ANALOG INTEGRATED CIRCUITS [15ES4GCAIC]

SELF STUDY

in

ELECTRONICS AND COMMUNICATION ENGINEERING

by

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Question 1

Plot the frequency response curve for any practical circuit using 741 op-amp and verify the following equation:

$$(Bandwidth * Gain)_{openloop} = (Bandwidth * Gain)_{closedloop}$$

Solution

For Open Loop configuration, the $Bandwidth * Gain = 5 \times 2 \times 10^5 = 1MHz$

Gain is represented in decibels. $Gain_{dB} = 20 \log_{10} Gain$
We have used Bode plot to represent the plot of $|Gain|\ vs.\ Frequency$
The circuit shown is an inverting amplifier.
From the graph, in Closed Loop configuration:

- $Bandwidth = 96.619kHz$
- $Gain = 10^{22.973/20} = 14.081$

$\therefore (Bandwidth * Gain)_{closedloop} = 1.36MHz \approx (Bandwidth * Gain)_{openloop}$

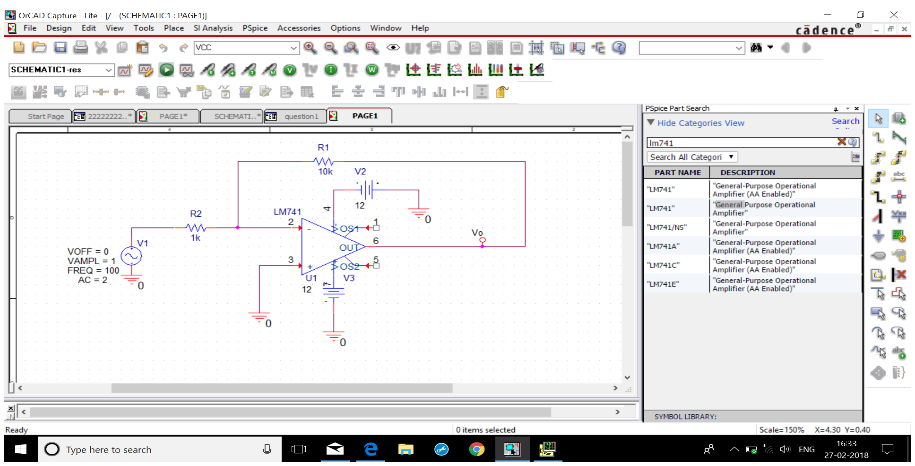

Figure 1: Circuit Diagram

Figure 2: Graph

Question 2

Calculate various DC and AC electrical parameters for a given OPAMP and verify the same with various datasheet.

Solution

The Operational Amplifier used is LM358NS. Bias Point Analysis was performed in order to obtain the DC parameters of the circuit.Current and Voltage readings in every branch have been found.

- $Input\ Bias\ Current\ I_B = \frac{-48.23nA - 41.70nA}{2} = -44.965nA$
- $Input\ Offset\ Current\ I_{OS} = -41.70nA - (-48.23nA) = 6.53nA$
- $Input\ Offset\ Voltage\ V_{OS} = 3mV,\ V_{Output} = 962.2\mu V \approx 0V$

The values obtained are verified as per the datasheet given below.

