**A REPORT ON**

# ANALOG CIRCUIT DESIGN ASSIGNMENT

**ANALOG AND DIGITAL VLSI DESIGN**

**SUBMITTED BY**


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Submitted in partial fulfillment of the course

**EEE/INSTR F313 - Analog and Digital VLSI Design**


**Birla Institute of Technology and Science - Pilani**
**29th October, 2020**
**Problem Statement No. 48**

# INDEX



## INTRODUCTION

Problem Statement:

**Ques 48**. Design a Two stage single-ended output CMOS OPAMP with a -3dB bandwidth of 5MHz.

(a) Analog schematic for OPAMP (choose appropriate OPAMP).
(b) Analysis of all equations for OPAMP, with a systematic derivation of all transistors W/L ratios. (Do not use hit-an-trial method)
(c) What is the settling time for your OPAMP?
(d) What is the closed loop gain and phase margin for your OPAMP using STB analysis?
(e) Calculate and plot the following parameters for your OPAMP: DC gain, Bode plot for AC gain and phase, CMRR plot, ICMR plot, PSRR plot, slew rate, settling time, output voltage swing (dc + Transient), power consumption, and input and output offset voltage.

## DESIGN SPECIFICATIONS

| | |
|---|---|
| Technology | TSMC 180nm technology* |
| $V_{DD}$ | **2.5V** |
| $C_L$ | $\leq$1 pF |
| Current mirror ratios | $\leq 20$ |
| Reference Current | Single ideal current source of arbitrary value, with the positive node tied to $V_{DD}$ or negative node tied to ground |
| Power Dissipation | $\leq$ 3mW unless stated |

**MOSFET SIZING**

Channel length used = 350 nm for all MOSFETS

| MOSFET | W/L |
|---|---|
| M1, M7, M8, M9 | 60.649 |
| M4, M5, M6 | 127.45 |
| M3 | 122.87 |
| M2, M13 | 121.298 |
| M11, M14 | 30.47 |
| M10, M12 | 60.94 |

