### Designing Constant-On-Time Buck Regulators for Low Drop-Out Voltage

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Constant-On-Time (COT) regulators provide a simple, costeffective way of implementing a step down buck regulator with nearly fixed frequency. Constant-On-Time regulators do not require loop compensation and provide excellent transient performance with minimum design effort and part count. In a COT buck regulator, the high side switch is controlled by a 'T<sub>ON</sub>' timer. Once the timer expires, the high side switch turns off and does not turn back on again until the voltage at the feedback node falls below the reference voltage. To avoid spurious turn-on caused by switching noise and to allow the bootstrap capacitor to charge, there is a minimum built-in 'OFF' time ( $T_{OFF}(min) = 347$ ns max) in LM5006. This minimum  $T_{OFF}$  restricts the maximum duty cycle of the converter for a given switching frequency. This effect is more pronounced at higher switching frequencies as shown in *Figure 2* for the circuit of *Figure 1*. The output voltage ( $V_{OUT}$ ) drops below 10V for input voltage ( $V_{IN}$ ) smaller than about 14.0V.







FIGURE 2. LM5006, V<sub>IN</sub> vs V<sub>OUT</sub> (Low V<sub>IN</sub> Range Extended for Zener Circuit)

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In some applications it may be desirable to minimize the dropout voltage in low input voltage condition. One way to minimize the drop out voltage is to reduce the switching frequency. But low frequency operation at high and nominal  $V_{\rm IN}$  does not allow the designer to choose smaller filter components. It is, therefore, desirable to keep higher switching frequency for high and nominal  $V_{\rm IN}$  range and reduce it only at low  $V_{\rm IN}$  to reduce the drop-out voltage. This can be done by modifying adding external components to  $R_{\rm T}$  pin as shown in *Figure 3*. The parts shown in blue are added to create nonlinear  $R_{\rm T}$  resistor. The zener and series resistors are selected so that the NFET turns on at a  $V_{\rm IN}$  slightly above 14V where

the converter of *Figure 1* dropped out of regulation. For V<sub>IN</sub> > 14V, the external NFET is 'on' and the effective R<sub>T</sub> is 90kΩ, the same as in *Figure 1*. For V<sub>IN</sub> <14V, the external NFET is 'off' and the effective R<sub>T</sub> is 360kΩ. For this higher R<sub>T</sub>, the 'T<sub>ON</sub>' of the converter increases resulting in higher duty cycles. As shown in *Figure 2* (red curve), the input voltage range of converter is extended down to V<sub>IN</sub>=12V for a well regulated output. A low leakage FET (such as BSP123) should be selected to emulate an ideal switch effect. The designer should select the zener and resistor dividers so that the maximum ratings of the components are not exceeded. As always the design should be verified over the input voltage range.





## Notes

# Notes

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