Power Electronics

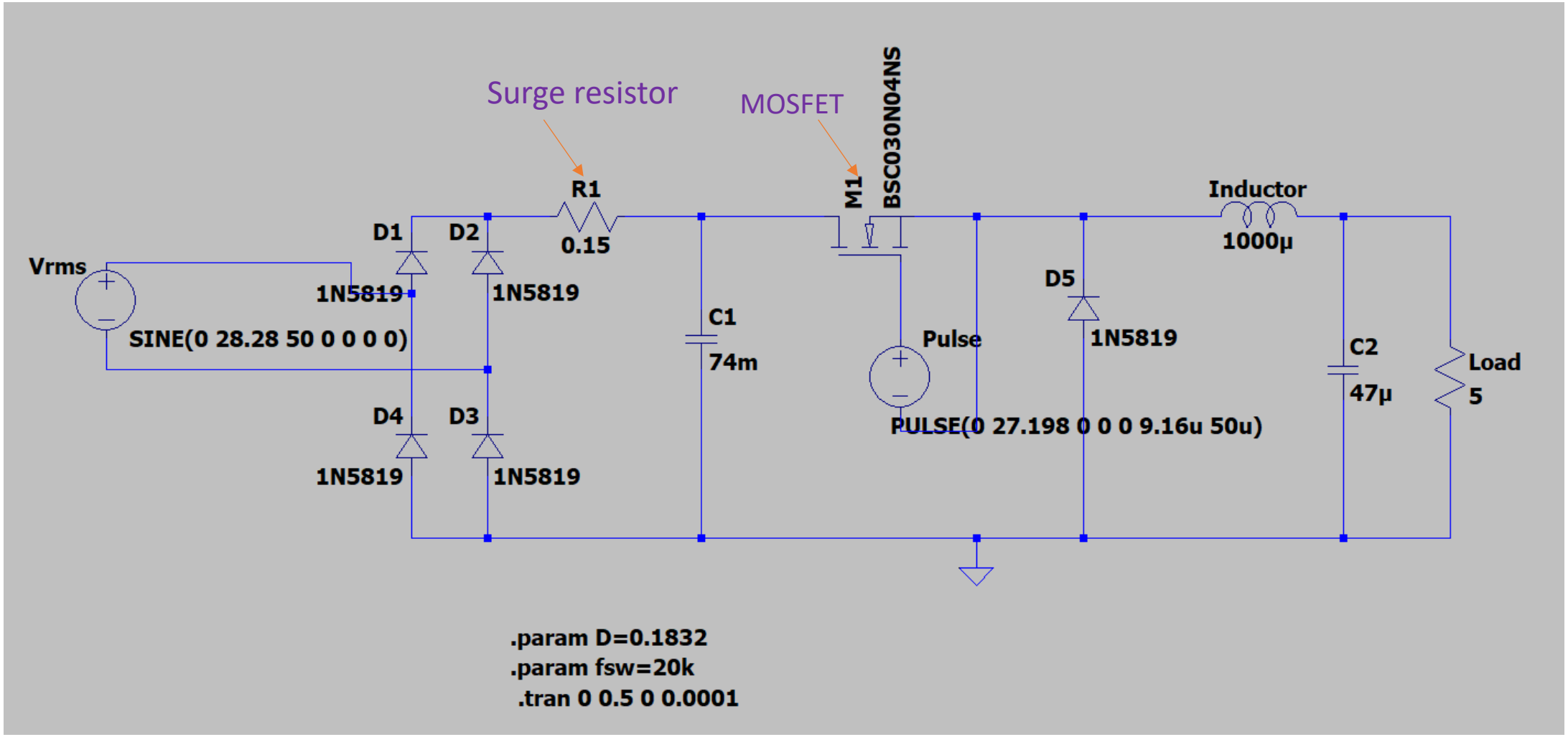
Project: Design of a Full-Wave Rectifier and Buck Converter

Name: Jaydeep Gupta
Matriculation No. 427044
RPTU Kaiserslautern
Course of Study:-Master in Commercial Vehicle Technology
Guided by:- M. Sc. Nielson Tschá

1. Introduction

- **Objective:**
- The goal of this project is to design a **power conversion system** consisting of a **single-phase full-wave rectifier** followed by a **buck converter** that meets specific ripple constraints under input voltage variations.

