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ECE531

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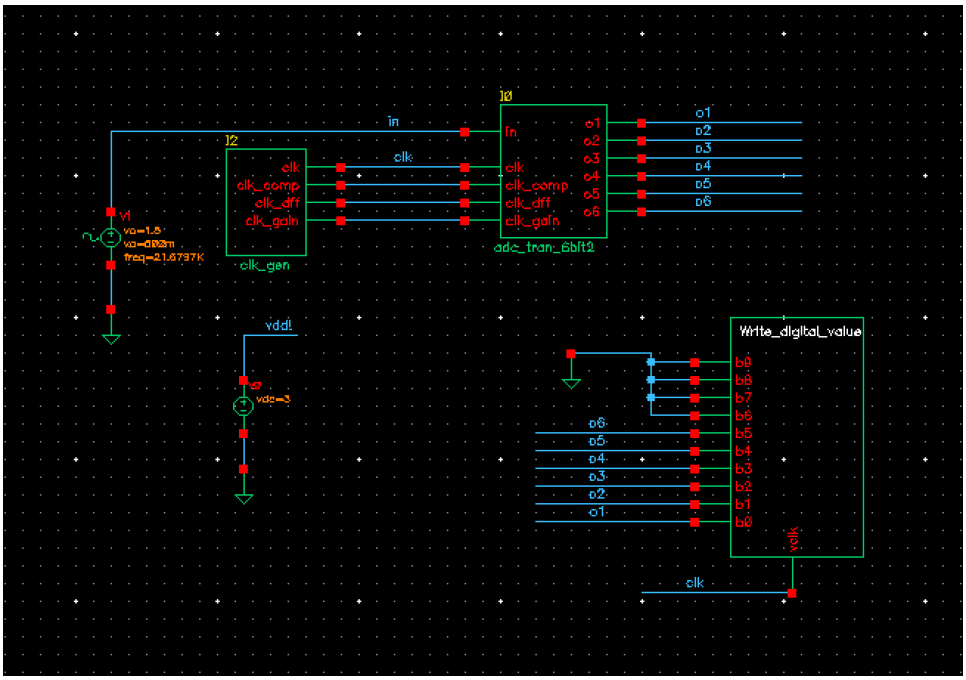
Lab2: Pipeline 6bit ADC with Estimated ADC SNR Value

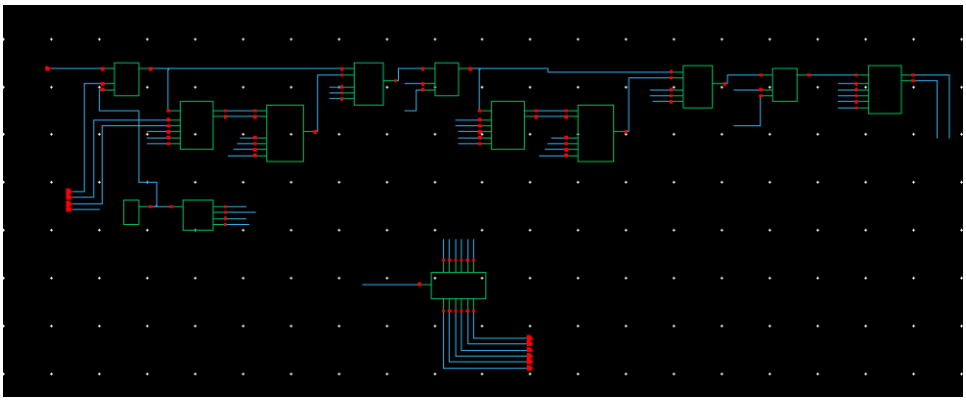
The objectives of this lab are to gain understanding about pipelined ADC operation and estimate ADC SNR value via simulation. The ADC circuit used in this lab is adc_tran_6bit2 circuit from a2dlib. The ADC input range is from 1V to 2V. It is a pipelined 6-bit ADC with three stages and 2 bits per stage. The test bench used in this lab is adc_tran_6bit2_tb2 from a2dlib. In the testbench, the sampling clock frequency is set at 0.1MHz and the ADC input is a sinusoidal signal
퓕푓푛(푡)=1.5+0.5sin(2휋푓푖푛푡), where fin=0.065039MHz.

1. Set the ADC input as a DC voltage of 1.2V. Perform transient simulation for 30us (3 sampling cycles). Plot the following voltages in the first stage circuit and check if their values make sense.

