Project 2: Differential Colpitts Oscillator using FBAR Resonator

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ECE 345

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Design Requirements

We must design a differential Colpitts oscillator using the provided FBAR resonator. There are six key factors we need to consider:

- The oscillator should be optimized for the highest Figure-of-Merit (FoM), which is a combination of loop gain, phase noise at 2MHz offset frequency, and power consumption.
- The target application is a Bluetooth module with a bandwidth per channel of 2MHz, so the phase noise at 2MHz offset frequency is important.
- The FoM is calculated as FoM = Loop Gain (dB) - Phase Noise (at 2MHz) - 10log(Power mW).
- The target Phase Noise is -150dBc/Hz at 2MHz offset frequency.
- The target power consumption is 2mW, with an average supply voltage of 1V and current of 1.8mA.
- The loop gain should be greater than 0dB. For the highest FoM, a loop gain of 15dB is recommended.

General Design and Strategies

The Colpitts oscillator using FBAR resonator is an electronic oscillator that relies on a frequency-selective element to produce a sinusoidal output signal. It uses a negative feedback loop provided by capacitors Ca and Cb to stabilize the output and cancel out the resistance of the FBAR resonator, which allows the circuit to oscillate without decay.

However, noise sources such as thermal noise and flicker noise can impact the oscillator's performance. The current sources Id and resistors connecting Vb to outn and outp are the main sources of thermal noise. Another source of noise that can affect the performance of the Colpitts oscillator using FBAR resonator is flicker noise, which is a type of low-frequency noise that arises from the random motion of charge carriers in the transistor channel. This noise can be modeled as a voltage source that is proportional to the inverse of the transistor's width, length, and oxide capacitance.

To ensure optimal noise performance of the Colpitts oscillator using FBAR resonator, it is important to carefully select the values of the circuit elements and to minimize the parasitic resistance of the inductors and capacitors. Additionally, techniques such as shielding and filtering can be used to further reduce the impact of external noise sources.

