Fundamentals of Power Electronics Prof. L. Umanand Department of Electronics System Engineering Indian Institute of Science, Bengaluru

Lecture - 79 Area products and mfiles

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Area products
1. Push pull converter - $A_p : \frac{\sqrt{2} \cdot \mathcal{B}(1+\frac{1}{2})}{4 \cdot K_w \cdot J \cdot B_m \cdot \xi}$
2. Half bridge converter - $A_p = \frac{P_o(\sqrt{2} + \frac{1}{2})}{4 \cdot K_w \cdot J \cdot B_m \cdot f_s}$
3. Full bridge converter - $A_p = \frac{P_o(\sqrt{2} + \frac{1}{2})}{4 \cdot K_w \cdot J \cdot B_m \cdot f}$

We discussed 3 converters; push pull converter, the half bridge converter and the full bridge converter. How do we design the transformers for this converters? We go by the area convert area product method we have discussed the area product method and then we use it to design the forward converter and we had developed generic area product equation. Using the generic area product equation we can find out the area product the push pull, I will give you the final derived formula for the push pull converter area product is equal to root 2 P naught 1 plus 1 by efficiency. Here efficiency is taken to be 0.8 first case.

So, efficiency will always be better than 0.8 and the denominator you have 4 K w window factor J current density which is 3 into 10 to the power of 6 ampere meter square B m for ferrites its point 2 for the transformer point 2 Tesla and then fs the switching frequency.

So, this is the area product for the push pull converter. If you use the same generic formula and then plugin the voltage and the power voltage and power into the generic

equation, that is a half cycle average voltage you will get this. Likewise for the half bridge converter; half bridge converter transformer also the area product I will be providing you, here derived along same lines P naught into root 2 plus 1 by efficiency 1 by 0.8 divided by 4 K w J B m and f s.

The full bridge converter half bridge converter the transformers are very similar and the voltage wave shape across the primary and the current through them are all similar and therefore, you will have a similar area product equation. The difference of course, will come in the actual values the currents and the amplitude of the voltage. So, this is the area product for the full bridge converter.

So, you can try to derive these and verify them by using the same generic method, for deriving the area products. That we discussed for the forward converter as an example and also the low frequency AC 50 Hertz transformers to. So, use all these transformers have the same generic basis.

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<pre>for i = 1:length(Vo)</pre>	Home / lums_dir / MO	OC / PE / wk10 / resources -	Q, ∷ ▼ ≡ ×	
<pre>fprintf(ld, '%s\t ss fprintf(id, '\t current, amps', Idbm(i) fprintf(id, '\t current, amps', Idbav(i fprintf(id, '\t</pre>	⊙ Recent ★ Starred ŵ Home fullbridge		NULL HARA off	\$ 8 ×
<pre>volts',Vdbrm(1)); end</pre>	Documents	natoroge mites pasip	uu utotopai	
<pre>fprintf(id, '\n\n%s\n\n for i=1:length(L), fprintf(id '%c)t %c)t</pre>	Downloads			
<pre>mH',L(i)*le3); fprintf(id,'%s\t %s\t</pre>	J Music	k		
<pre>fprintf(id,'%s\t %s\t windings',NL(i)); fprintf(id,'%s\t %s\t</pre>	Videos			
<pre>inductance',SWGL(1,:)) fprintf(id,'%s\t %s\t inductance,mm',Llg(i)*</pre>	Trash			
end	🖞 lumanand@gm			
<pre>for i=1:length(C), fprintf(id,'%s\t %s\t</pre>	🖞 lumanand@me			
<pre>UF',C(1)*le0); fprintf(id,'%s\t %s\t volts',Vcr(i)); fprintf(id,'%s\t %s\t ohms',Esr(i)); end</pre>	+ Other Locations			
	Octave - Tab Width: 8 - In	Comr	mand Window Editor Documen	tation

Let us now look at some m-files for designing the push pull converter the half bridge converter and the full bridge converter.

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<pre>for i = 1:length(Vo)</pre>	< >	lums_dir / MOOC	/ PE / wk1) / resources	/ mfiles 🕶	Q, ∷ ▼ Ξ	×
<pre>triant(id, '%s)t &set</pre>	 ⊘ Recent ★ Starred û Home i Documents j Downloads J Music i Pictures m Videos 	cores.m pushputl_ design.m	ferrite.m	fullbridge_ design.m	haftbridge_ design.m	metglas.m pow_iron.	σ m
<pre>nontifid: 'sst *st nductarce.mm',Llg(i) nd or i=:length(C), printf(id, '%st *st printf(id, '%st *st printf(id, '%st *st printf(id, '%st *st hms',Lsr(i); nd</pre>	Trash Ulumanand@gm Ulumanand@me Ulumanand@me Other Locations						

So, I have in the resources section a folder called mfiles within that like for the forward converter, we have some common mfiles that is a course, the ferrite, the ferrite course, the metglas core powder iron core and there is another m file on wire wires and wire gauges. So, these are common for all the converter design in the sense that they are data bases of the course and the wires.

