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Coss, Qoss and Eoss example of data use from model
extracted data (SPA11N80C3)

$C_{oss_dat} :=$

	0
0	...

$Q_{oss_dat} :=$

	0
0	...

$E_{oss_dat} :=$

	0
0	...

Import data from Excel using data import wizard

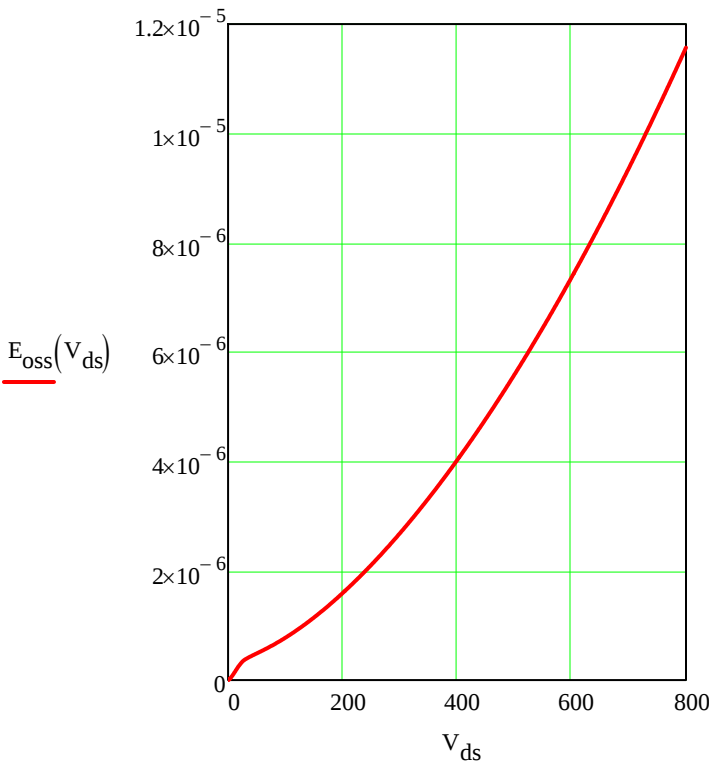
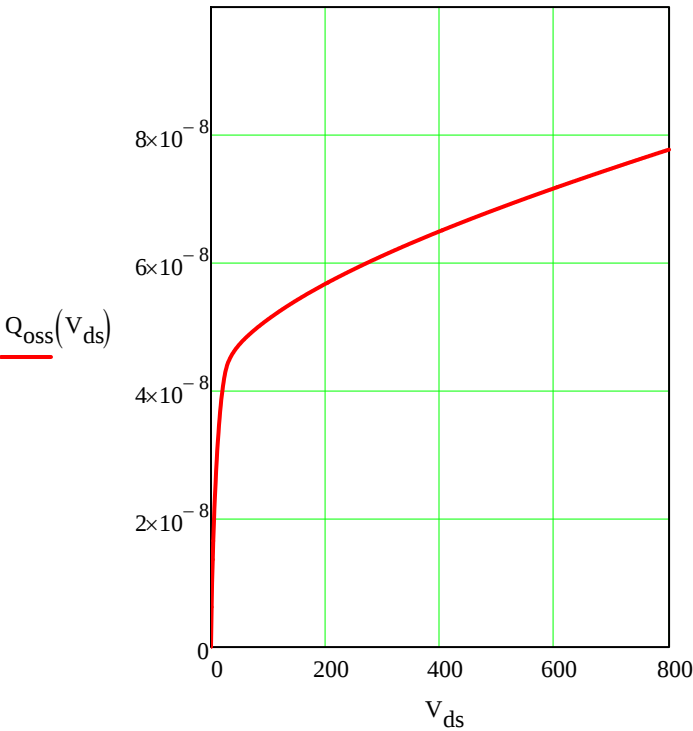
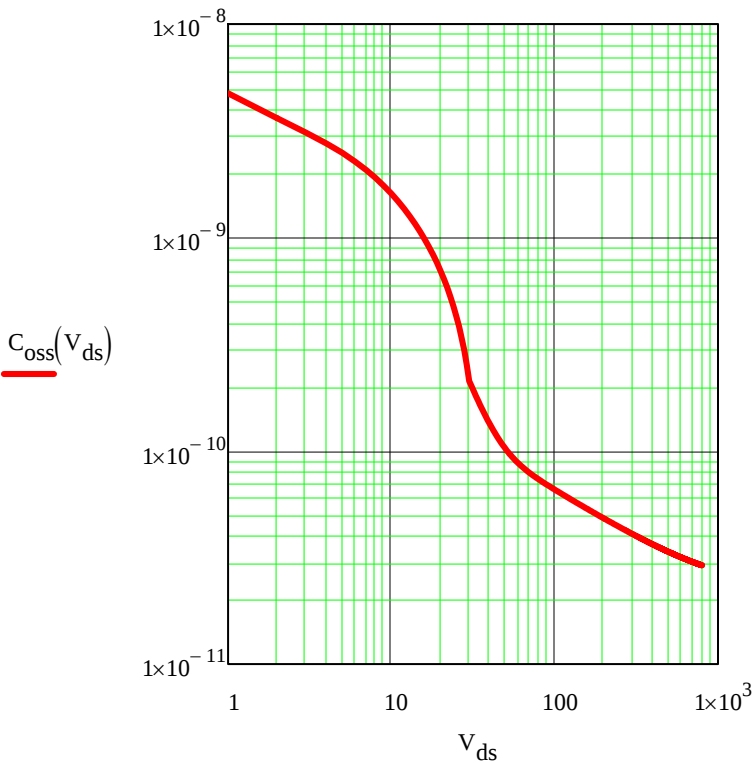
$V_{ds} := 0, 1 \dots 800$

