

Buck Converter Design - Part I

Specifications

Parameter	Value	Unit
Nominal Vin(avg)	20.00	V
Max I _{in} (avg)	1.25	A
Max V _{out} (avg)	10.00	V
Max R _L (max)	10.00	Ω
Min R _L (min)	2.00	Ω
Design η	90.00	%
Operating f _s	100.00	kHz

Evaluating Steady-State Operating Conditions

Parameter	Value	Unit (eq)	Value	Unit (eq)	Value	Unit (eq)
Load	2.00	Ω	4.00	Ω	10.00	Ω
P _{out}	22.50	W (1)	22.50	W (1)	10.00	W (2)
I _o =I _L (avg)	3.35	A (3)	2.37	A (3)	1.00	A (3)
I _{in} (avg)=I _s (avg)	1.25	A (4)	1.25	A (4)	0.56	A (4)
D	37.27	% (5)	52.70	% (5)	55.56	% (5)
V _{out}	6.71	V (6)	9.49	V (6)	10.00	V (6)

Evaluating Minimum Inductance

Parameter	Value	Unit (eq)
V _{in} (critical)	20.00	V
R _L (critical)	10.00	Ω
D @ R _L (critical)	55.56	%
L _{min}	22.22	μ H (7)

Selected Inductance

Parameter	Value	Unit (eq)
L(selected)	50.00	μ H

Evaluating Steady-State Ripple and RMS Currents

Parameter	Value	Unit (eq)	Value	Unit (eq)	Value	Unit (eq)
Load	2.00	Ω	4.00	Ω	10.00	Ω
Δ I _L	0.84	A (8)	0.90	A (8)	0.89	A (8)
I _L ,pk	3.77	A (9)	2.82	A (9)	1.44	A (9)
I _L ,rms	3.36	A (10)	2.39	A (10)	1.03	A (10)
I _{in} ,rms=I _s ,rms	2.05	A (11)	1.73	A (11)	0.77	A (11)
I _C ,rms	0.24	A (12)	0.26	A (12)	0.26	A (12)

Buck Converter Design - Part II

Specifications

Parameter	Value	Unit
Selected L	50.00	μH
Max $I_{L,pk}$	3.77	A
Max $I_{L,rms}$	3.36	A
Operating f_s	100.00	kHz
Design B_{max}	0.25	T
Design J_{max}	5.00	A/mm^2

Core, Former & Magnet Wire Details

Parameter	Value	Unit
Core type	EFD20	
Core material	N87	
A_e	31.00	mm^2
l_e	47.00	mm
V_e	1460.00	mm^3
AN	28.10	mm^2
l_n	40.20	mm
Wire ρ	1.8E-08	Ωm
Wire μ_0	1.3E-06	H/m
Achievable K_f	0.65	

Design Choices

Parameter	Value	Unit (eq)
Selected I_g	0.25	mm
Wire d_{cu}	0.43	mm (13)

Evaluating Inductor Parameters

Parameter	Value	Unit (eq)
N	25	Turns (14)
$B_c(\text{max})$	0.24	T (15)
Acu per strand	1.43E-07	m^2 (16)
N_p	5	Strands (17)
Acu per bundle	7.16E-07	m^2 (18)
J_{max}	4.70	A/mm^2 (19)
Bundle $R_w(\text{dc})$	25.3	$\text{m}\Omega$ (20)

Evaluating Steady-State Inductor Losses

Parameter	Value	Unit (eq)	Value	Unit (eq)	Value	Unit (eq)
Load	2.0	Ω	4.0	Ω	10.0	Ω
$I_{L,rms}$	3.4	A	2.4	A	1.0	A
ΔI_L	0.8	A	0.9	A	0.9	A
B_{ac}	26.44	mT (21)	28.19	mT (21)	27.93	mT (21)
P_{cu}	285.65	mW (22)	143.77	mW (22)	26.92	mW (22)
P_v	3.13	mW (23)	3.68	mW (23)	3.59	mW (23)
P_{total}	288.78	mW (24)	147.45	mW (24)	30.51	mW (24)

Buck Converter Design - Part III

Specifications

Parameter	Value	Unit
Max Vc	10.00	V
Max IC,rms	0.26	A
Max $\Delta I_C = \Delta I_L$	0.90	A
Ripple fs	100.00	kHz
Design ΔV_o	0.50	%

Minimum Capacitance to Meet ΔV_o

Parameter	Value	Unit (eq)
Co(min)	22.43	μF (25)
ESR(max)	55.72	m Ω (26)

Selecting a Capacitor

Parameter	Value	Unit
Manufacturer	Panasonic	
Series	TP	
Voltage rating	25	V
Capacitance Co	820	μF
ESR	52	m Ω
IC,rms rating	1.5	A

