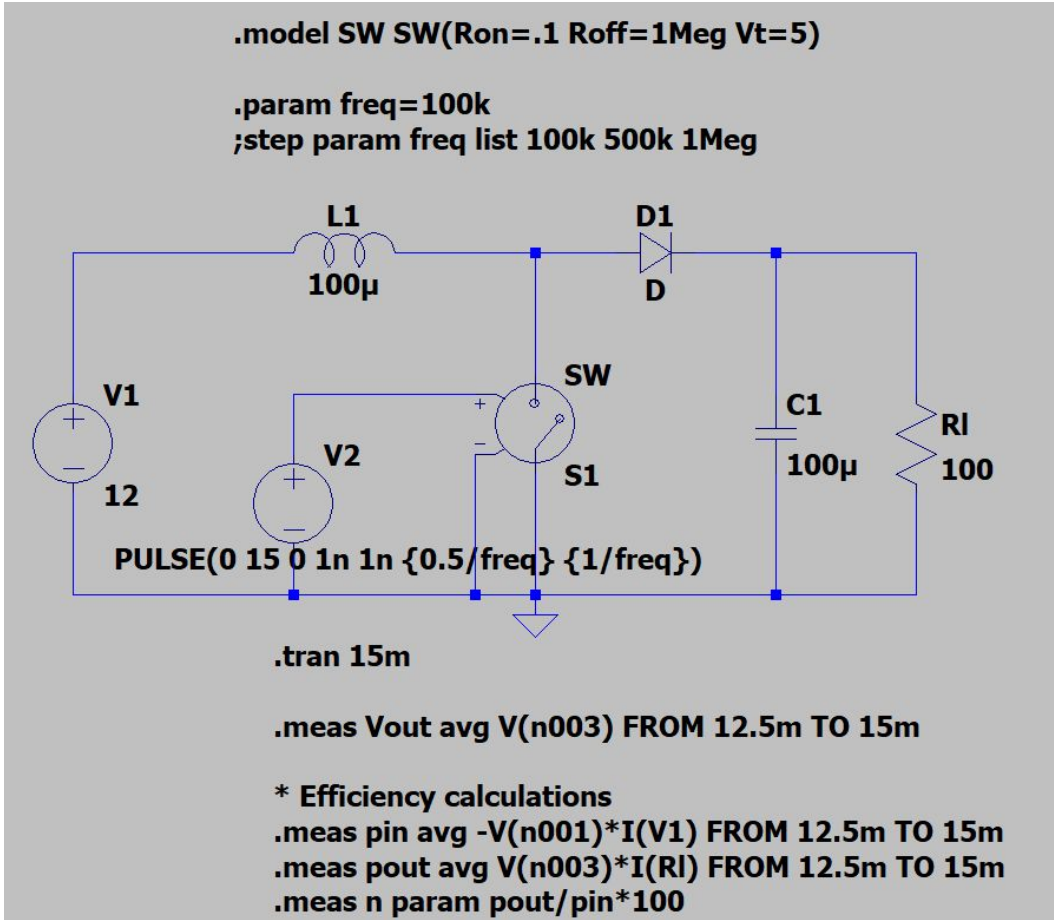
SIMULATIONS

THEORETICAL DESIGN

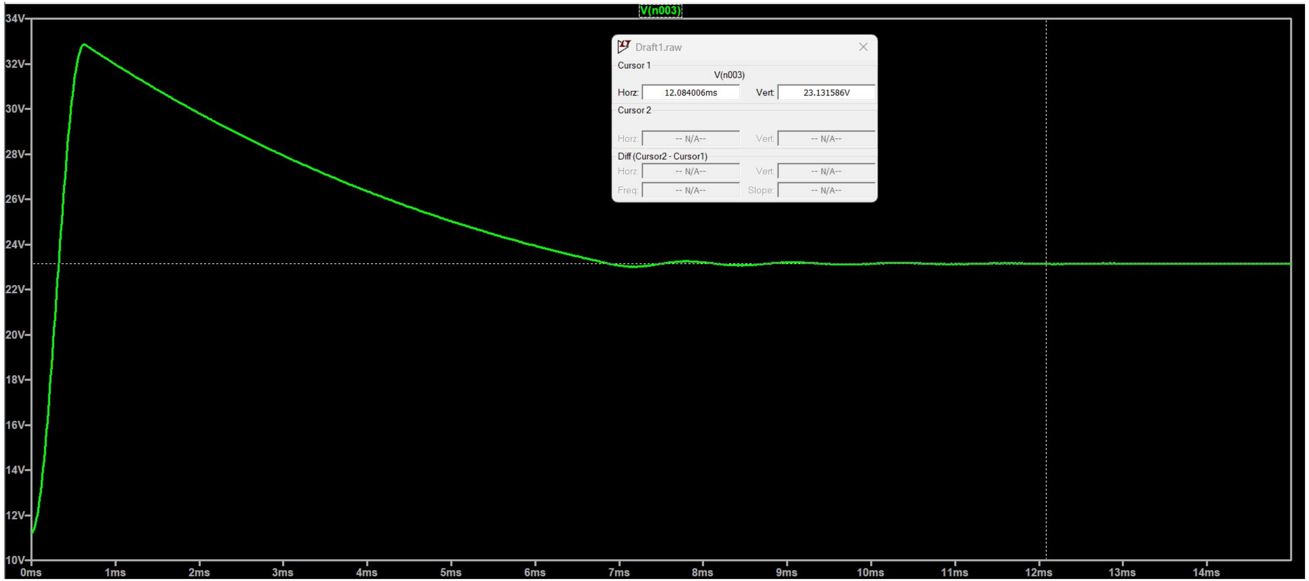
SAMPLE VALUES

Component	Value
Fs	100kHz
T	1 / 100k = 10us
Vin	12V
Vout	24V
Duty cycle	12 / 24 = 0.5
L1	100uH
Cout	100uF
Rload	100Ω

