Derivation of FD PSCA amplifier

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September 17, 2025

1 Derivation

The current array is active in phase 1 which is denoted by $V[n]$. The amplification phase if defined by $V[n+1]$.We consider the output input common mode are not equal. We can start by calculating charges on C_s and C_f

For the negative terminal of the amplifier we can write charges stored as

$$Q_{C_{st}}[n] \ = \ C_{st}.(V_{inm}[n]) \ - \ V_{CMI}) \tag{1}$$

$$Q_{C_{ft}}[n] \ = \ C_{ft}.(V_{op}[n] \ - \ V_{CMI}) \tag{2}$$

$$V_{inm}[n] \ = \ V_{BAT} - (I_{force}.R_{st}) \tag{3}$$

Now for the amplification phase $V[n+\frac{1}{2}]$, we can write

$$Q_{C_{st}}[n+\frac{1}{2}] \ = \ C_{st}.(V_{inm}[n+\frac{1}{2}]) \ - \ V_{CMI}) \tag{4}$$

$$Q_{C_{ft}}[n+\frac{1}{2}] \ = \ C_{ft}.(V_{op}[n+\frac{1}{2}]) \ - \ V_{CMI}) \tag{5}$$

$$V_{inm}[n+\frac{1}{2}] \ = \ V_{BAT} \tag{6}$$

Once we enter the amplification phase the charges on both capacitors can not change and have to distributed based on ratio of capacitors. Thus charges accumulated in two phase are equal and opposite. Equating these charges gives us

$$Q_{C_{st}}[n] \ = \ Q_{C_{st}}[n+\frac{1}{2}] \tag{7}$$

$$C_{st}.(V_{inm}[n]) \ - \ V_{CMI}) = \ C_{st}.(V_{inm}[n+\frac{1}{2}]) \ - \ V_{CMI}) \tag{8}$$

$$Q_{C_{ft}}[n] \ = \ Q_{C_{ft}}[n+\frac{1}{2}] \tag{9}$$

$$C_{ft}.(V_{op}[n] \ - \ V_{CMI}) = \ C_{ft}.(V_{op}[n+\frac{1}{2}]) \ - \ V_{CMI}) \tag{10}$$

Where $V_{op}[n] \ = \ V_{CMO} \ and \ V_{op}[n+\frac{1}{2}] \ = \ V_{opdiff} \ + \ V_{CMO}$
Solving 8 and 10 provides

$$C_{st}(V_{inm}[n]) \ + \ V_{inm}[n+\frac{1}{2}]) + \ C_{ft}(V_{op}[n] - V_{op}[n+\frac{1}{2}]) \ = 0 \tag{11}$$

$$C_{st}((V_{BAT} - I_{force}.R_s) - V_{BAT}) + C_{ft}((V_{CMO} - V_{opdiff}) - V_{CMO}) \ = 0 \tag{12}$$

$$C_{st}(-I_{force}.R_s) = C_{ft}(V_{opdiff}) \tag{13}$$

For the similar derivation on bottom side we get, by adding and equating charges in the two phases

$$C_{sb}(V_{inp}[n]) \ + \ V_{inp}[n+\frac{1}{2}]) + \ C_{fb}(V_{om}[n] - V_{om}[n+\frac{1}{2}]) \ = 0 \tag{14}$$

$$C_{sb}((V_{gnd} + I_{force}.R_s) - V_{gnd}) + \; C_{ft}(V_{CMO} - V_{omdiff} - V_{CMO}) \; = 0 \tag{15}$$

$$C_{sb}(I_{force}.R_{sb}) = \; C_{ft}(V_{omdiff}) \tag{16}$$

Assuming the top and bottom resistors to be equal and Subtracting 16 from 13 we get;

$$-C_s(I_{force}.(R_{st} + R_{sb})) = C_f(V_{opdiff} - V_{omdiff}) \tag{17}$$

Which gives us the gain of the topology as where $I_{force}.(R_{st} + R_{sb}) \; = \; V_{inp} - V_{inm}$

$$\frac{(V_{opdiff} - V_{omdiff})}{V_{inp} - V_{inm}} \; = \; -\frac{C_s}{C_f} \tag{18}$$

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