

# Vibration Training with Low Cost Tools

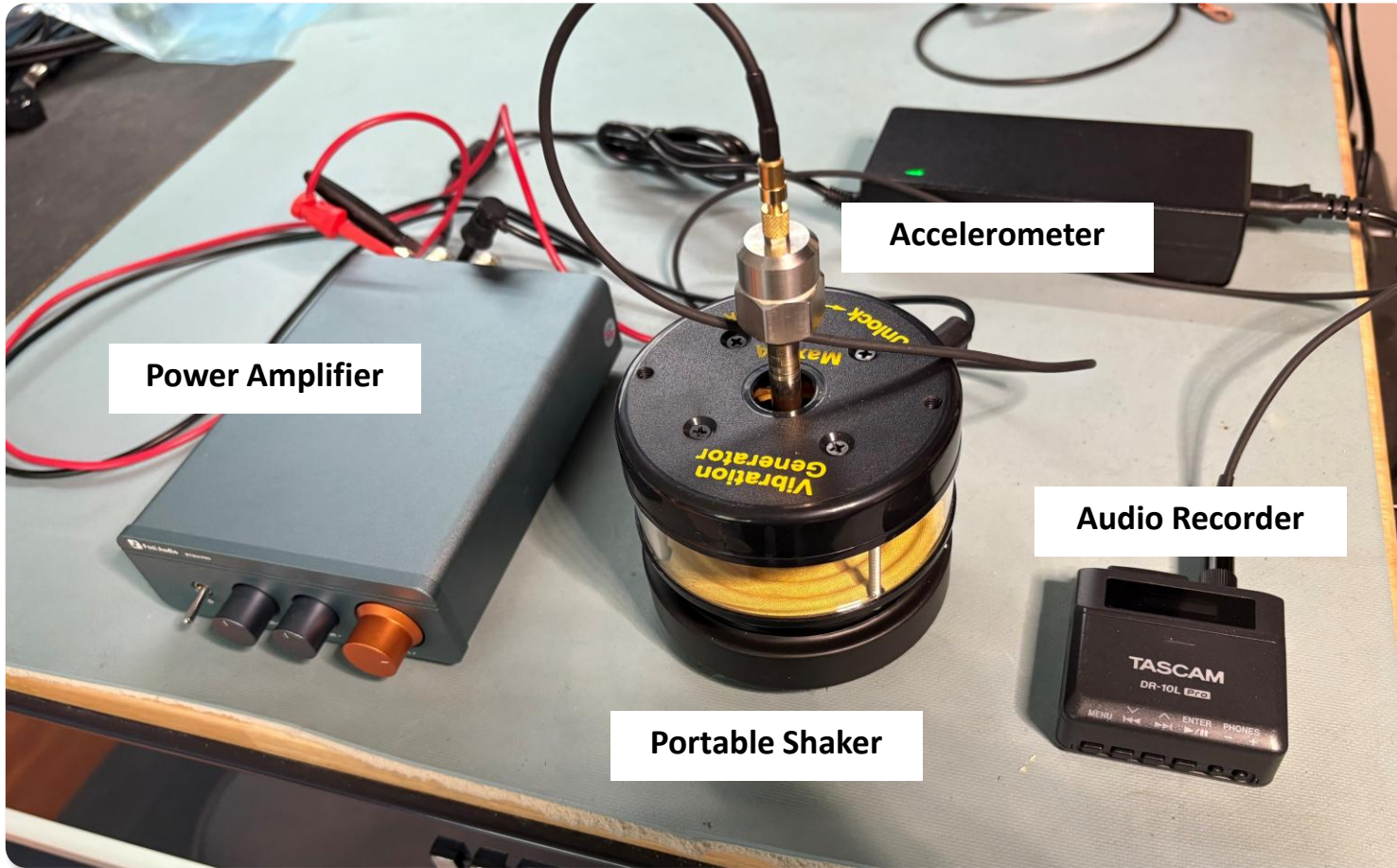
*Ed Spence, The Machine Instrumentation Group*

