VL804 Analog Power IC Design

Lab Assignment-1

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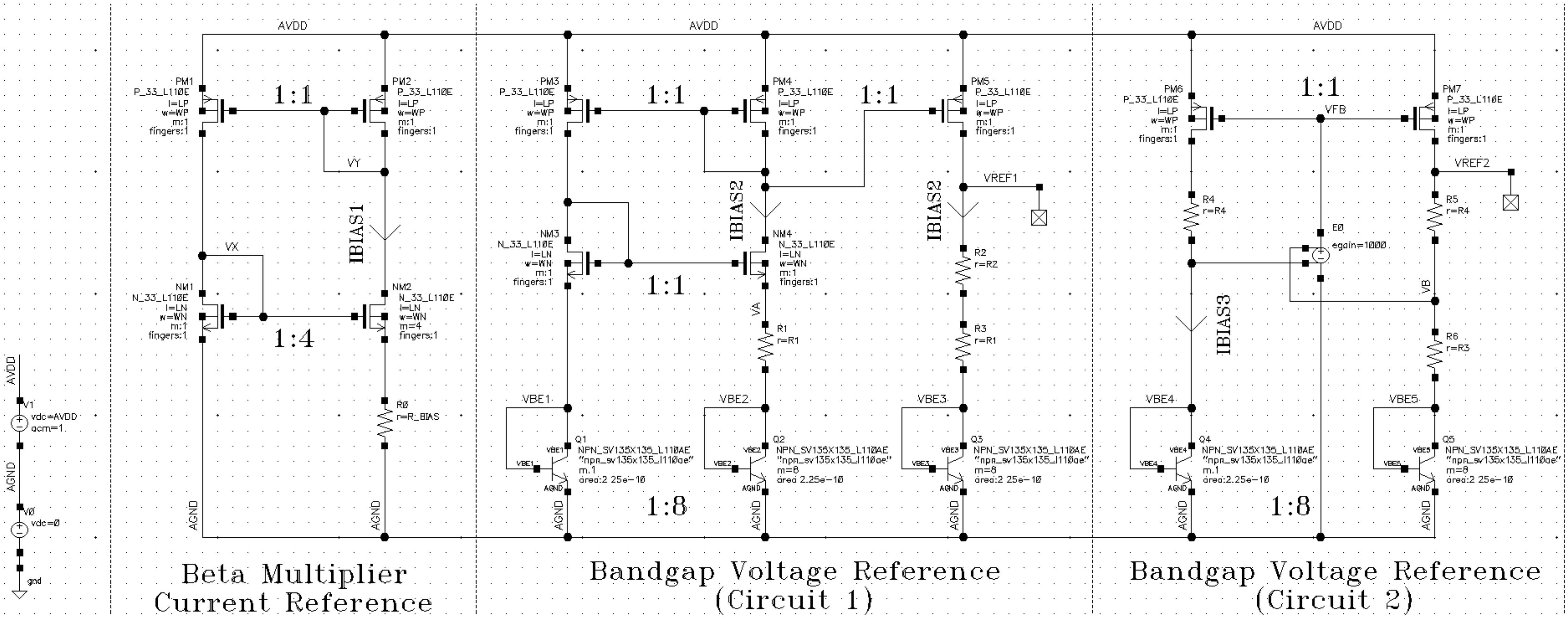
3.3V Transistor Parameters

Model File:
/Cadence_Work_110nm/_G-01-LOGIC_MIXED_MODE11-1P8M-MMC_AL_L110AE/Designkits/Cadence_IC6/umc110ae/../Models/Spectre/**l110ae_33_v102.lib.scs**

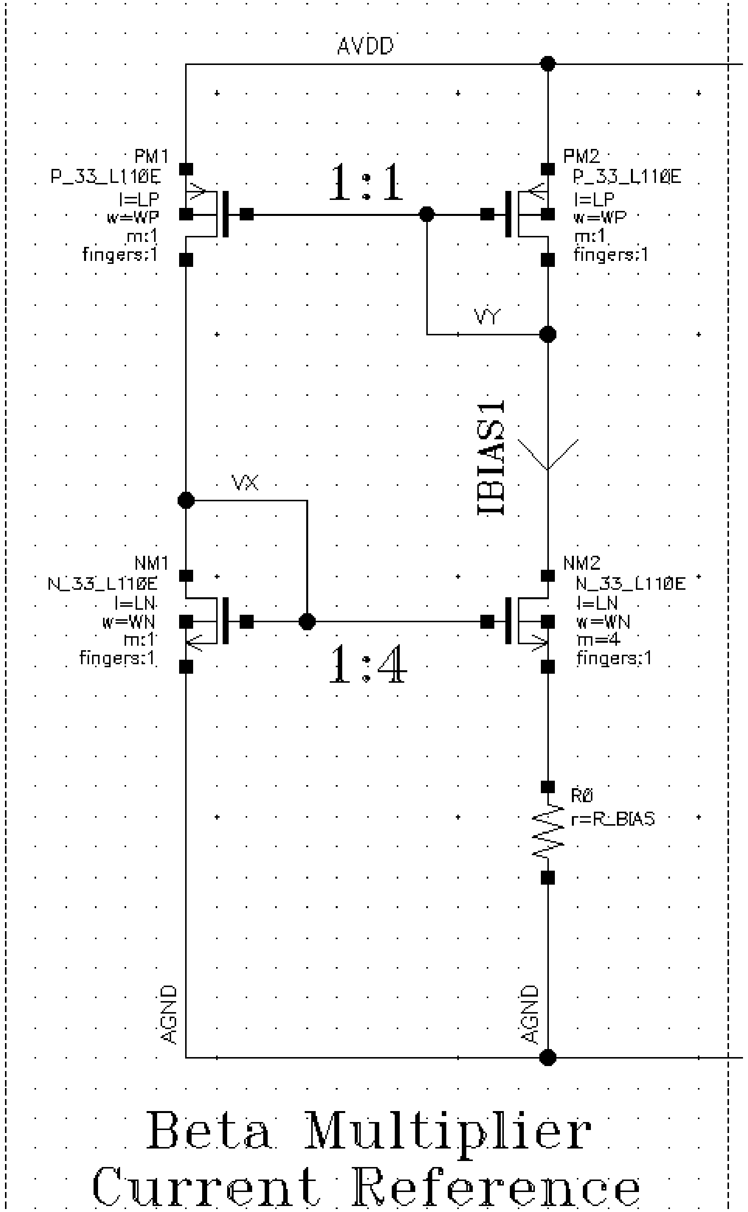
	Unit	N_33_L110E	P_33_L110E
L	um	8	8
Tox	nm	8	8
Cox	fF/um^2	4.60	4.60
u	$M^2/V/s$	0.0363	0.0097
Vth	V	0.6	0.6
Lambda	V^{-1}	0.0110	0.0065
Kfit		0.7733	0.7733

Physical Constants		
Permittivity of free space	F/m	8.854E-12
Relative permittivity of SiO2		3.9
Relative permittivity of Si		11.7
Boltzmann constant, (k)	J/K	1.38E−23
Charge of electron, (q)	C	1.602E−19

Assignment Test-Bench (Schematic)



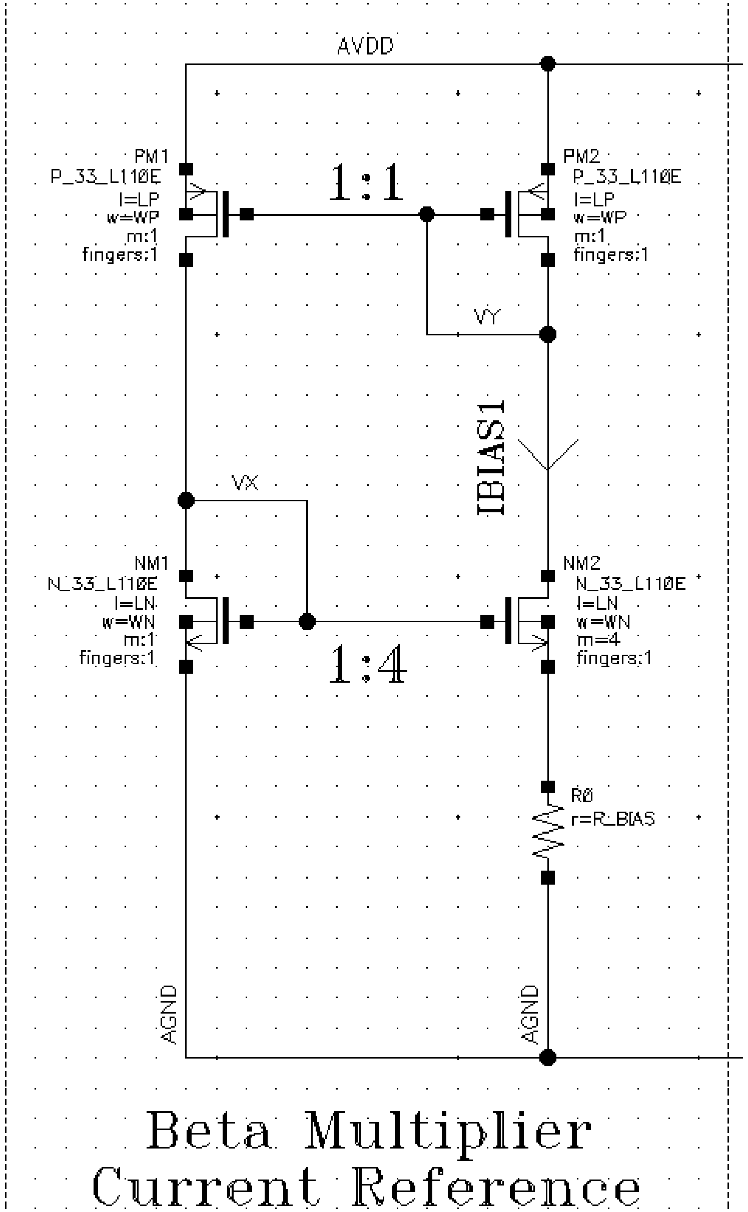
Beta Multiplier Current Reference



- Use "analogLib" resistors and capacitors.
- Given AVDD = 3.0 V, Over-drive voltage (V_{OV}) of 0.2 V for transistors, and L = 8 µm.
- Calculate the value of "R_BIAS", "WN", & "WP" for IBIAS = 100 nA. Use $\beta = [K_{fit} * \mu * C_{ox} * (W/L)]$ to calculate "R_BIAS".

- Perform DC operating point simulation with a temperature sweep from -40°C to 150°C and evaluate the following,
  - Plot IBIAS versus temperature across AVDD = 2.4V, 3.0V, 3.6V, and slow, typical, fast process corners
  - VTH_NM1 @ -40°C, 27°C, and 125°C
  - Gm_NM1 @ -40°C, 27°C, and 125°C
  - IBIAS @ 27°C
  - Average slope of IBIAS with respect to temperature

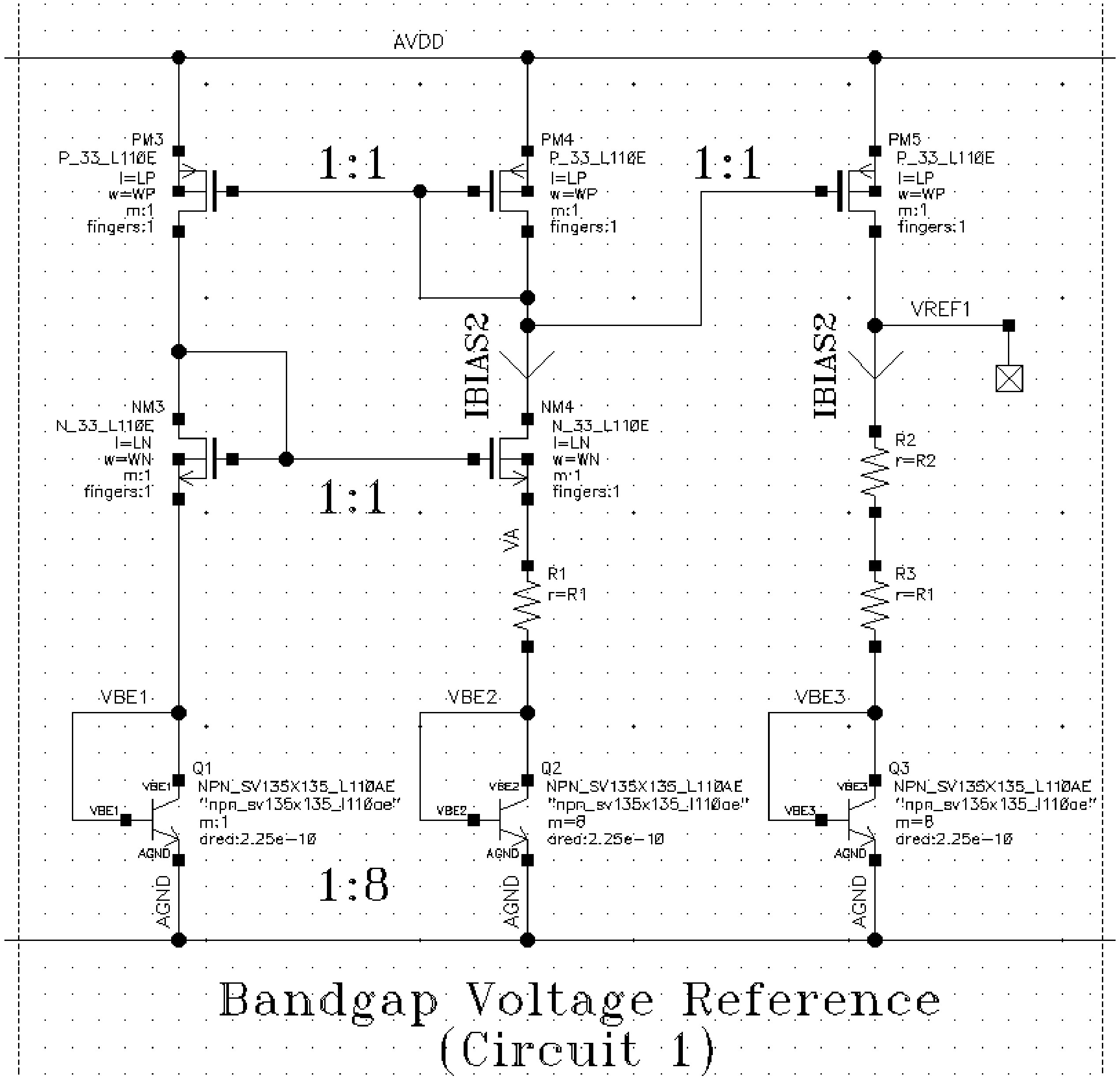
Beta Multiplier Current Reference



- Comment on the results of Gm_NM1 and IBIAS across PVT corners

		Slow			Typical			Fast		
AVDD		2.4 V	3.0 V	3.6 V	2.4 V	3.0 V	3.6 V	2.4 V	3.0 V	3.6 V
VTH_NM1	@ -40°C									
	@ 27°C									
	@ 125°C									
Gm_NM1	@ -40°C									
	@ 27°C									
	@ 125°C									
IBIAS	@ 27°C									
average (dIBIAS/dT)	pA/°C									

Bandgap Voltage Reference (Circuit 1)



