IEEE 802.3af DTE Power via MDI

PD AC Input impedance – Sensitivity Analysis

AD HOC A.I. 2.3

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Objectives

- Vac_close vs. PD input ac impedance
- PD input ac impedance – design equations
- Lab tests, simulations and equations verification

Test setup – PSE side

PARAMETERS:

Cpse = 0.22uF

Cprobe = 10uF

Rpse = 400k

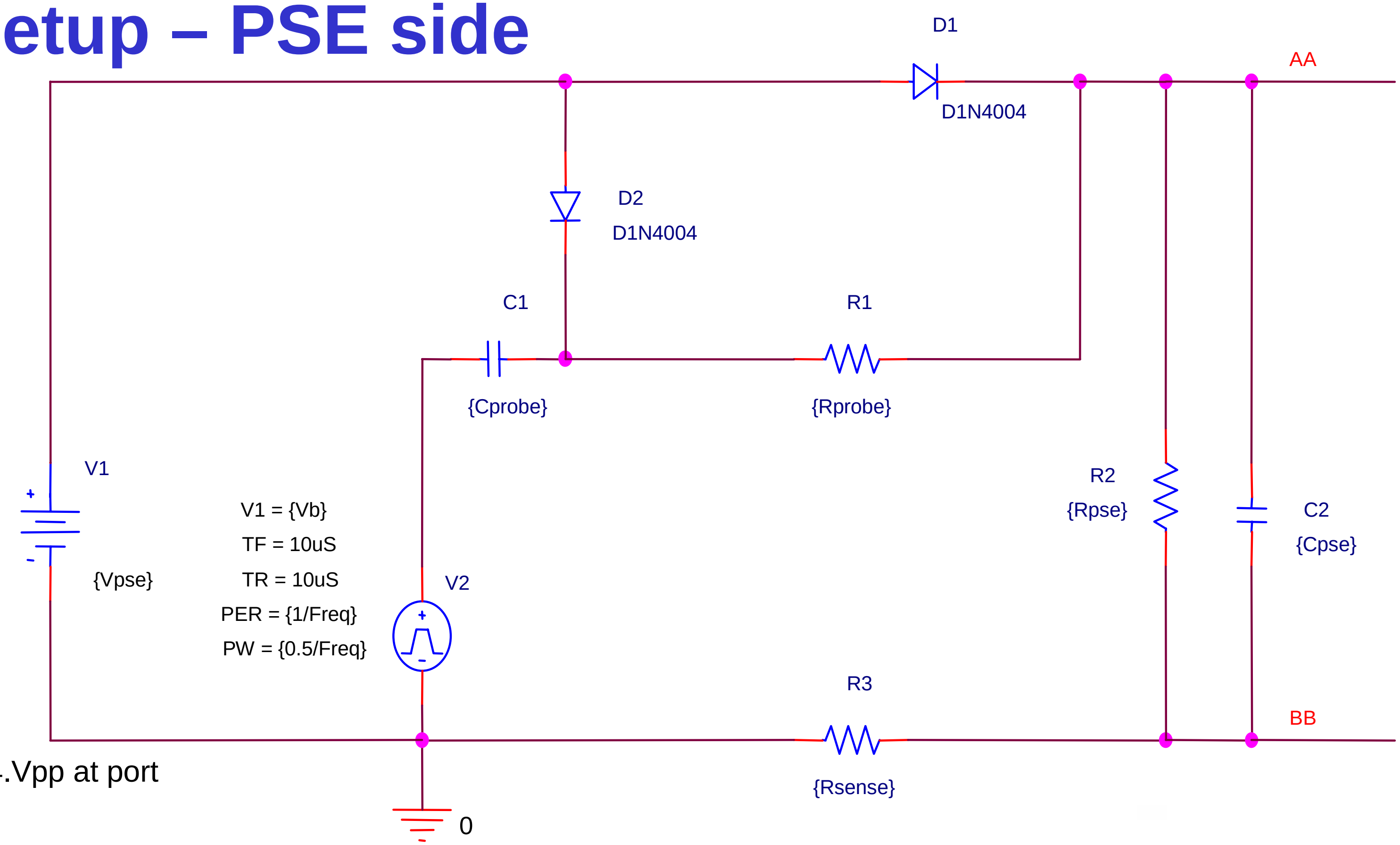
Rprobe = 7.5K

Rsense = 2

Freq = 125

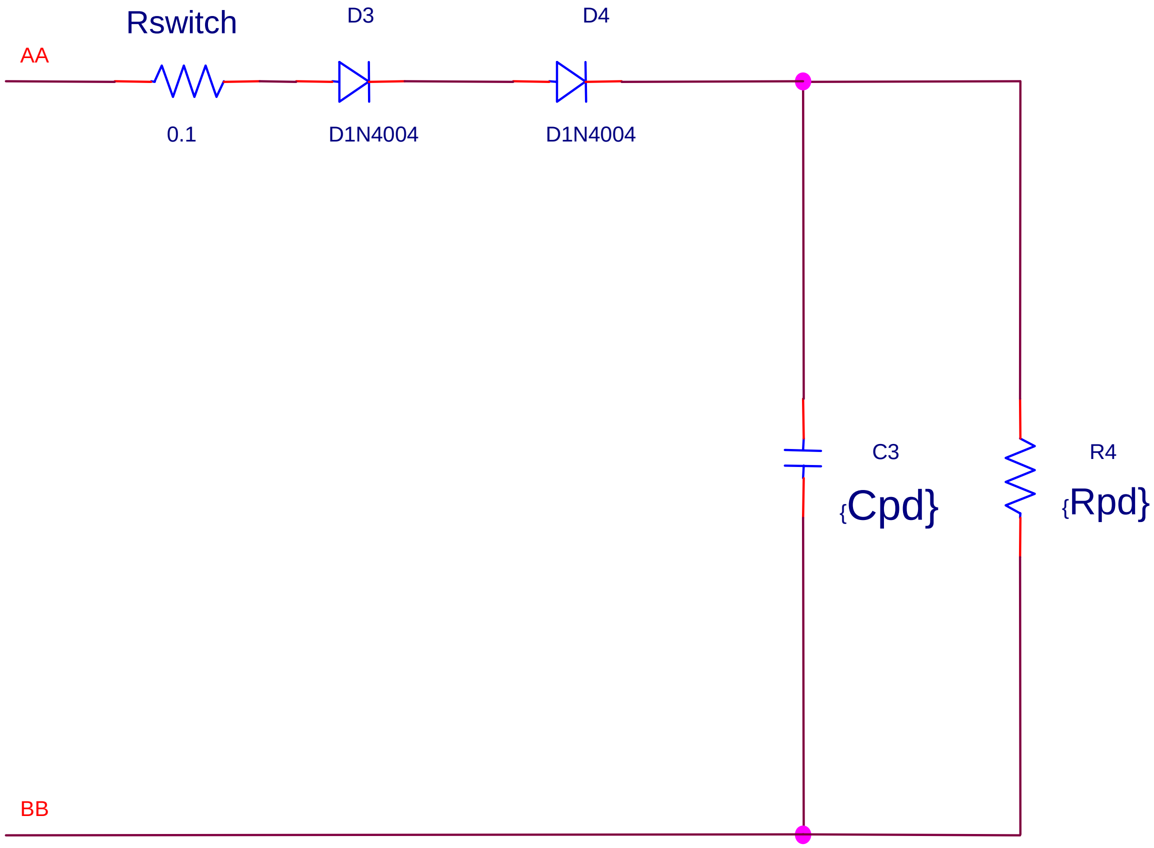
Vpse = 49

D1,D2 =1N4004

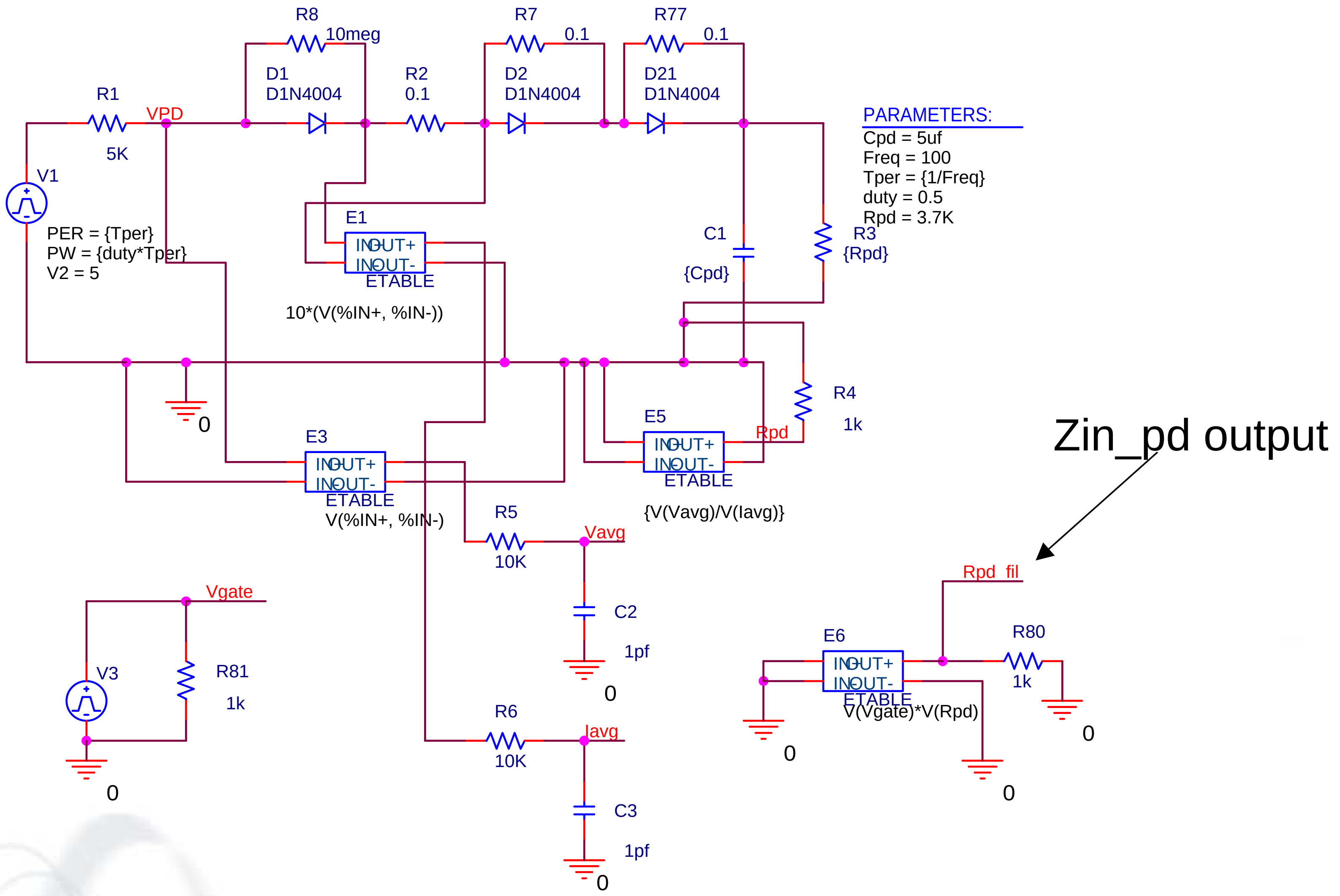


Vb = set to have 4.4.Vpp at port

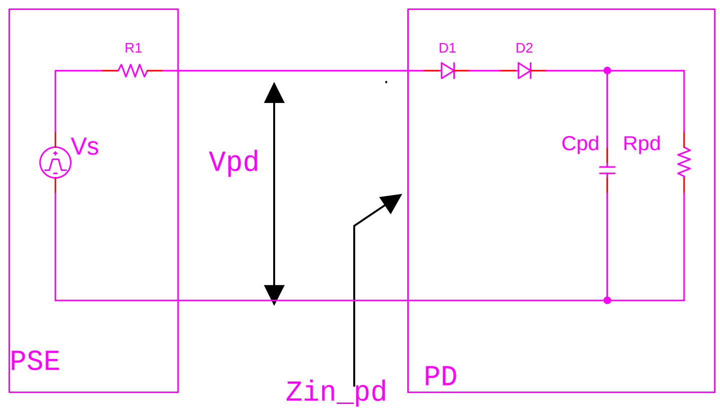
Test setup – PD side



Analysis of PD input impedance



Deriving Zin_pd- part A



$$\frac{Vpd}{Vs} = \frac{Zin\_pd}{Zin\_pd + R1} = \alpha \qquad \text{Eq-1}$$

$$\frac{Vpd}{Vs} = \alpha \qquad \text{Eq-2}$$

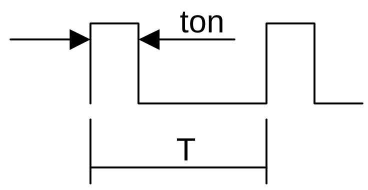
$$Zin\_pd = \frac{\alpha}{1-\alpha} \cdot R1 \qquad \text{Eq-3}$$