SIMULATION CIRCUIT

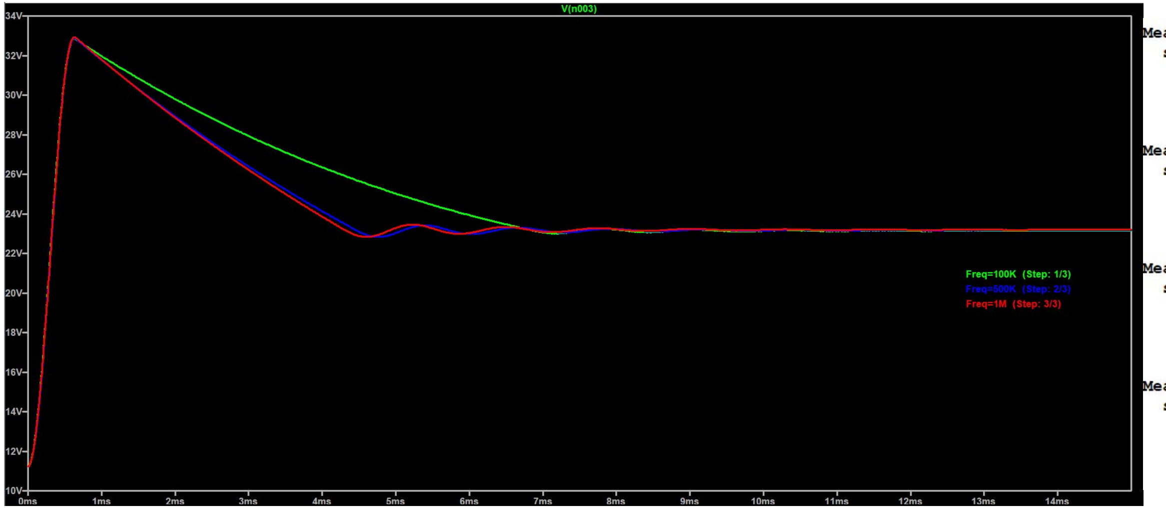


OUTPUT VOLTAGE PLOT



Parameter	Value
Vout	23.15V
Pin	5.56W
Pout	5.36W
n	96.38%

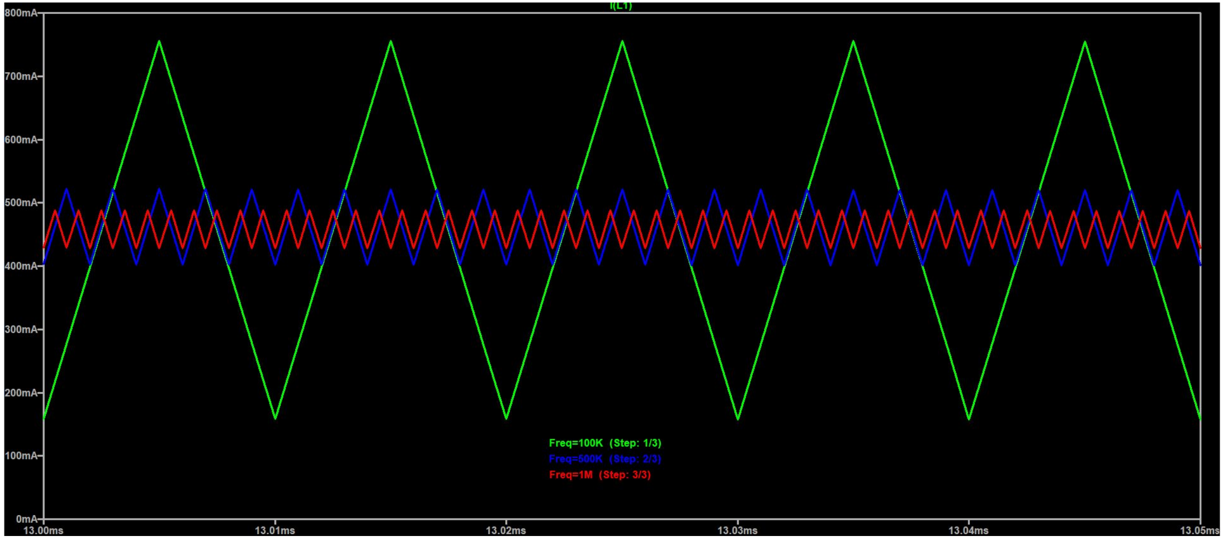
VARYING FREQUENCY: OUTPUT VOLTAGE




```
Measurement: vout
  step         AVG(V(n003))        FROM        TO
    1          23.145550036        0.0125      0.015
    2          23.1660674871       0.0125      0.015
    3          23.1928418999       0.0125      0.015

Measurement: pin
  step         AVG(-V(n001)*I(V1)) FROM        TO
    1          5.55881920216       0.0125      0.015
    2          5.57092760152       0.0125      0.015
    3          5.57869524817       0.0125      0.015

Measurement: pout
  step         AVG(V(n003)*I(R1))  FROM        TO
    1          5.35716519769       0.0125      0.015
    2          5.36666702304       0.0125      0.015
    3          5.37907934047       0.0125      0.015

