ISL6420B

DESIGN CALCULATIONS

FOR THE

FIREMC-PIHAT (FIREMC-3.14)

5 VOLTS DC

REQUIRED REFERENCES:

INTERSIL ISL6420B DATASHEET <HTTP://WWW.INTERSIL.COM/EN/PRODUCTS/POWER-MANAGEMENT/SWITCHING-CONTROLLERS/SINGLE-OUTPUT---BUCK-CONTROLLERS/ISL6420B.HTML>

ST MICROELECTRONICS STD86N3LH5 DATASHEET <HTTP://WWW.ST.COM/CONTENT/ST_COM/EN/PRODUCTS/POWER-TRANSISTORS/POWER-MOSFETS/N-CHANNEL-STRIPFET-12-V-TO-30-V/STD86N3LH5.HTML>

SCHELLE, D. ET AL: (2006, JUNE). BUCK-CONVERTER DESIGN DEMYSTIFIED. *POWER ELECTRONICS TECHNOLOGY*. RETRIEVED FROM HTTP://POWERELECTRONICS.COM/DC-DC-CONVERTERS/BUCK-CONVERTER-DESIGN-DEMYSTIFIED

$V_{IN_{MIN}} = 11V$ $\qquad$ $V_{IN_{NOM}} = 12V$ $\qquad$ $V_{IN_{MAX}} = 13V$

$V_{OUT} = 5V$ $\qquad$ $V_{OUT_{RIPPLE}} = 0.02 \cdot V_{OUT} = 0.1V$ $\qquad$ $I_{OUT_{MAX}} = 4A$

$f_{SW} = 300kHz$ $\qquad$ $LIR = 0.3$ $\qquad$ $T_{J_{MAX}} = 115°C$

$T_{A_{MAX}} = 60°C$ $\qquad$ $\Delta V = 0.1V$ $\qquad$ $V_{IN_{RIPPLE}} = 0.075V$

$$L = \frac{(V_{IN_{MAX}} - V_{OUT}) \cdot V_{OUT}}{V_{IN_{MAX}} \cdot f_{SW} \cdot LIR \cdot I_{OUT_{MAX}}}$$

$L = 8.547\mu H$ $\qquad$ CHOOSE $\qquad$ $8.2\mu H$

$$\Delta I_L = LIR \cdot I_{OUT_{MAX}} = \frac{(V_{IN_{MAX}} - V_{OUT}) \cdot V_{OUT}}{V_{IN_{MAX}} \cdot f_{SW} \cdot L}$$

$\Delta I_L = 1.2A$

$\Delta I_{L_{ACT}} = 1.251A$

$$I_{OUT_{PK}} = I_{OUT_{MAX}} + \frac{\Delta I_{L_{ACT}}}{2}$$

$I_{OUT_{PK}} = 4.63A$

$I_{L_{SAT}} > I_{OUT_{PK}} \cdot 1.2$

$I_{L_{SAT}} > 5.551A$

$$C_O = \frac{L \cdot \left(I_{OUT_{MAX}} + \frac{\Delta I_{L_{ACT}}}{2}\right)^2}{(\Delta V + V_{OUT})^2 - V_{OUT}^2} = \frac{L \cdot I_{OUT_{PK}}^2}{(\Delta V + V_{OUT})^2 - V_{OUT}^2}$$

$C_O = 174\mu F$

$C_{O_{ACT}} = C_O \cdot 1.2$

$C_{O_{ACT}} = 210\mu F$ $\qquad$ CHOOSE 3x 150μF

$$V_{OUT_{CAP}} = \frac{1}{2 \cdot C_O} \cdot \frac{V_{IN_{MAX}} - V_{OUT}}{L} \cdot \left(\frac{V_{OUT}}{V_{IN_{MAX}}} \cdot \frac{1}{f_{SW}}\right)^2$$

$$V_{OUT_{ESR}} = \Delta I_{L_{ACT}} \cdot ESR_{C_O}$$

$$V_{OUT_{RIPPLE}} = V_{OUT_{CAP}} + V_{OUT_{ESR}} = \frac{1}{2 \cdot C_O} \cdot \frac{V_{IN_{MAX}} - V_{OUT}}{L} \cdot \left(\frac{V_{OUT}}{V_{IN_{MAX}}} \cdot \frac{1}{f_{SW}}\right)^2 + \Delta I_{L_{ACT}} \cdot ESR_{C_O}$$