$C_{oss}(V_{ds}) := C_{oss_dat}_{V_{ds}}$

$Q_{oss}(V_{ds}) := Q_{oss_dat}_{V_{ds}}$

$E_{oss}(V_{ds}) := E_{oss_dat}_{V_{ds}}$

Convert to function for easy plotting



$$C_{oss_100Vds} := C_{oss}(100) \cdot F = 65.667 \cdot \text{pF}$$

Data sheet cross-check for data verification
(check against 65pF data sheet value)

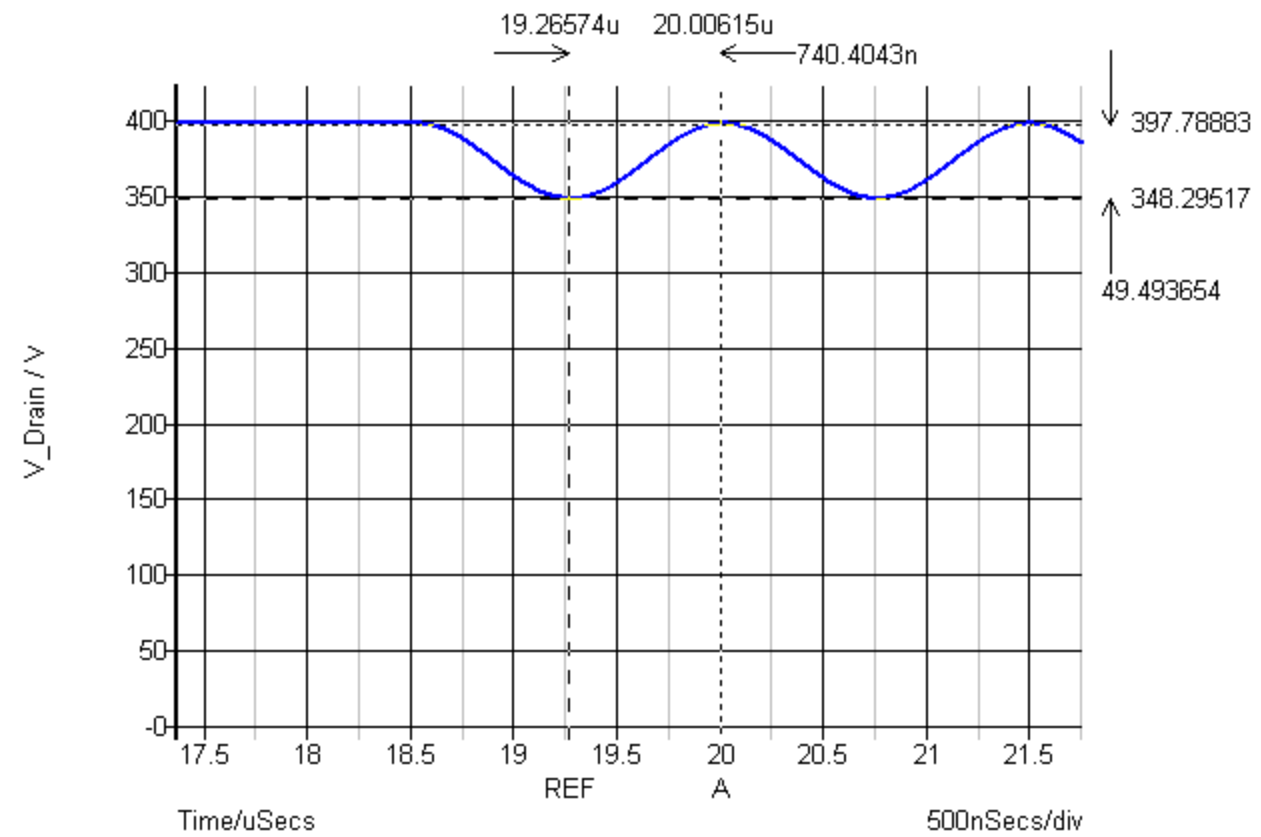