Measurement: n
  step         pout/pin*100
    1          96.3723590003
    2          96.3334548015
    3          96.42181731
```

Output voltage trend	Higher frequency ensures inductor operates in CCM with current high for most of cycle, leading to better energy transfer and slight overshoot.
Transient time trend	The output capacitor C1 is charged more frequently per second, reducing the output ripple and significantly shortening the time required to reach a stable, fina Vout.
Efficiency trend	Do not change since we are using ideal switch. If Mosfet is used, higher frequencies will lead to higher switching losses reducing efficiency.

VARYING FREQUENCY: INDUCTOR CURRENT

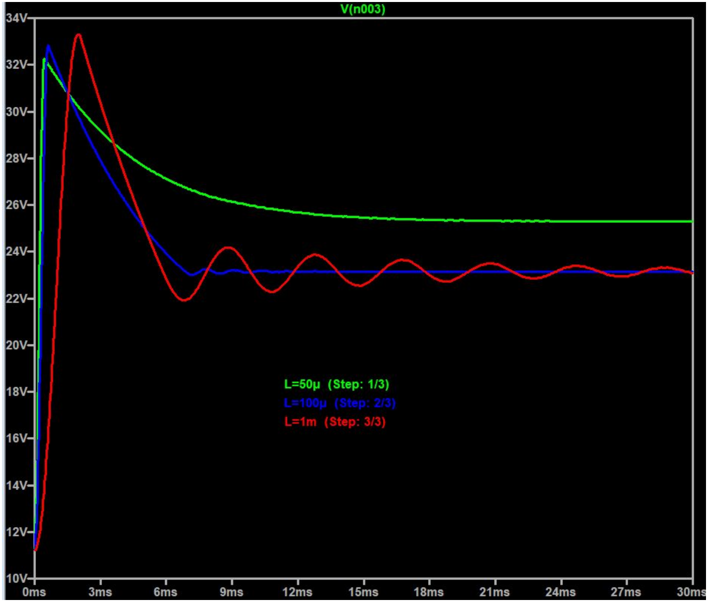


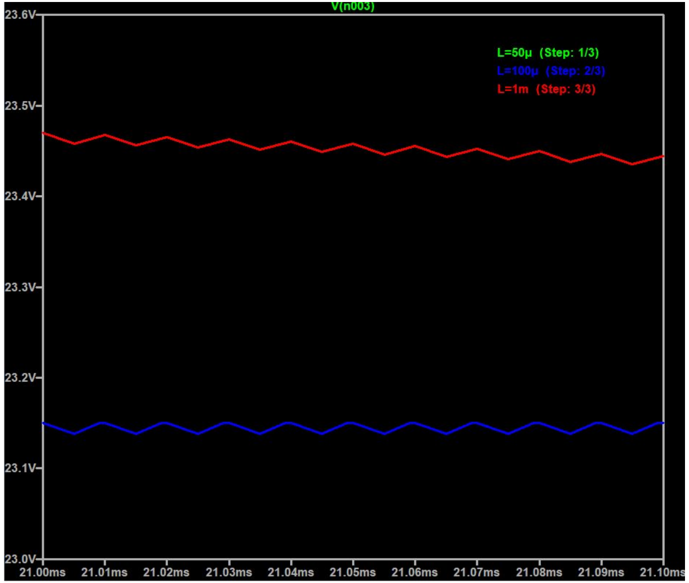
1. Vin/L = dIL / dt
   Since Vin and L are constant slope is linear.
2. The rise and fall time are identical due to 50% duty cycle.

