EN4430 Analog IC Design

Assignment 02

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This report is submitted as the fulfillment of Assignment 02 of Module EN4430

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1 Introduction to Type IV Fully Differential CC LC-VCO Circuit

The Type IV fully differential cross-coupled (CC) LC Voltage-Controlled Oscillator (VCO) is an advanced oscillator topology designed to enhance performance in RF integrated circuits. The LC tank, consisting of a center-tapped symmetric inductor L_{XY}, resonates at the output nodes X and Y. MOS varactors (M_{V1}, M_{V2}) enable fine tuning of frequencies by adjusting their capacitance in response to the control voltage V_{cont}. The dual NMOS-PMOS cross-coupled stages double the output voltage swing compared to the Type I CC LC-VCO and center the output voltage around $V_{DD}/2$, enhancing signal amplitude and symmetry. This topology is particularly advantageous in applications requiring low phase noise, wide tuning range, and high output swing, such as in modern wireless communication systems and frequency synthesizers.

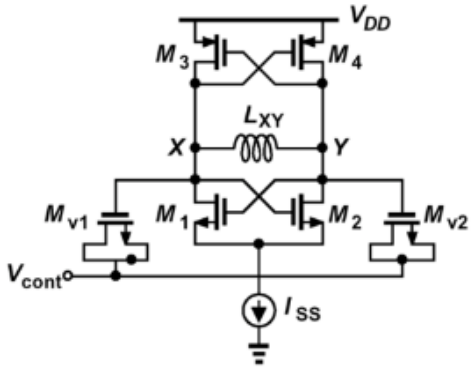

Figure 1: Schematic of the Type IV fully differential CC LC-VCO with MOS varactors.

1.1 Design Constraints

Table 1: Desired Project Performance Specifications

Parameter	**Project Specification**
Technology [Min. length of transistors (L_{min})]	45 nm CMOS
Supply voltage V_{DD}	1 V
Nominal input common-mode voltage $V_{DD}/2$	0.5 V
Bias current I_{bais}	10 μA (change accordingly)
Oscillation frequency f_0	3 GHz
Tuning range	$>$ 20% (i.e - 2.7 GHz to 3.3 GHz)
K_{VCO}	? GHz/V

1.2 Detailed Calculations and Device Sizes

1.2.1 LC Tank Design

The oscillation frequency is determined by the LC tank:

$$\omega_0 = \frac{1}{\sqrt{L_{tank} C_{tank}}}$$

where L_{tank} is a non-ideal inductor with Q(Quality Factor) 10, and C_{tank} includes the varactor capacitance (C_{var}) and parasitic capacitances (C_{par}) from transistors and the inductor.
Rearranging for C_{tank}:

$$C_{tank} = \frac{1}{\omega_0^2 L_{tank}}. \tag{1}$$

For $f_0 = 3\,\text{GHz}$, $\omega_0 = 2\pi \cdot 3 \times 10^9 \approx 1.885 \times 10^{10}\,\text{rad/s}$, and $L_{tank} = 10\,\text{nH}$ (achieved using a symmetric inductor composed of two 5 nH inductors connected in series within the LC tank):

$$\begin{aligned} C_{tank} &= \frac{1}{(1.885 \times 10^{10})^2 \cdot 10 \times 10^{-9}} \\ &= \frac{1}{3.553 \times 10^{20} \cdot 10 \times 10^{-9}} \approx \frac{1}{3.553 \times 10^{12}} \approx 281.45\,\text{fF}. \end{aligned} \tag{2}$$

1.2.2 Tuning Range (2.7 GHz to 3.3 GHz)

$$C_{tank,max} = \frac{1}{(2\pi \cdot 2.7 \times 10^9)^2 \cdot 10 \times 10^{-9}} \approx 347.47\,\text{fF}$$

$$C_{tank,min} = \frac{1}{(2\pi \cdot 3.3 \times 10^9)^2 \cdot 10 \times 10^{-9}} \approx 232.60\,\text{fF}$$

Assume parasitic capacitance (C_{par}) from transistors and the inductor is approximately 10 fF:

$$C_{var} = C_{tank} - C_{par}$$

- At $f_{min} = 2.7\,\text{GHz}$, $C_{var,max} = 232.60 - 10 = 222.60\,\text{fF}$.
- At $f_{max} = 3.3\,\text{GHz}$, $C_{var,min} = 347.47 - 10 = 337.47\,\text{fF}$.

1.2.3 Varactor Sizing (M_{V1}, M_{V2})

Each varactor contributes $C_{var}/2$ since they are in parallel across nodes X and Y:

$$C_{var,per} = \frac{C_{var}}{2}$$

- $C_{var,per,min} = 222.60/2 \approx 111.30\,\text{fF}$
- $C_{var,per,max} = 337.47/2 \approx 168.735\,\text{fF}$

$$C_{var} \approx \varepsilon_{ox} \cdot \frac{W \cdot L}{t_{ox}}$$

where:

- $\varepsilon_{ox} \approx 3.9 \times 8.85 \times 10^{-12}$ F/m (for SiO_2),
- $t_{ox} \approx 1$ nm (typical for 45 nm process),
- $W \cdot L$ is the gate area.

$$C_{var} \approx 3.45 \times 10^{-11} \cdot \frac{W \cdot L}{1 \times 10^{-9}} = 3.45 \times 10^{-2} \cdot W \cdot L \,\text{F}$$

For $C_{var,per,max} = 168.735\,\text{fF}$:

$$168.735 \times 10^{-15} = 3.45 \times 10^{-2} \cdot W \cdot L$$

$$W \cdot L \approx 48.9 \times 10^{-13} \approx 5 \times 10^{-12}\,\text{m}^2$$

Set $L = 1\,\mu$m :

$$W \approx \frac{5 \times 10^{-12}}{1 \times 10^{-6}} \approx 5\,\mu\text{m}$$

Varactor Dimensions:

- $W = 5\,\mu$m, $L = 1\,\mu$m for each varactor (M_{V1}, M_{V2}).

1.2.4 Tank Loos R_p

The tank loss is modeled by R_p, with quality factor of inductor $Q = 10$:

$$R_p = Q \cdot \omega_0 \cdot L_{tank}, \quad \omega_0 = 2\pi \cdot 3 \times 10^9 \approx 1.885 \times 10^{10}\,\text{rad/s} \tag{3}$$

$$R_p = 10 \cdot (1.885 \times 10^{10}) \cdot (10 \times 10^{-9}) \approx 1885\,\Omega \approx 1.885\,k\Omega$$

1.2.5 Transistor Sizing (M1, M2)

The cross-coupled NMOS pair provides a negative resistance, which is essential for sustaining oscillation in a circuit such as an oscillator. This negative resistance is approximated as:

$$R_{neg} \approx -\frac{2}{g_m}, \tag{4}$$

where g_m is the transconductance of each NMOS transistor in the pair.

$$g_m R_p >= 1 \tag{5}$$

Rearranging this inequality to solve for g_m:

$$g_m >= \frac{1}{1885}. \tag{6}$$

$$\frac{1}{1885} \approx 0.00053\,\text{S} = 0.53\text{mS}. \tag{7}$$

For design purposes and to include a safety margin, we set the requirement as:

$$g_m > 0.53\,\text{mS}. \tag{8}$$

The drain current I_D for a MOSFET in saturation is given by:

$$I_D = \frac{1}{2}\mu C_{ox}\frac{W}{L}(V_{GS} - V_t)^2$$

The transconductance g_m is the derivative of I_D with respect to V_{GS}:

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = \mu C_{ox}\frac{W}{L}(V_{GS} - V_t)$$

Squaring both sides and relating to I_D:

$$g_m^2 = 2\mu C_{ox}\frac{W}{L}I_D$$

Rearrange for I_D :

$$I_D = \frac{g_m^2}{2\mu C_{ox}\frac{W}{L}}$$

- $\mu C_{ox} \approx 0.3 \times 10^{-3}\,\text{A/V}^2$
- $g_m \approx 0.53\,\text{mS}$

Let

$$\frac{W}{L} = 5$$

$$I_D = \frac{(0.53 \times 10^{-3})^2}{2 \times 0.3 \times 10^{-3} \times 5} \approx 93.63uA \approx 100uA$$
$$I_{SS} = 2 \times I_D \approx 200uA$$

Since $\frac{W}{L} = 5$: Length for $M_{1,2} = 1\,\mu$m and Width for $M_{1,2} = 5\,\mu$m.
Also, for $M_{3,4}$,
Length = $1\,\mu$m and Width = $10\,\mu$m.

1.2.6 Summary of Calculated Values

To achieve the given design constraints, I have utilized slightly different values compared to the actual calculated results.

Table 2: Summary of Calculated & Chosen Values For Type IV Fully Differential CC LC-VCO

Parameter	Calculated	Chosen	Unit
Length of $M_{1,2}$	1	1	μm
Width of $M_{1,2}$	5	5	μm
Length of $M_{3,4}$	1	1	μm
Width of $M_{3,4}$	10	10	μm
Length of Varactors $M_{V1,V2}$	1	10	μm
Width of Varactors $M_{V1,V2}$	5	10	μm
Inductance	10	10	nH
Bias Current I_{bias}	200	500	μA

I set the control voltage V_{cont} to operate within a range of 0 to 1 V to enable precise tuning of the VCO frequency.

1.3 Simulation Results

1.3.1 Type IV CC Differential LC-VCO Circuit Diagram

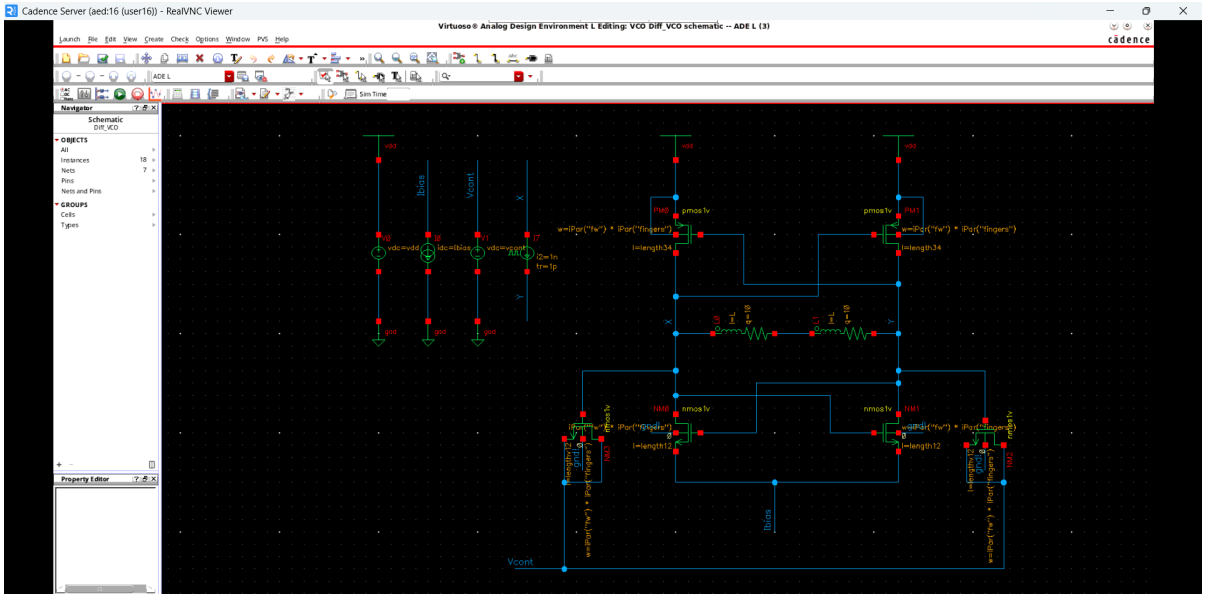

Figure 2: Circuit Diagram of the Type IV fully differential CC LC-VCO with MOS varactors.

- To initiate oscillation, a short signal pulse input was applied with the following features: Current 1 set to 0 A, Current 2 set to 1 nA, rise time of 1 ps, fall time of 1 ps, and pulse width of 3 ps.
- A symmetric inductor of 10 nH was implemented by placing two non-ideal inductors in series, each with a value of 5 nH.
- All other parameters were set according to the values listed in the “Chosen” column of Table 2.

1.3.2 Transient Simulation

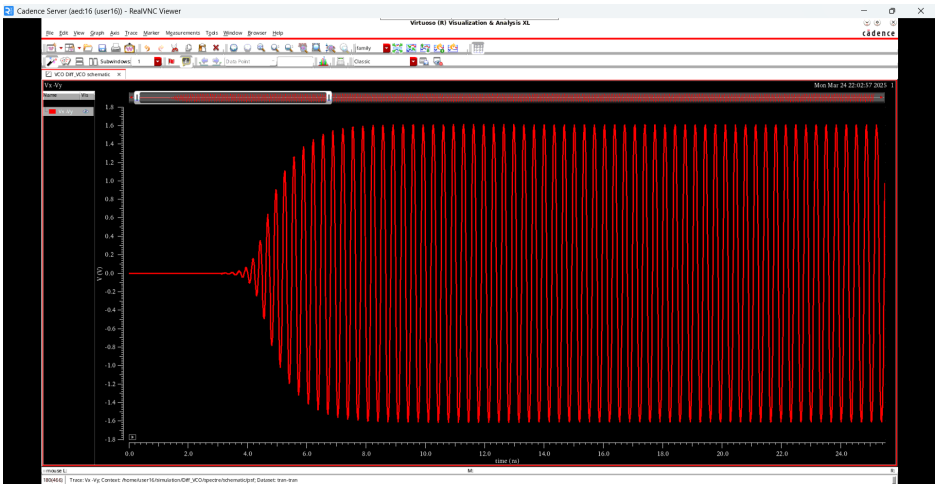

Figure 3: Transient simulation of $V_X - V_Y$ with $V_{cont} = 250\,\text{mV}$, peak-to-peak of 3.22 V (more than twice of V_{DD}).

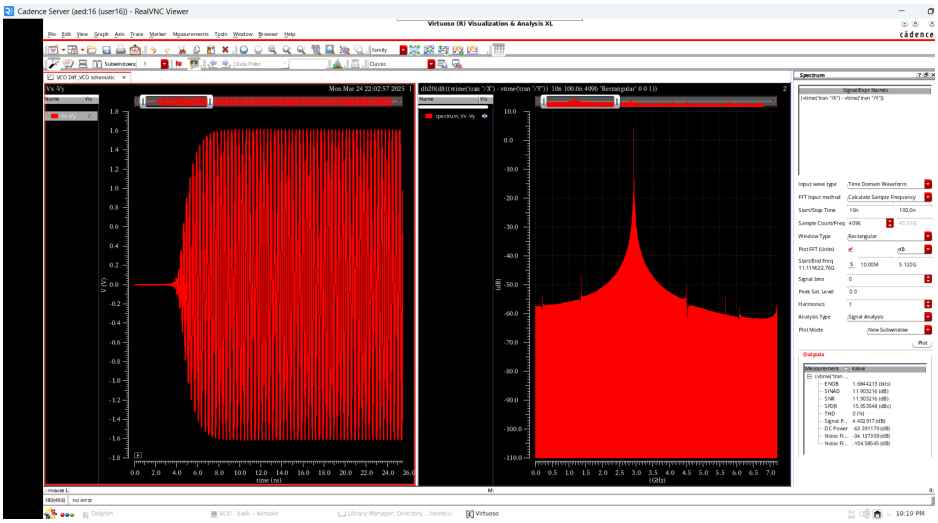

Figure 4: Transient simulation of $V_X - V_Y$ with $V_{cont} = 250\,\text{mV}$, and the FFT analysis revealed an oscillation frequency of 2.944 GHz.

