Calvin Passmore

A02107892

ECE 5420

Lab Amplifiers

1 Prelab

i = 1/2 * Kn * Vov^2

Vgs = Vds

i = (Vdd - Vds) / (Rref)

Vds = Vdd - i*Rref = Vgs

i = 1/2 * Kn * (Vdd - i * R - Vgs) ^ 2

i = 1/2 * Kn * [(Vdd^2 - Vdd * R - Vth*Vdd)* + *(-Vdd* i * R + i^2 * R^2 + Vth * i * R) + (-Vth * Vdd + Vth * i * R + Vthn^2)]

i = 1/2 * Kn[Vdd^2 + i^2 * R^2 + Vth ^ 2 - 2 * Vdd * i * R + 2 * Vth * i * R - 2 * Vth * Vdd]

0 = i^2(1/2 * Kn * R^2) + i(-2 * Vdd * R + 2 * Vth * R - 1) + (Vdd^2 + Vth^2 - 2 * Vth * Vdd)

i = ((2 * Vdd * r - 2 * Vth * R + 1) +- sqrt[(-2 * Vdd * R + 2 * Vth * r - 1)^2 - 2 * K * R^2 * (Vdd ^ 2 + Vth ^ 2 - 2 * Vth * Vdd)]) / (Kn * R)

In [ ]:
```
from math import sqrt
Vdd = 5 # V
Vth = 0.75
Kn = 0.7e-3 # A
R = 10e3 # Ohm

i_refp = ((2 * Vdd * R - 2 * Vth * R + 1) + sqrt((-2 * Vdd * R + 2 * Vth * R - 1)**2 - 2 * Kn * R**2 * (Vd
```

```
i_refn = ((2 * Vdd * R - 2 * Vth * R + 1) - sqrt((-2 * Vdd * R + 2 * Vth * R - 1)**2 - 2 * Kn * R**2 * (Vd

print(i_refp)
print(i_refn)
```

```
24283.874839036227
2.12516096377554
```

i_ref = 2.125 mA

gm = sqrt(2 * IB * Kn)

ro = 1 / (λ * IB)

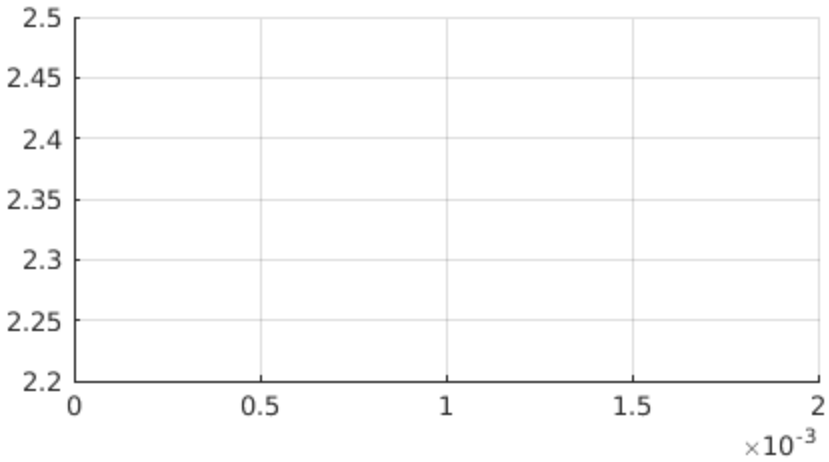
2

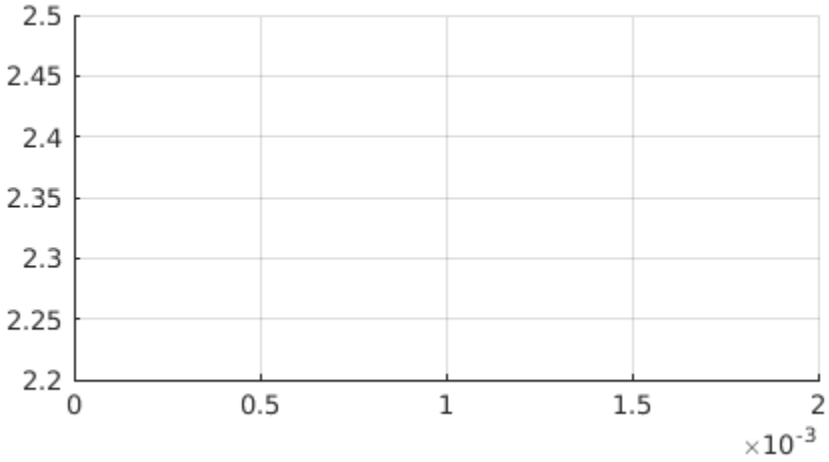
Here is the results table that I generated

```
0       -5.00000e+00    1.291116e-12    8.008670e-02    -2.19288e+01    2.257040e+00
1.359372e-11    2.440357e-10    5.888259e+12    2.172622e+11
1       -4.50000e+00    4.562770e-08    7.934292e+01    3.799016e+01    3.868502e+03
4.802508e-07    5.566229e-07    1.735504e+08    1.161310e+08
2       -4.00000e+00    6.795952e-05    1.064588e+02    4.054363e+01    6.098432e+05
2.204869e-04    1.200721e-04    8.519460e+05    1.011310e+06
3       -3.50000e+00    2.491448e-04    8.294510e+01    3.837581e+01    1.492871e+06
4.165233e-04    2.200303e-04    3.530310e+05    4.271133e+05
4       -3.00000e+00    4.547100e-04    7.023761e+01    3.693139e+01    2.396698e+06
5.626861e-04    2.916084e-04    2.170066e+05    2.773860e+05
5       -2.50000e+00    6.353315e-04    6.246272e+01    3.591242e+01    3.212763e+06
6.676993e-04    3.411058e-04    1.583717e+05    2.163229e+05
6       -2.00000e+00    7.405122e-04    5.791314e+01    3.525554e+01    3.784932e+06
7.257644e-04    3.665050e-04    1.309852e+05    1.926588e+05
7       -1.50000e+00    7.572604e-04    5.541913e+01    3.487319e+01    4.048810e+06
7.405037e-04    3.703683e-04    1.190680e+05    1.894083e+05
8       -1.00000e+00    7.669354e-04    5.323740e+01    3.452434e+01    4.277513e+06
7.506235e-04    3.725796e-04    1.098886e+05    1.875853e+05
9       -5.00000e-01    7.752391e-04    5.124653e+01    3.419329e+01    4.497689e+06
7.590347e-04    3.744656e-04    1.022302e+05    1.860515e+05
```

```
10      0.000000e+00    7.827466e-04    4.940070e+01    3.387466e+01    4.714083e+06
7.662185e-04    3.761616e-04    9.565915e+04    1.846886e+05
11      5.000000e-01    7.896944e-04    4.766377e+01    3.356377e+01    4.930925e+06
7.724354e-04    3.777235e-04    8.988962e+04    1.834469e+05
12      1.000000e+00    7.962122e-04    4.600242e+01    3.325561e+01    5.149585e+06
7.778460e-04    3.791819e-04    8.471235e+04    1.822989e+05
13      1.500000e+00    8.023825e-04    4.438177e+01    3.294409e+01    5.374236e+06
7.825525e-04    3.805568e-04    7.995818e+04    1.812266e+05
14      2.000000e+00    8.082623e-04    4.275979e+01    3.262071e+01    5.610062e+06
7.866128e-04    3.818618e-04    7.547212e+04    1.802178e+05
15      2.500000e+00    8.138936e-04    4.107699e+01    3.227197e+01    5.868826e+06
7.900404e-04    3.831069e-04    7.108454e+04    1.792632e+05
16      3.000000e+00    8.193079e-04    3.923251e+01    3.187292e+01    6.172022e+06
7.927870e-04    3.842998e-04    6.656053e+04    1.783559e+05
17      3.500000e+00    8.245299e-04    3.701496e+01    3.136754e+01    6.564790e+06
7.946772e-04    3.854463e-04    6.146744e+04    1.774904e+05
18      4.000000e+00    8.295776e-04    3.381623e+01    3.058250e+01    7.193957e+06
7.951190e-04    3.865509e-04    5.465628e+04    1.766626e+05
19      4.500000e+00    8.344579e-04    2.586071e+01    2.825281e+01    9.342615e+06
7.898892e-04    3.876154e-04    3.962895e+04    1.758704e+05
```

Here the plots I produced when running plot_tran.m in order (1 - 20)

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2.2
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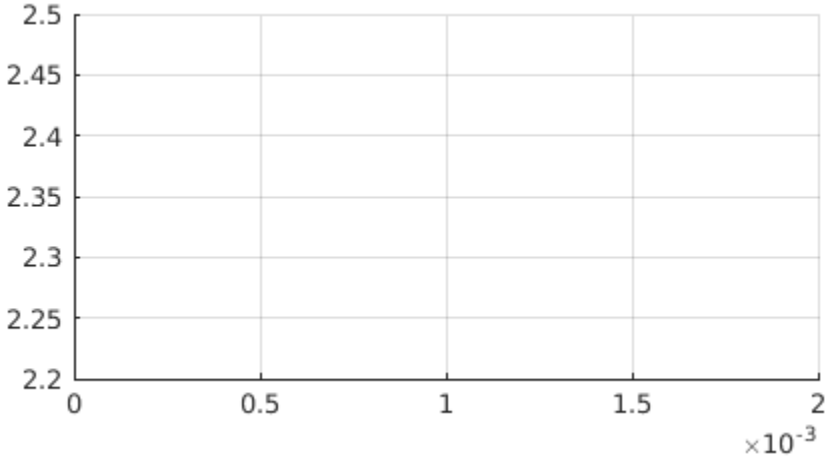
2
×10-3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0.5
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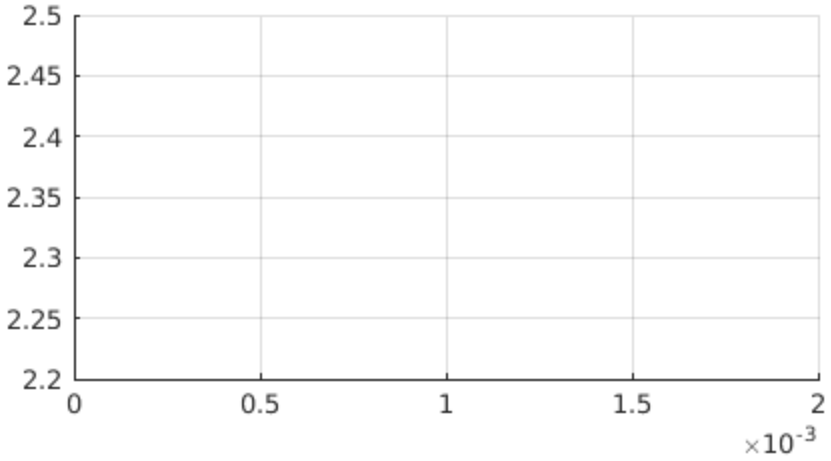
1.5
2
×10-3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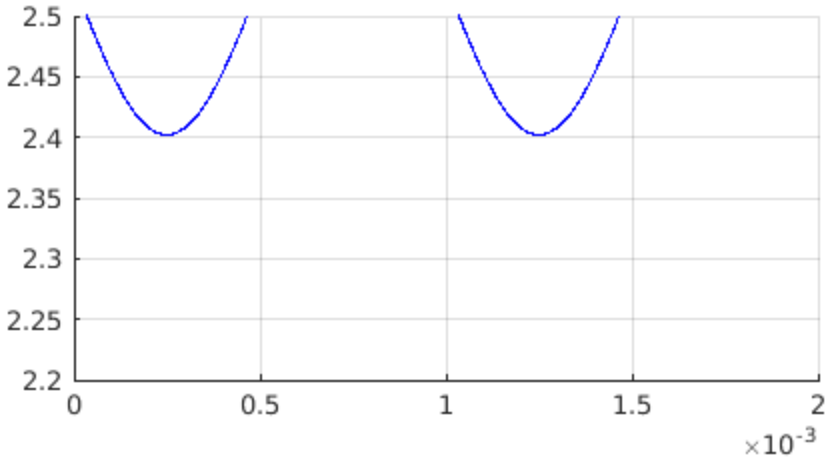
×10^-3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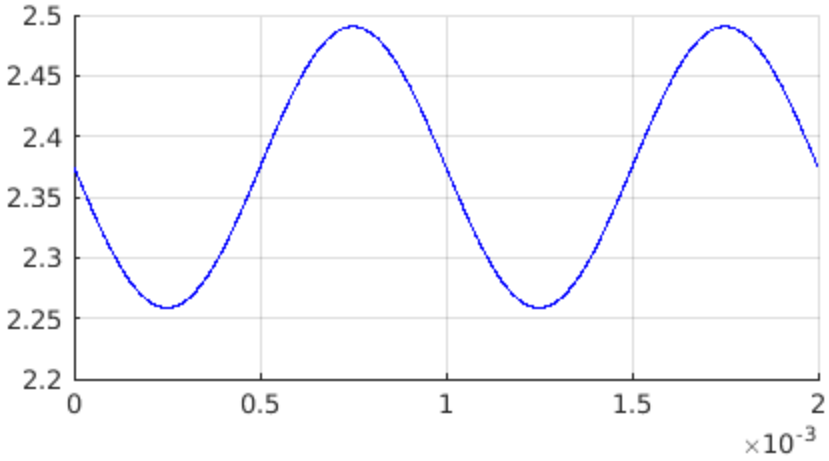
×10^-3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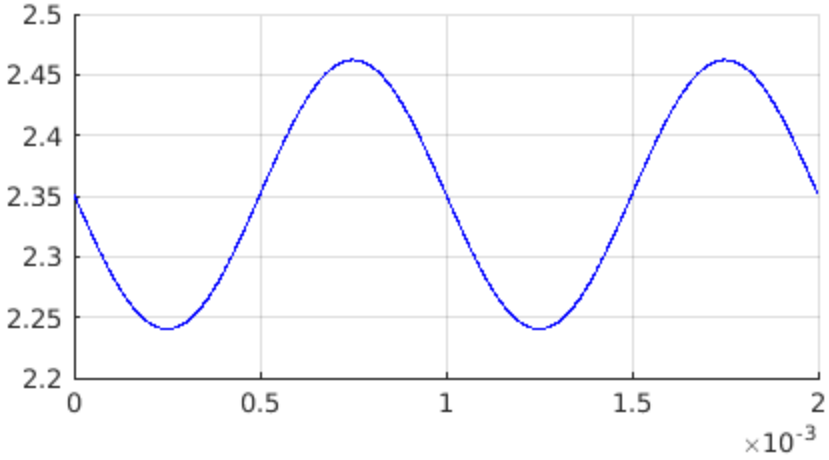
×10-3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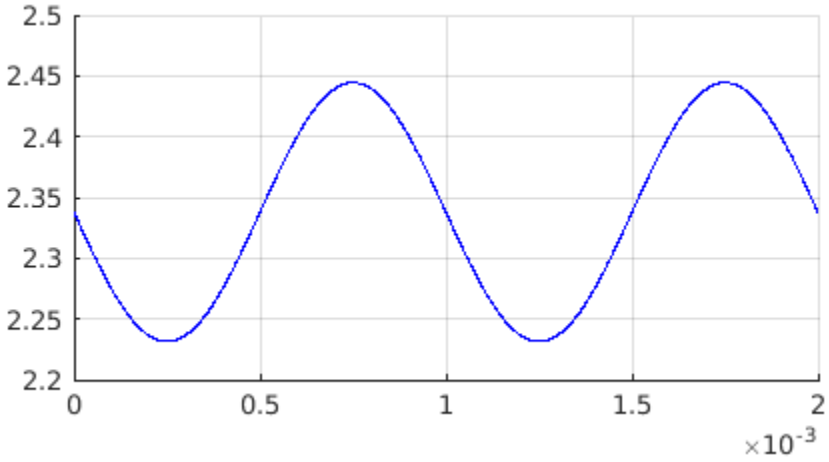
×10-3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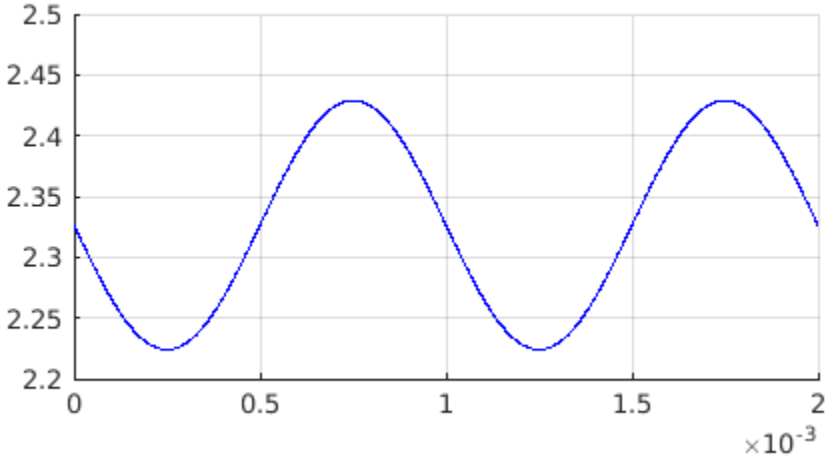
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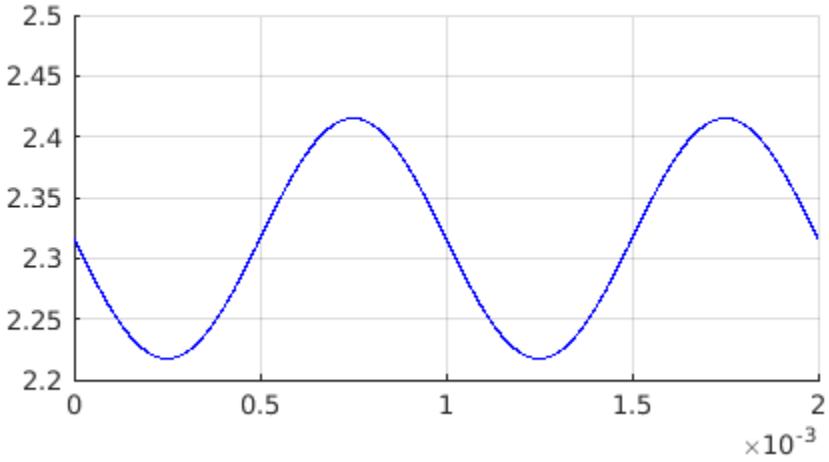
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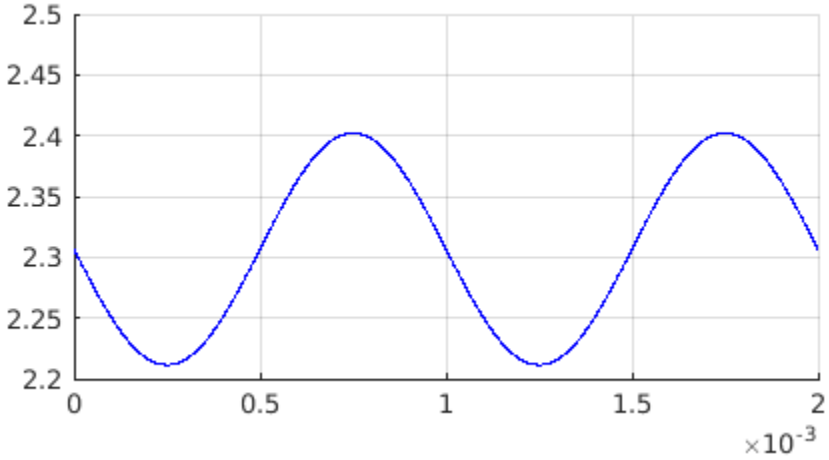
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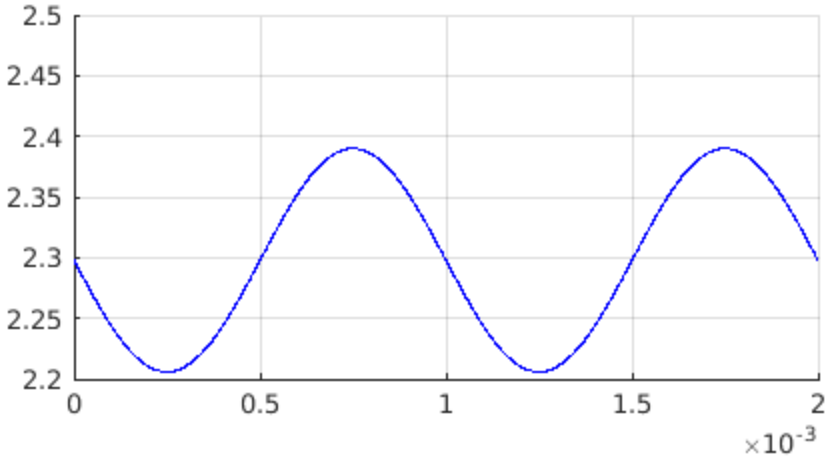
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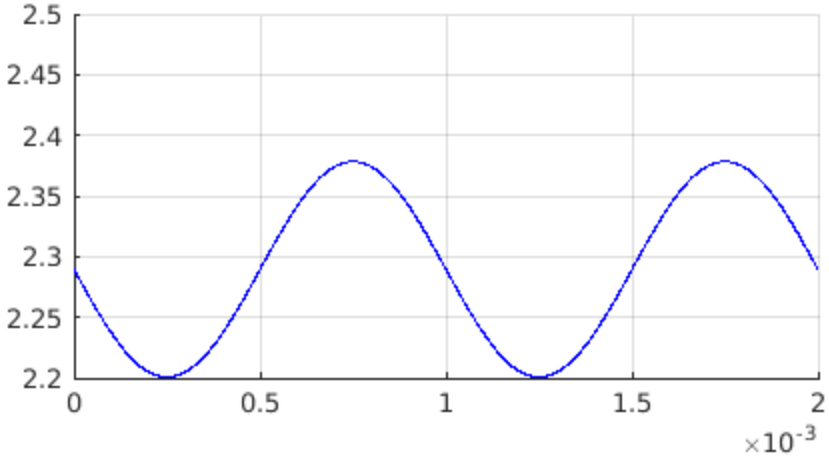
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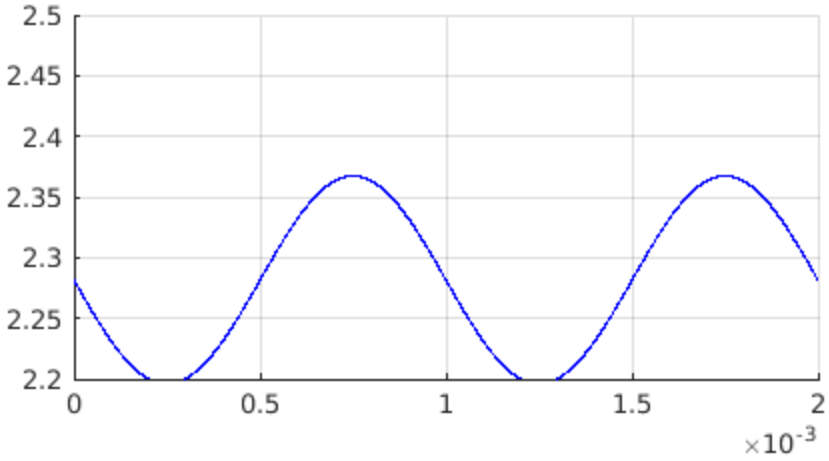
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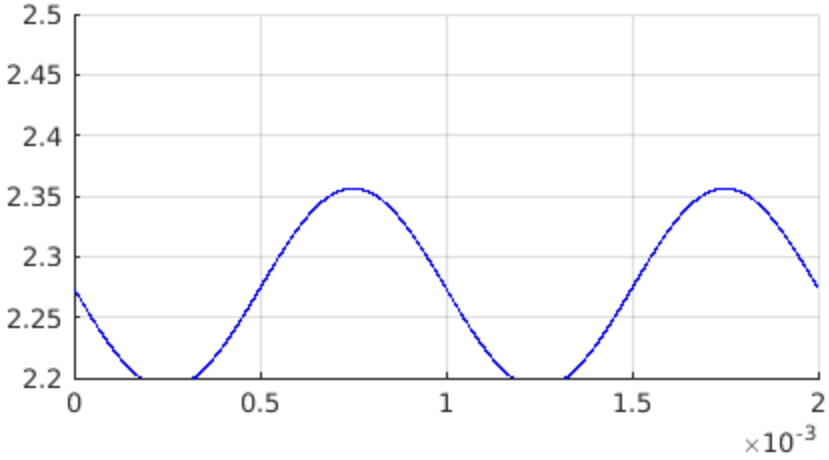
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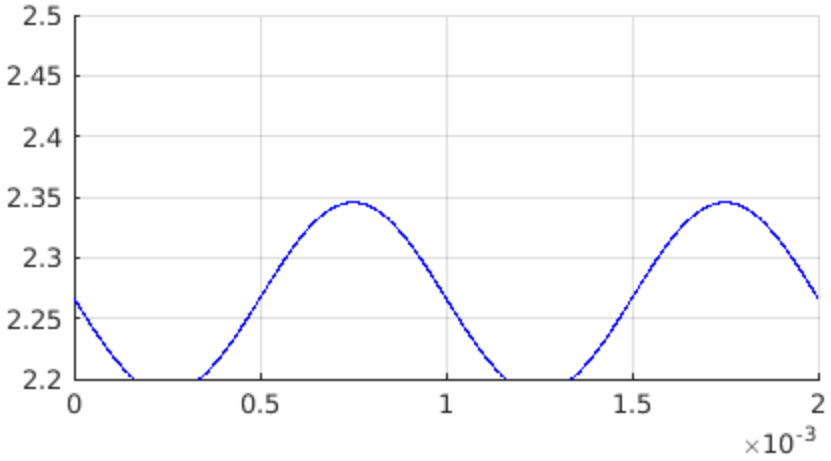
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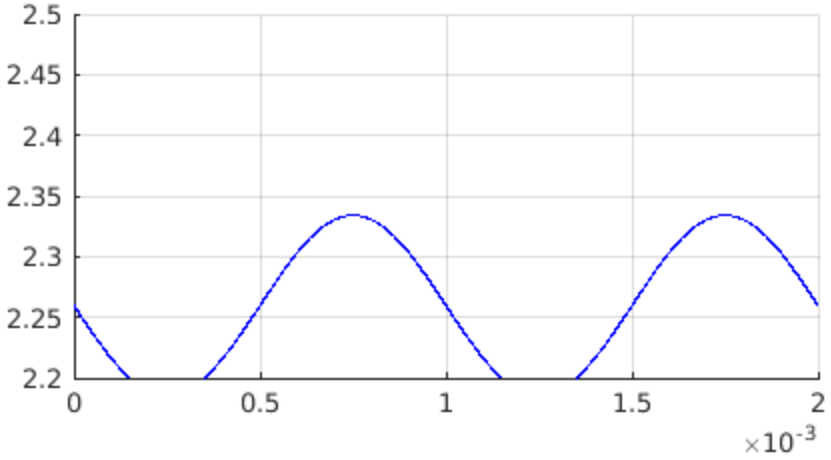
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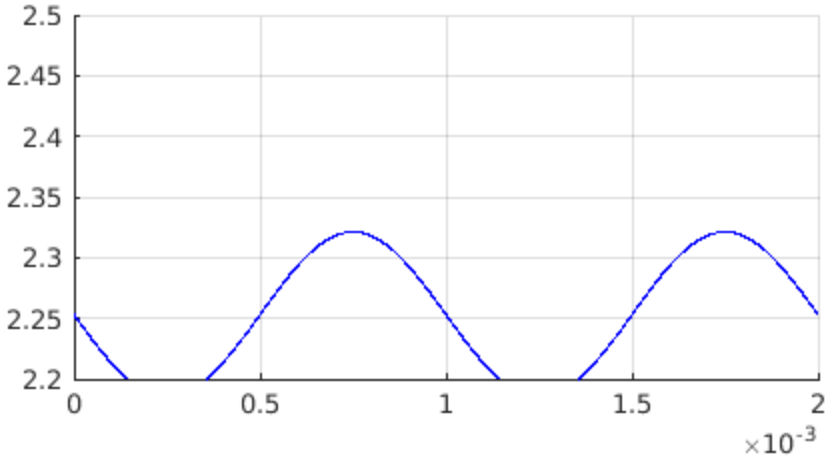
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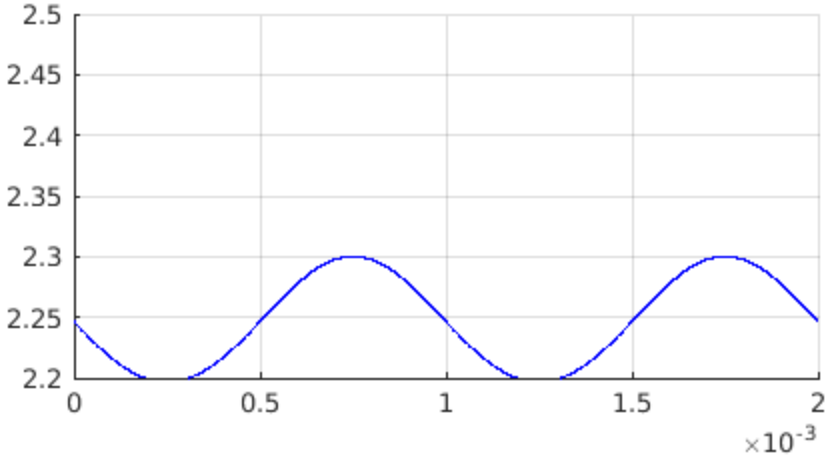
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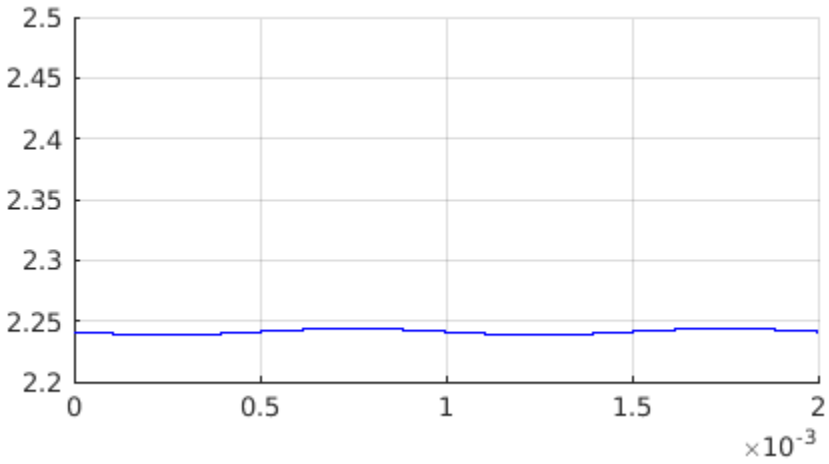
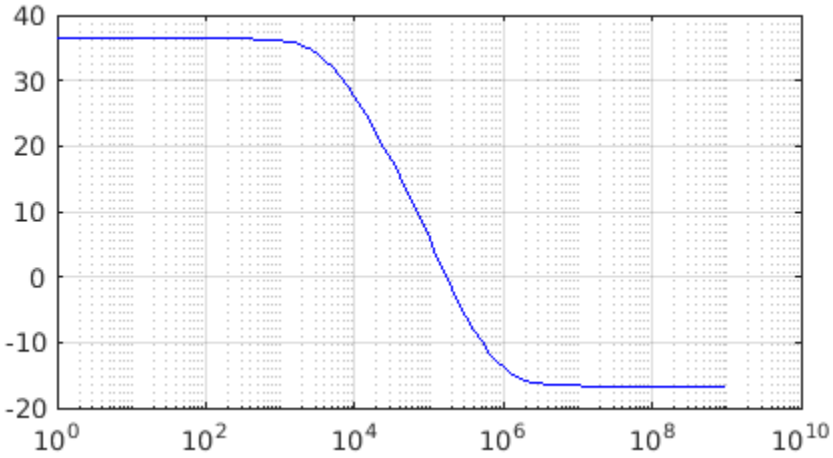
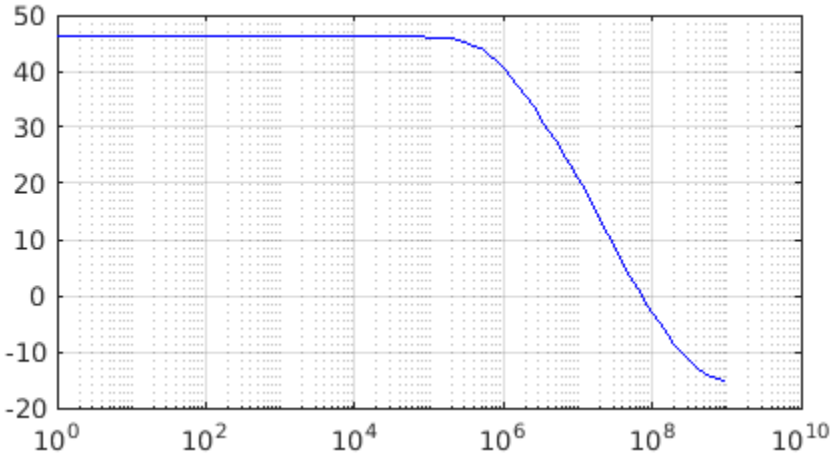
×10-3



Here the plots I generated when running plot_ac.m in order (1 - 20)