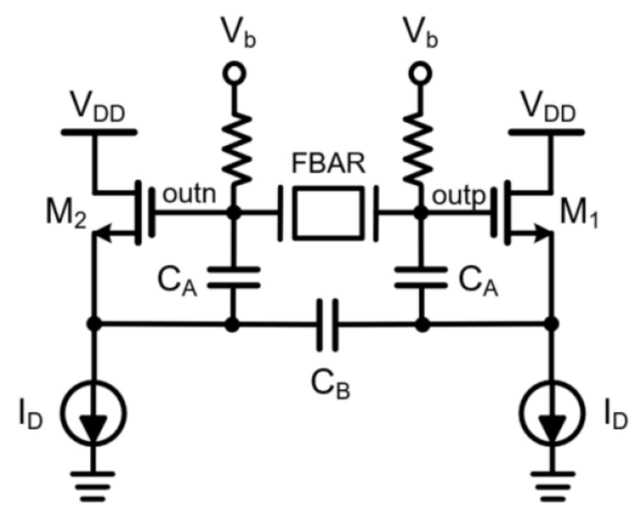
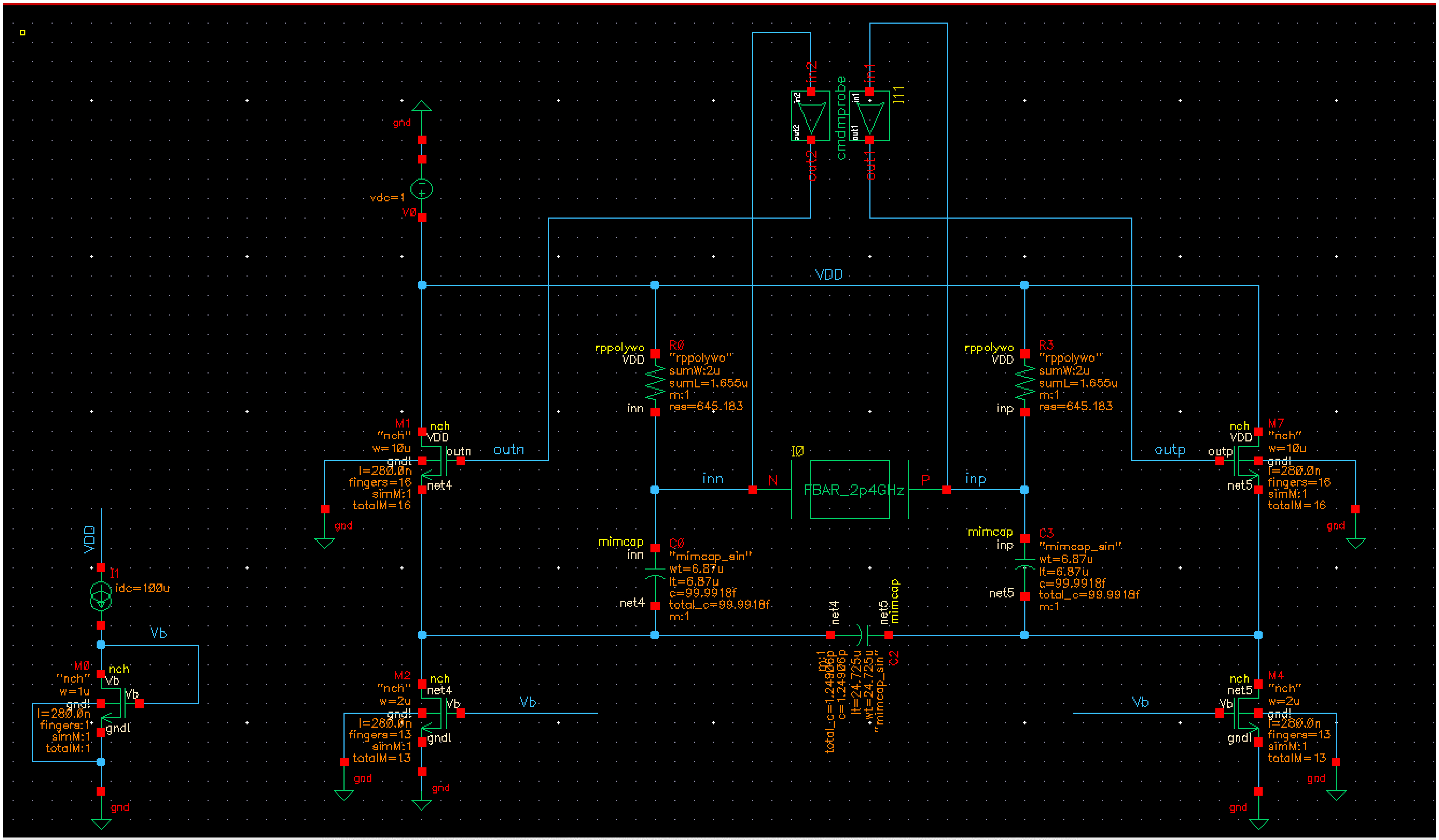
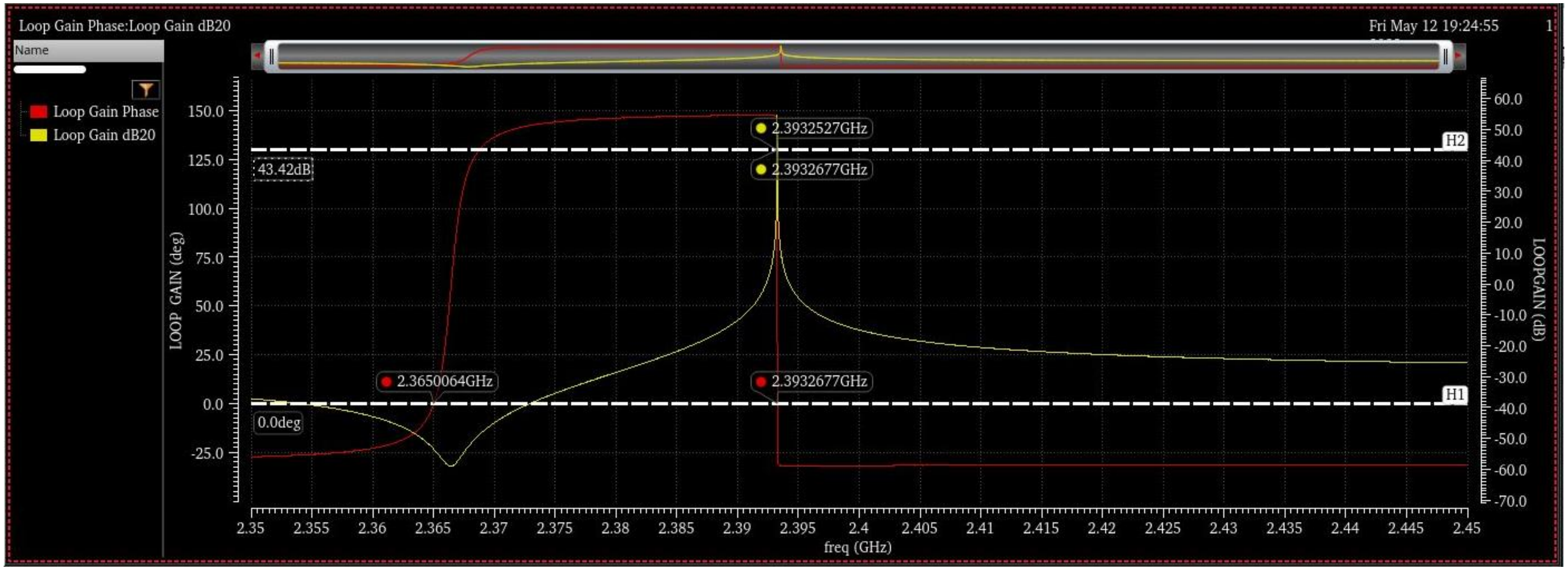


