Report

Build Instructions

Upgrade compiler and CMake (only needed when using ZID computers)

```
> module load gcc/7.2.0
> module load cmake/3.5.2
```

Run CMake (from project directory)

```
> mkdir build
> cd build
> cmake ../
```

Build project using Make

```
> make
```

Run program

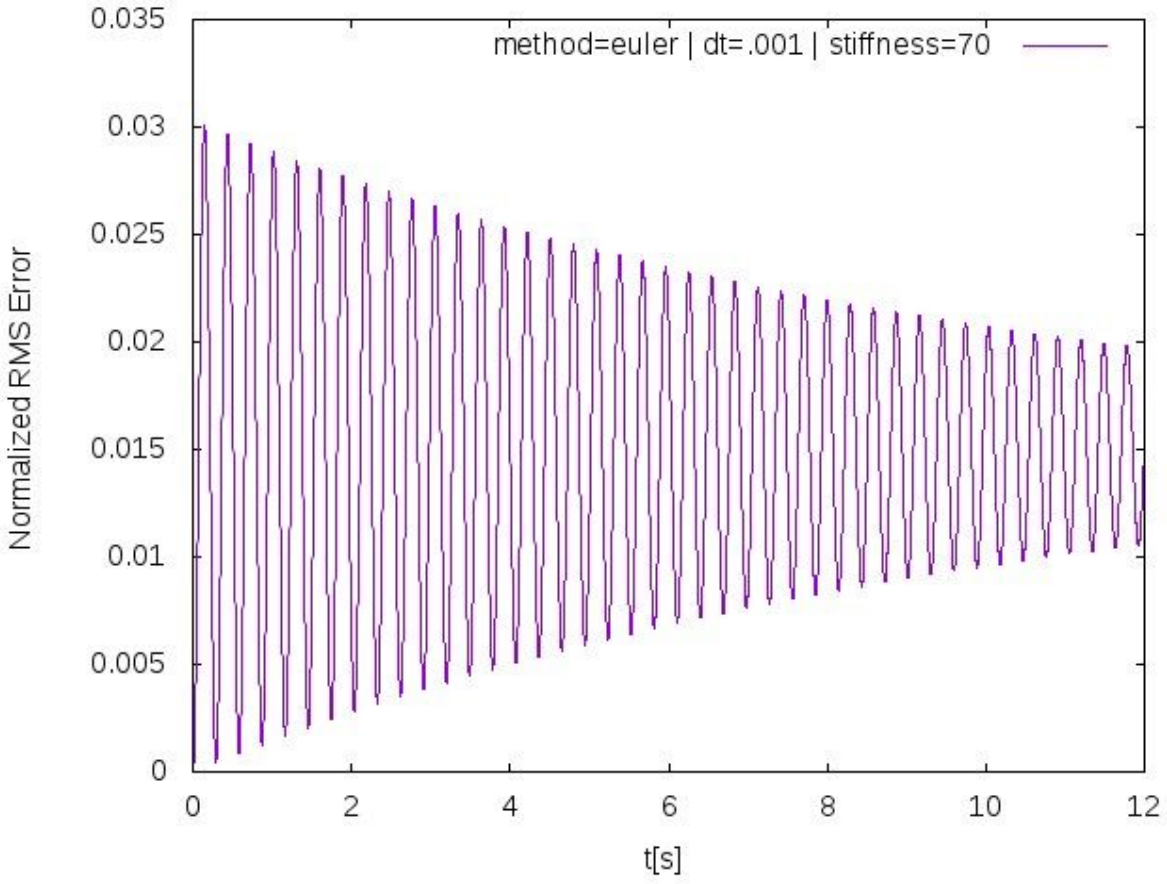
```
> ./Assignment1
```

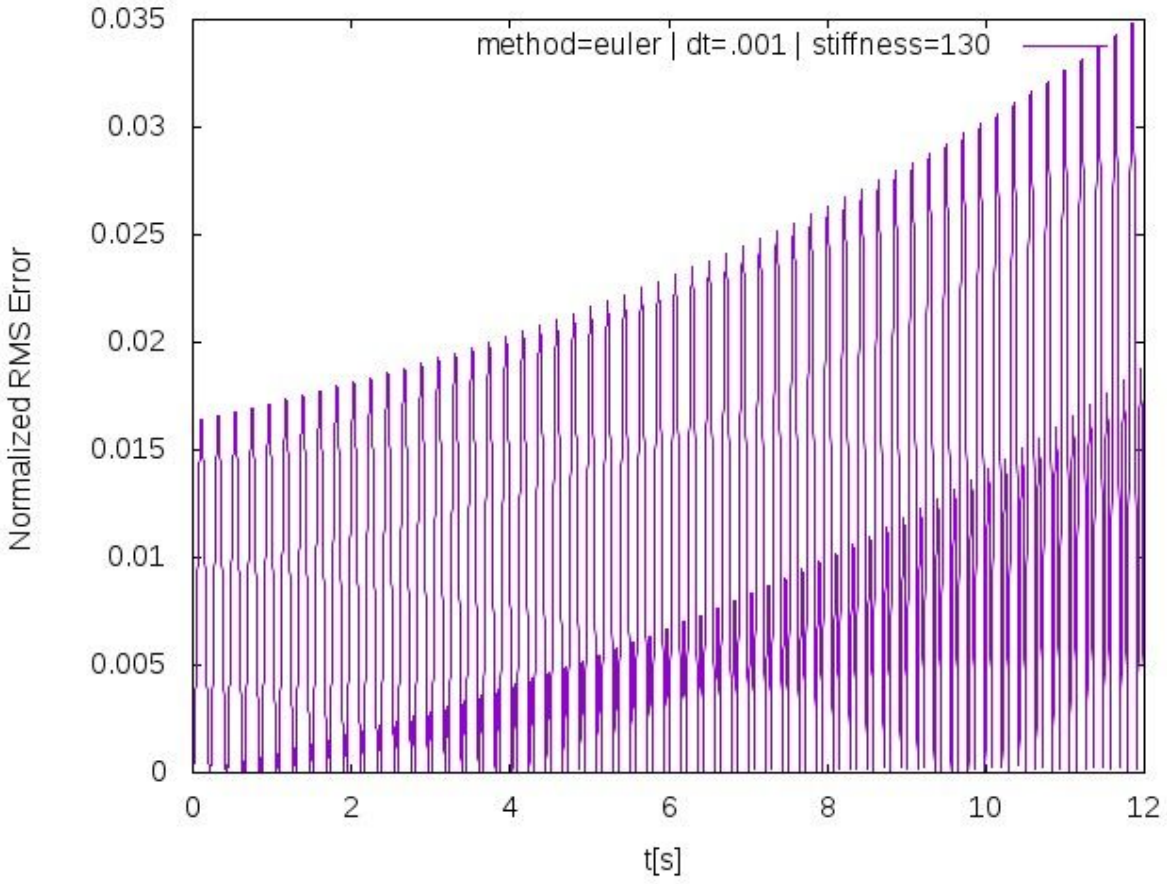
Overview

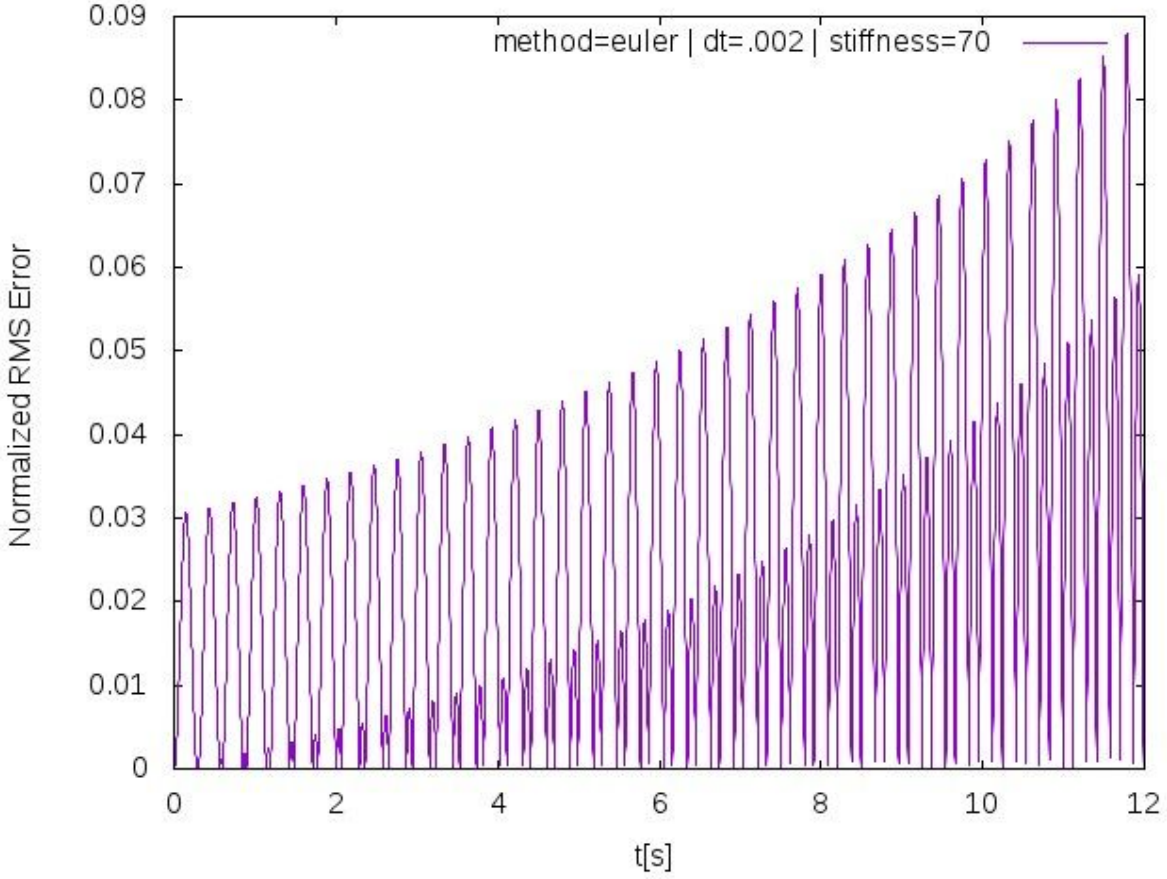
Comparison numerical solution to exact analytical solution.
We figured out that the stiffness and the step size are the most crucial parameter for the behavior of the spring. The experiments containing the borders of instability for each Method.
The plots are showing the normalized RMS error (compared to the analytical solution) as values between 0 and infinity..In the following tables the columns represent different stiffness configurations whereas the rows represent different values for the size of one timestep.