Since slope is linear we can use change instead of gradients:
$\Delta IL = Vin * T * D / L = (Vin*D)/(fs*L)$

Ripple	From formula we can see increasing frequency reduces ripple
Operation	All three frequencies are high enough to ensure CCM.
DC offset	In case of MOSFET we would expect current to have negative dc offset due to switching losses.

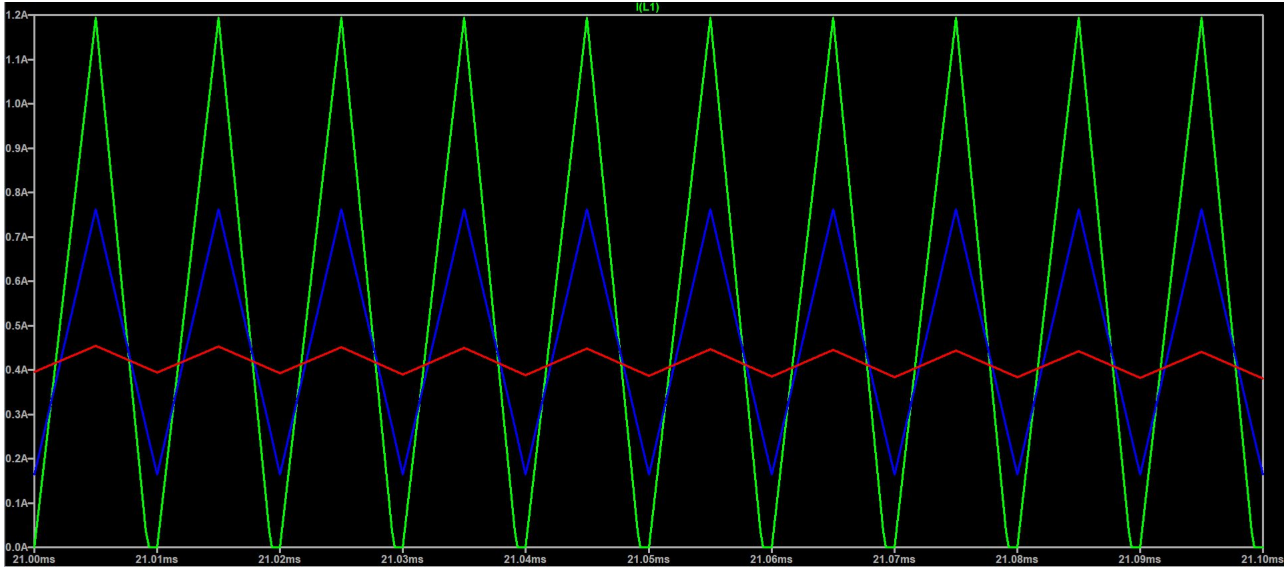
VARYING INDUCTOR: OUTPUT VOLTAGE





Transient time	Vout takes longer to settle, due to time constant being L / R
Ripple	Seems similar, theoretically have inverse relation.