You have 3 design files; one is the pushpull design dot mhalf bridge design dot m and the fullbridge design dot m and these are the design mfiles which you can run and they will make use of this course for right wires and other core and wire detail a details from these other mfiles. So, let me look at let me open the pushpull.

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<pre>for i = 1:length(Vo</pre>)				urces	/ mfiles 🕶	۹ ::		
fprintf(id, '%s\t	<pre>%% '''''''''''''''''''''''''''''''''''</pre>	nding', nu	m2str	(i));)
current, amps', Idbm	(i));	301(1/1)	reak						5 ×
fprintf(id,	'\t%s\t %s\t %5.2f\n',['winding',num2	str(i)],'	Avera	ge					
current, amps',Idba	w(i));				ie_	halfbridge_	metglas.m	pow_iron.m	
<pre>tprintf(id, wolts' Vdbrm(i));</pre>	'\t%s\t %s\t %5.2T\n',['winding',num2	str(1)],	PIV,		m	design.m	,		
end									
<pre>fprintf(id.'\n\n%s\</pre>	<pre>.n\n'.'INDUCTOR DESIGN');</pre>								
<pre>for i=1:length(L),</pre>									
<pre>fprintf(id,'%s\t %s</pre>	<pre>i\t %10.5f\n',['winding',num2str(i)],'</pre>	Inductanc	e val	ue,					
<pre>mH',L(i)*le3);</pre>	at the state fundament and the first state								
fprintf(id '%s\t %s	<pre>\t %S(h',['winding',num2str(i)], Core \t %Sd\n' ['winding' num2str(i)] 'Num</pre>	ber of	,:));						
windings'.NL(i)):	The south of winding characterizity in	ber or							
fprintf(id, '%s\t %s	<pre>i\t %s\n',['winding',num2str(i)],'Gauge</pre>	e of							
inductance',SWGL(i,	:));								
<pre>fprintf(id, '%s\t %s</pre>	<pre>i\t %10.5f\n\n',['winding',num2str(i)]</pre>	,'Airgap	for						
inductance, mm ⁺ , Ltg(1)+1e3);								
enu									
<pre>fprintf(id, '%s\n\n'</pre>	,'CAPACITOR FILTER RATINGS');								
<pre>for i=1:length(C),</pre>									
TPrintf(10, '%S\t %S	<pre>\t %10.5t\n',['winding',num2str(1)],'</pre>	Capacitan	ce va	tue,					
fprintf(id, '%s\t %s	<pre>\t %5.2f\n'.['winding'.num2str(i)].'V</pre>	oltage ra	ting.						
volts',Vcr(i));									
<pre>fprintf(id,'%s\t %s</pre>	<pre>\t %10.5f\n\n',['winding',num2str(i)]</pre>	,'ESR req	uirem	ent,					
ohms',Esr(i));									
ena					-		_		
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So, you see that here you have the pushpull design dot mfile.

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And it has a specification section as specified somethings observe here V naught is having is a vector of 2 elements which means it is a isolated multi output. There are two ORed secondarys. You have the delta v ripple and 1 amp and 0.5 amps for the 2 different outputs. And you have the set of designer variables and switching at 40 kilo Hertz here 0.2 Tesla for transformer flux density maximum 0.25 Tesla for inductors, Dmax of 0.45 which I have taken 3 amp per mm square or 3 into 10 to the power of 6 ampere meter square for the current density and window factors I have chosen like this.

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Open 🕶	Ð	pushpull_design.m ~/lums_dir/MQOC/PE/wk10/resources/mfiles	Save	Ξ	×			Octa	/e		×
PUSHPULL ap=(<mark>(sqrt</mark> ap_fir flag=0 a inde	TRANSFORM (2)*Po*(1+ st=ap; ; x=1:	<pre>MER DESIGN +(1/eff))/(4*Kw*J*Bm*fs));</pre>				urces	/ mfiles 🕶	۹ ::			5 ×
cnt=1; while	[flag==0,					je_ .m	halfbridge_ design.m	metglas.m	pow_iron.m		
% F. % Nu % Fr % clc dis [ac	ind Ac, Aw ote: cores or details p('PUSHPUL ,aw,ap,com	<pre>v for given Ap using cores function is a program core selection s contact Dr. L.Umanand, CEDT, IISc, B</pre>	angalore-:	560 01							
% % C: % Np= Ns=	alculation round((Vcr round(n*Ng	n of Number of turns. max)/(4+Bm*ac*fs)); %centre tap to end p); % centre tap to end									
* 0	alculation	n of Area of c/s of the windings.									
awp pri windi aws	=sum((n.*) ng. =(Io*sqrt)	<pre>[0)*sqrt(Dmax)/J); [Dmax))/J;</pre>	% Area of %	c/s c Area	of						
% % F. % N % F.	ind SWG of ote: Wires	, f the wire to be used using the wires s.m is a program for wire gauge select s contact Dr. L Umanand (EDT TIS- B	function ion	568 81				15-1			
*	or details	Octave - Tab Width: 8 - Ln 34	, Col 13	*	INS	-	Command	Window E	ditor Documer	ntation	

