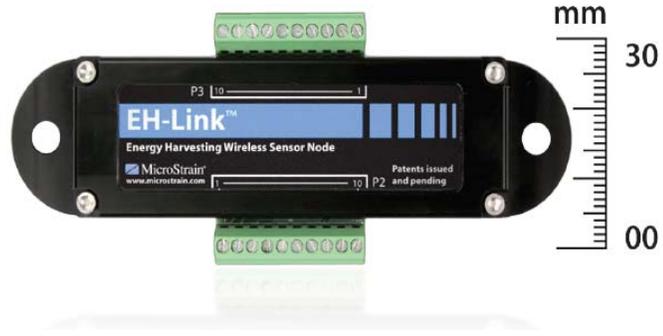


# EH-Link<sup>®</sup>



## Powering an EH-Link with piezoelectric source

### Overview

The EH-Link™ wireless node is a self powered sensor, harvesting energy from ambient energy sources. EH-Link™ is compatible with a wide range of generator types, including piezoelectric, electrodynamic, solar, and thermoelectric generators. In addition to multiple harvesting inputs, the EH-Link features an on-board triaxial accelerometer, relative humidity sensor, temperature sensor, and signal conditioning for a Wheatstone bridge which is compatible with strain gauges, load cells, torque sensors, pressure transducers, and magnetic sensors, all in a miniature package.

This technical note describes the use of EH-Link powered by strain energy generated with piezoelectric material. To demonstrate this we will follow a four step process.

- 1) **Determine how much energy is generated by our piezoelectric patch under varying loading conditions.**
- 2) **Based on the energy generation, determine what sample rate will be supported by this energy generation profile.**
- 3) **Configure the EH-Link to sample at the chosen rate.**
- 4) **Demonstrate that the EH-Link operates as predicted using the chosen sample rates and loading condition.**

### Powering a Wireless Sensor from Strain Energy

Piezoelectric material converts mechanical energy into electrical energy that can be used to power the EH-Link wireless sensor. The amount of energy generated is proportional to the input strain magnitude (microstrain) and rate (Hz). This note will describe how to characterize performance of the EH-Link when powered from piezoelectric material.

First, we started by measuring the output power generated by the piezoelectric patches independent of the EH-Link. Two piezoelectric patches (Smart Material Inc, Osprey, FL, Type 8528-P2) were bonded to a stainless steel bending beam. The



**Figure 1. Piezoelectric Patches**

two patches were connected electrically in parallel. To test the energy generation from the patches, the bending beam was loaded in a four point bending apparatus. The use of a four point bending beam ensured that a uniform strain is seen by the two patches. The bending beam was loaded at varying strain levels at two frequencies, 5 Hz and 10 Hz. The RMS AC voltage was measured across a number of load resistors to determine optimal load resistance (Figure 2). Once the

optimal load impedance was determined (50 kOhms), the average output power vs. strain was recorded at varying strain levels (Figure 3).

