1 Off-time:

$V_{start} \approx 0.6$
Assuming $R_1 \gg R_3$ and $V_{out} \gg I_{max} R_{14}$
$V_{stop} = V_{in} \frac{R_6}{R_6+R_2}$

1.1 For Design 1

(with off time set by simple RC network)
$t_{off} = R_1 C_1 \ln\left(\frac{V_{out}-V_{start}}{V_{out}-V_{stop}}\right)$
linear aproximation when $V_{out} \gg V_{stop} - V_{start}$
$t_{off} \approx R_1 C_1 \left(\frac{V_{stop}-V_{start}}{V_{out}-V_{stop}}\right)$

1.2 For design 2

(with off time set by C and const I)
Assuming $V_{out} - V_{in} \gg 0.6$
$t_{off} = \frac{R_1 C_1}{V_{out}-V_{in}} (V_{stop} - V_{start})$

2 Currents

2.1 Input and output current

$I_{avg,in} = I_{max} - t_{off}\left(\frac{V_{out}-V_{in}}{2L_1}\right)$
$I_{avg,out} = \frac{V_{in}}{V_{out}}\left[I_{max} - t_{off}\left(\frac{V_{out}-V_{in}}{2L_1}\right)\right]$

2.2 Input current, design 1

Accurate result
$I_{avg,in} = I_{max} - \frac{R_1 C_1 (V_{out}-V_{in})}{2L_1} \ln\left(\frac{V_{out}-V_{start}}{V_{out}-V_{stop}}\right)$
aproximate result
$I_{avg,in} \approx I_{max} - R_1 C_1 \frac{V_{stop}-V_{start}}{2L_1} \frac{V_{out}-V_{in}}{V_{out}-V_{stop}}$
as $V_{stop} \to V_{in}$ then
$I_{avg,in} \approx I_{max} - R_1 C_1 \frac{V_{in}-V_{start}}{2L_1}$
which is independent of V_{out}

We could like therefore to make V_{start} high, possibly clamping it a fixed voltage below V_{in}, but this comes into conflict with the requirement for the time constant $R_3 C_1$ to be low.

