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Operating Procedure for the Portable Acoustic Monitoring Package (PAMP)
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Operating Procedure for the Portable Acoustic Monitoring Package (PAMP)

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Disclaimer

Portable Acoustic Monitoring Package (PAMP) Operating Procedure

Abstract (250 words)

To detect natural gas pipeline infringements and leaks, the acoustic energy generated inside the line is monitored with a sensitive pressure-equalized microphone and a step function type Δp transducer. The assembly is mounted on a 1000 psig pipe fitting-tree called the Portable Acoustic Monitoring Package (PAMP). The electronics required to record, store and analyze the data are described within this report in the format of an operating manual.

Included is a section on data processing for infringement detection procedure.

Executive Summary

The Portable Acoustic Monitoring Package (PAMP) has been designed to record and monitor acoustic signals in high-pressure natural gas (NG) transmission lines. Of particular interest are the three acoustic signals associated with a pipeline fracture. The system is portable (less than 30 lbm) and can be used at all line pressures up to 1000 psig. The PAMP requires a shut-off valve equipped ½" NPT access port in the pipeline. It is fully functional over the typical pressure range found in the natural gas transmission pipelines in the West Virginia, Virginia, Pennsylvania, and Ohio areas. With the use of the PAMP, a full spectrum of acoustic signals can be recorded and defined in terms of acoustic energy in decibels.

Figure 1: The PAMP installed on Dominion Transmission pipelines.

I. Introduction

The Portable Acoustic Monitoring Package (PAMP) has been designed to record and monitor acoustic signals in high-pressure natural gas (NG) transmission lines. Of particular interest are the three acoustic signals associated with a pipeline fracture. The system is portable (less than 30 lbm) and can be used at all line pressures up to 1000 psig. The PAMP requires a shut-off valve equipped ½" NPT access port in the pipeline. It is fully functional over the typical pressure range found in the natural gas transmission pipelines in the West Virginia, Virginia, Pennsylvania, and Ohio areas. With the use of the PAMP, a full spectrum of acoustic signals can be recorded and defined in terms of acoustic energy in decibels.

II. Experimental

Hardware Required

TASCAM PS-5
Data Acquisition (DAQ) Center
Laptop Computer with DAQ-EZ DAQ Card Installed
PAMP Sensor Tree

Software Required

DAQ-EZ Professional, V 1.17
TASCAM PS-5, V2.04 (internal software)
Signal View, V 1.91

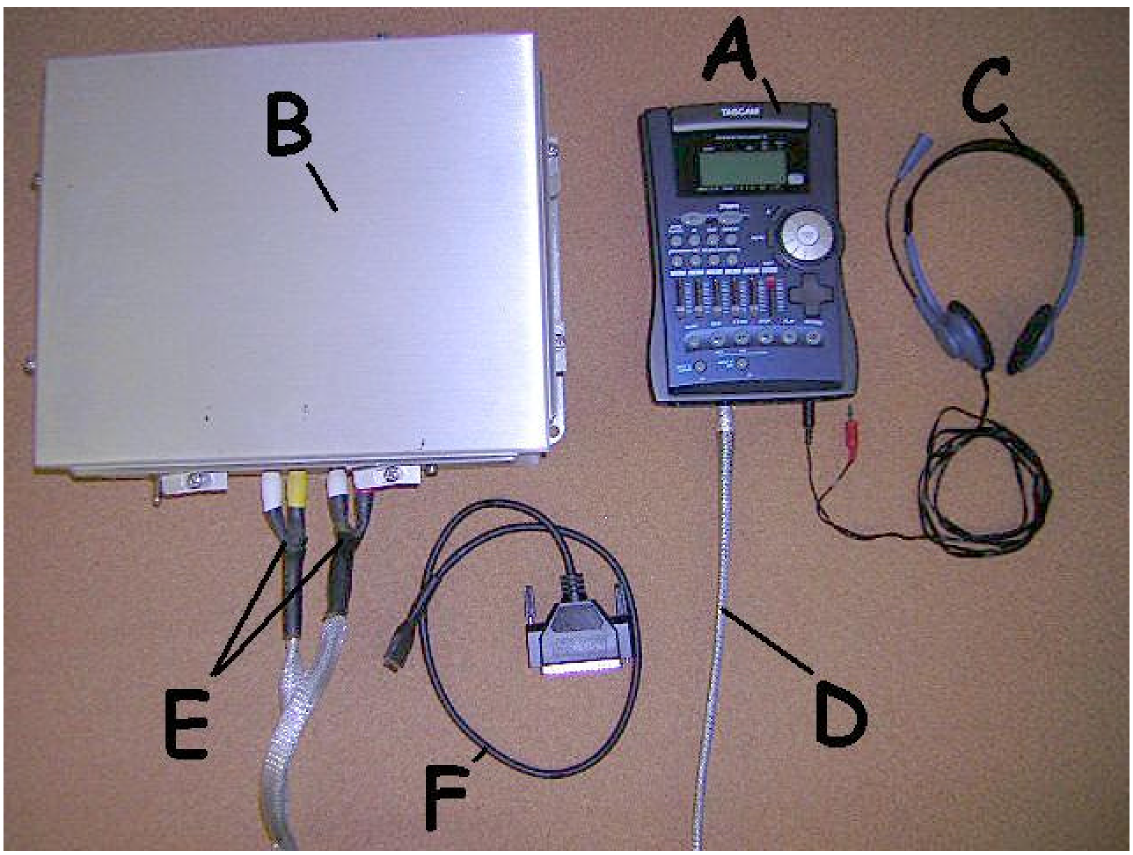

Figure 2: PAMP Hardware - DAQ Center and TASCAM PS-5.

A) TASCAM PS-5
B) DAQ Center
C) Headphones (optional)
D) ¼" Microphone Data Cable
E) ¼" Pressure Transducer Data Cables
F) 37-Pin Serial Data Cable

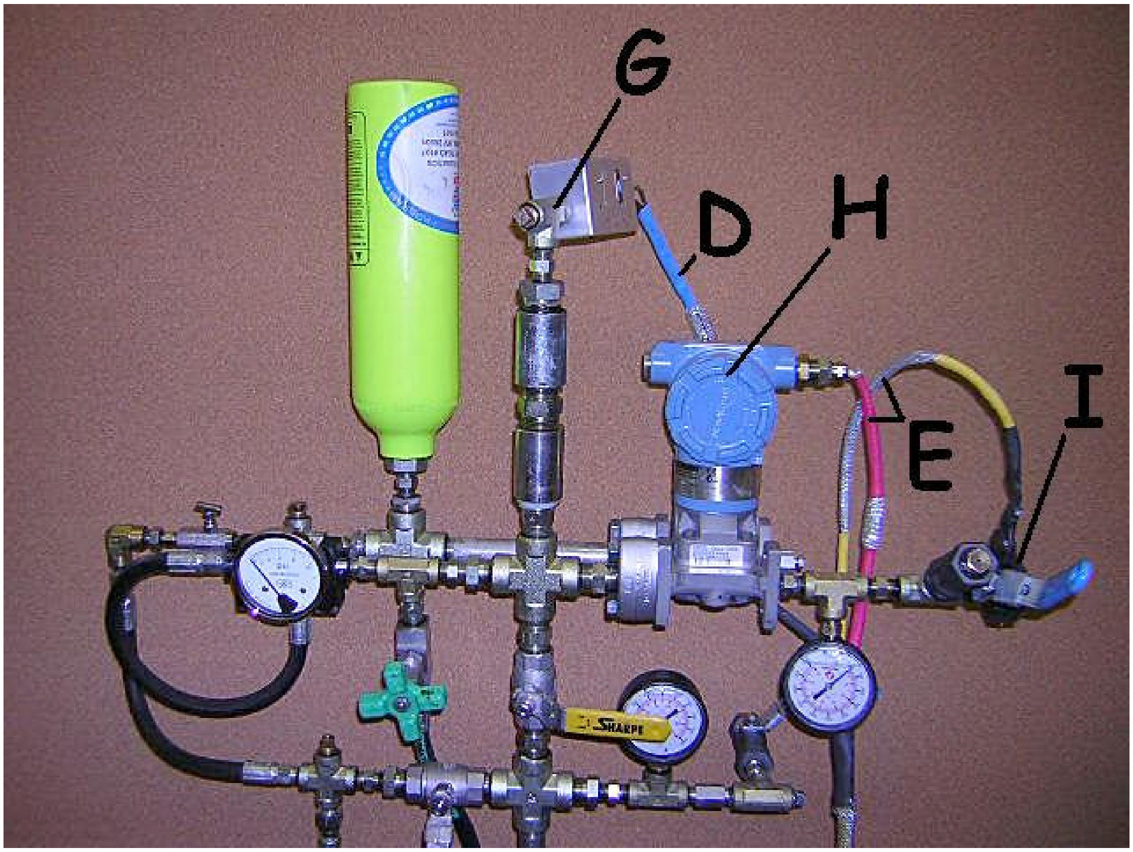

Figure 3: PAMP Hardware- Sensor Tree.

D) ¼" Microphone Data Cable
E) ¼" Pressure Transducer Data Cables
G) High-Pressure Microphone and Pre-Amplifier
H) Differential Pressure Transducer
I) Total Pressure Transducer

Hardware Settings

TASCAM PS-5 (Figure 2-A)

The TASCAM PS-5 has a variety of adjustable features. First, the physical switches available on the PS-5 will be covered.

On the front of the PS-5 (from left to right)…

- All of the gray fader switches (labeled "**1**", "**2**", "**3**", "**4**", & "**TG**") should be as far down as possible.
- The red fader switch (labeled "**MASTER**") should be as far up as possible.

On the top of the PS-5…

- The "**POWER**" switch should be in the "**ON**" position.

On the bottom of the PS-5 (from left to right)…

- The "**LINE**" rotary dial should be in the maximum position of "**10**".
- The "**MIC/LINE**" rotary dial should be in the maximum position of "**10**".
- The "**PHONES**" rotary dial can be adjusted to the operator's own comfort level since it does not affect the actual data recording level. If no headphones are being used, any position is acceptable for this dial.

On the right side of the PS-5 (from bottom to top)…

- The "**LINE**" switch should be set to "**LINE**" (switch should be as far up as possible).
- The "**BUILT IN MIC LINE**" switch should be set to "**MIC**" (switch should be in the center position).

Figure 4: Setting the switches on the TASCAM PS-5.

Data Acquisition (DAQ) Center (Figure 2-B)

The DAQ Center is used as both a power source for the PAMP sensors and as a central junction that adapts data input connectors to the appropriate data output connectors. This allows the PAMP to be quickly connected or disconnected during normal use. The DAQ Center has only one hardware setting requirement.
On the side of the DAQ Center…

- The "**ON OFF**" toggle switch should be set on "**ON**" during data recording sessions.
- The "**ON OFF**" toggle switch should be set on "**OFF**" while the PAMP is not being used to record data.

Laptop Computer with DAQ-EZ DAQ Card Installed

A portable computer is absolutely essential to the PAMP system. The DAQ-EZ data acquisition board should be properly installed on the computer, and adequate memory storage must be available to record any incoming data. Installation notes are available for both the DAQ-EZ card and its associated software in Appendix A: DAQ-EZ Installation. Aside from proper installation, the only hardware setting for the laptop computer is that the computer must be activated with a compatible soundcard.

PAMP Sensor Tree

The Sensor Tree is the part of the PAMP system that actually connects to the gas line using a standard pipe thread. Various sensors are hard-mounted to the Sensor Tree and are configured for high-pressure (up to 1000 psig) use. A pressure-equalized microphone is located at the top of the Sensor Tree to monitor sound in the line. A pressure transducer that monitors line total pressure and a differential pressure transducer that monitors relatively small fluctuations in line pressure are mounted on the side of the Sensor Tree. Before connecting the Sensor Tree to the gas line, it is imperative that the unit is checked for cracked or loose plumbing! All valves should be in the closed position prior to initial pressurization. Hardware settings for the Sensor Tree are as follows.

On the top of the Sensor Tree…

- The ¼" microphone output jack should be directly fitted with the microphone pre-amplifier (or pre-amp). The pre-amp has only one power switch, located on its side. The power should be turned to the "**ON**" setting during or just prior to data recording.
- When recording is complete, the pre-amp's power switch should be turned to the "**OFF**" position.

On the side of the Sensor Tree…

- During data recording, the valves of the Sensor Tree may be turned to a variety of settings to accommodate optimal recording levels.
- When the PAMP is not being used to collect data, all Sensor Tree valves should be returned to the closed position to prevent sudden pressurization during the subsequent test.

Connecting the Hardware

Once all hardware settings have been properly selected, cable connections must be made between the components of the PAMP to facilitate data transfer. A wiring schematic of these connections is shown in Figure 5.

Connecting the Sensor Tree to the DAQ Center…

- Connect the yellow 4-pin female plug to the total pressure transducer.
- A red cable is already hard wired in to the differential pressure transducer.
- Connect the white/yellow pair of ¼" male plugs into the side of the DAQ Center. The corresponding female plugs are labeled "**TPT (wht)**" and "**TPT (yel)**". (See Figure 6)
- Connect the white/red pair of ¼" male plugs into the side of the DAQ Center. The corresponding female plugs are labeled "**DPT (wht)**" and "**DPT (red)**". (See Figure 6)

Connecting the Sensor Tree to the PS-5…

- Connect the blue ¼" female plug to the ¼" male plug of the microphone pre-amp.
- Connect the blue ¼" male plug to the ¼" female plug on the PS-5 labeled "**MIC/LINE**".

Connecting the DAQ Center to the laptop computer…

- Connect the 37-pin serial connector to the circuit board located in the DAQ Center. Tighten both screws hand tight.
- Connect the 37-pin male connector to the DAQ-EZ card located on the side of the laptop.