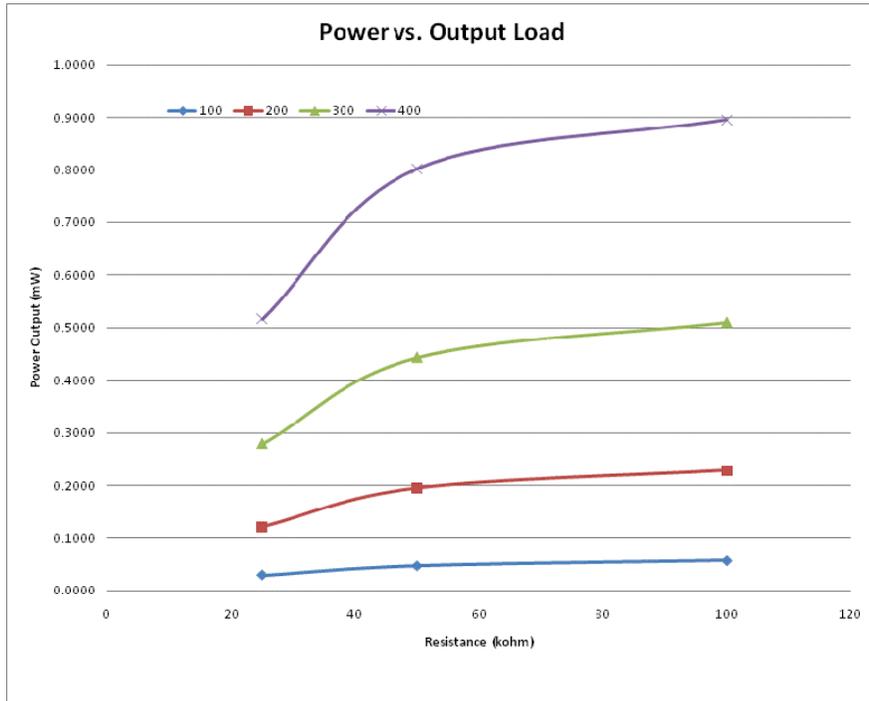


Figure 2. Power Output vs. Load Resistance

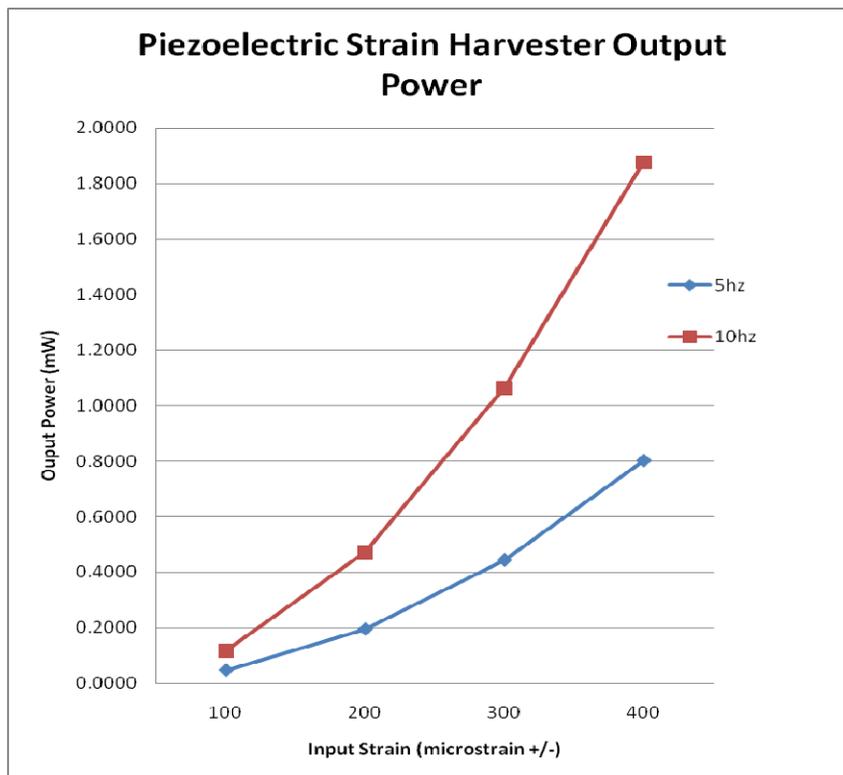


Figure 3. Power Output vs. Input Strain

Now that the raw output power of the piezoelectric material has been characterized, we can move on to configuring an appropriate sampling mode on the EH-Link.

## Choosing a Sample Mode in EH-Link

The EH-Link has a number of configurable sampling modes & sampling rates. Depending on the type of sample mode, the power consumption can vary greatly. There are two fundamental modes of transmission, *buffered* data mode and *single point* data mode. In *buffered* mode, a number of samples are acquired and stored before sending data in a packet to the receiver. This is the most efficient mode as it minimizes the amount of overhead required to send data per sampled data point. A finite number of information needs to be sent with each data packet, regardless of the number of data samples sent in the packet. This information includes the address of the sending unit, error checking bytes, number of channels, packet framing information, etc.. By sending more data in each packet the amount of energy required per data point is lower.

In *single point* mode, also called “charge and fire” mode, each data point sampled is immediately transmitted, no data buffering occurs. This is less energy efficient than buffering mode, but data latency is minimized. In buffered mode you must wait until all the points are sampled and the data buffer is full before the data arrives at the receiver. Generally, when you are using higher data rates (> 1 sample/second) it is good practice to use buffered data mode to minimize power consumption of the EH-Link.

The chart below outlines the power consumption at different combinations of sample rates and sensors in both the single point mode and buffered mode (Figure 4).

**Power Matrix**

Sample Rate [Hz] (Eeprom14)	Buffer Count (Eeprom40) [Samples]	Bridge (1k)	Ain	%RH	Temp	AccelA	AccelB	AccelC	Din	Current [uA]	Power [mW]
1	1	x								32	0.24
	1	x		x						228	1.71
	1	x		x	x					642	4.815
	1					x	x	x		288	2.16
	1								x	198	1.485
	1	x	x	x	x	x	x	x	x	740	5.55
256	48	x								644	4.83
	48	x		x						1100	8.25
	48	x		x	x					1456	10.92
	48					x	x	x		1133	8.4975
	48								x	381	2.8575
	48	x	x	x	x	x	x	x	x	2471	18.5325
64	48	x								172	1.29
	48	x		x						440	3.3
	48	x		x	x					881	6.6075
	48					x	x	x		365	2.7375
	48								x	102	0.765
	48	x	x	x	x	x	x	x	x	1320	9.9
16	48	x								45	0.3375
	48	x		x						256	1.92
	48	x		x	x					680	5.1
	48					x	x	x		170	1.275
	48								x	28	0.21
	48	x	x	x	x	x	x	x	x	876	6.57
1	5	x								14	0.105
	10	x		x						180	1.35
	15	x		x	x					351	2.6325
	15					x	x	x		270	2.025
	5								x	179	1.3425
	40	x	x	x	x	x	x	x	x	720	5.4

