ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

EE464 HARDWARE PROJECT PRESENTATION By Emine BOOSTancı

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1. Design Criteria

- **Minimum Input Voltage**: 20 V
- **Maximum Input Voltage**: 40 V
- **Output Voltage**: 12 V
- **Output Power**: 60 W
- **Output Voltage Peak-to-Peak Ripple**: 3%
- **Line Regulation:** 3%
- **Load Regulation:** 3%
- **Isolated Converter**
- **Close Loop Feedback**

2. Topology & Design Selection

- **Flyback Converter:** low power applications
(up to 100 Watts)
- **Forward Converter:** 50 Watts to a couple of hundred watts
- **Push Pull Converter:** medium power levels (100 Watts to a few kilowatts)
- **Half and Full Bridge Converter:** medium to high power ranges (100 Watts to over 500 Watts)
- Push Pull, Half and Full Bridge Convertes are **overdesign**.

2. Topology & Design Selection

Flyback Converter

- No restriction on D
- Less components (only transformer)
- No resetting the core's flux
- Easiest to design
- Leakage inductance
- Less efficiency
- More ripple and worse regulation

Forward Converter

- Restriction on D
- More components (transformer & inductor)
- Resetting the core's flux
- Harder to design
- Magnetizing inductance
- Higher efficiency
- Less ripple and better regulation

2. Topology & Design Selection

Single Switch Flyback Converter

- No restriction on D
- Simplicity
- Snubber Design
- Less efficiency

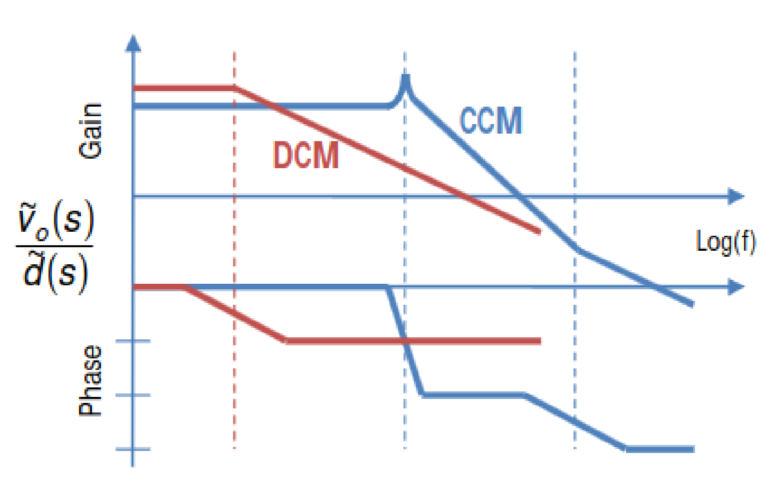
Two Switch Flyback Converter

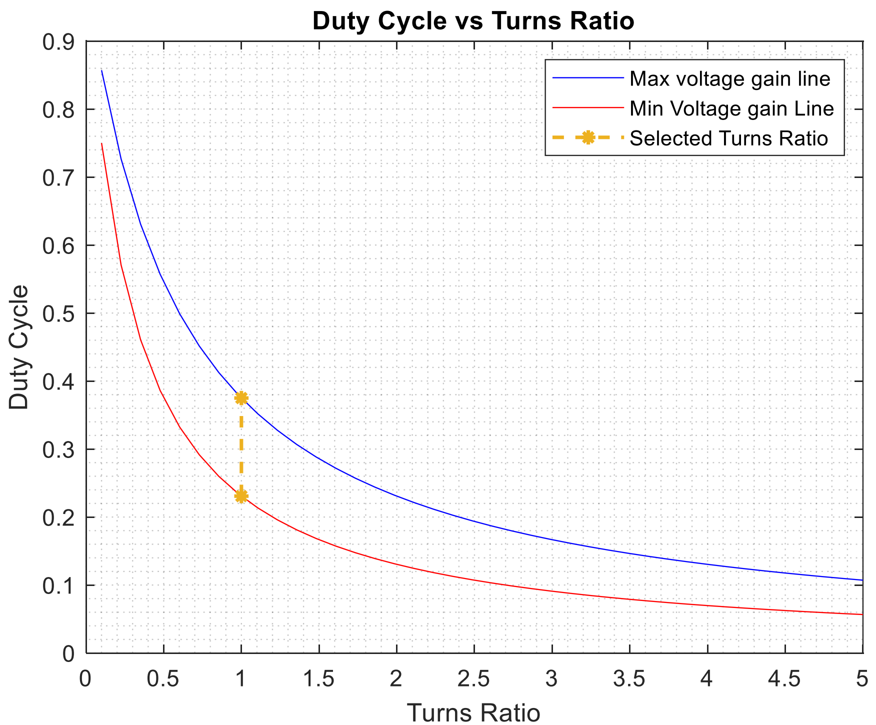
- D < 0.5 for CCM
- Complexity (high side switch)
- High input capacitance
- Higher efficiency

Target Efficiency = %80

2. Topology & Design Selection

- **CCM or DCM:** CCM. Less ripple but worse core utilization. Analytically easy but nonlineer Bode plot.
- **Switching Frequency:** 90 kHz.
- **Turns Ratio and Duty Cycle Range:** 0.23<D<0.375 N=1



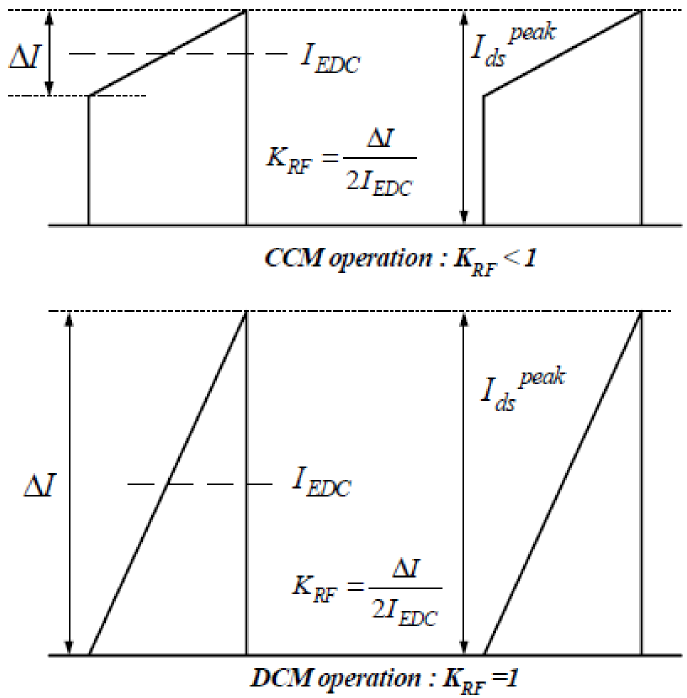


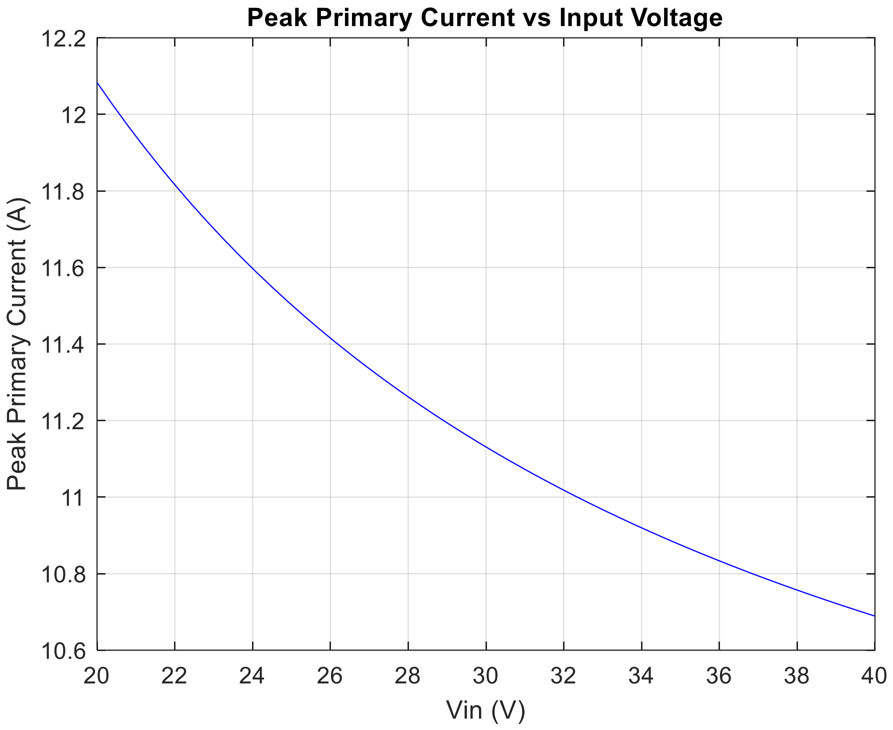
3. Magnetic Design

- **Lm Determination:**

$$L_m > \frac{(V_{in}^{max}\ D_{min})^2}{2\ P_{in} f_s K_{RF}} = \frac{(40V\ 0.238)^2}{2\ (75W)(90kHz)0.7} = 9.6\ \mu H$$

$$L_m = 20\ \mu H$$





3. Magnetic Design

- **Core Selection:**

Aim: Operate around 100mT to minimize losses.