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30
20
10
0
-10
-20
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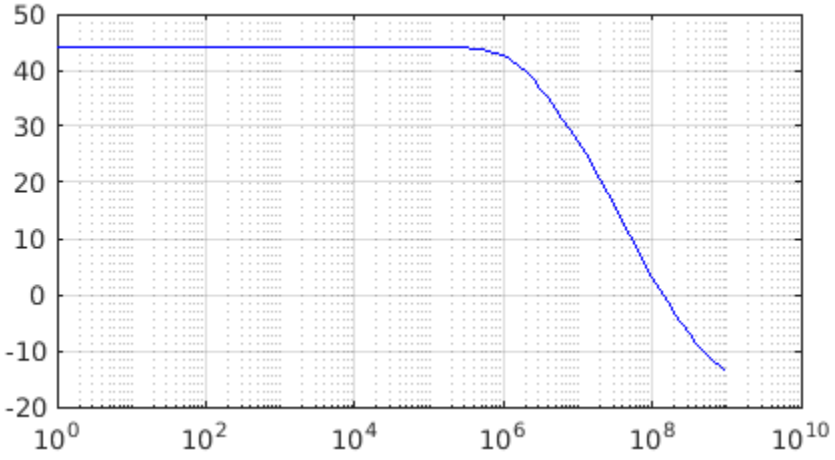
10^2
10^4
10^6
10^8
10^{10}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10^0
10^2
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10^8
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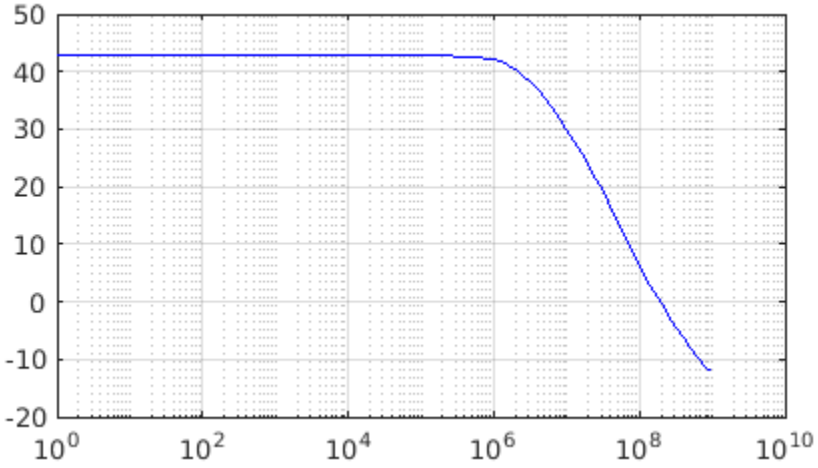
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10^0
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10^4
10^6
10^8
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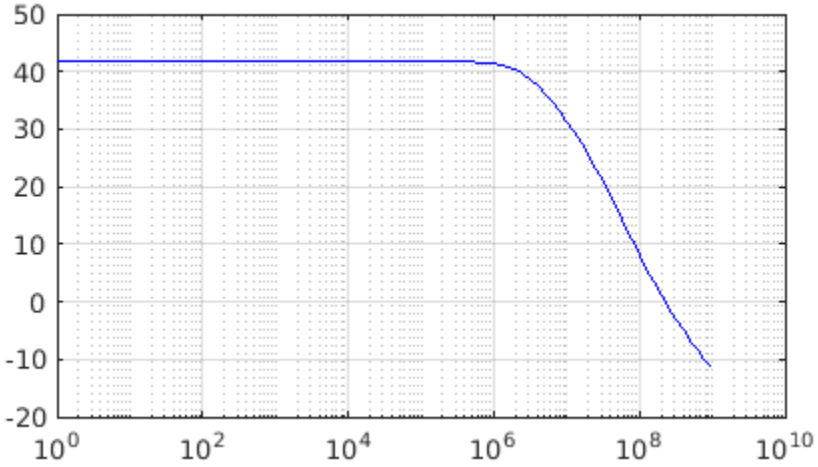
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10^4
10^6
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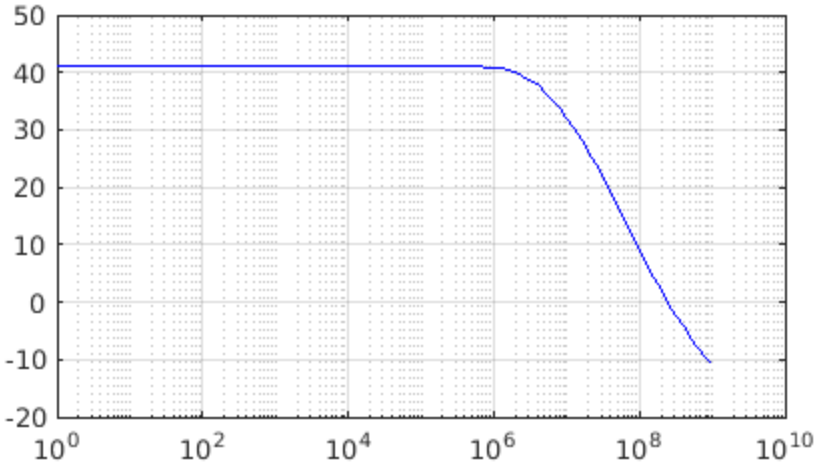
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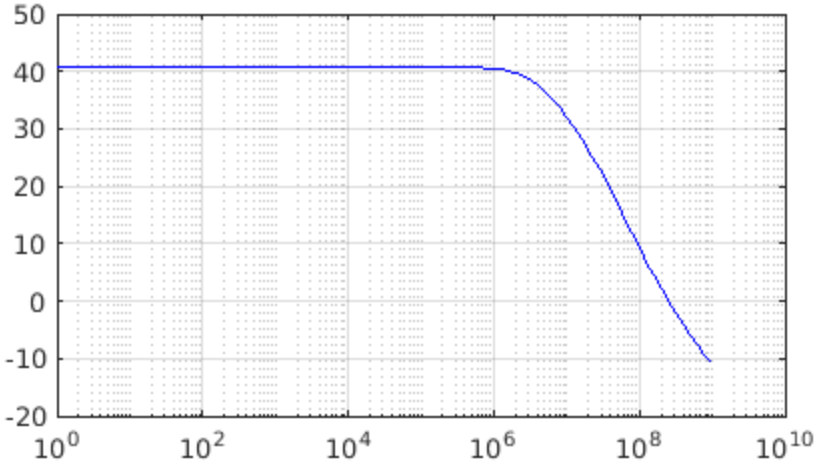
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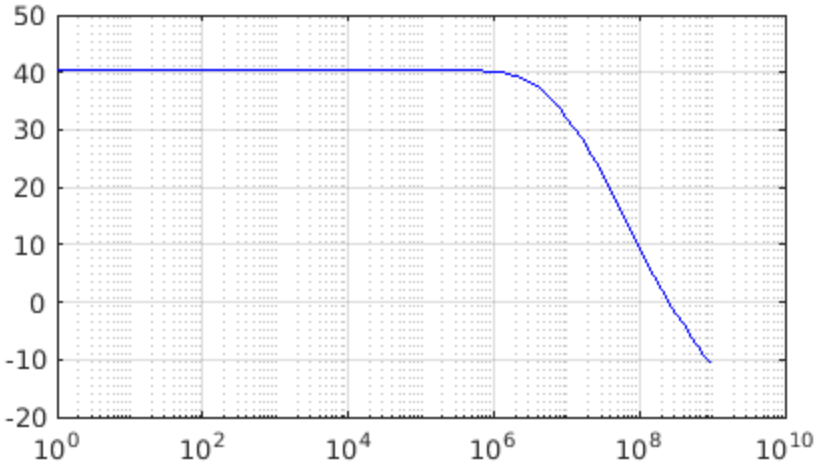
10^0
10^2
10^4
10^6
10^8
10^{10}


50
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10^2
10^4
10^6
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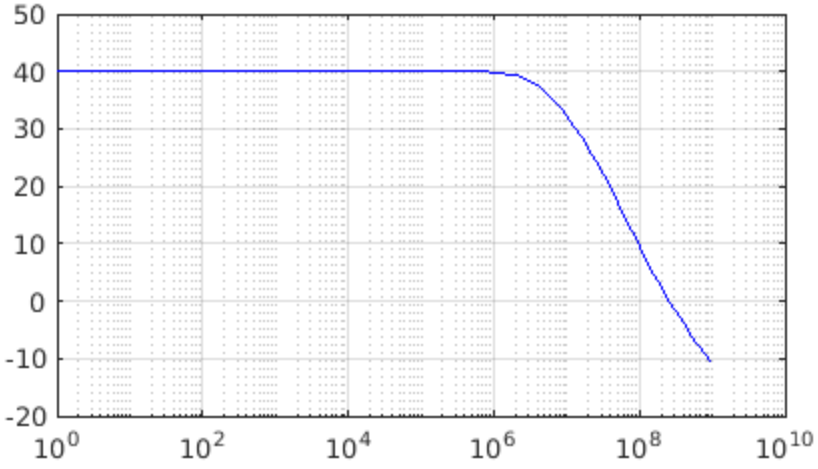
10^{10}


50
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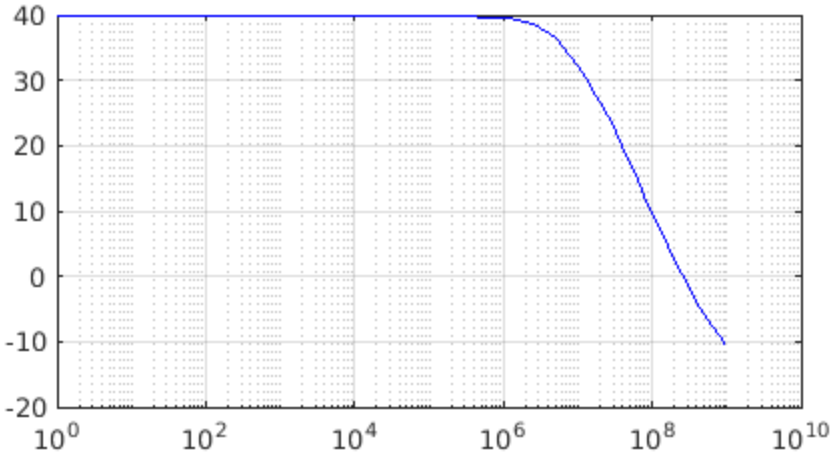
10^0
10^2
10^4
10^6
10^8
10^{10}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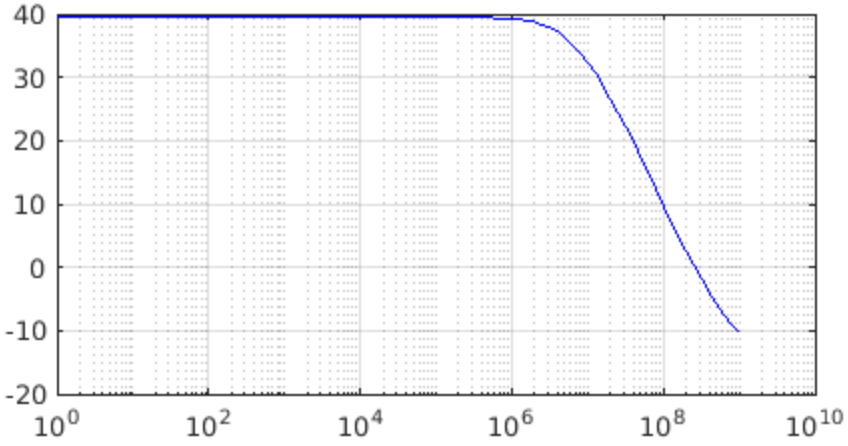
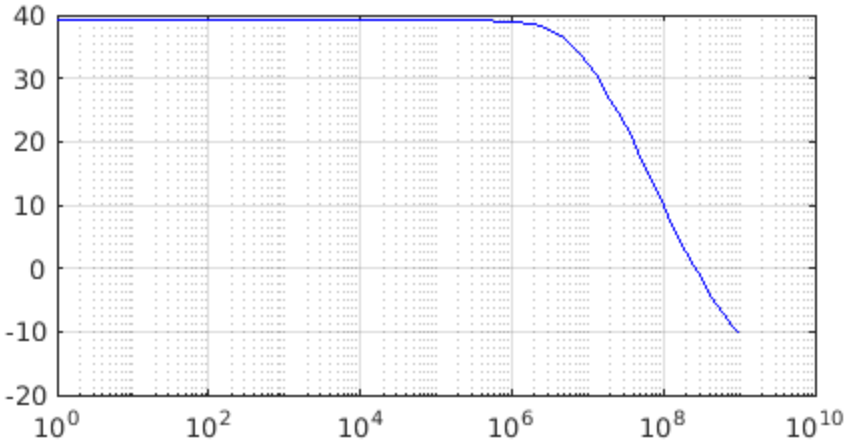
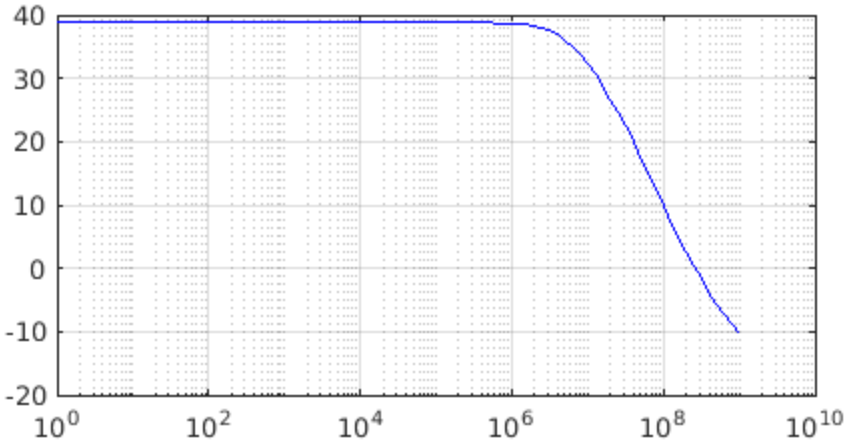
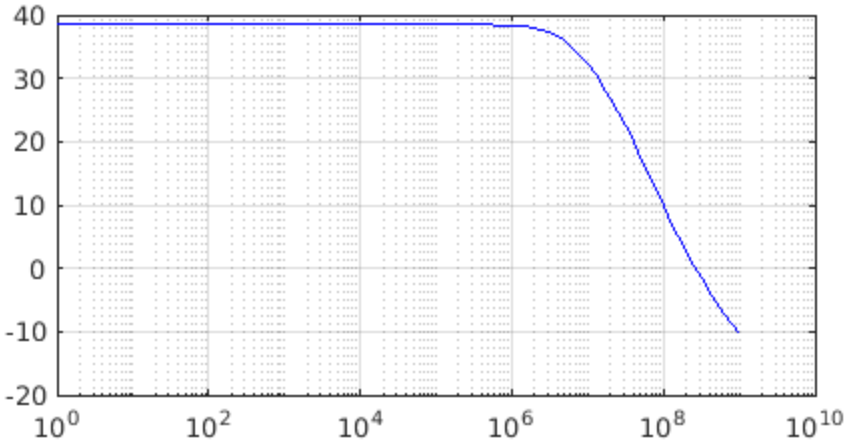
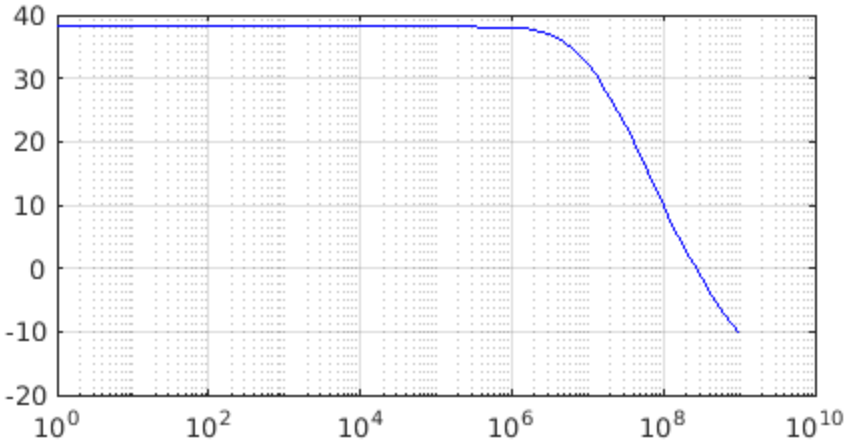
10^0
10^2
10^4
10^6
10^8
10^{10}

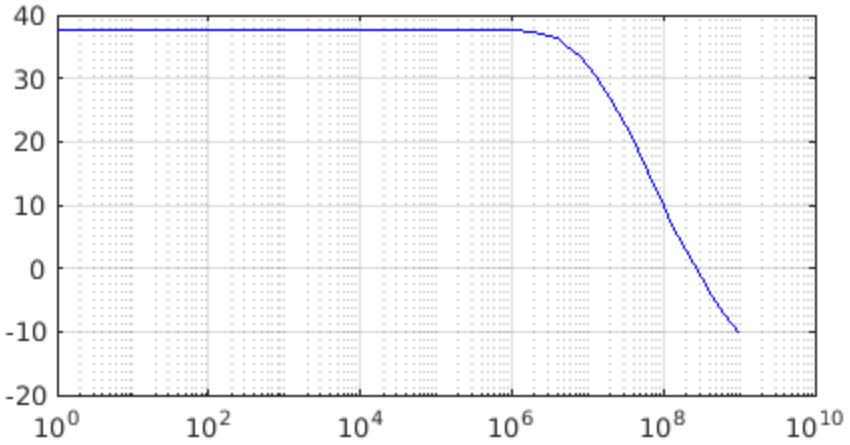

40
30
20
10
0
-10
-20
10^0
10^2
10^4
10^6
10^8
10^{10}

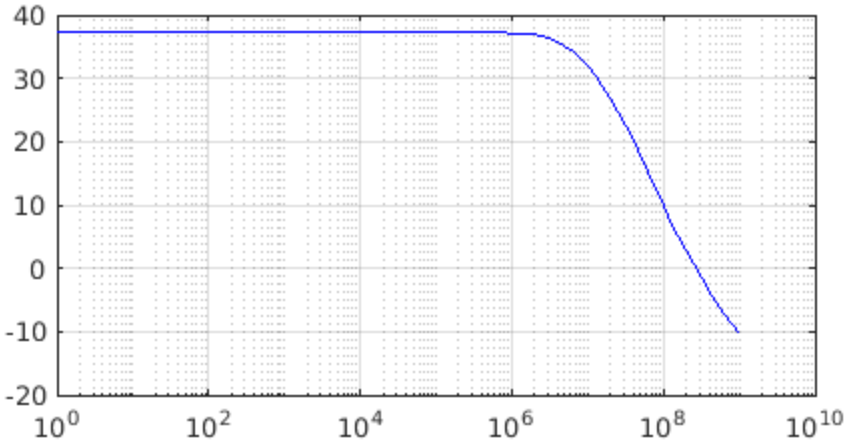

40
30
20
10
0
-10
-20
10^0
10^2
10^4
10^6
10^8
10^{10}

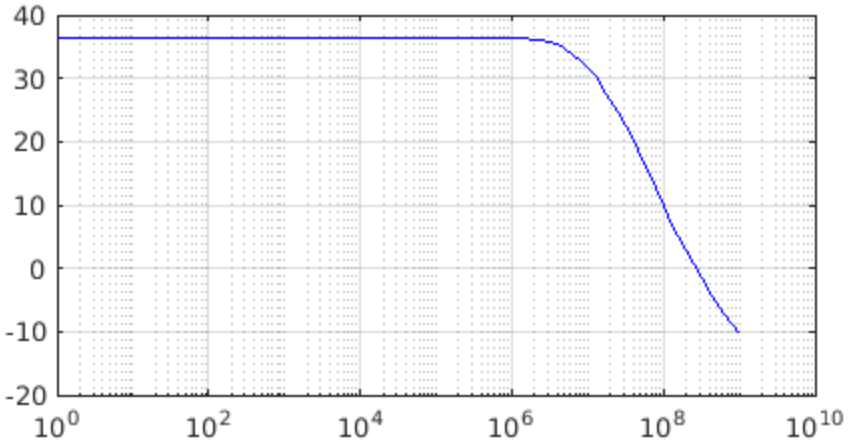

40
30
20
10
0
-10
-20
10^0
10^2
10^4
10^6
10^8
10^{10}

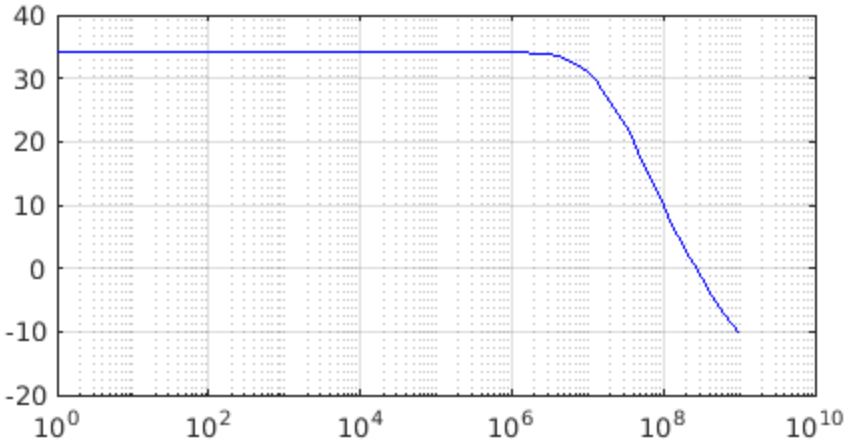

40
30
20
10
0
-10
-20
10^0
10^2
10^4
10^6
10^8
10^{10}

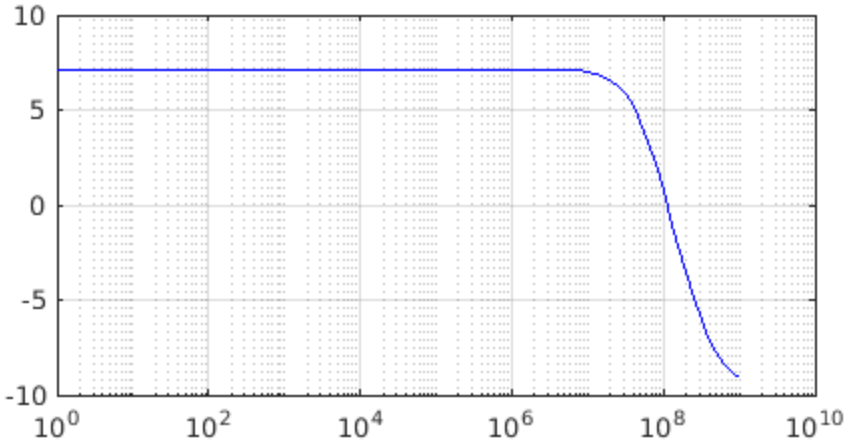

40
30
20
10
0
-10
-20
10^0
10^2
10^4
10^6
10^8
10^{10}


40
30
20
10
0
-10
-20
10^0
10^2
10^4
10^6
10^8
10^{10}

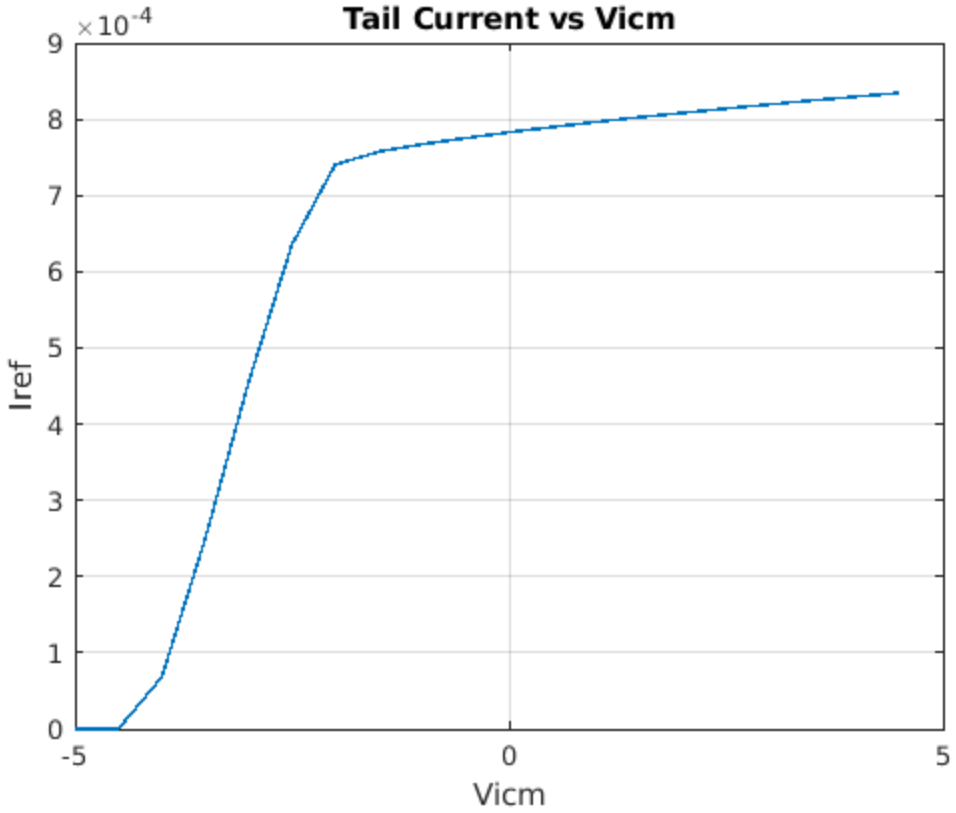

40
30
20
10
0
-10
-20
10^0
10^2
10^4
10^6
10^8
10^{10}

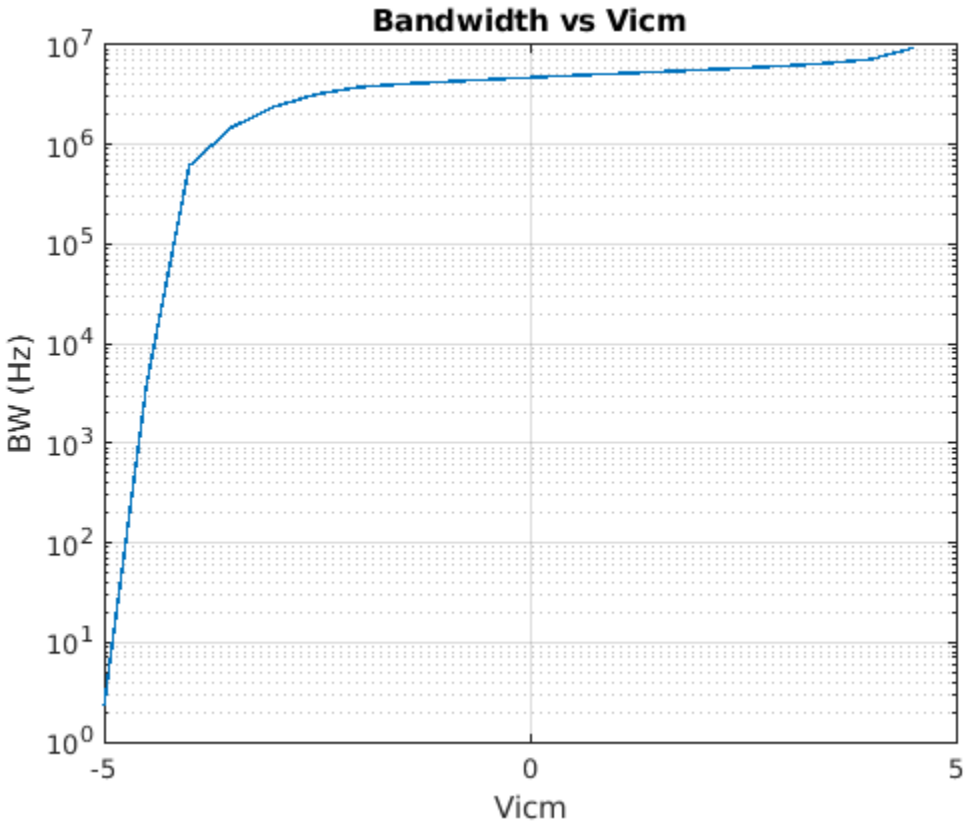

40
30
20
10
0
-10
-20
10^0
10^2
10^4
10^6
10^8
10^{10}

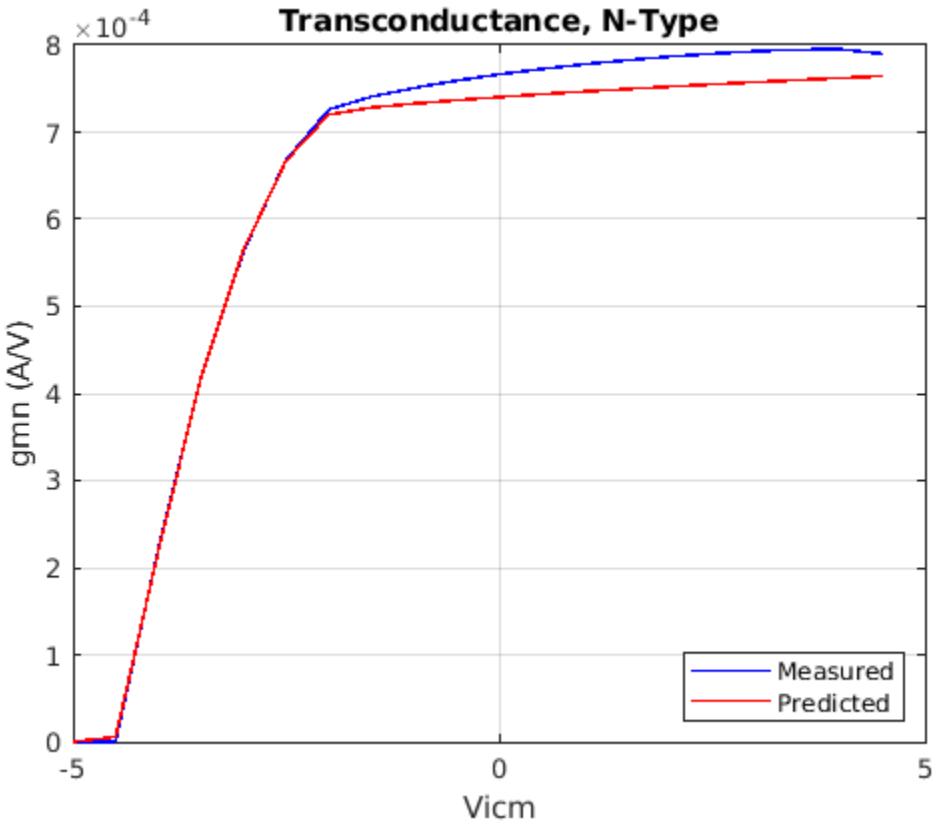

40
30
20
10
0
-10
-20
10^0
10^2
10^4
10^6
10^8
10^{10}

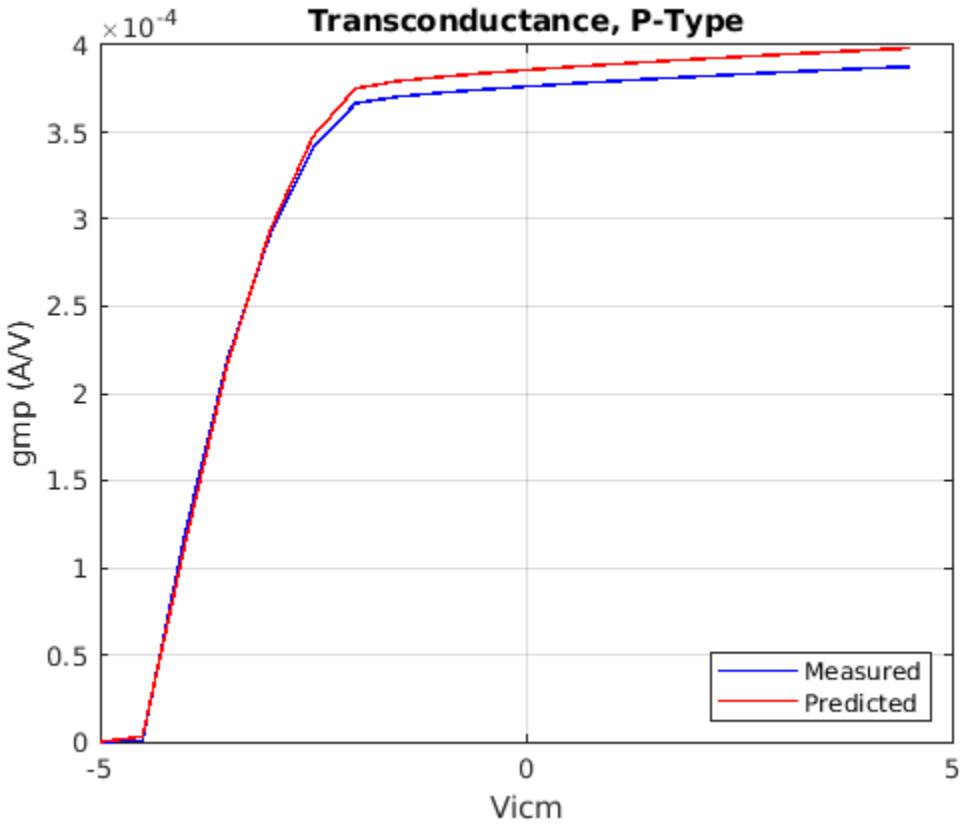


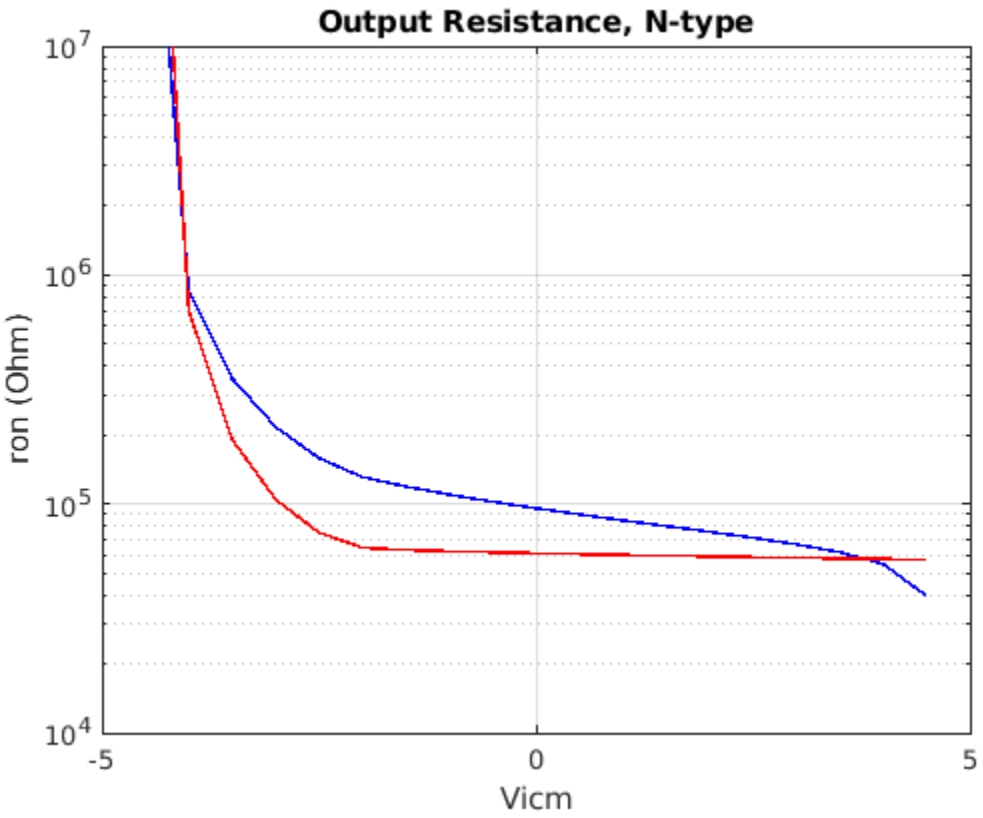
Here are the plots from plot_measurements.m in order of the figure numbers they popped up as

