1000W不对称半桥LLC谐振电源参数计算书

客户需求：

输入参数：　占空比　D := 0.5　　效率　η := 0.94

输入电压　Vin_min := 390V　　Vin_max := 410V　　Vin_nor := 400V

输出参数：　输出电压　Vout := 24V　　Vout_pk := Vout·0.01 = 0.24 V

输出电流　Iout := 41.7A

整流二极管压降　Vd := 0.7V

输出功率　Pout := Vout·Iout = 1.001×10^3 W

过流保护　Ocp := 1.3

预设参数：　谐振频率　fr := 100kHz

电感比　k := 6

MOS管输出电容　Coss := 80pF　　Cstray := 200pF

死区时间　Td := 300ns

谐振参数

输出最大电流　Iout_max := Iout·1.2 = 50.04 A

输出最小电流　Iout_min := Iout·0.001 = 0.042 A

额定输入功率　$Pin\_nor := \frac{Pout}{\eta} = 1.065 \times 10^3$ W

变压器匝比　$n := \frac{Vin\_nor}{2\cdot(Vout + Vd)} = 8.097$

最大增益　$Gmax := 2\cdot n\cdot\frac{Vout + Vd}{Vin\_min} = 1.026$

最小增益　$Gmin := 2\cdot n\cdot\frac{Vout + Vd}{Vin\_max} = 0.976$

峰值增益　Gmax_pk := Gmax·1.15 = 1.179

额定负载电阻　$Ro := \frac{Vout}{Iout} = 0.576\,\Omega$

最小负载电阻　$Ro\_min := \frac{Vout}{Iout\_max} = 0.48\,\Omega$

最大负载电阻 $Ro\_max := \frac{Vout}{Iout\_min} = 575.54\,\Omega$

等效交流电阻 $Rac := \frac{8 \cdot n^2 \cdot Ro}{\pi^2} = 30.587\,\Omega$

最小交流电阻 $Rac\_min := \frac{8 \cdot n^2 \cdot Ro\_min}{\pi^2} = 25.489\,\Omega$

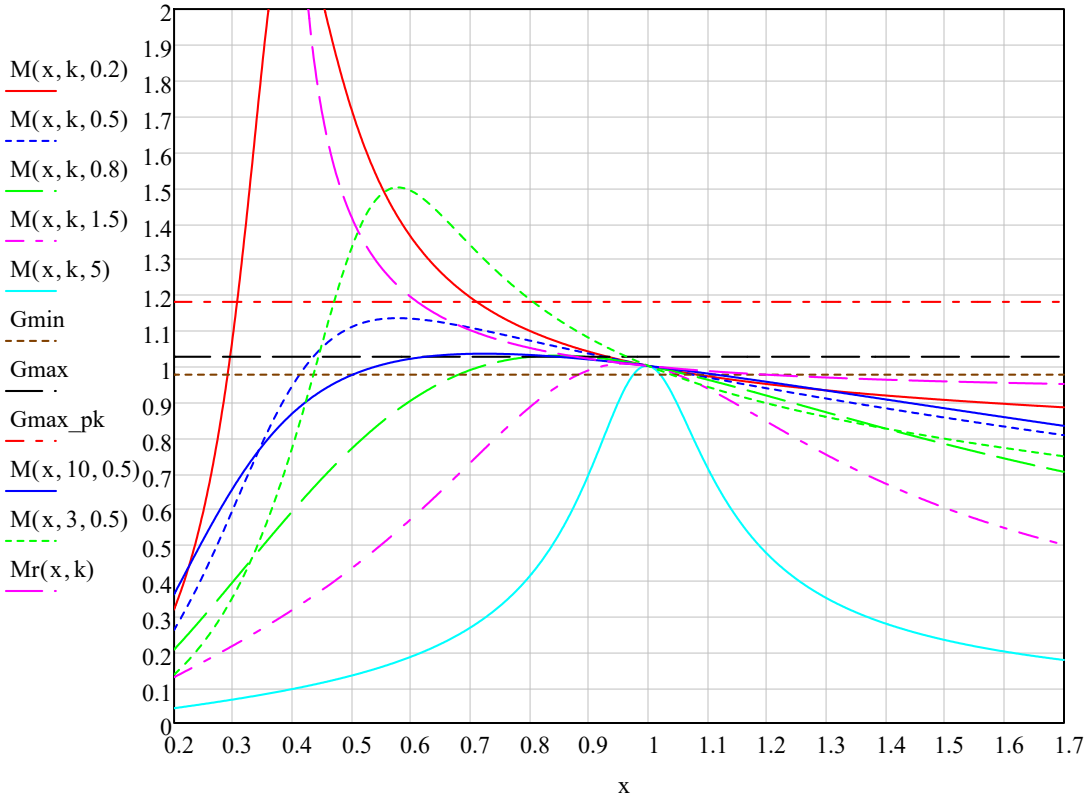
最大交流电阻 $Rac\_max := \frac{8 \cdot n^2 \cdot Ro\_max}{\pi^2} = 3.059 \times 10^4\,\Omega$

