Professional Signal & Spectrum Analysis

WHITE PAPER

Modal Analysis with the Impact Hammer Method

Measuring natural frequencies and damping with SIGVIEW

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Overview

The impact hammer test is the simplest, fastest, and most widely used technique for determining the natural frequencies of a mechanical structure — a machine frame, bridge section, building, turbine blade, or any object whose dynamic behaviour matters. A calibrated hammer with a force sensor strikes the structure while an accelerometer records the response. The Frequency Response Function (FRF) between the two signals reveals the structure's modal properties: which frequencies it likes to vibrate at, how strongly each mode responds, and how quickly it decays.

This paper describes the complete measurement procedure in SIGVIEW, from data-acquisition setup through FRF computation and peak identification. The example uses a Data Translation DT9837 multichannel DAQ device; the workflow is identical for any other supported multichannel device (National Instruments, LabJack T7, Digilent).

Background

Why impulse excitation works

The Fourier transform of a brief impulse is a flat spectrum across a wide frequency band. A perfect Dirac impulse would excite all frequencies equally, but a real hammer produces a short half-sine pulse whose spectrum is flat to within a few dB up to a useful upper limit determined by the tip stiffness: softer tips give lower upper limits but less coupling problems on light structures; harder tips reach higher but risk double-hits and damage. Choosing the tip and the strike location is the only real measurement skill the test requires.

The Frequency Response Function

The FRF H(f) is defined as the ratio of the response spectrum Y(f) to the excitation spectrum X(f): $H(f) = Y(f) / X(f)$. The magnitude $|H(f)|$ shows the structure's gain at each frequency — peaks mark resonances, i.e. natural modes. The phase $\angle H(f)$ jumps by ≈ 180° as the frequency sweeps across each resonance, providing a second, independent way to locate the modes. Damping is read from the −3 dB bandwidth of each peak in the magnitude plot.

Hardware Setup

- **Multi-channel DAQ device:** must accept two simultaneous IEPE/ICP inputs (force + acceleration). The DT9837 in this example samples 24-bit at up to 52 kHz per channel.
- **Impact hammer:** instrumented with a force sensor at the tip. Typical sensitivity: 10 mV/N or 50 mV/N. Connect to DAQ channel 1.
- **Accelerometer:** mounted on the structure with wax, beeswax, or a stud. Typical sensitivity: 100 mV/g. Connect to DAQ channel 2.
- **Cabling:** IEPE/ICP-powered low-noise coaxial cables; route away from power lines and motor drives.