The schematics of the pipeline ADC circuit



3 stage sampling circuit schematics of the adc_tran_6bit2_tb2 from a2dlib.

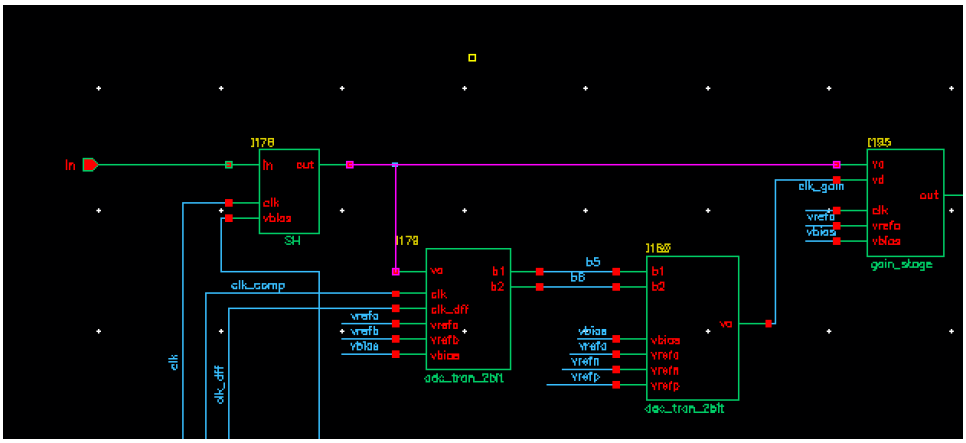


The circuit was run through a transient simulation of 30us with a ADC input DC voltage of 1.2V. Below are the calculated display of the estimated ADC SNR results.

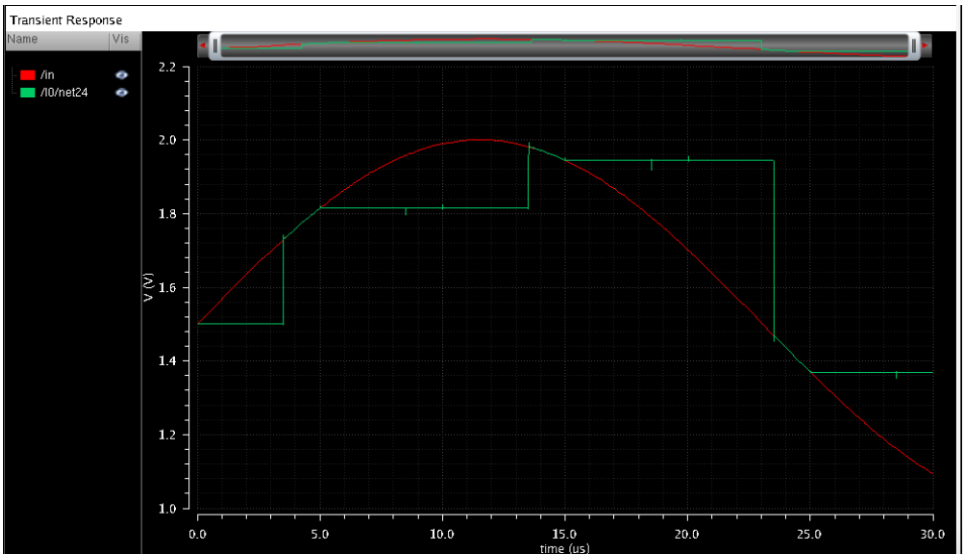
```
DC simulation time: CPU = 474.965 ms, elapsed = 479.058 ms.
Important parameter values:
    start = 0 s
    outputstart = 0 s
    stop = 30 us
    step = 30 ns
    maxstep = 600 ns
    ic = all
    useprevic = no
    skipdc = no
    reltol = 1e-03
    abstol(V) = 1 uV
    abstol(I) = 1 pA
    temp = 27 C
    tnom = 27 C
    tempeffects = all
    errpreset = moderate
    method = traponly
    lteratio = 3.5
    relref = sigglobal
    cmin = 0 F
    gmin = 1 pS

    tran: time = 1.329 us    (4.43 %), step = 600 ns          (2 %)
    tran: time = 2.529 us    (8.43 %), step = 600 ns          (2 %)
    tran: time = 3.851 us    (12.8 %), step = 110.1 ns     (367 m%)
    tran: time = 5.414 us      (18 %), step = 182.3 ns     (608 m%)
    tran: time = 7.01 us     (23.4 %), step = 323.2 ns     (1.08 %)
    tran: time = 8.301 us    (27.7 %), step = 188 ns       (627 m%)
    tran: time = 10.01 us    (33.4 %), step = 380.1 ns     (1.27 %)
    tran: time = 11.8 us     (39.3 %), step = 600 ns          (2 %)
    tran: time = 13 us       (43.3 %), step = 600 ns          (2 %)
    tran: time = 14.33 us    (47.8 %), step = 259.6 ns     (865 m%)
    tran: time = 16 us       (53.3 %), step = 268.5 ns     (895 m%)
    tran: time = 17.28 us    (57.6 %), step = 84 ns        (280 m%)
    tran: time = 18.78 us    (62.6 %), step = 68.12 ns     (227 m%)
    tran: time = 20.28 us    (67.6 %), step = 64.96 ns     (217 m%)
    tran: time = 21.95 us    (73.2 %), step = 600 ns          (2 %)
    tran: time = 23.5 us     (78.3 %), step = 475.1 ns     (1.58 %)
    tran: time = 25.01 us    (83.4 %), step = 279.4 ns     (931 m%)
    tran: time = 26.3 us     (87.7 %), step = 94.74 ns     (316 m%)
    tran: time = 27.77 us    (92.6 %), step = 42.27 ns     (141 m%)
    tran: time = 29.43 us    (98.1 %), step = 265.8 ns     (886 m%)
Number of accepted tran steps =             2710
```