Readings are taken at 7.5 VDC

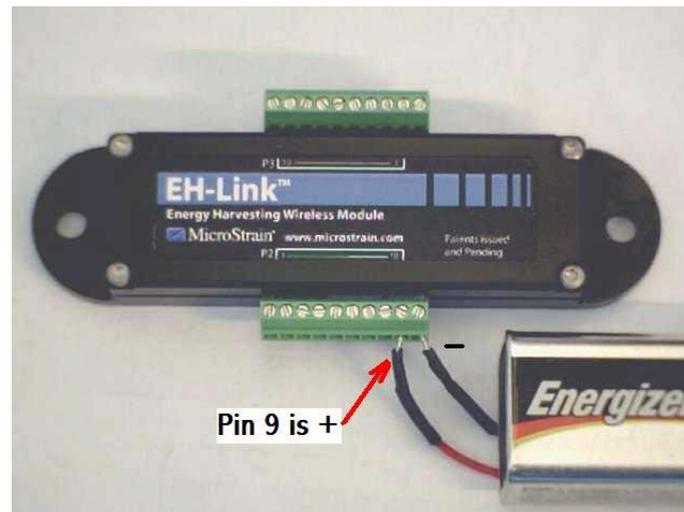
**Figure 4. Power versus sample rate and packet size**

The buffer count column indicates how many samples are stored in the buffer before transmitting the data. Referencing Figure 4 along with the power chart in Figure 3 we see that the amount of energy generated at 400 microstrain at 10 Hz should support sampling a 1K bridge sensor at 64 samples per second. The next step is to configure the EH-Link to sample at this rate and test to see that we indeed can sample at this rate when powered by a piezoelectric source.

### Configuring the EH-Link sampling parameters

Configuring the EH-Link sampling parameters requires writing two appropriate configuration eeprom registers: eeprom register 14 programs the sample rate, and eeprom register 40 programs the buffer size. By default, the EH\_Link ships to transmit a single sample at 1 Hz (Register 14 = 12, Register 40 = 1). To change the configuration, we need to use a 9 Volt battery to temporarily provide power to the EH-Link during configuration. In addition, a tester board is included that simulates a Wheatstone bridge and includes a switch that places the unit into configuration mode (See Figure 8).

Connect the 9 V battery to the two input pins shown on connector P2, the positive battery terminal (red) to pin 9 and negative battery terminal (black) to pin 10 using the screwdriver shipped with the kit (See Figure 5 below).

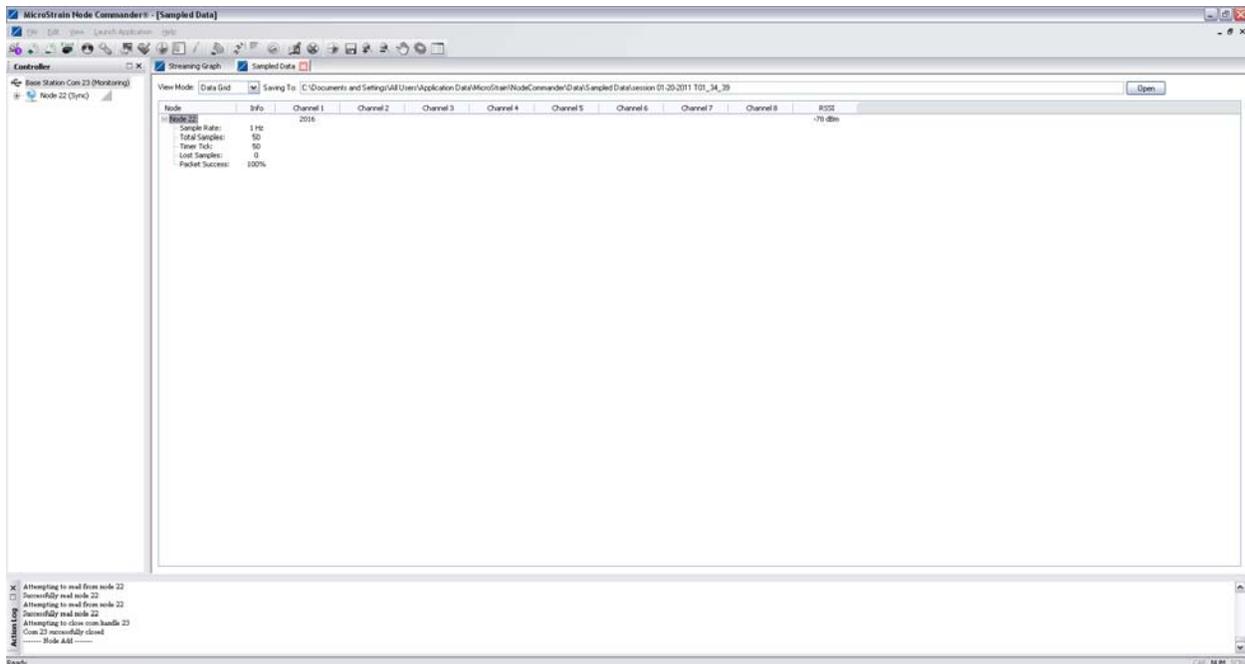


**Figure 5. Installing 9V battery for configuration mode**

Next, start Node Commander and right click on the installed base station (Figure 6) and select Monitor Mode. When this is selected a window will come up displaying sensor data. In the sensor window, the node address, sensor data, sample rate, and packet error rate will be displayed. At this point you are up and running and are ready to start configuring your EH-Link .