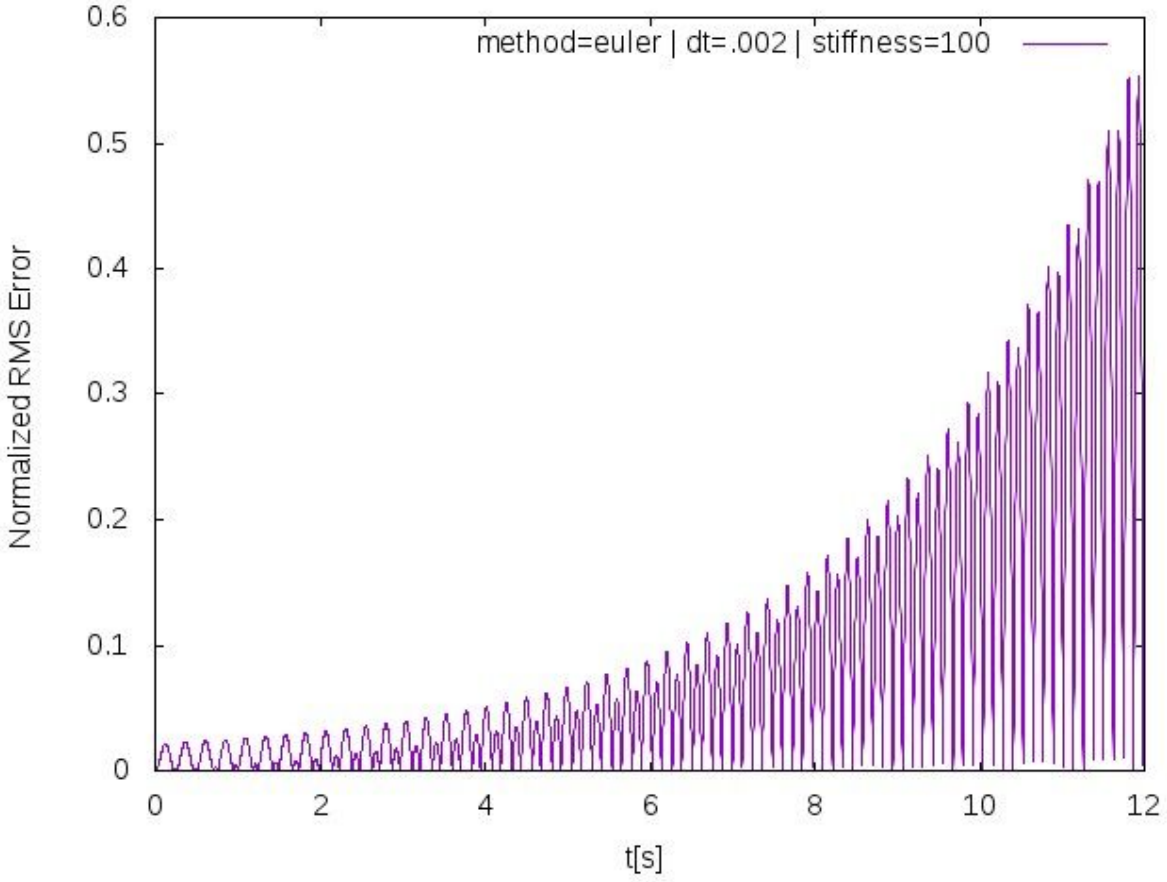
Euler:

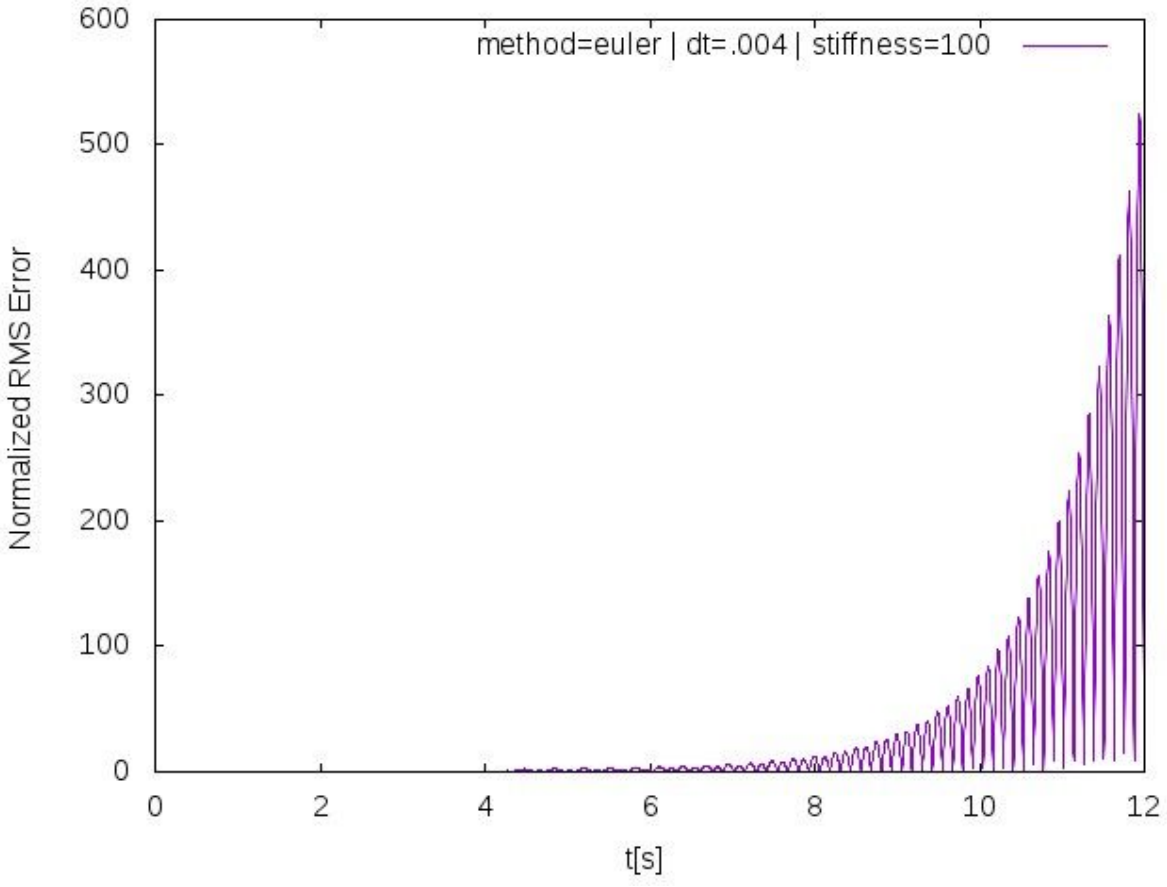
	160	130	100	70
0.001	unstable	almost stable	stable	stable
0.002	unstable	unstable	unstable	almost stable
0.003	unstable	unstable	unstable	unstable
0.004	unstable	unstable	unstable	unstable