a. Output of the sample and hold circuit

Selected input and output for simulation. Input: In (pin). Output: 10/net24.

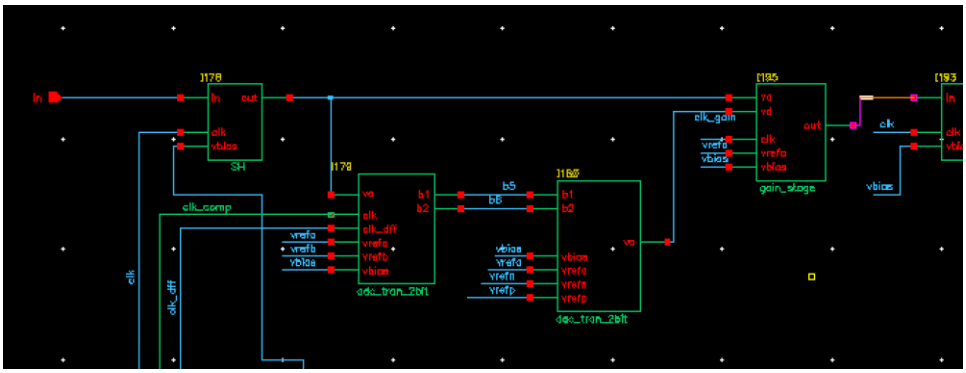


Simulation results.



b. The digital output of the 2-bit ADC

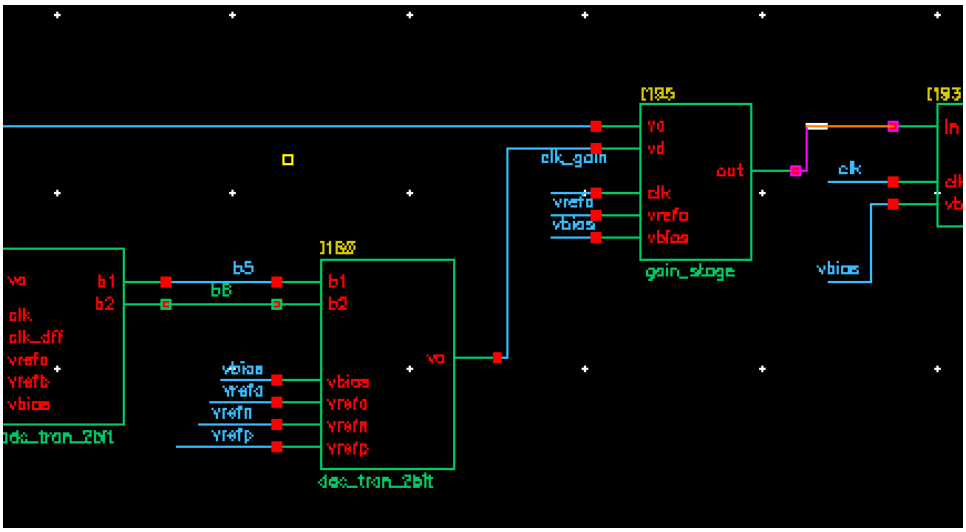
Selected input and output for simulation. Input: net4. Output: 10/net75.