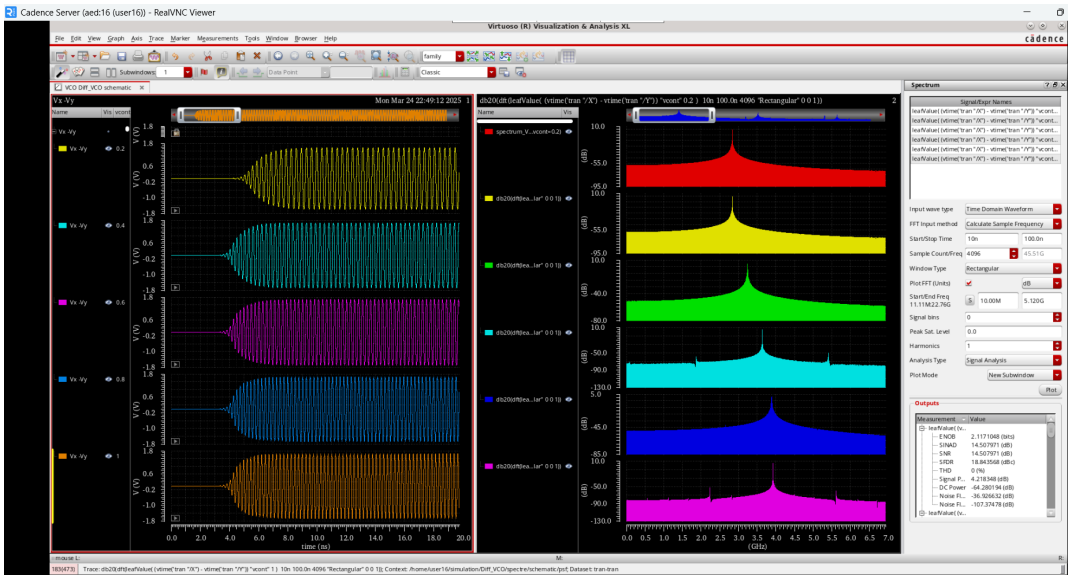

Figure 5: Transient simulation of $V_X - V_Y$ and FFT analysis for $V_{cont} = 0.2, 0.4, 0.6, 0.8, 1$ V

1.3.3 Parametric simulation results of oscillation frequency (f_0) versus control voltage (V_{cont}).

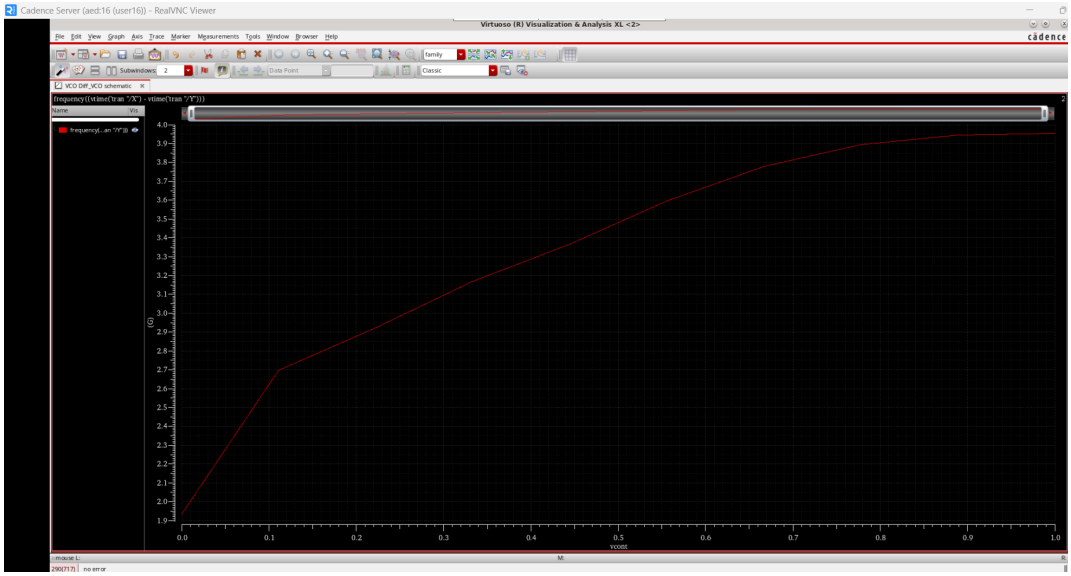

Figure 6: Oscillation frequency (f_0) vs control voltage (V_{cont})

The oscillation frequency f_{osc} increases with V_{cont} due to the positive gain of the VCO.

1.3.4 Periodic Steady State (PSS) simulation

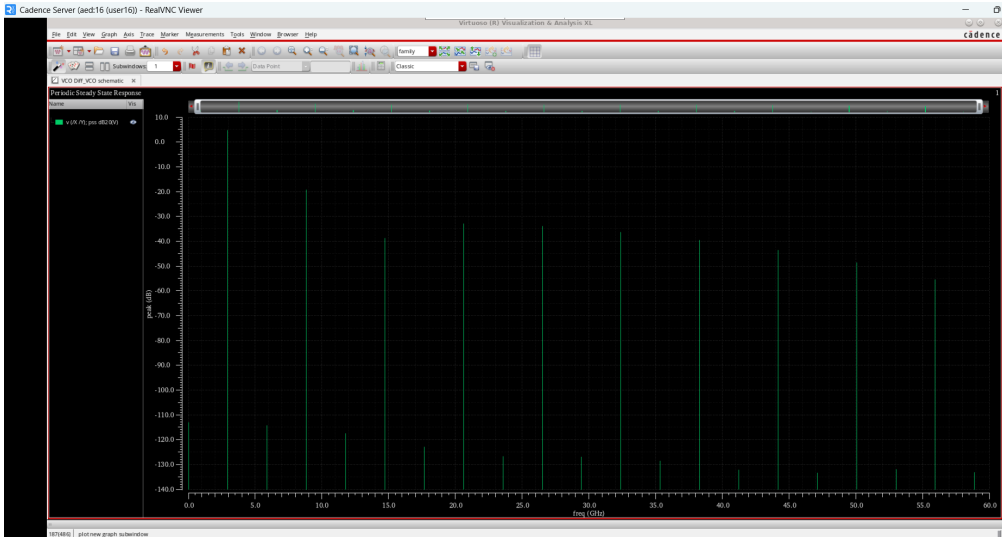

Figure 7: PSS simulation of $V_X - V_Y$ at $V_{cont} = 250\,\text{mV}$, showing a first harmonic frequency of 2.947 GHz.

1.3.5 Phase Noise (PS) Simulation

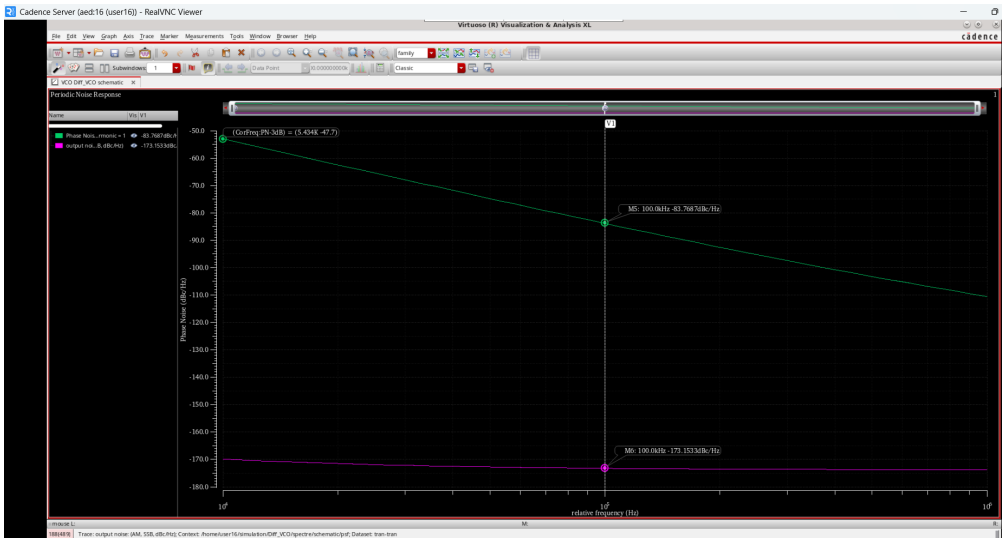

Figure 8: PSS simulation results: Green Curve For Phase Modulation(PM), Purple Curve For Amplitude Modulation(AM).

1.4 Discussion For Type IV Fully Differential CC LC-VCO

- **Tuning Range:** Figure 6
  - Center frequency: $f_{\text{center}} = \frac{f_{\text{max}}+f_{\text{min}}}{2} = \frac{3.9+1.9}{2} = 2.9\,\text{GHz}$.
  - Total tuning range: $\frac{f_{\text{max}}-f_{\text{min}}}{f_{\text{center}}} \times 100\% = \frac{3.9-1.9}{2.9} \times 100\% = 69\%$.
  - Deviation: $\pm\frac{69\%}{2} = \pm 34.5\%$, so frequency spans $2.9 \pm (0.345 \times 2.9) = 2.9 \pm 1\,\text{GHz}$.
  - Wide range enabled by MOS varactors' capacitance swing and symmetric inductor ensures balanced operation.
- **K**$_{VCO}$

$$K_{VCO} = \frac{\Delta f}{\Delta v_{\text{cont}}}, \quad \text{where} \quad \Delta f \propto \frac{1}{\sqrt{L(C_{var}(v_{cont}))}}$$

To calculate approximate K_{VCO}, I needed to calculate the gradient of the f_0 vs. v_{cont} curve. Therefore I selected, two points on the curve as follows:

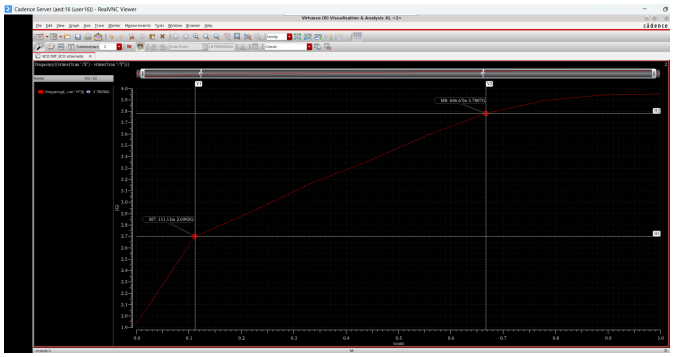

Figure 9: Kvco Calculation From V_{cont} vs f_0 curve

  - At $v_{\text{cont}} = 111.11\,\text{mV}$, the frequency $f = 2.6992\,\text{GHz}$.
  - At $v_{\text{cont}} = 666.67\,\text{V}$, the frequency $f = 3.7807\,\text{GHz}$.

The gradient is calculated as:

$$\frac{\Delta f}{\Delta v_{\text{cont}}} = \frac{f_2 - f_1}{v_{\text{cont2}} - v_{\text{cont1}}} = \frac{3.7807 - 2.6992}{0.66667 - 0.11111} = 1.9467\,\text{GHz/V}$$

Thus, the VCO gain is:

$$K_{VCO} \approx 1.9467\,\text{GHz/V} > 0$$

- **Output Voltage Swing**

  The peak-to-peak output voltage swing achieves more than twice the input voltage V_{dd} of 1 V.

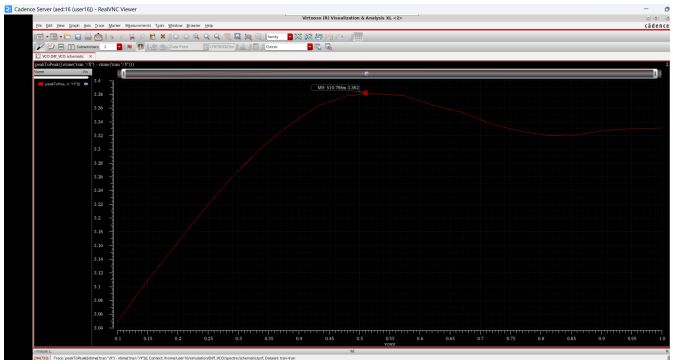

Figure 10: V_{cont} vs Peak-To-Peak curve, Max(Peak-To-Peak) = 3.382 V at V_{cont} = 510.788 mV

- **Noise performances with respect to phase & amplitude**
  - At a 100 kHz offset from the carrier Figure 8:
    - Phase Modulation (PM) Noise: -83.7687 dBc/Hz
    - Amplitude Modulation (AM) Noise: -173.1533 dBc/Hz

    The phase noise analysis reveals that the amplitude modulation (AM) noise is significant with respect to the phase modulation (PM) noise.

2 Introduction to Type I CC LC voltage-controlled oscillator (VCO) Circuit

The Type I cross-coupled LC Voltage-Controlled Oscillator (VCO) is a widely used topology in RF integrated circuits, designed to generate a stable, tunable oscillation frequency. This VCO employs a pair of NMOS transistors (M_1 and M_2) arranged in a cross-coupled configuration to provide the negative resistance necessary to sustain oscillations. The LC tank, formed by inductors L_1 and capacitors C_1, determines the resonant frequency, while the resistors R_p model the inherent losses of the tank. Frequency tuning is achieved through MOS varactors (C_{var}) connected at the output nodes (X and Y).

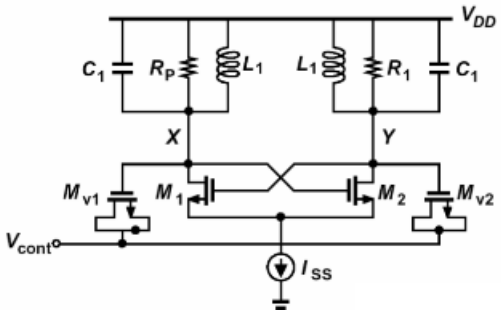

Figure 11: Schematic of the Type I CC LC-VCO with MOS varactors.

2.1 Detailed Calculations and Device Sizes

I have made slight modifications to the calculations for the Type I cross-coupled (CC) LC voltage-controlled oscillator (VCO) compared to the Type IV fully differential CC LC VCO.

2.1.1 LC Tank Design

The oscillation frequency is determined by the LC tank:

$$\omega_0 = \frac{1}{\sqrt{L_{tank} C_{tank}}}$$

where L_{tank} is a non-ideal inductor with Q(Quality Factor) 10, and C_{tank} includes the varactor capacitance (C_{var}) and parasitic capacitances (C_{par}) of transistors & the inductor and fixed capacitances of $C_{1,2}$.
Rearranging for C_{tank}:

$$C_{tank} = \frac{1}{\omega_0^2 L_{tank}}. \tag{9}$$

For $f_0 = 3\,\text{GHz}$, $\omega_0 = 2\pi \cdot 3 \times 10^9 \approx 1.885 \times 10^{10}\,\text{rad/s}$, and $L_{tank} = 2\,\text{nH}$:

$$\begin{aligned} C_{tank} &= \frac{1}{(1.885 \times 10^{10})^2 \cdot 2 \times 10^{-9}} \\ &= \frac{1}{3.553 \times 10^{20} \cdot 2 \times 10^{-9}} \approx \frac{1}{7.106 \times 10^{11}} \approx 1.41\,\text{pF}. \end{aligned} \tag{10}$$

2.1.2 Tuning Range (2.7 GHz to 3.3 GHz)

$$C_{tank,max} = \frac{1}{(2\pi \cdot 2.7 \times 10^9)^2 \cdot 2 \times 10^{-9}} \approx 1.74\,\text{pF}$$

$$C_{tank,min} = \frac{1}{(2\pi \cdot 3.3 \times 10^9)^2 \cdot 2 \times 10^{-9}} \approx 1.16\,\text{pF}$$

Assume parasitic capacitance (C_{par}) from transistors and the inductor is approximately 10 fF & ($C_{1,2}$) is approximately 500 fF:

$$C_{var} = C_{tank} - C_{par} - 2 \times C1, 2$$

- At $f_{min} = 2.7\,\text{GHz}$, $C_{var,max} = 1.74 - 0.01 - 2 \times 0.5 = 0.73\,\text{pF}$.
- At $f_{max} = 3.3\,\text{GHz}$, $C_{var,min} = 1.16 - 0.01 - 2 \times 0.5 = 0.15\,\text{pF}$.

2.1.3 Varactor Sizing (M_{V1}, M_{V2})

Each varactor contributes $C_{var}/2$ since they are in parallel across nodes X and Y:

$$C_{var,per} = \frac{C_{var}}{2}$$

- $C_{var,per,min} = 0.73/2 \approx 0.365\,\text{pF} \approx 365\,\text{fF}$
- $C_{var,per,min} = 0.15/2 \approx 0.075\,\text{pF} \approx 75\,\text{fF}$

$$C_{var} \approx \varepsilon_{ox} \cdot \frac{W \cdot L}{t_{ox}}$$

where:

- $\varepsilon_{ox} \approx 3.9 \times 8.85 \times 10^{-12}\,\text{F/m}$ (for SiO_2),
- $t_{ox} \approx 1\,\text{nm}$ (typical for 45 nm process),
- $W \cdot L$ is the gate area.

$$C_{var} \approx 3.45 \times 10^{-11} \cdot \frac{W \cdot L}{1 \times 10^{-9}} = 3.45 \times 10^{-2} \cdot W \cdot L\,\text{F}$$

For $C_{var,per,max} = 365\,\text{fF}$:

$$365 \times 10^{-15} = 3.45 \times 10^{-2} \cdot W \cdot L$$
$$W \cdot L \approx 105.79 \times 10^{-13} \approx 10 \times 10^{-12}\,\text{m}^2$$

Set $L = 2\,\mu\text{m}$:

$$W \approx \frac{10 \times 10^{-12}}{2 \times 10^{-6}} \approx 5\,\mu\text{m}$$

Varactor Dimensions:

- $W = 5\,\mu\text{m}$, $L = 2\,\mu\text{m}$ for each varactor (M_{V1}, M_{V2}).

