Logbook → Remote lab — Buck converter

2022/6/14

LTSpice runs the circuit

V_{out} =	3.769	3.792	3.805
R_L —	3	4	5

Different from pdf → 6V around output

⇒ Frequency different

LTC 7800 determine the switching frequency

Pin, FREQ → R_{freq} = 100k ⇒ Freq typical = 2.1 MHz

☆ But Week 1 pdf simulation graph — R_{freq} = 33k ⇒ 500kHz

(Page. 22 datasheet)

frequency? can change $\frac{V_{out}}{V_{in}}$ ratio?

Normally V_{out}/V_{in} = Duty → what determine duty cycle in LTC 7800?

continuous mode

dis-continus mode

$$V_{out} = V_{in} \times \frac{2}{1+\sqrt{1+\frac{4k}{D^2}}} \quad \text{where } k = \frac{2L}{R_L T_s}$$

X can't happen

TLC 7800 → Typical on-time 45ns (minimum on-time

m μ n p

10^{-9}

22.22 MHz

As the peak sense voltage decrease ↓

the minimum on-time graduelly increase up to 70ns

Forced Continuous Application

$$T_{on(min)} < \frac{V_{out}}{V_{IN}(f)}$$

Page 24 of LTC 7800 datasheet:

Design example V_{in} = 12V (normal) V_{IN} = 22 V (max)

V_{out} = 3.3V I_{max} = 5A $V_{sense-max}$ = 75mV

f = 1MHz → 55kΩ to FREQ — GND

Inductance value → ripple current 30%

Highest value of ripple current occurs at V_{in-max}

$$\Delta I_L = \frac{V_{out}}{(f)(L)} \times \left(1 - \frac{V_{out}}{V_{in(nom)}}\right)$$

Inductor ripple current

$$1 - \frac{3.3}{12} = 0.725$$

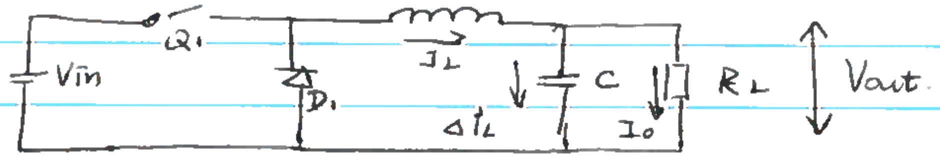
$$V_L = L \times \frac{di_L}{dt} \Rightarrow \Delta I_L = \frac{V_L}{L} \times \Delta T$$

$$\underset{\text{current ripple}}{\Delta I_L} = \frac{(V_{in} - \cancel{\quad} - \cancel{\quad}) - V_o}{L} \times T_{on}$$

$$= \frac{V_{in} - \cancel{\quad} - V_o}{L} \times T_{on}$$

$$T_{on} \downarrow \frac{1}{f} \times D$$

Typical Buck Converter



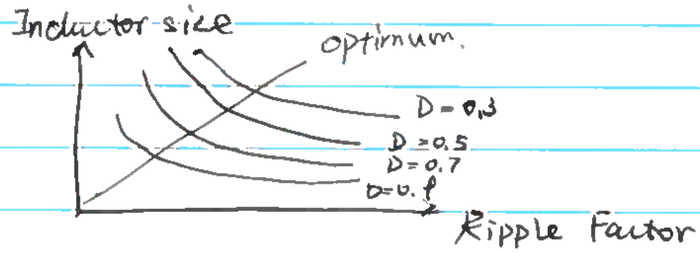
$\delta i_L = i_L(T_{on}) - i_L(0)$ ripple factor: $\frac{\Delta i_L}{I_o} < 2$

$I_o = \frac{i_L(T_{on}) + i_L(0)}{2}$ continuous mode.

$$\Delta i_L = \frac{V_{in} - V_o}{L} \times D \cdot T_s$$

$$\text{ripple factor} = \frac{\Delta i_L}{I_o} = \frac{(V_{in} - V_o) \cdot D \cdot T_s}{L I_o}$$

$$= \frac{V_{in}(1-D) \cdot D \cdot T_s}{L I_o}$$



High ripple factor — Low Inductor

Low ripple factor — Large Inductor.

For D = 0.1, ripple factor (good) = 0.33 ~ 0.66

D = 0.3 0.28 ~ 0.56

D = 0.5 0.25 ~ 0.48

D = 0.7 0.2 ~ 0.4

$\Downarrow$

30% ripple design

$$0.3 = \frac{V_{in}(1-D) D \cdot T_s}{L I_o}$$

? V

$$\frac{V_{out}}{V_{in}} = D$$

$$\text{Ripple factor} = \frac{\Delta i_L}{I_o} = \frac{V_{out} \times (1-D) \cdot \frac{1}{f}}{L}$$

$$\Delta i_L = \frac{V_{out}}{f \times L} \times \left(1 - \frac{V_{out}}{V_{in}}\right)$$ ☆ make sense

⇒ Inductor chosen First principle: 30% ripple current

1.5 μH inductor — 32% ripple current

$$\text{Ripple factor} = \frac{V_{out}}{f \times L}\left(1 - \frac{V_{out}}{V_{in}}\right) \times \frac{1}{I_o}\ ?$$

$$I_{L\text{-}peak} = I_{DC\text{-}max} + \frac{1}{2}\Delta i_L = 5A + \frac{1}{2} \times 5 \times 32\%$$

$$= 5 + 2.5 \times 0.32$$

$$= 5.8A$$

m · μ n . p

$$T_{on\,(min)} = \frac{V_{out}}{V_{in\text{-}max}} \times \frac{1}{f} = \frac{3.3V}{22V\ (V_{in\_max})} \times \frac{1}{1\,MHz} = 1.5 \times 10^{-7} = 150\,ns$$

(D)

Solved: Duty cycle $D = \frac{V_{out}}{V_{in}}$ (modify Vout or Vin → get Duty get Ton)

Always operate in continuous mode

Vout is set by V_{FB}: $V_{out} = 0.8 \times \left(1 + \frac{R_B}{R_A}\right)$ V

What is Isense & Vsense? How does them related to Duty cycle?

I_{LIM} – foldback Current Limit

Sense− / sense+ } inputs to the differential current comparator

when > INTVcc − 0.5V Sense− supply power to the current comparator

→ normally connect to DCR sensing network

current sensing resistor

ITH pin voltage → offset of sense− & sense+ with Rsense

set the current trip threshold.

I_{LIM} = { SGND / FLOAT / INTVcc } sets the max current sense threshold to three different levels for the comparator

☆ Forced Continuous Mode (Burst mode, Phase Skipping)

PLLIN/MODE Pin connected to SGND ⇒ Burst Mode Operation

→ INTVcc ⇒ Continuous operation

INTVcc −1.3V > DC voltage > 1.2V ⇒ Pulse Skipping

LC Mode (Need to do actions further)