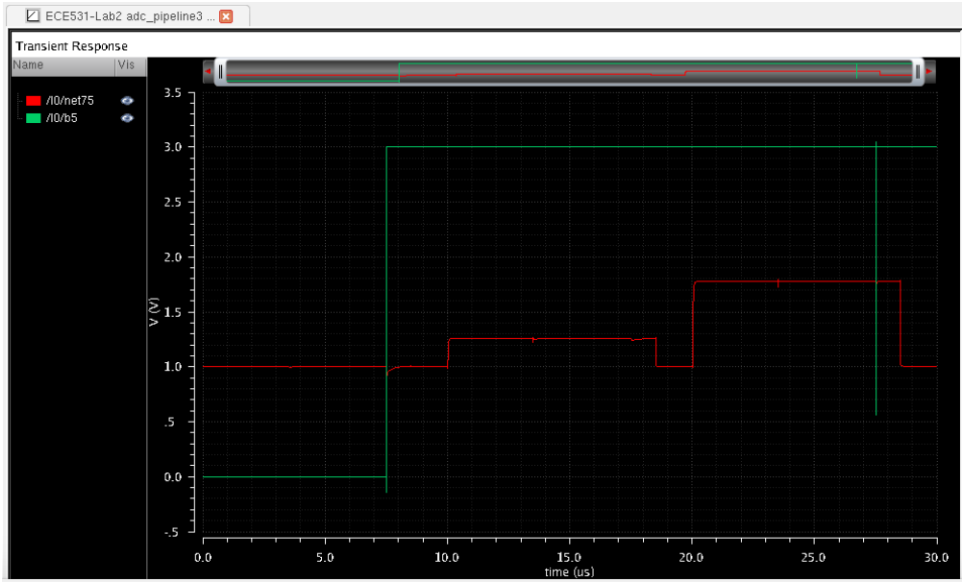
Simulation results.

c. The analog output of the 2-bit DAC

Selected input and output for simulation. Input: 10/b6. Output: 10/net75.

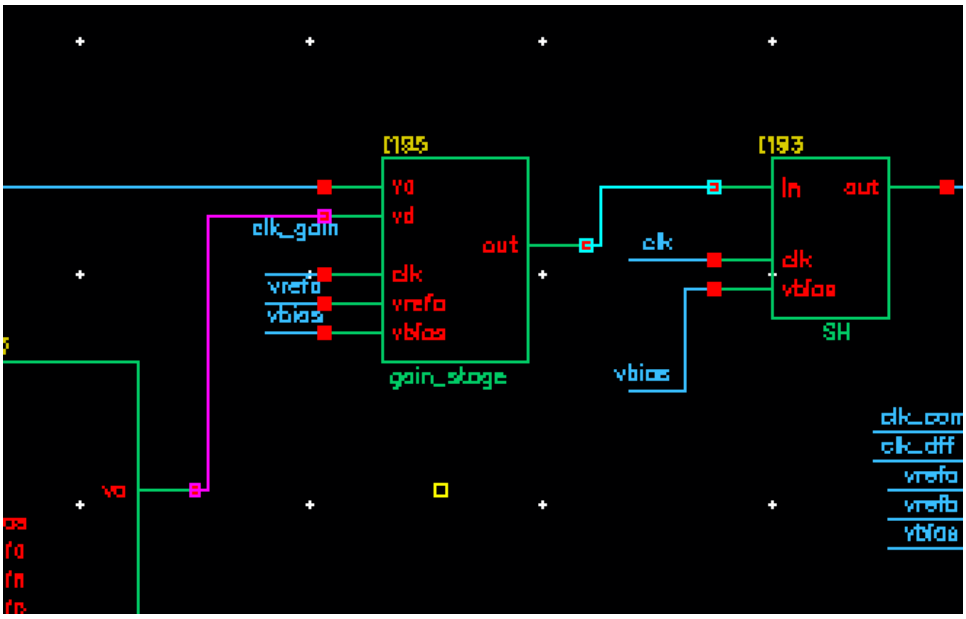


Simulation results.



d. The output of the gain stage

Selected input and output for simulation. Input: 10/net55. Output: 10/net75.