2.1.4 Tank Loos R_p

The tank loss is modeled by R_p, with quality factor of inductor $Q = 10$:

$$R_p = Q \cdot \omega_0 \cdot L_{tank}, \quad \omega_0 = 2\pi \cdot 3 \times 10^9 \approx 1.885 \times 10^{10}\,\text{rad/s} \tag{11}$$
$$R_p = 10 \cdot (1.885 \times 10^{10}) \cdot (2 \times 10^{-9}) \approx 377\,\Omega \approx 500\,\Omega$$

2.1.5 Transistor Sizing (M1, M2)

The cross-coupled NMOS pair provides a negative resistance, which is essential for sustaining oscillation in a circuit such as an oscillator. This negative resistance is approximated as:

$$R_{neg} \approx -\frac{2}{g_m}, \tag{12}$$

where g_m is the transconductance of each NMOS transistor in the pair.

$$g_m R_p >= 1 \tag{13}$$

Rearranging this inequality to solve for g_m:

$$g_m >= \frac{1}{500}. \tag{14}$$

$$\frac{1}{500} \approx 0.002\,\text{S} = 2\text{mS}. \tag{15}$$

For design purposes and to include a safety margin, we set the requirement as:

$$g_m > 2\,\text{mS}. \tag{16}$$

The drain current I_D for a MOSFET in saturation is given by:

$$I_D = \frac{1}{2}\mu C_{ox}\frac{W}{L}(V_{GS} - V_t)^2$$

The transconductance g_m is the derivative of I_D with respect to V_{GS}:

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = \mu C_{ox}\frac{W}{L}(V_{GS} - V_t)$$

Squaring both sides and relating to I_D:

$$g_m^2 = 2\mu C_{ox}\frac{W}{L}I_D$$

Rearrange for I_D :

$$I_D = \frac{g_m^2}{2\mu C_{ox}\frac{W}{L}}$$

- $\mu C_{ox} \approx 0.3 \times 10^{-3}\,\text{A/V}^2$
- $g_m \approx 2\,\text{mS}$

Let

$$\frac{W}{L} = 100$$

$$I_D = \frac{(2 \times 10^{-3})^2}{2 \times 0.3 \times 10^{-3} \times 100} \approx 66.67\mu A$$
$$I_{SS} = 2 \times I_D \approx 133.33\mu A$$

Since $\frac{W}{L} = 100$: Length for $M_{1,2} = 50\,\text{nm}$ and Width for $M_{1,2} = 5\,\mu\text{m}$.

2.1.6 Summary of Calculated Values

To achieve the given design constraints, I have utilized slightly different values compared to the actual calculated results.

Table 3: Summary of Calculated & Chosen Values For Type I CC LC VCO

Parameter	Calculated	Chosen	Unit
Length of $M_{1,2}$	50	50	nm
Width of $M_{1,2}$	5	5	μm
Length of Varactors $M_{V1,V2}$	2	2	μm
Width of Varactors $M_{V1,V2}$	5	5	μm
Inductance L_1	1	3.5	nH
Capacitance C_1	500	700	fF
Resistance R_p	500	400	fF
Bias Current I_{bias}	133.33	800	μA

I set the control voltage V_{cont} to operate within a range of 0 to 1 V to enable precise tuning of the VCO frequency.

2.2 Simulation Results

2.2.1 Type I CC LC-VCO Circuit Diagram

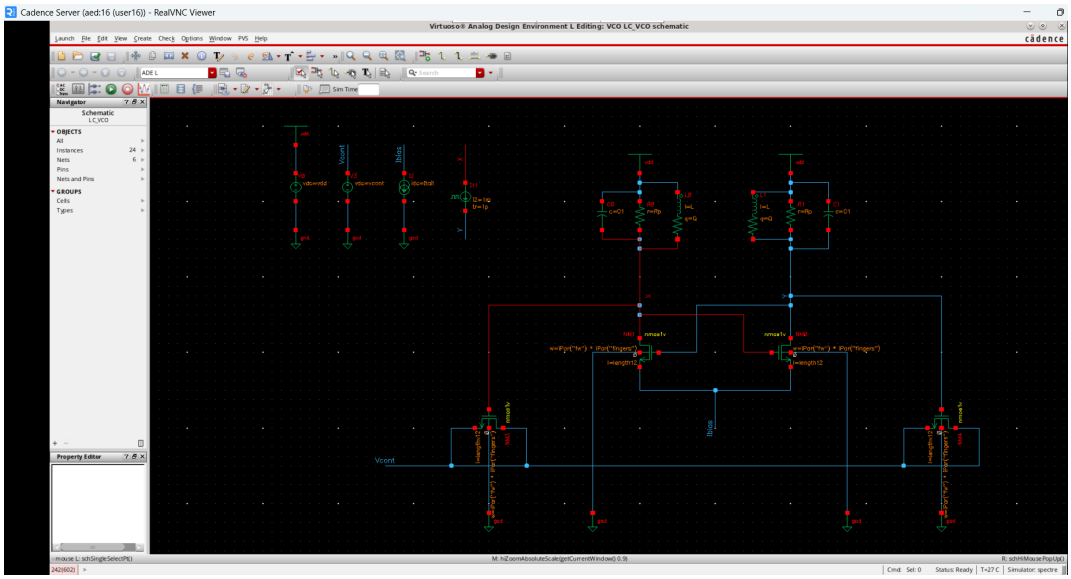

Figure 12: Circuit Diagram of the Type I CC LC VCO with MOS varactors.

– To initiate oscillation, a short signal pulse input was applied with the following features: Current 1 set to 0 A, Current 2 set to 1 mA, rise time of 1 ps, fall time of 1 ps, and pulse width of 3 ps.

– All other parameters were set according to the values listed in the “Chosen” column of Table 3.

2.2.2 Transient Simulation

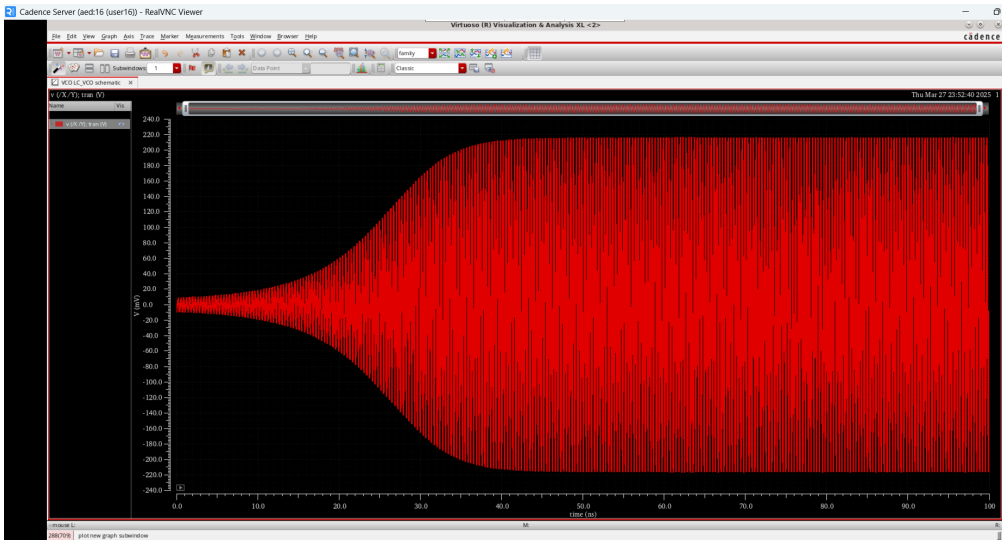

Figure 13: Transient simulation of $V_X - V_Y$ with $V_{cont} = 250\,\text{mV}$, peak-to-peak of 432.1 mV.

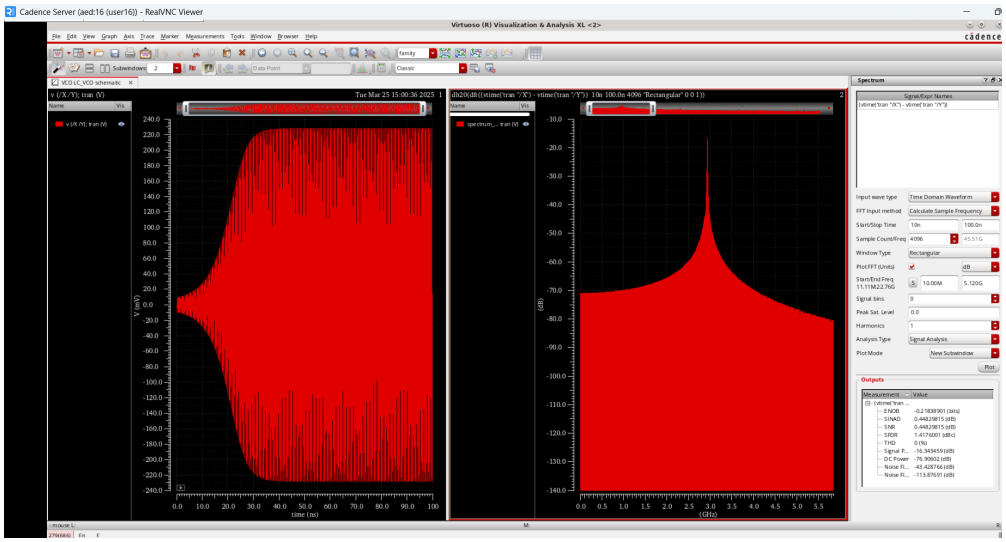

Figure 14: Transient simulation of $V_X - V_Y$ with $V_{cont} = 250\,\text{mV}$, and the FFT analysis shows an oscillation frequency of 2.933 GHz.

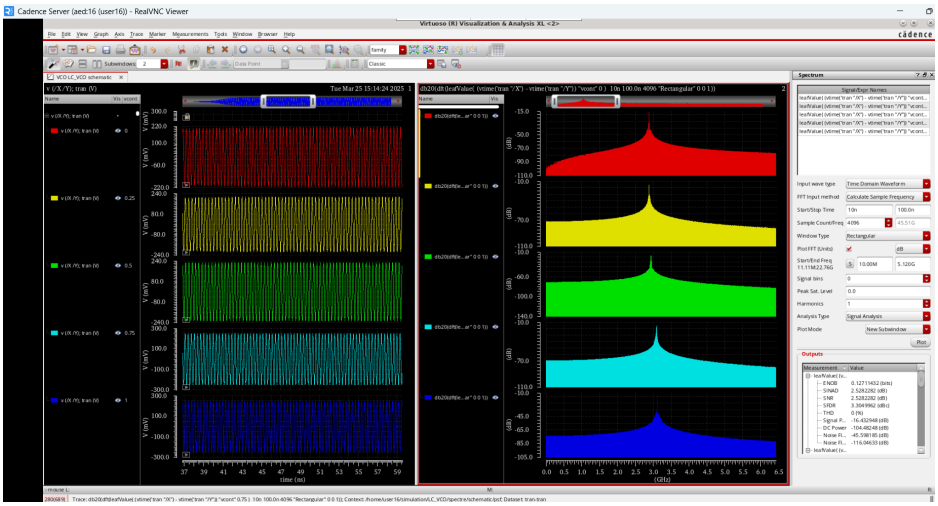

Figure 15: Transient simulation of $V_X - V_Y$ and FFT analysis for $V_{cont} = 0, 0.25, 0.5, 0.75, 1\,\text{V}$

2.2.3 Parametric simulation results of oscillation frequency (f_0) versus control voltage (V_{cont}).

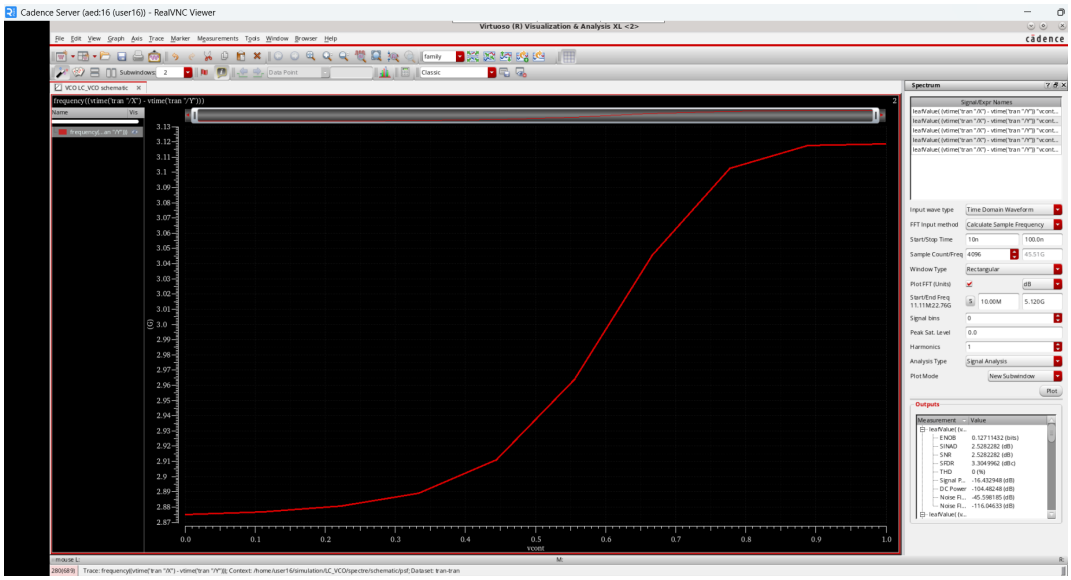

Figure 16: Oscillation frequency (f_0) vs control voltage (V_{cont})

The oscillation frequency f_{osc} increases with V_{cont} due to the positive gain of the VCO.

2.2.4 Periodic Steady State (PSS) simulation

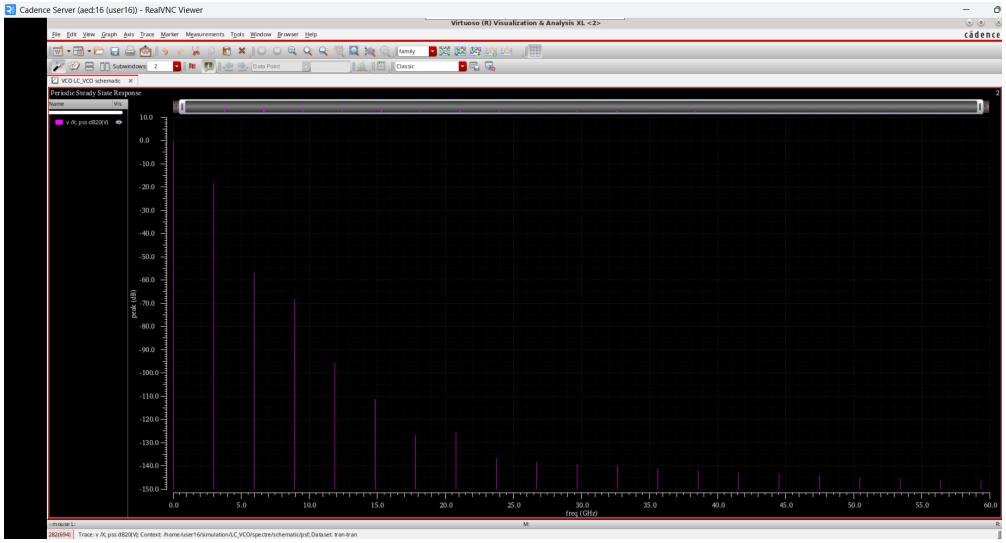

Figure 17: PSS simulation of $V_X - V_Y$ at $V_{cont} = 500\,\text{mV}$, showing a first harmonic frequency of 2.969 GHz.

2.2.5 Phase Noise (PS) Simulation

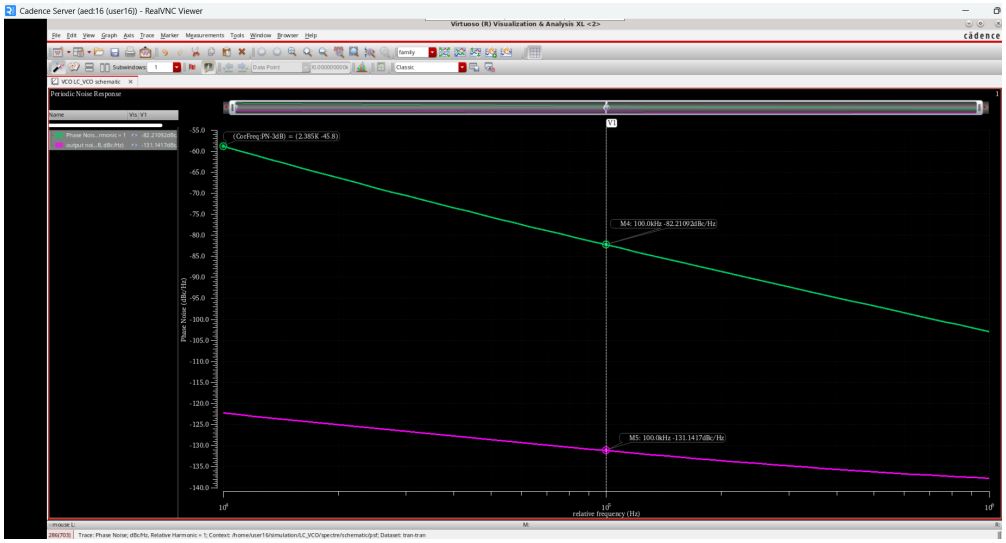

Figure 18: PSS simulation results: Green Curve For Phase Modulation(PM), Purple Curve For Amplitude Modulation(AM).