Disadvantage: Volume increase. Losses might increase.

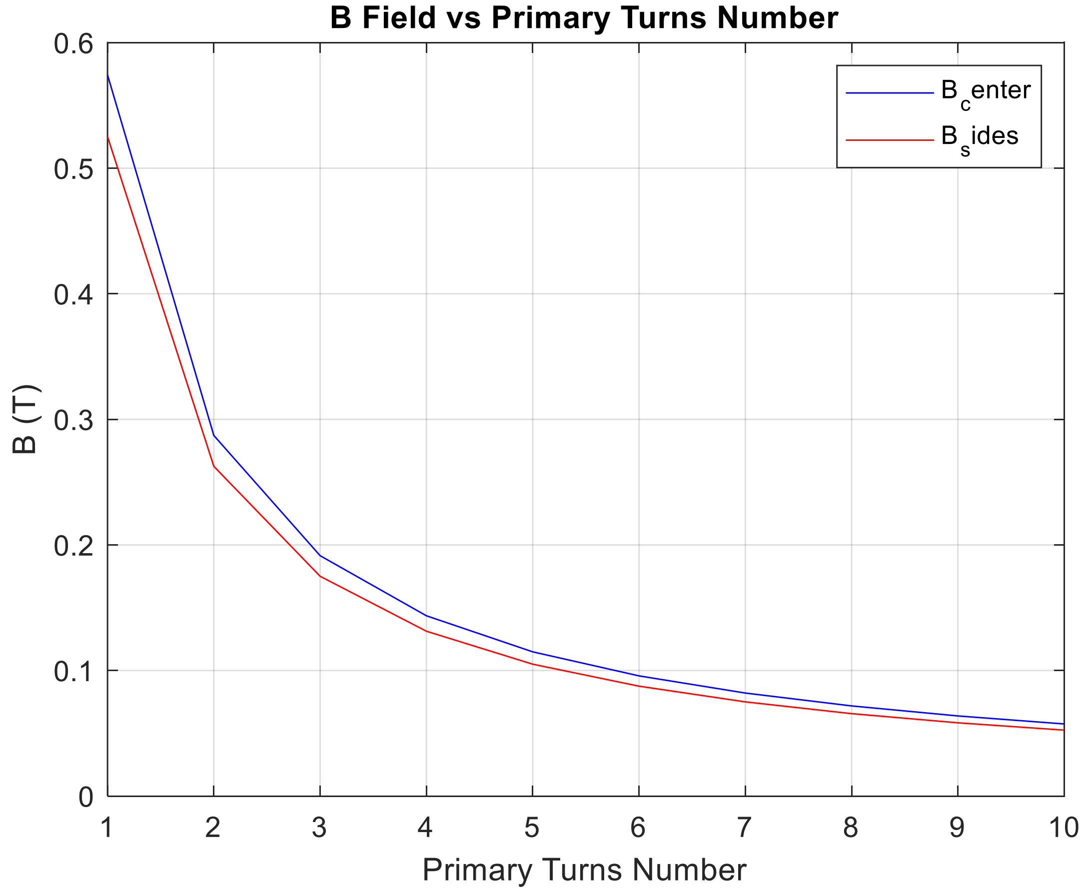
Choose ferrite core → less leakage. Fringing fields problem

Higher window area → fill factor ↘ auxilary winding

0R45530EC

3. Magnetic Design

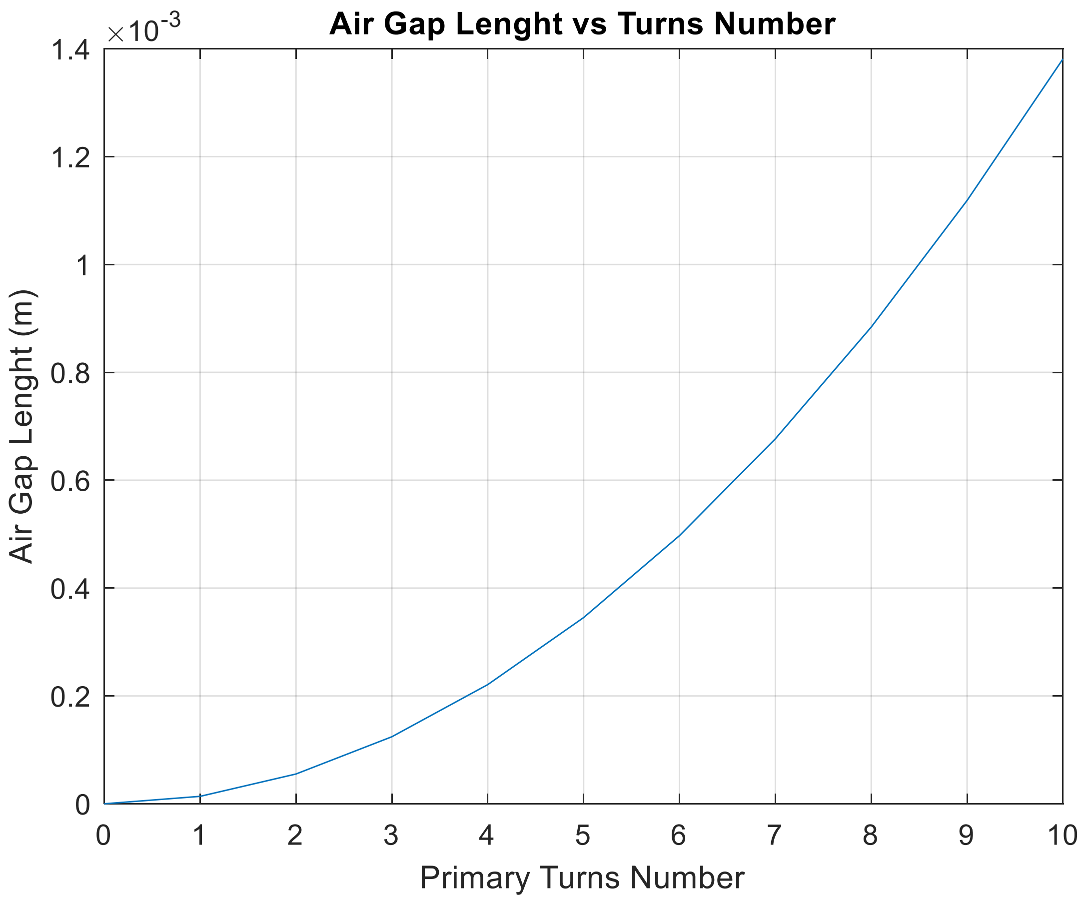
- **Core Selection:** $N_1 \emptyset = L_m I_{max,pri}$



3. Magnetic Design

- **Core Selection:**

$$L_m = \frac{N_1^2}{R_{gap}}$$



N1=N2=7 turns

lgap=0.7 mm

Bmax=96 mT

3. Magnetic Design

- **Cable Selection:**

Choose 2δ (@90kHz 0.44 mm) > Dconductor

AWG 26 $(D = 0.4\,mm, A = 0.129\,mm^2)$

Maximum RMS Current is 10A.

$$J = 3\ \mathrm{A}/mm^2$$

$$\#parallels = \frac{I_{rms,max}}{J\ A} = 26$$

For safety take 30 parallel.