*Dr. George Zusman, Vibration Measurements Solution Inc.*

*Matthew Moore, Moore Reliability Limited*

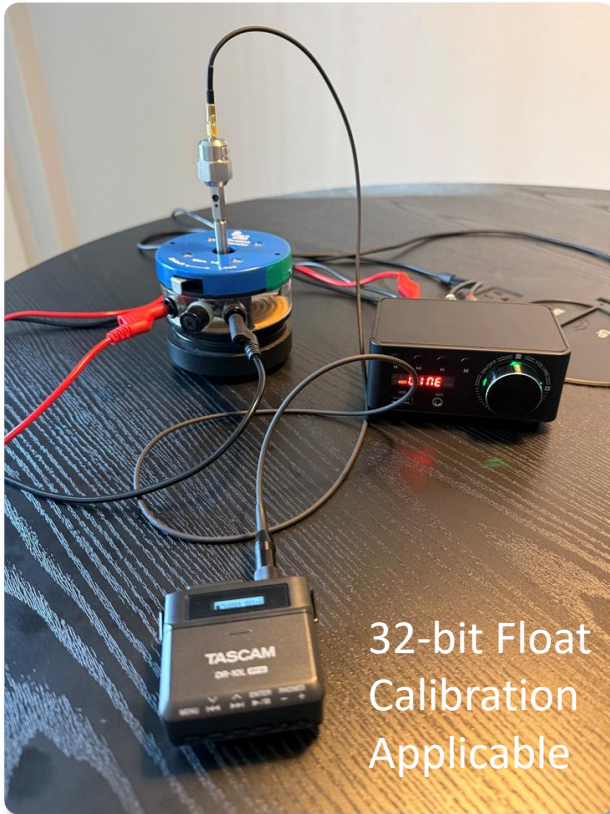
# Example Low Cost System

< \$1,000



- Relatively Cheap
- Portable
- No Shipping Logistics / Custom Concerns
- Simple for Basic Tasks / Covers Fundamentals
- Accessible to All Students

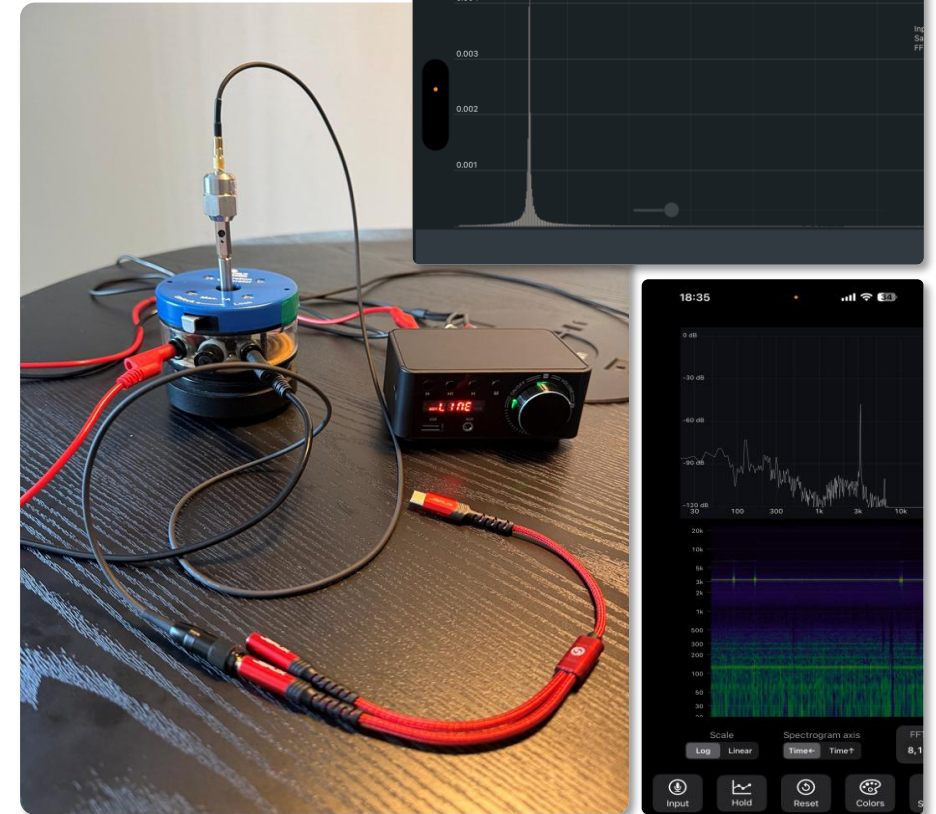
# Data Capture & A/D Conversion



Audio Recorder  
(3.5 mm Mic Input)



USB Sound Card  
(3.5 mm Mic Input)



USB-C Phone Input  
(3.5 mm Headphone / Mic Splitter)

# System Calibration (Optional)



Calibrated Vibration Signal  
10 mm/s rms & 159.2 Hz

Calibration

Number of channels in this calibration file: 1

Channel 1

1) Use Data acquisition function to record constant signal with known amplitude (for example 5V) from your DAQ device. Use only "default.cal" calibration file for this step.