$$Vpd = N \cdot Vd + 0.5 \cdot v1 + 0.5 \cdot v2$$

For N>0, toff< τ2. Eq-4

$$Vpd = N \cdot Vd + v1$$

For N>0, toff> τ2. Eq-5



$$v1 = \frac{Veqv \cdot \left[1 - e^{\frac{-D \cdot T}{\tau 1}}\right]}{1 - e^{\frac{-DT}{\tau 1}} \cdot e^{\frac{-(1-D)T}{\tau 2}}}$$

$$v2 = v1 \cdot \left[e^{\frac{-(1-D)\cdot T}{\tau 2}}\right]$$

$$Veqv = \frac{(Vs - N \cdot Vd) \cdot Rpd}{Rpd + R1}$$

$$\tau 1 = \frac{R1 \cdot Rpd}{Rpd + R1} \cdot Cpd$$

$$\tau 2 = Rpd \cdot Cpd \qquad \text{For N>0}$$

$$\tau 2 = \tau 1 \qquad \text{For N=0}$$

Vs=pulse source

F=frequency,

D=ton/T

T=1/f

Tr=tf<<T

N=number of series diode in the PD

Vd=diode forward voltage drop

Deriving Zin_pd- part B

For τ2<toff ➔ v1(t)=Veqv ➔Vpd=N*Vd+Veqv

➔Zin_pd= R1*(N*Vd+Veqv)/(1- N*Vd+Veqv)

➔For N=0 ➔ Zin_pd=Rpd

➔For N>0 ➔ Zin>Rpd due to the diode drop in series to Rpd.

➔For τ2>toff , the RC filter is integrate the voltage across Cpd by averaging it.

➔In this case Zin_pd < Rpd or Zin_pd>Rpd pending on all parameters

➔The highest impedance occur for N=Nmax and τ2<toff , ➔Zin_pd>Rpd

Worst case PD input ac impedance w/o DC bias

- Rpd_min at normal powering mode = 37/10mA=3.7K
- Rpd_max at normal powering mode = 57/10mA = 5.7K
- Cpd varies from 5uF to 500uF
- 1Hz< f < 500Hz
- Zin_pd max with 3 series diode = 10.97K