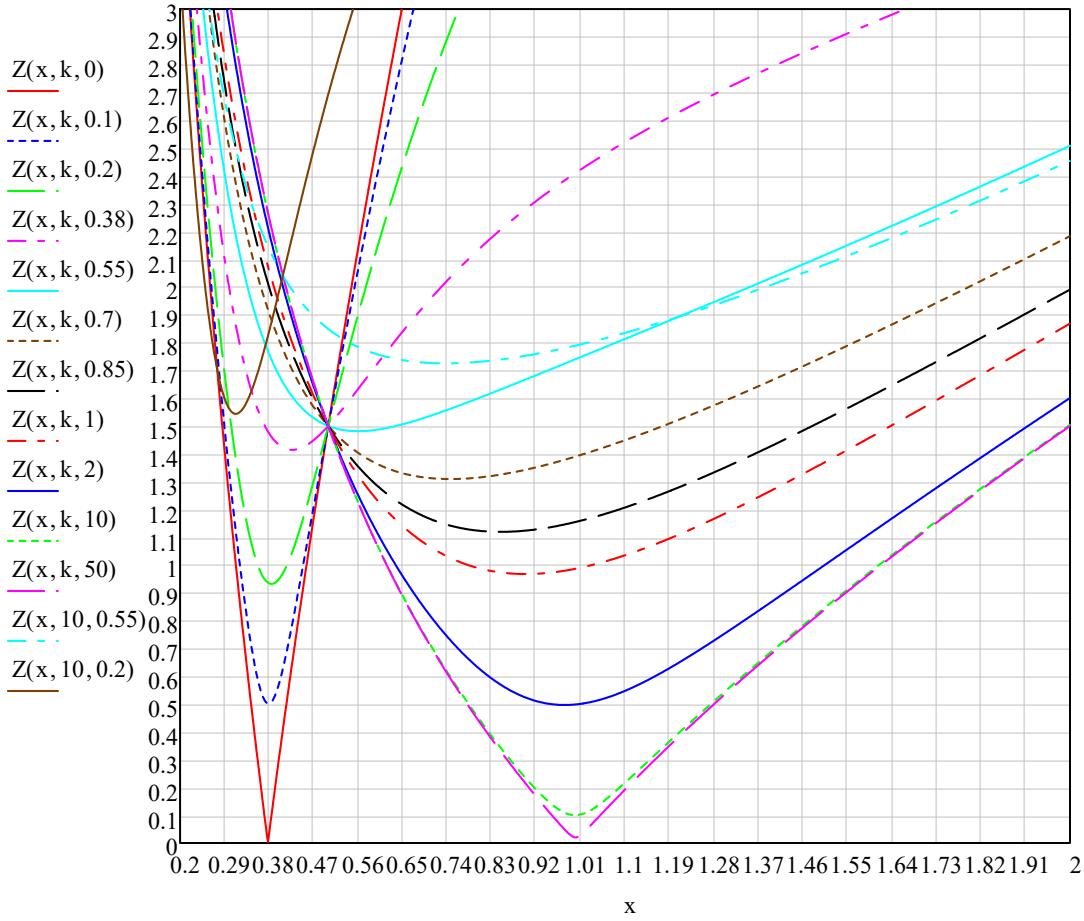
直流增益 $M(x,k,Q) := \frac{1}{\sqrt{\left[1 + \frac{1}{k} \cdot \left(1 - \frac{1}{x^2}\right)\right]^2 + \left(x - \frac{1}{x}\right)^2 Q^2}}$

