IN2P3

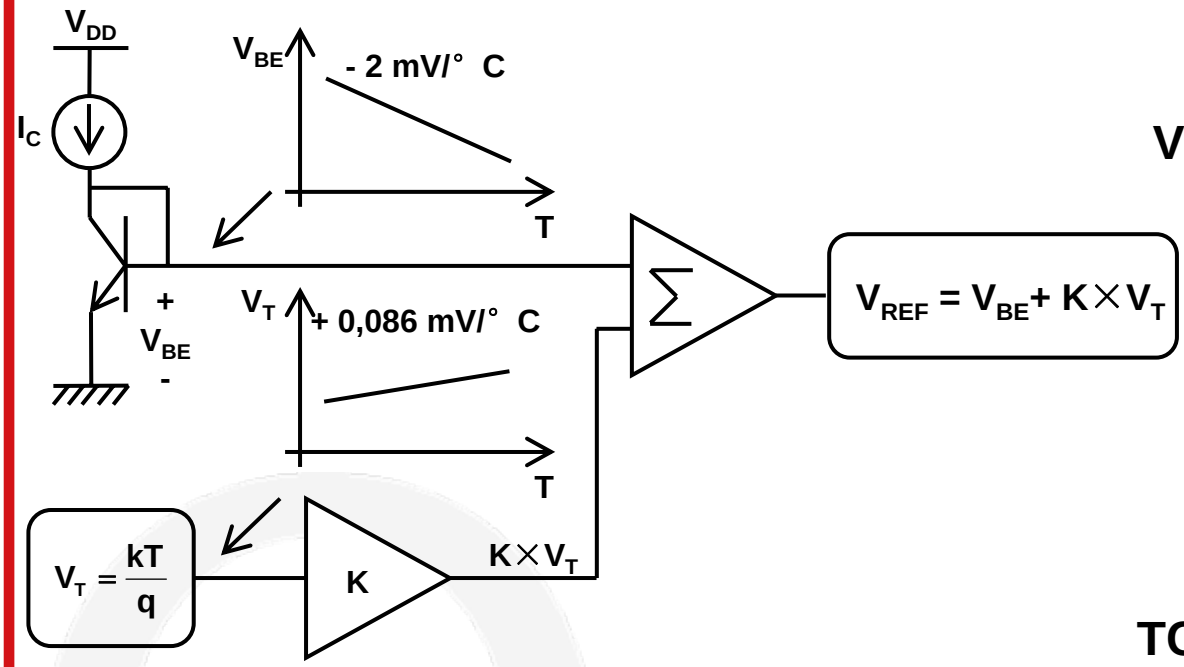
Omega

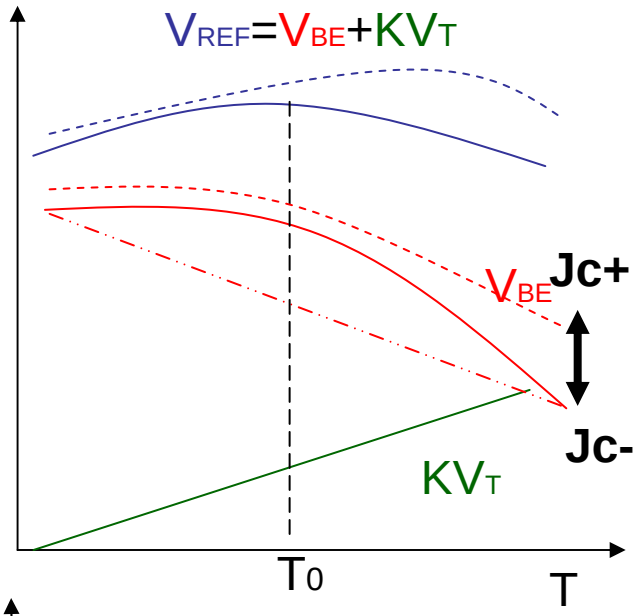
LAC

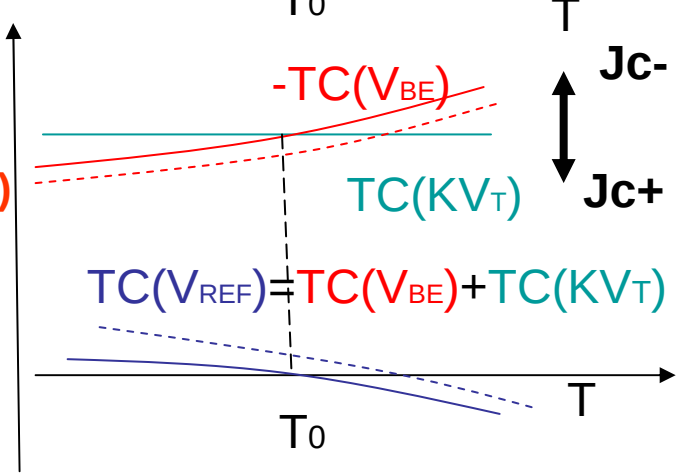
Bandgap design

Xiongbo Yan
LAL,ORSAY
xiongbo@lal.in2p3.fr

Orsay MicroElectronic Group Associated







- $V_{BE}(T) = V_{G0} + (V_{BE0}-V_{G0})(T/T_0) - \gamma V_T \ln(T/T_0) + V_T \ln(J_C/J_{C0})$

