Vehicle vibration monitoring using Minisense 100

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Introduction

The Minisense 100, with its extremely high open-circuit voltage sensitivity to acceleration, is well-suited to detecting vibration or motion of a vehicle. The purpose of the following test was to compare the response of the sensor with the output of a "reference" accelerometer under a range of conditions and speed. Vehicle "vibration" could result from any or all of the following: engine and transmission vibration, tire/road contact noise, road roughness. The data presented here is only a summary of the test output, and in all cases, the "quietest" signals were selected for analysis (i.e. with minimum possible influence from distinct bumps in road surface). A relatively high quality vehicle with good suspension and quiet interior was used for the tests. The Minisense 100 and the reference accelerometer were mounted side-by-side on a substantial steel plate, which was then laid on the carpeted floor of the rear passenger space. Identical charge preamplifiers were used to buffer the signals, which were captured using a 12 bit x 4,096 dp digital signal analyzer. In the attached traces, excerpts of 512 data points (2 s duration) were taken from the original 4,096 point (16 s) time records for frequency analysis.

Presentation of results

The attached plots show results from the following conditions:

engine switched off
engine idling, vehicle stopped
20 kph (12.5 mph) on village side-street
60 kph (37.5 mph) on B486 country road
80 kph (50 mph) on A661 autobahn
100 kph (62.5 mph) on B43 airport approach
130 kph (81.5 mph) on A661 autobahn

Finally, a comparison between engine idling, and driving at 20 kph, is shown with increased detail in Y-axis (voltage output) for the Minisense 100 only. This comparison indicates that a threshold of +30 mV open-circuit output was never crossed with the engine idling, but was exceeded at least 25 times per second at a running speed of 20 kph. At all higher speeds, this threshold would be exceeded more often, and by higher margin.

In the attached plots, all spectra are shown on identical scale. The left hand Y-axis is expressed in dBV (logarithmic volts rms), the right-hand scale in log g rms to same scaling. The time traces vary in scale to show detail at each condition, but in all cases the Minisense 100 output (in volts) and the acceleration (in g) from the reference accelerometer are shown with same numerical "per division" scaling, with an offset to allow ease of reading.

Observations:

Engine off: very low level vibration seen on reference accelerometer trace. A single small transient shows a decaying exponential burst on the Minisense 100 trace, typical of a resonant transducer. The resonance (at around 85 Hz) is at slightly higher frequency than measured indoors on lab bench, probably due to lower temperature (starting from cold car, at minimum –5 deg C).

Engine idling: various periodic components may be seen in the spectra, with lowest peak at approx 12 Hz (720 rpm) – presumably the engine idling speed. Also a strong peak at 40 Hz (2400 rpm), and some activity at twice this frequency. As the Minisense 100 has sensitivity "boost" in this range, this component is accentuated in the time trace (clearly obvious in the first 0.3 s of time record).

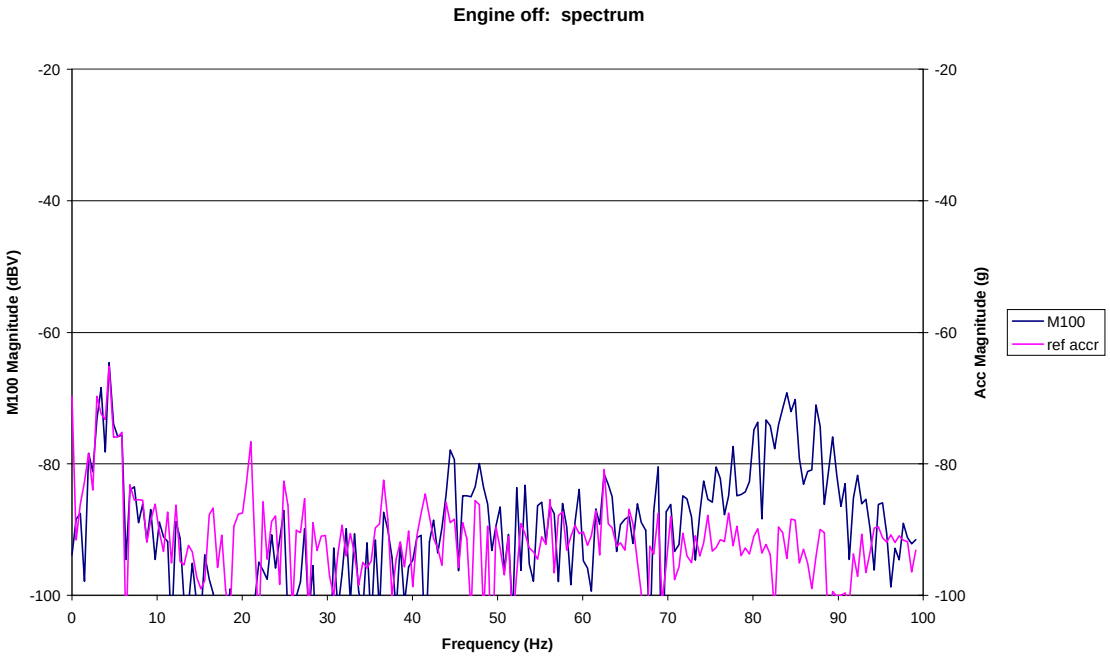
20 kph: with the vehicle now moving, there is a significant increase in the level of "random" vibration. Few distinct peaks are visible in the spectrum (perhaps due to slight speed variations during the time record). A small discrete shock can be seen from both transducers at time = 1.36 s (with amplitude –0.073 g).