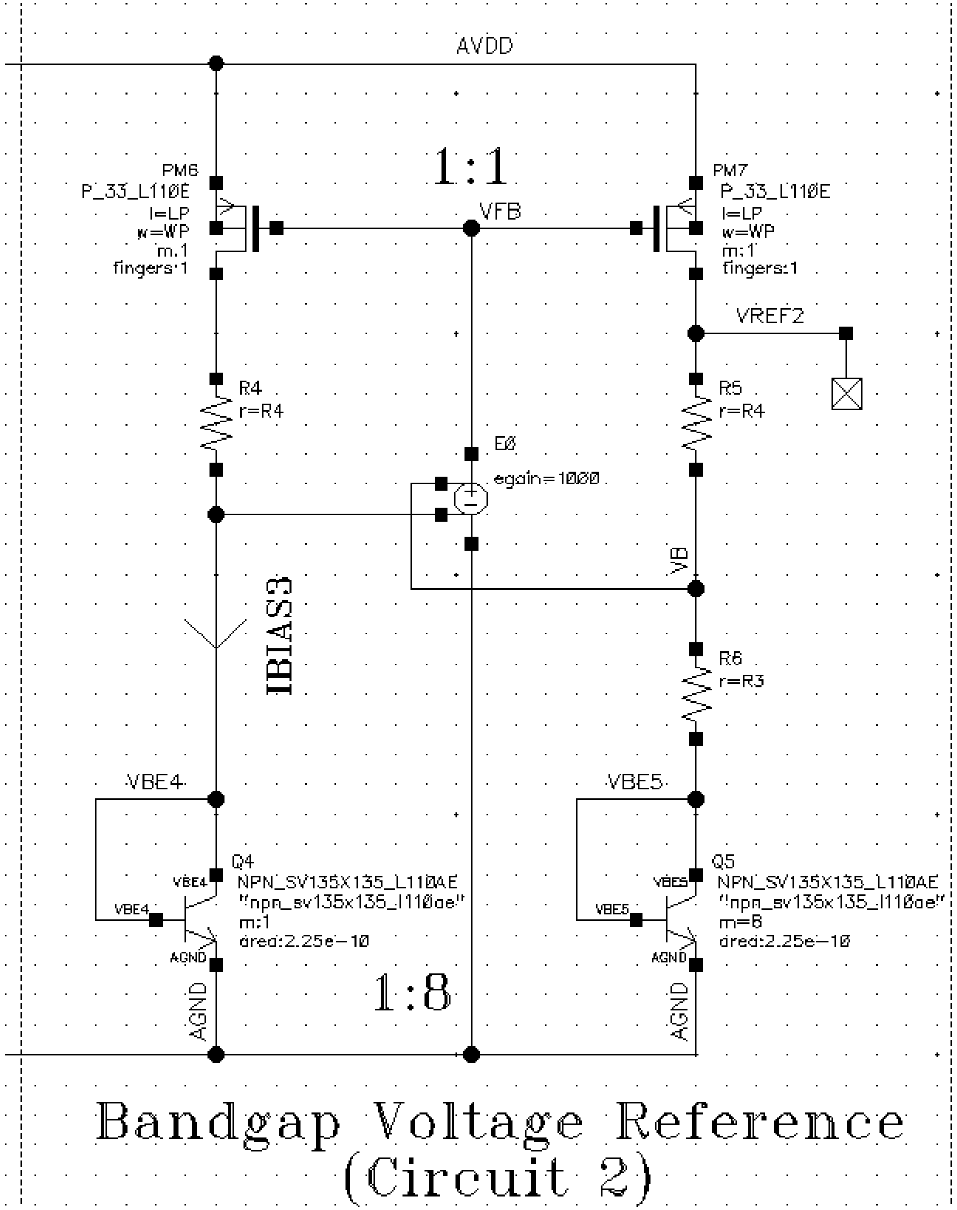
- Use "analogLib" resistors and capacitors.
- Given AVDD = 3.0 V, Over-drive voltage (V_{OV}) of 0.2 V for transistors, and L = 8 µm.
- Calculate the value of "R1" (R1 = VT*ln(8)/IBIAS1), "WN", & "WP" for IBIAS1 = 100 nA.
  - Calculate the value of "R1"
  - R2 = R1*[((dVBE3/dT)*Q/K/ln(8)) – 1]
  - Adjust the value of R2, to adjust for the errors in (dVREF1/dT) = 0 due to channel length modulation effect and other non-idealities.

Bandgap Voltage Reference (Circuit 1)

- Perform DC operating point simulation with a temperature sweep from -40°C to 150°C and evaluate the following,
  - Plot VREF1 across PVT corners

		Slow			Typical			Fast		
AVDD		2.4 V	3.0 V	3.6 V	2.4 V	3.0 V	3.6 V	2.4 V	3.0 V	3.6 V
VBE3	@ 27°C									
average (dVBE3/dT)	mV/°C									
(VA - VBE2)	mV									
average d(VA - VBE2)/dT	mV/°C									
R1	kOhm									
R2	kOhm									
IBIAS1 (nA)	@ 27°C									
average (dIBIAS1/dT)	pA/°C									
VREF1 (V)	@ 27°C									
VREF1_Max (V)										
VREF1_Min (V)										
(VREF1_Max - VREF1_Min)										
VREF1 Temp CO	ppm/°C									

Bandgap Voltage Reference (Circuit 2)



- ➢ Use "analogLib" resistors and capacitors.
- ➢ Given AVDD = 3.0 V, Over-drive voltage (V_{OV}) of 0.2 V for transistors, and L = 8 µm.

- ➢ Calculate the value of "R3" (R3 = VT*ln(8)/IBIAS2), "WN", & "WP" for IBIAS2 = 100 nA.

  - ➢ Calculate the value of "R3"
  - ➢ R4 = R3*[((dVBE5/dT)*Q/K/ln(8)) – 1]
  - ➢ Adjust the value of R4, to adjust for the errors in (dVREF2/dT) = 0 due to channel length modulation effect and other non-idealities.

Bandgap Voltage Reference (Circuit 2)

- Perform DC operating point simulation with a temperature sweep from -40^{o}C to 150^{o}C and evaluate the following,
  - Plot VREF2 across PVT corners

		Slow			Typical			Fast		
AVDD		2.4 V	3.0 V	3.6 V	2.4 V	3.0 V	3.6 V	2.4 V	3.0 V	3.6 V
VBE5	@ 27^{o}C									
average (dVBE5/dT)	mV/^{o}C									
(VB - VBE5)	mV									
average d(VB - VBE5)/dT	mV/^{o}C									
R3	kOhm									
R4	kOhm									
IBIAS2 (nA)	@ 27^{o}C									
average (dIBIAS2/dT)	pA/^{o}C									
VREF2 (V)	@ 27^{o}C									
VREF2_Max (V)										
VREF2_Min (V)										
(VREF2_Max - VREF2_Min)										
VREF2 Temp CO	ppm/^{o}C									

VL 804

Analog Power Integrated Circuits

ASSIGNMENT 1

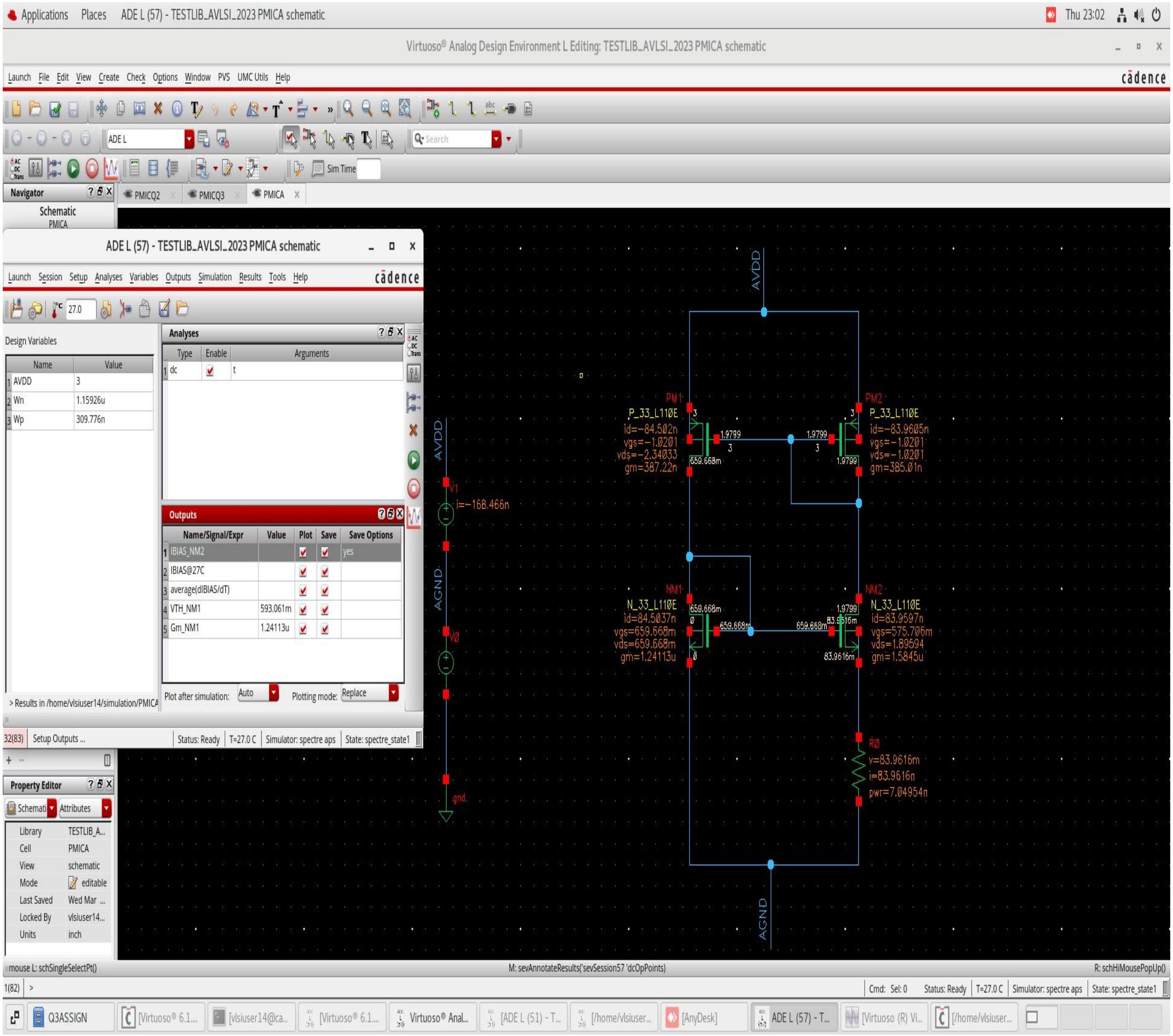
Made_By: Solanki Pratikkumar Ashokkumar

Roll_No: MT2023527

Acknowledgement: Prof. Manikandan R.R.

Q1

Schematic And DC Operating Point with ADE L



- Calculation of Width of NMOS(Wn) and PMOS(Wp) and RBIAS

Sol^n Q1

(*) Beta Multiplier Current Reference & Same for Bandgap Voltage Reference Circuit Wn & Wp values :-

Given ; AVDD = 3V ; $V_{ov} = 0.2V$; $L = 8\mu m$; $I_{BIAS} = 100nA$ @ 27°C

NMOS :
$K_{fit} = 0.7733$
$\mu_n = 0.0363\ M^2/V/s$
$C_{ox} = 4.6 \times 10^{-3}\ F/m^2$

PMOS :
$K_{fit} = 0.7733$
$\mu_p = 0.0097\ M^2/V/s$
$C_{ox} = 4.6 \times 10^{-3}\ F/m^2$

NMOS

- In saturation ;

$$\rightarrow I_{Bias_n} = \frac{K_{fit}\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_n V_{ov}^2$$

$$\therefore \frac{10^{-7} \times 2}{0.7733 \times 0.0363 \times 4.6 \times 10^{-3} \times (0.2)^2} = \left(\frac{W}{L}\right)_n$$

$$\therefore \left(\frac{W}{L}\right)_n = 38721.978\ \mu m$$

$$W_n = 38721.978 \times 8 \times 10^{-6} \times 10^{-6}$$

$$\boxed{W_n = 309.776\ nm}$$

PMOS

In saturation,

$$\rightarrow I_{Bias_p} = \frac{K_{fit}\mu_p C_{ox}}{2}\left(\frac{W}{L}\right)_p V_{ov}^2$$

$$\frac{10^{-7} \times 2 \times 8 \times 10^{-6}}{0.7733 \times 0.0097 \times 4.6 \times 10^{-3} \times (0.2)^2} = \left(\frac{W}{L}\right)_p$$

$$\left(\frac{W}{L}\right)_p = 144.908 \times 10^{-3}$$

$$\boxed{W_p = 1.159\ \mu m}$$

$$\beta_n = \mu_n C_{ox}\left(\frac{W}{L}\right)_n K_{fit}$$

$$= 0.7733 \times 0.0363 \times 4.6 \times 10^{-3} \times 38.7219 \times 10^{-3}$$

$$\boxed{\beta_n = 5 \times 10^{-6}}$$

$$\rightarrow I_{BIAS} = I_{ref} = \frac{1}{R_{BIAS}}\left(\frac{2}{\beta_n}\right)\left(1 - \frac{1}{\sqrt{k}}\right)$$

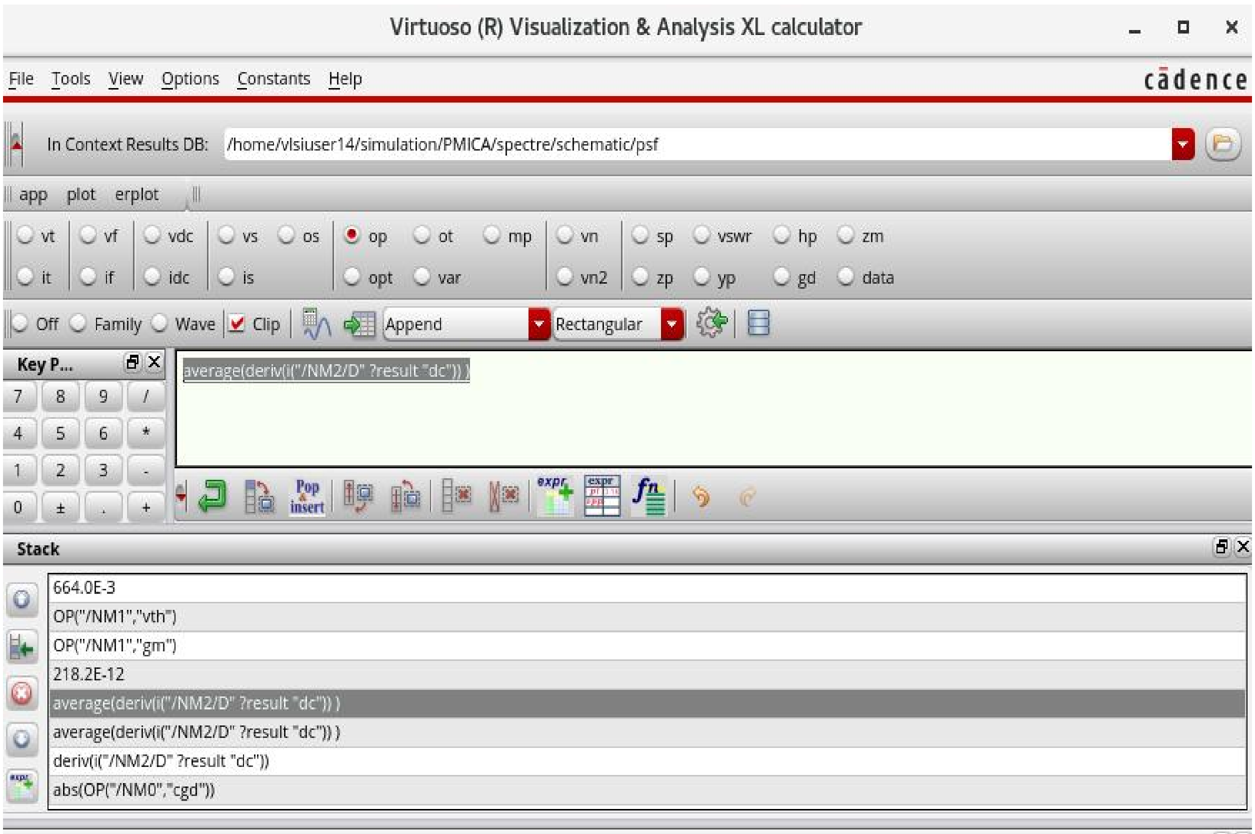
Here $\beta_n = 5\times10^{-6}$; $k = 4$ (multiplier)

$$R_{BIAS} = \frac{1}{10^{-7}} \times \frac{2}{5\times10^{-6}}\left(1 - \frac{1}{\sqrt{4}}\right)$$

