

## 1. DC-DC Fundamentals

XIANG FANG: Hello, everyone. Welcome to the DC-DC Fundamentals. I'm Xiang. In this section, we'll talk about a switching regulator.

...

## 2. What is a Switching Regulator?

So what is a switching regulator? It is a DC-DC converter that delivers power by using switcher components. As you can see in this graph, it usually contains a switcher network and an L-C component tank. It can offer high power conversion efficiency and design flexibilities.

...

## 3. Pros and Cons

The advantage of using switching regulators is you can offer high efficiency and have good thermal performance. And it has high power density to allow wide input voltage range. And the  $V_{out}$  can be smaller or be larger than  $V_{in}$ . And it has the option to provide isolation. And it also can create multiple outputs by using transformer. The disadvantage of using a switching regulator is that the switching actually creates high output ripples and noise. The transient response is relatively slow. And it has high complexity as more external components are used. And there are many more design variables to consider.

...

## 4. How Does a Switching Regulator Work?

So how does a switching regulator work? As you can see, the inductors store and release energy to output load. And it gets the energy from the input source. And the switching is controlled by the controller. As an example, we show a Buck converter here in the bottom graph. When the switcher is in position one, the inductor is actually storing energy. And when the switch is switched to position two, the inductor is releasing the energy to the output. And the average voltage over an inductor is actually zero. So by doing some equation derivation, we can get that  $V_{out}$  is actually equal to the  $D$  times  $V_{in}$ , which the  $D$  is the duty cycle. It's the percent on time divided by the total switching time. Since  $D$  is smaller than 1, that means in the Buck converter, your  $V_{out}$  is always smaller than your  $V_{in}$ .

...

## 5. Basic Topologies

And in these slides, we show three basic topologies of the switching DC-DC converters. There are Buck converters, Boost converters, and Buck-Boost converters. For the Buck converter, you can only step down the voltage from  $V_{in}$ . For the Boost converter, the  $V_{out}$  can be higher than your  $V_{in}$ . And for the Buck-Boost, your  $V_{out}$  can be either higher or lower than your  $V_{in}$ , depends how you configure your duty cycle.

...

## 6. Synchronous vs. Non-Synchronous

So when we talk about the switching converters, there are usually people talking about synchronous switching converters and non-synchronous. So what's the difference of these two types of switching regulators? For a non-sync regulator, usually one of the switches are diode, as you can see on the graph here. The bottom switch is replaced by a diode. The diode voltage job is fairly constant with the output current. So it's less efficient. But using the diode, it's less expensive. And it's easier to control. On the bottom graph, there's a synchronous Buck converter. As you can see, the bottom switch is using a MOSFET switch, rather than a diode. So the MOSFET has lower voltage drop than a diode. So it's more efficient. But it requires additional control to control these two switches. So it costs more. And it's more complex to configure.

...

## 7. Isolated vs. Non-isolated

And there's isolated and non-isolated switching regulators. The isolated switching regulator has no DC current flowing between the input and the output. It's achieved by using transformer. The transformer couples energy from the primary to secondary through the magnetic field. The isolated typically is used in medical and offline applications, which requires safety requirements. But it's not typical for this type of isolation to be used in the standard point of low solution. As you can see in these typical graph here, the transformer to couple the energy from the input to the output and the feedback signals is going through this output coupler. So there's no direct connection between the output and input.

...

## 8. Controller vs. Regulator

Also, there's controller type and regulator type of switching regulator. For controller type, it usually uses discrete MOSFETs. That means the MOSFET is external. So the controller is only providing the brain to control the power stage. It's more complicated to design. But you have more flexibility. You can choose which FET to use, depends on your needs. And for the regulator, it usually indicates that the switching FETs is integrated in the power IC. There's fully integrated regulator--that means your outside FET and the bottom FET are both integrated. So it's easier because both FETs that are inside, you don't need to worry about the selection. But it has a limited range of the filter components since the FETs are set. And it's limited control of the functionality. Also there's partially integrated regulator, like in the non-synchronized Buck converter, you can have diode outside, but you can integrate the outside FETs inside your regulator. And it's similar to the fully integrated regulator.

...

## 9. Summary

So in summary, in this section, we gave you an introduction of the switching regulator. We talked about operation and some basic concepts of the switching regulators.

...

10. Thank you!

Thank you.

...