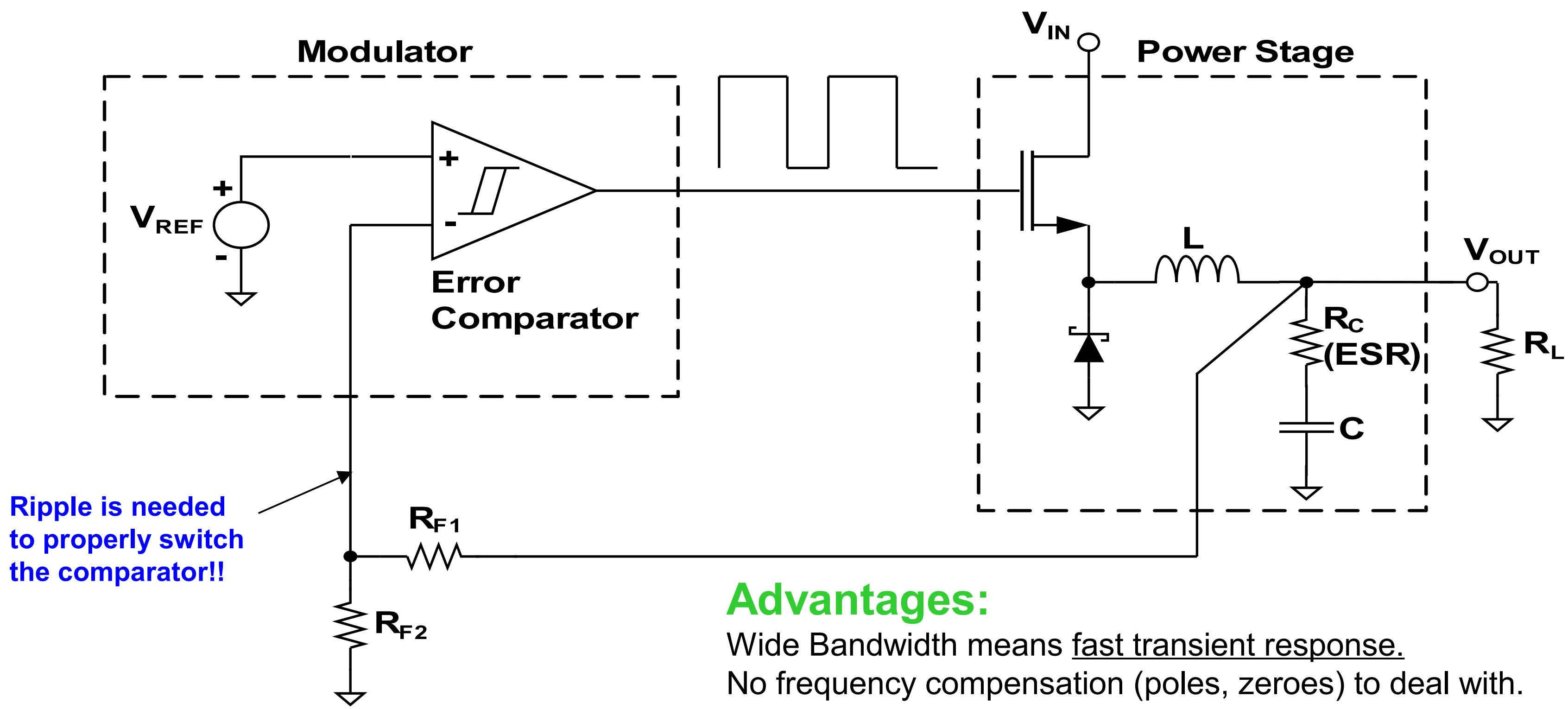
Hysteretic Buck Regulators



Advantages:

Wide Bandwidth means <u>fast transient response.</u>
No frequency compensation (poles, zeroes) to deal with.
VIN feedforward is inherent.

