Resonance half bridge LLC converter analysis.

▶ Main iteration routine
▶ Ferrite loss calculator

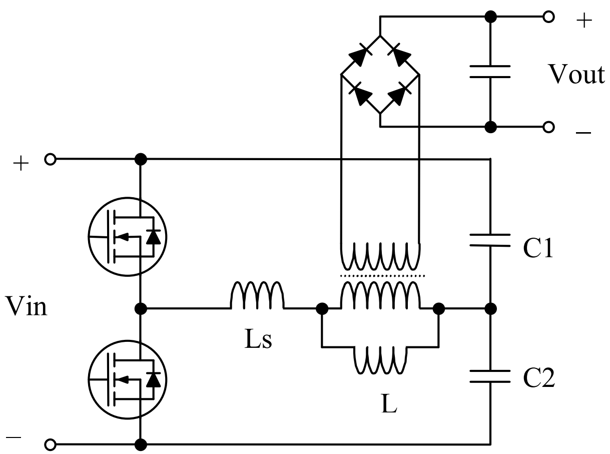
Logarithmic sweep of capacitor start voltage:

Min. capacitor start voltage: $V_{cmin} \equiv 1$

Max. capacitor start voltage: $V_{cmax} \equiv 1000$

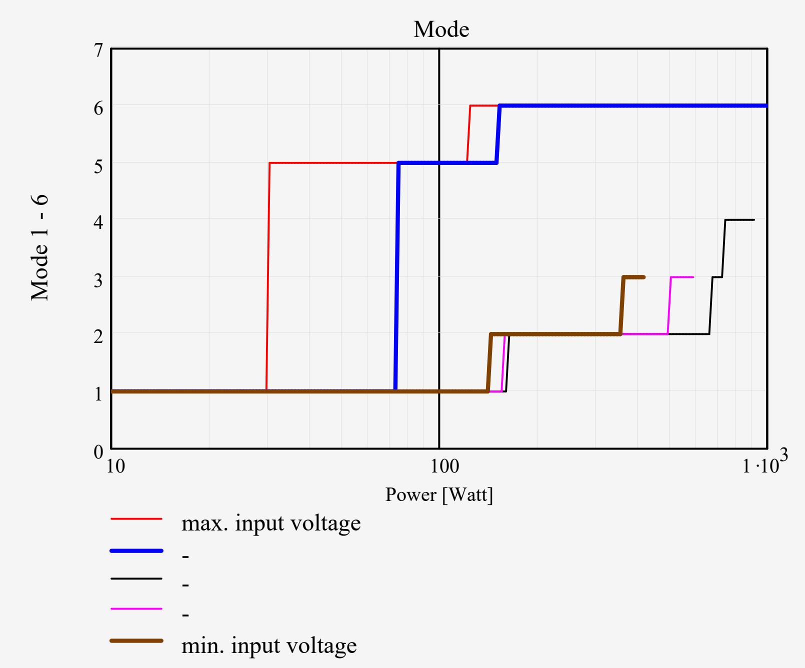
Number of steps pr. decade: $S \equiv 100$ $\quad i \equiv 0, 1 .. S \cdot \log\left(\frac{V_{cmax}}{V_{cmin}}\right)$ $\quad V_i \equiv V_{cmin} \cdot 10^{\frac{i}{S}}$