Connecting the PS-5 to the laptop computer…

- Connect the appropriate end of the USB interface cable to the top of the PS-5.
- Connect the opposite end of the USB cable to the USB port of the computer (usually located in the back or side of most laptops).

Connecting the optional headphones…

- Connect the 1/8" male plug of the headphones to the 1/8" female plug (labeled "**PHONES**") of the PS-5. *Note:* When using the TASCAM headphone with the available headset microphone, *do not* connect the red 1/8" male plug labeled "**MIC**".

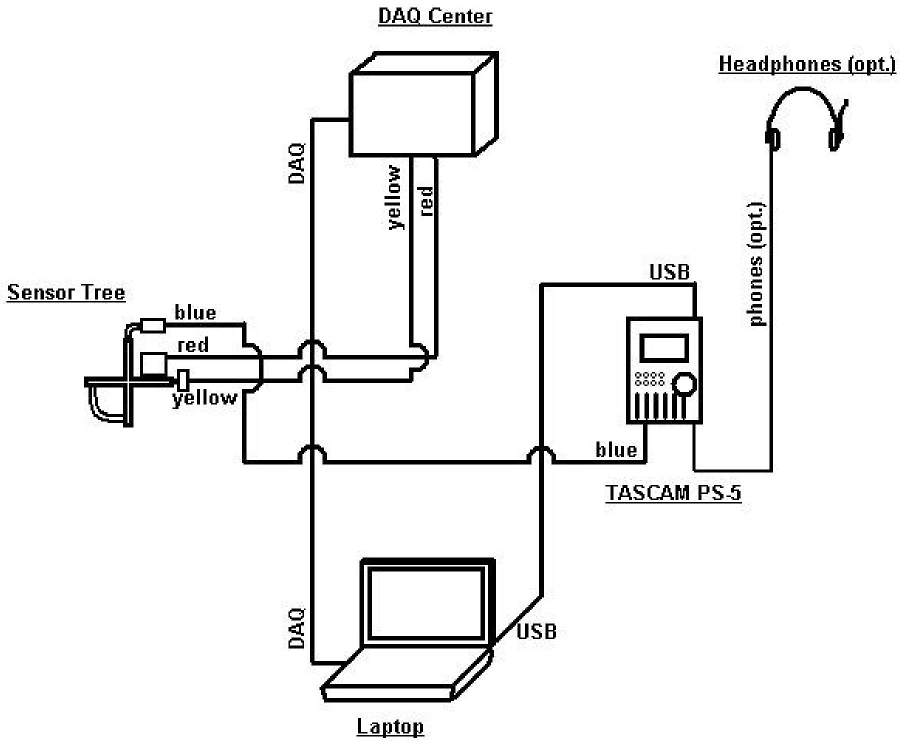

Figure 5: Hardware wiring diagram.

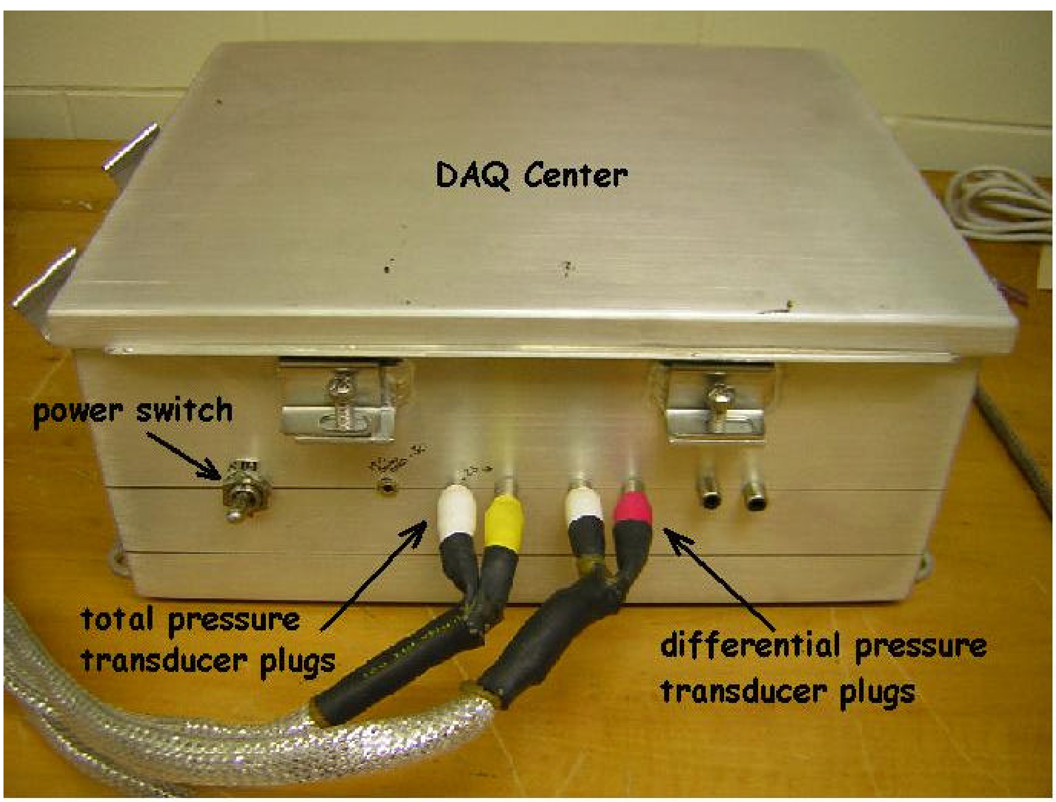

Figure 6: DAQ Center shown with transducer data cables.

Software Settings

There are two main categories of software required by the PAMP. The first is a data collection type software that records the analog voltage signals of various sensors. With the push of a button, the software begins recording from all three sensors over a preset time interval. Discrete values are recorded digitally, usually using binary code. The second type of software used by the PAMP system is an analytical program for data analysis. This software has the ability to use many different mathematical algorithms to "filter" raw data so that it can be analyzed. The PAMP uses DAQ-EZ Professional and the PS-5's built in software to convert analog signals to recorded digital files. The PAMP system then uses Signal View to obtain meaningful data "signatures" which can be easily interpreted by the operator.

DAQ-EZ Professional, V1.17

Creating the Virtual Circuit…

We will begin by setting up the simple schematic required to perform the data collection. In general terms, we want to connect a virtual circuit. This means that we need a source (the DAQ card) that sends signals to a file ("**Save Disk**"). While this is occurring, we may as well see what it is recording, so we can also hook up a virtual digital meter ("**Digital Meter**") to the circuit.

- From the Windows Desktop, select the "**DaqEZ Professional**" icon.
- From the DaqEZ Professional window, select "**File**", then select "**New Project**"
- In the left hand column (under "**Source**"), select the "**DAQP 208H**" icon. *Note:* This will bring up a small box labeled "**DAQP-208H**" inside the program window, and the left hand column will show many new icons.
- From the left hand column, select the "**Digital Meter**" icon. *Note:* This will bring up another small box in the program window labeled "**DigMet 1**".
- From the left hand column, select the "**Save Data**" icon. *Note:* This will bring up yet another small box in the program window labeled "**SaveDisk 1**".
- Repeat the previous step by selecting the "**Save Data**" icon again. *Note:* This time, the small box that comes up will be labeled "**SaveDisk 2**".
- Click and drag the two SaveDisk boxes and the DigMet box so that the terminals on their left sides (labeled T0, T1, T2, etc.) can be cleanly connected to the right side channel outputs of the DAQP-208H box (labeled CH00-00, CH01-00, etc.). *Note:* Refer to Figure 7 for more help.

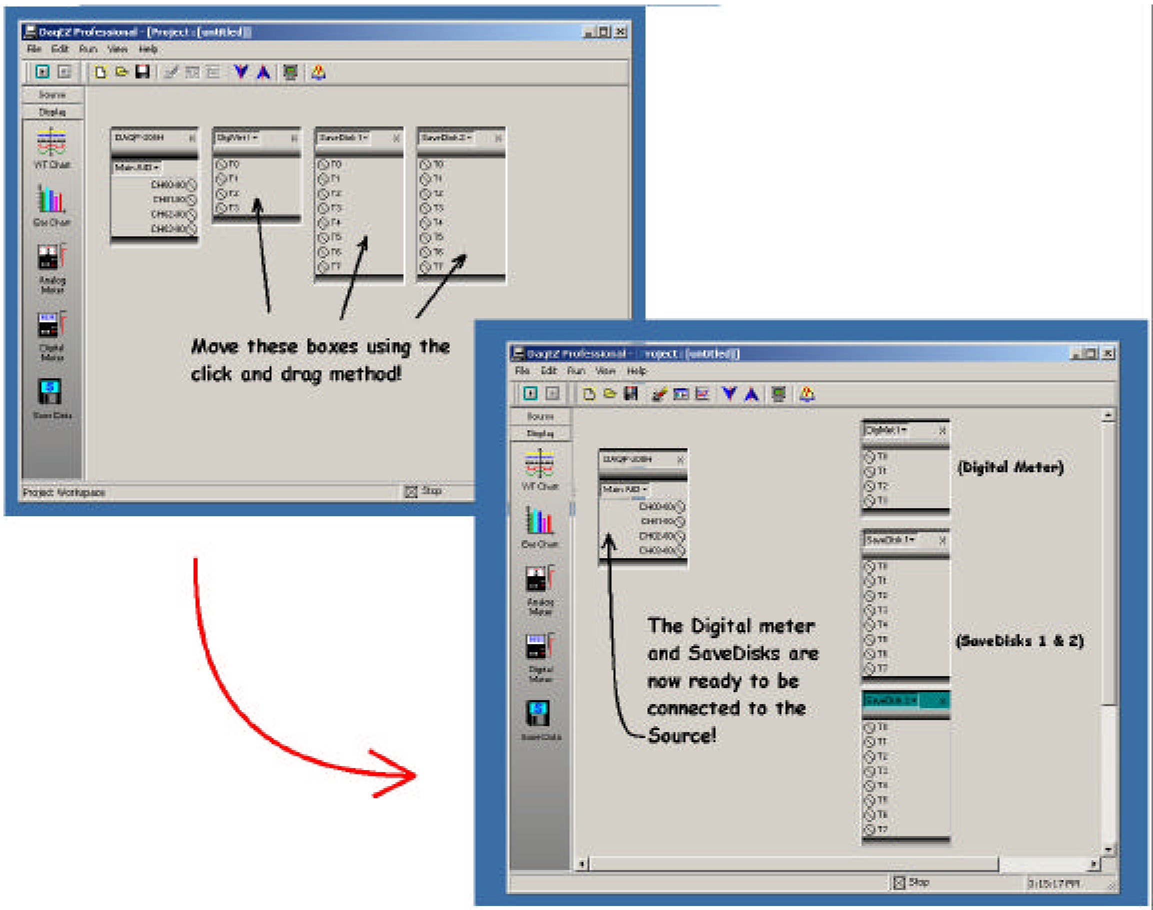

Figure 7: DAQ-EZ virtual circuit preparation.

- Now connect the terminals of the boxes by left clicking on a terminal block (T1, T2,…,TX) and then left clicking on the channel blocks (CH00-00, CH01-00,…, CH0X-00). Once the channel block is left clicked, the thin straight black line coming from the terminal block becomes a thick bent green line. *Note:* After successful completion of a connection, the terminal block label changes from TX to CH0X-00. See Figure 8 for more help.
- Connect the terminals in exactly this way: From "**DigMet**"- Connect T1 to CH01-00, connect T2 to CH02-00. From "**SaveDisk 1**"- Connect T0 to CH01-00. From "**SaveDisk 2**"- Connect T0 to CH02-00. *Note:* As the terminals from the "**DigMet**" box are connected, a small meter window will appear. Likewise, as the terminals from the "**SaveDisk X**" boxes are connected, small file save windows appear.

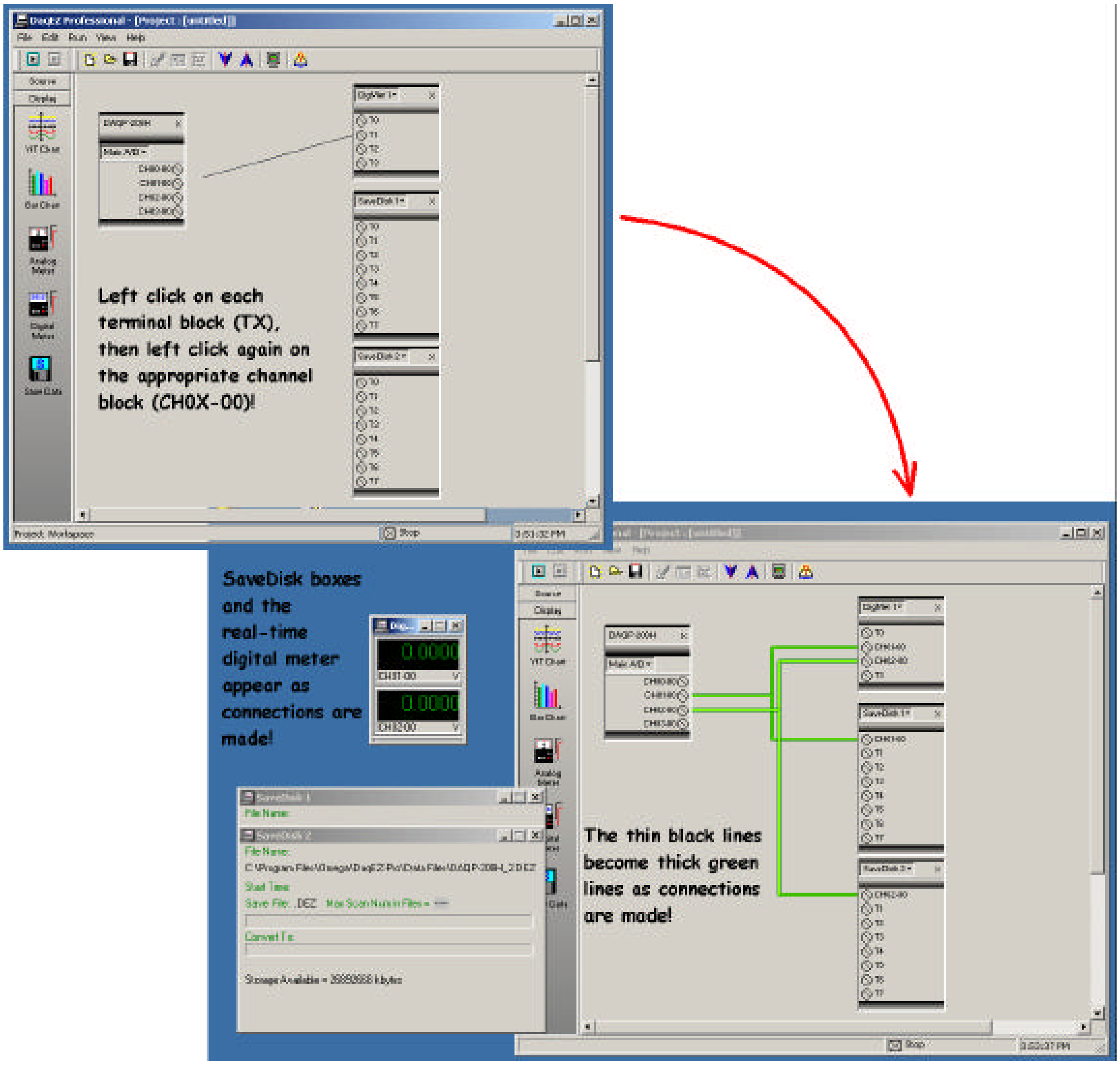

Figure 8: Complete DAQ-EZ virtual circuit.