Schematic


Surge resistor
MOSFET
BSC030N04NS
M1
R1
0.15
D1
D2
1N5819
1N5819
Vrms
SINE(0 28.28 50 0 0 0 0)
C1
74m
Pulse
PULSE(0 27.198 0 0 0 9.16u 50u)
D5
1N5819
Inductor
1000µ
C2
47µ
Load
5
D4
D3
1N5819
1N5819
.param D=0.1832
.param fsw=20k
.tran 0 0.5 0 0.0001

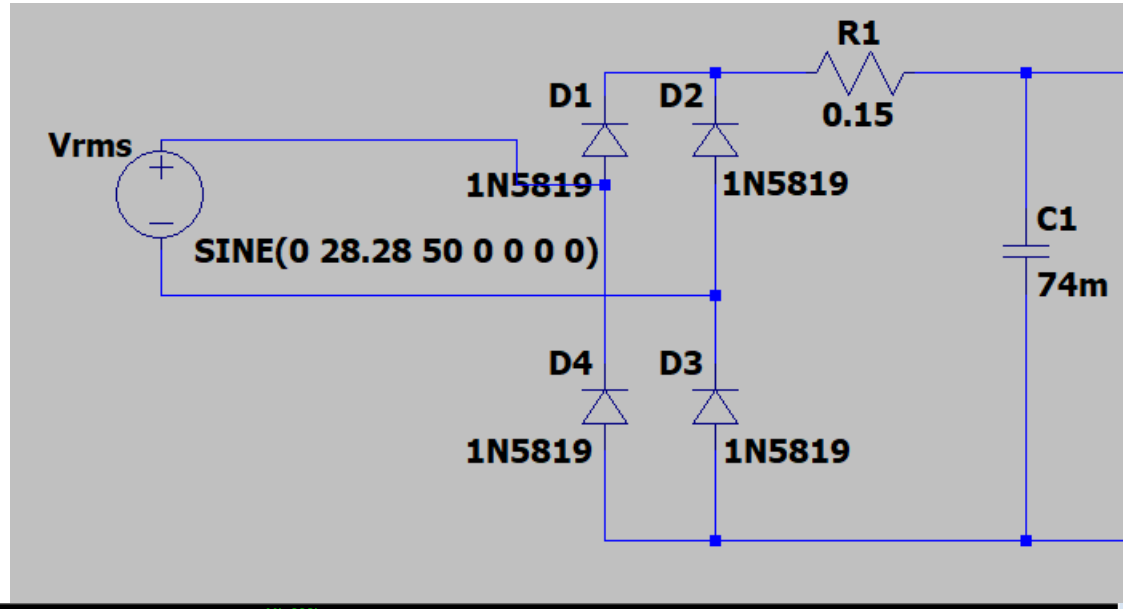
Design requirements

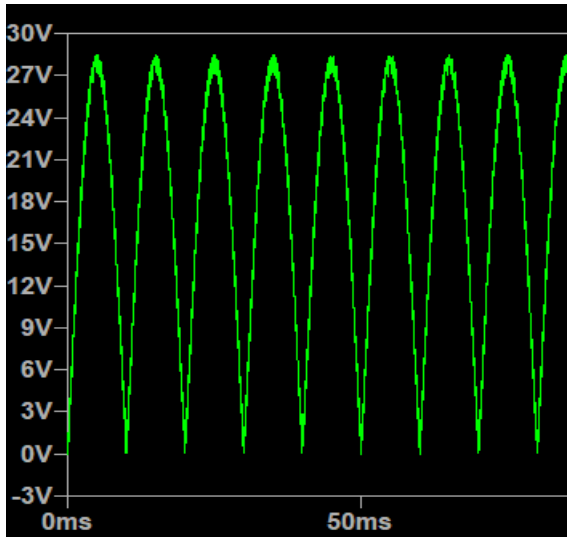
- Input Voltage = 20Vrms
- Switching frequency = 20kHz
- Output ripple current = 25%
- Output voltage ripple = 1.5%
- Load current = 1 Amp
- Output load = 5 ohm

