$m := 10^{-3}$ $k := 10^{3}$ $u := 10^{-6}$ $n := 10^{-9}$

Load conditions

$V_{out} := 12$ $I_{out} := 2.1$

$V_{Bias} := 22$ $I_{bias} := 0.1$

Load conditions

I/O Spec of UCC28700

I/O Specifications: $85\sqrt{2} = 120.208$ $264\sqrt{2} = 373.352$

Input Voltage: $Vin_{min} := 80$ $Vin_{max} := 375$

Switching Frequency: $F_{sw} := 57k$

$$Vin := (Vin_{min} - 10), Vin_{min} + \frac{Vin_{max} - Vin_{min}}{10} .. Vin_{max}$$

I/O Spec of UCC28700

UCC28700

Turns Ratio:

Assumed Diode Drop: $V_d := 0.6\ \text{V}$

$D_{max} := 1 - \left(\frac{F_{sw}}{2 \cdot 500k}\right) - 0.425$ $D_{max} = 0.518$ From datasheet

$$N_{p2s} := \frac{Vin_{min} \cdot D_{max}}{(V_{out} + V_d)(1 - D_{max})}$$

$N_{p2s} = 6.823$ Maximum Primary to Secondary Turns Ratio - Limited by Dmax

Primary Turns: $N_p := 40$

$$N_s := \frac{N_p}{N_{p2s}}$$

$N_s = 5.862$

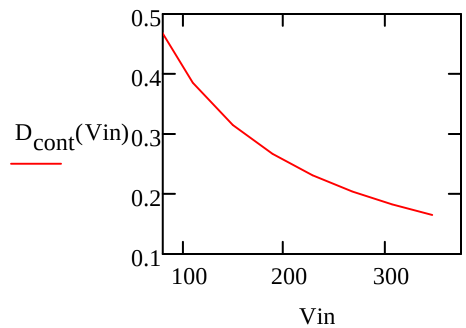
$13 \cdot \frac{10}{3} = 43.333$

Secondary Turns: $N_s := 7$

$12 \cdot \frac{5}{20} = 3$

$\frac{1}{4.2} = 0.238$

$$D_{cont}(Vin) := \frac{V_{out} \cdot \frac{N_p}{N_s}}{Vin + \frac{V_{out} \cdot N_p}{N_s}}$$



Determine Current Sense Resistance:

$V_{CCR} := 0.33$ From Datasheet: constant current regulation voltage

$I_{OCC} := 2.3$ Output over current level.

$\eta_{XFMR} := 0.9$ Estimated transformer efficiency

$$R_{CS} := \frac{V_{CCR} \cdot \frac{N_p}{N_s}}{2 \cdot I_{OCC}} \cdot \sqrt{\eta_{XFMR}}$$

$R_{CS} = 0.389$ Current sense resistance should be equal or less than this value.

$R_{CS} := 0.375$

Determine Primary Inductance:

$Pout := V_{out} \cdot I_{out}$ $Pout = 25.2$ W Maximum Output Power

Output Power at DCM Boundary (Low Line):

$Pout_{boundary} := 28$ W To ensure a DCM Flyback operation.

$$L_{dis} := \frac{Vin_{min}^{\,2} \cdot D_{cont}\left(Vin_{min}\right)^2}{2 \cdot Pout_{boundary} \cdot F_{sw}}$$

$L_{dis} = 427.103\,u$ H Maximum Inductance to Remain Discontinuous

$V_{CST\_max} := 0.78$ From Datasheet

$$I_{pp\_max} := \frac{V_{CST\_max}}{R_{CS}}$$

$I_{pp\_max} = 2.08$

$$L_p := \frac{2 \cdot \left(V_{out} + V_d\right) \cdot I_{OCC}}{\eta_{XFMR} \cdot I_{pp\_max}^{\,2} \cdot F_{sw}}$$

$L_p = 261.147\,u$

Actual Inductance:

$L_{act} := 250u$ H

$$Pout_{boundary}(Vin) := \frac{Vin^2 \cdot D_{cont}(Vin)^2}{2 \cdot L_{act} \cdot F_{sw}}$$

$$D_{DCM}(Vin) := \sqrt{\frac{2 \cdot Pout \cdot L_{act} \cdot F_{sw}}{Vin^2}}$$

DCM Duty cycle

$$D_{CCM}(Vin) := \frac{N_p \cdot V_{out}}{N_s \cdot Vin + N_p \cdot V_{out}}$$

CCM Duty cycle

$$CCM(Vin) := \left(D_{DCM}(Vin) > D_{CCM}(Vin)\right)$$

$$D(Vin) := \text{if}\left(CCM(Vin), D_{CCM}(Vin), D_{DCM}(Vin)\right)$$

$$Vus(Vin) := \frac{Vin \cdot D(Vin)}{F_{sw}} \qquad Ton(Vin) := \frac{D(Vin)}{F_{sw}}$$

$$Ipri_{pkpk}(Vin) := \frac{Vin \cdot D(Vin)}{L_{act} \cdot F_{sw}}$$

Peak to peak primary current

$$Ipri_{le}(Vin) := \text{if}\left(CCM(Vin), \frac{Pout}{Vin \cdot D(Vin)} - \frac{Ipri_{pkpk}(Vin)}{2}, 0\right)$$

Leading edge primary current

$$Ipri_{te}(Vin) := \text{if}\left(CCM(Vin), \frac{Pout}{Vin \cdot D(Vin)} + \frac{Ipri_{pkpk}(Vin)}{2}, Ipri_{pkpk}(Vin)\right)$$

Trailing edge primary current

$$t := 0, \left(\frac{1}{10^3 \cdot F_{sw}}\right) .. \frac{1}{F_{sw}}$$

$$Ipri(Vin, t) := if\left[t \le \frac{D(Vin)}{F_{sw}}, \left(\frac{Ipri_{pkpk}(Vin) \cdot F_{sw}}{D(Vin)} \cdot t + Ipri_{le}(Vin)\right), 0\right]$$

Instantaneous Primary Current

$$Ipri_{rms}(Vin) := \sqrt{F_{sw} \cdot \int_0^{\frac{D(Vin)}{F_{sw}}} Ipri(Vin, t)^2 \, dt}$$

RMS Primary Current

Primary MOSFET:

On resistance: $Rds_{qpri} := 2.9$ Ω   Gate charge: $Qgate_{qpri} := 9.9n$ C

Rise time: $Trise_{qpri} := 17n$ S   Bias voltage: $V_{bias} := 12$ V

$$V_{ds}(Vin) := Vin + \left(V_{out} + V_d\right) \cdot \left(\frac{N_p}{N_s}\right)$$

Primary Drain Voltage

$$Pdrv_{qpri} := Qgate_{qpri} \cdot F_{sw} \cdot V_{bias} \qquad Pdrv_{qpri} = 6.772\,m \quad W$$

Driving Losses

$$Pcond_{qpri}(Vin) := Ipri_{rms}(Vin)^2 \cdot Rds_{qpri}$$

Conduction Losses

$$Poff_{qpri}(Vin) := \frac{1}{4} \cdot V_{ds}(Vin) \cdot Ipri_{te}(Vin) \cdot Trise_{qpri} \cdot F_{sw}$$

Turn-off Losses

$$Ptot_{qpri}(Vin) := Pcond_{qpri}(Vin) + Poff_{qpri}(Vin)$$

Total MOSFET Losses
excluding driving losses

Diode Rectifier (Regulated Output):