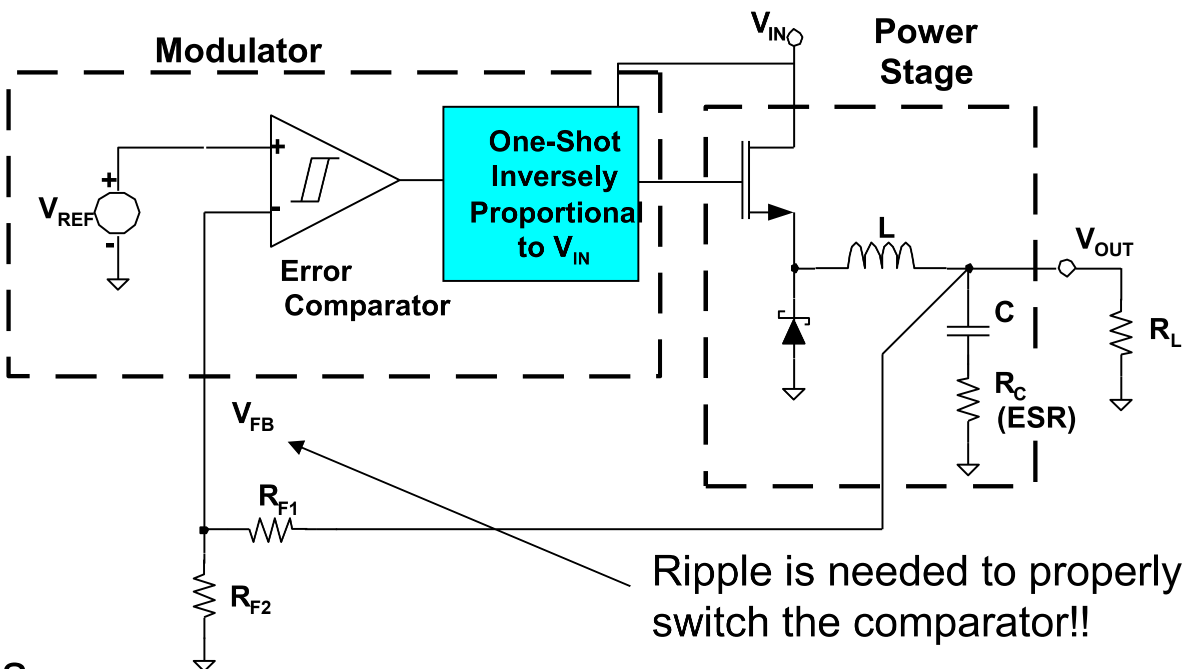
Disadvantages:

t_{ON} and t_{OFF} , and therefore the frequency, are functions of:
V_{IN}, V_{OUT}, I_L, L, ESR, ESL, V_{HYS}*$(R_{F1}+R_{F2})/R_{F2}$, and t_d

→ Frequency is difficult to control!!

Constant On-Time (COT) Hysteretic Regulator

ON-time is constant, for a given V_{IN}, as load current varies.

