## Background

Industrial facilities have hundreds of critical rotating assets such as motors, pumps, gearboxes, and compressors. Unexpected failures result in costly down-time. An equipment health monitoring (EHM) preventative maintenance solution uses machine learning to identify when assets exceed pre-defined parameters.

Value

- **Increase Uptime**—Eliminate unplanned shut-downs
- **Reduce Maintenance Cost**—Repair prior to failure or extensive collateral damage
- **Effective Maintenance/Parts Scheduling**—Spare parts and labor planning
- **Ease of Use**—Reduce installation costs and eliminate complexity of traditional data analysis
- **Improve Asset Selection**—Use data to assist in root cause and reliability analysis
- **IIoT**—Real-time alerts for better decision making and remote asset management
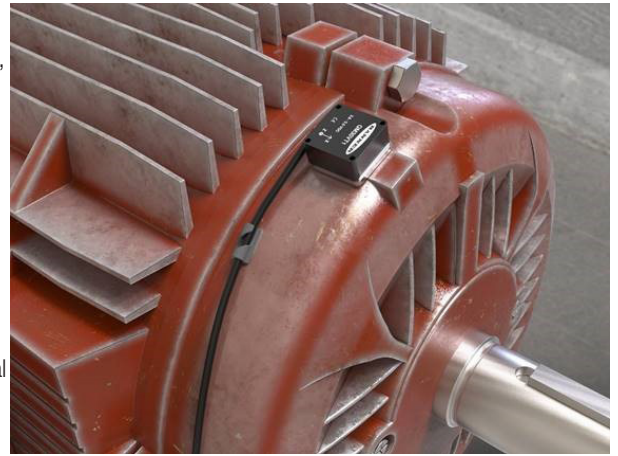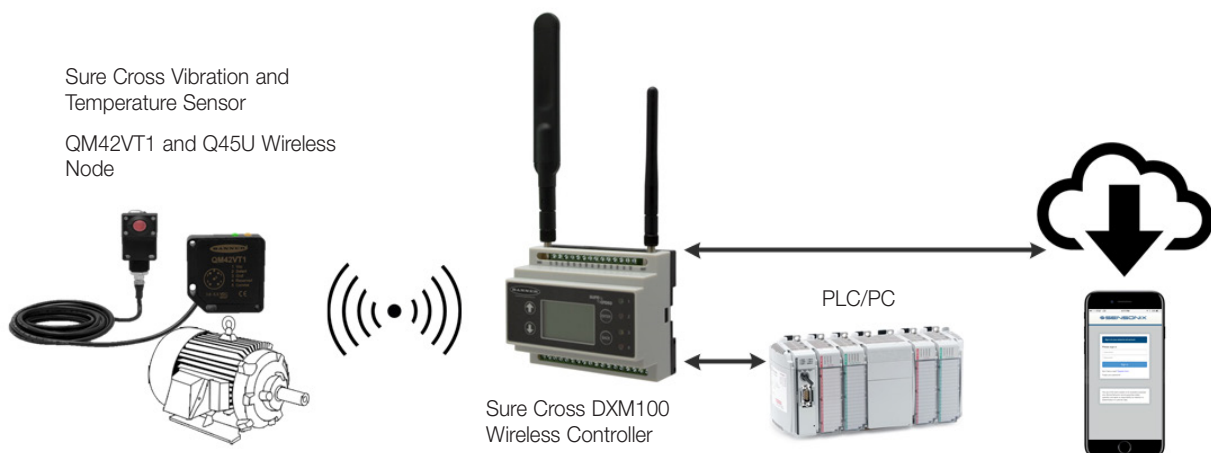
Banner Solution – Monitors Vibration Levels on Rotating Assets to Detect

- Imbalanced/Misaligned Condition
- Loose or Worn Components
- Improperly Driven or Mounted Components
- Over-temperature Condition
- Early bearing failure