6.5 Electrical Characteristics for LMx58

at specified free-air temperature, V_{CC} = 5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS(1)	T_A(2)	LM158 LM258 MIN	TYP(3)	MAX	LM358 MIN	TYP(3)	MAX	UNIT
V_{IO}	Input offset voltage	V_{CC} = 5 V to MAX, $V_{IC} = V_{ICR(min)}$, V_O = 1.4 V	25°C		3	5		3	7	mV
			Full range			7			9	
αV_{IO}	Average temperature coefficient of input offset voltage		Full range		7			7		μV/°C
I_{IO}	Input offset current	V_O = 1.4 V	25°C		2	30		2	50	nA
			Full range			100			150	
αI_{IO}	Average temperature coefficient of input offset current		Full range		10			10		pA/°C
I_{IB}	Input bias current	V_O = 1.4 V	25°C		–20	–150		–20	–250	nA
			Full range			–300			–500	
V_{ICR}	Common-mode input voltage range	V_{CC} = 5 V to MAX	25°C	0 to V_{CC} – 1.5			0 to V_{CC} – 1.5			V
			Full range	0 to V_{CC} – 2			0 to V_{CC} – 2			
V_{OH}	High-level output voltage	R_L ≥ 2 kΩ	25°C	V_{CC} – 1.5			V_{CC} – 1.5			V
		R_L ≥ 10 kΩ	25°C							
		V_{CC} = MAX, R_L = 2 kΩ	Full range	26			26			
		V_{CC} = MAX, R_L ≥ 10 kΩ	Full range	27	28		27	28		
V_{OL}	Low-level output voltage	R_L ≤ 10 kΩ	Full range		5	20		5	20	mV
A_{VD}	Large-signal differential voltage amplification	V_{CC} = 15 V, V_O = 1 V to 11 V, R_L ≥ 2 kΩ	25°C	50	100		25	100		V/mV
			Full range	25			15			
CMRR	Common-mode rejection ratio	V_{CC}= 5 V to MAX, $V_{IC} = V_{ICR(min)}$	25°C	70	80		65	80		dB
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD} / \Delta V_{IO}$)	V_{CC} = 5 V to MAX	25°C	65	100		65	100		dB
V_{O1}/V_{O2}	Crosstalk attenuation	f = 1 kHz to 20 kHz	25°C		120			120		dB
I_O	Output current	V_{CC} = 15 V, V_{ID} = 1 V, V_O = 0; Source	25°C	–20	–30		–20	–30		mA
			Full range	–10			–10			
		V_{CC} = 15 V, V_{ID} = –1 V, V_O = 15 V; Sink	25°C	10	20		10	20		
			Full range	5			5			
		V_{ID} = –1 V, V_O = 200 mV	25°C	12	30		12	30		μA
I_{OS}	Short-circuit output current	V_{CC} at 5 V, GND at –5 V, V_O = 0	25°C		±40	±60		±40	±60	mA