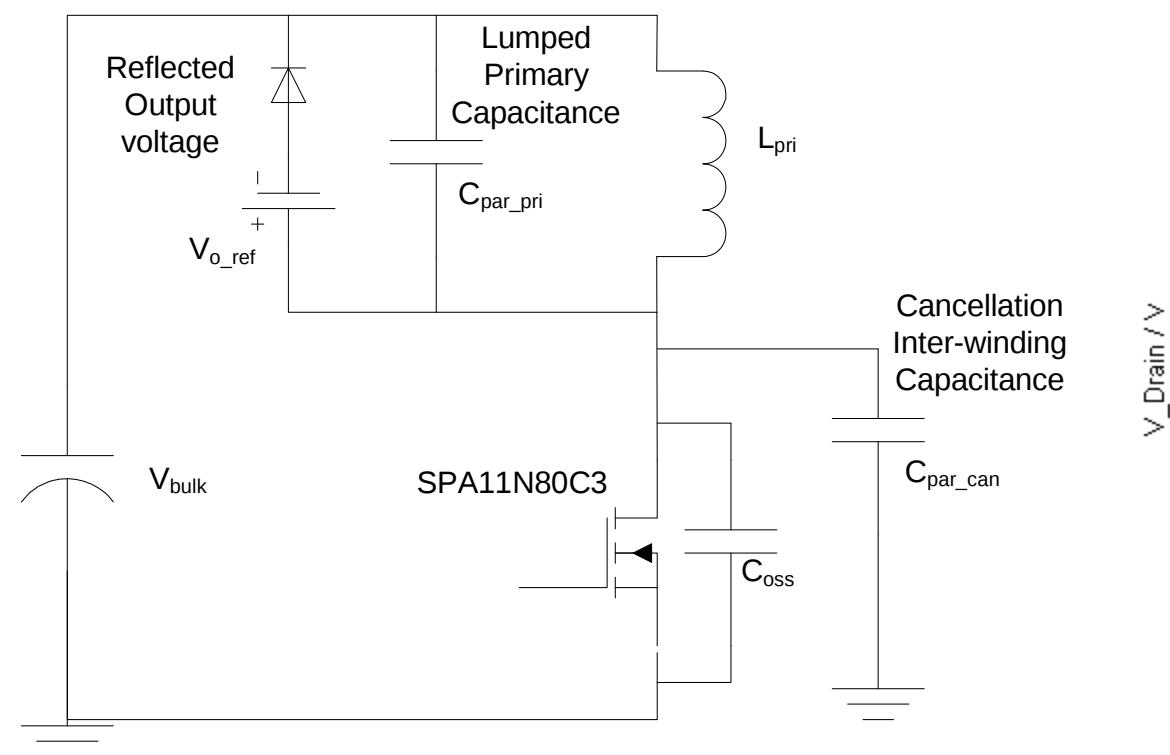
$$C_{o_er} := \frac{2 \cdot (E_{oss}(480) - E_{oss}(0))}{480^2 - 0^2} \cdot F = 45.553 \cdot \text{pF}$$

Data sheet cross-check for data verification
(check against 50pF data sheet value)

$$C_{o_tr} := \frac{(Q_{oss}(480) - Q_{oss}(0))}{480 - 0} \cdot F = 141.188 \cdot \text{pF}$$