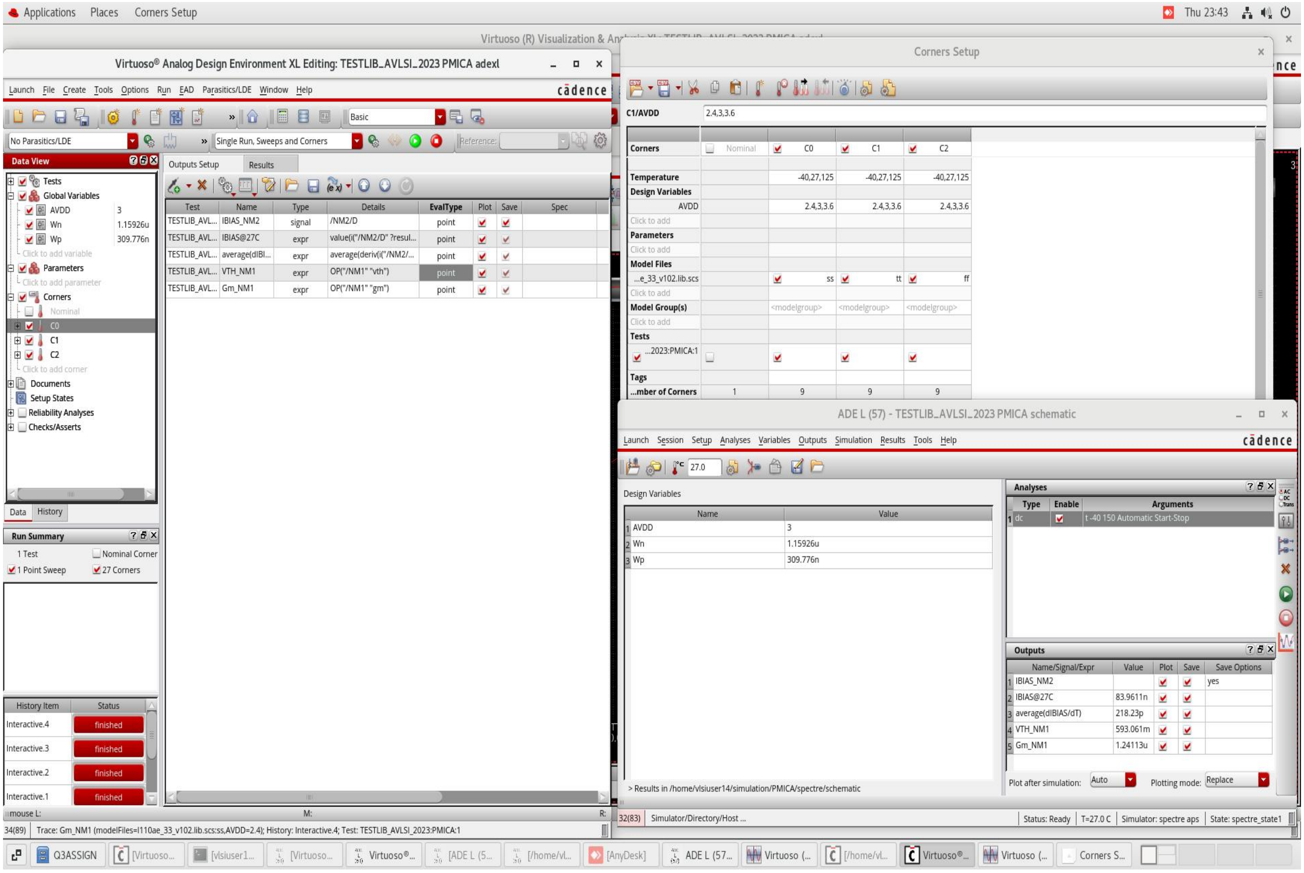
$$= 10^{6}$$

$$\boxed{R_{BIAS} = 1M\Omega}$$

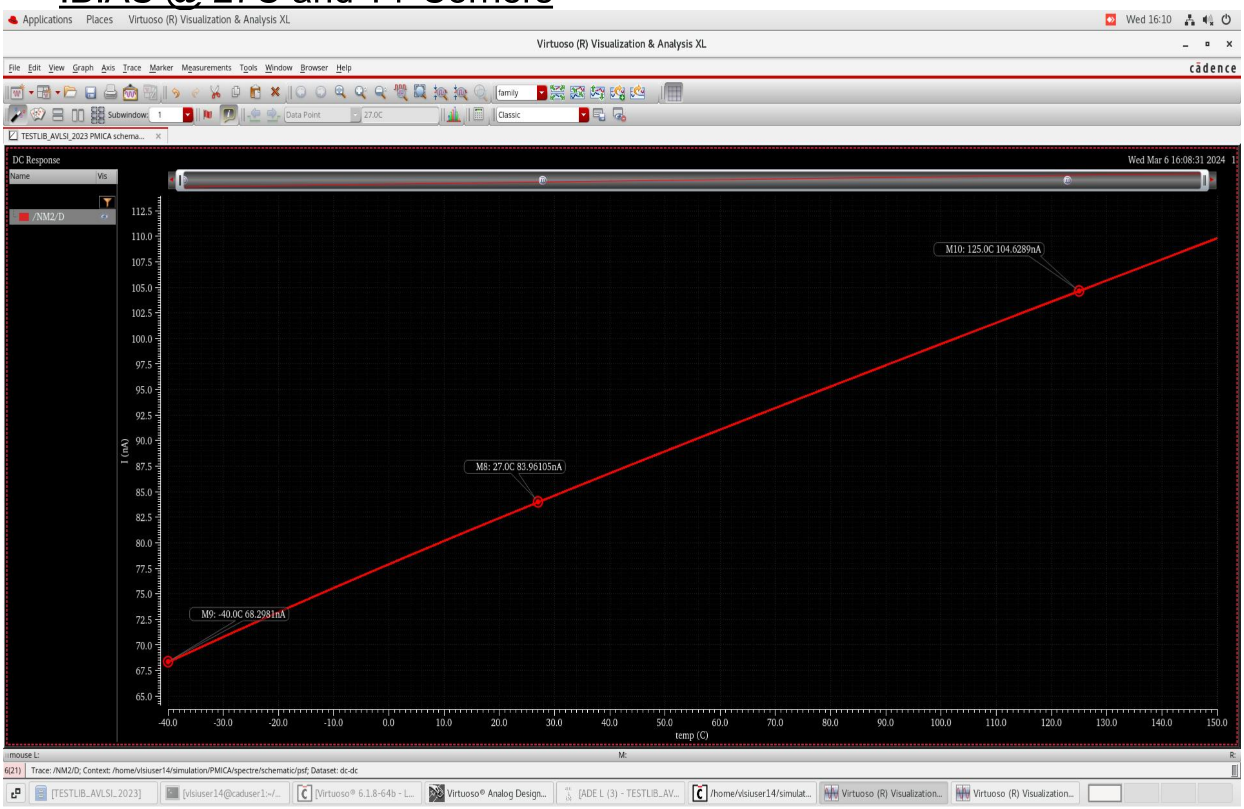
- <u>Average Derivative of IBIAS Calculation in Virtuoso Calculator</u>