Figure 3: Datasheet of LM358 Operational Amplifier

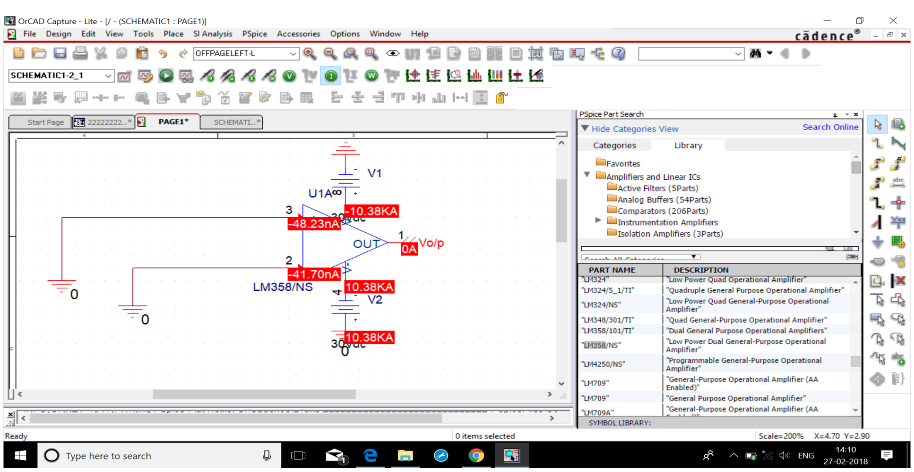

Figure 4: Circuit Diagram with Current Markers

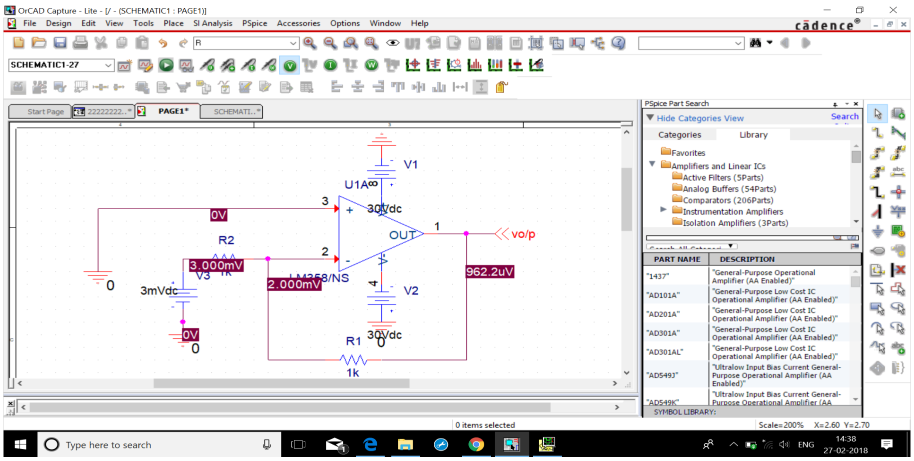

Figure 5: Circuit Diagram with Voltage Markers

Question 3

Design and simulate working of an Instrumentation amplifier for measuring temp change using wheat-stone bridge and instrumentation amplifier.

Solution

- R_4 is the Resistor which is the parameter under consideration.
- The resistance parameter is varied by graphical conditions. The resistor is analogue to the temperature.
- Assume, $R_1, R_2, R_3 = 100\Omega$ Initially $R_4 = 50\Omega$
  Assume $Gain(G) = 10 \therefore R_G = 49.4k/(G-1) = 5.488k\Omega$
- Due to supply voltage limiting factor the output of instrumentation saturates for $R_4 < 72\Omega$

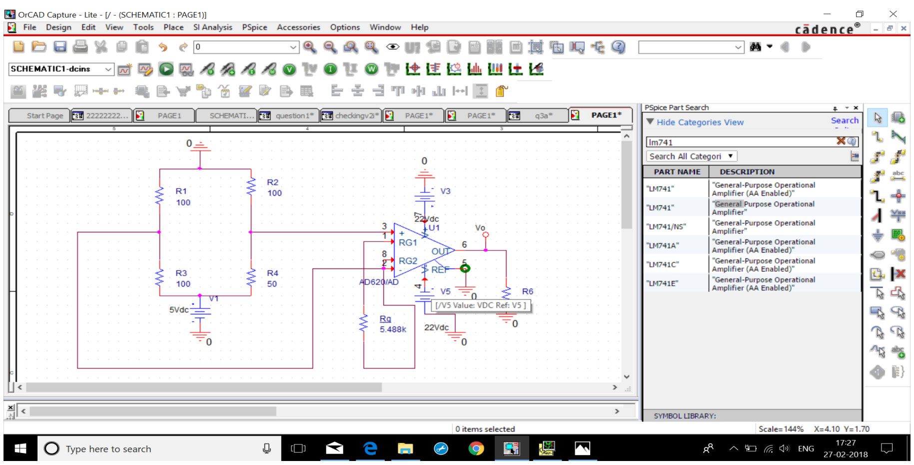

Figure 6: Circuit Diagram

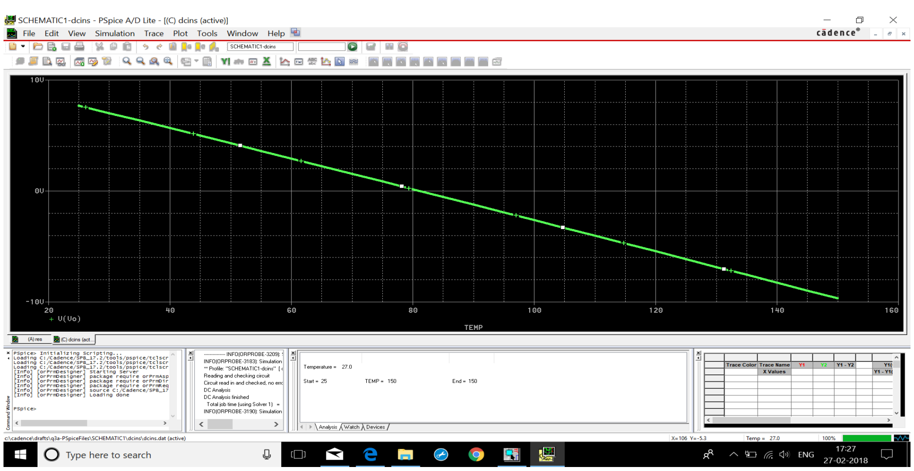

Figure 7: Graph

Question 4

Design and Simulate a V to I converter with grounded load for an application. Measure sensitivity of the circuit.

