

1. DC-DC Fundamentals

XIANG FANG: Hello. Welcome to the DC-DC Fundamentalists. I'm Xiang. In this section, we will talk about the charge pump regulator.

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2. What is a Charge Pump Regulator?

What is a charge pump regulator? It is a kind of switching regulator that delivers the power by only charging and discharging capacitors. It's suitable for application that has low currents and has moderate input to output voltage difference.

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3. Pros and Cons

The advantage of using charge pump regulator is that it has no inductor in the regulator. You can achieve smaller size. The efficiency is moderate, but it's higher than the linear regulator. And the V_{out} can be higher or lower than your V_{in} . And fewer components are needed, so it makes it easy to decide and use. The disadvantage is that the switching can produce high output ripples and noise. And the output current capacity is limited by the capacitor.

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4. How Does a Charge Pump Work?

How does a charge pump work? The capacitor connection is altered by the switches so that the charge and discharge are controlled. As you can see on this simplified graph here, the switch S_1 to S_4 are switching. When S_1 and S_3 are on, S_2 and S_4 are off. The capacitor is charging by the input voltage source. And when the switch one, S_1 , S_3 is off, then the ends S_2 and S_4 will switch on. And the charge capacitor--you can discharge to the output load. And it's also interesting to know by reversing the connection of the output and ground, you can get from a unity gain converter to a negative gain inverter.

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5. Voltage Doubler

On this page, we show a popular configuration of the charge pump regulator. It's called a voltage doubler. As you can see, it's very similar to the unity gain charge pump regulator. And actually, it requires four switches. And these four switches are switching similar. It's switching the same as the unity gain regulator. But instead of connecting your V_{out} ground to the ground, your V_{out} is actually on top of your V_{in} . So in this case, your V_{out} is actually your V_{in} plus the capacitor's voltage. So that will give you two times V_{in} output. So that's why it's called the voltage doubler.

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6. More Gain Combinations

And for the previous two slides, we only show using one capacitor in this regulator. So if you have two capacitors in the charge pump regulator, that actually gives you more combination of the gain configurations. And the following figures show some typical configuration of two capacitor's connections. And a different gain can be achieved.

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7. Charge Pump Regulation

Charge pump regulations. By including a post regulator stage, the charge pump can achieve fine granular of the output voltage. Also the switch impedance can be controlled to act effectively as a post regulator. As you can see, instead of using switch S1 and S3, it's actually replaced by a linear regulator type of transistor. And the R_{out} is the effective output impedance, including the switch impedance off switch and the switch cap impedance, which is determined by the frequency of your switch and the capacity of the CFCAP. And fine adjustment can be accomplished by controlling the switching frequency and the switch impedance.

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8. Charge Pump Regulation

And there are two types of charge pump regulations. One, is by controlling the frequency. We call it pulse-frequency modulation. As you can see here, the output voltage is how constant by skipping the unneeded pulse. And an advantage of using the PFM is that it has very low quiescent currents. And you can achieve high efficiency, especially at low condition. But the disadvantage is that it has high output voltage ripple. And your frequency varies. And the other type--we call it constant frequency regulation. It's achieved by controlling the resistance of the switch. In this type of regulation, the advantage is that you can achieve low voltage ripple. And the switching frequency is relatively fixed. But the disadvantage is it has a high quiescent current. So the efficiency is lower.

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9. Summary

In summary, in this section, we introduced the charge pump regulator, and operation, and regulation, of this type of DC-DC converter.

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10. Thank you!

Thank you.

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