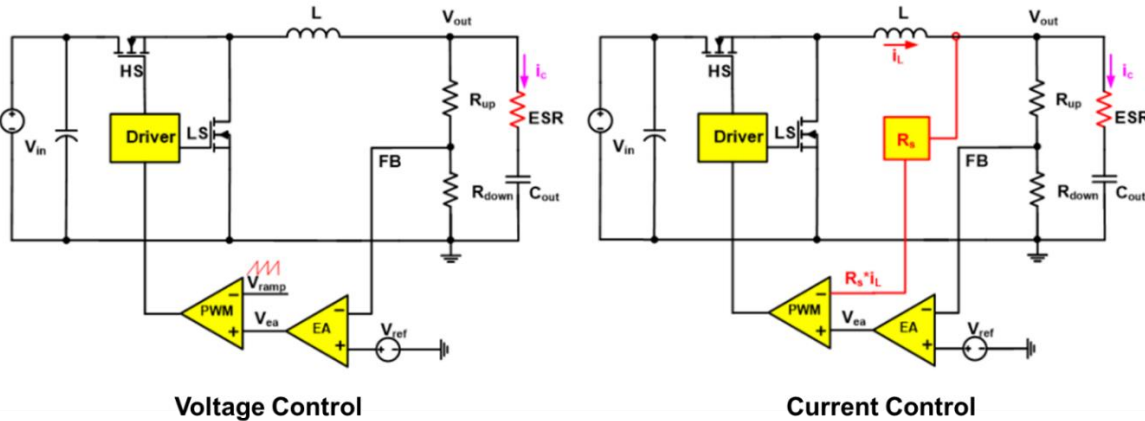


To obtain a lower dynamic ripple, engineers often have to balance tradeoffs between the bandwidth and stability of a system's power supply, whether they're looking at a wireless PA system or the core of a CPU.

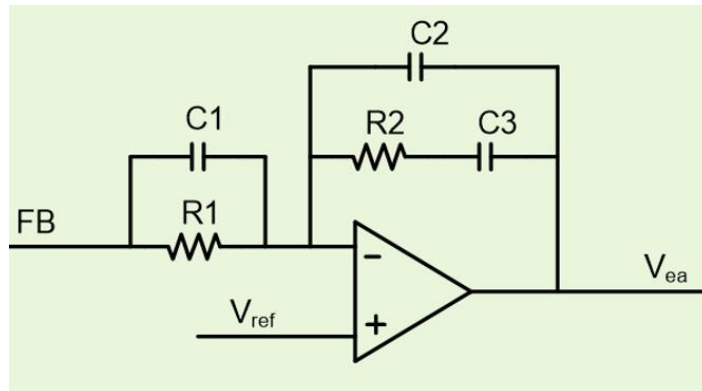
Constant-on-time (COT) control is gaining traction in the power management industry, and is widely used in the computing field for the core IC's power supply. As artificial intelligence becomes more popular, the use of COT will become even more extensive.

Before introducing COT control, let's look at the two other control methods: voltage control and current control (see Figure 1). These methods were commonly used before COT control became more popular.



**Figure 1: Voltage and Current Control**

An error amplifier (EA) is a component used in both voltage and current control. Figure 2 shows an example of an EA schematic.



**Figure 2: Error Amplifier Schematic**

Figure 2 shows how EAs operate within a resistor-capacitor (RC) compensation network. For a steady circuit, each parameter (C1, R1, C2, R2, and C3) has to be individually designed, which can be tedious and time-consuming. In addition to the stability issues described above, there are often transient response problems as well.

If the output voltage changes, the RC network of the error amplifier delays the change in the output voltage, and then reacts to the control circuit, which reduces the response speed. Even if the control circuit receives feedback on changes in the output voltage, it does not respond immediately. Instead, it responds at a set clock frequency, which exacerbates the slow transient response (see Figure 3).