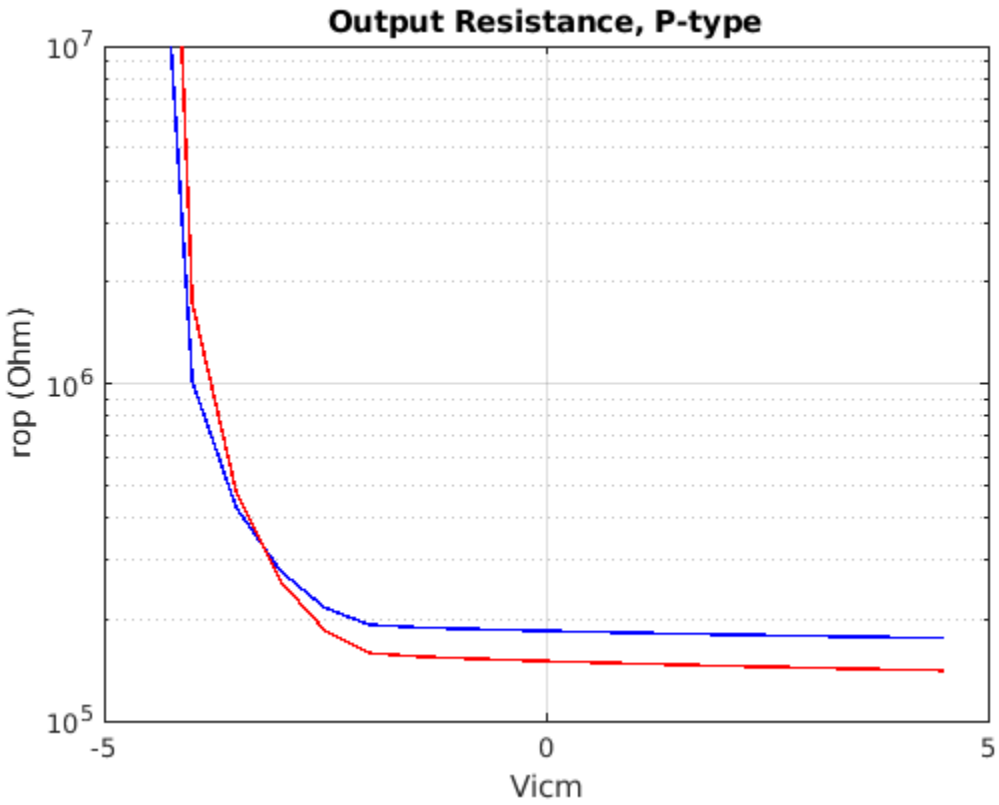


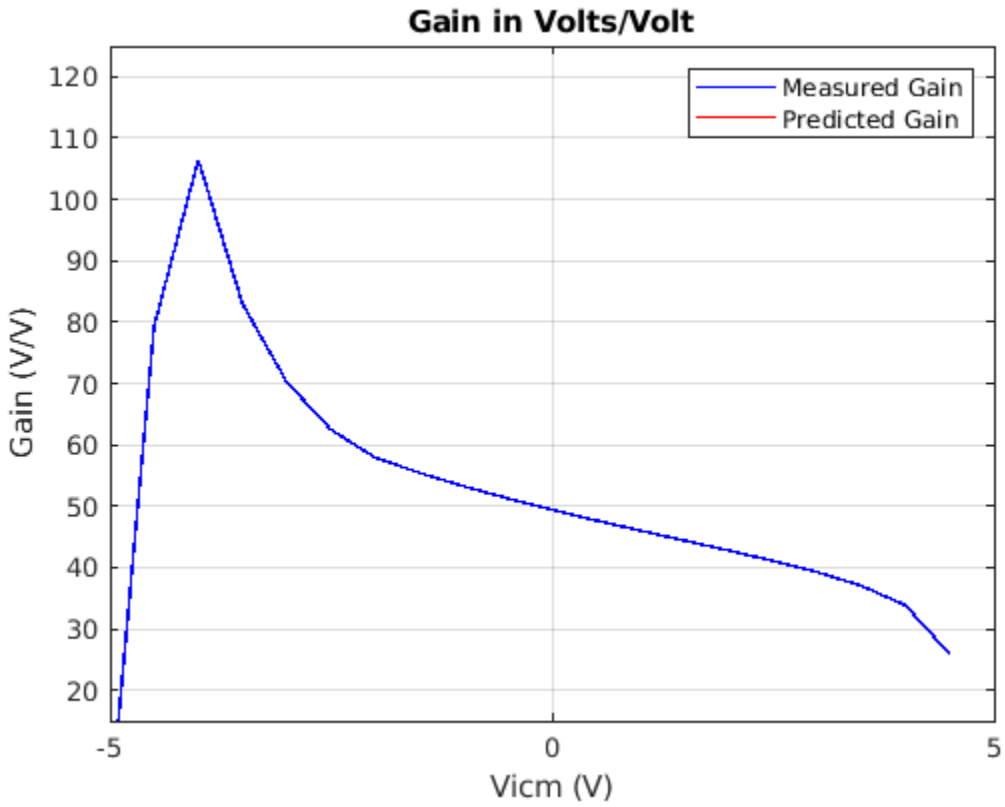

Bandwidth vs Vicm
BW (Hz)
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
-5
0
5
Vicm

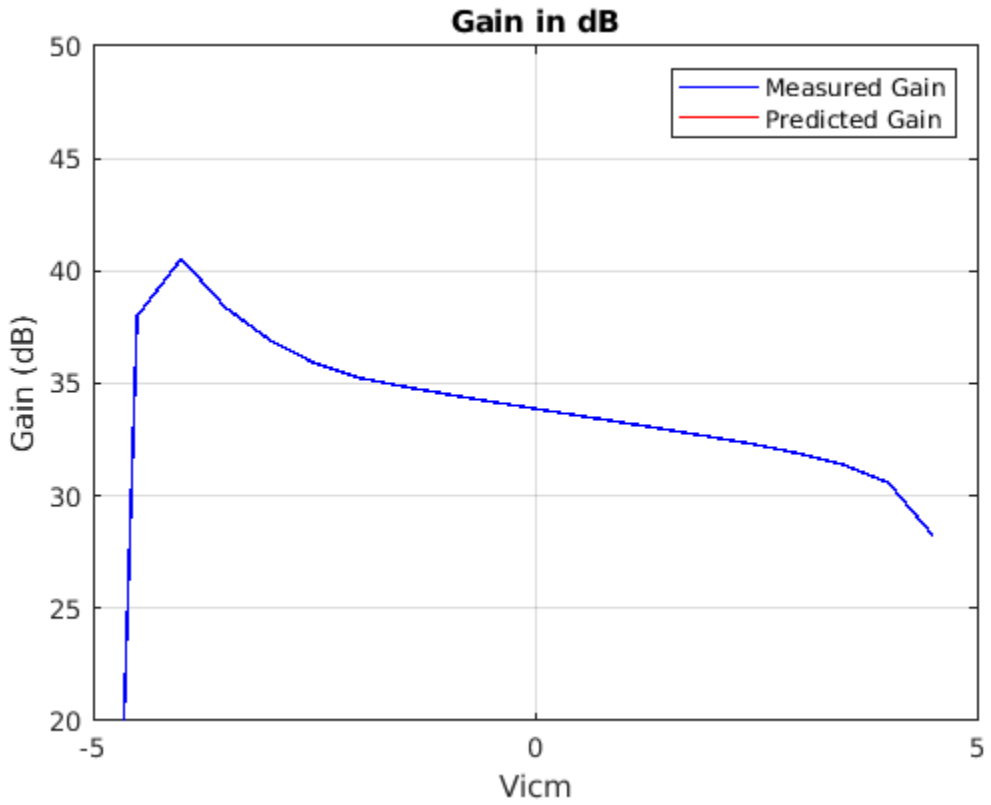

Transconductance, N-Type
×10^-4
8
7
6
5
4
3
2
1
0
gmn (A/V)
-5
0
5
Vicm
Measured
Predicted

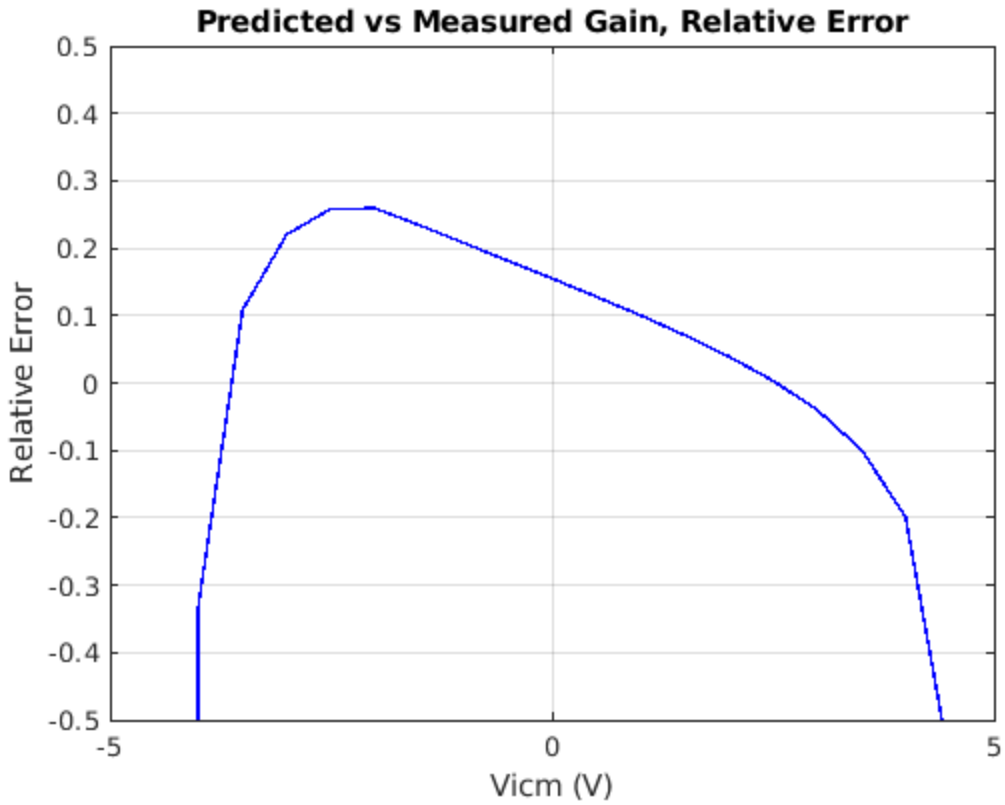

Transconductance, P-Type
×10^-4
4
3.5
3
2.5
2
1.5
1
0.5
0
gmp (A/V)
-5
0
5
Vicm
Measured
Predicted

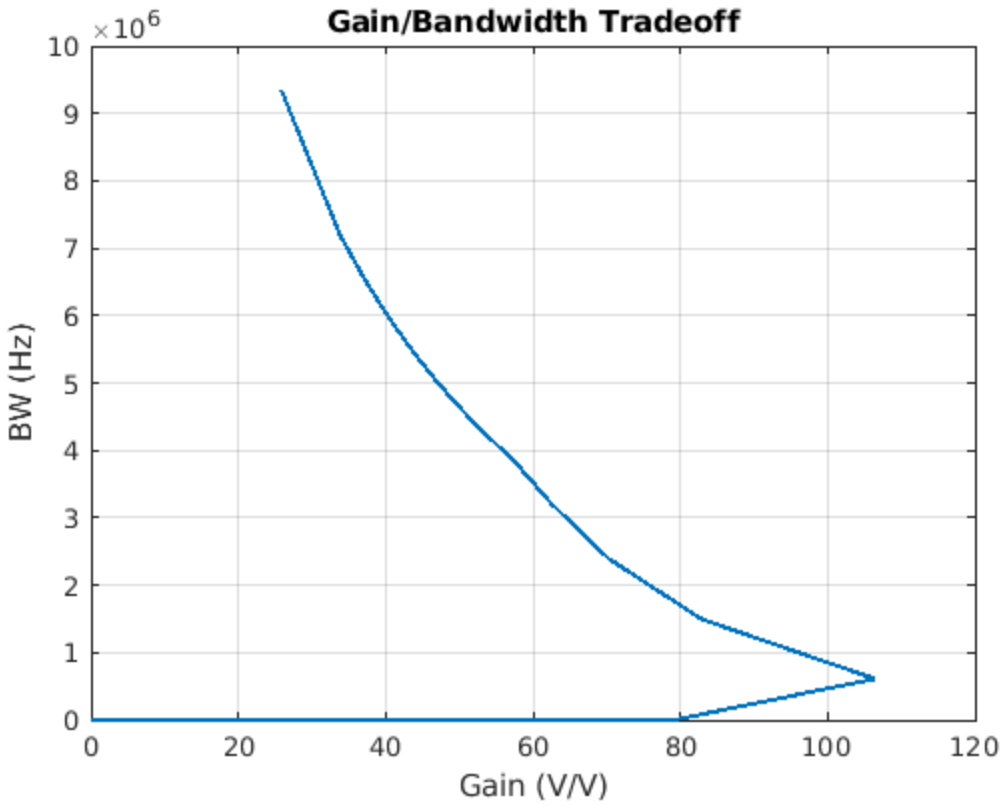

Output Resistance, N-type
10^7
10^6
10^5
10^4
ron (Ohm)
-5
0
5
Vicm

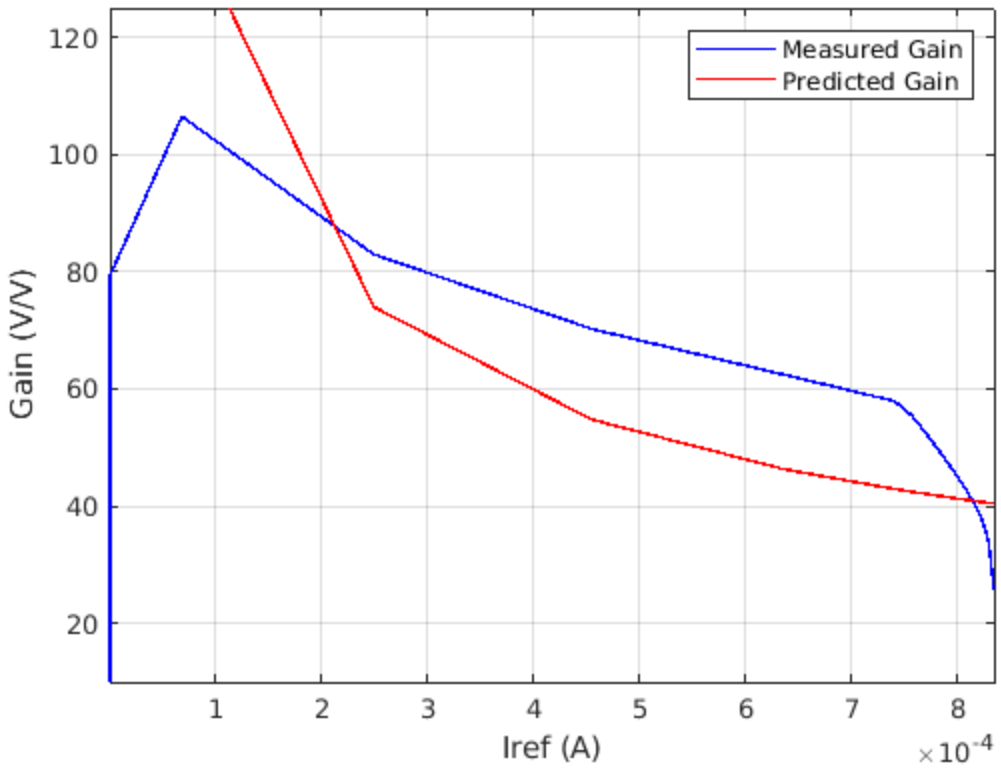

Output Resistance, P-type
10^7
10^6
10^5
rop (Ohm)
-5
0
5
Vicm

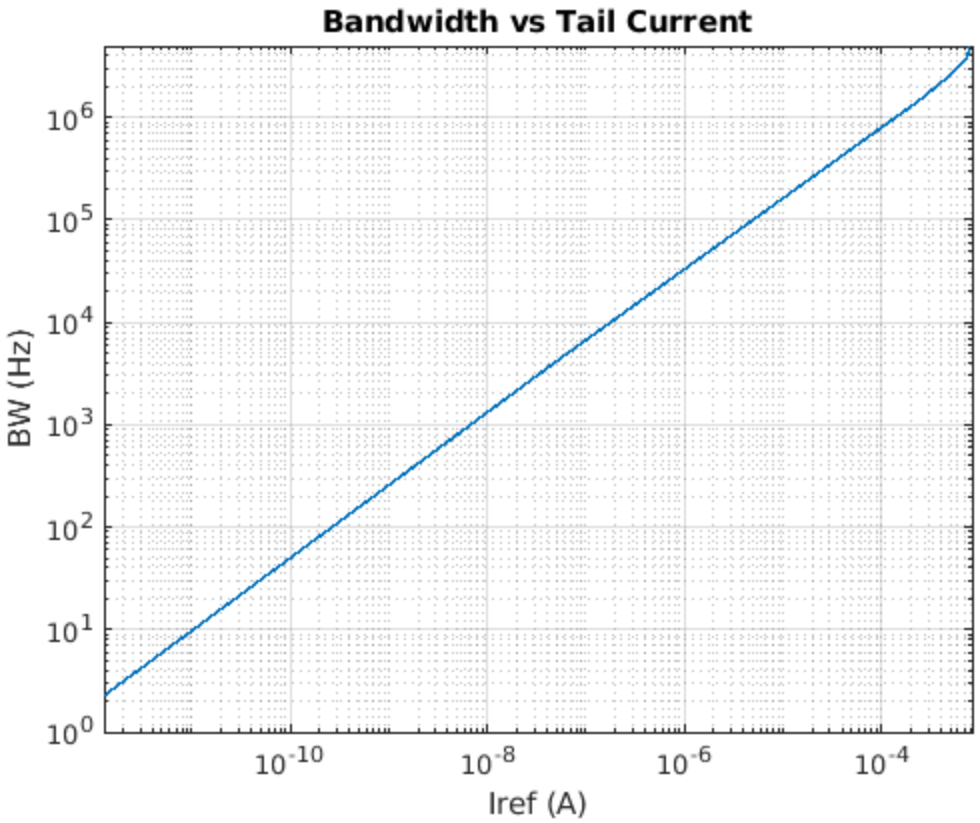

Gain in Volts/Volt
Measured Gain
Predicted Gain
120
110
100
90
80
70
60
50
40
30
20
Gain (V/V)
-5
0
5
Vicm (V)


Gain in dB
Measured Gain
Predicted Gain
Gain (dB)
Vicm
50
45
40
35
30
25
20
-5
0
5


Predicted vs Measured Gain, Relative Error
Relative Error
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-5
0
5
Vicm (V)


Gain/Bandwidth Tradeoff
×10^6
10
9
8
7
6
5
4
3
2
1
0
BW (Hz)
0
20
40
60
80
100
120
Gain (V/V)


Measured Gain
Predicted Gain
Gain (V/V)
Iref (A)
120
100
80
60
40
20
1
2
3
4
5
6
7
8
×10^-4



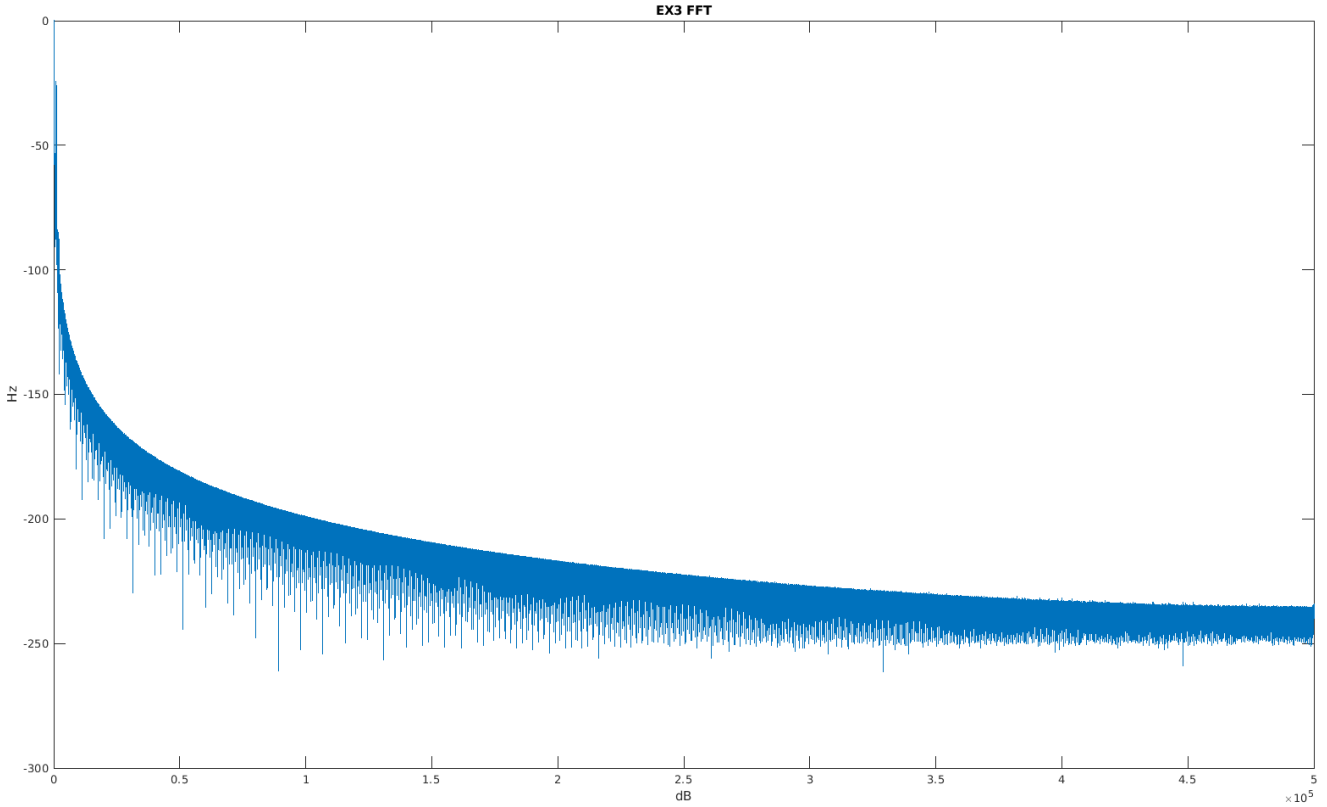
Conclusions

The accuracy of the predictions were fairly close to the simulated solutions, but there were obvious differences. For instance the transconductance and output resistances were fairly close; however the difference of the predictions vs the simulation gets quite exaggerated when using the resistance and transconductance in calculations like Gain/Current.

The trade of between Bandwidth and Gain is that after about .75 MHz the gain is slowling getting lower. So using this circuit for high frequency systems would be not as useful as using them for low frequency systems.

3

Here is the plot for the FFT

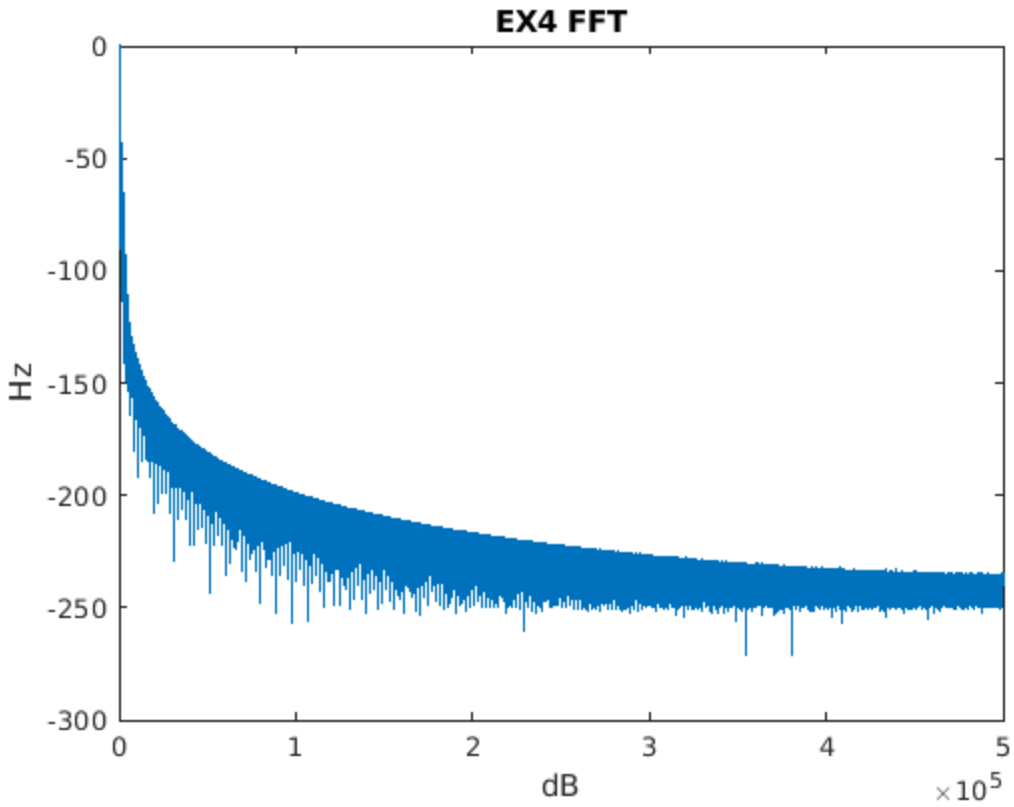


and the calculated SNR is -62.3347

```
data = importdata("fft.dat"); plot(data(:,1),data(:,2)); title("EX3 FFT") ylabel('Hz') xlabel('dB') axis([0, 500000, -300, 0]) fftsnr = snr(data(:,2),data(:,1))
```

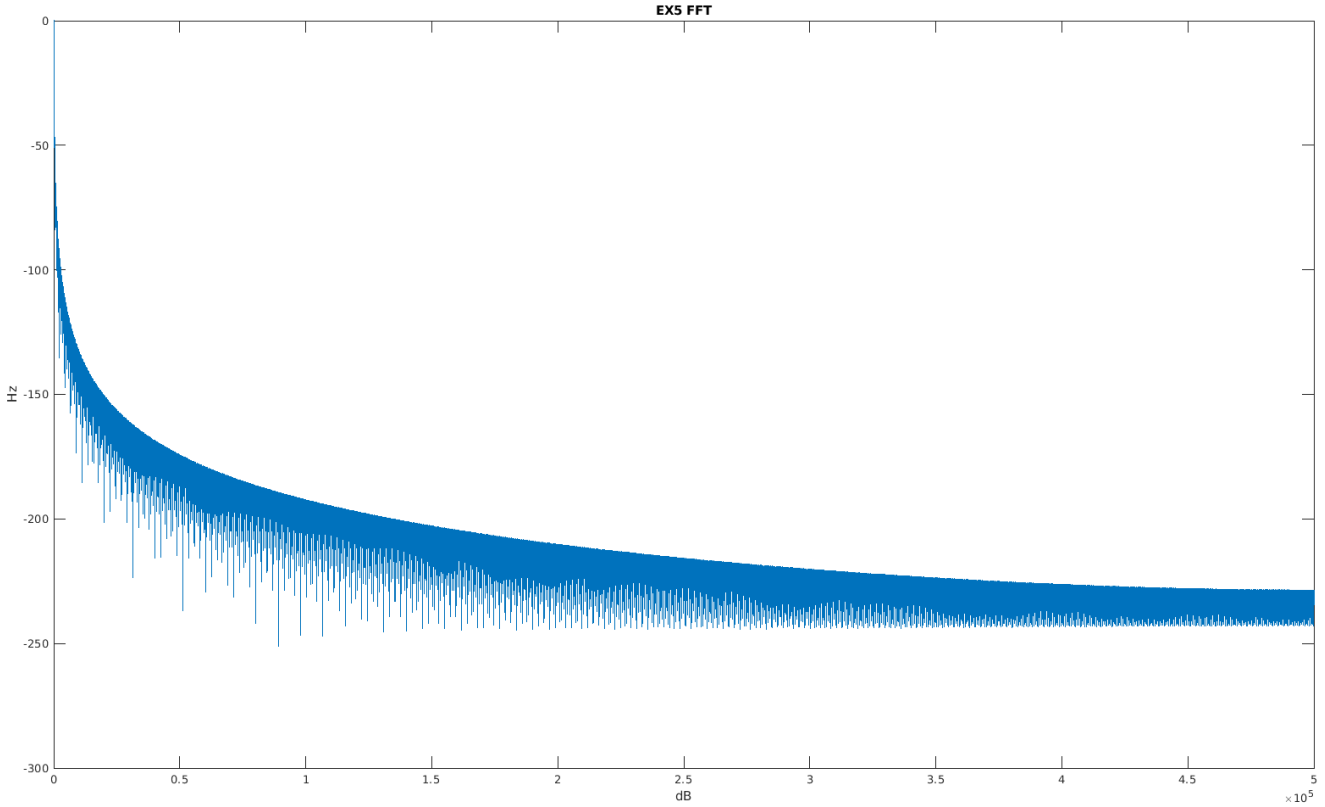
4

Changed Vin to 10mV in ex3.sp. Below is the float, and the SNR is -62.3353



5

Below is the fft analysis and the SNR is -62.5993



6

Calculating Av0 and gm

In [ ]:
```
from math import sqrt

Kp = 0.19
Vthp = -0.74
Vdd = 5 # v
Vg = 4
Vgs = Vg - Vdd
```

```
Vov = Vgs - Vthp
ID = 1/2 * Kp * Vov**2

gm = sqrt(2 * ID * Kp)
av = -gm * R

print(gm)
print(av)
```

```
0.049400000000000006
-494.00000000000006
```

gm = 0.0494 Av0 = -494

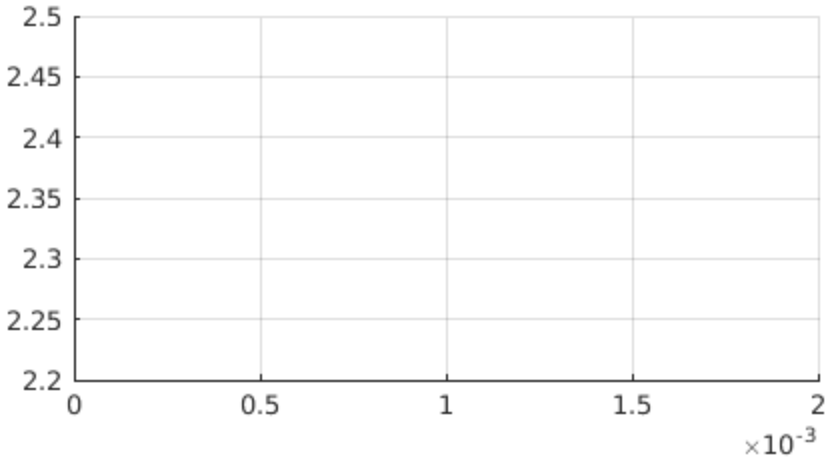
7

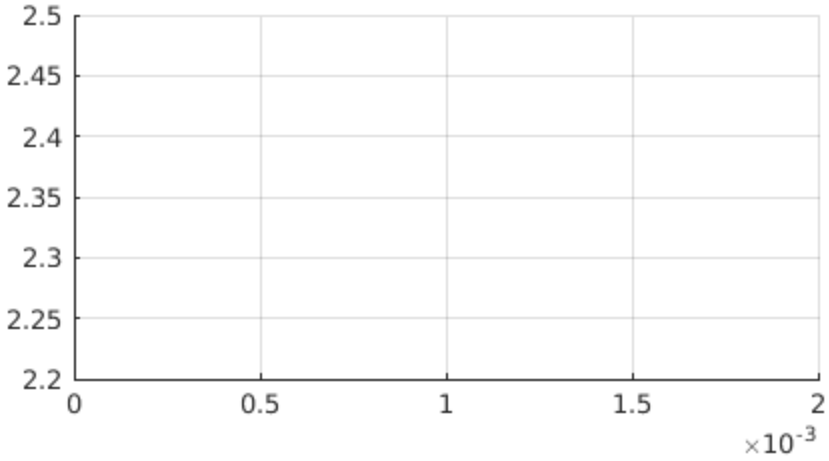
ex2.sp with opamp.sp:

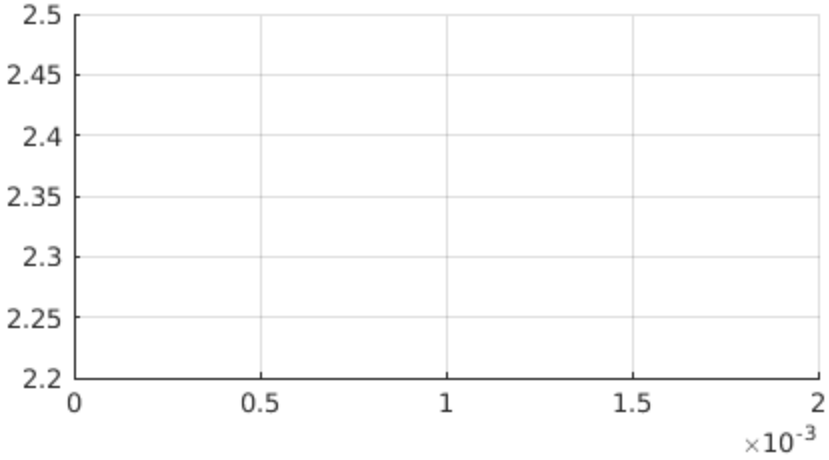
```
0       -5.00000e+00    1.291126e-12    1.085331e-02    -3.92888e+01    0.000000e+00
1.359389e-11    2.427459e-10    5.888254e+12    2.183838e+11
1       -4.50000e+00    4.562162e-08    2.239358e-01    -1.29975e+01    0.000000e+00
4.802516e-07    5.563758e-07    1.735504e+08    1.161814e+08
2       -4.00000e+00    6.795952e-05    1.735734e-03    -5.52103e+01    0.000000e+00
2.204869e-04    1.200720e-04    8.519460e+05    1.011311e+06
3       -3.50000e+00    2.491448e-04    5.259033e-04    -6.55819e+01    0.000000e+00
4.165233e-04    2.200303e-04    3.530310e+05    4.271133e+05
4       -3.00000e+00    4.547100e-04    5.926116e-04    -6.45446e+01    0.000000e+00
5.626861e-04    2.916084e-04    2.170066e+05    2.773860e+05
5       -2.50000e+00    6.353315e-04    9.510242e-04    -6.04362e+01    0.000000e+00
6.676993e-04    3.411058e-04    1.583717e+05    2.163229e+05
6       -2.00000e+00    7.405122e-04    2.248149e-04    -7.29635e+01    0.000000e+00
7.257644e-04    3.665050e-04    1.309852e+05    1.926588e+05
7       -1.50000e+00    7.572604e-04    2.131827e-04    -7.34250e+01    0.000000e+00
7.405037e-04    3.703683e-04    1.190680e+05    1.894083e+05
8       -1.00000e+00    7.669354e-04    2.038254e-04    -7.38148e+01    0.000000e+00
7.506235e-04    3.725796e-04    1.098886e+05    1.875853e+05
9       -5.00000e-01    7.752391e-04    1.962282e-04    -7.41448e+01    0.000000e+00
7.590347e-04    3.744656e-04    1.022302e+05    1.860515e+05
10      0.000000e+00    7.827466e-04    1.871757e-04    -7.45550e+01    0.000000e+00
```

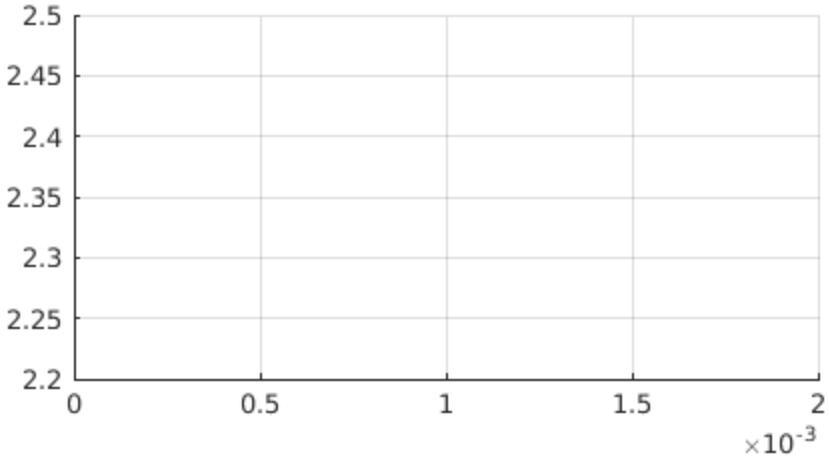
```
7.662185e-04    3.761616e-04    9.565915e+04    1.846886e+05
11      5.000000e-01    7.896944e-04    1.799763e-04    -7.48957e+01    0.000000e+00
7.724354e-04    3.777235e-04    8.988962e+04    1.834469e+05
12      1.000000e+00    7.962122e-04    1.732769e-04    -7.52252e+01    0.000000e+00
7.778460e-04    3.791819e-04    8.471235e+04    1.822989e+05
13      1.500000e+00    8.023825e-04    1.666835e-04    -7.55622e+01    0.000000e+00
7.825525e-04    3.805568e-04    7.995818e+04    1.812266e+05
14      2.000000e+00    8.082623e-04    1.601143e-04    -7.59114e+01    0.000000e+00
7.866128e-04    3.818618e-04    7.547212e+04    1.802178e+05
15      2.500000e+00    8.138936e-04    1.533663e-04    -7.62854e+01    0.000000e+00
7.900404e-04    3.831069e-04    7.108454e+04    1.792632e+05
16      3.000000e+00    8.193079e-04    1.460529e-04    -7.67098e+01    0.000000e+00
7.927870e-04    3.842998e-04    6.656053e+04    1.783559e+05
17      3.500000e+00    8.245299e-04    1.379676e-04    -7.72045e+01    0.000000e+00
7.946772e-04    3.854463e-04    6.146744e+04    1.774904e+05
18      4.000000e+00    8.295776e-04    1.259132e-04    -7.79986e+01    0.000000e+00
7.951190e-04    3.865509e-04    5.465628e+04    1.766626e+05
19      4.500000e+00    8.344579e-04    9.580314e-05    -8.03724e+01    0.000000e+00
7.898892e-04    3.876154e-04    3.962895e+04    1.758704e+05
```