So, there is the power calculation and after you do the power calculation the terms ratio calculation and this is where it will be different from the forward transformer design which is a pushpull transformer. The area product of the pushpull transformer I have taken it according to the area product of the pushpull that I have just listed down. And the part of the design is similar to that in the forward converter where we call the course.

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Open 👻 🖻	pushpull_design.m ~/lums_dir/MOOC/PE/wk10/resources/mfiles	Save								
\$			=	×	-		Oct	ave		,
					irces /	mfiles 👻	Q	: v	≡×	
% Calculation	of Number of turns.									-
ş										
Np=round((Vcma Ns=round(n*Np)	<pre>x)/(4*Bm*ac*fs)); %centre tap to ; % centre tap to end</pre>	end								5 >
				3	e_	halfbridge_	metglas.m	р	w_iron.m	
*				·· ,	m	design.m				
% Calculation	of Area of c/s of the windings.			.						
awp=sum((n.*Io)*sqrt(Dmax)/J);	% Area of	c/s 0	f						
ori winding.				- 1						
aws=(Io*sqrt(D	max))/J;	١	Area	of						
/s of sec windings.										
8										
% Find SWG of	the wire to be used using the wir	es function								
% Note: Wires.	m is a program for wire gauge sel	ection								
<pre>% For details</pre>	contact Dr. L.Umanand, CEDT, IISc	, Bangalore-	560 01	2.						
\$										
[awp,ethp,SWGp] = wires(awp);									
SWGs='';%initi	alise to null string			- 1						
for i = 1:leng	th(aws),									
[aws(i),eth SWGs=strvca	s(i),swg] = wires(aws(i)); t(SWGs.swg);									
end										
\$										
% Check for Wi	ndow Area									
\$										
awreg=(awp*Np*	2 + sum(aws,*Ns*2))/Kw:%factor tw	o is to acco	unt of	No						
and Ns being centre	tapped wdos.			· •						
if (awreg>aw)&	(cnt<=20).									
flag=0:				- 1						
disn(['An f	irst = '.num2str(ap first).' '.	core.' An =						-		
num2str(an)]).	,					Command	window	Editor	Docum	entation
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And the course selects the course and then wires for selecting the wire gauges and cross check the design.

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ctivities	🗉 Text I	Editor 🔻		Sun 22:4	• 0				en	▼ 〒 •0 €
Open 👻	Ð	pushpull_design.m ~/lums_dir/MOOC/PE/wk10/resources/mfiles	Save	= ×			Octa	ve		
num2str(c else f end	disp(['A (ap)]); disp(['A disp('No flag=1;	p_first = ',num2str(ap_first),' ', core wreq = ',num2str(awreq),' Aw = ',num2str t fitting - Click again to choose bigger	,' Ap = (aw)]); core');		urces	/ mfiles 💌 halfbridge_ design.m	Q :	pow_iro	n.m	5
cnt= end %of %INDUCT L=(Io.* Iml=Io+ EL=0.5* alp=2*E coreL=' SWGL='	<pre>=cnt+1; f WHILE FOR DESI *RO*(1-2 +(di/2); *L.*(Iml EL/(Kwl* ';%initi';%initi</pre>	, ™Dmin)./(di*2*f\$); .^?); J*Bml); Talise with null string alise with null string								
<pre>for i=1 alp_fir flag=0; a_index cnt=1; while flag=0;</pre>	L:length rst=alp(; x=1; flag==0,	<pre>(L), %for as many secondary windings i);</pre>								
disp [alc core % % Ca %	D(['PUSH C(i),alw eL=strvc	<pre>PULL CONVERTER OUTPUT INDUCTOR FOR WINDI (i),alp(i),corL]=cores(alp(i),1,a_index) at(coreL,corL); on of Number of turns.</pre>	NG ',num ;	2str(i)]						
NL ()	L)=round	(L(1)*1ml(1)/(alc(1)*Bml));				Command	Window E	ditor De	ocumentation	
		Octave Tab Width: 8 In 34	Col 13	▼ INS						

Then you have the inductors; inductors for every output mm isolated output we have 2 isolated output. So, 2 times it has to be done. So, inductor value calculation followed by energy calculation.