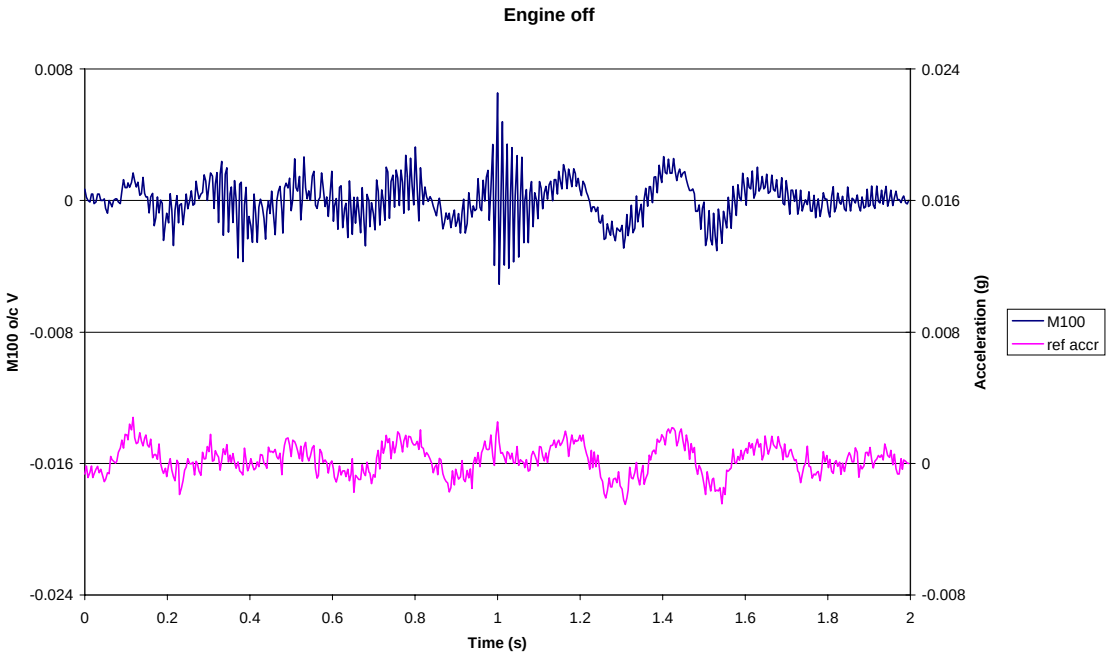
60 kph: a further rise in overall broad-band random vibration

80 kph: distinct peak at 22.5 Hz (1350 rpm) and at 38.6 Hz (2316 rpm), plus harmonics. Random level similar to 60 kph

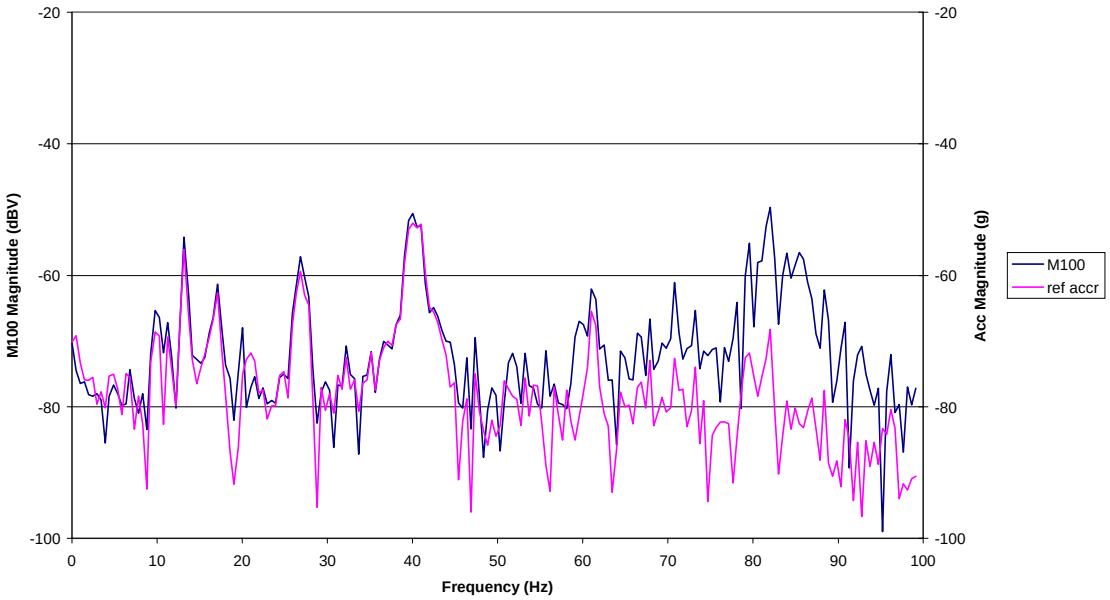
100 kph: strong peaks at 26.4 Hz (1580 rpm), 45.4 Hz (2724 rpm), and 81 Hz (4860 rpm)

130 kph: peaks less distinct, Minisense 100 output is becoming dominated by energy around its resonance frequency