From core geometry find MLT and length of the copper.

$$R_{primary} = R_{secondary} = 3.9m\Omega$$

$$P_{Cu} = P_{primary} + P_{secondary} = 0.793\ W$$

$$Fill\ Factor = 0.1683$$

[1]

3. Magnetic Design

- **Core Losses:**

Steinmetz Coefficients

$$P_{CL} = \frac{a\, f^{x} B^{y} L(T)}{100}\ mW/cm^{3}$$

$$L(T) = b - cT + dT^{2}$$

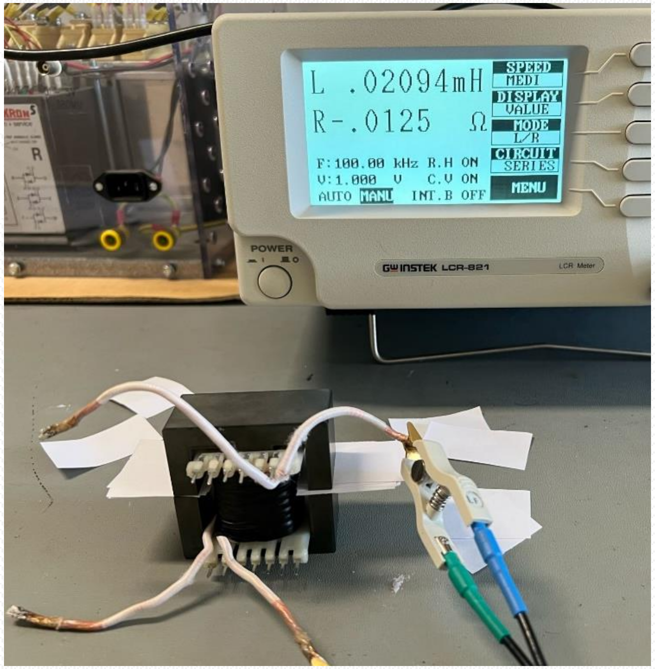
Material	Frequency Range	a	x	y	b	c	d	Core Loss P_{CL} (mW/cm3)
R Material	20kHz-150kHz	3.53	1.420	2.880	1.970000000	0.022260000	0.0001250000	30.89
	150kHz-400kHz	5.88E-04	2.120	2.700	2.160000000	0.023270000	0.0001170000	

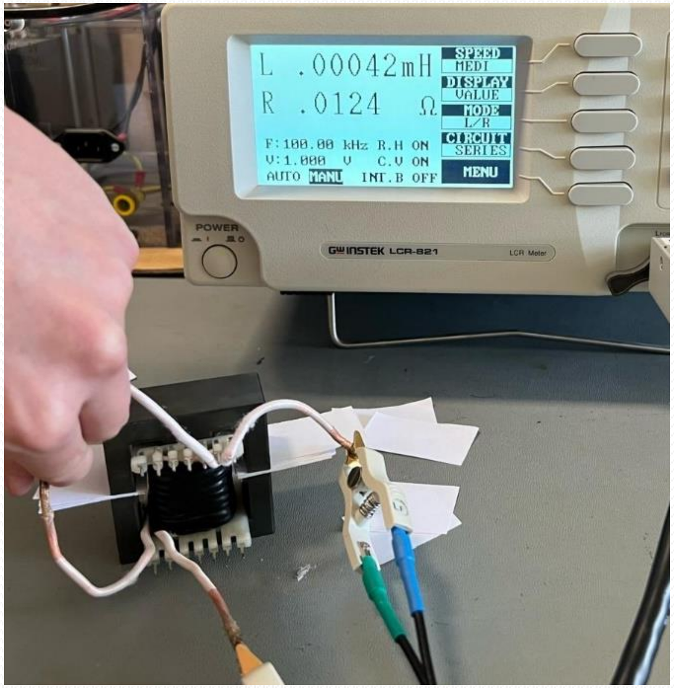
$$P_{core} = 2VP_{CL} = 3.21\ W$$

[2]