2.3 Discussion For Type I CC LC-VCO

- **Tuning Range:** Figure 16
  - Center frequency: $f_{\text{center}} = \frac{f_{\text{max}}+f_{\text{min}}}{2} = \frac{3.12+2.875}{2} = 2.9975\,\text{GHz}$.
  - Total tuning range: $\frac{f_{\text{max}}-f_{\text{min}}}{f_{\text{center}}} \times 100\% = \frac{3.12-2.875}{2.9975} \times 100\% = 8.17\%$.
  - Deviation: $\pm\frac{8.17\%}{2} = \pm 4.085\%$, so frequency spans $2.9975 \pm (0.04085 \times 2.9975) = 2.9 \pm 122.45\,\text{MHz}$.
- **K$_{VCO}$**

$$K_{VCO} = \frac{\Delta f}{\Delta v_{\text{cont}}}, \quad \text{where} \quad \Delta f \propto \frac{1}{\sqrt{L(C_{var}(v_{cont}))}}$$

To calculate approximate K_{VCO}, I needed to calculate the gradient of the f_0 vs. v_{cont} curve. Therefore I selected, two points on the curve as follows:

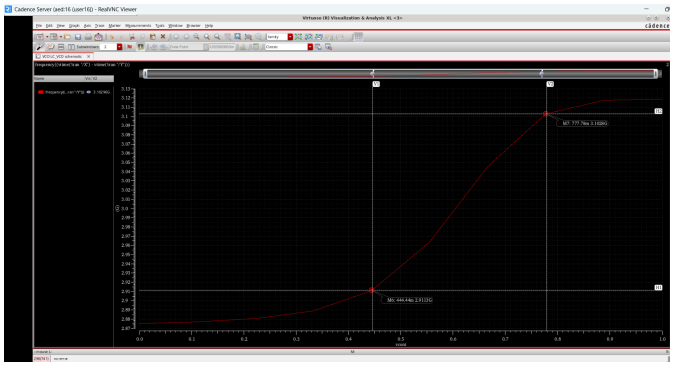

Figure 19: Kvco Calculation From V_{cont} vs f_0 curve

- At $v_{\text{cont}} = 444.44\,\text{mV}$, the frequency $f = 2.9113\,\text{GHz}$.
- At $v_{\text{cont}} = 777.78\,\text{V}$, the frequency $f = 3.1028\,\text{GHz}$.

The gradient is calculated as:

$$\frac{\Delta f}{\Delta v_{\text{cont}}} = \frac{f_2 - f_1}{v_{\text{cont2}} - v_{\text{cont1}}} = \frac{3.1028 - 2.9113}{0.77778 - 0.44444} = 0.5745\,\text{GHz/V}$$

Thus, the VCO gain is:

$$K_{VCO} \approx 0.5745\,\text{GHz/V} > 0$$

- **Output Voltage Swing**
  The maximum swing reaching approximately 501.4 mV, which is nearly the half of V_{DD}.

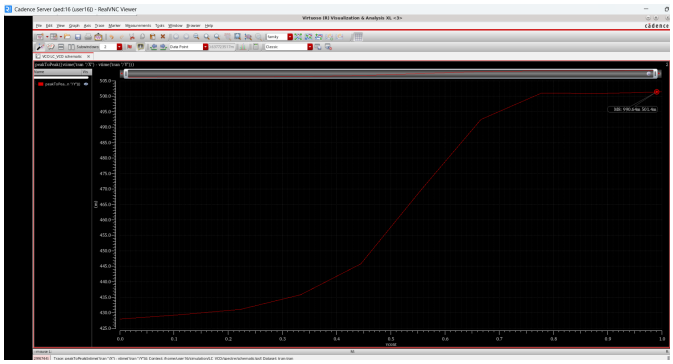

Figure 20: V_{cont} vs Peak-To-Peak curve, Max(Peak-To-Peak) = 501.4 mV at V_{cont} = 990.64 mV

– **Noise performances with respect to phase & amplitude**

* At a 100 kHz offset from the carrier Figure 18:
  · Phase Modulation (PM) Noise: -82.2109 dBc/Hz
  · Amplitude Modulation (AM) Noise: -131.1417 dBc/Hz

  The phase noise analysis reveals that the amplitude modulation (AM) noise is significant with respect to the phase modulation (PM) noise.

3 Comparison between Type I CC LC-VCO & Type IV Fully Differential CC LC-VCO

Table 4: Comparison of Type I CC LC-VCO and Type IV Fully Differential CC LC-VCO

Parameter	**Type I CC LC-VCO**	**Type IV Fully Differential CC LC-VCO**
Center Frequency	2.9975 GHz	2.9 GHz
Tuning Range	4.085% ($\pm$122.45 MHz)	34.5% ($\pm$1 GHz)
$\approx K_{VCO}$	0.5745 GHz/V	1.9467 GHz/V
Output Voltage Swing (Peak-to-Peak)	501.4 mV (nearly half of $V_{DD} = 1$ V)	3.382 V (more than twice $V_{DD} = 1$ V)
PM Noise (at 100 kHz offset)	-82.2109 dBc/Hz	-83.7687 dBc/Hz
AM Noise (at 100 kHz offset)	-131.1417 dBc/Hz	-173.1533 dBc/Hz

* **Superior Tuning Range**: Type IV achieves a wider tuning range of 34.5% ($\pm$1 GHz) compared to Type I's 4.085% ($\pm$122.45 MHz), enabling multi-band operation for modern wireless standards.
* **Enhanced Output Swing**: Type IV delivers a maximum output swing of 3.382 V compared to Type I's 501.4 mV, enabling robust signal generation and improved system performance.

4 Improvements for Wider and Stable Tuning Range

* **Hybrid Capacitor Bank with Floating Switches**
  - Combines switched capacitors in a binary-weighted array with varactors for dual-mode tuning.
  - Widens tuning range by enabling large discrete frequency steps through the capacitor bank, supplemented by continuous fine tuning via varactors.
  - Enhances stability by using floating switches to minimize parasitic capacitance, preserving the tank circuit's quality factor (Q).
  - Achieves stable operation by decoupling coarse and fine tuning, reducing sensitivity of the VCO gain (K_{VCO}) to control voltage changes.

$$\Delta f \propto \frac{\sum b_n C_u}{\sqrt{L(C_{var} + \sum b_n C_u)}}$$

  where b_n are binary control bits, C_u is unit capacitance, and C_{var} is varactor capacitance.

* **Enhanced Symmetric Varactor Topology with Bias Optimization**
  - Employs back-to-back varactors in a differential configuration with adjustable bias control.
  - Broadens tuning range by optimizing bias to maximize capacitance variation across the varactors, matching the flexibility of single-ended designs.
  - Improves stability through symmetric capacitance modulation, which reduces distortion and enhances rejection of supply noise.
  - Maintains consistent K_{VCO} by balancing the capacitance-voltage relationship, minimizing phase noise fluctuations.

$$C_{diff} = \frac{C_{var1}(V) \cdot C_{var2}(V)}{C_{var1}(V) + C_{var2}(V)}$$

  where $C_{var1}(V)$ and $C_{var2}(V)$ are symmetrically tuned capacitances.

5 Appendices

5.1 Netlist for Type IV fully differential CC LC-VCO

```
// Generated for: spectre
// Generated on: Mar 24 18:51:03 2025
// Design library name: VCO
// Design cell name: Diff_VCO
// Design view name: schematic
simulator lang=spectre
global 0 vdd!
parameters Ibias=500u L=5n length12=500n length34=500n lengthv12=10u \
    vcont=250m vdd=1 width12=5u width34=10u widthv12=10u F0=3G delF=10k
include "/home/aed/cadence/dicd_source/cadence_pdk/gpdk045_v_6_0/gpdk045/../
    models/spectre/gpdk045.scs" section=mc

// Library name: VCO
// Cell name: Diff_VCO
// View name: schematic
PM1 (Y X vdd! vdd!) g45p1svt w=((width34) * (1)) l=length34 nf=1 as=((width34
    ) < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))
    * 120n) + ((width34) * 50n)) + (floor(((1) - 1) / 2.0) * (((((60n) - 0) +
     60n) * 120n) + ((width34) * 100n))) + ((((1) / 2) - floor((1) / 2) == 0)
     ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) * 120n) + ((
    width34) * 50n)) : 0)) / 1 : (((100n > (((60n) - 0) + 80n) ? 100n : (((60
    n) - 0) + 80n)) * (width34)) + (floor(((1) - 1) / 2.0) * ((60n > (((60n)
    - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width34))) + ((((1) / 2) -
    floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0)
     + 80n)) * (width34)) : 0)) / 1 \
        ad=((width34) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n)
            * 120n) + ((width34) * 100n))) + ((((1) / 2) - floor((1) / 2) !=
            0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
            120n) + ((width34) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) * ((60n
             > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width34)))
             + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60n) - 0) +
            80n) ? 100n : (((60n) - 0) + 80n)) * (width34)) : 0)) / 1 \
        ps=((width34) < 119.5n) ? (((2 * (50n > (((60n) - 0) + 60n) ? 50n :
            (((60n) - 0) + 60n))) + 340n) + (floor(((1) - 1) / 2.0) * ((2 *
            (((60n) - 0) + 60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) ==
            0) ? ((2 * (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)
            )) + 340n) : 0)) / 1 : (((2 * (100n > (((60n) - 0) + 80n) ? 100n
            : (((60n) - 0) + 80n))) + (2 * (width34))) + (floor(((1) - 1) /
            2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50
            n))) + (2 * (width34)))) + ((((1) / 2) - floor((1) / 2) == 0) ?
            ((2 * (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)))
            + (2 * (width34))) : 0)) / 1 \
        pd=((width34) < 119.5n) ? ((floor((1) / 2.0) * ((2 * (((60n) - 0) +
            60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) != 0) ? ((2 * (50n
            > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))) + 340n) : 0))
```

```
        / 1 : ((floor((1) / 2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60
    n : (((60n) - 0) + 50n))) + (2 * (width34)))) + ((((1) / 2) -
    floor((1) / 2) != 0) ? ((2 * (100n > (((60n) - 0) + 80n) ? 100n :
     (((60n) - 0) + 80n))) + (2 * (width34))) : 0)) / 1 \
nrd=((width34) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n)
     * 120n) + ((width34) * 100n))) + ((((1) / 2) - floor((1) / 2) !=
     0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
     120n) + ((width34) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) * ((60
    n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width34))
    ) + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60n) - 0) +
    80n) ? 100n : (((60n) - 0) + 80n)) * (width34)) : 0)) / 1 / ((
    width34) * (1) * (width34) * (1)) \
nrs=((width34) < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n :
    (((60n) - 0) + 60n)) * 120n) + ((width34) * 50n)) + (floor(((1) -
     1) / 2.0) * (((((60n) - 0) + 60n) * 120n) + ((width34) * 100n)))
     + ((((1) / 2) - floor((1) / 2) == 0) ? (((50n > (((60n) - 0) +
    60n) ? 50n : (((60n) - 0) + 60n)) * 120n) + ((width34) * 50n)) :
    0)) / 1 : (((100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) +
    80n)) * (width34)) + (floor(((1) - 1) / 2.0) * ((60n > (((60n) -
    0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width34))) + ((((1) /
    2) - floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n :
     (((60n) - 0) + 80n)) * (width34)) : 0)) / 1 / ((width34) * (1) *
     (width34) * (1)) \
sa=((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
    - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
    n) - 0) + 80n)) \
sb=((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
    - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
    n) - 0) + 80n)) \
sd=((width34) < 119.5n) ? (((60n) - 0) + 60n) + (2*5e-08) : (60n >
    (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) \
sca=(( (width34) * ( (((1u) * (1u) / (((width34) < 119.5n) ? (50n >
    (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
    > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)) - ((1u)
     * (1u) / ((((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n) ?
    50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n)
    ? 100n : (((60n) - 0) + 80n))+60n)+length34))) + ((1u) * (1u) /
    (((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
    ) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
    (((60n) - 0) + 80n))+60n)) - ((1u) * (1u)/ ((((width34) < 119.5n)
     ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e
    -08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))
    +60n)+length34)))) + ( length34 * ( (((1u) * (1u) / (60n)) - ((1u
    ) * (1u) / ((60n)+(width34)))) + ((1u) * (1u) / (60n)) - ((1u) *
    (1u)/ ((60n)+(width34)))))) / ((width34) * length34) \
scb=(((width34) * (((((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n
    ) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) +
    80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp(-10 *
    (((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
    ) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
```

```
        (((60n) - 0) + 80n))+60n) / (1u)) - (((((width34) < 119.5n) ? (50
        n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
        (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length34)/10 + (1u)/100)*exp(-10 * ((((width34) < 119.5n) ? (50n
        > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
        n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length34) / (1u)) + ((((width34) < 119.5n) ? (50n > (((60n) - 0)
        + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) -
        0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp
        (-10 * (((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
         (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100
        n : (((60n) - 0) + 80n))+60n) / (1u)) - (((((width34) < 119.5n) ?
         (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
        : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length34)/10 + (1u)/100)*exp(-10 * ((((width34) < 119.5n) ? (50n
        > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
        n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length34) / (1u)))) + (length34 * (((60n)/10 + (1u)/100)*exp(-10
        * (60n) / (1u)) - (((60n)+(width34))/10 + (1u)/100)*exp(-10 *
        ((60n)+(width34)) / (1u)) + ((60n)/10 + (1u)/100)*exp(-10 * (60n)
         / (1u)) - (((60n)+(width34))/10 + (1u)/100)*exp(-10 * ((60n)+(
        width34)) / (1u))))) / ((width34) * length34) \
26      scc=(((width34) * (((((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n
        ) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) +
        80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp(-20 *
        (((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
        ) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
        (((60n) - 0) + 80n))+60n) / (1u)) - (((((width34) < 119.5n) ? (50
        n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
        (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length34)/20 + (1u)/400)*exp(-20 * ((((width34) < 119.5n) ? (50n
        > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
        n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length34) / (1u)) + ((((width34) < 119.5n) ? (50n > (((60n) - 0)
        + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) -
        0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp
        (-20 * (((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
         (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100
        n : (((60n) - 0) + 80n))+60n) / (1u)) - (((((width34) < 119.5n) ?
         (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
        : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length34)/20 + (1u)/400)*exp(-20 * ((((width34) < 119.5n) ? (50n
        > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
        n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length34) / (1u)))) + (length34 * (((60n)/20 + (1u)/400)*exp(-20
        * (60n) / (1u)) - (((60n)+(width34))/20 + (1u)/400)*exp(-20 *
        ((60n)+(width34)) / (1u)) + ((60n)/20 + (1u)/400)*exp(-20 * (60n)
         / (1u)) - (((60n)+(width34))/20 + (1u)/400)*exp(-20 * ((60n)+(
        width34)) / (1u))))) / ((width34) * length34) \
27      m=(1)
```

```
28 PM0 (X Y vdd! vdd!) g45p1svt w=((width34) * (1)) l=length34 nf=1 as=((width34
       ) < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))
       * 120n) + ((width34) * 50n)) + (floor(((1) - 1) / 2.0) * (((((60n) - 0) +
        60n) * 120n) + ((width34) * 100n))) + ((((1) / 2) - floor((1) / 2) == 0)
        ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) * 120n) + ((
       width34) * 50n)) : 0)) / 1 : (((100n > (((60n) - 0) + 80n) ? 100n : (((60
       n) - 0) + 80n)) * (width34)) + (floor(((1) - 1) / 2.0) * ((60n > (((60n)
       - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width34))) + ((((1) / 2) -
       floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0)
        + 80n)) * (width34)) : 0)) / 1 \
29         ad=((width34) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n)
               * 120n) + ((width34) * 100n))) + ((((1) / 2) - floor((1) / 2) !=
               0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
               120n) + ((width34) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) * ((60n
                > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width34)))
                + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60n) - 0) +
               80n) ? 100n : (((60n) - 0) + 80n)) * (width34)) : 0)) / 1 \
30         ps=((width34) < 119.5n) ? (((2 * (50n > (((60n) - 0) + 60n) ? 50n :
               (((60n) - 0) + 60n))) + 340n) + (floor(((1) - 1) / 2.0) * ((2 *
               (((60n) - 0) + 60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) ==
               0) ? ((2 * (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)
               )) + 340n) : 0)) / 1 : (((2 * (100n > (((60n) - 0) + 80n) ? 100n
               : (((60n) - 0) + 80n))) + (2 * (width34))) + (floor(((1) - 1) /
               2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50
               n))) + (2 * (width34)))) + ((((1) / 2) - floor((1) / 2) == 0) ?
               ((2 * (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)))
               + (2 * (width34))) : 0)) / 1 \
31         pd=((width34) < 119.5n) ? ((floor((1) / 2.0) * ((2 * (((60n) - 0) +
               60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) != 0) ? ((2 * (50n
               > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))) + 340n) : 0))
                / 1 : ((floor((1) / 2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60
               n : (((60n) - 0) + 50n))) + (2 * (width34)))) + ((((1) / 2) -
               floor((1) / 2) != 0) ? ((2 * (100n > (((60n) - 0) + 80n) ? 100n :
                (((60n) - 0) + 80n))) + (2 * (width34))) : 0)) / 1 \
32         nrd=((width34) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n)
                * 120n) + ((width34) * 100n))) + ((((1) / 2) - floor((1) / 2) !=
                0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
                120n) + ((width34) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) * ((60
               n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width34))
               ) + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60n) - 0) +
               80n) ? 100n : (((60n) - 0) + 80n)) * (width34)) : 0)) / 1 / ((
               width34) * (1) * (width34) * (1)) \
33         nrs=((width34) < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n :
               (((60n) - 0) + 60n)) * 120n) + ((width34) * 50n)) + (floor(((1) -
                1) / 2.0) * (((((60n) - 0) + 60n) * 120n) + ((width34) * 100n)))
                + ((((1) / 2) - floor((1) / 2) == 0) ? (((50n > (((60n) - 0) +
               60n) ? 50n : (((60n) - 0) + 60n)) * 120n) + ((width34) * 50n)) :
               0)) / 1 : (((100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) +
               80n)) * (width34)) + (floor(((1) - 1) / 2.0) * ((60n > (((60n) -
               0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width34))) + ((((1) /
```