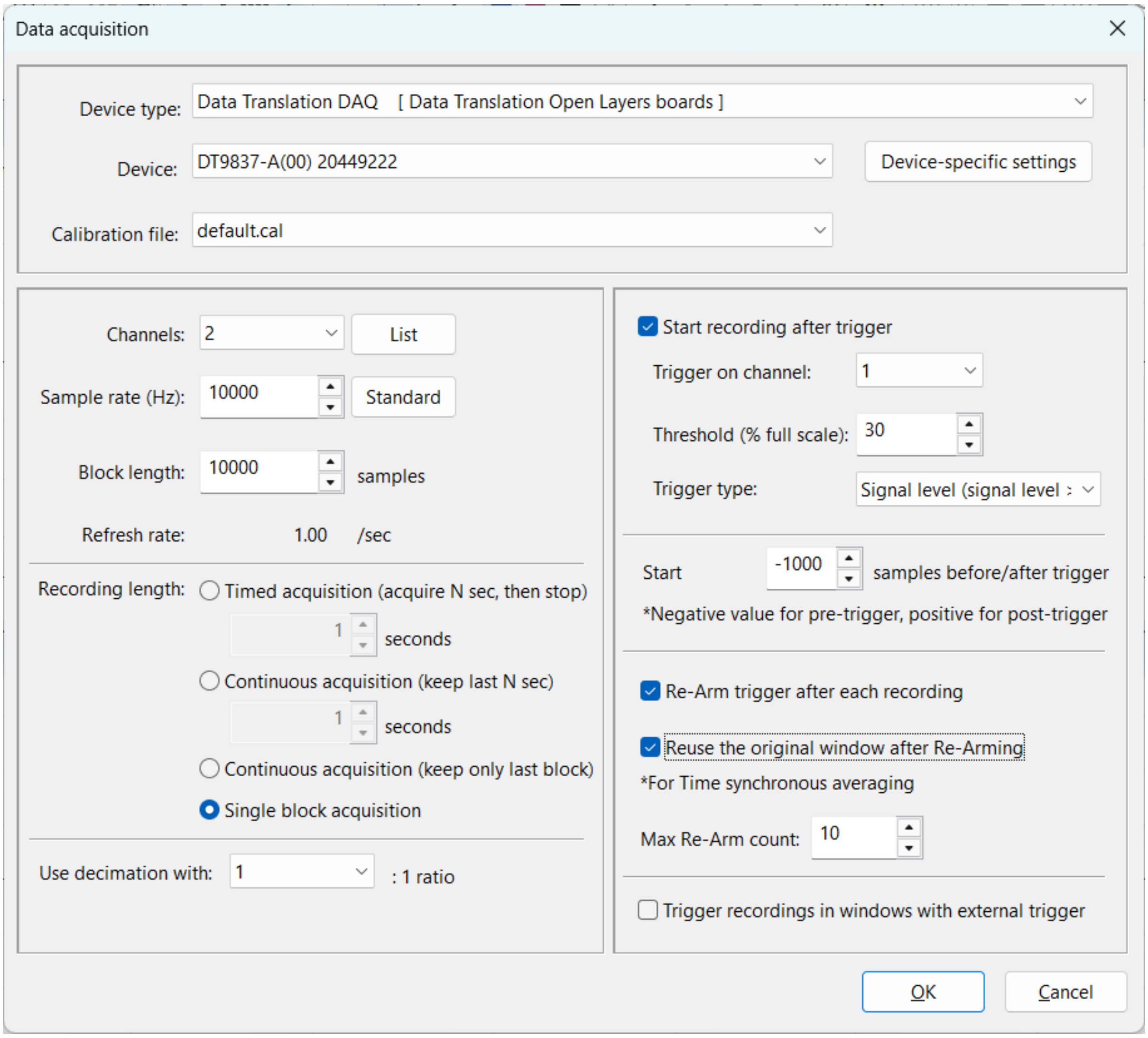
Test Signal

A pre-recorded 2-channel signal is provided to verify your SIGVIEW workflow without needing a hammer rig on hand:

- `hammer_impact_2ch.wav` — 1 s, 10 000 Hz, 2 channels. Channel 1: force pulse at t = 0.10 s (0.5 ms half-sine). Channel 2: acceleration response containing three structural modes at 87 Hz, 245 Hz, and 612 Hz with realistic damping. Useful for rehearsing the FRF computation, peak detection, and averaging steps.