Setting the Scan Rate…

Now that the circuit has been constructed, it is time to fine-tune the specific sampling rate with which we acquire digitized signals from the DAQ-EZ software. Too high a sampling rate will lead to very large data file sizes, but too low a sampling rate can lead to inaccurate data. For the purpose of the total and differential pressure transducers, a sampling rate of 10 samples per second (10 Hz) is ideal.

- With the schematic in plain view, double click on the blank spot just to the left of the channel blocks on the small "**DAQP-208H**" box (see Figure 9). *Note:* A window should appear titled "**A/D Request Information**"

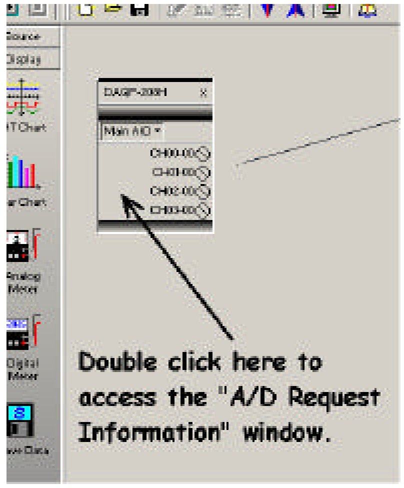

Figure 9: Accessing DAQ-EZ's adjustable sampling rate menu.

- In the "**A/D Request Information**" window under "**Scan Settings**", click on the down arrow of the upper box. From the drop menu, select "**Scans / Second (Hz)**".
- Now click and hold on the sliding needle selector just below the box you were just at. Move the needle sideways to the left side of the box so that the number above it gets to "**10**" (see Figure 10). *Note:* It may be difficult to get the needle exactly at "**10**" with the mouse. You can use the keyboard directional keys once you get close to "**10**" to avoid over or undershooting. For reasons that will be explained later, you must make a note of the sampling frequency with which you are recording.
- Click on "**OK**". *Note:* Remember to write down your sampling rate!

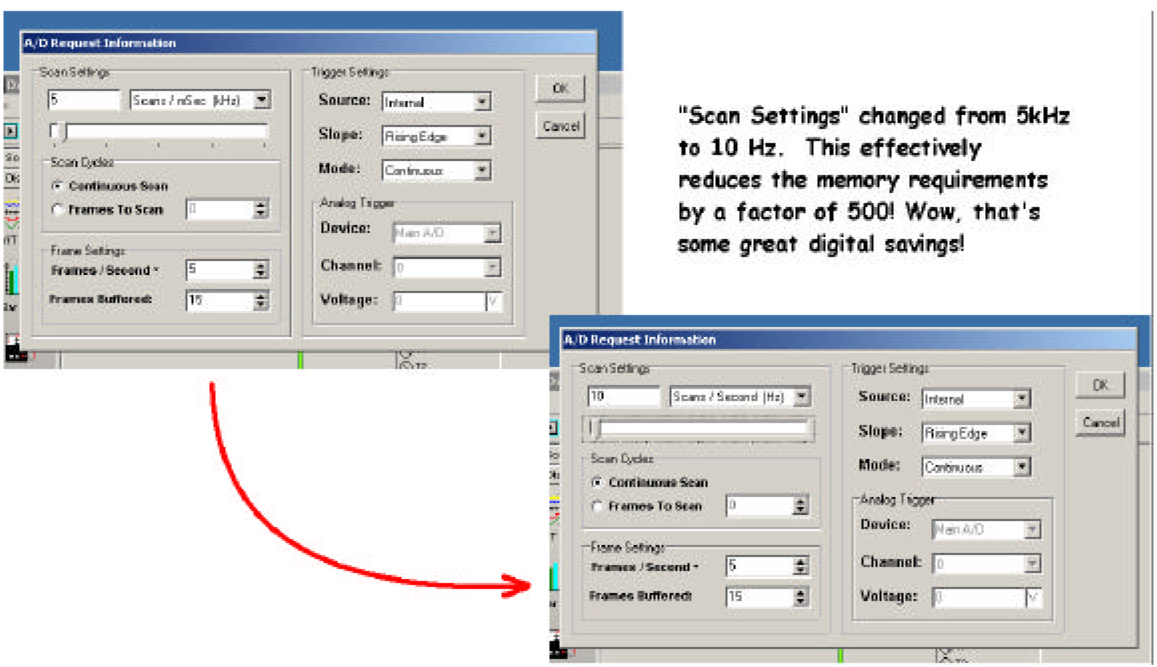

Figure 10: Adjusting the data acquisition sampling rate.

Naming Saved Files…

Finding the stored data for different test runs can become a problem if DAQ-EZ is allowed to automatically name your files. Giving the file a particular name will allow the operator to quickly find the specific sample. To name a file, perform the following steps.

- With the schematic in plain view, double click on the blank spot just to the right of the terminal blocks on the small "**SaveDisk X**" box. *Note:* This will bring up a window titled "**SaveDisk X Configuration**". (See Figure 11)
- Click inside the box labeled "Data File Name" and enter the file name you wish to save as.
- Click "**OK**". *Note:* If the file name you have chosen already exists, DAQ-EZ will alert you and allow you the option to overwrite it or change the file name.

Setting Up Files for ASCII Format…

DAQ-EZ's system of file storage (in particular its file type system) makes it very hard to read the file with anything other than DAQ-EZ software. Since the PAMP system uses Signal View to analyze the stored data, a common file type is needed. To do this, we need to set DAQ-EZ so that it can record in ASCII format. As will be seen later, Signal View has the ability to read this type of file. For ASCII formatting, perform the following steps.

- Access the "**SaveDisk X Configuration**" window (see Naming Saved Files…).
- Click in the box labeled "**ASCII Format (.TXT)**" (see Figure 11). *Note:* This will make a small check mark appear in the box.
- Click "**OK**".

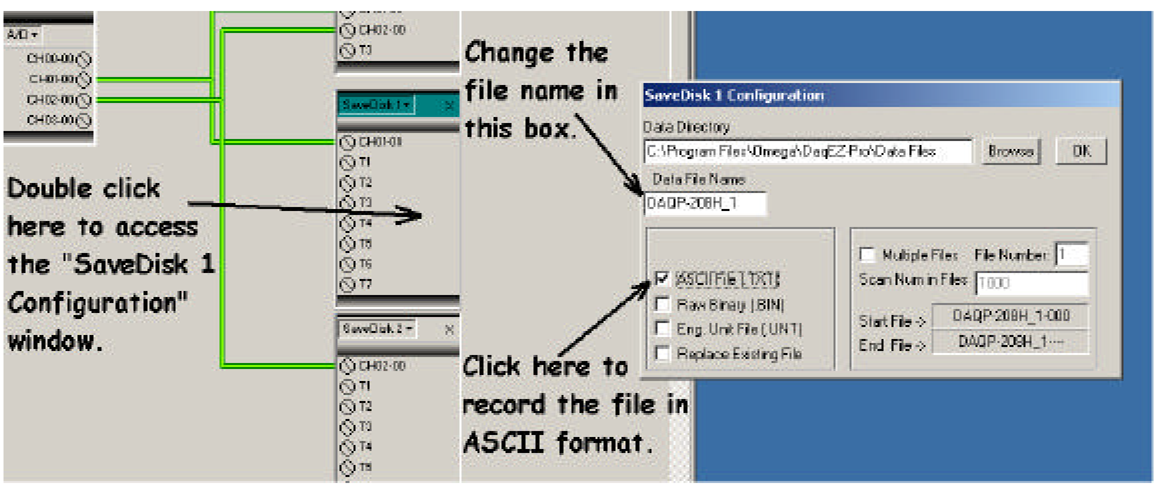

Figure 11: DAQ-EZ allows the user to record in common ASCII format.

TASCAM PS-5 Internal Software

The internal software available on the TASCAM PS-5 is the second of the two data recording programs used in the PAMP system. Starting the PS-5 digital recorder is a relatively simple procedure. Once the power to the unit has been turned on, follow these steps to configure the software. For additional help, refer to Figure 12.

Creating and Saving MP3 Files…

- Turn the power switch to "**ON**". *Note:* The screen will display "**TASCAM PS 5 V2.04**", then "**Card Inserted!**", then "**Song Loading…**".
- After startup, the screen will display a timer in the upper right hand corner and "**SONGX**" on the left hand side of the screen. Press the "**MP3**" button located under the screen. *Note:* After displaying "**MIX TO MP3 mode…**", the "**MP3**" button will flash red while the screen shows "**Create MP3 Name Þ STMIX Sure?>>[ENTER]**". "**STMIX**" is the factory default name of the new MP3 file, but this name is easy enough to change.
- Using the pointer cross, move the cursor to each letter position that you wish to change. To change a letter, simply rotate the silver dial located above the pointer cross. Rotating clockwise will go forward in the alphabet while rotating counterclockwise will go backward. Once the file name has been selected, simply push the "**ENTER/YES**" button located in the center of the silver dial to confirm the new name. *Note:* After pressing "**ENTER/YES**", the "**MP3**" button will be steadily lit red and the screen will display the new file name along with the timer.
- Press the "**PLAY**" and "**RECORD**" buttons located at the lower right corner of the PS-5 to begin recording. *Note:* While recording, the "**PLAY**" button will be lighted green and the "**RECORD**" button will be lighted red. See Hardware Settings and Connecting the Hardware to ensure proper setup before you record.
- Press the "**STOP**" button to finish recording. *Note:* When "**STOP**" is pushed, the screen will display the name of the file at the top of the screen. Below this the screen will display "**Record again? Sure?>>[ENTER]**". If you wish to overwrite the last sample taken with a new sample of the same file name press "**ENTER/YES**". To save the file press the "**EXIT**" button located near the 7 o'clock position of the silver dial. Remember, if you wish to keep the sample you just recorded, you must push "**EXIT**".
- After "**EXIT**" has been pushed, the "**MP3**" button will be steadily lit green to indicate "**MP3 PLAY mode…**". In this mode, the file can be played back through the headphones to review the sample.
- After each file is recorded, it will be necessary to toggle the "**MP3**" button back to MP3 recording mode. *Note:* If you try to create a new MP3 file using a preexisting filename, the PS-5 will alert you that the file already exists. You will then have the option to overwrite the old file or rename the new file.

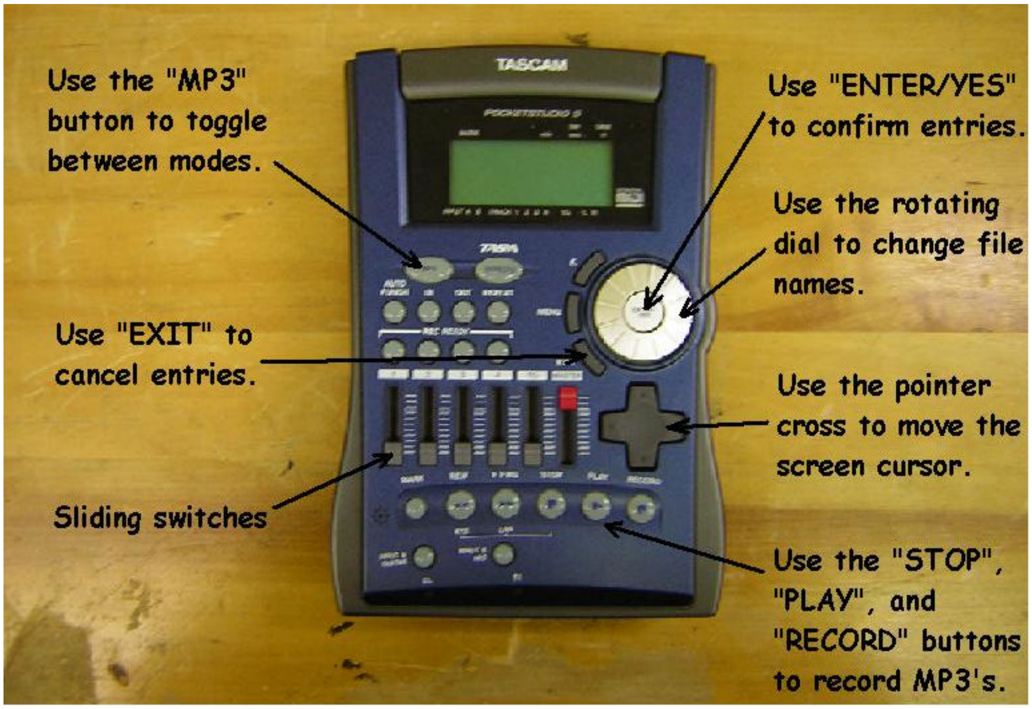

Figure 12: Front view of the TASCAM PS-5.