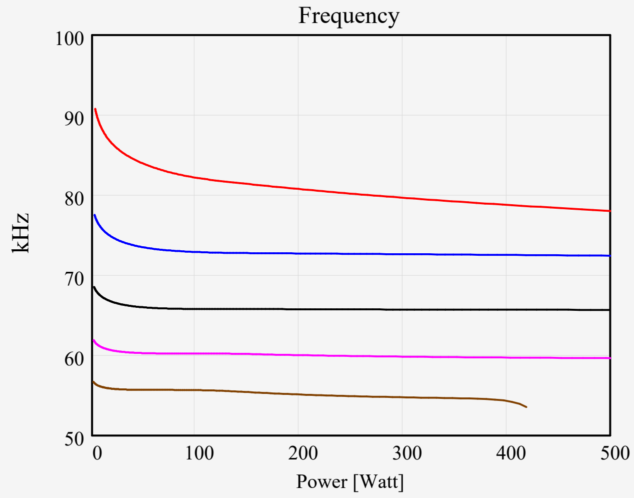
Plot to max. power: $Pmax \equiv 500$

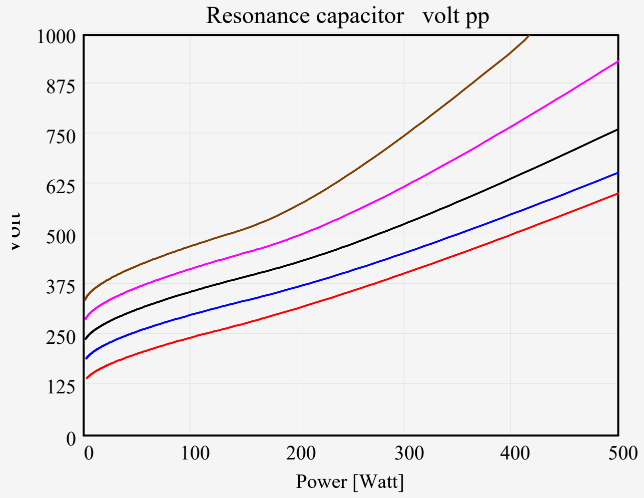


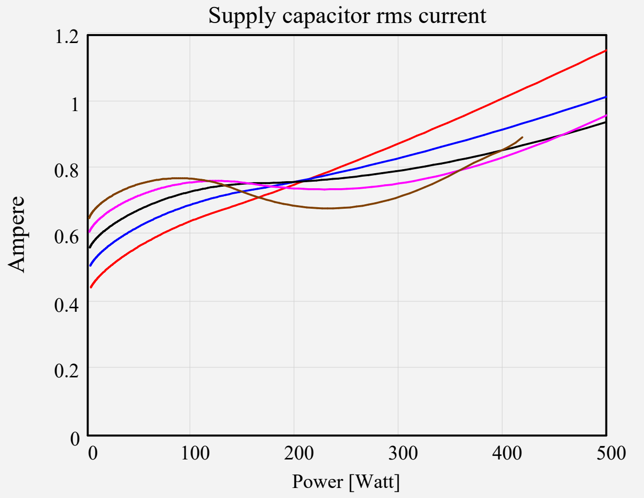
Basic half bridge resonance LLC converter.

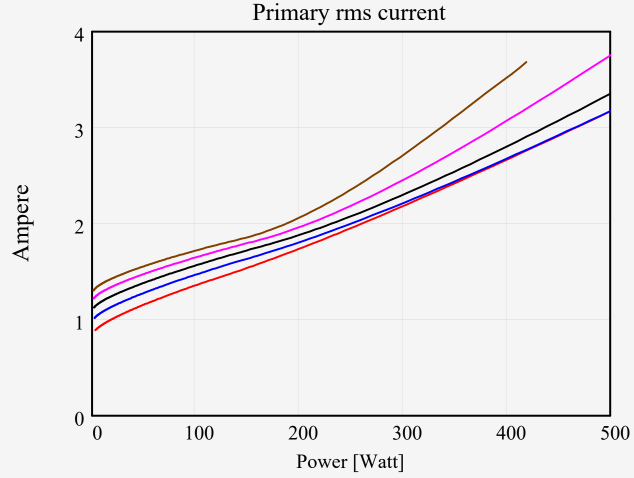
Input voltages: $\begin{pmatrix} VI_4 \\ VI_3 \\ VI_2 \\ VI_1 \\ VI_0 \end{pmatrix} = \begin{pmatrix} 460 \\ 410 \\ 360 \\ 310 \\ 260 \end{pmatrix}$

