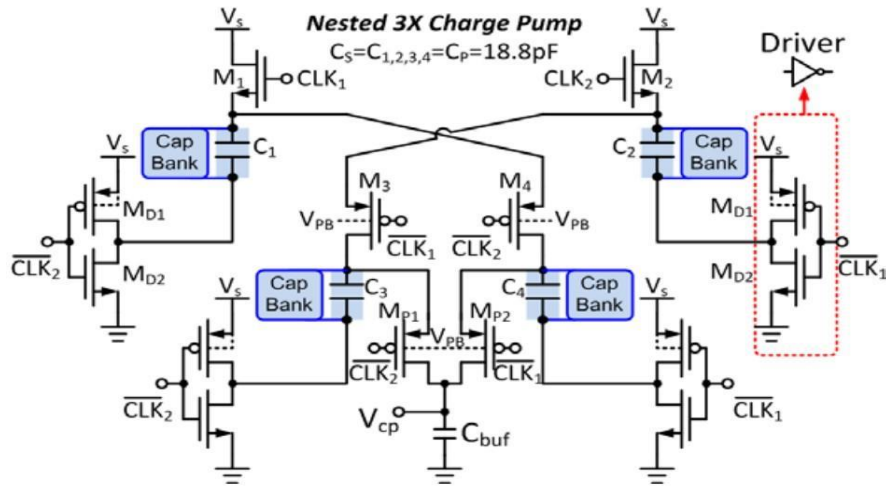


NESTED VOLTAGE TRIPLER

The Dickson charge pump is widely used in solar energy harvesting. The first stage provides two times voltage boosting, and the nested second stage provides 1.5 times voltage boosting, resulting in an overall CR of three.

In Figure, the switch transistors M1 and M2 are cross-connected and self-switched. However, such architecture limits the turn-on voltage of NMOS transistors to less than V_s , which ranges from 1.1-1.5 V. The low turn-on voltage drastically increases the conduction resistance and degrades boosting efficiency. Furthermore, the self-switching transistors suffer from shoot-through current, which ruins the conversion efficiency. Other coupled parasitic capacitors also affect the self-switching and require additional damping branches.



To eliminate these problems, we propose to break the cross-connected gates of M1,2,3,4 and MP1,2, and drive them separately with the higher

supply voltage non-overlapping clock $\text{clk}_{1,2}$ as shown in Figure . The four drivers used in Figure are implemented with transistor MD1 and MD2. For the second stage, M3,4 are replaced with PMOS switches to allow conducting voltage as high as $2V_s$. The operating waveforms of the $3\times$ charge pump are depicted in Figure .

When $\text{vclk}_1 = 1$ (logic) and $\text{vclk}_2 = 0$ (logic), C1 and C3 are charged to V_{solar} and $2V_{\text{solar}}$, respectively. C4 is discharged to the output cb as $3V_s$. When $\text{CLK}_1 = 0$ and $\text{CLK}_2 = 1$, C2 and C4 are charged to V_s and $2V_s$, respectively. C3 is discharged to Cb as $3V_s$. When $\text{vclk}_1 = 0$ and $\text{vclk}_2 = 0$, all of the switches are turned off to prevent the shoot-through current. $\text{clk}_{1,2}$ are generated by following auxiliary circuits.

Capacitor charge bank is used as the switched capacitors are programmable and split into fixed part CS and N programmable capacitors. In this design, C1,2,3,4 represent CS and its value is 18.8pF .

CIRCUIT DESIGN & EXECUTION

The following circuit designs have been implemented in LTspice software and results have been attested following it.

Parameters:

Vsolar:1.5V

NOCG clock signal: 1.5V,250KHz

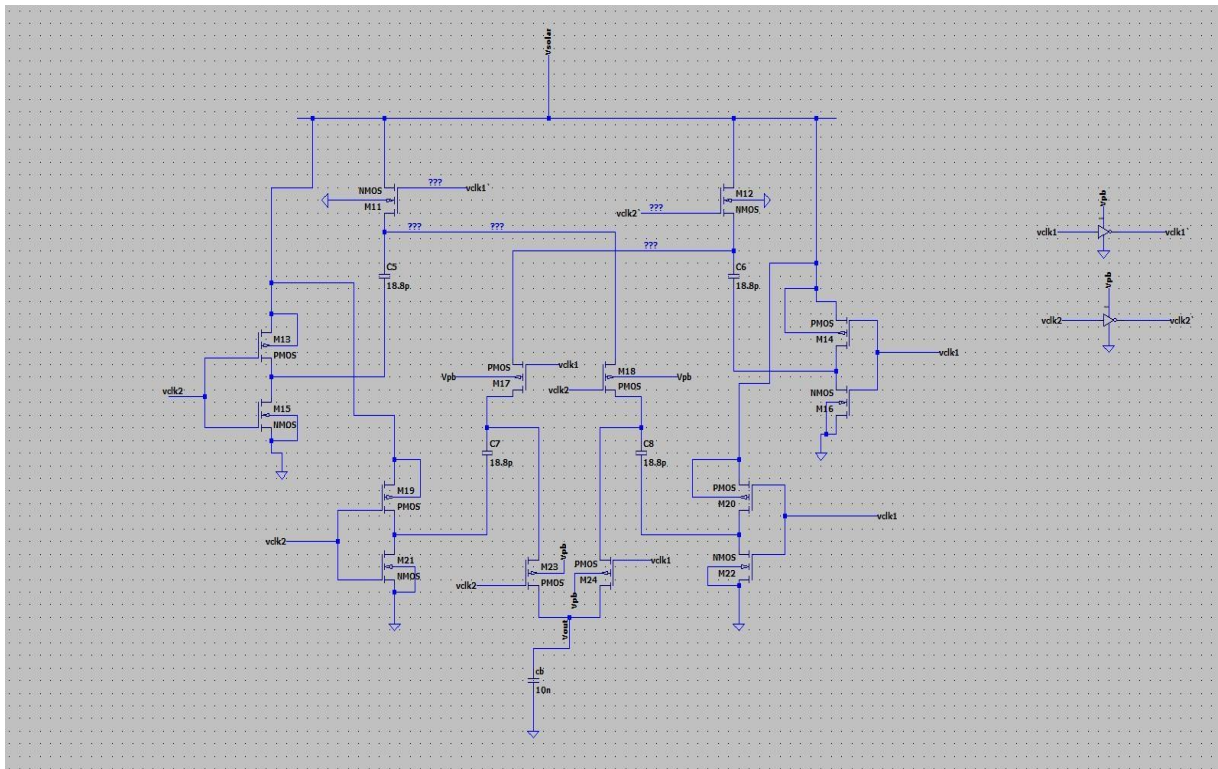


fig: Nested Voltage Tripler