Simulation results.

2. Perform transient simulation for 5.6 ms. The write_digital_value module will record 550 ADC outputs into a matlab file digiData.m at your user directory. Use the matlab code given in the adc_fft_analysis to perform FFT analysis to estimate the ADC SNR value. In FFT analysis, you may use 512 data points. The FFT plot is like the figure below.

Transient Simulation of the circuit run with 5.6ms

```
DC simulation time: CPU = 486.658 ms, elapsed = 490.505 ms.
Important parameter values:
    start = 0 s
    outputstart = 0 s
    stop = 5.6 ms
    step = 5.6 us
    maxstep = 112 us
    ic = all
    useprevic = no
    skipdc = no
    reltol = 1e-03
    abstol(V) = 1 uV
    abstol(I) = 1 pA
    temp = 27 C
    tnom = 27 C
    tempeffects = all
    errpreset = moderate
    method = traponly
    lteratio = 3.5
    relref = sigglobal
    cmin = 0 F
    gmin = 1 pS

    tran: time = 140 us       (2.5 %), step = 405.8 ns    (7.25 m%)
    tran: time = 288.5 us    (5.15 %), step = 20.04 ps     (358 n%)
    tran: time = 420 us       (7.5 %), step = 285.8 ns     (5.1 m%)
    tran: time = 567.5 us    (10.1 %), step = 6.044 ps     (108 n%)
    tran: time = 700 us      (12.5 %), step = 427.6 ns    (7.64 m%)
    tran: time = 847.5 us    (15.1 %), step = 3.898 ps    (69.6 n%)
    tran: time = 980 us      (17.5 %), step = 377 ns      (6.73 m%)
    tran: time = 1.128 ms    (20.1 %), step = 3.708 ps    (66.2 n%)
    tran: time = 1.26 ms     (22.5 %), step = 264.5 ns    (4.72 m%)
    tran: time = 1.408 ms    (25.1 %), step = 3.109 ps    (55.5 n%)
    tran: time = 1.54 ms     (27.5 %), step = 222.1 ns    (3.97 m%)
    tran: time = 1.688 ms    (30.1 %), step = 1.934 ps    (34.5 u%)
    tran: time = 1.82 ms     (32.5 %), step = 390.7 ns    (6.98 m%)
    tran: time = 1.969 ms    (35.2 %), step = 22.1 ps      (395 n%)
    tran: time = 2.1 ms      (37.5 %), step = 293 ns      (5.23 m%)
    tran: time = 2.246 ms    (40.1 %), step = 435.9 ps    (7.78 u%)
    tran: time = 2.38 ms     (42.5 %), step = 326 ns      (5.82 m%)
    tran: time = 2.53 ms     (45.2 %), step = 6.749 ps     (121 n%)
    tran: time = 2.66 ms     (47.5 %), step = 303.3 ns    (5.42 m%)
    tran: time = 2.808 ms    (50.1 %), step = 3.421 ps    (61.1 n%)
    tran: time = 2.94 ms     (52.5 %), step = 223.2 ns    (3.99 m%)
    tran: time = 3.094 ms    (55.2 %), step = 76.55 ps    (1.37 u%)
    tran: time = 3.22 ms     (57.5 %), step = 318.9 ns    (5.69 m%)
    tran: time = 3.365 ms    (60.1 %), step = 868.7 ps    (15.5 u%)
    tran: time = 4.9 ms      (87.5 %), step = 409.6 ns    (7.32 m%)
    tran: time = 5.049 ms    (90.2 %), step = 12.94 ps     (231 n%)
    tran: time = 5.18 ms     (92.5 %), step = 273.5 ns    (4.88 m%)
    tran: time = 5.328 ms    (95.1 %), step = 8.754 ps     (156 n%)
    tran: time = 5.46 ms     (97.5 %), step = 304.1 ns    (5.43 m%)
Number of accepted tran steps =            569969

Notice from spectre during transient analysis `tran'.
    Trapezoidal ringing is detected during tran analysis.
        Please use method=trap for better results and performance.

Initial condition solution time: CPU = 486.676 ms, elapsed = 490.525 ms.
Intrinsic tran analysis time:    CPU = 381.538 s, elapsed = 381.607 s.
Total time required for tran analysis `tran': CPU = 382.029 s (6m  22.0s), elapsed = 382.124 s (6m  22.1s).
Time accumulated: CPU = 382.383 s (6m  22.4s), elapsed = 385.455 s (6m  25.5s).
Peak resident memory used = 85.5 Mbytes.
```