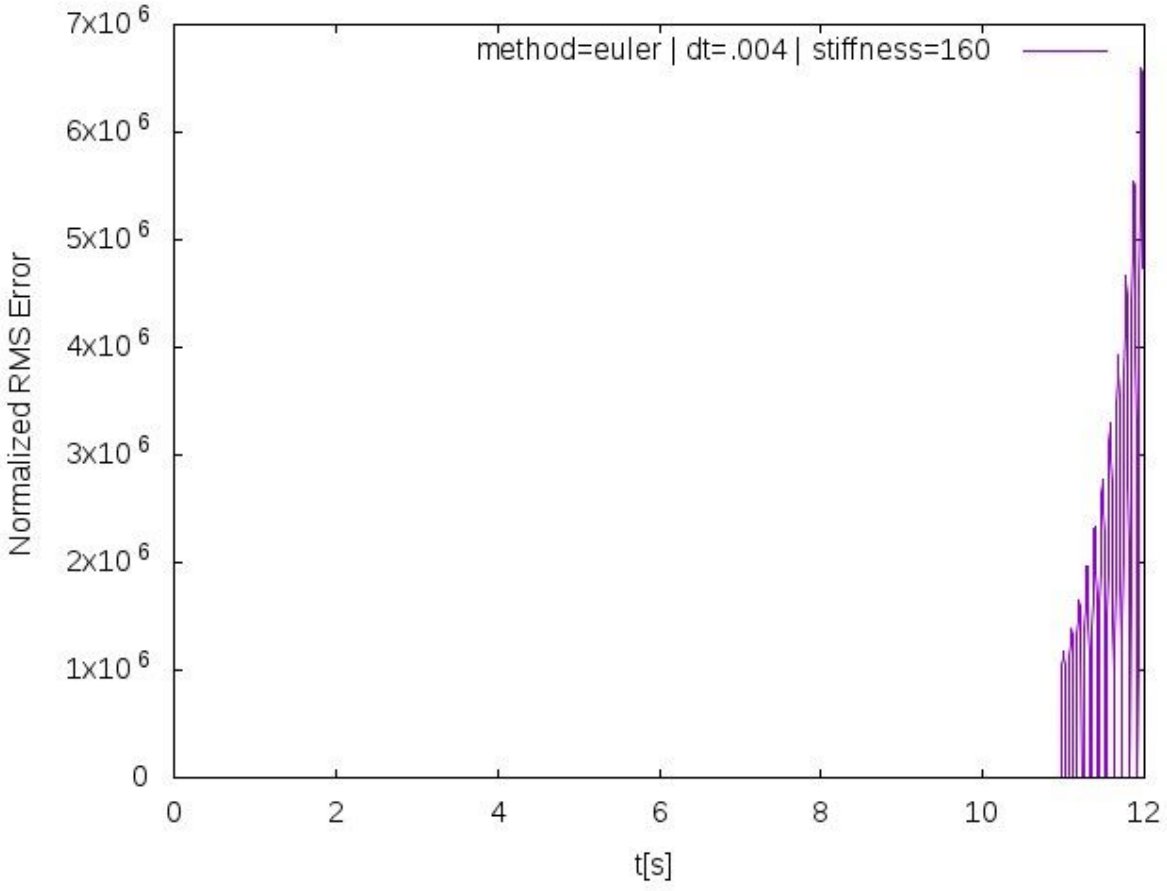

method=euler | dt=.001 | stiffness=70
Normalized RMS Error
t[s]
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
2
4
6
8
10
12


method=euler | dt=.001 | stiffness=130
Normalized RMS Error
t[s]
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
2
4
6
8
10
12


method=euler | dt=.002 | stiffness=70
Normalized RMS Error
t[s]
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
2
4
6
8
10
12

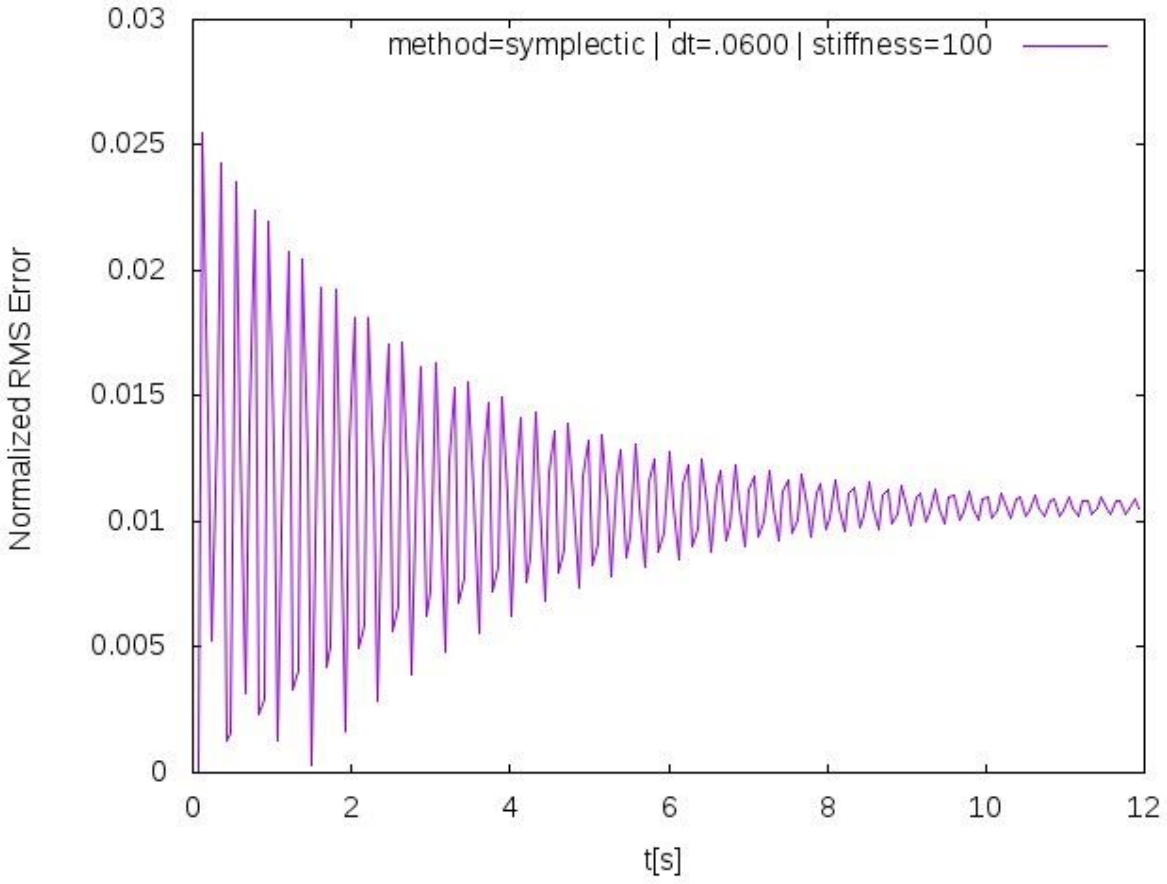

method=euler | dt=.002 | stiffness=100
Normalized RMS Error
t[s]
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12

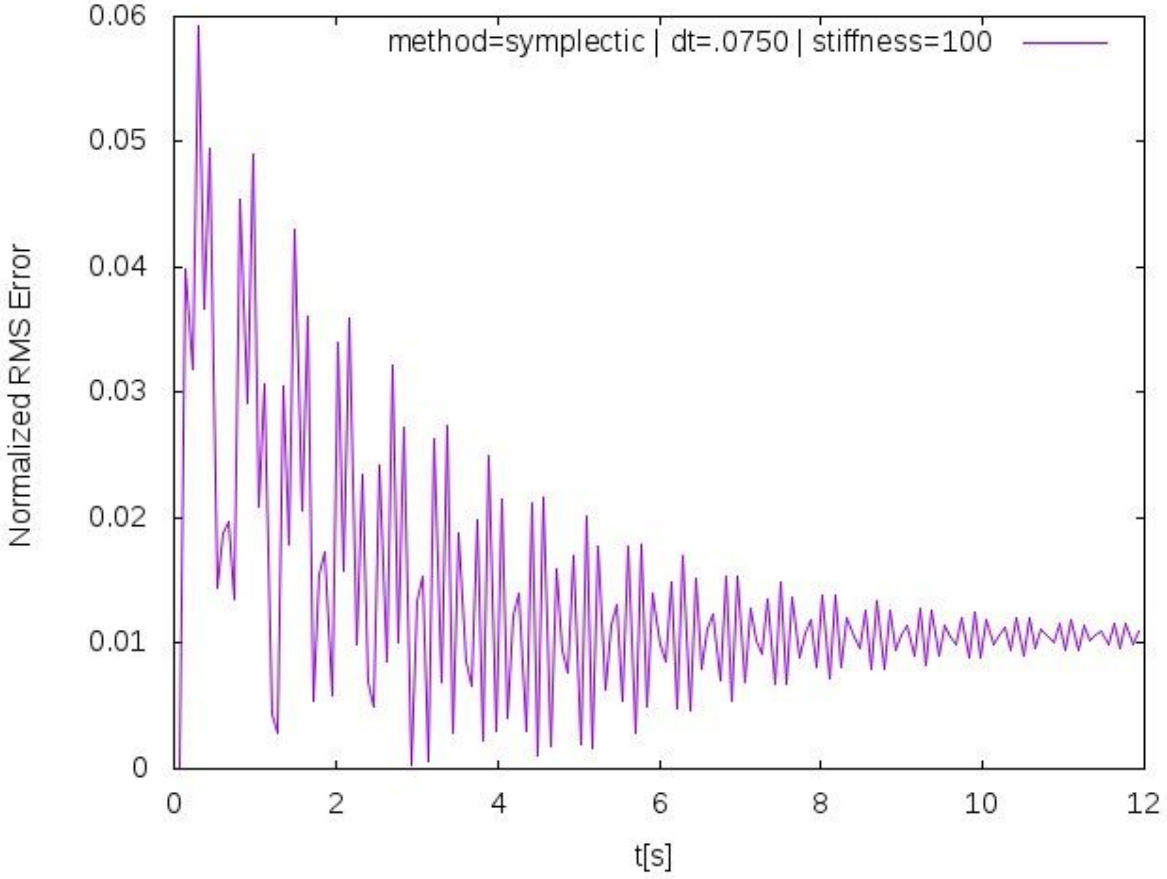

method=euler | dt=.004 | stiffness=100
Normalized RMS Error
t[s]
0
100
200
300
400
500
600
0
2
4
6
8
10
12