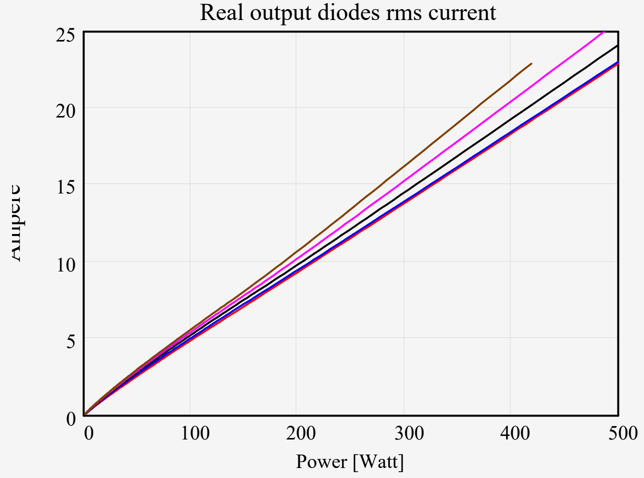


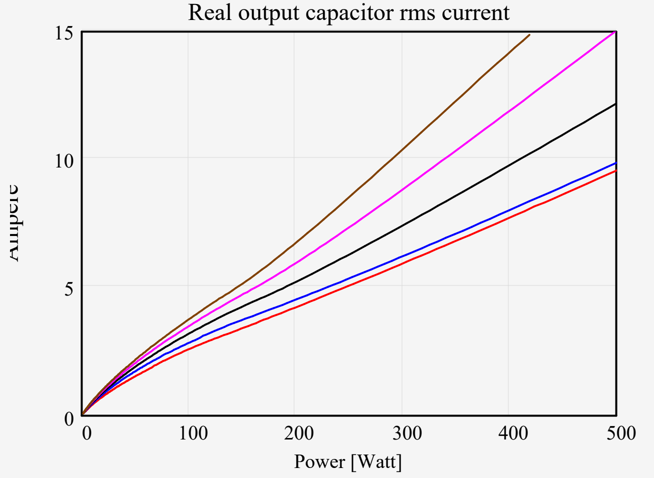


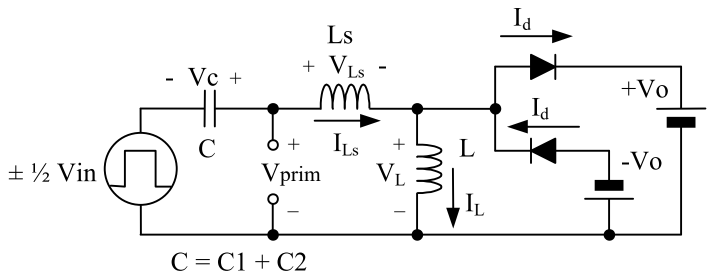












LLC converter model

Data input:

Selected component values: $C \equiv 30 \cdot 10^{-9}$ $Ls \equiv 172 \cdot 10^{-6}$ $L \equiv 344 \cdot 10^{-6}$

Input voltage Vin: $Vmin \equiv 260$ $Vmax \equiv 460$

Real output voltage: $Vout \equiv 24$

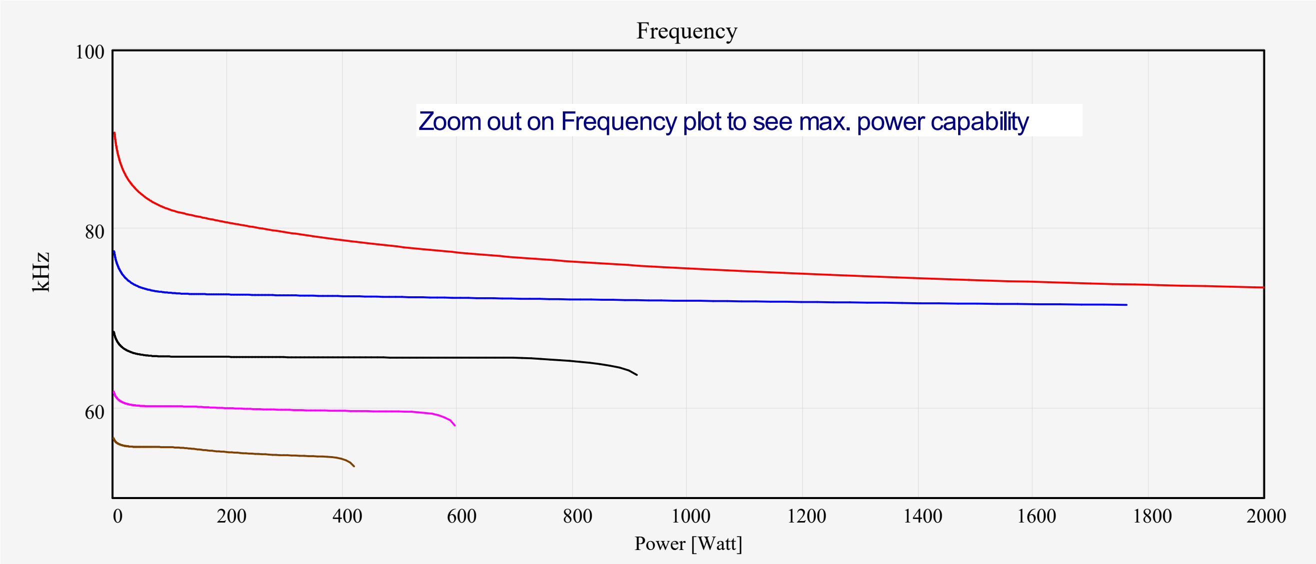
Fictitious output voltage in model: $Vo \equiv 196$