Matlab code given in the adc_fft_analysis to perform FFT analysis to estimate the ADC SNR value.

```
datafile = input('Please type matlab data file name:', 's');

if exist(datafile, 'file')

   run(datafile);

else

   disp('Data file does not exist')

   return;

end
```

Given data inputted into the Matlab to estimate ADC SNR values.

Please type Matlab data file name: digiData2.m

Please type sampling frequency (MHz):0.1

Please type input signal frequency (MHz):0.065039

Please type the number of considered harmonic:5

Please specify the starting data point:2

Please specify number of data points used in FFT:512

Please specify if window function is to be used (1: to use window; otherwise, no window):1

minimum 4-Term Blackman-Harris window \n

Warning: MATLAB has disabled some advanced graphics rendering features by switching to software OpenGL. For more information, click here.

The center frequency of fh(1) = 0.034961 MHz

The center powers of fh(1) = 0.000000 dB

The center frequency of fh(2) = 0.030078 MHz

The center powers of fh(2) = -61.111832 dB

The center frequency of fh(3) = 0.004883 MHz

The center power of fh(3) = -54.473225 dB

The center frequency of fh(4) = 0.039844 MHz

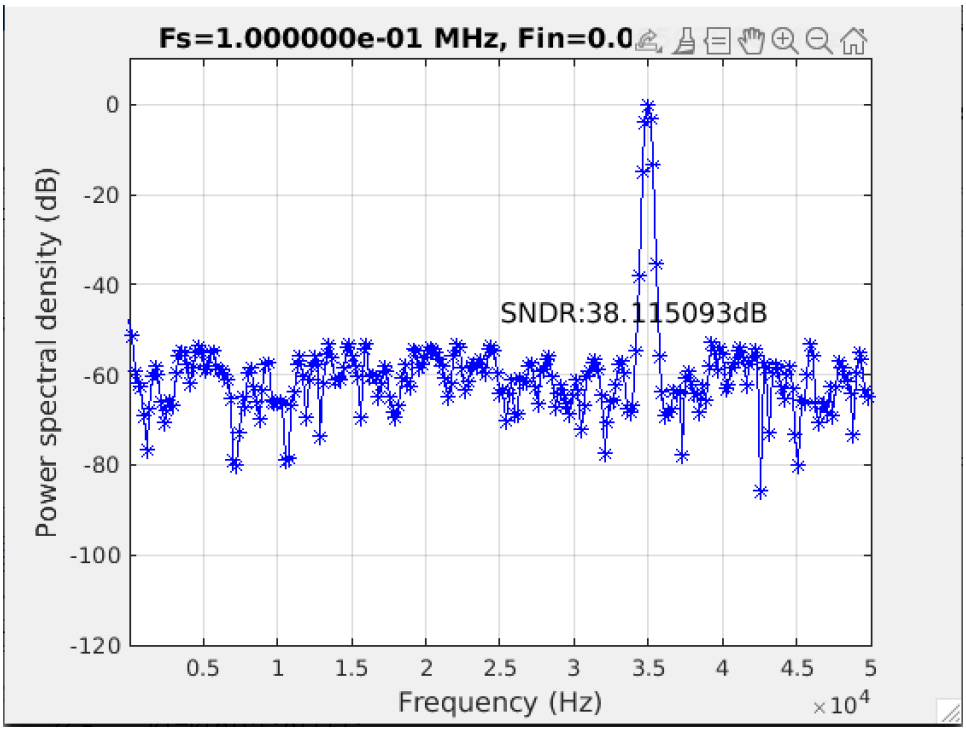
The center power of fh(4) = -53.998023 dB

The center frequency of fh(5) = 0.025195 MHz

The center power of fh(5) = -63.410483 dB

SNR is 39.027394 dB

SNDR is 38.115093 dB


Fs=1.000000e-01 MHz, Fin=0.0
SNDR:38.115093dB
Power spectral density (dB)
0
-20
-40
-60
-80
-100
-120
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Frequency (Hz)
×10^4