2.System Design

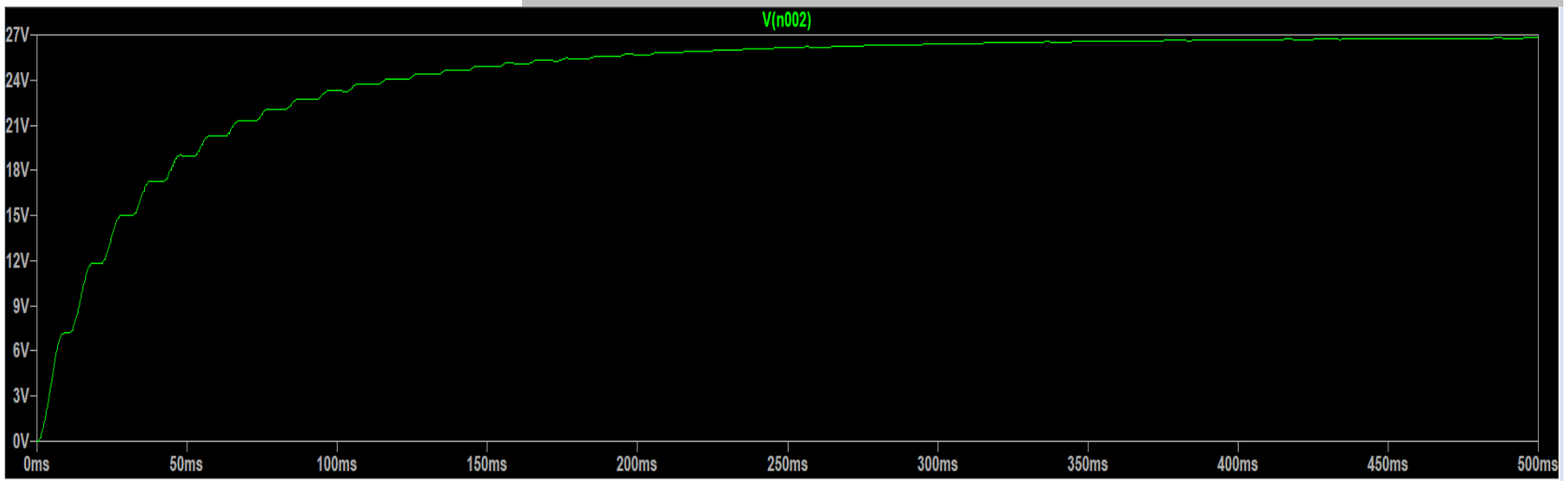
2.1 Rectifier stage

- Four 1N5819 Schottky diodes are arranged to rectify AC Vrms to DC supply.
- Resistor R1(0.15ohm) protects capacitor C1 from surge current
- Capacitor C1(74mf) stabilizes rectified voltage to constant 27.2v