How Banner Solves

- Banner's Wireless vibration/temperature sensor continually monitors RMS velocity, high frequency acceleration, and temperature on rotating equipment, but uses vibration data only when asset is operational
- DXM Controller uses a machine learning algorithm to baseline values and set control limits for alerts with limited end-user interaction; creates a "Check Engine Light" for each motor
- DXM Controller collects data for trending and analysis; a script defines acute verses chronic issues
- Data and alerts can be sent to the host control or to the cloud for IIoT connectivity

Sure Cross Vibration and Temperature Sensor

QM42VT1 and Q45U Wireless Node

PLC/PC

Sure Cross DXM100 Wireless Controller

A PDF version of this Application Guide is available at https://goo.gl/6S3RBD

Guide Features and Benefits

CONTINUOUS VIBRATION MONITORING	Monitor vibration data on up to 16 motors sensing X and Z axis RMS Velocity and high frequency RMS Acceleration. RMS Velocity is indicative of general rotating machine health (unbalance, misalignment, looseness) and high frequency RMS Acceleration is indicative of early bearing wear.
SELF-LEARNING BASELINE & THRESHOLDS	Prevent users from having to generate baselines or alarms by using machine learning algorithms to create an initial baseline reading and warning/alarm thresholds for each motor individually.
ACUTE & CHRONIC ALARMS	"Check Engine Light" Alarms and Warnings are generated for both acute and chronic conditions for each motor. Acute thresholds indicate a short-term condition such as a motor jam or stall which cross the threshold rapidly. Chronic thresholds use a multi-hour moving average of the vibration signals to indicate a long-term condition such as a wearing/failing bearing or motor.
MOTOR RUN-TIME	Recognize and differentiate running vs OFF state to track cumulative run-time for each motor.
TEMPERATURE ALARMS	Each vibration sensor will also monitor Temperature and alarm when the threshold is exceeded.
REMOTE MASTER LIGHT	Use a master tower light to indicate an OR'd status of all vibration alarms
SMS TEXT/EMAIL ALERTS	Generate SMS text and/or email alerts based on individual warnings and/or alarms
CLOUD MONITORING	Push data to Cloud Webserver or PLC (via LAN or Cellular connection) for remote viewing, alerting, and logging.

Application Components

Model	Description
QM42VT1	Sure Cross® Vibration and Temperature Sensor
DX80N9Q45U or DX80N2Q45U	Sure Cross® Wireless Q45 Sensor Node Universal 1-Wire Serial; select either 900 MHz or 2.4 GHz ISM radio to match the DXM100
DXM100-B1C1R1 or DXM100-B1C1R3 with firmware version 2.0	DXM100 Wireless Controller with Cell; select either 900 MHz or 2.4 GHz ISM radio to match the Q45Us; C1 only necessary if Cell Module is desired

The following mounting options are listed from least effective to most effective. In all mounting options, eliminate any sensor movement that could lead to inaccurate information or changes from the time-trended data.

Mounting Options	Bracket	Application Description
BWA-HW-057 Thermal Conductive Adhesive Tape (Ships with sensor)		Single use flexible mounting option, but can introduce flex that reduces accuracy.
BWA-BK-001 Flat magnet sensor bracket		Highly flexible and re-usable, flat magnetic mount for larger diameter surfaces or flat surface.
BWA-BK-008 Center mounting bracket with curved surface magnet attached to sensor bracket (includes BWK-BK-005)		Curved surface magnet mounts are best suited to smaller curved surfaces. Orient in the correct direction for the strongest mount. Offers flexibility for future sensor placement and provides sensor thermal isolation from surface temperature up to approximately 150 °F (65 °C).
BWA-BK-005 Center mounting bracket – accepts any #4 or M6 flathead screw (Ships with sensor)		Flat bracket permanently epoxied to motor and sensor screwed to bracket (very effective) or flat bracket with direct screw mount to motor and sensor (most effective). Ensures best sensor accuracy and frequency response. Recommend epoxy designed for accelerometer mounting: Loctite Depend 330 and 7388 activator

The following guide demonstrates how to bind the wireless Q45U nodes to the DXM and load a preconfigured XML file and script for up to 16 vibration monitors. The XML file only requires some minor modifications to be customized for any site.