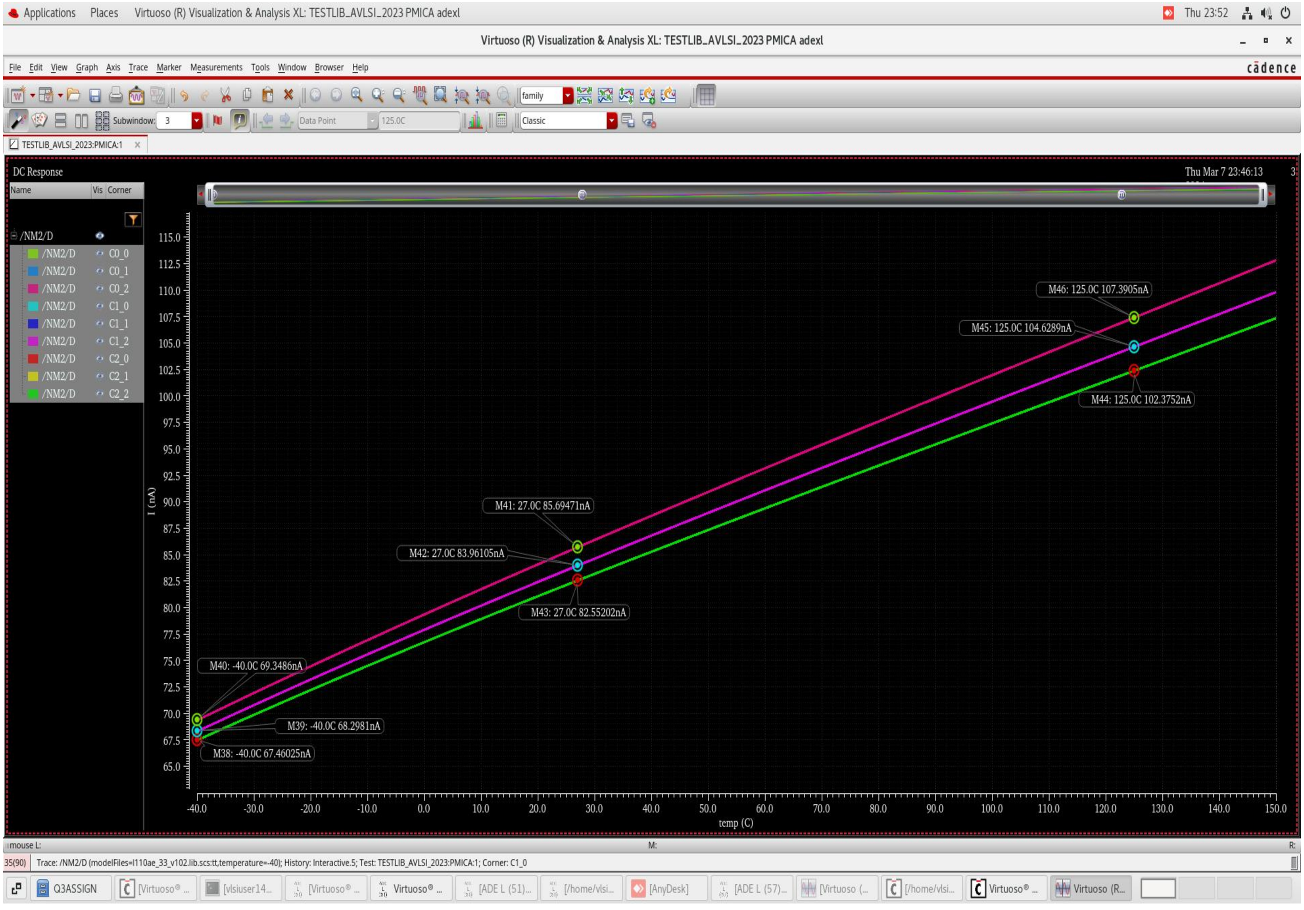
- ADE XL and Corner Setup and ADE L



- IBIAS @ 27C and TT Corners

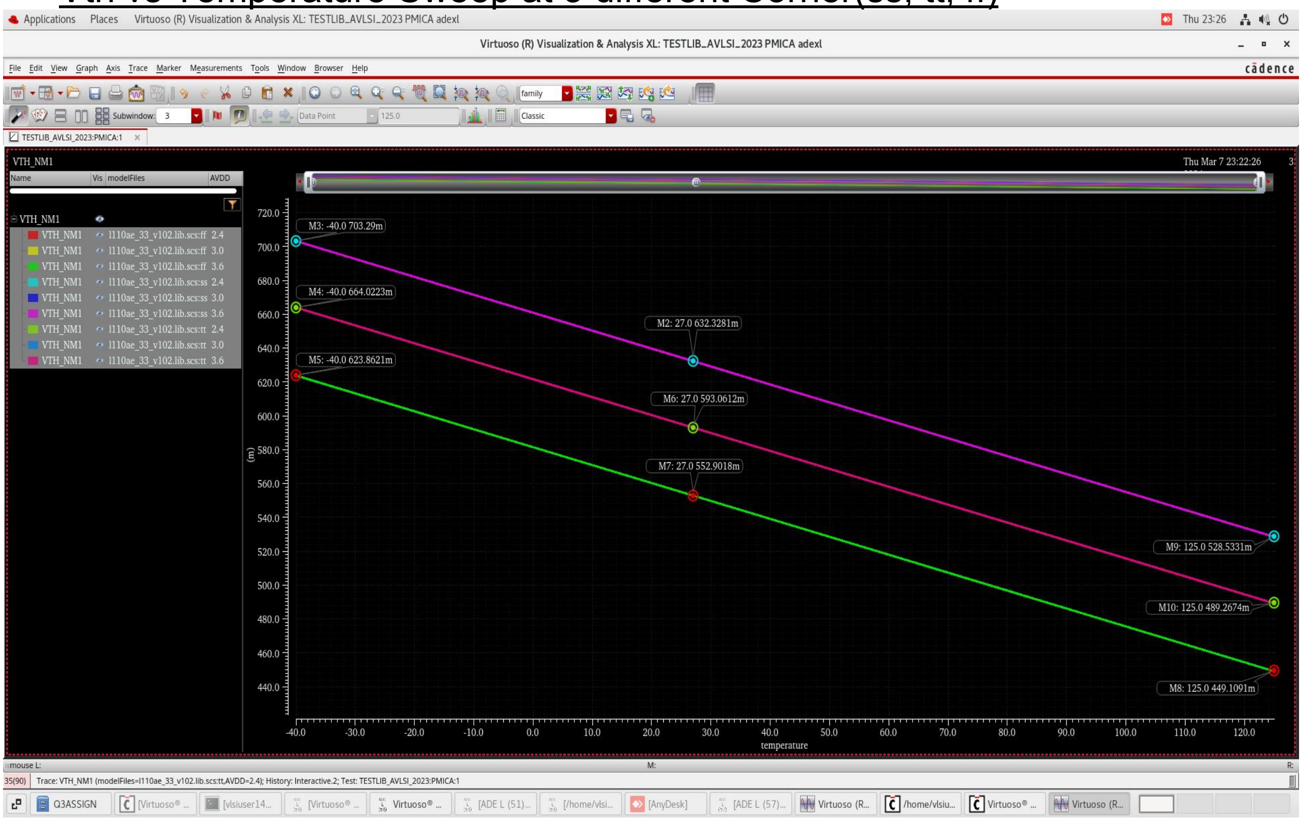


- <u>IBIAS at 3V and 3 Different Corner(ss, tt, ff) Temperature Sweep</u>

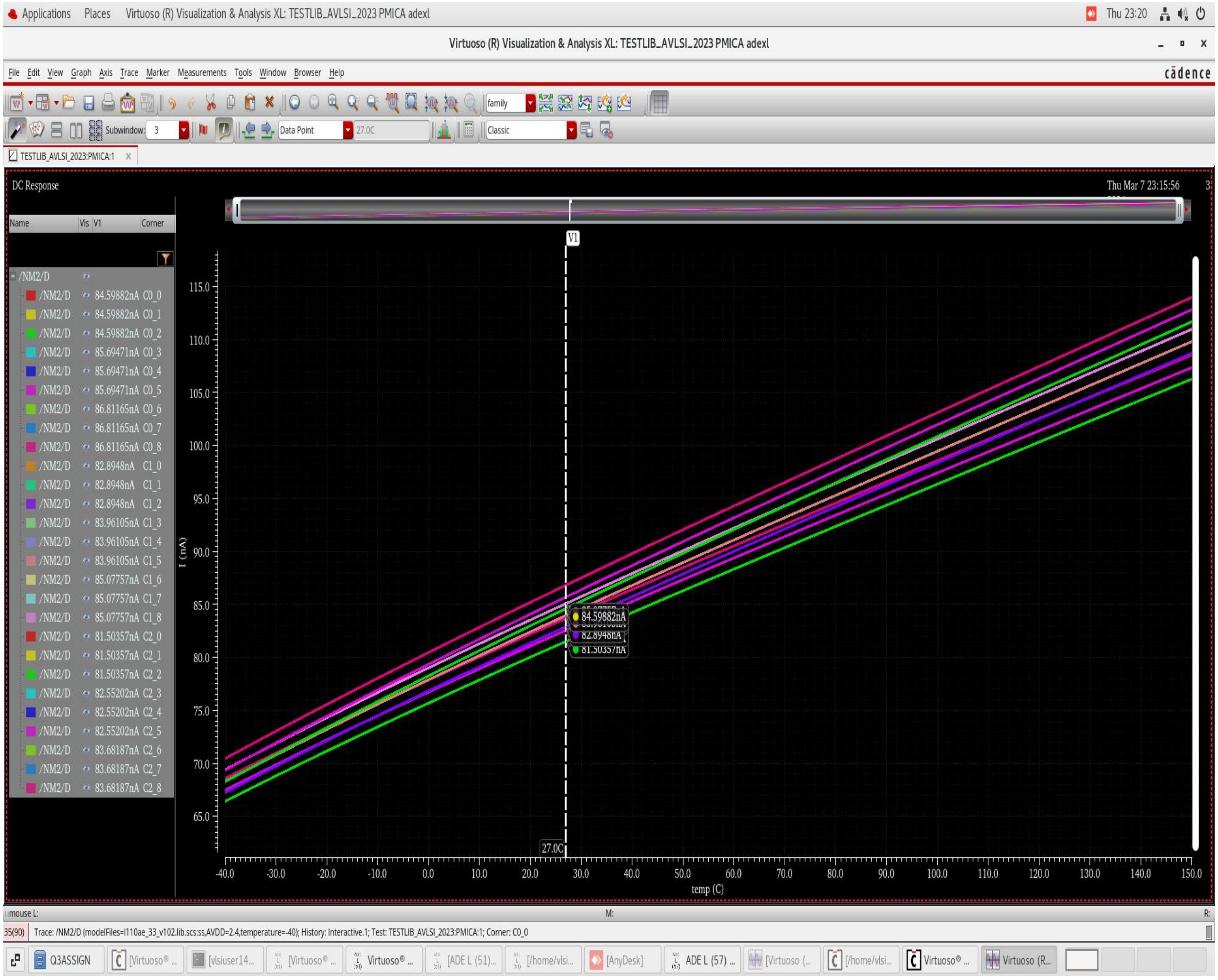


- <u>gm vs Temperature Sweep at 3 different Corner(ss, tt, ff)</u>

- <u>Vth vs Temperature Sweep at 3 different Corner(ss, tt, ff)</u>



- IBIAS at 2.4V,3V,3.6V and 3 Different Corner(ss, tt, ff) Temperature Sweep



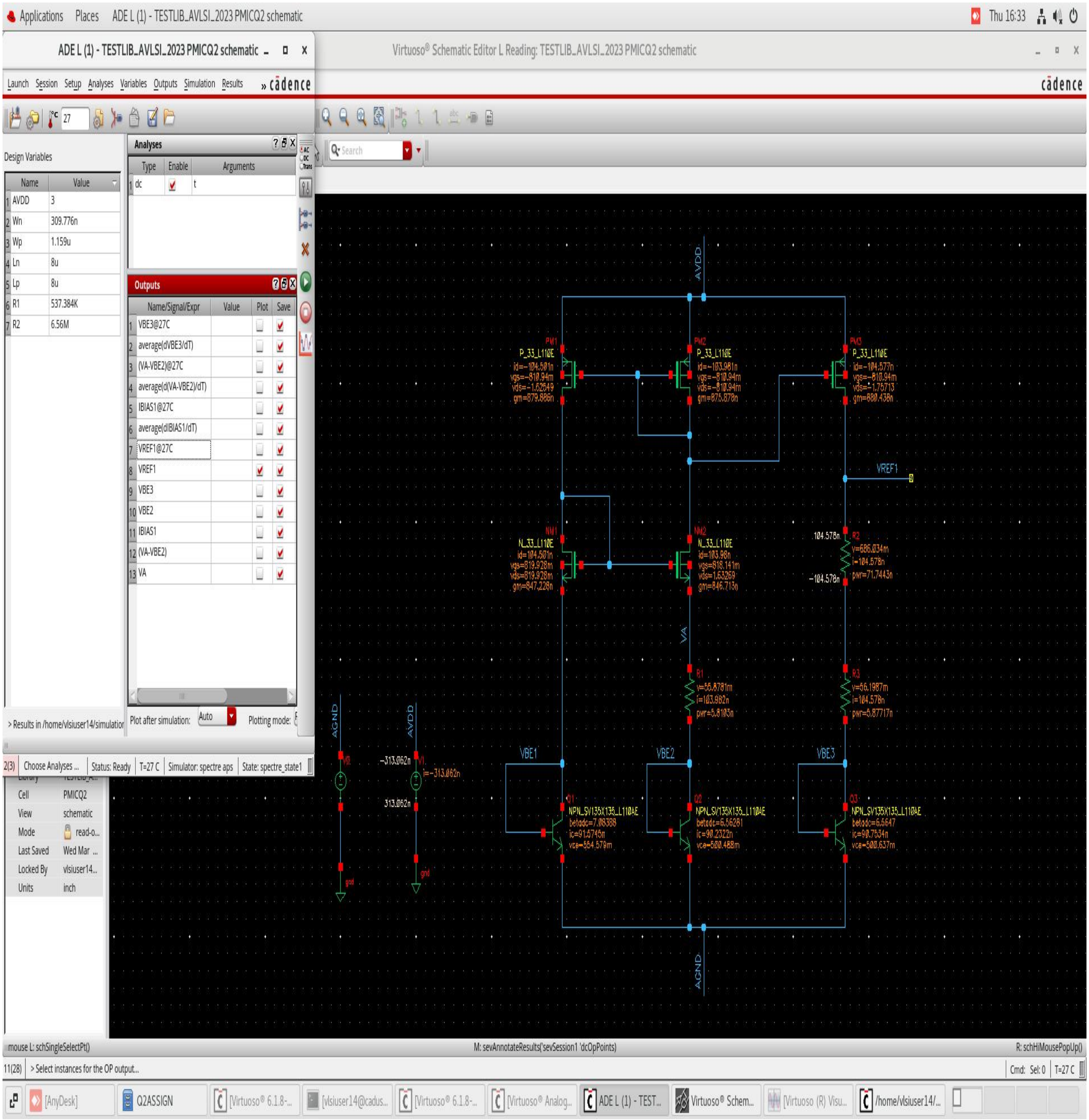
- <u>OBSERVATION TABLE:</u>

Q1 B-MULTIPLIER CIRCUIT

		Slow			Typical			Fast		
AVDD		2.4 V	3.0 V	3.6 V	2.4 V	3.0 V	3.6 V	2.4 V	3.0 V	3.6 V
VTH_ NM1(mV)	@ -40 C	703.29	703.29	703.29	664.022	664.022	664.022	623.862	623.862	623.862
	@ 27 C	703.29	703.29	703.29	664.022	664.022	664.022	623.862	623.862	623.862
	@ 125 C	703.29	703.29	703.29	664.022	664.022	664.022	623.862	623.862	623.862
Gm_NM1(uS)	@ -40 C	1.24361	1.26183	1.28045	1.25775	1.27626	1.29571	1.27025	1.28912	1.30942
	@ 27 C	1.24361	1.26183	1.28045	1.25775	1.27626	1.29571	1.27025	1.28912	1.30942
	@ 125 C	1.24361	1.26183	1.28045	1.25775	1.27626	1.29571	1.27025	1.28912	1.30942
IBIAS(nA)	@ 27 C	84.5988	85.6947	86.8116	82.8948	83.9611	85.0776	81.5036	82.552	83.6819
average (dIBIAS/dT)	pA/C	228.282	228.565	228.822	218.015	218.23	218.527	209.526	209.703	210.09

(Q3) BANDGAP VOLTAGE REFERENCE (CIRCUIT_1)

- Schematic and DC Operating Point



- <u>Calculation of Width Wn and Wp and R1 and R2</u>

Given ; $AVDD = 3V$; $V_{ov} = 0.2V$; $L = 8\mu m$; $I_{BIAS} = 100nA$ @ 27°C

<u>NMOS</u>:

$K_{fit} = 0.7733$

$\mu_n = 0.0363\ M^2/V/s$

$C_{ox} = 4.6 \times 10^{-3}\ F/m^2$

<u>PMOS</u>:

$K_{fit} = 0.7733$

$\mu_p = 0.0097\ M^2/V/s$

$C_{ox} = 4.6 \times 10^{-3}\ F/m^2$

NMOS

- <u>In saturation</u>;

$$\rightarrow I_{Bias_n} = \frac{K_{fit}\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_n V_{ov}^2$$

$$\therefore \frac{10^{-7} \times 2}{0.7733 \times 0.0363 \times 4.6 \times 10^{-3} \times (0.2)^2} = \left(\frac{W}{L}\right)_n$$

$$\therefore \left(\frac{W}{L}\right)_n = 38721.978\ \mu m$$

$$W_n = 38721.978 \times 8 \times 10^{-6} \times 10^{-6}$$

$$\boxed{W_n = 309.776\ nm}$$

PMOS

<u>In saturation</u>,

$$\rightarrow I_{Bias_p} = \frac{K_{fit}\mu_p C_{ox}}{2}\left(\frac{W}{L}\right)_p V_{ov}^2$$

$$\frac{10^{-7} \times 2 \times 8 \times 10^{-6}}{0.7733 \times 0.0097 \times 4.6 \times 10^{-3} \times (0.2)^2} = \left(\frac{W}{L}\right)_p$$

$$\left(\frac{W}{L}\right)_p = 144.908 \times 10^{-3}$$

$$\boxed{W_p = 1.159\ \mu m}$$

$$\beta_n = \mu_n C_{ox}\left(\frac{W}{L}\right)_n K_{fit}$$

$$= 0.7733 \times 0.0363 \times 4.6 \times 10^{-3} \times 38.7219 \times 10^{-3}$$

$$\boxed{\beta_n = 5 \times 10^{-6}}$$

$\boxed{\text{Sol}^n \; | \; Q2}$

$\rightarrow R_1 = \frac{V_T \ln(8)}{I_{BIAS1}}$

$= \frac{\left(\frac{kT}{q}\right) \ln(8)}{I_{BIAS1}}$

$= \frac{1.38 \times 10^{-23} \times 300 \; \ln(8)}{1.602 \times 10^{-19} \times 100 \times 10^{-9}}$

$\boxed{R_1 = 537.384 k\Omega}$

$\rightarrow$ Here, $V_T = \frac{kT}{q}$ @27°C $= \frac{1.38 \times 10^{-23} \times 300}{1.602 \times 10^{-19}} = 25.843 mV$

$\rightarrow V_{be} = V_T \ln\left(\frac{I_c}{I_s}\right)$

$= 25.875 \times 10^{-3} \ln\left(\frac{100 \times 10^{-9}}{10^{-16}}\right)$

$V_{be} = 0.5362 V$

$\rightarrow \dfrac{\partial V_{BE3}}{\partial T} = \dfrac{V_{be} - (4+n)V_T - E_g/q}{T}$

Here E_g for Si is given, $E_g = 1.12\ eV = 1.12 \times 1.602 \times 10^{-19}\ V$
$= 1.12 \times q\ V$

$n = -\frac{3}{2}$;

$$\frac{\partial V_{BE3}}{\partial T} = \frac{0.5362 - \left(4 - \frac{3}{2}\right) \times 25.875 \times 10^{-3} - 1.12\cancel{q}/\cancel{q}}{300}$$

$$\frac{\partial V_{BE3}}{\partial T} = -2.3658 \times 10^{-3}$$

By KVL,

$\rightarrow$ Now, $V_{REF} = I_{BIAS}(R_1 + R_2) + V_{be3}$

$$\frac{\partial V_{REF}}{\partial T} = \frac{\partial I_{BIAS}}{\partial T}(R_1 + R_2) + \frac{\partial V_{be3}}{\partial T}$$

Here Consider, $\dfrac{\partial V_{REF}}{\partial T} = 0$

$$\frac{\partial V_{be3}}{\partial T} = -\left(\frac{\partial I_{BIAS}}{\partial T}\right)(R_1 + R_2)$$

$$= -\frac{\partial}{\partial T}\left[\frac{V_A - V_{be2}}{R_1}\right](R_1 + R_2)$$

By KVL; $V_{be1} - V_{GS} + V_{GS} - V_A = 0$

$V_A = V_{be1} \Rightarrow V_A - V_{be2} = V_{be1} - V_{be2} = \Delta V_{be}$

$$\frac{\partial V_{be3}}{\partial T} = -\left[\frac{\partial}{\partial T}\left(\frac{\Delta V_{be}}{R_1}\right)\right][R_1 + R_2]$$

$$= -\left(1 + \frac{R_2}{R_1}\right)\frac{\partial}{\partial T}[V_T \ln(m)]$$

$$= -\left(1 + \frac{R_2}{R_1}\right)\left[\frac{k}{q}\ln(m)\right]$$

$$\rightarrow \frac{\partial V_{be3}}{\partial T} = -\left(1+\frac{R_2}{R_1}\right)\left[\frac{k}{q}\ln(8)\right]$$

$$-2.3658\times10^{-3} = -\left(1+\frac{R_2}{R_1}\right)\left(\frac{k}{q}\right)\ln(8)$$