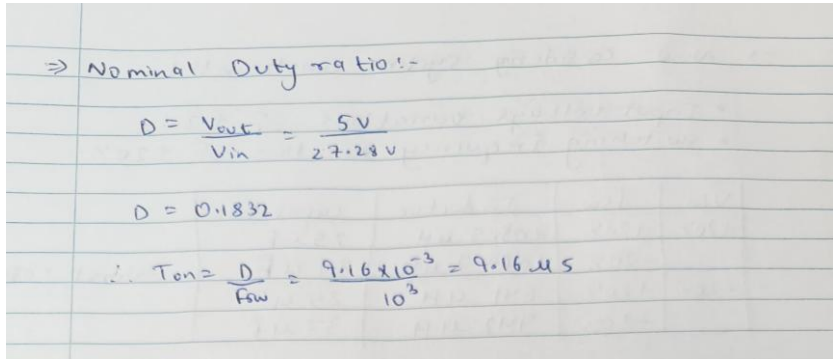
Without capacitor

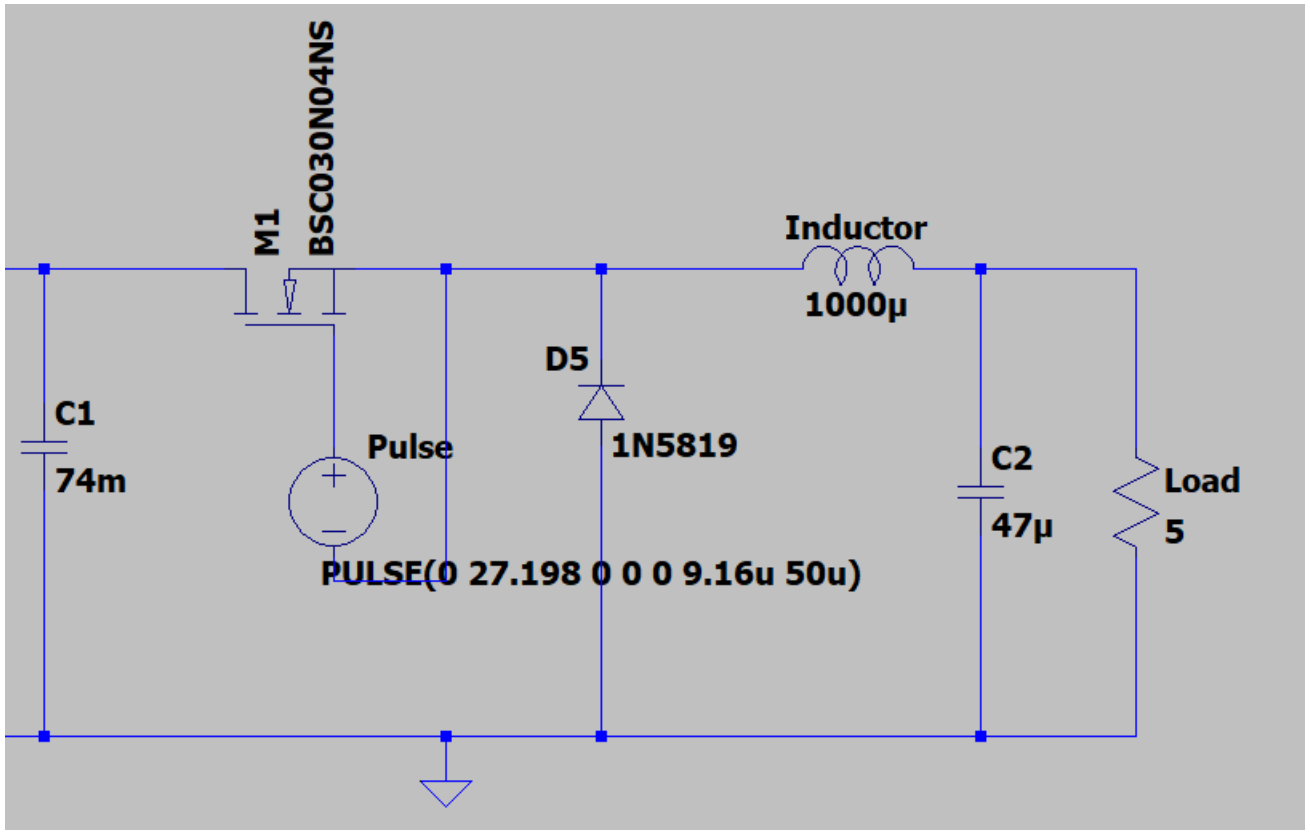


With capacitor

2.3 Buck converter stage

- Mosfet BSC030N04NS is use as a switch driven by pulse generator for that we need Ton time which can be calculated with Duty ratio





Calculations of Inductor and Output capacitor

⇒ Calculation of Inductance and capacitor under nominal conditions:-

$$\Delta i_L = \frac{-(V_{out} - V_{in})\, t_{on}}{L} = \frac{(V_{in} - V_{out}) \cdot D \cdot T_S}{L}$$

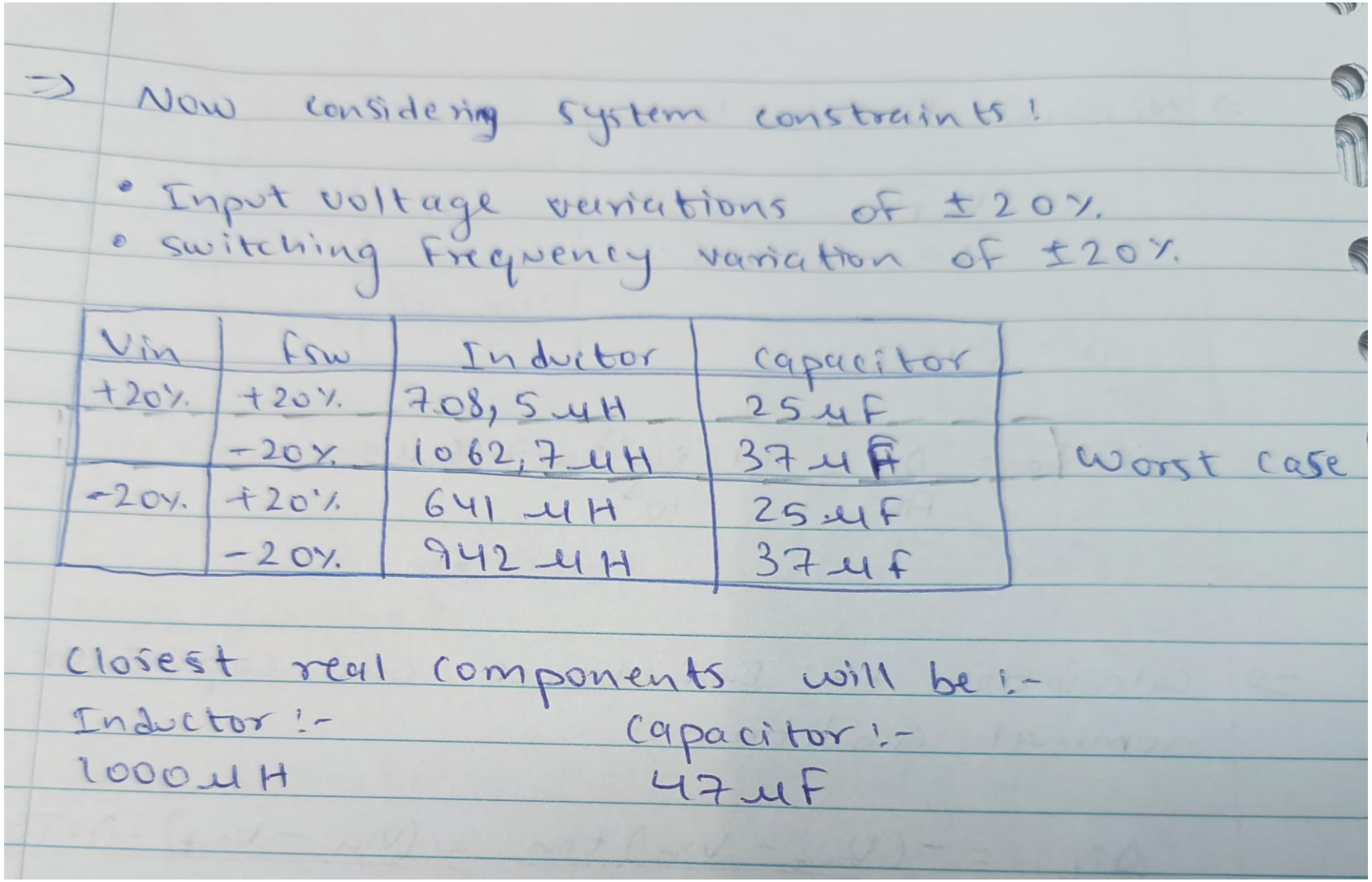
$$\therefore L = \frac{(27.28\,v - 5\,v)\ 0.1832 \times 1}{0.25 \qquad 20 \times 10^3\, Hz}$$