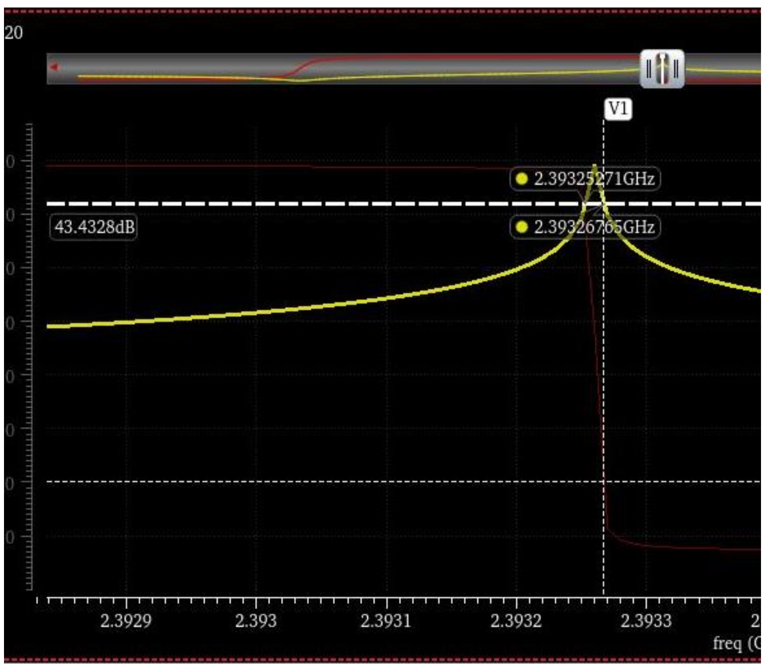
Fig.1 Block diagram of the differential Colpitts oscillator