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		~/lums_dir/MOOC/PE/wk10/resources/mhles			urces	/ mfiles 🔻	Q ::	× = ×	
cnt= end %of	Cnt+1;				unces.				
SINDUCT	OR DESI	GN							5 >
L=(I0.*	Ro*(1-2	*Dmin))./(di*2*fs);							
Imt=10+	(01/2);	421.			je_	halfbridge_	metglas.m	pow_iron.m	
210-28F	L.*(III)	· 2/; 188ml)·			m	design.m			
corel ='	'sinit	ialise with null string							
SWGL='	%initia	alise with null string							
for i=1	:length	(L), %for as many secondary windings							
alp_fir	st=alp(i);							
flag=0;									
a_index	(=1;								
while f	00								
clc	cay,								
disp	(['PUSH	PULL CONVERTER OUTPUT INDUCTOR FOR WIND	ENG ', nur	2str(i)])					
[alc	(i),alw	(i),alp(i),corL]=cores(alp(i),1,a_index));						
core	L=strvca	at(coreL,corL);							
8									
% Ca	lculatio	on of Number of turns							
MI (4	1-round	(1(i)*Tml(i)/(alc(i)*Dml)).							
%)=round	(L(1) · Im((1)) (acc(1) · Dm()),							
% Ca	lculatio	on of Area of c/s of the windings.							
8									
awl(i)=Io(i)/J; % awl is the calculated area of c/s	5						
[awl	(i).eth	l(i).SWL] = wires(awl(i)):							
SWGL	=strvca	t(SWGL,SWL);							
							_		6

Then the selection of the core from the course function file and then the wires from the wires function file.

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Open 🔻	F	pushpull_design.m	Save	=	x			Octa	ve	×
open -		~/lums_dir/MOOC/PE/wk10/resources/mfiles	Jave	_						
	disp(['A	<pre>p_first = ',num2str(alp_first(i)),' ',</pre>	core,'	Ap =	urc	es	mfiles 🔻	Q :	= * = ×	
,numzstr	(atp(1))]); wreg = ' pum2str(awlreg) ' Aw = ' pum2st	r(alw(i)	111.)
	disp('No	t fitting - Click again to choose bigge	core'):	/1//						
else					- 1					8 ×
	flag=1;									
end					le-		halfbridge_	metglas.m	pow_iron.m	
a_i	ndex=1.1	;			.m		design.m			
cnt	cnt+1;									
end %o	WHILE									
end %of F	OR for a	ll windings								
OUTPUT FI	LTER CA	PACITOR DESIGN								
C=di./(0.1	L*dv*2*8	*fs); %design for C with 10% of allowal	le Vo ri	pple						
/cr=2*abs	(Vo);									
Esr=(0.8*0	dv)./di;	%design for ESR with 80% of allow	able Vo	ripple						
OUTPUT [D:	LODE DES	IGN								
*Second	darv win	ding blocking diodes								
I	dbm=Io+(di/2);								
I	dbav=Idb	m*0.5;								
Ve	dbrm=2*n	*Vcmax;			- 1					
		100			- 1					
Trages	m(0 1#/	n #To)#cast(Dmox)).								
Inay=St	(0.1+(+(di(2))) + Tmag								
Vceo=2	Vcmax	(u1/2/// · Imag,								
1000-2	remux,				- 1					
					- 1					
Display	the res	ults.				-		_		
							C	14.0	ditan Desumer	testion.

Then you have the design of the capacitors the output diodes power switch and then finally, to display the results.

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						urces	/ mfiles 👻	۹ :	= - = -	×	
Imag=st	um(0.1*(n.*Io)*sqrt(Dmax));)
Icm=sur	n(n.*(Io+(di/	2))) + Imag;								-	5 ×
Vceo=2	*Vcmax;									-	
						e_	halfbridge_	metglas.m	pow_iron.m	1	
§						m	design.m				
% Display	the results.										
clc											
id=1;											
<pre>for i=1:le fprint: ['Vo',num2 end for i=1:le fprint:</pre>	ength(Vo), f(id,'%s\t %s 2str(i)],Vo(i ength(dv), f(id,'%s\t %s	\t %5.2f\n','Output voltage, volt:)); \t %5.2f\n','Output voltage ripple	s', e, volts',								
['ripple'	,num2str(i)],	dv(i));									
ena for i=1:le	ength(Io),										
fprint	f(id, '%s\t %s	t %5.2f\n','Output current, amps	',								
['IO', NUM	2str(1)],10(1));									
for inlule	ength(di),										
101 1=1:00	flid iscit se	t \$5 2f\n! 'Inductor current ring	ple, amps'	,							
fprint	1170' aple ap	te solariti , mudecor current ripp									
fprint: ['ripple',	,num2str(i)],	fi(i));				-					