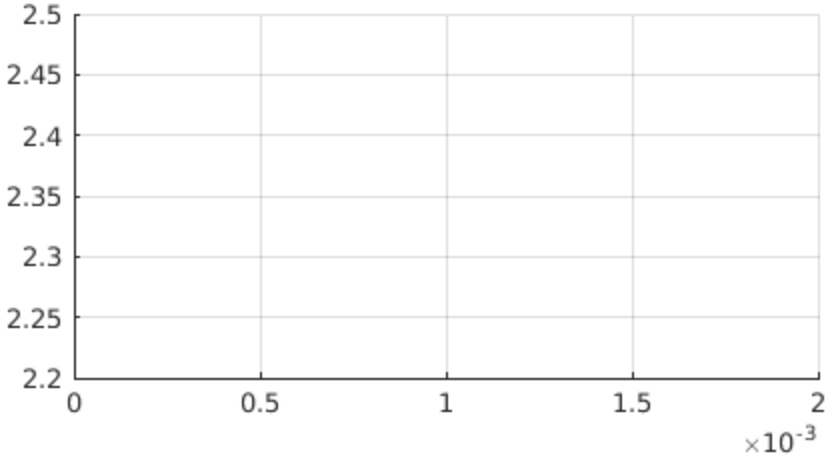
Transient plots in order of their figure numbers

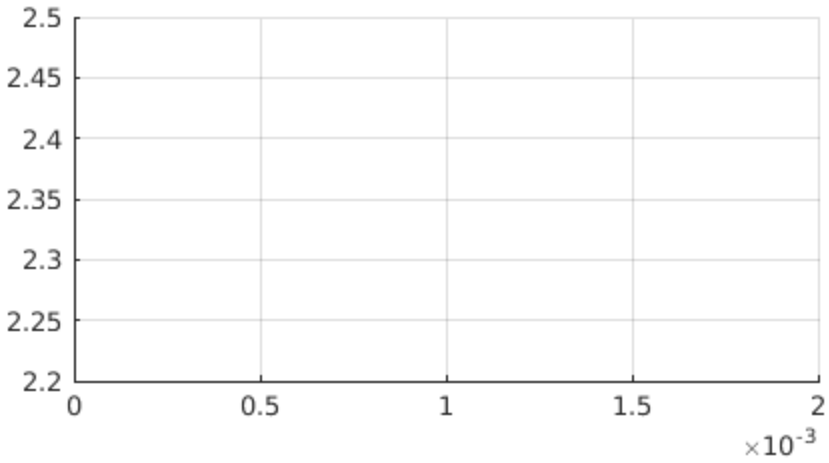


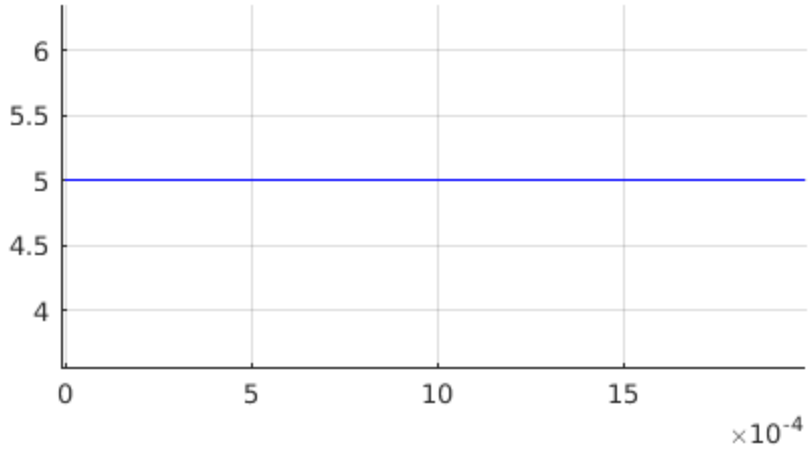

2.5
2.45
2.4
2.35
2.3
2.25
2.2
0
0.5
1
1.5
2
×10^-3

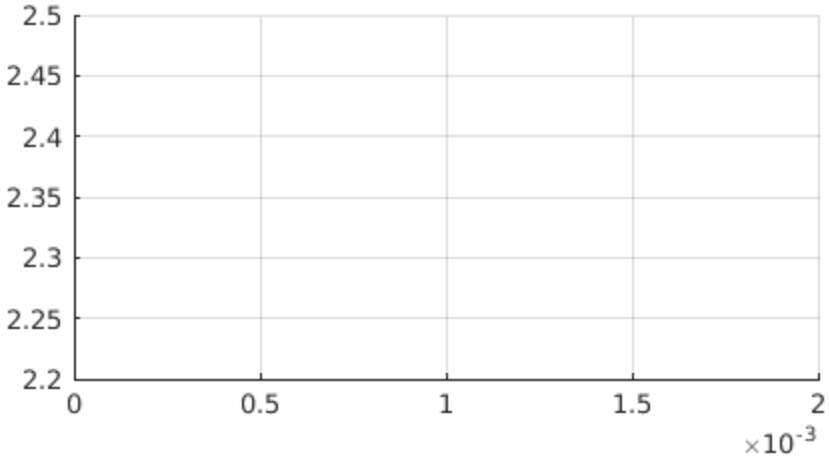

2.5
2.45
2.4
2.35
2.3
2.25
2.2
0
0.5
1
1.5
2
×10^-3


2.5
2.45
2.4
2.35
2.3
2.25
2.2
0
0.5
1
1.5
2
×10^-3


2.5
2.45
2.4
2.35
2.3
2.25
2.2
0
0.5
1
1.5
2
×10^-3


2.5
2.45
2.4
2.35
2.3
2.25
2.2
0
0.5
1
1.5
2
×10^-3


6
5.5
5
4.5
4
0
5
10
15
×10^-4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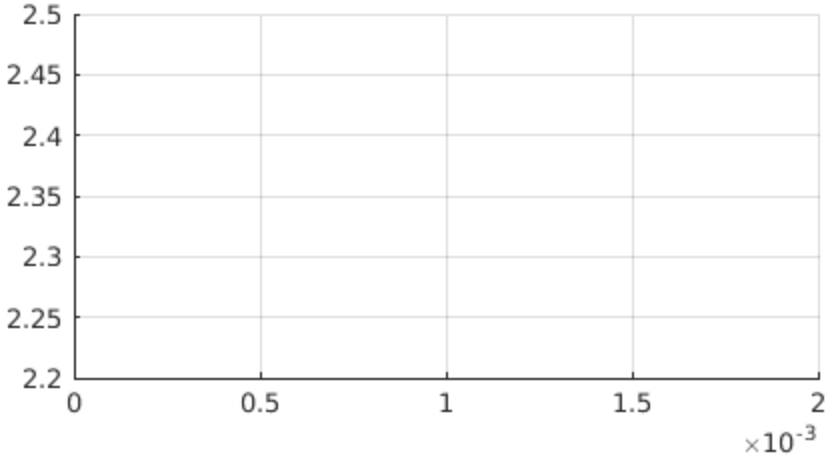
1
1.5
2
×10-3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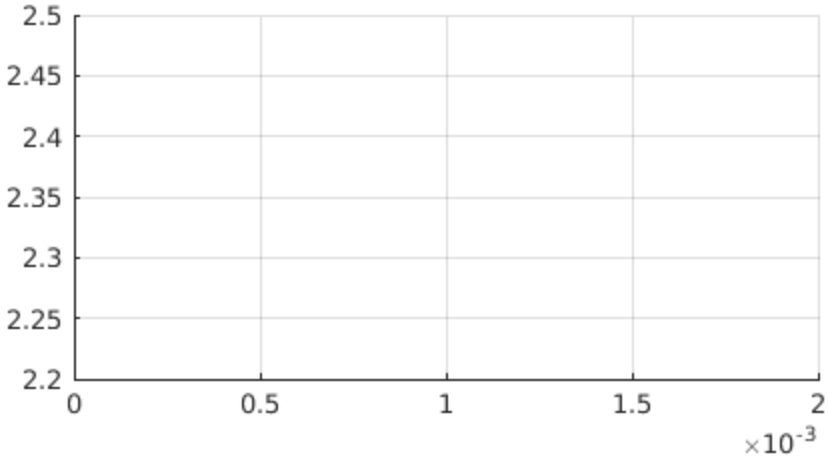
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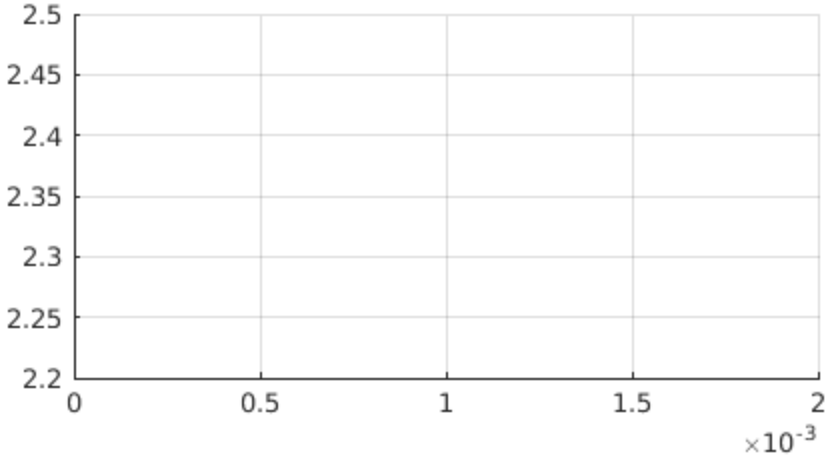
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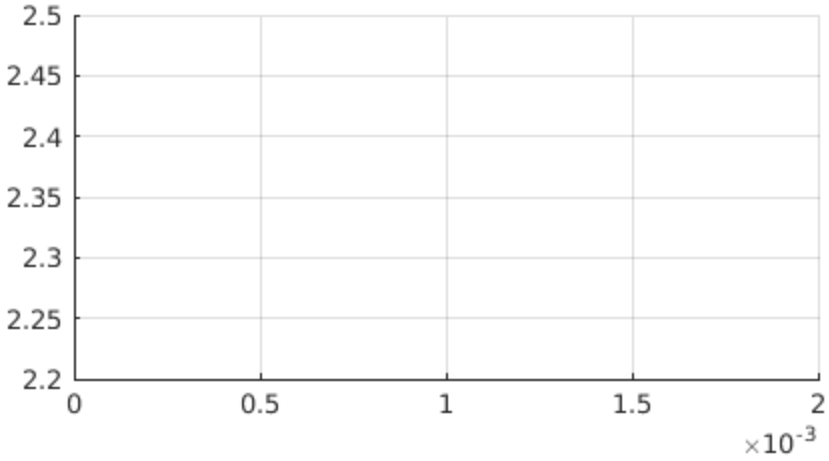
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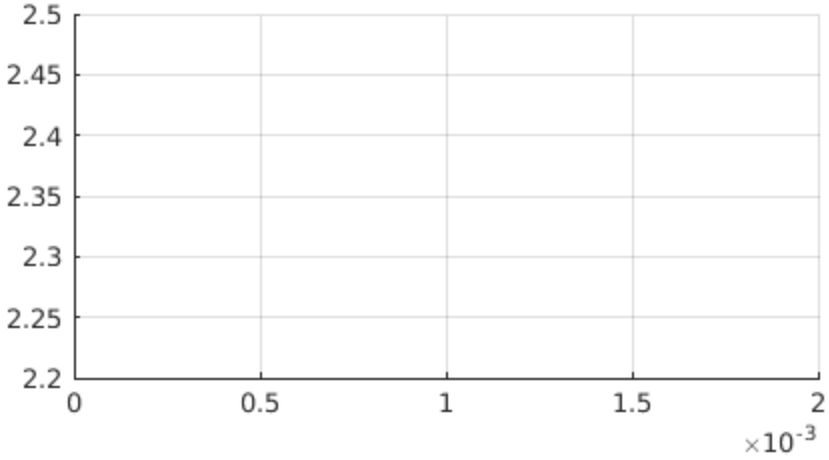
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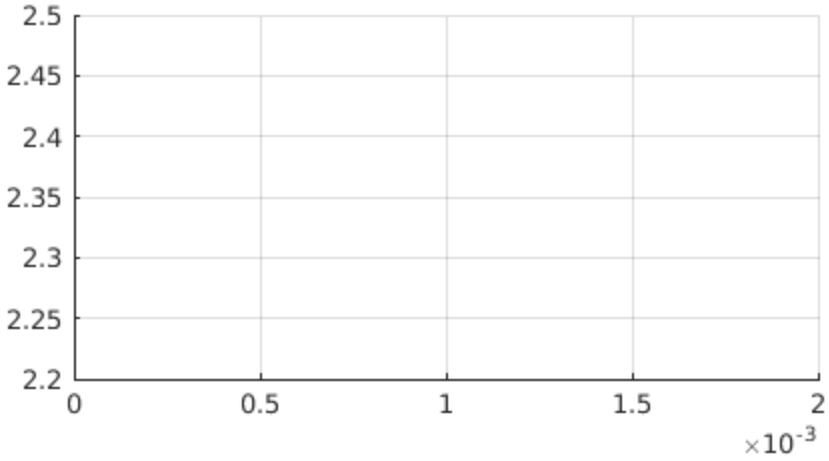
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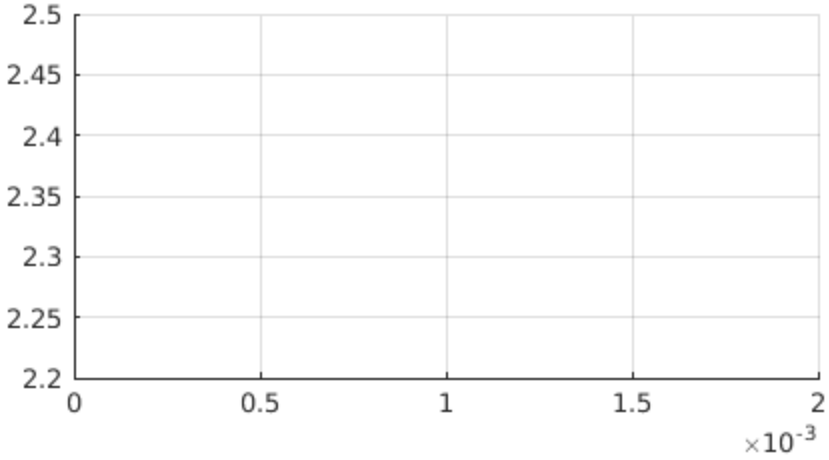
×10^-3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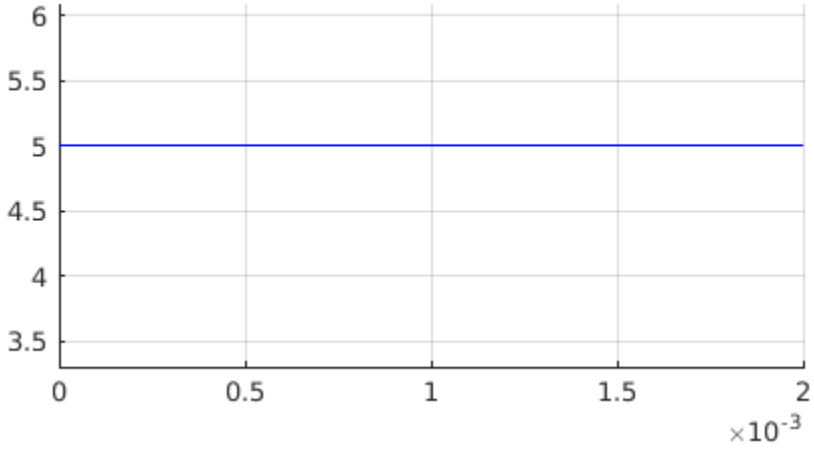
×10^-3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1.5
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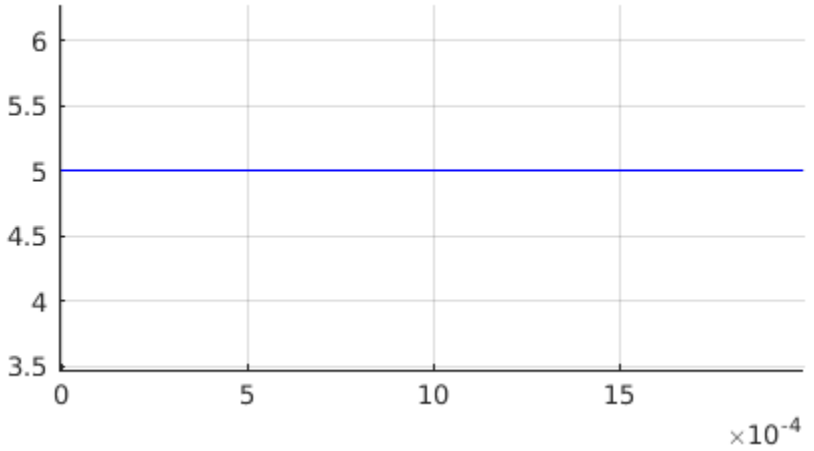
×10^-3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5.5
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4.5
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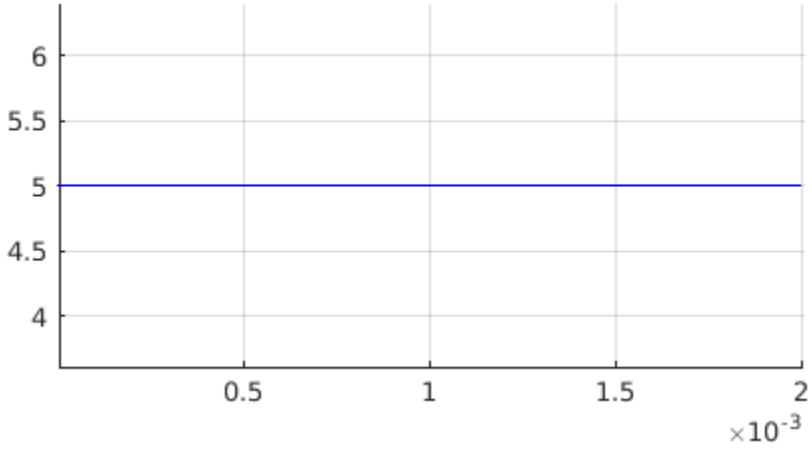
3.5
0
5
10
15
×10^-4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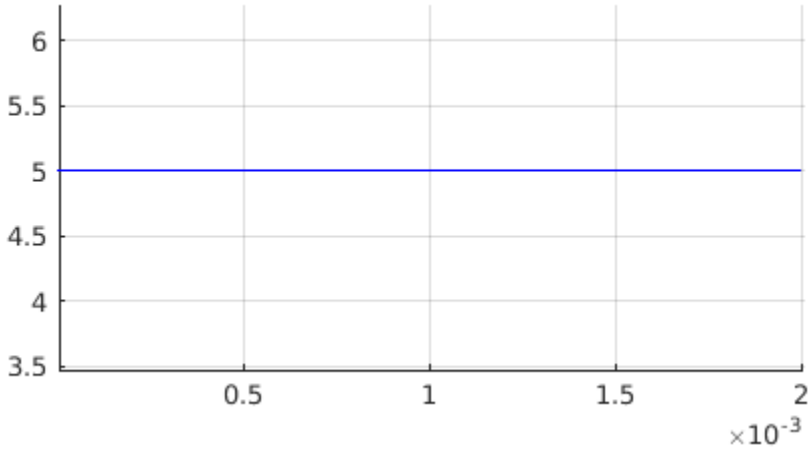
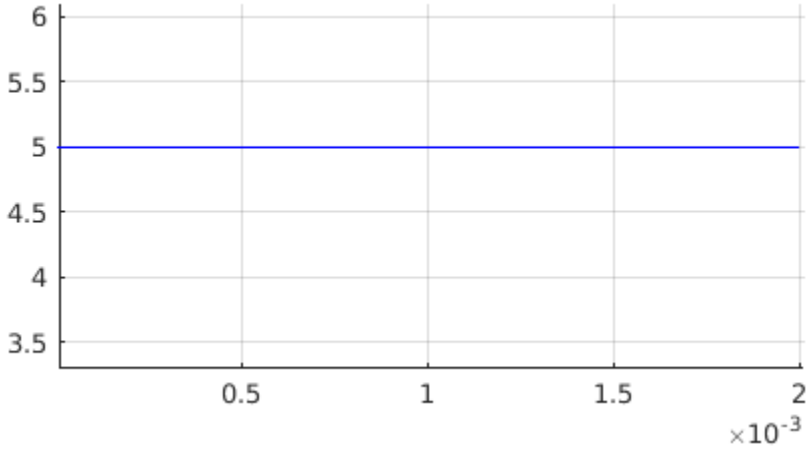
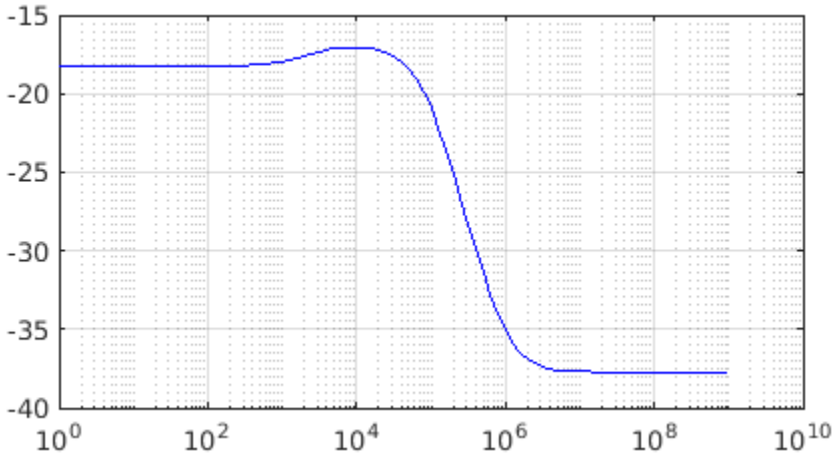
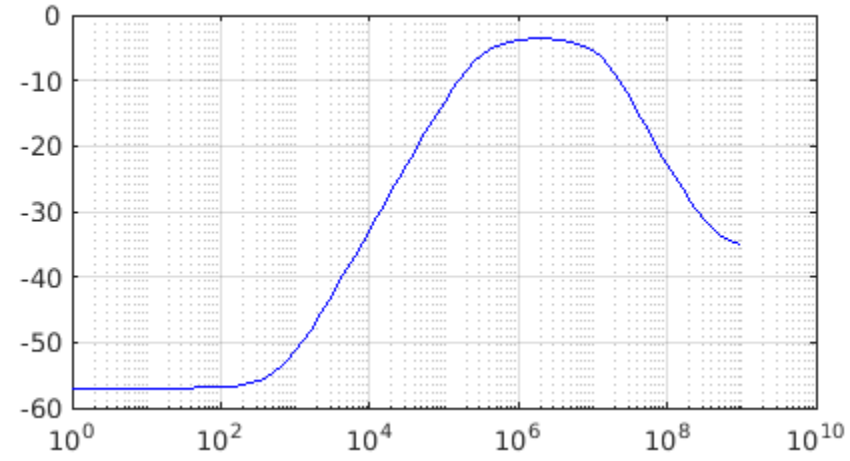
5.5
5
4.5
4
0.5
1
1.5
2
×10^-3