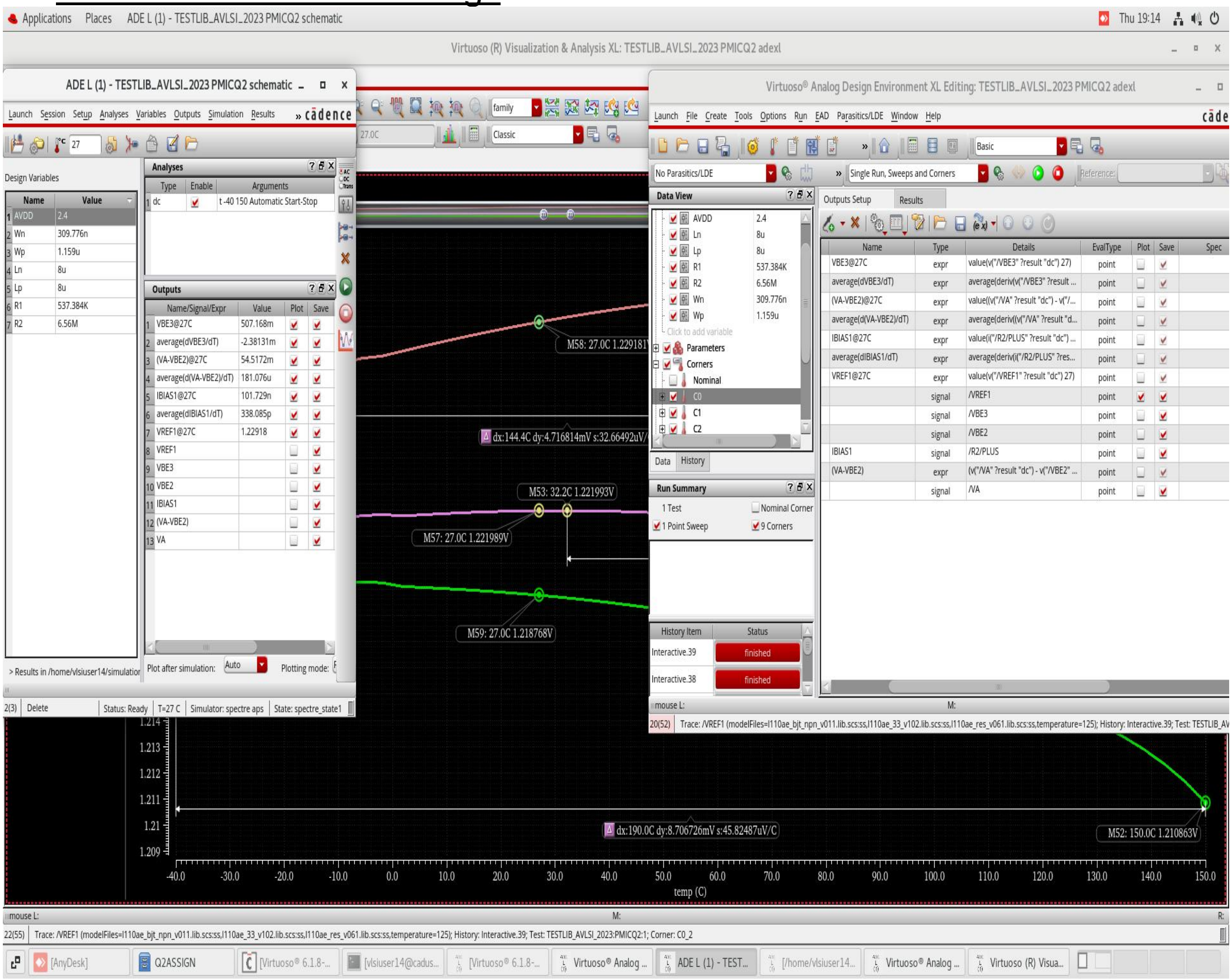
$$1+\frac{R_2}{R_1} = \frac{2.3658\times10^{-3}\times1.602\times10^{-19}}{\ln(8)\times1.38\times10^{-23}}$$

$$13.2076 = 1+\frac{R_2}{R_1}$$

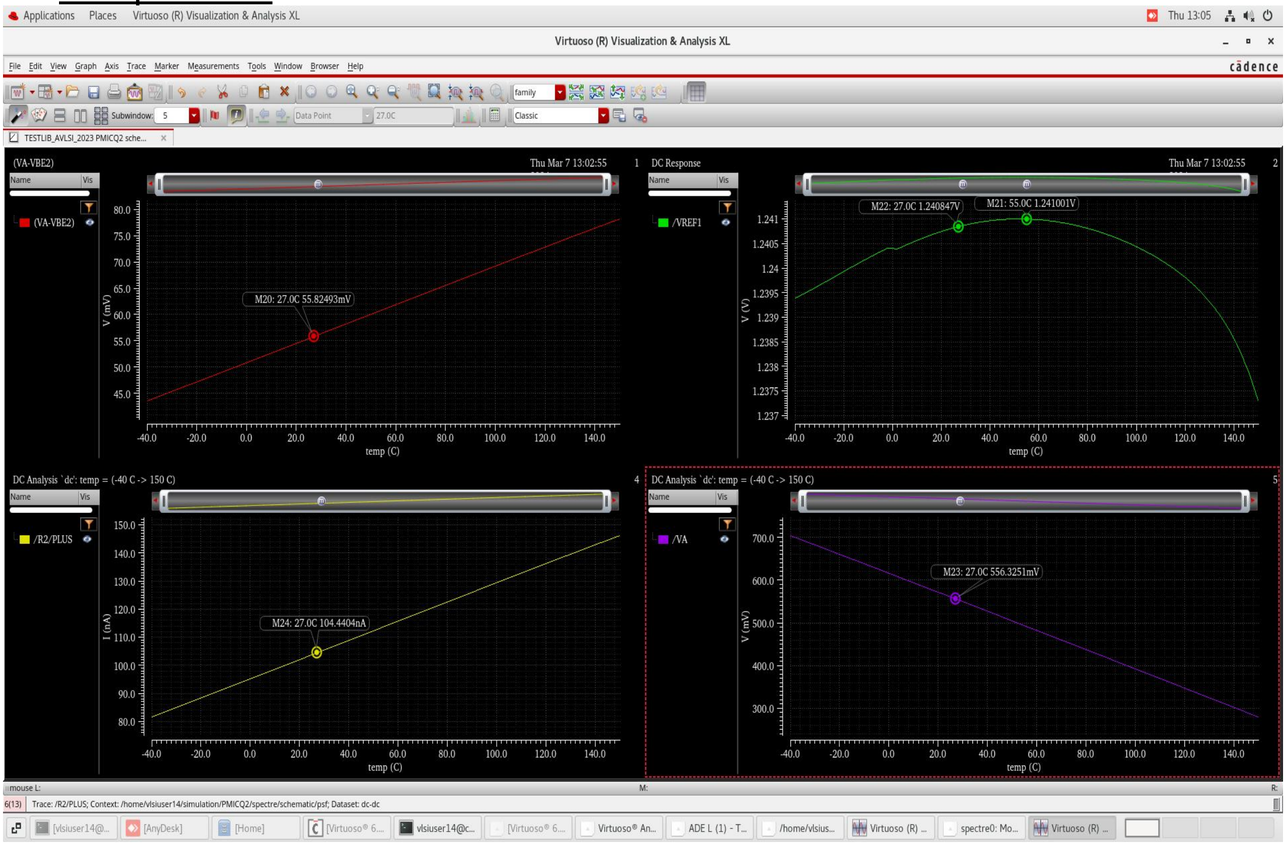
$$\boxed{R_2 = 6.56\ M\Omega} \quad \&$$

$$\boxed{R_1 = 537.384\ k\Omega}$$

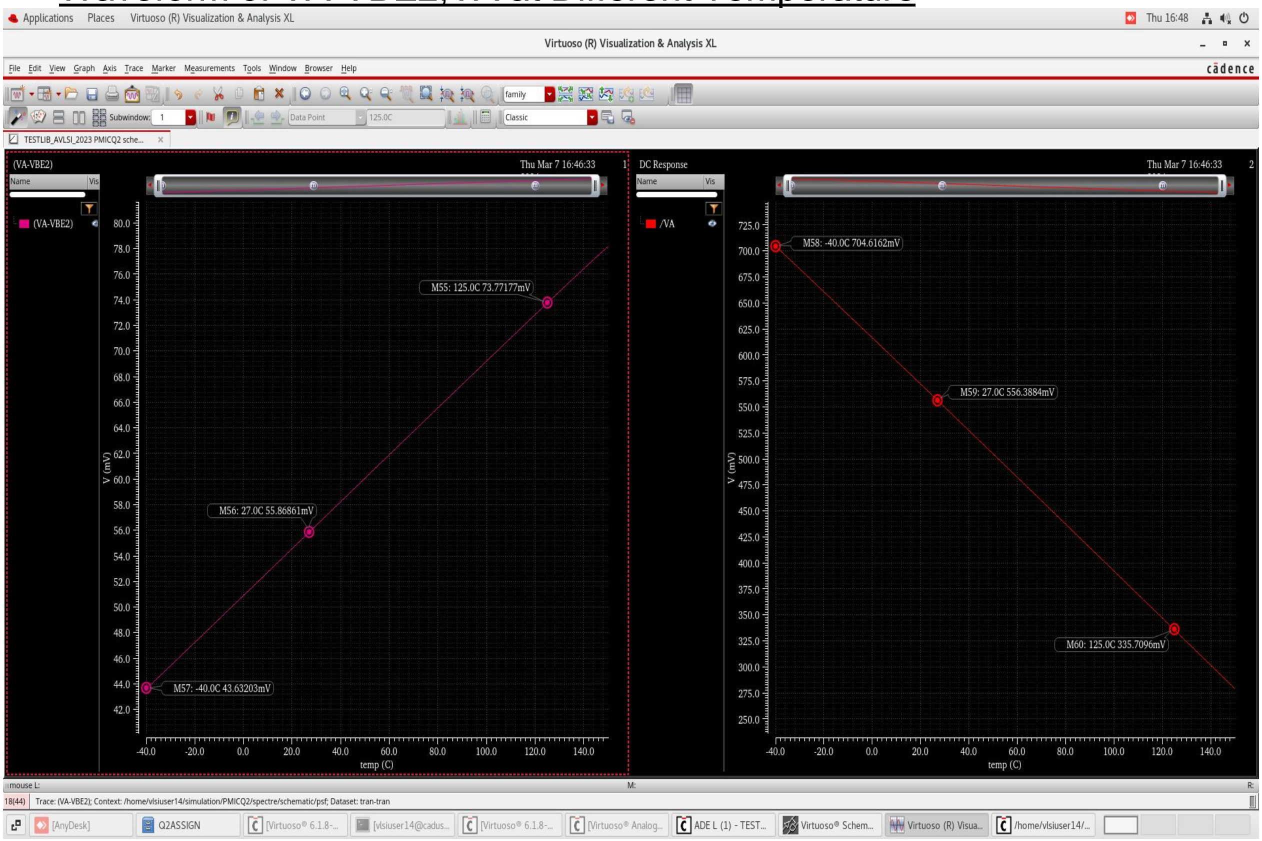
- <u>ADE XL and ADE L Settings</u>



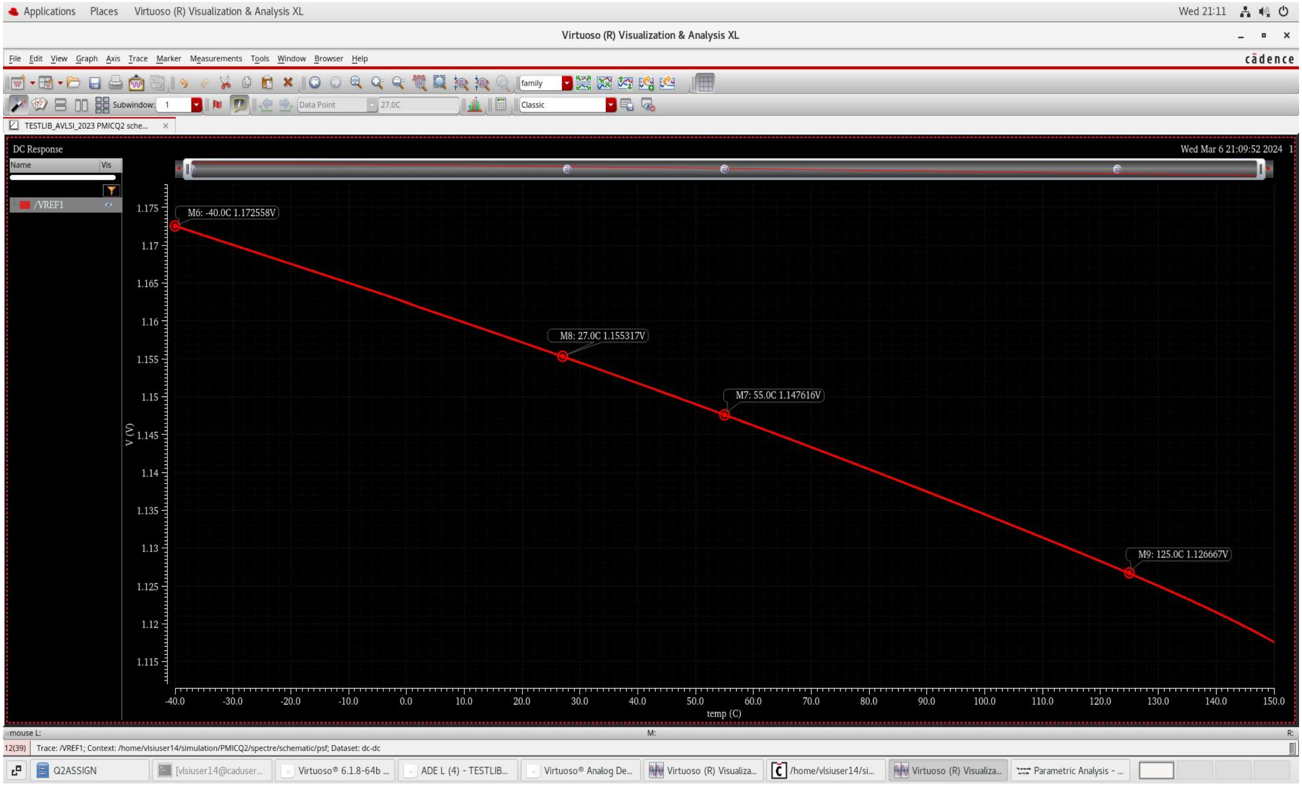
- <u>Waveform of VA,IBIAS,VREF,VA-VBE2 at Different Temperature</u>



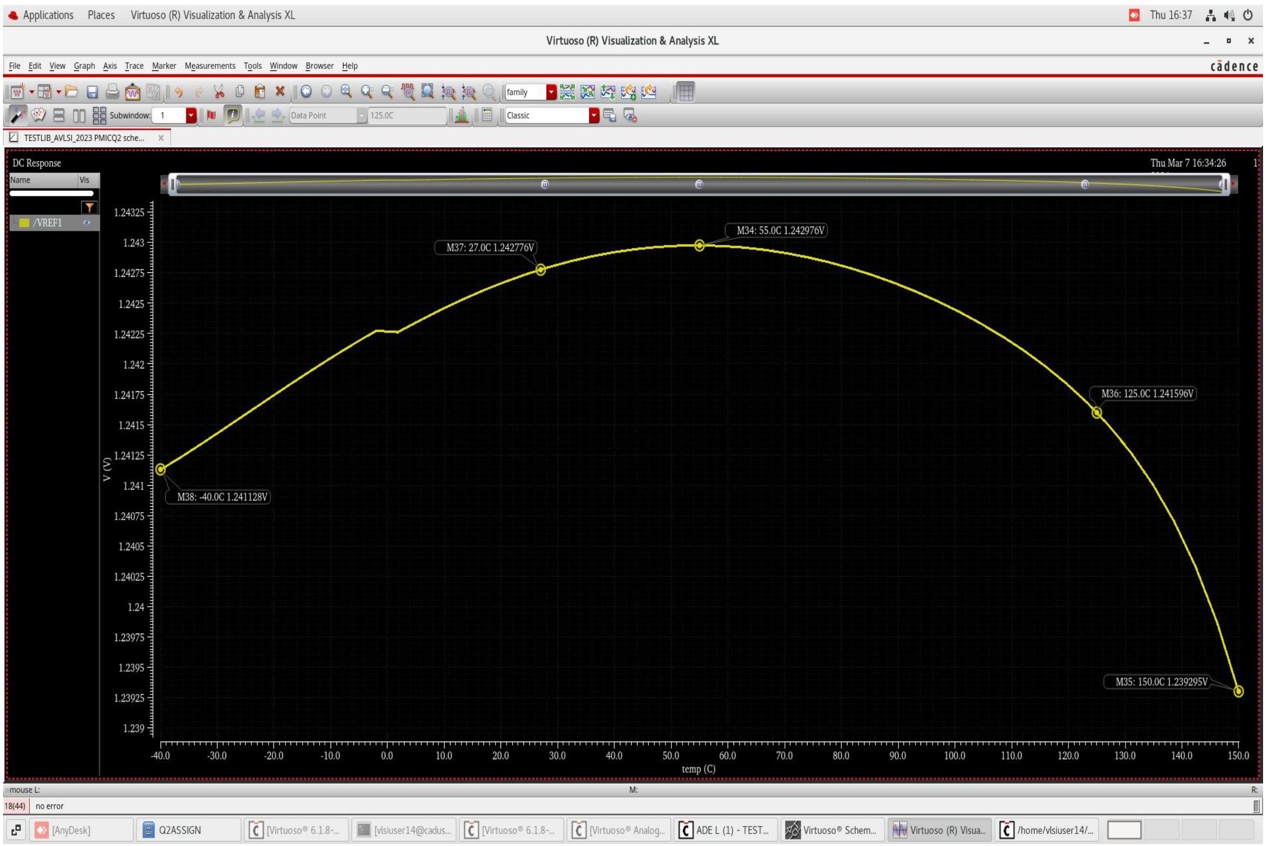
- <u>Waveform of VA-VBE2,VA at Different Temperature</u>