Inductance pr. turn^2 ratio: $ALp/ALs \equiv 1$

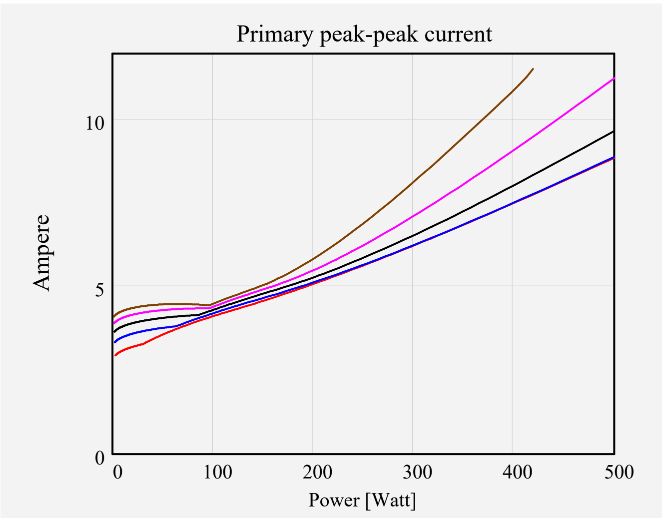
Primary inductance: $Lprim = 516 \times 10^{-6}$

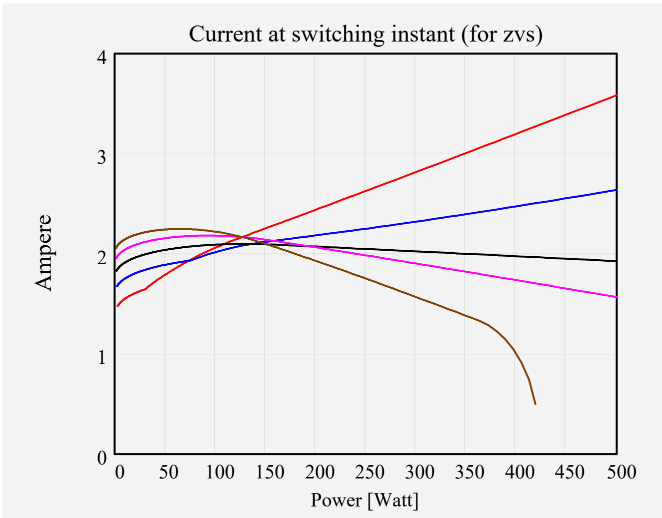
Coupling coefficient: $k = 0.816$

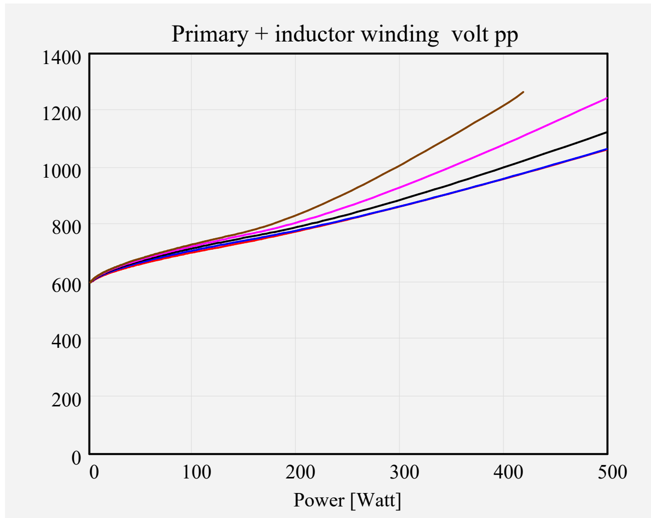
Turns ratio: $Np / Ns = 10.00$



$$\begin{pmatrix} VI_4 \\ VI_3 \\ VI_2 \\ VI_1 \\ VI_0 \end{pmatrix} = \begin{pmatrix} 460 \\ 410 \\ 360 \\ 310 \\ 260 \end{pmatrix}$$