3. Magnetic Design

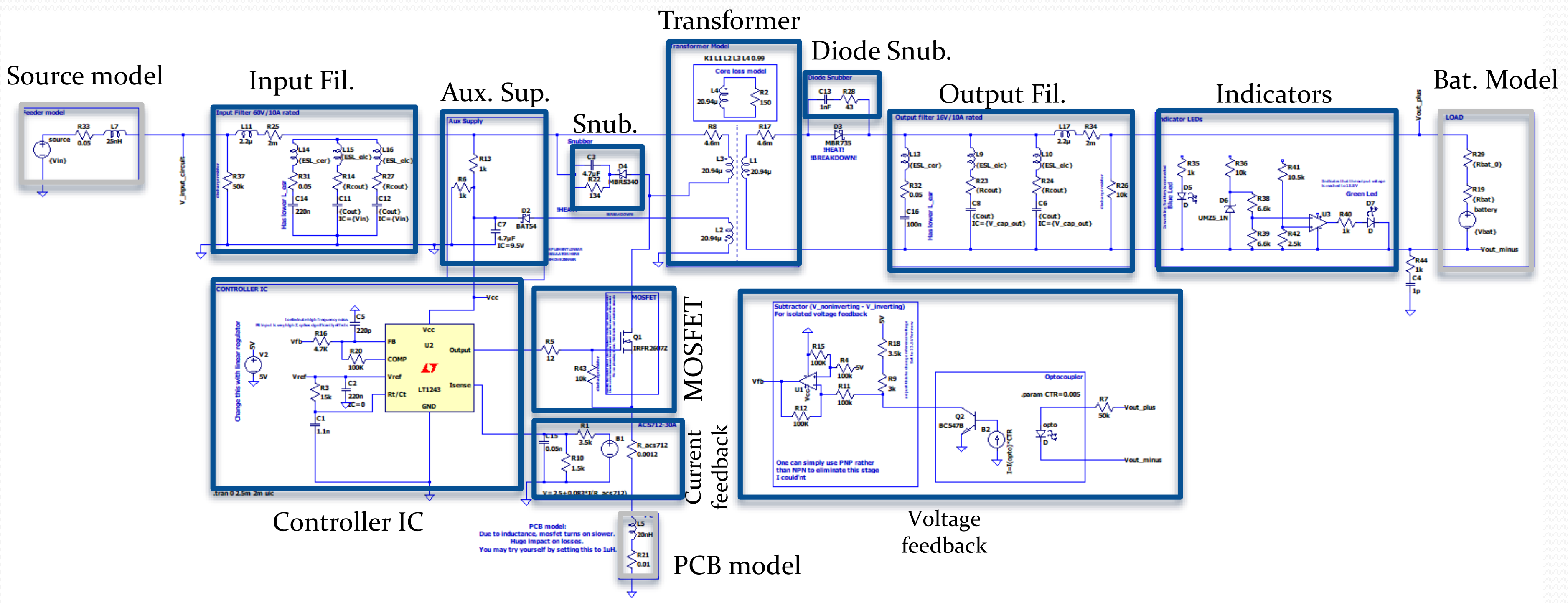
- **Experimental Results:**





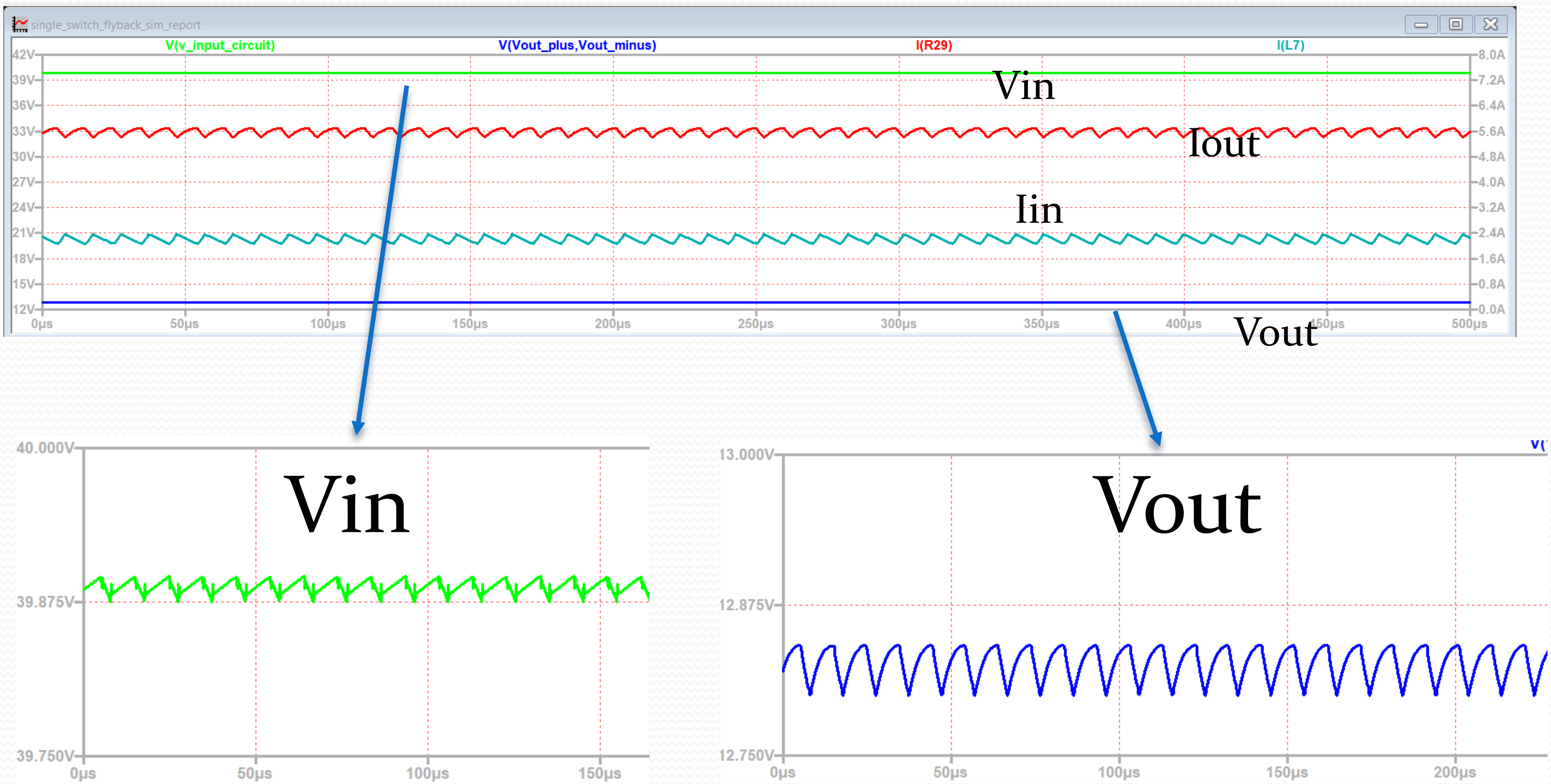
$$L_m = 20.94\ \mu H \quad L_{leak} = 0.21 \mu H \quad R_{Cu} = 4.6\ m\Omega$$