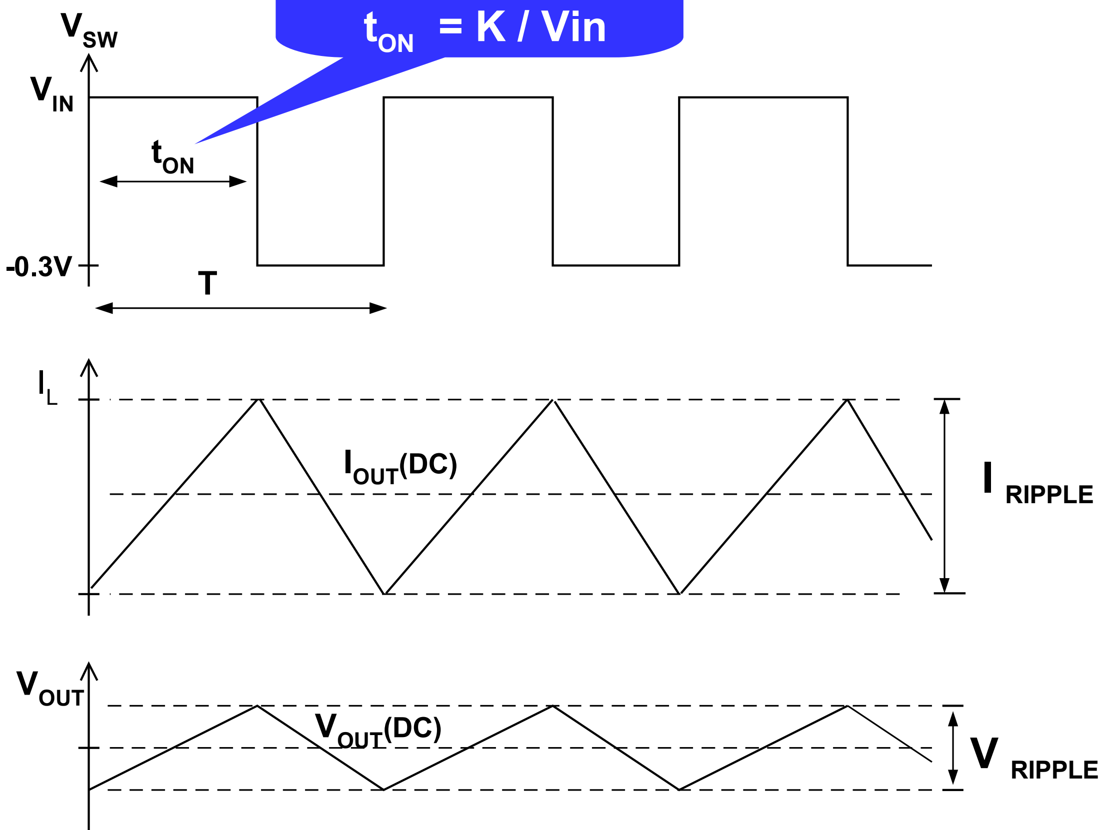


- Advantages
  1. Constant frequency vs V_{IN}
  2. High Efficiency at light load
  3. Fast transient response

- Disadvantages
  1. Requires ripple at feedback comparator
  2. Sensitive to output noise, because it translates to feedback ripple

COT regulation with V_{IN} Feedforward

Switch On-time
t_{ON} = K / Vin



Frequency is constant for constant V_{OUT}

Definition of Duty Cycle:

$$D = \frac{t_{ON}}{T} = t_{ON} \cdot f_{SW} \qquad \text{EQ1}$$

For Buck Regulator:

$$D = \frac{V_{OUT}}{V_{IN}} \qquad \text{EQ2}$$

Setting EQ1 = EQ2:

$$t_{ON} \cdot f_{SW} = \frac{V_{OUT}}{V_{IN}} \qquad \text{EQ3}$$

For COT with Feed-forward:

$$t_{ON} = \frac{K \bullet R_{ON}}{V_{IN}} \qquad \text{EQ4}$$

K is a constant = 1.3x10 $^{-10}$

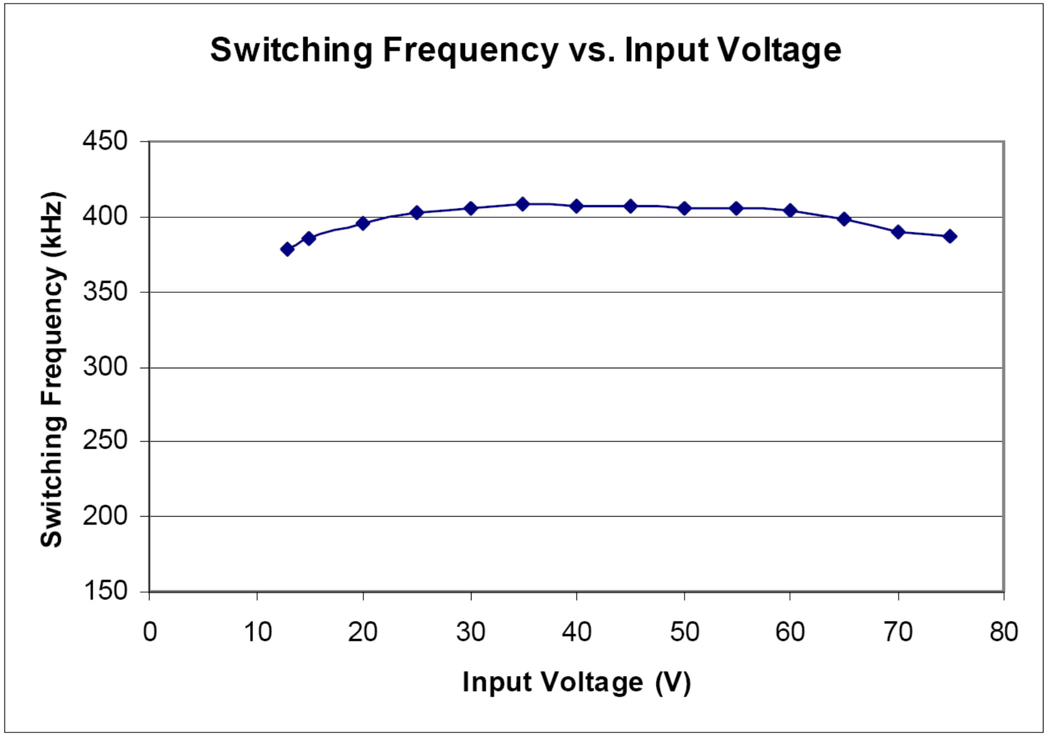
Insert EQ4 in EQ3:

$$\frac{K \bullet R_{ON}}{V_{IN}} \cdot f_{SW} = \frac{V_{OUT}}{V_{IN}}$$

Solve for f_{SW}:

$$f_{SW} = \frac{V_{OUT}}{K \bullet R_{ON}}$$

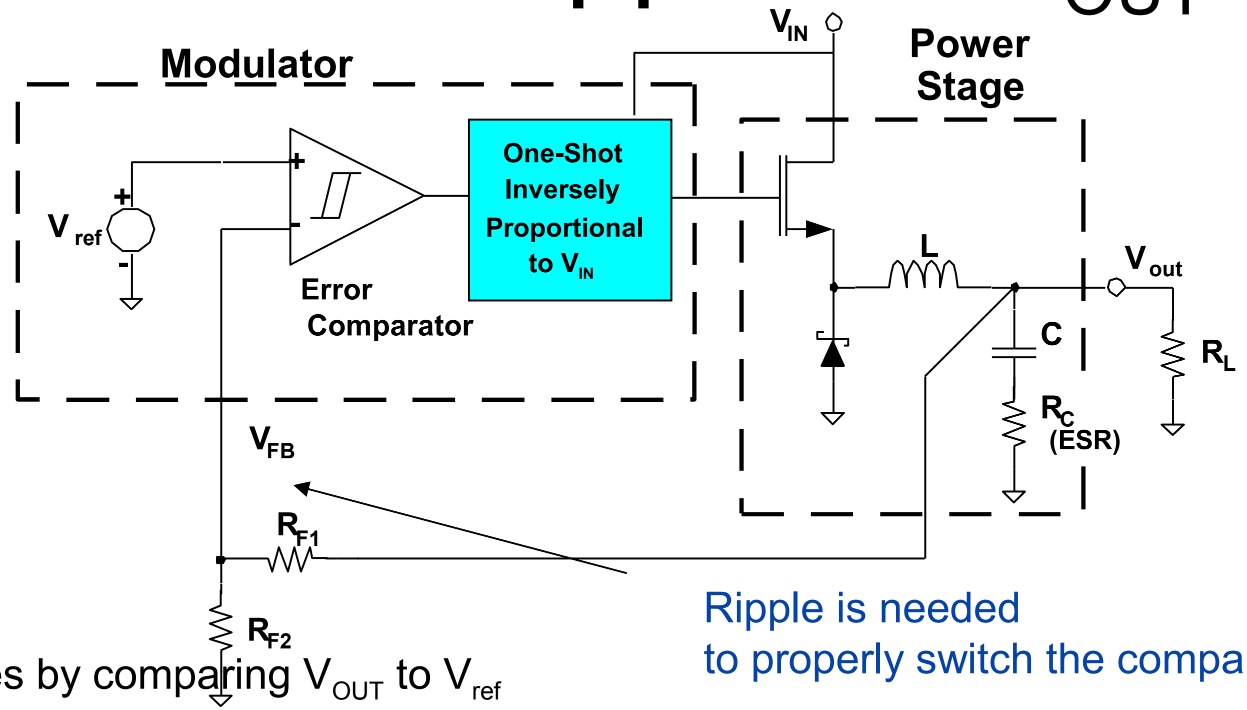
Constant ON-Time Achieves Nearly Constant Frequency



Switching frequency is almost constant; the variations are due to effects of $R_{DS\text{-}ON}$, diode voltage and input impedance of the R_{on} pin

Note: A resistor from V_{IN} to R_{on} sets the ON-time

COT needs ESR for Sufficient Ripple on V_{OUT}



Ripple is needed
to properly switch the comparator!!