Transferring and Deleting Saved MP3 Files from the PS-5 to the Laptop…

- Turn the PS-5 power switch to "**OFF**". Make sure that the USB interface cable has been properly installed (see Connecting the Hardware for more details).
- While holding the "**ENTER/YES**" button down, turn the power switch back to "**ON**". *Note:* After a few seconds, the screen will display "**USB MODE**".
- The laptop will automatically detect the PS-5's internal memory as a removable drive- all you must do now is access the appropriate drive letter from the Windows My Computer window.
- Double click on the folder labeled "**MP3**" to copy and/or delete your recorded MP3 files from the PS-5. *Note:* Be sure to copy these files to an easily recognizable folder on the computer's hard drive to avoid losing your data. It is also recommended that you do not delete MP3 files from the PS-5 until you have verified the condition of the copied MP3 files on the computer's hard drive.

Signal View, V1.91

Signal View is used by the PAMP system to analyze the data recorded earlier by both the DAQ-EZ and PS-5 software. While perhaps the most difficult of the three programs to operate, Signal View is quite a powerful tool that allows the operator to use various techniques to characterize digitized data. Let's get started.

- From Windows Program Files, select the "**Sigview**" icon.
- Click on "**Start SIGVIEW**".

Opening Files Recorded by DAQ-EZ (as shown in Figure 13)…

- From the top of the Sigview main window, select "**File**".
- Place the mouse pointer over "**ASCII files…**".
- Select "**Import signal…**".
- To access the files recorded by DAQ-EZ, look in **C:\Program Files\Omega\DaqEZ-Pro\Data Files**. *Note:* In this folder, there will be three files listed with the same filename but different file types. The first listed is strictly used with DAQ-EZ software and is a .DEZ file type. The second is a DAQ-EZ version of an ASCII file and is a .TX^ file type. The third is a pure ASCII file and is a .TXT file type. This last file type is the one that Signal View can understand.
- Double click on the file you would like to view, making sure that it is a .TXT file type. *Note:* This will bring up a small box titled "**Sample rate**".
- Enter the sample rate (or "**scan rate**") that you used during recording sessions with the DAQ-EZ software. *Note:* See Software Settings, DAQ-EZ Professional V1.17, Setting the Scan Rate… for more details
- Click "**OK**".

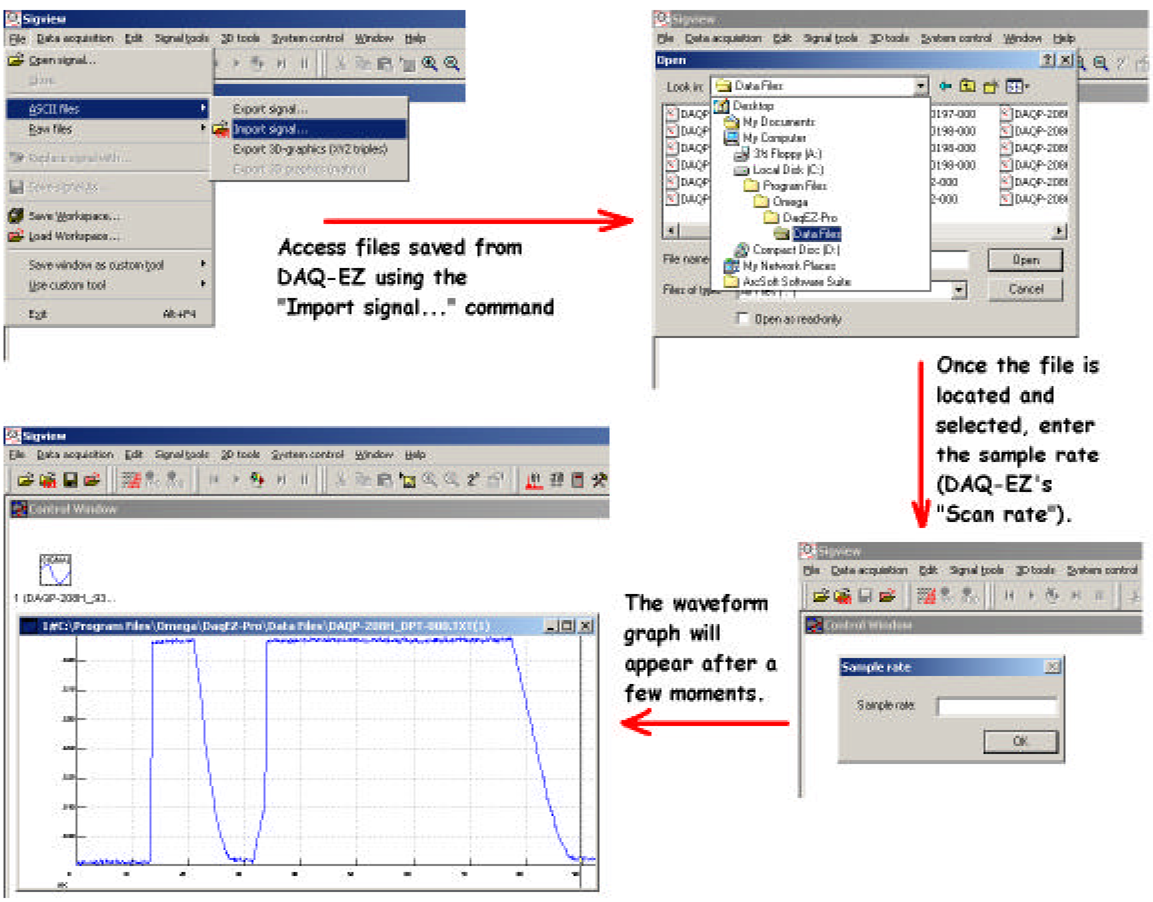

Figure 13: Opening ASCII files in Signal View.

Opening Files Recorded by the TASCAM PS-5 (as shown in Figure 14)…

- From the top of the Sigview main window, select "**File**".
- Select "**Open signal…**"
- Go to the folder on the hard drive in which your MP3 files are stored. *Note:* To see the MP3 files in the file select window, it will be necessary to change the "**Files of type**" drop down menu so that "**MPEG Audio Layer III (.MP3)**" is shown in the box.
- Double click on the file you wish to open.

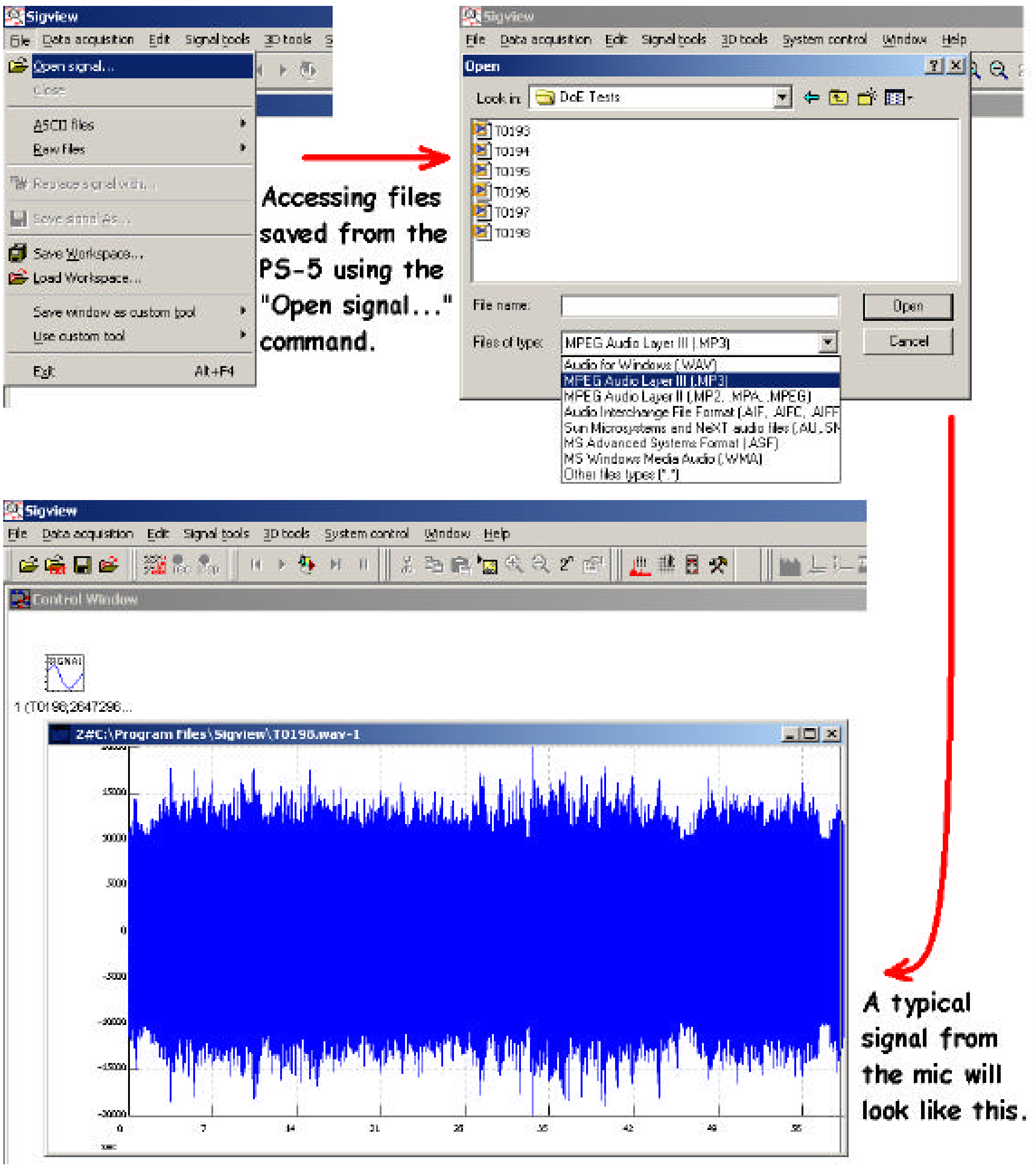

Figure 14: Opening MP3 files in Signal View.

Preparation of the PAMP

After reviewing the procedures for the setup of the PAMP system, preparation for gas line acoustic monitoring is relatively simple. Begin by looking at the parts of the system in a checklist format.

Connect the Hardware…

- Set up the DAQ Center, laptop computer, and TASCAM PS-5 on a rigid surface at least 15 ft from the intended Sensor Tree gas line mount location.
- Thread the Sensor Tree into the gas line tap. *Note:* You must use a high-pressure pipe joint compound when connecting the plumbing. Permatex 51H Pipe Joint Compound is recommended. Be sure that all valves on the tree are in the closed position before mounting.
- Connect the three color coded data cables to the Sensor Tree.
  - Blue connects to the microphone pre-amp.
  - Red is pre-wired to the differential pressure transducer.
  - Yellow connects to the total pressure transducer.
- Connect the red and yellow data cables to the DAQ Center. *Note:* See Connecting the Hardware for more details.
- Connect the blue data cable to the PS-5. *Note:* See Connecting the Hardware for more details.
- Connect the DAQ cable between the DAQ Center and the laptop.
- Connect USB cable between the PS-5 and the laptop.
- Connect the headphones to the PS-5 (Optional).

Powering Up the PAMP System…

- At the Sensor Tree, turn the microphone pre-amp power switch to "**ON**".
- Turn the laptop on.
- Turn the TASCAM PS-5 on.
- At the DAQ Center, turn the power switch to "**ON**".

Prepare the Software for Signal Recording…

- Refer to Software Settings while performing the following steps for more detailed information.
- On the laptop, load and prepare DAQ-EZ for data acquisition.
- On the PS-5, load and prepare the device for MP3 data acquisition.

That's it! You are now ready to begin recording gas line acoustic signals!

Recording Data

Now that the PAMP system is properly connected and powered up, you may begin recording. To start recording the pressure transducer signals, click on the play button of the DAQ-EZ software. The play button is located in the upper left corner of the program's main window. Just as you are clicking on DAQ-EZ's play button, press the "**PLAY**" and "**RECORD**" buttons of the PS-5 simultaneously.

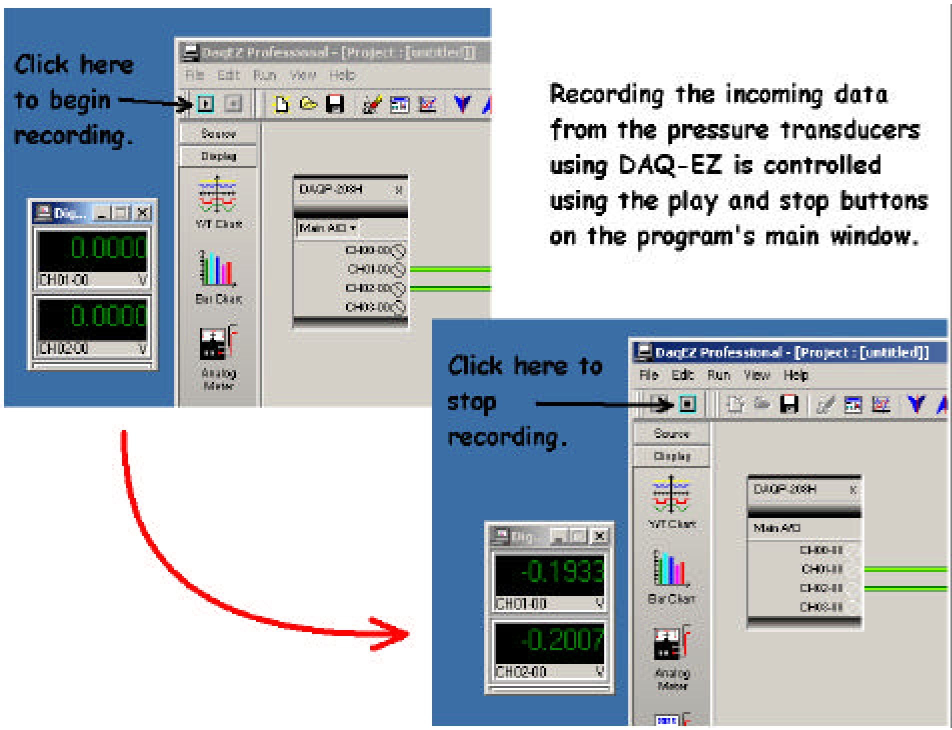

Figure 15: Recording files with DAQ-EZ.