2) Measure the average value of the signal recorded by SIGVIEW during first step and enter it here:

Recorded input level: 0.4376

Level type (RMS or Peak): RMS

Level type (dB or Linear): Linear

3) Enter the actual amplitude level in physical units which corresponds to the signal recorded during first step, i.e. the value you would like to see in SIGVIEW after the calibration:

Input level in physical units: 10

Level type (RMS or Peak): RMS

Level type (dB or linear) is the same as in step 2)

4) Enter the description of your physical units (for example V or Volt):

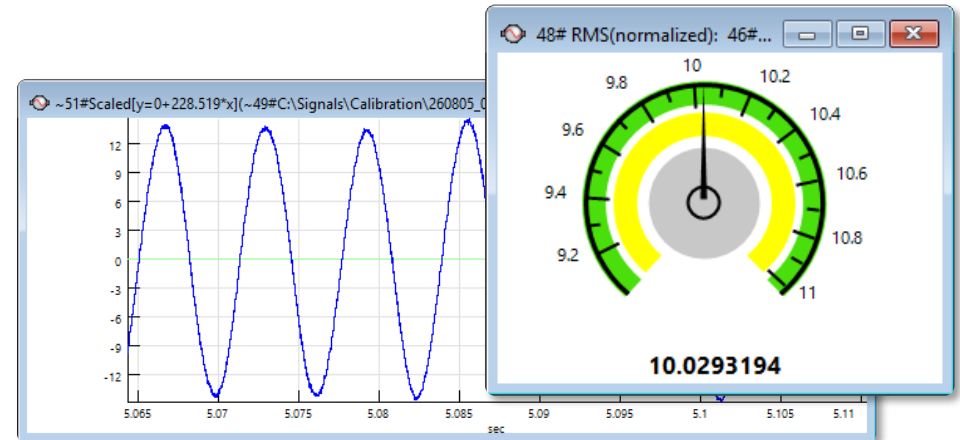
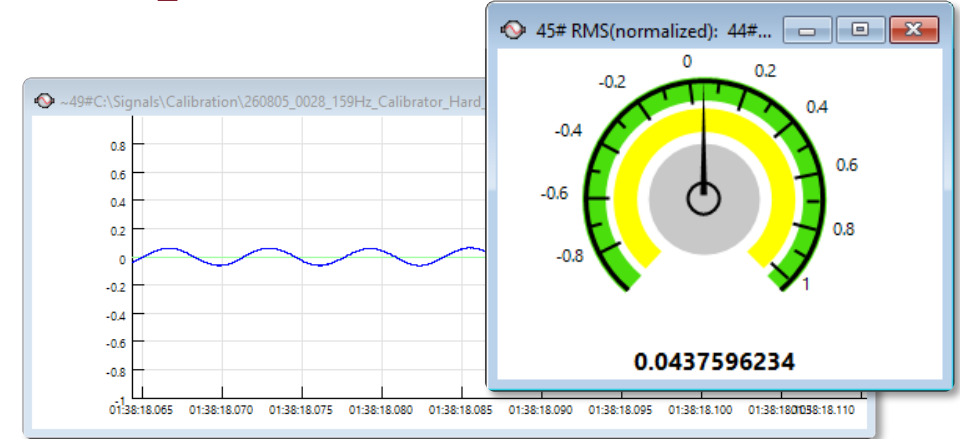
Physical unit used:

5) You can also define offset to be added to recorded values (in physical units, after the scaling):

Offset: 0.000000

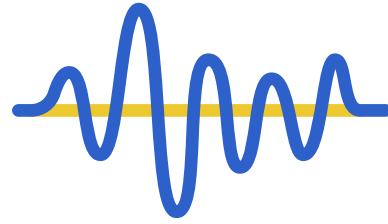
6) Save your calibration file and use it later for data acquisition in Data acquisition dialog or for Scale/Normalize function.

C:\Users\Matthew Moore\AppData\Local\Temp\sigview\calibration\default.cal

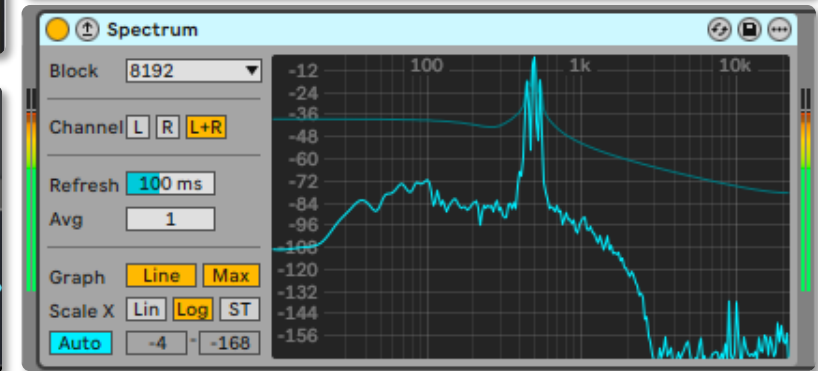
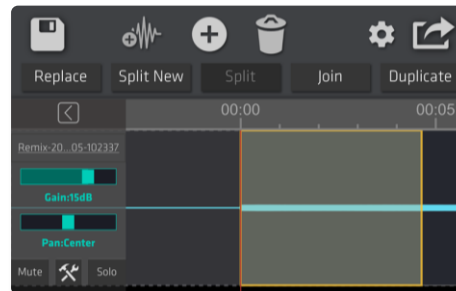
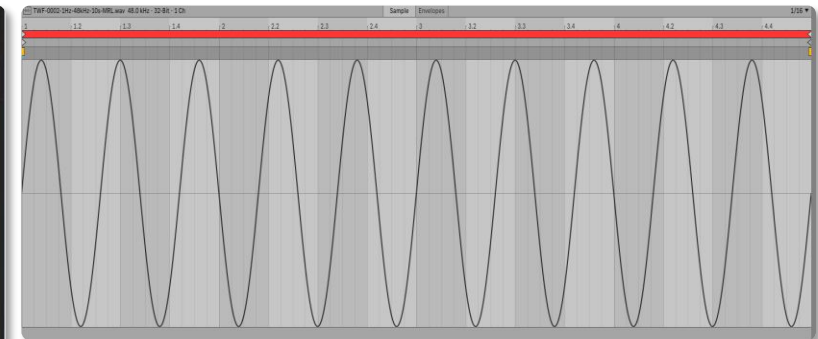