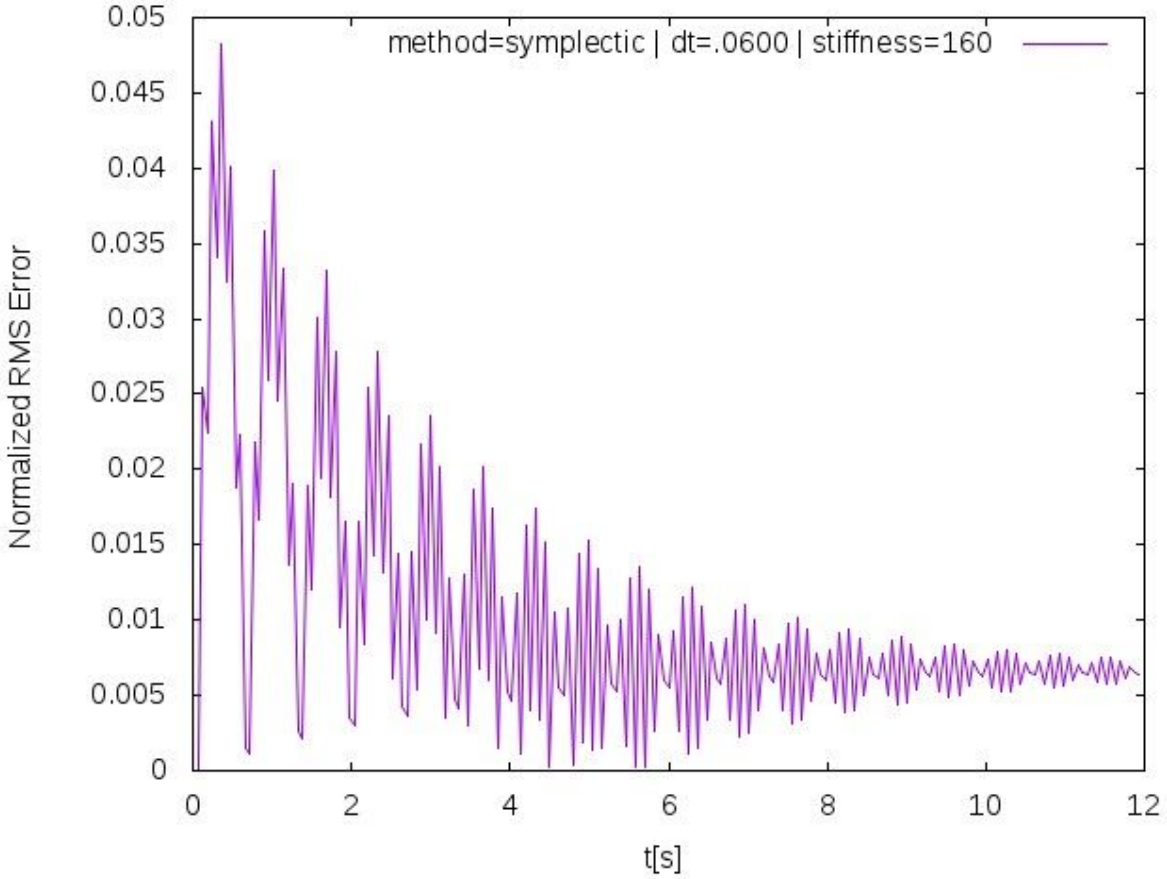

method=euler | dt=.004 | stiffness=160
Normalized RMS Error
t[s]
0
1x10^6
2x10^6
3x10^6
4x10^6
5x10^6
6x10^6
7x10^6
0
2
4
6
8
10
12

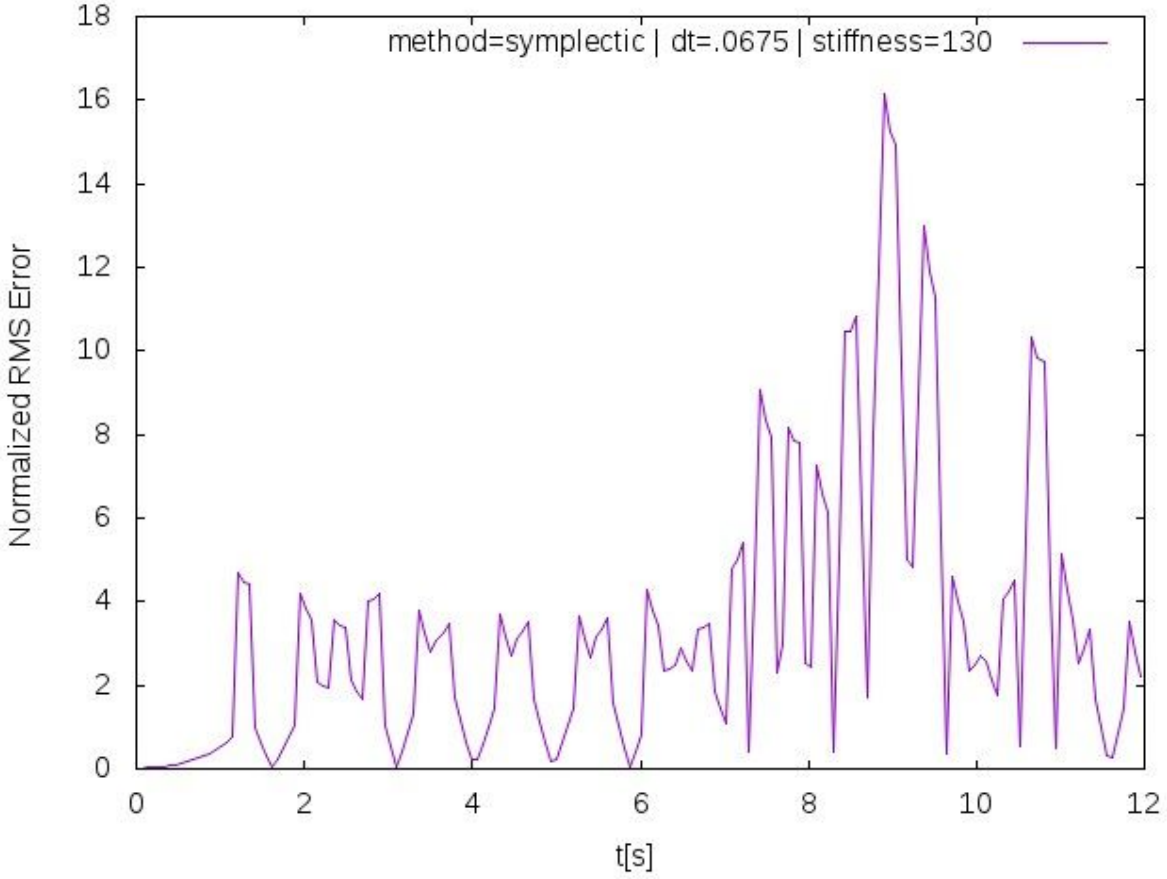
Symplectic:

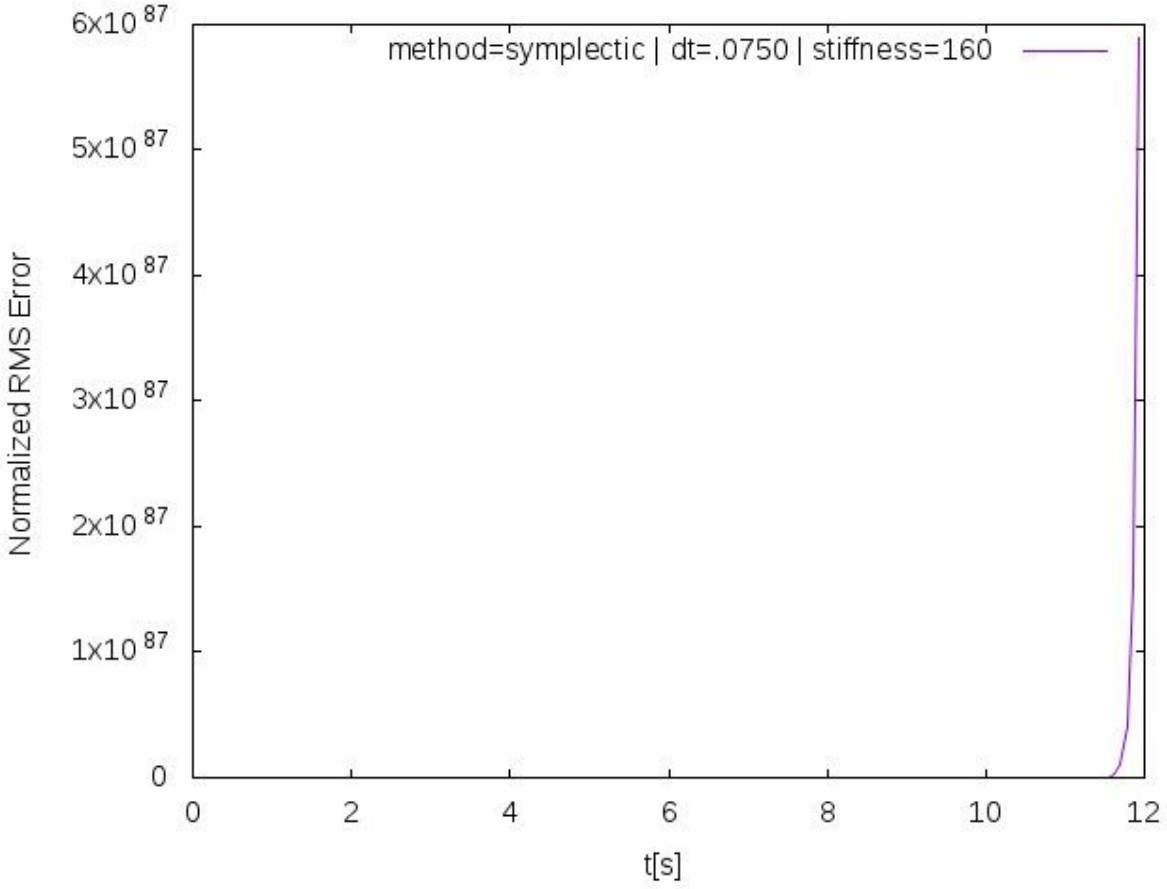
	160	130	100	70
0.0525	stable	stable	stable	stable
0.06	stable	stable	stable	stable
0.0675	unstable	unstable	stable	stable
0.075	unstable	unstable	stable	stable




method=symplectic | dt=.0750 | stiffness=100
Normalized RMS Error
t[s]
0.06
0.05
0.04
0.03
0.02
0.01
0
0
2
4
6
8
10
12