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Activities 🛛 🔾 GNU Octa	ave 🔻	Sun 22:41 ● en ▼ 후 📢 🕑 ▼
Open 👻 🖪	pushpull_design.m -/lums_dir/MOOC/PE/wk10/resources/mfiles	Octave
<pre>%Design of multi-out</pre>	put PUSHPULL CONVERTER	File Edit Debug Window Help News
SPECIFICATIONS		🕑 🛄 🦷 ն Current Directory:
VC=335; VCmix=210; VCmax=280; VCmax=280; VCmax=280; VCmax=280; Adve[0.15,0.15]; Io=[1,0.5]; Io=[1,0.5]; Bm=0.2; Bm=0.2; Bm=0.2; Bm=0.2; Bm=0.2; Ff=0.8; KCmax=0.4;KCmax=0.4; KCmax=0.4;KCmax=0.4; KC	<pre>innoinal dc-link voltage innimum dc-link voltage innaximum dc-link voltage innaximum dc-link voltage ipples ippek to peak output voltage ripples ipples ipples</pre>	File Browser * Command Window 5 × Puseult_Transcore RESIGN Condec CoR MERAL TYPE Name 1. Portise * Motispace 7 × Motispace 7 × * Filter • * Command 8 × Filter • • Enter the number of your choice = Command 8 × Filter • • • Command 8 × Filter • • •
PUSHPULL TRANSFORME	R DESIGN	Command Window Editor Documentation
in the start	Octave ▼ Tab Width: 8 ▼ Ln 34, Col 13	

So, this is the pushpull design, I have given the specification here you can go in to octave or even matlab for that matter go into the respective folder resource folder I already have and I have here full bridge half bridge and pushpull. So, you type in pushpull design and it will ask for the type of the core material I am going to choose 1 which is Ferrite and then it will ask for the shape of the core material I am going to choose EE.

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Activities 🌔 GNU Octave	•	Sun 22:41 ●	en 🔻 후 📢 🕑 🖷
Open 👻 🖪	pushpull_design.m -/lums_dir/MOOC/PE/wk10/resources/mfiles	Octave	>
%Design of multi-outpu	t PUSHPULL CONVERTER	File Edit Debug Window Help News	
SPECIFICATIONS		🕐 🚊 🖷 📄 Current Directory:	
VC=325; VC=11=210; VC=12=210; VC=12=210; VC=125.015]; lot=[0.	<pre>%nominal dc-link voltage %ininum dc-link voltage %maxium dc-link voltage %isolated multi output voltages %peak to peak output voltage ripples %uotput currents %inductor current ripple %switching freque %flux density, T for ind %stimated effici %maximum duty cycle %current density, Arma %indow factor for trans %uindow factor for trans%uindow factor for trans%uindow</pre>	File Browser \$ × Image Command Window Ap.frst 2.1752-09 Eddesson 2.762-09 Image Command Window Ap.frst 2.00065 March Image Command Window Possibilit 2.60055 March Possibilit 2.60055 March Vorkspace 0.0005 CORE MATERIAL 1702 Image 1.6001 Control Image 1.6001 Control Image 2.6005 CORE MATERIAL 1702 Image 1.6001 Control Image 1.6001 Contro Image 1.6001 Con	ර x = 3.12e-09 bigger core
PUSHPULL TRANSFORMER	DESIGN	Command Window Editor Do	ocumentation
	Octave ▼ Tab Width: 8 ▼ Ln 34, Col 13		

And I am going to choose 2 and you see here the area product calculated and then the window area cross check is not fitting. So, again you will have to choose the next bigger

size core you can change the material if you want, but I will strict to ferried go ahead with ferried and the EE core.