Solution

- The Operational Amplifier used is LM741 and the application specified in this circuit is an LED Tester.
- The LED and the Load Resistance are connected in parallel to each other.
- The Op-Amp is sensing the input voltage thereby producing the output voltage which in turn produces a current flowing through the load.
  where, $I_L = V_i/R_f$
- The LED glows when required amount of current flows through it.The current flowing through the LED is 0.849 mA.

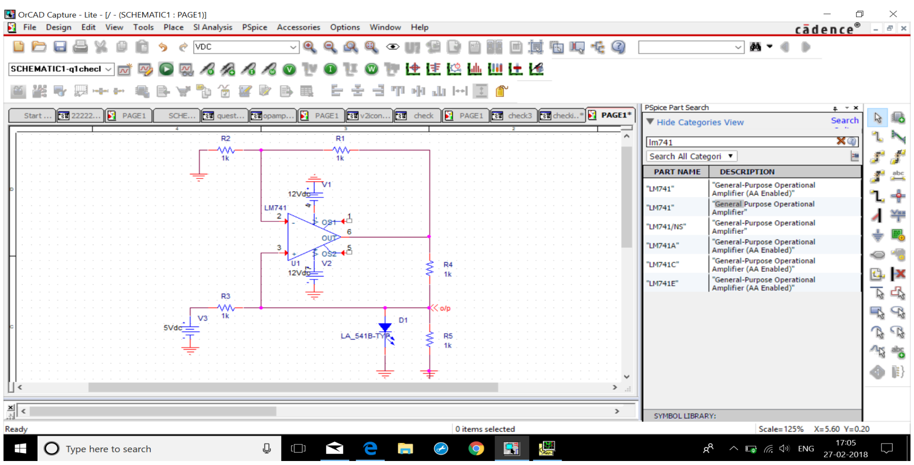

Figure 8: Circuit Diagram

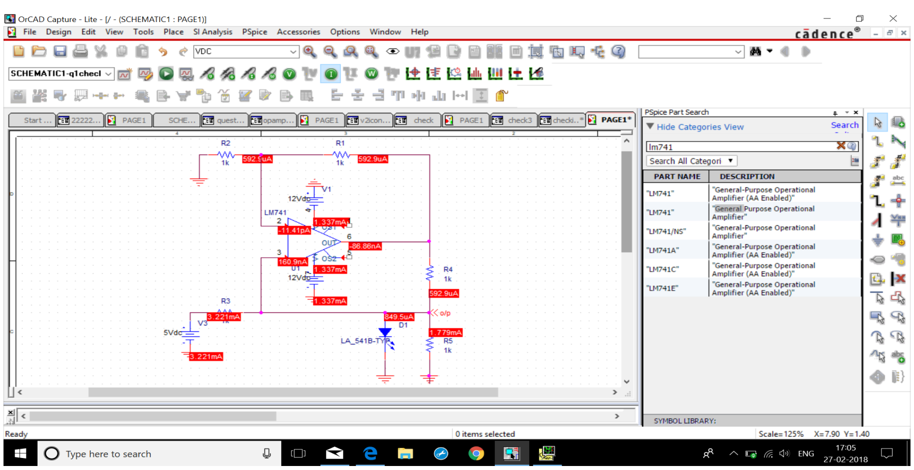

Figure 9: Circuit Diagram with Current Markers

Question 4 continued on next page. . .