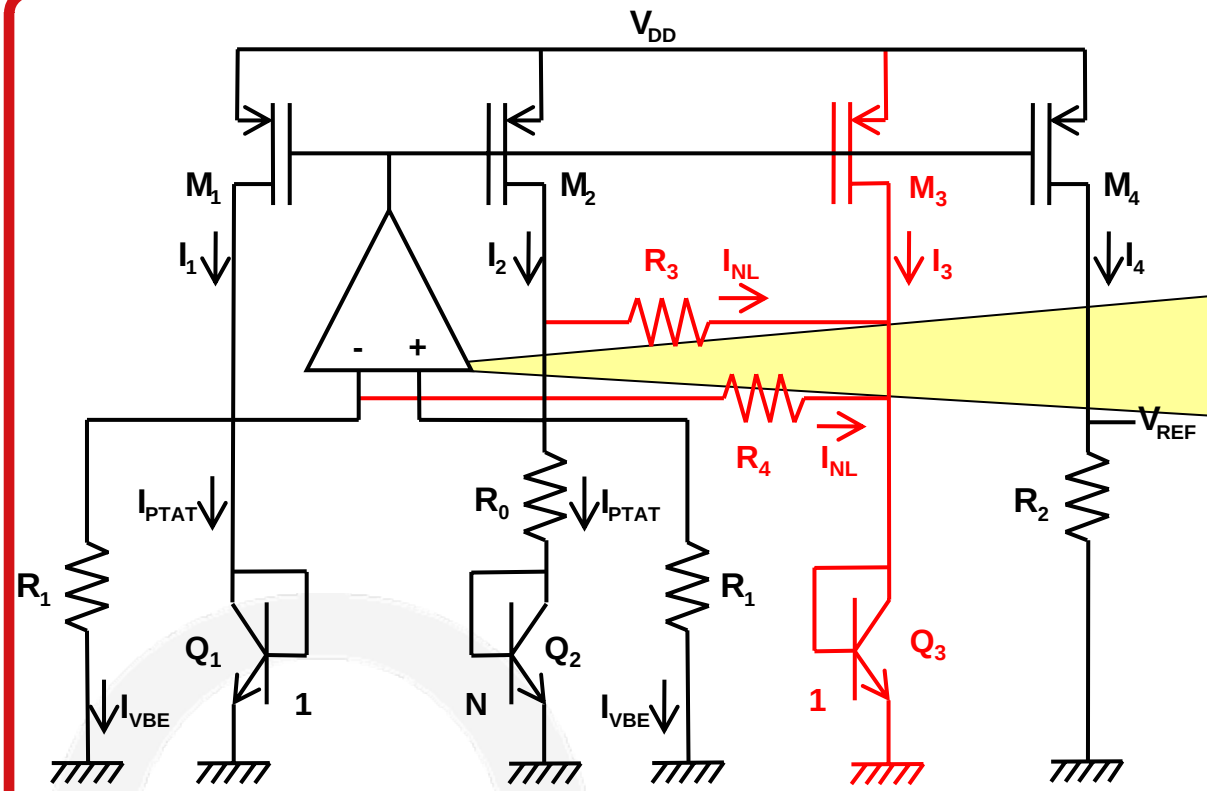
↳ $J_C \propto T^{\alpha} \rightarrow V_{BE}(T) = V_{G0} + (V_{BE0}-V_{G0})(T/T_0) - (\gamma - \alpha) V_T \ln(T/T_0)$

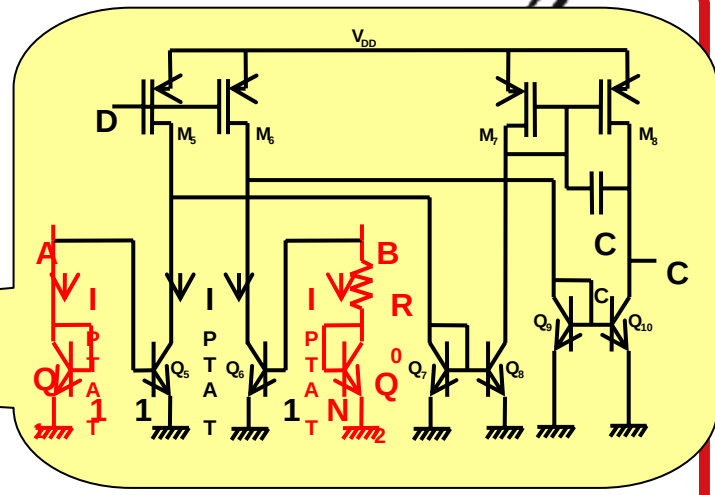
for V_{G0} = 1,2 V, V_{BE0} = 0,7 V, γ = 3,5 and α = 1

