



Charge Pump Design Additional Slides

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Adjust bulk voltage to get rid of the body effect [3].

Better than Dickson CP, but V_{THN0} drop still exists.





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Non-Overlapping Clocks: State Machine

State Diagram



Truth Table								
CK	ϕ_1	ϕ_2	$\phi_1^{'}$	$\phi_{2}^{'}$				
0	0	1	0	1				
1	0	1	0	0				
1	0	0	1	0				
1	1	0	1	0				
0	1	0	0	0				
0	0	0	0	1				



Non-Overlapping Clocks: Karnaugh Ma

$\operatorname{CK}/\phi_1 \phi_2$	00	01	11	10
0	0	0	Х	0
1	1	0	Х	1

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$$\phi_1' = CK \cdot \overline{\phi_2} = \overline{CK \cdot \overline{\phi_2}}$$

$$\phi_2' = \overline{CK} \cdot \overline{\phi_1} = \overline{\overline{CK} \cdot \overline{\phi_1}}$$

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Implements logic
$$\phi'_1 = CK \cdot \overline{\phi_2}$$
 and $\phi'_2 = \overline{CK} \cdot \overline{\phi_1}$

Non-overlap time is set by the NAND's t_{pLH}







Implements logic \$\phi_1' = CK \cdot \overline{\phi_2}\$ and \$\phi_2' = \overline{CK} \cdot \overline{\phi_1}\$
Non-overlap time is set by the NAND's \$\phi_{pLH}\$





Can increase non-overlap time be inserting extra delay





■ Insert a matched delay to the inverter for perfect timing.





Another topology with larger non-overlap time.





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Regulated Charge Pump



- A sensing circuit compares the pump output to a reference and enables the clock
- A simple method is to switch the ring oscillator on and off
 - large ripples in the output







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Pump Regulation: Capacitor Divider



• Cap values C_1 and C_2 change with parasitics.

- Capacitive loading on the pump (may be insignificant w.r.t. $C_L)$
- Faster feedback control.





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- \blacksquare Use large resistors \rightarrow Large layout area
- RC delay







Pump Regulation: Resistor Divider

Resistors may load the pump output.

• Use large resistors \rightarrow Large layout area



Figure 4-20 Resistive divider feedback control.





Pump Regulation: Resistor Divider



 \blacksquare Use large resistors \rightarrow Large layout area



Figure 4-20 Resistive divider feedback control.







• Use a NAND gate in the ring, while ensuring there are odd number of inverting stages





• Use a voltage-controlled oscillator (VCO) for smoother regulation of the output[5].

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Regulation with Dynamic Buffer

• Automatically tune the buffer strength to regulate the output[5].









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