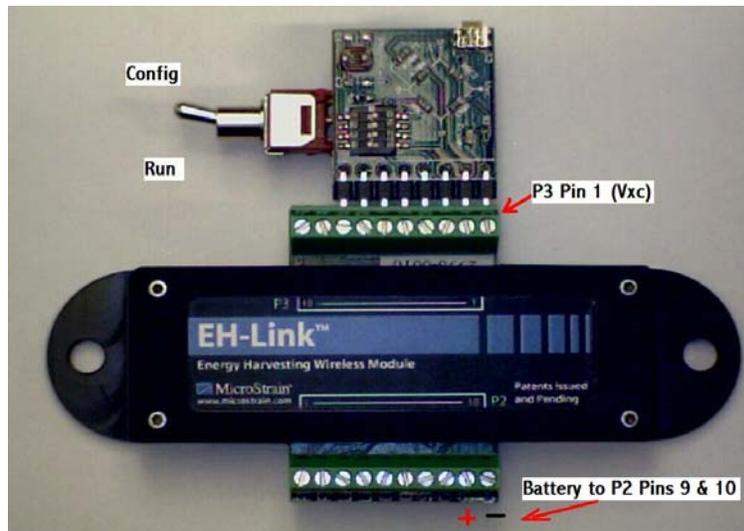
**Figure 6. Starting Monitor Mode in Node Commander**



**Figure 7. Monitor Mode Screen in Node Commander**

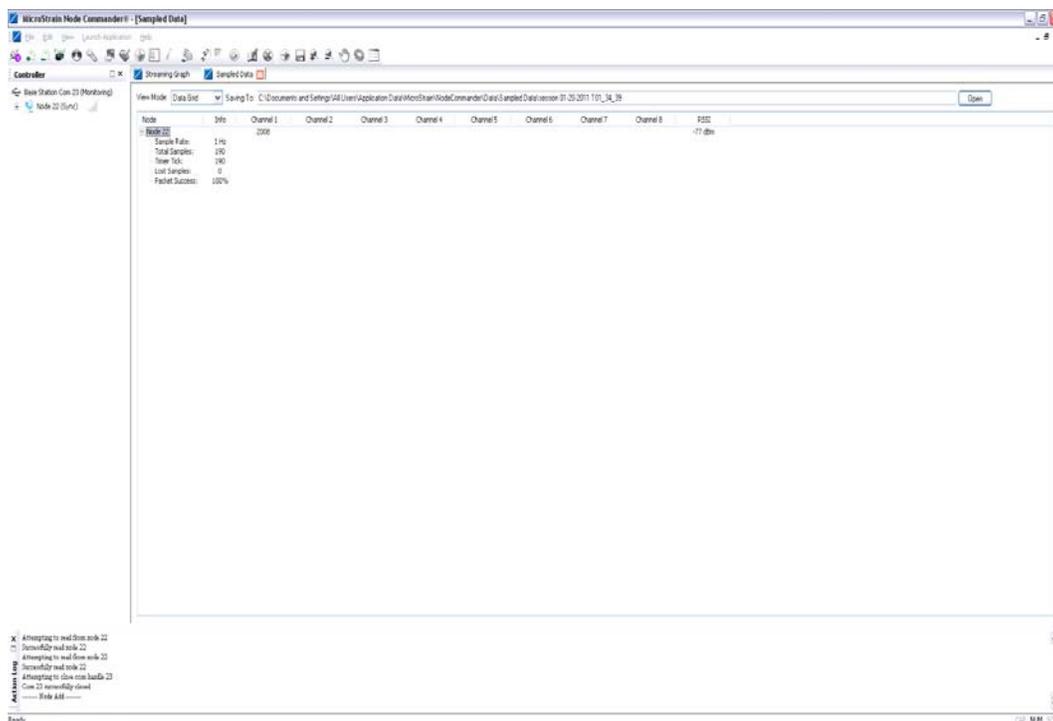
A step by step guide to configure the sample rate and number of active channels follows:

- First connect the tester board as shown in figure 8, below.
- Ensure the 9V battery is connected to P2 pins 9(+) & 10(-) as shown in figure 8, this may require temporary removal of the storage capacitor.