$$\therefore L = 816\ \mu H$$

$$\because \Delta V_{CPP} = \frac{\Delta I_L}{8 f_{sw} C} \Rightarrow C = \frac{\Delta I_L}{\Delta V_{CPP} \times 8 \times f_{sw}}$$

$$C = \frac{0.25}{0.015 \times 5 \times 8 \times 20 \times 10^3\, Hz} = 20{,}8\ \mu F$$

Considering System constraints



⇒ Now considering system constraints!

- Input voltage variations of ±20%.
- switching frequency variation of ±20%.

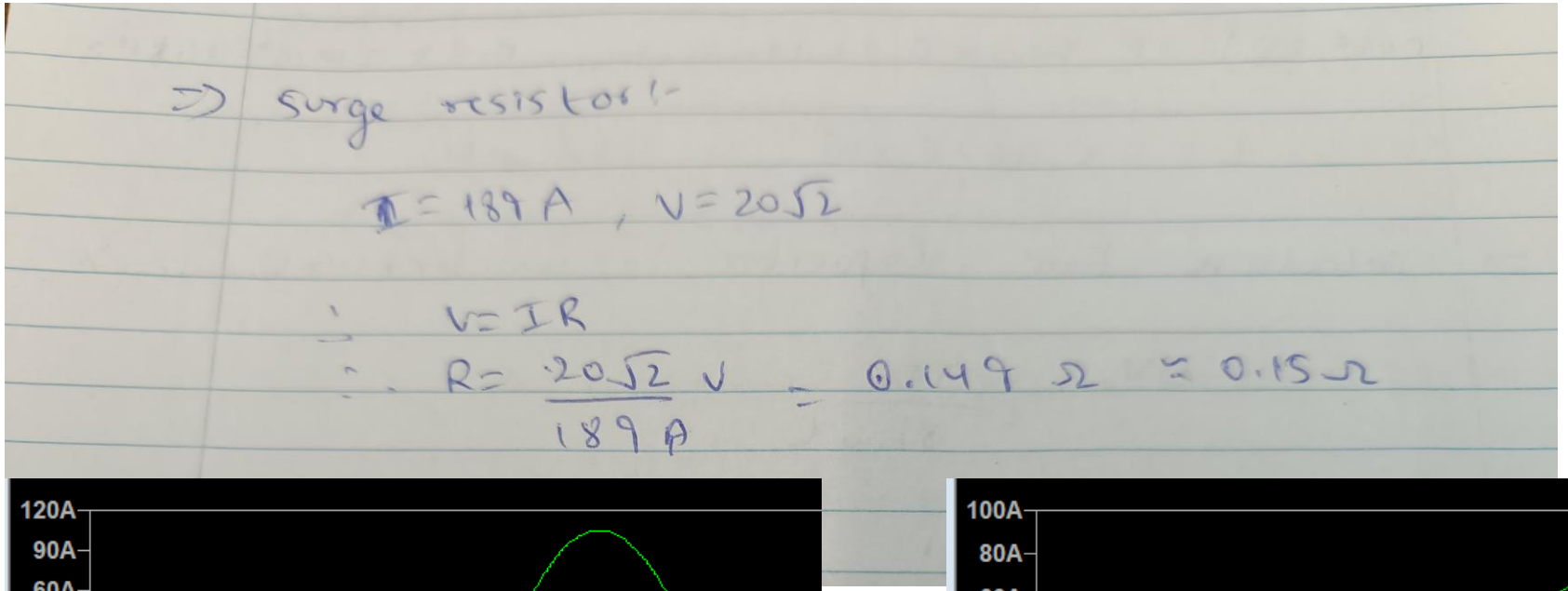
Vin	fsw	Inductor	capacitor	
+20%	+20%	708,5 μH	25 μF	
	-20%	1062,7 μH	37 μF	Worst case
-20%	+20%	641 μH	25 μF	
	-20%	942 μH	37 μf	