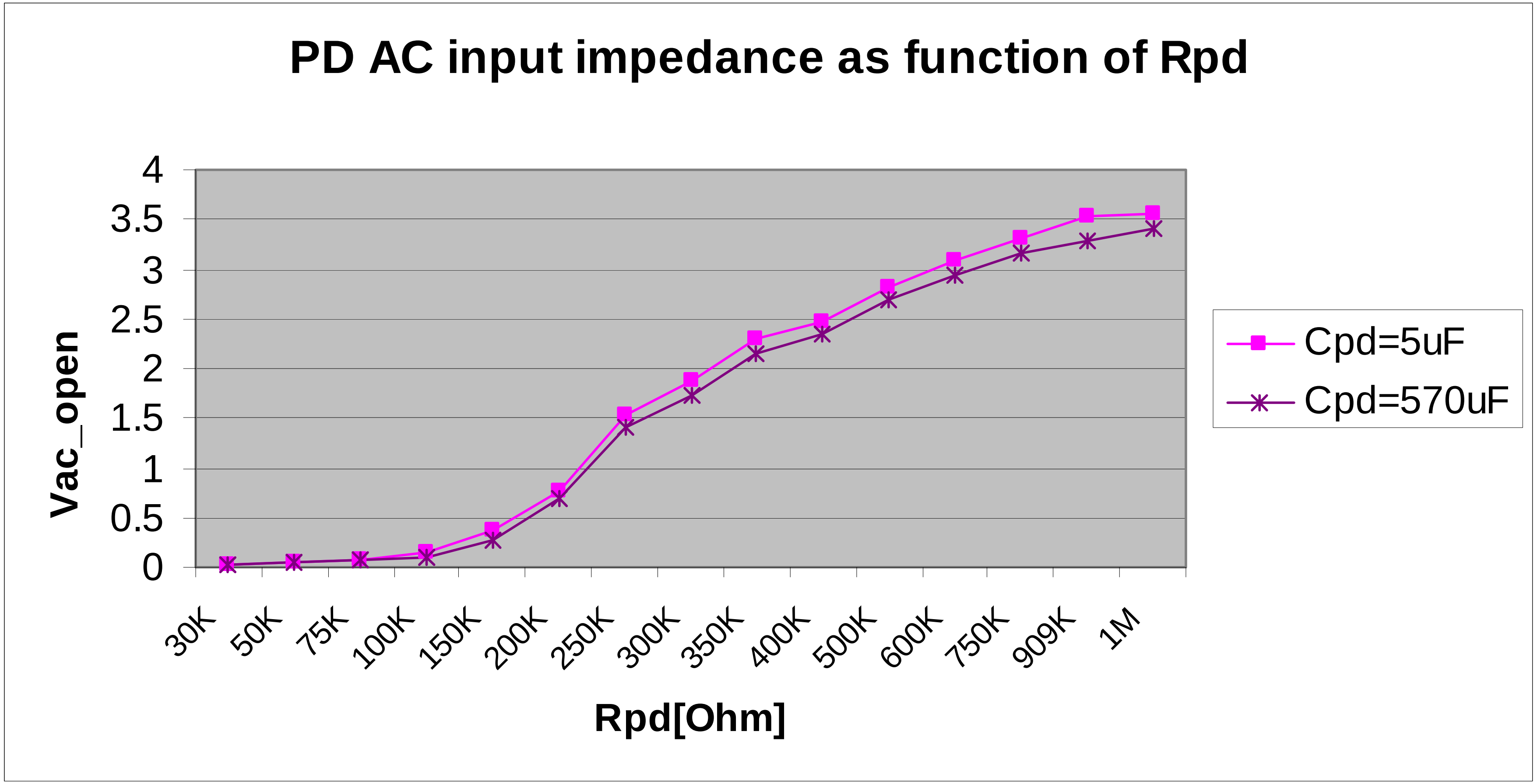
Lab tests

- Changing Rpd and measuring PSE port ac voltage, Vac_close.

Test Conditions

- With DC bias
- Vac_open=4.4Vpp, F=125Hz
- Changing Rpd from 30K to 1MEG.

Lab Test Results



Summary and Conclusions

- Vac_close is kept low for wide rang of PD input ac impedance
  - Not sensitive the external noise source when PD is connected

- Similar behavior for Cpd=5uF and up.

- PD input ac impedance is well defined in IEEE802.3af , table 12.

Calculations and Simulations verifications

Calculation example

Step 1, For :
* N=0 (NO DIODES IN SERIES)
* Voltage across C alway > 0 (Tau2>Toff)

$R1 := 5000$ $Vs := 5$ $N := 0$ $D := 0.5$

$Vd := 0.55$

$Rpd := 5000$ $f := 100$

$Cpd := 0.000005$ $Ts := \frac{1}{f}$ $toff := (1 - D)\cdot Ts$

$\tau1 := R1\cdot\frac{Rpd\cdot Cpd}{R1 + Rpd}$ $\tau2 := \tau1$ $Veqv := (Vs - N\cdot Vd)\cdot\frac{Rpd}{R1 + Rpd}$

$\tau1 = 0.013$ $\tau2 = 0.013$ $Veqv = 2.5$

Check if Tau2>Toff if not, jump to step 3 $\tau2 = 0.013$ $toff = 5\cdot 10^{-3}$

$$V1 := Veqv\cdot\frac{\left(1 - \exp\left(-D\cdot\frac{Ts}{\tau1}\right)\right)}{1 - \left(\exp\left(-D\cdot\frac{Ts}{\tau1}\right)\right)\cdot\left[\exp\left[-(1 - D)\cdot\frac{Ts}{\tau2}\right]\right]}$$

$$V2 := V1\cdot\exp\left[-(1 - D)\cdot\frac{Ts}{\tau2}\right]$$

$V\_avg := (V1 + V2)\cdot 0.5$ $Ripple := V1 - V2$

$V\_avg = 1.25$ $Ripple = 0.493\ Vpp$ $V1 = 1.497$

$Vpd := N\cdot Vd + V\_avg$

$alfa := \frac{Vpd}{Vs}$

$alfa = 0.25$

$Zin\_pd := \frac{alfa\cdot R1}{1 - alfa}$

$Zin\_pd = 1.667\cdot 10^{3}$ VERIFIED IN SIMULATIONS!!!