4. Simulation Results:Block diagram

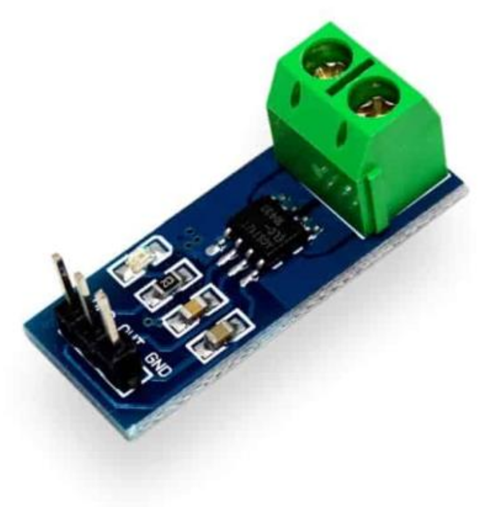


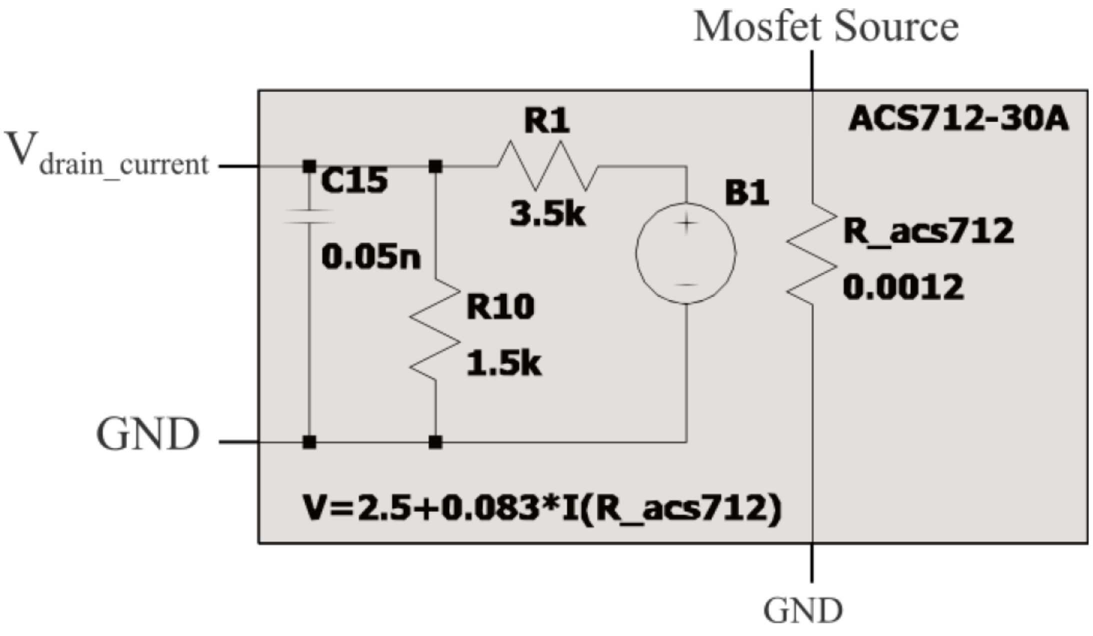
4. Simulation Results:Block diagram

Single run for Vin = 40V, Vbat = 12V

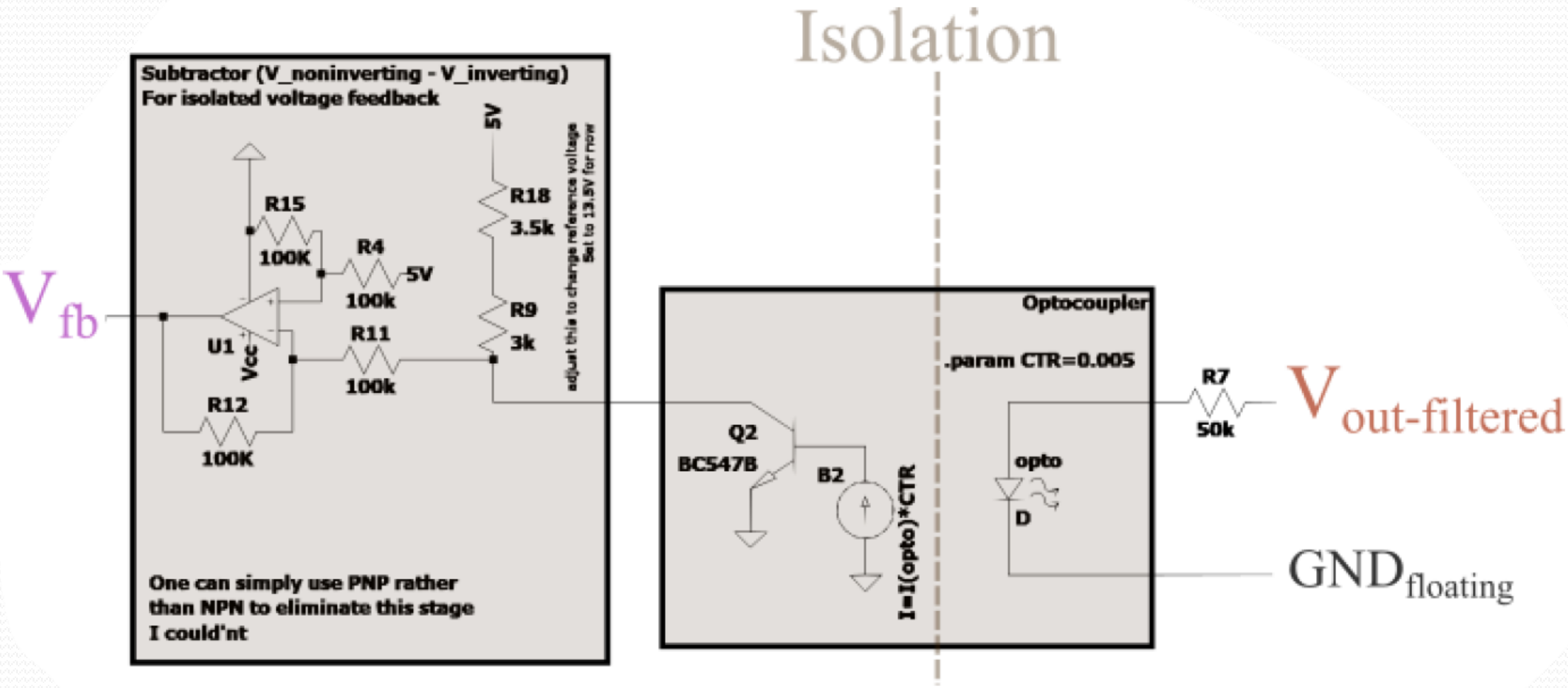


4. Simulation models: Current Feedback

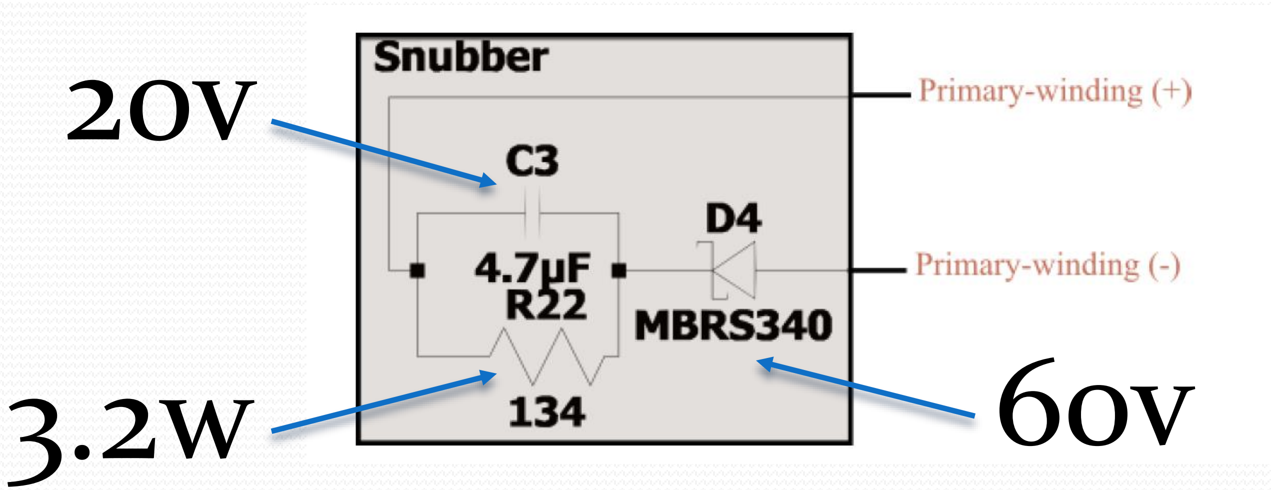


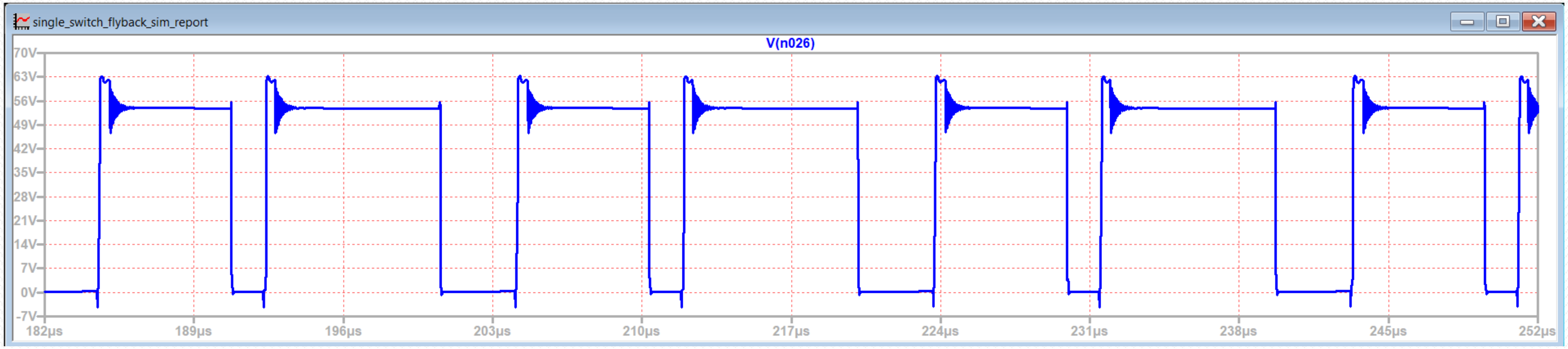


4. Simulation Results: Voltage Feedback



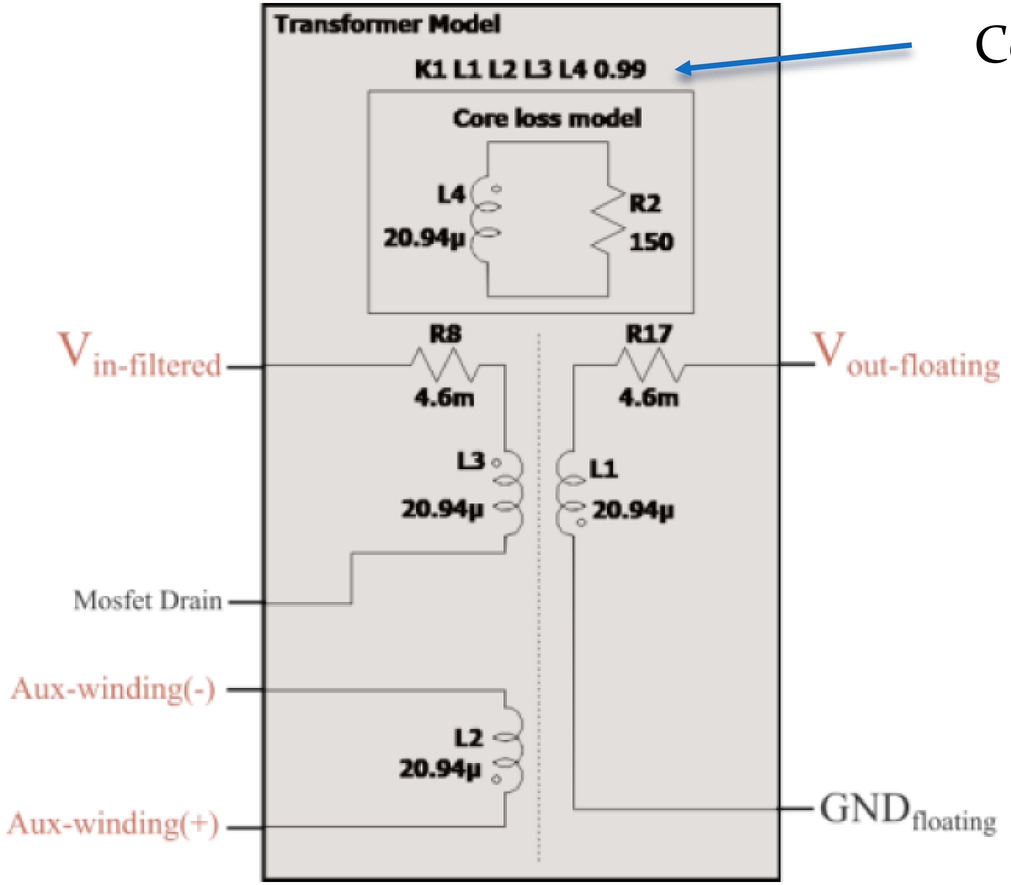
4. Simulation Results: Snubber (40V Vin)