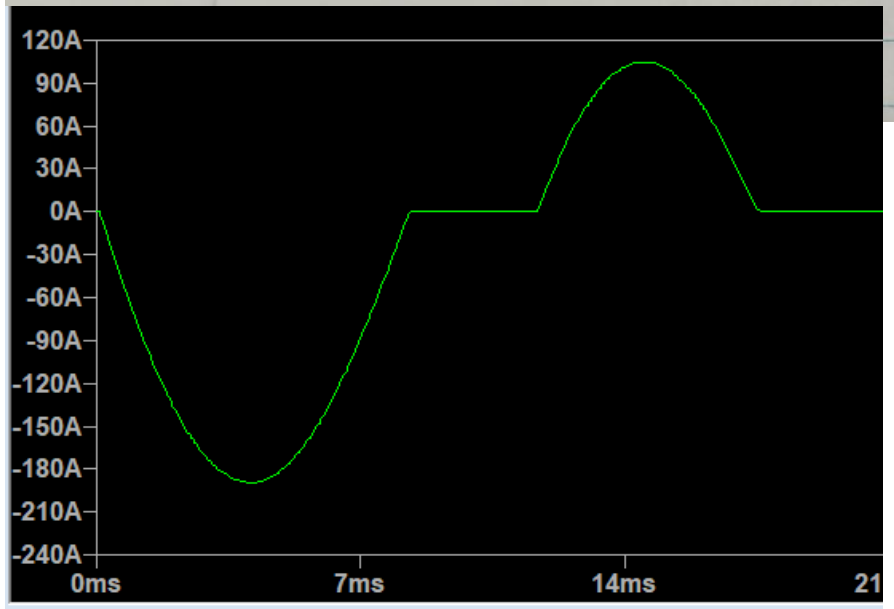
Closest real components will be :-

Inductor :- 1000 μH

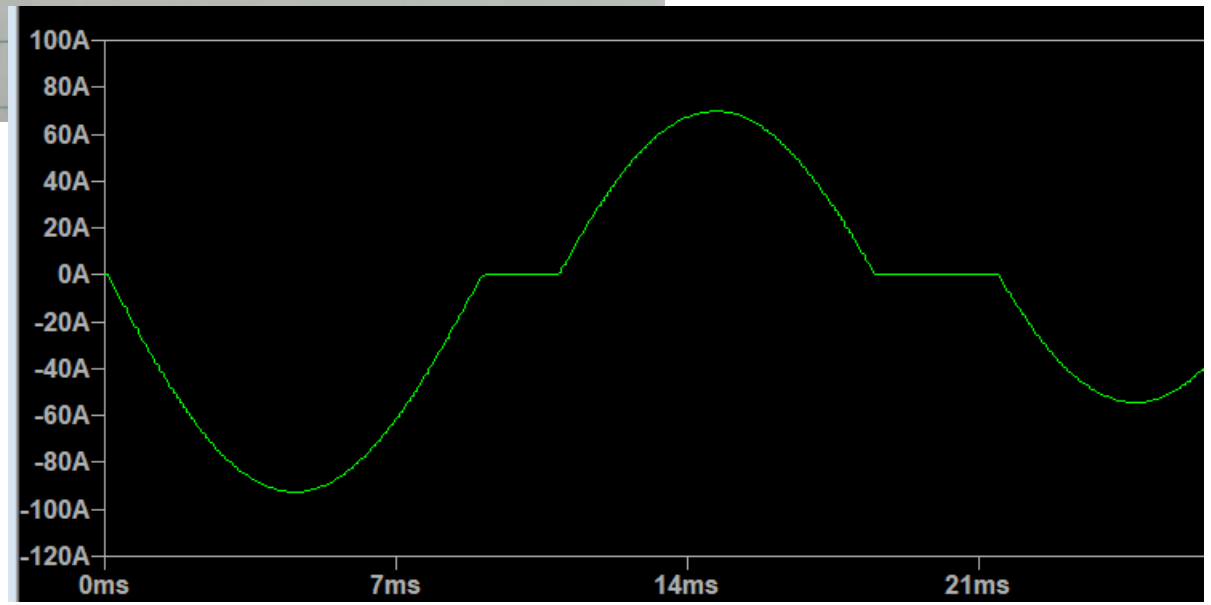
Capacitor :- 47 μF

Surge current resistor



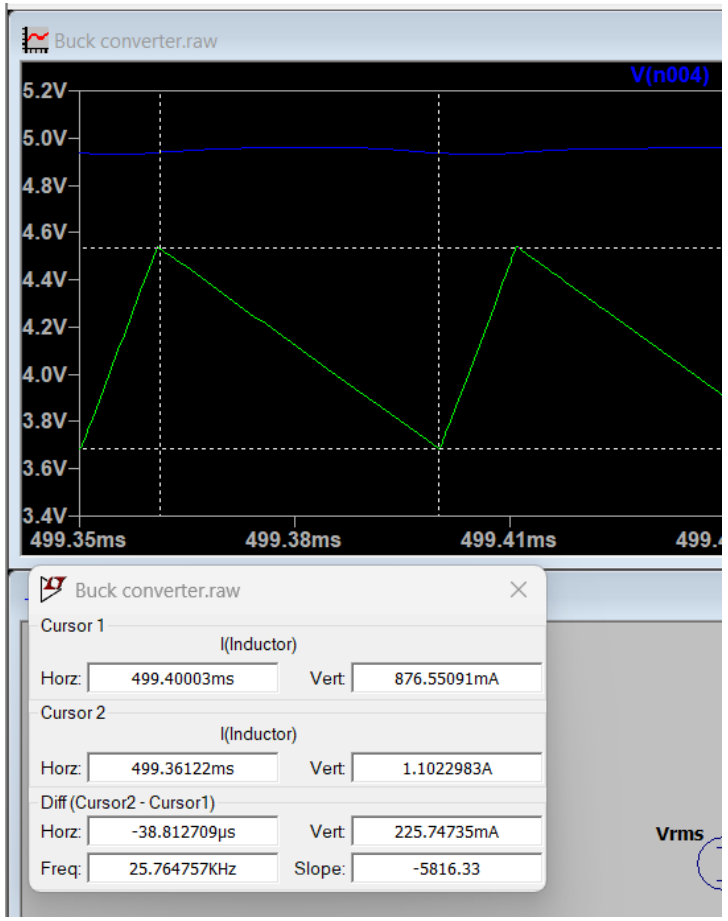


Initial current through capacitor w/o surge resistor

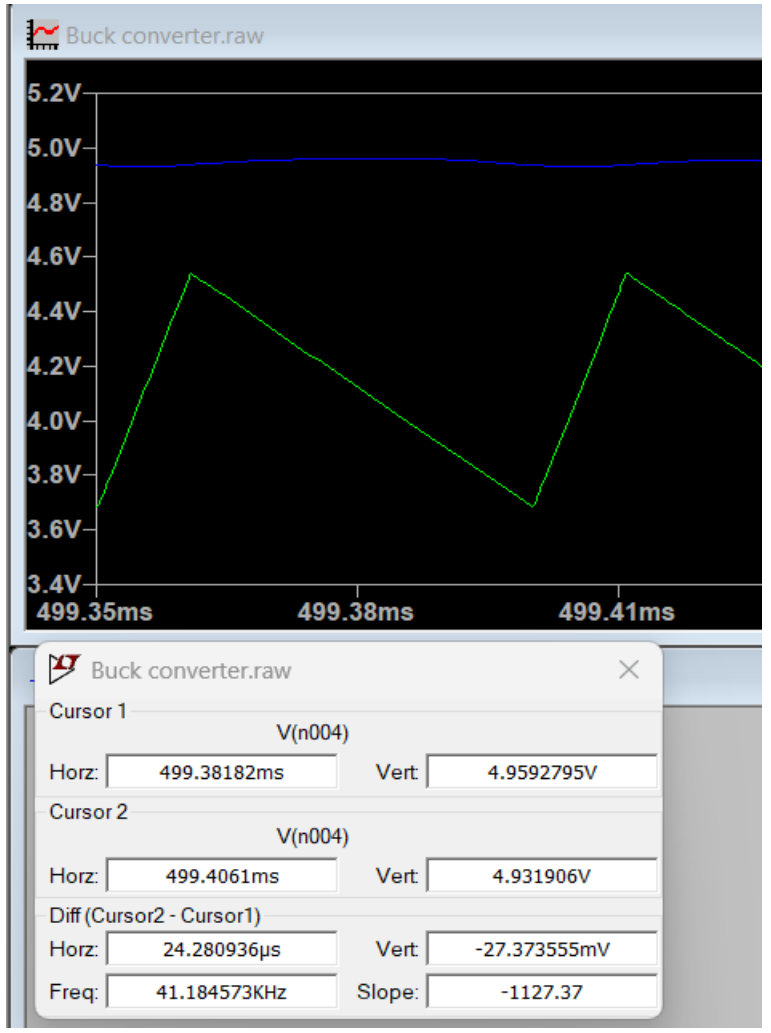


With surge resistor

Output ripple



Current ripple = 22.5%



Voltage ripple = 2.5%

*can be reduced by reducing resistance through inductor

Real Components with data sheets

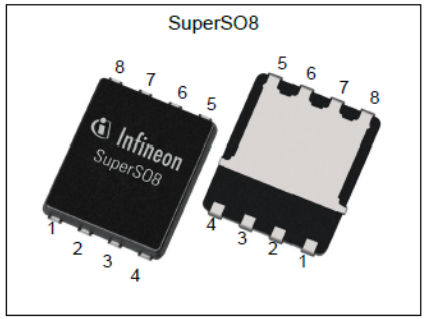
BSC030N04NS G

MOSFET

OptiMOS™3 Power-Transistor, 40 V

Features

- Fast switching MOSFET for SMPS
- Optimized technology for DC/DC converters
- Qualified according to JEDEC[1] for target applications
- N-channel; Normal level
- Excellent gate charge x $R_{DS(on)}$ product (FOM)
- Very low on-resistance $R_{DS(on)}$
- Superior thermal resistance
- 100% Avalanche tested
- Pb-free plating; RoHS compliant
- Halogen-free according to IEC61249-2-21