阻性增益 $Mr(x,k) := \frac{1}{\sqrt{\left[1 + \frac{1}{k} \cdot \left(1 - \frac{1}{x^2}\right)\right]^2 + \left(x - \frac{1}{x}\right)^2 \left[\frac{1}{k\left(1 - x^2\right)} - \frac{1}{(k \cdot x)^2}\right]}}$

$$Q = \frac{2\pi f_r L_r}{R_{ac}} \qquad Z = \frac{Z_{in}}{R_{ac} Q} = \frac{Z_{in}}{2\pi f_r L_r}$$

阻抗 $Z(x,k,Q) := \sqrt{\left(\frac{k^2 \cdot x^2 Q}{1 + x^2 \cdot k^2 \cdot Q^2}\right)^2 + \left[x - \frac{1}{x} + \frac{x \cdot k}{1 + (k \cdot Q \cdot x)^2}\right]^2}$


M(x, k, 0.2)
M(x, k, 0.5)
M(x, k, 0.8)
M(x, k, 1.5)
M(x, k, 5)
Gmin
Gmax
Gmax_pk
M(x, 10, 0.5)
M(x, 3, 0.5)
Mr(x, k)
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
x



最小开关频率 $$fmin := \frac{fr}{\sqrt{1 + k \cdot \left(1 - \frac{1}{Gmax^2}\right)}} = 8.783 \times 10^4 \, Hz$$

最大开关频率 $$fmax := \frac{fr}{\sqrt{1 + k \cdot \left(1 - \frac{1}{Gmin}\right)}} = 1.085 \times 10^5 \, Hz$$

最大负载 $Qmax := \frac{1}{k \cdot Gmax} \cdot \sqrt{k + \frac{Gmax^2}{Gmax^2 - 1}} = 0.833$

谐振电容 $Cr := \frac{1}{2 \cdot \pi \cdot fr \cdot Rac\_min \cdot Qmax} = 7.499 \times 10^{-8}\,F$

谐振电感 $Lr := \frac{Qmax \cdot Rac\_min}{2 \cdot \pi \cdot fr} = 3.378 \times 10^{-5}\,H$

励磁电感 $Lm := k \cdot Lr = 2.027 \times 10^{-4}\,H$

谐振电流有效值 $ILr\_rms := \frac{Vout}{8 \cdot n \cdot Ro\_min} \cdot \sqrt{8\pi^2 + \frac{2 \cdot n^4 \cdot Ro\_min^2}{Lm^2 \cdot fr^2}} = 7.07\,A$

谐振电流峰值 $ILr\_pk := \sqrt{2} \cdot ILr\_rms = 9.999\,A$

谐振电容电压峰值 $VCr\_pk := \frac{Vin\_max}{2} + \frac{ILr\_pk}{2 \cdot \pi \cdot fmin \cdot Cr} = 446.6\,V$

ZVS验证 $ILm\_min > Ip$ 电容的充电电流小于放电电流

$ILm\_min := \frac{Vin\_max}{Lm} \cdot \frac{1}{4 \cdot fmax} = 4.663\,A$

电容充电电流 $Ip := (2Coss + Cstray) \cdot \frac{Vin\_nor}{Td} = 0.48\,A$ 满足ZVS

MOS管应力 $Imos := 3 \cdot ILr\_pk = 29.997\,A$ $Vmos := \frac{Vin\_max}{0.7} = 585.714\,V$

整流二极管应力 $Idd := 3 \cdot \frac{\pi \cdot Iout\_max}{4} = 117.904\,A$ $Vdd := \frac{2(Vout + Vd)}{0.7} = 70.571\,V$

输出电流纹波 $ICo := \sqrt{\frac{\pi^2 - 8}{8}} \cdot Iout\_max = 24.191\,A$

等效电阻ESR $ESR := \frac{Vout\_pk}{0.5 \cdot \pi \cdot Iout\_max} = 3.053 \times 10^{-3}\,\Omega$