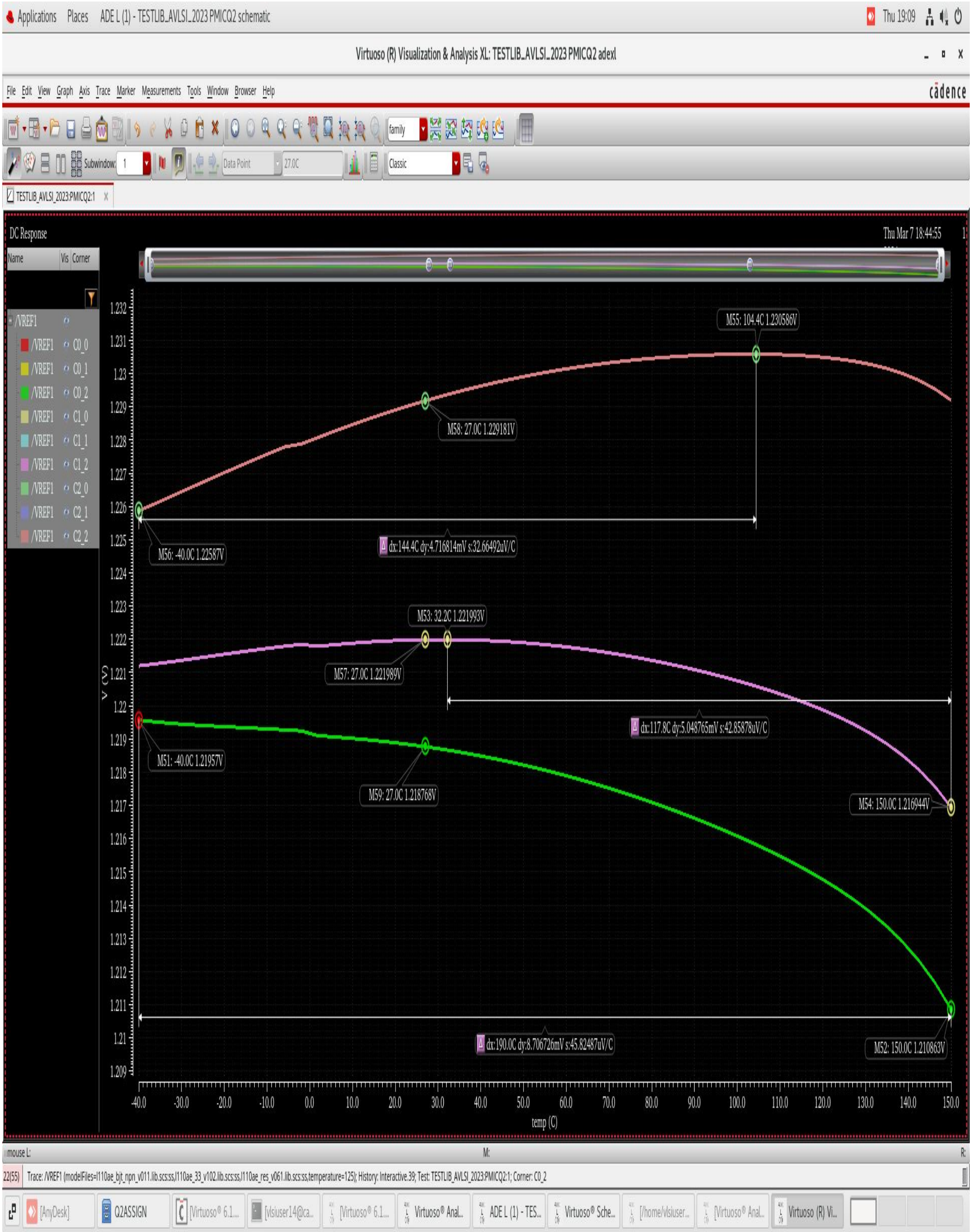
- <u>Waveform at VREF=3V for R2 =5.7MOhm</u>



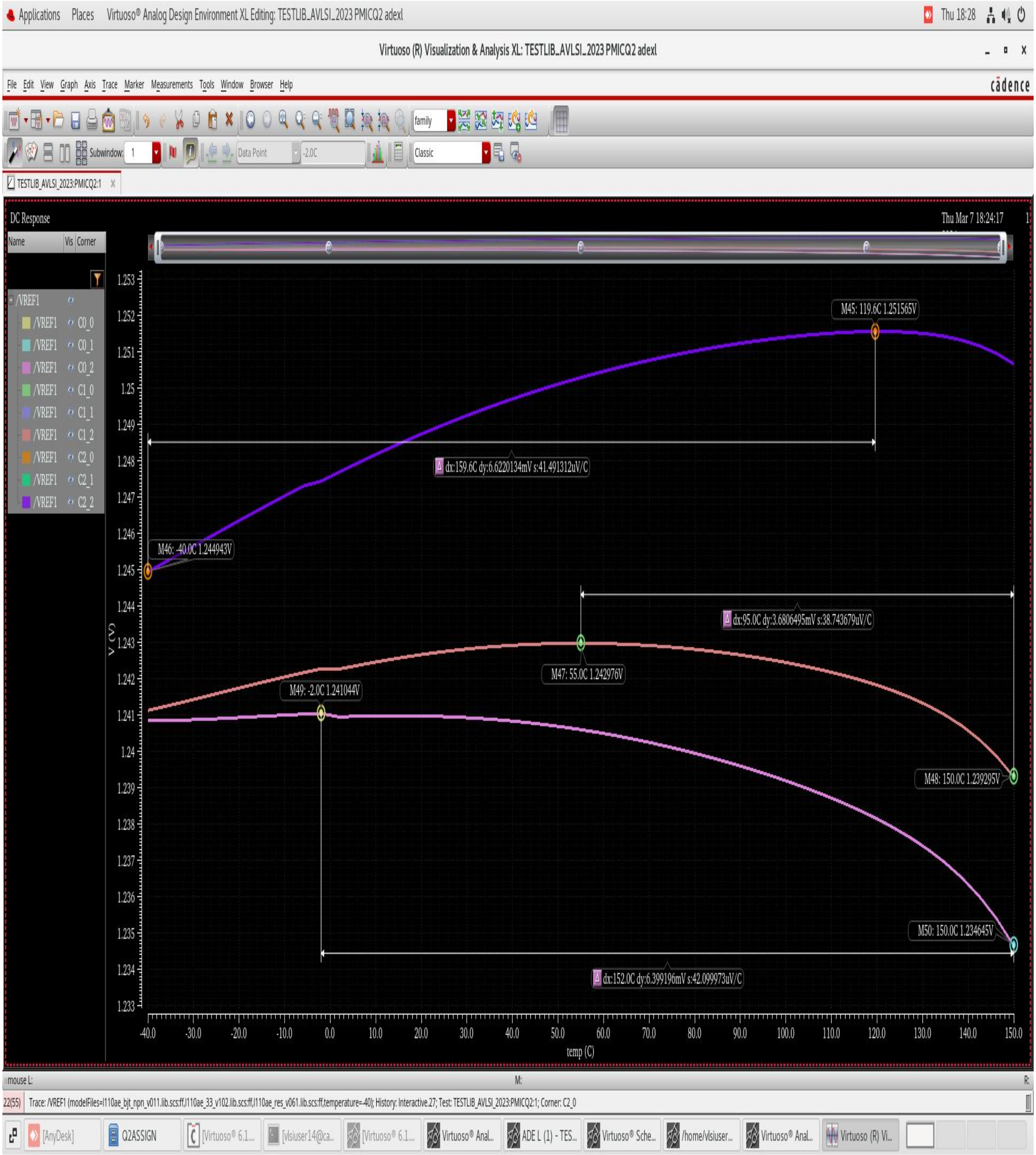
- <u>Waveform of VREF=3V at TT Corner Different Temperature</u>



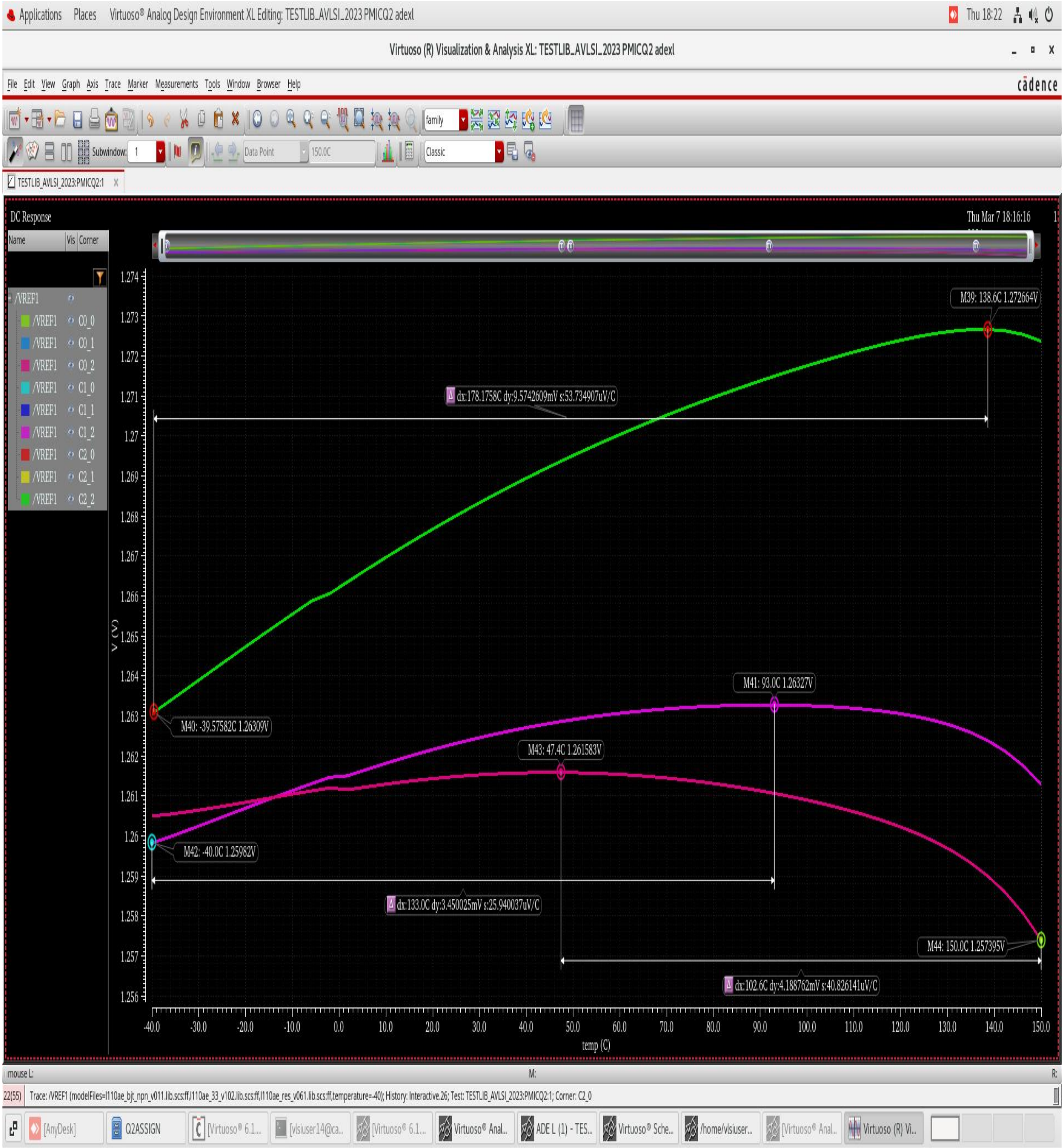
- <u>Waveform of VREF=2.4V with Temperature Sweep at SS,TT,FF Corner and VMAX and VMIN Calculation</u>



- <u>Waveform of VREF=3V with Temperature Sweep at SS,TT,FF Corner VMAX and VMIN Calculation</u>



- <u>Waveform of VREF=3.6V with Temperature Sweep at SS,TT,FF Corner and VMAX and VMIN Calculation</u>



- Observation Table

Q2 BANDGAP VOLTAGE REFERENCE (CIRCUIT_1)

