2022/06/21

Duty cycle, Inductor current ripple & Capacitor ripple measurement.

Q1 Relation between Vin, Vout, duty cycle — In Continuous Mode.

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

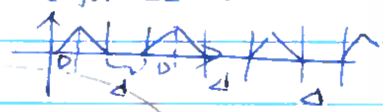
↑ discover from signal

$D > \frac{V_{in}}{V_{out}}$ but Linearly related.

loss contained.

Discontinuous. $\frac{V_{in}}{V_{out}} = \frac{D}{\Delta + D}$

Δ time for $I_L = 0$



Q2 $\Delta I = \frac{(V_{in} - V_{out}) \cdot t_{on}}{L}$ Inductor current ripple VS duty cycle.

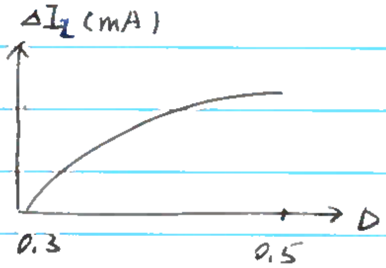
$= \frac{V_{out} \times t_{off}}{L}$

$= \frac{V_{out}}{V_{in}} \times \frac{V_{in}}{L} \times (1 - D) T$

$= \underline{D(1-D) \cdot T} \times \frac{V_{in}}{L}$

$= (D - D^2) \cdot T \times \frac{V_{in}}{L}$

quadratic



Q2 Inductor current ripple ΔI vs load current

$\Delta I = \frac{I_o R}{L} \times t_{off} = \frac{I_o R}{L} \times (1 - D) T = \frac{I_o R}{L f} (1 - D)$

change little. unchange. most effective

ΔI will change since I_o change

But basically remain the same

Inductor current ripple ΔI_L VS switching frequency

$\Delta I_L = \frac{I_o R}{L f} (1 - D)$

Inversely proportional

Q3. ΔV_c vs V_{in} ΔV_c vs I_{out} ΔV_c vs f_s

Capacitor current ripple → (V_{out} + — V_{across} R_{sense}) for AC mode

coupling AC mode

$\Delta V_c = \frac{Q}{C} = \frac{V_o(1-D)}{8LC} \times T^2 = \frac{D(1-D) \cdot V_{in}}{8LC} \times T^2$

Vin. freq $\frac{1}{f_s^2}$

$= \frac{I_o R (1-D)}{8LC} \times T^2$

Iout

ΔV_c proportional ~~to Iout~~, to Vin ~~and~~

ΔV_c Capacitor ripple $\propto V_{in}$

unchange to I_{out} since $V_o = I_o \times \underset{\substack{\uparrow \\ \text{change}}}{R}$

$$\Delta V_c = \frac{(1-D)\cdot D \cdot V_{in}}{8LC \cdot f_s^2} = \frac{V_{out}(1-D)}{8LC \cdot f_s^2} = \frac{I_o \times R_L (1-D)}{8LC \cdot f_s^2}$$

Q4 $\Delta V_c = \dfrac{V_{out}(1-D)T^2}{8LC}$

$$\frac{\Delta V_{C1}}{\Delta V_{C2}} = \underset{\substack{\uparrow \\ \text{Cap Select.}}}{\frac{C_2}{C_1}}$$

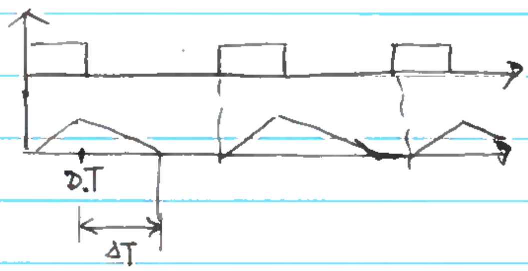
Discontinuous Operation $\rightarrow$ Sync Buck - off

Q1 33Ω resistor $\rightarrow$ Boundary Condition. $\rightarrow$

increase R_L see V_{out}, I_L, Duty cycle, I_o

verify

Inductor current



Q2

$$\Delta = \frac{2 I_{out} L}{DT(V_{in} - V_{out})} - D$$

$$\Rightarrow I_{out} = \frac{DT(\Delta + D)(V_{in} - V_{out})}{2L} = \frac{DT(V_{in} - V_{out})}{L} \times \frac{(\Delta + D)}{2}$$

$$= \frac{DT(V_{in} - DV_{in})}{2L} \times (\Delta + D)$$

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

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

$$= \frac{(DTV_{in} - D^2T V_{in})(\Delta + D)}{2L}$$

$$= \frac{DTV_{in}(1-D)(\Delta + D)}{2L}$$

$(1-D)(\Delta + D)$

$= \Delta - \Delta D + D - D^2$

$=$

$$I_{out} = \frac{V_{in}T}{2L} \times D \times \Delta$$

$$\frac{V_o}{V_d} = \frac{D}{\Delta + D} \rightarrow \frac{V_o}{V_{in}} = \frac{D}{\Delta + D}$$

$$I_{out} = \frac{DT(\Delta + D)(V_{in} - V_{out})}{2L}$$

$$= \frac{DT(\Delta + D) V_{in} (1 - \frac{D}{\Delta + D})}{2L} = \frac{DT(\Delta + D) \times (\frac{\Delta}{\Delta + D}) \times V_{in}}{2L} = \frac{V_{in} \cdot T \cdot \Delta \cdot D}{2L}$$