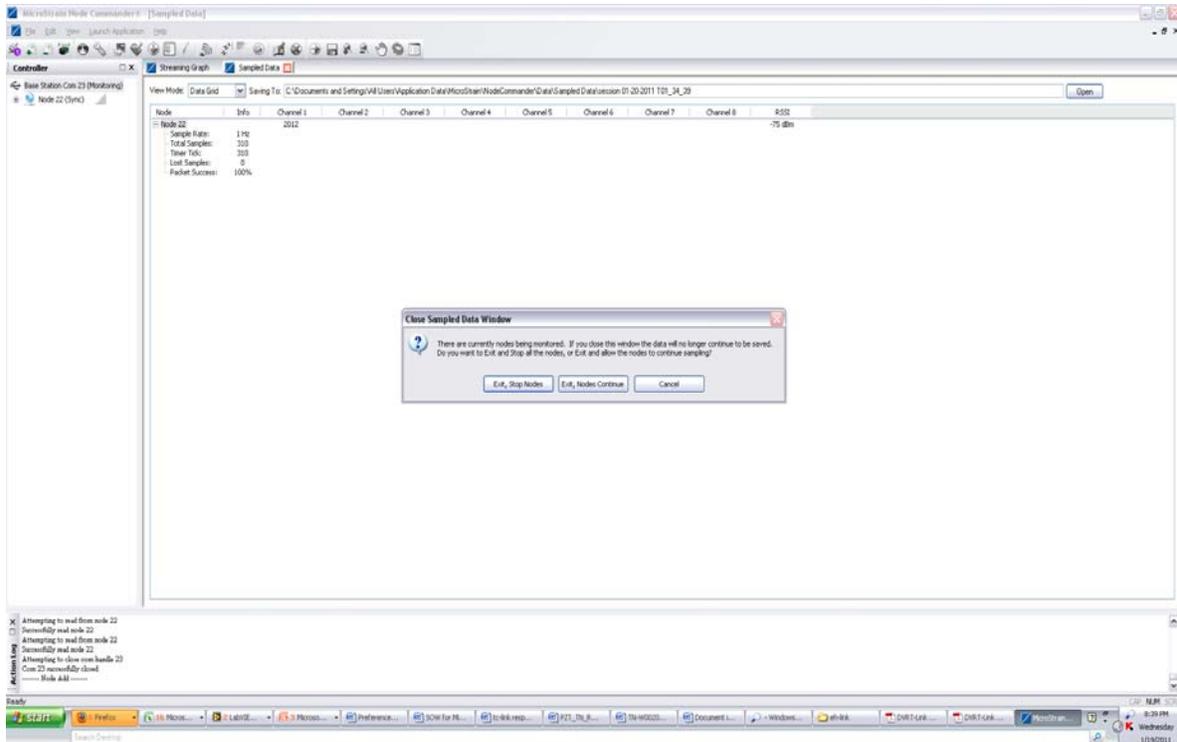


**Figure 8. Installing Tester Board w/ Configuration Switch**

- Set the configure/operate toggle switch to the **run** position (Figure 8)
- Data should be updating in the Node Commander monitor screen
- Set the configure/operate toggle switch to the **configure** position (Figure 8).
- Close the Sampled Data tab in Node Commander by clicking on the red X box on the right hand side of the Sampled Data Tab (Figure 7)
- A window will display, select nodes continue option (Figure 10)

