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>

$V_{IN_{MIN}} = 11V$
$V_{IN_{NOM}} = 12V$
$V_{IN_{MAX}} = 13V$
$V_{OUT} = 5V$
$V_{OUT_{RIPPLE}} = 0.02 \cdot V_{OUT} = 0.1V$
$I_{OUT_{MAX}} = 5A$
$f_{SW} = 300kHz$
$LIR = 0.3$
$T_{J_{MAX}} = 115°C$
$T_{A_{MAX}} = 60°C$
$\Delta V = 0.1V$
$V_{IN_{RIPPLE}} = 0.075V$

$$L = \frac{(V_{IN_{MAX}} - V_{OUT}) \cdot V_{OUT}}{V_{IN_{MAX}} \cdot f_{SW} \cdot LIR \cdot I_{OUT_{MAX}}}$$
$L = 6.838\mu H$ CHOOSE $6.8\mu H$

$$\Delta I_L = LIR \cdot I_{OUT_{MAX}} = \frac{(V_{IN_{MAX}} - V_{OUT}) \cdot V_{OUT}}{V_{IN_{MAX}} \cdot f_{SW} \cdot L}$$
$\Delta I_L = 1.5A$
$\Delta I_{L_{ACT}} = 1.509A$

$$I_{OUT_{PK}} = I_{OUT_{MAX}} + \frac{\Delta I_{L_{ACT}}}{2}$$
$I_{OUT_{PK}} = 5.76A$

$I_{L_{SAT}} > I_{OUT_{PK}} \cdot 1.2$
$I_{L_{SAT}} > 6.912A$

$$C_O = \frac{L \cdot \left(I_{OUT_{MAX}} + \frac{\Delta I_{L_{ACT}}}{2}\right)^2}{(\Delta V + V_{OUT})^2 - V_{OUT}^{\,2}} = \frac{L \cdot I_{OUT_{PK}}^{\,2}}{(\Delta V + V_{OUT})^2 - V_{OUT}^{\,2}}$$
$C_O = 223.4\mu F$

$C_{O_{ACT}} = C_O \cdot 1.2$
$C_{O_{ACT}} = 268.05\mu F$ CHOOSE 3x 150µF

$$V_{OUT_{CAP}} = \frac{1}{2 \cdot C_O} \cdot \frac{V_{IN_{MAX}} - V_{OUT}}{L} \cdot \left(\frac{V_{OUT}}{V_{IN_{MAX}}} \cdot \frac{1}{f_{SW}}\right)^2$$
$$V_{OUT_{ESR}} = \Delta I_{L_{ACT}} \cdot ESR_{C_O}$$
$$V_{OUT_{RIPPLE}} = V_{OUT_{CAP}} + V_{OUT_{ESR}} = \frac{1}{2 \cdot C_O} \cdot \frac{V_{IN_{MAX}} - V_{OUT}}{L} \cdot \left(\frac{V_{OUT}}{V_{IN_{MAX}}} \cdot \frac{1}{f_{SW}}\right)^2 + \Delta I_{L_{ACT}} \cdot ESR_{C_O}$$
$$ESR_{C_O} = \frac{1}{\Delta I_{L_{ACT}}} \cdot \left(V_{OUT_{RIPPLE}} - \frac{1}{2 \cdot C_O} \cdot \frac{V_{IN_{MAX}} - V_{OUT}}{L} \cdot \left(\frac{V_{OUT}}{V_{IN_{MAX}}} \cdot \frac{1}{f_{SW}}\right)^2\right)$$
$ESR_{C_O} \leq 0.063\Omega$
COMBINE CAPS IN PARALLEL TO SO EFFECTIVE ESR IS LESS THAN OR EQUAL TO THE ABOVE VALUE.

$$I_{C_{I_{RMS}}} = I_{OUT_{MAX}} \cdot \frac{\sqrt{V_{OUT} \cdot (V_{IN_{MIN}} - V_{OUT})}}{V_{IN_{MIN}}}$$
$I_{C_{I_{RMS}}} = 2.49A$

$C_{IN} \geq 10uF \cdot I_{C_{I_{RMS}}}$
$C_{IN} \geq \frac{10\mu F}{A} \cdot 2.49A$
$C_{IN} \geq 24.9\mu F$ CHOOSE 40µF

$T_{J_{RISE}} = T_{J_{MAX}} - T_{A_{MAX}}$
$T_{J_{RISE}} = 55℃$

$P_{D_{TOT}} = \frac{T_{J_{RISE}}}{\Theta_{JA}}$ Θ_{JA} FROM STD86N3lH5 DATASHEET IS 50°C ($R_{thj\text{-}pcb}$ ON THE DATASHEET)
$P_{D_{TOT}} = 1.1W$

$R_{DS(ON)_{HOT}} = R_{DS(ON)_{25}} \cdot \left[1 + 0.005 \cdot \left(T_{J_{HOT}} - 25℃\right)\right]$
$R_{DS(ON)_{25}} \leq \frac{V_{IN_{MIN}}}{V_{OUT}} \cdot \frac{1}{I_{OUT_{MAX}}{}^2 \cdot \left[1 + 0.005 \cdot \left(T_{J_{HOT}} - 25℃\right)\right]} \cdot P_{D_{TOT}} \cdot 0.6$
$R_{DS(ON)_{25}} \leq 0.0422\Omega$ $R_{DS(ON)_{25}}$ FROM STD86N3lH5 DATASHEET IS 0.0065Ω
$R_{DS(ON)_{HOT}} = 0.0093\Omega$

$P_{D_{RDS}} = \frac{V_{OUT} \cdot I_{OUT_{MAX}}{}^2 \cdot R_{DS(ON)_{HOT}}}{V_{IN_{MIN}}}$
$P_{D_{RDS}} = 0.1057W$

***** 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 $I_{GATE} = 0.7A$
$P_{D_{SW}} = 0.021W$

$P_D = P_{D_{RDS}} + P_{D_{SW}}$
$P_D = 0.1267W$

$T_{J_{RISE_{EST}}} = P_D \cdot \Theta_{JA}$
$T_{J_{RISE_{EST}}} = 6.34℃$

$T_{J_{EST}} = T_{J_{RISE_{EST}}} + T_{A_{MAX}}$
$T_{J_{EST}} = 66.34℃$
***** 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.

$I_{OC} > I_{L_{SAT}}$
$I_{OC} > 6.912A$
$I_{OC} = 7A$
$I_{OC} = \frac{I_{OCSET} \cdot R_{OCSET}}{R_{DS(ON)_{MAX}}}$
$R_{DS(ON)_{100}} \approx 1.45 \cdot R_{DS(ON)_{25}}$

$R_{DS(ON)_{100}} \approx 0.0095\Omega$

$R_{DS(ON)_{100}} = R_{DS(ON)_{MAX}}$

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

$R_{OCSET} = 665\Omega$ CHOOSE 665Ω

$f_{LC} = \frac{1}{2 \cdot \pi \cdot \sqrt{L \cdot C_O}}$ WHERE $C_O = 450\mu F$ AND $L = 6.8\mu H$

$f_{LC} = 2.877kHz$

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

$f_{ESR} = 6.636kHz$

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

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

$R4 = 1.364k\Omega$ CHOOSE 1.37kΩ

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

$R2 = 5.62 \cdot R1$

$R2 = 56.2k\Omega$

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

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

$C1 = 1.312nF$ CHOOSE 1300pF

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

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

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

$C3 = 5.426\text{nf}$ CHOOSE 5600pF

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

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

$R3 = 189.47\Omega$ CHOOSE 191Ω

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

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

$C2 = 61pF$ CHOOSE 62pF