Final Schematic



Transient Response: Open Loop Gain at 0 deg : 43.42 dB

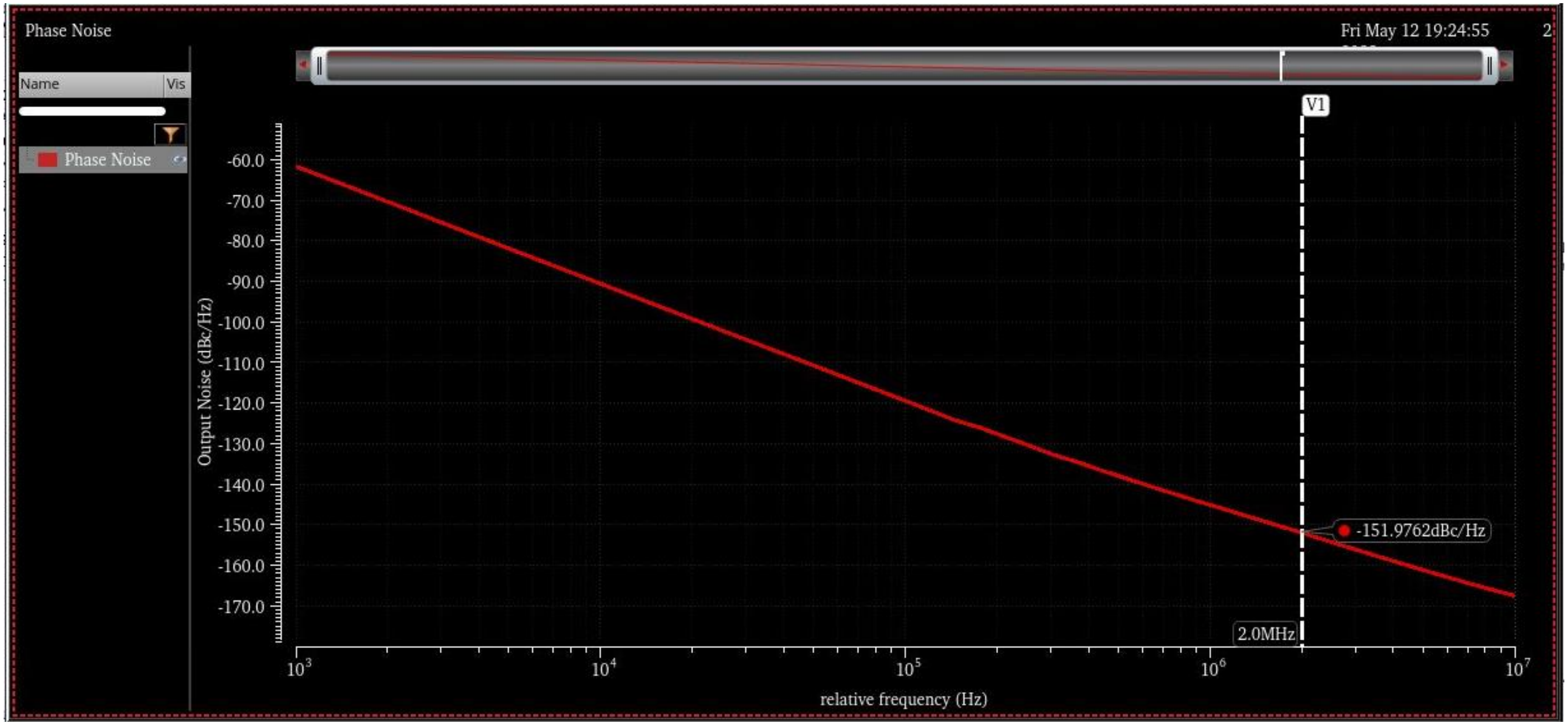




Outputs

	Name/Signal/Expr	Value	Plot	Save	Save Opt
1	outp		✔	☐	allv
2	outn		✔	☐	allv
3	Loop Gain Phase	wave	✔	✔	
4	Loop Gain dB20	wave	✔	✔	
5	Phase Noise	wave	✔	☐	
6	Open Loop Gain 0dB	43.42	✔	☐	
7	Peak-to-Peak difference	825m	✔	☐	
8	Peak-to-Peak Negative	412.5m	✔	☐	
9	Peak-to-Peak Positive	412.4m	✔	☐	
10	Phase Noise at 2MHz	-152	✔	☐	
11	Power	wave	✔	☐	
12	Average Power	5.865m	✔	☐	

