RC circuit operation and power dissipation analysis

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1 Power clock equation

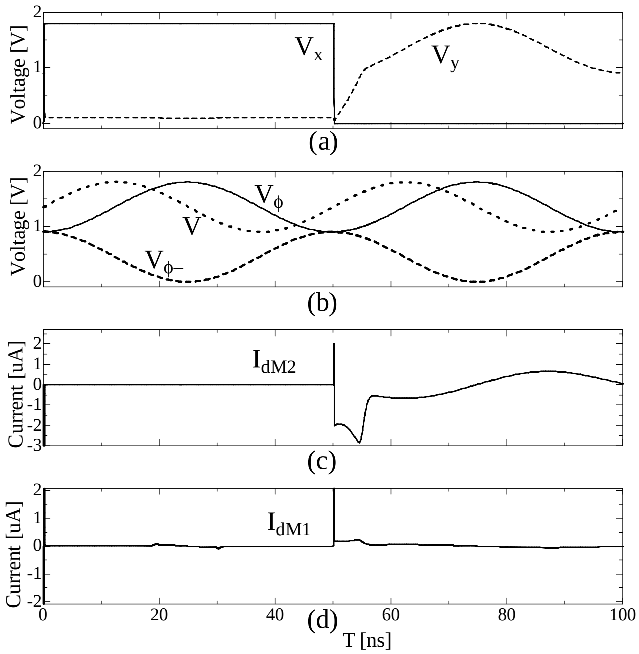

Fig. 1 (a) Input frequency (b) Power supply clocks for 2PASCL and reference sinusoidal waveform, V (c) Current that flow through the circuit after pMOS is ON.

$$V = \frac{V_{dd}}{4}\sin(\omega_o t) + \frac{3}{4}V_{dd} \quad (1)$$

$$V_\phi = \frac{V_{dd}}{4}\sin(\omega_o t + \theta) + \frac{3}{4}V_{dd} \quad (2)$$

$$V_{\bar{\phi}} = -\frac{V_{dd}}{4}\sin(\omega_o t + \theta) + \frac{1}{4}V_{dd} \quad (3)$$

For Eqs. 2 and 3

$$\begin{aligned} \theta &= \omega_o(3.77 \times 10^{-9}s) \quad (4) \\ &= 2\pi f(3.77 \times 10^{-9}s) \\ &= 4.73 \end{aligned}$$

For Eq. 2, as in Fig 1, for power clock frequency f of 20 MHz, at t=50 ns, V_{dd} is 1.8 V, the instantaneous value of V_ϕ can be written as

$$\begin{aligned} V_\phi &= \frac{1.8}{4}\sin(2\pi(20 \times 10^6)t + 4.73) + \frac{3}{4}(1.8) \quad (5) \\ &= 0.9V \end{aligned}$$

which is as in the simulation in Fig. 1

2 RC Operation

2.1 Pull up networks

2.1.1 Transient state

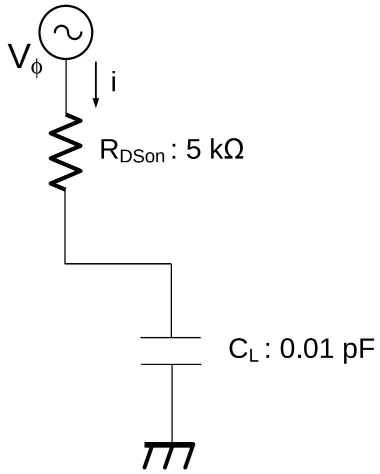

Fig. 2 Pull up networks of 2PASCL.

As shown in Fig. 2, the current $i(t)$ can be calculated as

$$i(t) = \frac{V_\phi}{\sqrt{R^2 + (\frac{1}{\omega_o C})^2}} \quad (6)$$

From Eq. 6, at 51 ns, the i(t) can be calculated as

$$\begin{aligned} i(t) &= \frac{0.905}{\sqrt{(2.5 \times 10^7) + (6.3326 \times 10^{11})}} \quad (7) \\ &= 1.14\ \mu A \end{aligned}$$

This is smaller than the plotted current at 51 ns which is 1.93 μA. Here we observed that 0.8 μA current flow through transistor M1 as short-circuit current.

2.1.2 Steady state

By taking the steady state of adiabatic charging at 80 ns, we calculate the current $i(t)$ as in Eq. 6. The calculated instantaneous voltage is 1.46 V, where in the simulation graph 1.70 V.

$$
\begin{aligned}
i(t) &= \frac{1.46}{\sqrt{(2.5 \times 10^7) + (6.3326 \times 10^{11})}} \quad (8) \\
&= 1.83\ \mu A
\end{aligned}
$$

From the graph, the current that flow during steady state at 80 ns is 0.4 μA.

2.1.3 Instantaneous voltage of load capacitance C

The voltage at C can be written as this

$$
V_c = \frac{1}{C}\int i dt \quad (9)
$$

From Eqs. 2 and 6, we can rewrite the equation as

$$
V_c = \frac{V_{dd}}{4C}\int \frac{\sin(\omega_o t + \theta) + \frac{3}{4}V_{dd}}{\sqrt{R^2 + (\frac{1}{\omega_o C})^2}} dt \quad (10)
$$

2.1.4 Instantaneous power dissipation p, at R

$$
\begin{aligned}
p &= Ri(t) \quad (11) \\
&= \frac{RV_{dd}}{4}\frac{\sin(\omega_o t + \theta) + \frac{3}{4}V_{dd}}{\sqrt{R^2 + (\frac{1}{\omega_o C})^2}}
\end{aligned}
$$

2.1.5 Instantaneous accumulated energy at C

$$
\begin{aligned}
i(t) &= C\frac{dv(t)}{dt} \quad (12) \\
p(t) &= \frac{dw(t)}{dt} \\
&= i(t)v(t) \quad (13) \\
&= C\frac{dv(t)}{dt}v(t) \\
\frac{dw(t)}{dt} &= C\frac{dv(t)}{dt}v(t) \\
w(t) &= \frac{1}{2}Cv(t)^2 \\
&= \frac{C}{2}\left(\frac{V_{dd}}{4}\frac{\sin(\omega_o t + \theta) + \frac{3}{4}V_{dd}}{\sqrt{R^2 + (\frac{1}{\omega_o C})^2}}\right)^2
\end{aligned}
$$