Step 1: Bind the System and Assign Addresses

Binding each of the Q45U Nodes to the DXM100 establishes a secure connection between them and assigns a specific network address to each Q45U in the wireless network.

1. For each VT1 and Q45U pair, connect the VT1 to the Q45U's integral 5-pin connector.
2. Apply power to the DXM.
3. On the DXM: Use the arrow buttons to select the **ISM Radio** menu on the DXM's LCD. Press **Enter**.
4. Select the **Binding** submenu. Push **Enter**.
5. On the Q45U: Starting with the Q45U for Motor #1, triple-click the button to begin the binding procedure.

    The green and red LEDs flash four times after the Node is bound. This Node is now bound to the Gateway in the DXM as Node ID 1. The amber light may turn on after binding, indicating the Q45U has entered into a faster sampling mode, and stops after 15 minutes.
6. Label the device for future reference using the included label.
7. On the DXM: If you are done binding the devices, press **Back** to return to the main menu. If not, continue to the next step.
8. If you are binding another Q45U to the Gateway, change the DXM menu to **Bind to > 2** and press **Enter**. Triple-click the Q45U button to begin binding. The Node binds to the Gateway in the DXM as Node ID 2.
9. Continue repeat the previous step for as many VT1/Q45U pairs that you have.
10. On the DXM: Press **Back** to return to the main menu.
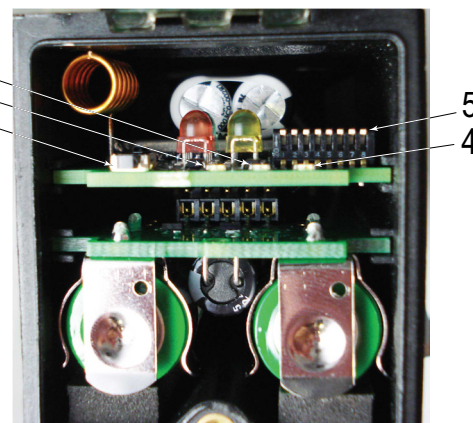
1 - Button   4 - Not Used
2 - Red LED   5 - DIP Switches
3 - Green LED

Step 2: Conduct a Site Survey

Conduct a Site Survey to verify the wireless connection between your Q45s and the DXM.

1. On the DXM: Use the arrow buttons to select the **ISM Radio** menu. Push **Enter**.
2. Select the **Site Survey** submenu, and press **Enter**.
3. Select each Node ID within the system to verify the wireless connection between the Node and the DXM.
4. When you are finished running the site survey, press **Back** twice to return to the main menu.

Forgetting to exit the site survey causes system issues and reduces the battery life of the Q45Us.

Step 3: Install the Vibration Sensor

It is important to mount the vibration sensors on a motor correctly for the most accurate readings. There are some considerations when it comes to the installation of the sensor.

The vibration sensors have an X and Z axis indication on the face of the sensor. The Z axis goes in a plane through the sensor while the X is horizontal.

- Install the line corresponding to the X axis in line with the shaft of the motor or axially.
- Install the Z axis of the sensor to go into/through the motor.