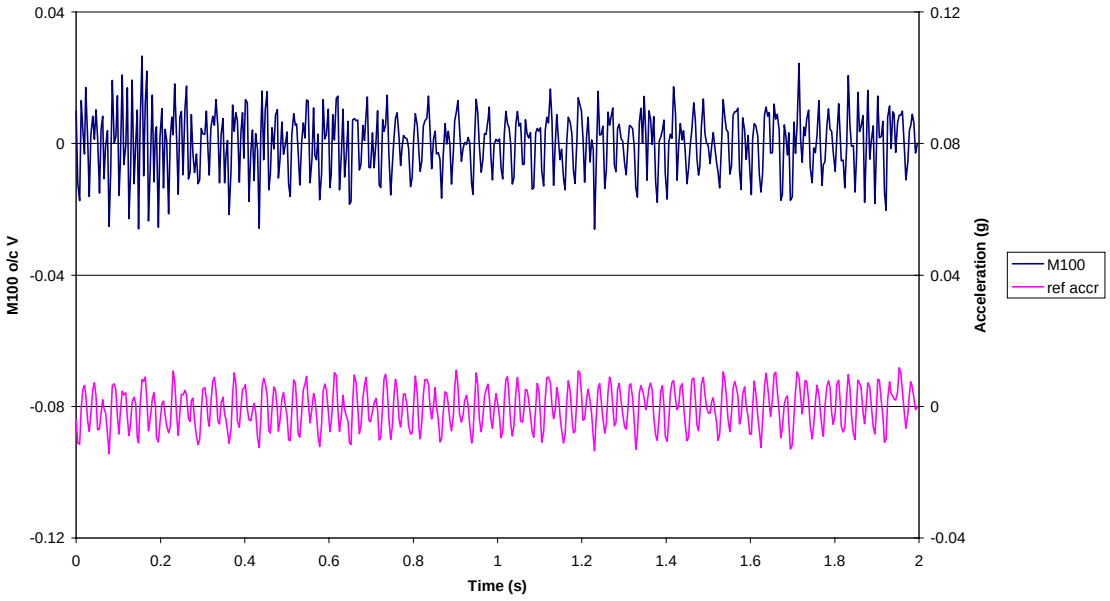

Engine off: spectrum
-20
-40
-60
-80
-100
M100 Magnitude (dBV)
Acc Magnitude (g)
0
10
20
30
40
50
60
70
80
90
100
Frequency (Hz)
M100
ref accr

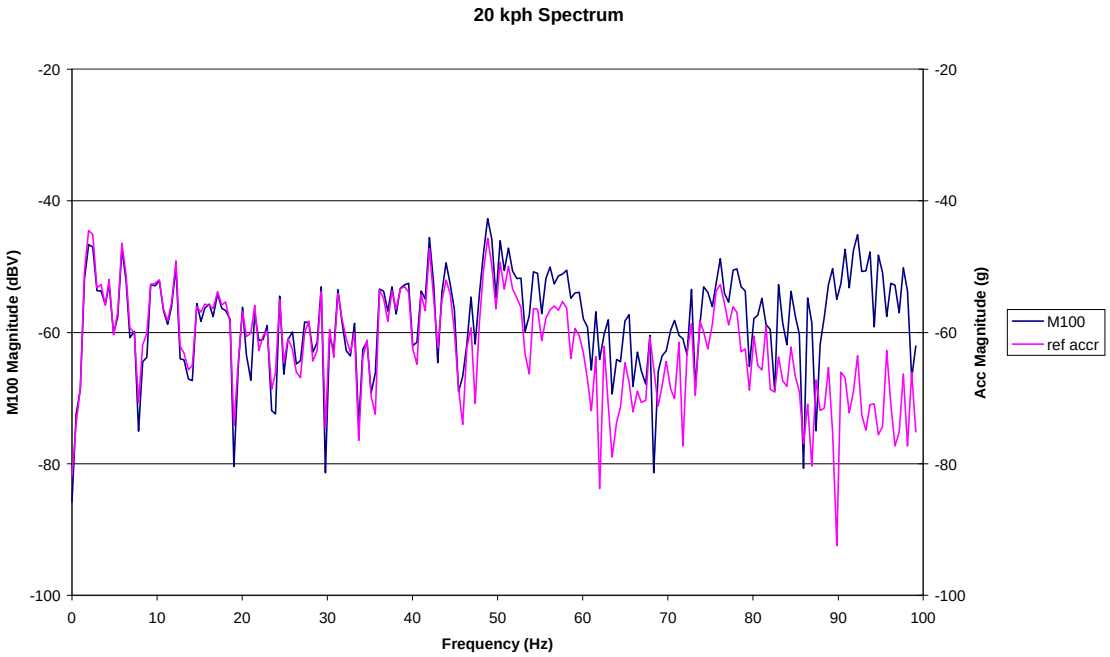

Engine off
0.008
0
-0.008
-0.016
-0.024
0.024
0.016
0.008
0
-0.008
M100 o/c V
Acceleration (g)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (s)
M100
ref accr

