Modeling PFC Converter Using 1200V GaNPower devices

GANPOWER INTERNATIONAL INC

By
Simon Li

Content

Simulation of inductor current control

Circuit implementation

Totem pole PFC

M. Giesselmann and V. Roy, "Modeling Power Factor Correction Circuits with LTspice," *2018 IEEE International Power Modulator and High Voltage Conference (IPMHVC)*, Jackson, WY, USA, 2018, pp. 162-165, doi: 10.1109/IPMHVC.2018.8936816.

Method: Use of tanh() hysteresis control

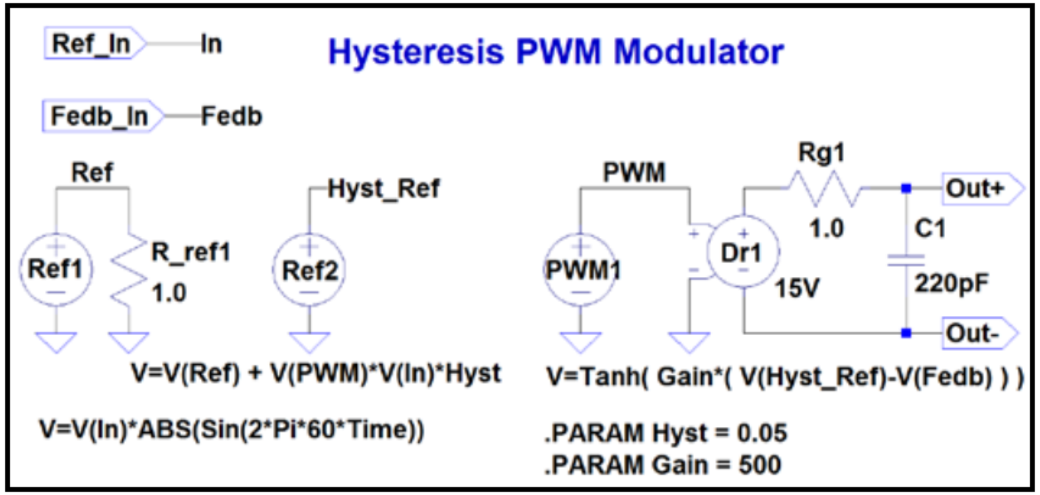


Fig. 6. Schematic of the sub-circuit for the Hysteresis PWM modulator.

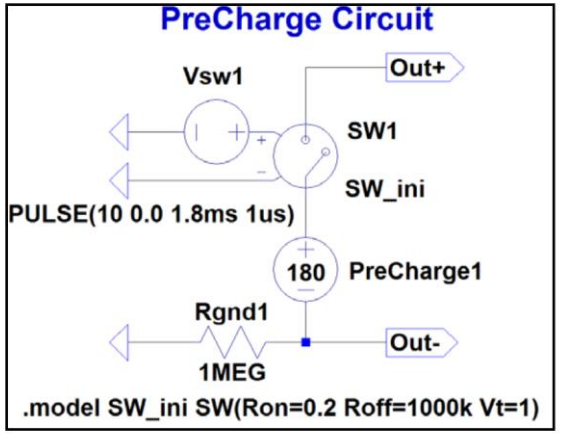
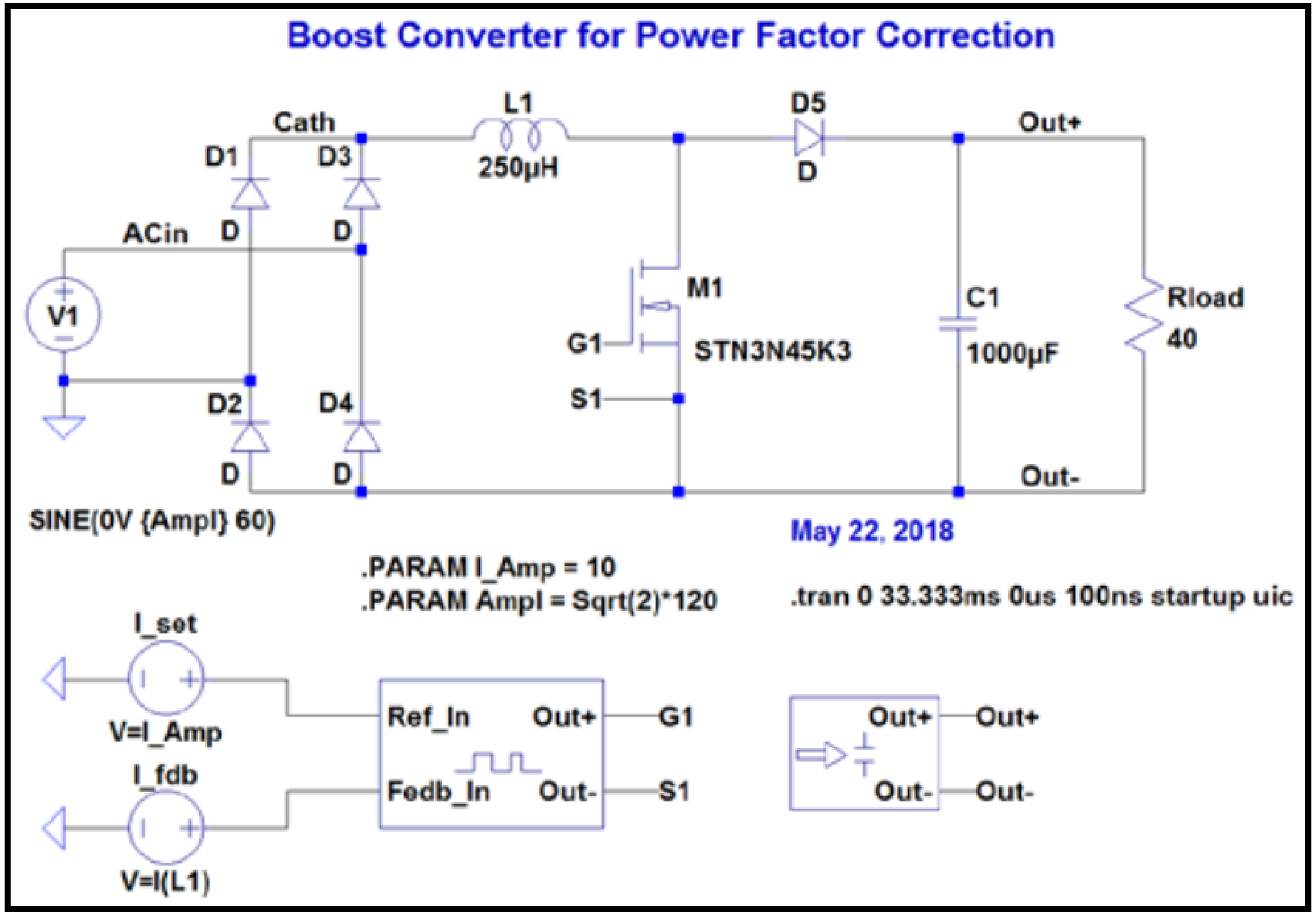
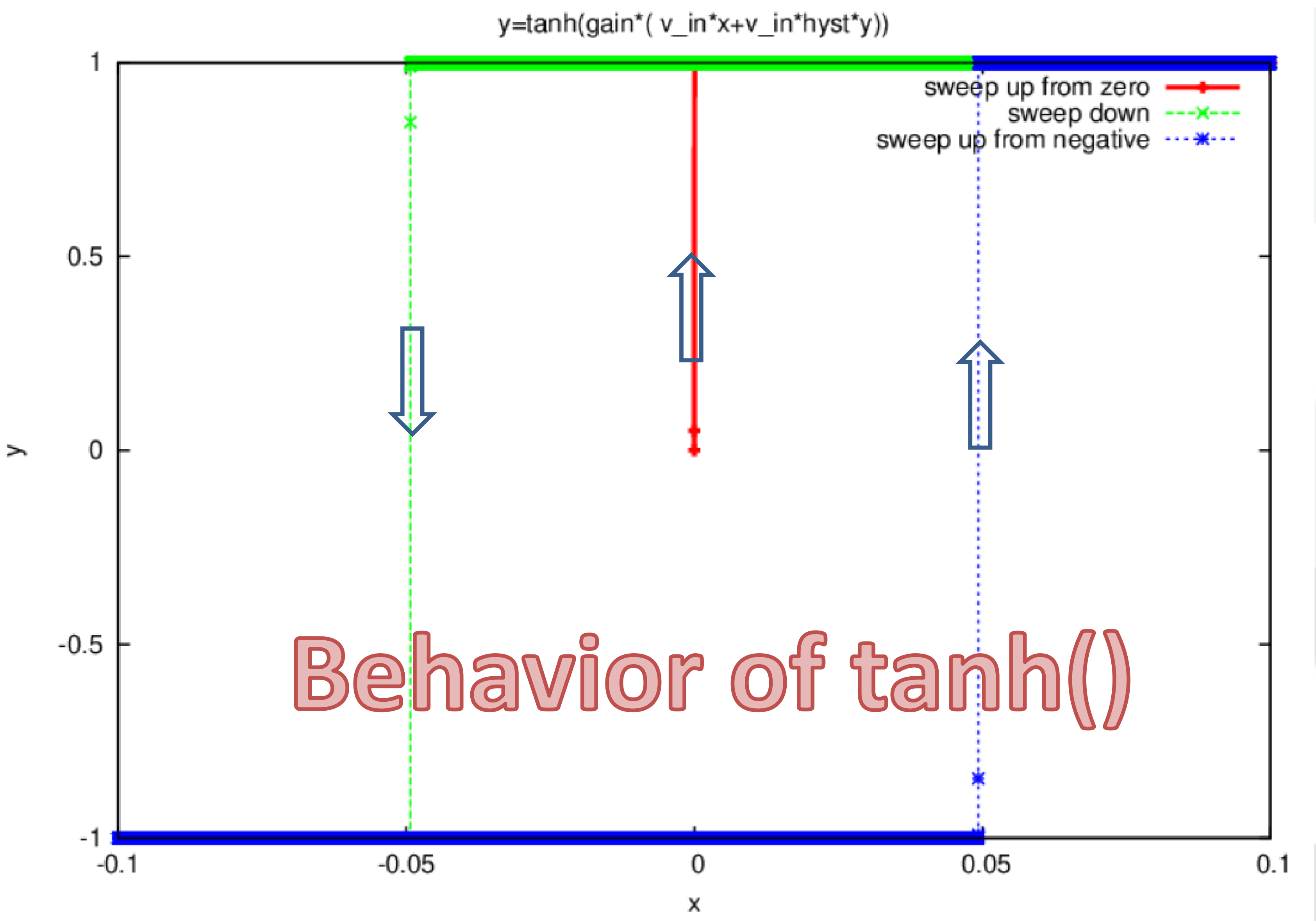