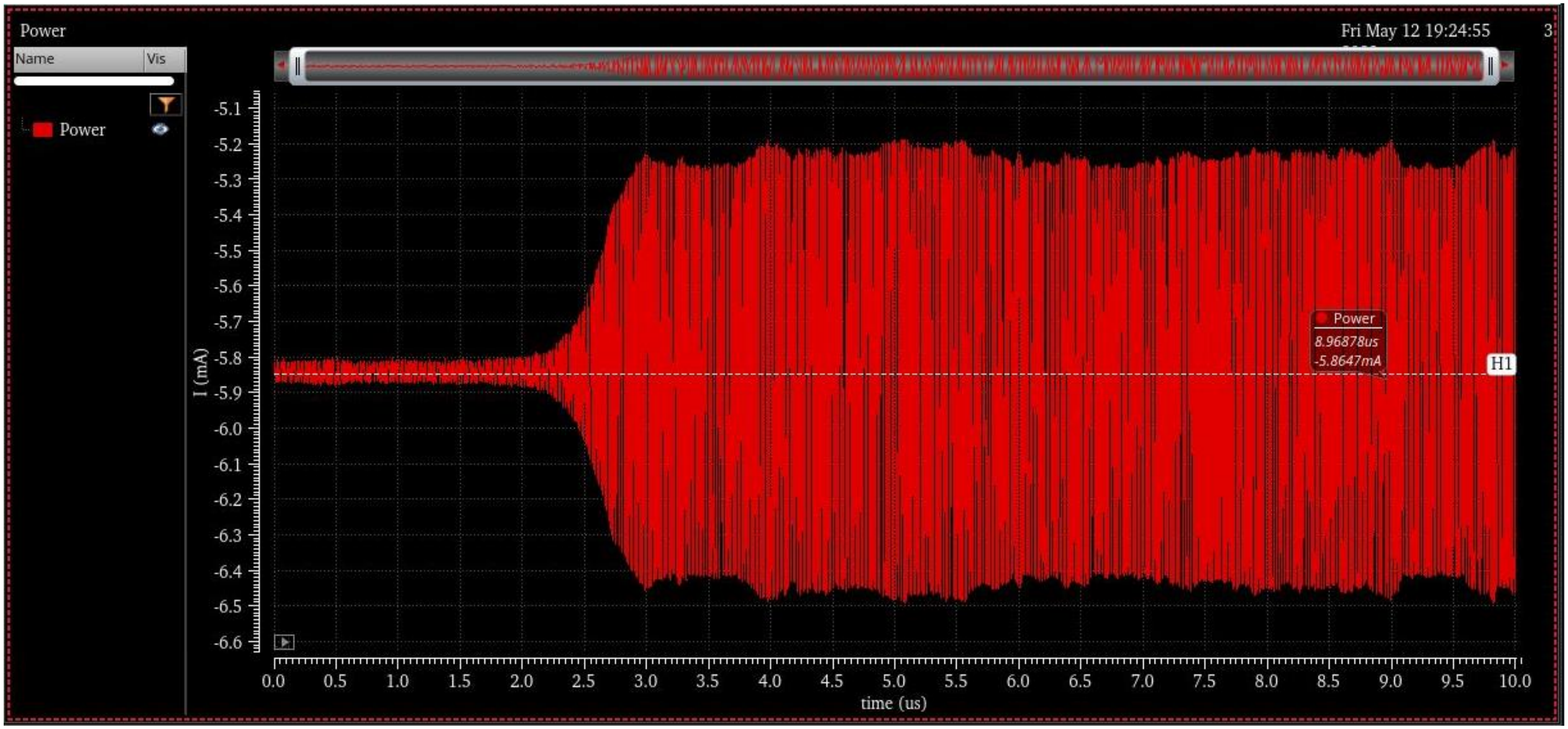
AC Response: Phase Noise at 2MHz = -152dB