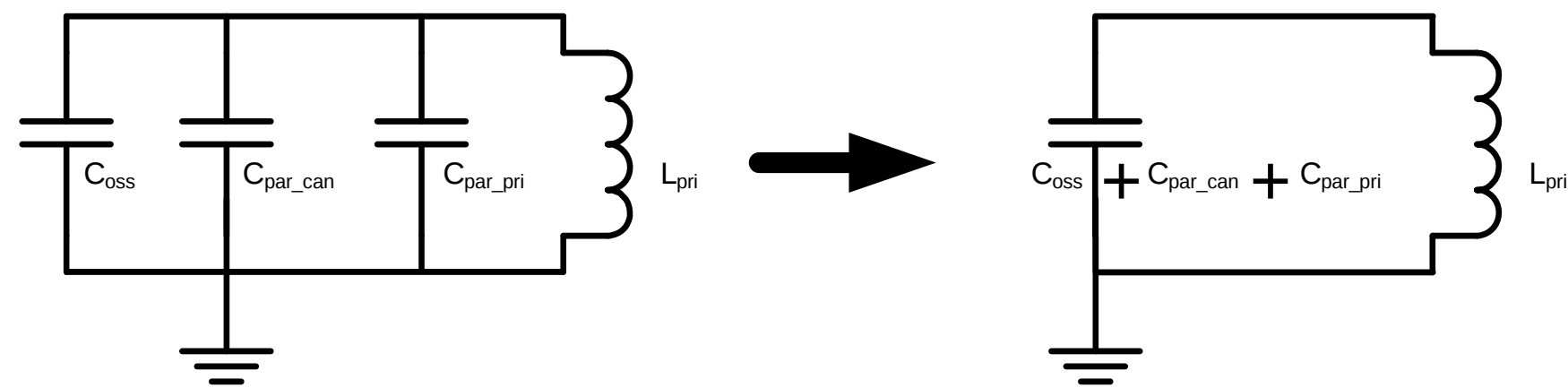
Data sheet cross-check for data verification
(check against 140pF data sheet value)

Equivalent quasi resonant flyback tank circuit:

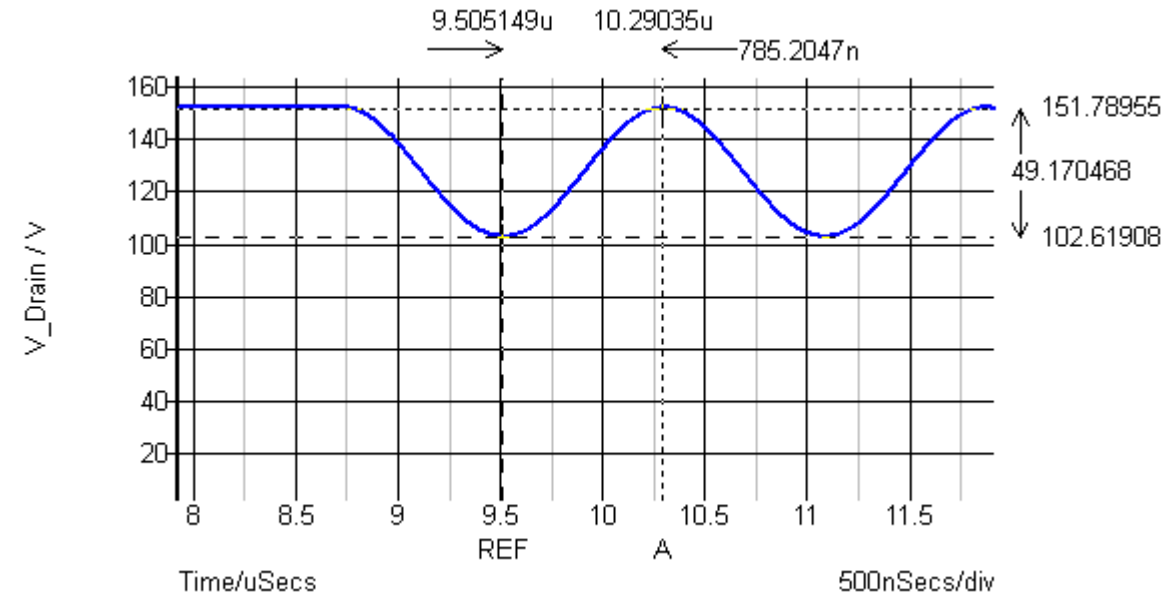


Example QR waveform from simulation

Simplification of quasi resonant flyback tank circuit during QR period:



$V_{pk} := 398$	V	Recorded peak and valley voltages on the primary side (Vds)
$V_{val} := 348$	V	
$t_{QR} := 1.48 \cdot 10^{-6}$	s	Recorded QR full-period time
$f_{QR} := \frac{1}{t_{QR}} = 6.757 \times 10^5$	Hz	QR frequency (based on time-measurement)
$L_{mag} := 300 \cdot 10^{-6}$	H	Known/measurable resonant component values
$L_{lkg} := 5 \cdot 10^{-6}$	H	
$L_{pri} := L_{mag} + L_{lkg} = 3.05 \times 10^{-4}$	H	
$C_{par_can} := 75 \times 10^{-12}$	F	Calculated time-related MOSFET Coss over voltage range (based on charge difference over voltage range)
$C_{oss_tr} := \frac{Q_{oss}(V_{pk}) - Q_{oss}(V_{val})}{V_{pk} - V_{val}} = 3.728 \times 10^{-11}$	F	
$C_{par_pri} := \frac{\left(\frac{1}{2 \cdot \pi \cdot f_{QR}}\right)^2}{L_{pri}} - C_{oss_tr} - C_{par_can} = 6.963 \times 10^{-11}$	F	
		Primary-reference lumped capacitance only un-known quantity in formula



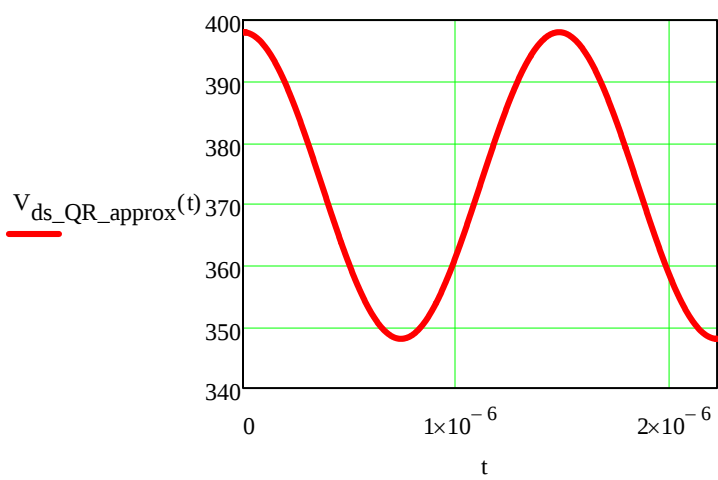
Example QR waveform from simulation

$V_{pk2} := 152$	V	
$V_{val2} := 103$	V	
$t_{QR2} := 1.570 \cdot 10^{-6}$	s	Values pertaining to QR period with low-line input voltage
$f_{QR2} := \frac{1}{t_{QR2}} = 6.369 \times 10^5$	Hz	
$C_{oss_tr2} := \frac{Q_{oss}(V_{pk2}) - Q_{oss}(V_{val2})}{V_{pk2} - V_{val2}} = 5.9 \times 10^{-11}$	F	
$C_{par_pri2} := \frac{\left(\frac{1}{2 \cdot \pi \cdot f_{QR2}}\right)^2}{L_{pri}} - C_{oss_tr2} - C_{par_can} = 7.071 \times 10^{-11}$	F	Equivalent lumped primary-side referenced capacitance under low-line input

$_N := 5$	T	Transformer turns-ratio
$V_{\text{bulk}} := 373$	V	Simulated bulk voltage measurement
$V_o := 5$	V	Output voltage
$V_{o_ref} := V_o \cdot _N$	V	Output voltage reflected through transformer to primary side

$$V_{ds_QR_approx}(t) := V_{\text{bulk}} - V_{o_ref} \cdot \sin\left[\frac{1}{\sqrt{L_{\text{pri}} \cdot (C_{\text{oss_tr}} + C_{\text{par_pri}} + C_{\text{par_can}})}} \cdot t + \frac{3}{2} \cdot \pi\right]$$

Approximating the QR-period Vds waveform with a sine-wave



Plot of approximate Vds (in volts) vs. time (in seconds)

$$i_{QR}(t) := (C_{\text{oss_tr}} + C_{\text{par_can}}) \cdot \left(\frac{d}{dt} V_{ds_QR_approx}(t)\right)$$