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Activities 🜔 GNU Octave 🕇		Sun 22:42 •	en 🔻	<pre> € • • • • •</pre>
Open 🔻 🖪	pushpull_design.m	iave	Octave	×
%Design of multi-output	PUSHPULL CONVERTER	File Edit Debug	Window Help News	
SPECIFICATIONS		• 🖪 🖷	Current Directory:	•
Vc=325.	spominal dc-link volt	File Browser 🗗 🛪	Command Window	đ×
Vcmin=210; Vcmax=380;	%minimum dc-link volt %maximum dc-link volt	age ; • 🔗 🔘	PUSHPULL CONVERTER OUTPUT INDUCTOR FOR WINDING 2 CHOOSE CORE MATERIAL TYPE	
Vo=[15,-15];	%isolated multi output voltag	es News	1. Ferrite	
dv=[0.15,0.15];	%peak to peak output voltage ripp	les Name ^	2. Metglas	
10=[1,0.5];	soutput currents	- 📄 ferrite.m	3. Powdered Iron	
SDESIGNER'S VARIABLES		- 🖹 fullbridge	Enter the number of your choice = 1	
di=0.1*Io;	%inductor current rip	ple _ balfbridg	CHOOSE CORE SHAPE TYPE	
fs=40e3;	%switching fr	equen	1. POT CORES	
Bm=0.2;	%flux density, T for	trans Workspace 🗗 🛪	2. EE CORES	
Bml=0.25;	%flux density, T for	induc	3. UU CORES	
eff=0.8;	%estimated ef	ficie Filter	5. TOROID CORES	
the transformer	And the second sec	Numerica di se		
Dmax=0.45;	smaximum duty cycle	Name A Clas	Enter the number of your choice =	
J=300; Ku=0.4.	Swindow factor for tr	ancto		
Kw]=0.4;	Swindow facto	ansion for		
Vd=1.0:	%diode forward drop			
muo=4*pi*le-7:	Suo - permeability of air	_		
Ro=abs(Vo)./Io;	%output load resistance	Command 🗗 ×		
SPOWER CALCULATIONS				
Po=sum((1.1*abs(Vo)+Vd)	*Io):	Fitter		
		clear		
%TURNS RATIO and DUTY R	ATIO	clear		
n=(1.1*abs(Vo)+Vd)/(2*D	max*Vcmin);	clc		
Dmin=(Dmax*Vcmin)/Vcmax	;	pushpull_design		
SPUSHPULL TRANSFORMER D	ESIGN	_	Command Window Editor Documentation	
in all the second secon	Octave - Tab Width: 8 - Ln 34, Col 1:	3		

Let it choose the next higher one, it has chosen then it has gone for inductor a winding 1 I will choose Ferrite and EE CORE to keep the same inventory list, then inductor for winding 2 again you choose ferrite and I am choosing EE core.

(Refer Slide Time: 07:56)

Activities 🜔 GNU Oct	ave 🔻	Sun 22:42 •	en 🔻	? 40 € -
Open 👻 🖪	pushpull_design.m -/lums_dir/MOOC/PEJwk10/resources/mfiles	ive	Octave	×
%Design of multi-ou	tput PUSHPULL CONVERTER	File Edit Debug	Window Help News	
SPECIFICATIONS		P 🖪 🖷	Current Directory:	1
Vc=325.	spominal dc-link volt	File Browser 🗗 🗙	Command Window	ð ×
Vcmin=210:	%minimum dc-link volt		PUSHPULL CONVERTER SPECIFICATIONS	
Vcmax=380;	%maximum dc-link volt	age ; 🔭 😵 😳	Output Davies H DE DE	
Vo=[15,-15];	%isolated multi output voltag	es	Input DC voltage, volts 325.00	
dv=[0.15,0.15];	<pre>%peak to peak output voltage ripp</pre>	les Name 🔺	Minimum DC input voltage, volts 210.00	
Io=[1,0.5];	<pre>%output currents</pre>	- ferrite.m	Maximum DC input voltage, volts 380.00	
		E Allhaldes	Output voltage, volts Vol 15.00	
%DESIGNER'S VARIABL	ES	Tuttoriage	Output voltage ripple, volts ripple1 0.15	
di=0.1*Io;	%inductor current rip	ole – 📄 halfbridg	Output voltage ripple, volts ripple2 0.15	
ts=40e3;	%switching fr	equen	Output current, amps Io1 1.00	
Bm=0.2;	Stlux density, T for	trans Workspace 🖸 ×	Output current, amps 102 0.50	
Bm(=0.25;	situx density, i for	Ficio Filter	Inductor current ripple, amps ripple2 0.05	
the transformer	sestimated er	Tere mer U		
Dmax=0.45	Smovimum dutu cucle	Nama A Cla		
1=306:	Scurrent density A/m	Ivanie – Cie	DESIGNER VARIABLES	
Kw=8.4:	Swindow factor for tr	Bm do	Switching frequency, KHz 40.00	
Kwl=0.6:	%window facto	for Bml do	Bm for transformer, Tesla 0.20	
Vd=1.0:	%diode forward drop	C dou	Bm for inductors, Tesla 0.25	
muo=4*pi*le-7;	%uo - permeability of air		Maximum Duty cycle. Dmax 0.45	
Ro=abs(Vo)./Io;	%output load resistance	C	Minimum Duty cycle calculated, Dmin 0.25	
		Command D' X	Window factor for transformer, Kw 0.40	
%POWER CALCULATIONS		Filter	Window factor for inductor 0.60	
Po=sum((1.1*abs(Vo)-	+Vd).*Io);		Secondary side blocking didde drops, voits 1.00	
		clear		
%TURNS RATIO and DU	TY RATIO	clear	PUSHPULL TRANSFORMER	
n=(1.1*abs(Vo)+Vd)/	<pre>(2*Dmax*Vcmin);</pre>	de	loss (floruprd (block (a)uit	
Dmin=(Dmax*Vcmin)/V	cmax;	pushpull_design	iess (f)orwaru, (b)ack, (q)uit	
SPUSHPULL TRANSFORM	ER DESIGN	_	Command Window Editor Documentation	
and the second s	Octave Tab Width 8 T In 34 Col 13			
	Conter Top Friding Conter			