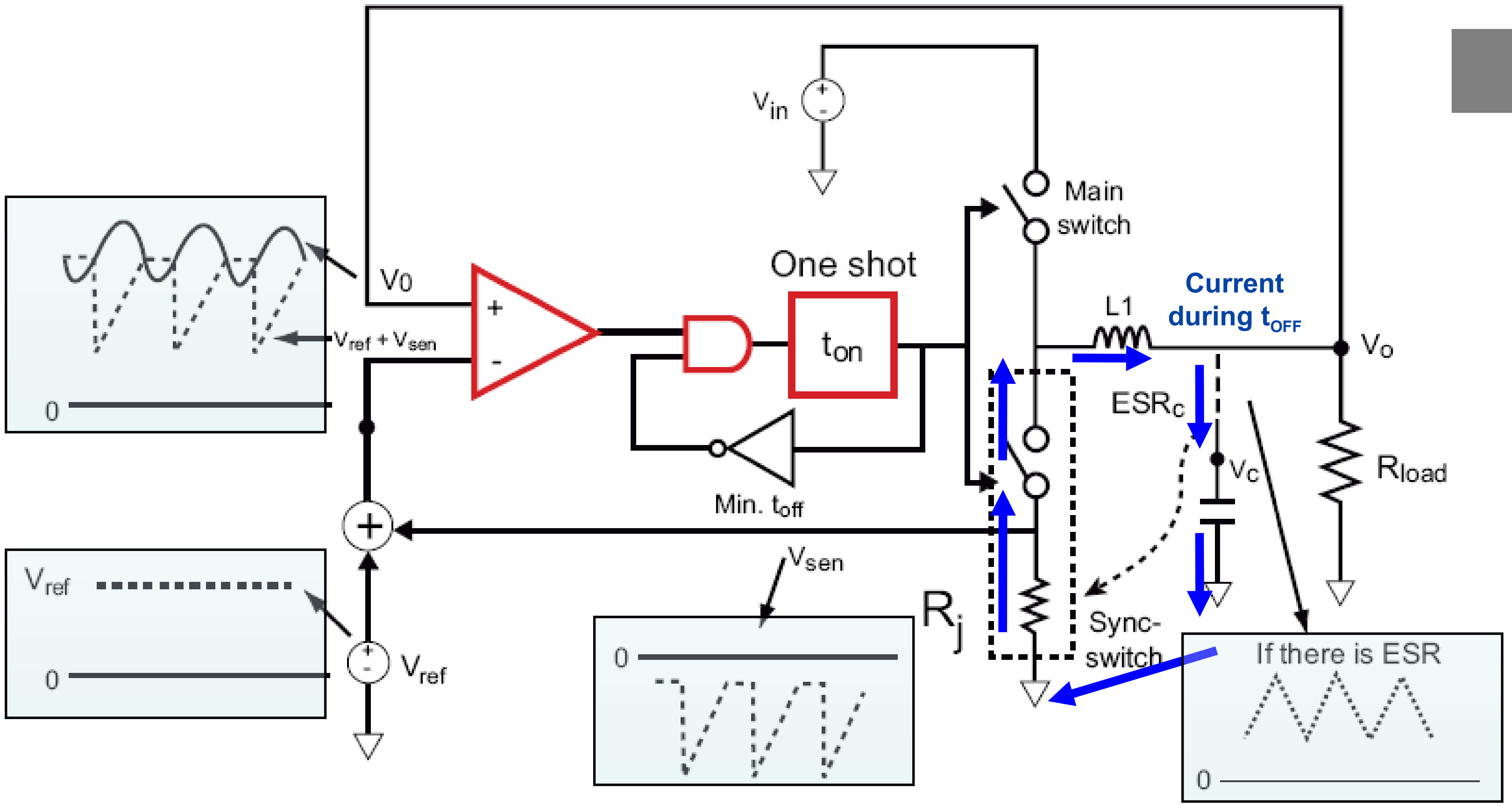
- COT regulates by comparing V_{OUT} to V_{ref}
- V_{OUT} ripple must be large enough to overcome the comparator hysteresis
- ESR of output capacitor is directly proportional to V_{OUT} ripple
- ESR must be large enough to create sufficient V_{OUT} ripple to properly switch the comparator

New Emulated Ripple Mode (ERM) Constant-On-Time

New patented ERM technology allows COT regulators to:

- Eliminate the need for large output ripple
- Eliminate the need for high ESR output capacitor
- Allows the use of smaller, less expensive ceramic capacitors

How does it work?



- ESR current can be sensed through Rj (R_{DS_ON} of the Low Side Mosfet)
- The inverted V_{SEN} is the replication of V_{ESR} ripple during t_{OFF}
- This is added to the DC reference voltage V_{ref} before comparing to V_{OUT}
- No ESR is required on the output capacitor

New ERM Constant-On-Time Allows Use of Ceramic Capacitors

Benefits of Ceramic Capacitors:

Clean Output Voltage

- Low Output Ripple
- comparable to voltage-mode and current-mode control schemes

Low profile and small size

- Can reduce required output ESR ~ 1/3
- Save PCB area

Not sensitive to Transient Voltage Stress

- Higher reliability

No polarity – ease for production

Summary of Advantages of Constant On Time with ERM

- No loop compensation needed
  - Low external component count
  - Excellent transient response
    - Lower cost
    - Easy to use
    - Reliable
- Operates in fixed frequency mode
  - External discrete component values don’t affect frequency
    - Reliable/Robust Operation
    - Makes design easier
- Emulated Ripple Mode (ERM) Circuitry
  - **Allows the use of low ESR output capacitors without additional ESR compensation**
    - Lower output ripple
    - Smaller size (ceramic caps)
    - Lower cost