↳ $\partial V_{BE}/\partial T = (V_{BE0}-V_{G0})/T_0 - (\gamma - \alpha)(k/q) \approx$ - 2 mV/° C @ T_0 = 300 K

- $V_T = kT/q \rightarrow \partial V_T/\partial T = k/q \approx$ + 0,086 mV/° C

structure





N=21

R0=10K, R1=5*10K

R3,4=2*10K,R2=12*10K

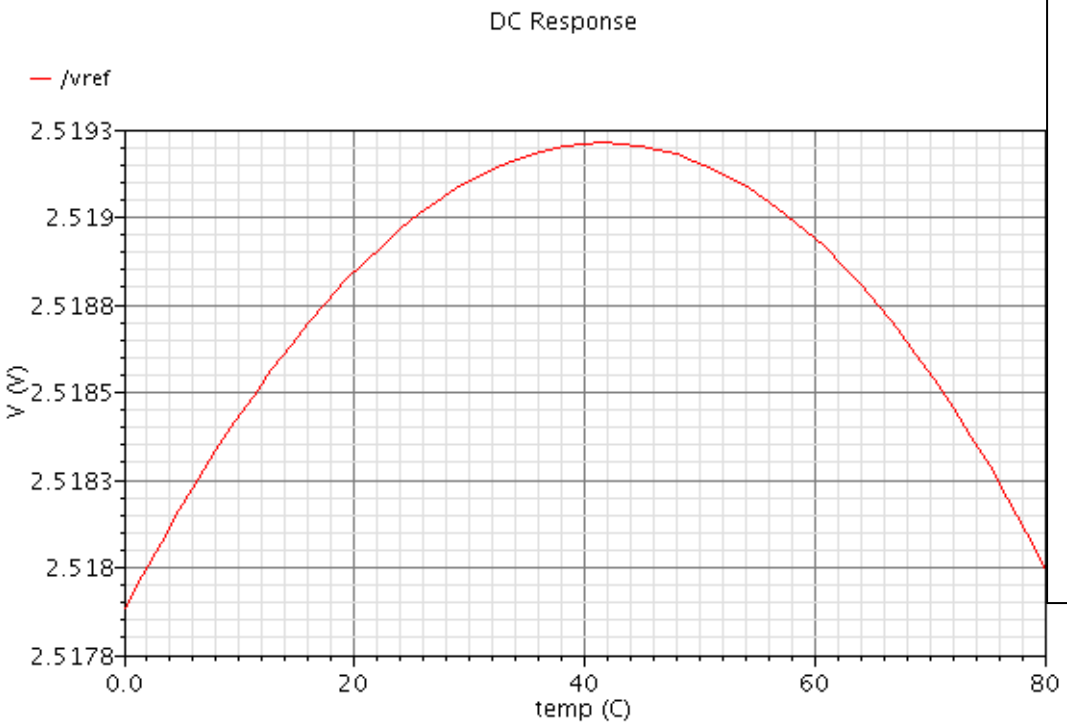
↳ $V_{REF} = R_2 I_4 = (R_2/R_1)[\ V_{BE,Q1,2} + V_T (R_1/R_0) \ln(N) + V_T (R_1/R_{3,4}) \ln(T/T_0)\ ]$

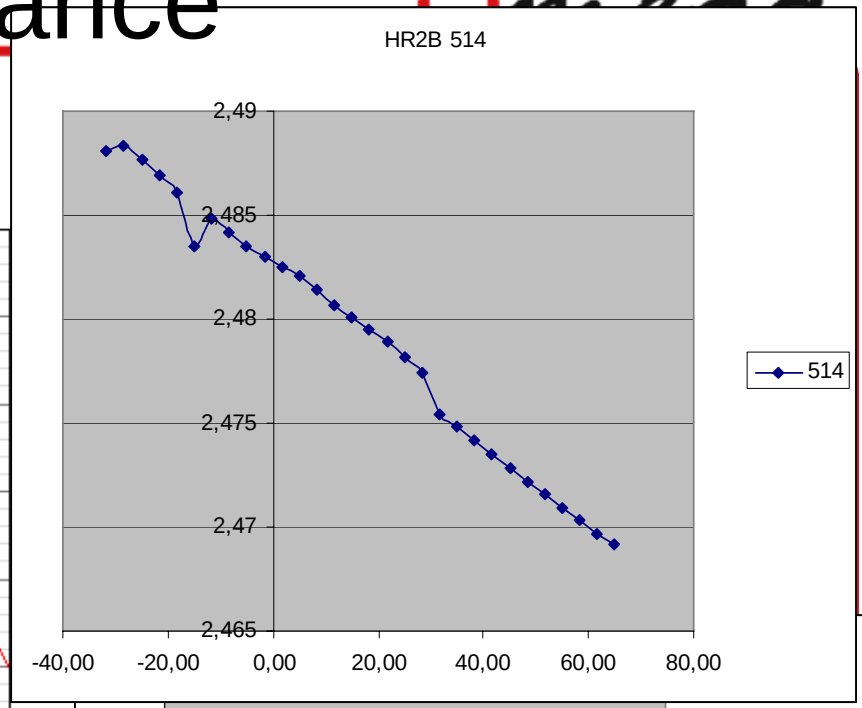
for $V_{BE,Q1,2}(T) = V_{G0} + (V_{BE0}-V_{G0})(T/T_0) - (\gamma - 1) V_T \ln(T/T_0)$