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        2) - floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n :
         (((60n) - 0) + 80n)) * (width34)) : 0)) / 1 / ((width34) * (1) *
         (width34) * (1)) \
34      sa=((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
        - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
        n) - 0) + 80n)) \
35      sb=((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
        - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
        n) - 0) + 80n)) \
36      sd=((width34) < 119.5n) ? (((60n) - 0) + 60n) + (2*5e-08) : (60n >
        (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) \
37      sca=(( (width34) * ( (((1u) * (1u) / (((width34) < 119.5n) ? (50n >
        (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
        > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)) - ((1u)
         * (1u) / ((((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n) ?
        50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n)
        ? 100n : (((60n) - 0) + 80n))+60n)+length34))) + ((1u) * (1u) /
        (((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
        ) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
        (((60n) - 0) + 80n))+60n)) - ((1u) * (1u)/ ((((width34) < 119.5n)
         ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e
        -08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))
        +60n)+length34)))) + ( length34 * ( (((1u) * (1u) / (60n)) - ((1u
        ) * (1u) / ((60n)+(width34)))) + ((1u) * (1u) / (60n)) - ((1u) *
        (1u)/ ((60n)+(width34)))))) / ((width34) * length34) \
38      scb=(((width34) * (((((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n
        ) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) +
        80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp(-10 *
        (((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
        ) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
        (((60n) - 0) + 80n))+60n) / (1u)) - (((((width34) < 119.5n) ? (50
        n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
        (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length34)/10 + (1u)/100)*exp(-10 * ((((width34) < 119.5n) ? (50n
        > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
        n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length34) / (1u)) + ((((width34) < 119.5n) ? (50n > (((60n) - 0)
        + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) -
        0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp
        (-10 * (((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
         (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100
        n : (((60n) - 0) + 80n))+60n) / (1u)) - (((((width34) < 119.5n) ?
         (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
        : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length34)/10 + (1u)/100)*exp(-10 * ((((width34) < 119.5n) ? (50n
        > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
        n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length34) / (1u)))) + (length34 * (((60n)/10 + (1u)/100)*exp(-10
        * (60n) / (1u)) - (((60n)+(width34))/10 + (1u)/100)*exp(-10 *
        ((60n)+(width34)) / (1u)) + ((60n)/10 + (1u)/100)*exp(-10 * (60n)
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           / (1u)) - (((60n)+(width34))/10 + (1u)/100)*exp(-10 * ((60n)+(
           width34)) / (1u))))) / ((width34) * length34) \
39         scc=(((width34) * (((((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n
           ) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) +
           80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp(-20 *
           (((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
           ) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
           (((60n) - 0) + 80n))+60n) / (1u)) - (((((width34) < 119.5n) ? (50
           n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
           (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           length34)/20 + (1u)/400)*exp(-20 * ((((width34) < 119.5n) ? (50n
           > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
           n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           length34) / (1u)) + ((((width34) < 119.5n) ? (50n > (((60n) - 0)
           + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) -
           0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp
           (-20 * (((width34) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
            (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100
           n : (((60n) - 0) + 80n))+60n) / (1u)) - (((((width34) < 119.5n) ?
            (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
           : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           length34)/20 + (1u)/400)*exp(-20 * ((((width34) < 119.5n) ? (50n
           > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
           n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           length34) / (1u)))) + (length34 * (((60n)/20 + (1u)/400)*exp(-20
           * (60n) / (1u)) - (((60n)+(width34))/20 + (1u)/400)*exp(-20 *
           ((60n)+(width34)) / (1u)) + ((60n)/20 + (1u)/400)*exp(-20 * (60n)
            / (1u)) - (((60n)+(width34))/20 + (1u)/400)*exp(-20 * ((60n)+(
           width34)) / (1u))))) / ((width34) * length34) \
40         m=(1)
41 NM3 (Vcont X Vcont 0) g45n1svt w=((widthv12) * (1)) l=lengthv12 nf=1 as=((
       widthv12) < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0)
       + 60n)) * 120n) + ((widthv12) * 50n)) + (floor(((1) - 1) / 2.0) * (((((60
       n) - 0) + 60n) * 120n) + ((widthv12) * 100n))) + ((((1) / 2) - floor((1)
       / 2) == 0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
       120n) + ((widthv12) * 50n)) : 0)) / 1 : (((100n > (((60n) - 0) + 80n) ?
       100n : (((60n) - 0) + 80n)) * (widthv12)) + (floor(((1) - 1) / 2.0) *
       ((60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (widthv12))) +
        ((((1) / 2) - floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n
        : (((60n) - 0) + 80n)) * (widthv12)) : 0)) / 1 \
42         ad=((widthv12) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n)
            * 120n) + ((widthv12) * 100n))) + ((((1) / 2) - floor((1) / 2)
           != 0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))
            * 120n) + ((widthv12) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) *
           ((60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (
           widthv12))) + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60
           n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)) * (widthv12)) : 0))
           / 1 \
43         ps=((widthv12) < 119.5n) ? (((2 * (50n > (((60n) - 0) + 60n) ? 50n :
           (((60n) - 0) + 60n))) + 340n) + (floor(((1) - 1) / 2.0) * ((2 *
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    (((60n) - 0) + 60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) ==
    0) ? ((2 * (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)
    )) + 340n) : 0)) / 1 : (((2 * (100n > (((60n) - 0) + 80n) ? 100n
    : (((60n) - 0) + 80n))) + (2 * (widthv12))) + (floor(((1) - 1) /
    2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50
    n))) + (2 * (widthv12)))) + ((((1) / 2) - floor((1) / 2) == 0) ?
    ((2 * (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)))
    + (2 * (widthv12))) : 0)) / 1 \
pd=((widthv12) < 119.5n) ? ((floor((1) / 2.0) * ((2 * (((60n) - 0) +
    60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) != 0) ? ((2 * (50n
    > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))) + 340n) : 0))
     / 1 : ((floor((1) / 2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60
    n : (((60n) - 0) + 50n))) + (2 * (widthv12)))) + ((((1) / 2) -
    floor((1) / 2) != 0) ? ((2 * (100n > (((60n) - 0) + 80n) ? 100n :
     (((60n) - 0) + 80n))) + (2 * (widthv12))) : 0)) / 1 \
nrd=((widthv12) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n
    ) * 120n) + ((widthv12) * 100n))) + ((((1) / 2) - floor((1) / 2)
    != 0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))
     * 120n) + ((widthv12) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) *
    ((60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (
    widthv12))) + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60
    n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)) * (widthv12)) : 0))
    / 1 / ((widthv12) * (1) * (widthv12) * (1)) \
nrs=((widthv12) < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n :
    (((60n) - 0) + 60n)) * 120n) + ((widthv12) * 50n)) + (floor(((1)
    - 1) / 2.0) * (((((60n) - 0) + 60n) * 120n) + ((widthv12) * 100n)
    )) + ((((1) / 2) - floor((1) / 2) == 0) ? (((50n > (((60n) - 0) +
     60n) ? 50n : (((60n) - 0) + 60n)) * 120n) + ((widthv12) * 50n))
    : 0)) / 1 : (((100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) +
     80n)) * (widthv12)) + (floor(((1) - 1) / 2.0) * ((60n > (((60n)
    - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (widthv12))) + ((((1)
    / 2) - floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n
     : (((60n) - 0) + 80n)) * (widthv12)) : 0)) / 1 / ((widthv12) *
    (1) * (widthv12) * (1)) \
sa=((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
     - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
    (((60n) - 0) + 80n)) \
sb=((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
     - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
    (((60n) - 0) + 80n)) \
sd=((widthv12) < 119.5n) ? (((60n) - 0) + 60n) + (2*5e-08) : (60n >
    (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) \
sca=(( (widthv12) * ( (((1u) * (1u) / (((widthv12) < 119.5n) ? (50n >
     (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
     > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)) - ((1u
    ) * (1u) / ((((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ?
     50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n)
     ? 100n : (((60n) - 0) + 80n))+60n)+(45n)))) + ((1u) * (1u) / (((
    widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
    - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
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        n) - 0) + 80n))+60n)) - ((1u) * (1u)/ ((((widthv12) < 119.5n) ?
        (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
         (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)
        +(45n))))) + ( (45n) * ( (((1u) * (1u) / (60n)) - ((1u) * (1u) /
        ((60n)+(widthv12)))) + ((1u) * (1u) / (60n)) - ((1u) * (1u)/ ((60
        n)+(widthv12)))))) / ((widthv12) * (45n)) \
51      scb=(((widthv12) * (((((widthv12) < 119.5n) ? (50n > (((60n) - 0) +
        60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0)
        + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp(-10
        * (((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
        (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n
         : (((60n) - 0) + 80n))+60n) / (1u)) - (((((widthv12) < 119.5n) ?
         (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
        : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)
        +(45n))/10 + (1u)/100)*exp(-10 * ((((widthv12) < 119.5n) ? (50n >
         (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
         > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+(45n))
        / (1u)) + ((((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ?
        50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n)
        ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp(-10 * (((
        widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
        - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
        n) - 0) + 80n))+60n) / (1u)) - (((((widthv12) < 119.5n) ? (50n >
        (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
        > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+(45n))
        /10 + (1u)/100)*exp(-10 * ((((widthv12) < 119.5n) ? (50n > (((60n
        ) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n >
        (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+(45n)) /
        (1u)))) + ((45n) * (((60n)/10 + (1u)/100)*exp(-10 * (60n) / (1u))
         - (((60n)+(widthv12))/10 + (1u)/100)*exp(-10 * ((60n)+(widthv12)
        ) / (1u)) + ((60n)/10 + (1u)/100)*exp(-10 * (60n) / (1u)) - (((60
        n)+(widthv12))/10 + (1u)/100)*exp(-10 * ((60n)+(widthv12)) / (1u)
        )))) / ((widthv12) * (45n)) \
52      scc=(((widthv12) * (((((widthv12) < 119.5n) ? (50n > (((60n) - 0) +
        60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0)
        + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp(-20
        * (((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
        (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n
         : (((60n) - 0) + 80n))+60n) / (1u)) - (((((widthv12) < 119.5n) ?
         (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
        : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)
        +(45n))/20 + (1u)/400)*exp(-20 * ((((widthv12) < 119.5n) ? (50n >
         (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
         > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+(45n))
        / (1u)) + ((((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ?
        50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n)
        ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp(-20 * (((
        widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
        - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
        n) - 0) + 80n))+60n) / (1u)) - (((((widthv12) < 119.5n) ? (50n >
```