VARYING INDUCTOR: INDUCTOR CURRENT

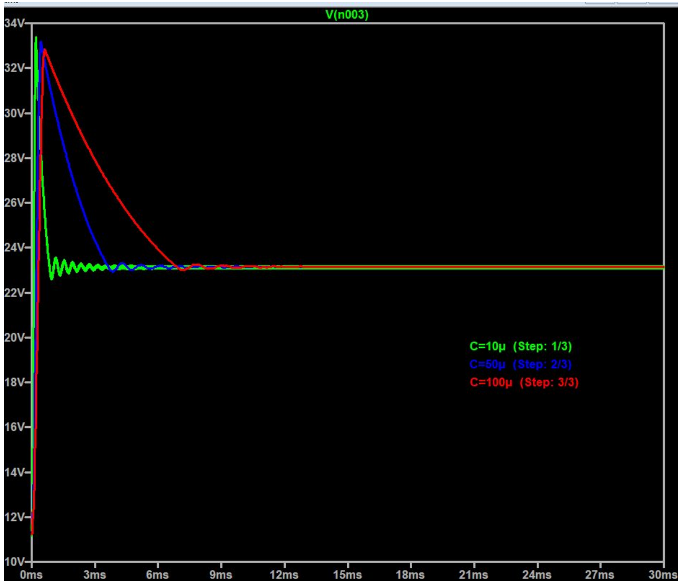


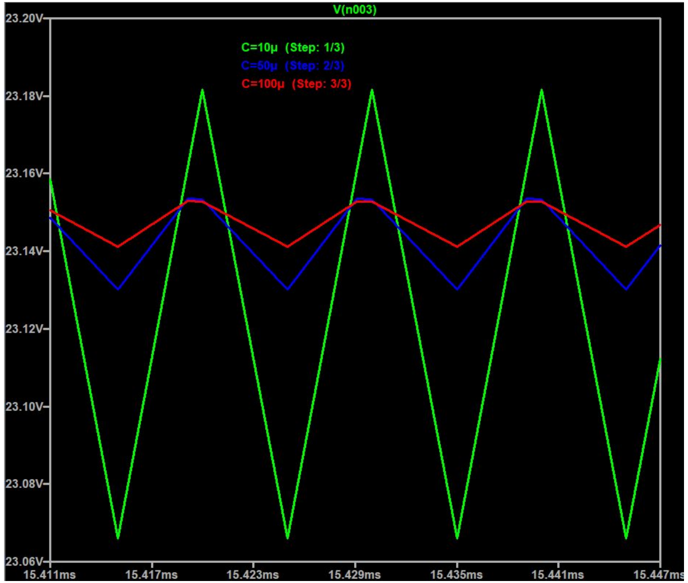
1. Vin/L = dIL / dt
   Since Vin and L are constant slope is linear.
2. The rise and fall time are identical due to 50% duty cycle.

Since slope is linear we can use change instead of gradients:
ΔIL = Vin * T * D / L = (Vin*D)/(fs*L)

Ripple	From formula we can see increasing inductance reduces ripple
Operation	For 50uH the converter operates in DCM and inductor current reaches 0.