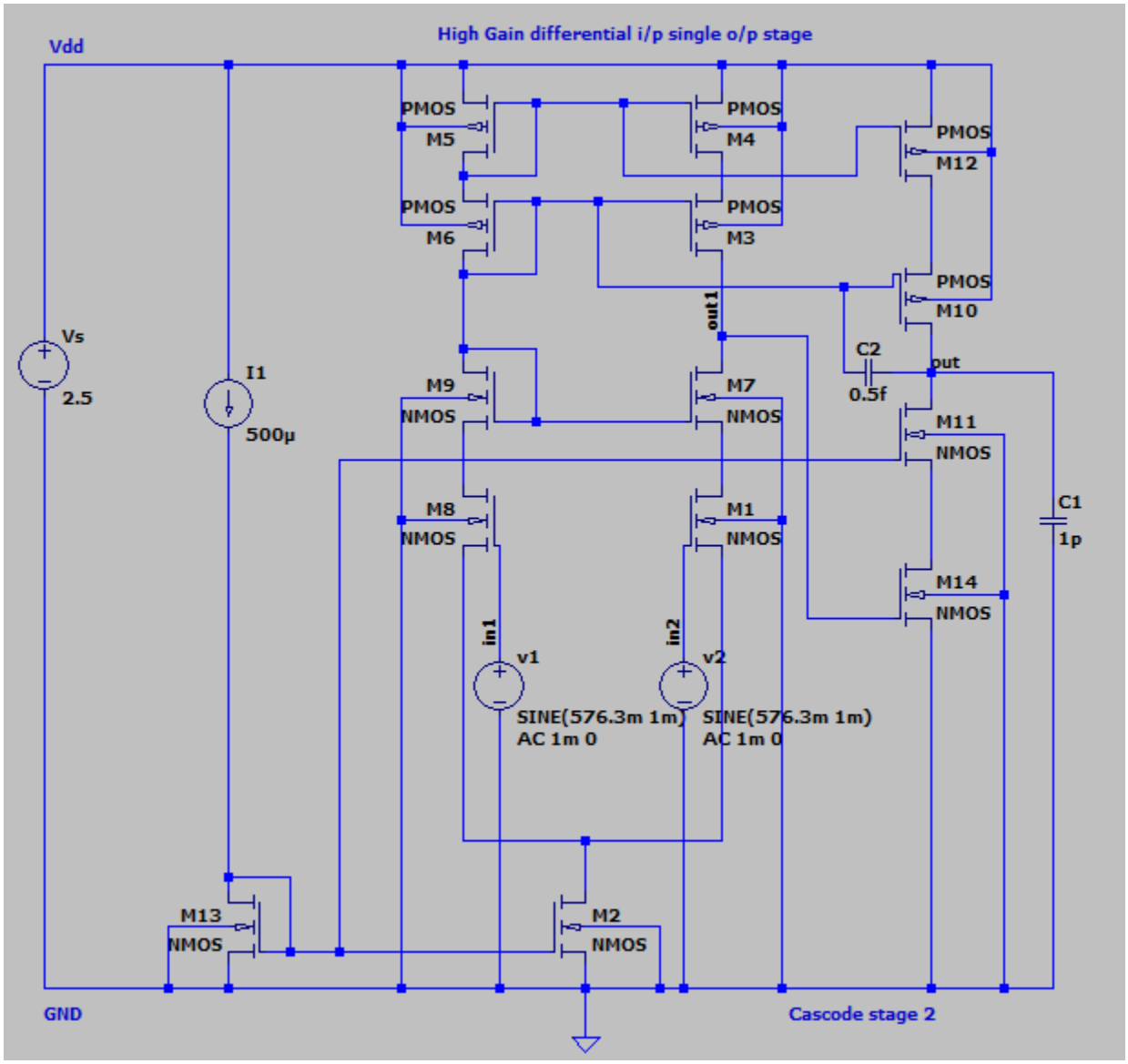
Stage 1 was used as differential amplifier with single ended output to obtain a single ended output with some gain

Stage 2 was used as a cascode amplifier in order to boost gain and obtain 3dB frequency by matching Rout