Figure 16: Recording files with the TASCAM PS-5.

Analyzing Data

Now that you have the files saved from the recording software, Signal View can be used to analyze the data. It is important to keep in mind that although Signal View allows quick access to key information about a string of data, it is the job of the operator to critically evaluate that information. Some minor equations will be given later on to help in this evaluation process.

Opening Signal View/Opening Files in Signal View…

- See Software Settings, Signal View, V1.91 for a detailed procedure list.

Looking at Waveform Graphs (as shown in Figures 17 and 18)…

Once a graph has been opened on Signal View's main window, you will need to decide what part(s) of the graph are of importance. Pressure graphs can be read directly from Signal View's initial intensity-versus-time setup. Investigating acoustic waves, however, requires the additional step of performing a Fast Fourier Transform (FFT) analysis. This is done in Signal View by first highlighting a section of the initial graph and then selecting "**FFT**" from the "**Signal tools**" menu. Within a few seconds, an intensity-versus-frequency graph will appear showing the different frequency components of the original highlighted section.

On any Signal View graph the specific y value of a peak or trough can be determined relatively quickly by first highlighting the area of interest and then using the zoom function. Follow the proceeding steps to find output values of interest.

- Left click, hold, and drag the mouse pointer along the waveform to highlight the peak(s) of interest.
- Release the left mouse button to end highlighting.
- While the mouse pointer is inside the highlighted section, right click to access the scrolling options menu.
- Click on "**Zoom In**". *Note:* A new zoomed in waveform will appear after clicking "**Zoom In**". You may continue the same procedure multiple times to achieve the desired view of the waveform.
- Moving the mouse along the waveform produces a vertical black line indicating the mouse pointer's x position on the waveform. Another smaller horizontal line will appear that crosses the vertical black line and the nearest y value of the recorded data point. The value of the x and y coordinates is given in the lower right hand portion of the Signal View window.
- Zoom out of the close up view by simply right clicking anywhere on the graph and selecting "**Zoom Out**" from the scrolling options menu.

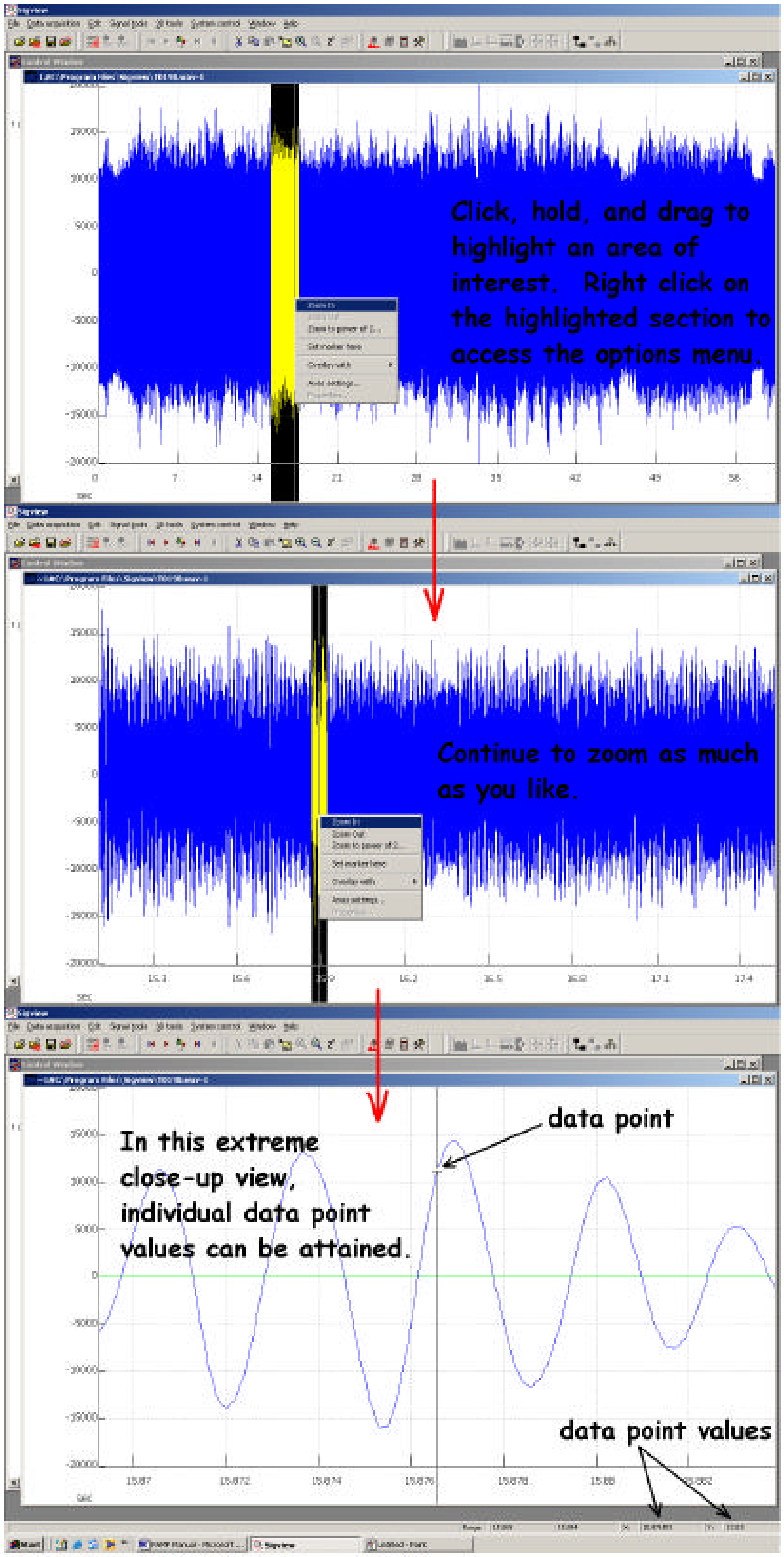

Figure 17: Close-up examination of waveforms in Signal View.

Preparing an FFT Analysis...

Acoustic signals from the microphone can best be analyzed using Signal View's built in FFT tool. This allows the operator to characterize specific acoustic signals in a format that is easily identifiable. Complete the following steps to produce an FFT graph.

- Highlight a section of the intensity-versus-time graph as discussed in the previous section.
- Click on "**Signal tools**" at the top of the main window.
- Click on "**FFT**". *Note:* Signal View may take several seconds to perform the requested calculations.
- A new graph will appear showing intensity plotted along increasing frequency rather than time.

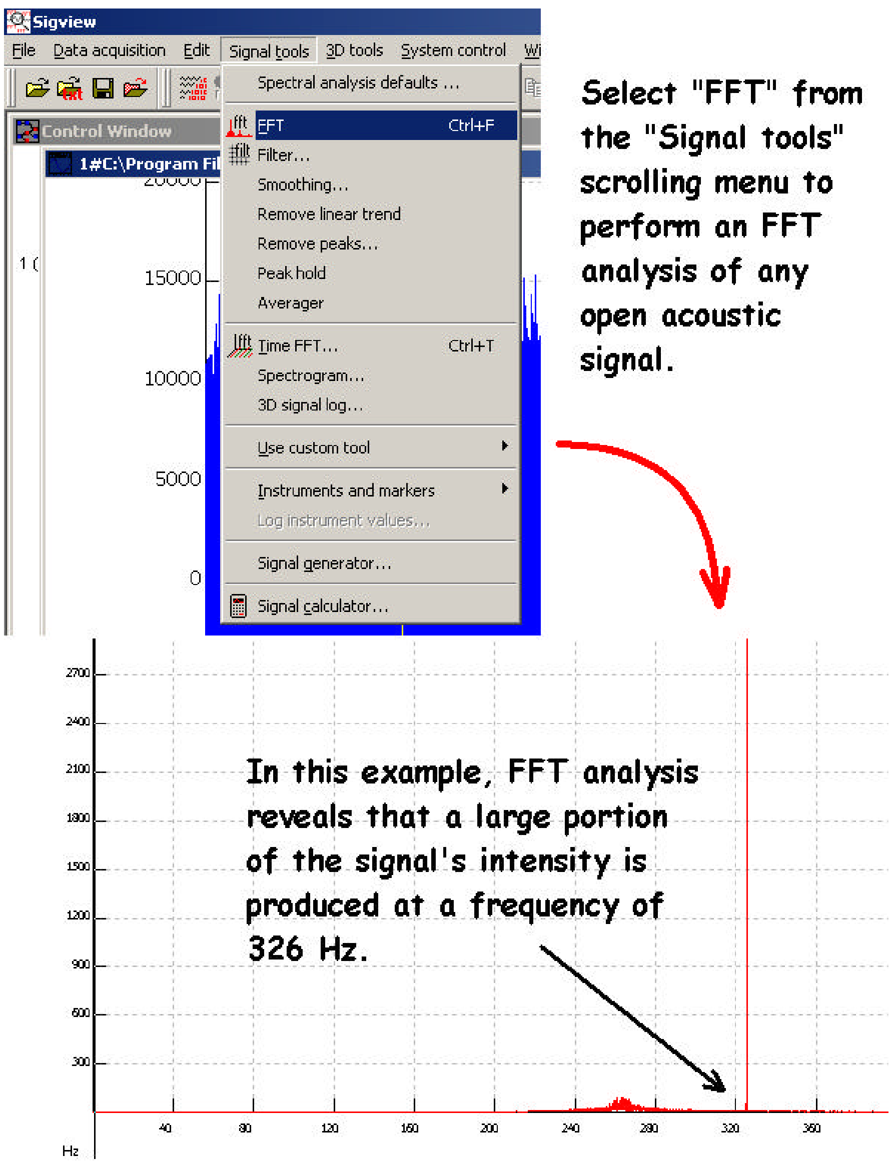

Figure 18: Sample result of Signal View's FFT analysis.

Interpreting Waveform Graphs…

The x and y coordinate values given for each data point in Signal View must be interpreted separately. All x values can be taken exactly as they are displayed: initial intensity-versus-time graphs show all x values in terms of time in seconds while intensity-versus-frequency graphs show all x values in terms of frequency in Hertz. Y values, on the other hand, must be translated directly into volts. Pressure can then be determined based on the new voltage output. It is also possible to change the voltage output into terms of decibels, a useful unit when examining the output of the microphone.

Changing Signal View's numbers into a more useful format requires the introduction of a few simple formulae. The linear relationship between Signal View units (svu's) and volts (V) is as follows.

$$1 \text{ V} = 3266 \text{ svu}; \; 1 \text{ mV} = 3.266 \text{ svu} \quad \textbf{(1a)}$$

$$1 \text{ svu} = 0.0003062 \text{ V}; \; 1\text{svu} = 0.3063 \text{ mV} \quad \textbf{(1b)}$$

Voltage output from the total pressure transducer (V_T) may be changed to pressure (P_T) using the following equation.

$$P_T \text{ (psig)} = [V_T \text{ (Volts)} - 0.7837] / 0.005 \quad \textbf{(2)}$$

Graphs and conversion tables of the above formulae are also available in Appendix B: Unit Conversion.

Copying Waveform Graphs…

It may be beneficial to copy Signal View graphs for later review. To copy a graph, place the mouse pointer over "**Edit**" at the top of Signal View's main window. Select "**Copy picture to clipboard**" from the scroll down menu. Now that the graph is on the clipboard, it is possible to paste the image in many different programs including MS Word, Excel, or Paint (see Figure 19).

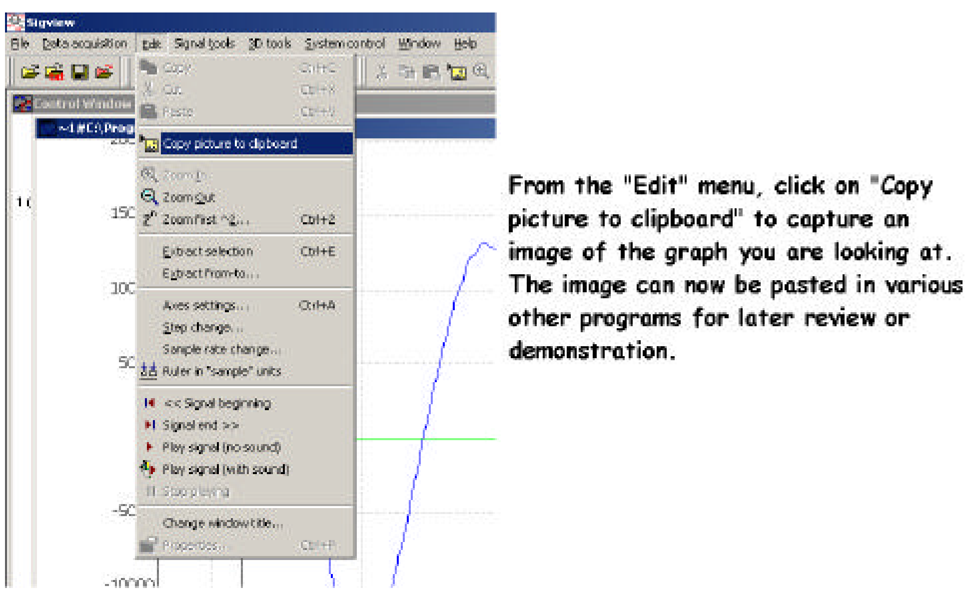

Figure 19: Copy and paste waveform images to outside documents.