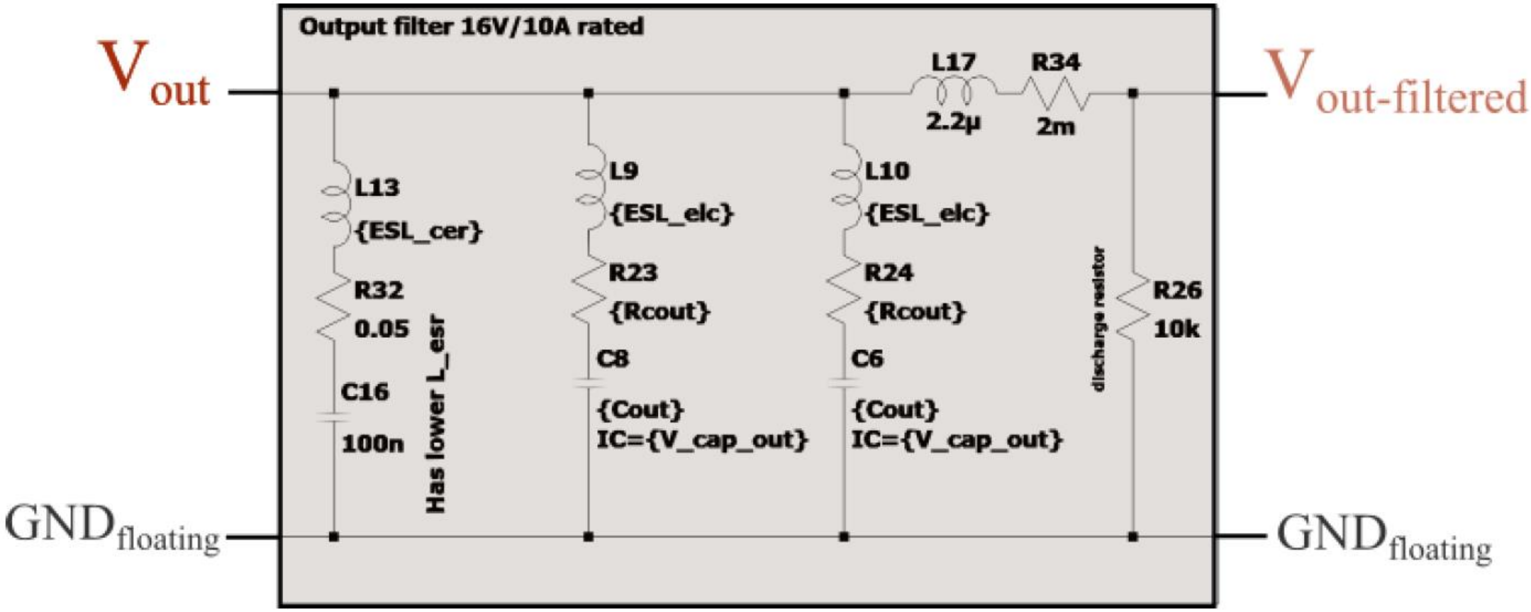
Drain-to-Source Voltage of MOSFET

4. Simulation Results: Transformer Model



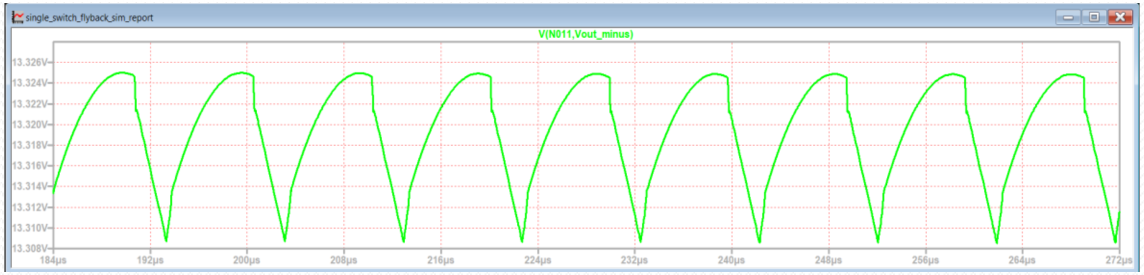
Coupling Factor
%1

4. Simulation Results: Output Filter Model

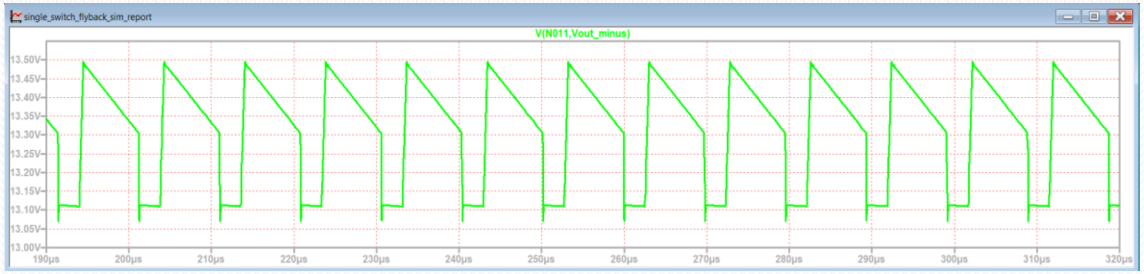


4. Simulation Results: Capacitor Model

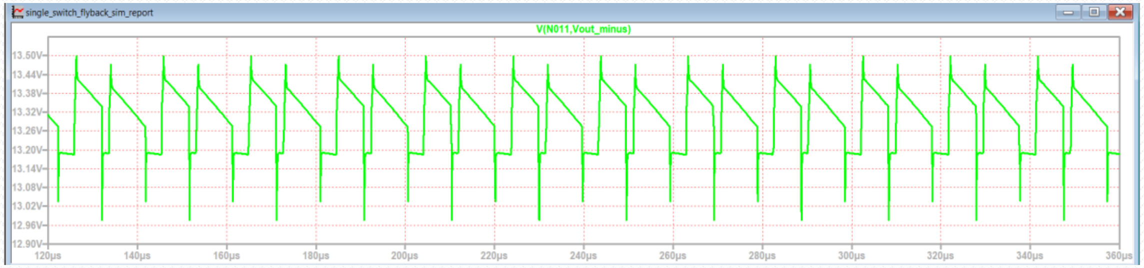
C

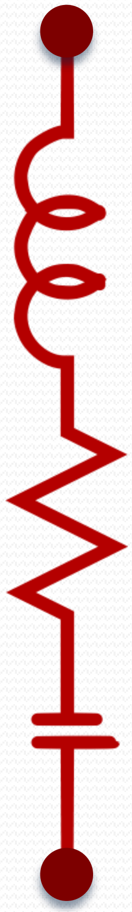


C-R



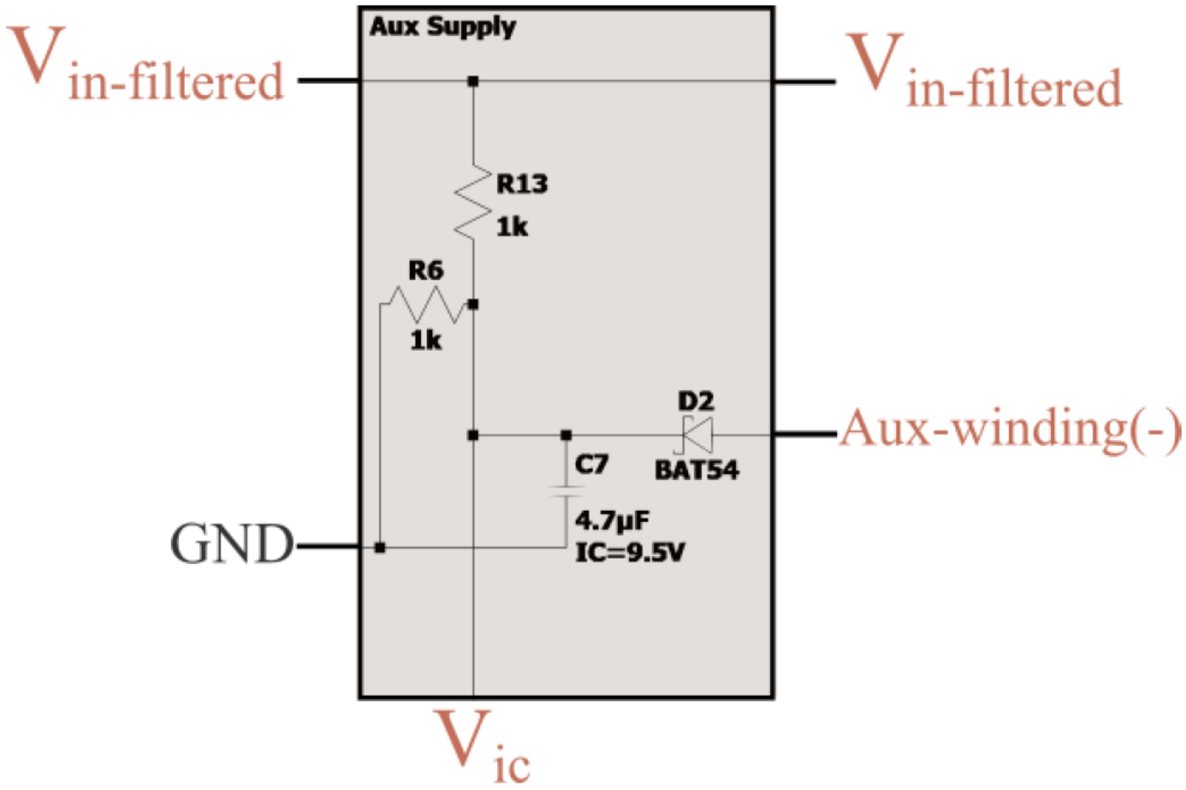
C-R-L



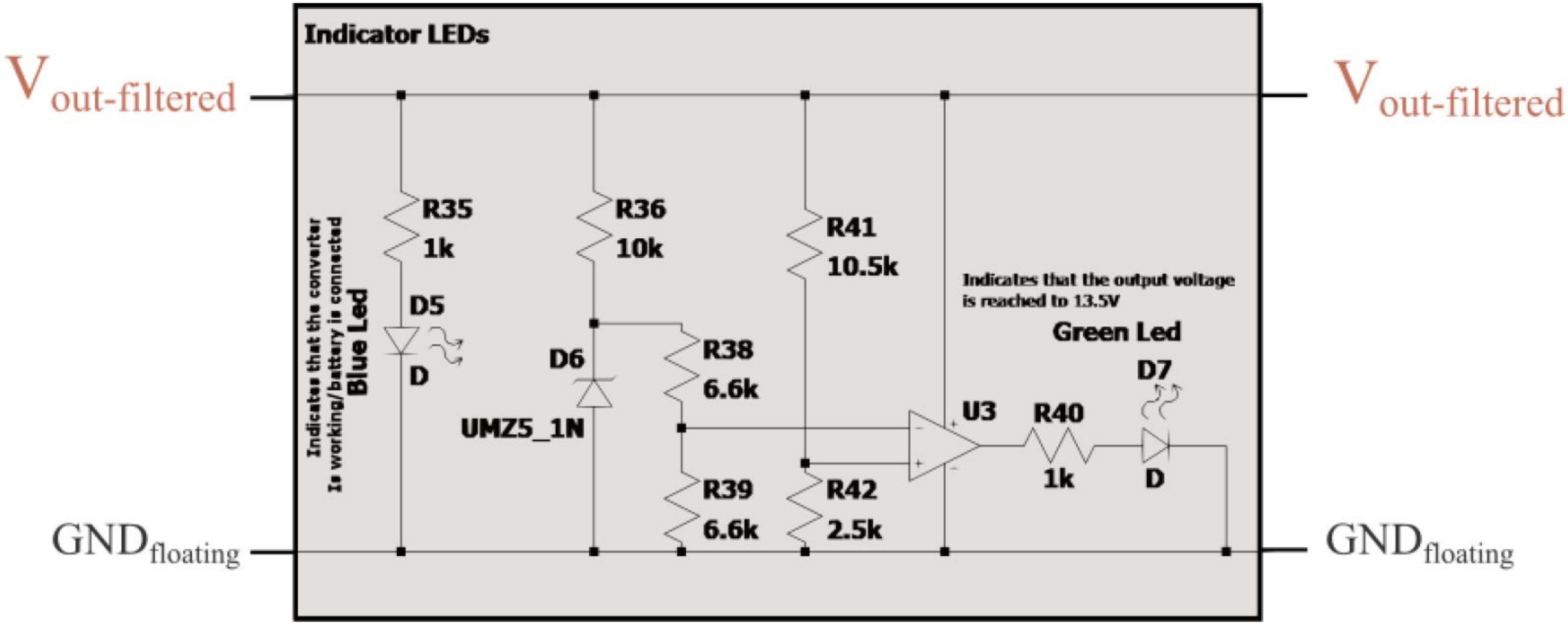


Output voltages seen at secondary terminals

4. Simulation Results: Auxiliary Supply Model

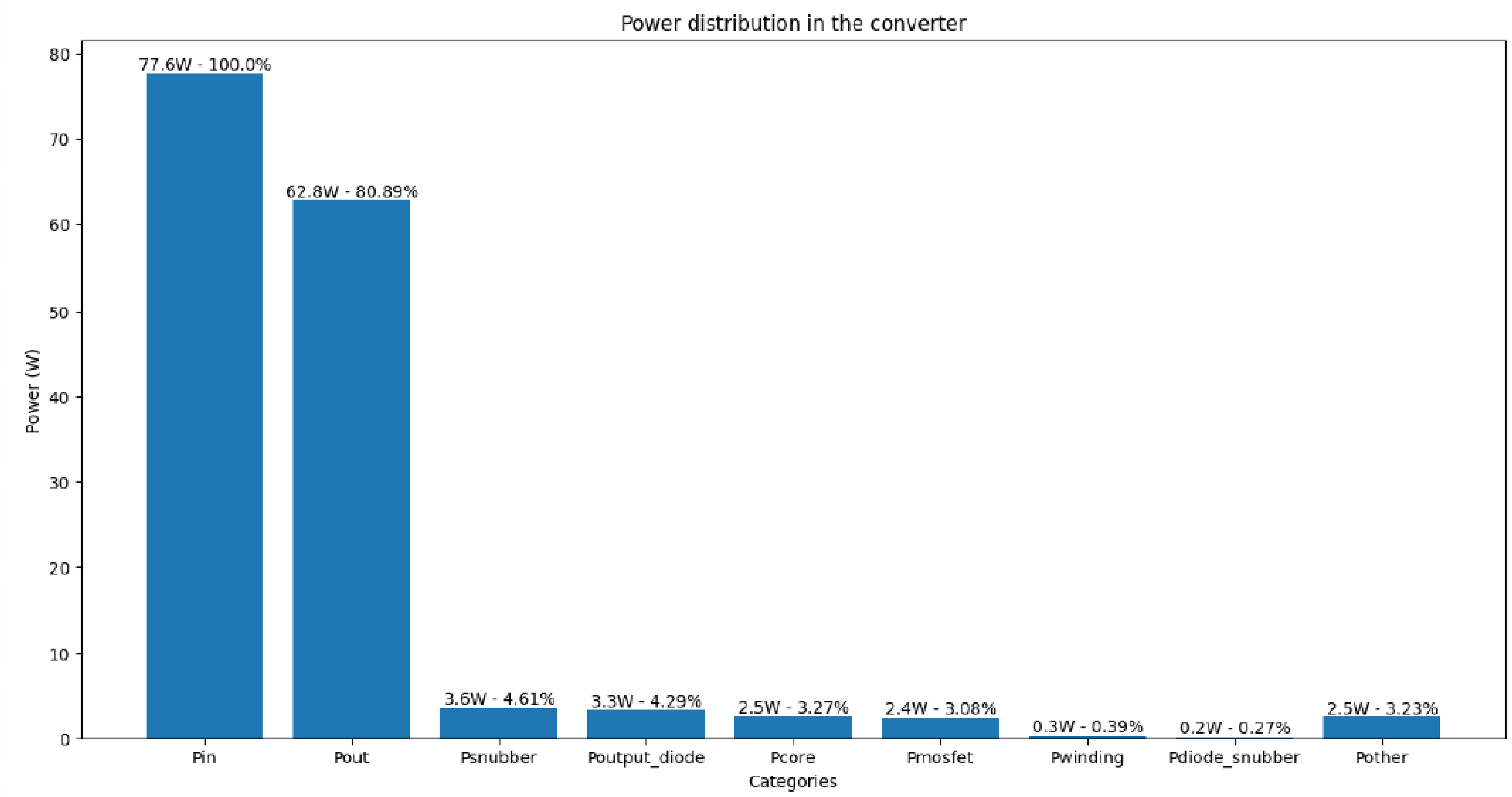


4. Simulation Results: Indicator LEDs



4. Simulation Results: Summary

Vin = {20, 25, 30, 35, 40}V ⟷ Vbat = {11, 12, 13}V



4. Simulation Results: Detailed results

Vin (V)	Vbat (V)	efficiency (%)	Duty	Iin-mean (A)	Iin-ripple(A)	Ibat (A)	Ibat_ripple (A)	Pin (W)	Pout (W)	Psnubber (W)	Pdiode_snubber (W)	Pmosfet (W)	Poutput_diode (W)	Pcore (W)	Pwinding (W)	Vsnubber_diode (V)	Vds (V)	VoutRipple (V)
20	11	80	0,40	3,44	0,40	4,86	0,37	68,20	54,76	3,46	0,10	2,13	3,22	1,55	0,33	45,00	45,00	0,02
20	12	81	0,40	3,57	0,41	4,65	0,37	70,72	57,14	3,70	0,10	2,15	3,10	1,68	0,30	45,00	45,00	0,05
20	13	81	0,40	3,59	0,40	4,33	0,36	71,12	57,46	3,80	0,10	2,08	2,83	1,80	0,30	45,00	45,00	0,05
25	11	81	0,35	2,94	0,37	5,24	0,35	73,14	59,15	3,34	0,10	2,26	3,45	1,95	0,30	50,00	50,00	0,06
25	12	81	0,35	3,05	0,38	5,01	0,35	75,99	61,70	3,70	0,13	2,30	3,30	2,14	0,30	50,00	50,00	0,06
25	13	81	0,35	3,07	0,37	4,67	0,34	76,40	62,00	3,80	0,14	2,20	3,00	2,30	0,30	50,00	50,00	0,08