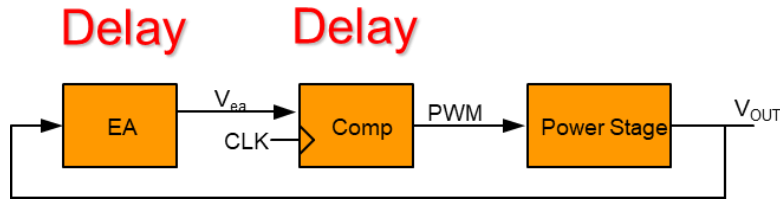


Figure 3: EA Operation in a Compensation Network

To improve the transient performance, it may be necessary to redesign the parameters of the error amplifier and RC network (C1, R1, C2, R2, and C3). This means the engineer has to determine how to balance stability and transient response.

To navigate these issues, the error amplifier can be replaced with a comparator to eliminate the need for compensation, which also eliminates the RC delay. At the same time, the clock can be replaced with a clock-controlled PWM generator that has a voltage-controlled on-time generator, which then eliminates the clock delay (see Figure 4). This solution provides constant-on-time (COT) control.

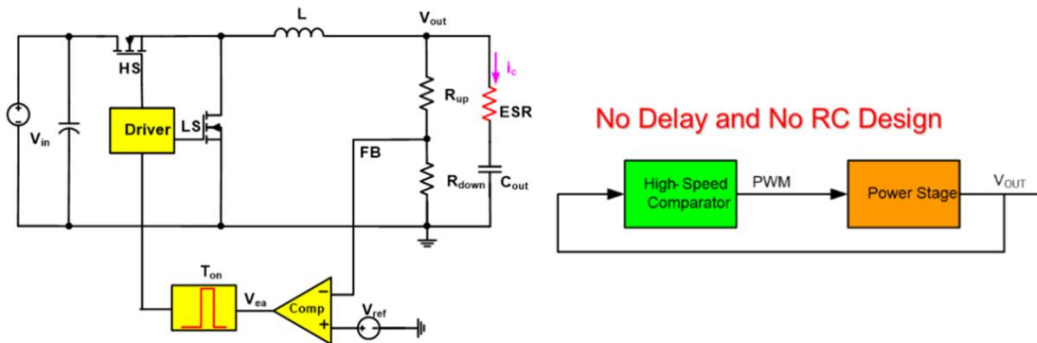


Figure 4: Constant-On-Time Control

Figure 4 shows the most basic example of constant-on-time (COT) control. The basic principle is that the FB voltage is below the reference voltage ( $V_{REF}$ ), which produces a COT pulse to control the opening of the upper tube MOSFET (see Figure 5).

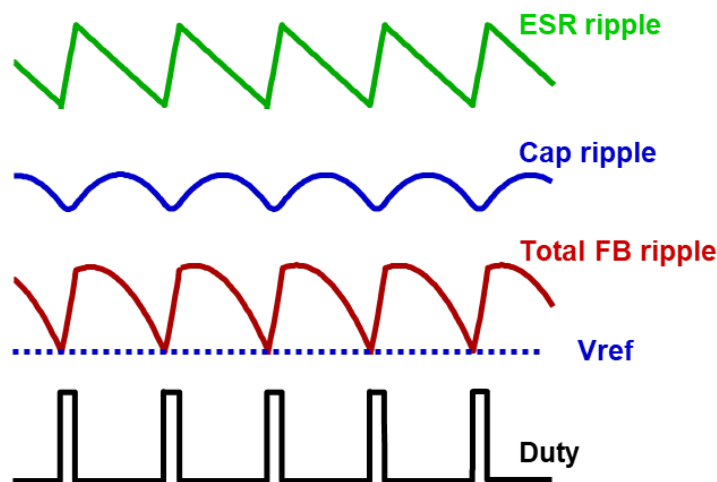


Figure 5: Parameters with Constant-On-Time Control

However, if the input voltage is different at each COT pulse, this can change the switching frequency. To solve this problem, constant-on-time control detects the input voltage and achieves a constant switching frequency when the input voltage changes. Similarly, COT control detects a constant switching frequency when the output voltage achieves different output voltages. Figure 6 shows a commonly used COT control schematic.