```
           (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
           > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+(45n))
           /20 + (1u)/400)*exp(-20 * ((((widthv12) < 119.5n) ? (50n > (((60n
           ) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n >
           (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+(45n)) /
           (1u)))) + ((45n) * (((60n)/20 + (1u)/400)*exp(-20 * (60n) / (1u))
            - (((60n)+(widthv12))/20 + (1u)/400)*exp(-20 * ((60n)+(widthv12)
           ) / (1u)) + ((60n)/20 + (1u)/400)*exp(-20 * (60n) / (1u)) - (((60
           n)+(widthv12))/20 + (1u)/400)*exp(-20 * ((60n)+(widthv12)) / (1u)
           )))) / ((widthv12) * (45n)) \
53         m=(1)
54 NM2 (Vcont Y Vcont 0) g45n1svt w=((widthv12) * (1)) l=lengthv12 nf=1 as=((
   widthv12) < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0)
   + 60n)) * 120n) + ((widthv12) * 50n)) + (floor(((1) - 1) / 2.0) * (((((60
   n) - 0) + 60n) * 120n) + ((widthv12) * 100n))) + ((((1) / 2) - floor((1)
   / 2) == 0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
   120n) + ((widthv12) * 50n)) : 0)) / 1 : (((100n > (((60n) - 0) + 80n) ?
   100n : (((60n) - 0) + 80n)) * (widthv12)) + (floor(((1) - 1) / 2.0) *
   ((60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (widthv12))) +
    ((((1) / 2) - floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n
    : (((60n) - 0) + 80n)) * (widthv12)) : 0)) / 1 \
55         ad=((widthv12) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n)
               * 120n) + ((widthv12) * 100n))) + ((((1) / 2) - floor((1) / 2)
           != 0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))
            * 120n) + ((widthv12) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) *
           ((60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (
           widthv12))) + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60
           n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)) * (widthv12)) : 0))
           / 1 \
56         ps=((widthv12) < 119.5n) ? (((2 * (50n > (((60n) - 0) + 60n) ? 50n :
           (((60n) - 0) + 60n))) + 340n) + (floor(((1) - 1) / 2.0) * ((2 *
           (((60n) - 0) + 60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) ==
           0) ? ((2 * (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)
           )) + 340n) : 0)) / 1 : (((2 * (100n > (((60n) - 0) + 80n) ? 100n
           : (((60n) - 0) + 80n))) + (2 * (widthv12))) + (floor(((1) - 1) /
           2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50
           n))) + (2 * (widthv12)))) + ((((1) / 2) - floor((1) / 2) == 0) ?
           ((2 * (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)))
           + (2 * (widthv12))) : 0)) / 1 \
57         pd=((widthv12) < 119.5n) ? ((floor((1) / 2.0) * ((2 * (((60n) - 0) +
           60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) != 0) ? ((2 * (50n
           > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))) + 340n) : 0))
            / 1 : ((floor((1) / 2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60
           n : (((60n) - 0) + 50n))) + (2 * (widthv12)))) + ((((1) / 2) -
           floor((1) / 2) != 0) ? ((2 * (100n > (((60n) - 0) + 80n) ? 100n :
            (((60n) - 0) + 80n))) + (2 * (widthv12))) : 0)) / 1 \
58         nrd=((widthv12) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n
           ) * 120n) + ((widthv12) * 100n))) + ((((1) / 2) - floor((1) / 2)
           != 0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))
            * 120n) + ((widthv12) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) *
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    ((60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (
    widthv12))) + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60
    n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)) * (widthv12)) : 0))
    / 1 / ((widthv12) * (1) * (widthv12) * (1)) \
nrs=((widthv12) < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n :
    (((60n) - 0) + 60n)) * 120n) + ((widthv12) * 50n)) + (floor(((1)
    - 1) / 2.0) * (((((60n) - 0) + 60n) * 120n) + ((widthv12) * 100n)
    )) + ((((1) / 2) - floor((1) / 2) == 0) ? (((50n > (((60n) - 0) +
     60n) ? 50n : (((60n) - 0) + 60n)) * 120n) + ((widthv12) * 50n))
    : 0)) / 1 : (((100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) +
     80n)) * (widthv12)) + (floor(((1) - 1) / 2.0) * ((60n > (((60n)
    - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (widthv12))) + ((((1)
    / 2) - floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n
     : (((60n) - 0) + 80n)) * (widthv12)) : 0)) / 1 / ((widthv12) *
    (1) * (widthv12) * (1)) \
sa=((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
     - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
    (((60n) - 0) + 80n)) \
sb=((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
     - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
    (((60n) - 0) + 80n)) \
sd=((widthv12) < 119.5n) ? (((60n) - 0) + 60n) + (2*5e-08) : (60n >
    (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) \
sca=(( (widthv12) * ( (((1u) * (1u) / (((widthv12) < 119.5n) ? (50n >
     (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
     > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)) - ((1u
    ) * (1u) / ((((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ?
     50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n)
     ? 100n : (((60n) - 0) + 80n))+60n)+lengthv12))) + ((1u) * (1u) /
     (((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
    (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n
     : (((60n) - 0) + 80n))+60n)) - ((1u) * (1u)/ ((((widthv12) <
    119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))
     + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80
    n))+60n)+lengthv12)))) + ( lengthv12 * ( (((1u) * (1u) / (60n)) -
     ((1u) * (1u) / ((60n)+(widthv12)))) + ((1u) * (1u) / (60n)) -
    ((1u) * (1u)/ ((60n)+(widthv12)))))) / ((widthv12) * lengthv12) \
scb=(((widthv12) * (((((widthv12) < 119.5n) ? (50n > (((60n) - 0) +
    60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0)
    + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp(-10
    * (((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
    (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n
     : (((60n) - 0) + 80n))+60n) / (1u)) - (((((widthv12) < 119.5n) ?
     (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
    : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
    lengthv12)/10 + (1u)/100)*exp(-10 * ((((widthv12) < 119.5n) ? (50
    n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
    (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
    lengthv12) / (1u)) + ((((widthv12) < 119.5n) ? (50n > (((60n) -
    0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n)
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          - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp
          (-10 * (((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n
          : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ?
          100n : (((60n) - 0) + 80n))+60n) / (1u)) - (((((widthv12) < 119.5
          n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e
          -08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))
          +60n)+lengthv12)/10 + (1u)/100)*exp(-10 * ((((widthv12) < 119.5n)
           ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e
          -08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))
          +60n)+lengthv12) / (1u)))) + (lengthv12 * (((60n)/10 + (1u)/100)*
          exp(-10 * (60n) / (1u)) - (((60n)+(widthv12))/10 + (1u)/100)*exp
          (-10 * ((60n)+(widthv12)) / (1u)) + ((60n)/10 + (1u)/100)*exp(-10
           * (60n) / (1u)) - (((60n)+(widthv12))/10 + (1u)/100)*exp(-10 *
          ((60n)+(widthv12)) / (1u))))) / ((widthv12) * lengthv12) \
65        scc=(((widthv12) * (((((widthv12) < 119.5n) ? (50n > (((60n) - 0) +
          60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0)
          + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp(-20
          * (((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
          (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n
           : (((60n) - 0) + 80n))+60n) / (1u)) - (((((widthv12) < 119.5n) ?
           (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
          : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
          lengthv12)/20 + (1u)/400)*exp(-20 * ((((widthv12) < 119.5n) ? (50
          n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
          (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
          lengthv12) / (1u)) + ((((widthv12) < 119.5n) ? (50n > (((60n) -
          0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n)
          - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp
          (-20 * (((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n
          : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ?
          100n : (((60n) - 0) + 80n))+60n) / (1u)) - (((((widthv12) < 119.5
          n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e
          -08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))
          +60n)+lengthv12)/20 + (1u)/400)*exp(-20 * ((((widthv12) < 119.5n)
           ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e
          -08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))
          +60n)+lengthv12) / (1u)))) + (lengthv12 * (((60n)/20 + (1u)/400)*
          exp(-20 * (60n) / (1u)) - (((60n)+(widthv12))/20 + (1u)/400)*exp
          (-20 * ((60n)+(widthv12)) / (1u)) + ((60n)/20 + (1u)/400)*exp(-20
           * (60n) / (1u)) - (((60n)+(widthv12))/20 + (1u)/400)*exp(-20 *
          ((60n)+(widthv12)) / (1u))))) / ((widthv12) * lengthv12) \
66        m=(1)
67  NM1 (Y X Ibias 0) g45n1svt w=((width12) * (1)) l=length12 nf=1 as=((width12)
    < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
    120n) + ((width12) * 50n)) + (floor(((1) - 1) / 2.0) * (((((60n) - 0) +
    60n) * 120n) + ((width12) * 100n))) + ((((1) / 2) - floor((1) / 2) == 0)
    ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) * 120n) + ((
    width12) * 50n)) : 0)) / 1 : (((100n > (((60n) - 0) + 80n) ? 100n : (((60
    n) - 0) + 80n)) * (width12)) + (floor(((1) - 1) / 2.0) * ((60n > (((60n)
    - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width12))) + ((((1) / 2) -
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    floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0)
     + 80n)) * (width12)) : 0)) / 1 \
68      ad=((width12) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n)
           * 120n) + ((width12) * 100n))) + ((((1) / 2) - floor((1) / 2) !=
           0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
           120n) + ((width12) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) * ((60n
            > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width12)))
            + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60n) - 0) +
           80n) ? 100n : (((60n) - 0) + 80n)) * (width12)) : 0)) / 1 \
69      ps=((width12) < 119.5n) ? (((2 * (50n > (((60n) - 0) + 60n) ? 50n :
           (((60n) - 0) + 60n))) + 340n) + (floor(((1) - 1) / 2.0) * ((2 *
           (((60n) - 0) + 60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) ==
           0) ? ((2 * (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)
           )) + 340n) : 0)) / 1 : (((2 * (100n > (((60n) - 0) + 80n) ? 100n
           : (((60n) - 0) + 80n))) + (2 * (width12))) + (floor(((1) - 1) /
           2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50
           n))) + (2 * (width12)))) + ((((1) / 2) - floor((1) / 2) == 0) ?
           ((2 * (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)))
           + (2 * (width12))) : 0)) / 1 \
70      pd=((width12) < 119.5n) ? ((floor((1) / 2.0) * ((2 * (((60n) - 0) +
           60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) != 0) ? ((2 * (50n
           > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))) + 340n) : 0))
            / 1 : ((floor((1) / 2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60
           n : (((60n) - 0) + 50n))) + (2 * (width12)))) + ((((1) / 2) -
           floor((1) / 2) != 0) ? ((2 * (100n > (((60n) - 0) + 80n) ? 100n :
            (((60n) - 0) + 80n))) + (2 * (width12))) : 0)) / 1 \
71      nrd=((width12) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n)
            * 120n) + ((width12) * 100n))) + ((((1) / 2) - floor((1) / 2) !=
            0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
            120n) + ((width12) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) * ((60
           n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width12))
           ) + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60n) - 0) +
           80n) ? 100n : (((60n) - 0) + 80n)) * (width12)) : 0)) / 1 / ((
           width12) * (1) * (width12) * (1)) \
72      nrs=((width12) < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n :
           (((60n) - 0) + 60n)) * 120n) + ((width12) * 50n)) + (floor(((1) -
            1) / 2.0) * (((((60n) - 0) + 60n) * 120n) + ((width12) * 100n)))
            + ((((1) / 2) - floor((1) / 2) == 0) ? (((50n > (((60n) - 0) +
           60n) ? 50n : (((60n) - 0) + 60n)) * 120n) + ((width12) * 50n)) :
           0)) / 1 : (((100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) +
           80n)) * (width12)) + (floor(((1) - 1) / 2.0) * ((60n > (((60n) -
           0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width12))) + ((((1) /
           2) - floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n :
            (((60n) - 0) + 80n)) * (width12)) : 0)) / 1 / ((width12) * (1) *
            (width12) * (1)) \
73      sa=((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
           - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
           n) - 0) + 80n)) \
74      sb=((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
           - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
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           n) - 0) + 80n)) \
75       sd=((width12) < 119.5n) ? (((60n) - 0) + 60n) + (2*5e-08) : (60n >
           (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) \
76       sca=(( (width12) * ( (((1u) * (1u) / (((width12) < 119.5n) ? (50n >
           (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
           > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)) - ((1u)
            * (1u) / ((((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ?
           50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n)
           ? 100n : (((60n) - 0) + 80n))+60n)+length12))) + ((1u) * (1u) /
           (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
           ) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
           (((60n) - 0) + 80n))+60n)) - ((1u) * (1u)/ ((((width12) < 119.5n)
            ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e
           -08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))
           +60n)+length12)))) + ( length12 * ( (((1u) * (1u) / (60n)) - ((1u
           ) * (1u) / ((60n)+(width12)))) + ((1u) * (1u) / (60n)) - ((1u) *
           (1u)/ ((60n)+(width12)))))) / ((width12) * length12) \
77       scb=(((width12) * (((((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n
           ) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) +
           80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp(-10 *
           (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
           ) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
           (((60n) - 0) + 80n))+60n) / (1u)) - (((((width12) < 119.5n) ? (50
           n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
           (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           length12)/10 + (1u)/100)*exp(-10 * ((((width12) < 119.5n) ? (50n
           > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
           n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           length12) / (1u)) + ((((width12) < 119.5n) ? (50n > (((60n) - 0)
           + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) -
           0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp
           (-10 * (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
            (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100
           n : (((60n) - 0) + 80n))+60n) / (1u)) - (((((width12) < 119.5n) ?
            (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
           : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           length12)/10 + (1u)/100)*exp(-10 * ((((width12) < 119.5n) ? (50n
           > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
           n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           length12) / (1u)))) + (length12 * (((60n)/10 + (1u)/100)*exp(-10
           * (60n) / (1u)) - (((60n)+(width12))/10 + (1u)/100)*exp(-10 *
           ((60n)+(width12)) / (1u)) + ((60n)/10 + (1u)/100)*exp(-10 * (60n)
            / (1u)) - (((60n)+(width12))/10 + (1u)/100)*exp(-10 * ((60n)+(
           width12)) / (1u))))) / ((width12) * length12) \
78       scc=(((width12) * (((((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n
           ) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) +
           80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp(-20 *
           (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
           ) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
           (((60n) - 0) + 80n))+60n) / (1u)) - (((((width12) < 119.5n) ? (50
```

```
            n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
            (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
            length12)/20 + (1u)/400)*exp(-20 * ((((width12) < 119.5n) ? (50n
            > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
            n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
            length12) / (1u)) + ((((width12) < 119.5n) ? (50n > (((60n) - 0)
            + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) -
            0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp
            (-20 * (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
             (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100
            n : (((60n) - 0) + 80n))+60n) / (1u)) - (((((width12) < 119.5n) ?
             (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
            : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
            length12)/20 + (1u)/400)*exp(-20 * ((((width12) < 119.5n) ? (50n
            > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
            n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
            length12) / (1u)))) + (length12 * (((60n)/20 + (1u)/400)*exp(-20
            * (60n) / (1u)) - (((60n)+(width12))/20 + (1u)/400)*exp(-20 *
            ((60n)+(width12)) / (1u)) + ((60n)/20 + (1u)/400)*exp(-20 * (60n)
             / (1u)) - (((60n)+(width12))/20 + (1u)/400)*exp(-20 * ((60n)+(
            width12)) / (1u))))) / ((width12) * length12) \
        m=(1)
NM0 (X Y Ibias 0) g45n1svt w=((width12) * (1)) l=length12 nf=1 as=((width12)
    < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
    120n) + ((width12) * 50n)) + (floor(((1) - 1) / 2.0) * (((((60n) - 0) +
    60n) * 120n) + ((width12) * 100n))) + ((((1) / 2) - floor((1) / 2) == 0)
    ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) * 120n) + ((
    width12) * 50n)) : 0)) / 1 : (((100n > (((60n) - 0) + 80n) ? 100n : (((60
    n) - 0) + 80n)) * (width12)) + (floor(((1) - 1) / 2.0) * ((60n > (((60n)
    - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width12))) + ((((1) / 2) -
    floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0)
     + 80n)) * (width12)) : 0)) / 1 \
        ad=((width12) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n)
            * 120n) + ((width12) * 100n))) + ((((1) / 2) - floor((1) / 2) !=
            0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
            120n) + ((width12) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) * ((60n
             > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width12)))
             + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60n) - 0) +
            80n) ? 100n : (((60n) - 0) + 80n)) * (width12)) : 0)) / 1 \
        ps=((width12) < 119.5n) ? (((2 * (50n > (((60n) - 0) + 60n) ? 50n :
            (((60n) - 0) + 60n))) + 340n) + (floor(((1) - 1) / 2.0) * ((2 *
            (((60n) - 0) + 60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) ==
            0) ? ((2 * (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)
            )) + 340n) : 0)) / 1 : (((2 * (100n > (((60n) - 0) + 80n) ? 100n
            : (((60n) - 0) + 80n))) + (2 * (width12))) + (floor(((1) - 1) /
            2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50
            n))) + (2 * (width12)))) + ((((1) / 2) - floor((1) / 2) == 0) ?
            ((2 * (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)))
            + (2 * (width12))) : 0)) / 1 \
```

```
83        pd=((width12) < 119.5n) ? ((floor((1) / 2.0) * ((2 * (((60n) - 0) +
              60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) != 0) ? ((2 * (50n
              > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))) + 340n) : 0))
               / 1 : ((floor((1) / 2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60
              n : (((60n) - 0) + 50n))) + (2 * (width12)))) + ((((1) / 2) -
              floor((1) / 2) != 0) ? ((2 * (100n > (((60n) - 0) + 80n) ? 100n :
               (((60n) - 0) + 80n))) + (2 * (width12))) : 0)) / 1 \
84        nrd=((width12) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n)
               * 120n) + ((width12) * 100n))) + ((((1) / 2) - floor((1) / 2) !=
               0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
               120n) + ((width12) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) * ((60
              n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width12))
              ) + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60n) - 0) +
              80n) ? 100n : (((60n) - 0) + 80n)) * (width12)) : 0)) / 1 / ((
              width12) * (1) * (width12) * (1)) \
85        nrs=((width12) < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n :
              (((60n) - 0) + 60n)) * 120n) + ((width12) * 50n)) + (floor(((1) -
               1) / 2.0) * (((((60n) - 0) + 60n) * 120n) + ((width12) * 100n)))
               + ((((1) / 2) - floor((1) / 2) == 0) ? (((50n > (((60n) - 0) +
              60n) ? 50n : (((60n) - 0) + 60n)) * 120n) + ((width12) * 50n)) :
              0)) / 1 : (((100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) +
              80n)) * (width12)) + (floor(((1) - 1) / 2.0) * ((60n > (((60n) -
              0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width12))) + ((((1) /
              2) - floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n :
               (((60n) - 0) + 80n)) * (width12)) : 0)) / 1 / ((width12) * (1) *
               (width12) * (1)) \
86        sa=((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
              - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
              n) - 0) + 80n)) \
87        sb=((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
              - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
              n) - 0) + 80n)) \
88        sd=((width12) < 119.5n) ? (((60n) - 0) + 60n) + (2*5e-08) : (60n >
              (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) \
89        sca=(( (width12) * ( (((1u) * (1u) / (((width12) < 119.5n) ? (50n >
              (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
              > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)) - ((1u)
               * (1u) / ((((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ?
              50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n)
              ? 100n : (((60n) - 0) + 80n))+60n)+length12))) + ((1u) * (1u) /
              (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
              ) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
              (((60n) - 0) + 80n))+60n)) - ((1u) * (1u)/ ((((width12) < 119.5n)
               ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e
              -08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))
              +60n)+length12)))) + ( length12 * ( (((1u) * (1u) / (60n)) - ((1u
              ) * (1u) / ((60n)+(width12)))) + ((1u) * (1u) / (60n)) - ((1u) *
              (1u)/ ((60n)+(width12)))))) / ((width12) * length12) \
90        scb=(((width12) * (((((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n
              ) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) +
```

```
        80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp(-10 *
        (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
        ) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
        (((60n) - 0) + 80n))+60n) / (1u)) - (((((width12) < 119.5n) ? (50
        n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
        (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length12)/10 + (1u)/100)*exp(-10 * ((((width12) < 119.5n) ? (50n
        > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
        n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length12) / (1u)) + ((((width12) < 119.5n) ? (50n > (((60n) - 0)
        + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) -
        0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp
        (-10 * (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
         (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100
        n : (((60n) - 0) + 80n))+60n) / (1u)) - (((((width12) < 119.5n) ?
         (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
        : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length12)/10 + (1u)/100)*exp(-10 * ((((width12) < 119.5n) ? (50n
        > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
        n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length12) / (1u)))) + (length12 * (((60n)/10 + (1u)/100)*exp(-10
        * (60n) / (1u)) - (((60n)+(width12))/10 + (1u)/100)*exp(-10 *
        ((60n)+(width12)) / (1u)) + ((60n)/10 + (1u)/100)*exp(-10 * (60n)
         / (1u)) - (((60n)+(width12))/10 + (1u)/100)*exp(-10 * ((60n)+(
        width12)) / (1u))))) / ((width12) * length12) \
91      scc=(((width12) * (((((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n
        ) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) +
        80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp(-20 *
        (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
        ) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
        (((60n) - 0) + 80n))+60n) / (1u)) - (((((width12) < 119.5n) ? (50
        n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
        (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length12)/20 + (1u)/400)*exp(-20 * ((((width12) < 119.5n) ? (50n
        > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
        n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length12) / (1u)) + ((((width12) < 119.5n) ? (50n > (((60n) - 0)
        + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) -
        0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp
        (-20 * (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
         (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100
        n : (((60n) - 0) + 80n))+60n) / (1u)) - (((((width12) < 119.5n) ?
         (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
        : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length12)/20 + (1u)/400)*exp(-20 * ((((width12) < 119.5n) ? (50n
        > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
        n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length12) / (1u)))) + (length12 * (((60n)/20 + (1u)/400)*exp(-20
        * (60n) / (1u)) - (((60n)+(width12))/20 + (1u)/400)*exp(-20 *
        ((60n)+(width12)) / (1u)) + ((60n)/20 + (1u)/400)*exp(-20 * (60n)
```

