**Lab 4**

Common Drain Amplifier

Part 1: Sizing Chart

Required Spec:

|  |  |
| --- | --- |
| L | 1um |
| V\* | 200mV |
| Quiescent (DC) Input Voltage | 0 𝑉 |
| Supply Voltage | 1.8 𝑉 |
| Bias Current | 10 uA |

A screenshot of a computer

AI-generated content may be incorrect.Analytic Calculations:

Sizing Using ADT:

Inputting the Design parameters into ADT SA we get:

Figure Sizing Using ADT

Part 2: Common Drain Amplifier

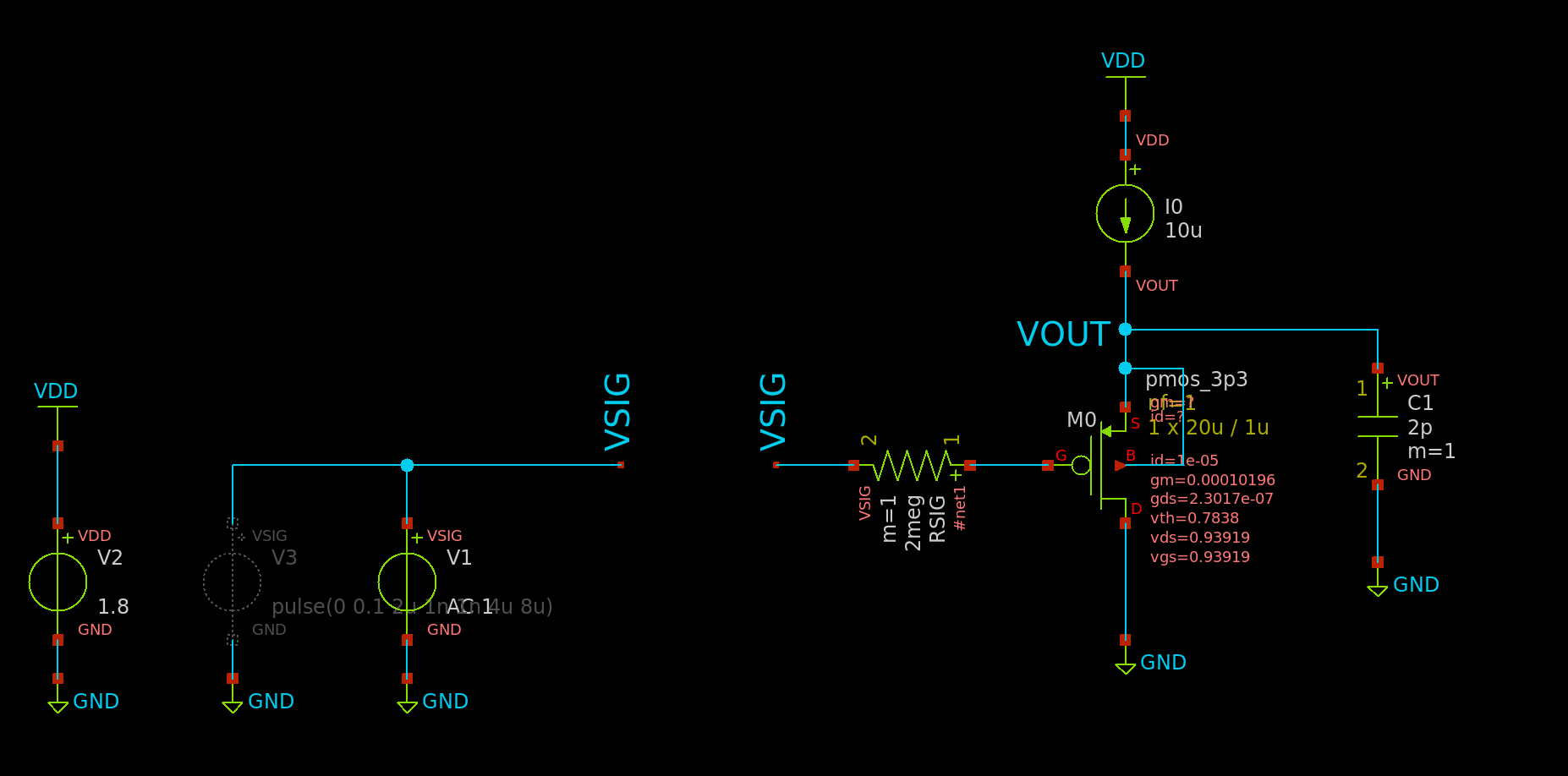


Figure Testbench Schematic for both AC and Tran Analysis

Operating Point:

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | id | vgs | vds | vth | vdsat | gm | gds | gmbs | Cdb | Cgd | Cgs | Csb |
| M0 | 10uA | 0.94V | 0.94V | 0.785V | 0.153V | 102uS | 230nS | 48.2uS | 9.97fF | 14.2aF | 51.1fF | 14.9fF |

Transistor Operates in Saturation!