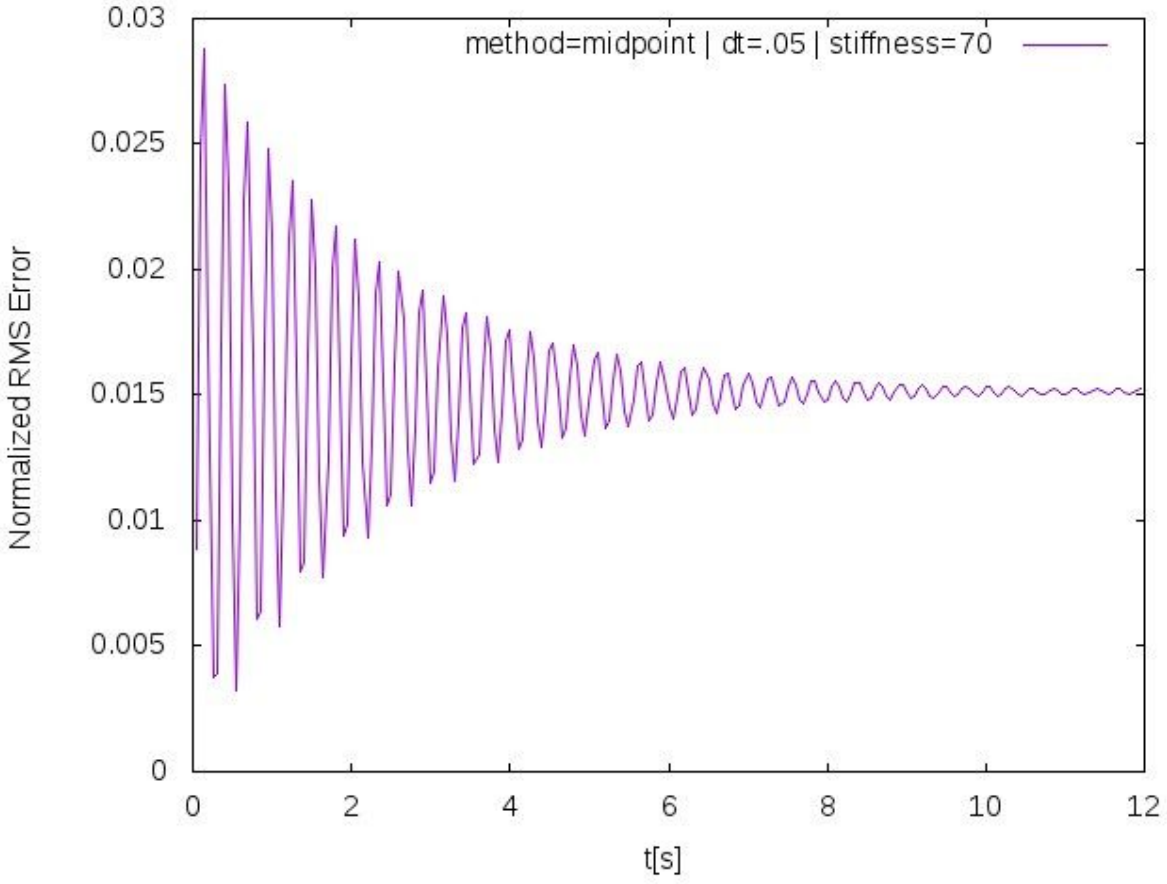

method=symplectic | dt=.0600 | stiffness=160
Normalized RMS Error
t[s]
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
2
4
6
8
10
12

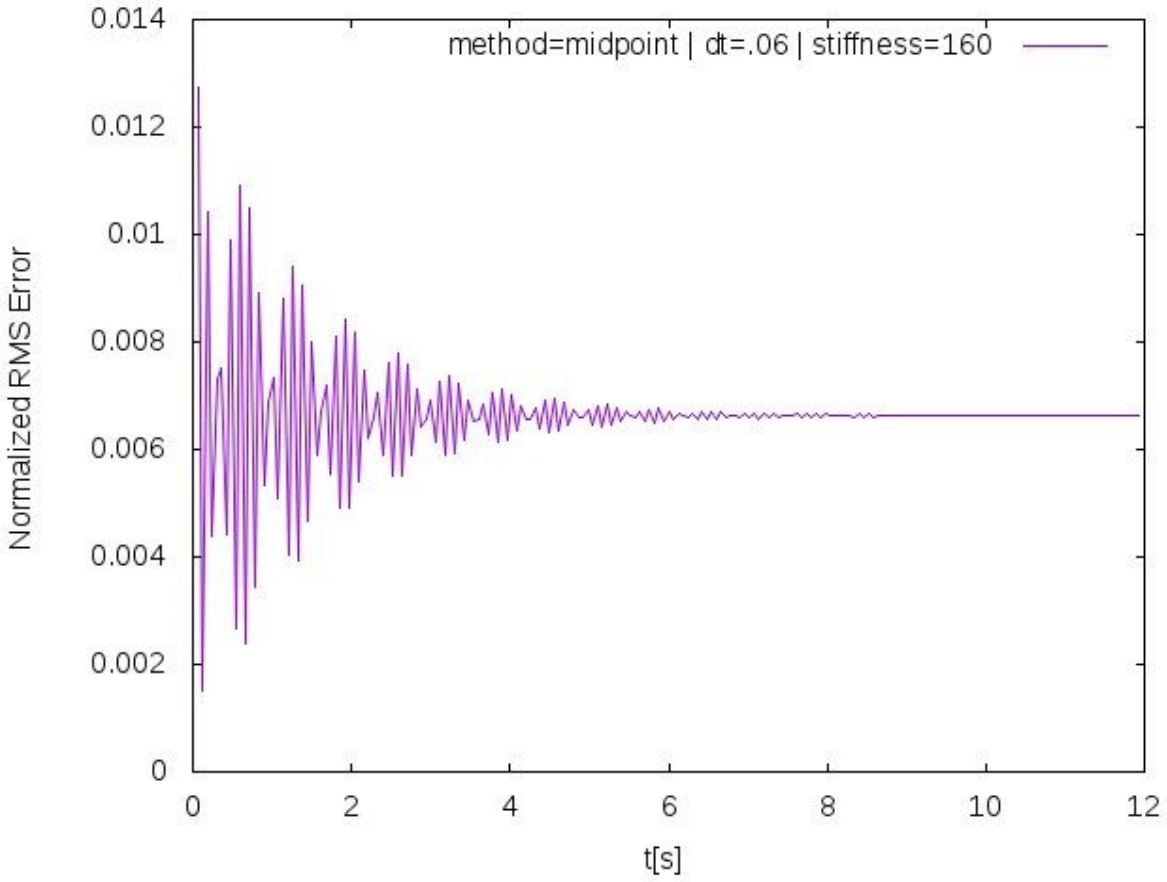

method=symplectic | dt=.0675 | stiffness=130
Normalized RMS Error
t[s]
0
2
4
6
8
10
12
14
16
18

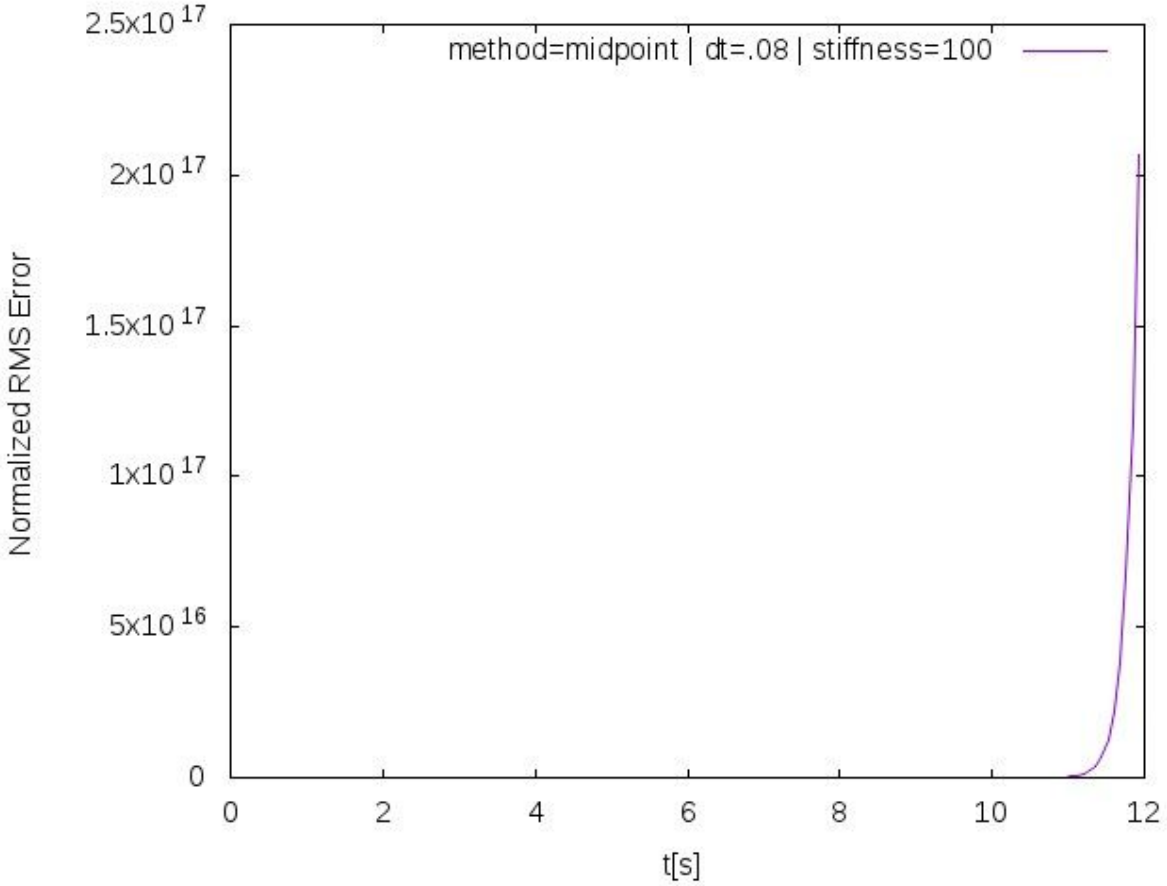

method=symplectic | dt=.0750 | stiffness=160
Normalized RMS Error
t[s]
0
1x10 87
2x10 87
3x10 87
4x10 87
5x10 87
6x10 87
0
2
4
6
8
10
12