Procedure in SIGVIEW

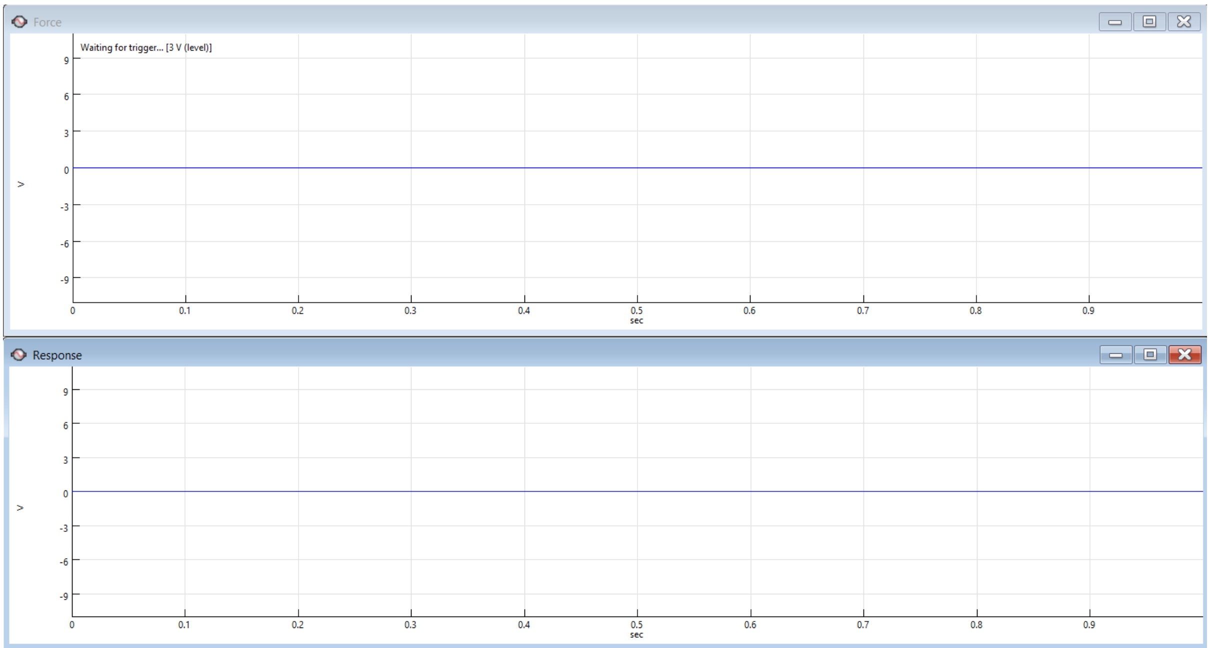
1. **Configure data acquisition.** Choose `Data acquisition / Open Data acquisition ...` from the main menu. Select your device (e.g. Data Translation DT9837). Enable Channel 1 (force) and Channel 2 (response). Set sampling rate to 10 000 Hz and block length to 10 000 samples (1 s per block).
2. **Configure pre-trigger and trigger.** In the same dialog, select *Start recording after trigger* option. Set trigger source to Channel 1 (force), level to 30 % of full range, and pre-trigger samples to 1000 (-1000 samples = 100 ms before the trigger). The pre-trigger ensures the moment of impact is captured even though the trigger fires slightly after the rising edge. Select `Re-Arm trigger after each recording` and `Reuse the original window after Re-Arming` options to be able to perform the test multiple times, without opening new windows.



Data Acquisition Setup dialog with the DT9837 selected, two channels enabled, sample rate 10000 Hz, block length 10000 samples.

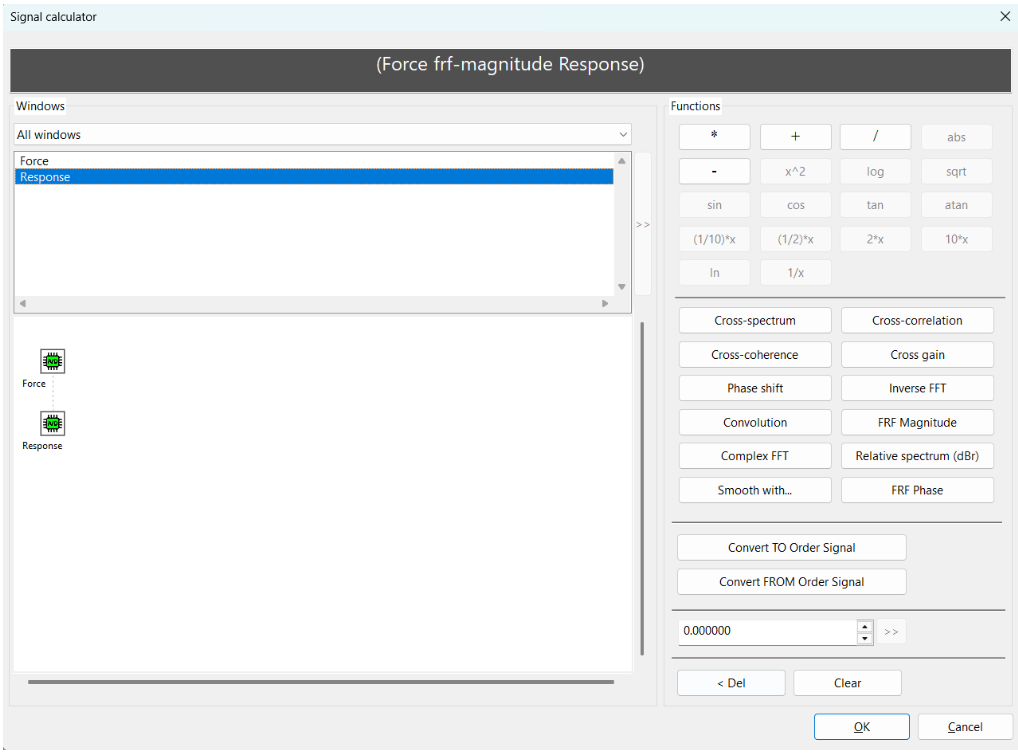
> **Why pre-trigger matters:** Without pre-trigger samples, the FRF magnitude is biased low because part of the force pulse is missing from the record. SIGVIEW's pre-trigger buffer guarantees the full pulse is included.