Step 2, For :
* N>0 (DIODES IN SERIES)
* Voltage across C alway > 0 (Tau2>>Toff)

$R1 := 5000$ $Vs := 5$ $N := 1$ $D := 0.5$

$Vd := 0.55$

$Rpd := 5000$ $f := 100$

$Cpd := 0.000005$ $Ts := \frac{1}{f}$ $toff := (1 - D)\cdot Ts$

$\tau1 := R1\cdot\frac{Rpd\cdot Cpd}{R1 + Rpd}$ $\tau2 := Rpd\cdot Cpd$ $Veqv := (Vs - N\cdot Vd)\cdot\frac{Rpd}{R1 + Rpd}$

$\tau1 = 0.013$ $\tau2 = 0.025$

Check if Tau2>Toff if not, jump to step 3 $\tau2 = 0.025$ $toff = 5\cdot 10^{-3}$

$$V1 := Veqv\cdot\frac{\left(1 - \exp\left(-D\cdot\frac{Ts}{\tau1}\right)\right)}{1 - \left(\exp\left(-D\cdot\frac{Ts}{\tau1}\right)\right)\cdot\left[\exp\left[-(1 - D)\cdot\frac{Ts}{\tau2}\right]\right]}$$

$$V2 := V1\cdot\exp\left[-(1 - D)\cdot\frac{Ts}{\tau2}\right]$$

$V1 = 1.626$ $V2 = 1.331$

$V\_avg := (V1 + V2)\cdot 0.5$ $Ripple := V1 - V2$

$V\_avg = 1.478$ $Ripple = 0.295\ Vpp$

$Vpd := N\cdot Vd + V\_avg$

$Vpd = 2.028$

$alfa := \frac{Vpd}{Vs}$

$Zin\_pd := \frac{alfa\cdot R1}{1 - alfa}$

$Zin\_pd = 3.413\cdot 10^{3}$ VERIFIED IN SIMULATIONS!!!

Calculation example

Step 3, For :
* N>0 (DIODES IN SERIES)
* Voltage across C aproach zero befor new cycle starts (Tau2<<Toff)

$R1 := 5000 \quad Vs := 5 \quad N := 1 \quad D := 0.5$

$Rpd := 5000 \quad Vd := 0.55 \quad f := 1$

$Cpd := 0.000005 \quad Ts := \frac{1}{f} \quad toff := (1 - D)\cdot Ts$

$$\tau 1 := R1\cdot\frac{Rpd\cdot Cpd}{R1 + Rpd} \qquad \tau 2 := Rpd\cdot Cpd \qquad Veqv := (Vs - N\cdot Vd)\cdot\frac{Rpd}{R1 + Rpd}$$

$\tau 1 = 0.013 \quad \tau 2 = 0.025 \quad Veqv = 2.225$

Check if Tau2<Toff if not, jump to step 2 $\quad \tau 2 = 0.025 \quad toff = 0.5$

$$V1 := Veqv\cdot\frac{\left(1 - \exp\left(-D\cdot\frac{Ts}{\tau 1}\right)\right)}{1 - \left(\exp\left(-D\cdot\frac{Ts}{\tau 1}\right)\right)\cdot\left[\exp\left[-(1 - D)\cdot\frac{Ts}{\tau 1}\right]\right]}$$

$$V2 := V1\cdot\exp\left[-(1 - D)\cdot\frac{Ts}{\tau 2}\right]$$

$V1 = 2.225 \quad V2 = 4.586\cdot 10^{-9} \quad Ripple := V1 - V2 \quad Vpd := N\cdot Vd + V1$