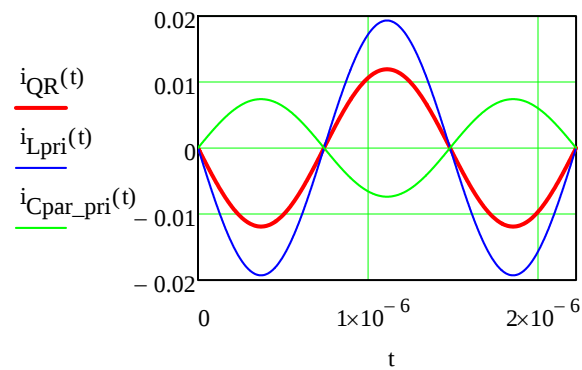
total loop current flows through the parallel combination of Coss and primary-to-cancellation inter-winding capacitance Cpar_can

$$i_{Lpri}(t) := 0 + \frac{1}{L_{\text{pri}}} \cdot \int_0^t V_{\text{bulk}} - V_{ds_QR_approx}(t) \, dt$$

Standard current/voltage relationship for inductors with initial condition of 0A flowing at the start-time of T_QR

$$i_{Cpar_pri}(t) := i_{QR}(t) - i_{Lpri}(t)$$

Kirchoff's current law applied to find the last unknown current



Sanity-check plot of currents (in A) vs. time (in s)

$$E_{\text{cpri_v}}(V_{\text{ds}}) := \frac{1}{2} \cdot C_{\text{par_pri}} \cdot (V_{\text{ds}} - V_{\text{bulk}})^2 \quad \text{J}$$

Total capacitive energy vs. Vds for Cpar_pri (has Vds - Vbulk across it)

$$E_{\text{ccan_v}}(V_{\text{ds}}) := \frac{1}{2} \cdot C_{\text{par_can}} \cdot V_{\text{ds}}^2 \quad \text{J}$$

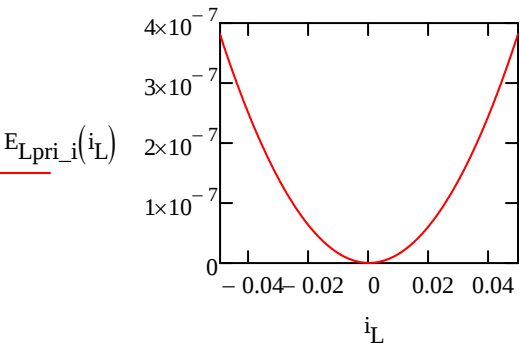
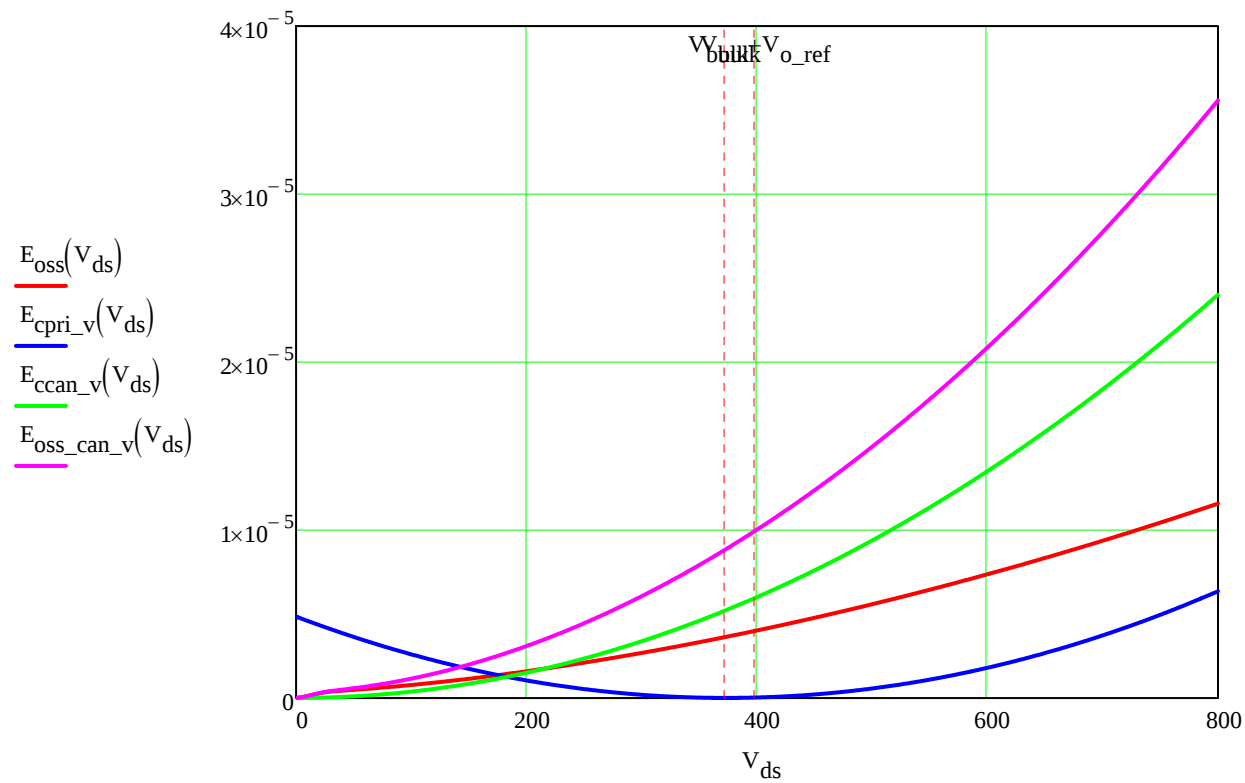
Total capacitive energy vs. Vds for Cpar_can (has Vds across it)