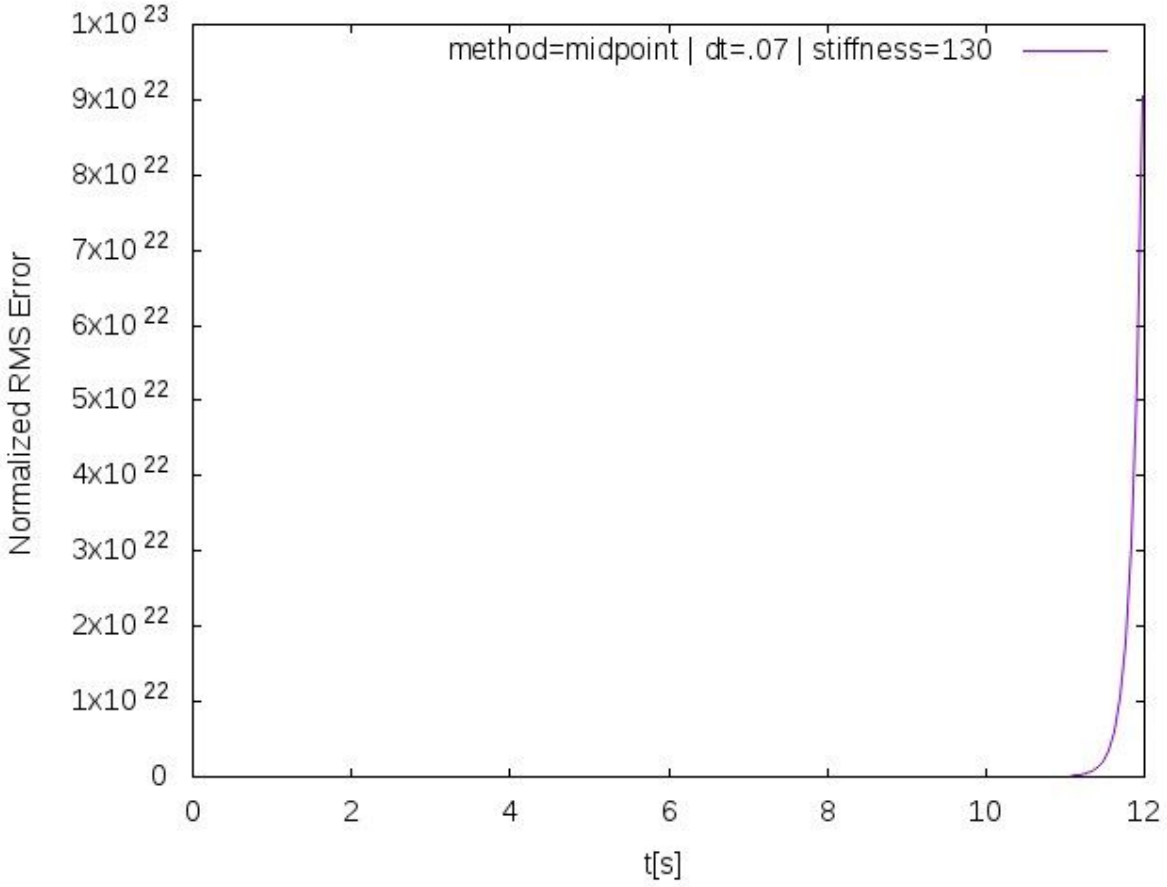
Midpoint:

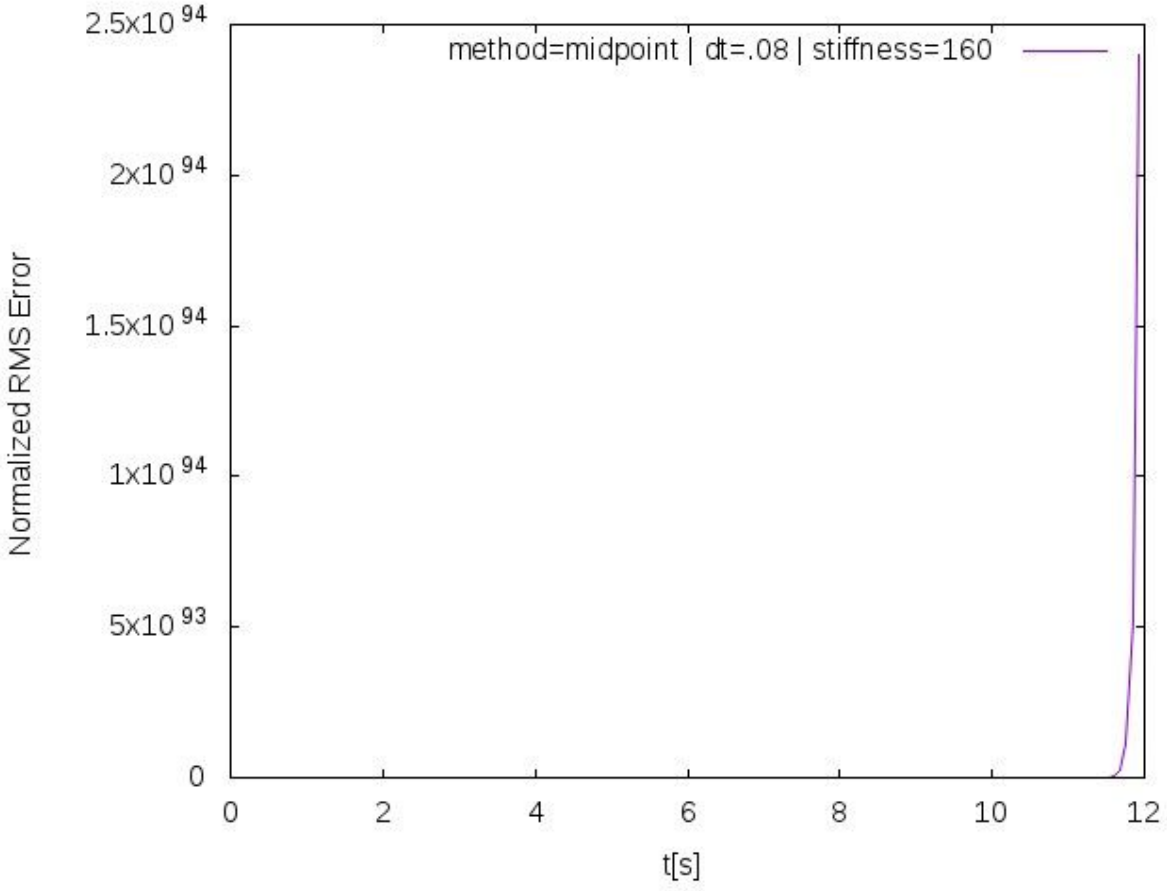
	160	130	100	70
0.05	stable	stable	stable	stable
0.06	stable	stable	stable	stable
0.07	unstable	unstable	stable	stable
0.08	unstable	unstable	unstable	stable




method=midpoint | dt=.06 | stiffness=160
Normalized RMS Error
t[s]
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0
2
4
6
8
10
12

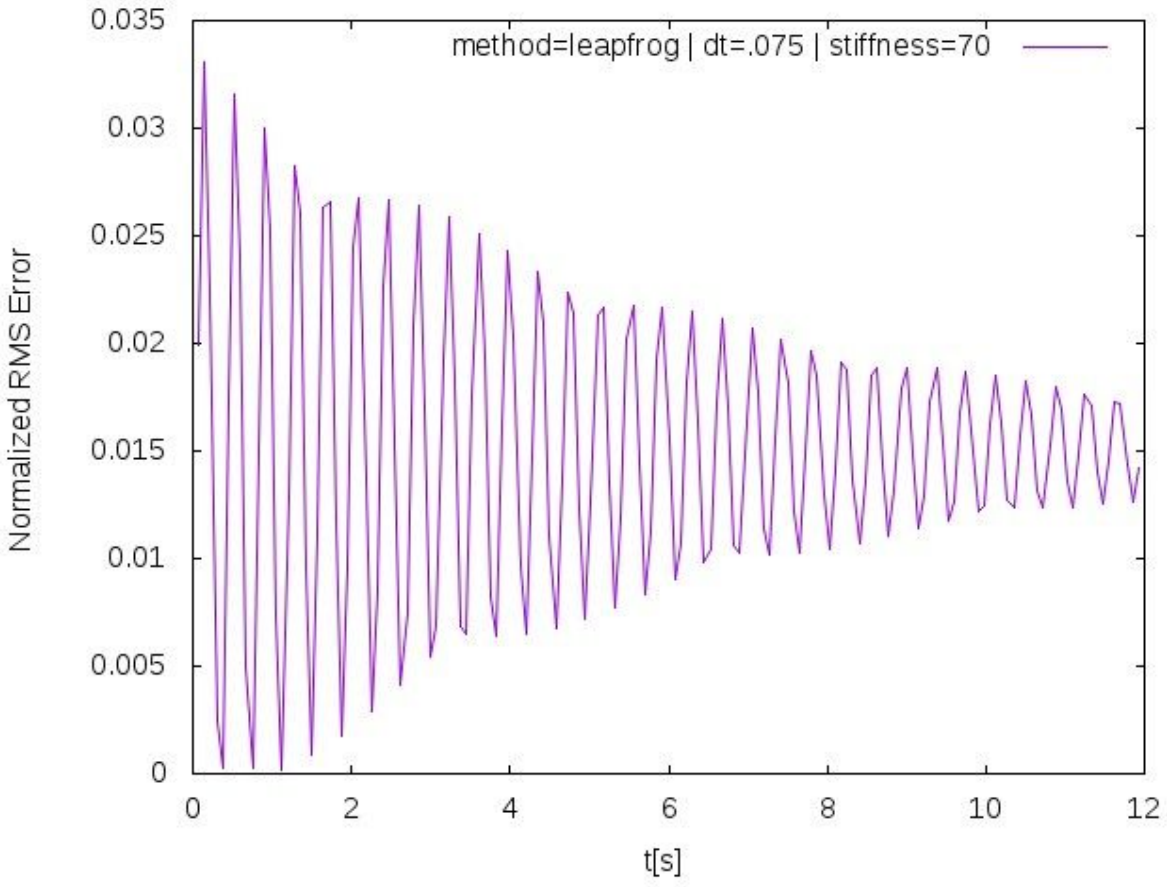

method=midpoint | dt=.08 | stiffness=100
Normalized RMS Error
t[s]
2.5x10 17
2x10 17
1.5x10 17
1x10 17
5x10 16
0
0
2
4
6
8
10
12