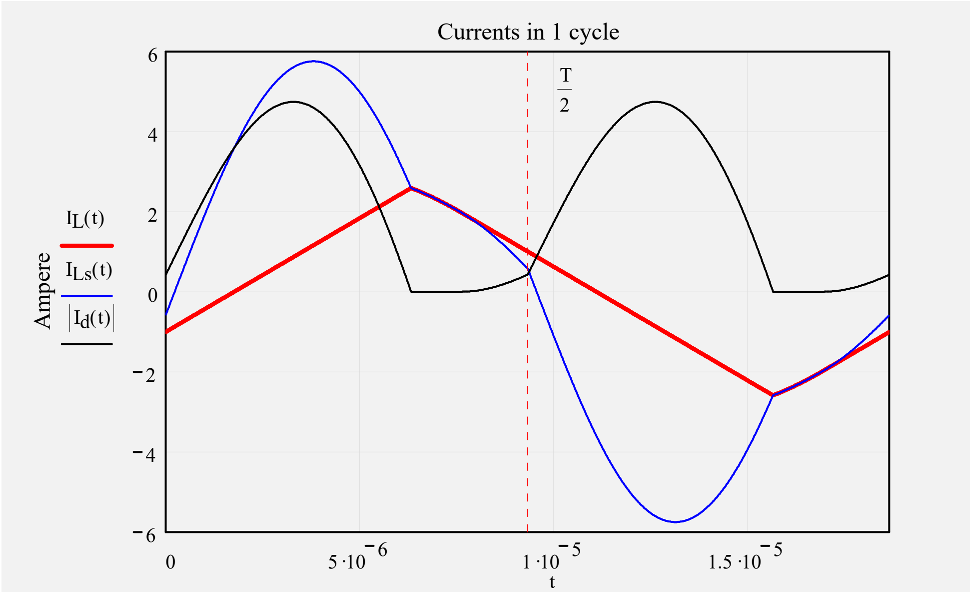




Time plots.

For check of the above results and for comparison with scope pictures or simulation, currents and voltages in the model are plotted within one switching cycle in which the input voltage starts positive.
Input voltage is switched between -½ Vin and ½ Vin.
Choose a capacitor start voltage Vc and an input voltage Vin.
Note the "Status" sign to keep an eye on problems.

Status = "OK"



Currents and voltages in the model.

$I_L(t)$: current in magnetising inductor.

$I_{Ls}(t)$: current in primary winding and switches.

$|I_d(t)|$: current in output diodes all together (in model).

Time plot data input:

Power: Power ≡ 420

Input DC voltage: Vin ≡ 261

$Frequency = 54 \times 10^3$

$Ii_{RMS} = 3.68$

$Io_{RMS} = 22.96$

$I_{LYT} = 14.87$

$V_{C.pp} = 1 \times 10^3$

$\Delta I_{LS} = 11.51$

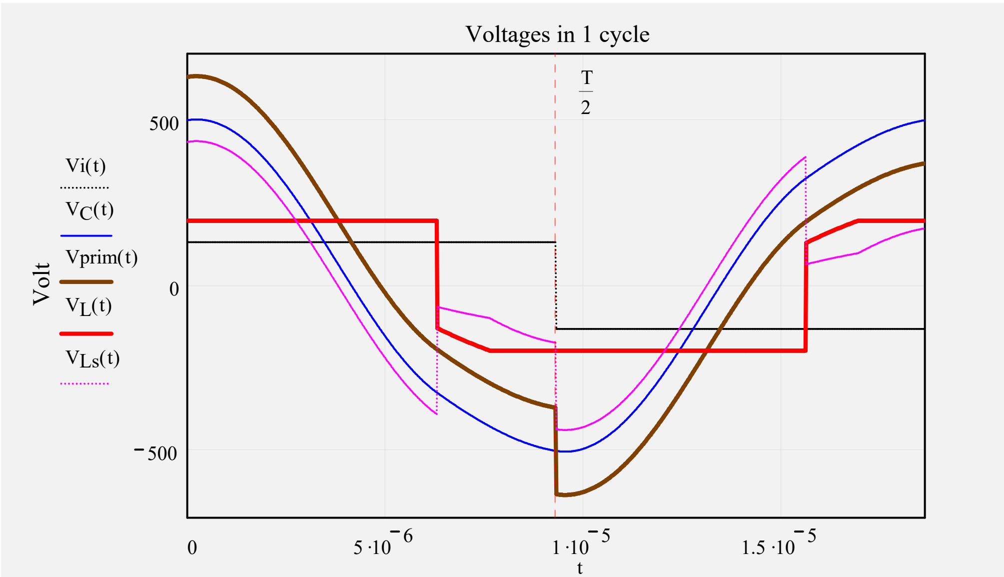
Vout = 24

Vo = 196

$C = 30 \times 10^{-9}$

$Ls = 172 \times 10^{-6}$

$L = 344 \times 10^{-6}$



Vi(t): Input square wave voltage.