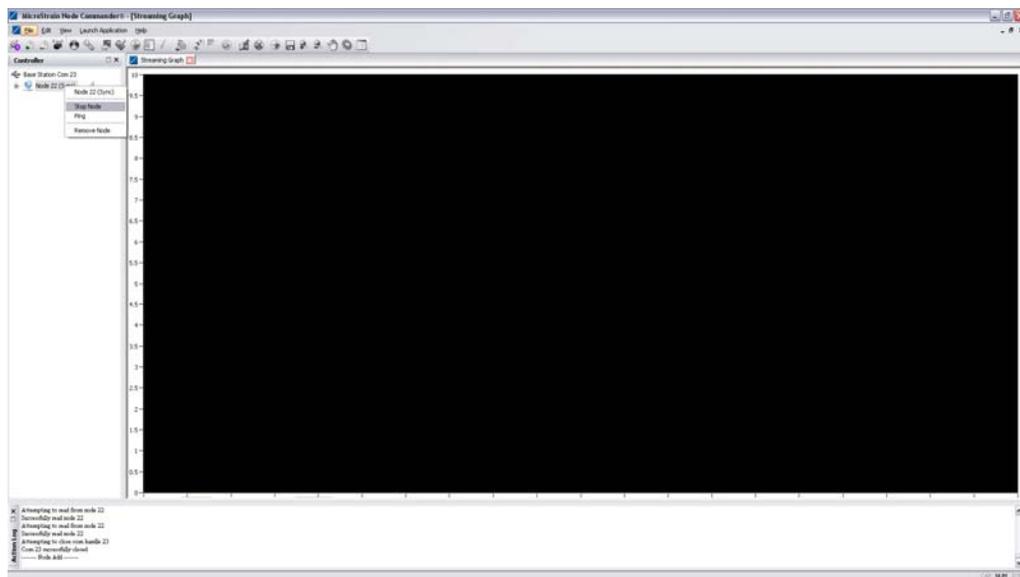


**Figure 9. Monitoring Mode Screen**



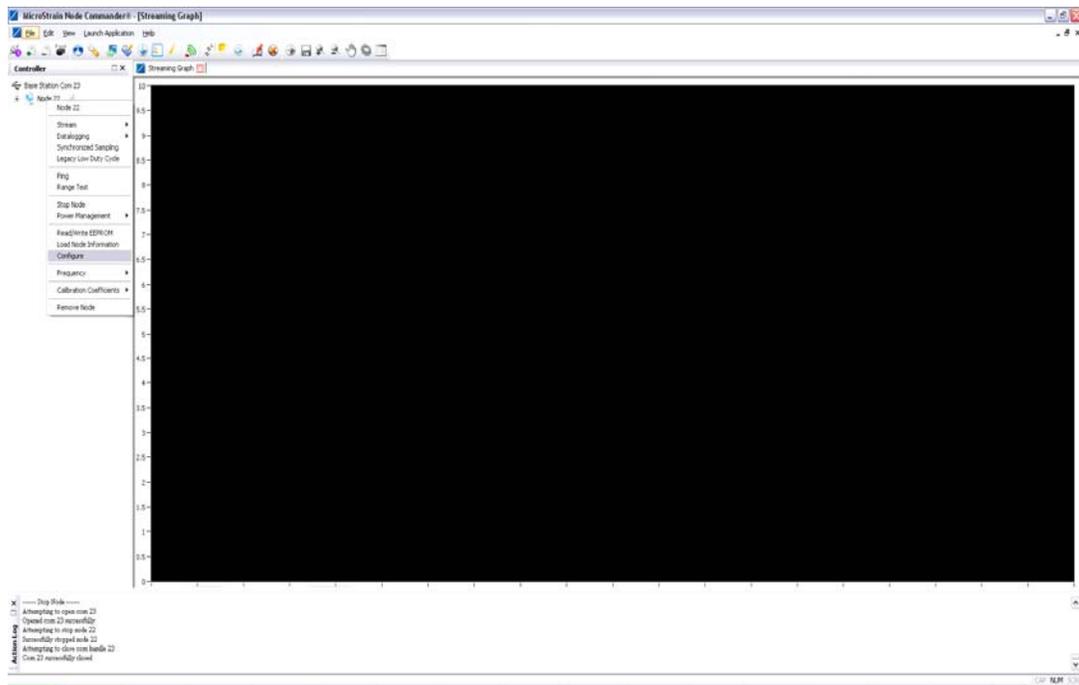
**Figure 10. Closing the Monitor Screen, Select Nodes Continue**

- Right click on the node number and select Stop Node (Figure 11)



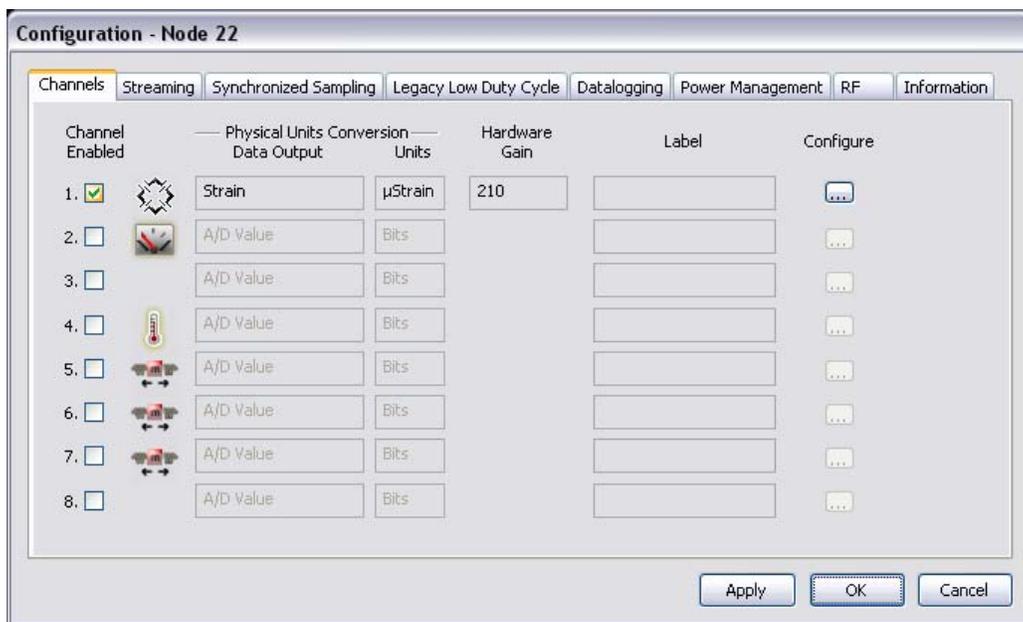
**Figure 11. Stopping Node to Enter Config Mode**

- When the node is stopped, right click, and select Configure (Figure 12)