Fig. 2. LTspice schematic of the Pre-Charge sub-circuit





Hyst controls hysteresis transition at +/- hyst

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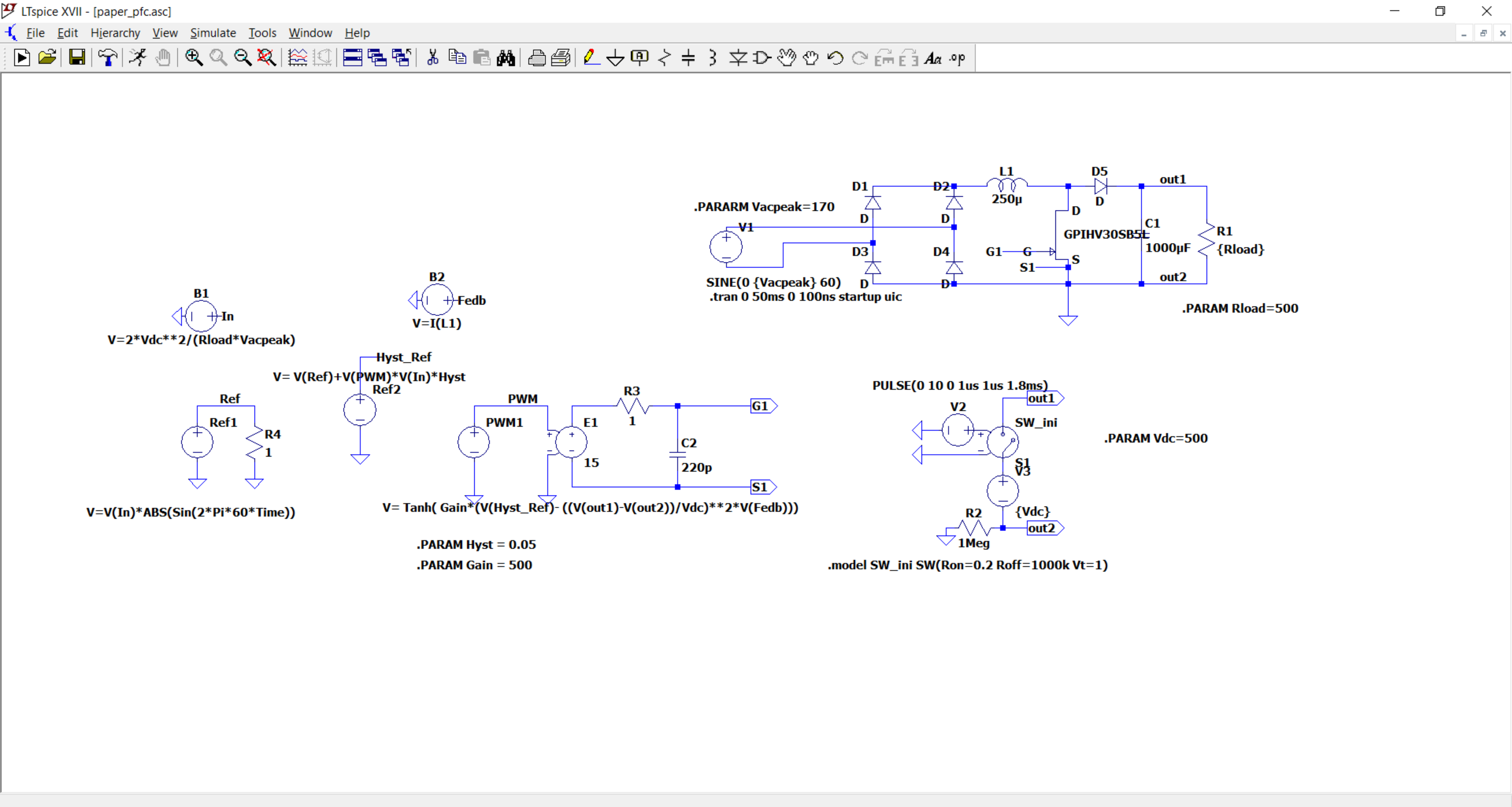
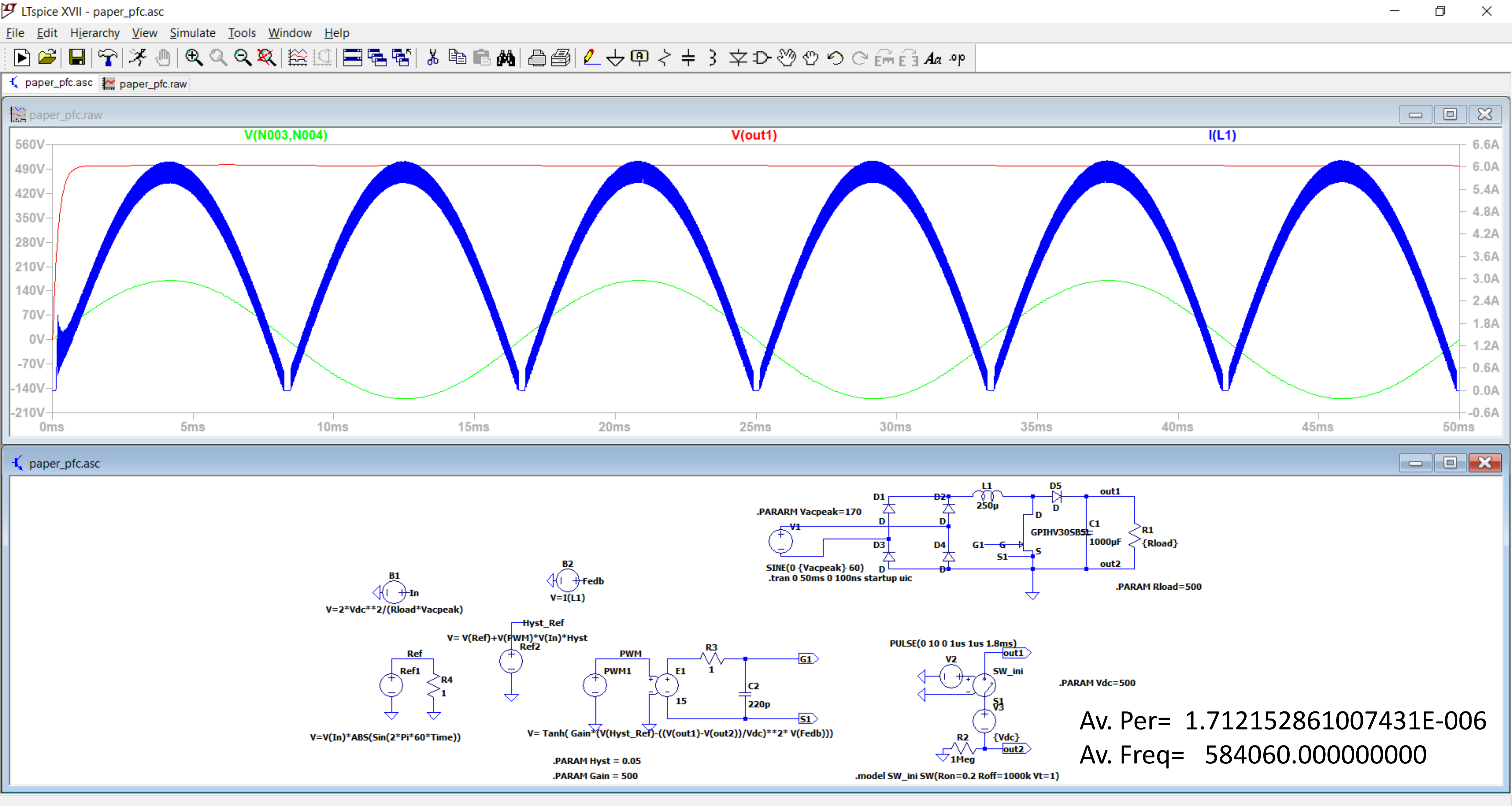
Control Consideration:

Purpose is to construct a method that is valid for arbitrary Vacpeak, Vdc, and Rload.

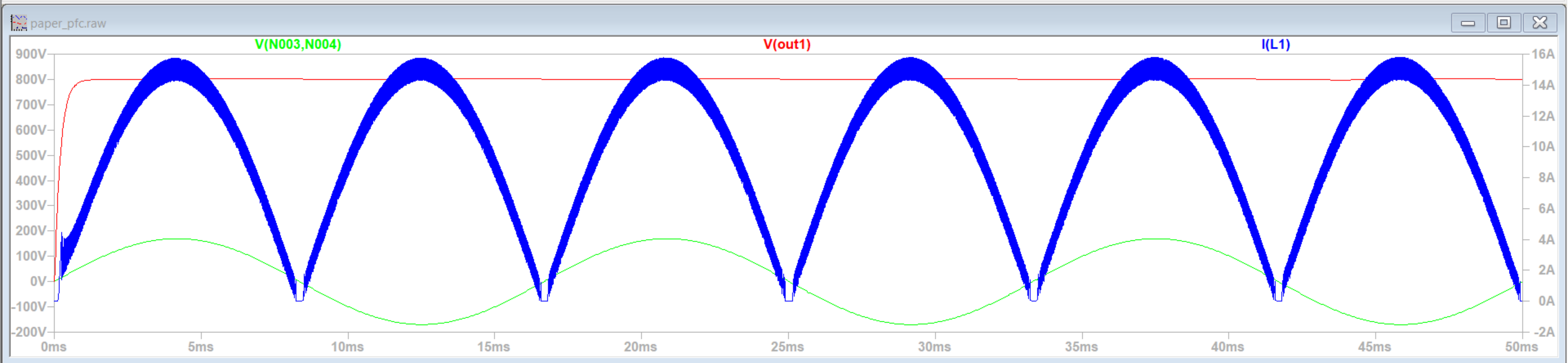
1) I_L inductor current must follow the reference current within the hysteresis control function. The feedback from I_L is critical here.
2) For Vdc output feedback, system power must be conserved. Therefore, a Vout feedback must be used such that I_L is adjusted to increase or decrease according to Vout/Vdc. Since ½*Vacpeak*I_L_peak=Vout**2/Rload via power conservation, any deviation from Vdc must cause I_L to correct itself with a factor of the form (Vout)**2 . Using the term (Vout/Vdc)**2*I_L to replace the I_L term in the hysteresis function would serve the purpose of correction without changing the hysteresis switching condition. For example, if Vout > Vdc, the current I_L would be too large and must reduce so that the term (Vout/Vdc)**2*I_L would match the reference current. Alternatively, factor (Vdc/Vout)**2 can be used to scale I_ref. Testing shows they result in similar circuit behavior. But since Vout may be accidentally zero so as to blow up the factor, the former factor would be used.
3) The reference current used in hysteresis function must obey power conservation such that ½ *Vacpeak*I_ref_preak=Vdc**2/Rload. Thus I_ref_peak=2*Vdc**2/(Rload*Vacpeak).
4) To control the average duty cycle and frequency, inductor L can be varied. The smaller the L, the higher the frequency (faster the charging/discharging). The higher the Vdc, the higher the average duty cycle and the lower the frequency.