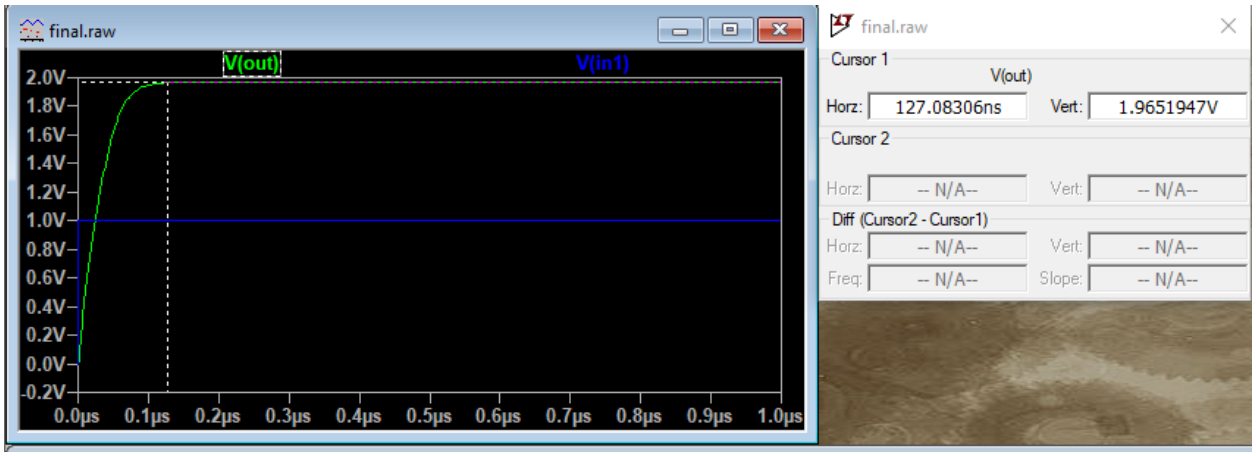
**Design Equations Used**

| Quantity | Formula |
|---|---|
| $g_m$ | $\frac{2I_D}{V_{OV}}$ |
| $r$ | $\frac{1}{\lambda I_D}$ |
| $I_D$ | $\frac{1}{2}\mu C_{ox}\frac{W}{L}(V_{GS}-V_T)^2(1+\lambda V_{DS})$ |
| CMRR | $20\,log_{10}(\frac{A_D}{A_{CM}})$ |
| PSRR | $20\,log_{10}(\frac{A_D \Delta Vsupply}{\Delta Vout})$ |

Schematic Diagram

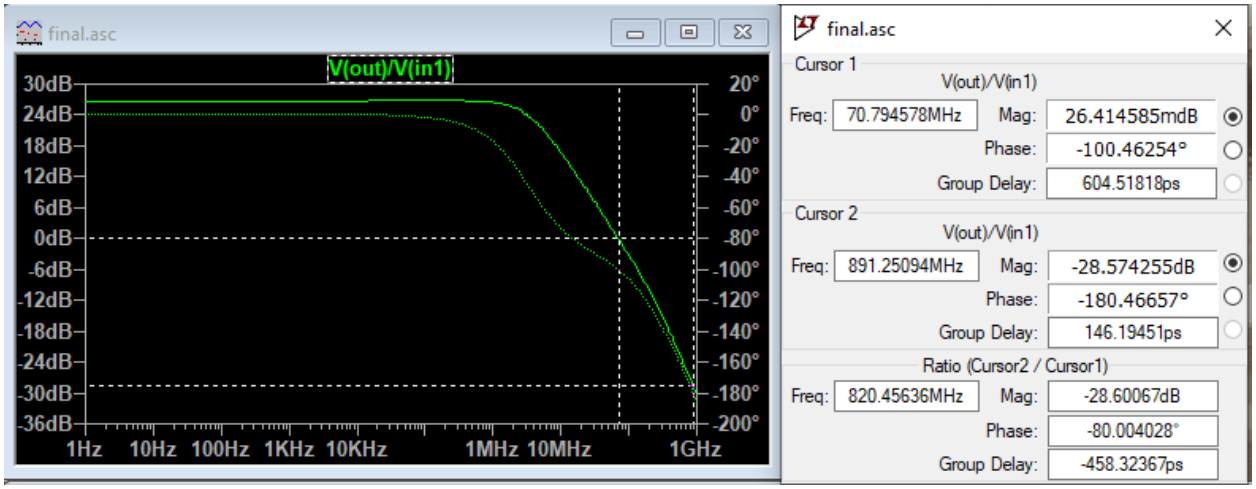


## SETTLING TIME ANALYSIS




***Settling time = 0.127 us  (non-inverting feedback configuration)***
***Slew Rate = 2960 V/us***

## CLOSED LOOP GAIN AND PHASE MARGIN




We connect the op-amp in a closed loop fashion and use miller compensation capacitor of 0.5f to adjust for Gain and Phase margin