$V_C(t)$: Resonance capacitor AC voltage.

Vprim(t): Voltage on input of resonance inductor Ls.

$V_L(t)$: secondary voltage (in model).
Will be clamped to ± Vo

$V_{Ls}(t)$: Voltage over external inductor Ls.

Mode = 3

Approx. air gap in core [mm]: gap = 0.92

Load independent point at

Frequency: $F_{lip} = 70.1 \times 10^3$ Hz

Input voltage: $Vin_{lip} = 392$

Transformer core and winding data input:

Core cross section: $A_{fe} \equiv 125 \cdot 10^{-6}$ [m^2] **ETD39**

Core volume: $vol_{fe} \equiv 11.5$ [cm^3]

Primary turns number: $Np \equiv 50$

Ferrite type: $ferrite \equiv 3$

ferrite = 1 ~ 3C90
ferrite = 2 ~ 3C94
ferrite = 3 ~ 3C95
ferrite = 4 ~ 3F3

copper resistivity @ 25ºC [Ω∗mm] $\rho ocu \equiv 17 \cdot 10^{-6}$

wire temperature	[ºC]	$temp \equiv 100$
diameter primary	[mm]	$Øprim \equiv 20$
diameter secondary	[mm]	$Øsek \equiv 20$
diameter primary wire	[mm]	$Øprimwire \equiv 0.05$
diameter secondary wire	[mm]	$Øsekwire \equiv 0.05$
parallel primary wires		$parprim \equiv 225$
parallel secondary wires		$parsek \equiv 1260$

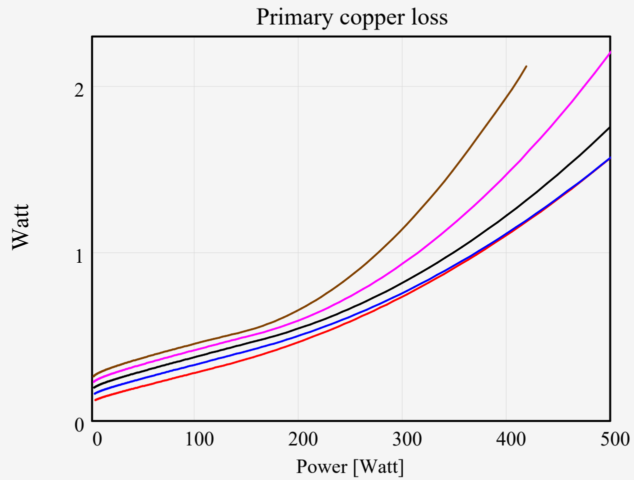
If you use external inductor on input side, write **inductor = "external"**.
Otherwise Ls is integrated in the transformer:

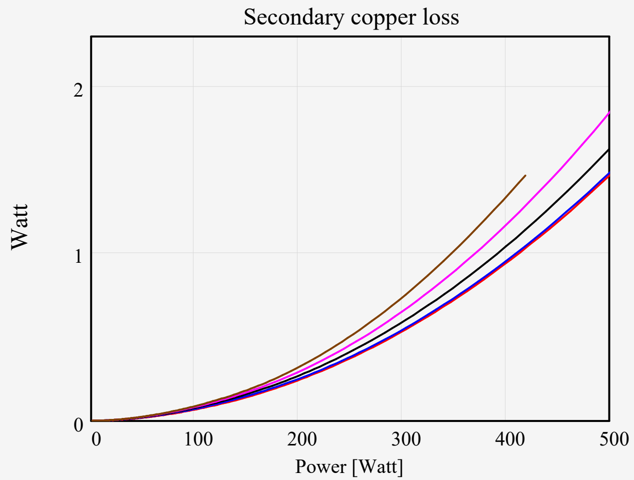
inductor ≡ "internal"