Install the sensor as close to the bearing of the motor as possible. Using a cover shroud or location far from the bearing may result in reduced accuracy or ability to detect certain vibration characteristics.
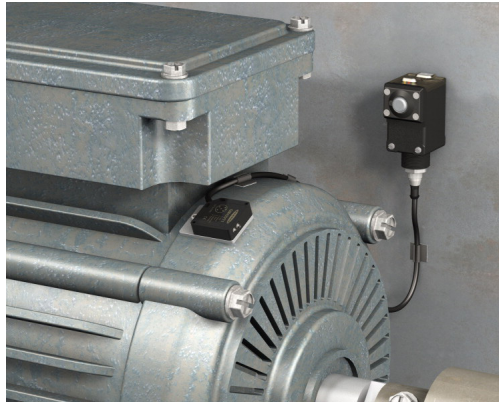
Step 4: Configure the System

To customize the system to an application, make some basic modifications to the template files. There are three files uploaded to the DXM: the XML file sets the DXM's initial configuration, the SbFile1.dat Data file, and the ScriptBasic file reads vibration data, performs the machine learning, sets the thresholds for warnings and alarms, and organizes the information in logical and easy-to-find registers in the DXM.

Loading these files and making adjustments requires using Banner's DXM Configuration Tool software and the Vibration Monitoring files available via in the links below.

1. After binding the Q45s pairs and running the Site Survey, install the Q45/VT1 pairs.

   Since the files automatically baseline after being loaded on the DXM, avoid creating installation vibrations by installing the sensors before uploading the files.
2. Download the preconfigured files. (https://goo.gl/F8cvZQ)
3. Extract the ZIP files into a folder on your computer. Note the location where the files were saved.
4. Connect the DXM, via the USB cable supplied with the DXM, to a computer containing the DXM Configuration Tool version 3 software or download the software and install it on a computer.
5. Launch the software.
6. Open the Vibration Monitoring XML file by going to the **File** > **Open** menu and choosing the configuration files.
7. Connect the software to the DXM by going to the **Device** > **Connection Settings** menu. Select **Serial** and then select the COM port that the USB cable is plugged into. Click **Connect**. If you are unsure which COM port to select, and multiple appear, attempt to connect to each one of them until you are successful.
8. Upload the Vibration Monitoring script file (.sb) by going to the **Settings** > **Scripting** screen. Click **Upload file** and select the script file.
9. Select the uploaded file in the window to the right of the **Upload file** button.
10. Click **Add Selected to Startup** so that the DXM will run this script every time it restarts.
11. Upload the Vibration Monitoring data file (.dat) using the same **Scripting** screen. Click **Upload file**, change the dropdown to "All Files(*.*)", and select the data file (.dat).
12. Save the XML file using the **File** > **Save** menu. Save the XML file any time the XML has been changed because the tool DOES NOT autosave.

Optional Steps: Customize the XML file

1. Within the DXM Tool, go to the **Local Registers** > **Local Registers in Use** screen.
2. Rename the Motors using the text boxes within the **Register Name** column. Because there are five registers per motor being monitored, copy and paste names for efficiency.

   To display the motor vibration data, warnings and alarms on the website you must change the Web column drop-down lists to Read and Cloud Reporting to ON for each motor' information piece (velocity, acceleration, alert mask, etc.) that you would like to appear on the website.

3. To display multiple Node's motor vibration data on the website, change the cloud permissions.

   a. On the **Modify Multiple Registers** screen, select **Change** in the drop-down list next to **Cloud Permissions**.

   b. In the drop-down list to the right, select **Read** for **Cloud Permissions**.

   c. Set the Starting Register to 1 and the Ending Register to the value equal to 5 × Number of motors in the system (for example, set the ending register 80 for 16 motors).

   d. Click **Change Registers** on the bottom right of the section.

4. To display the baselines, warning thresholds, and alarm thresholds on the website, change the **Cloud Permissions** to **Read**. Follow step 3 except change the **Starting Register** to **501** and the **Ending Register** to 512 + 12 × (Number of vibration sensors in the system minus 1). Do not exceed an ending register 693 for 16 Nodes.

5. Warnings and alarms within the system are contained within a single register for each of the up to 16 Nodes in local registers 101–116. The registers are labeled "NXX VibMask" where XX is the Node number. The number displayed is a decimal form of a 18-bit binary number with a value of 0 or 1 due to there being a potential of 18 warnings or alarms for each Node.