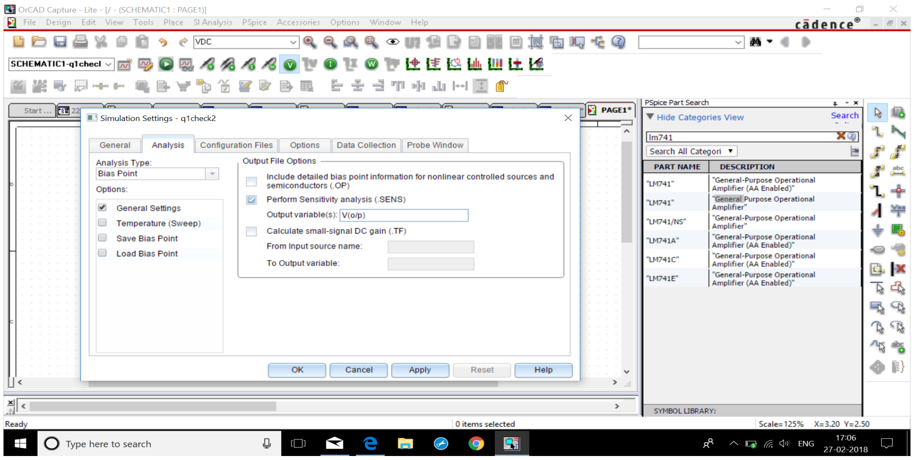

Figure 10: Simulation Settings

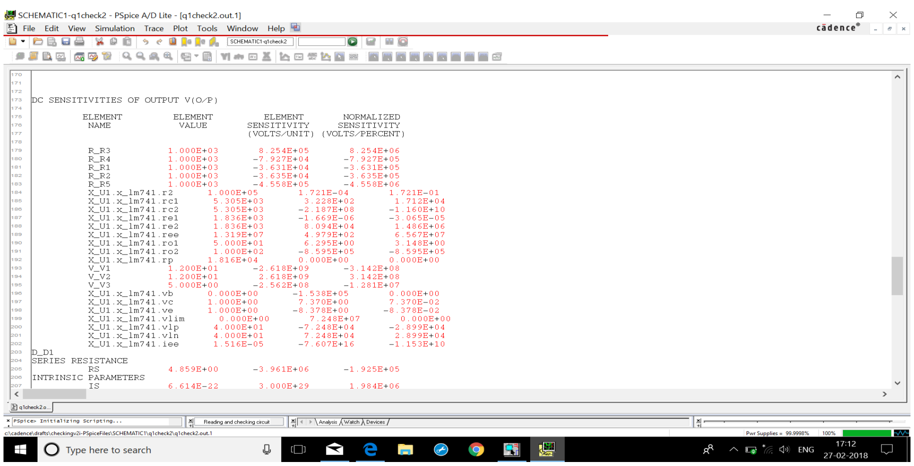

Figure 11: Output File

Question 5

Design and Simulate an experiment to Plot transfer characteristics of any practical amp.

Solution

Inverting Open Loop Configuration

- The practical Operational Amplifier LM101A was used for this simulation experiment
- An input voltage of 0.7 V is provided to the inverting terminal. The non-inverting terminal is grounded.
- The circuit was constructed as show in Figure 12.