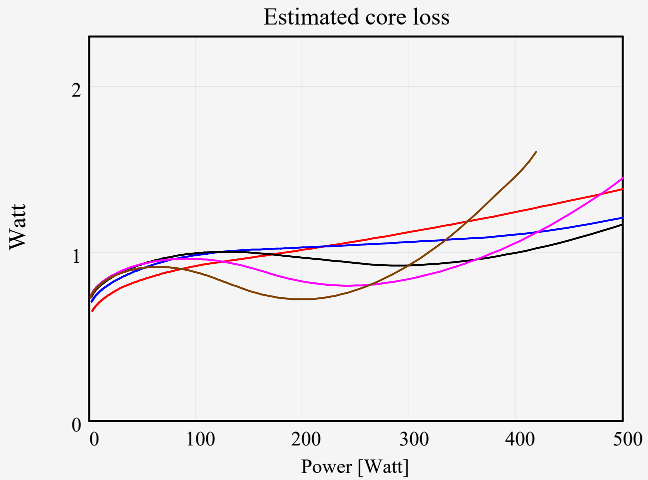
Transformer turns numbers: $Np = 50$, $Ns = 5.0$

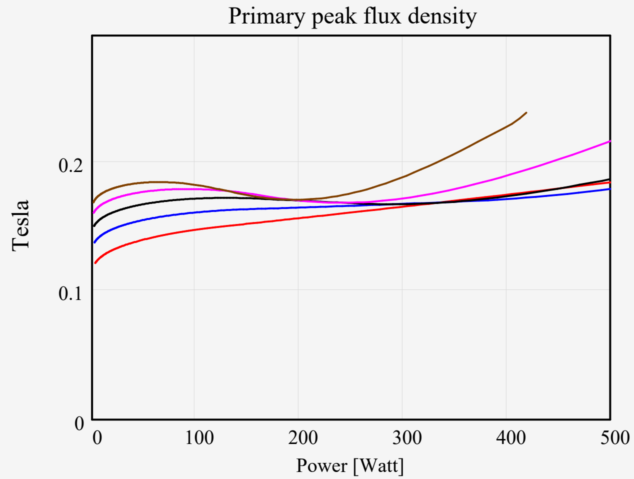
Primary wire resistance: $R_{prim} = 157 \times 10^{-3}$

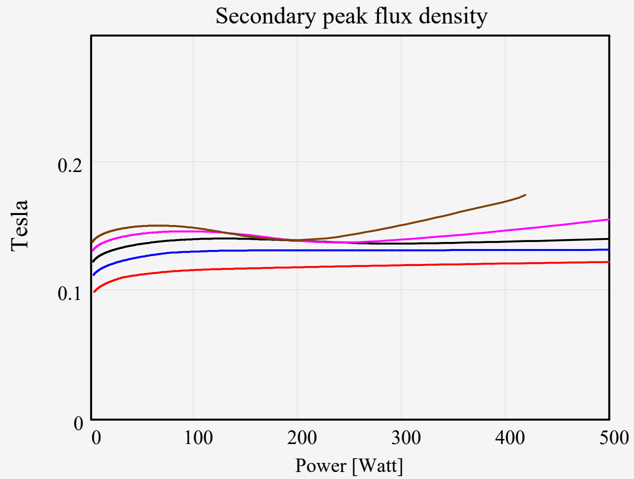
Secondary wire resistance: $R_{sek} = 2.79 \times 10^{-3}$