$Ripple = 2.225$ Vpp $\quad Vpd = 2.775$

$$alfa := \frac{Vpd}{Vs}$$

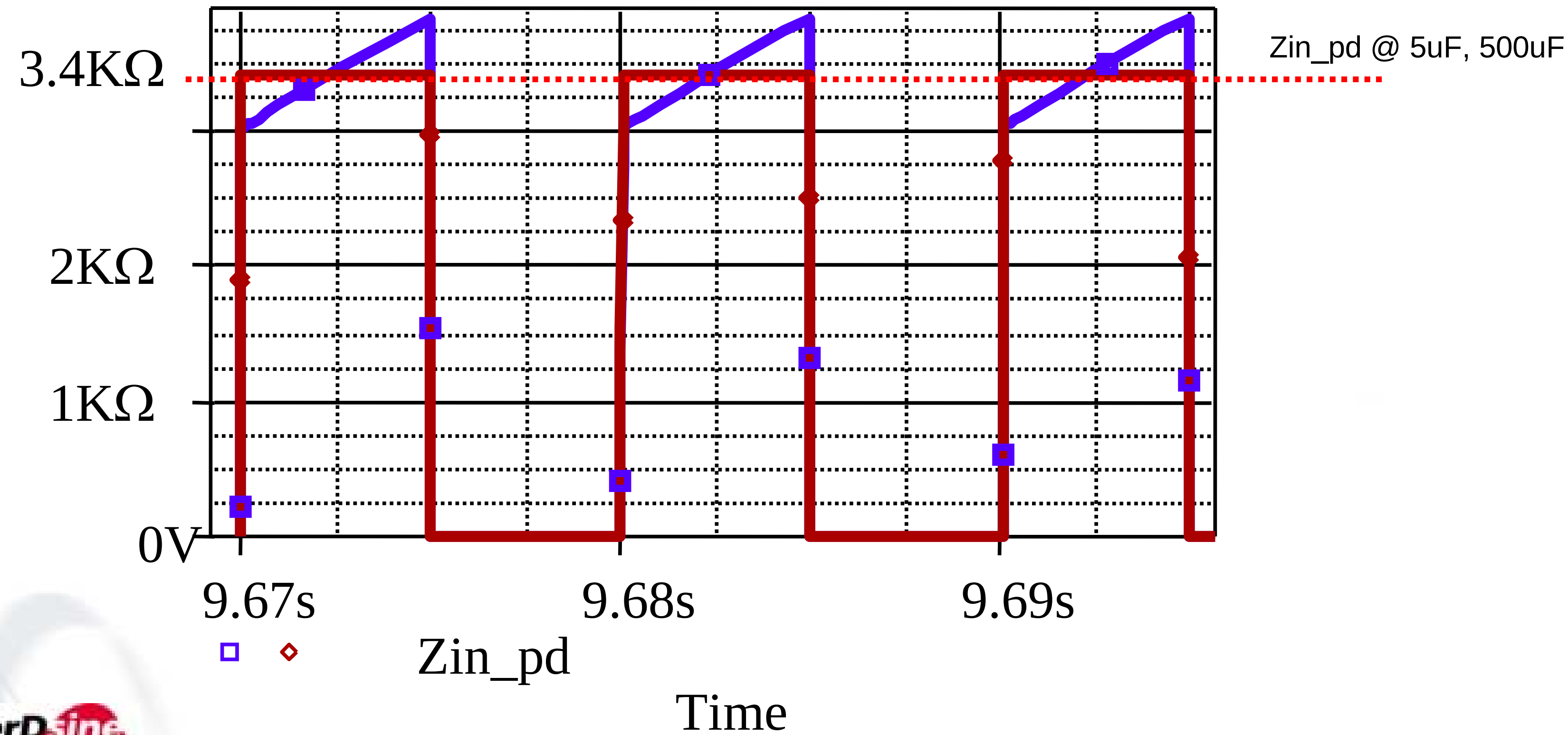
$$Zin\_pd := \frac{alfa\cdot R1}{1 - alfa}$$

$Zin\_pd = 6.236\cdot 10^{3}$ VERIFIED IN SIMULATIONS!!!