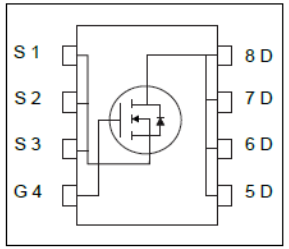


Table 1 Key Performance Parameters

Parameter	Value	Unit
V_{DS}	40	V
$R_{DS(on),max}$	3.0	mΩ
I_D	132	A

Justification

- As our circuit operates with an input voltage of 22v to 33v, we need MOSFET with Vds >33v with Id > 1amp

Shielded Power Inductors MSS1812T

- 7 inductance values from 100 µH to 1000 µH
- Very low DCR and excellent current handling
- AEC-Q200 Grade 1 (–40°C to +125°C)
- **Designer's Kit C499** contains 3 of each part

Core material Ferrite
Core and winding loss See www.coilcraft.com/coreloss
Environmental RoHS compliant, halogen free
Terminations RoHS compliant matte tin over nickel over phos bronze. Other terminations available at additional cost.
Weight: 11.82 – 13.26 g
Operating voltage 400 V max
Ambient temperature –40°C to +125°C with (40°C rise) Irms current.
Maximum part temperature +165°C (ambient + temp rise). Derating.
Storage temperature Component: –40°C to +165°C. Tape and reel packaging: –40°C to +80°C
Resistance to soldering heat Max three 40 second reflows at +260°C, parts cooled to room temperature between cycles
Moisture Sensitivity Level (MSL) 1 (unlimited floor life at <30°C / 85% relative humidity)
PCB washing Tested to MIL-STD-202 Method 215 plus an additional aqueous wash. See Doc787_PCB_Washing.pdf.

Part number[1]	Inductance[2] (µH)		DCR (Ohms)[3] typ	DCR (Ohms)[3] max	SRF typ[4] (MHz)	Isat (A)[5] 10% drop	Isat (A)[5] 20% drop	Isat (A)[5] 30% drop	Irms (A)[6] 20°C rise	Irms (A)[6] 40°C rise
MSS1812T-104MED	100	±20%	0.045	0.052	3.3	5.2	5.8	6.0	2.87	4.35
MSS1812T-154KED	150	±10%	0.057	0.066	2.8	4.2	4.6	4.8	2.50	3.80
MSS1812T-224KED	220	±10%	0.086	0.098	2.3	3.6	3.8	4.0	2.09	3.16
MSS1812T-334KED	330	±10%	0.13	0.15	1.8	2.9	3.1	3.1	1.68	2.55
MSS1812T-474KED	470	±10%	0.20	0.23	1.35	2.4	2.7	2.8	1.39	2.10
MSS1812T-684KED	680	±10%	0.24	0.27	1.33	2.0	2.2	2.3	1.24	1.88
MSS1812T-105KED	1000	±10%	0.45	0.52	0.85	1.7	1.8	1.8	0.93	1.40

Inductor for worst case

muRata

Chip Monolithic Ceramic Capacitor for General

GRM32ER61A476KE20_ (1210, X5R:EIA, 47uF, DC10V)

_: packaging code

Reference Sheet

1.Scope

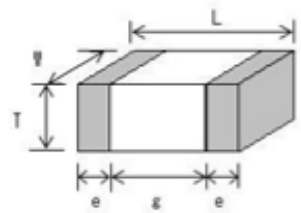
This product specification is applied to Chip Monolithic Ceramic Capacitor used for General Electronic equipment.

2.MURATA Part NO. System

(Ex.)

GRM	32	E	R6	1A	476	K	E20	L
	(1)L/W Dimensions	(2)T Dimensions	(3)Temperature Characteristics	(4)Rated Voltage	(5)Nominal Capacitance	(6)Capacitance Tolerance	(7)Murata's Control Code	(8)Packaging Code

3. Type & Dimensions



(Unit:mm)

(1)-1 L	(1)-2 W	(2) T	e	g
3.2±0.3	2.5±0.2	2.5±0.2	0.3 min.	1.0 min.

4.Rated value

(3) Temperature Characteristics (Public STD Code):X5R(EIA)		(4) Rated Voltage	(5) Nominal Capacitance	(6) Capacitance Tolerance	Specifications and Test Methods (Operating Temp. Range)
Temp. coeff or Cap. Change	Temp. Range (Ref.Temp.)				
-15 to 15 %	-55 to 85 °C (25 °C)	DC 10 V	47 uF	±10 %	-55 to 85 °C

Output Capacitor

Thanks for your attention