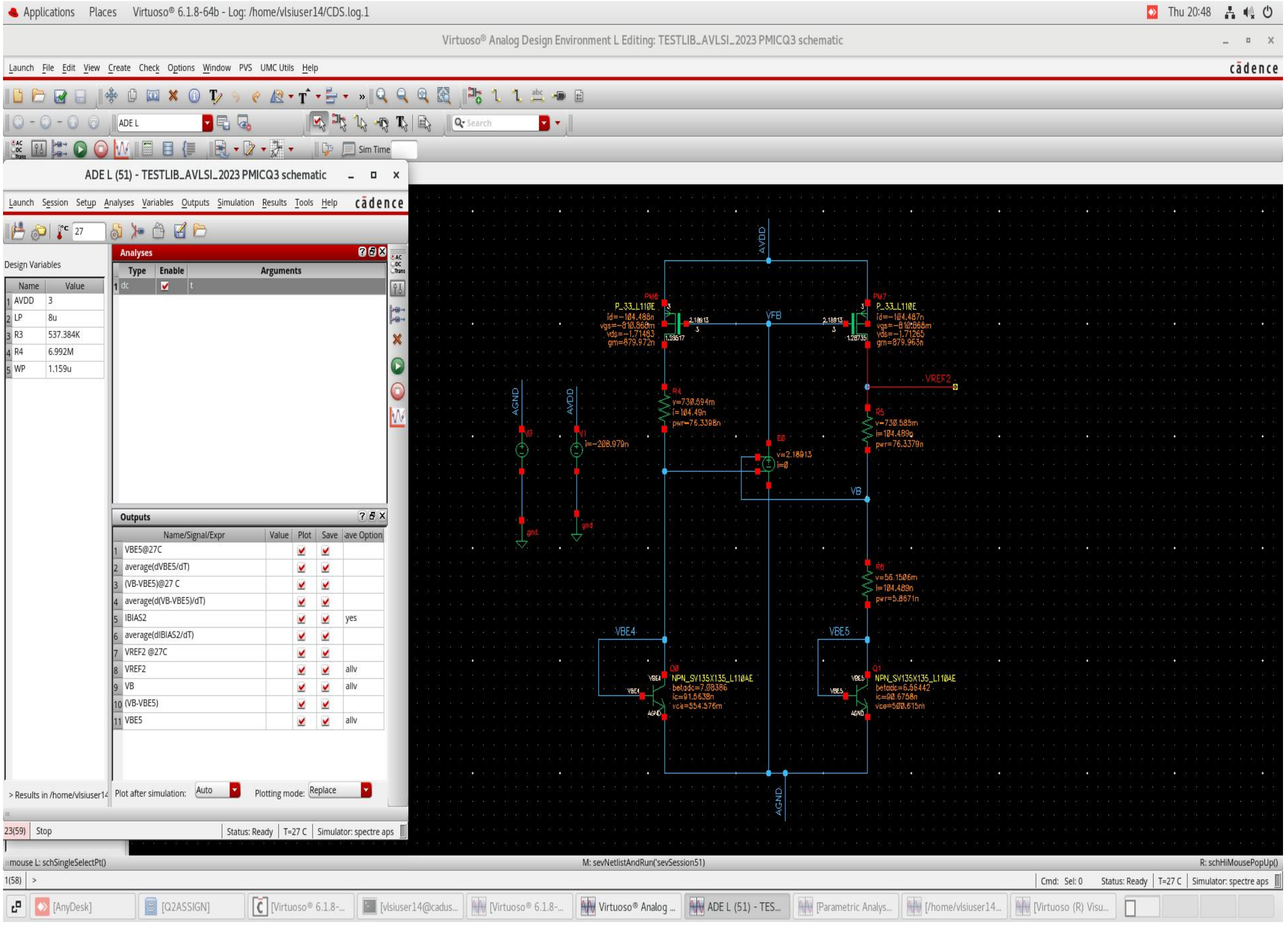
		Slow			Typical			Fast		
AVDD		*2.4V*	*3.0V*	*3.6 V*	*2.4V*	*3.0V*	*3.6V*	*2.4 V*	*3.0 V*	*3.6 V*
VBE3	@ 27°C (mV)	496.9	497.665	498.355	499.955	500.669	501.324	507.168	507.848	508.482
average (dVBE3/dT)	*mV/C*	-2.44732	-2.44696	-2.44646	-2.42167	-2.42132	-2.42079	-2.38131	-2.38095	-2.38035
(VA - VBE2)	@ 27°C (mV)	54.5389	55.9631	57.2701	54.5358	55.8686	57.1152	54.5172	55.7918	57.0028
average d(VA - VBE2)/dT	*uV/°C*	181.477	182.293	183.405	181.222	182.005	183.18	181.076	181.842	183.114
R1	kOhm	537.369								
R2	kOhm	6560								
IBIAS1 (nA)	@ 27°C (nA)	101.709	104.726	107.525	101.732	104.561	107.229	101.729	104.44	107.033
average (dIBIAS1/dT)	pA/C	338.557	340.356	342.584	338.2	339.945	342.309	338.085	339.813	342.376
VREF1 (V)	@ 27°C	1.21877	1.24094	1.2615	1.22199	1.24278	1.26237	1.22918	1.2491	1.26814
VREF1_Max (V)	(V)	1.21957	1.241044	1.261583	1.221993	1.242976	1.26327	1.230586	1.251565	1.272664
VREF1_Min (V)	(V)	1.210863	1.234645	1.257395	1.216944	1.239295	1.25982	1.22587	1.244943	1.26309
(VREF1_Max - VREF1_ Min)	(mV)	8.71	6.399	4.188	5.049	3.68	3.45	4.716	6.622	9.574
VREF1 Temp CO	ppm/°C	37.5887	27.1376	17.4718	21.7462	15.5823	14.3737	20.1701	27.8472	39.5937

- **Formula**

VREF1 Temp-Co=[VREF1_Max - VREF1_Min]*10^(6)/ [Tmax-Tmin]/VREF1_Max

(Q3) BANDGAP VOLTAGE REFERENCE (CIRCUIT 2)

- Schematic and DC Operating Point



- Calculation of Width Wn and Wp and R3 and R4

Given; AVDD = 3V ; V_{ov} = 0.2V ; L = 8μm ; I_{BIAS} = 100nA @ 27°C

NMOS: $K_{fit} = 0.7733$

$\mu_n = 0.0363\ M^2/V/s$

$C_{ox} = 4.6 \times 10^{-3}\ F/m^2$

PMOS: $K_{fit} = 0.7733$

$\mu_p = 0.0097\ M^2/V/s$

$C_{ox} = 4.6 \times 10^{-3}\ F/m^2$

NMOS

- In saturation;

$\rightarrow I_{Bias_n} = \frac{K_{fit}\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_n V_{ov}^2$

$\therefore \frac{10^{-7} \times 2}{0.7733 \times 0.0363 \times 4.6 \times 10^{-3} \times (0.2)^2} = \left(\frac{W}{L}\right)_n$

$\therefore \left(\frac{W}{L}\right)_n = 38721.978\ \mu m$

$W_n = 38721.978 \times 8 \times 10^{-6} \times 10^{-6}$

$\boxed{W_n = 309.776\ nm}$

PMOS

In saturation,

$\rightarrow I_{Bias_p} = \frac{K_{fit}\mu_p C_{ox}}{2}\left(\frac{W}{L}\right)_p V_{ov}^2$

$\frac{10^{-7} \times 2 \times 8 \times 10^{-6}}{0.7733 \times 0.0097 \times 4.6 \times 10^{-3} \times (0.2)^2} = \left(\frac{W}{L}\right)_p$

$\left(\frac{W}{L}\right)_p = 144.908 \times 10^{-3}$

$\boxed{W_p = 1.159\ \mu m}$

$\beta_n = \mu_n C_{ox}\left(\frac{W}{L}\right)_n K_{fit}$

$= 0.7733 \times 0.0363 \times 4.6 \times 10^{-3} \times 38.7219 \times 10^{-3}$

$\boxed{\beta_n = 5 \times 10^{-6}}$

$$\boxed{\text{Sol}^n\ Q3}$$

$\rightarrow$ $$R_3 = \frac{V_T \ln(8)}{I_{BIAS2}}$$

$$= \left(\frac{kT}{q}\right)\frac{\ln(8)}{I_{BIAS2}}$$

$$= \frac{1.38\times10^{-23}\times300\,[\ln(8)]}{1.602\times10^{-19}\times100\times10^{-9}}$$

$$\boxed{R_3 = 537.384\,k\Omega}$$

$\Rightarrow$ $$R_4 = R_3\left[\left(\frac{\partial V_{BE5}}{\partial T}\right)\frac{q}{k\ln(8)} - 1\right]$$

& $$V_{REF} = I_T(R_3+R_4) + V_{BE5}$$

$$= \frac{V_T}{R_3}(R_3+R_4)\ln(8) + V_{BE5}$$

$$\therefore V_{REF} = \left(1+\frac{R_4}{R_3}\right)V_T\ln(8) + V_{BE5}$$

$$\rightarrow \frac{\partial V_{REF}}{\partial T} = \left(1 + \frac{R_4}{R_3}\right)\frac{k}{Q}\ln(8) + \frac{\partial V_{BES}}{\partial T}$$

Here $V_{bes} = V_T \ln\left(\frac{I_c}{m I_s}\right)$ & $\frac{\partial V_{REF}}{\partial T} = 0$ (Given)

$$0 = \left(1 + \frac{R_4}{R_3}\right)\frac{k}{Q}\ln(8) + \frac{V_{bes} - (4+n)T - E_g/q}{T}$$

$$\therefore \left[1 + \frac{R_4}{R_3}\right] = \frac{-0.4818 + \left(4 - \frac{3}{2}\right)(300) + \frac{1.12q}{q}}{\frac{1.38\times10^{-23}}{1.602\times10^{-19}} \times \ln(8) \times 3}$$

$$1 + \frac{R_4}{R_3} = 14.01118$$

$$\therefore \boxed{R_4 = 6.992\ M\Omega}$$

& here, given; $V_{bes} = V_T \ln\left(\frac{I_c}{n I_s}\right)$

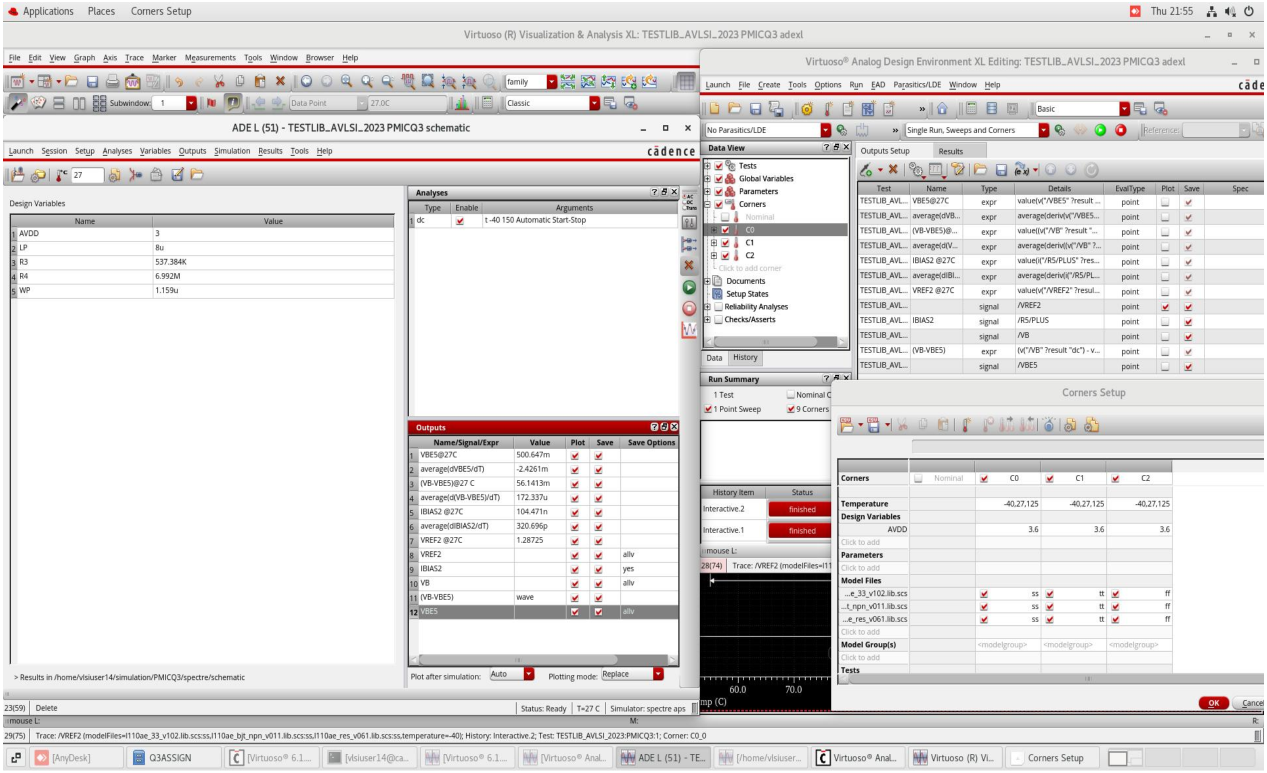
$$= \frac{kT}{q}\ln\left(\frac{10^{-7}}{8\times10^{-16}}\right)$$

$$= \frac{1.38\times10^{-23}\times300}{1.602\times10^{-19}}\ln\left(\frac{10^{-7}}{8\times10^{-16}}\right)$$