Calibration File Scales Future  
Measurements

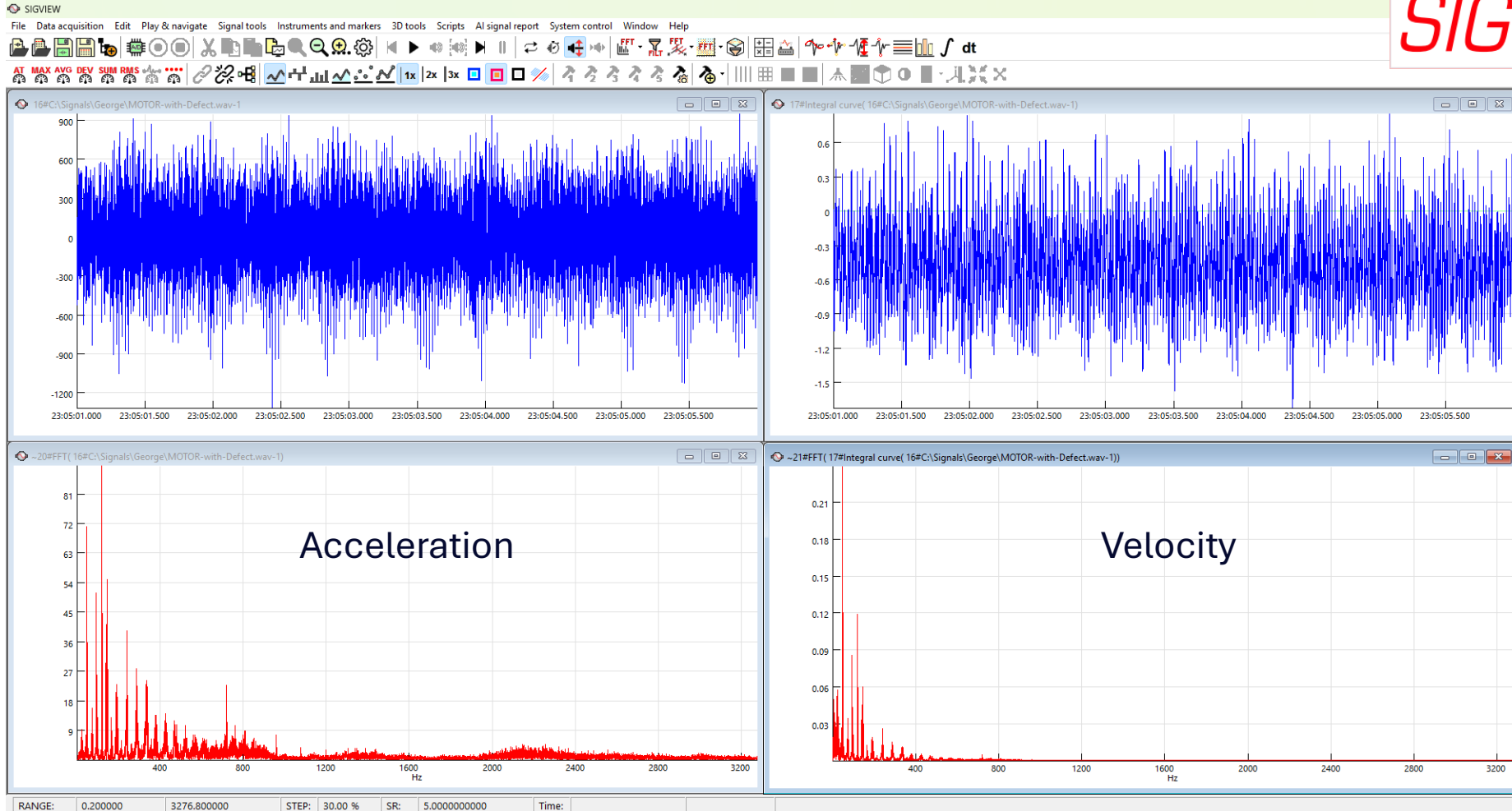
# WAV Format



- Time waveform format
- High sample rate of 44.1 kHz or 48 kHz
- Up to 24 kHz vibration Fmax
- Audio applications or equipment
- Voice recorder apps
- Music production apps / software
- Any phone app using mic input
- Mix, edit, combine
- Note: Audible Fmin 20 Hz (lower frequencies achievable on shaker)



