

Multi-Resolution for Random Control

Application Note 032

An Innovative Approach to Improve the Control Accuracy in Low Frequency

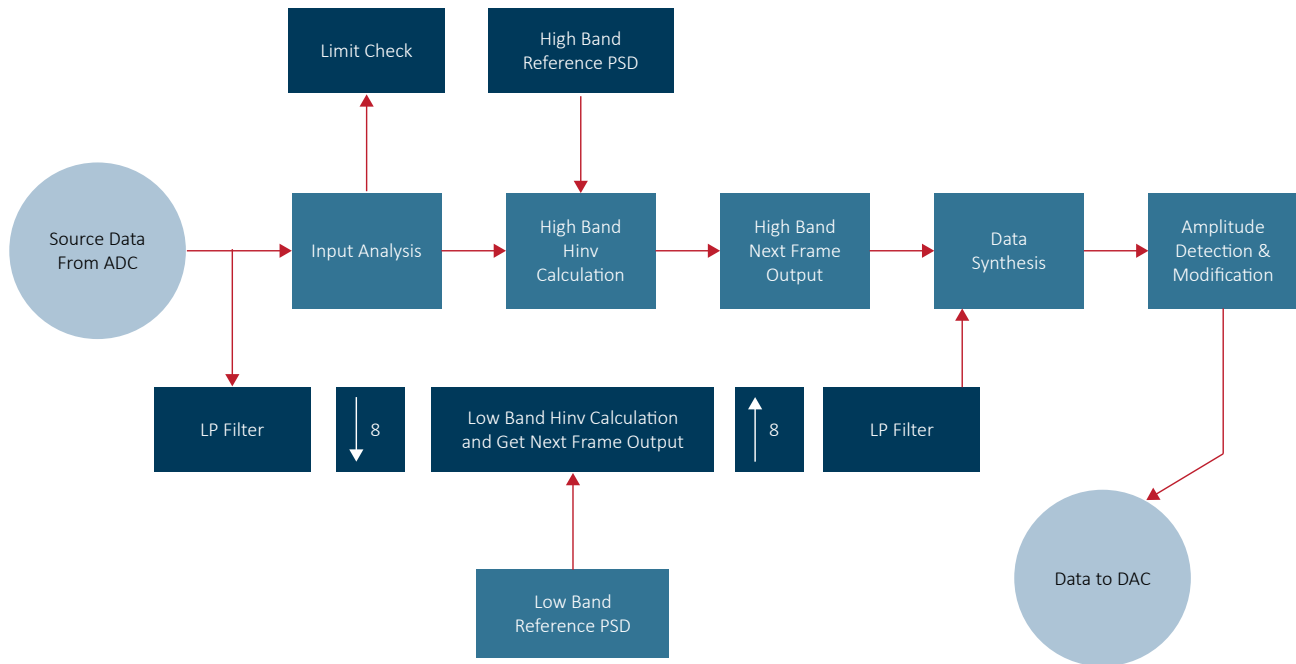


Figure 2: Two Bands Multi-resolution Random Control

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Many characteristics of mechanical systems are better described logarithmically in the frequency domain. In vibration control tests, uniform frequency resolution that FFT offers is not ideal because the resolution is enough in the high-frequency range may be not enough in the low frequency and the control performance is impacted.

For example, many popular Random test standards require a profile up to 2kHz and high resolution in the low-frequency range. To meet the requirement, high resolution (large block size) that is not needed in high frequency must be used. Therefore, loop time and storage space increase and spectrum refresh rate decrease in the high-frequency range.

To increase the control performance in the low-frequency range and maintain reasonable loop time, different resolutions should be applied to the low and high-frequency range in the entire control process. EDM provides the multi-resolution feature that applies the selected resolution in the high-frequency range and 8 times of the resolution in the low-frequency range. The cutoff frequency, which divides the low and high-frequency range, is calculated by the software. A few adjacent frequencies can also be selected by the user to avoid system resonance or anti-resonance.