And then that is it the calculations are done and the results are displayed, you have the pushpull converter specifications then the designer variables.

(Refer Slide Time: 08:07)

Activities 🌔 GNU Octa	ve 🕶	Sun 22:42 •	en ▼ 후 40) 🕑 ▼
Open 🔻 🖪	pushpull_design.m -/lums_dir/MOOC/PE/wk10/resources/mfiles		Octave ×
%Design of multi-out	put PUSHPULL CONVERTER	File Edit Debug	Window Help News
SPECIFICATIONS		P 🖪 🖷	Current Directory:
Vc=325:	<pre>%nominal dc-link voltage</pre>	File Browser 🗗 🗵	Command Window & ×
Vcmin=210; Vcmax=380;	%minimum dc-link voltage %maximum dc-link voltage	; • ÷ ©	Primary VA 32.81 Secondary VA 26.25 Code = 55/13/07
Vo=[15,-15]; dv=[0.15,0.15];	%isolated multi output voltages %peak to peak output voltage ripples	Name 🔺	Number of windings in centre tapped primary, Np 432 Gauge of Np SWG 35
Io=[1,0.5];	%output currents	- ferrite.m	Number of windings in centre tapped secondary, Ns 1 40 Gauge of Ns 1 SWG 24
<pre>%DESIGNER's VARIABLE di=0.1*Io;</pre>	S %inductor current ripple	- fullbridge	Number of windings in centre tapped secondary, Ns 2 40 Gauge of Ns 2 SWG 27
TS=40e3; Bm=0.2; Bml=0.25:	%switching frequen %flux density, T for trans %flux density. T for induc	Workspace ♂ ×	POWER SWITCH RATINGS
eff=0.8; the transformer	%estimated efficie	Filter	Maximum continuous current, Icm, amps 0.16 Maximum off state voltage drop 760.00
Dmax=0.45; J=3e6;	%maximum duty cycle %current density, A/m2	Name A Cla Bm do	DIODE RATINGS
KW=0.4; KWl=0.6; Vd=1.0:	Window factor for transfo Window factor for Window factor	Bml do	Blocking diode ratings for winding 1 winding1 Peak current, amps 1.05
<pre>muo=4*pi*le-7; Ro=abs(Vo)./Io;</pre>	%uo - permeability of air %output load resistance		windingi Average current, anps 0.53 windingi PIV, volts 70.37 Blocking diode ratings for winding 2
SPOWER CALCULATIONS	Vd) *To).	Filter	winding2 Peak current, amps 0.53 winding2 Average current, amps 0.26 winding2 PIV, volts 70.37
<pre>%TURNS RATIO and DUT n=(1.1*abs(V0)+Vd)/(Dmin=(Dmax*Vcmin)/Vc</pre>	Y RATIO 2*Omax*Vcmin); max;	clear clear clc pushpull_design	INDUCTOR DESIGN
PUSHPULL TRANSFORME	R DESIGN		Command Window Editor Documentation
	Octave 🔻 Tab Width: 8 👻 🛛 Ln 34, Col 13		

Then followed by the POWER SWITCH RATINGS diode ratings, inductor design.