```
            / (1u)) - (((60n)+(width12))/20 + (1u)/400)*exp(-20 * ((60n)+(
           width12)) / (1u))))) / ((width12) * length12) \
        m=(1)
L1 (net19 Y) inductor l=L q=10 fq=100M mode=1
L0 (X net19) inductor l=L q=10 fq=100M mode=1
V1 (Vcont 0) vsource dc=vcont type=dc
V0 (vdd! 0) vsource dc=vdd type=dc
I0 (Ibias 0) isource dc=Ibias type=dc
I7 (X Y) isource type=pulse val0=0 val1=1n rise=1p fall=1p width=3p
simulatorOptions options reltol=1e-3 vabstol=1e-6 iabstol=1e-12 temp=27 \
    tnom=27 scalem=1.0 scale=1.0 gmin=1e-12 rforce=1 maxnotes=5 maxwarns=5 \
    digits=5 cols=80 pivrel=1e-3 sensfile="../psf/sens.output" \
    checklimitdest=psf
pss ( X Y ) pss fund=F0 harms=20 errpreset=conservative
+   oscic=lin annotate=status
pnoise ( X Y ) pnoise sweeptype=relative relharmnum=1
+      start=10k stop=1M noisetype=timeaverage noiseout=[am pm usb
+      lsb] annotate=status
modelParameter info what=models where=rawfile
element info what=inst where=rawfile
outputParameter info what=output where=rawfile
designParamVals info what=parameters where=rawfile
primitives info what=primitives where=rawfile
subckts info what=subckts where=rawfile
save NM0:d NM1:d
saveOptions options save=allpub
```

5.2 Netlist for Type I CC LC-VCO

```
// Generated for: spectre
// Generated on: Mar 25 15:31:30 2025
// Design library name: VCO
// Design cell name: LC_VCO
// Design view name: schematic
simulator lang=spectre
global 0 vdd!
parameters Rp=400 Q=10 vdd=1 vcont=500m Itail=800u lengthv12=2u width12=5u \
    widthv12=5u length12=50n L=3.5n C1=700f F0=3G delF=10k
include "/home/aed/cadence/dicd_source/cadence_pdk/gpdk045_v_6_0/gpdk045/../
    models/spectre/gpdk045.scs" section=mc

// Library name: VCO
// Cell name: LC_VCO
// View name: schematic
NM4 (Vcont Y Vcont 0) g45n1svt w=((widthv12) * (1)) l=lengthv12 nf=1 as=((
    widthv12) < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0)
    + 60n)) * 120n) + ((widthv12) * 50n)) + (floor(((1) - 1) / 2.0) * (((((60
    n) - 0) + 60n) * 120n) + ((widthv12) * 100n))) + ((((1) / 2) - floor((1)
    / 2) == 0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
    120n) + ((widthv12) * 50n)) : 0)) / 1 : (((100n > (((60n) - 0) + 80n) ?
    100n : (((60n) - 0) + 80n)) * (widthv12)) + (floor(((1) - 1) / 2.0) *
    ((60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (widthv12))) +
     ((((1) / 2) - floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n
     : (((60n) - 0) + 80n)) * (widthv12)) : 0)) / 1 \
        ad=((widthv12) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n)
             * 120n) + ((widthv12) * 100n))) + ((((1) / 2) - floor((1) / 2)
            != 0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))
             * 120n) + ((widthv12) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) *
            ((60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (
            widthv12))) + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60
            n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)) * (widthv12)) : 0))
            / 1 \
        ps=((widthv12) < 119.5n) ? (((2 * (50n > (((60n) - 0) + 60n) ? 50n :
            (((60n) - 0) + 60n))) + 340n) + (floor(((1) - 1) / 2.0) * ((2 *
            (((60n) - 0) + 60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) ==
            0) ? ((2 * (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)
            )) + 340n) : 0)) / 1 : (((2 * (100n > (((60n) - 0) + 80n) ? 100n
            : (((60n) - 0) + 80n))) + (2 * (widthv12))) + (floor(((1) - 1) /
            2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50
            n))) + (2 * (widthv12)))) + ((((1) / 2) - floor((1) / 2) == 0) ?
            ((2 * (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)))
            + (2 * (widthv12))) : 0)) / 1 \
        pd=((widthv12) < 119.5n) ? ((floor((1) / 2.0) * ((2 * (((60n) - 0) +
            60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) != 0) ? ((2 * (50n
            > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))) + 340n) : 0))
             / 1 : ((floor((1) / 2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60
            n : (((60n) - 0) + 50n))) + (2 * (widthv12)))) + ((((1) / 2) -
```

```
        floor((1) / 2) != 0) ? ((2 * (100n > (((60n) - 0) + 80n) ? 100n :
         (((60n) - 0) + 80n))) + (2 * (widthv12))) : 0)) / 1 \
19      nrd=((widthv12) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n
        ) * 120n) + ((widthv12) * 100n))) + ((((1) / 2) - floor((1) / 2)
        != 0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))
         * 120n) + ((widthv12) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) *
        ((60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (
        widthv12))) + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60
        n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)) * (widthv12)) : 0))
        / 1 / ((widthv12) * (1) * (widthv12) * (1)) \
20      nrs=((widthv12) < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n :
        (((60n) - 0) + 60n)) * 120n) + ((widthv12) * 50n)) + (floor(((1)
        - 1) / 2.0) * (((((60n) - 0) + 60n) * 120n) + ((widthv12) * 100n)
        )) + ((((1) / 2) - floor((1) / 2) == 0) ? (((50n > (((60n) - 0) +
         60n) ? 50n : (((60n) - 0) + 60n)) * 120n) + ((widthv12) * 50n))
        : 0)) / 1 : (((100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) +
         80n)) * (widthv12)) + (floor(((1) - 1) / 2.0) * ((60n > (((60n)
        - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (widthv12))) + ((((1)
        / 2) - floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n
         : (((60n) - 0) + 80n)) * (widthv12)) : 0)) / 1 / ((widthv12) *
        (1) * (widthv12) * (1)) \
21      sa=((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
         - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
        (((60n) - 0) + 80n)) \
22      sb=((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
         - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
        (((60n) - 0) + 80n)) \
23      sd=((widthv12) < 119.5n) ? (((60n) - 0) + 60n) + (2*5e-08) : (60n >
        (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) \
24      sca=(( (widthv12) * ( (((1u) * (1u) / (((widthv12) < 119.5n) ? (50n >
         (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
         > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)) - ((1u
        ) * (1u) / ((((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ?
         50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n)
         ? 100n : (((60n) - 0) + 80n))+60n)+lengthv12))) + ((1u) * (1u) /
         (((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
        (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n
         : (((60n) - 0) + 80n))+60n)) - ((1u) * (1u)/ ((((widthv12) <
        119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))
         + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80
        n))+60n)+lengthv12)))) + ( lengthv12 * ( (((1u) * (1u) / (60n)) -
         ((1u) * (1u) / ((60n)+(widthv12)))) + ((1u) * (1u) / (60n)) -
        ((1u) * (1u)/ ((60n)+(widthv12)))))) / ((widthv12) * lengthv12) \
25      scb=(((widthv12) * (((((widthv12) < 119.5n) ? (50n > (((60n) - 0) +
        60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0)
        + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp(-10
        * (((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
        (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n
         : (((60n) - 0) + 80n))+60n) / (1u)) - (((((widthv12) < 119.5n) ?
         (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
```