Control Algorithms

In the implementation, two different control loops with different sampling rates are used. Suppose that the sampling rate in the control system is F_s , we divide the whole frequency range into two bands: $(0, F_s/20]$ and $(F_s/20, F_h)$. ΔF is the resolution in frequency band $(F_s/20, F_h)$, then we use $\Delta F/8$ as the resolution in $(0, F_s/20]$. Down sampling 8 is used in the algorithm. Fig.2 shows us the multiresolution control method to be used. (Figure 1.1)

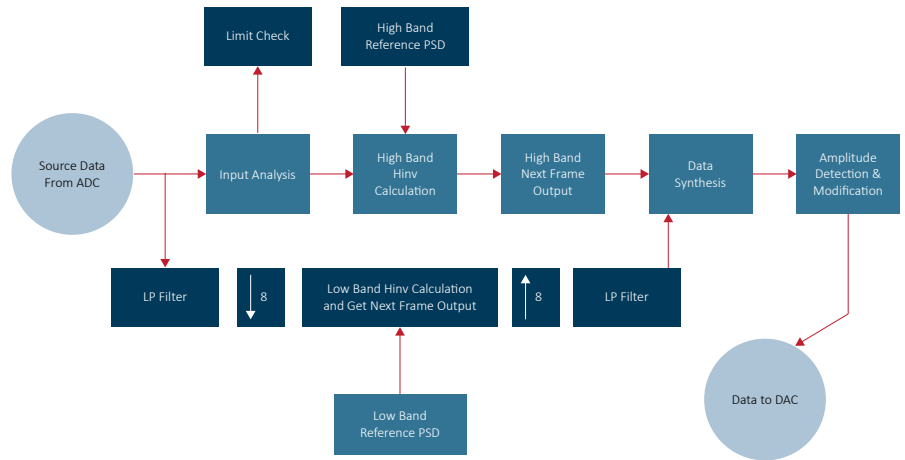


Figure 2: Two Bands Mult-resolution Random Control

Figure 1.1

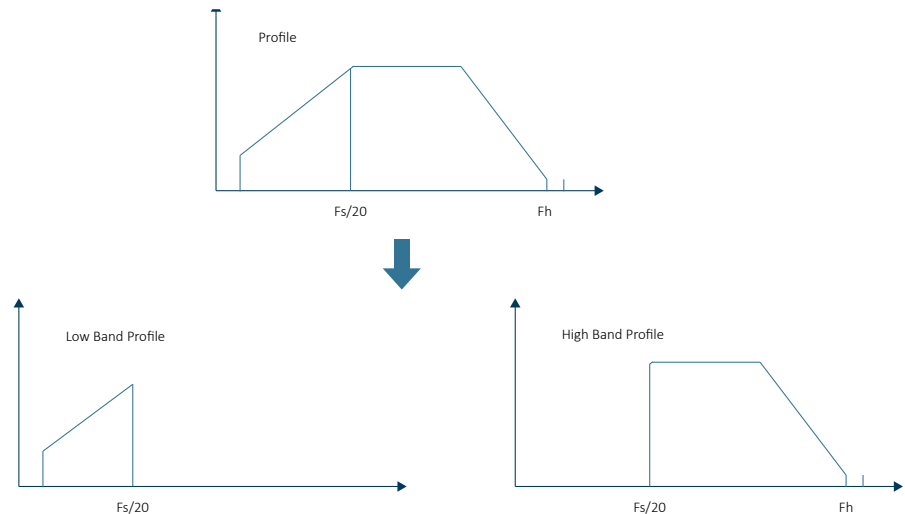


Figure 3: Profile Divide into Two Bands

Figure 1.2

The output peak detection and modification also remain unchanged. In the CalOutput() function, we just add data from different bands, and send the result to the following detection and modification model, just as what in the now using system. The user defined profile shall be decomposed into 2 bands in the initializing period, to get the low band reference profile. The Spider will operate on these two profiles simultaneously. (Figure 1.2)

Testing Comparison

In the composite window below, a test is running without multi-resolution control at 400 lines.

The blue line is the control spectrum. The green line is the profile spectrum. Yellow and red lines are alarm and abort limits.

In this case, a Spider is running a Random test with a profile where there are a few peaks and valleys below 100 Hz and between 200 to 500 Hz. We can see that control

spectrum matches the profile very well between 200 to 500 Hz, but not satisfactory below 100 Hz. The reason is described in the first paragraph of this article. (Figure 1.3)

With multi-resolution control enabled, the resolution in the low-frequency range is much higher and the control performance is greatly improved. The control spectrum matches the profile below 100 Hz as well as 200 to 500 Hz. (Figure 1.4)

By zooming to 13~100 Hz range in the control composite window in both cases. The top chart shows how control(f) matches profile(f) WITHOUT multi-resolution control. The bottom chart shows how control(f) matches profile(f) WITH multi-resolution control. Control(f) matches profile(f) better with the multi-resolution control. (Figure 1.5)