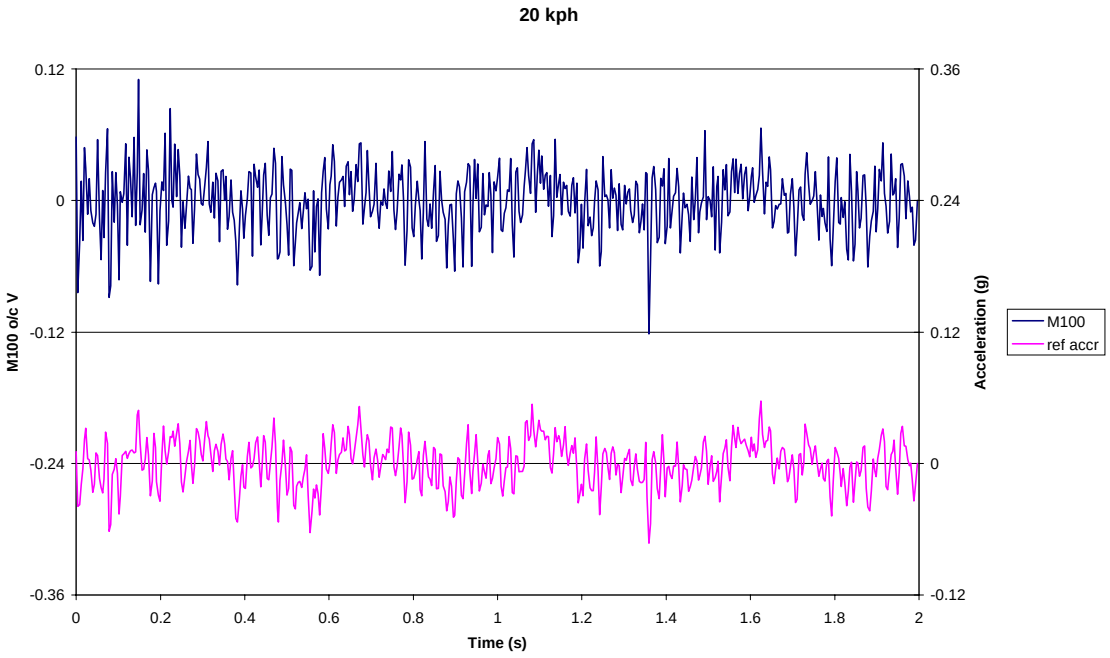
Engine idling: spectrum

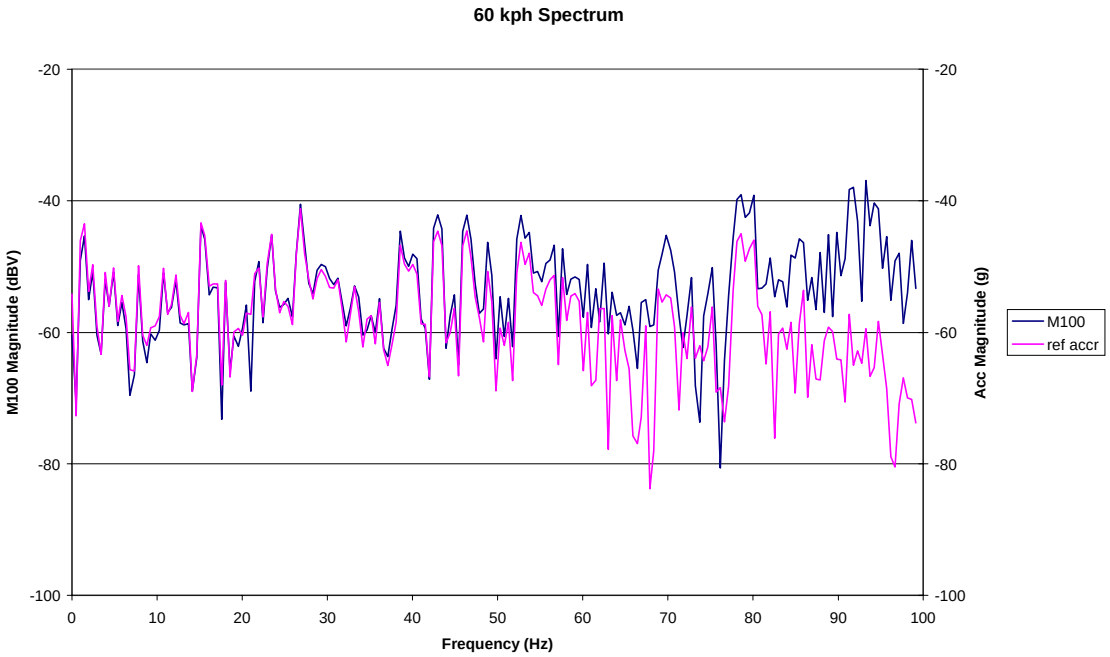


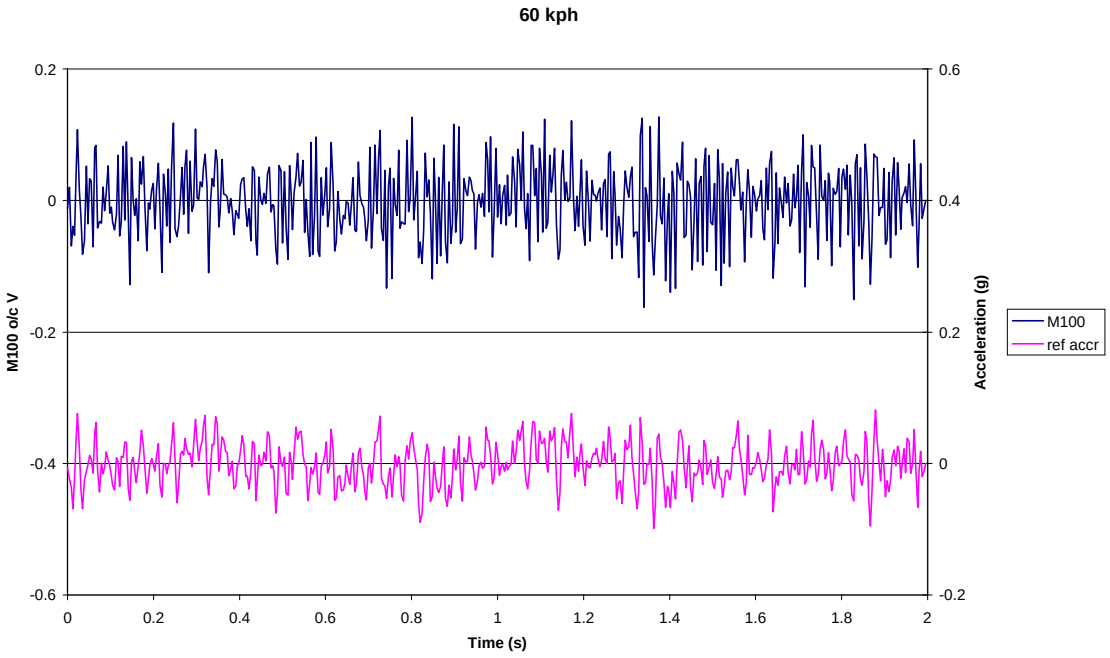
Engine idling

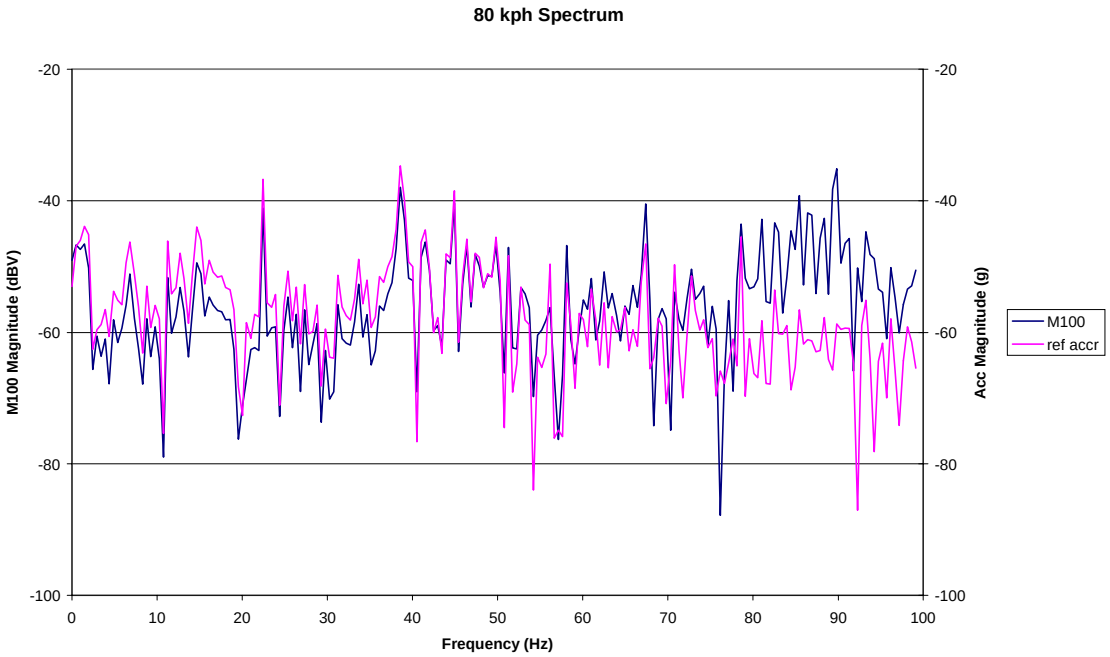