***Phase Margin = 79.537 degrees***
***Gain Margin = 28.60067 dB***

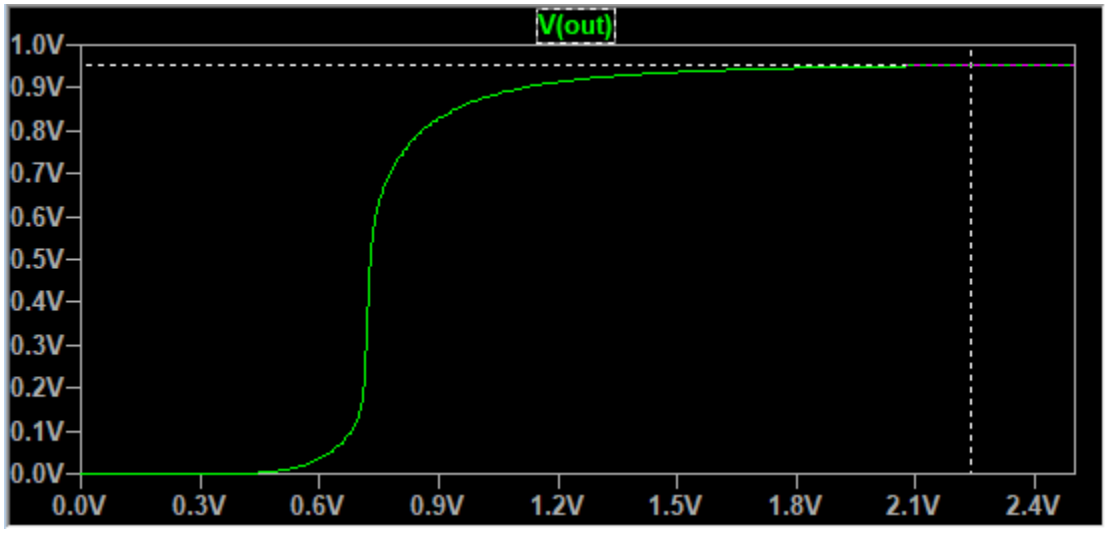
## OTHER PARAMETERS

### 1) AC Gain and Phase


***Max Gain = 60.9 dB***

***3 dB frequency = 5.248 MHz (target was 5 MHz)***

### 2) ICMR plot

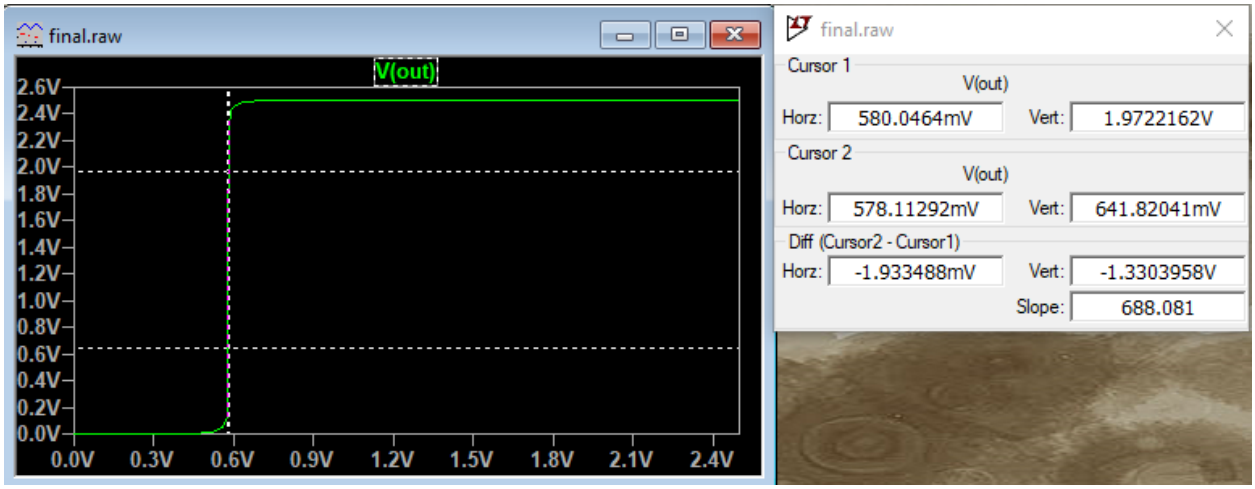


***ICMR = 0.952 volt***

### 3) CMRR Plot

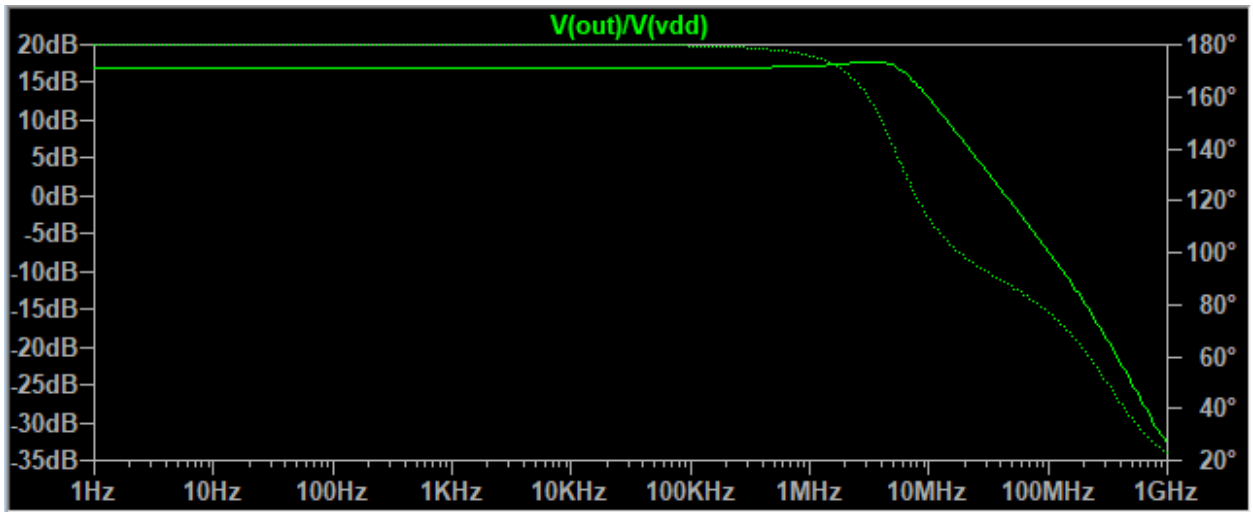

**CMRR = 26.88 dB**

### 4) DC Gain



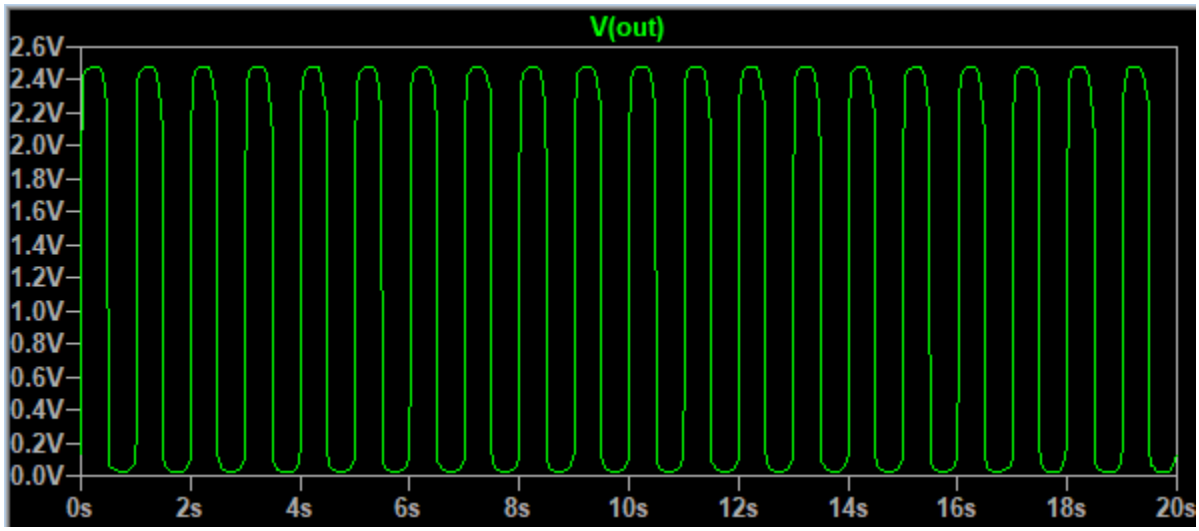

***DC Gain = 688.081 (slope of VTC)***

5) **PSRR**




***PSRR = 17dB***

6) **Output Voltage Swing**




