TY ENTC - C

ESED - SMPS problem (Group - C27)

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Q) Design Buck (using LM3524)

$V_{in} = 13.5 - 16.5V$, $V_o = 5V$, $I_o\ min = \cancel{0.1\%}$ 0.1,

$I_o\ max = 1A$, $f_s = 40kHz$, $(\Delta I_L = 2 \times I_{omin} = 200\,mA)$

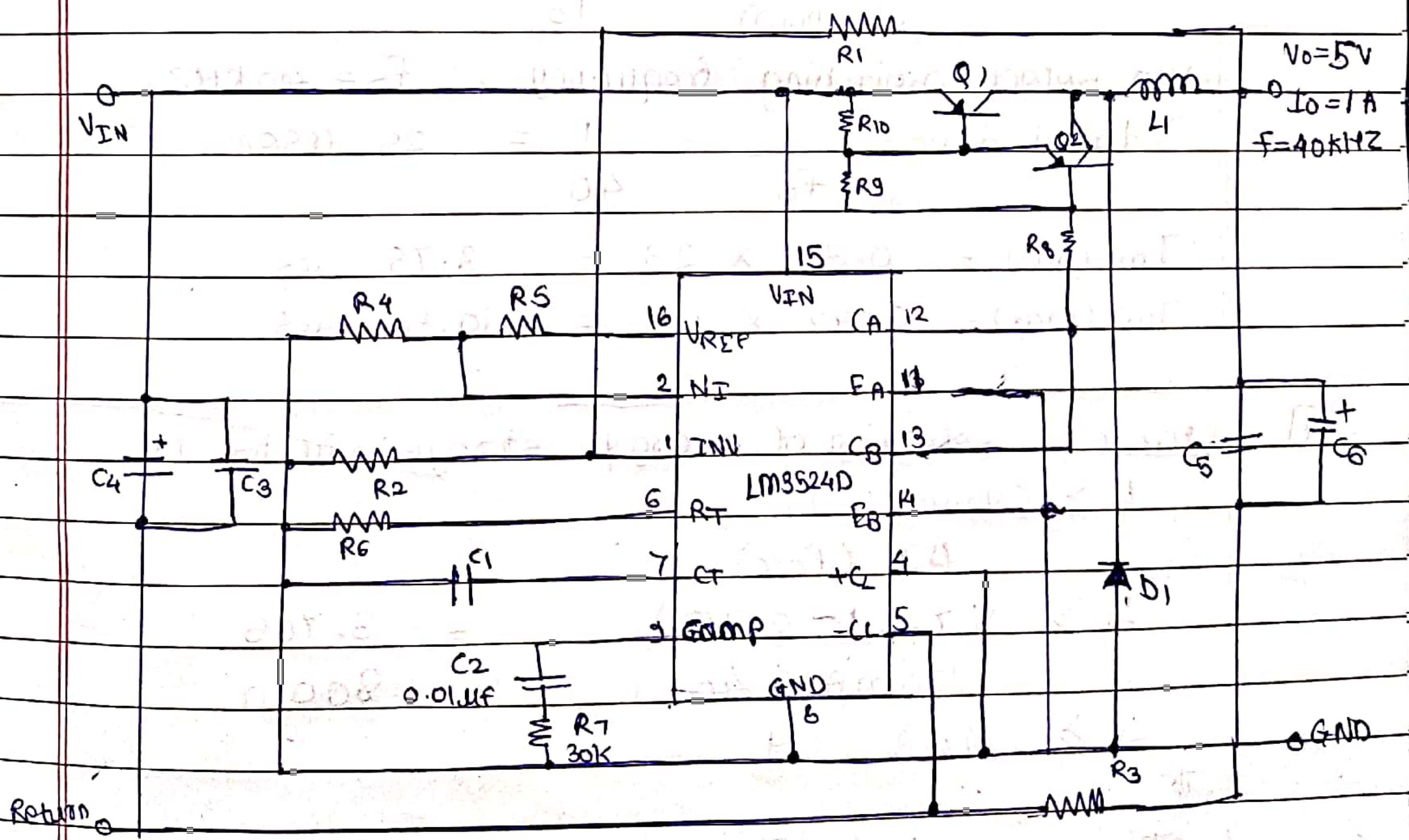
ripple = 100 mVp-p, $I_L\ max = 1.3A$

Efficiency = 80 %, Temperature = 0 to 80°C.

→

1] Step 1 : Selection of topology :

Consider, Nominal Input Voltage (Vin nom) = 15 V



2] Step 2: Calculation of net actual output considering drop across diode & inductor.

Assume voltage drop across diode $V_d = 0.3$ to 0.5 V

& Voltage drop across inductor $V_i = 0.1$ to 0.2 V

Net O/P voltage (V_{onet}) = $V_o + V_{diode} + V_{inductor}$

$$= 5 + 0.5 + 0.2$$

$$= 5.7 \text{ V}$$

3] Step 3: Calculate the required Duty cycle:

① $D(max) = \dfrac{V_o}{V_{in}(min)} = \dfrac{5.7}{13.5} = 0.42$

② $D(min) = \dfrac{V_o}{V_{in}(max)} = \dfrac{5.7}{16.5} = 0.35$

③ $D(nom) = \dfrac{V_o}{V_{in}(nom)} = \dfrac{5.7}{15} = 0.38$

We select switching frequency, $f_s = 40$ KHZ

∴ total time $= \dfrac{1}{f_s} = \dfrac{1}{40} = 25\ \mu sec$

∴ $T_{on}(min) = 0.35 \times 25 = 8.75\ \mu s$

∴ $T_{on}(max) = 0.42 \times 25 = 10.5\ \mu s$

4] Step 4: selection of energy storage inductor L_1

$L_1 \geq \dfrac{(V_{onet})(1 - D_{min})}{\Delta I_L\ (f_{osc})}$

$L_1 \geq \dfrac{5.7\ (1 - 0.35)}{200\text{mA}\ (40\text{k})} = \dfrac{3.705}{8000}$