VARYING CAPACITOR: OUTPUT VOLTAGE

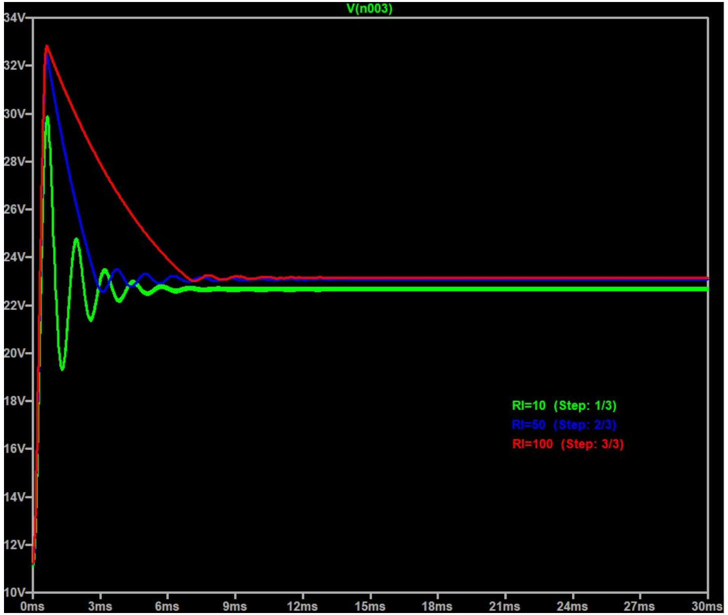


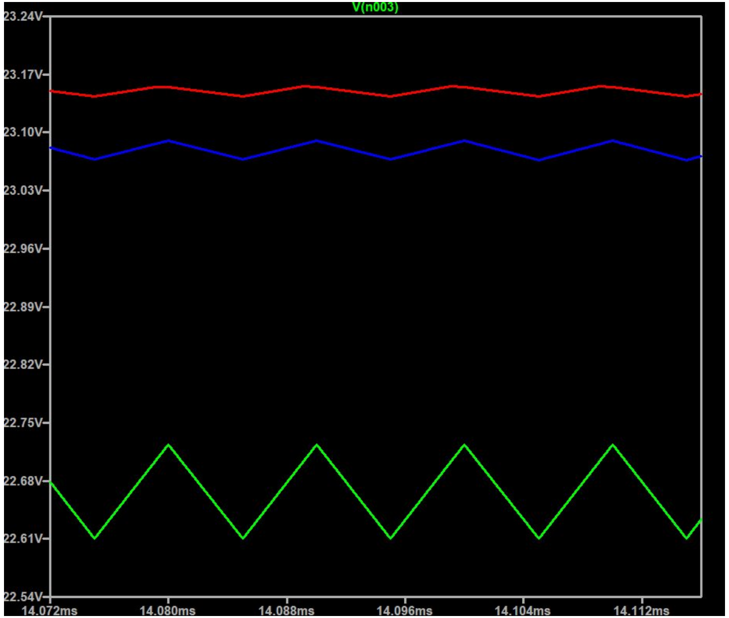


$\Delta Vout = [Iout\_max * Dmax] / [fs * C]$

Transient time	Vout takes longer to settle (time constant = RC)
Ripple	Lager capacitor reduces ripple

VARYING RESISTOR: OUTPUT VOLTAGE





ΔVout = [Iout_max * Dmax] / [fs * C]

Transient time	Vout takes longer to settle (time constant = RC)
Ripple	Vout / RL = Iout_max, so increasing R should reduce the ripple

PRACTICAL DESIGN

PRE-DEFINED PARAMETERS

Parameter	Value
Vin	5V
Vout	12V
Io(max)	0.5A
fs	100kHz
ΔIL	30%
ΔVout	1%
n	0.9

CALCULATIONS

Parameter	Calculation	Value
RL	Vout / Iout(max) = 12 / 0.5	24Ω
D	1 - Vin / Vout = 1 - 5 * 0.9 / 12	0.625
T	1 / f = 1 / 100k	10us
Ton	D / f = 0.625 / 100k	6.25us
Pout	Vout * Iout(max) = 12 * 0.5	6W
Pin	Pout / n = 6 / 0.9	6.67W
Iin = IL	Pin / Vin = 6.67 / 5	1.34A
ΔIL	0.3 * IL = 0.3 * 1.33	0.4A
ΔVout	0.01*Vout = 0.01*12	0.12V
IL(peak)	IL + ΔIL/2 = 1.34 + 0.4/2	1.54A
Lmin	[Vin*D] / [fs*ΔIL] = [5*0.625] / [100k*0.4] =	78.125uH
Cout(min)	[Iout(max)*D] / [fs*ΔVout] = [0.5*0.625] / [100k*0.12]	26.04uF

INDUCTOR, CAPACITOR & DIODE SELECTION

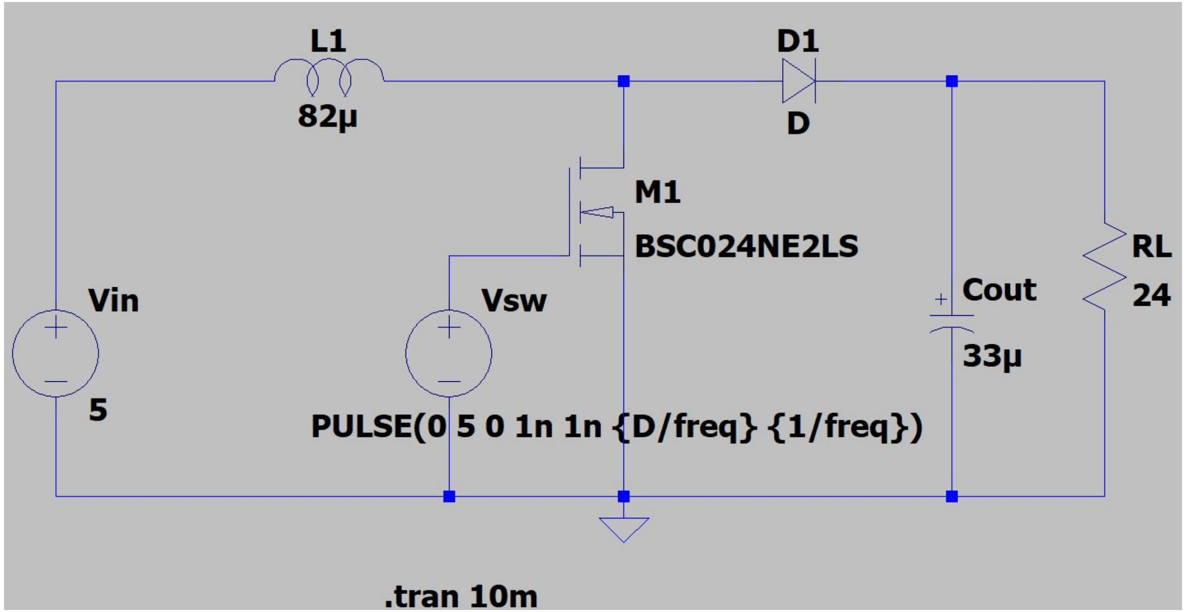
Value	Criterion	Value
L	Close to Lmin = 78.125uH	82uH
Ipk	>IL(peak) => >1.52 A	2.1
Rs	Minimum (reduce losses)	0.1204