Here are more test results for comparison: (line = 400, Fa = 2000 Hz, deltaF = 5 Hz)

Signals in the left chart are saved in a Random test WITH multi-resolution. Signals in the right chart are saved in a Random test WITHOUT multi-resolution. Both charts show the frequency range of 10 Hz to 2000 Hz. (Figure 1.6)

Zoom to 15 to 100 Hz range. (Figure 1.7)

The following table shows the deviation in decibels between the control(f) and profile(f) (|Control(f)-Profile(f)|) at each FFT bin frequency. (Table 1)

Plot averaged difference of 5 signals at each frequency in both cases. (Table 2)

Conclusion: the difference between control(f) and profile(f) is much more minimized in the low-frequency range with multi-resolution control.

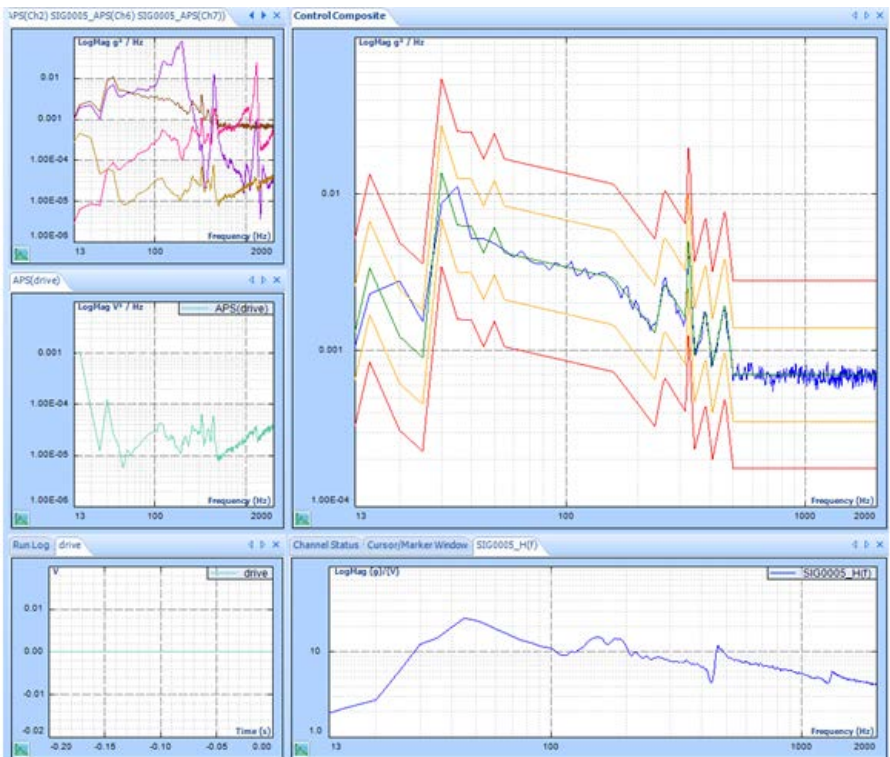


Figure 1.3

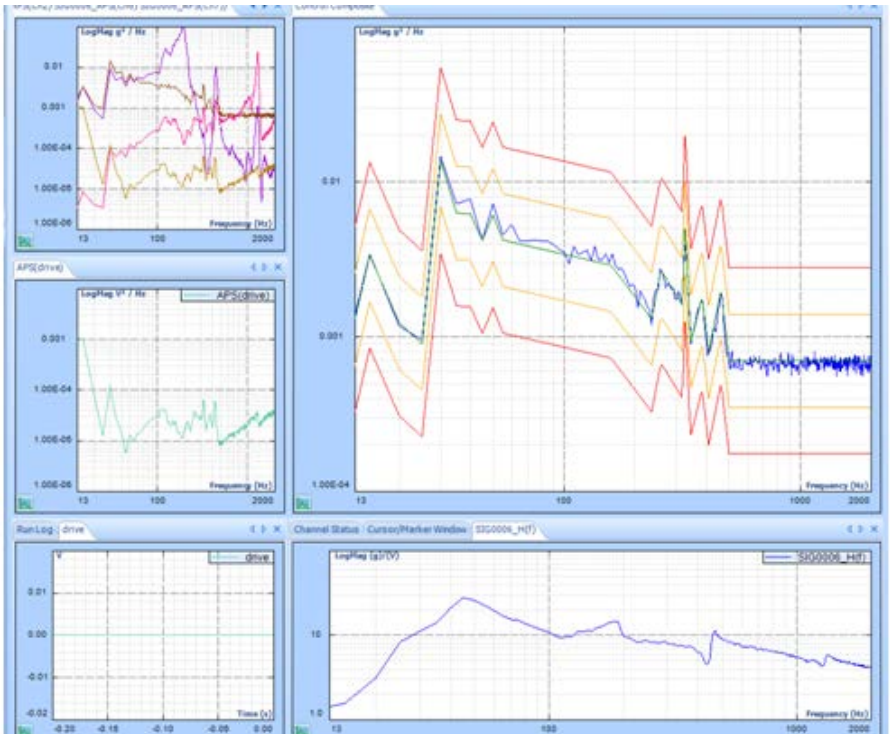


Figure 1.4

(Figure 1.8)



Figure 1.5

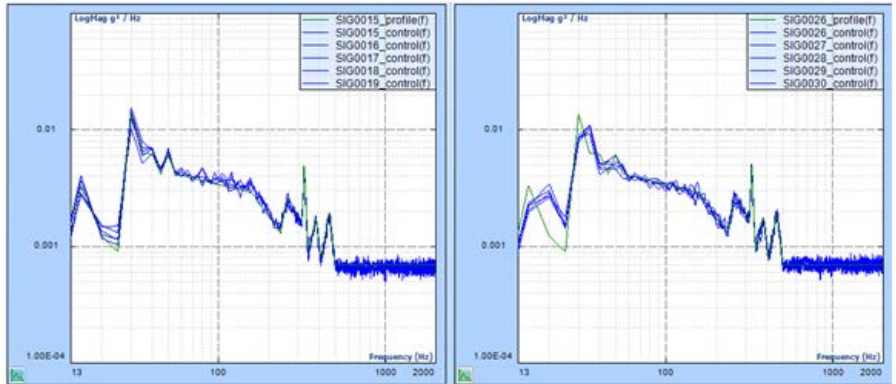


Figure 1.6