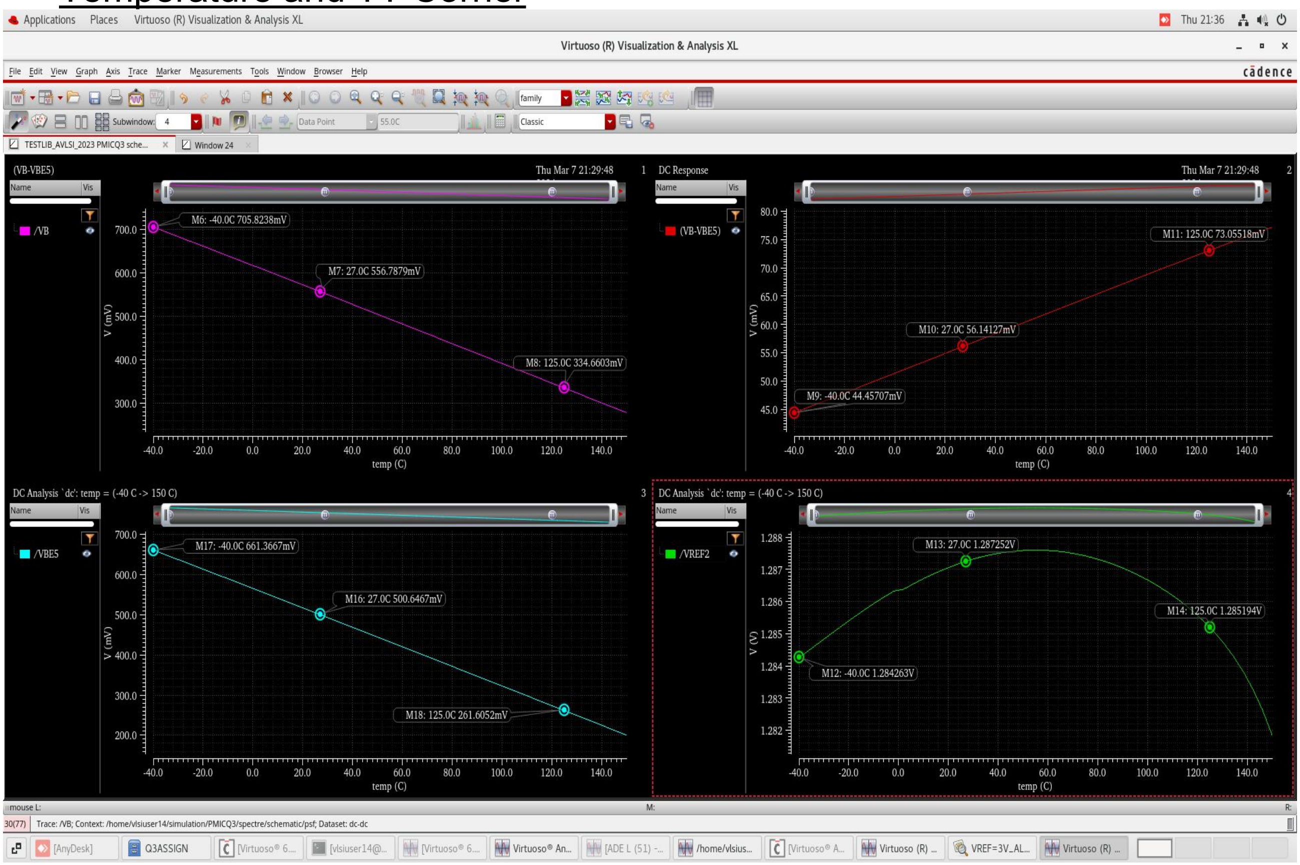
$$V_{bes} = 0.4818$$

So, $\boxed{R_4 = 6.992\ M\Omega}$ & $\boxed{R_3 = 537.384\ k\Omega}$

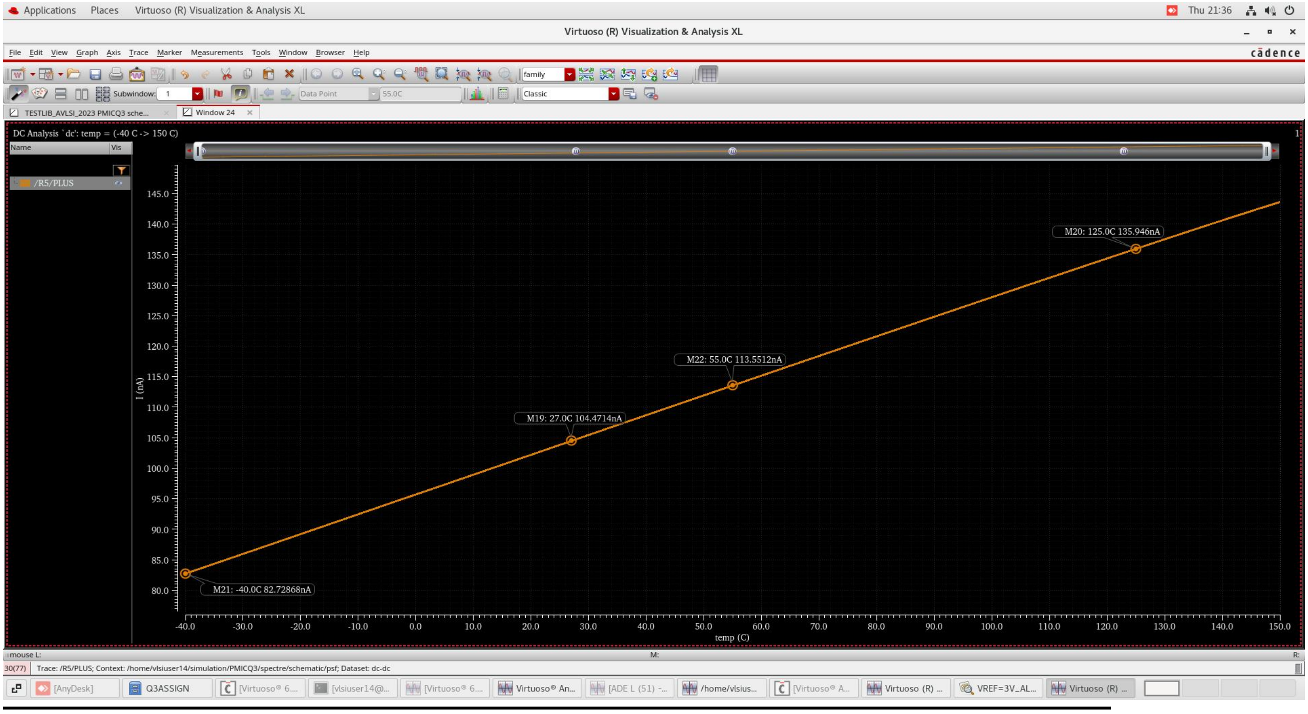
- <u>ADE XL and ADE L Settings</u>



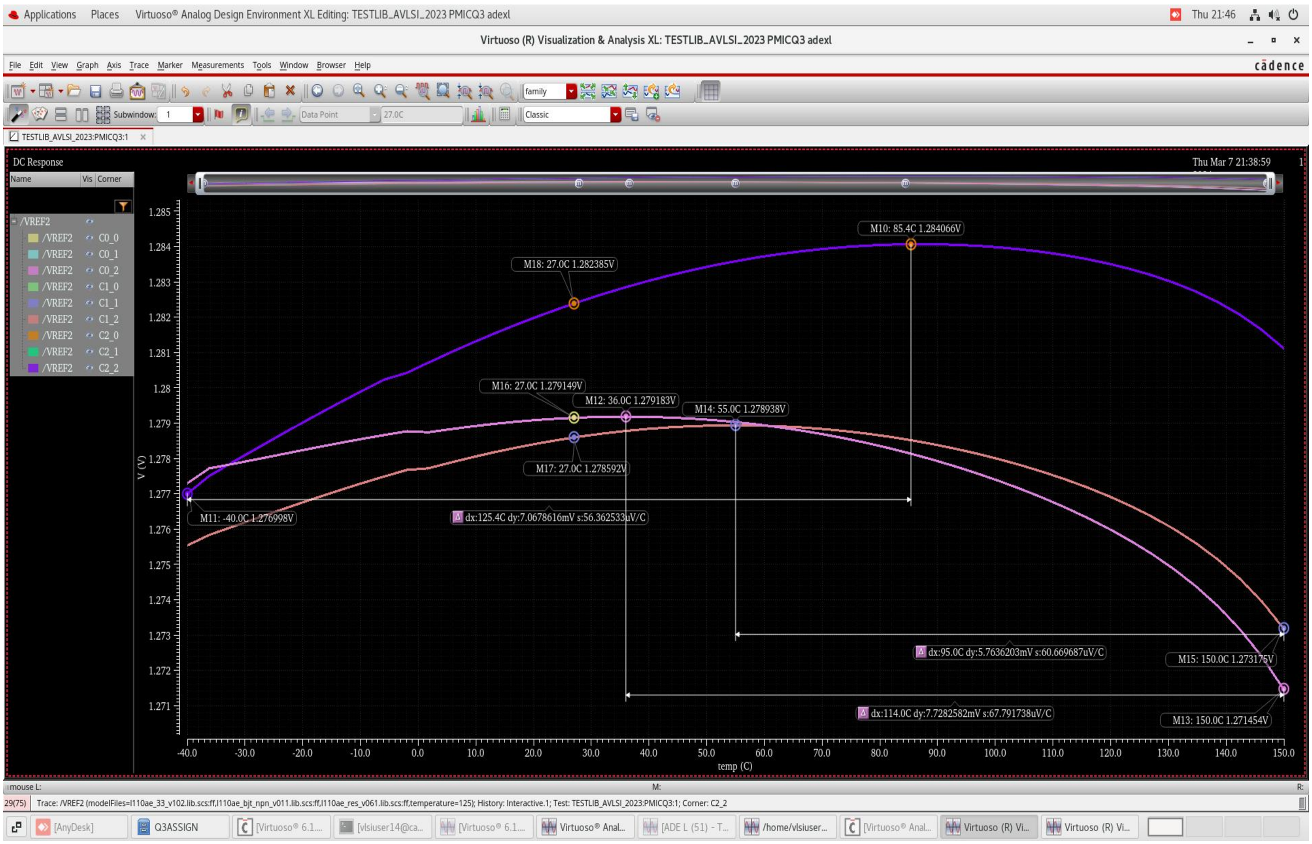
- <u>Waveform of VB,VBE5,VB-VBE5,VREF2 at Different Temperature and TT Corner</u>



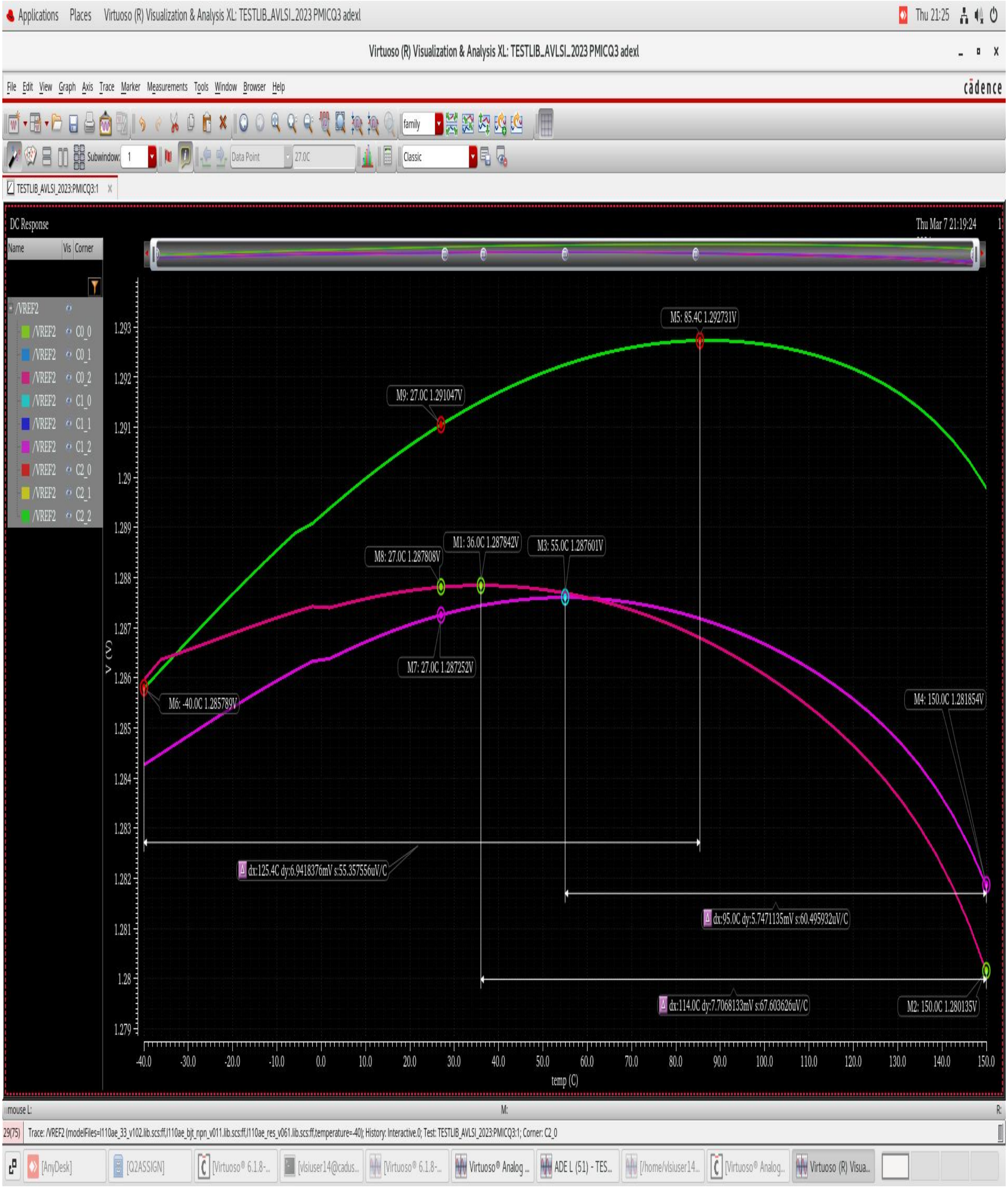
- <u>Waveform of IBIAS at Different Temperature and TT Corner</u>



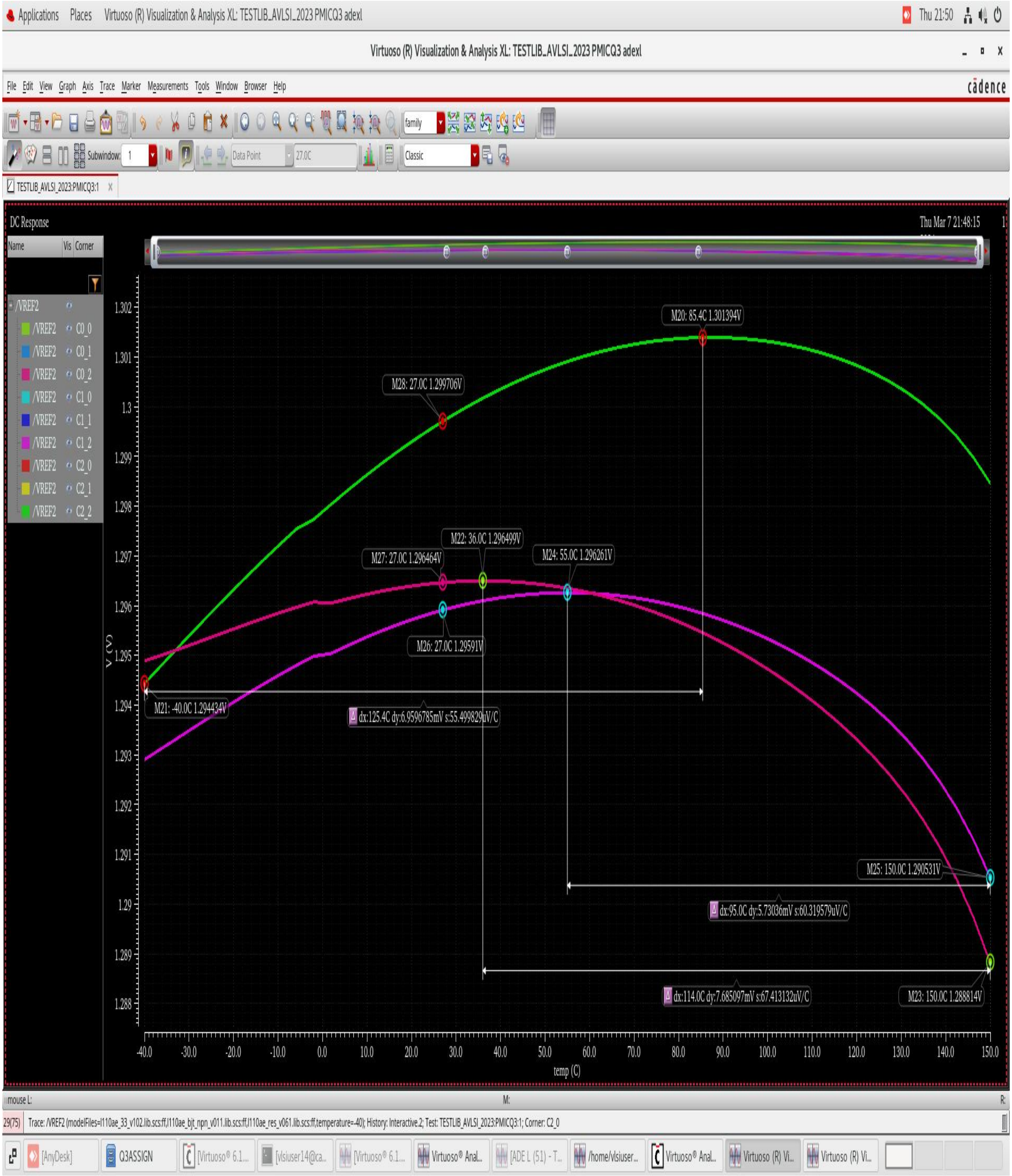
- <u>Waveform of VREF=2.4V with Temperature Sweep at SS,TT,FF Corner and VMAX and VMIN Calculation</u>



- <u>Waveform of VREF=3.0V with Temperature Sweep at SS,TT,FF Corner and VMAX and VMIN Calculation</u>



- <u>Waveform of VREF=3.6V with Temperature Sweep at SS,TT,FF Corner and VMAX and VMIN Calculation</u>



- <u>Observation Table</u>

Q3 BANDGAP VOLTAGE REFERENCE (CIRCUIT_2)

		Slow			Typical			Fast		
AVDD		*2.4V*	*3.0V*	*3.6 V*	*2.4V*	*3.0V*	*3.6V*	*2.4 V*	*3.0 V*	*3.6 V*
VBE5	@ 27°C(mV)	497.438	497.717	497.993	500.368	500.647	500.922	507.469	507.747	508.022
average (dVBE5/dT)	*mV/C*	-2.45171	-2.45169	-2.45162	-2.42613	-2.4261	-2.42607	-2.38595	-2.38591	-2.38588
(VB - VBE5)	*mV@ 27C (V)*	55.7919	56.39	56.9881	55.543	56.1413	56.7395	55.307	55.9053	56.5037
average d(VA - VBE5)/dT	*uV/°C*	172.841	172.849	172.802	172.343	172.337	172.347	171.87	171.849	171.857
R3	kOhm	537.384								
R4	kOhm	6992								
IBIAS2 (nA)	@ 27°C	103.821	104.934	106.047	103.358	104.471	105.585	102.919	104.032	105.146
average (dIBIAS2/dT)	pA/C	321.635	321.649	321.562	320.707	320.696	320.715	319.827	319.789	319.804
VREF2 (V)	@ 27°C	1.27915	1.28781	1.29646	1.27859	1.28725	1.29591	1.28239	1.29105	1.29971
VREF2_Max (V)		1.279183	1.287842	1.296499	1.278938	1.287601	1.296261	1.284066	1.292731	1.301394
VREF2_Min (V)		1.271454	1.280135	1.288814	1.273175	1.281854	1.290531	1.276998	1.285789	1.294434
(VREF2_Max - VREF2_ Min)	(mV)	7.729	7.707	7.685	5.763	5.747	5.73	7.068	6.942	6.96
VREF2 Temp CO	ppm/°C	31.8007	31.497	31.1974	23.7162	23.4912	23.2653	28.9705	28.2633	28.1479

- **<u>Formula</u>**

VREF1 Temp-Co=[VREF1_Max - VREF1_Min]*10^(6)/ [Tmax-Tmin]/VREF1_Max