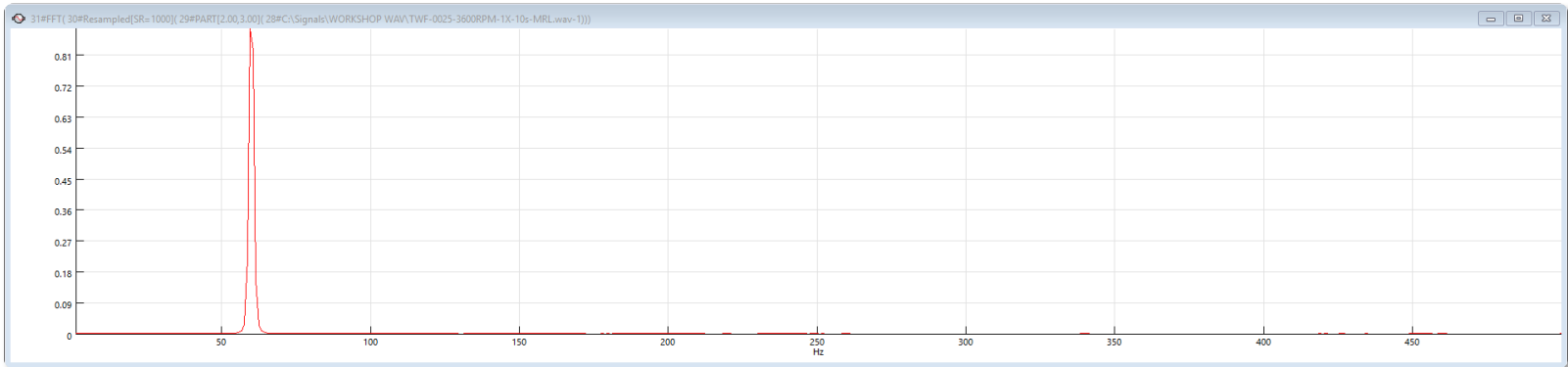
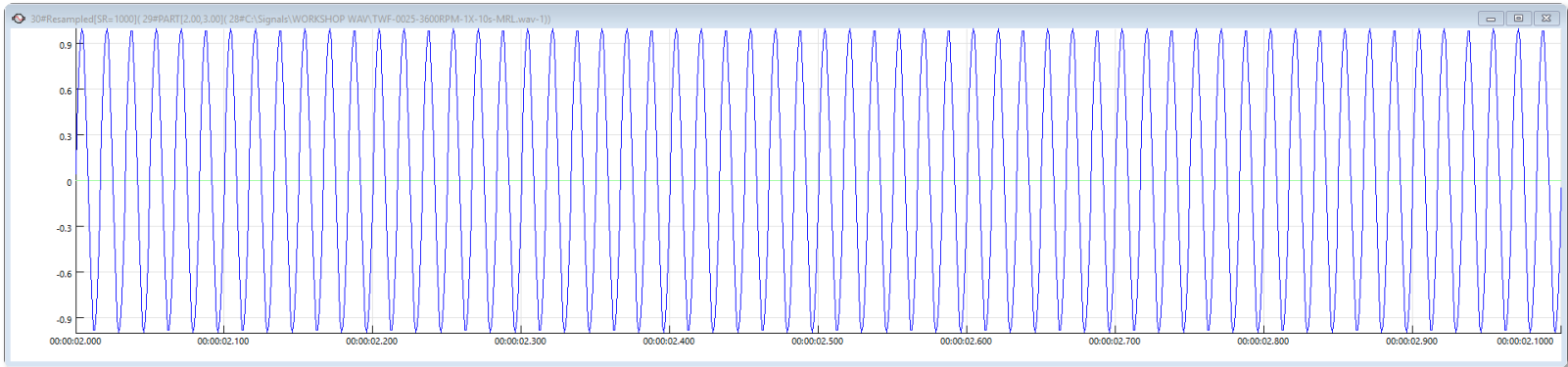
# Signal Processing Software



- Sampling
- Time Waveform
- Resampling
- Scaling
- Calibration
- Filtering
- Integration
- FFT Spectrum
- Averaging