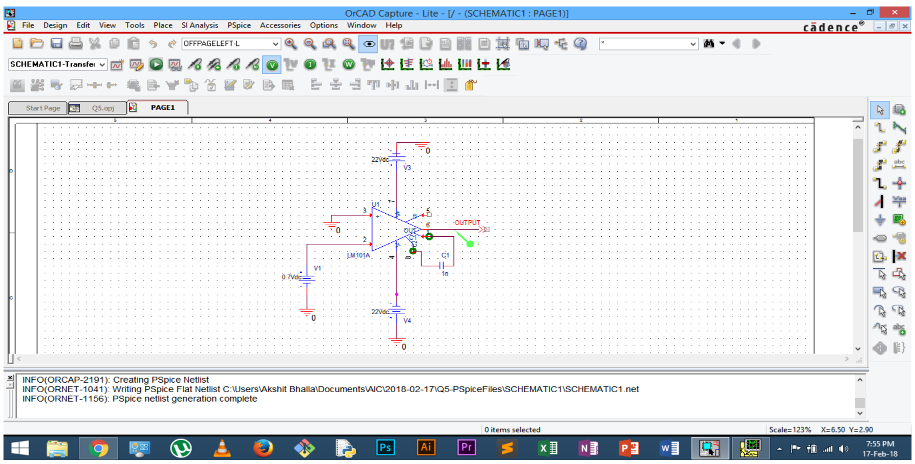

Figure 12: Circuit Diagram

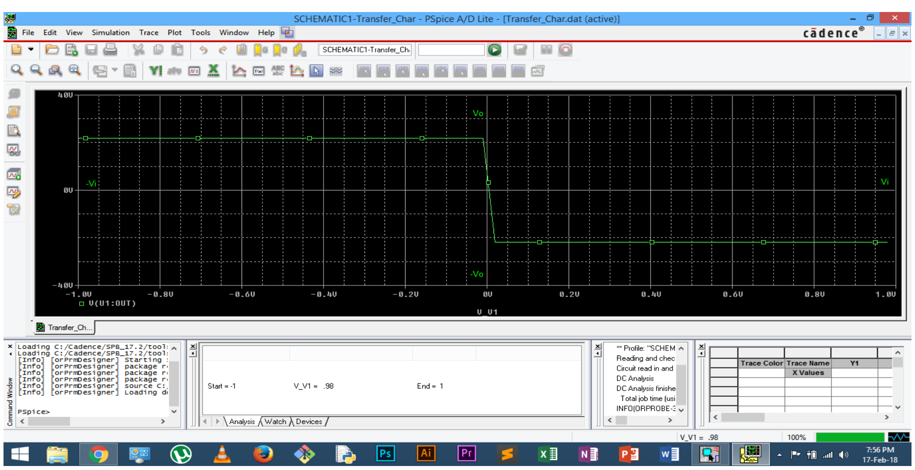

Figure 13: Transfer Characteristics

Open Loop Configuration with Inverting and Non-Inverting Inputs - 1

- The practical Operational Amplifier LM101A was used for this simulation experiment
- An input voltage of 0.7 V is provided to the inverting terminal and 0.3 V to the non-inverting terminal. $V_{inv} > V_{non-inv}$
- The circuit was constructed as show in Figure 14.