Value	Criterion	Value
Cout	Closest to Cout(min) = 26.04uF	33uF
V (voltage rating)	2*Vout(max) = 2*12 = 24V	25V
Rs	Minimum (for lower ripple)	0.06Ω

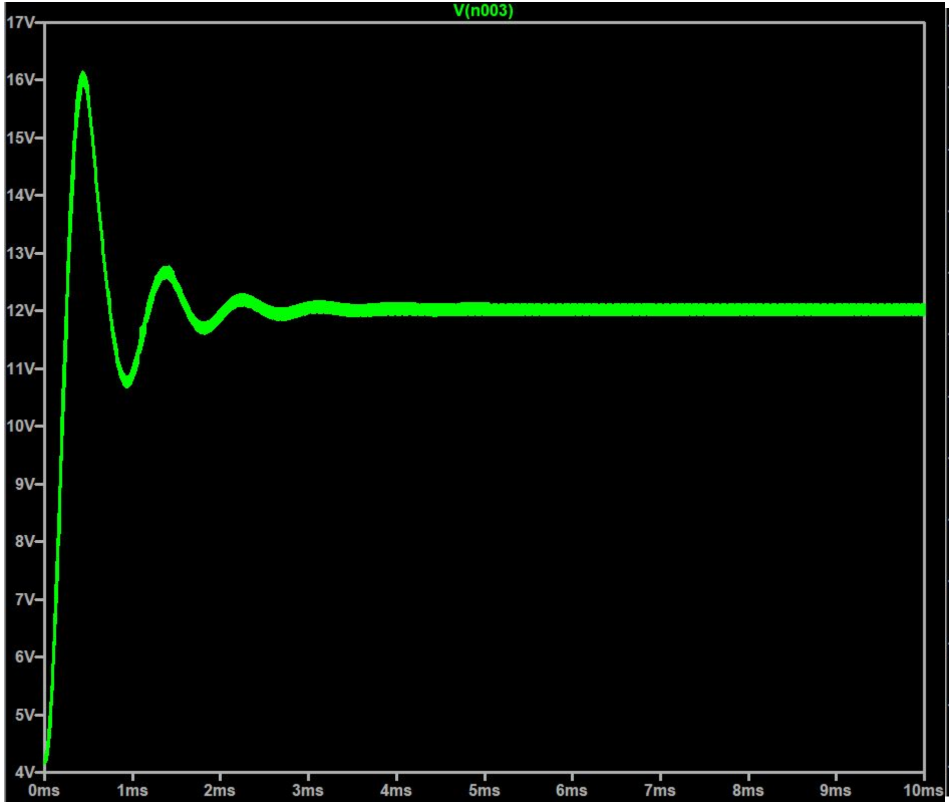
Value	Criterion	Value
Type	Schottky diodes for faster switching and low forward voltage drop	82uH
Vbrkdn	>1.5*Vout = 18V	2.1
Iave	>Io(max) = 0.5A	0.1204