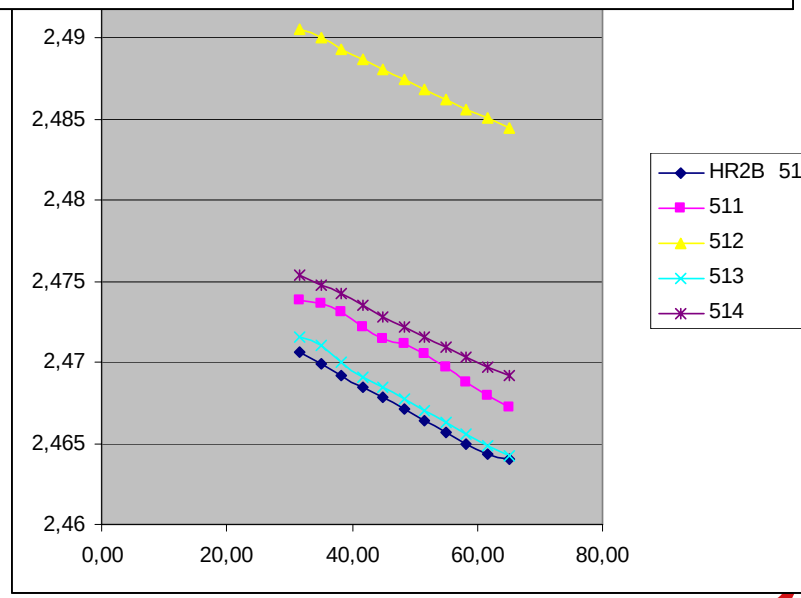
$V_{BE,Q3}(T) = V_{G0} + (V_{BE0}-V_{G0})(T/T0) - (\gamma - 0) V_T \ln(T/T0)$

↳ Second order compensation --->$R_{3,4} = R_1/(\gamma - 1)$

performance







Parameter	*simulation*	*mearsurement*
V_{REF} @ T = 40° C	2.52 V	2.47 V
ΔV_{REF} (0° C ≤ T ≤80° C)	± 1,3 mV → 6.5 ppm/° C 50uV /° C	± 15 mV → 75 ppm/° C 200uV /° C

Source of error

Type of error	Res. Mismatch	Res. Tolerance	Res. T.C.	Trans. mismatch	Current mirror mismatch
Error in devices	2%	20%		2%	10%
Relative magnitude	Small	large	small	small	large

$$I_{PTAT} = \frac{V_T}{R_0}\ln(\frac{N \cdot I_{C1}}{I_{C2}}) = \frac{V_T}{R_0}\ln(N)$$

For Res. Tolerance:

$$I_{PTAT_R} = \frac{V_T}{R_0(1+\delta_R)}\ln(N) \approx \frac{V_T}{R_0}\ln(N)(1-\delta_R) = I_{PTAT}(1-\delta_R)$$

For current mirror mismatch:

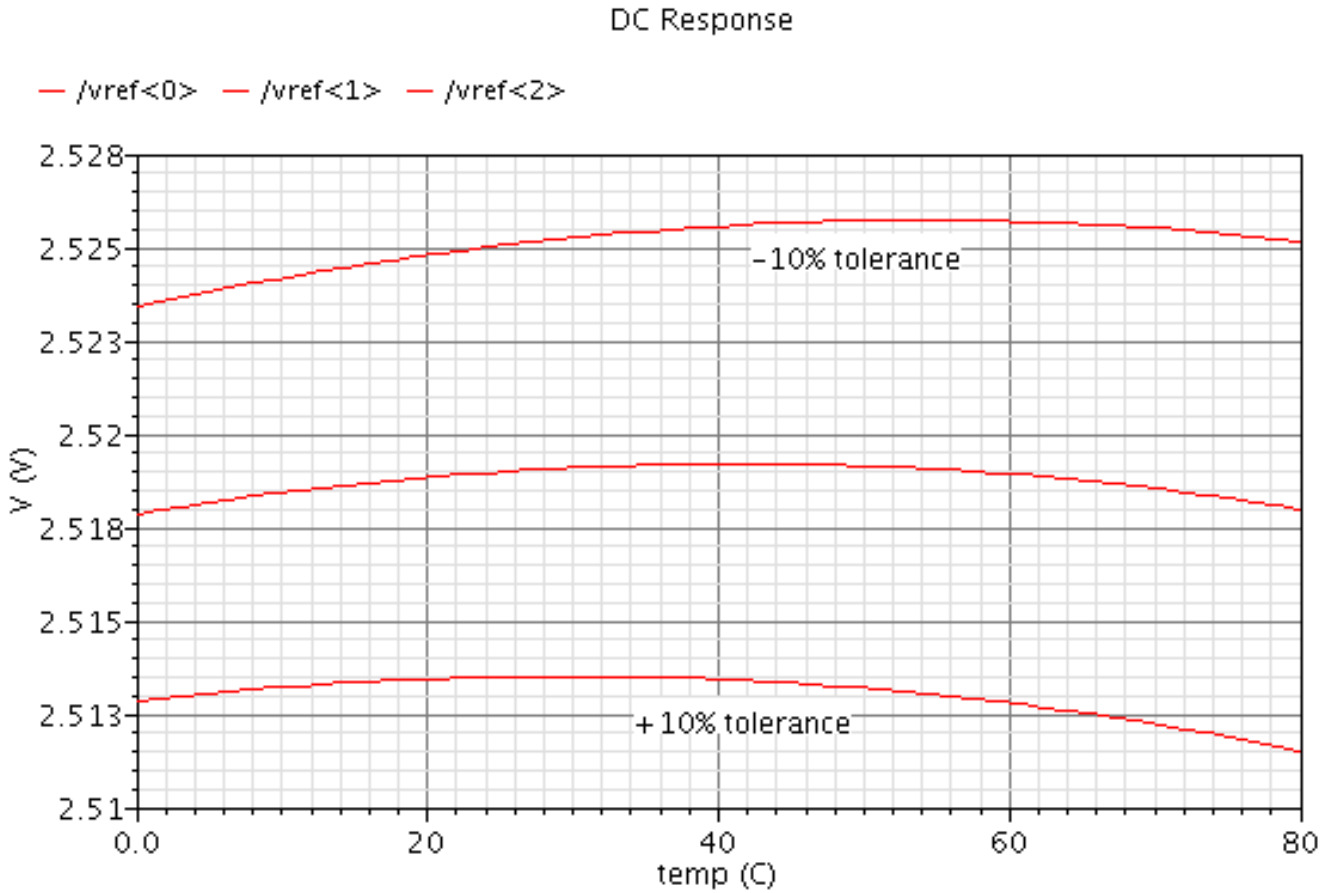
$$I_{PTAT_I} = \frac{V_T}{R_0}\ln(\frac{N \cdot I_{C1}}{I_{C2}}) = \frac{V_T}{R_0}\ln[\frac{N \cdot I_{C2}(1+\delta_I)}{I_{C2}}] = I_{PTAT} + \frac{V_T}{R_0}\delta_I$$

Layout:

all the transistors and resistors are common-centroid, identical

use low T.C. and low Tolerance Res.

