APPENDIX C

Analysis of the relative DCELL row current error

due to IN_AMP non idealities and leakage currents

Detailed analysis of relative DCELL row current error with respect to random non idealities of the block IN_AMP and template value change due to the leakage current.DCELL row current I_I can be expressed as

$$I_i = \sum_{j=1}^{m} I_{ij}$$

We assume that each DCELL have the same input and template voltage. Thus, standard deviation of I_I

$$\sigma^2[I_i] = m\sigma^2[I_{ij}]$$

DCELL output current can be expressed as

$$I_{ij} = \frac{\beta}{2}\left\{V_{DD} + V_{TP} - V_{bias} + \frac{C}{C_T}\left[K\left(X_j - T_{ij}\right)\right]\right\}^2$$

K and V_{bias} are random variables. Gain accuracy of unity gain amplifier in IN_AMP is not important. We can model its gain error as a coefficient in front of term $\frac{C}{C + C_T}$ in Equation [2.1.18]. This coefficient is smaller than one, thus it will not increase voltage range on nodes N1 and N2. Standard deviation of DCELL output current with respect to random variable K and V_{bias}.

$$\sigma^2[I_{ij}] = \frac{\beta^2}{4}\left[\underbrace{V_{DD} + V_{TP} - V_{bias} + \frac{C}{C_T}\left[K\left(X_j - T_{ij}\right)\right]}_{M_1}\right]^2 \sigma^2\left[V_{DD} + V_{TP} - V_{bias} + \frac{C}{C_T}\left[K\left(X_j - T_{ij}\right)\right]\right]$$

$$= \frac{\beta^2}{4} M_1{}^2\left[\sigma^2[V_{bias}] + \left[\frac{C}{C_T}\left(X_j - T_{ij}\right)\right]^2 \sigma^2[K]\right]$$

$$I_{ij}{}^2 = \frac{\beta^2}{4} M_1{}^4$$

$$\frac{\sigma^2[I_{ij}]}{I_{ij}^2} = \frac{\sigma^2[V_{bias}] + \left[\frac{C}{C_T}(X_j - T_{ij})\right]^2 \sigma^2[K]}{\left[\underbrace{V_{DD} + V_{TP} - V_{bias} + \frac{C}{C_T}[K(X_j - T_{ij})]}_{M_1}\right]^2}$$

$$= \frac{V_{bias}^2}{M_1^2}\frac{\sigma^2[V_{bias}]}{V_{bias}^2} + \frac{K^2\left[\frac{C}{C_T}(X_j - T_{ij})\right]^2}{M_1^2}\frac{\sigma^2[K]}{K^2}$$

All DCELL have the template and input voltage. Thus

$$I_i = mI_{ij}$$

$$I_i^2 = m^2 I_{ij}^2$$

Relative DCELL current error can be expressed as follows

$$\frac{\sigma^2[I_i]}{I_i^2} = \frac{1}{m}\frac{\sigma^2[I_{ij}]}{I_{ij}^2}$$

$$\frac{\sigma^2[I_i]}{I_i^2} = \frac{1}{m}\left[\frac{V_{bias}^2}{M_1^2}\frac{\sigma^2[V_{bias}]}{V_{bias}^2} + \frac{K^2\left[\frac{C}{C_T}(X_j - T_{ij})\right]^2}{M_1^2}\frac{\sigma^2[K]}{K^2}\right]$$

We substitute V_{bias} and K by their mean value.

$$V_{bias} = V_{DD} + V_{TP} \quad \text{and} \quad K = 1$$

Then relative error is

$$\frac{\sigma^2[I_i]}{I_i^2} = \frac{1}{m}\left[\left[\frac{V_{DD} + V_{TP}}{\frac{C}{C_T}(X_j - T_{ij})}\right]^2 \frac{\sigma^2[V_{bias}]}{V_{bias}^2} + \frac{\sigma^2[K]}{K^2}\right]$$