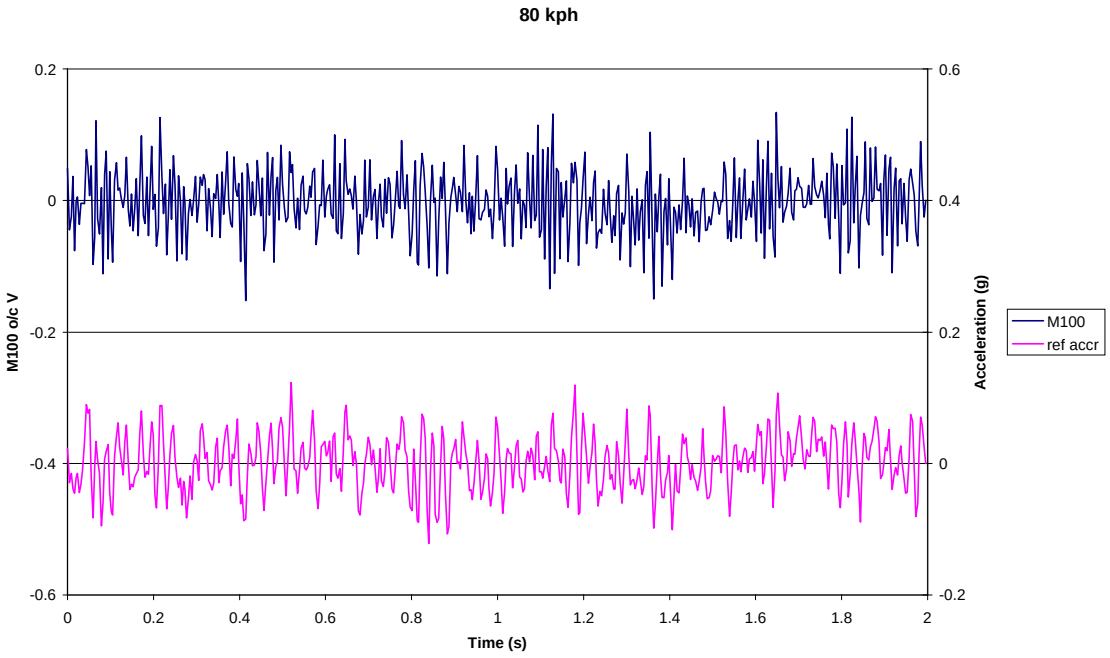

20 kph Spectrum
M100 Magnitude (dBV)
Acc Magnitude (g)
Frequency (Hz)
M100
ref accr
-20
-40
-60
-80
-100
0
10
20
30
40
50
60
70
80
90
100