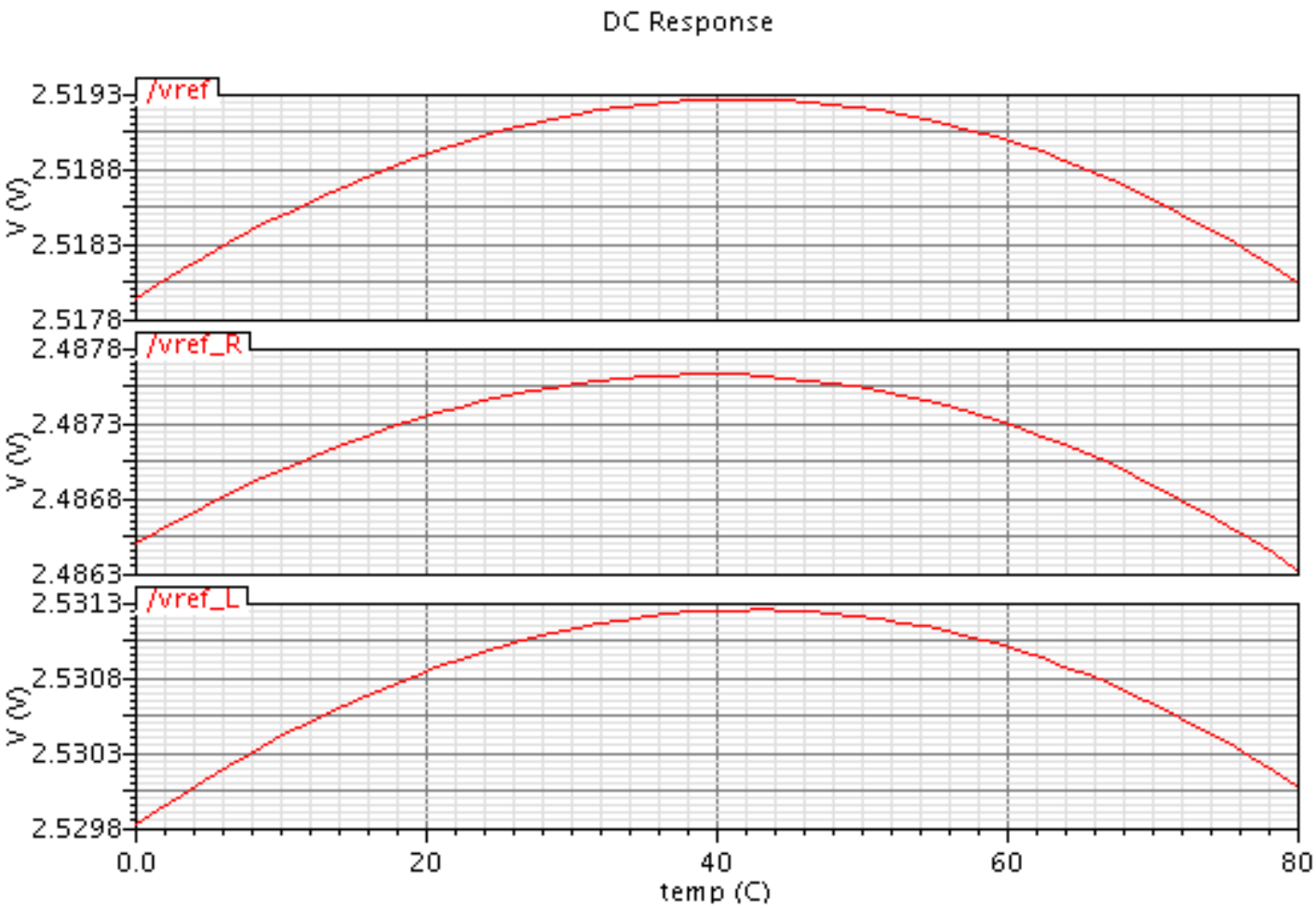
Resistor tolerance 10%

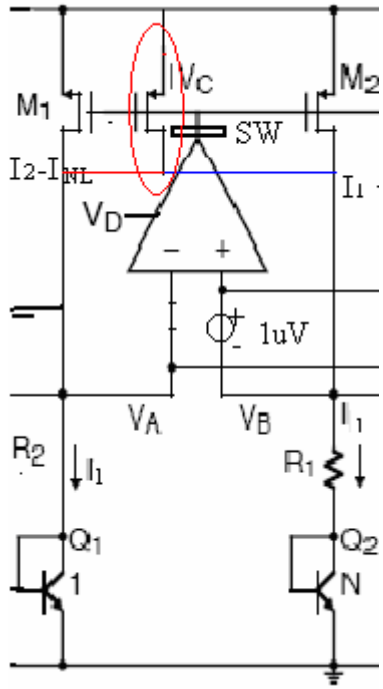


Peak diff:-6mv@30C~+10%

7mv@50C~-10%

current mirror mismatch 1%

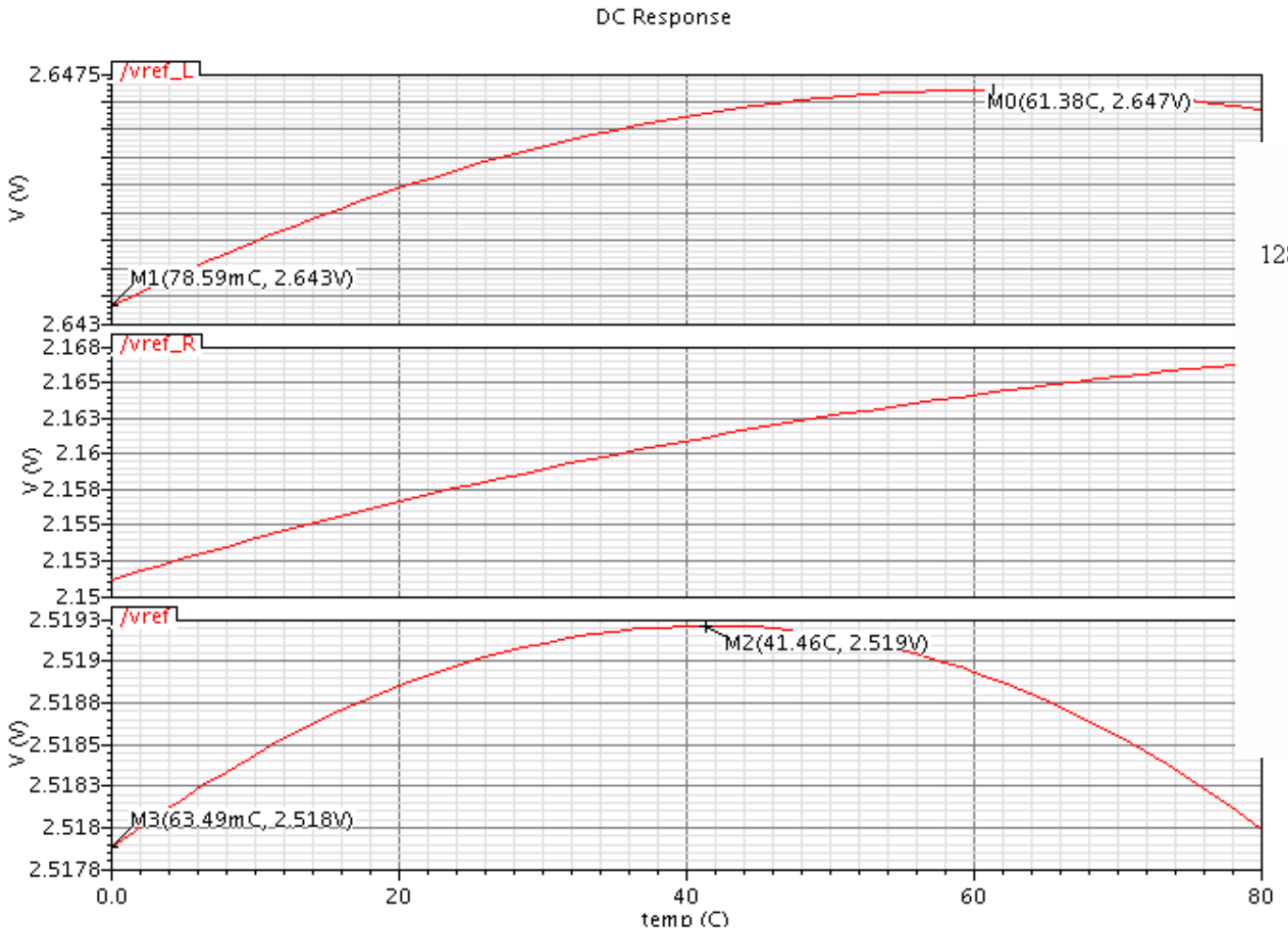


