Introduction

5V regulated Charge Pumps are essential to convert a low input voltage to a high output voltage in today's portable mobile applications. For example, nowadays mobile phones or PDAs normally use 3.7V battery. This voltage is too low to power up some components of the electronic devices such as the monitor, the background light etc. The charge pump is one way to power up the voltage to these high-voltage required components.

![Diagram of a charge pump](image1)

2x Charge Pump

**2x Charge Pump Circuit Simulation Results:**

- **First Improvement**: Non-overlapping Oscillator
  - Purpose: using non-overlapping oscillator to avoid turning on both power transistor at the same time.
  - Prevents reverse current flow occurring
  - Power efficiency increases

![Simulation graph of non-overlapping circuit](image2)

- **Second Improvement**: New Approach To Reduce the Output Glitch
  - One more transistor M5 is added
  - Gate of M5 is connected to the input of the buffer

![Diagram of new approach](image3)

1.5x Charge Pump

**Why using 1.5x Charge pump for vin = 3.3 to 4.5V:**

- The efficiency of 1.5x Charge Pump = 5 / 1.5 * 4.5 = 70%
- The efficiency of 2x Charge Pump = 5 / 2 * 4.5 = 50% at Vin = 3.5V
- The efficiency of 1.5x Charge Pump = 5 / 1.5 * 4.5 = 70%
- The efficiency of 2x Charge Pump = 5 / 2 * 4.5 = 50% at Vin = 4.5V

**Topologies:**

- **Phase One:**
  - As phase one, two flying capacitors are charged in series. That means that $\phi_1$ switches are turned on and $\phi_2$ switches are turned off.

- **Phase Two:**
  - As second stage, two flying capacitors are discharged in parallel. This time, $\phi_1$ switches are turned off and $\phi_2$ switches are turned on.

![Diagram of topology](image4)

**Simulation Result:**

- **Output voltage (about 5.1V) when Vin = 3.5V**
  - Power efficiency of 1.5x charge pump

![Graph of output voltage and power efficiency](image5)

**Key Specifications:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Input Voltage</td>
<td>$V_in$</td>
<td>2.7</td>
<td>4.5</td>
<td></td>
<td>V</td>
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<tr>
<td>Load Current</td>
<td>$I_{load}$</td>
<td>0.5</td>
<td></td>
<td></td>
<td>mA</td>
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<tr>
<td>Efficiency</td>
<td>$\eta$</td>
<td>50</td>
<td></td>
<td>60</td>
<td>%</td>
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<tr>
<td>Switching Frequency</td>
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<td>3.5</td>
<td>5kHz</td>
<td>MHz</td>
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<tr>
<td>Dropout Voltage</td>
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<td>80</td>
<td>mV</td>
</tr>
<tr>
<td>Dropout Ripple</td>
<td>$R_{drop}$</td>
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<td>mV</td>
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</table>

![Table of specifications](image6)