The 18-bit binary masks are broken out as follows:

Bit	Description	Decimal Value
Bit0	Warning – X-Axis – Acute Velocity	$(0/1) \times 2^1$
Bit1	Warning – X-Axis – Acute Acceleration (Hi Freq)	$(0/1) \times 2^2$
Bit2	Warning – Z-Axis – Acute Velocity	$(0/1) \times 2^3$
Bit3	Warning – Z-Axis – Acute Acceleration (Hi Freq)	$(0/1) \times 2^4$
Bit4	Alarm – X-Axis – Acute Velocity	$(0/1) \times 2^5$
Bit5	Alarm – X-Axis – Acute Acceleration (Hi Freq)	$(0/1) \times 2^6$
Bit6	Alarm – Z-Axis – Acute Velocity	$(0/1) \times 2^7$
Bit7	Alarm – Z-Axis – Acute Acceleration (Hi Freq)	$(0/1) \times 2^8$
Bit8	Warning – X-Axis – Chronic Velocity	$(0/1) \times 2^9$
Bit9	Warning – X-Axis – Chronic Acceleration (Hi Freq)	$(0/1) \times 2^{10}$
Bit10	Warning – Z-Axis – Chronic Velocity	$(0/1) \times 2^{11}$
Bit11	Warning – Z-Axis – Chronic Acceleration (Hi Freq)	$(0/1) \times 2^{12}$
Bit12	Alarm – X-Axis – Chronic Velocity	$(0/1) \times 2^{13}$
Bit13	Alarm – X-Axis – Chronic Acceleration (Hi Freq)	$(0/1) \times 2^{14}$
Bit14	Alarm – Z-Axis – Chronic Velocity	$(0/1) \times 2^{15}$

Bit15	Alarm – Z-Axis – Chronic Acceleration (Hi Freq)	$(0/1) \times 2^{16}$
Bit16	Warning Temperature (> 158°F or 70°C)	$(0/1) \times 2^{17}$
Bit17	Alarm Temperature (> 176°F or 80°C)	$(0/1) \times 2^{18}$

Acute X-Vel Warn	Acute X-Accel Warn	Acute Z-Vel Warn	Acute Z-Accel Warn	Acute X-Vel Alarm	Acute X-Accel Alarm	Acute Z-Vel Alarm	Acute Z-Accel Alarm	Chronic X-Vel Warn	Chronic X-Accel Warn	Chronic Z-Vel Warn	Chronic Z-Accel Warn	Chronic X-Vel Alarm	Chronic X-Accel Alarm	Chronic Z-Vel Alarm	Chronic Z-Accel Alarm	Temp Warning	Temp Alarm
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The decimal version is the sum of the calculations shown in the right column for each Node's mask register. Note that any value greater than zero in registers 101–116 indicates a warning or alarms for that particular Node. To know the exact warning or alarm, convert the decimal value back into a binary value, which is done on the Banner CDS site or can be done with a PLC or HMI. Multiple warnings and alarms may trigger on an event depending on severity.

6. Configure to **Receive Email or Text Alerts** based on an **Action Rule**. An easy example of an action rule to use is when the warning/alarm masks in registers 101–116 are greater than zero, trigger to send an email or text immediately. There are six threshold rules set up, which trigger on Any Error, Any Acute Warning or Alarm, Any Chronic Warning or Alarm, or Any Radio Connection Error. To change the action rules:

   a. Go to the **Action Rules** screen and expand any rule using the arrow next to the rule OR create a new action rule using the **Add Threshold Rule** button on the top.

   b. Click on the arrow next to **Email/SMS on State Transition**.

   c. Select the recipient of the SMS and/or email upon the action rule becoming true.

In the example shown, both SMS Recipient 1 and 2 and Email Recipient 1 and 2 receive a message when the action rule meets its criteria.