Outputs

	Name/Signal/Expr	Value	Plot	Save	Save Opt
1	outp		✓		allv
2	outn		✓		allv
3	Loop Gain Phase	wave	✓	✓	
4	Loop Gain dB20	wave	✓	✓	
5	Phase Noise	wave	✓		
6	Open Loop Gain 0dB	43.42	✓		
7	Peak-to-Peak difference	825m	✓		
8	Peak-to-Peak Negative	412.5m	✓		
9	Peak-to-Peak Positive	412.4m	✓		
10	Phase Noise at 2MHz	-152	✓		
11	Power	wave	✓		
12	Average Power	5.865m	✓		

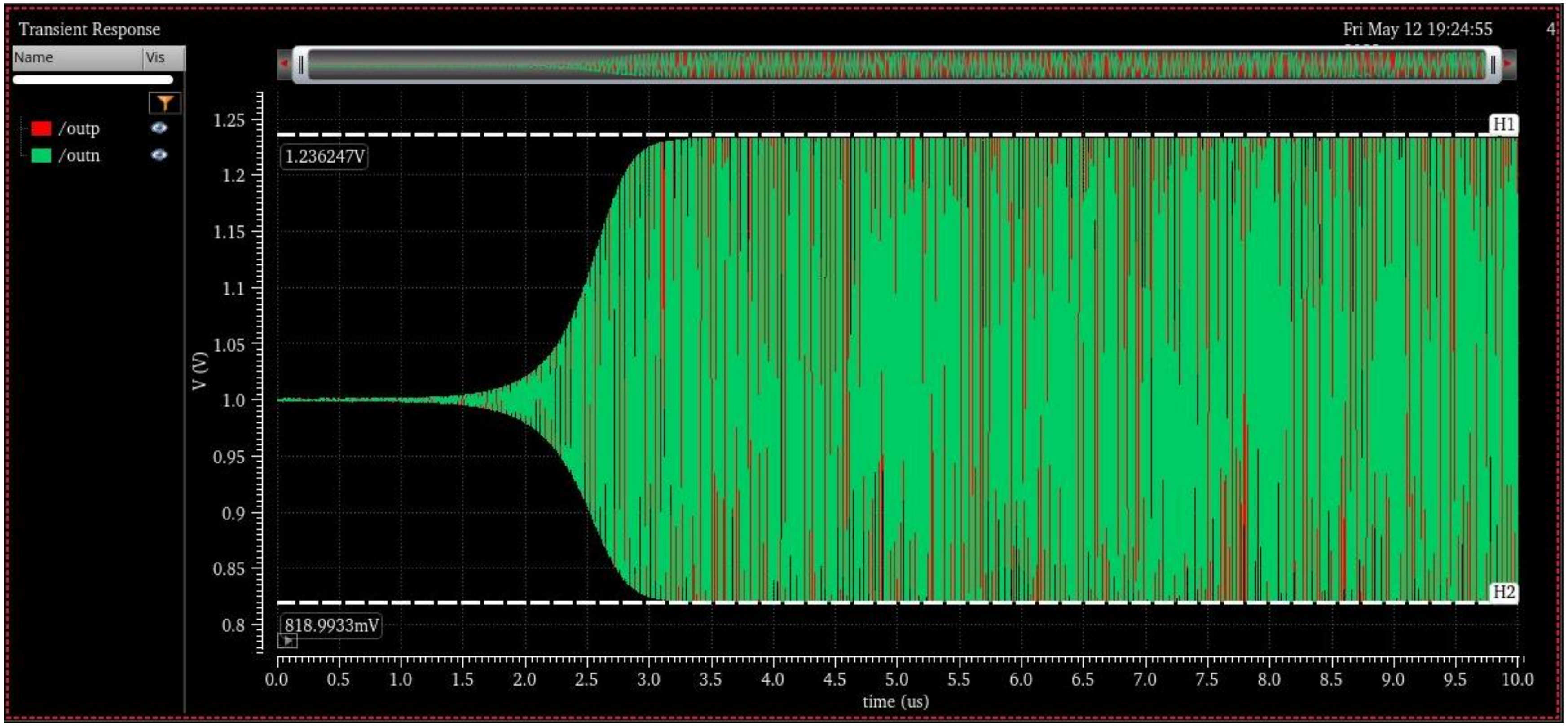
Transient Response: Power Consumption = 5.865mW