**Figure 12. Entering The Configuration Screen**

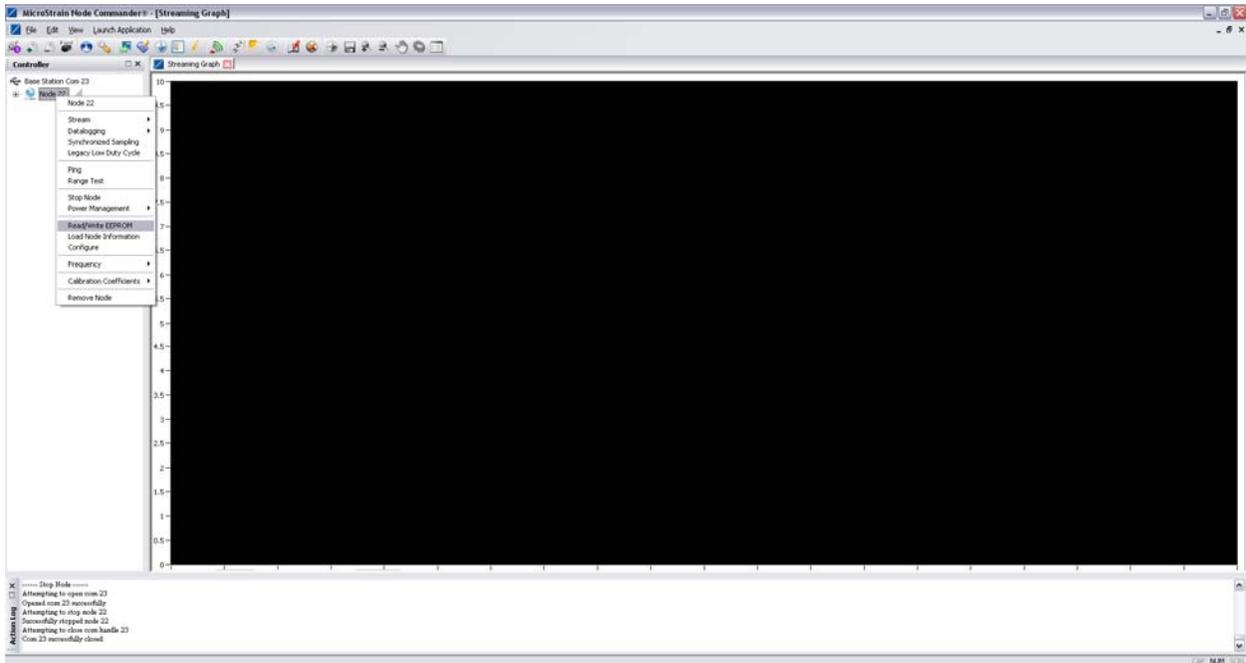
- Select the number of channels under the Channels tab, in this case, we are monitoring the Wheatstone bridge channel, so check they first box. (Figure 13)



**Figure 13. Selecting Active Sensors**

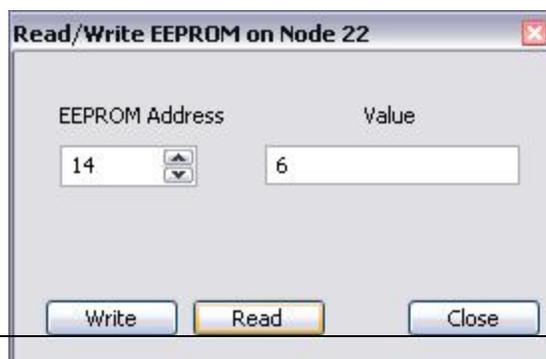
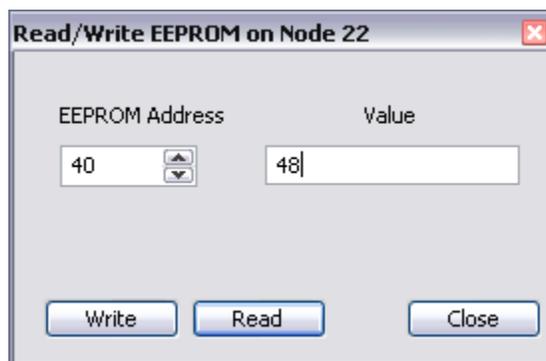
- Close configuration tab by selecting OK
- Now we setup our sampling parameters

- Select Read/Write EEPROM from the pull down tab (Figure 14)