Checking the equations:

Zin_pd @ T<τ1, τ2; N=0, Rpd=5K, Cpd=5uF, f=100Hz, D=50%

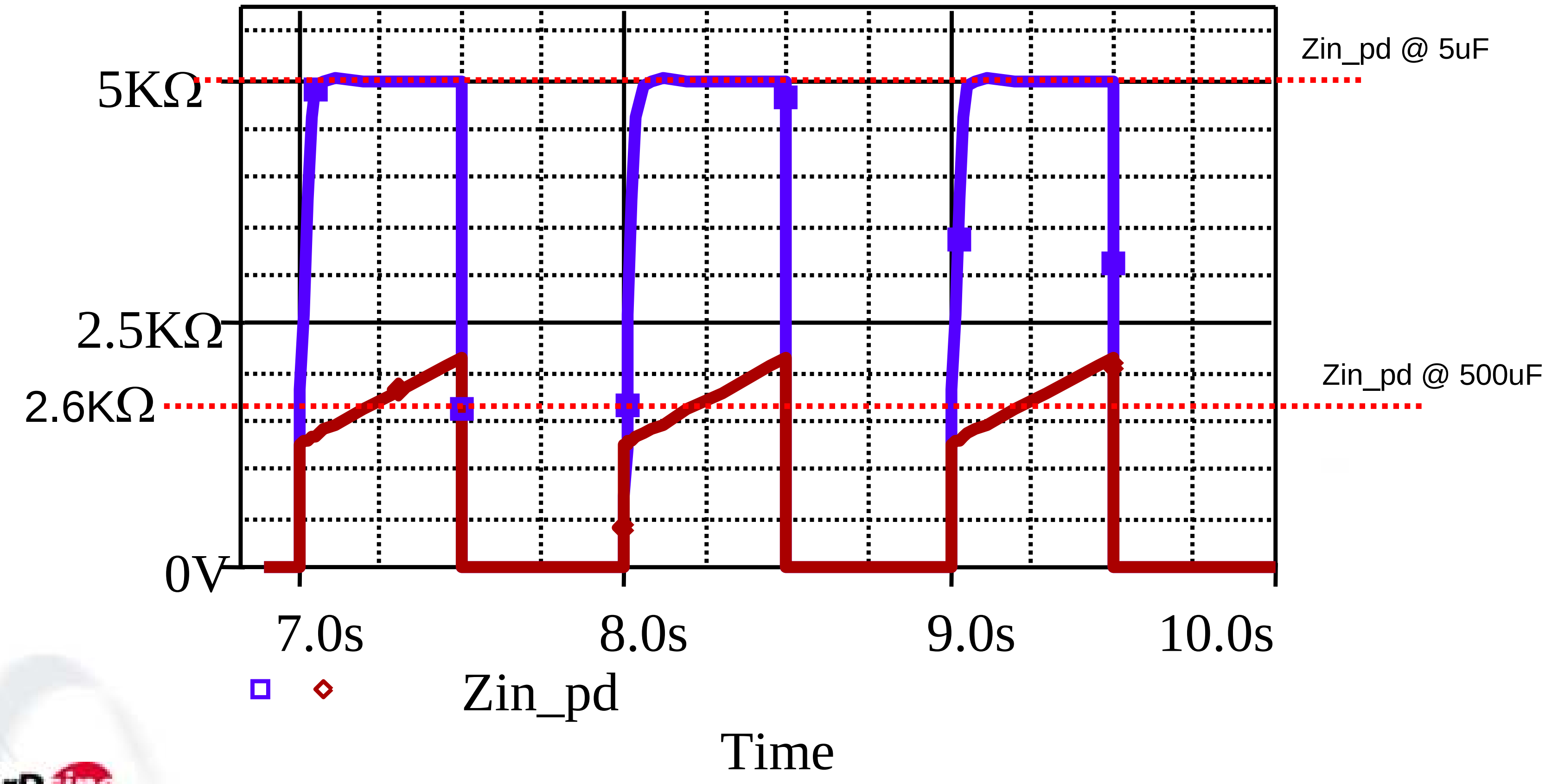
Zin_pd @ T< τ1, τ2; N=0, Rpd=5K, Cpd=500uF, f=100Hz, D=50%



Checking the equations:

Zin_pd @ T>>τ1, τ2; N=0, Rpd=5K, Cpd=5uF, f=1Hz, D=50%

Zin_pd @ T< τ1, τ2; N=0, Rpd=5K, Cpd=500uF, f=1Hz, D=50%



Checking the equations:

Zin_pd @ T>>τ1, τ2; N=3, Rpd=5K, Cpd=5uF, f=1Hz, D=50%

Zin_pd @ T< τ1, τ2; N=3, Rpd=5K, Cpd=500uF, f=1Hz, D=50%