6
5.5
5
4.5
4
3.5
0.5
1
1.5
2
×10^-3



AC plots in order of their figure number

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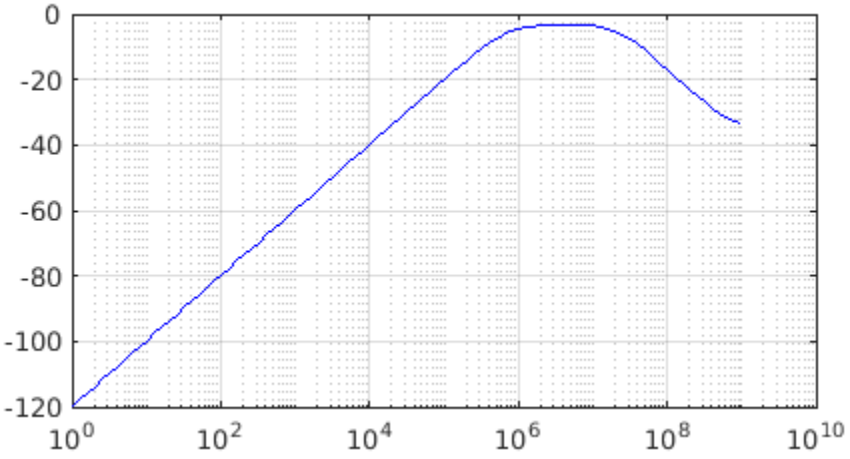
-20
-30
-40
-50
-60
10^0
10^2
10^4
10^6
10^8
10^{10}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-120
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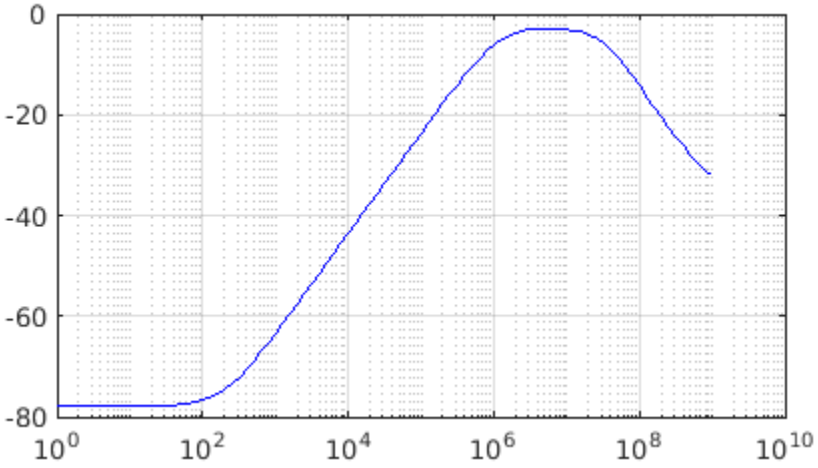
10^2
10^4
10^6
10^8
10^{10}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10^4
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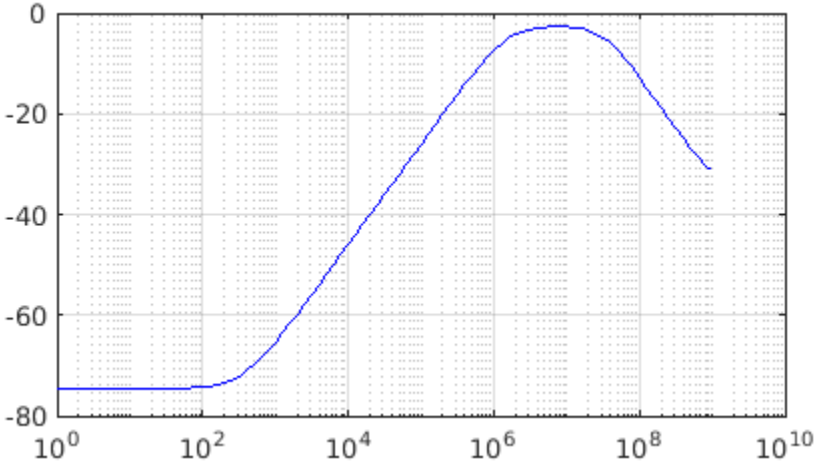
10^8
10^{10}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-80
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10^2
10^4
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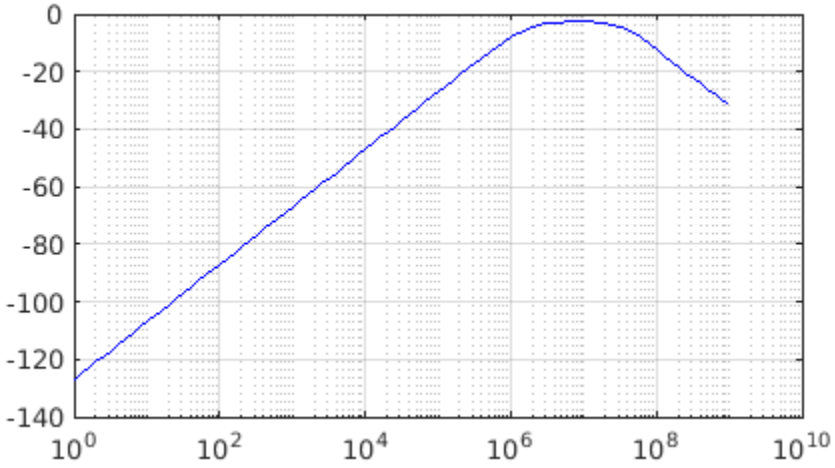
10^8
10^{10}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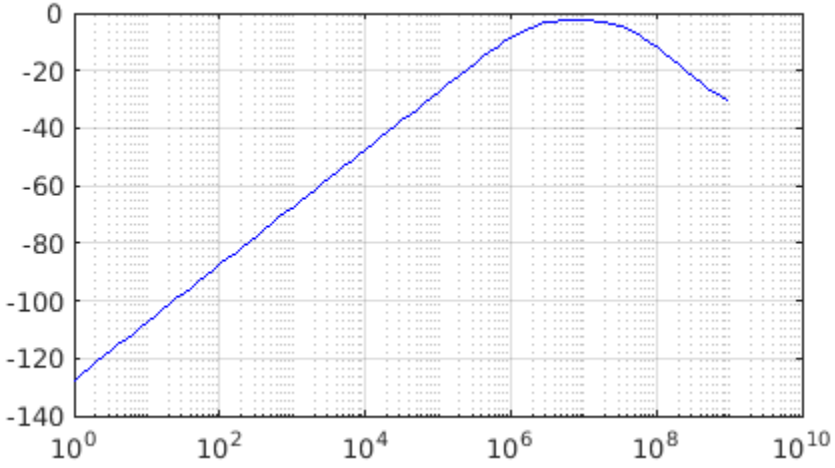
-100
-120
-140
10^0
10^2
10^4
10^6
10^8
10^{10}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-100
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-140
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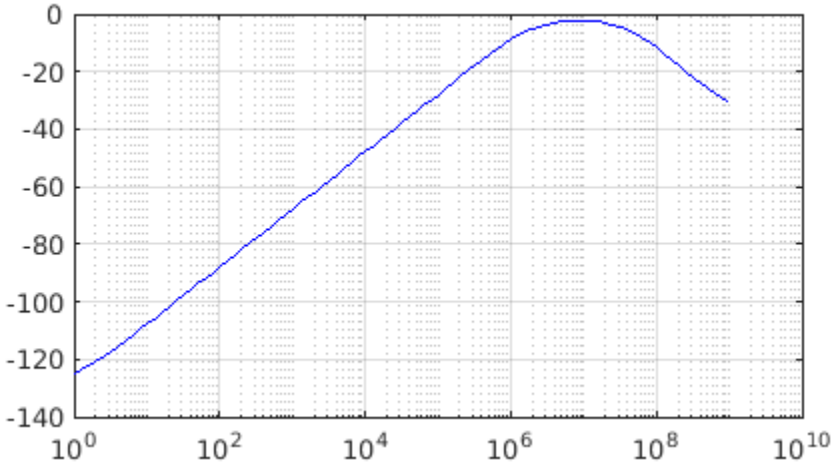
10^2
10^4
10^6
10^8
10^{10}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10^6
10^8
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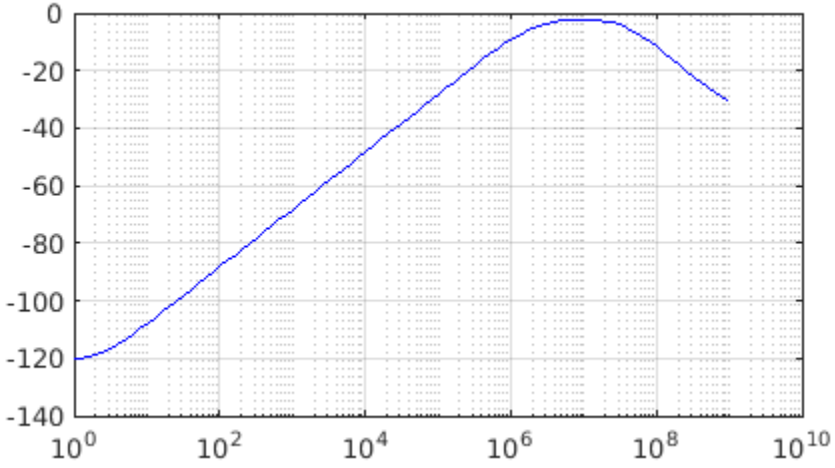
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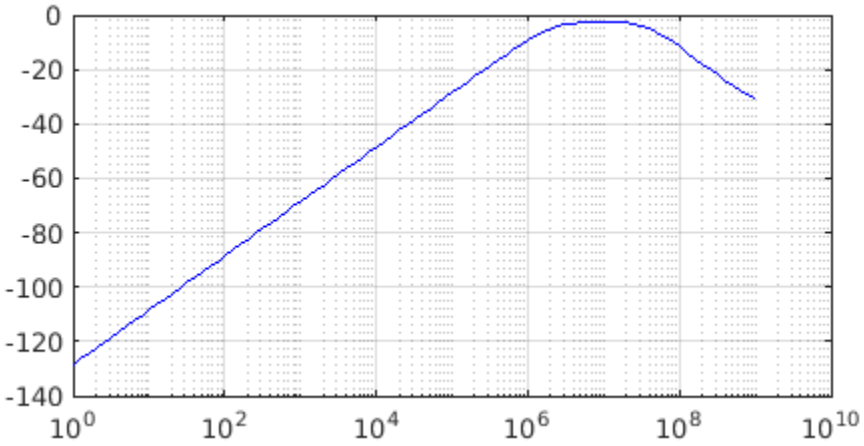
10^8
10^{10}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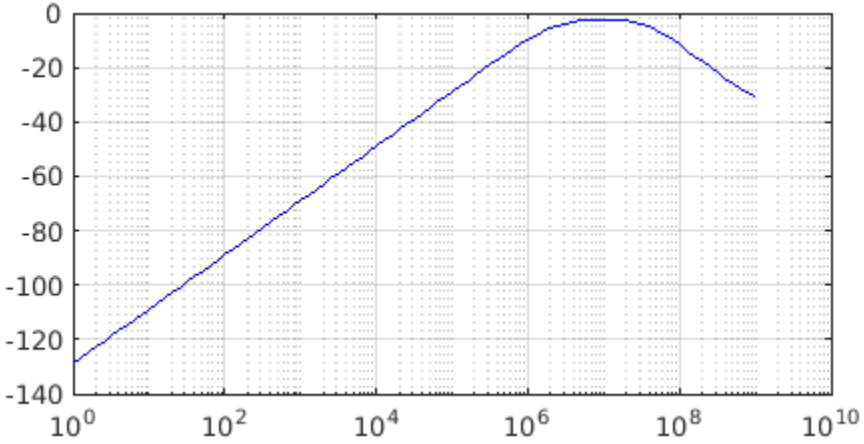
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10^4
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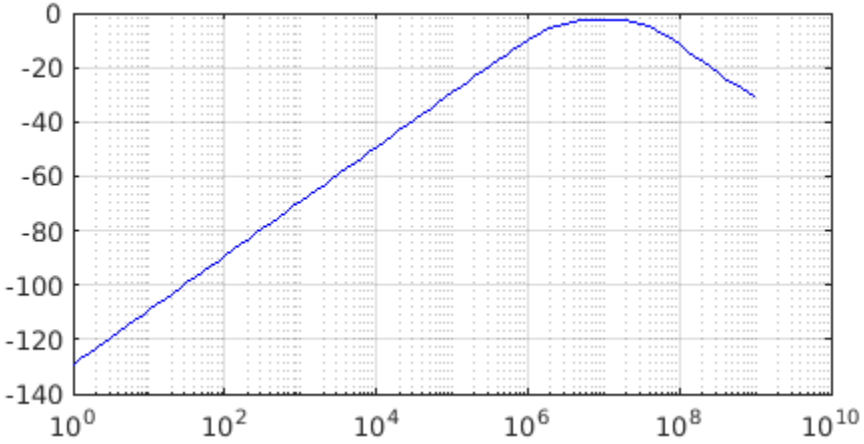
10^8
10^{10}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-140
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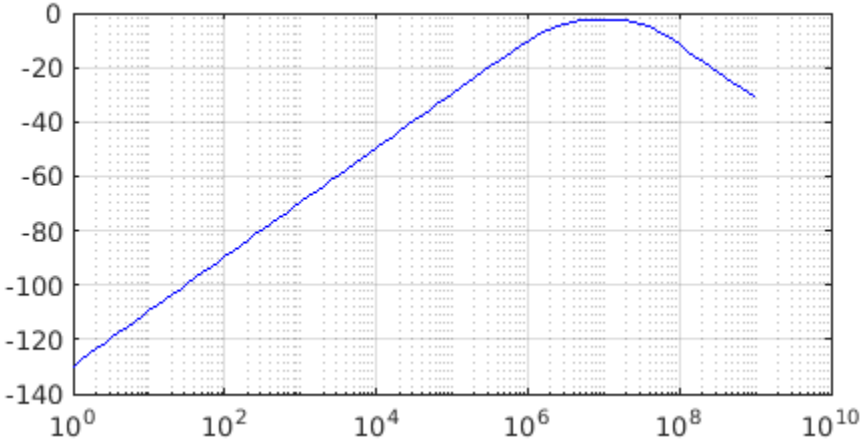
10^6
10^8
10^{10}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-100
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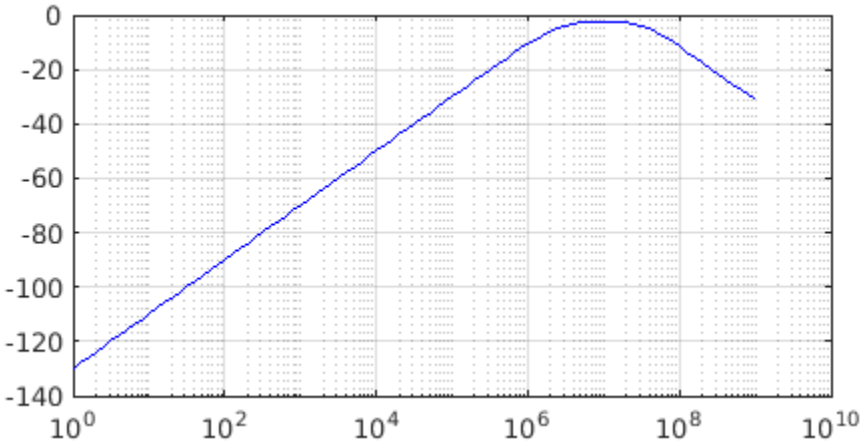
-140
10^0
10^2
10^4
10^6
10^8
10^{10}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10^6
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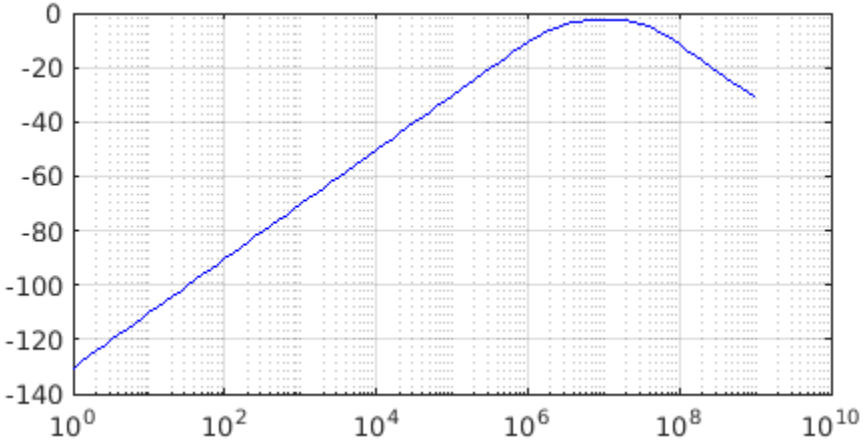
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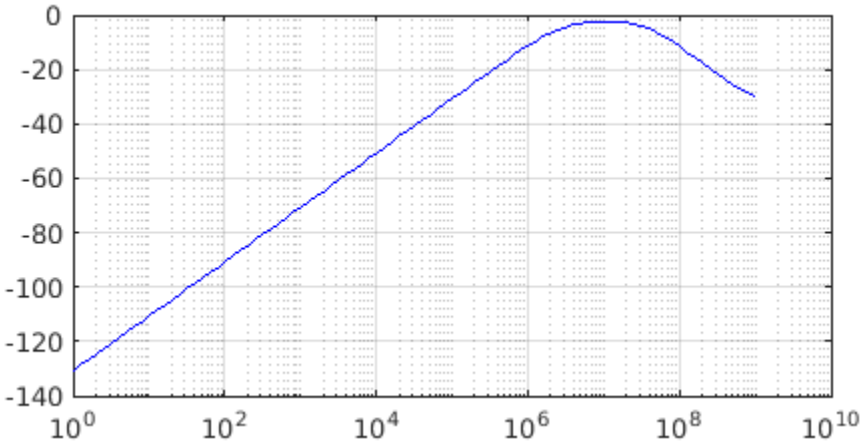
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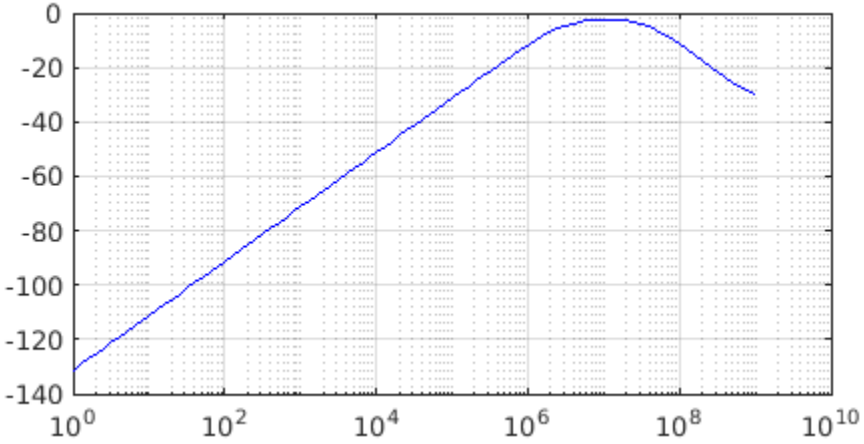
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10^4
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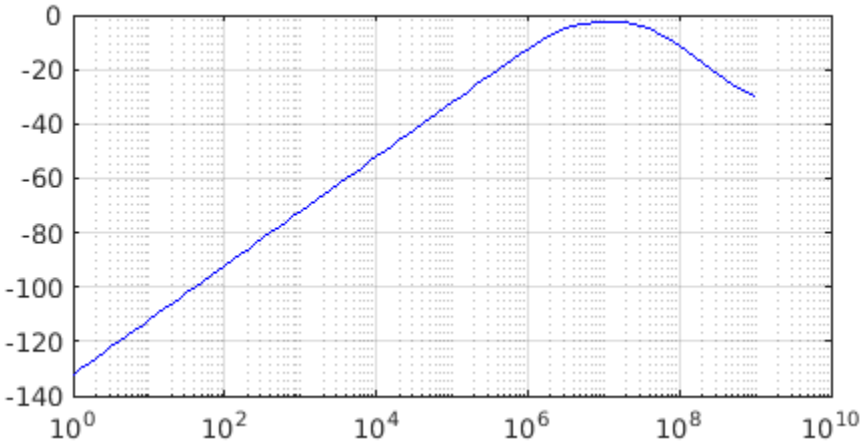
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10^2
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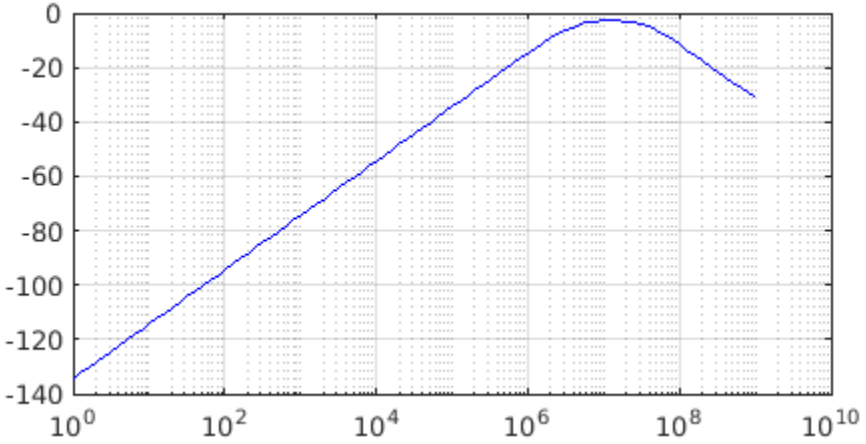
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10^2
10^4
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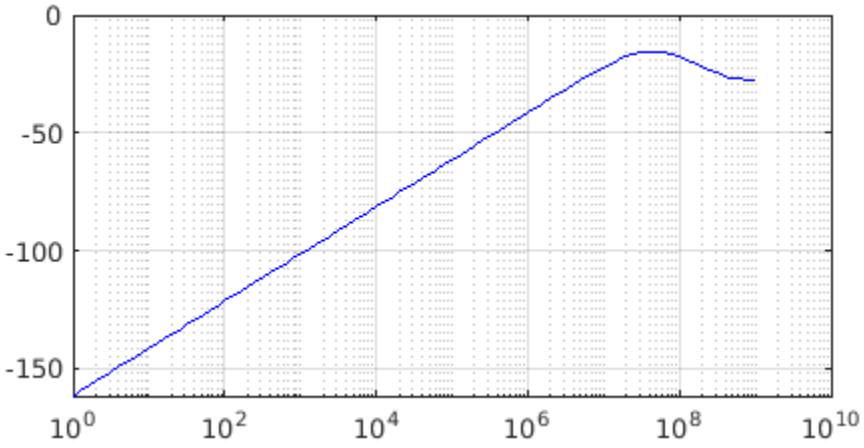
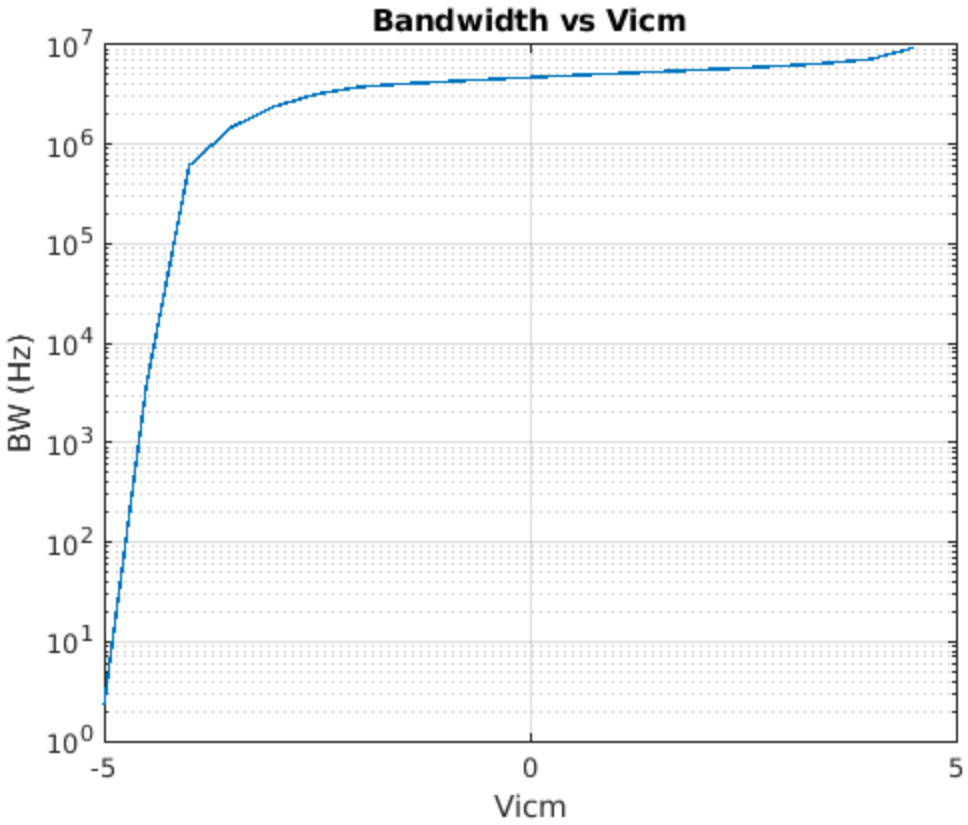
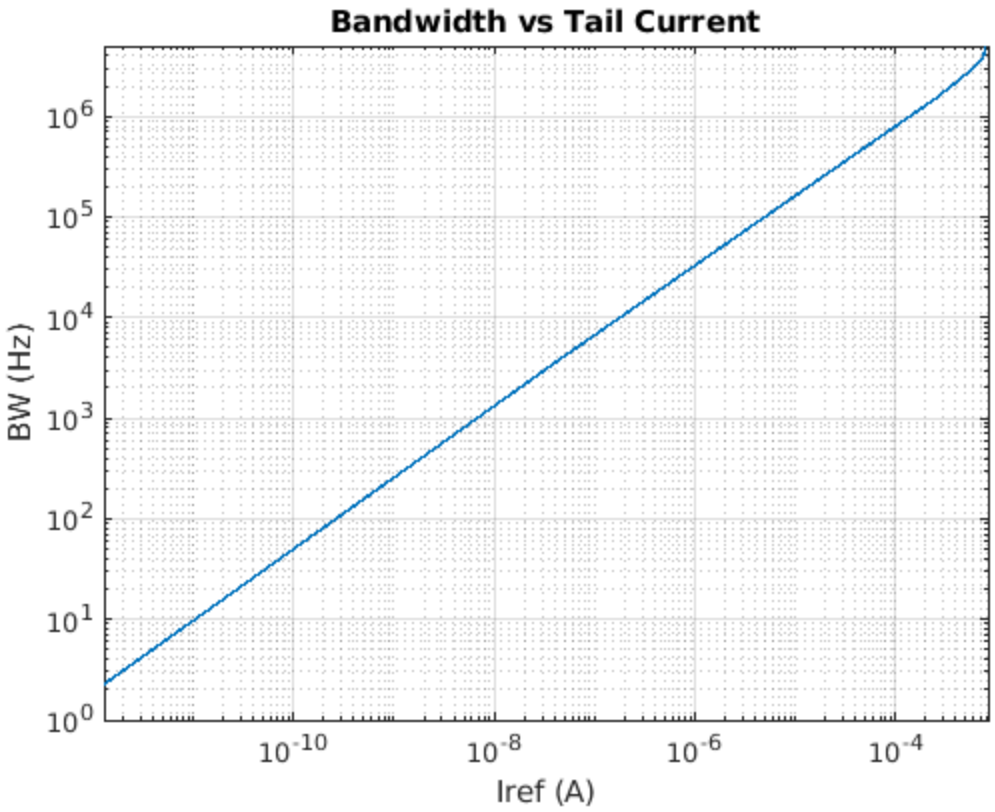
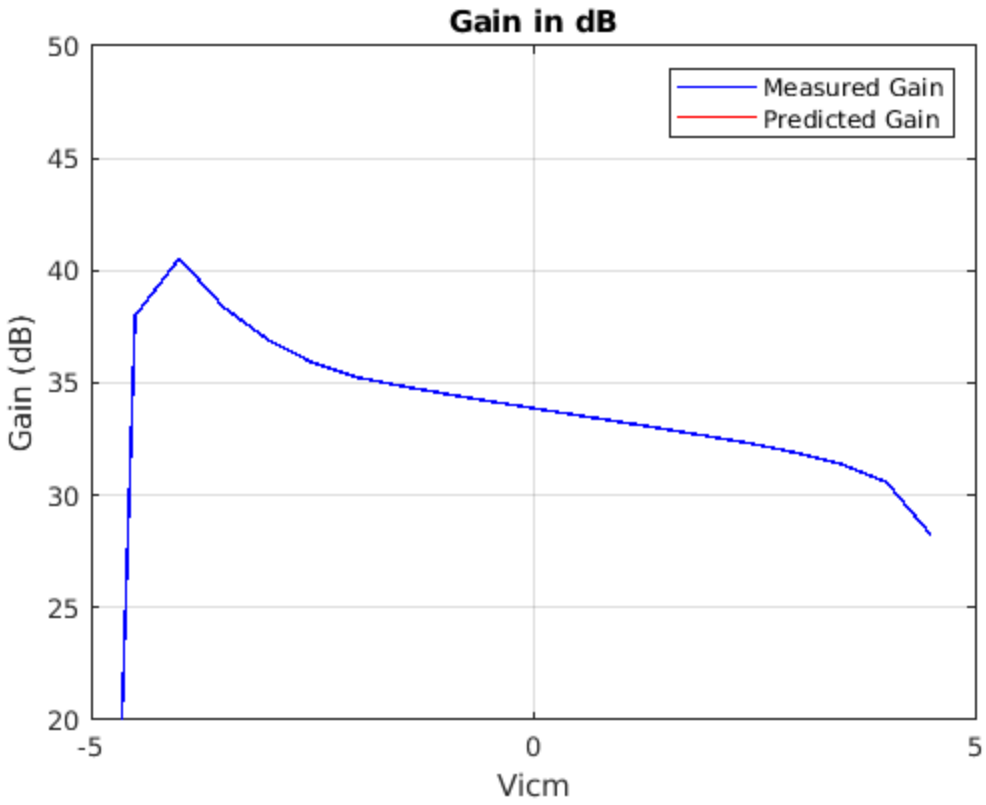
10^8
10^{10}

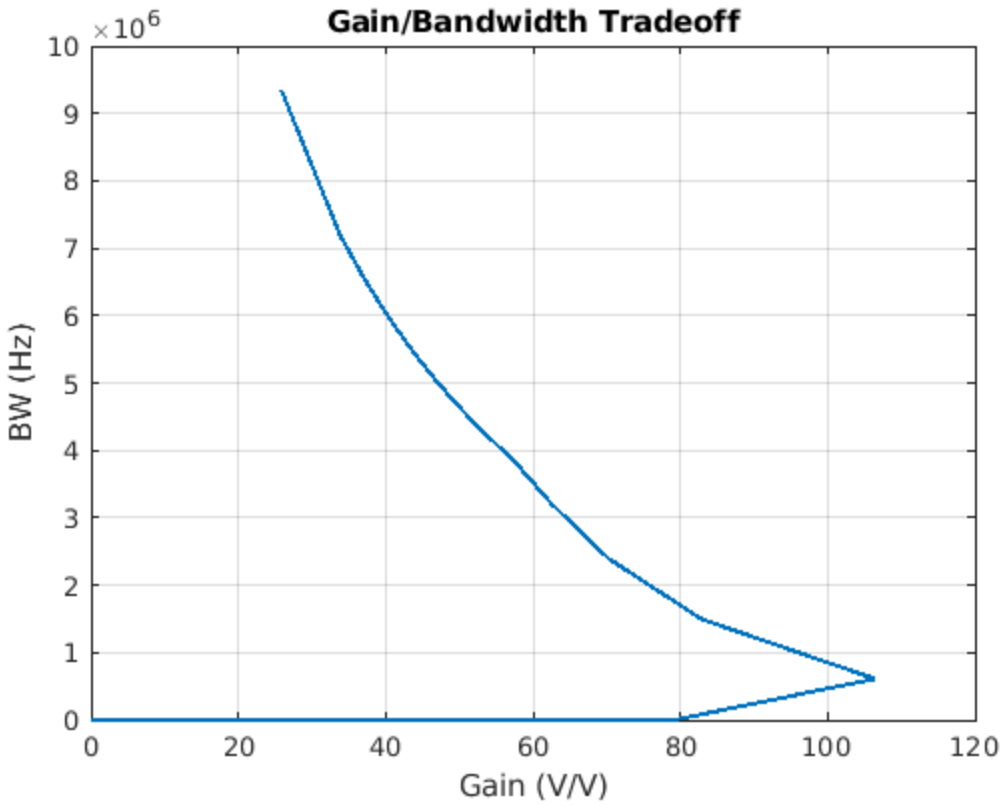


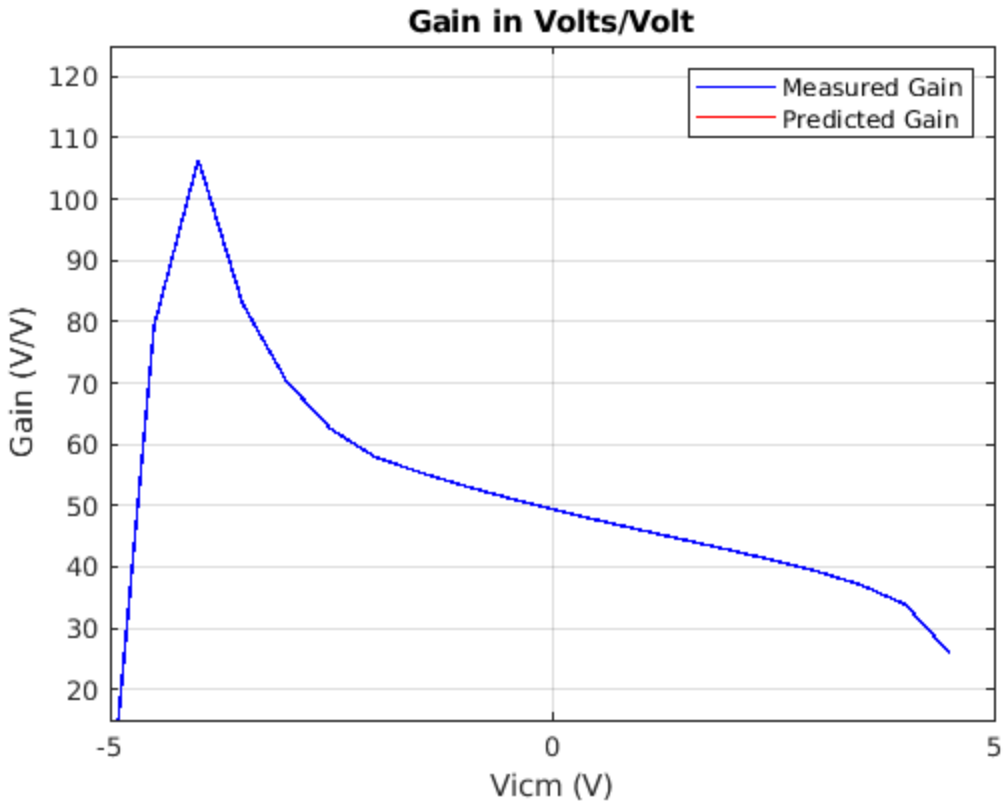
Plot Measurements:

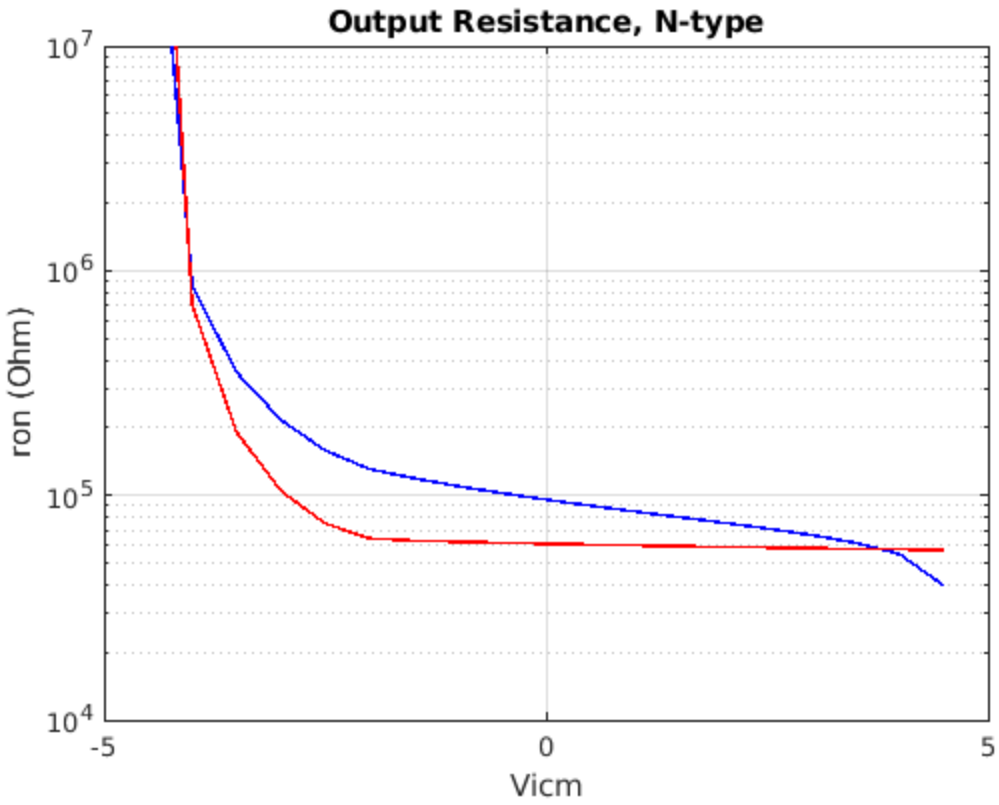

Bandwidth vs Vicm
BW (Hz)
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
-5
0
5
Vicm

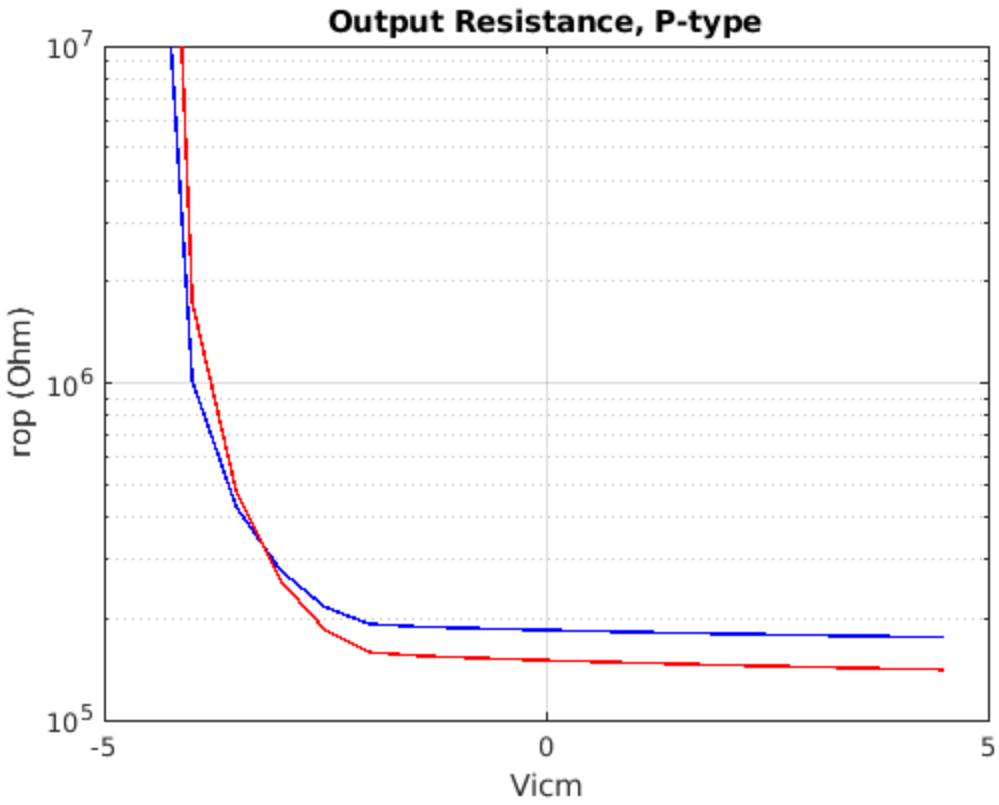

Bandwidth vs Tail Current
BW (Hz)
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^{-10}
10^{-8}
10^{-6}
10^{-4}
Iref (A)

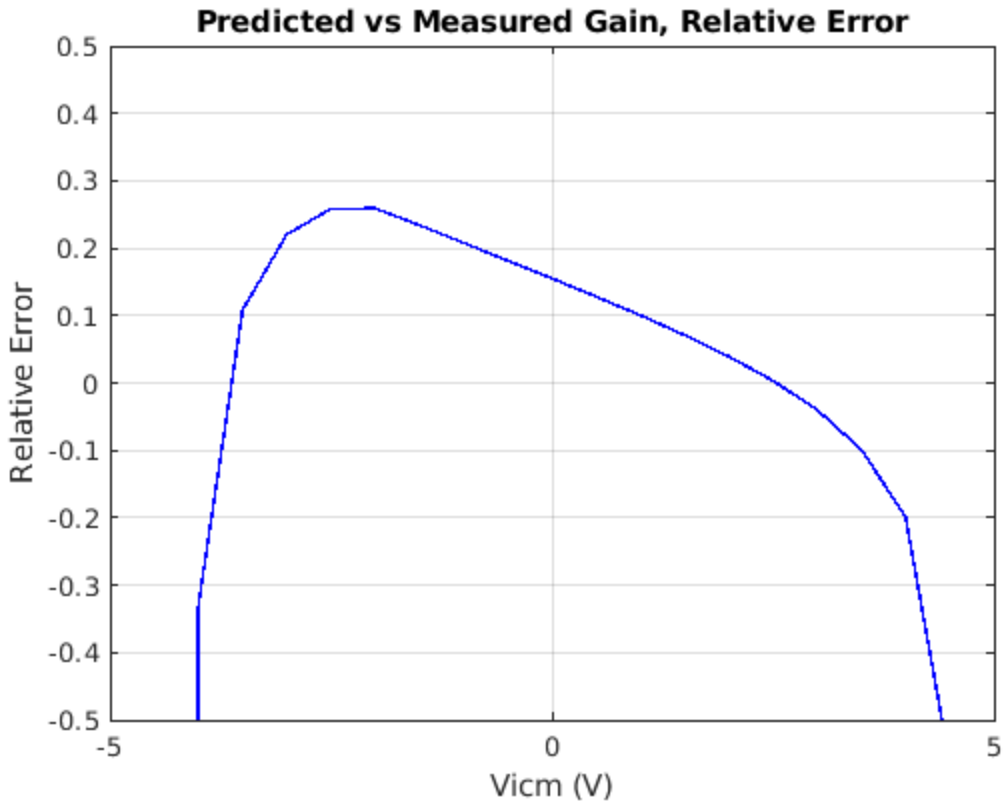

Gain in dB
Measured Gain
Predicted Gain
Gain (dB)
Vicm
50
45
40
35
30
25
20
-5
0
5

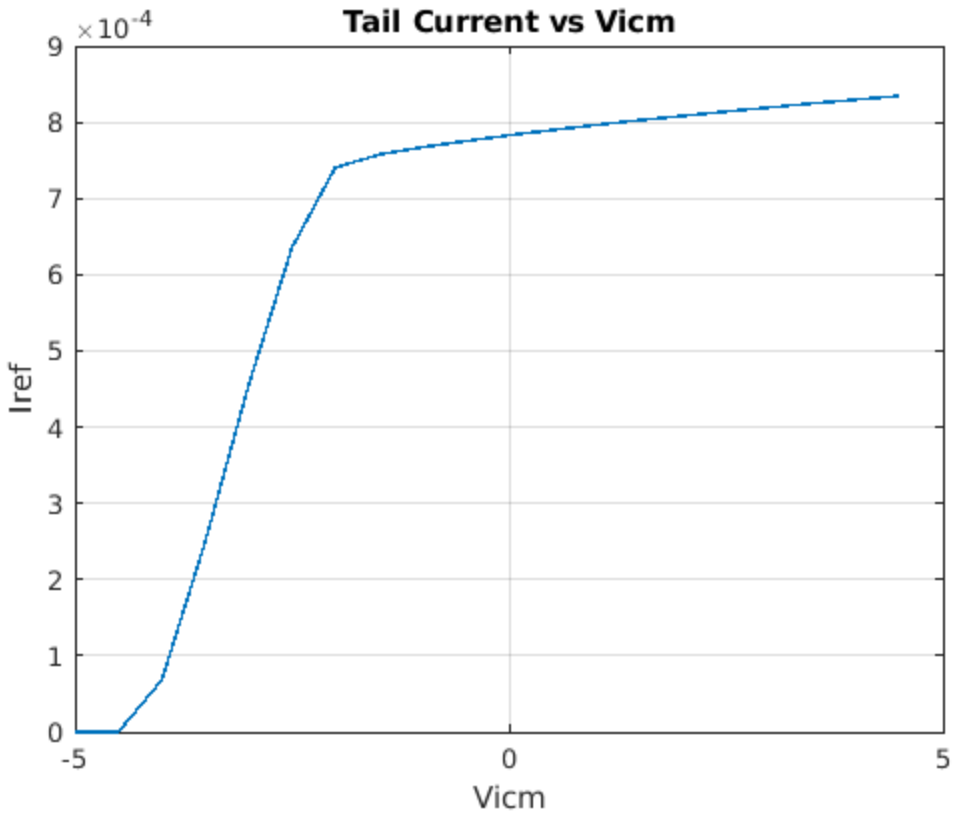

Gain/Bandwidth Tradeoff
×10^6
10
9
8
7
6
5
4
3
2
1
0
BW (Hz)
0
20
40
60
80
100
120
Gain (V/V)