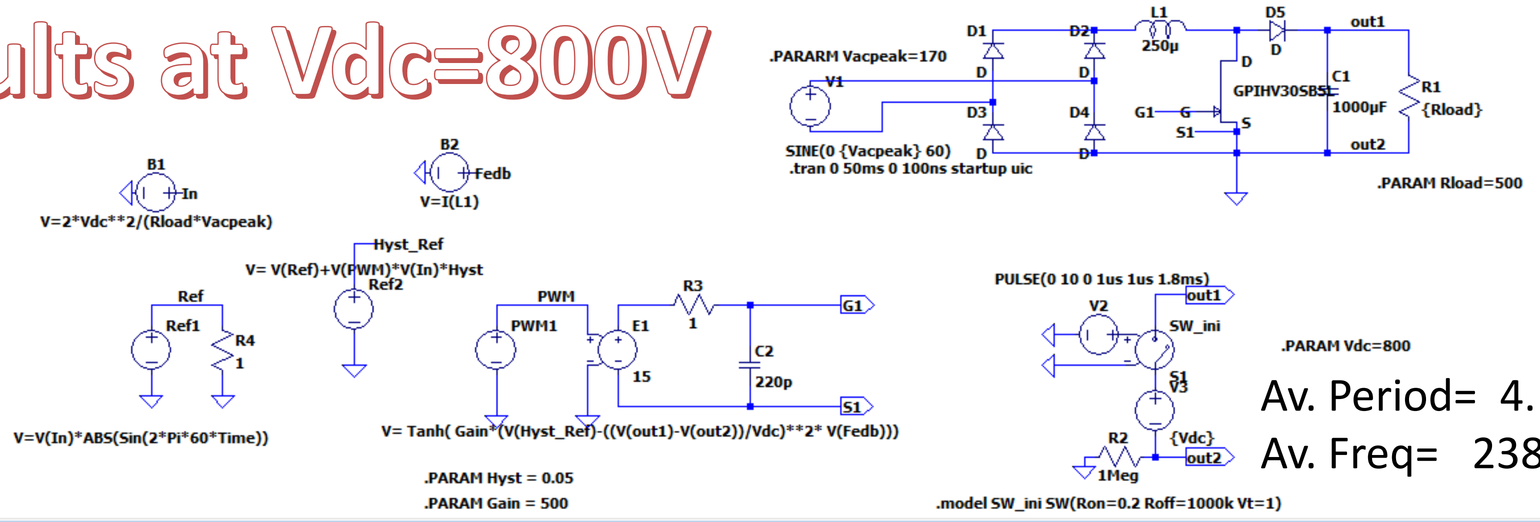


LTspice XVII - [paper_pfc.asc]
File Edit Hierarchy View Simulate Tools Window Help
.PARARM Vacpeak=170
V1
SINE(0 {Vacpeak} 60)
.tran 0 50ms 0 100ns startup uic
D1
D2
D3
D4
L1
250µ
D5
out1
out2
GPIHV30SB5L
G1
S1
C1
1000µF
R1
{Rload}
.PARAM Rload=500
B1
In
V=2*Vdc**2/(Rload*Vacpeak)
B2
Fedb
V=I(L1)
Hyst_Ref
V= V(Ref)+V(PWM)*V(In)*Hyst
Ref2
Ref
Ref1
R4
1
V=V(In)*ABS(Sin(2*Pi*60*Time))
PWM
PWM1
E1
15
R3
1
C2
220p
V= Tanh(Gain*(V(Hyst_Ref)- ((V(out1)-V(out2))/Vdc)**2*V(Fedb)))
.PARAM Hyst = 0.05
.PARAM Gain = 500
PULSE(0 10 0 1us 1us 1.8ms)
V2
SW_ini
S1
V3
{Vdc}
R2
1Meg
.PARAM Vdc=500
.model SW_ini SW(Ron=0.2 Roff=1000k Vt=1)


LTspice XVII - paper_pfc.asc
paper_pfc.raw
V(N003,N004)
V(out1)
I(L1)
paper_pfc.asc
.PARARM Vacpeak=170
SINE(0 {Vacpeak} 60)
.tran 0 50ms 0 100ns startup uic
L1
250µ
GPIHV30SBSL
C1
1000µF
R1
{Rload}
.PARAM Rload=500
V=2*Vdc**2/(Rload*Vacpeak)
V=I(L1)
V= V(Ref)+V(PWM)*V(In)*Hyst
V=V(In)*ABS(Sin(2*Pi*60*Time))
V= Tanh(Gain*(V(Hyst_Ref)-((V(out1)-V(out2))/Vdc)**2* V(Fedb)))
.PARAM Hyst = 0.05
.PARAM Gain = 500
PULSE(0 10 0 1us 1us 1.8ms)
.PARAM Vdc=500
.model SW_ini SW(Ron=0.2 Roff=1000k Vt=1)
Av. Per= 1.712152861007431E-006
Av. Freq= 584060.000000000