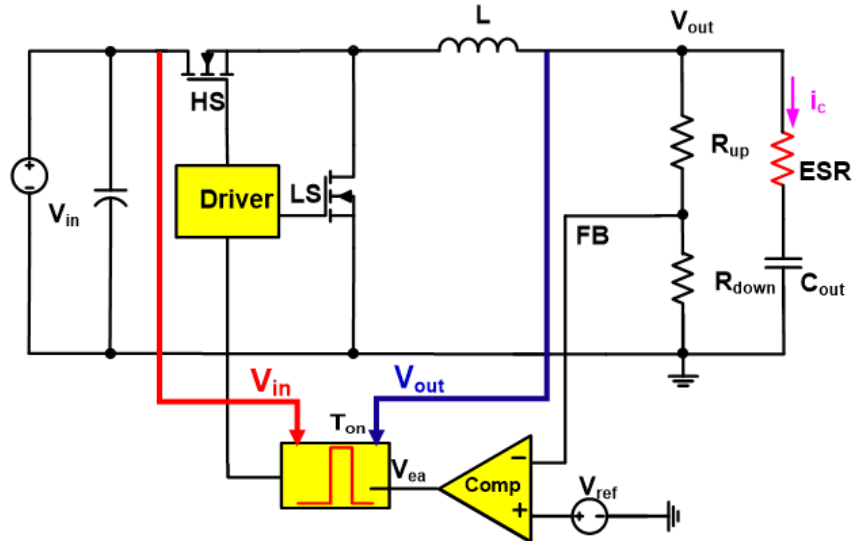


Figure 6: Common COT Control Schematic

However, instability can be experienced if COT control is utilized while the output uses porcelain capacitors (MLCC) (see Figure 7).

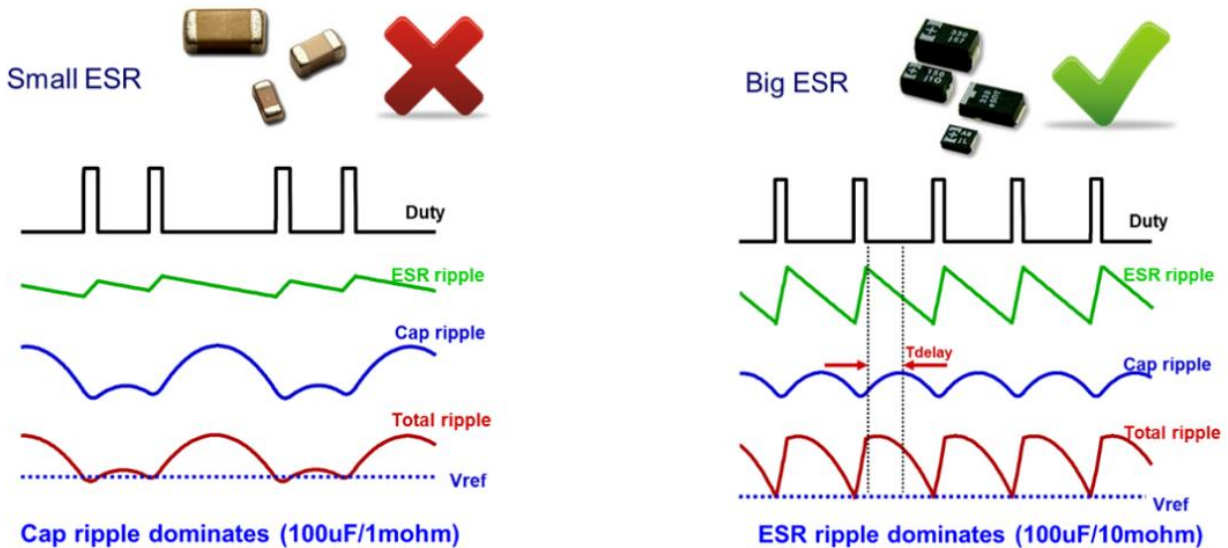


Figure 7: Instability Caused by MLCC

This instability occurs because COT control requires the FB voltage to have a phase-to-phase ripple with the inductor current. Because the equivalent series resistance (ESR) is relatively large with polymer or electrolytic capacitors, this phase ripple is present and the system maintains stability. However, porcelain capacitors do not have sufficient ESR to guarantee that the ripple voltage and inductive current on FB are the same phase.