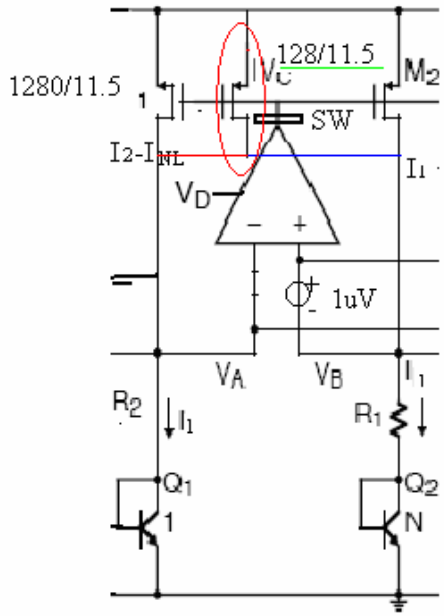


Peak diff:-32mv @35C~R

12mv @45C~L

current mirror mismatch 10%



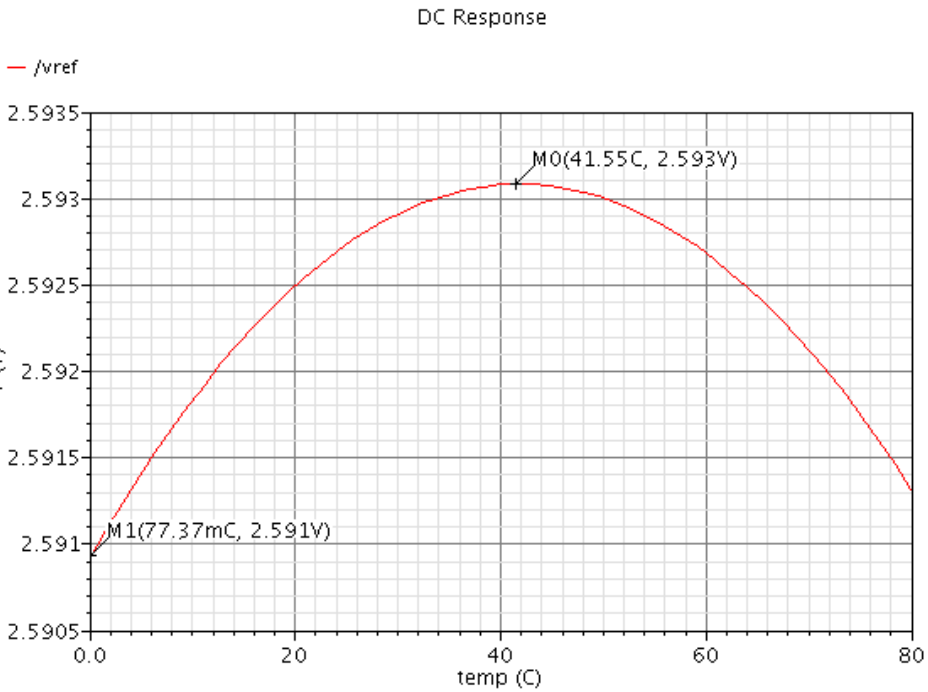


Peak diff: 350 mv @ 120C ~R

128mv @ 60C ~L

