Power Stage Calculations

The battery voltage range is 2.5V to 3.65V per cell, 37.5V to 54.75V total, and the capacitor voltage will charge up to a bit less than that. To avoid extreme duty cycles, the converter should only be capable of 3:1 voltage step up, which still removes 90% of the capacitor's stored energy. The output current is up to 95A

Output current up to 95A with up to 3:1 voltage step up, I_{IN} = 95*3 = 285 per phase

Input voltage of 18V to 54V

Switching frequency of 500kHz, interleaved to make it effectively 1MHz for the capacitors

$R_{Load} = V_{Out}/I_{Out}$ = 3.2*15/150 = 0.32 ohms

Duty Cycle = 1 - V_I/V_O

D_{Min} = 0

D_{Max} = 1 - 18/55 = 67.3%

Peak I_{Out} = 95*2 = 190A

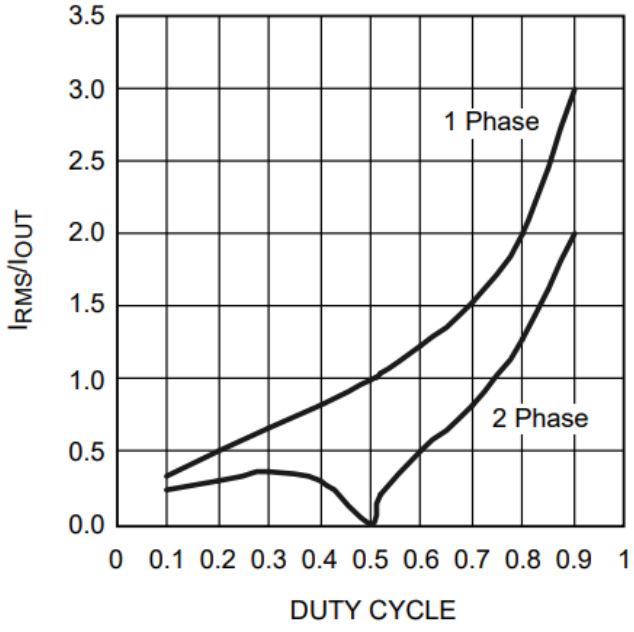
$$I_{L(avg)} = \frac{0.5 \times I_{OUT}}{1 - D_{MAX}} \qquad I_{PEAK} = I_{L(avg)} + \frac{\Delta I_L}{2} \qquad L_{(MIN)} = \frac{(V_{IN(MIN)} - V_{(ON)}) \times D_{MAX}}{f_S \times \Delta I_L}$$

I_L = 0.5*190/(1-0.673) = 290.5A

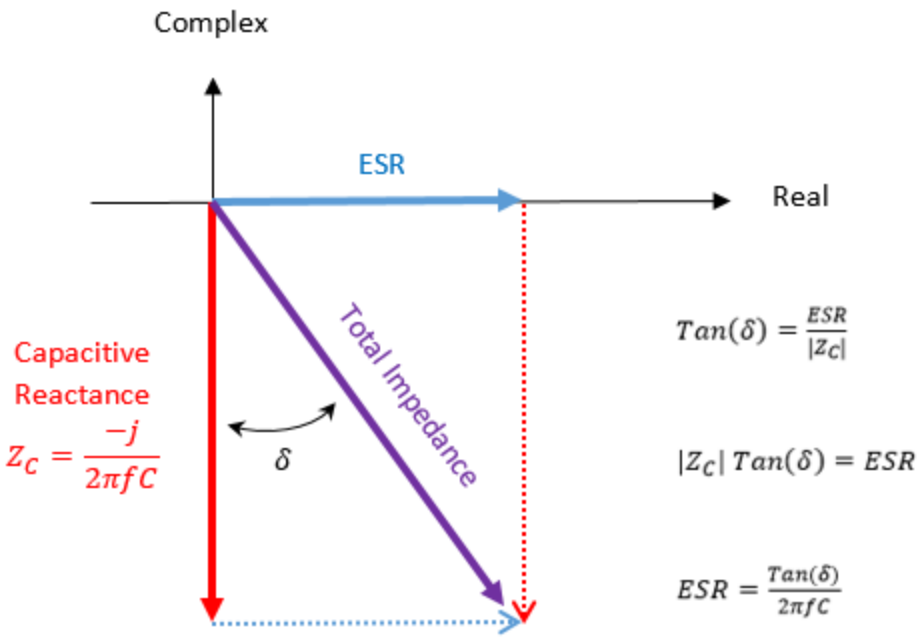
ΔI_L = 290.5*0.2 = 58.1A

I_{Peak} = 290.5+58.1/2 = 320A

L_{Min} = 18*0.673/(500000*58.1) = 0.417 uH



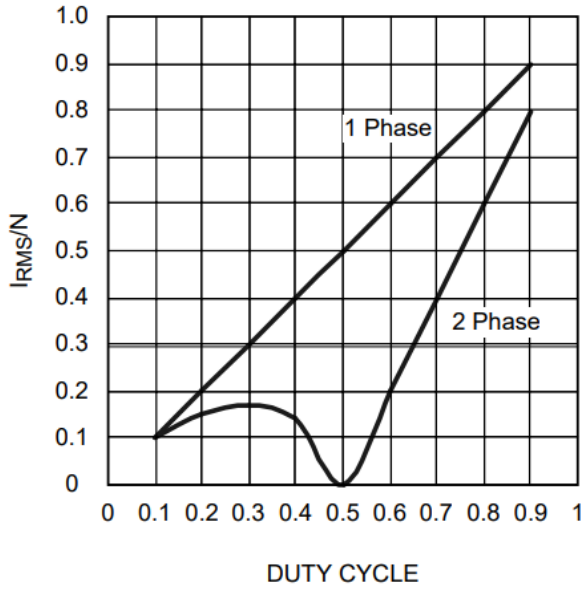
$I_{Cap-RMS}$ = 0.7*190 = 133A



Use 4 x 10uF capacitors, X7R loses 10% of capacitance at 1 MHz, DF = 2.5%
ESR = DF/(2π*f*C) = 0.025/(2*3.14*9) = 0.442 mohms
P_{Cap} = (133/4)^2*0.000442 = 0.489 W

$$\Delta V_{OUT} = \frac{I_{OUT(MAX)} \times (1 - D_{MIN})}{f_S \times C_{OUT}} + I_{PEAK} \times ESR$$

ΔV_{Out} = 190*(1-0.673)/(10^6*4*10*0.9) + 320*0.000442/4 = 35.4 mV



$$I_{RIPPLE(Normalized)} = \frac{V_{IN}}{L \times f_S}$$

I_N = 54/(0.47*0.5) = 230A
I_{Ripple} = 0.35*I_N = 0.35*230 = 80.5A
Again, use 4 x 10uF

P_{Cap} = (80.5/4)^2*0.000442 = 0.179 W

$$P_{MOSFET} = \left(\frac{I_{OUT(MAX)}}{2 \times (1 - D)}\right) \times R_{DS(ON)} \times D \times 1.3 + V_{IN(MAX)} \times Q_g \times f_S$$

P_{FET} = 190/(2*(1-0.673))*0.0011*0.673*1.3 + 12*0.178*0.5 = 1.35 W