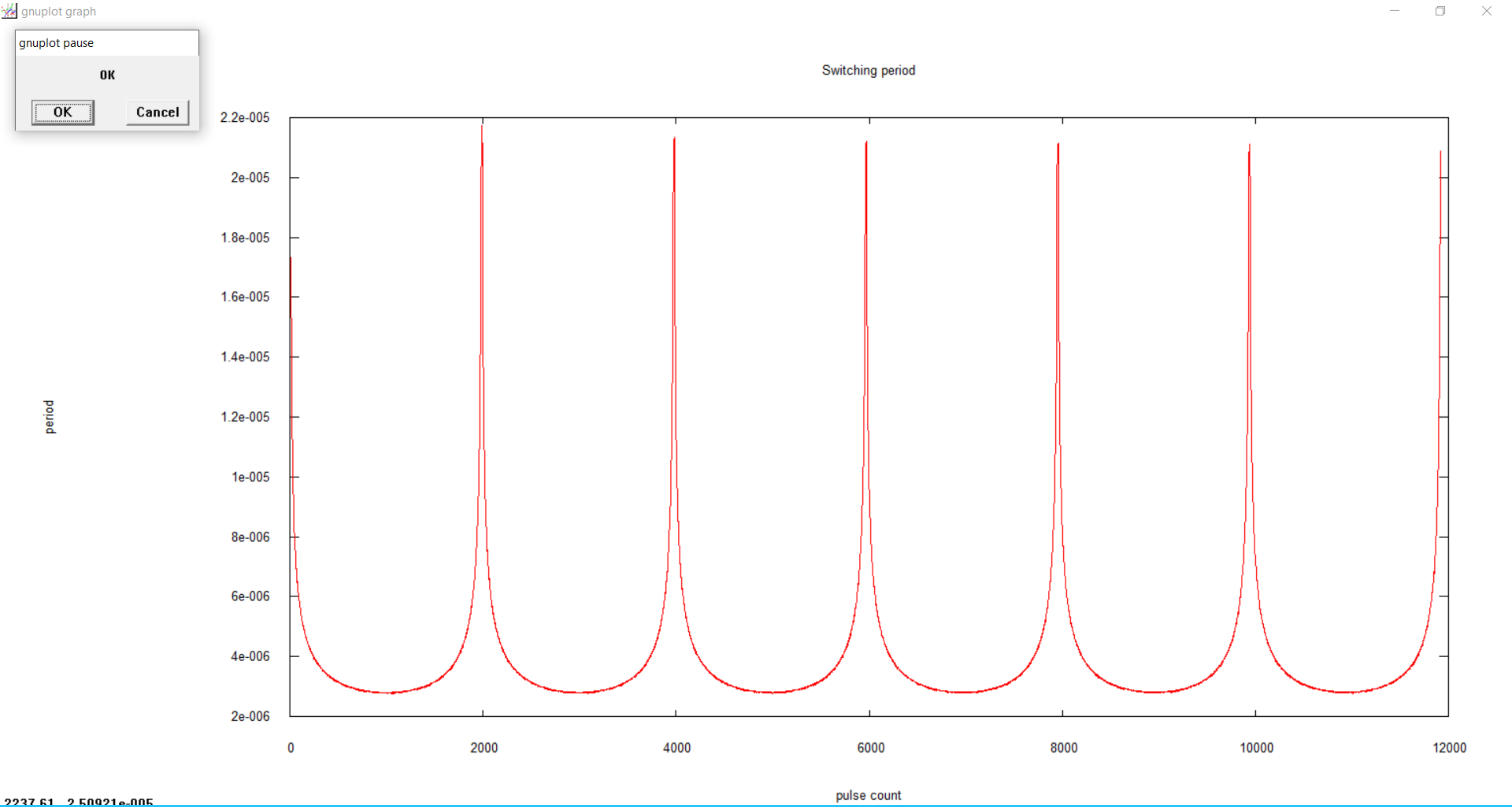
More results at Vdc=800V

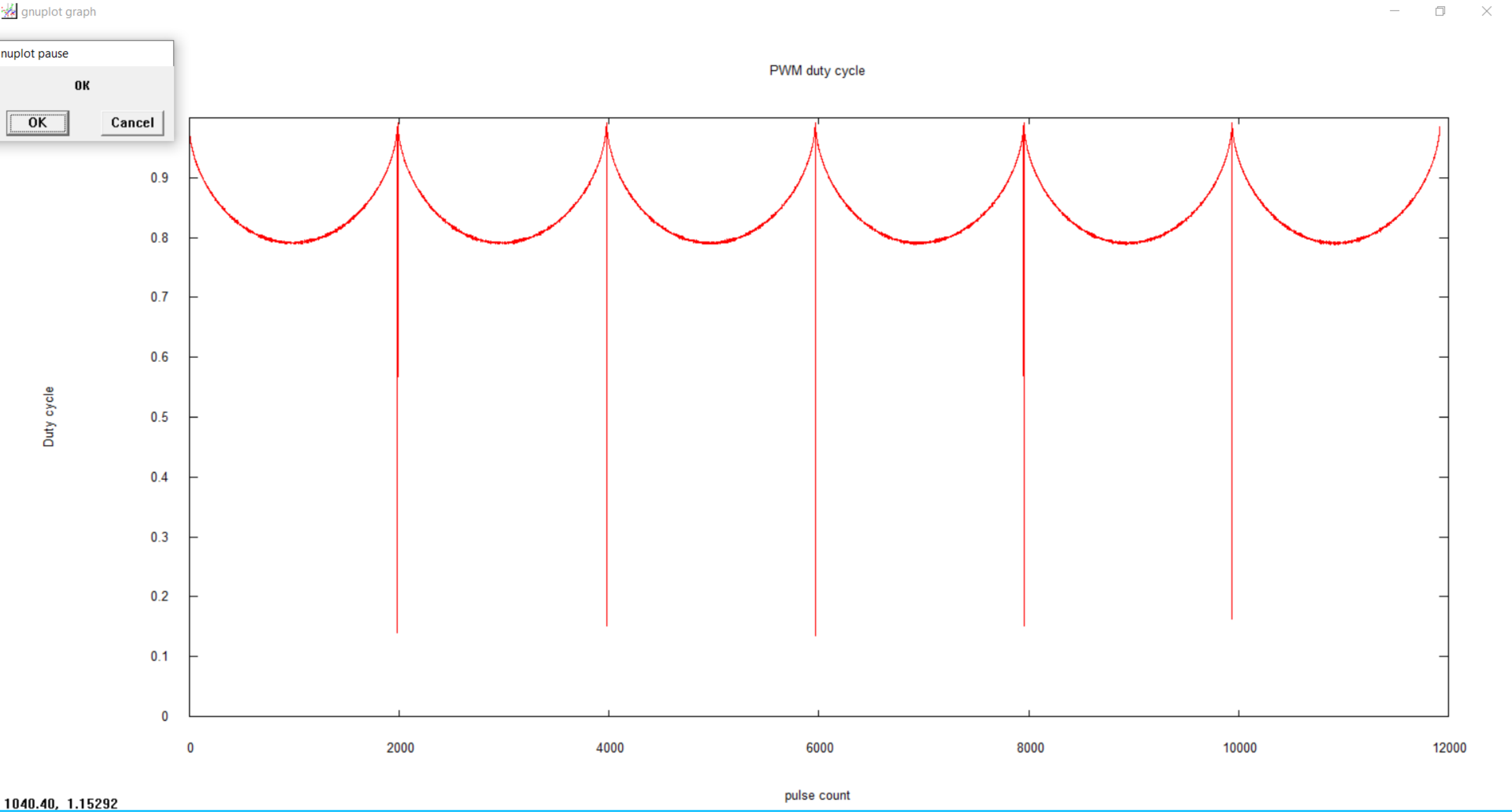




Av. Period= 4.19463087248322E-006

Av. Freq= 238400.000000000


gnuplot graph
gnuplot pause
OK
OK
Cancel
Switching period
2.2e-005
2e-005
1.8e-005
1.6e-005
1.4e-005
1.2e-005
1e-005
8e-006
6e-006
4e-006
2e-006
period
0
2000
4000
6000
8000
10000
12000
pulse count
2237.61, 2.50921e-005