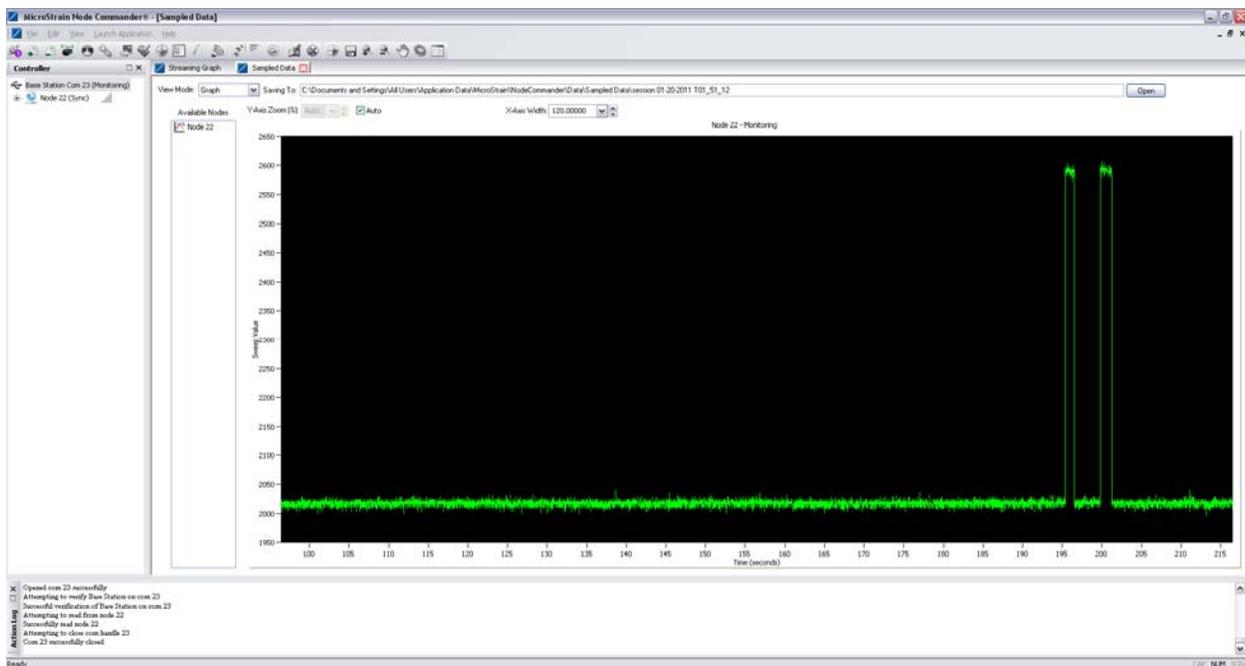
**Figure 14. Read/Write EEPROM**

- Program location 14 & 40 to the appropriate values, in this case location 14 should be programmed to 64 Hz and 40 to a buffer size of 48 (which is maximum). To program enter the address in the EEPROM Address box and the value to program in the Value box and press the Write button. The written value can be verified by pressing the read button. When complete press the Close button. (Figures 13 & 14)

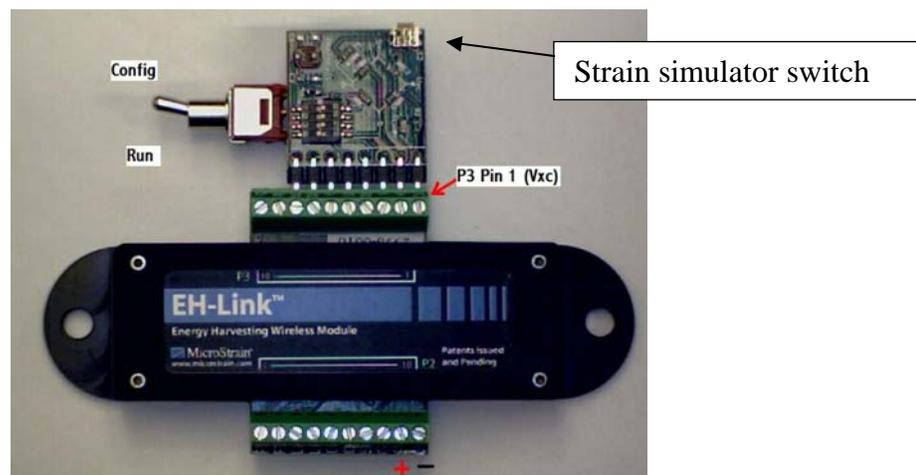


**Figure 15 & 16. Programming Sampling Parameters**

- Return switch on tester board to Run position
- When you return to the monitor screen (right click on basestation, select Monitor Mode), the sensor will be updating at 64 Hz. The tester board includes a Wheatstone bridge, there is a small switch that simulates a strain input by shunting a resistor across one arm of the Wheatstone bridge
- Configuration complete! Note the current configuration is stored in nonvolatile memory does not have to be configured again, unless the user would like to change the configuration.



**Figure 17. Monitor Mode Graph (Steps are when strain simulation applied)**



**Figure 18. Tester Board Strain Simulator Switch**

## **Final Testing with a Piezoelectric Harvester**

Now that the EH-Link is configured, we are ready to test with piezoelectric material. Remove the configuration battery from the EH-Link and put the energy storage capacitor back across pins 9 & 10. **Note!**: To avoid damage, the correct polarity of the capacitor is important, the positive capacitor terminal should go to pin 9, the negative to pin 10.

Next, the inputs of the piezoelectric material are connected to pins 1 & 2 of P2. (Labeled PZ1 & PZ2). When the device was loaded to 400 microstrain at 10 Hz, the EH-Link starts to transmit data at 64 Hz continuously.

## **What if there is not enough energy to support continuous transmission?**

If there is not enough energy supplied by the energy harvesting source, the EH-Link will run until the energy is depleted from the storage capacitor. Then it will accumulate energy on capacitor until enough is stored to run the EH-Link again. The amount of time that the EH-Link will run is proportional to the size of the storage capacitor.

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