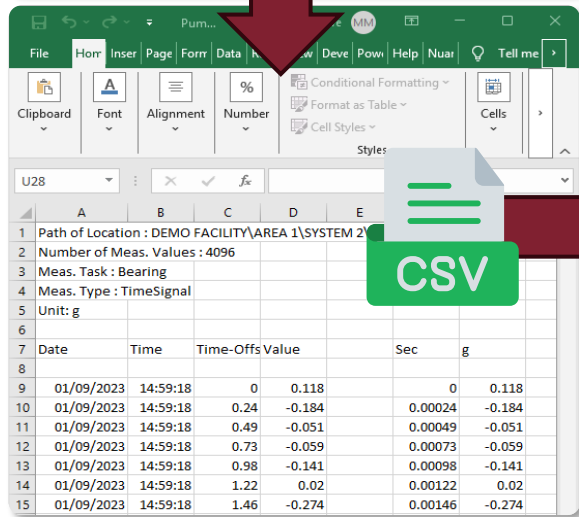
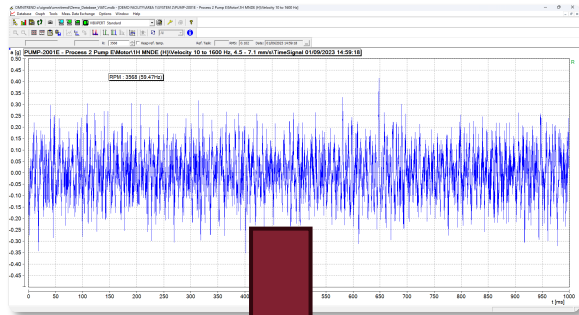
# Example Simulated Fault – Unbalance

| TABLE I<br>ILLUSTRATED VIBRATION DIAGNOSTIC CHART |                                                                 |                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|---------------------------------------------------|-----------------------------------------------------------------|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PROBLEM SOURCE                                    | TYPICAL SPECTRUM                                                | PHASE RELATIONSHIP | REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>MASS UNBALANCE</b><br>A. FORCE UNBALANCE       | 1X RADIAL                                                       |                    | Force Unbalance will be in phase and steady. Amplitude due to unbalance will increase by the square of speed below first rotor critical (as 1X speed increases $\rightarrow$ 6X higher vibration). 1X RPM always present and normally dominates spectrum. Can be corrected by placement of only one balance correction weight in one plane at rotor center of gravity (CG). Approx. 90° phase difference should exist between CR & 18° horizontal, as well as between CR & 18° vertical. Also, approx. 90° phase difference between horizontal & vertical readings usually occurs on each bearing of unbalanced rotor ( $\pm 90^\circ$ ).                                                                                                                                                 |
| <b>B. COUPLE UNBALANCE</b>                        | 1X RADIAL                                                       |                    | Couple Unbalance results in 180° out of phase motion on same shaft. 1X RPM always present and normally dominates spectrum. Amplitude varies with square of increasing speed below first rotor critical speed. May cause high axial vibration as well as radial. Correction requires placement of balance weights in at least 2 planes. Note that approx. 180° phase difference should exist between CR & 18° horizontal, as well as between CR & 18° vertical. Also, approx. a 90° difference between the horizontal & vertical phase readings on each bearing usually occurs ( $\pm 90^\circ$ ).                                                                                                                                                                                         |
| <b>C. DYNAMIC UNBALANCE</b>                       | 1X RADIAL                                                       |                    | Dynamic Unbalance is the dominant type of unbalance found and is a combination of both force and couple unbalance. 1X RPM dominates the spectrum, and truly requires 3 plane correction. Here, the radial phase difference between outward and inward bearings can range anywhere from 0° to 180°. However, the horizontal phase difference should closely match the vertical phase difference, when comparing outward and inward bearing measurements ( $\pm 90^\circ$ ). Secondly, if unbalance predominates, roughly a 90° phase difference usually results between the horizontal and vertical readings on each bearing ( $\pm 90^\circ$ ).                                                                                                                                           |
| <b>D. OVERHUNG ROTOR UNBALANCE</b>                | 1X AXIAL & RADIAL                                               |                    | Overhung Rotor Unbalance causes high 1X RPM in both Axial and Radial directions. Axial readings tend to be in-phase whereas radial phase readings might be completely opposite. However, the horizontal phase difference will usually match the vertical phase differences on the unbalanced rotor ( $\pm 90^\circ$ ). Overhung rotors have both force and couple unbalance, each of which will likely require correction. Thus, correction weights will most likely have to be placed in 2 planes to counteract both force and couple unbalance.                                                                                                                                                                                                                                         |
| <b>ECCENTRIC ROTOR</b>                            | 1X FAN, 1X MOTOR, 1X RADIAL                                     |                    | Eccentricity occurs when center of rotation is offset from geometric centerline of a pulley, gear, bearing, motor armature, etc. Largest vibration occurs at 1X RPM of eccentric component in a direction thru centerline of the fan rotor. Comparative horizontal and vertical phase readings usually differ either by 0° or by 180° (each of which indicate straight line motion). Attempts to balance eccentric rotors often result in reducing vibration in one radial direction, but increasing it in the other radial direction (depending on amount of eccentricity).                                                                                                                                                                                                              |
| <b>BENT SHAFT</b>                                 | 1X AXIAL, 1X RADIAL                                             |                    | Bent shaft problems cause high axial vibration with axial phase differences, bending towards 180° on the same machine component. Constant vibration normally occurs at 1X if bent near shaft center, but at 2X if bent near the coupling. (Be careful to account for translational vibration for each axial measurement if you measure probe direction.) Use dial indicators to confirm bent shaft.                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>MISALIGNMENT</b><br>A. ANGULAR MISALIGNMENT    | 1X AXIAL, 1X RADIAL                                             |                    | Angular Misalignment is characterized by high axial vibration, 180° out of phase across the coupling. Typically will have high axial vibration with both 1X and 2X RPM. However, not unusual for either 1X, 2X or 3X to dominate. These symptoms may also indicate coupling problems as well. Severe angular misalignment may excite many 1X RPM harmonics. Unlike Mechanical Unbalance Type 1, these multiple harmonics do not typically have a related node line on the spectra.                                                                                                                                                                                                                                                                                                        |
| <b>B. PARALLEL MISALIGNMENT</b>                   | 1X AXIAL, 1X RADIAL                                             |                    | Offset Misalignment has similar vibration symptoms to Angular, but shows high radial vibration which approaches 180° out of phase across coupling. 2X often larger than 1X, but its height relative to 1X is often dictated by coupling type and construction. When either Angular or Parallel Misalignment becomes severe, they can generate either high amplitude peaks at much higher harmonics (2X, 4X, etc.) or even a whole series of high frequency harmonics similar in appearance to mechanical resonance. Coupling type and material will often greatly influence the entire spectrum when misalignment is severe. Does not typically have related node line.                                                                                                                   |
| <b>C. MISALIGNED BEARING COCKED ON SHAFT</b>      | 2X AXIAL, 1X RADIAL                                             |                    | Cocked Bearing will generate considerable axial vibration. 90° cause bearing failure with approximately 180° phase shift top to bottom and/or side to side as measured in axial direction on early bearing housing. Attempts to align coupling or balance the rotor will not alleviate problem. Bearing usually needs to be removed and replaced.                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>RESONANCE</b>                                  | Amplitude vs. Frequency graph showing resonance peak at 1X RPM. |                    | Resonance occurs when a forcing frequency coincides with a system's Natural Frequency, and can cause dramatic amplitude amplification, which might result in permanent, or even catastrophic failure. This may be natural frequency of the rotor, but can often originate from support frame, foundation, gearbox or even drive belt. It's not a 1X or 2X resonance, it can be almost impossible to balance due to the great phase shift it experiences (360° at resonance, nearly 180° when passing thru). Often requires changing natural frequency to a higher or lower frequency. Natural Frequencies do not generally change with a change in speed which helps facilitate their identification unless on a large plan bearing machine or on a rotor which has significant bearings. |