Values of Capacitances from ADT:

Calculating the capacitance value from ADT instead of Xschem as it is more accurate for hand analysis.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Cdb | Cgd | Cgs | Csb |
| M0 | 8.969fF | 3.073fF | 51.1fF | 14.9fF |

AC Analysis:

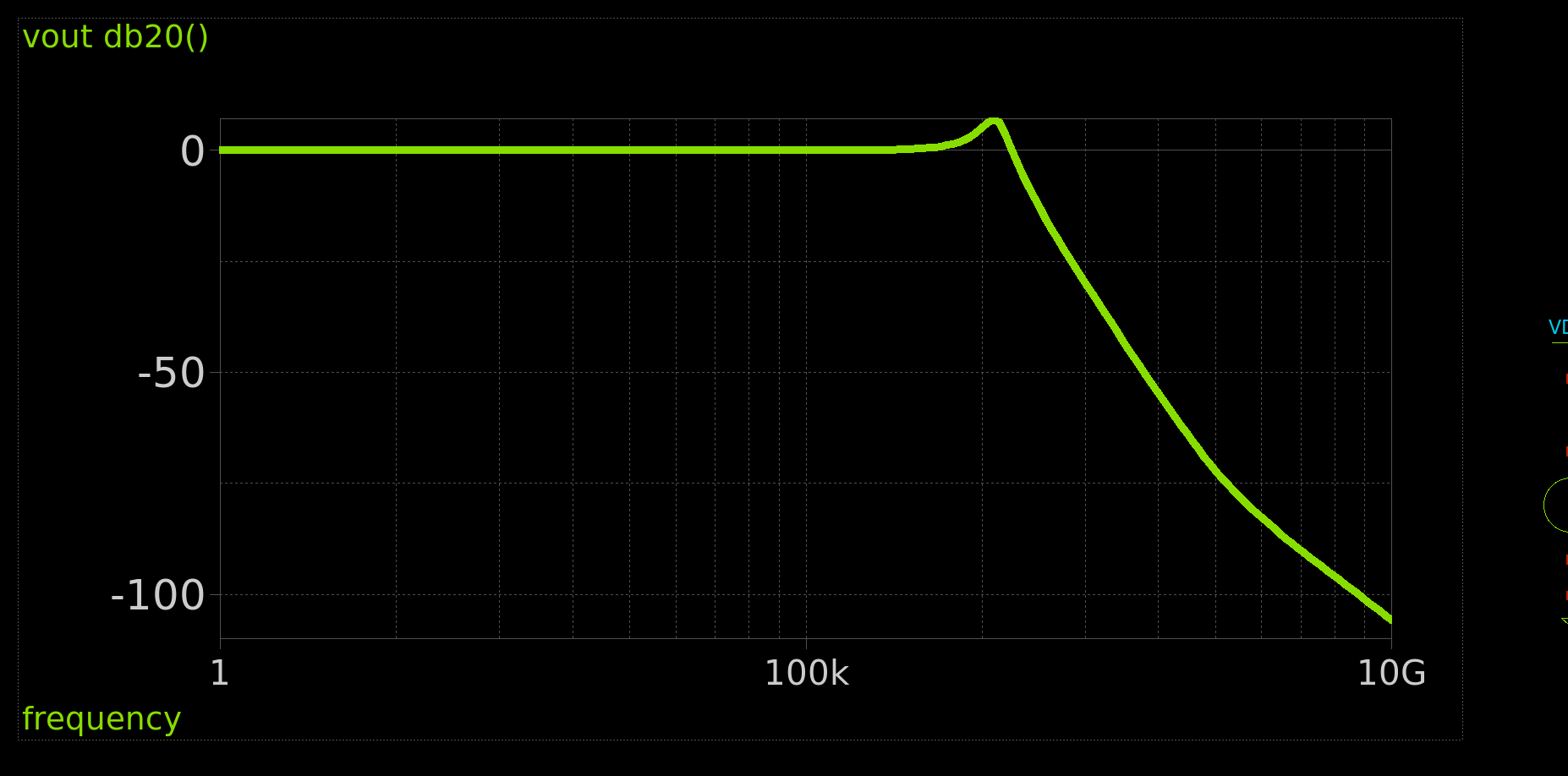
**Outputs:** 

Figure Bode Plot of Common Drain Amplifier

* Do you notice frequency domain peaking? How much is the peaking?

Yes, there is peaking. Its value is about **2 in magnitude** or around **6dB**



Figure Value of Peaking from Simulation

Quality Factor Calculation:

Using the values calculated earlier from OP Analysis

,

The System is Underdamped!

Note: Using the approximated equation for Q here is not recommended as the poles are close to each other resulting in inaccurate variables

* Parametric sweep: CL = 2p, 4p, 8p:

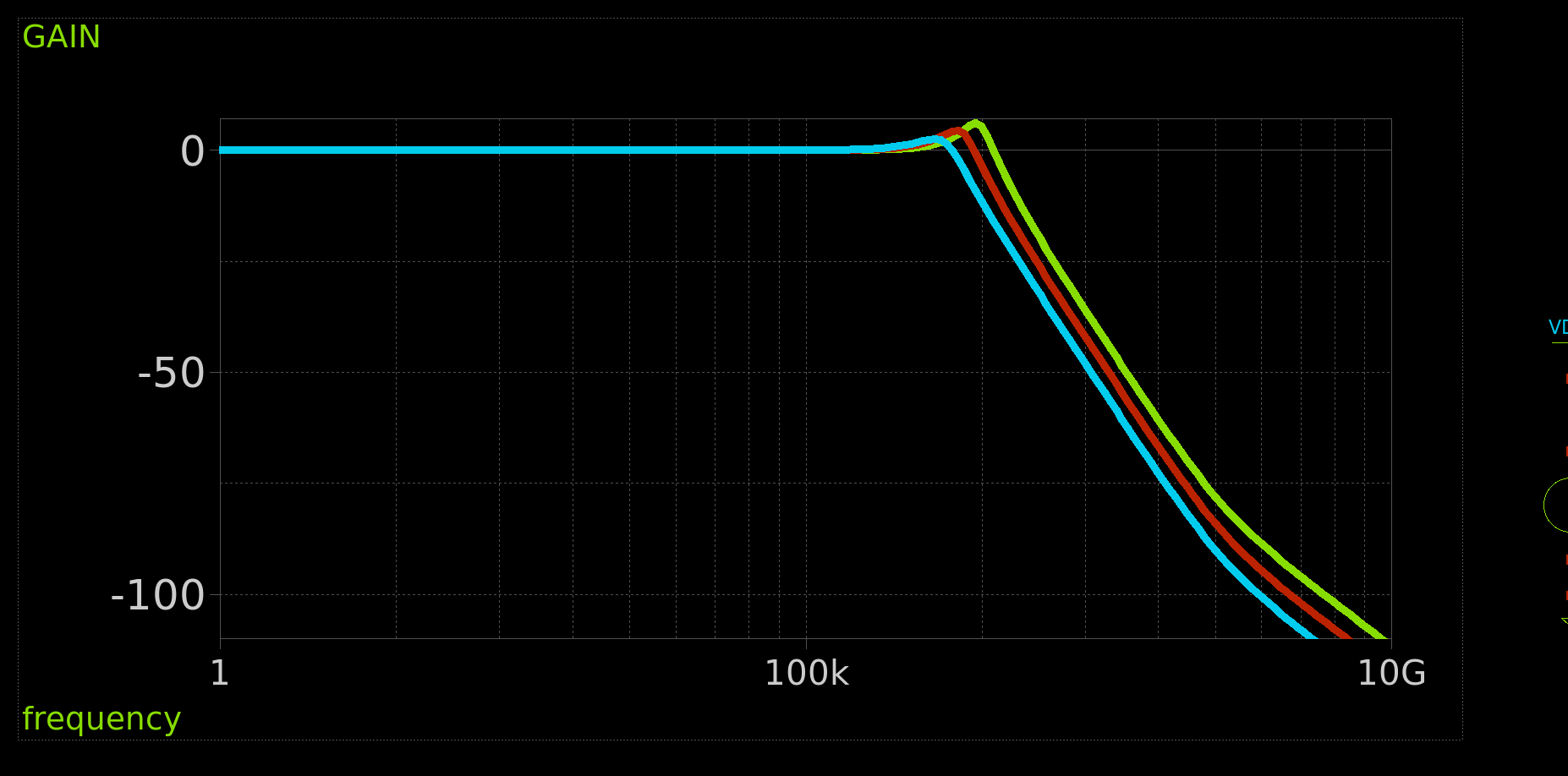


Figure AC Analysis Parametric Sweep of CL

|  |  |  |  |
| --- | --- | --- | --- |
| **CL Value** | 2pF | 4pF | 8pF |
| **Peaking** | 2.0161 | 1.667 | 1.3358 |

Peaking vs CL:

Peaking decreases as we increase the Value of CL

Comment:

Increasing CL decreases Q closer to 0.5 thus reducing the Peaking and making the system overdamped.

* Parametric sweep: Rsig = 20K, 200K, 2M:

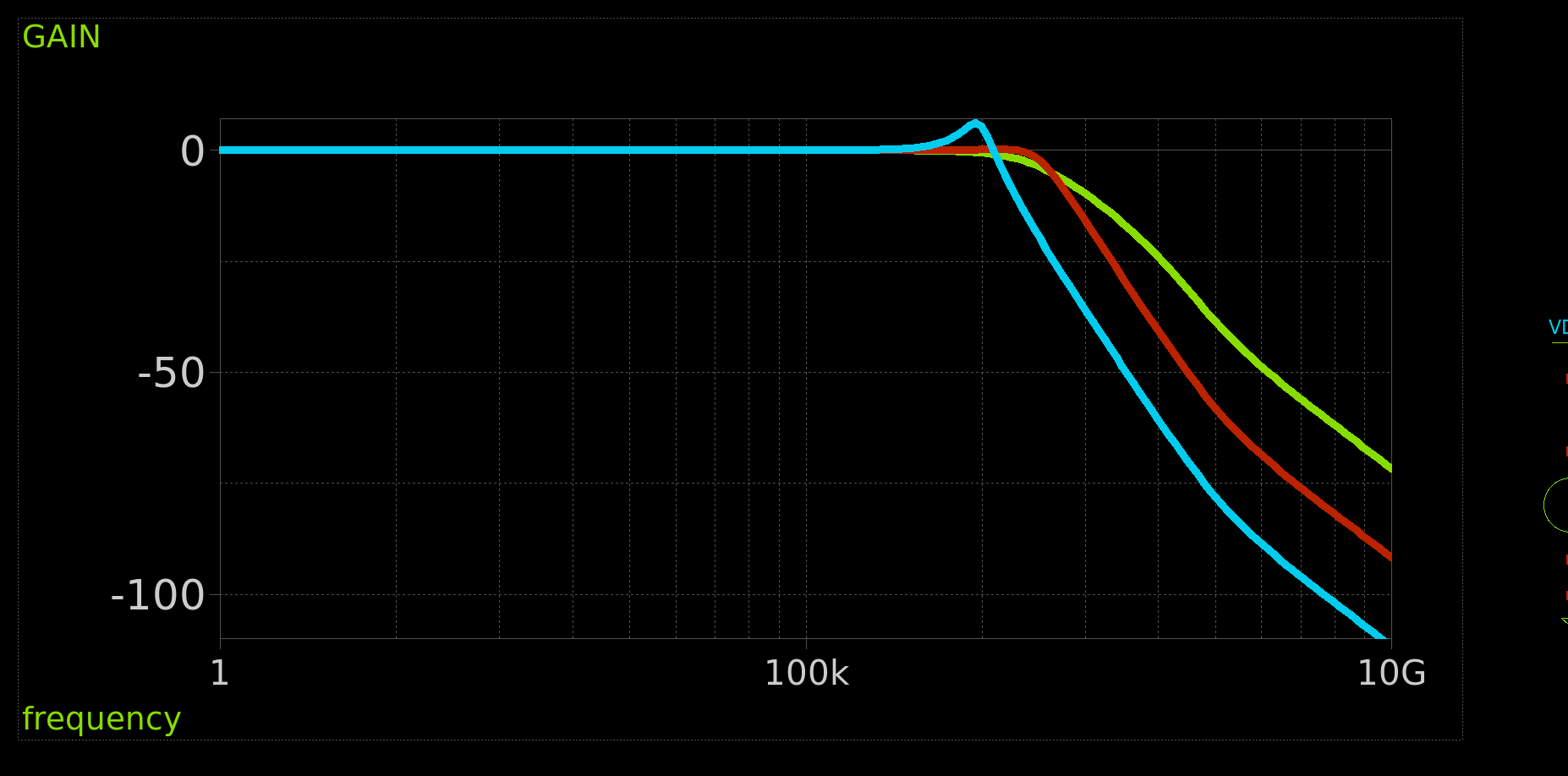


Figure AC Analysis Parametric Sweep of Rsig

|  |  |  |  |
| --- | --- | --- | --- |
| **Rsig Value** | 20K | 200K | 2M |
| **Peaking** | 0.997 | 1.021 | 2.0161 |

Peaking vs Rsig:

Peaking increases as we increase the value of Rsig

Comment:

Increasing Rsig Increases Q thus increasing the peaking and underdamping the system.

Transient Analysis:

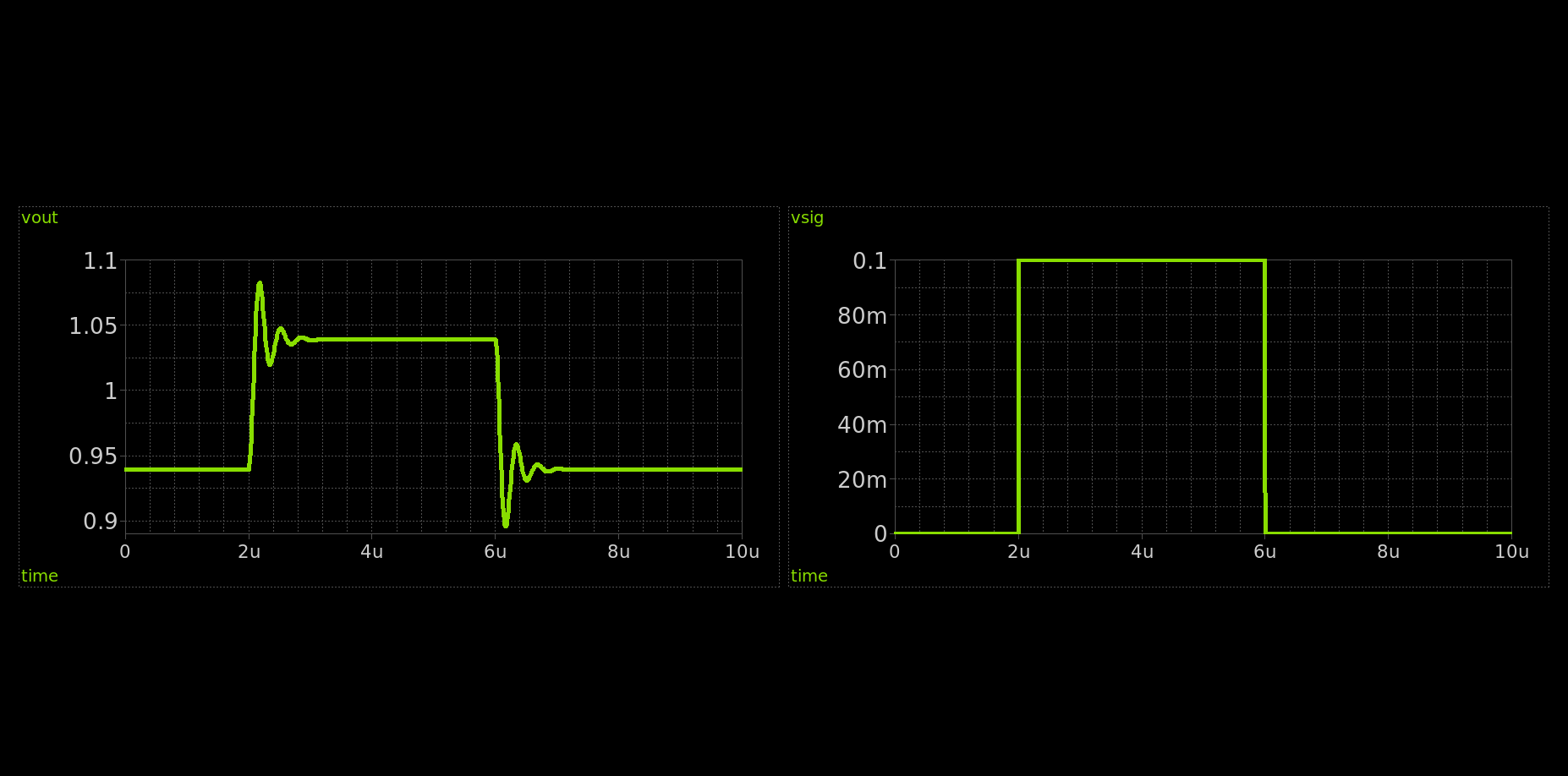
**Outputs:** 

Figure VIN and VOUT vs Time (Transient Analysis)

* DC Voltage difference:

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AI-generated content may be incorrect.