$L_1 \geq 463\ \mu H$

∴

$I_{omax} = (\Delta I_L / 2) + I_o = 1.1$ A

$L_1 \leq \dfrac{(V_{onet})(t_{tr})}{I_{omax}} \times ((D_{max} / D_{T1}) - 1)$

(t_{tr} = transient recovery time)

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$D_{nom} \geq D_{T1} > D_{min}$

Select $D_{T1} = 0.37$

$L1 \leq \frac{5.7 \times 500 \mu s}{1} \times [(0.42/0.37)] - 1]$

$L1 \leq \cancel{560 \mu H}$ $350 \mu H$

inductor value $3560 \mu H$ assuming $T_{tr} = 500 \mu sec$.

Instead of $500 \mu sec$, we select $1000 \mu sec$ $= 700 \mu H$

Select inductor value between minimum and maximum value.

Let $L = 1600 \mu F$

4] ~~Step~~ ~~50~~: Calculation of no. of turns of inductor:

$\cancel{N = \sqrt{\frac{L}{A_L}}} = 22$

$A_L = 2750$ nH

$\therefore N = 22$.

5] Step 5: Selection of filter capacitor.

$C_o \geq \frac{\Delta I_L}{8 \times \Delta V_o \times F_{osc}} \geq \frac{200 mA}{8 \times 0.05 \times 40 k} = \frac{200 mA}{16 k}$

$= 12.5 \mu F \cong 13 \mu F$

$W V_{dc} = 2 \times V_{in\,max}$

calculate ESR of capacitor $\leq \frac{\Delta V_o}{2 \times \Delta I_L} \leq \frac{0.01 \times 5}{2 \times 200 mA} \leq 0.125$

6] Step 6: (Calculations for PWM IC LM 3524)

Feedback resistance R1 (Rf).

Assumption, value of R_G is 5 K

$R_F = 5 k\Omega \left(\frac{V_o}{2.5} - 1\right) = 5k \left(\frac{5}{2.5}\right) - 1$

$R_F = 5 k\Omega$

Internal voltage available is of 5V.
select values of R_4 & R_5 = 5k, reference voltage at non inverting terminal of error amplifier is 2.5 Volts

7] Step 7 : current Limiting Resistance R_{CL} / R_3

$$R_{CL} = \frac{\text{current limit sense Volt}}{I_{O(MAX)}}$$

consider, current limit v/g = 0.6V

$R_{CL} = 0.461\ \Omega$

- Calculate voltages across the R_{CL}

$P_{RCL} = I_{peak}^2 \times R_{CL}$

$= (1.3)^2 \times 0.461 = 0.78$ watt

Select the power watt of resistance ≥ 2 Watt

8) Step 8 - calculations for R_T (R_6) & C_T (C_1)

$$f_{osc} \cong \frac{1}{R_T C_T}$$

f_{osc} is 40 KHZ

Refer $R_T C_T$ graph from datasheet

lets $C_T = 0.01\ \mu F$

From datasheet, $R_T = 5\ k\Omega$

9] Step 9 :

We can select,

$R_2 = 5\ k\Omega$, $R_4 = 5\ k\Omega$, $R_5 = 5\ k\Omega$

10] Step 10 : calculation of R_8, R_9, R_{10} :

$\therefore I_O = I_{C1} + I_{C2}$

Initially assume that $I_{C1} = I_O$

$$\text{So } I_{B1} \approx \frac{I_{C1}}{h_{fe1}}$$

$I_{E1} = I_{B1} + I_{C1}$

Assume, $I_{E2} = I_{B1}$ (i.e. no current is taken from R_{10} & R_9 branch)

So, $I_{B2} \approx \frac{I_{e2}}{h_{fe2}}$

To calculate R8,

Lets see the branch containing resistance R8 R9 R10

In order to turn on Q_1, we need the voltage $V_{be} > V_{th}$ i.e 0.7 V & current should be greater than base current I_b

Hence,

$I_{B1} = \frac{I_{C1}}{h_{fe}} = \frac{1\,A}{20}$ ∵ consider $h_{fe} = 20$

condition driving a BJT in saturation $I_B > I_C/h_{fe}$

$I_{B1} = 55\ mA$

$I_{B2} \approx \frac{I_{B1}}{h_{fe}} = \left(\frac{55\,m}{50}\right)$ consider $h_{fe} = 50$

$I_{B2} \approx 1.1\ mA$

let driving current should be > $10 * I$ i.e 11 mA

current through R8 is 11 mA. Apply KVL from input, voltage across R10, R9, R8 and VCE sat of internal transistor.

Applying KVL across the R8, R9, R10, Vce sat of internal transistor.

Min input voltage $= V_{R10} + V_{R9} + V_{R8} + V_{CE\,sat}$

$13.5 = 0.7 + 0.7 + V_{R8} + 0.2$

$V_{R8} = 11.9\,V$

$R_8 = \frac{V_{R8}}{I_{R8}} = \frac{11.9}{11\,mA}$ ∴ $\underline{R_8 = 1\,k\Omega}$

R9 & R10 can be found by just voltage divider circuit

∴ Hence $R_9 = R_{10} = 100\ \Omega$

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Verification :

- current in R_9 & R_{10} branch is $0.7/100\ \Omega = 7\,mA$
- current assumed through R_8 is $11\,mA$.
- $I_{B2} = 11 - 7 = 4\,mA$, still I_{B2} is $4/1.1 = 3.63$ times I_{B1}/h_{fe2} & q_2 will be well driven in to saturation.