**AC**

**DC Swing can be seen from VTC (0 to 2.5 volts)**

7) **Power Consumption**

**Is(M5): 4.78678e-05 device_current**
**Is(M4): 4.8014e-05 device_current**
**Is(M12): 2.3021e-05 device_current**
**I(bias): 50e-5**

**Power = 1.547 mW (within the 3mW budget)**

8) **Input Offset Voltage = 0.5763 volt**
9) **Output Offset Voltage = 0.131584 volt**

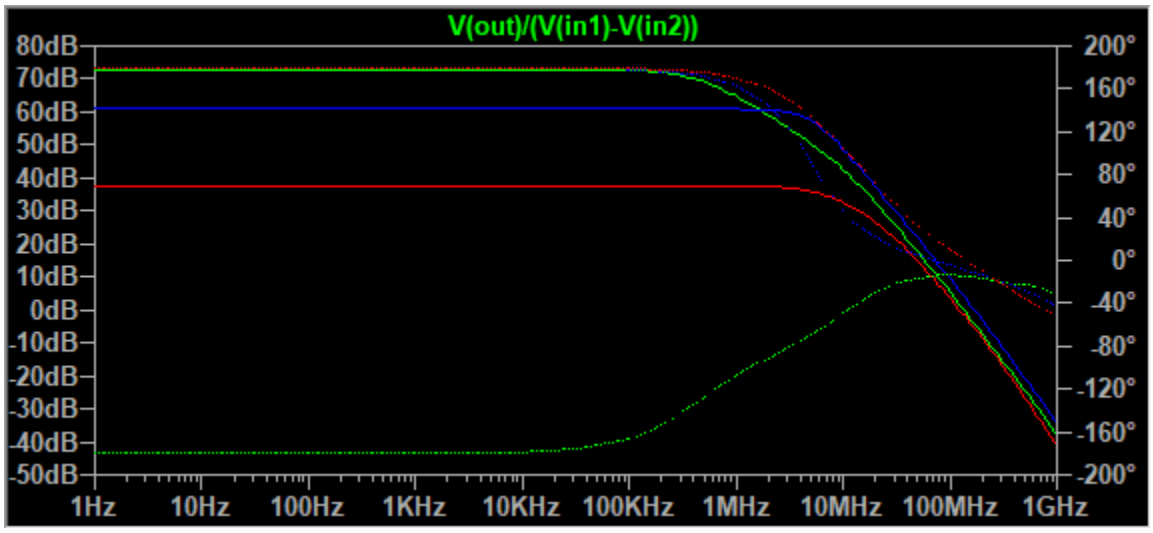
| Parameter | Target | Achieved |
|---|---|---|
| Open Loop Gain | - | 60.9 dB |
| 3dB Frequency | 5 MHz | 5.248 MHz |
| ICMR | - | 0.952 volt |
| Power Consumption | <= 3mW | 1.547 mW |
| CMRR | - | 26.88 dB |
| PSRR | - | 17 dB |
| Gain Margin | - | 28.60067 dB |
| Phase Margin | 50-60 degrees | 79.537 degrees |
| DC Gain | - | 688.081 |

**INNOVATION**

1) We added a compensation capacitor (Miller Compensation) to obtain such a high 3dB frequency.

2) Normally people use Common Drain stage for Output Impedance matching, but we used a Cascode for the same, so that we get both gain as well as output impedance, which helped in setting the 3dB frequency, as cascode offers high Rout.

## TEMPERATURE EFFECTS ON Adm




**100 degrees**
**27 degrees**
**0 degrees**