Figure Values of VOUT from simulation

The DC shifted up about **0.94V**, the minimum value of Vin is 0 and the Minimum value of Vout is 0.94V.

**How to shift the signal down instead of shifting it up?**

By using an NMOS CD configuration instead of the PMOS configuration.

* Do you notice time domain ringing ? How much is the overshoot?

Yes, there is an overshoot of about **43.45%**



Figure Value of overshoot from Simulation

Parametric sweep: CL = 2p, 4p, 8p:

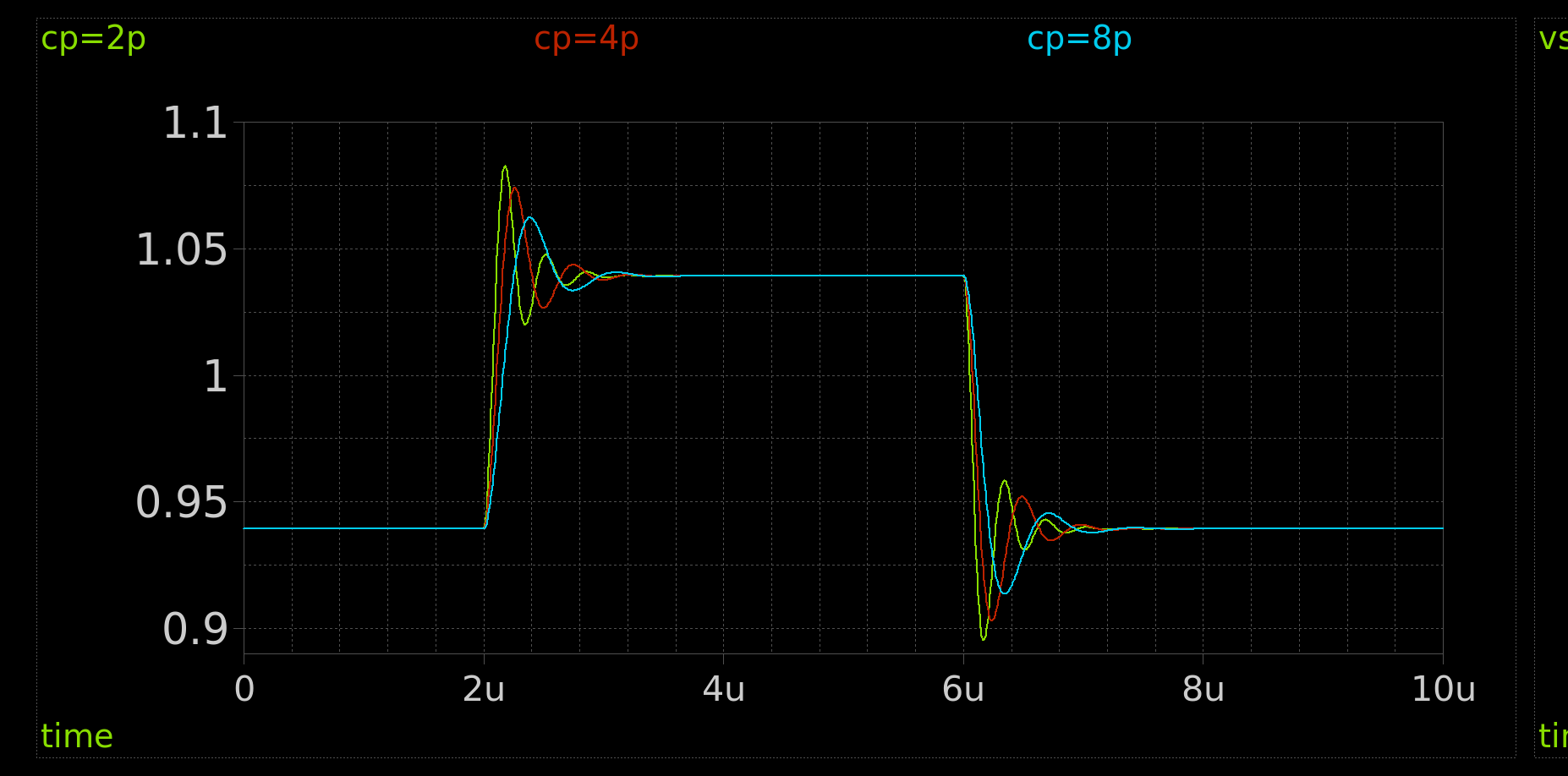


Figure Transient Analysis Parametric Sweep of CL

|  |  |  |  |
| --- | --- | --- | --- |
| **CL Value** | 2pF | 4pF | 8pF |
| **Peaking** | 43.456% | 34.77% | 23.2% |

Peaking vs CL:

Overshoot decreases as we increase the Value of CL

Comment:

Increasing CL decreases Q closer to 0.5 thus reducing the ringing and making the system overdamped.