MPS has solved this problem by adding an RC compensation circuit on FB to produce a ripple that is same phase as the inductor (see Figure 8).

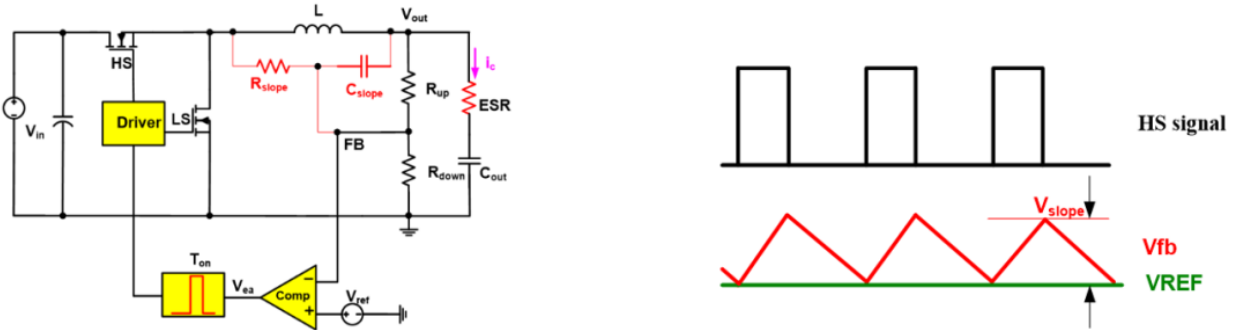


Figure 8: Using an RC Compensation Network with COT Control

The addition of an RC compensation circuit provides the porcelain plate capacitor with a stable output. The [NB638](#) chip uses this solution to maintain stability (see Figure 9). The [NB679](#) is a similar device with a porcelain capacitor, but without an RC compensation circuit. Instead, the NB679 internally produces additional ramp compensation on the FB voltage.

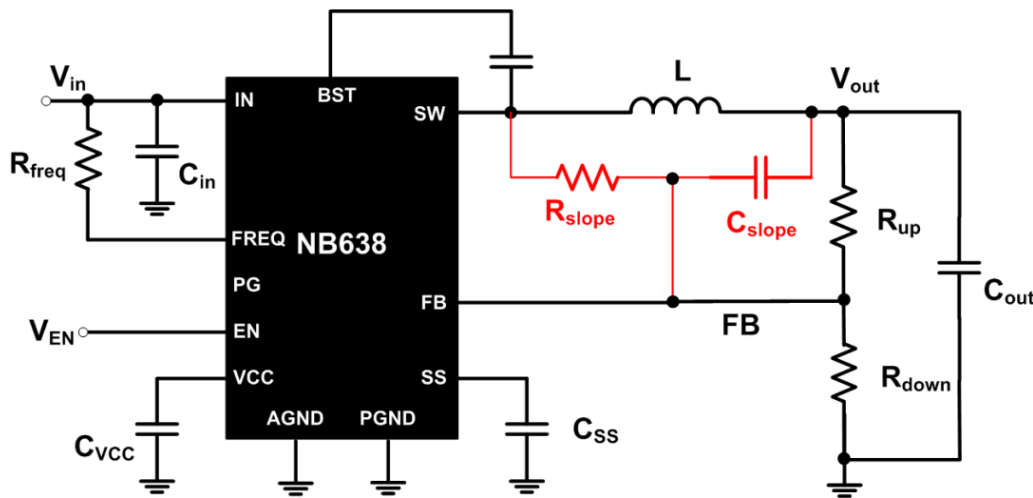


Figure 9: The NB638

In addition to the instability of porcelain capacitors, engineers who use COT control can encounter another problem with the output voltage adjustment rate (see Figure 10). Because the device uses COT control mode, we know that the actual output voltage caused by the FB voltage ripple exceeds the target output capacitance set by  $V_{REF}$ . Since different ripple voltages lead to different output voltages, there can be a problem with the adjustment rate (see Figure 10).