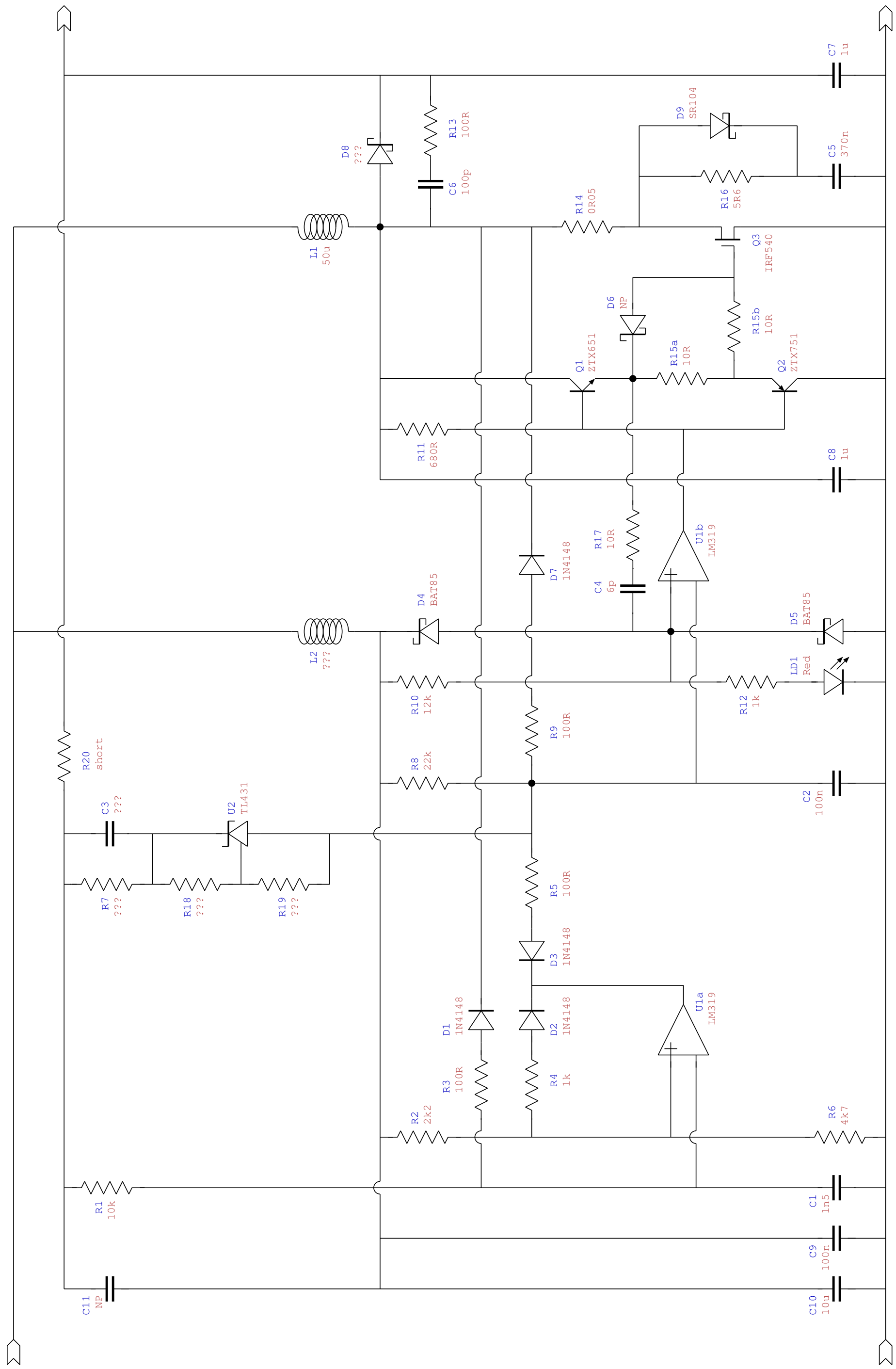

Figure 1: Design 1

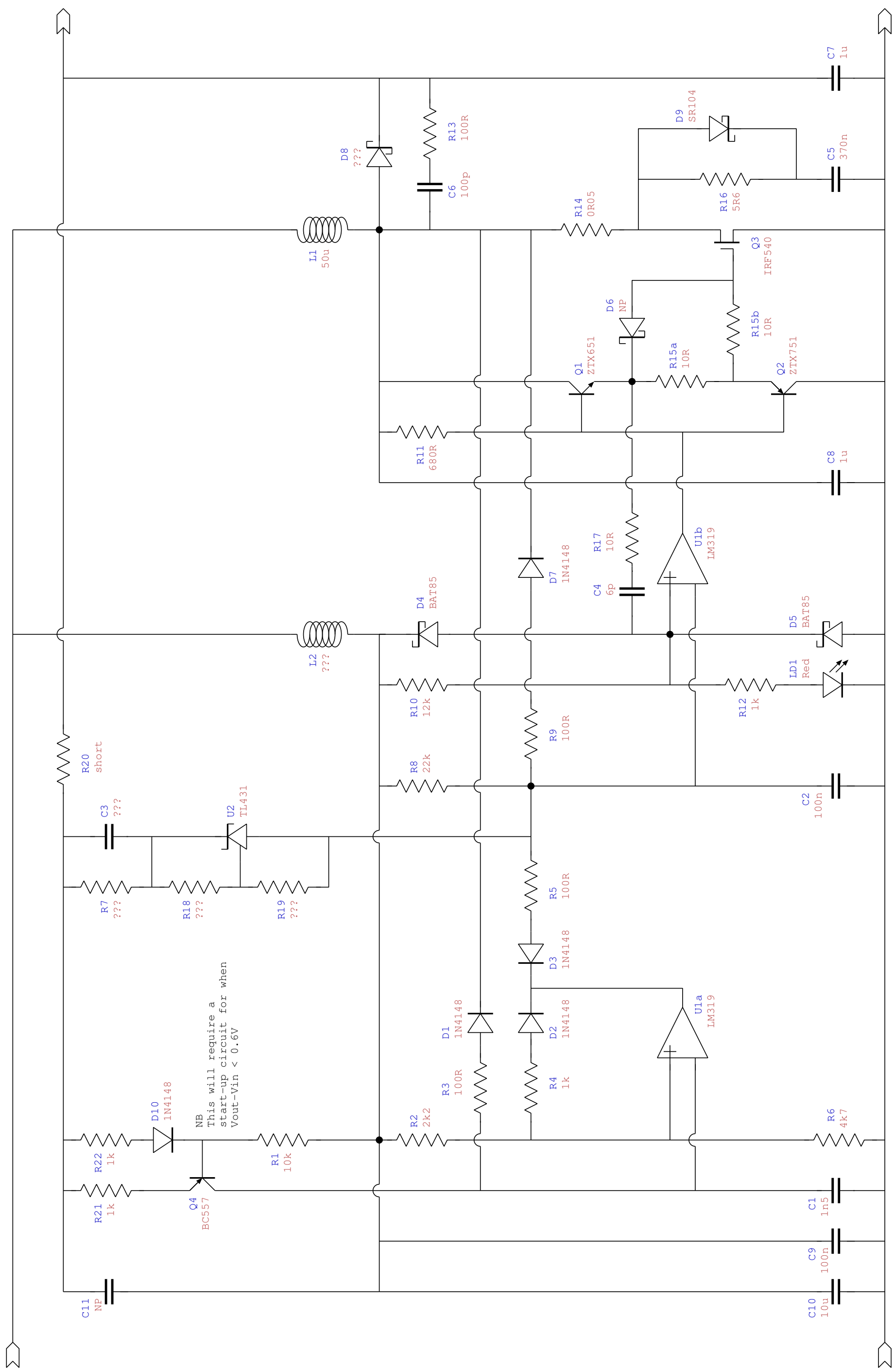

Figure 2: Design 2

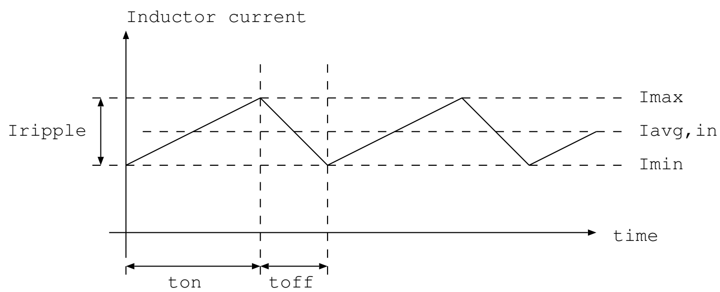

Figure 3: Inductor current

2.3 Input current, design 2

$I_{avg,in} = I_{max} - \frac{R_1 C_1}{2L_1}\left(V_{stop} - V_{start}\right)$
If V_{start} is small,
$I_{avg,in} = I_{max} - \frac{R_1 C_1 V_{in}}{2L_1}\frac{R_6}{R_6+R_2}$
Input current decreases with V_{in} but is independent of V_{out}
replace R_6 with constant-voltage to remove this dependance

3 Threshold

Let inputs to U1b be V_{comp+} and V_{comp-}

$V_{comp+} = \frac{V_{in}\frac{R_{12}}{R_{10}}+V_{LD1}}{\frac{R_{12}}{R_{10}}+1}$

$V_{comp-} = \frac{I_{L1}R_{14}+V_{D7}+V_{in}\frac{L_1}{L_{stray,R14}}+V_{in}\frac{R_9}{R_8}+V_{out}\frac{R_9}{R_7}-V_{U2}\frac{R_9}{R_7}}{\frac{R_9}{R_7}+\frac{R_9}{R_8}+1}$

the term $V_{in}\frac{L_1}{L_{stray,R14}}$ is valid only during the "on" period
When $V_{comp-} = V_{comp+}$ then $I_{L1} = I_{max}$

$I_{max} = \frac{\left(\frac{R_9}{R_8}+\frac{R_9}{R_7}+1\right)\left(V_{in}\frac{R_{12}}{R_{10}}+V_{LD1}\right)}{R_{14}\left(\frac{R_{12}}{R_{10}}+1\right)} - \frac{V_{D7}+V_{in}\frac{L_1}{L_{stray,R14}}+V_{in}\frac{R_9}{R_8}+V_{out}\frac{R_9}{R_7}}{R_{14}} + \frac{V_{U2}R_9}{R_{14}R_7}$

3.0.1 Aproximation