* Parametric sweep: Rsig = 20K, 200K, 2M:

A graph of a graph

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Figure AC Analysis Parametric Sweep of Rsig

|  |  |  |  |
| --- | --- | --- | --- |
| **Rsig Value** | 20K | 200K | 2M |
| **Peaking** | 0.997 | 1.021 | 2.0161 |

Peaking vs Rsig:

Peaking increases as we increase the value of Rsig

Comment:

Increasing Rsig Increases Q thus increasing the peaking and underdamping the system.

* Parametric sweep: Rsig = 20K, 200K, 2M:

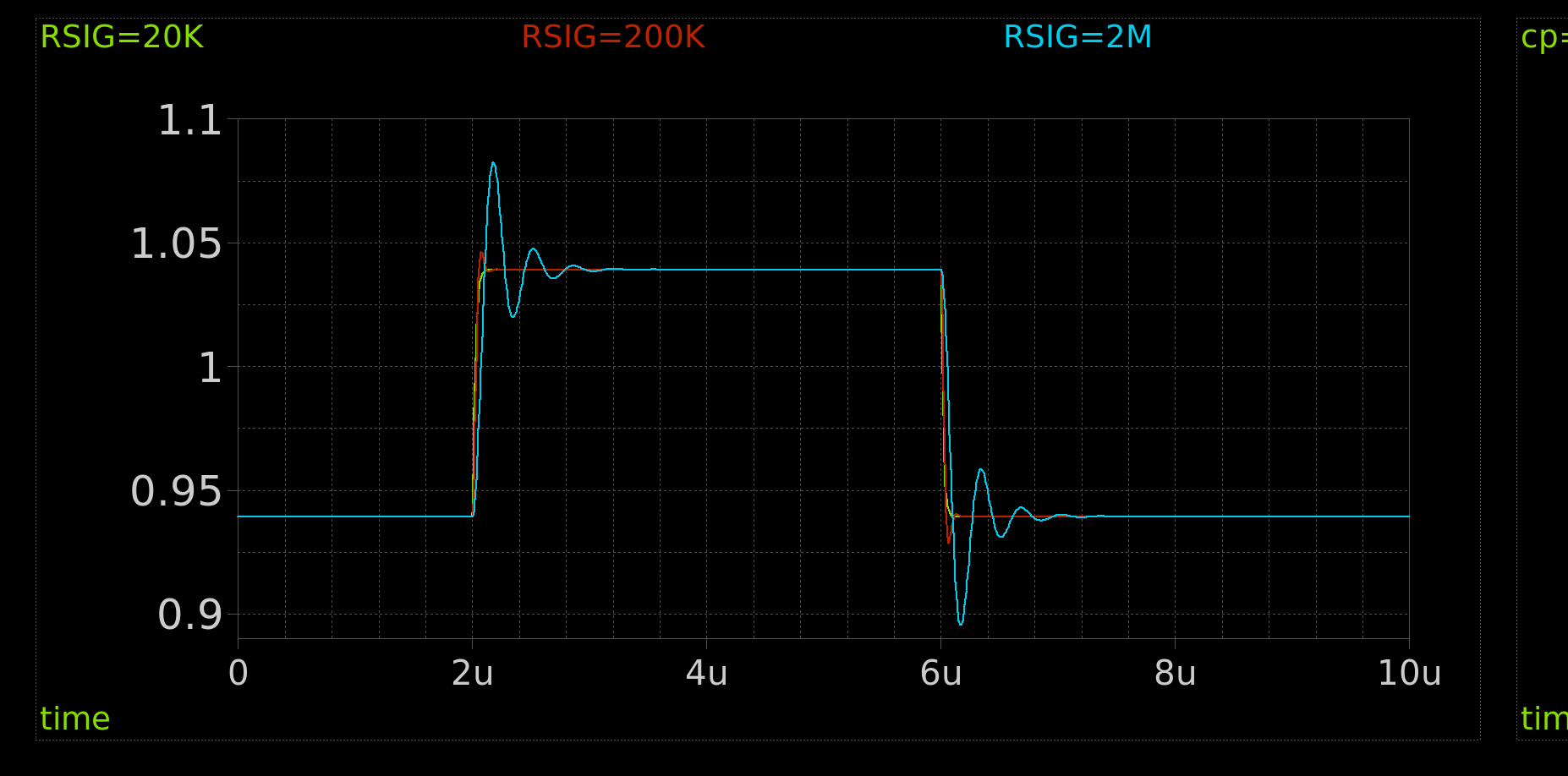


Figure Transient Analysis Parametric Sweep of Rsig

|  |  |  |  |
| --- | --- | --- | --- |
| **Rsig Value** | 20K | 200K | 2M |
| **Peaking** | 0% | 7.23% | 43.456% |

Peaking vs Rsig:

Ringing increases massively as we increase the value of Rsig

Comment:

Increasing Rsig Increases Q thus increasing the ringing and underdamping the system.