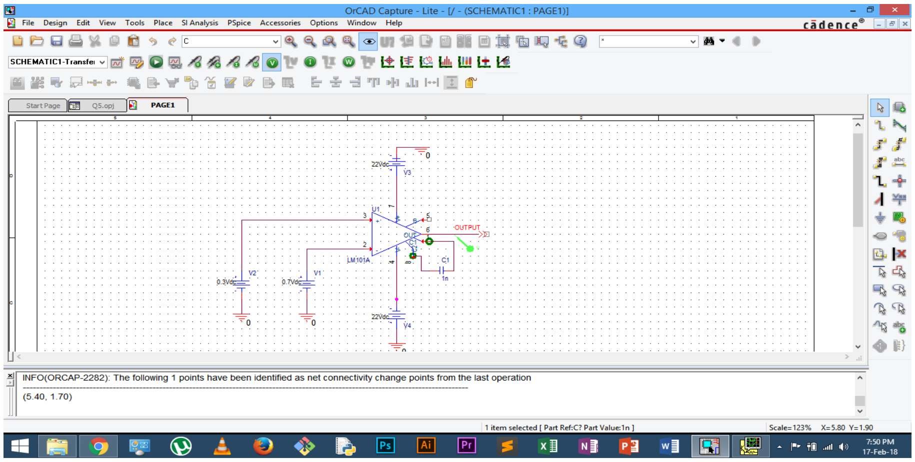

Figure 14: Circuit Diagram

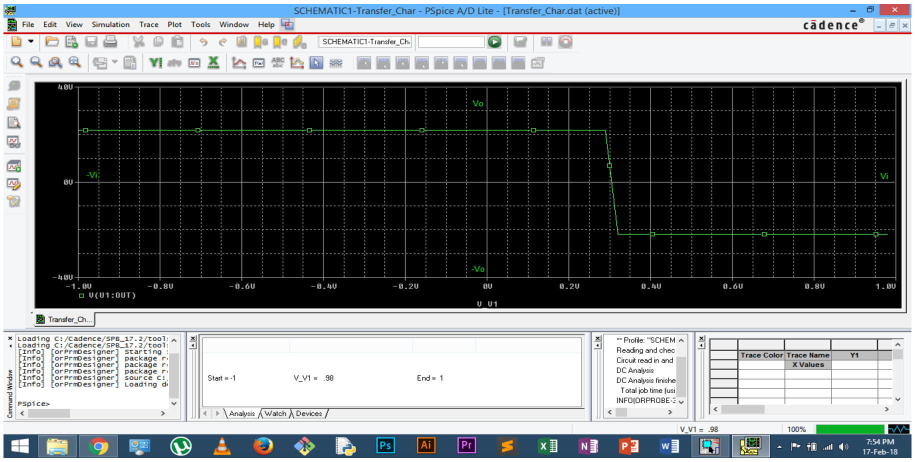

Figure 15: Transfer Characteristics

Open Loop Configuration with Inverting and Non-Inverting Inputs - 2

- The practical Operational Amplifier LM101A was used for this simulation experiment
- An input voltage of 0.3 V is provided to the inverting terminal and 0.7 V to the non-inverting terminal. $V_{inv} < V_{non-inv}$
- The circuit was constructed as show in Figure 16.

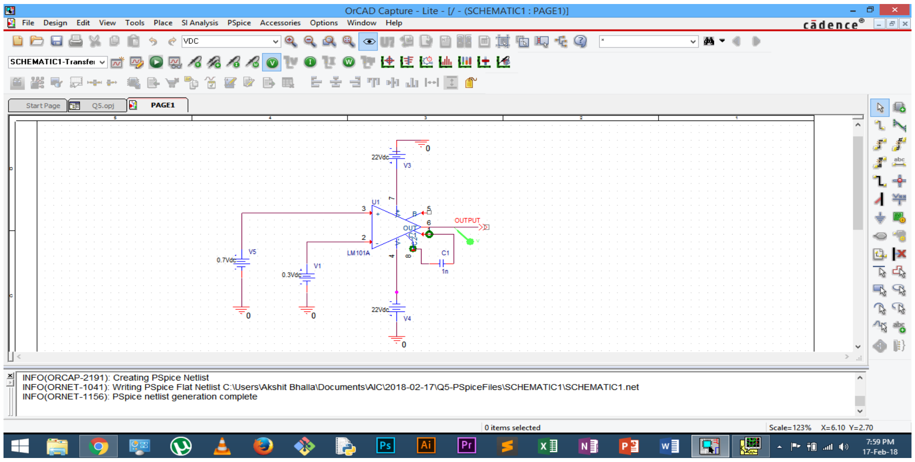

Figure 16: Circuit Diagram

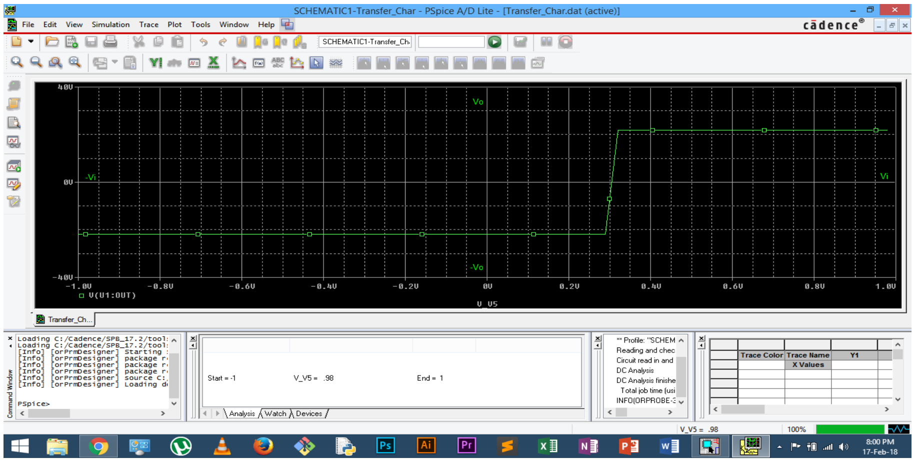

Figure 17: Transfer Characteristics

Conclusion

- Graphs for open loop gain and closed loop gain could not be merged together on the same graph.
- The Op-Amp could not be modeled internally to change the pre-defined parameters.
- The 3 Op-Amp instrumentation amplifier could not be simulated since the maximum number of nodes in the circuit should be ≈ 75. Instead a built-in instrumentation amplifier was used.