30	11	81	0,32	2,58	0,35	5,51	0,33	77,02	62,29	3,50	0,16	2,41	3,63	2,35	0,30	55,00	57,00	0,10
30	12	81	0,32	2,68	0,37	5,29	0,33	80,16	65,10	3,65	0,17	2,44	3,46	2,54	0,30	55,00	57,00	0,10
30	13	82	0,32	2,61	0,35	4,77	0,31	78,00	63,69	3,65	0,18	2,25	3,00	2,71	0,30	55,00	57,00	0,10
35	11	81	0,27	2,23	0,33	5,73	0,30	80,26	64,76	3,40	0,20	2,59	3,76	2,75	0,30	60,00	60,00	0,10
35	12	81	0,27	2,40	0,33	5,50	0,30	83,62	67,76	3,54	0,20	2,62	3,60	2,98	0,30	60,00	60,00	0,10
35	13	81	0,27	2,28	0,30	4,83	0,30	79,11	64,35	3,60	0,22	2,32	3,00	3,19	0,30	60,00	60,00	0,10
40	11	80	0,23	2,08	0,30	5,90	0,28	83,11	66,75	3,40	0,24	2,77	3,86	3,14	0,30	65,00	65,00	0,10
40	12	81	0,23	2,17	0,30	5,67	0,28	86,64	69,90	3,64	0,26	2,89	3,70	3,40	0,30	65,00	65,00	0,10
40	13	81	0,23	2,02	0,29	4,88	0,26	80,67	64,94	3,50	0,27	2,42	3,08	3,64	0,30	65,00	65,00	0,10

4. Simulation Results: Summary

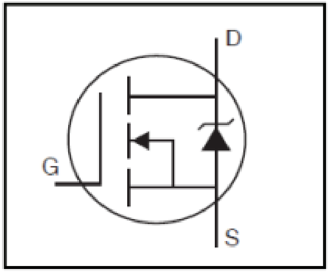
- About %75-80 efficiency is expected
- Ratings are acceptable
- The snubber works properly
- Voltage regulations are satisfied

5. Component Selection

- **MOSFET:** IRFU3710ZPbF

$I_{D,max} \approx 10A$

$V_{DS,max} \approx 65V$



V_{DSS}	100V
$R_{DS(on)}$	18mΩ
I_D	42A

	Parameter	Max.	Units
I_D @ TC = 25°C	Continuous Drain Current VGS @ 10V	56	A
I_D @ TC = 100°C	Continuous Drain Current, VGS @ 10V	39	A
V_{GS}	Gate-to-Source Voltage	± 20	V
$R_{DS(on)}$	Drain-to-Source On-Resistance	18	mΩ
$V_{GS(th)}$	Gate Threshold Voltage	4.0	V
t_r	Rise Time	43	ns
t_f	Fall Time	42	ns

[3]

5. Component Selection

- **Diode:** DSA30C100PB (Both for the snubber and the secondary side)