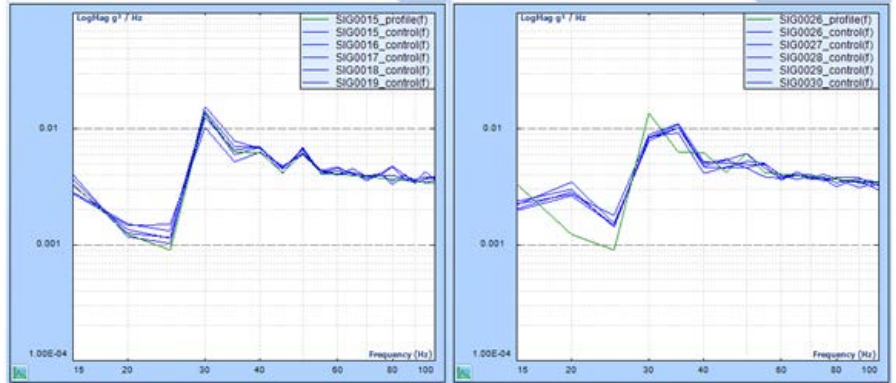


Figure 1.7

Signal Name:		SIG0015	SIG0016	SIG0017	SIG0018	SIG0019	
Freq (Hz)	Profile(f) (dB)	Control (f)-Profile(f) (dB)					Average Control (f)-Profile(f) (dB)
15.0	-24.75	0.82	0.70	0.13	0.43	0.82	0.58
20.0	-29.10	0.77	0.91	0.41	0.10	0.21	0.48
25.0	-30.46	2.21	1.64	1.02	1.08	0.57	1.31
30.0	-18.63	1.25	0.15	0.07	0.41	0.57	0.49
35.0	-22.02	0.82	0.51	0.21	0.19	0.99	0.54
40.0	-22.05	0.05	0.49	0.47	0.52	0.36	0.38
45.0	-23.77	0.58	0.37	0.06	0.30	0.45	0.35
50.0	-22.14	0.10	0.32	0.55	0.46	0.06	0.30
55.0	-23.77	0.14	0.05	0.02	0.09	0.21	0.10
60.0	-23.90	0.62	0.51	0.25	0.02	0.04	0.29
65.0	-24.02	0.09	0.21	0.25	0.59	0.26	0.28
70.0	-24.14	0.15	0.35	0.07	0.00	0.01	0.12
75.0	-24.24	0.39	0.35	0.36	0.22	0.22	0.31
80.0	-24.34	0.46	0.19	1.11	1.08	0.34	0.64
85.0	-24.43	0.38	0.54	0.49	0.11	0.10	0.32
90.0	-24.52	0.14	0.16	0.16	0.11	0.13	0.14
95.0	-24.60	0.06	0.31	0.27	0.94	0.46	0.41
100.0	-24.68	0.26	0.56	0.51	0.29	0.37	0.40

