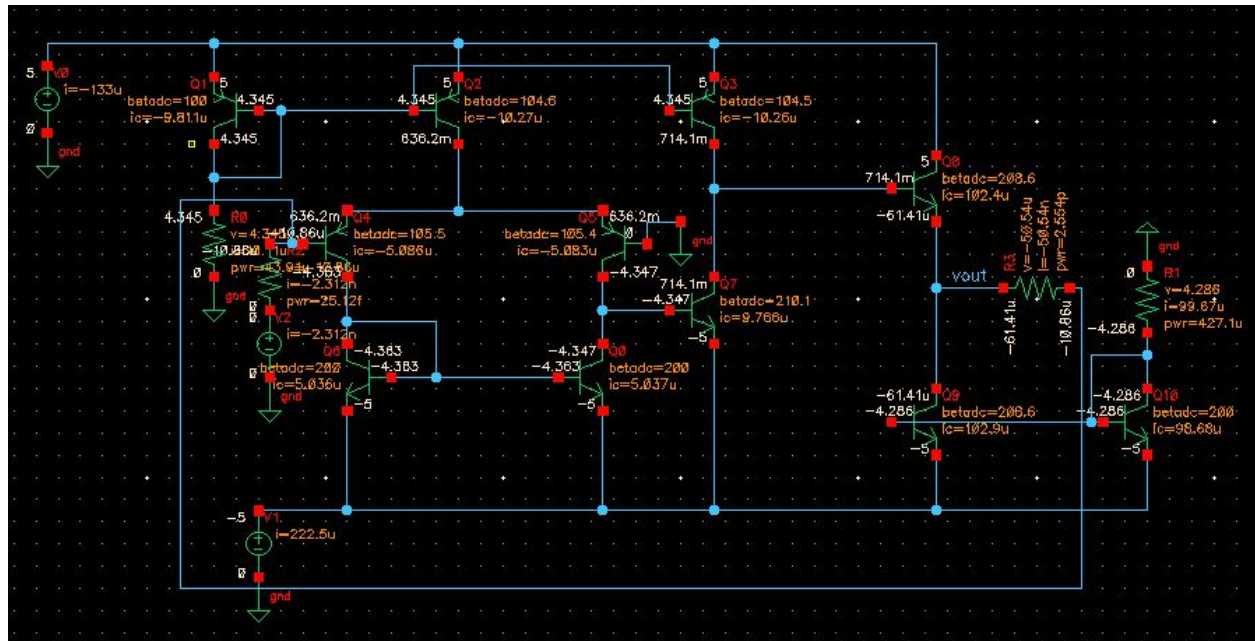


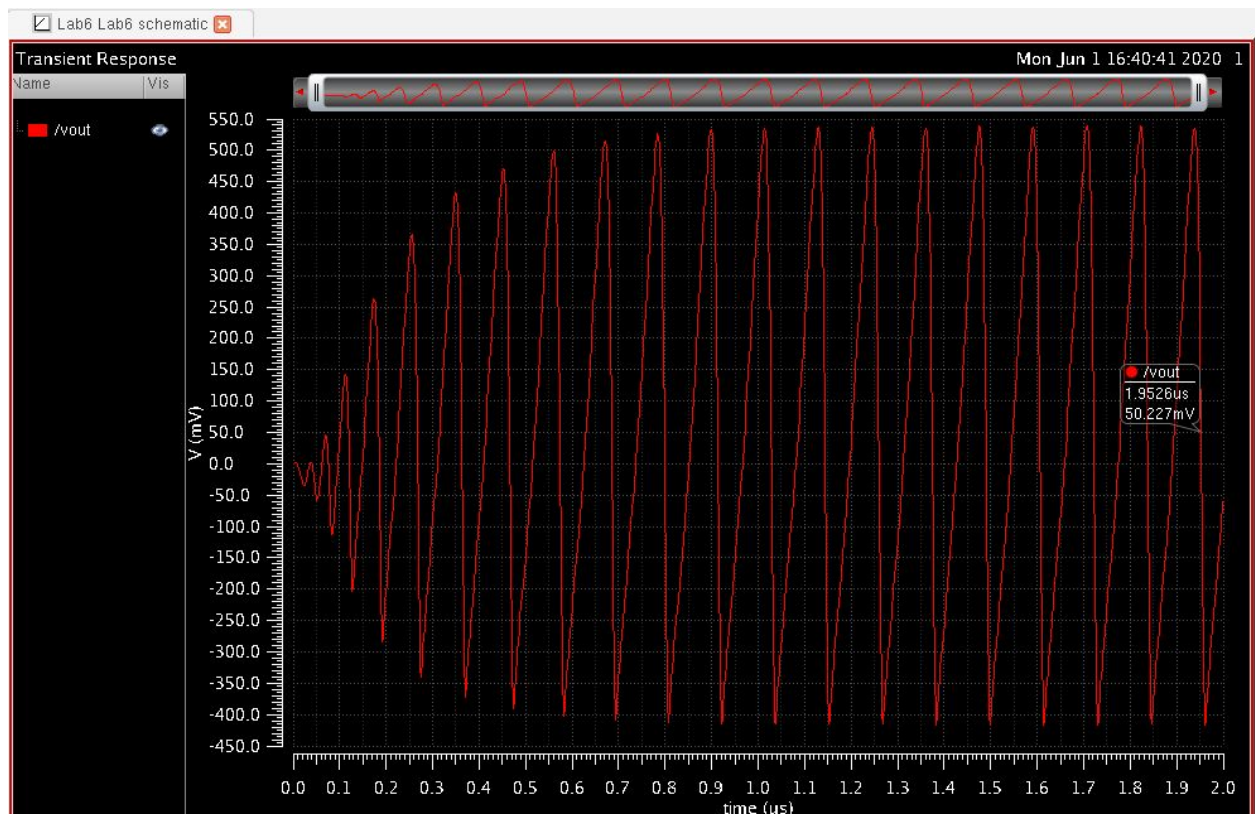
6/2/2020

SIM 1



- All transistors are in forward active since $V_{ce} = 4.4V$ which is higher than $V_{ce(sat)} = 0.2V$.
- The simulated values for the collector currents are similar to the actual values of $10\mu A$ and $100\mu A$. The simulated values are $10.27\mu A$ and $102.9\mu A$.
- The simulated values for the DC voltages are close to zero with $V_- = 0V$ and $V_{out} = -61\mu V$
- Resistor in 1st stage:
 - $R_{ref} = 4.3V/10\mu A = 430k\Omega$
- Resistor in 2nd stage:
 - $R_{ref2} = 4.3V/100\mu A = 43k\Omega$