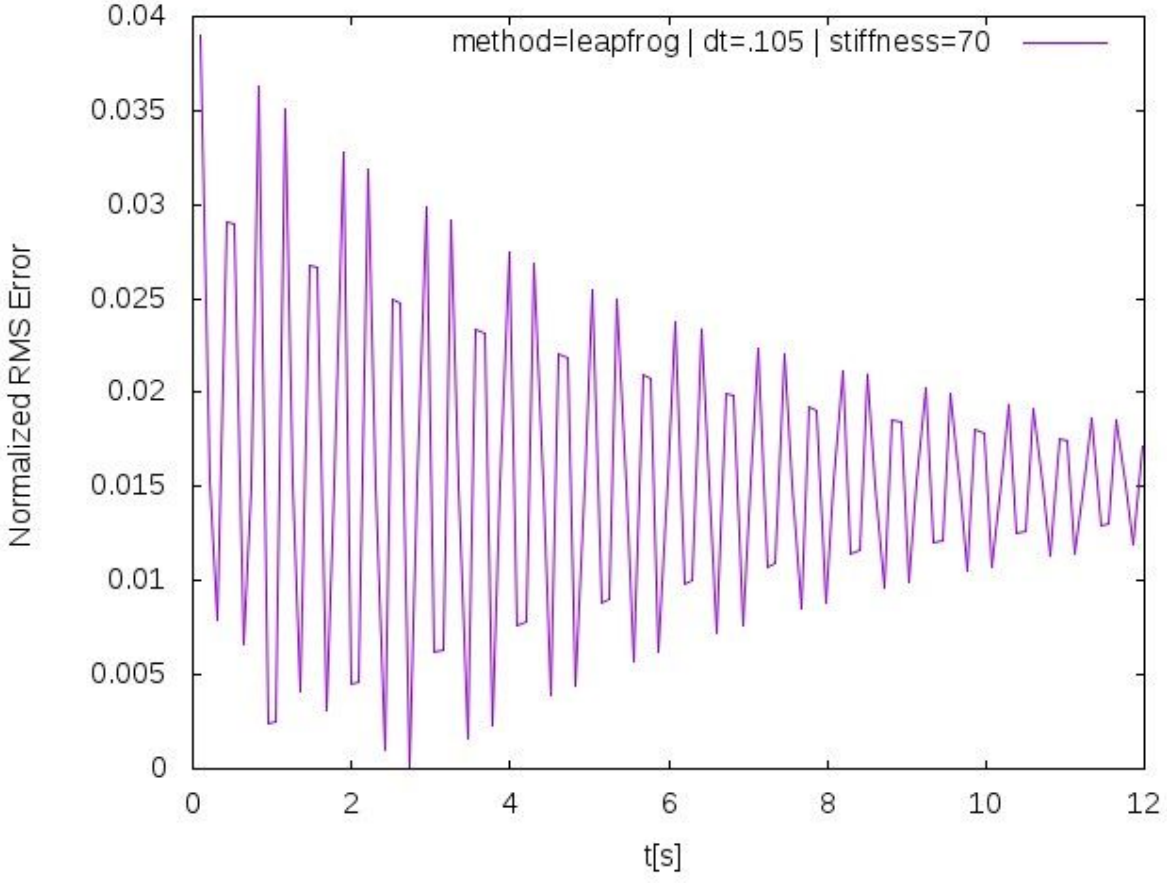

method=midpoint | dt=.07 | stiffness=130
Normalized RMS Error
t[s]
1x10 23
9x10 22
8x10 22
7x10 22
6x10 22
5x10 22
4x10 22
3x10 22
2x10 22
1x10 22
0
0
2
4
6
8
10
12

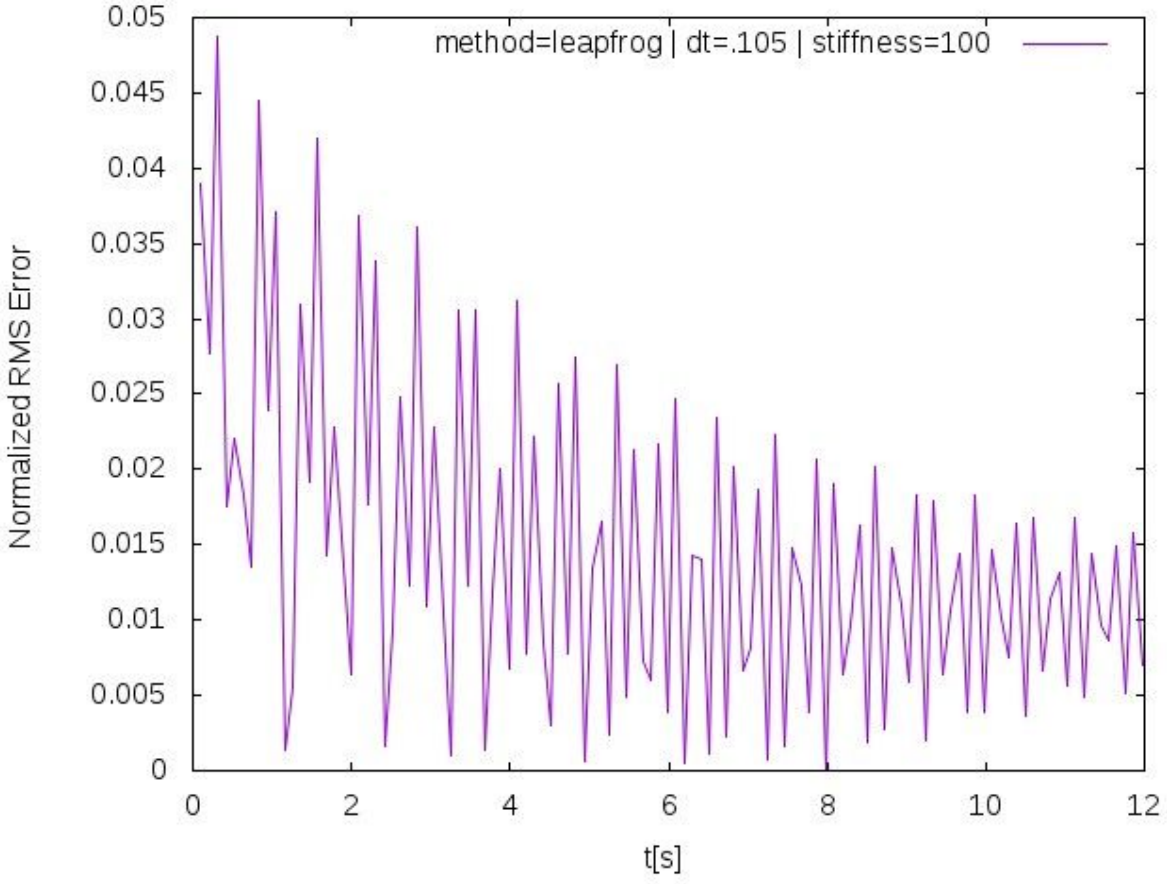

method=midpoint | dt=.08 | stiffness=160
Normalized RMS Error
t[s]
2.5x10 94
2x10 94
1.5x10 94
1x10 94
5x10 93
0
0
2
4
6
8
10
12