Forward Drop: $V_{fwd} := 0.8$

$$L_{sec} := L_{act} \cdot \frac{N_s^{\,2}}{N_p^{\,2}}$$ Secondary inductance

$$Isec_{pkpk}(Vin) := Ipri_{pkpk}(Vin) \cdot \frac{N_p}{N_s}$$ Secondary peak current

$$T_{diode}(Vin) := \text{if}\left(CCM(Vin), \frac{1 - D(Vin)}{F_{sw}}, L_{sec} \cdot \frac{Isec_{pkpk}(Vin)}{V_{out}}\right)$$ Diode conduction time

$$I_{sec}(Vin, t) := \text{if}\left[t \ge \frac{D(Vin)}{F_{sw}}, \text{if}\left[t < T_{diode}(Vin) + \frac{D(Vin)}{F_{sw}}, Ipri_{te}(Vin) \cdot \frac{N_p}{N_s} - \frac{Isec_{pkpk}(Vin)}{T_{diode}(Vin)} \cdot \left(t - \frac{D(Vin)}{F_{sw}}\right), 0\right], 0\right]$$ Instantaneous secondary current

$$Isec_{rms}(Vin) := \sqrt{F_{sw} \cdot \int_{\frac{D(Vin)}{F_{sw}}}^{\frac{1}{F_{sw}}} I_{sec}(Vin, t)^2 \, dt}$$ Secondary RMS current

$$Vds_{qsec}(Vin) := V_{out} + Vin \cdot \frac{N_s}{N_p}$$ Reverse voltage

$Pcond_{qsec} := I_{out} \cdot V_{fwd}$ $Pcond_{qsec} = 1.68$ W

Voltage Sense:

Desired Bias Voltage: $V_b := 12$

$$N_B := N_s \cdot \frac{V_b + 1}{V_{out} + V_{fwd}}$$ $N_B = 7.109$

Actual Bias Turns: $N_B := 11$

Turn On Voltage(DC): $V_{en} := 85$

From Datasheet: $I_{VSLRUN} := 220u$

$$R_{S1} := \frac{N_B}{N_p} \cdot \frac{V_{en}}{I_{VSLRUN}}$$ $R_{S1} = 106.25\,k$ Actual resistance: $R_{S1} := 75k$

From Datasheet: $V_{VSR} := 4.05$

$$R_{S2} := \frac{V_{VSR}}{\frac{\left(V_{out}+V_{fwd}\right)\cdot\frac{N_B}{N_s}-V_{VSR}}{R_{S1}}}$$ $R_{S2} = 18.908\,k$ Actual resistance: $R_{S2} := 19.6k$

$$V_{out\_verify} := \left(1 + \frac{R_{S1}}{R_{S2}}\right) \cdot V_{VSR} \cdot \frac{N_s}{N_B} - V_{fwd}$$ $V_{out\_verify} = 11.639$

Current Sense:

From Datasheet: $K_{LC} := 25$

From Datasheet: $t_D := 50n$

$$R_{LC} := \frac{K_{LC} \cdot R_{S1} \cdot R_{CS} \cdot t_D \cdot \frac{N_p}{N_B}}{L_{act}}$$

$R_{LC} = 511.364$

$$I_{OCCact} := \frac{V_{CCR} \cdot \frac{N_p}{N_s}}{2 \cdot R_{CS}} \cdot \eta_{XFMR}$$

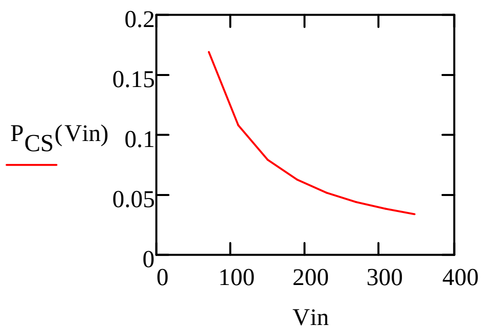
$I_{OCCact} = 2.263$

$$P_{limit} := \frac{1}{2} \cdot L_{act} \cdot \left(\frac{0.71}{R_{CS}}\right)^2 \cdot F_{sw}$$

$P_{limit} = 25.541$

$$P_{CS}(Vin) := Ipri_{rms}(Vin)^2 \cdot R_{CS}$$

Current sense losses



VDD Capacitor calculation:

From datasheet: $I_{RUN} := 2m$

$V_{OCC} := 8.5$

$V_{DDon} := 21$

$V_{DDoff} := 8.5$

$I_{START} := 2.1m$ Start-up bias supply current

$I_{tran} := 3$ Assumed load transient current

$dV_{tran} := 0.36$ Allowed voltage difference durning transient.

