Type here to search
3:24 PM
19-Jul-17

QC SUMMARY

If you click on **ACCEPT** button, the server automatically stocks and generates the serial number for the SensorTag. A QC Summary tab is displayed ("QC Stock Successful") with the serial number and the mac id.



- After the QC, each sensor is assigned a serial number. The format of the sensor serial number shall be as shown below:

Serial Number	*Example*
CS - YR - z#####	CS - 17 - a00215

CS	Condition Sensor
YR	Last two digits of the year
z	location code for test (a = Kolkata; b = Baltimore)
#####	Sequential number

The serial number and the mac id shall now be mapped and stored at the server.

9. INSTALLATION

10. CUSTOMER SUPPORT

11. DOCUMENTATION

12. TRAINING

13. WARRANTY

14. SERVICING AND MAINTENANCE