Table 1

Signal Name:		SIG0026	SIG0027	SIG0028	SIG0029	SIG0030	
Freq (Hz)	profile(f) (dB)	Control (f)-Profile(f) (dB)					Average Control(f)-Profile(f) (dB)
15.0	-24.75	1.72	2.30	2.15	1.82	1.51	1.90
20.0	-29.10	3.44	3.33	3.68	4.50	3.89	3.77
25.0	-30.46	2.98	2.14	2.13	2.32	1.97	2.31
30.0	-18.63	1.86	2.03	2.14	2.39	2.10	2.10
35.0	-22.02	2.47	1.67	2.12	2.13	2.38	2.16
40.0	-22.05	0.79	1.79	0.93	1.24	1.16	1.18
45.0	-23.77	0.81	0.50	1.14	0.39	1.09	0.78
50.0	-22.14	0.91	1.22	1.24	0.63	0.04	0.81
55.0	-23.77	0.66	0.77	0.37	0.79	0.38	0.59
60.0	-23.90	0.53	0.14	0.37	0.21	0.37	0.32
65.0	-24.02	0.33	0.32	0.12	0.08	0.01	0.17
70.0	-24.14	0.08	0.02	0.24	0.06	0.17	0.12
75.0	-24.24	0.24	0.08	0.07	0.30	0.11	0.16
80.0	-24.34	0.13	0.65	0.31	0.02	0.05	0.23
85.0	-24.43	0.27	0.15	0.05	0.09	0.26	0.17
90.0	-24.52	0.32	0.04	0.21	0.12	0.54	0.25
95.0	-24.60	0.06	0.30	0.14	0.01	0.27	0.16
100.0	-24.68	0.21	0.12	0.05	0.15	0.63	0.23

Table 2

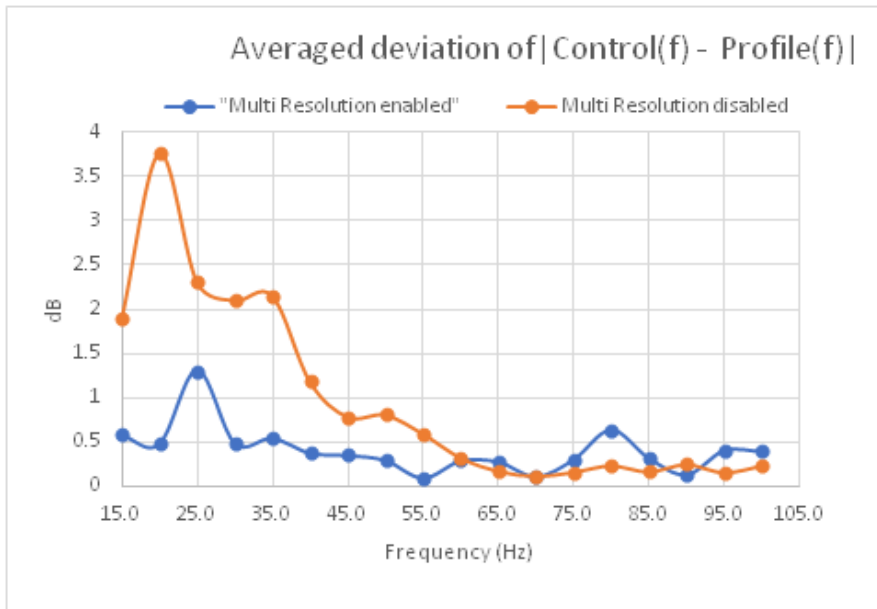


Figure 1.8

Crystal Instruments Corporation
 2090 Duane Avenue
 Santa Clara, CA 95054

Crystal Instruments Testing Lab
 15661 Producer Lane, STE H
 Huntington Beach, CA 92649

Crystal Instruments Testing Lab
 1548A Roger Dale Carter Boulevard
 Kannapolis, NC 28081

Phone: +1 (408) 986-8880
 Fax: +1 (408) 834-7818
www.crystalinstruments.com

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