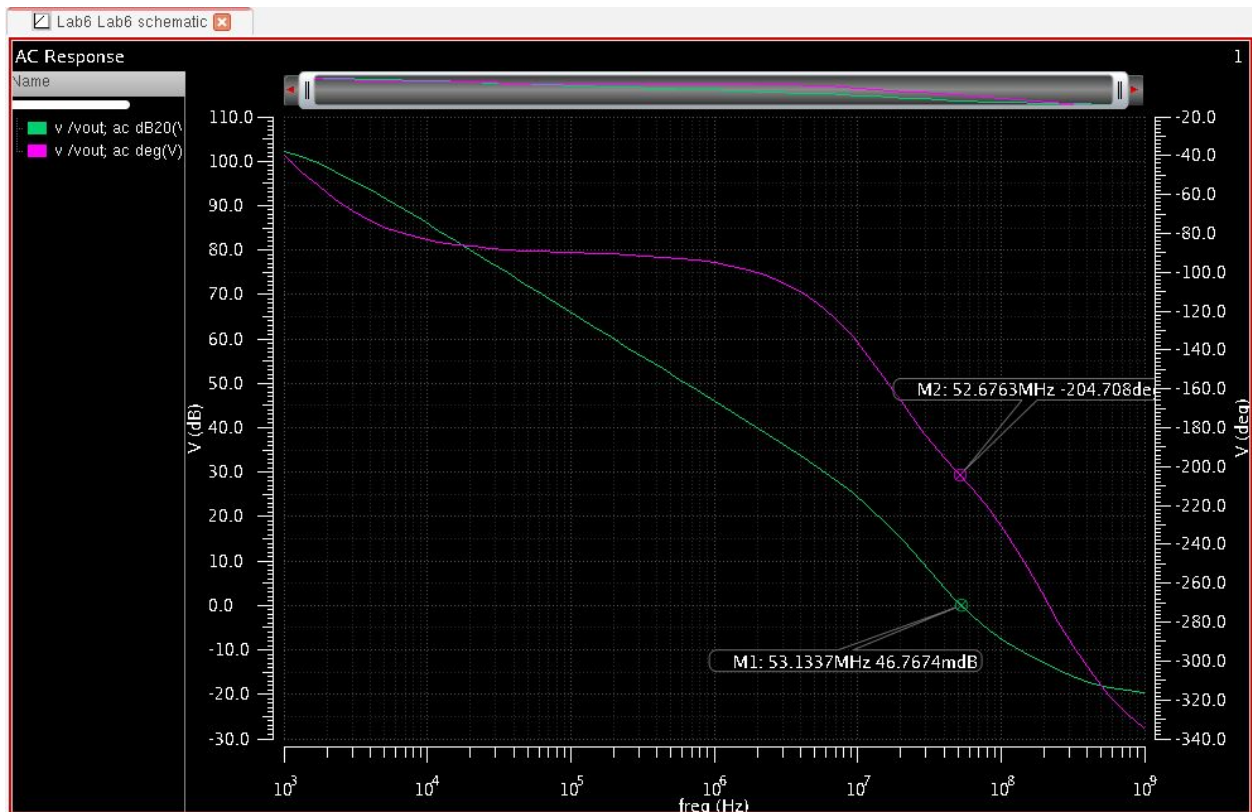
SIM 2



- The output is oscillating which indicates that the circuit is unstable.