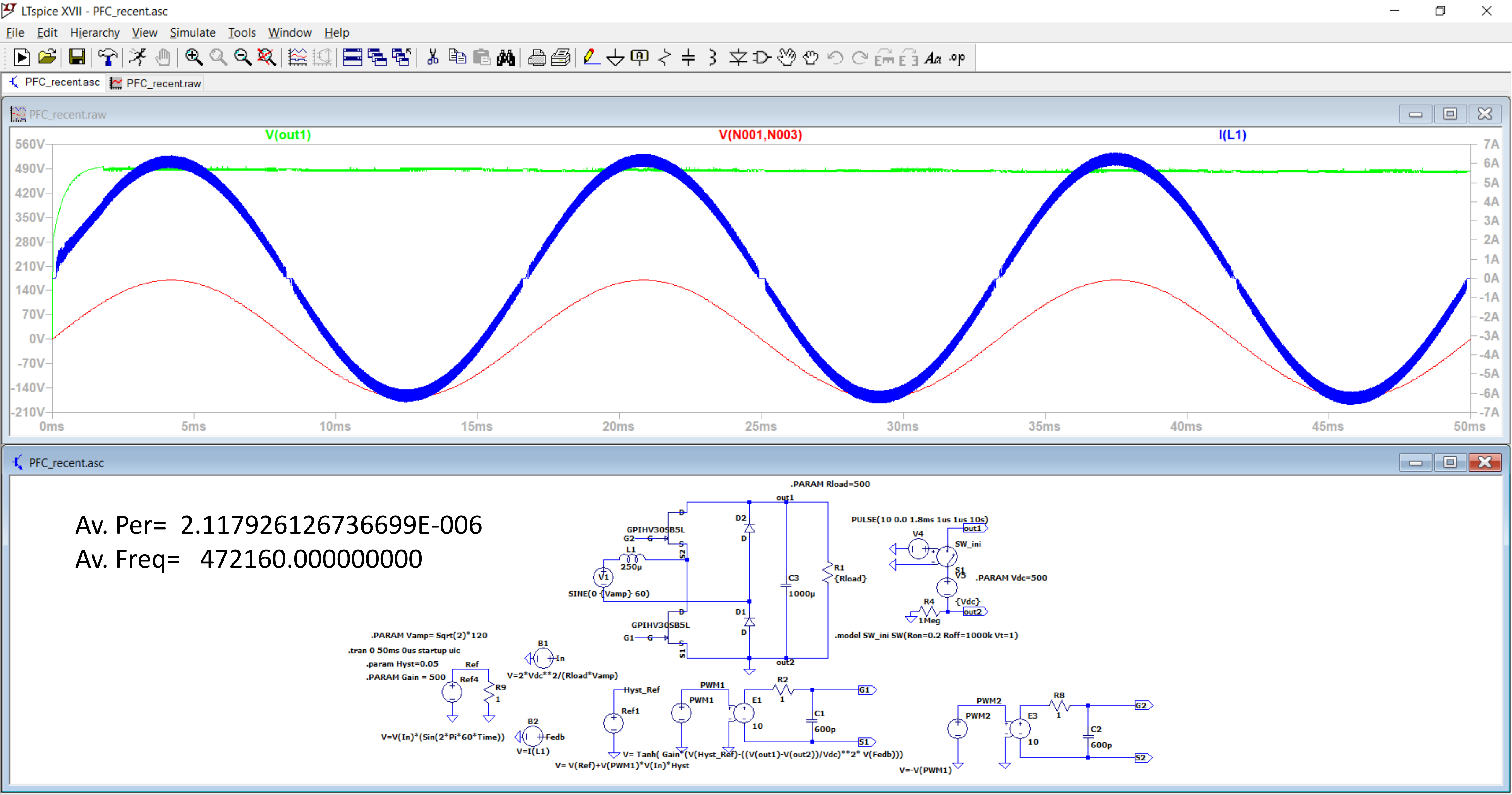

gnuplot graph
nuplot pause
OK
OK
Cancel
PWM duty cycle
Duty cycle
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2000
4000
6000
8000
10000
12000
pulse count
1040.40, 1.15292