$$ESR_{C_O} = \frac{1}{\Delta I_{L_{ACT}}} \cdot \left(V_{OUT_{RIPPLE}} - \frac{1}{2 \cdot C_O} \cdot \frac{V_{IN_{MAX}} - V_{OUT}}{L} \cdot \left(\frac{V_{OUT}}{V_{IN_{MAX}}} \cdot \frac{1}{f_{SW}} \right)^2 \right)$$

$$ESR_{C_O} \leq 0.077\Omega$$

COMBINE CAPS IN PARALLEL TO SO EFFECTIVE ESR IS LESS THAN OR EQUAL TO THE ABOVE VALUE.

$$I_{C_{I_{RMS}}} = I_{OUT_{MAX}} \cdot \frac{\sqrt{V_{OUT} \cdot (V_{IN_{MIN}} - V_{OUT})}}{V_{IN_{MIN}}}$$

$$I_{C_{I_{RMS}}} = 1.992A$$

$$C_I = \frac{10\mu F}{A} \cdot I_{C_{I_{RMS}}} \qquad \text{TO} \qquad C_I = \frac{22\mu F}{A} \cdot I_{C_{I_{RMS}}}$$

$$C_I = 19.92\mu F \qquad \text{TO} \qquad C_I = 43.82\mu F$$

$$C_{IN_{MIN}} = \frac{I_{OUT_{MAX}} \cdot \frac{V_{OUT}}{V_{IN_{NOM}}} \cdot \left(1 - \frac{V_{OUT}}{V_{IN_{NOM}}} \right) \cdot 1000}{f_{SW} \cdot V_{IN_{RIPPLE}}}$$

$$C_{IN_{MIN}} = 43.21\mu F$$

$$ESR_{C_{IN}} \leq \frac{V_{IN_{RIPPLE}}}{2 \cdot \sqrt{3} \cdot I_{C_{I_{RMS}}}}$$

$$ESR_{C_{IN}} \leq 0.011\Omega$$

$$T_{J_{RISE}} = T_{J_{MAX}} - T_{A_{MAX}}$$

$$T_{J_{RISE}} = 55°C$$

$$P_{D_{TOT}} = \frac{T_{J_{RISE}}}{\Theta_{JA}} \qquad \Theta_{JA} \text{ FROM STD86N31H5 DATASHEET IS } 50°C \; (R_{thj-pcb} \text{ ON THE DATASHEET})$$

$$P_{D_{TOT}} = 1.1W$$

$$R_{DS(ON)_{HOT}} = R_{DS(ON)_{25}} \cdot \left[1 + 0.005 \cdot (T_{J_{HOT}} - 25°C) \right]$$

$$R_{DS(ON)_{25}} \leq \frac{V_{IN_{MIN}}}{V_{OUT}} \cdot \frac{1}{I_{OUT_{MAX}}^2 \cdot \left[1 + 0.005 \cdot (T_{J_{HOT}} - 25°C) \right]} \cdot P_{D_{TOT}} \cdot 0.6$$

$$R_{DS(ON)_{25}} \leq 0.0626\Omega \qquad \text{STD86N31H5 } R_{DS(ON)25} \leq 0.0065\Omega \; (\text{FROM DATASHEET})$$

$$R_{DS(ON)_{HOT}} = 0.0094\Omega$$

$$P_{D_{RDS}} = \frac{V_{OUT} \cdot I_{OUT_{MAX}}^2 \cdot R_{DS(ON)_{HOT}}}{V_{IN_{MIN}}}$$

$$P_{D_{RDS}} = 0.0684W$$

***** ESTIMATE (REQUIRES LAB VERIFICATION *****

$$P_{D_{SW}} = \frac{C_{RSS} \cdot V_{IN_{MAX}}^2 \cdot f_{SW} \cdot I_{OUT_{MAX}}}{I_{GATE}}$$ WHERE $C_{RSS} = 58pF$ AND $I_{GATE} = 0.7A$