SIM 3

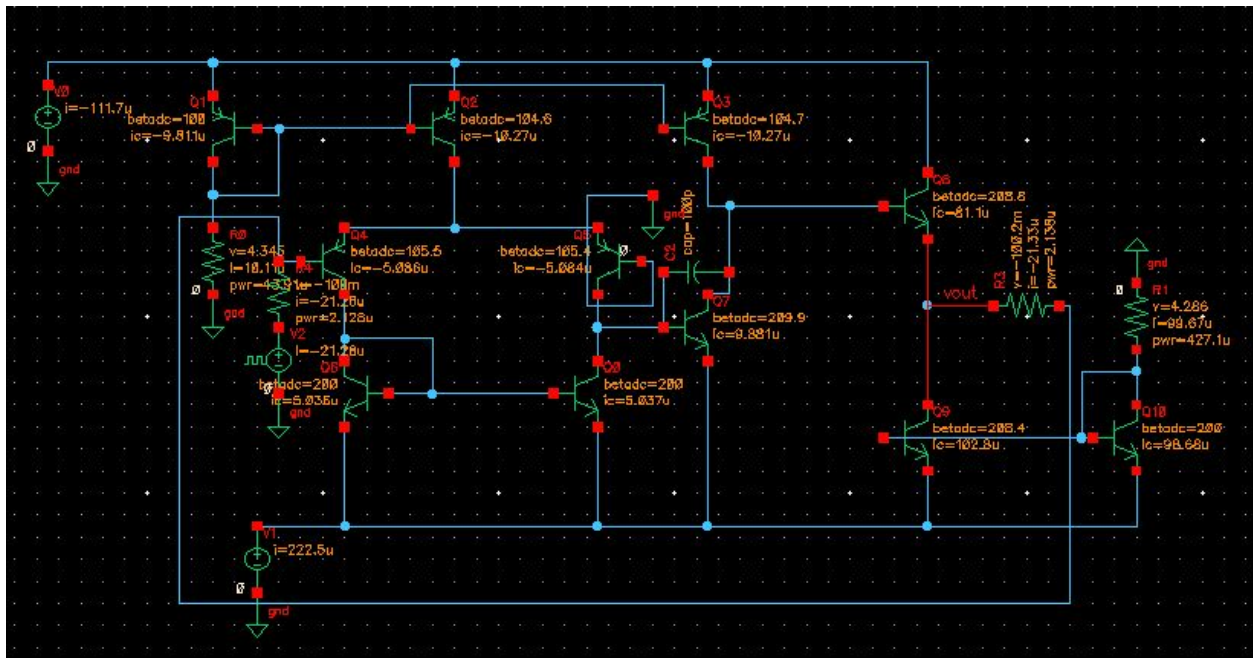
Magnitude and Phase of Op-Amp



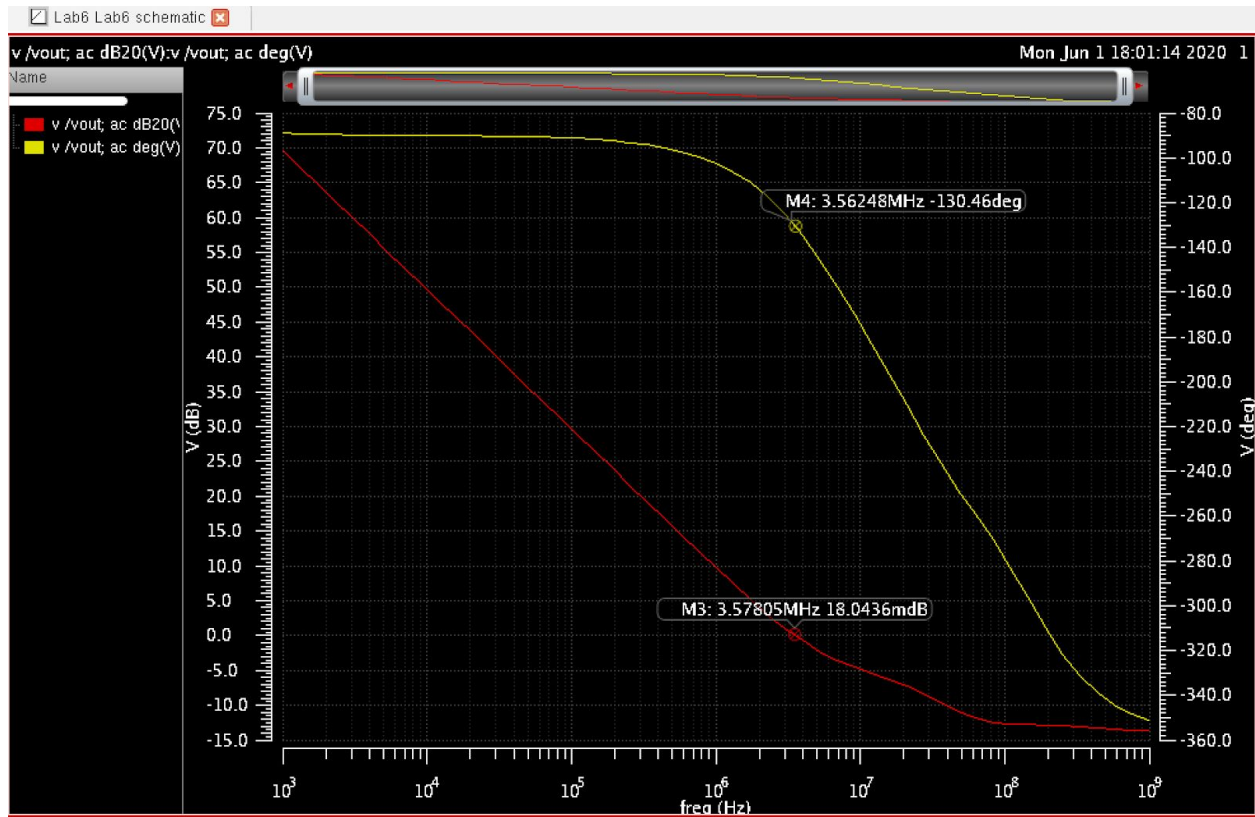
- Unity gain frequency (near 0dB): **53.12MHz**
- Phase (near 53.12MHz): **-204.7°**
- Phase Margin: $-204.7^\circ - (-180^\circ) = -24.7^\circ$
 - Since the phase margin is negative the circuit is unstable.