3. **Close the Data acquisition dialog, rename the windows and verify channel routing.** A DAQ window opens with two trace panes. Rename the windows in "Force" and "Response" (*Edit/Change window title…*). Press Rec button in the toolbar. SIGVIEW now waits for a trigger and the status bar shows "Waiting for trigger…".



DAQ window with two empty time-trace panels labelled "Force" and "Response". The toolbar shows the Rec button highlighted and the status bar reads "Waiting for trigger…".

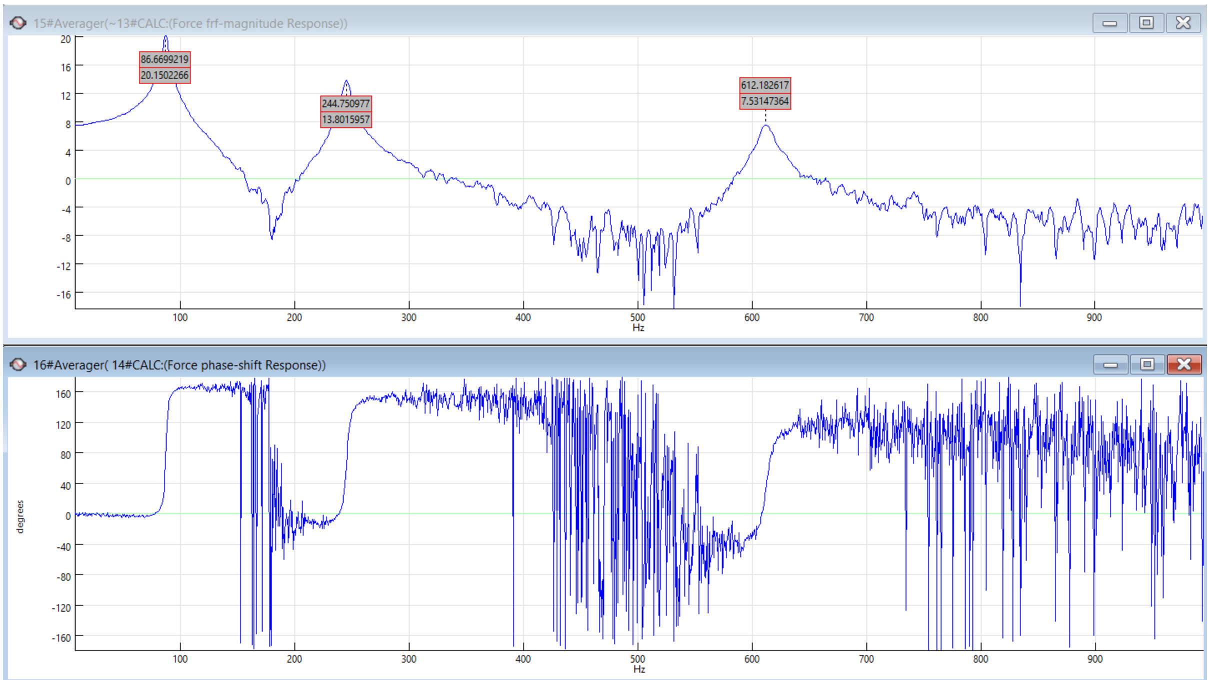
4. **Add the FRF Magnitude calculation.** Right-click in the Control Window and choose `Signal calculator...`. Select the force signal as the first input, the response signal as the second, and pick `FRF Magnitude` from the function list. Click OK — a new analysis window is created and linked to both channels. Switch Y-Axis to dB values (`Properties`…) if not already set in your `Spectral analysis defaults`.