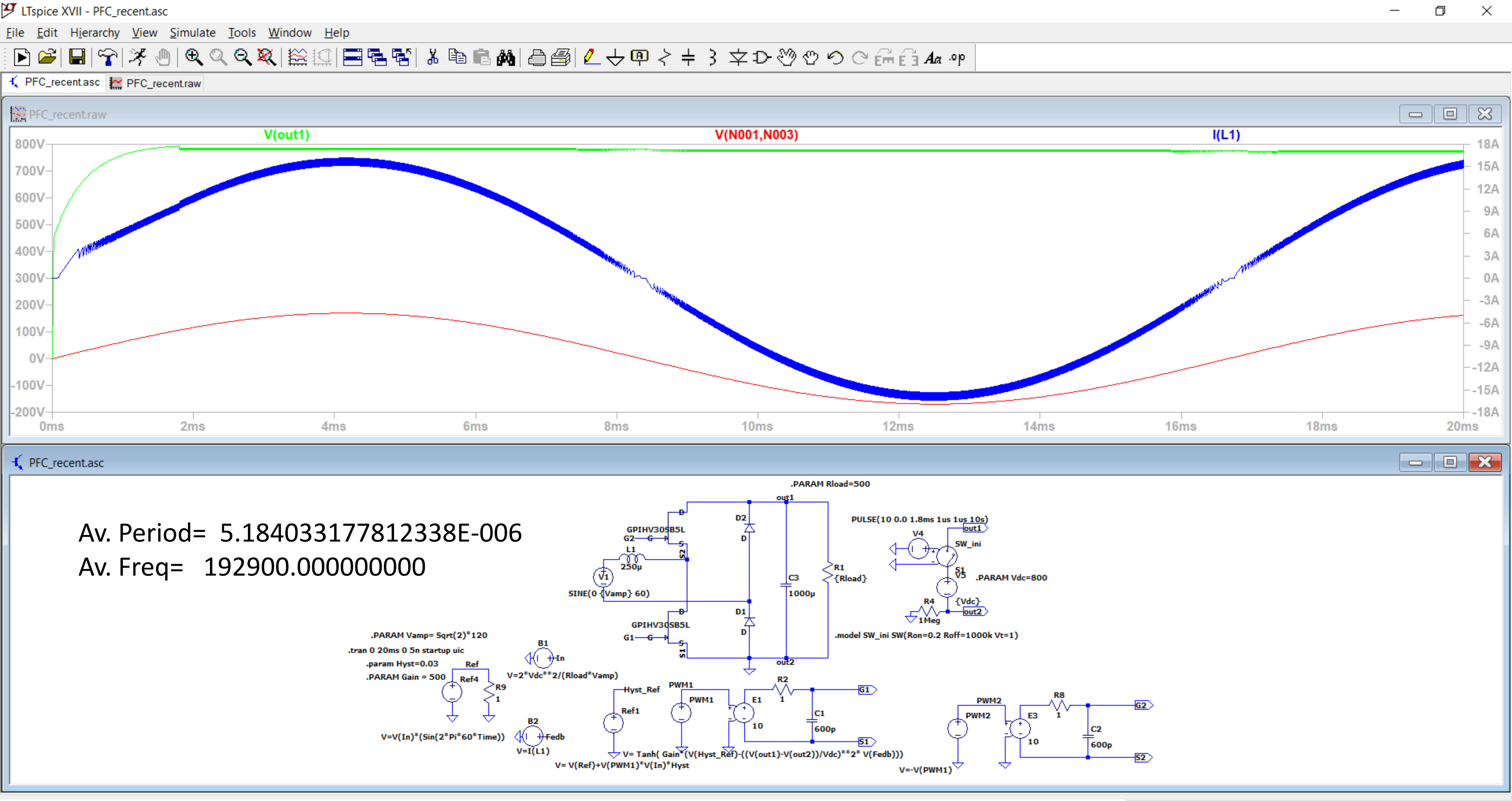
Content

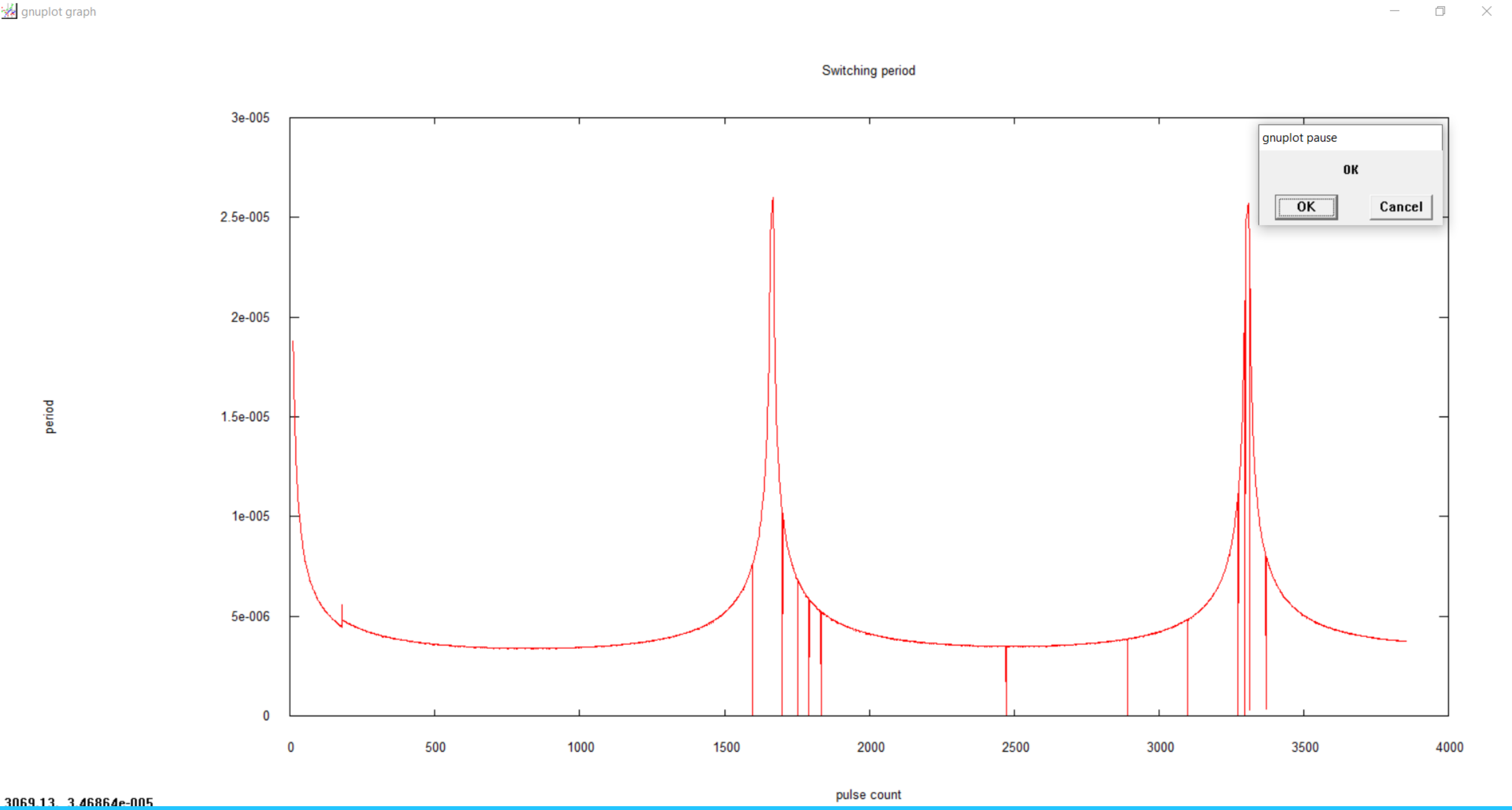
Simulation of inductor current control

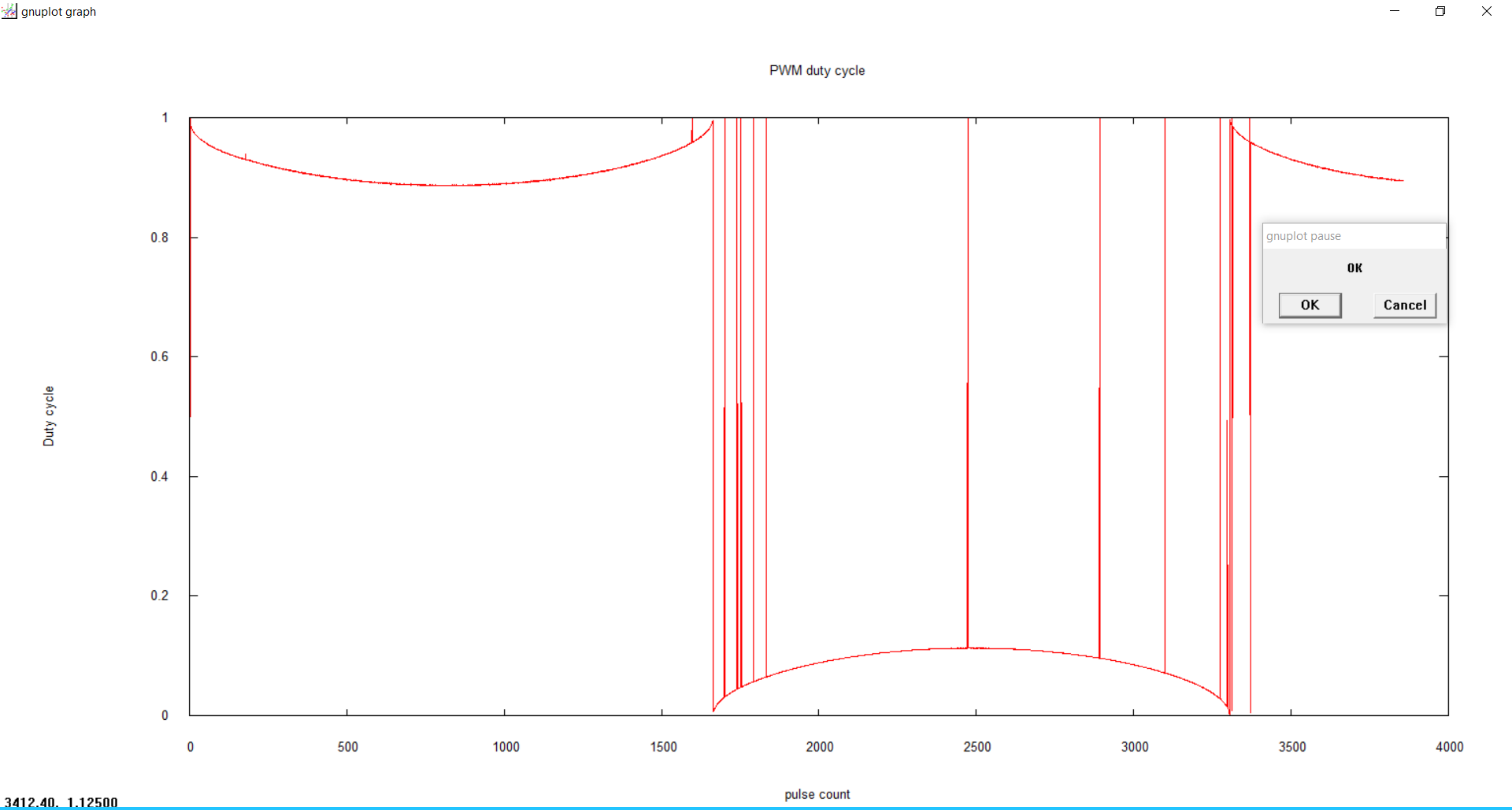
Circuit implementation

Totem pole PFC


LTspice XVII - PFC_recent.asc
File Edit Hierarchy View Simulate Tools Window Help
PFC_recent.asc
PFC_recent.raw
V(out1)
V(N001,N003)
I(L1)
560V 490V 420V 350V 280V 210V 140V 70V 0V -70V -140V -210V
7A 6A 5A 4A 3A 2A 1A 0A -1A -2A -3A -4A -5A -6A -7A
0ms 5ms 10ms 15ms 20ms 25ms 30ms 35ms 40ms 45ms 50ms
Av. Per= 2.117926126736699E-006
Av. Freq= 472160.000000000
.PARAM Rload=500
out1
GPIHV30SB5L
D2
L1
250µ
V1
SINE(0 {Vamp} 60)
C3
1000µ
R1
{Rload}
D1
out2
PULSE(10 0.0 1.8ms 1us 1us 10s)
V4
SW_ini
S1
V5
.PARAM Vdc=500
R4
1Meg
{Vdc}
.model SW_ini SW(Ron=0.2 Roff=1000k Vt=1)
.PARAM Vamp= Sqrt(2)*120
.tran 0 50ms 0us startup uic
.param Hyst=0.05
.PARAM Gain = 500
Ref
Ref4
R9
B1
V=2*Vdc**2/(Rload*Vamp)
V=V(In)*(Sin(2*Pi*60*Time))
B2
V=I(L1)
Hyst_Ref
Ref1
PWM1
E1
R2
C1
600p
V= Tanh(Gain*(V(Hyst_Ref)-((V(out1)-V(out2))/Vdc)**2* V(Fedb)))
V= V(Ref)+V(PWM1)*V(In)*Hyst
PWM2
E3
R8
C2
V=-V(PWM1)


LTspice XVII - PFC_recent.asc
File Edit Hierarchy View Simulate Tools Window Help
PFC_recent.asc
PFC_recent.raw
V(out1)
V(N001,N003)
I(L1)
800V 700V 600V 500V 400V 300V 200V 100V 0V -100V -200V
18A 15A 12A 9A 6A 3A 0A -3A -6A -9A -12A -15A -18A
0ms 2ms 4ms 6ms 8ms 10ms 12ms 14ms 16ms 18ms 20ms
Av. Period= 5.18403317781 2338E-006