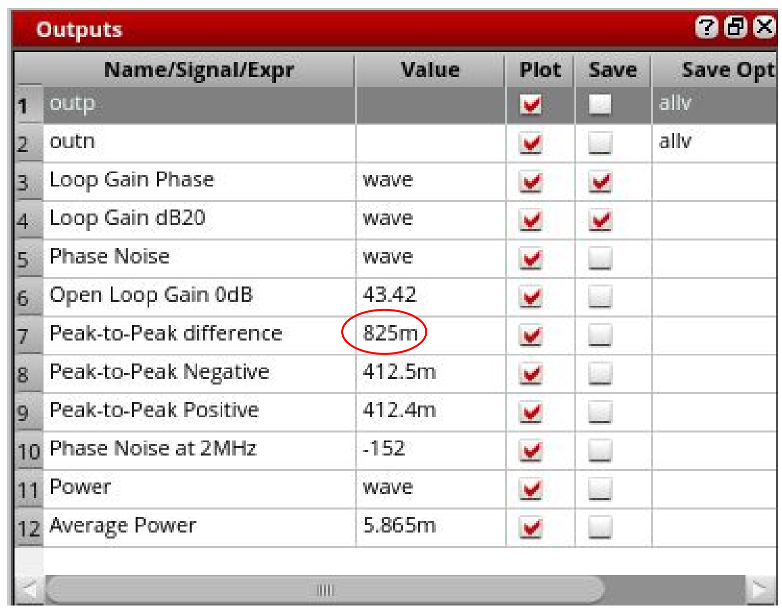


Outputs

	Name/Signal/Expr	Value	Plot	Save	Save Opt
1	outp		✓		allv
2	outn		✓		allv
3	Loop Gain Phase	wave	✓	✓	
4	Loop Gain dB20	wave	✓	✓	
5	Phase Noise	wave	✓		
6	Open Loop Gain 0dB	43.42	✓		
7	Peak-to-Peak difference	825m	✓		
8	Peak-to-Peak Negative	412.5m	✓		
9	Peak-to-Peak Positive	412.4m	✓		
10	Phase Noise at 2MHz	-152	✓		
11	Power	wave	✓		
12	Average Power	5.865m	✓		

Transient Response: Peak to Peak = 825mV




Outputs

	Name/Signal/Expr	Value	Plot	Save	Save Opt
1	outp		✓		allv
2	outn		✓		allv
3	Loop Gain Phase	wave	✓	✓	
4	Loop Gain dB20	wave	✓	✓	
5	Phase Noise	wave	✓		
6	Open Loop Gain 0dB	43.42	✓		
7	Peak-to-Peak difference	825m	✓		
8	Peak-to-Peak Negative	412.5m	✓		
9	Peak-to-Peak Positive	412.4m	✓		
10	Phase Noise at 2MHz	-152	✓		
11	Power	wave	✓		
12	Average Power	5.865m	✓		

Table of Results:

	Target	Simulation Results
Low Frequency Gain	>40 dB	42.751dB
Phase Noise	<-150dB	-152dB°
Average Power Consumption	<2mW	5.865mW
Peak to Peak Output	800mV	825mV
LVS Clean	Clean	Error > 5
FOM	162	187.73