SIM 4

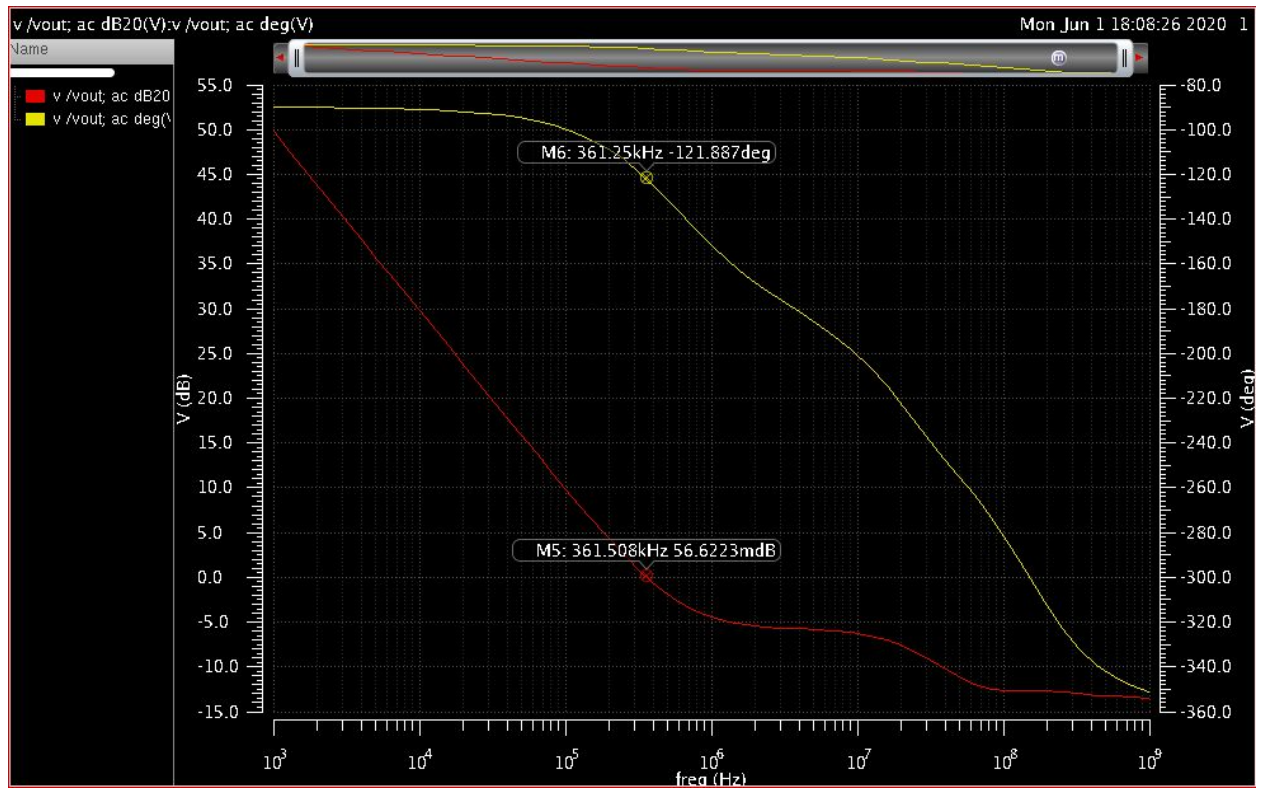
Compensate the Amplifier



- Additional capacitors need to be added to the circuit
 - $C_c = 10\text{pF}$
 - Dominant Pole:
 - $P_c = 1/\text{rout} * C_c(1+A_2)$
- Phase Margin: $\text{phase}(\omega_0) - (-180^\circ) = 60^\circ$
 - PM = -120° (theoretical value)