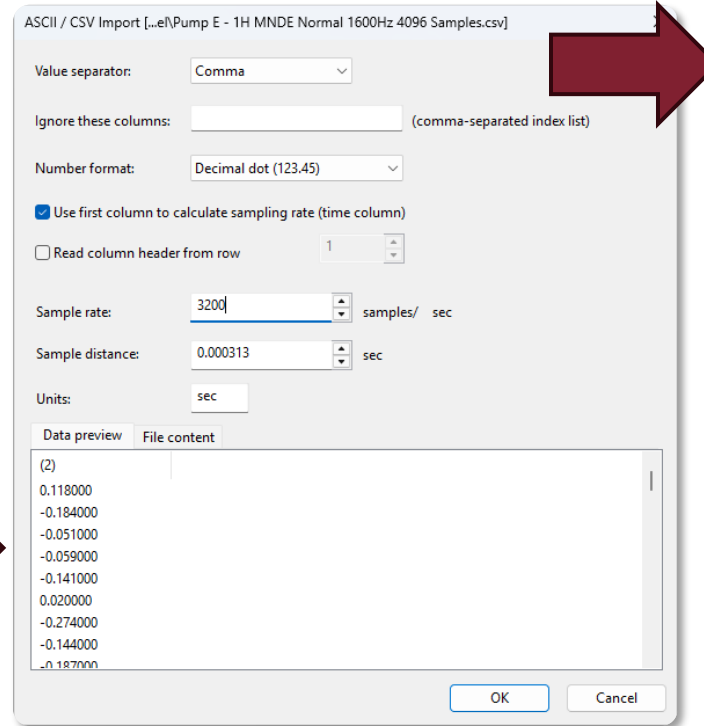


# Real Machine Vibration

- Signal Processing Software (CSV Import)