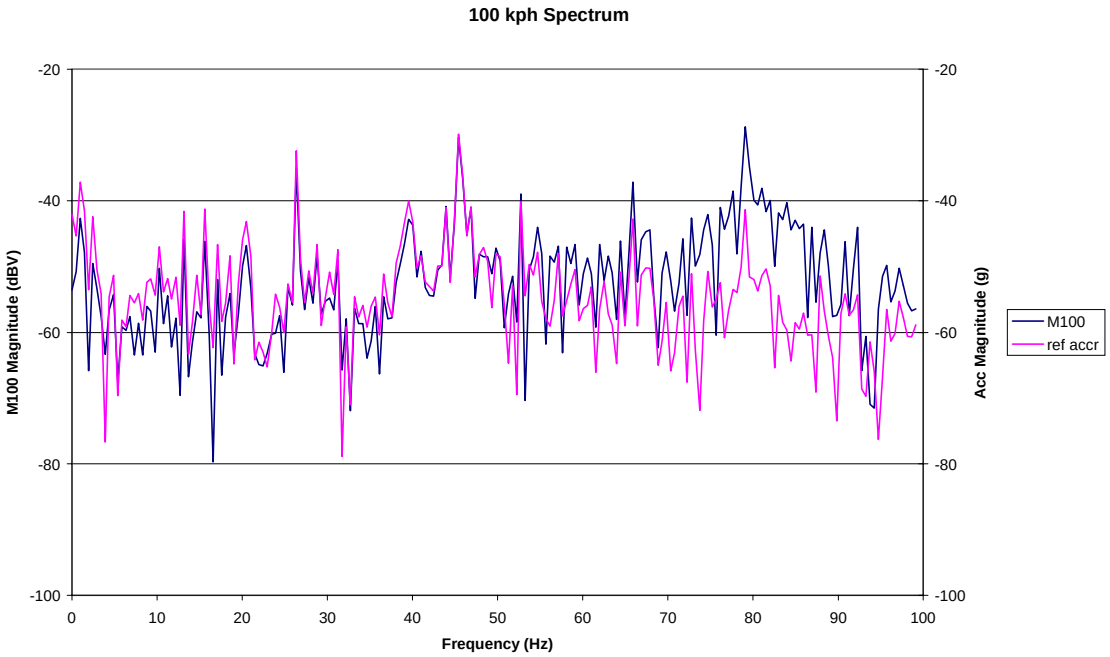

20 kph
M100 o/c V
Acceleration (g)
Time (s)
M100
ref accr
0.12
0
-0.12
-0.24
-0.36
0.36
0.24
0.12
0
-0.12
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