Av. Freq= 192900.000000000
.PARAM Rload=500
out1
PULSE(10 0.0 1.8ms 1us 1us 10s)
GPIHV30SB5L
L1
250µ
V1
SINE(0 {Vamp} 60)
D2
D1
C3
1000µ
R1
{Rload}
V4
SW_ini
S1
V5
.PARAM Vdc=800
R4
1Meg
{Vdc}
out2
.model SW_ini SW(Ron=0.2 Roff=1000k Vt=1)
.PARAM Vamp= Sqrt(2)*120
.tran 0 20ms 0 5n startup uic
.param Hyst=0.03
.PARAM Gain = 500
Ref
Ref4
R9
B1
V=2*Vdc**2/(Rload*Vamp)
V=V(In)*(Sin(2*Pi*60*Time))
B2
Fedb
V=I(L1)
Hyst_Ref
Ref1
PWM1
E1
R2
C1
600p
G1
S1
V= Tanh(Gain*(V(Hyst_Ref)-((V(out1)-V(out2))/Vdc)**2* V(Fedb)))
V= V(Ref)+V(PWM1)*V(In)*Hyst
PWM2
E3
R8
C2
600p
G2
S2
V=-V(PWM1)


gnuplot graph
Switching period
period
pulse count
3e-005
2.5e-005
2e-005
1.5e-005
1e-005
5e-006
0
0
500
1000
1500
2000
2500
3000
3500
4000
gnuplot pause
OK
OK
Cancel
3069.13, 3.46864e-005


gnuplot graph
PWM duty cycle
Duty cycle
1
0.8
0.6
0.4
0.2
0
0
500
1000
1500
2000
2500
3000
3500
4000
pulse count
gnuplot pause
OK
OK
Cancel
3412.40, 1.12500

Summary

- Using LTSpice simulator, Boost PFC and totem Pole PFC can be designed using GaNPower 1200V GaNFET

- Circuit implementation takes feedbacks from output voltage and inductor current in a form easy to implement using op-amp or digitally controlled using the tanh() function.

LET'S WORK TOGETHER

Our Believes

Integrity

Technology Innovation

Fast Growing

GaNPOWER

THANKS FOR YOUR PATIENCE AND SUPPORT

衷 心 感 謝 您 的 耐 心 與 支 持

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