Set up the Ethernet or Cellular Connection

By default, the XML file configures the DXM100 with an Ethernet Push interface with the ability to send emails and push the data registers to a webserver. The device can also be configured to use a cellular push if the DXM Controller contains a cellular module and data plan. This section is only necessary if the user wants to receive or display information beyond just the DXM Controller's LCD.

1. If the DXM will text, email, or push to the cloud webserver, set up the push interface.
    a. On the DXM Configuration Tool, go to the **Settings** > **Cloud Services** screen.
    b. Select the appropriate **Push Interface** (Ethernet or Cell) from the drop-down list.

    Selecting **Cell** requires a cellular module be installed in the DXM Controller and a wireless plan be set up for sending data.

2. The **Cloud Push Interval** and **Samples** are set to 0 for this solutions guide because the script associated with this file establishes the push interval internally so it occurs immediately after the sample of the Nodes.

3. Set up the email and text messages. SMS works only if the DXM has a cellular module. Expand the **Email Recipients** and **SMS Recipients** to enter up to 10 email addresses and 10 phone numbers, along with a custom message.
    a. Go to the **Settings** > **Mail and Messaging** screen.
    b. All SMTP fields should remain set to their default values, except the **Password** field. Enter "sxiemail1" into the password field.
    c. Click **Send SMTP Password**.
    d. Click **Yes** when asked to reboot the device.

Step 5: Save and Load the XML File to DXM

When changes are made to the XML file, save the changes. To apply the changes, load the XML file to the DXM.

1. **Save** the file by going to the **File** > **Save** menu.
2. **Load** the file onto the DXM by going to the **Device** > **Send XML Configuration to DXM** menu.

    Because of the size of the XML file, the file may take up to three minutes to load. Verifying the file is loading by looking at the Application Status indicator in the status bar.

    If the Application Status indicator is RED, close and restart the DXM Configuration Tool, unplug and re-plug in the USB cable and reconnect the DXM to the software. If the Application Status indicator is GREEN, the file upload is complete. If the Application Status indicator is YELLOW, the file transfer is in progress.

Step 6: Push Information to the Cloud

The DXM100 can connect to the web via Ethernet or an internal cell module to push data from the site to the cloud and displayed on a website. To enable this capability for remote monitoring and alarms settings, modify the XML file.

The Banner website for storing and monitoring the system's data is bannercds.com.

1. Connect the DXM to a computer with the DXM Configuration Tool software.
2. Launch the software and connect to the DXM.
3. **Load** the saved XML file.
4. Go to the **Settings** > **Cloud Services** screen.
5. Visit the website (bannercds.com) and log into an existing account or register a new account.
6. Click **+ New Site.** Name your site.
7. Highlight and copy the Site ID.
8. On the DXM Configuration Tool: Return to the **Settings** > **Cloud Services** screen and paste the copied ID into the **Site ID** field.
9. **Save** the XML file (**File** > **Save**).
10. Upload the file to the DXM (**Device** > **Send XML Configuration to DXM**).
11. On the website: Click **Options** on the row of the newly created site. Click the checkbox next to **XML Config** and select the XML file that was just saved/uploaded to the DXM.
12. Click **Save** to complete the connection to the website.

This creates continuity between the site created on the website with the DXM used in the field. The DXM pushes data to the website, which can be viewed at any time. Refer to the Banner Cloud Data Service Instruction Manual to review all the features available for monitoring, comparing data, and establishing warnings/alarms on the website.