$f_{min} := 30k$ Minimum switching frequency.

Minimum output capacitance required:

$$C_{OUT} := \frac{I_{tran} \cdot \left(\frac{1}{f_{min}} + 150u \right)}{dV_{tran}} \qquad C_{OUT} = 1.528 \times 10^{3} u$$

$$C_{OUT} := 2200u$$

Target lowest converter output voltage in CC regulation:

$T_{STR} := 2$ converter start-up time requirement

$$C_{Vdd} := \frac{\left(I_{RUN} + 1m \right) \frac{C_{OUT} \cdot V_{OCC}}{I_{OCC}}}{\left(V_{DDon} - V_{DDoff} \right) - 1} \qquad C_{Vdd} = 2.121 u$$

Start up resistor:

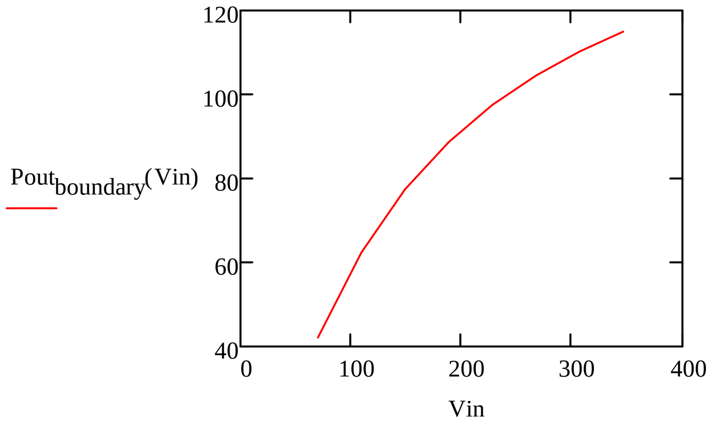
$$R_{STR} := \frac{\sqrt{2} \cdot Vin_{min}}{I_{START} + \frac{V_{DDon} \cdot C_{Vdd}}{T_{STR}}}$$

$$R_{STR} = 5.331 \times 10^{4}$$

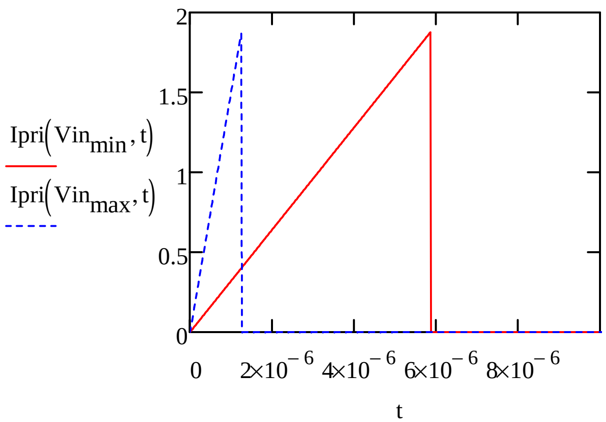
UCC28700

Plots for UCC28710

Output power for the current Flyback coupled inductor setting to operate at boundary mode:

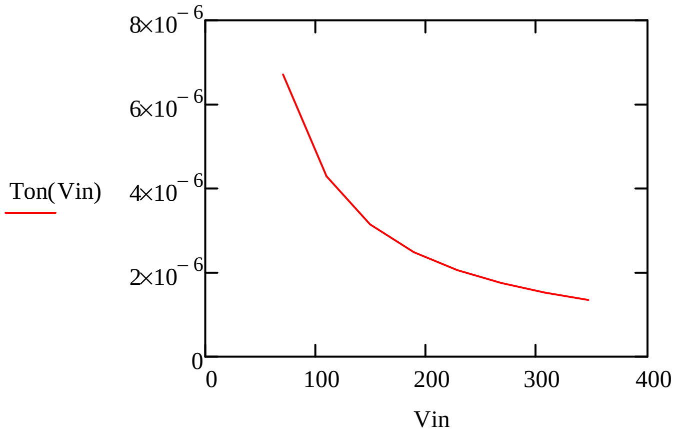


Instantaneous primary current:

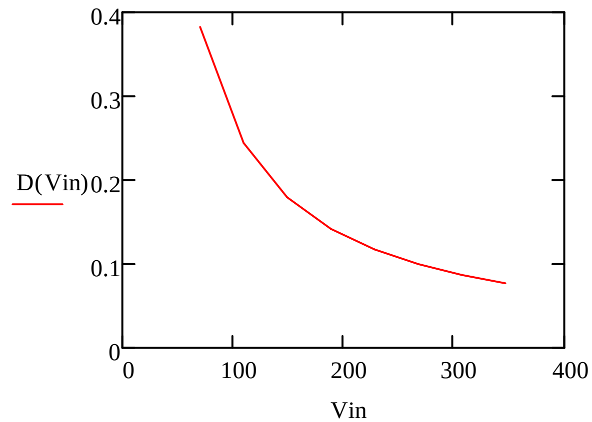


Need to make sure if the minimum on time @ Vin_max is greater than 400nS.
If and only if Ton_min>400nS, the design is valid!

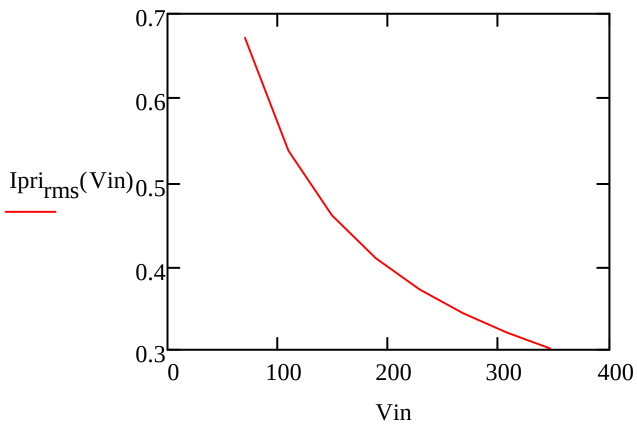
Primary MOSFET on time:



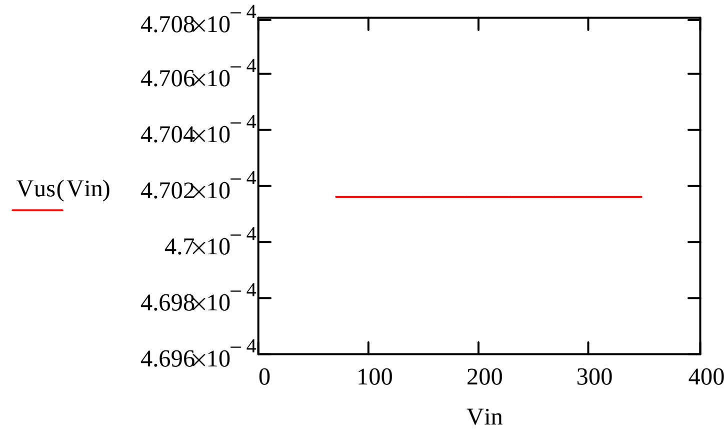
Duty cycle:



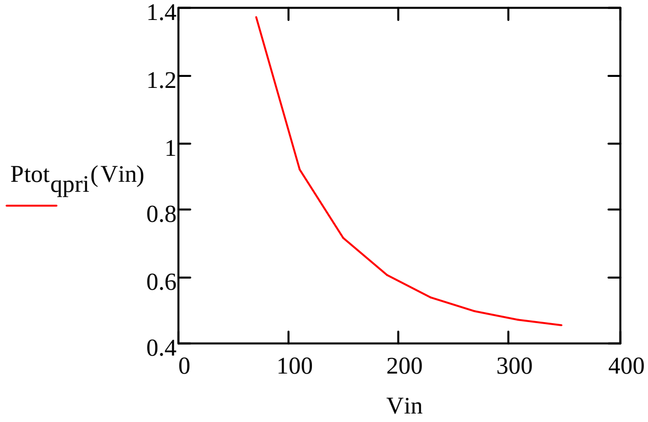
Primary MOSFET current:



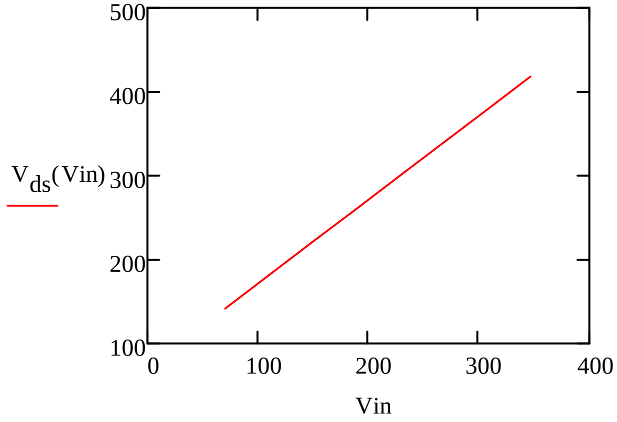
Voltage second:



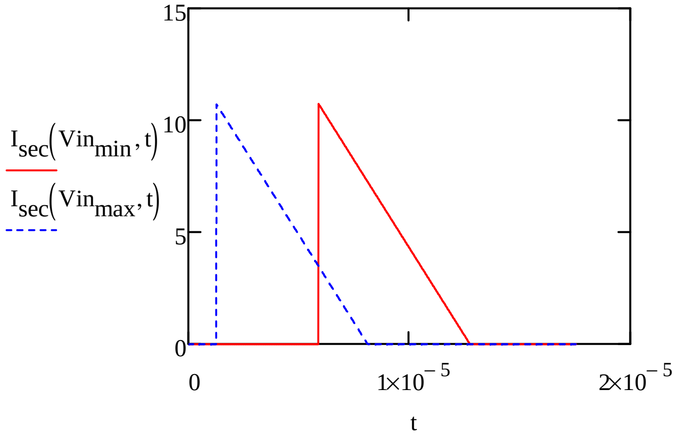
MOSFET losses:



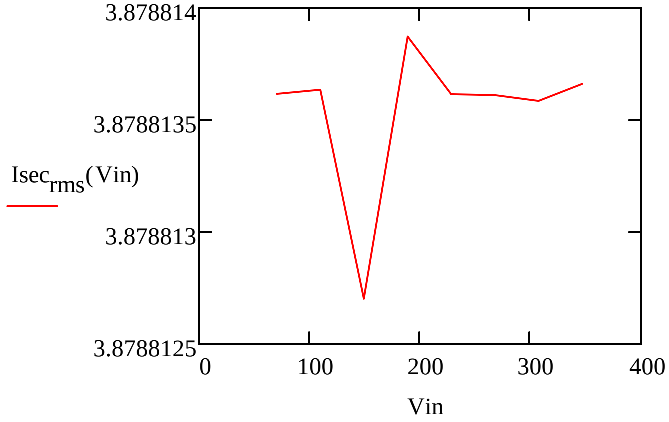
Voltage stress:



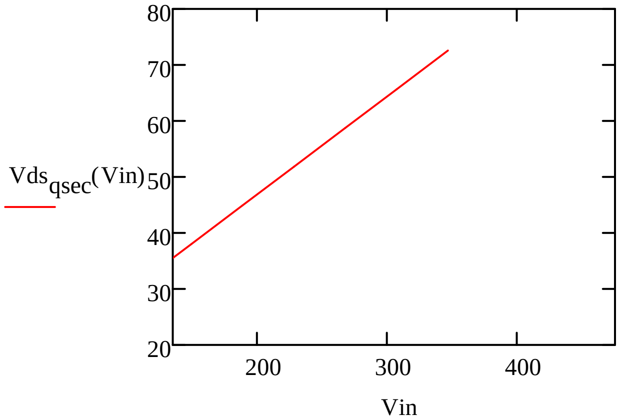
Instantaneous secondary current:



Secondary RMS current:



Instantaneous secondary voltage:



Plots for UCC28710