Signal Calculator dialog. Inputs: window 1 = "Force", window 2 = "Response". "FRF Magnitude" from Force and Response window selected. Other selectable functions include FRF Phase, Coherence, Cross-spectrum.

5. **Add FRF Phase.** Repeat the previous step but select `FRF Phase`. You now have two analysis windows tracking the structure's magnitude and phase response.

6. **Add averagers.** Each impact gives one FRF estimate; averaging across several impacts dramatically reduces variance. Select each FRF window in the Control Window, right-click, and choose `Signal tools / Signal averager...`. The averager accumulates the running mean of each new FRF block. Select logarithmic averaging for FRF magnitude, since you use dB values.
7. **Windowing**. SIGVIEW applies an Exponential window automatically when computing FRF magnitude — this is the correct choice for impact-hammer measurements, since it suppresses leakage from the response ring-down. No manual configuration is required. If you ever need to override the default (for example, for special test conditions), open the FRF magnitude window's Properties... and change the window type.
8. **Start the test.** With recording armed, strike the structure once at a chosen point. The DAQ window updates with the captured force pulse and response, and both averagers add one entry. Wait 1–2 s, then strike again. Repeat 5–10 times.
9. **Find peaks automatically.** On the averaged FRF magnitude, choose `Peak detection...` from the context menu, set a minimum prominence threshold (e.g. 4 dB above local floor) and a minimum spacing (e.g. 20 Hz). SIGVIEW marks each detected mode and labels its frequency. With the test signal this returns ~87 Hz, ~245 Hz, and ~612 Hz.



Both Averager windows after 3 impacts (zoomed-in to 0 – 1000Hz). Three clear peaks in FRF magnitude at ~87, ~245, ~612 Hz. FRF Phase window with phase jumps near each magnitude peak

1. **Estimate damping (optional).** For each peak you can use the half-power (−3 dB) method: place mouse cursors at the −3 dB points on either side of a peak; the damping ratio is $\zeta \approx (f_2 - f_1) / (2 \cdot f\_n)$. SIGVIEW's `Custom tools / Damping factor` tool does this automatically when applied to a PSD or FRF magnitude with a clearly visible peak.

Interpretation Cheat-Sheet

What you see	What it means
Strong, well-separated peaks with clean 180° phase jumps	Healthy modal estimate; resonance frequencies and shapes are identifiable

What you see	What it means
Broad, low peaks; noisy phase	Insufficient excitation energy; use harder tip or larger hammer mass
Double-peaked structure near a single mode	Double-hit during impact — discard and re-strike
Coherence < 0.8 across passband (add a Coherence window via Signal calculator)	Non-linear behaviour, leakage, or extraneous noise; repeat with averaging and check windowing
Identical peaks regardless of strike point	Structure is excited globally; strike at a node of the suspected mode to confirm mode shape

Summary

SIGVIEW reduces the impact-hammer test to a small, repeatable workflow: a triggered DAQ block pair, two Signal Calculator entries for FRF magnitude and phase, two averagers, and a Peak Detection on the result. The same workspace can be saved as a template and applied to any future structure.