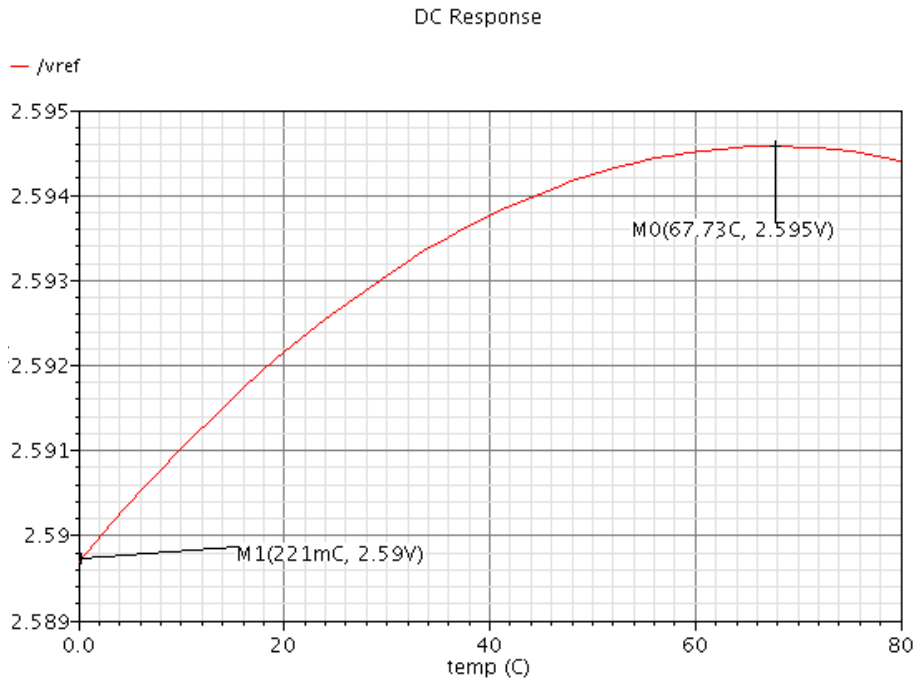
With different cadence simulator versions

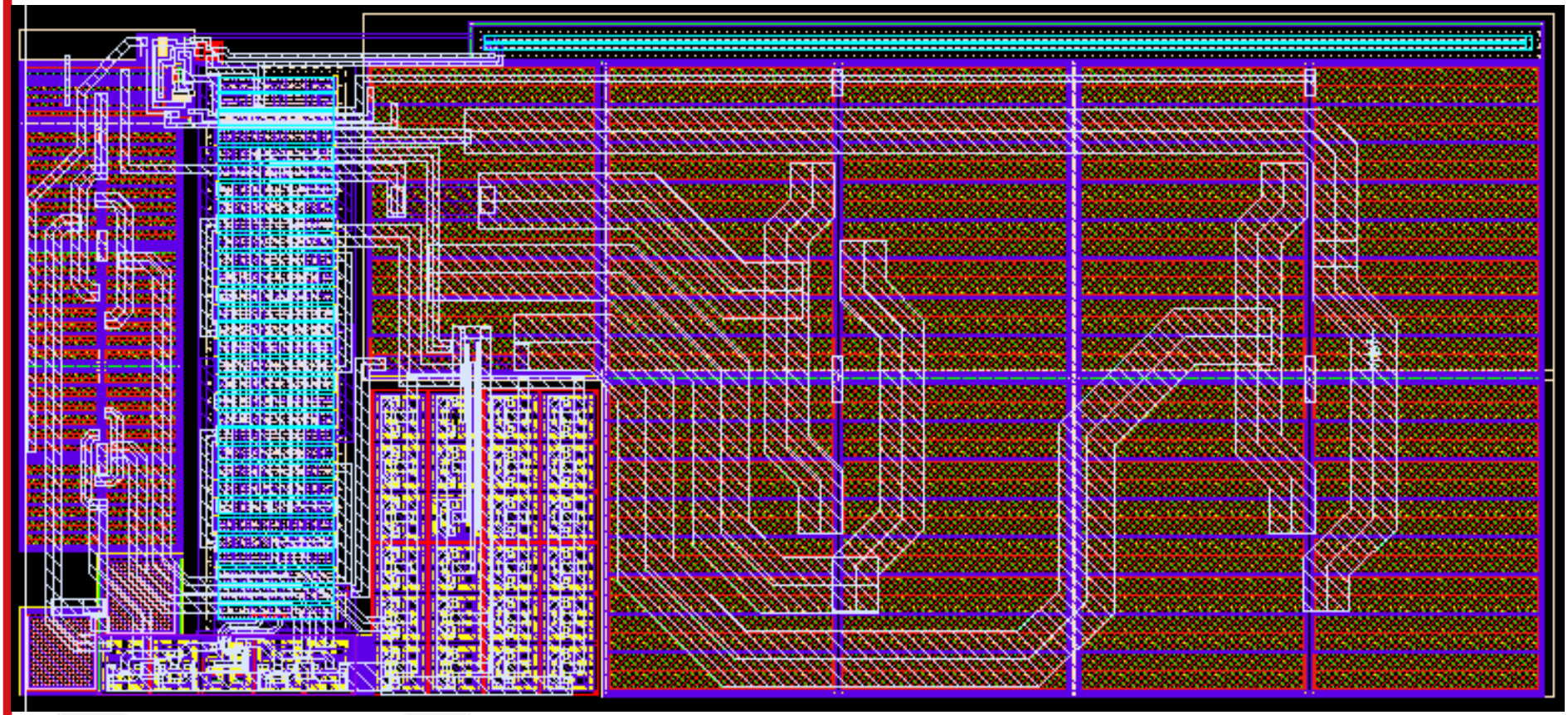
- Use Cadence -mmsim60



peak: @ 41˚C

- Use Cadence-mmsim62



@ 68˚C

layout