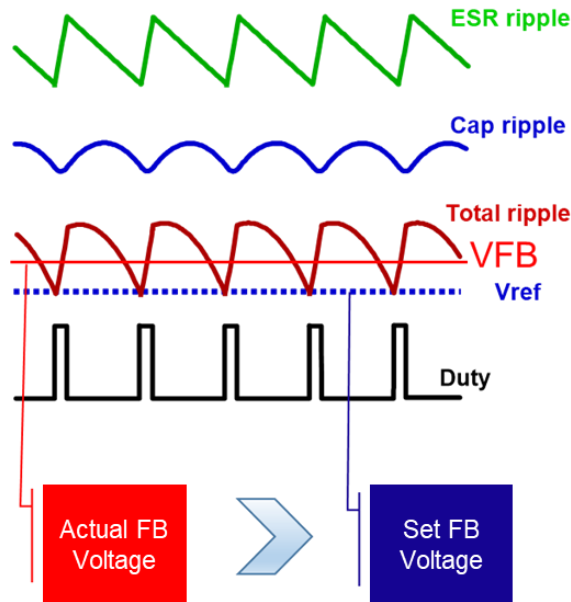


Figure 10

To address this problem, COT control can also introduce a slow EA. This slow EA eliminates the problem caused by the high output voltage due to the FB ripple, which ensures that the actual output voltage and set voltage remain consistent (see Figure 11).

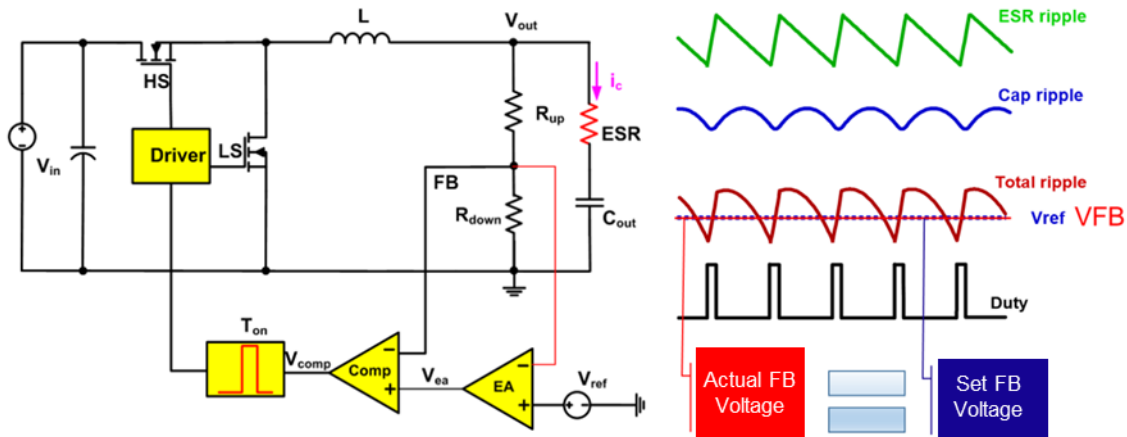


Figure 11: Constant Output and Set Voltage

Another benefit to a slow EA is that it does not affect the rapidly changing transient response.

Due to its fast transient response and simple loop compensation, COT control is ideal for power supplies that provide core power. Over time, this core is expected to process more and more data, resulting in more and more required current. The corresponding COT control has gradually been developed from single-phase control, to single-phase multi-way parallel control, to multi-phase multi-loop control.

MPS’s digital COT control can not only achieve multi-phase, multi-loop control, but also can support phase number configuration, automatic loop compensation, and other benefits that greatly simplify the design and improve product design efficiency. One example is the [MP2888A](#), which received the 2018 Global Electronic Achievement Award. For more information on MPS COT control solutions, [browse our products](#).