Comparing Waveform Graphs…

Graphs can be overlapped using Signal View's overlay function. To put two or more sets of data on the same graph, perform the following procedure (see Figure 20).

- Open all the data files that you wish to compare.
- Right click on any of the graph windows to access the scrolling option menu.
- Place the mouse pointer over "**Overlay with**" to reveal a menu of all open data files in the Signal View window.
- Click on the file(s) you want to overlap the file you are currently looking at.

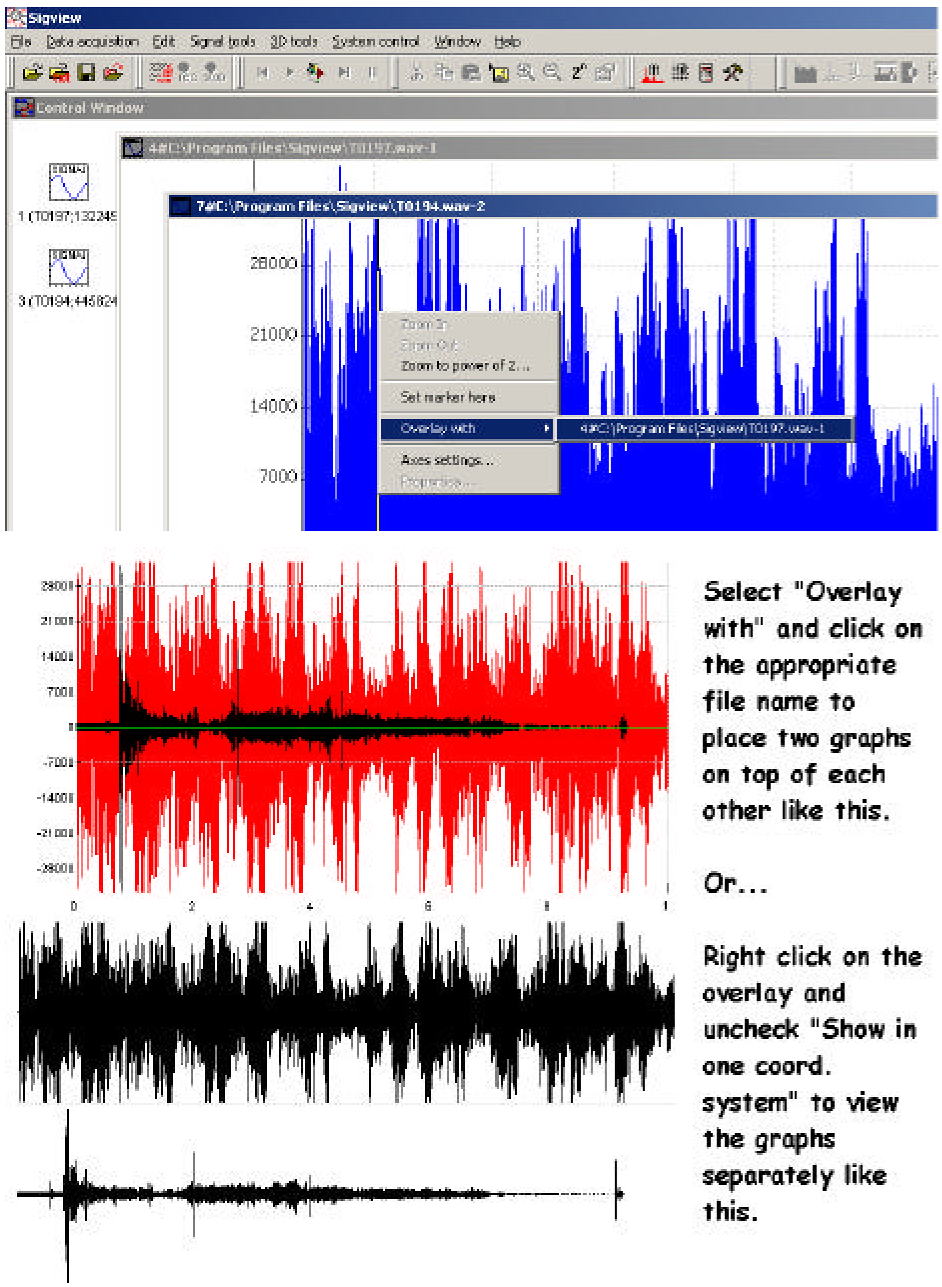

Figure 20: Waveform images can be overlapped or displayed side by side.

DAQ-EZ Installation

Installation of the DAQ-EZ software onto the laptop computer will require the following items:

- Omega data acquisition card ("**DAQP-208H-OM**")
- Omega "**DaqSuite Data Acquisition Software**" CD
- Driver update for DAQ-EZ ("**DAQPDRV.sys**")

Begin installation by placing the software CD into the CD drive of the computer. Follow all the onscreen instructions and setup procedures. After installation, slide the DAQ-EZ hardware card labeled "**DAQP-208H-OM**" into the PCMCIA port on the side or back of the computer. Windows will now be able to recognize the new hardware and will attempt to auto configure it for use. It will now be necessary to "patch" one of the driver files from the original disk. Copy the file "**DAQPDRV.sys**" from the CD labeled "**DAQ-EZ Driver Patch**" to the following location: **C:\WINNT\SYSTEM32\DDRIVERS**. A window will appear notifying you that the file already exists. This is not a problem, just overwrite the existing file. If this patch is not completed, DAQ-EZ will not be able to recognize any data coming from an outside source.

The DAQ-EZ software may not be able to auto configure correctly on the laptop. If this occurs, you will need to manually configure the hardware so that data may be acquired. Manually configure the card by performing the following steps.

Finding the Correct Configuration Information (as shown in Figure A.1)…

- From the Windows main window, click on the "**Start**" menu.
- Place the mouse pointer over "**Settings**".
- From the "**Settings**" scroll menu, select "**Control Panel**".
- Double click on the "**System**" icon.
- From the System Properties window, click on the "**Hardware**" tab.
- Click on the "**Device Manager…**" button.
- Double click on "**Data_Acquistion**".
- Double click on "**Omega DAQP-208H: PCMCIA 12-bit High Gain Analog I/O**".
- From the pop-up window, click on the "**Resources**" tab.
- Look under "**Resource Settings:**" for the interrupt request (IRQ) and input/output range (base address) numbers. *Note:* The IRQ is typically a two-digit number (e.g. "03") and the base address is usually shown as a range between two hexadecimal numbers (e.g. "DFF0-DFFF"). Use only the first hexadecimal number listed in the given range for your base address.
- Write these numbers down so that you can type them in the next few steps.
  - Interrupt Request (IRQ): ____________
  - Input/Output Range (base address): ____________
- Close all open windows and return to the Windows main screen.

Entering the Configuration Information (as shown in Figure A.2)…

- Double click on the "**DAQDRIVE Config Utility**" icon.
- From the DAQDRIVE Configuration Utility window, right click on "**Computer**".
- Place the mouse pointer over "**Add Board**".
- From the Add Board scroll menu, highlight and click on "**DAQP-208H**".
- Right click on "**BOARD: DAQP-208H**".
- Click on "**Configure…**".
- In the "**General Configuration**" menu, click the "**USE AUTO CONFIGURATION**" checkbox to remove the check mark. *Note:* When the box is unchecked, the first uppermost box below will become white to indicate that it is ready for user input.
- Type in the base address and IRQ as it was listed in "**Resource Settings:**".
- Click on "**OK**" at the bottom of the menu to confirm the new settings.

That's it! DAQ-EZ is now ready for action!

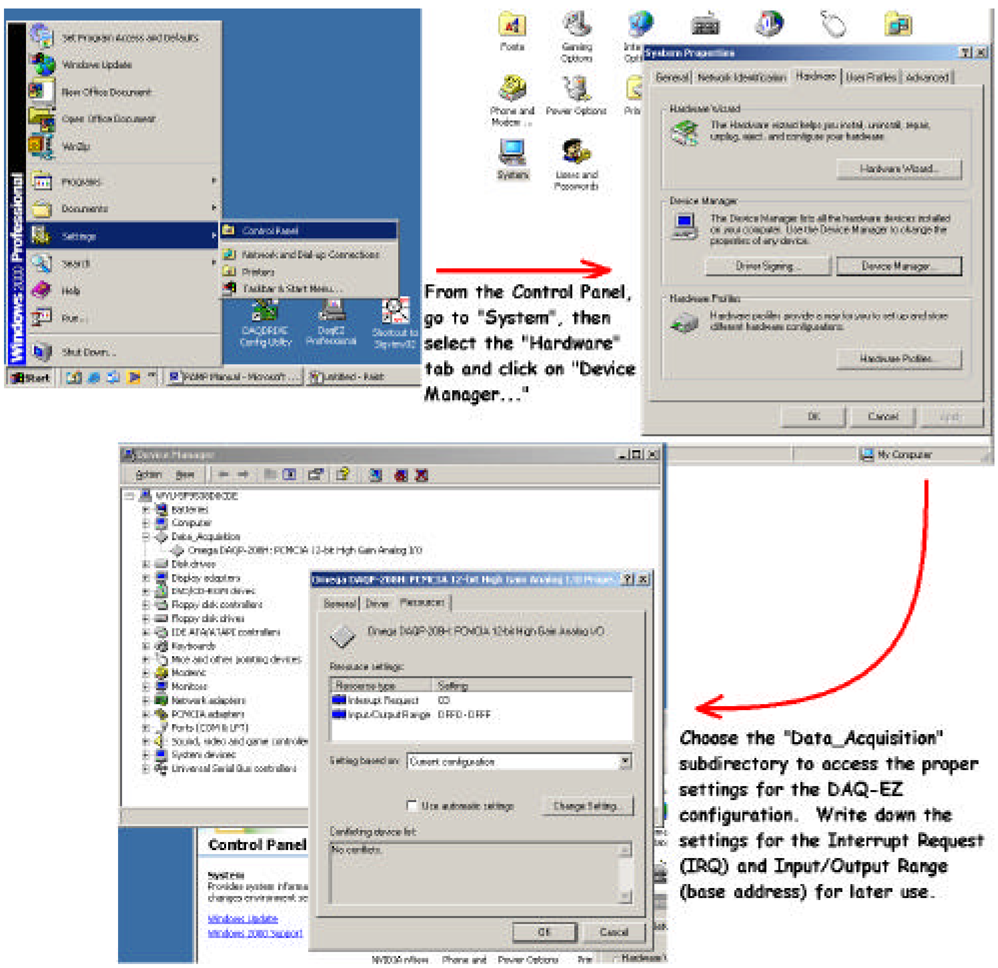

Figure 21: Locating DAQ-EZ's configuration information.

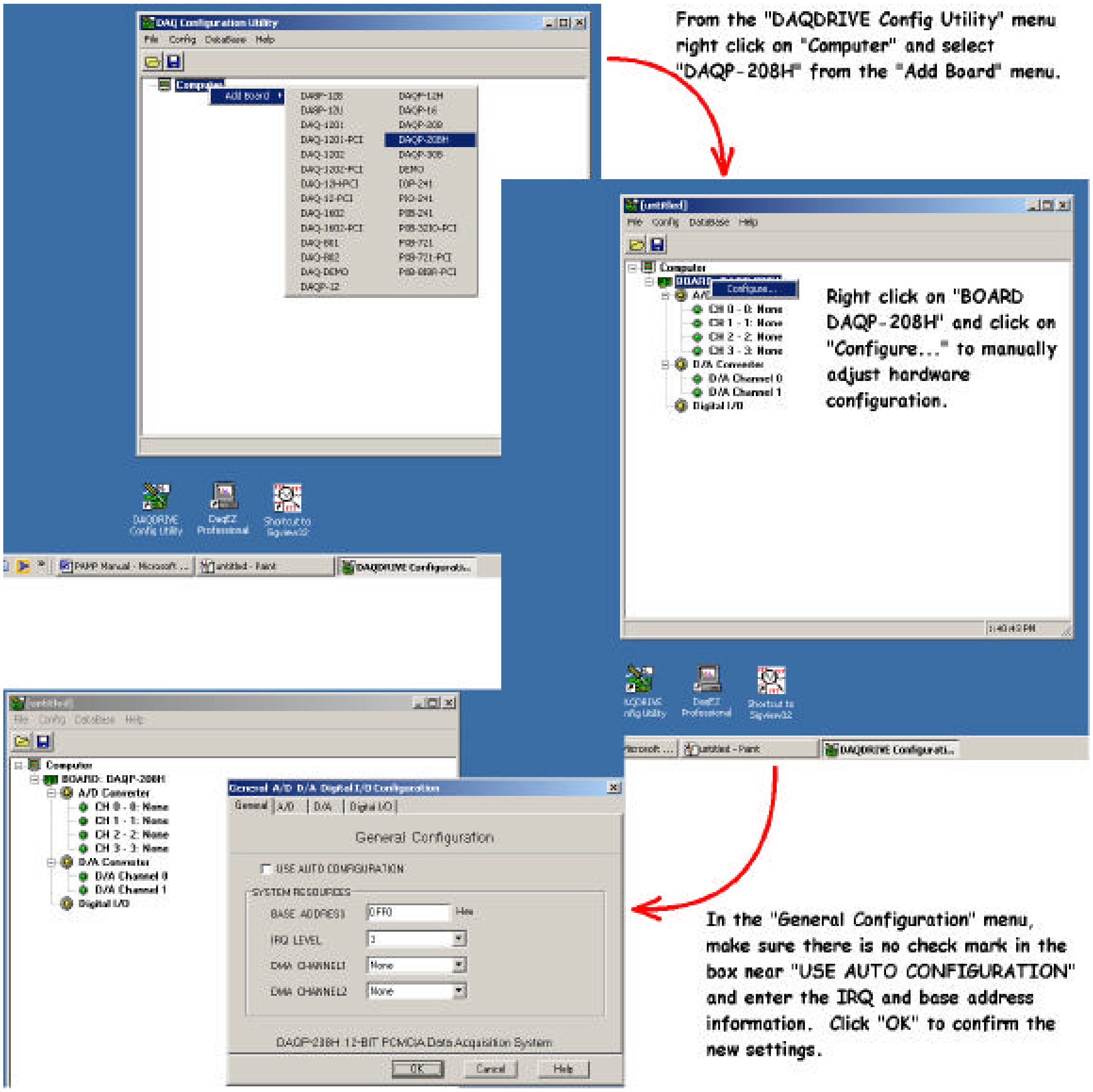

Figure 22: Manual configuration of DAQ-EZ.