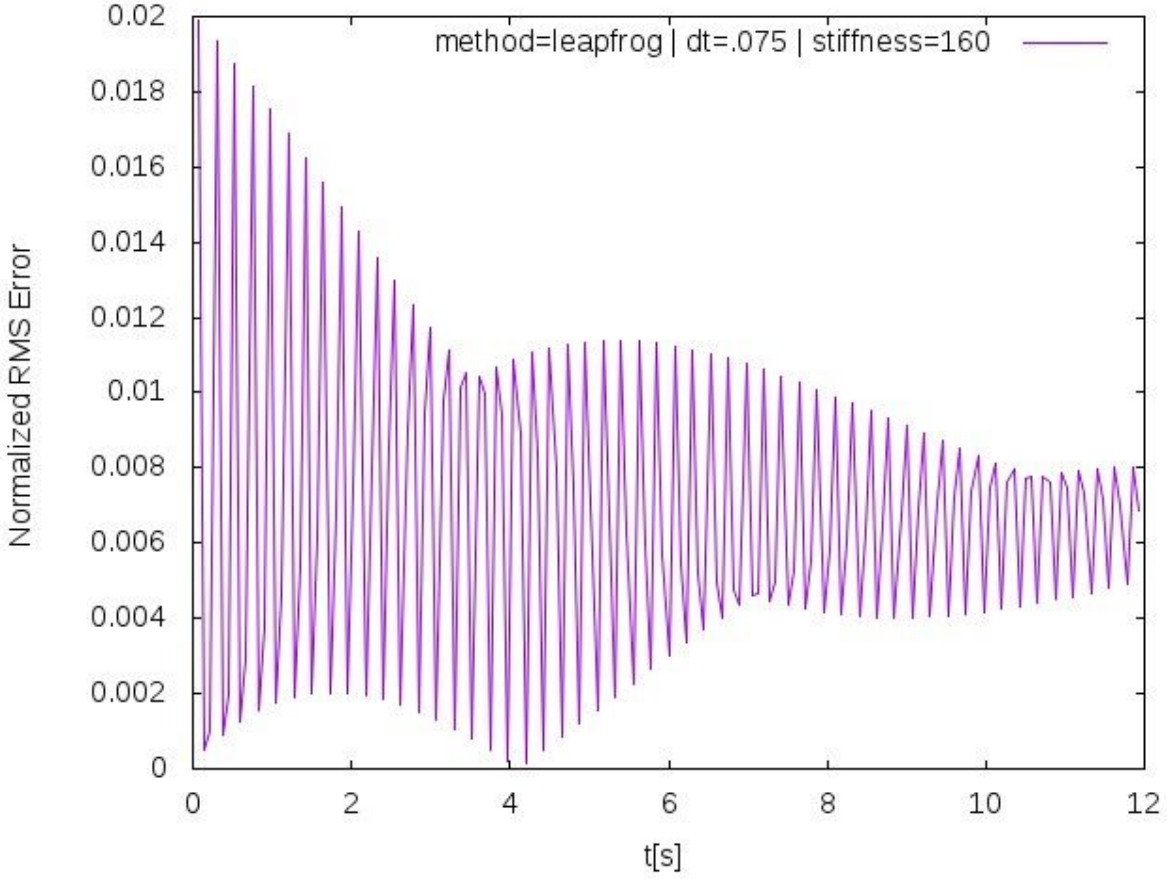
Leapfrog:

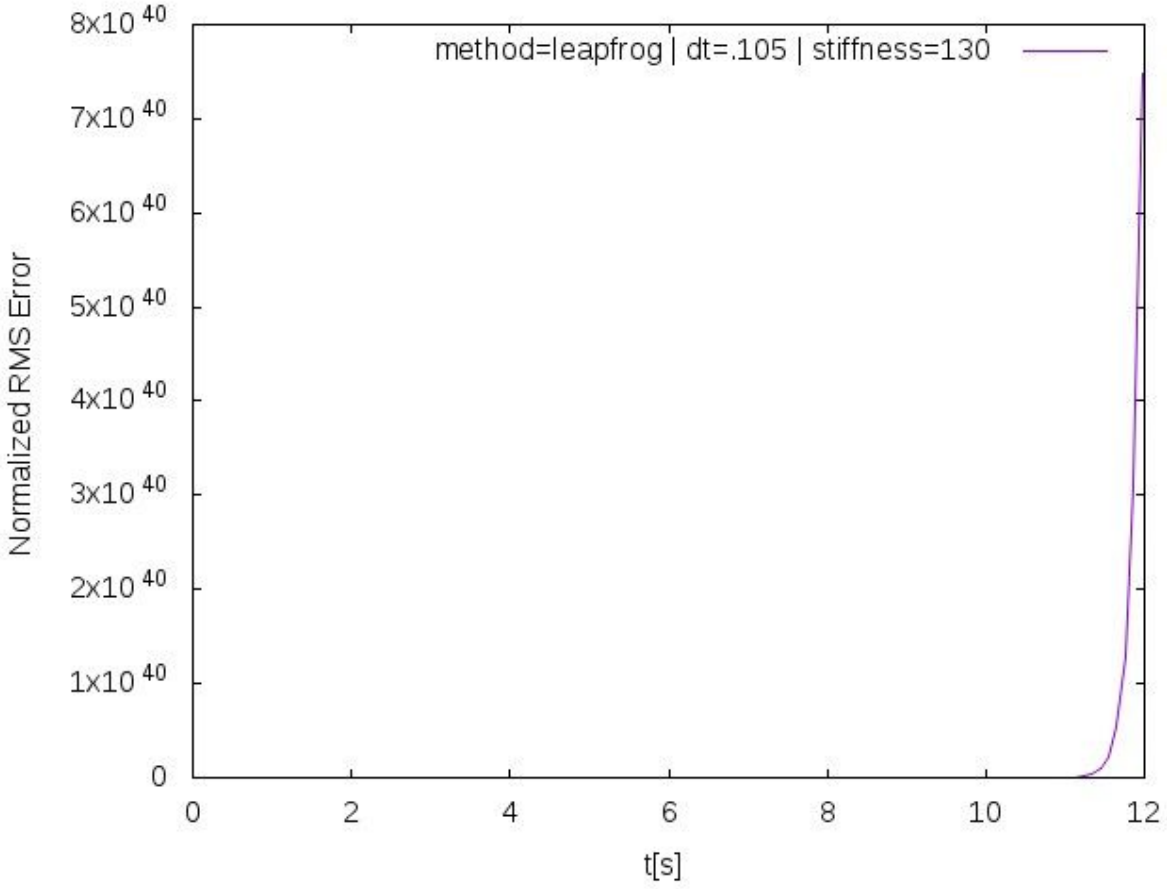
	160	130	100	70
0.075	stable	stable	stable	stable
0.09	unstable	stable	stable	stable
0.105	unstable	unstable	stable	stable
0.12	unstable	unstable	unstable	stable

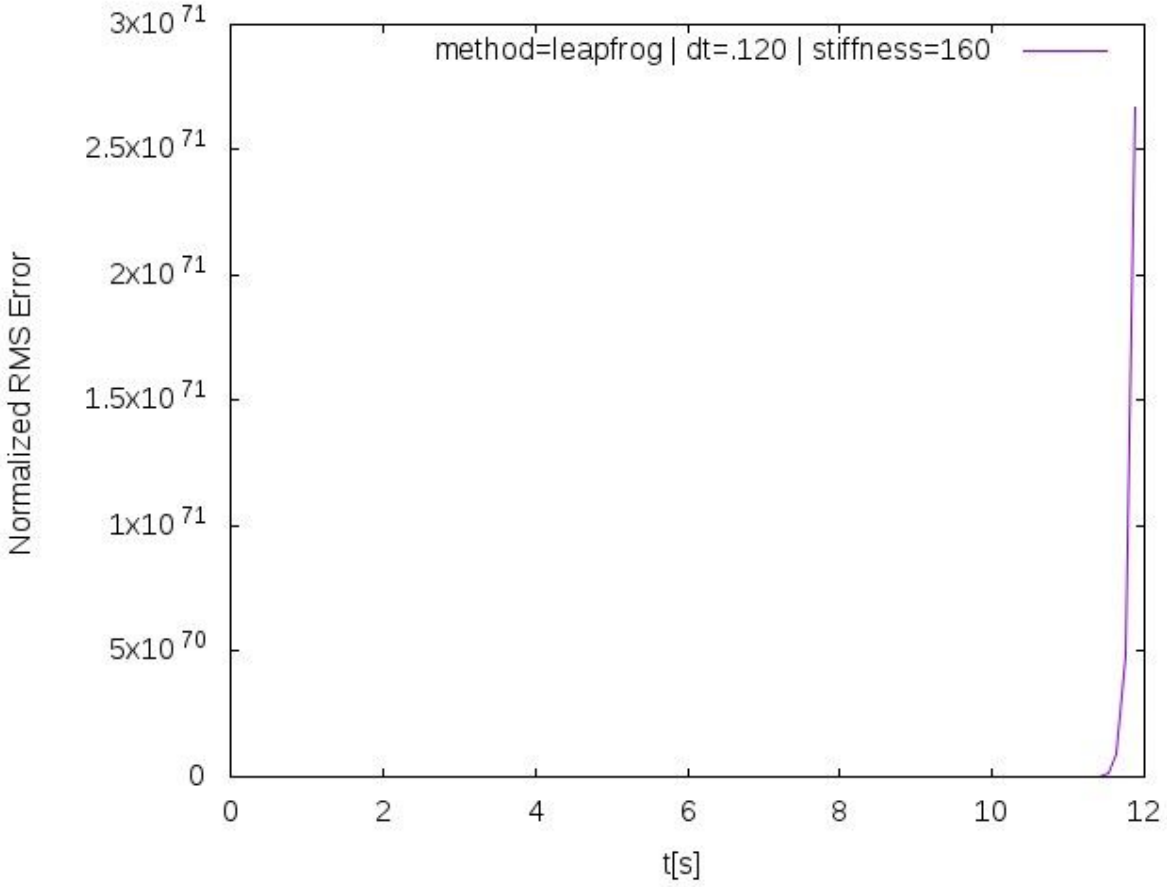



method=leapfrog | dt=.105 | stiffness=70
Normalized RMS Error
t[s]
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
2
4
6
8
10
12


method=leapfrog | dt=.105 | stiffness=100
Normalized RMS Error
t[s]
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
2
4
6
8
10
12


method=leapfrog | dt=.075 | stiffness=160
Normalized RMS Error
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0
2
4
6
8
10
12
t[s]


method=leapfrog | dt=.105 | stiffness=130
Normalized RMS Error
8x10 40
7x10 40
6x10 40
5x10 40
4x10 40
3x10 40
2x10 40
1x10 40
0
0
2
4
6
8
10
12
t[s]


method=leapfrog | dt=.120 | stiffness=160
Normalized RMS Error
3x10 71
2.5x10 71
2x10 71
1.5x10 71
1x10 71
5x10 70
0
0
2
4
6
8
10
12
t[s]