$$E_{\text{oss_can_v}}(V_{\text{ds}}) := E_{\text{ccan_v}}(V_{\text{ds}}) + E_{\text{oss}}(V_{\text{ds}}) \quad \text{J}$$

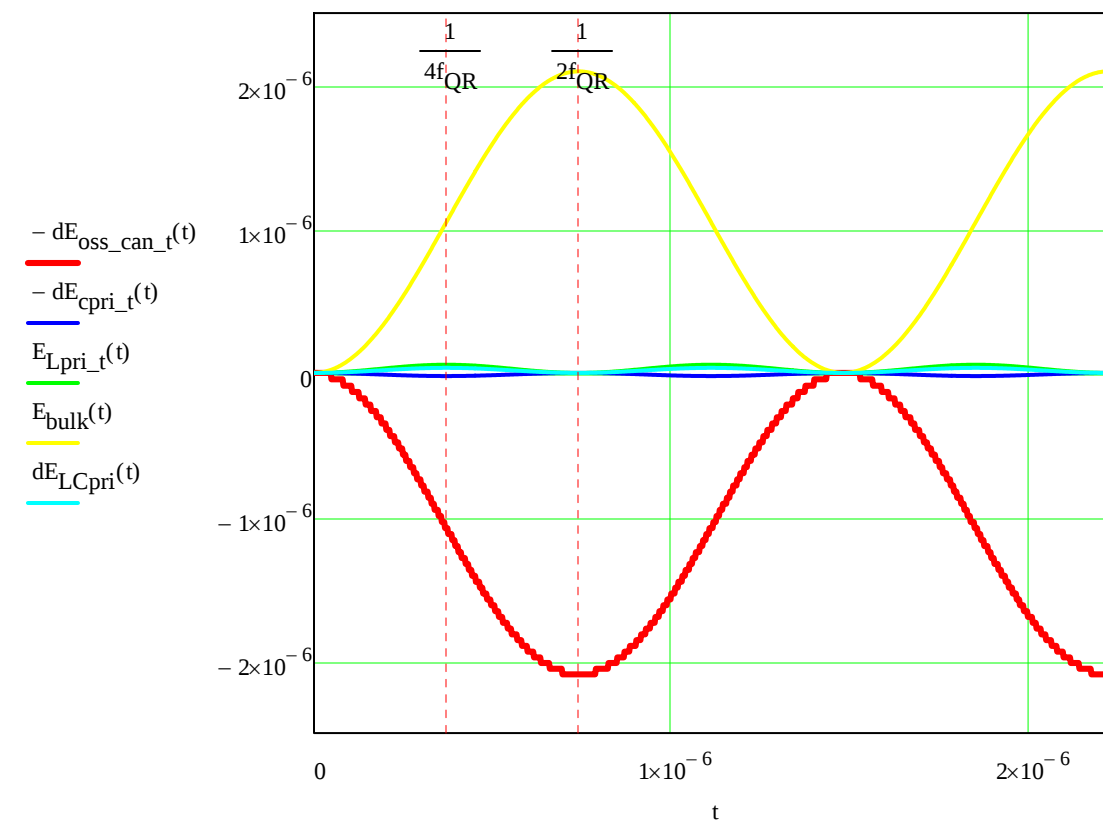
Total capacitive energy in parallel connection of Coss and Cpar_can Vs. Vds

$$E_{\text{Lpri_i}}(i_{\text{Lpri}}) := \frac{1}{2} \cdot i_{\text{Lpri}}^2 \cdot L_{\text{pri}} \quad \text{J}$$