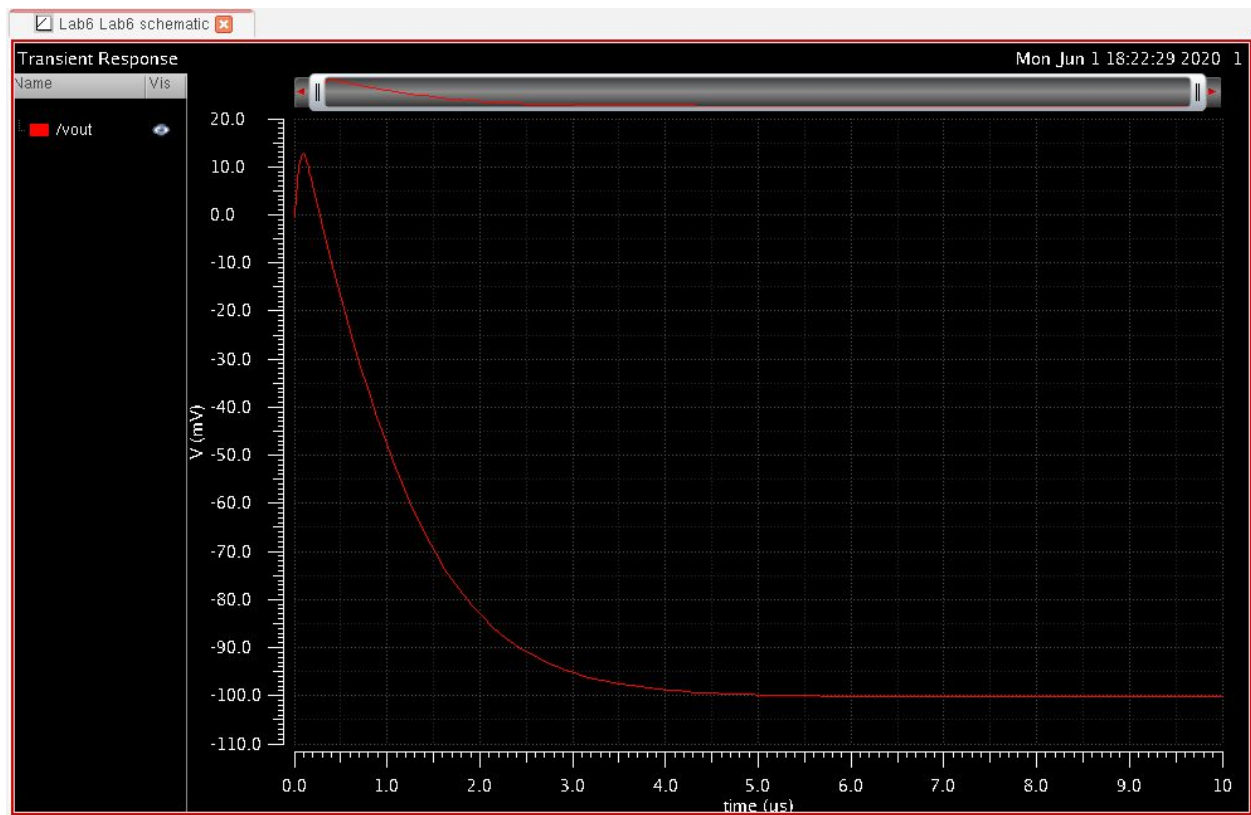


- Phase Margin: $-130.4^\circ - (-180^\circ) = 49.6^\circ$
 - Although the phase margin is now positive and the circuit is stable, it is not at 60° . In order for there to be a 60° phase margin, the value of the capacitor needs to be increased.



- $C_c = 100\text{pF}$
- Phase Margin: $-121.8^\circ - (-180^\circ) = 58.2^\circ$
 - This value is close to the 60° phase margin.

SIM 5



- After compensation, there is no oscillation in the circuit which means the circuit is now stable. Since V_{pulse} is added to the input, the transient response increases to about 14mV and flat lines around -100mV due to the negative feedback.

Conclusion

In this circuit we were asked to design inverting amplifiers to observe the transient response of the op-amps. When capacitors are not present in the circuit the output waveform is oscillating, meaning the circuit is unstable. We used two different inputs, V_{pulse} and V_{ac} to prove that the circuit is unstable. We looked at the magnitude and phase plots to determine the phase margins. A negative phase margin indicates that the circuit is unstable. After adding capacitors to the circuit, we see that the phase margin becomes positive. However, in order to get a 60° phase margin the value of the capacitor needs to be increased. We increased the values of the capacitor from 10pF to 100pF. Through compensation, the circuit becomes stable.