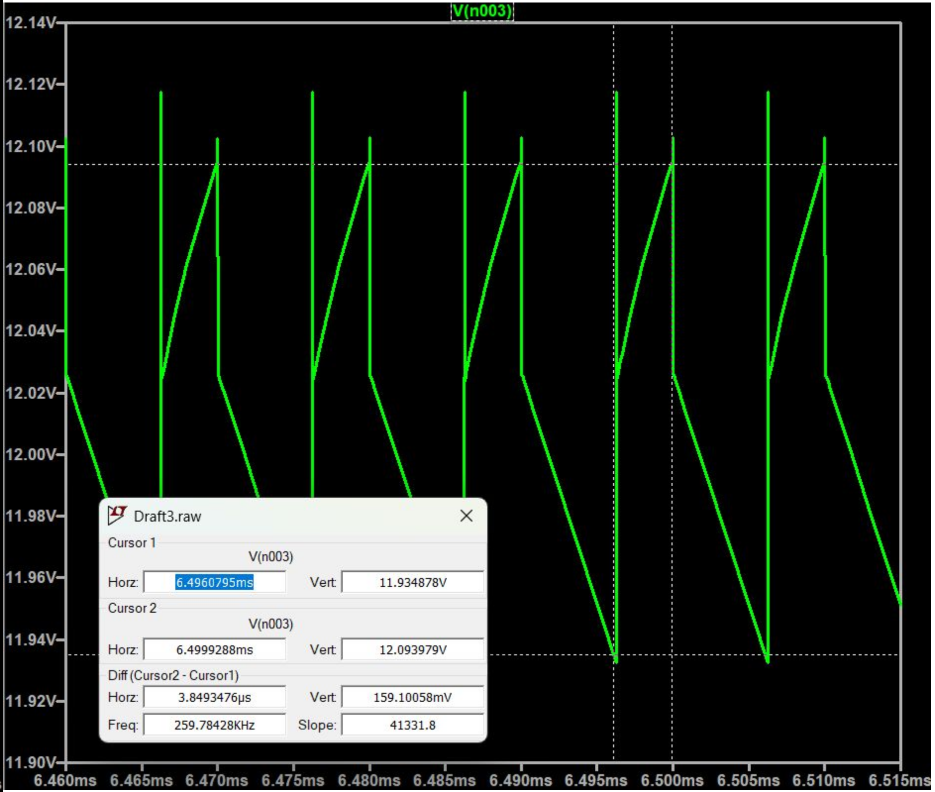
MOSFET SELECTION

Value	Criterion	Value
Vds	2*Vout = 2*12 = 24V	25V
Rds(on)	Minimum (less heat generated)	0.0024
Qg	Minimum (less switching losses)	1.1e-8



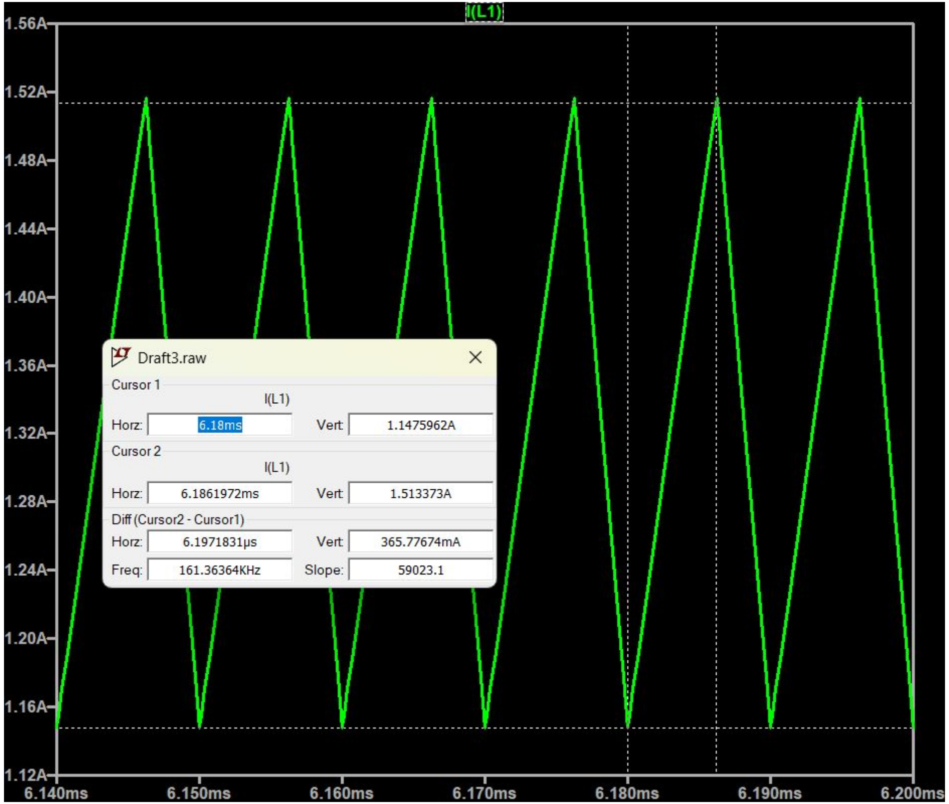
WAVEFORMS





$\Delta V_{out} = 0.16V$

WAVEFORMS



ΔIL = 0.366A

Additional directives

```
.param D=0.625 freq=100k

.meas Iin avg I(L1) FROM 9m TO 10m
.meas Vout avg V(n003) FROM 9m TO 10m
.meas Pin avg -V(n001)*I(Vin) FROM 9m TO 10m
.meas Pout avg V(n003)*I(RL) FROM 9m TO 10m
.meas n param Pout*100/Pin
```

RESULTS

Parameter	Expected	Simulated	Absolute Error(%)
Iin	1.34	1.332322	0.57
Vout	12	12.010380	0.0865
ΔVout	0.12	0.16	33.33%
ΔIL	0.4	0.366	8.5%
n	0.9	0.902256	0.25