- Schottky diode is chosen due to its speed.

Snubber

$I_{F,max} \approx 8A$

$V_{max} \approx 65V$

Secondary Side

$I_{F,max} \approx 9.5A$

$V_{max} \approx 62V$

	Parameter	Max.	Units
V_{RRM} (T_{VJ} = 25°C)	max. repetitive reverse blocking voltage	100	V
V_F (I_F = 15A, T_{VJ} = 25°C)	forward voltage drop	0.91	V
V_F (I_F = 15A, T_{VJ} = 125°C)	forward voltage drop	0.73	V
I_{FAV} (T_{VJ} = 125°C)	average forward current	15	A
C_J	junction capacitance	146	pF
I_R	reverse current, drain current	250	μA

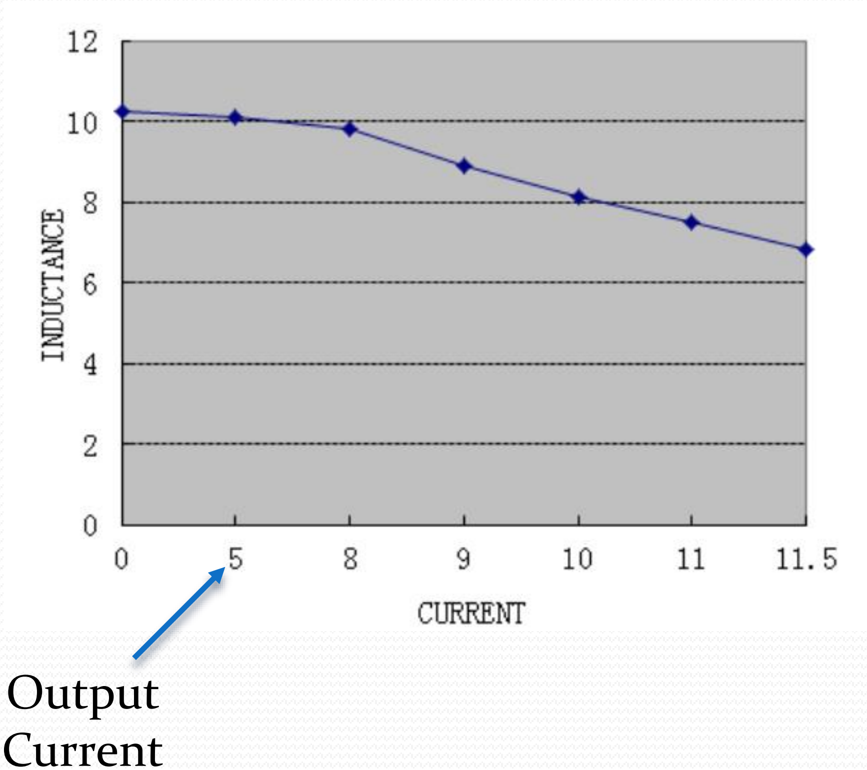
[4]

5. Component Selection

- **Output Filter Inductance:** SRI1209-100M

Parameter	Max.	Units
L	10 ± 20%	µH
R_{DC}	0.03	Ω
I_{DC}	10	A

Test Conditions:
1KHZ / 0.25V



[5]

5. Component Selection

Input Capacitor:
4xPKLH-063V471
63V 470µF

Output Capacitor:
4xPKLH-016V471
16V 470µF

Current Sensor IC:
ACS712-30A

Control IC:
UC3845AN
Due to duty cycle limiting behaviour

And various resistors

[6-9]

6. Future Work

- Optocoupler Design Finalization
- Design Implementation on Stripboard
- Thermal Analysis
- PCB Design (Bonus)
- Case Design (Bonus)

6. References

[1] W. (n.d.). Round Wire ac Resistance Calculator. https://chemandy.com/calculators/round-wireac-resistance-calculator.htm
[2]"Magnetics - Ferrite Core Loss Calculator." https://www.mag-inc.com/Design/DesignTools/Ferrite-Core-Loss-Calculator
[3] https://cdn.ozdisan.com/ETicaret_Dosya/652386_243124.pdf
[4]https://cdn.ozdisan.com/ETicaret_Dosya/483083_5853486.pdf
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In memory of ...

Thank you for your attention.