Unit Conversion

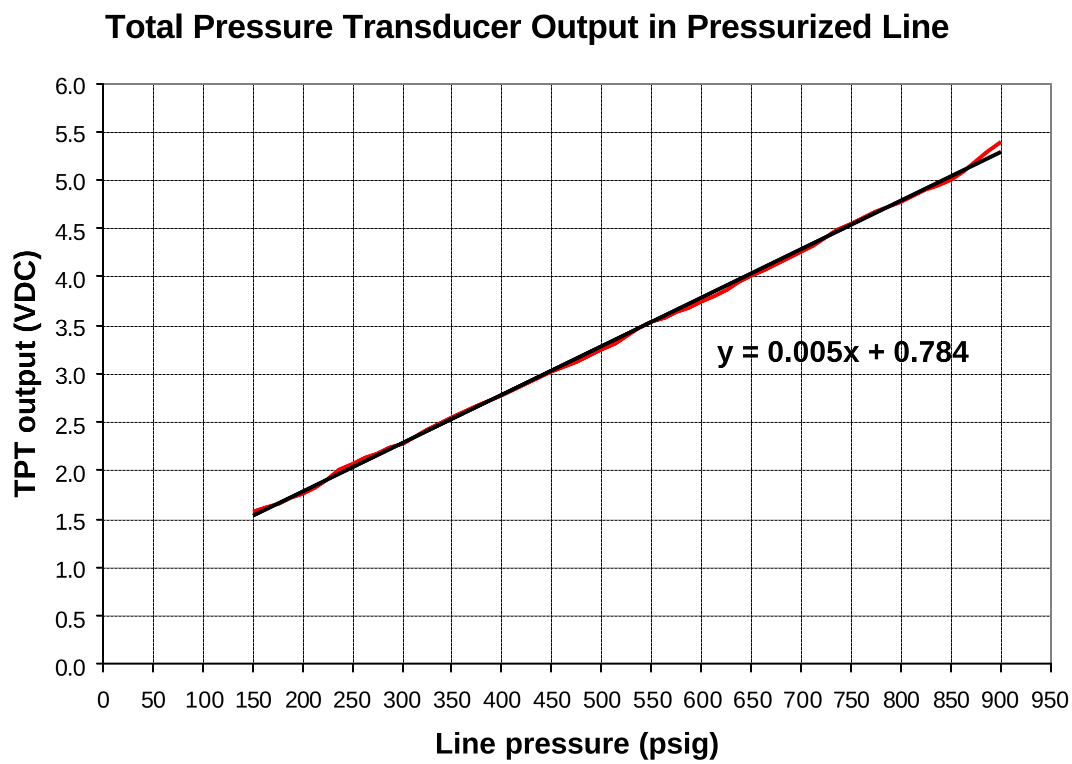

Figure 23: Total pressure transducer output in a pressurized line.

	Volts (V)	millivolts (mV)	Signal View Units (svu)
1 Volt (1 V) =	1	1000	3266
1 millivolt (1 mV) =	0.001	1	3.266
1 Signal View Unit (1 svu) =	0.0003062	0.3062	1

Table 1: Signal view unit (svu) conversion in volts and millivolts.

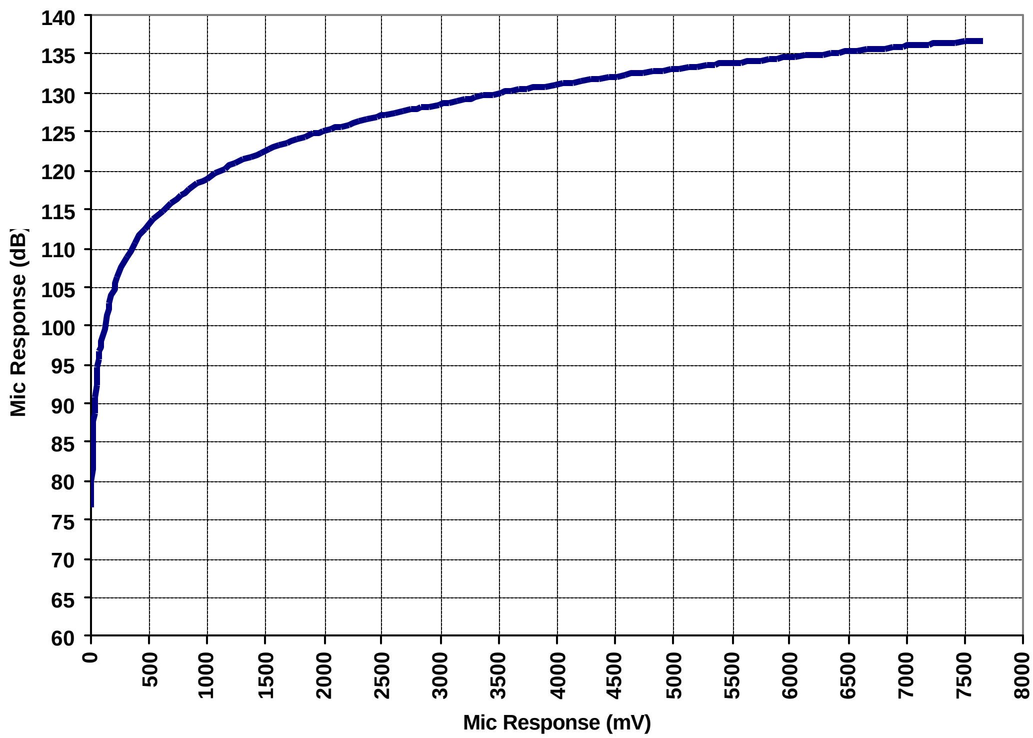

Figure 24: Microphone decibel response as a function of mV output.

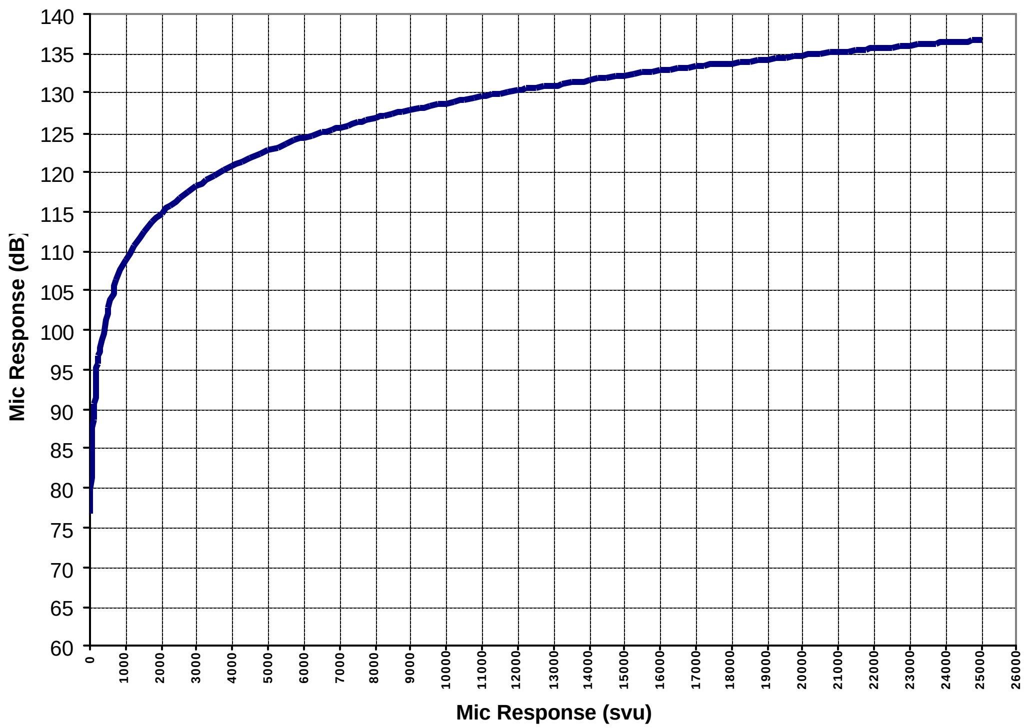

Figure 25: Microphone decibel response as a function of svu output.

DAQ Center Schematic

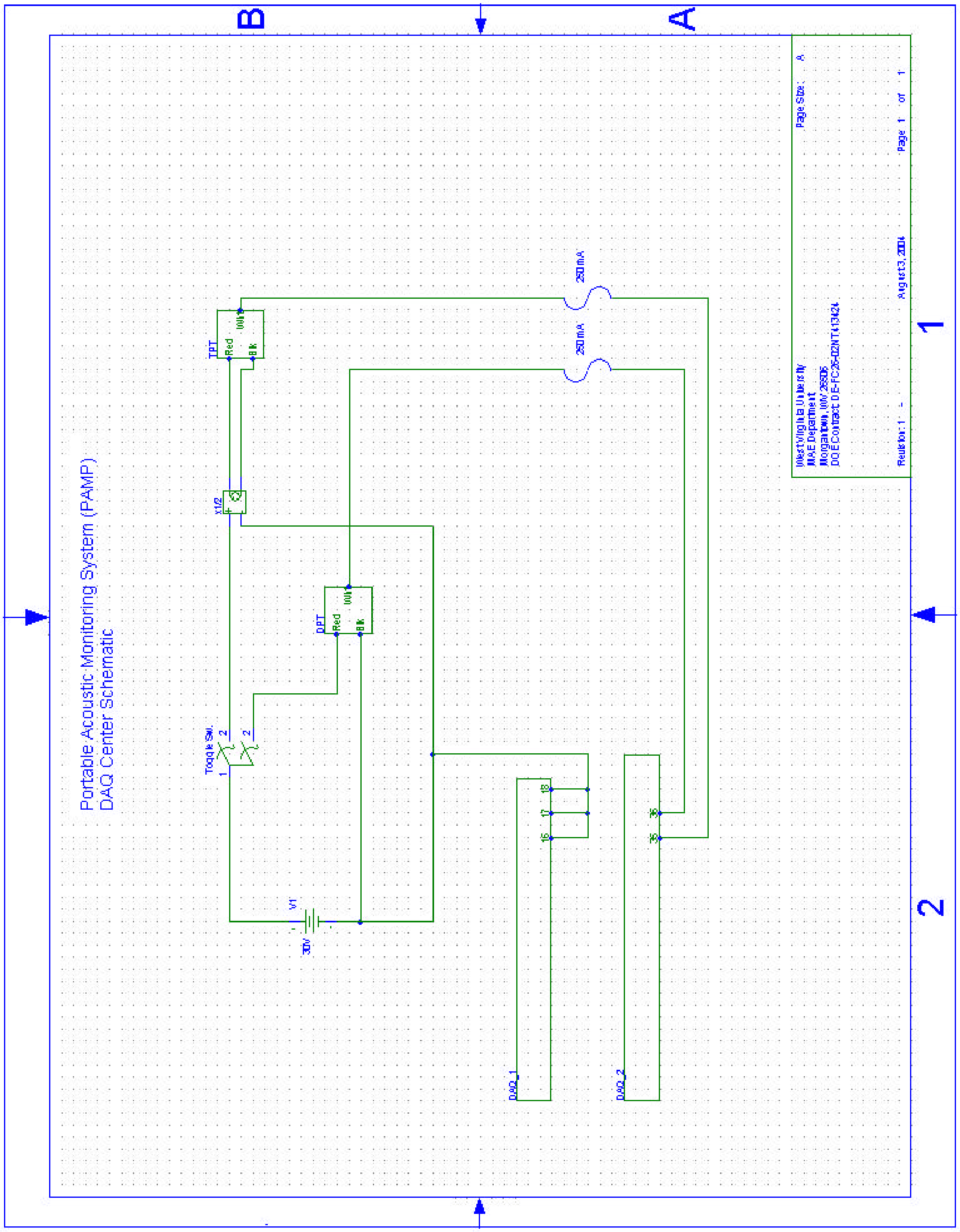

Figure 26: Electrical schematic of the PAMP DAQ Center.

III. Results and Discussion

Signal Processing for Infringement Detection

Pipeline infringement by accidental heavy equipment impact or deliberate terrorist activity can be detected by monitoring acoustic signals carried by the gas. Difficulty in detection arises because these burst signals can be very short in duration (less than 0.1 second). Burst signals may also be much lower in amplitude than the normal background acoustic signals that reflect the dynamics of the particular region including local pipeline geometry, gas flow rate, and online equipment such as compressors and turbines. In order to detect infringements, it becomes necessary to continually compare new acoustic signals to the normal acoustic signal of the location. Only by removing the normal acoustic signal from newly acquired acoustic signals can burst signals be easily identified.

An acoustic signal in its raw (amplitude versus time) state is difficult to interpret and not recommended. Using Fast Fourier Transform (FFT) analysis, an acoustic signal may be broken down into its individual frequency components. FFTs provide the synchronized signal characteristics required to properly remove background signal characteristics from new acoustic signals so that unique frequency variations caused by pipeline impacts can be revealed. Because low frequency (0-2000 Hz) waves travel much farther than high frequency (>2000 Hz) waves without substantial attenuation, FFT analysis is only performed within the range of 0-1200 Hz.