```
           : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           lengthv12)/10 + (1u)/100)*exp(-10 * ((((widthv12) < 119.5n) ? (50
           n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
           (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           lengthv12) / (1u)) + ((((widthv12) < 119.5n) ? (50n > (((60n) -
           0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n)
           - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp
           (-10 * (((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n
           : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ?
           100n : (((60n) - 0) + 80n))+60n) / (1u)) - (((((widthv12) < 119.5
           n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e
           -08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))
           +60n)+lengthv12)/10 + (1u)/100)*exp(-10 * ((((widthv12) < 119.5n)
            ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e
           -08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))
           +60n)+lengthv12) / (1u)))) + (lengthv12 * (((60n)/10 + (1u)/100)*
           exp(-10 * (60n) / (1u)) - (((60n)+(widthv12))/10 + (1u)/100)*exp
           (-10 * ((60n)+(widthv12)) / (1u)) + ((60n)/10 + (1u)/100)*exp(-10
            * (60n) / (1u)) - (((60n)+(widthv12))/10 + (1u)/100)*exp(-10 *
           ((60n)+(widthv12)) / (1u))))) / ((widthv12) * lengthv12) \
26       scc=(((widthv12) * (((((widthv12) < 119.5n) ? (50n > (((60n) - 0) +
           60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0)
           + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp(-20
           * (((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
           (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n
            : (((60n) - 0) + 80n))+60n) / (1u)) - (((((widthv12) < 119.5n) ?
            (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
           : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           lengthv12)/20 + (1u)/400)*exp(-20 * ((((widthv12) < 119.5n) ? (50
           n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
           (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           lengthv12) / (1u)) + ((((widthv12) < 119.5n) ? (50n > (((60n) -
           0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n)
           - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp
           (-20 * (((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n
           : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ?
           100n : (((60n) - 0) + 80n))+60n) / (1u)) - (((((widthv12) < 119.5
           n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e
           -08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))
           +60n)+lengthv12)/20 + (1u)/400)*exp(-20 * ((((widthv12) < 119.5n)
            ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e
           -08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))
           +60n)+lengthv12) / (1u)))) + (lengthv12 * (((60n)/20 + (1u)/400)*
           exp(-20 * (60n) / (1u)) - (((60n)+(widthv12))/20 + (1u)/400)*exp
           (-20 * ((60n)+(widthv12)) / (1u)) + ((60n)/20 + (1u)/400)*exp(-20
            * (60n) / (1u)) - (((60n)+(widthv12))/20 + (1u)/400)*exp(-20 *
           ((60n)+(widthv12)) / (1u))))) / ((widthv12) * lengthv12) \
27       m=(1)
28 NM3 (Vcont X Vcont 0) g45n1svt w=((widthv12) * (1)) l=lengthv12 nf=1 as=((
     widthv12) < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0)
```

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    + 60n)) * 120n) + ((widthv12) * 50n)) + (floor(((1) - 1) / 2.0) * (((((60
    n) - 0) + 60n) * 120n) + ((widthv12) * 100n))) + ((((1) / 2) - floor((1)
    / 2) == 0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
    120n) + ((widthv12) * 50n)) : 0)) / 1 : (((100n > (((60n) - 0) + 80n) ?
    100n : (((60n) - 0) + 80n)) * (widthv12)) + (floor(((1) - 1) / 2.0) *
    ((60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (widthv12))) +
     ((((1) / 2) - floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n
     : (((60n) - 0) + 80n)) * (widthv12)) : 0)) / 1 \
29      ad=((widthv12) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n)
            * 120n) + ((widthv12) * 100n))) + ((((1) / 2) - floor((1) / 2)
        != 0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))
            * 120n) + ((widthv12) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) *
        ((60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (
        widthv12))) + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60
        n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)) * (widthv12)) : 0))
        / 1 \
30      ps=((widthv12) < 119.5n) ? (((2 * (50n > (((60n) - 0) + 60n) ? 50n :
            (((60n) - 0) + 60n))) + 340n) + (floor(((1) - 1) / 2.0) * ((2 *
            (((60n) - 0) + 60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) ==
            0) ? ((2 * (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)
            )) + 340n) : 0)) / 1 : (((2 * (100n > (((60n) - 0) + 80n) ? 100n
            : (((60n) - 0) + 80n))) + (2 * (widthv12))) + (floor(((1) - 1) /
            2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50
            n))) + (2 * (widthv12)))) + ((((1) / 2) - floor((1) / 2) == 0) ?
            ((2 * (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)))
            + (2 * (widthv12))) : 0)) / 1 \
31      pd=((widthv12) < 119.5n) ? ((floor((1) / 2.0) * ((2 * (((60n) - 0) +
            60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) != 0) ? ((2 * (50n
            > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))) + 340n) : 0))
             / 1 : ((floor((1) / 2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60
            n : (((60n) - 0) + 50n))) + (2 * (widthv12)))) + ((((1) / 2) -
            floor((1) / 2) != 0) ? ((2 * (100n > (((60n) - 0) + 80n) ? 100n :
             (((60n) - 0) + 80n))) + (2 * (widthv12))) : 0)) / 1 \
32      nrd=((widthv12) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n
            ) * 120n) + ((widthv12) * 100n))) + ((((1) / 2) - floor((1) / 2)
        != 0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))
            * 120n) + ((widthv12) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) *
        ((60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (
        widthv12))) + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60
        n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)) * (widthv12)) : 0))
        / 1 / ((widthv12) * (1) * (widthv12) * (1)) \
33      nrs=((widthv12) < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n :
            (((60n) - 0) + 60n)) * 120n) + ((widthv12) * 50n)) + (floor(((1)
            - 1) / 2.0) * (((((60n) - 0) + 60n) * 120n) + ((widthv12) * 100n)
            )) + ((((1) / 2) - floor((1) / 2) == 0) ? (((50n > (((60n) - 0) +
             60n) ? 50n : (((60n) - 0) + 60n)) * 120n) + ((widthv12) * 50n))
            : 0)) / 1 : (((100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) +
             80n)) * (widthv12)) + (floor(((1) - 1) / 2.0) * ((60n > (((60n)
            - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (widthv12))) + ((((1)
            / 2) - floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n
```

```
        : (((60n) - 0) + 80n)) * (widthv12)) : 0)) / 1 / ((widthv12) *
       (1) * (widthv12) * (1)) \
34     sa=((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
        - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
       (((60n) - 0) + 80n)) \
35     sb=((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
        - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
       (((60n) - 0) + 80n)) \
36     sd=((widthv12) < 119.5n) ? (((60n) - 0) + 60n) + (2*5e-08) : (60n >
       (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) \
37     sca=(( (widthv12) * ( (((1u) * (1u) / (((widthv12) < 119.5n) ? (50n >
        (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
        > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)) - ((1u
       ) * (1u) / ((((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ?
        50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n)
        ? 100n : (((60n) - 0) + 80n))+60n)+(45n)))) + ((1u) * (1u) / (((
       widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
       - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
       n) - 0) + 80n))+60n)) - ((1u) * (1u)/ ((((widthv12) < 119.5n) ?
       (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
        (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)
       +(45n))))) + ( (45n) * ( (((1u) * (1u) / (60n)) - ((1u) * (1u) /
       ((60n)+(widthv12)))) + ((1u) * (1u) / (60n)) - ((1u) * (1u)/ ((60
       n)+(widthv12)))))) / ((widthv12) * (45n)) \
38     scb=(((widthv12) * (((((widthv12) < 119.5n) ? (50n > (((60n) - 0) +
       60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0)
       + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp(-10
       * (((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
       (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n
        : (((60n) - 0) + 80n))+60n) / (1u)) - (((((widthv12) < 119.5n) ?
        (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
       : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)
       +(45n))/10 + (1u)/100)*exp(-10 * ((((widthv12) < 119.5n) ? (50n >
        (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
        > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+(45n))
       / (1u)) + ((((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ?
       50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n)
       ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp(-10 * (((
       widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
       - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
       n) - 0) + 80n))+60n) / (1u)) - (((((widthv12) < 119.5n) ? (50n >
       (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
       > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+(45n))
       /10 + (1u)/100)*exp(-10 * ((((widthv12) < 119.5n) ? (50n > (((60n
       ) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n >
       (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+(45n)) /
       (1u)))) + ((45n) * (((60n)/10 + (1u)/100)*exp(-10 * (60n) / (1u))
        - (((60n)+(widthv12))/10 + (1u)/100)*exp(-10 * ((60n)+(widthv12)
       ) / (1u)) + ((60n)/10 + (1u)/100)*exp(-10 * (60n) / (1u)) - (((60
       n)+(widthv12))/10 + (1u)/100)*exp(-10 * ((60n)+(widthv12)) / (1u)
```

```
           )))) / ((widthv12) * (45n)) \
39         scc=(((widthv12) * (((((widthv12) < 119.5n) ? (50n > (((60n) - 0) +
              60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0)
              + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp(-20
              * (((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
              (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n
               : (((60n) - 0) + 80n))+60n) / (1u)) - (((((widthv12) < 119.5n) ?
               (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
              : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)
              +(45n))/20 + (1u)/400)*exp(-20 * ((((widthv12) < 119.5n) ? (50n >
               (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
               > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+(45n))
              / (1u)) + ((((widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ?
              50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n)
              ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp(-20 * (((
              widthv12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
              - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
              n) - 0) + 80n))+60n) / (1u)) - (((((widthv12) < 119.5n) ? (50n >
              (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
              > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+(45n))
              /20 + (1u)/400)*exp(-20 * ((((widthv12) < 119.5n) ? (50n > (((60n
              ) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n >
              (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+(45n)) /
              (1u)))) + ((45n) * (((60n)/20 + (1u)/400)*exp(-20 * (60n) / (1u))
               - (((60n)+(widthv12))/20 + (1u)/400)*exp(-20 * ((60n)+(widthv12)
              ) / (1u)) + ((60n)/20 + (1u)/400)*exp(-20 * (60n) / (1u)) - (((60
              n)+(widthv12))/20 + (1u)/400)*exp(-20 * ((60n)+(widthv12)) / (1u)
              )))) / ((widthv12) * (45n)) \
40         m=(1)
41 NM1 (X Y Ibias 0) g45n1svt w=((width12) * (1)) l=length12 nf=1 as=((width12)
     < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
     120n) + ((width12) * 50n)) + (floor(((1) - 1) / 2.0) * (((((60n) - 0) +
     60n) * 120n) + ((width12) * 100n))) + ((((1) / 2) - floor((1) / 2) == 0)
     ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) * 120n) + ((
     width12) * 50n)) : 0)) / 1 : (((100n > (((60n) - 0) + 80n) ? 100n : (((60
     n) - 0) + 80n)) * (width12)) + (floor(((1) - 1) / 2.0) * ((60n > (((60n)
     - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width12))) + ((((1) / 2) -
     floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0)
      + 80n)) * (width12)) : 0)) / 1 \
42         ad=((width12) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n)
              * 120n) + ((width12) * 100n))) + ((((1) / 2) - floor((1) / 2) !=
              0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
              120n) + ((width12) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) * ((60n
               > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width12)))
               + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60n) - 0) +
              80n) ? 100n : (((60n) - 0) + 80n)) * (width12)) : 0)) / 1 \
43         ps=((width12) < 119.5n) ? (((2 * (50n > (((60n) - 0) + 60n) ? 50n :
              (((60n) - 0) + 60n))) + 340n) + (floor(((1) - 1) / 2.0) * ((2 *
              (((60n) - 0) + 60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) ==
              0) ? ((2 * (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)
```

```
    )) + 340n) : 0)) / 1 : (((2 * (100n > (((60n) - 0) + 80n) ? 100n
    : (((60n) - 0) + 80n))) + (2 * (width12))) + (floor(((1) - 1) /
    2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50
    n))) + (2 * (width12)))) + ((((1) / 2) - floor((1) / 2) == 0) ?
    ((2 * (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)))
    + (2 * (width12))) : 0)) / 1 \
pd=((width12) < 119.5n) ? ((floor((1) / 2.0) * ((2 * (((60n) - 0) +
    60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) != 0) ? ((2 * (50n
    > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))) + 340n) : 0))
     / 1 : ((floor((1) / 2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60
    n : (((60n) - 0) + 50n))) + (2 * (width12)))) + ((((1) / 2) -
    floor((1) / 2) != 0) ? ((2 * (100n > (((60n) - 0) + 80n) ? 100n :
     (((60n) - 0) + 80n))) + (2 * (width12))) : 0)) / 1 \
nrd=((width12) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n)
     * 120n) + ((width12) * 100n))) + ((((1) / 2) - floor((1) / 2) !=
     0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
     120n) + ((width12) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) * ((60
    n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width12))
    ) + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60n) - 0) +
    80n) ? 100n : (((60n) - 0) + 80n)) * (width12)) : 0)) / 1 / ((
    width12) * (1) * (width12) * (1)) \
nrs=((width12) < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n :
    (((60n) - 0) + 60n)) * 120n) + ((width12) * 50n)) + (floor(((1) -
     1) / 2.0) * (((((60n) - 0) + 60n) * 120n) + ((width12) * 100n)))
     + ((((1) / 2) - floor((1) / 2) == 0) ? (((50n > (((60n) - 0) +
    60n) ? 50n : (((60n) - 0) + 60n)) * 120n) + ((width12) * 50n)) :
    0)) / 1 : (((100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) +
    80n)) * (width12)) + (floor(((1) - 1) / 2.0) * ((60n > (((60n) -
    0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width12))) + ((((1) /
    2) - floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n :
     (((60n) - 0) + 80n)) * (width12)) : 0)) / 1 / ((width12) * (1) *
     (width12) * (1)) \
sa=((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
    - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
    n) - 0) + 80n)) \
sb=((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
    - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
    n) - 0) + 80n)) \
sd=((width12) < 119.5n) ? (((60n) - 0) + 60n) + (2*5e-08) : (60n >
    (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) \
sca=(( (width12) * ( (((1u) * (1u) / (((width12) < 119.5n) ? (50n >
    (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
    > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)) - ((1u)
     * (1u) / ((((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ?
    50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n)
    ? 100n : (((60n) - 0) + 80n))+60n)+length12))) + ((1u) * (1u) /
    (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
    ) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
    (((60n) - 0) + 80n))+60n)) - ((1u) * (1u)/ ((((width12) < 119.5n)
     ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e
```

```
-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))
+60n)+length12)))) + ( length12 * ( (((1u) * (1u) / (60n)) - ((1u
) * (1u) / ((60n)+(width12)))) + ((1u) * (1u) / (60n)) - ((1u) *
(1u)/ ((60n)+(width12)))))) / ((width12) * length12) \
scb=(((width12) * (((((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n
) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) +
80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp(-10 *
(((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
(((60n) - 0) + 80n))+60n) / (1u)) - (((((width12) < 119.5n) ? (50
n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
(100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
length12)/10 + (1u)/100)*exp(-10 * ((((width12) < 119.5n) ? (50n
> (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
length12) / (1u)) + ((((width12) < 119.5n) ? (50n > (((60n) - 0)
+ 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) -
0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp
(-10 * (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
 (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100
n : (((60n) - 0) + 80n))+60n) / (1u)) - (((((width12) < 119.5n) ?
 (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
: (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
length12)/10 + (1u)/100)*exp(-10 * ((((width12) < 119.5n) ? (50n
> (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
length12) / (1u)))) + (length12 * (((60n)/10 + (1u)/100)*exp(-10
* (60n) / (1u)) - (((60n)+(width12))/10 + (1u)/100)*exp(-10 *
((60n)+(width12)) / (1u)) + ((60n)/10 + (1u)/100)*exp(-10 * (60n)
 / (1u)) - (((60n)+(width12))/10 + (1u)/100)*exp(-10 * ((60n)+(
width12)) / (1u))))) / ((width12) * length12) \
scc=(((width12) * (((((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n
) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) +
80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp(-20 *
(((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
(((60n) - 0) + 80n))+60n) / (1u)) - (((((width12) < 119.5n) ? (50
n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
(100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
length12)/20 + (1u)/400)*exp(-20 * ((((width12) < 119.5n) ? (50n
> (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
length12) / (1u)) + ((((width12) < 119.5n) ? (50n > (((60n) - 0)
+ 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) -
0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp
(-20 * (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
 (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100
n : (((60n) - 0) + 80n))+60n) / (1u)) - (((((width12) < 119.5n) ?
 (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
: (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
```

```
           length12)/20 + (1u)/400)*exp(-20 * ((((width12) < 119.5n) ? (50n
           > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
           n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           length12) / (1u)))) + (length12 * (((60n)/20 + (1u)/400)*exp(-20
           * (60n) / (1u)) - (((60n)+(width12))/20 + (1u)/400)*exp(-20 *
           ((60n)+(width12)) / (1u)) + ((60n)/20 + (1u)/400)*exp(-20 * (60n)
            / (1u)) - (((60n)+(width12))/20 + (1u)/400)*exp(-20 * ((60n)+(
           width12)) / (1u))))) / ((width12) * length12) \
       m=(1)
NM0 (Y X Ibias 0) g45n1svt w=((width12) * (1)) l=length12 nf=1 as=((width12)
   < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
   120n) + ((width12) * 50n)) + (floor(((1) - 1) / 2.0) * (((((60n) - 0) +
   60n) * 120n) + ((width12) * 100n))) + ((((1) / 2) - floor((1) / 2) == 0)
   ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) * 120n) + ((
   width12) * 50n)) : 0)) / 1 : (((100n > (((60n) - 0) + 80n) ? 100n : (((60
   n) - 0) + 80n)) * (width12)) + (floor(((1) - 1) / 2.0) * ((60n > (((60n)
   - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width12))) + ((((1) / 2) -
   floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0)
    + 80n)) * (width12)) : 0)) / 1 \
       ad=((width12) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n)
           * 120n) + ((width12) * 100n))) + ((((1) / 2) - floor((1) / 2) !=
           0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
           120n) + ((width12) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) * ((60n
            > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width12)))
            + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60n) - 0) +
           80n) ? 100n : (((60n) - 0) + 80n)) * (width12)) : 0)) / 1 \
       ps=((width12) < 119.5n) ? (((2 * (50n > (((60n) - 0) + 60n) ? 50n :
           (((60n) - 0) + 60n))) + 340n) + (floor(((1) - 1) / 2.0) * ((2 *
           (((60n) - 0) + 60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) ==
           0) ? ((2 * (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)
           )) + 340n) : 0)) / 1 : (((2 * (100n > (((60n) - 0) + 80n) ? 100n
           : (((60n) - 0) + 80n))) + (2 * (width12))) + (floor(((1) - 1) /
           2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50
           n))) + (2 * (width12)))) + ((((1) / 2) - floor((1) / 2) == 0) ?
           ((2 * (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n)))
           + (2 * (width12))) : 0)) / 1 \
       pd=((width12) < 119.5n) ? ((floor((1) / 2.0) * ((2 * (((60n) - 0) +
           60n)) + 440n)) + ((((1) / 2) - floor((1) / 2) != 0) ? ((2 * (50n
           > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n))) + 340n) : 0))
            / 1 : ((floor((1) / 2.0) * ((2 * (60n > (((60n) - 0) + 50n) ? 60
           n : (((60n) - 0) + 50n))) + (2 * (width12)))) + ((((1) / 2) -
           floor((1) / 2) != 0) ? ((2 * (100n > (((60n) - 0) + 80n) ? 100n :
            (((60n) - 0) + 80n))) + (2 * (width12))) : 0)) / 1 \
       nrd=((width12) < 119.5n) ? ((floor((1) / 2.0) * (((((60n) - 0) + 60n)
            * 120n) + ((width12) * 100n))) + ((((1) / 2) - floor((1) / 2) !=
            0) ? (((50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) *
            120n) + ((width12) * 50n)) : 0)) / 1 : ((floor((1) / 2.0) * ((60
           n > (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width12))
           ) + ((((1) / 2) - floor((1) / 2) != 0) ? ((100n > (((60n) - 0) +
           80n) ? 100n : (((60n) - 0) + 80n)) * (width12)) : 0)) / 1 / ((
```

```
        width12) * (1) * (width12) * (1)) \
59      nrs=((width12) < 119.5n) ? ((((50n > (((60n) - 0) + 60n) ? 50n :
        (((60n) - 0) + 60n)) * 120n) + ((width12) * 50n)) + (floor(((1) -
         1) / 2.0) * (((((60n) - 0) + 60n) * 120n) + ((width12) * 100n)))
         + ((((1) / 2) - floor((1) / 2) == 0) ? (((50n > (((60n) - 0) +
        60n) ? 50n : (((60n) - 0) + 60n)) * 120n) + ((width12) * 50n)) :
        0)) / 1 : (((100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) +
        80n)) * (width12)) + (floor(((1) - 1) / 2.0) * ((60n > (((60n) -
        0) + 50n) ? 60n : (((60n) - 0) + 50n)) * (width12))) + ((((1) /
        2) - floor((1) / 2) == 0) ? ((100n > (((60n) - 0) + 80n) ? 100n :
         (((60n) - 0) + 80n)) * (width12)) : 0)) / 1 / ((width12) * (1) *
         (width12) * (1)) \
60      sa=((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
        - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
        n) - 0) + 80n)) \
61      sb=((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n)
        - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60
        n) - 0) + 80n)) \
62      sd=((width12) < 119.5n) ? (((60n) - 0) + 60n) + (2*5e-08) : (60n >
        (((60n) - 0) + 50n) ? 60n : (((60n) - 0) + 50n)) \
63      sca=(( (width12) * ( (((1u) * (1u) / (((width12) < 119.5n) ? (50n >
        (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n
        > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)) - ((1u)
         * (1u) / ((((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ?
        50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n)
        ? 100n : (((60n) - 0) + 80n))+60n)+length12))) + ((1u) * (1u) /
        (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
        ) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
        (((60n) - 0) + 80n))+60n)) - ((1u) * (1u)/ ((((width12) < 119.5n)
         ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e
        -08 : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))
        +60n)+length12)))) + ( length12 * ( (((1u) * (1u) / (60n)) - ((1u
        ) * (1u) / ((60n)+(width12)))) + ((1u) * (1u) / (60n)) - ((1u) *
        (1u)/ ((60n)+(width12)))))) / ((width12) * length12) \
64      scb=((width12) * (((((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n
        ) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) +
        80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp(-10 *
        (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
        ) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
        (((60n) - 0) + 80n))+60n) / (1u)) - (((((width12) < 119.5n) ? (50
        n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
        (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length12)/10 + (1u)/100)*exp(-10 * ((((width12) < 119.5n) ? (50n
        > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
        n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
        length12) / (1u)) + ((((width12) < 119.5n) ? (50n > (((60n) - 0)
        + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) -
        0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/10 + (1u)/100)*exp
        (-10 * (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
         (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100
```

```
           n : (((60n) - 0) + 80n))+60n) / (1u)) - (((((width12) < 119.5n) ?
            (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
           : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           length12)/10 + (1u)/100)*exp(-10 * ((((width12) < 119.5n) ? (50n
           > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
           n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           length12) / (1u)))) + (length12 * (((60n)/10 + (1u)/100)*exp(-10
           * (60n) / (1u)) - (((60n)+(width12))/10 + (1u)/100)*exp(-10 *
           ((60n)+(width12)) / (1u)) + ((60n)/10 + (1u)/100)*exp(-10 * (60n)
            / (1u)) - (((60n)+(width12))/10 + (1u)/100)*exp(-10 * ((60n)+(
           width12)) / (1u))))) / ((width12) * length12) \
       scc=(((width12) * (((((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n
           ) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) +
           80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp(-20 *
           (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n : (((60n
           ) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100n :
           (((60n) - 0) + 80n))+60n) / (1u)) - (((((width12) < 119.5n) ? (50
           n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 :
           (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           length12)/20 + (1u)/400)*exp(-20 * ((((width12) < 119.5n) ? (50n
           > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
           n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           length12) / (1u)) + ((((width12) < 119.5n) ? (50n > (((60n) - 0)
           + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) -
           0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)/20 + (1u)/400)*exp
           (-20 * (((width12) < 119.5n) ? (50n > (((60n) - 0) + 60n) ? 50n :
            (((60n) - 0) + 60n)) + 5e-08 : (100n > (((60n) - 0) + 80n) ? 100
           n : (((60n) - 0) + 80n))+60n) / (1u)) - (((((width12) < 119.5n) ?
            (50n > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08
           : (100n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           length12)/20 + (1u)/400)*exp(-20 * ((((width12) < 119.5n) ? (50n
           > (((60n) - 0) + 60n) ? 50n : (((60n) - 0) + 60n)) + 5e-08 : (100
           n > (((60n) - 0) + 80n) ? 100n : (((60n) - 0) + 80n))+60n)+
           length12) / (1u)))) + (length12 * (((60n)/20 + (1u)/400)*exp(-20
           * (60n) / (1u)) - (((60n)+(width12))/20 + (1u)/400)*exp(-20 *
           ((60n)+(width12)) / (1u)) + ((60n)/20 + (1u)/400)*exp(-20 * (60n)
            / (1u)) - (((60n)+(width12))/20 + (1u)/400)*exp(-20 * ((60n)+(
           width12)) / (1u))))) / ((width12) * length12) \
       m=(1)
C1 (vdd! Y) capacitor c=C1
C0 (vdd! X) capacitor c=C1
R1 (vdd! Y) resistor r=Rp
R0 (vdd! X) resistor r=Rp
L1 (vdd! Y) inductor l=L q=Q fq=100M mode=1
L0 (vdd! X) inductor l=L q=Q fq=100M mode=1
V3 (Vcont 0) vsource dc=vcont type=dc
V0 (vdd! 0) vsource dc=vdd type=dc
I2 (Ibias 0) isource dc=Itail type=dc
I11 (X Y) isource type=pulse val0=0 val1=1m rise=1p fall=1p width=3p
simulatorOptions options reltol=1e-3 vabstol=1e-6 iabstol=1e-12 temp=27 \
```

```
78      tnom=27 scalem=1.0 scale=1.0 gmin=1e-12 rforce=1 maxnotes=5 maxwarns=5 \
79      digits=5 cols=80 pivrel=1e-3 sensfile="../psf/sens.output" \
80      checklimitdest=psf
81  tran tran stop=100n errpreset=conservative write="spectre.ic" \
82      writefinal="spectre.fc" annotate=status maxiters=5
83  finalTimeOP info what=oppoint where=rawfile
84  pss ( X Y ) pss fund=F0 harms=20 errpreset=conservative
85  +    autosteady=yes oscic=lin annotate=status
86  pnoise ( X Y ) pnoise sweeptype=relative relharmnum=1
87  +       start=10k stop=1M noisetype=timeaverage noiseout=[am pm usb
88  +       lsb] annotate=status
89  modelParameter info what=models where=rawfile
90  element info what=inst where=rawfile
91  outputParameter info what=output where=rawfile
92  designParamVals info what=parameters where=rawfile
93  primitives info what=primitives where=rawfile
94  subckts info what=subckts where=rawfile
95  saveOptions options save=allpub
```