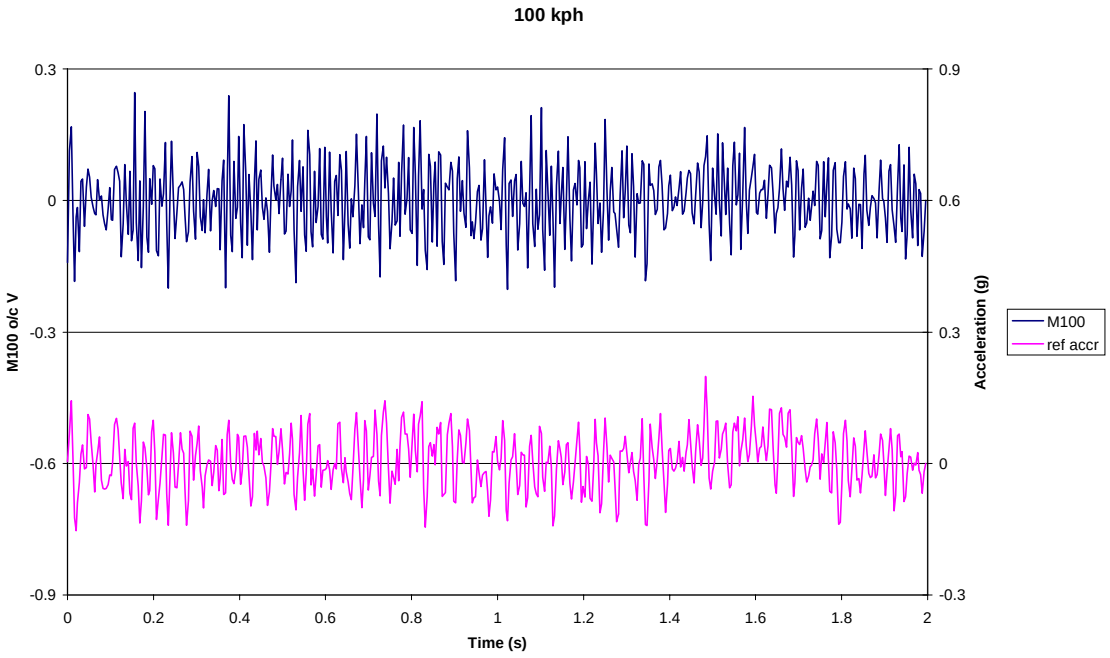

60 kph Spectrum
M100 Magnitude (dBV)
Acc Magnitude (g)
Frequency (Hz)
-20
-40
-60
-80
-100
0
10
20
30
40
50
60
70
80
90
100
M100
ref accr


60 kph
M100 o/c V
Acceleration (g)
Time (s)
0.2
0
-0.2
-0.4
-0.6
0.6
0.4
0.2
0
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
M100
ref accr

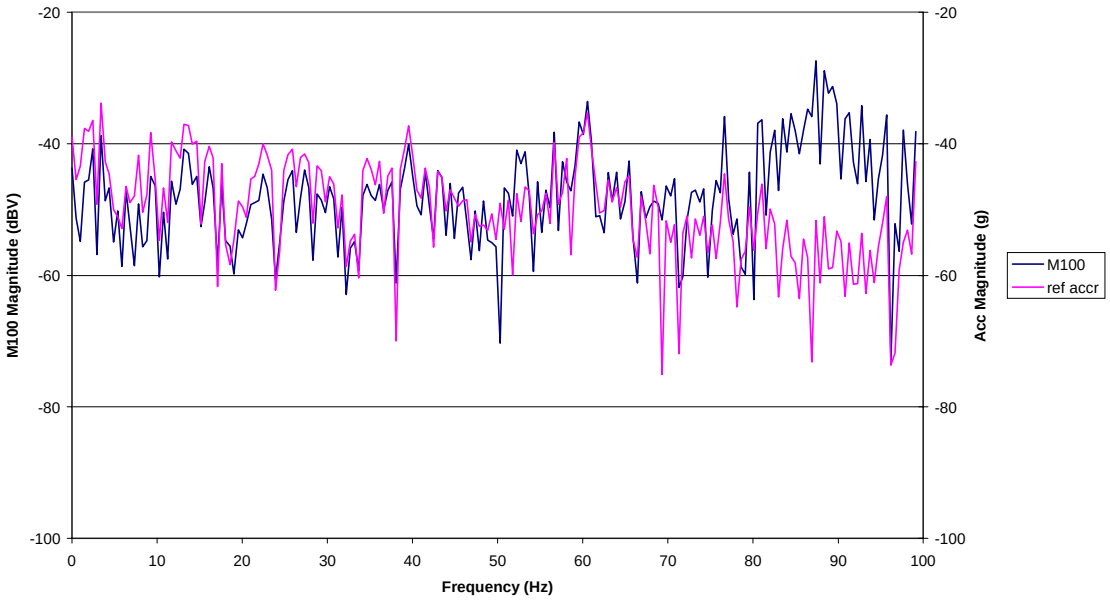

80 kph Spectrum
-20
-40
-60
-80
-100
0
10
20
30
40
50
60
70
80
90
100
M100 Magnitude (dBV)
Acc Magnitude (g)
Frequency (Hz)
M100
ref accr


80 kph
0.2
0
-0.2
-0.4
-0.6
0.6
0.4
0.2
0
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
M100 o/c V
Acceleration (g)
Time (s)
M100
ref accr

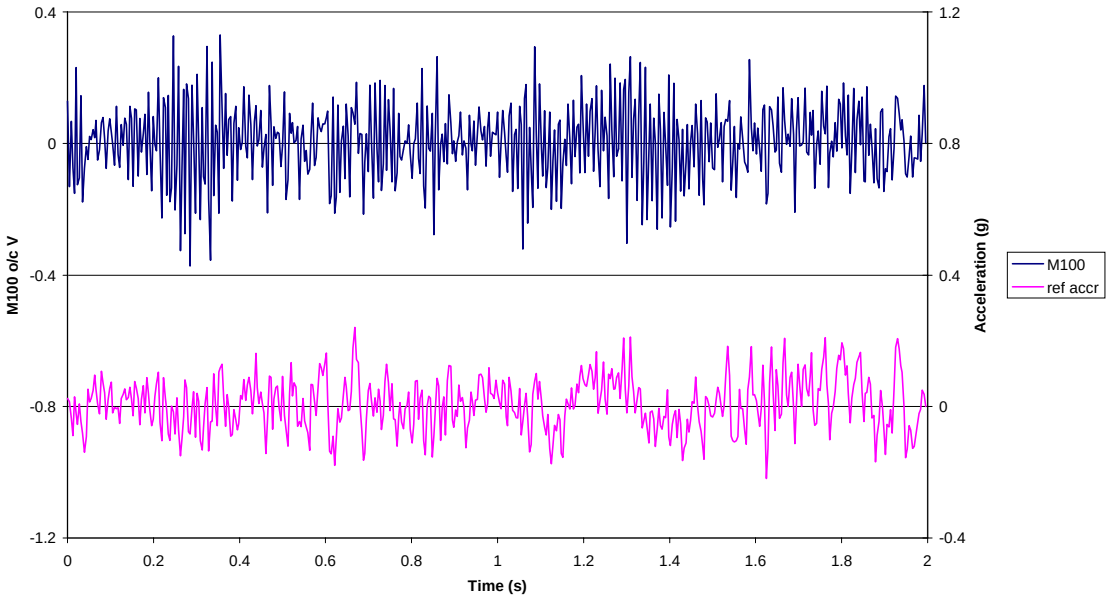

100 kph Spectrum
M100 Magnitude (dBV)
Acc Magnitude (g)
Frequency (Hz)
-20
-40
-60
-80
-100
0
10
20
30
40
50
60
70
80
90
100
M100
ref accr