As an acoustic signal is received by monitoring equipment, it can be split into two separate channels. Both signals are broken into 0.1-second data packets for FFT analysis, but one of the signals is delayed for 1 second. Once a new signal is processed, the delayed signal's FFT may be subtracted from it. This new "difference FFT" reveals information about any variations in frequency and power that have occurred within the 1-second time lapse. This process is best illustrated in the example of Figure 2. When Sample A reaches the monitoring equipment, it undergoes FFT analysis and is then delayed for one second. Once Sample B has been processed into FFT format, the delayed FFT from Sample A may be subtracted from the FFT of Sample B. If no burst has occurred within the 0.1-second time frame of Sample B, there will be almost no difference between the two curves (Figure 3). However, if a burst has taken place in Sample B, then the difference between the two FFTs will be substantial (Figure 4). These rapidly changing frequency spectra are clear indicators of pipeline bursts and infringement.

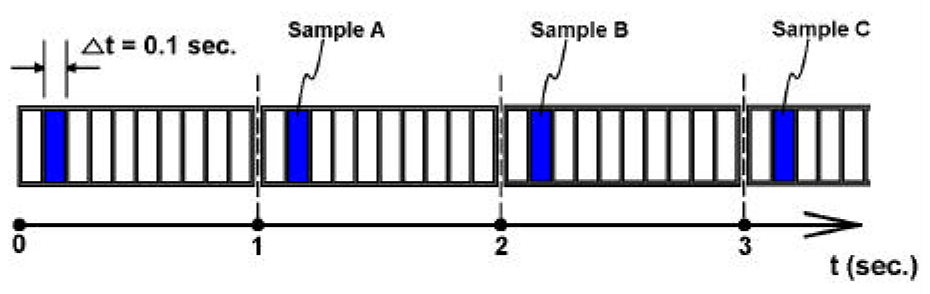

Figure 27: 0.1-second acoustic signal sampling occurs at 1-second intervals.

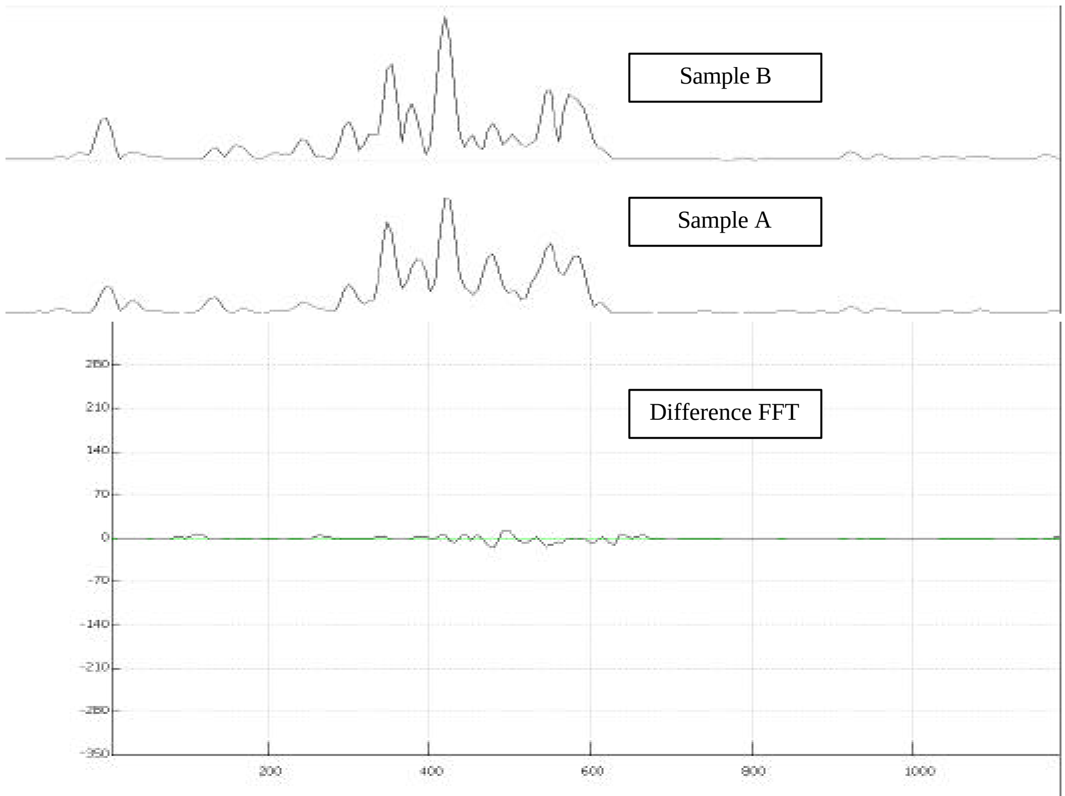

Figure 28: When Sample A's FFT is subtracted from Sample B's FFT, the difference FFT shows only slight frequency variation, indicating an absence of any burst signal.

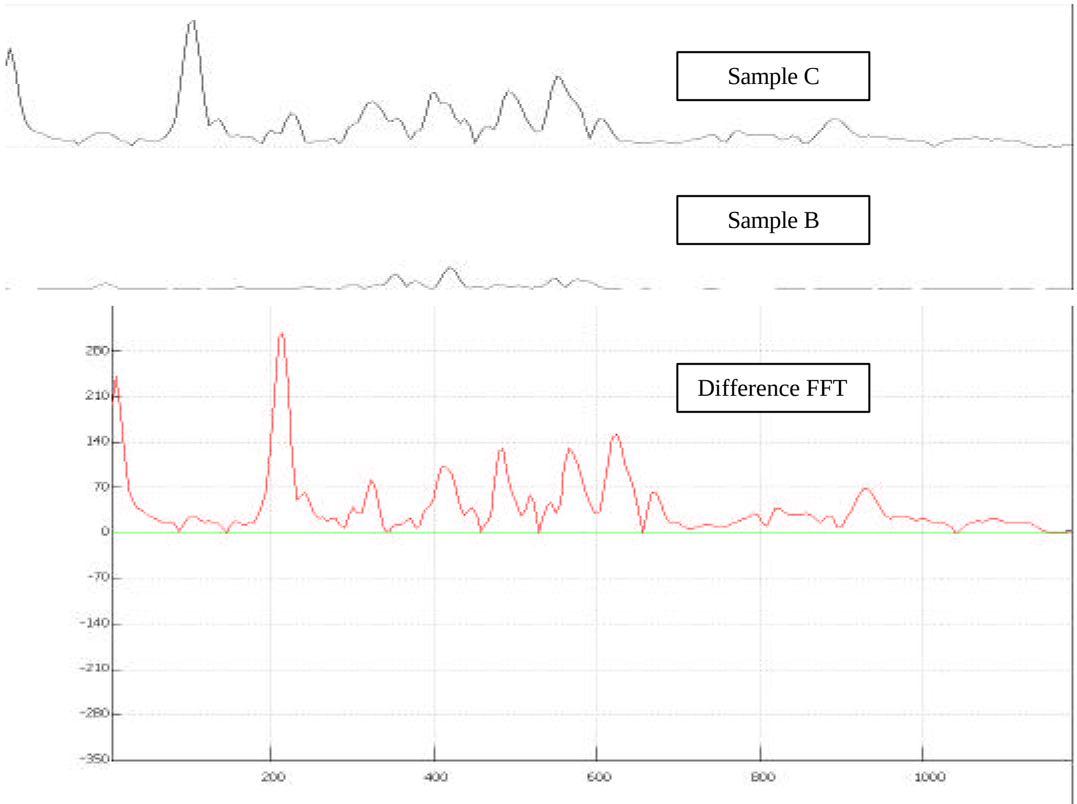

Figure 29: When Sample B's FFT is subtracted from Sample C's FFT, the difference FFT shows obvious frequency variation, indicating the presence of a burst signal.

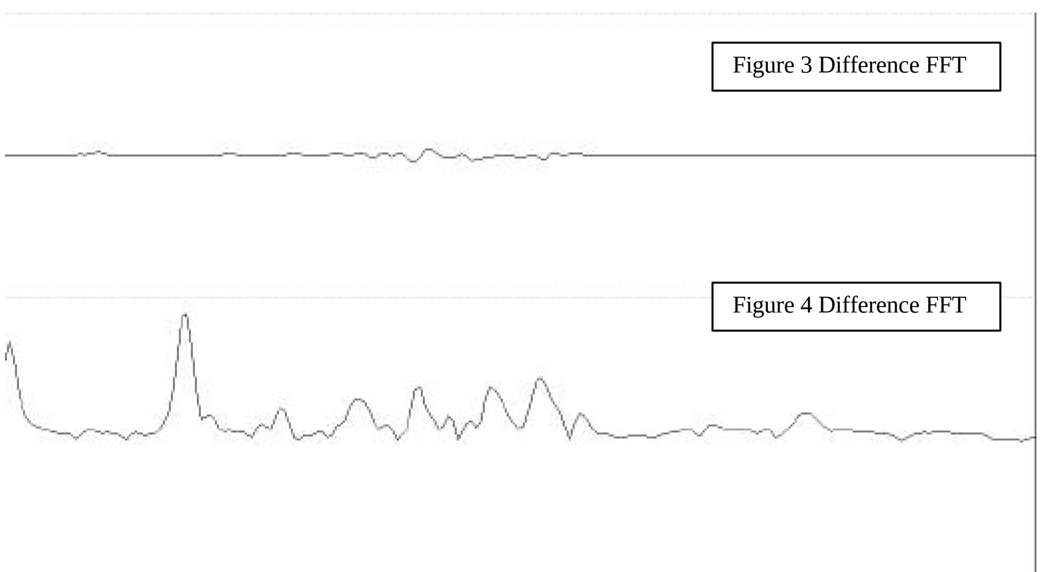

Figure 30: Comparing the difference FFTs of Figures 3 and 4 reveals the vast difference between normal and burst difference FFTs.

Readily available digital recording devices with FFT analysis software can be used in conjunction with the 2nd generation PAMP sensor technology to provide low-cost 24-hour monitoring of natural gas (NG) pipelines. Wireless data links (i.e., FM or cellular transmission) will allow NG providers and carriers to quickly respond to expensive pipeline bursts and infringements (Figure 6). Further programming of these units will also allow users to develop an extensive database of normal background acoustic signals. This information can then be compared with current signals to determine maintenance needs along the pipeline such as identifying line leak noise or abnormal compressor knock.

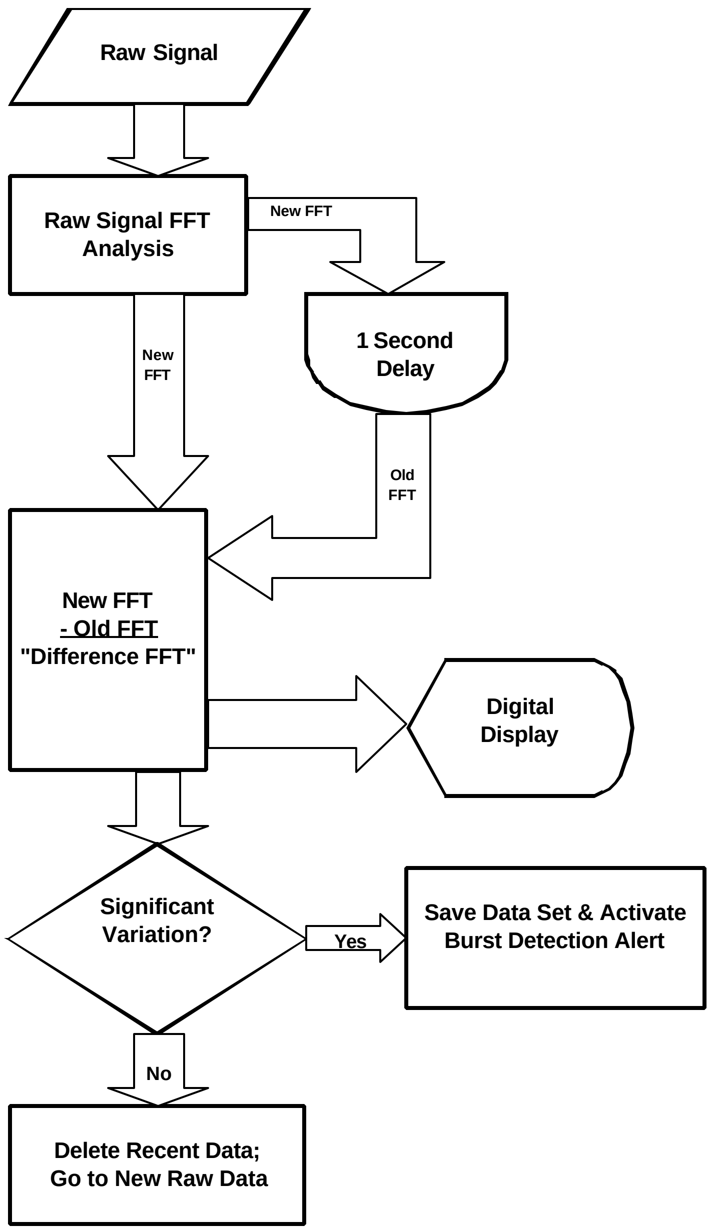

Figure 31: Open loop programming flow chart for NG pipeline burst detection.

IV. Conclusions

The current design of the PAMP has been used successfully in various locations with a wide variety of data recorded. Future field test sites have been arranged for the purpose of testing acoustic signal attenuation, with unobstructed straight pipeline sections ranging in length from ½ to 30 miles. Future tests will also be performed using a new miniaturized version of the 2nd generation PAMP. This 3rd generation PAMP promises to be lower in weight and cost without suffering any signal degradation during data collection and analysis.

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