| Date       | Time     | Time-Offs | Value  | Sec     | g      |
|------------|----------|-----------|--------|---------|--------|
| 01/09/2023 | 14:59:18 | 0         | 0.118  | 0       | 0.118  |
| 01/09/2023 | 14:59:18 | 0.24      | -0.184 | 0.00024 | -0.184 |
| 01/09/2023 | 14:59:18 | 0.49      | -0.051 | 0.00049 | -0.051 |
| 01/09/2023 | 14:59:18 | 0.73      | -0.059 | 0.00073 | -0.059 |
| 01/09/2023 | 14:59:18 | 0.98      | -0.141 | 0.00098 | -0.141 |
| 01/09/2023 | 14:59:18 | 1.22      | 0.02   | 0.00122 | 0.02   |
| 01/09/2023 | 14:59:18 | 1.46      | -0.274 | 0.00146 | -0.274 |



ASCII / CSV Import [...e\Pump E - 1H MNDE Normal 1600Hz 4096 Samples.csv]

Value separator: Comma

Ignore these columns: (comma-separated index list)

Number format: Decimal dot (123.45)

☒ Use first column to calculate sampling rate (time column)

☐ Read column header from row 1

Sample rate: 3200 samples/ sec

Sample distance: 0.000313 sec

Units: sec

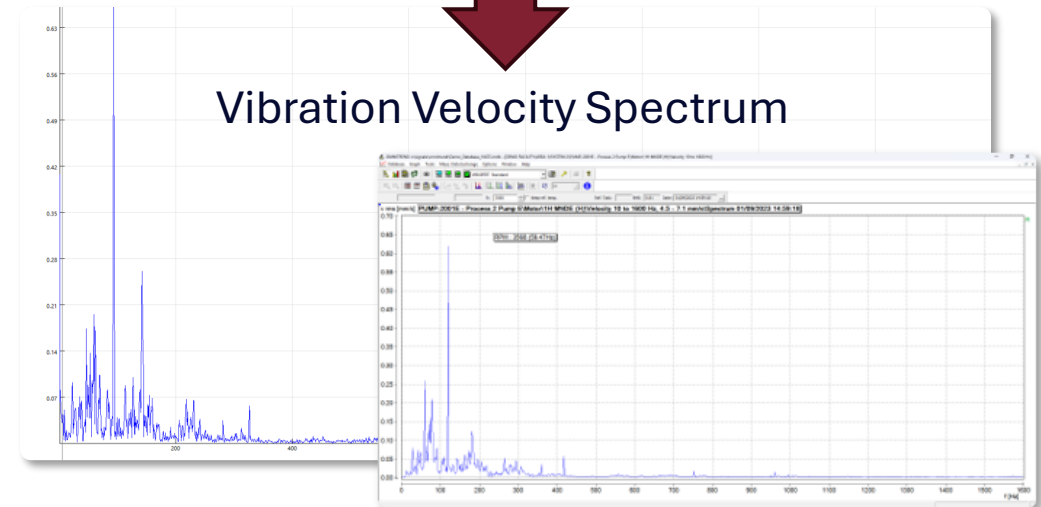
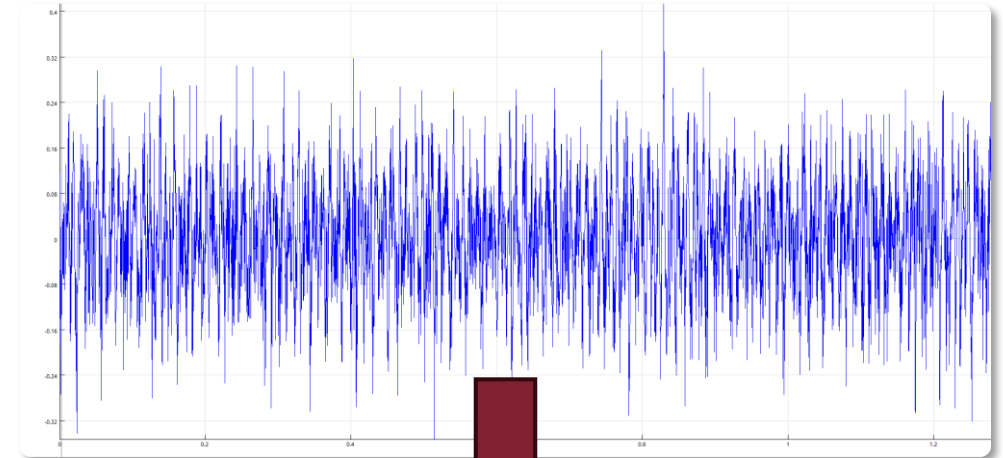
Data preview

|           |
|-----------|
| (2)       |
| 0.118000  |
| -0.184000 |
| -0.051000 |
| -0.059000 |
| -0.141000 |
| 0.020000  |
| -0.274000 |
| -0.144000 |
| -0.187000 |

OK Cancel

CSV Import

Integrate time waveform if measured in g



# Training Setup