Zout Inductive Rise:

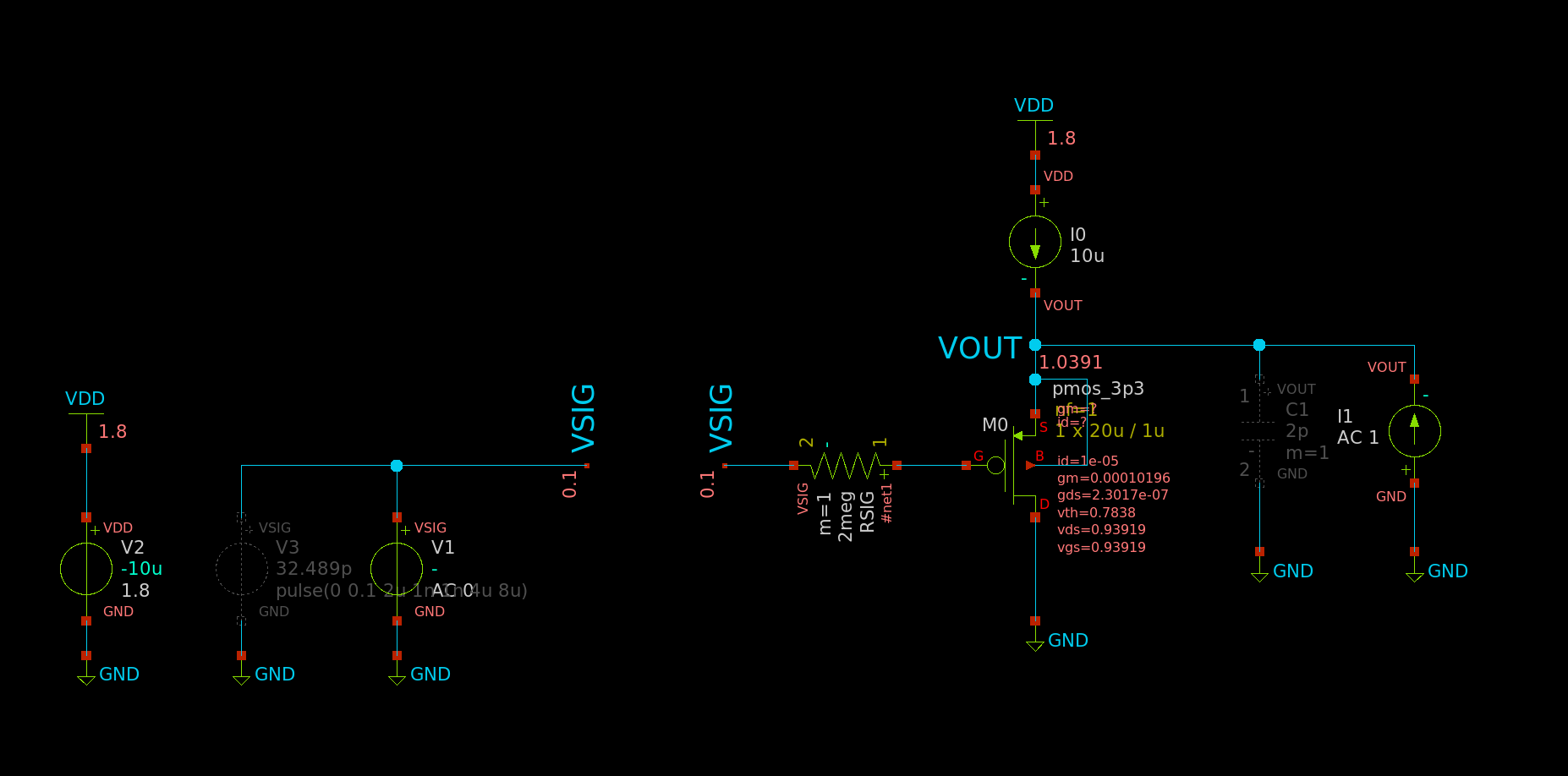


Figure Modified Testbench to Calculate Zout

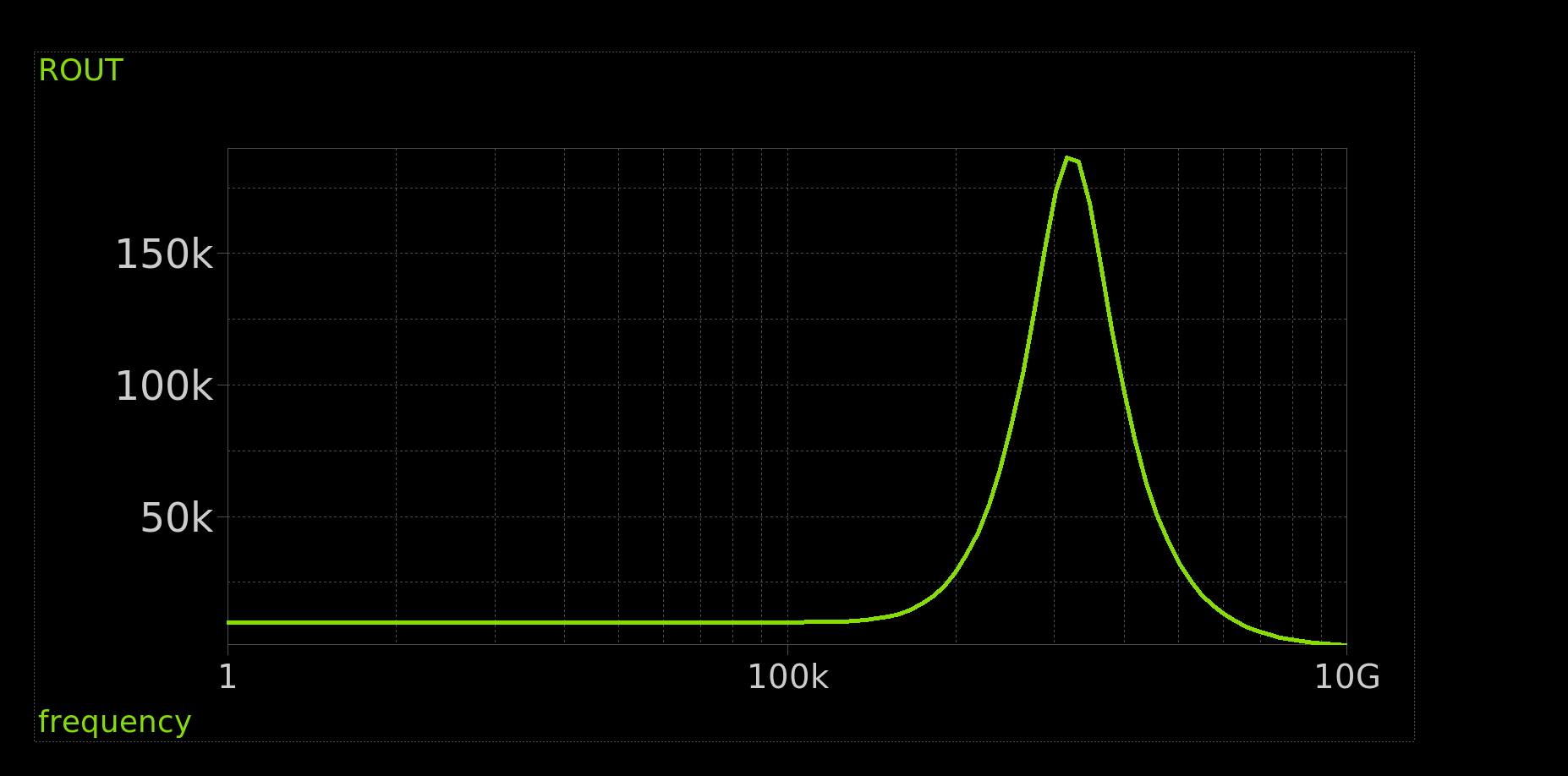


Figure ZOUT vs Frequency



Figure Zout at High and Low Frequencies

* Do you notice an inductive rise? Why?

Yes, because at high frequencies, Cgs is shorted so Zout becomes equal to Rsig.

But in the simulation the it does not quite reach Rsig this is due to Cgd taking over before Cgs can short completley

* Does 𝑍𝑜𝑢𝑡 fall at high frequency? Why?

Due to the Pole generated by Cgs Zout falls quickly.

* Analytically calculate the zeros, poles, and magnitude at low/high frequency for 𝑍𝑜𝑢𝑡. Compare with simulation results in a table.

**Poles and Zeros Analytically:**

Simulation Results:

A graph with lines and numbers

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Figure Zero Location @ 1.1MHz

**A graph with a green line

AI-generated content may be incorrect.**

Figure First Pole Location @ 16.683 MHz

***A green line on a black background

AI-generated content may be incorrect.***

Figure Second Pole Location @ 70MHz

|  |  |  |
| --- | --- | --- |
|  | Hand Analysis | Simulation |
| Zout HFR | Rsig=2Mohm | 186.6Kohm |
| Zout LFR | 1/gm =9.8Kohm | 9.78Kohm |
| Zero | 1.55MHz | 1.11MHz |
| First Pole | 25.89MHz | 16.683MHz |
| Second Pole | 318.3MHz | 70MHz |

Comment:

There is a huge difference between the hand analysis calculation and the simulation results, this is because the hand analysis I used assumed the poles are further away from each other than they really are, which is incorrect as the poles are close to each other and are complex thus causing the ringing and peaking in transient and frequency analyses.

Only values calculated at the LFR (Zero and ZOUT at LFT) produced accurate results compared to the simulation, but the HFR results are far off especially the second pole which was expected at a way higher range that it was found.