100 kph
M100 o/c V
Acceleration (g)
Time (s)
0.3
0
-0.3
-0.6
-0.9
0.9
0.6
0.3
0
-0.3
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
M100
ref accr

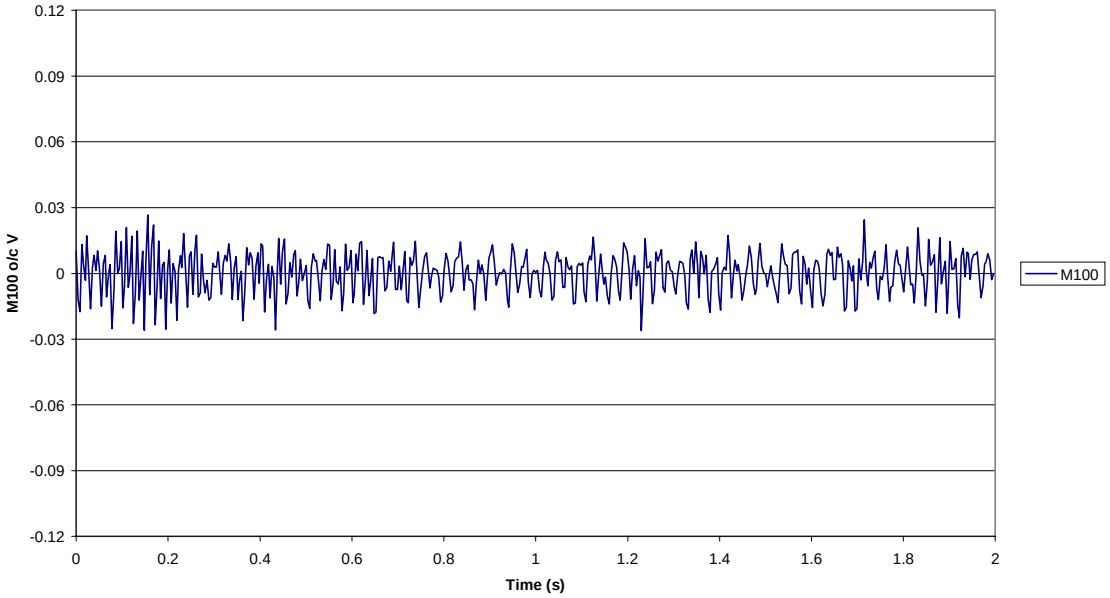
130 kph Spectrum



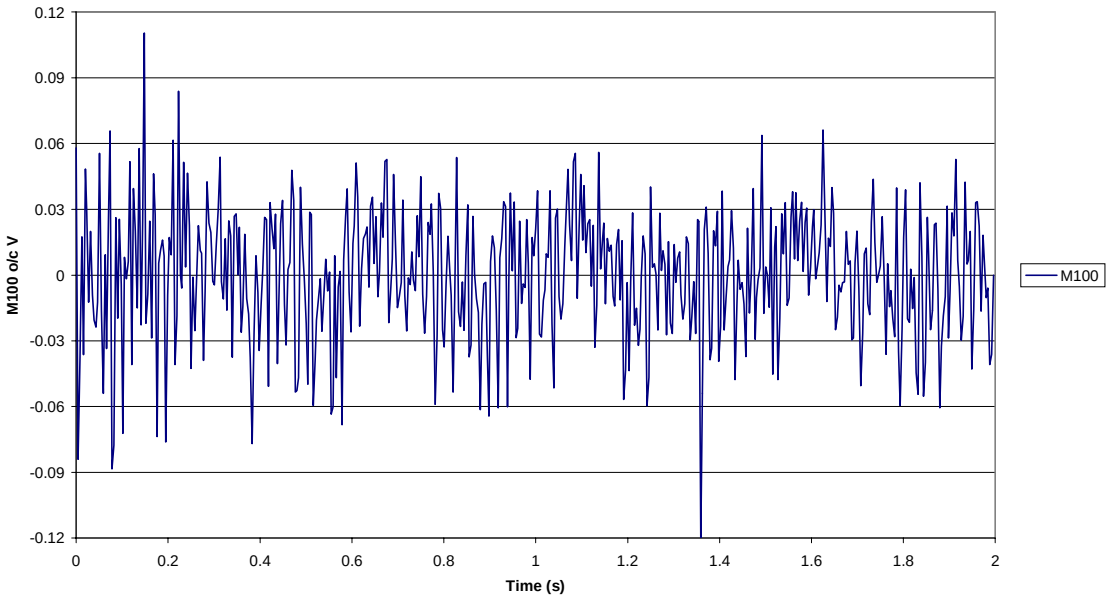
130 kph



Engine idling



20 kph



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