To access a demo version of the website please contact your local Banner distributor and follow the instructions in the technical note: Connecting to the Banner Cloud Data Service for modified instructions on how to send data to the demo site.
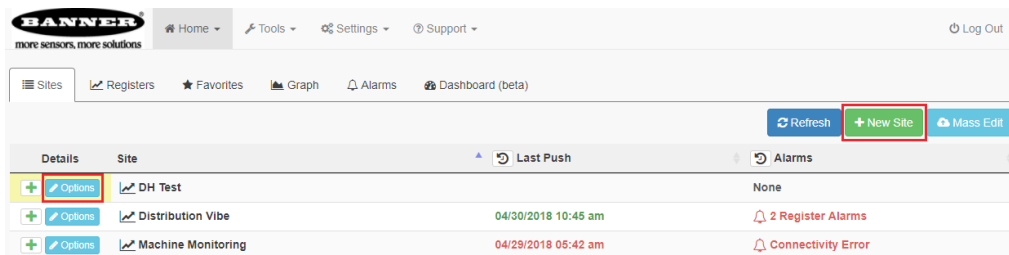
Additional Features

Viewing Run Flags, Run Timers, and Run Counts

The Vibration monitoring guide also tracks when a motor is running, how long it has been running, and how many times it has turned on an off. The following registers are used for each type of data:

- Motor Run Flag On/Off (0/1) – Local Registers 131–146
- Motor Run Timers (mins) – Local Registers 151–166
- Motor Run On/Off Counts – Local Registers 171–186

To view these on the web, change the cloud reporting and permissions using Optional Step #3.

Adjusting the Velocity Thresholds for Run Flag

The script in this Vibration Solutions guide uses a function to automatically generate baselines and standard deviations by recognizing when a motor is running and collecting data. If a motor has a very low RMS velocity and acceleration when running, it can be very difficult to distinguish. To ensure the system is working properly, it is best to look at the Run Flag and X/Z RMS velocity over time. Visually it can be seen when a motor is running vs. off and if the Run Flag doesn't turn ON (1) when the motor turns on, the Running Motor RMS Velocity threshold may need to be decreased. To assess this look at the data over time as shown below:
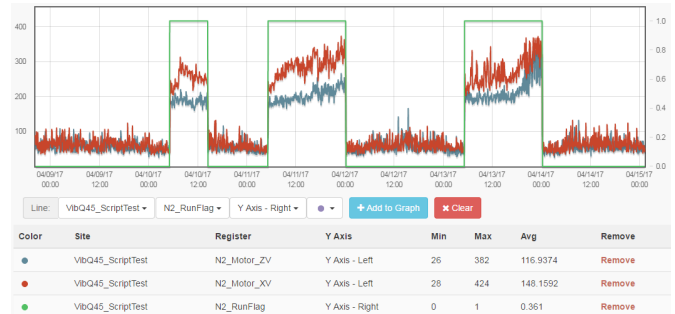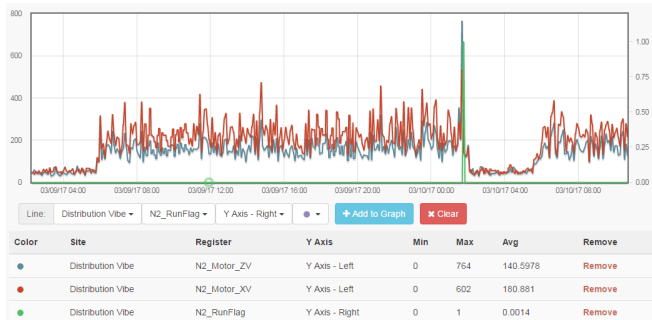
On the left, we can see that the motor Node 2 is between 150–425 for RMS velocity when running and below 100 when not running. Looking at the Run Flag (green line) it only indicates "Running" at one point in time when the velocity has a spike. In comparison, if we look at the RMS velocities for Node 2 on the right, we can see the Run Flag (green line) clearly indicates when the motor is running and not running even if the velocities are fairly low. This means the acceleration is high enough to distinguish a "Running" state.