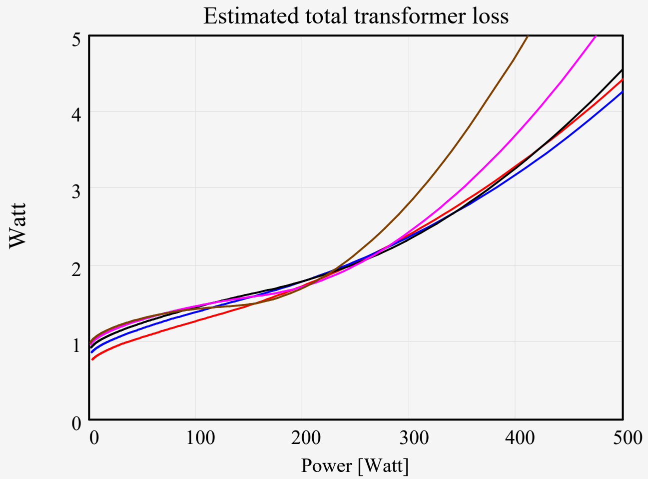






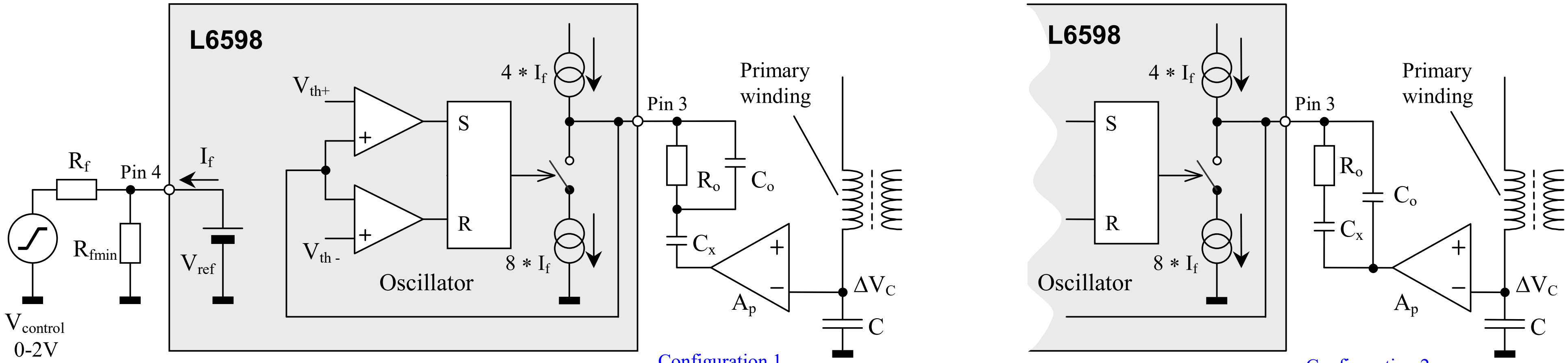






Charge mode application with L6598.

Design of control graphs for regulation loop linearity.

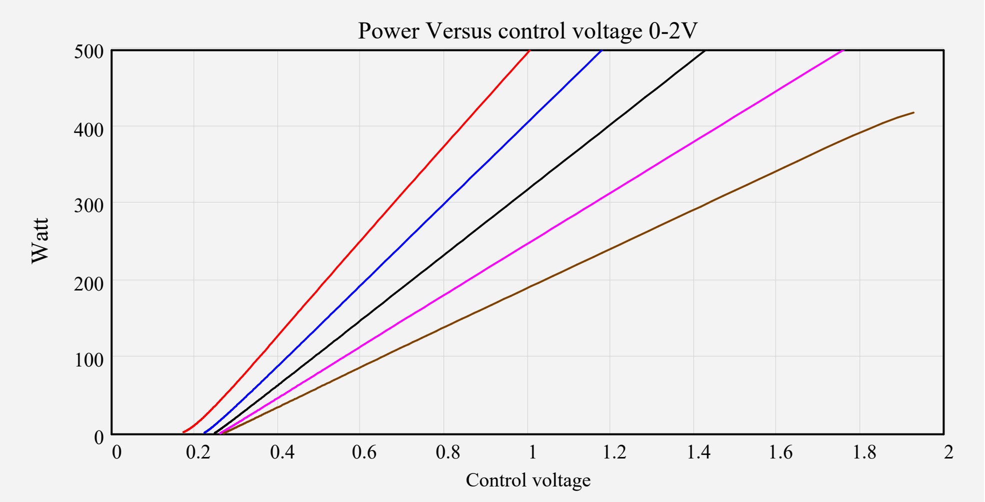


Charge mode model

Charge mode equations

Control data input:

Oscillator peak-peak voltage pin 3:	$\Delta V_{th} \equiv 2.9$
Pin 4 reference voltage:	$V_{ref} \equiv 2$
RC configuration - see above:	configuration ≡ 2
Oscillator capacitor:	$C_o \equiv 220 \cdot 10^{-12}$
Resistor in RC network:	$R_o \equiv 6800$
DC blocking capacitor:	$C_x \equiv 1$
Start-up resistor:	$R_{fmin} \equiv 220 \cdot 10^{3}$
Frequency programming resistor:	$R_f \equiv 39 \cdot 10^{3}$
Charge signal inverter gain:	$A_p \equiv 2.3 \cdot 10^{-3}$



Input voltages:

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