$$P_{D_{SW}} = 0.0168W$$

$$P_D = P_{D_{RDS}} + P_{D_{SW}}$$

$$P_D = 0.0852W$$

$$T_{J_{RISE_{EST}}} = P_D \cdot \Theta_{JA}$$

$$T_{J_{RISE_{EST}}} = 4.26°C$$

$$T_{J_{EST}} = T_{J_{RISE_{EST}}} + T_{A_{MAX}}$$

$$T_{J_{EST}} = 64.26°C$$

***** END ESTIMATE *****

THE FOLLOWING CALCULATIONS REQUIRE THE ISL6420B DATASHEET AS THE COMPONENT REFERENCES USED IN THE CALCULATIONS COME RIGHT FROM THE DATASHEET AND NOT THE FIREMC-PIHAT (FIREMC-3.14) DESIGN SCHEMATIC.

$$I_{OC} > I_{L_{SAT}}$$

$$I_{OC} > 5.551A$$

$$I_{OC} = 5.6A$$

$$I_{OC} = \frac{I_{OCSET} \cdot R_{OCSET}}{R_{DS(ON)_{MAX}}}$$

$$R_{DS(ON)_{90}} \approx 1.375 \cdot R_{DS(ON\ 25}}$$

$$R_{DS(ON)_{90}} \approx 0.009\Omega$$

$$R_{DS(ON)_{90}} = R_{DS(ON)_{MAX}}$$

$$R_{OCSET} = \frac{I_{OC} \cdot R_{DS(ON)_{90}}}{I_{OCSET}}$$ WHERE $I_{OCSET} = 100\mu A = 0.0001A$

$$R_{OCSET} = 504\Omega$$ CHOOSE   510Ω

$$f_{LC} = \frac{1}{2 \cdot \pi \cdot \sqrt{L \cdot C_O}}$$ WHERE $C_O = 450\mu F$ AND $L = 8.2\mu H$

$$f_{LC} = 2.620 kHz$$

$$f_{ESR} = \frac{1}{2 \cdot \pi \cdot ESR_{C_{O(AC}} \cdot C_O}$$ WHERE $ESR_{C_{O(ACT}} = 0.0533\Omega$

$$f_{ESR} = 6.636 kHz$$

$$V_{FB} = V_{OUT} \cdot \frac{R4}{R1 + R4}$$ WHERE $V_{FB} = V_{REF} = 0.6V$ AND $R1 = 10 k\Omega$

$$R4 = \frac{V_{FB} \cdot R1}{V_{OUT} - V_{FB}}$$

$$R4 = 1.364 k\Omega$$ CHOOSE   1.37kΩ

$$\frac{R2}{R1} = 5.62$$

$$R2 = 5.62 \cdot R1$$

$$R2 = 56.2 k\Omega$$

$$f_{Z1} = 0.75 \cdot f_{LC} = \frac{1}{2 \cdot \pi \cdot R2 \cdot C1}$$

$$C1 = \frac{1}{2 \cdot \pi \cdot R2 \cdot 0.75 \cdot f_{LC}}$$

$$C1 = 1.441 nF$$ CHOOSE

$$f_{Z2} = f_{LC} = \frac{1}{2 \cdot \pi \cdot (R1 + R3) \cdot C3}$$

$$f_{Z2} = \frac{1}{2 \cdot \pi \cdot \left(R1 + \left(\frac{1}{2 \cdot \pi \cdot \left(\frac{f_{SW}}{2} \right) \cdot C3} \right) \right) \cdot C3}$$

$$C3 = \frac{\frac{f_{SW}}{2 \cdot f_{LC}} - 1}{\frac{2 \cdot \pi \cdot R1 \cdot f_{SW}}{2}}$$

$$C3 = 5.985 nf$$ CHOOSE

$$f_{P2} = \frac{f_{SW}}{2} = \frac{1}{2 \cdot \pi \cdot R3 \cdot C3}$$

$$R3 = \frac{1}{2 \cdot \pi \cdot \frac{f_{SW}}{2} \cdot C3}$$

$R3 = 178\Omega$ CHOOSE

$$f_{P1} = f_{ESR} = \frac{1}{2 \cdot \pi \cdot R2 \cdot \frac{C1 \cdot C2}{C1 + C2}}$$

$$C2 = \frac{C1}{(f_{ESR} \cdot 2 \cdot \pi \cdot R2 \cdot C1) - 1}$$

$C2 =$