To adjust for this, we need to move the Running RMS Velocity Thresholds for the X and Z axis down to a level that is above the "OFF" state and below the lowest data collected in the "Running" state. In this case a value of 100 would be the appropriate value but it will vary depending on the motor and should be assessed for each individual situation. To change the Run Velocity thresholds:

1. Using the DXM Configuration tool, go to Local Registers -> Local Registers in Use
2. The X Velocity Run thresholds are in registers 301-316 and are labeled NX_RunThres_XV (where X is the motor ID number)
3. Change the value in the Constant or Timer column to an appropriate threshold for that motor as described above.
4. The Z Velocity Run thresholds are in registers 317-332 and are labeled NX_RunThres_ZV (where X is the motor ID number)
5. Change the value in the Constant or Timer column to an appropriate threshold for that motor as described above.
6. Once completed for each motor, follow Step 5: Save and Load XML File to DXM

After this velocity threshold adjustment has been made, re-baseline the motor.

Re-Baselining a Motor

The script included with this guide uses the first few days' worth of data points of a motor running after loading the script to the DXM to generate a baseline and statistics for determining warning and alarm threshold levels. If changes are made to the motor or vibration sensor, generate a new baseline. This ensures the system is running as accurately as possible. There are two ways to re-baselining a motor:

Baselining from the DXM

1. On the DXM: Use the arrows to select **Registers**. The registers are labeled NX_Baseline (where X is the motor node ID you want to baseline).
2. Select the appropriate register to reset.
3. Click the **Enter** button.
4. Change the value to 1 then push **Enter** three times. The reset register automatically returns to zero after baselining.

Baselining from the Website

1. Go to the **Dashboard** > **Sites** screen.
2. Click **Options** for the site where the particular motor exists.
3. Click the **Update** tab in the pop-up window that appears.
4. From the **Type** drop-down list, select **Register**.
5. From the **Register Name** drop-down list, select the motor Node ID you want to baseline.
6. Enter 1 into the **Value** field and click **Queue**.
7. Repeat steps 4 and 5 for each motor Node to reset.

Adjust the Temperature Warning and Alarm Thresholds

The default settings are 158 °F (70 °C) for a warning and 176 °F (80 °C) for an alarm. To change the temperature thresholds, follow these steps:

1. Using the DXM Configuration tool, go to the **Local Registers** > **Local Registers in Use** screen.
2. The temperature warning thresholds are in registers 365–380 and are labeled NX_TempW (where X is the motor ID number). Change the value in the **Constant** or **Timer** column to your desired setting for that motor.
3. The temperature alarm thresholds are in registers 381–396 and are labeled NX_TempA (where X is the motor ID number). Change the value in the **Constant** or **Timer** column to your desired setting for that motor.
4. After changing the settings for each motor, follow the steps in **Step 5: Save and Load the XML File to DXM**.

Local Registers

	Local Register #	Description
Motor Processed Data	$1 + 5 \times (N - 1)$	Z-Axis Velocity
	$2 + 5 \times (N - 1)$	Z-Axis High Freq. Acceleration
	$3 + 5 \times (N - 1)$	X-Axis Velocity
	$4 + 5 \times (N - 1)$	X-Axis High Freq. Acceleration
	$5 + 5 \times (N - 1)$	Motor Temperature F
Sample Counter	90	1 second timer for script sampling
Read Rule Enable	91	Script Trigger register for read rules
Vibration Alert Mask	101–116	Warnings and Alert Mask
Warning/Alarm OR'd	117–130	Multiple variations of OR'd warning and alarms for thresholds
Motor Run Flag	131–146	Motor Run Flag
Motor Run Time	151–166	Motor running timers
Motor On Off Count	171–186	Motor Run On/Off Count
Motor Connection Status	191–206	Node Connection Status
Connection Status OR'd	207–208	Connection status registers for threshold rules
Baseline	211–226	Trigger New Motor Baseline (Read/Write)
Motor Run Thresholds	301–396	Initial Motor Run and Temperature Thresholds
Trended Data	401–464	Trended Vibration Data
Raw Motor Info	701–796	Raw Sensor data

Where N represents the Motor Node ID number.

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