Evaluating Steady-State Capacitor Losses

Parameter	Value	Unit (eq)	Value	Unit (eq)	Value	Unit (eq)
Load	2.0	Ω	4.0	Ω	10.0	Ω
IC,rms	0.2	A	0.3	A	0.3	A
PC	3.1	mW (27)	3.5	mW (27)	3.4	mW (27)

Buck Converter Design - Part IV

Specifications

Parameter	Value	Unit
Max Vsw	20.00	V
Max Is,rms	2.05	A
Max Isw,pk	3.77	A
Switching fs	100.00	kHz
Ta	30.00	Degrees C

Selecting a N-Channel MOSFET

Parameter	Value	Unit
Manufacturer	IR	
Model no	IRF3710	
Vdss	100	V
ID(max)	23	A
tr	58	ns
tf	47	ns
Crss @ Max Vsw/2	200	pF
Vgs(lo)	5	V
Rds,on	14	mΩ
RthJA - no heatsink	62	C/W

Gate Drive Details

Parameter	Value	Unit (eq)
Design Vgg	15.00	V
Design Igg	1.00	A
Rg	15.00	Ω (28)

Evaluating Steady-State Switch Losses

Parameter	Value	Unit (eq)	Value	Unit (eq)	Value	Unit (eq)
Load	2.00	Ω	4.0	Ω	10.0	Ω
IL,avg	3.35	A	2.4	A	1.0	A
Is,rms	2.05	A	1.73	A	0.77	A
ΔIL	0.84	A	0.9	A	0.9	A
Is @ on	2.93	A (29)	1.92	A (29)	0.56	A (29)
Is @ off	3.77	A (30)	2.82	A (30)	1.44	A (30)
tvf	5.99	ns (31)	5.99	ns (31)	6.00	ns (31)
trv	11.97	ns (31)	11.98	ns (31)	11.99	ns (31)
ts,on	63.99	ns (32)	63.99	ns (32)	64.00	ns (32)
ts,off	58.97	ns (33)	58.98	ns (33)	58.99	ns (33)
Pswitching	410.29	mW (34)	289.39	mW (34)	120.76	mW (34)
Pconduction	59.00	mW (35)	42.00	mW (35)	8.29	mW (35)
Ptotal	469.30	mw (36)	331.39	mw (36)	129.05	mw (36)

Evaluating Junction Temperature

Parameter	Value	Unit (eq)
Tj,max	59.10	C (37)

Buck Converter Design - Part V

Specifications

Parameter	Value	Unit (eq)
Max Vd	20.00	V
Max Id,avg	2.10	A
Switching fs	100.00	kHz
Ta	30.00	Degrees C

Selecting a Diode

Parameter	Value	Unit
Manufacturer	Vishay	
Model no	40CTQ045	
Vr(max)	45	V
IF(max) - dual	40	A
VF	0.3	V
RthJA - D2Pak	45	C/W

Evaluating Steady-State Switch Losses

Parameter	Value	Unit (eq)	Value	Unit (eq)	Value	Unit (eq)
Load	2.00	Ω	4.0	Ω	10.0	Ω
IL,avg	3.35	A	2.37	A	1.00	A
D	37.27	%	52.70	%	55.56	%
ID,avg	2.10	A (39)	1.12	A (39)	0.44	A (39)
Pconduction	0.63	W (40)	0.34	W (40)	0.13	W (40)
Prr	0.00	W (41)	0.00	W (41)	0.00	W (41)
Ptotal	0.63	W (42)	0.34	W (42)	0.13	W (42)

Evaluating Junction Temperature

Parameter	Value	Unit (eq)
Tj,max	58.41	C (43)

Buck Converter Design - Part VI

Specifications

Parameter	Value	Unit
Vout,nominal	10.00	V
Max Is	3.77	A
Co	820.00	μF
ESR	52	m Ω
Switching fs	100.00	kHz
Max Td	5.00	%

Oscillator Setup

Parameter	Value	Unit (eq)
CT	1	nF
RT	22	k Ω
Td	400	ns

Current Feedback Setup

Parameter	Value	Unit (eq)
Rs	0.26	Ω (44)
RC filter - Rrc	100.00	Ω
RC filter - Crc	159.15	pF (45)

Voltage Feedback Setup

Parameter	Value	Unit (eq)
Tp(s) Pole fo @ 2 Ω	97.05	Hz (46)
Tp(s) Zero fz @ 2 Ω	3.73	kHz (47)
Tp(0) @ 2 Ω	17.56	dB (48)
Design TOL(s) fcross	10.00	kHz
Tm(s)	1.00	
Required TOL(0) @ 2 Ω	40.26	dB (49)
Required Tc(0)	22.70	dB (50)
Compensator Rf	22.00	k Ω
Compensator Cf	1.94	nF (51)
Compensator Ri	1.61	k Ω (52)
Diff Amp Gain Gdiff	0.25	Gain (53)

Schematic of Controller