Q3 beyond 20V input $\rightarrow$ LED red lighted up & No output.

verify

Advanced Performance & Features

Q1. Load Regulation

V_{out} at light loads, medium loads, heavy loads

Q2. Current limiting

2.1. LTC7800 current limiting function

Sense+ Sense- ILIM.

↓

floated. I_{max} = 75mV threshold.

verify

R_{sense} = 0.015 Ω → $\frac{75mV}{0.015} = \frac{0.075}{0.015}$ = 5 A max current limiting

2.2. R_{Load} made smaller and smaller

V_{out} drop ~~....~~ dramatically ✓

2.3. Suddenly short circuited.

→ V_{out} → reduce above zero oscillate → zero

→ I_{out} → Max Limit 5A

$R_L = \frac{V_{out}}{I_{load}} = \frac{3.3V}{50mA} \approx 66\Omega$

Q3 Light Load Operation → LTSpice since PCB not function.

3.1 Light load operation mode → impact. operation & Eff & performance

↓

V_{out}

LTspice study modes operation

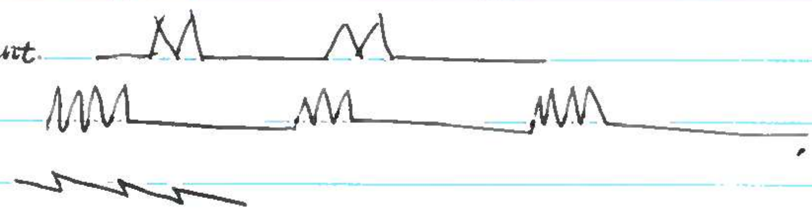
① Burst Mode. — SGND 68.1% eff.

PLLIN/Mode —/\/\/\/→
100k

Inductor current.

Switch.

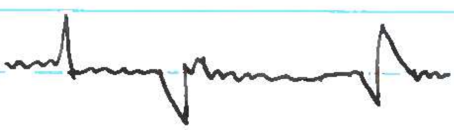
V_{out}



② Pulse-skipping. 13.5%

PLLIN/Mode —/\/\/\/→ 5V
100k

I_L



③ Force-Continuous. 12.4%

→ INTVcc

Burst Mode — highest efficiency.

Forced Continuous Mode — Output ripple independent of load current.

Pulse Skipping Mode — I_L not allowed to reverse.

higher efficiency than forced Continuous (low current).

Low output ripple

Low audio noise.

Cannot do these mode on PCB since Rsense doesn't connect to Sense+ Sense−

Q4 Impact of feedback Controller gain on Steady-State & Transient.

ITH pin →

(V_{FB}. & Track/SS)

controls

Vout

4.1 How the feedback gain is adjusted by PCB.

study control system Feedback loop.

RV2 ⟺ R_c (on LTC78xx internal circuit)

4.2. Feedback gain impacts the steady-state output voltage regulation.

↑ cause ripple in Vout ↑

But Vout rms same

Check by oscilloscope ✓

How to set up Oscilloscope

4.3 Feedback gain impacts the transient output voltage regulation

step in output voltage

Setpoint from 2V to 4V (switches)

Problem: How to operate "single mode" in Oscilloscope ?

(2022/06/22) Figure it out tomorrow.

step in output voltage reference RV3 & R~~4~~ switches

step in R_2 → Load resistance !

Same design?

More than 2 adjustable resistance

Feedback gain increase ⟶ Transient time ~~xxxx~~ decrease

But overshot increase

was

Now

4.4. Output capacitance size impact Transient response

↓

Cap Select ↑ ~~longer~~ shorter transient time ↓ less overshoot ↓

4.5. Using Fan bank as a load / Compared to resistive load.

↓

DC motor → Gap at begining

↓

DC → 0 resistance

→ ~~longer~~ shorter transition time ✓

(response quickly)

Three modes { Iout Vout Eff

↓

Burst

Burst Iout ↓

Eff ↑

Forced Continuous - less ripple ΔV_{out}

Question: Single Mode in Oscilloscope - Transient

✓ { step in Vout_reference - achieved by switches

✓ step in R_L - connection of 2 R

solved (RUN)

Source → trigger → channel 3 → Trigger 3V → Switch → Capture

↑ from 2-4V

Vout+