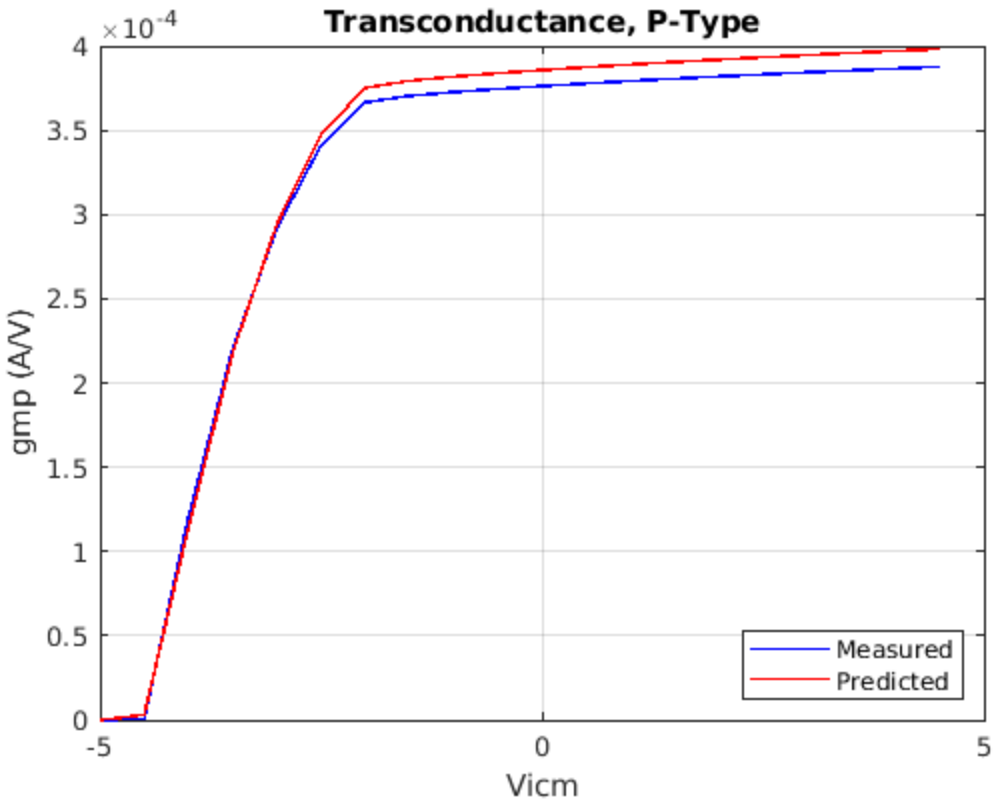

Gain in Volts/Volt
Measured Gain
Predicted Gain
120
110
100
90
80
70
60
50
40
30
20
Gain (V/V)
-5
0
5
Vicm (V)

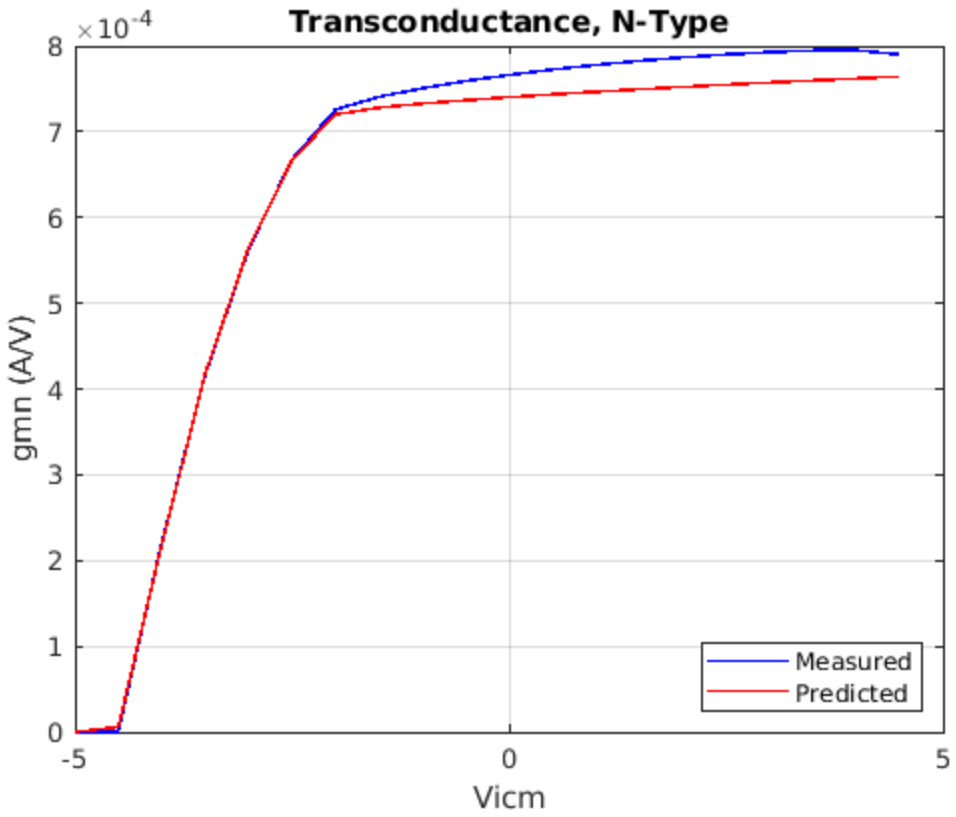

Output Resistance, N-type
10^7
10^6
10^5
10^4
ron (Ohm)
-5
0
5
Vicm


Output Resistance, P-type
10^7
10^6
10^5
rop (Ohm)
-5
0
5
Vicm


Predicted vs Measured Gain, Relative Error
Relative Error
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-5
0
5
Vicm (V)

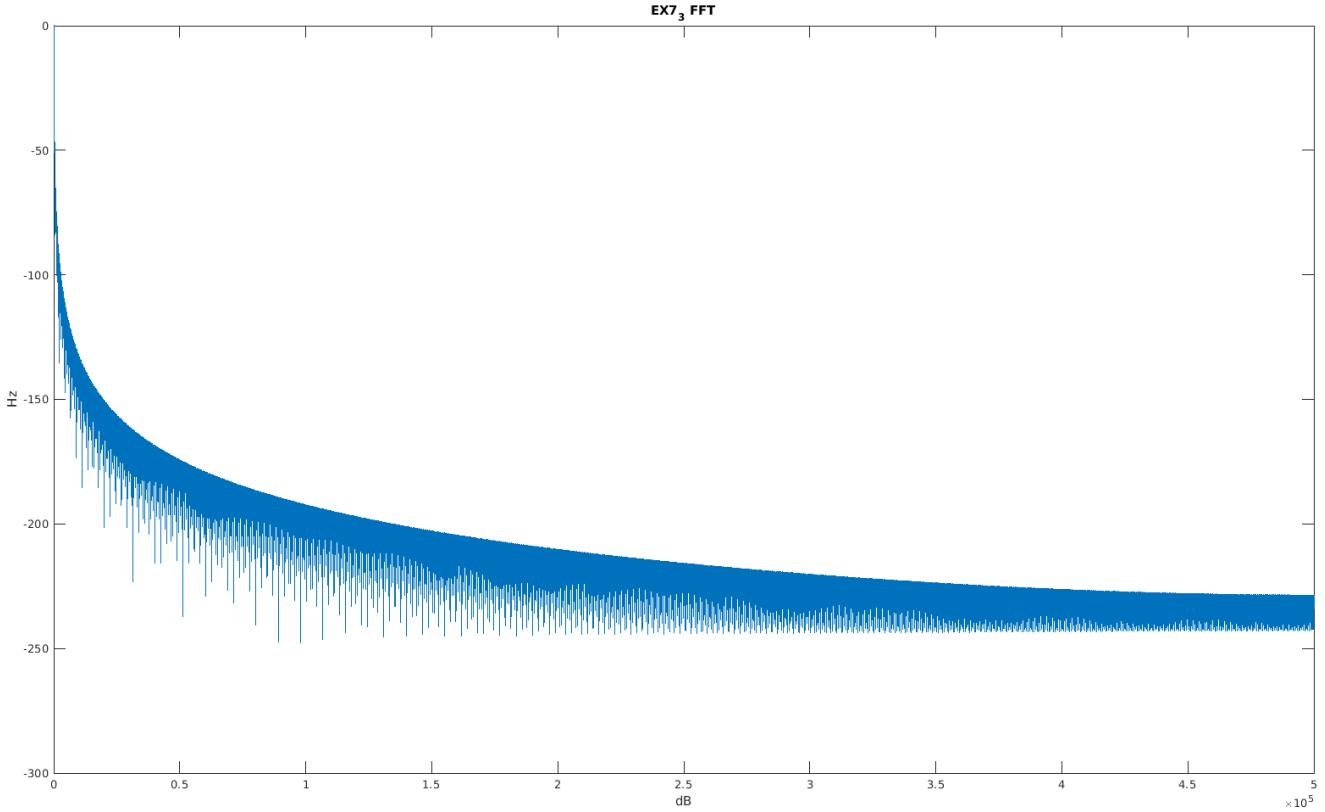

Tail Current vs Vicm
×10^-4
9
8
7
6
5
4
3
2
1
0
Iref
-5
0
5
Vicm


Transconductance, P-Type
×10^-4
4
3.5
3
2.5
2
1.5
1
0.5
0
gmp (A/V)
-5
0
5
Vicm
Measured
Predicted



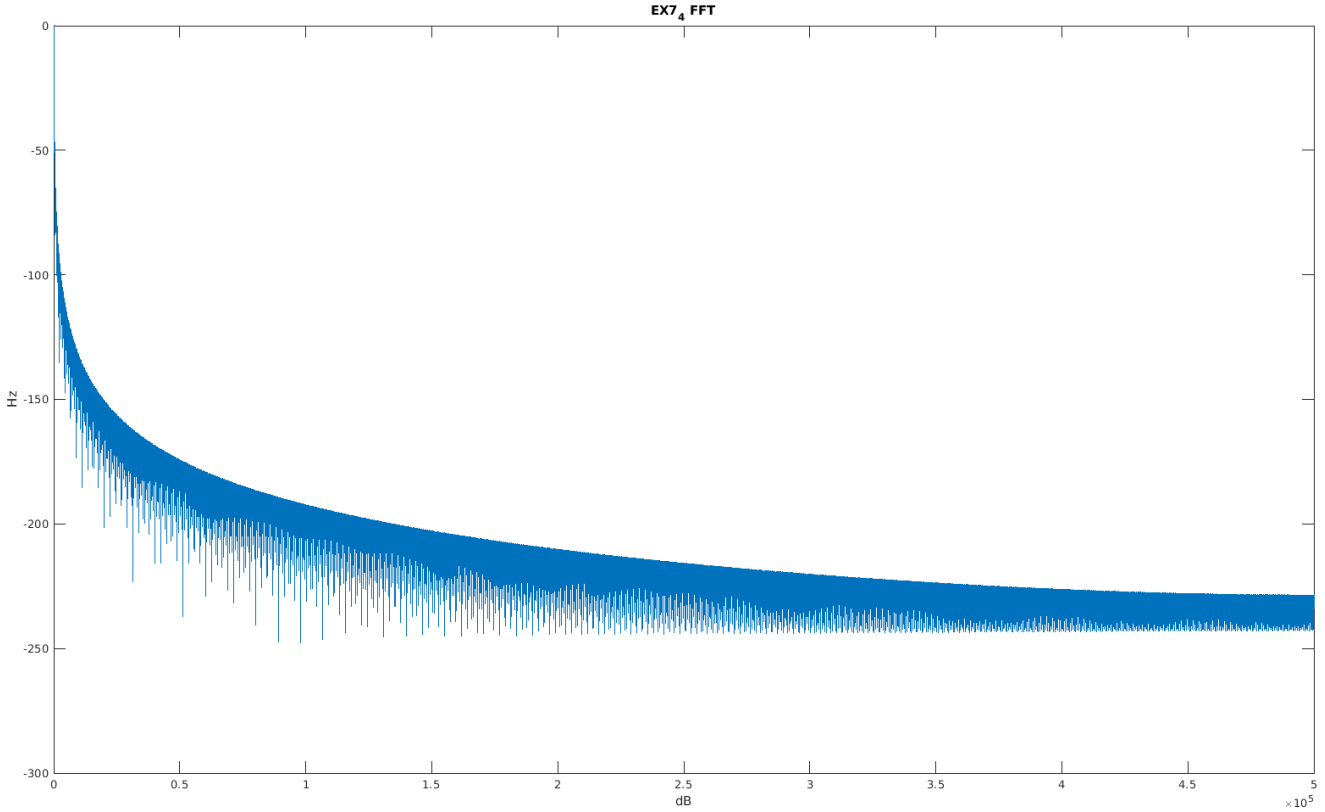
ex3:

SNR: -62.5993



ex4:

SNR: -62.5993



8

The open loop gain would be Vout/(Vin+Vicm-Vicm) = Vout/Vin

In [ ]:
```
R1 = 1e3
R2 = 10e3

closed_gain = 1 + (R2/R1)
print(closed_gain)
```

```
11.0
```

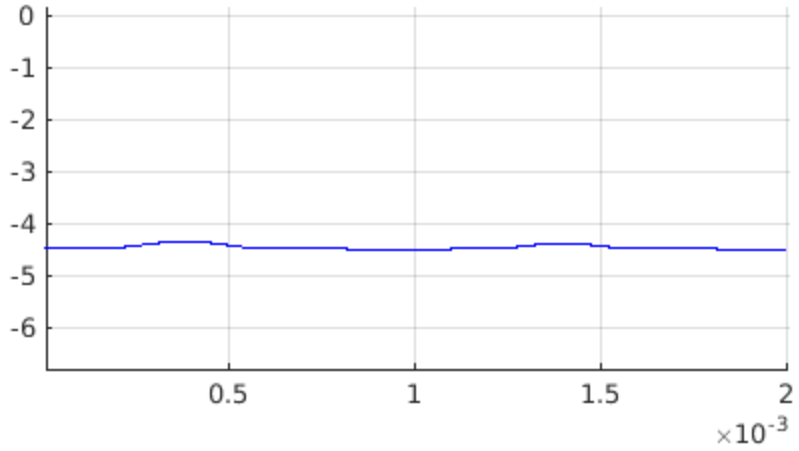
9

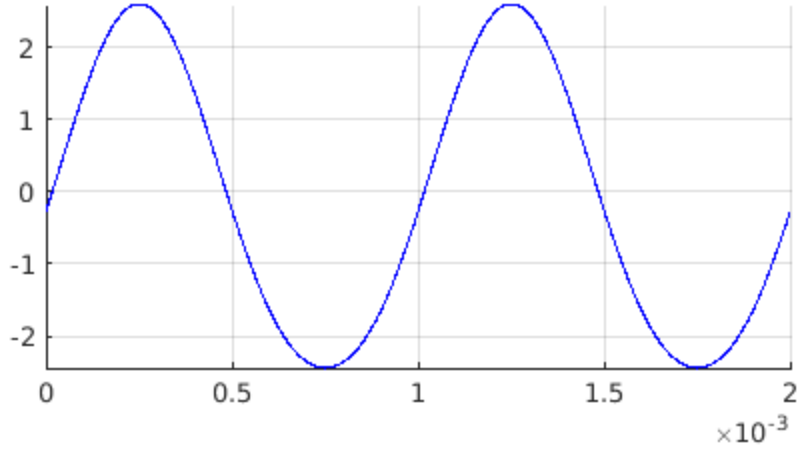
running ex2.sp with the added resistors:

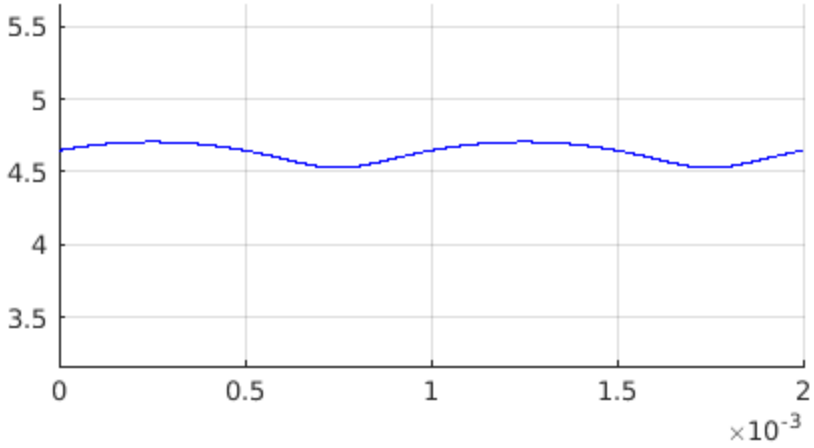
```
0       -5.00000e+00    1.291131e-12    5.000013e-01    -6.02058e+00    5.240041e+06
1.359370e-11    2.440341e-10    5.888260e+12    2.172636e+11
1       -4.50000e+00    4.562245e-08    3.599480e+01    3.112480e+01    2.352601e+03
4.802516e-07    5.563800e-07    1.735504e+08    1.161806e+08
2       -4.00000e+00    6.795952e-05    1.258725e+03    6.199861e+01    2.213339e+05
2.204869e-04    1.200721e-04    8.519460e+05    1.011310e+06
3       -3.50000e+00    2.491448e-04    4.463809e+01    3.299411e+01    6.453134e+05
4.165233e-04    2.200303e-04    3.530310e+05    4.271133e+05
4       -3.00000e+00    4.547100e-04    1.081790e+01    2.068286e+01    1.082363e+06
5.626858e-04    2.916081e-04    2.170067e+05    2.773866e+05
5       -2.50000e+00    6.353315e-04    5.716284e+00    1.514228e+01    1.466356e+06
6.676968e-04    3.411038e-04    1.583725e+05    2.163249e+05
6       -2.00000e+00    7.405122e-04    4.059474e+00    1.216939e+01    1.738711e+06
7.257644e-04    3.665050e-04    1.309852e+05    1.926588e+05
7       -1.50000e+00    7.572604e-04    3.468593e+00    1.080307e+01    1.866346e+06
7.405037e-04    3.703683e-04    1.190680e+05    1.894083e+05
8       -1.00000e+00    7.669354e-04    2.992677e+00    9.521197e+00    1.983660e+06
7.506235e-04    3.725796e-04    1.098886e+05    1.875853e+05
9       -5.00000e-01    7.752391e-04    2.576169e+00    8.219487e+00    2.104502e+06
7.590347e-04    3.744656e-04    1.022302e+05    1.860515e+05
10      0.000000e+00    7.827466e-04    2.206006e+00    6.872132e+00    2.231213e+06
7.662185e-04    3.761616e-04    9.565915e+04    1.846886e+05
11      5.000000e-01    7.896944e-04    1.873938e+00    5.455102e+00    2.372117e+06
7.724354e-04    3.777235e-04    8.988962e+04    1.834469e+05
12      1.000000e+00    7.962122e-04    1.574001e+00    3.940101e+00    2.542911e+06
7.778460e-04    3.791819e-04    8.471235e+04    1.822989e+05
13      1.500000e+00    8.023825e-04    1.301645e+00    2.289854e+00    2.772334e+06
7.825525e-04    3.805568e-04    7.995818e+04    1.812266e+05
14      2.000000e+00    8.082623e-04    1.053305e+00    4.510856e-01    3.126418e+06
7.866128e-04    3.818618e-04    7.547212e+04    1.802178e+05
15      2.500000e+00    8.138936e-04    8.261552e-01    -1.65877e+00    3.927282e+06
7.900404e-04    3.831069e-04    7.108454e+04    1.792632e+05
16      3.000000e+00    8.193079e-04    6.179622e-01    -4.18076e+00    9.629904e+06
```

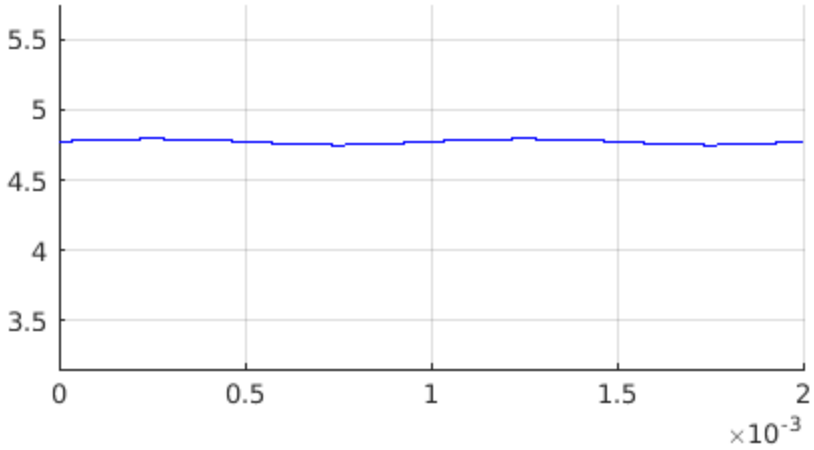
```
7.927870e-04    3.842998e-04    6.656053e+04    1.783559e+05
17      3.500000e+00    8.245299e-04    4.270001e-01    -7.39144e+00    0.000000e+00
7.946772e-04    3.854463e-04    6.146744e+04    1.774904e+05
18      4.000000e+00    8.295776e-04    2.519136e-01    -1.19750e+01    0.000000e+00
7.951190e-04    3.865509e-04    5.465628e+04    1.766626e+05
19      4.500000e+00    8.344579e-04    8.870148e-02    -2.10414e+01    0.000000e+00
7.898892e-04    3.876154e-04    3.962895e+04    1.758704e+05
```

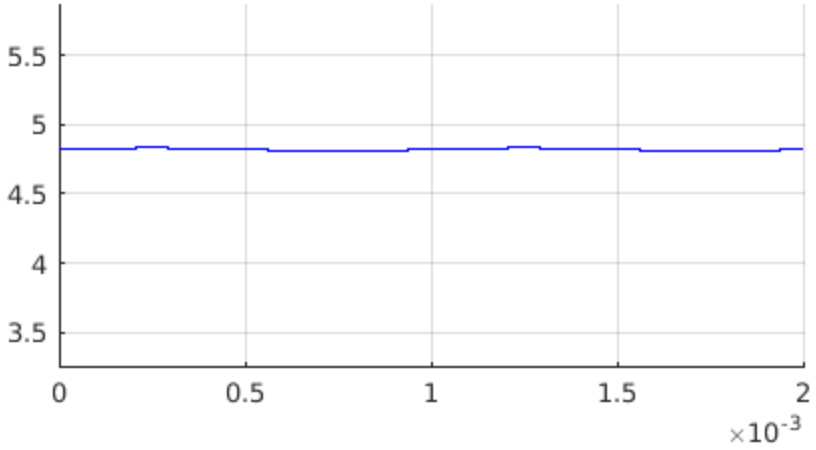
Plot Transient in order of their figure number:

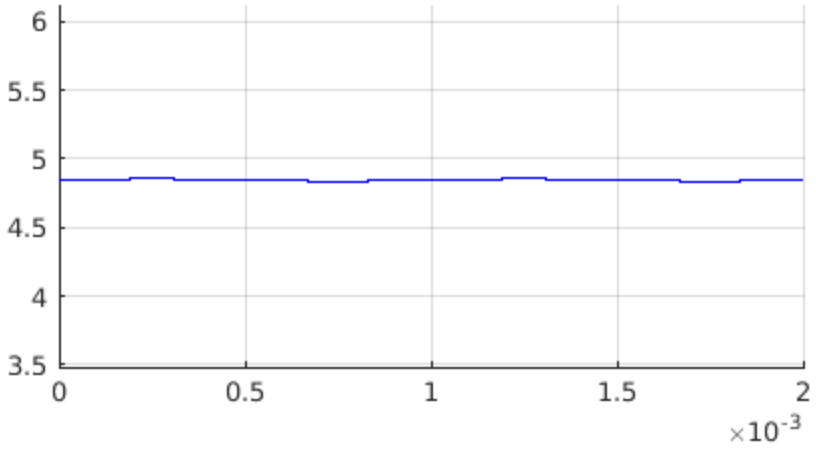


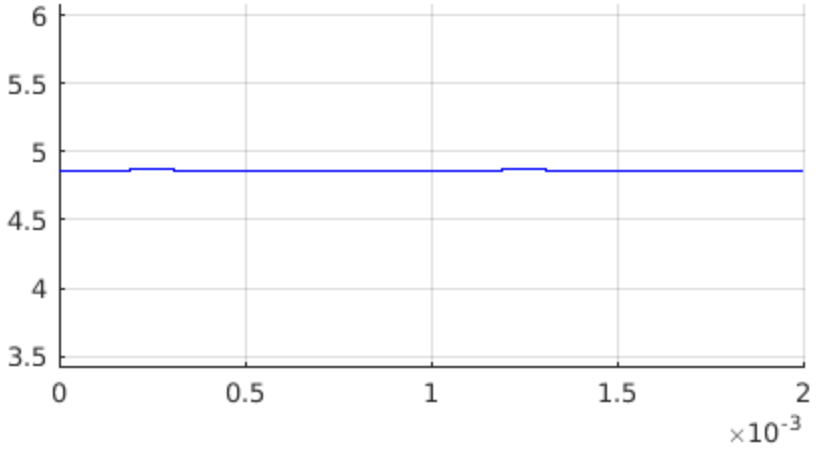


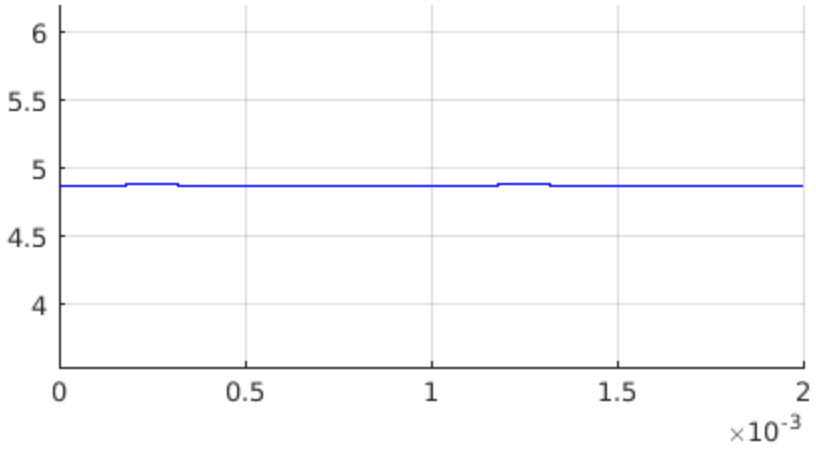

5.5
5
4.5
4
3.5
0
0.5
1
1.5
2
×10^-3

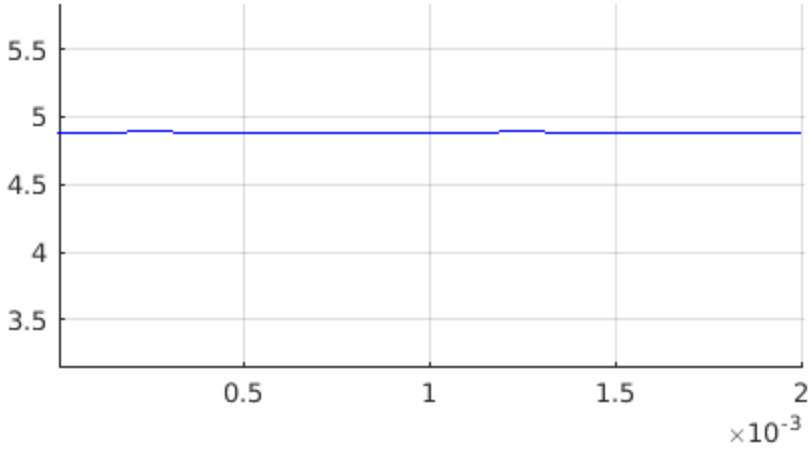

5.5
5
4.5
4
3.5
0
0.5
1
1.5
2
×10^-3

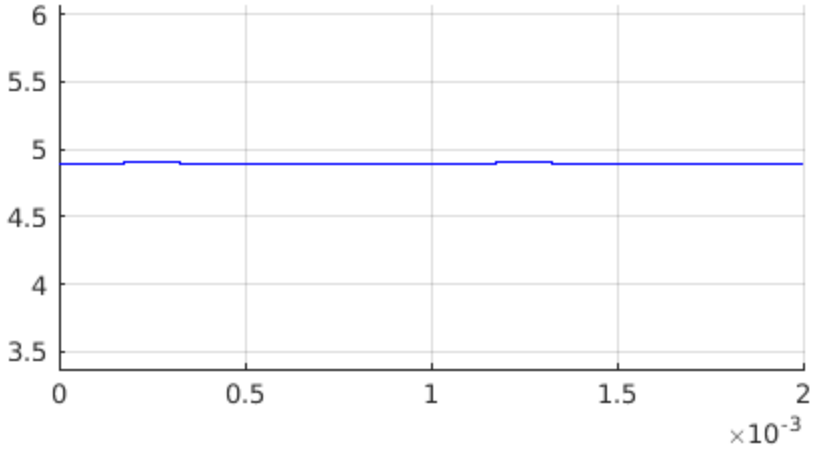

5.5
5
4.5
4
3.5
0
0.5
1
1.5
2
×10^-3

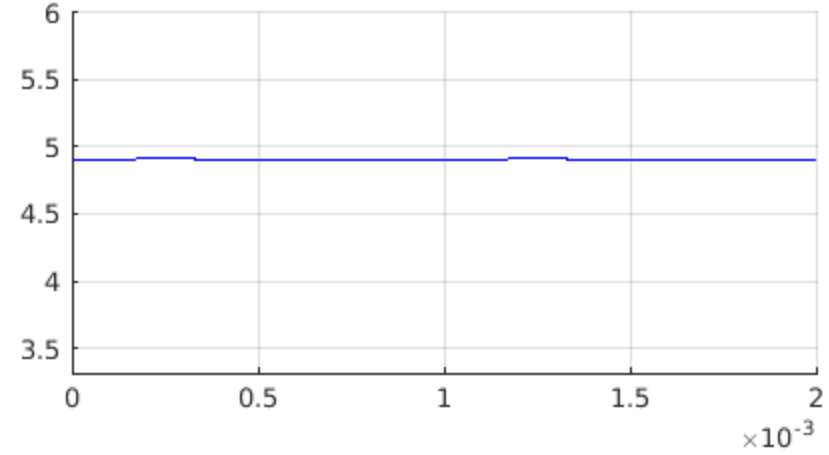

6
5.5
5
4.5
4
3.5
0
0.5
1
1.5
2
×10^-3

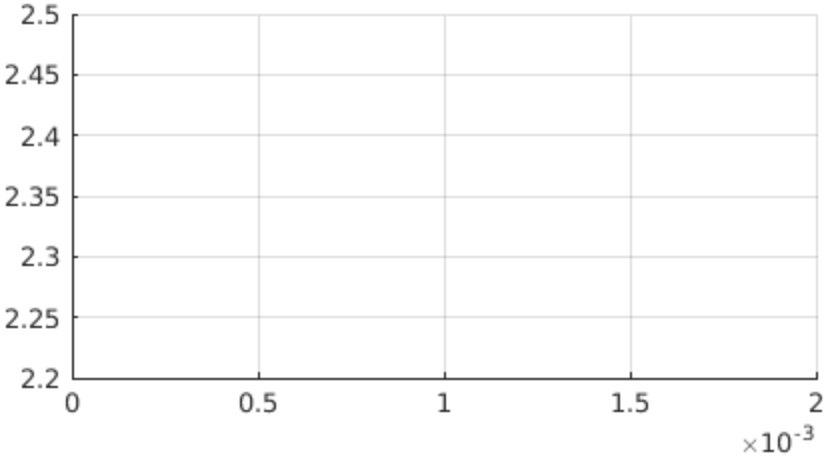

6
5.5
5
4.5
4
3.5
0
0.5
1
1.5
2
×10-3

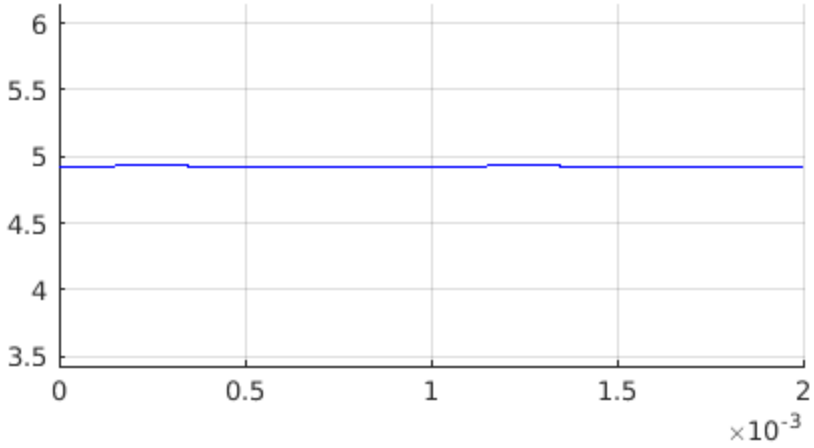

6
5.5
5
4.5
4
0
0.5
1
1.5
2
×10-3

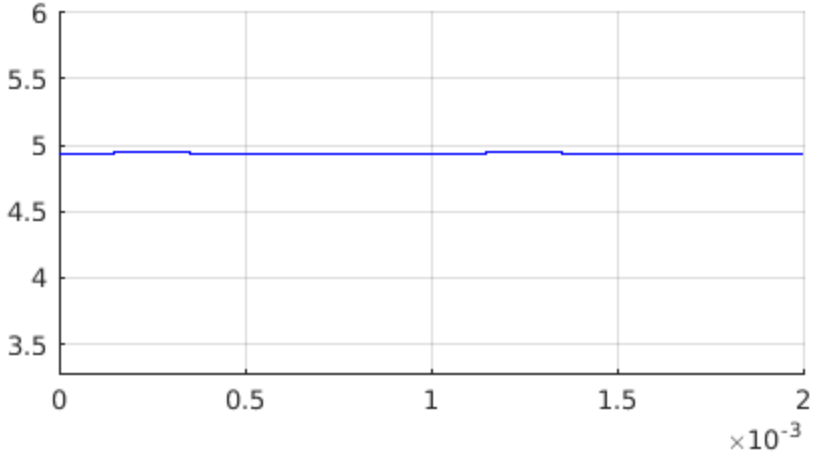

5.5
5
4.5
4
3.5
0.5
1
1.5
2
×10^-3

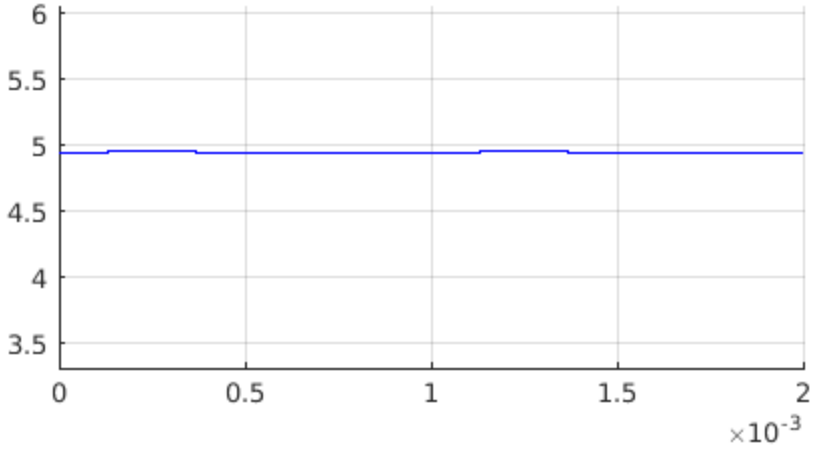

6
5.5
5
4.5
4
3.5
0
0.5
1
1.5
2
×10^-3

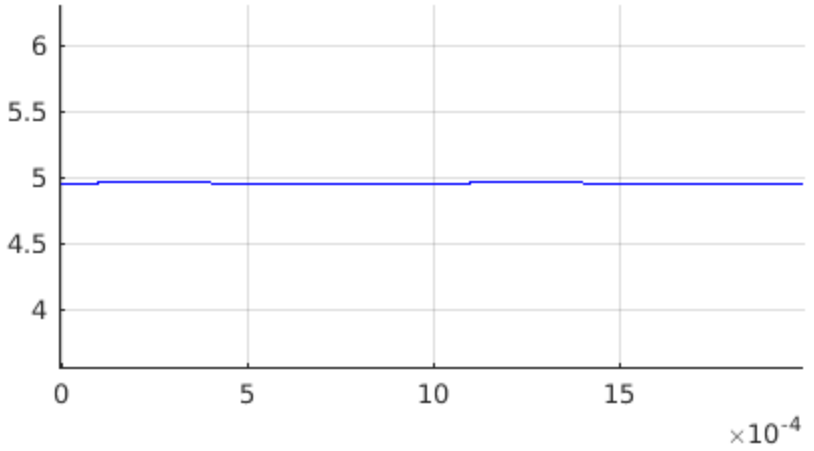

6
5.5
5
4.5
4
3.5
0
0.5
1
1.5
2
×10-3

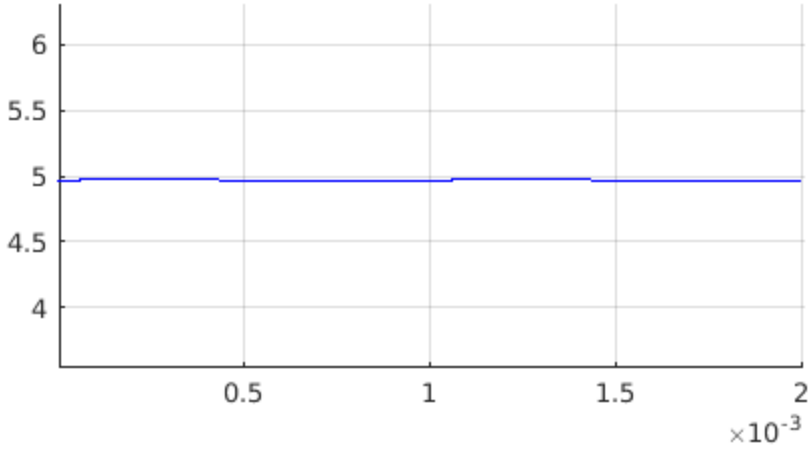

2.5
2.45
2.4
2.35
2.3
2.25
2.2
0
0.5
1
1.5
2
×10-3

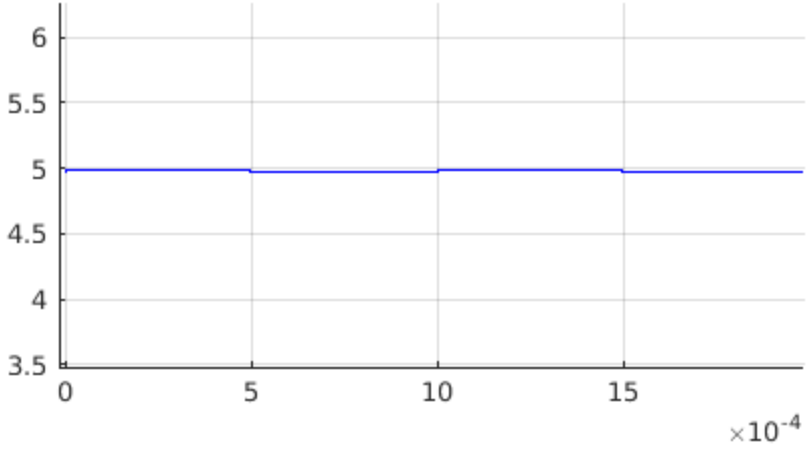

6
5.5
5
4.5
4
3.5
0
0.5
1
1.5
2
×10-3

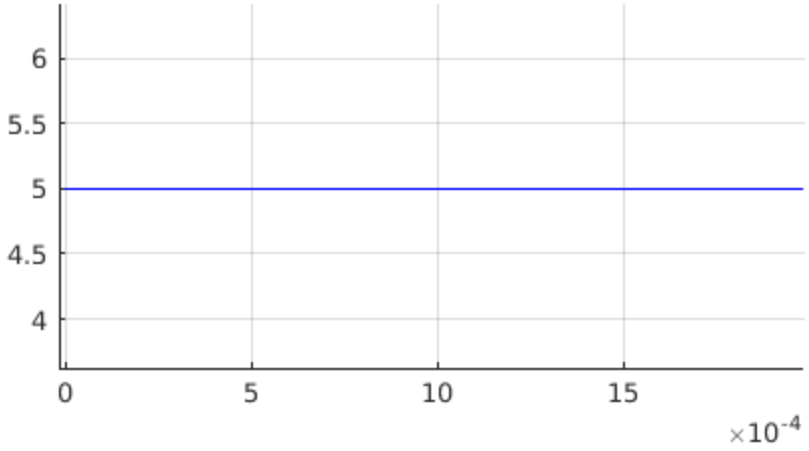

6
5.5
5
4.5
4
3.5
0
0.5
1
1.5
2
×10-3

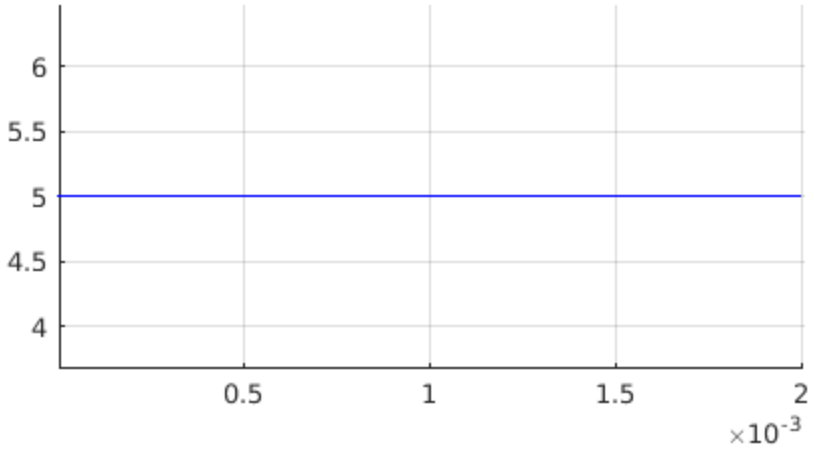

6
5.5
5
4.5
4
3.5
0
0.5
1
1.5
2
×10-3


6
5.5
5
4.5
4
0
5
10
15
×10-4

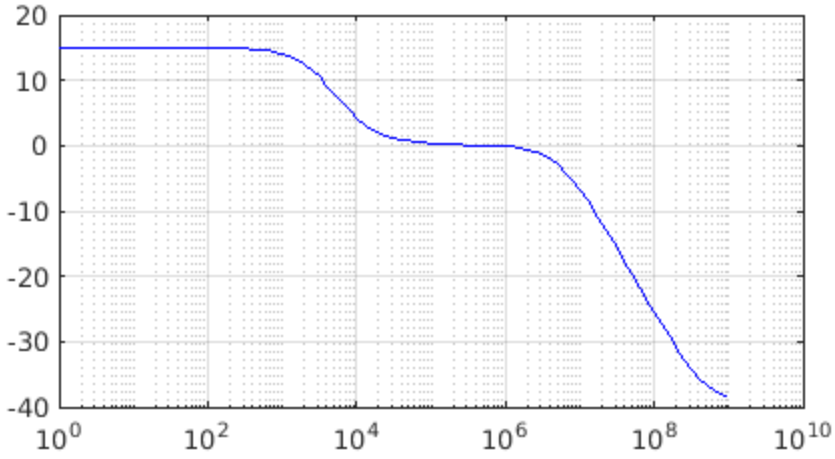

6
5.5
5
4.5
4
0.5
1
1.5
2
×10^-3

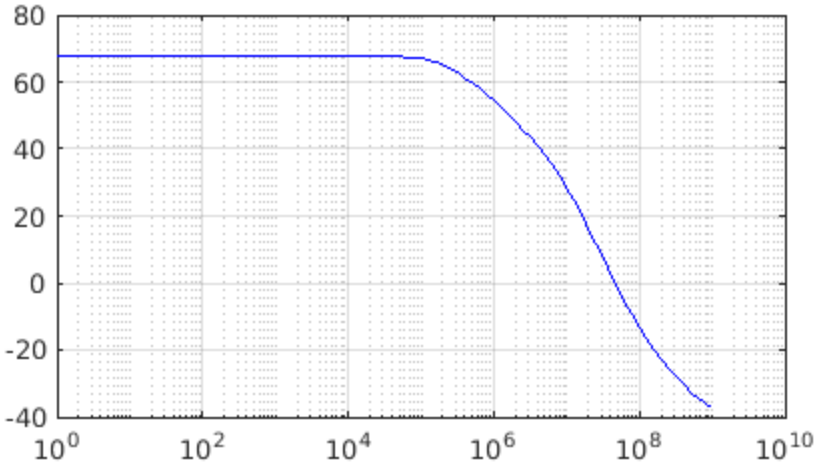

6
5.5
5
4.5
4
3.5
0
5
10
15
×10^-4

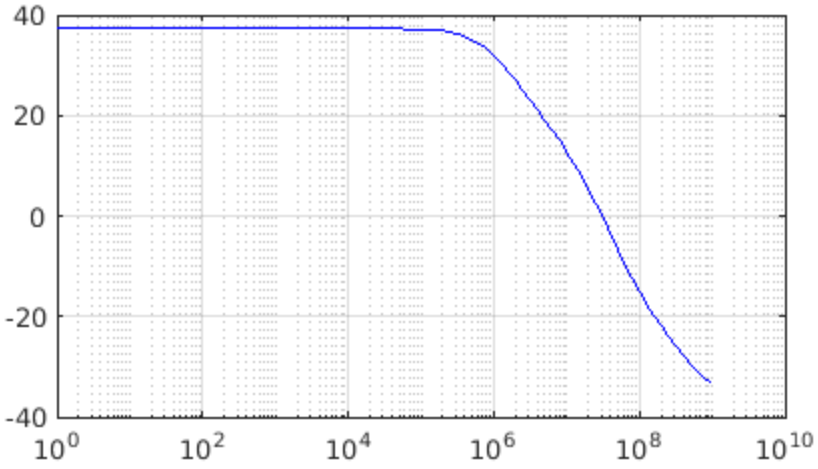


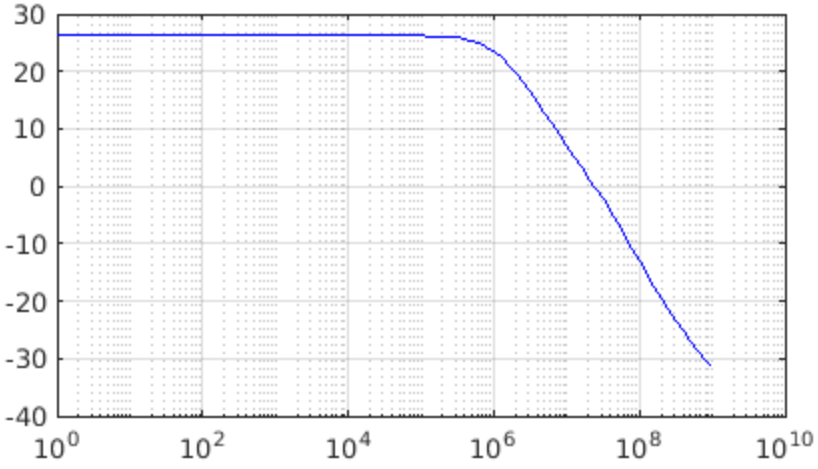


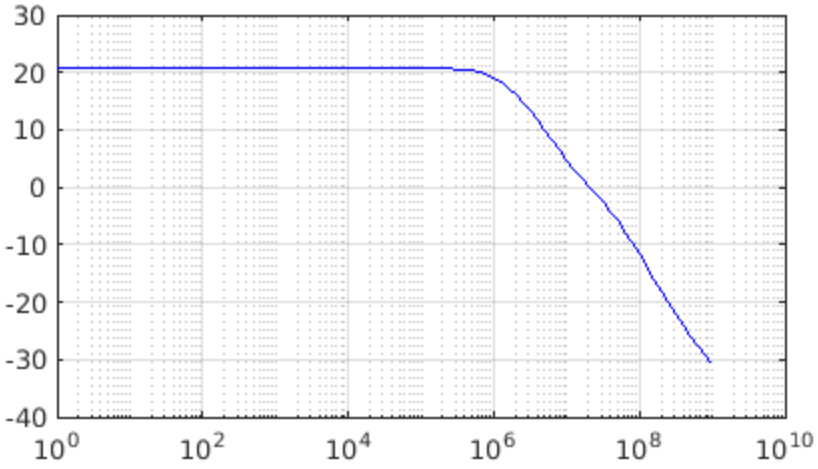
Plot AC in order of their figure:

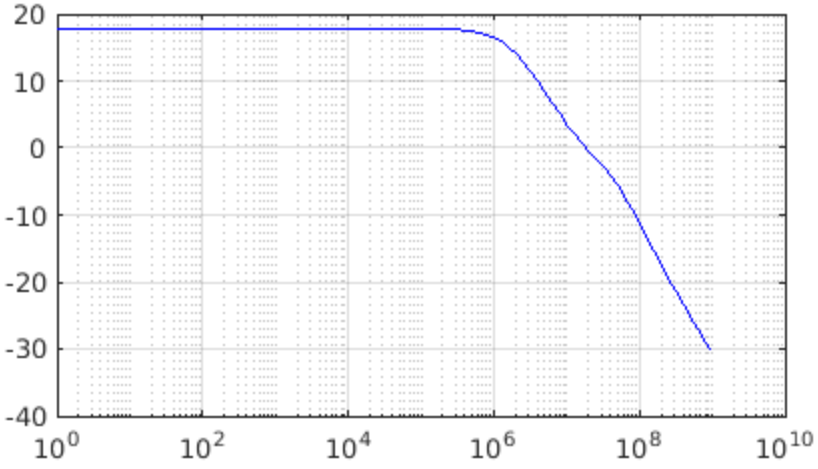

20
10
0
-10
-20
-30
-40
10^0
10^2
10^4
10^6
10^8
10^{10}

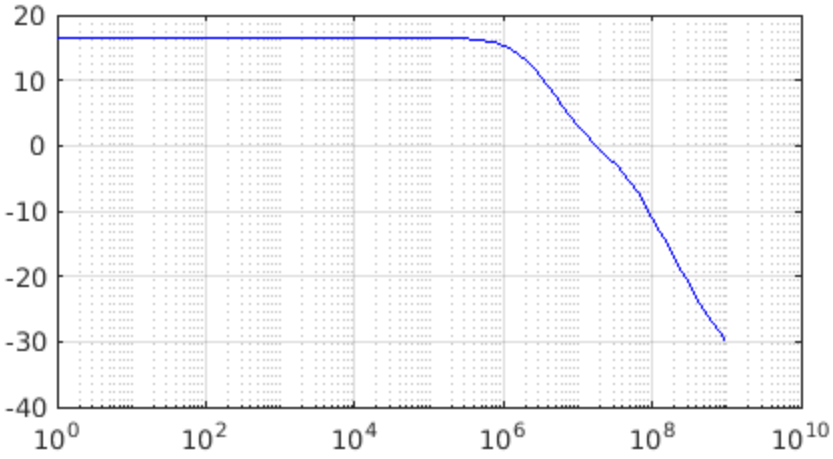

80
60
40
20
0
-20
-40
10^0
10^2
10^4
10^6
10^8
10^{10}

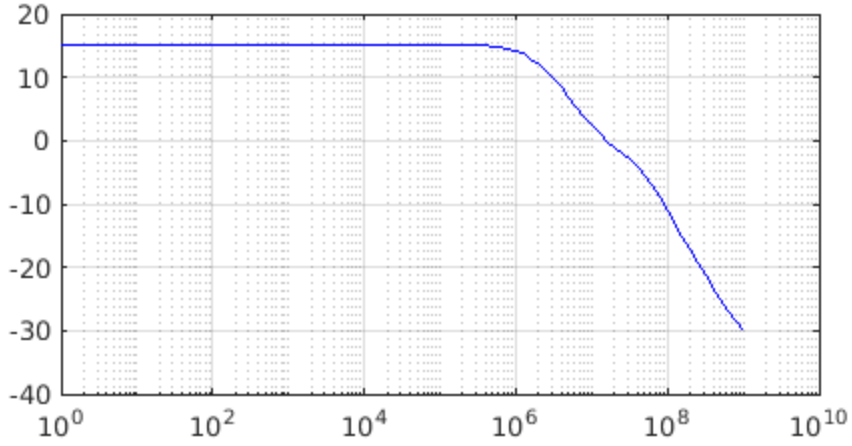

40
20
0
-20
-40
10^0
10^2
10^4
10^6
10^8
10^{10}

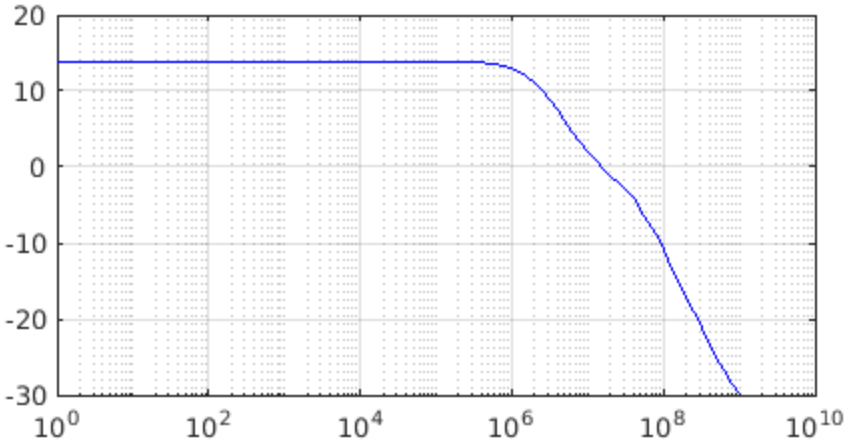

30
20
10
0
-10
-20
-30
-40
10^0
10^2
10^4
10^6
10^8
10^{10}

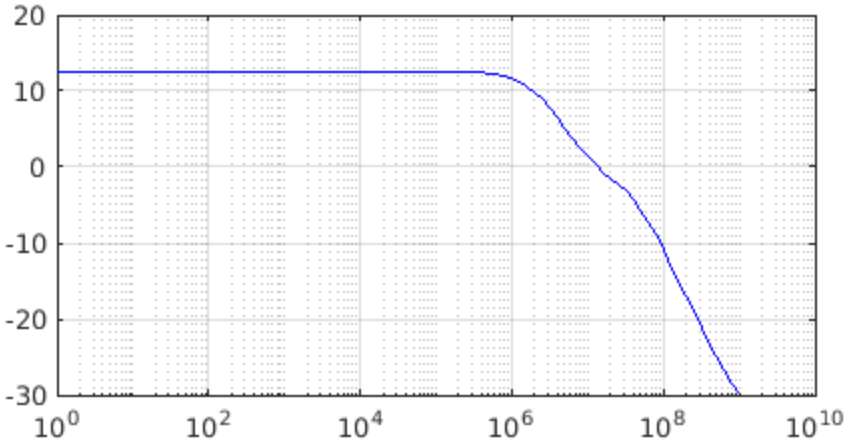

30
20
10
0
-10
-20
-30
-40
10^0
10^2
10^4
10^6
10^8
10^{10}

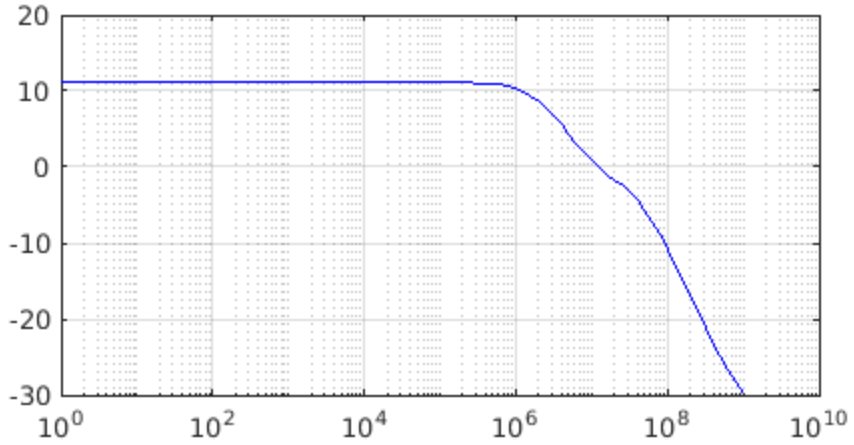

20
10
0
-10
-20
-30
-40
10^0
10^2
10^4
10^6
10^8
10^{10}

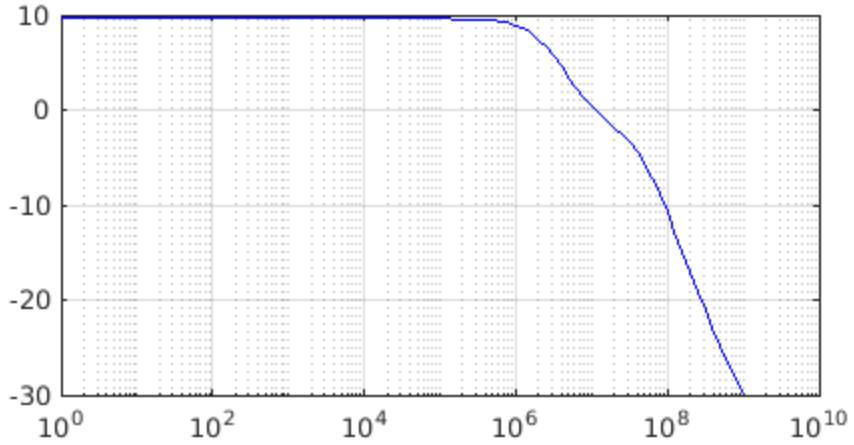

20
10
0
-10
-20
-30
-40
10^0
10^2
10^4
10^6
10^8
10^{10}

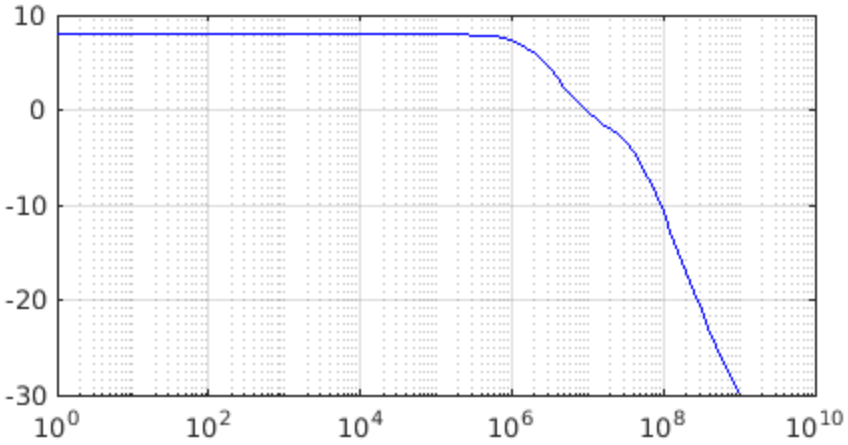

20
10
0
-10
-20
-30
-40
10^0
10^2
10^4
10^6
10^8
10^{10}

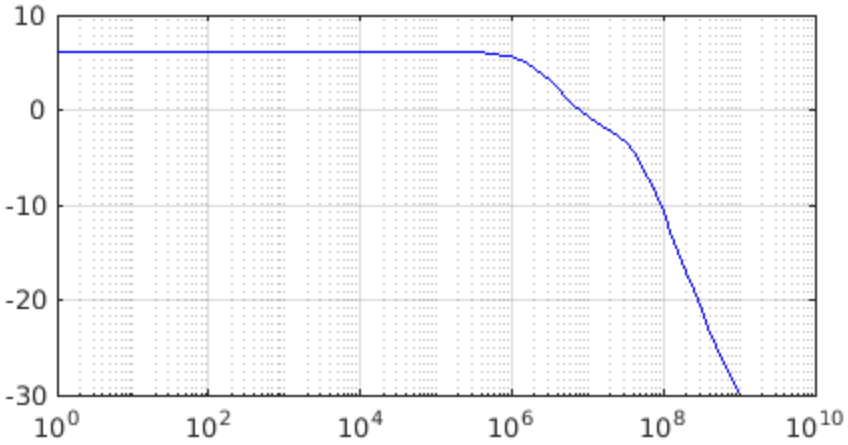

20
10
0
-10
-20
-30
10^0
10^2
10^4
10^6
10^8
10^{10}

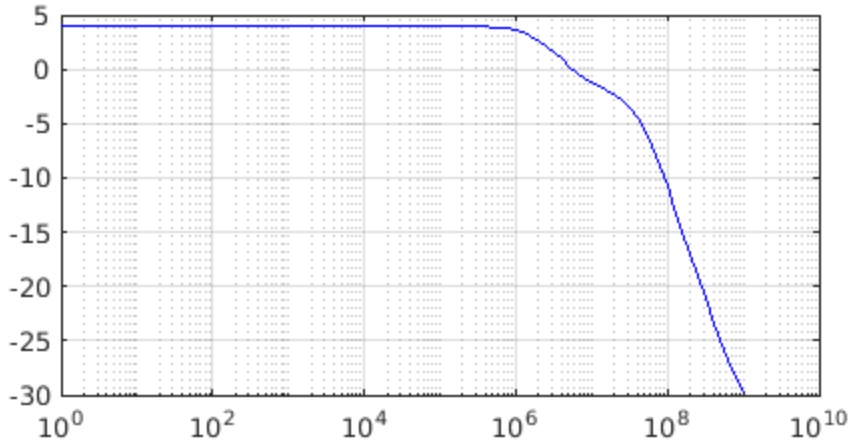

20
10
0
-10
-20
-30
10^0
10^2
10^4
10^6
10^8
10^{10}

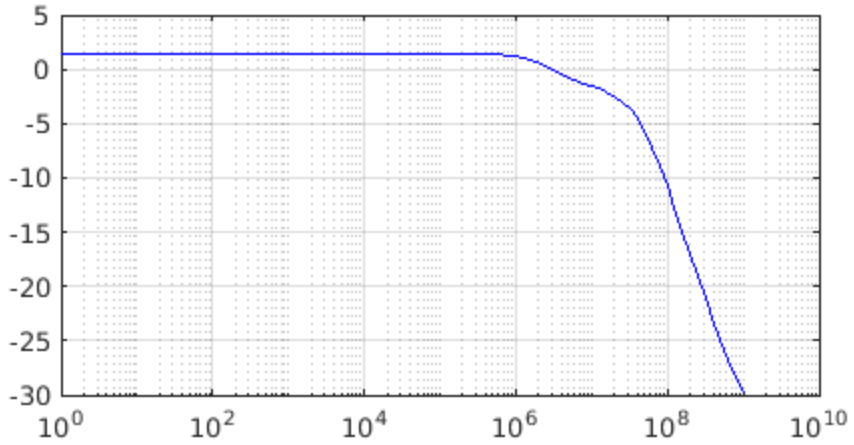

20
10
0
-10
-20
-30
10^0
10^2
10^4
10^6
10^8
10^{10}

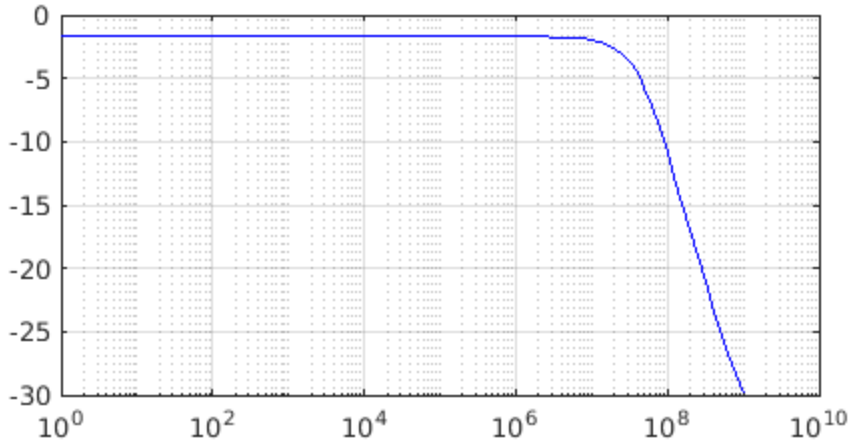

10
0
-10
-20
-30
10^0
10^2
10^4
10^6
10^8
10^{10}

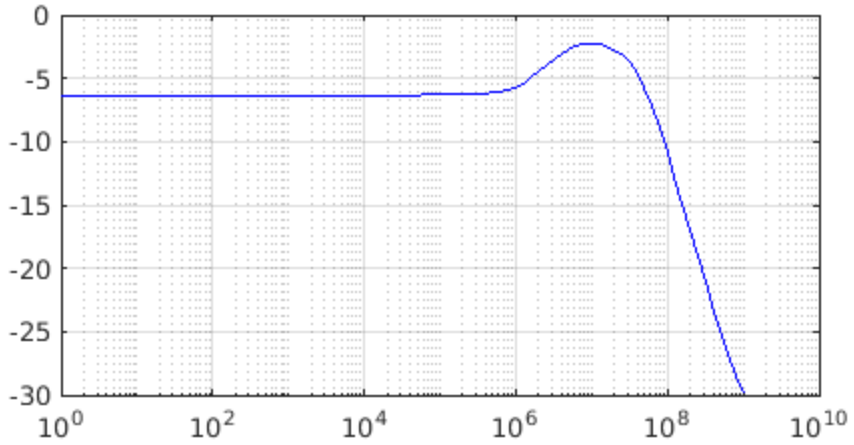

10
0
-10
-20
-30
10^0
10^2
10^4
10^6
10^8
10^{10}

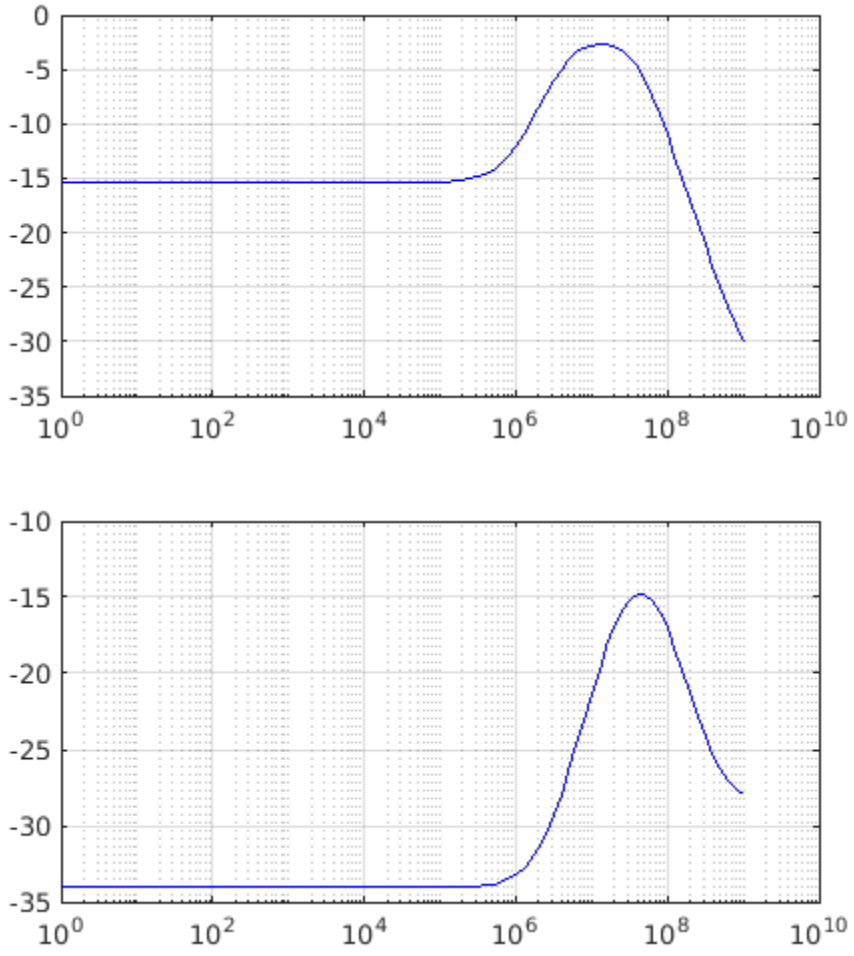

10
0
-10
-20
-30
10^0
10^2
10^4
10^6
10^8
10^{10}


5
0
-5
-10
-15
-20
-25
-30
10^0
10^2
10^4
10^6
10^8
10^{10}

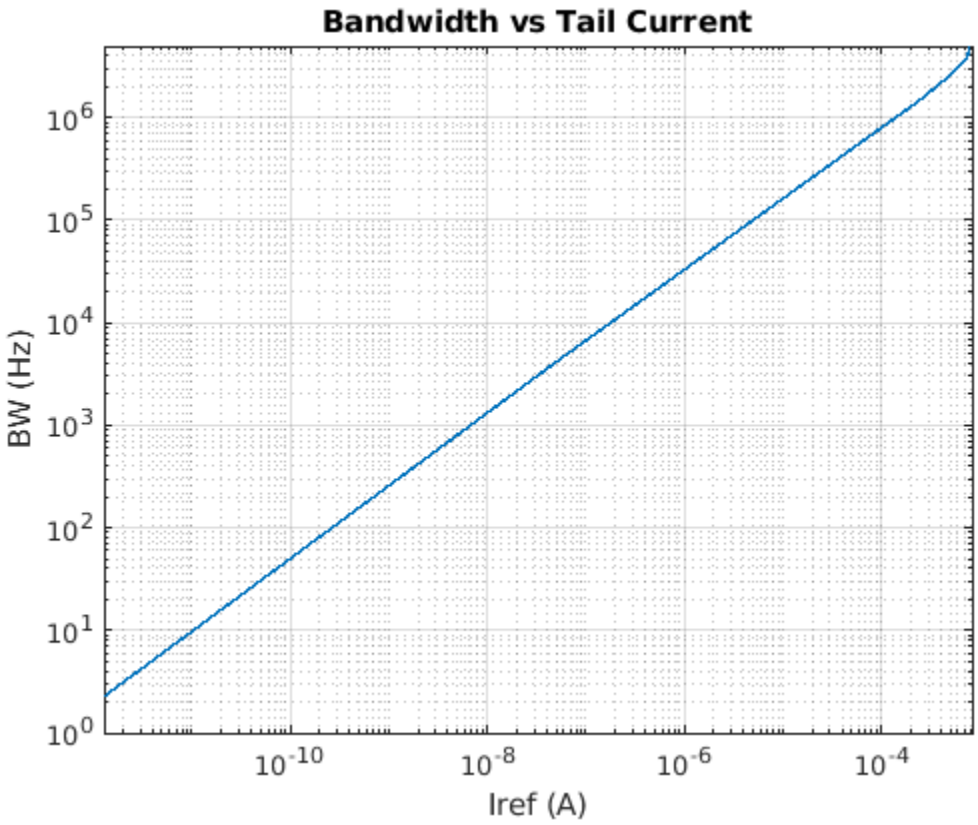

5
0
-5
-10
-15
-20
-25
-30
10^0
10^2
10^4
10^6
10^8
10^{10}

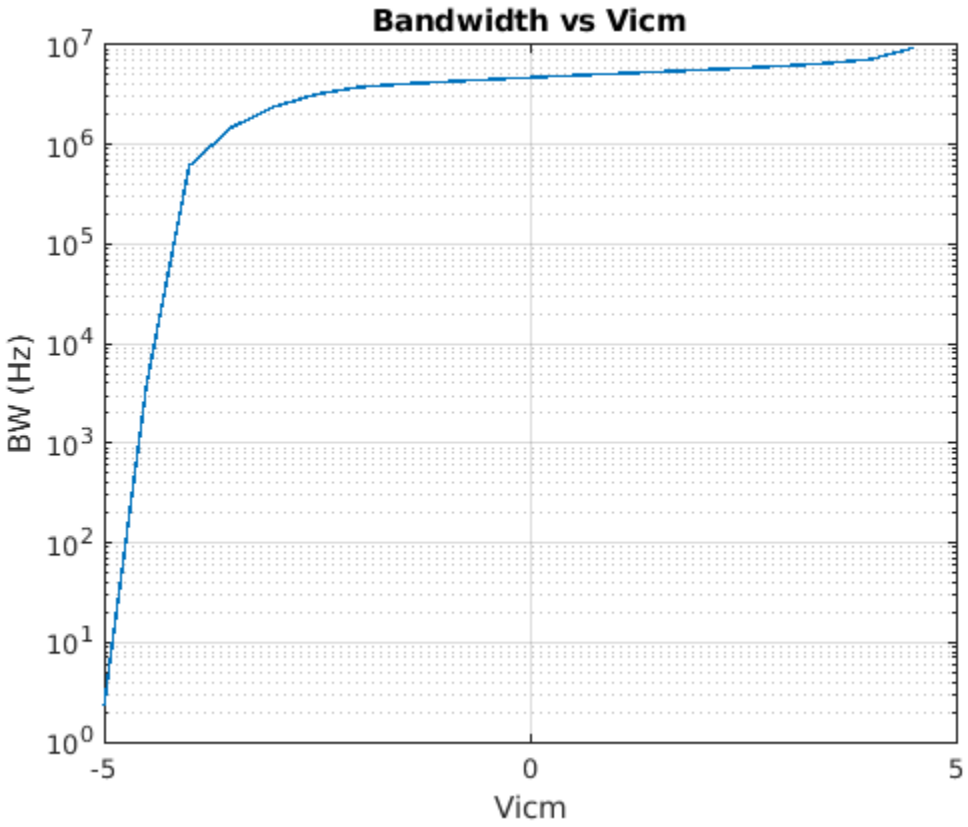

0
-5
-10
-15
-20
-25
-30
10^0
10^2
10^4
10^6
10^8
10^{10}

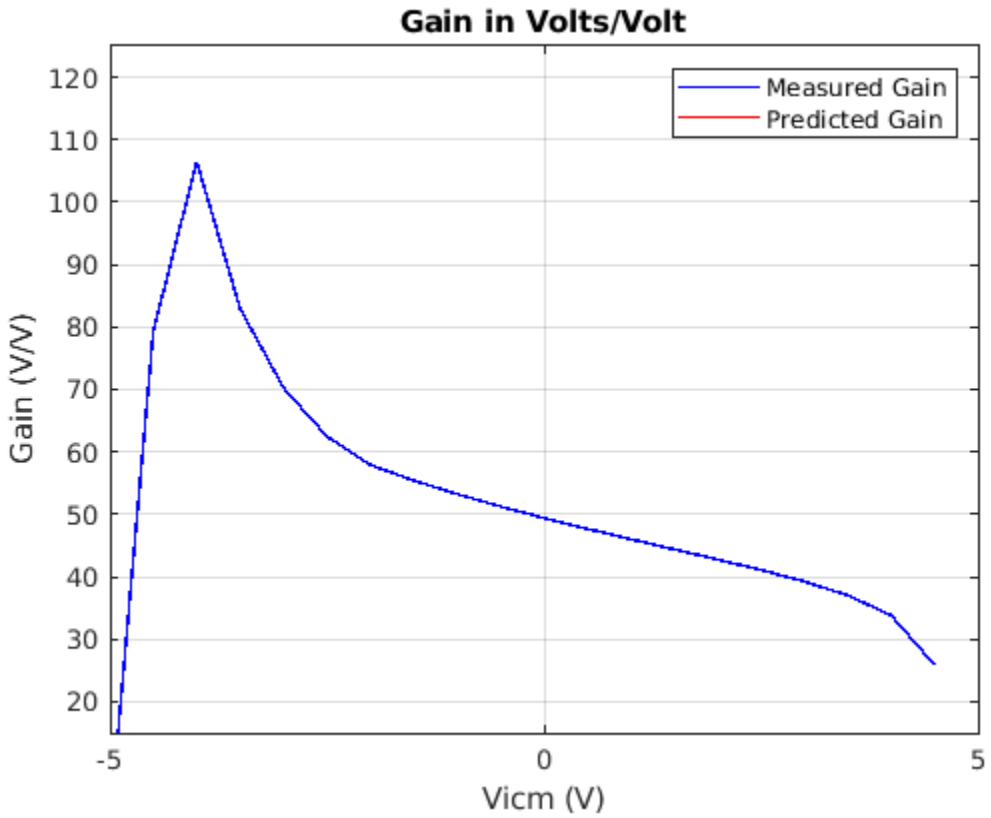

0
-5
-10
-15
-20
-25
-30
10^0
10^2
10^4
10^6
10^8
10^{10}

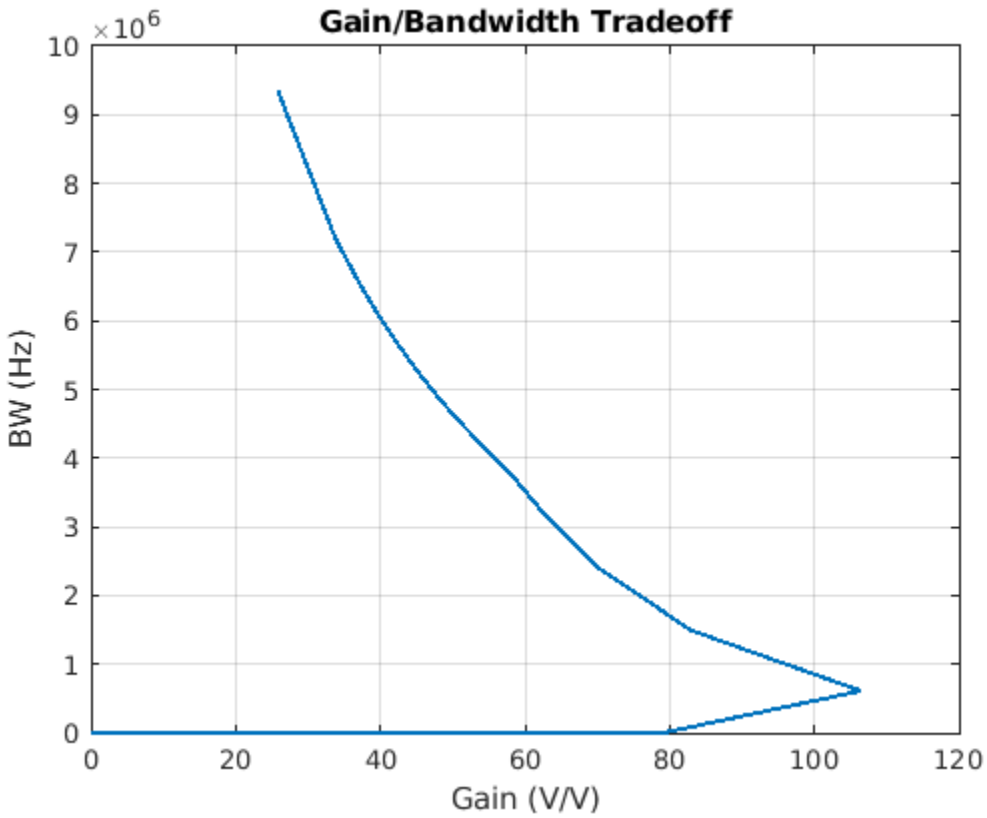


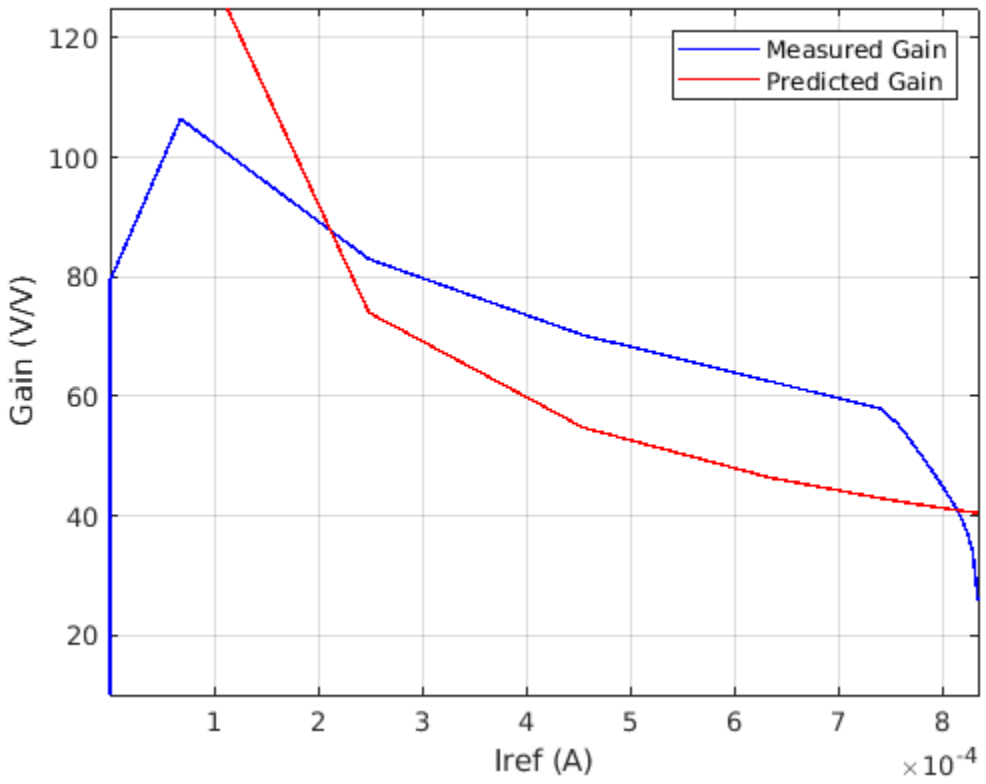
Plot Measurements:

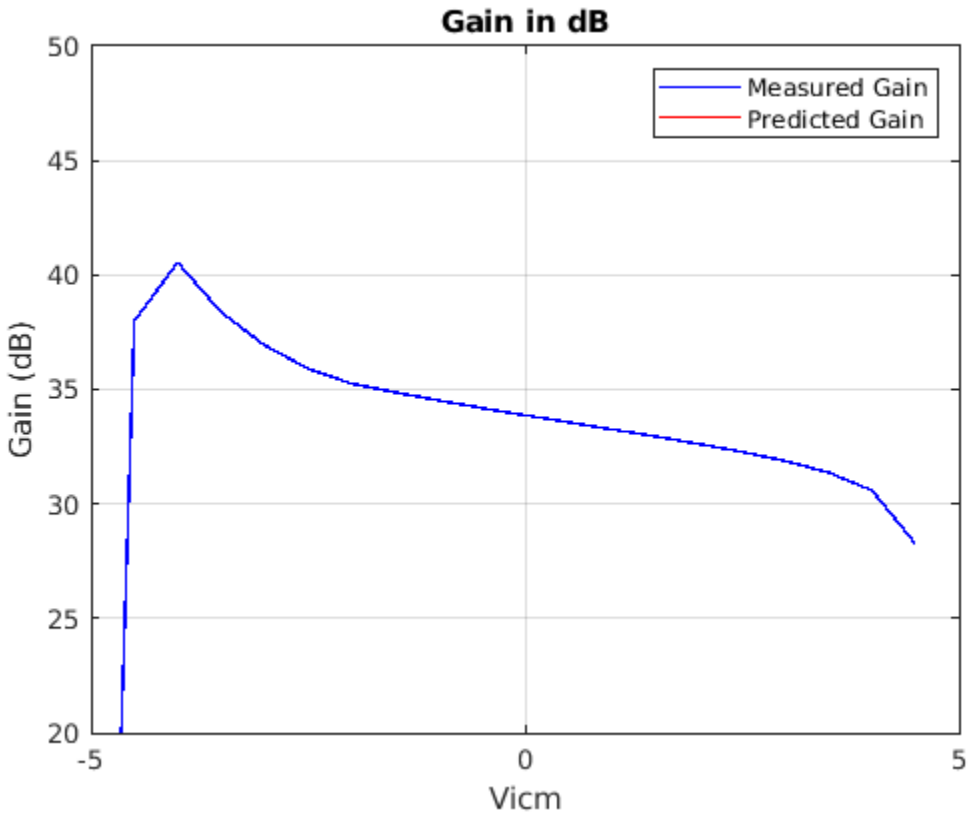

Bandwidth vs Tail Current
BW (Hz)
Iref (A)
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^{-10}
10^{-8}
10^{-6}
10^{-4}

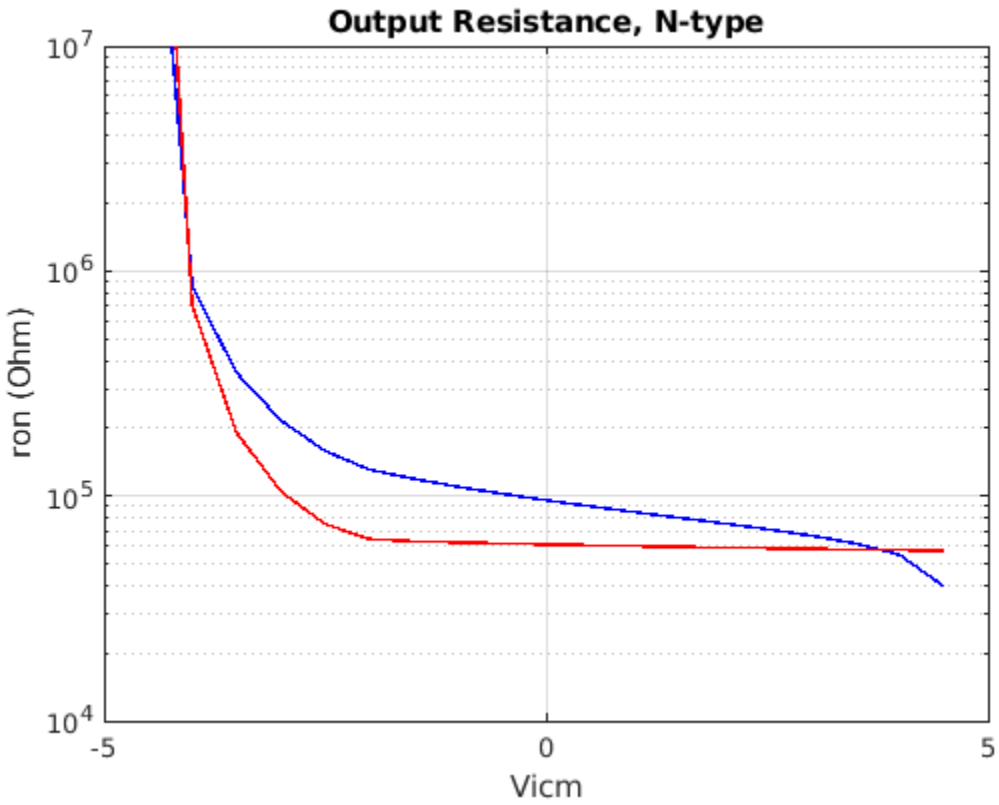

Bandwidth vs Vicm
BW (Hz)
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
-5
0
5
Vicm

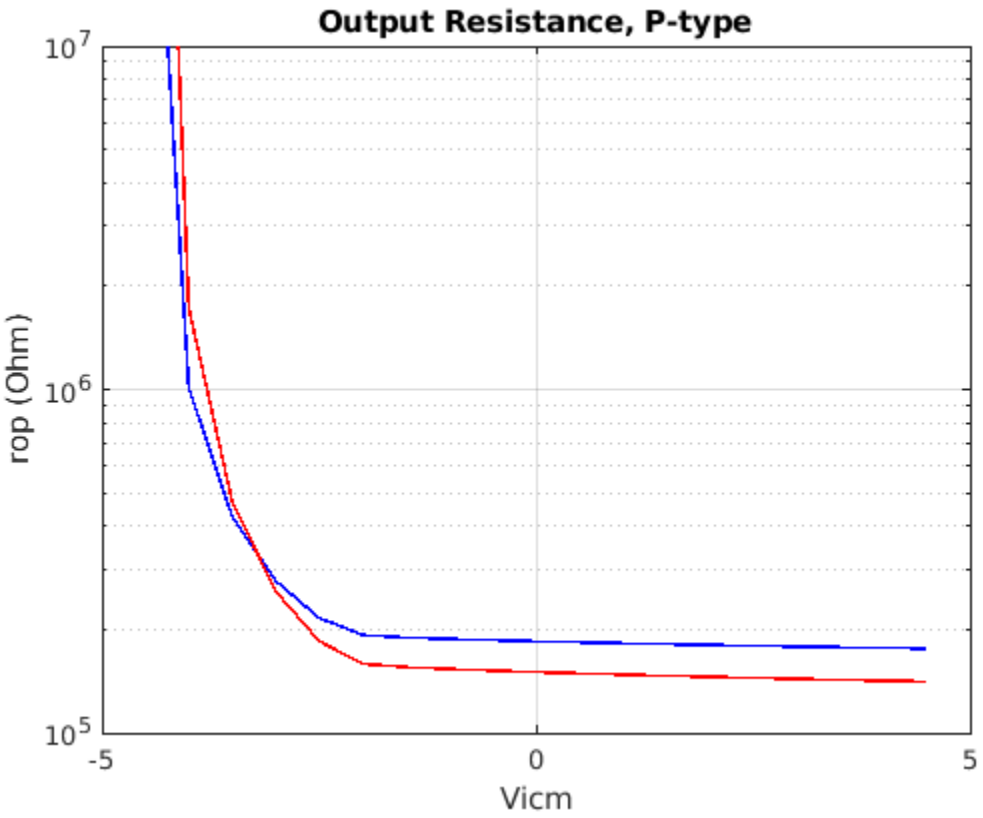

Gain in Volts/Volt
Measured Gain
Predicted Gain
120
110
100
90
80
70
60
50
40
30
20
Gain (V/V)
-5
0
5
Vicm (V)

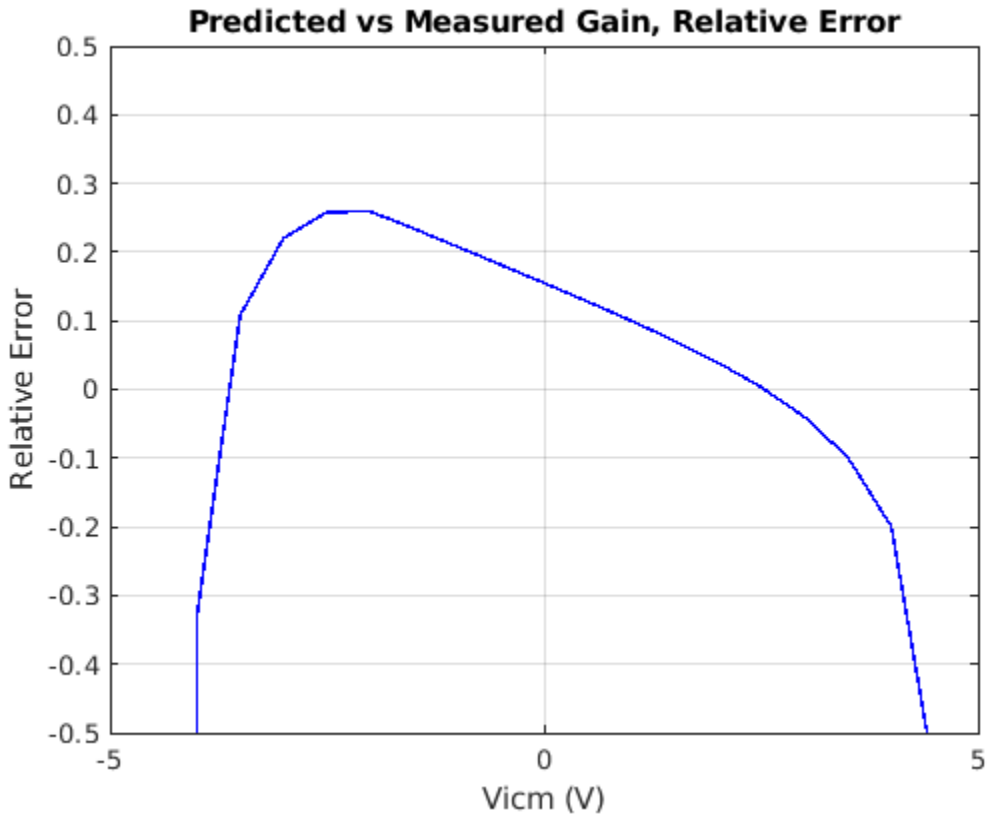

Gain/Bandwidth Tradeoff
×10^6
10
9
8
7
6
5
4
3
2
1
0
BW (Hz)
0
20
40
60
80
100
120
Gain (V/V)

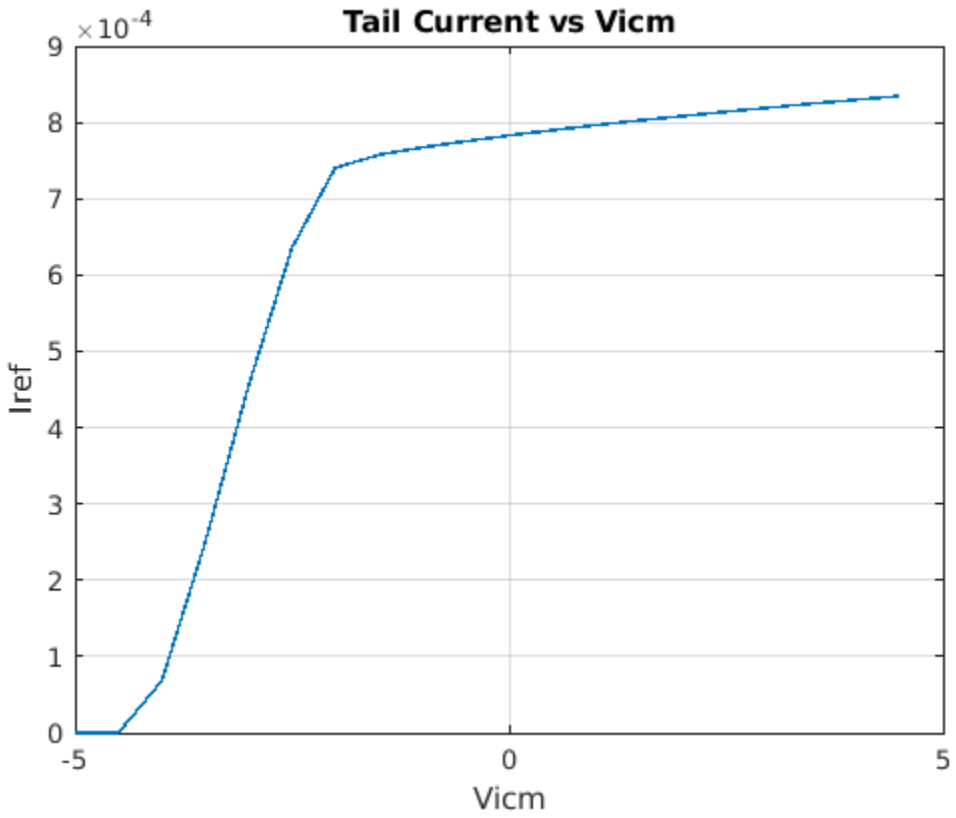

Measured Gain
Predicted Gain
120
100
80
60
40
20
Gain (V/V)
1
2
3
4
5
6
7
8
Iref (A)
×10^-4

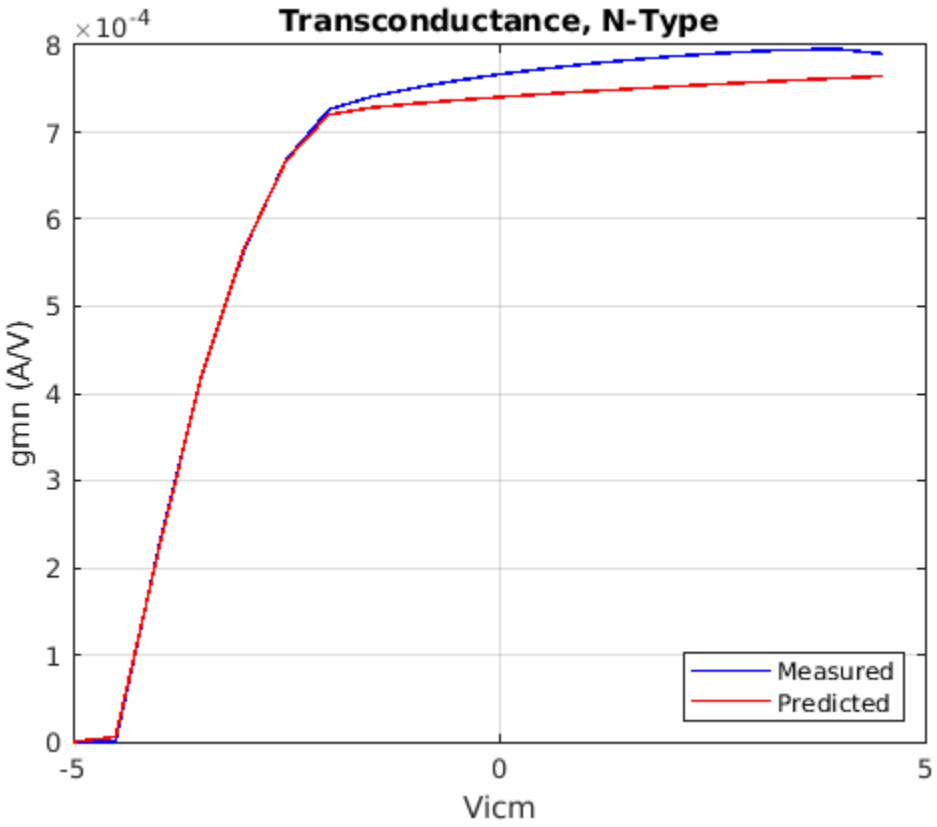

Gain in dB
Measured Gain
Predicted Gain
Gain (dB)
Vicm
50
45
40
35
30
25
20
-5
0
5

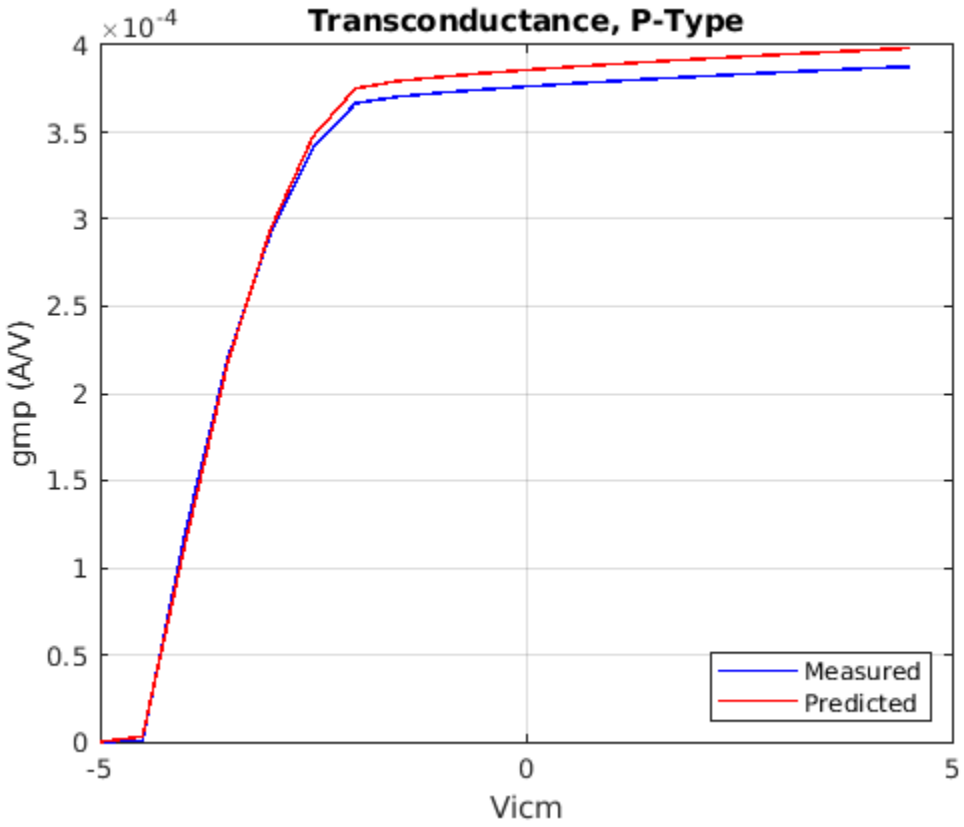

Output Resistance, N-type
10^7
10^6
10^5
10^4
ron (Ohm)
-5
0
5
Vicm


Output Resistance, P-type
10^7
10^6
10^5
rop (Ohm)
-5
0
5
Vicm

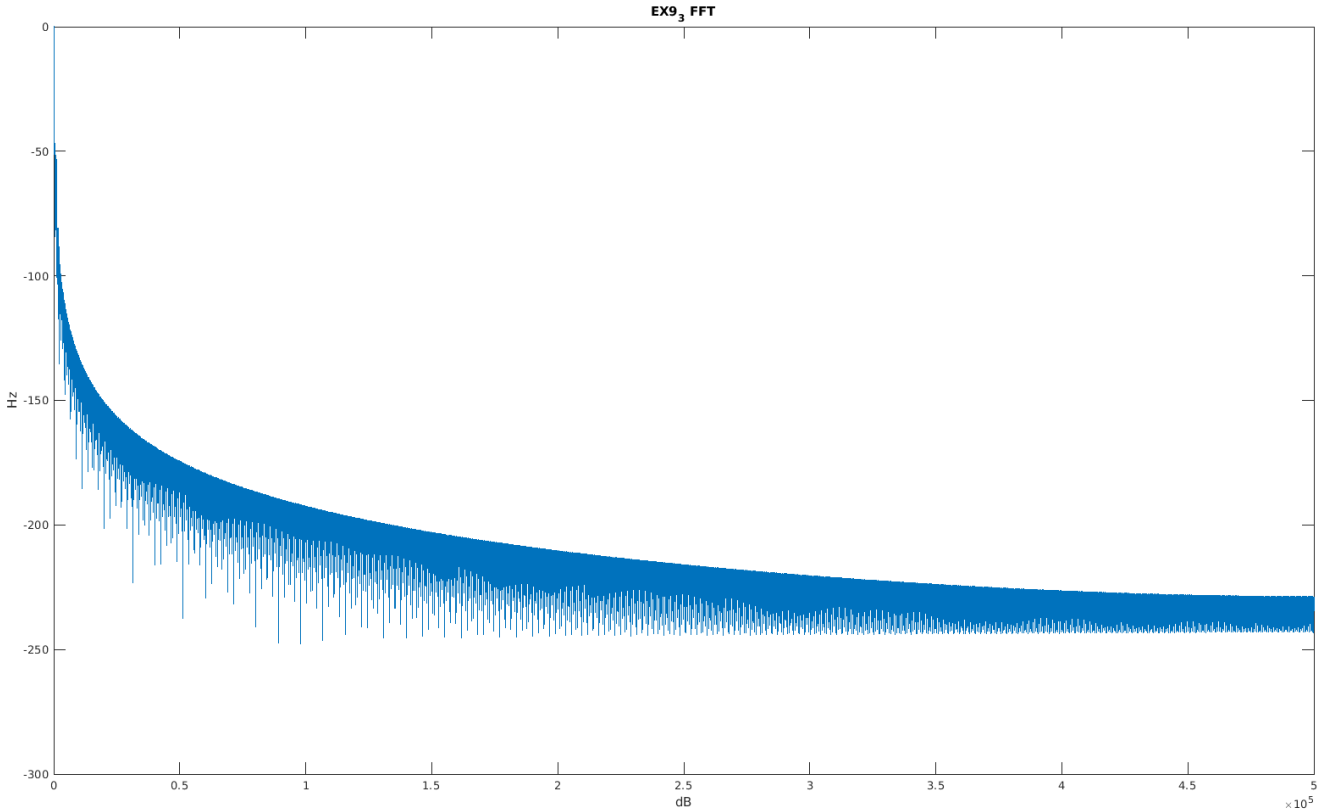

Predicted vs Measured Gain, Relative Error
Relative Error
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-5
0
5
Vicm (V)


Tail Current vs Vicm
×10^-4
9
8
7
6
5
4
3
2
1
0
Iref
-5
0
5
Vicm

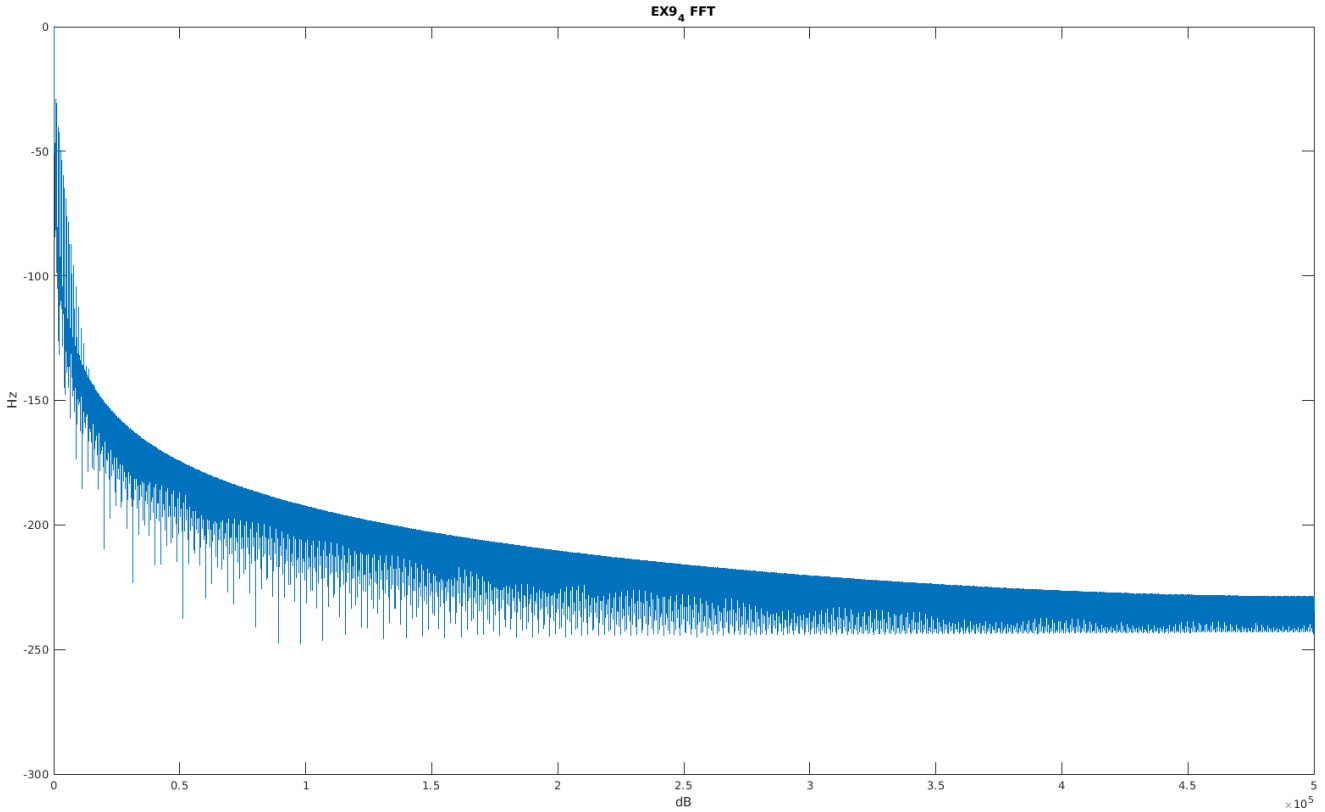

Transconductance, N-Type
×10^-4
8
7
6
5
4
3
2
1
0
gmn (A/V)
-5
0
5
Vicm
Measured
Predicted



ex3.sp with the added resistors SNR: -62.5920



3x4.sp with the added resistors SNR: -62.5950



These results compare relatively well with what was predicted in problem 8, except for non-idealities of the OTA