To get more accurate poles using hand analysis the original long form equation should be used:

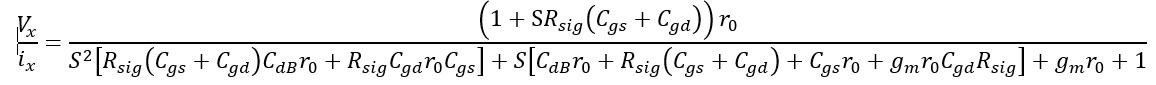


Figure Zout Out long form equation for this configuration

Further more, from the simple hand analysis we did earlier we neglected the effect of Cgd and assumed its pole would come after Cgs giving us Rsig at the HFR, this is incorrect as seen from the simulation, Zout drops before it reaches Rsig as Cgd shorts the output and drops quickly to zero.

**Overall, I do realize my hand analysis equations are inaccurate due to the above mentioned reasons and the proper way to calculate the poles would be using the equation in Figure 19. But it’s still a good indicator for understanding how the circuit behaves and should be analyzed correctly using the long equation when designing a system that utilizes it**

Also their might be an error in the simulation results as I had to depend on the graph due to the pz simulation not functioning correctly. But again, it’s a good indicator as to how the circuit behaves.

Compensation Network:

From [Johns and Martin, 2012] Section 4.4 we conclude that a compensating RC network can be connected in parallel to the input to fix the ringing problem in the circuit, it looks as follows:

A computer screen shot of a circuit board

AI-generated content may be incorrect.

Figure Altered Circuit using Compensation Network

We can calculate the values of R and C using the equations analyzed in reference.

Using the values found from ADT again for the capacitances.

Results:

A graph on a black background

AI-generated content may be incorrect.

Figure VOUT Bode Plot Parametric Sweep with CL

A graph with lines and numbers

AI-generated content may be incorrect.

Figure Transient Vout vs Time, Parametric Sweep with CL

In the bode plot the circuit seems to not be affected by CL at all anymore after adding the compensating circuit, also in the transient analysis overshooting seems to be greatly reduced.