Total inductive energy in primary inductance vs. current through it



$dE_{oss_can_t}(t) := E_{oss_can_v}(V_{bulk} + V_{o_ref}) - E_{oss_can_v}(\text{round}(V_{ds_QR_approx}(t), 0))$	Energy delta over time for Coss parallel with Cpar_can (referencing initial energy at initial voltage)
$dE_{cpri_t}(t) := E_{cpri_v}(V_{bulk} + V_{o_ref}) - E_{cpri_v}(V_{ds_QR_approx}(t))$	Energy delta over time for primary referenced cap (initial energy based on initial voltage across it)
$E_{oss_t}(t) := E_{oss}(\text{round}(V_{ds_QR_approx}(t), 0))$	Energy in Coss over time (not a delta)
$E_{ccan_t}(t) := E_{ccan_v}(V_{ds_QR_approx}(t))$	Energy in Cpar_can over time (not a delta)
$E_{Lpri_t}(t) := E_{Lpri_i}(i_{Lpri}(t))$	Energy in magnetizing inductance over time (starting energy is exactly 0, so absolute energy over time <i>is</i> the delta)
$P_{bulk}(t) := -i_{QR}(t) \cdot V_{bulk}$	Instantaneous power in the bulk-voltage source
$E_{bulk}(t) := \int_0^t P_{bulk}(t) dt$	Energy delta in the bulk-voltage source (based on power integrated)
$dE_{LCpri}(t) := (-dE_{cpri_t}(t) + E_{Lpri_t}(t))$	Energy delta in the primary side reference lumped capacitance and primary side inductance combined (IC = 0)



$E_{oss_can_init} := E_{oss_can_v}(V_{bulk} + V_{o_ref}) \cdot J = 9.926 \times 10^{-6} \text{ J}$	Energy stored on capacitance initially
$E_{oss_can_bulk} := E_{oss_can_v}(V_{bulk}) \cdot J = 8.848 \times 10^{-6} \text{ J}$	Energy stored on capacitace at Vds=Vbulk
$E_{qrt_diff} := E_{oss_can_init} - E_{oss_can_bulk} = 1.078 \times 10^{-6} \text{ J}$	Energy delivered to source during first 1/4 period
$E_{oss_can_val} := E_{oss_can_v}(V_{bulk} - V_{o_ref}) \cdot J = 7.832 \times 10^{-6} \text{ J}$	Energy stored on capacitance at Vds=Vval
$E_{2ndqrt_diff} := E_{oss_can_bulk} - E_{oss_can_val} = 1.016 \times 10^{-6} \text{ J}$	Energy delivered to source during second 1/4 period
$E_{turn_on_loss} := E_{oss}(\text{round}(V_{val}, 0)) + E_{ccan_v}(V_{val}) = 7.832 \times 10^{-6} \text{ J}$	Energy burnt in Rds(on) during MOSFET turn-on
$P_{turn_on_loss} := E_{turn_on_loss} \cdot 100 \cdot 10^3 \cdot W = 783.19 \cdot \text{mW}$	Expected MOSFET turn-on power loss in 100kHz switching frequency application based on Eoss and Epar_can
$E_{turn_on_398V} := E_{oss}(V_{bulk} + V_{o_ref}) + E_{ccan_v}(V_{bulk} + V_{o_ref}) = 9.926 \times 10^{-6} \text{ J}$	Energy dissipated if hard-switching at the peak (probabillity in DCM)
$P_{turn_on_398V} := E_{turn_on_398V} \cdot 100 \cdot 10^3 \cdot W = 992.575 \cdot \text{mW}$	Equivalent turn-on power dissipation for peak-switching in DCM at 100kHz
$E_{turn_on_20V} := E_{oss}(20) + E_{ccan_v}(20) = 2.837 \times 10^{-7} \text{ J}$	Energy dissipated if valley voltage is 20V (at low input- and high output-voltage)
$P_{turn_on_20V} := E_{turn_on_20V} \cdot 100 \cdot 10^3 \cdot W = 28.368 \cdot \text{mW}$	Equivalent turn-on power dissipation for lower valley switching

LLC resonant transition time example

$V_{bulk_llc} := 400$	V	
$I_{Lr} := 1$	A	
$t_{res_trans} := \frac{Q_{oss}(V_{bulk_llc}) \cdot 2}{I_{Lr}} \cdot s = 129.93 \cdot \text{ns}$		Time it takes for the "constant" resonant inductor current to charge twice (half-bridge) Qoss to the full bulk-voltage (typically 400V in PFC-front stage LLC application)