As an aproximation, if $V_{comp} \ll V_{in}$, we can assume that all of V_{in} is dropped accross R_{10} and R_8 (terms in R_9 and R_{12} disapear from the first half of above equation)

$I_{max} \approx \frac{V_{in}\frac{R_{12}}{R_{10}}+V_{LD1}}{R_{14}} - \frac{V_{D7}+V_{in}\frac{L_1}{L_{stray,R14}}+V_{in}\frac{R_9}{R_8}+V_{out}\frac{R_9}{R_7}}{R_{14}} + \frac{V_{U2}R_9}{R_{14}R_7}$
if $\frac{R_{12}}{R_{10}} = \frac{R_9}{R_8} + \frac{L_1}{L_{stray,R14}}$ then I_{max} is independent of V_{in}
$I_{max} \approx \frac{V_{LD1}}{R_{14}} - \frac{V_{D7}}{R_{14}} + \left(V_{U2} - V_{out}\right)\frac{R_9}{R_7 R_{14}}$

3.1 Current limit

When out of regulation (U2 not conducting) all terms in R_7 become 0.

$I_{max,limit} = \frac{\left(\frac{R_9}{R_8}+1\right)\left(V_{in}\frac{R_{12}}{R_{10}}+V_{LD1}\right)}{R_{14}\left(\frac{R_{12}}{R_{10}}+1\right)} - \frac{V_{D7}+V_{in}\frac{L_1}{L_{stray,R14}}+V_{in}\frac{R_9}{R_8}}{R_{14}}$

$I_{max,limit} \approx \frac{V_{LD1}}{R_{14}} - \frac{V_{D7}}{R_{14}}$

3.1.1 Design 1

Using the linear aproximation of average current

$I_{avg,in,limit} \approx \frac{V_{LD1}}{R_{14}} - \frac{V_{D7}}{R_{14}} - R_1 C_1 \left(\frac{V_{stop}-V_{start}}{2L_1}\frac{V_{out}-V_{in}}{V_{out}-V_{stop}}\right)$

3.2 Voltage limit

$V_{out,limit} \approx V_{U2} + \frac{R_7}{R_9}(V_{LD1} - V_{D7})$

The difference $V_{out,limit} - (V_{U2} + V_{LD1})$ represents the output sag from unloaded to full load