(Refer Slide Time: 08:12)

Activities 🜔 GNU Octa	ve 🔻	Sun 22:42 •	en 🔻 후 📢 🖻	
Open 👻 🖪	pushpull_design.m ~/lums_dir/MOOC/PE/wk10/resources/mfiles		Octave	×
Design of multi-out	put PUSHPULL CONVERTER	File Edit Debug	Window Help News	
SPECIFICATIONS		P 🖪 🖷	Current Directory:	•
Vc=325.	spominal dc-link voltage	File Browser 🗗 🛛	Command Window 8	×
Vemin=218	Sminimum dc-link voltage		winding1 PIV, volts 70.37	
Vcmax=380	Smaximum dc-link voltage	; • 🔗 🔘	Blocking diode ratings for winding 2	
Vo=[1515]:	sisolated multi output voltage		winding2 Peak current, amps 0.53	
dv=[0.15.0.15]:	%peak to peak output voltage ripples	Name 🔺	winding2 Average current, amps 0.26	
Io=[1,0.5];	%output currents	- ferrite.m	Handings Par, Total 10.07	
SDECTONER'S VARIABLE	s	- 🖹 fullbridge	INDUCTOR DESIGN	
di=8 1*To:	Sinductor current rinnle	B 1. 10.11		
fc=4003.	Scutching freque	halfbridg	winding1 Inductance value, mH 0.94243	
Rm=A 2	Sflux density I for tra	Workensen A X	windingi Core E25769760 windingi Number of windings 99	
Bm1=0.25:	%flux density. T for indu	in workspace o	winding1 Gauge of inductance SWG 22	
eff=0.8:	%estimated effici	e Filter	winding1 Airgap for inductance,mm 0.52274	
the transformer			udedian2 Tedusteens us3us all 4 00407	
Dmax=0.45:	%maximum duty cycle	Name A Cla	winding2 Inductance Value, MH 1.88487 winding2 Core E20/10/05	
J=3e6;	%current density, A/m2	Day day	winding2 Number of windings 128	
Kw=0.4;	%window factor for transf	0 00	winding2 Gauge of inductance SWG 25	
Kwl=0.6;	%window factor fo	r Bml do	winding2 Airgap for inductance, mm 0.33862	
Vd=1.0;	%diode forward drop	C doi	CADACITOR ETLIER PATTINGS	
muo=4*pi*le-7;	<pre>%uo - permeability of air</pre>			
Ro=abs(Vo)./Io;	%output load resistance	Command 5 ×	winding1 Capacitance value, uF 10.41667	
			windingi Voltage Fating, Volts 30.00	
SPOWER CALCULATIONS		Filter 🗌 👻	and and a second s	
Po=sum((1.1*abs(Vo)+	Vd).*Io);		winding2 Capacitance value, uF 5.20833	
		clear	winding2 Voltage rating, volts 30.00	
STURNS RATIO and DUT	Y RATIO	clear	winding2 ESR requirement, onms 2.40000	
n=(1.1*abs(V0)+Vd)/(2*Umax*Vcmin);	clc	less (190%) (f)orward, (b)ack, (g)uit	
umin=(umax*Vcmin)/Vc	max;	pushpull_design		4
SPUSHPULL TRANSFORME	R DESIGN	_	Command Window Editor Documentation	
in the second second second second	Octave Tab Width: 8 Ln 34. Col 13			

Inductor design with its core, air gap all those things capacitor filter rating and everything that is needed for rigging up the converter.

So, the pushpull converter design is designed in this fashion, I will allow you to play around with this specification and look into the equations and try to get more insight into the multi output push pull converter mfile.

(Refer Slide Time: 08:44)

Activities	Text Editor 🔻	Sun 22:43	•				en ▼ 후 📢 🗗 ▼
Open 👻	halfbridge_design.m -/lums_dir/MOOC/PE/wk10/resources/mfiles	Save = ×			Octa	ve	×
Design of r	ulti-output HALFBRIDGE CONVERTER		urces	/ mfiles 👻	Q ::	: * ≡ ×	
SPECIFICAT	ONS						•
T							
/c=325;	<pre>%nominal dc-link vo</pre>	ltage	1.				0 ^
Vcmin=210;	%minimum dc-link vo	ltage		0.00			
Vcmax=380;	%maximum dc-link vo	ltage	le_	halfbridge_	metglas.m	pow_iron.m	
Vo=[15,-15];	%isolated multi output volt	ages	m	design.m			
dv=[0.15,0.1	[5]; %peak to peak output voltage ri	pples					
Io=[1,0.5];	%output currents						
DESIGNER's	VARIABLES						
di=0.1*Io;	%inductor current r	ipple					
fs=40e3;	%switching	frequency,Hz					
Bm=0.2;	%flux density, T fo	r transformer					
Bml=0.25;	%flux density, T fo	r inductor					
eff=0.8;	%estimated	efficiency of					
the transfor	mer						
Dmax=0.45;	%maximum duty cycle						
J=3e6;	%current density, A	/m2					
Kw=0.4;	%window factor for	transformer					
Kwl=0.6;	%window fac	tor for inductor					
Vd=1.0;	%diode forward drop						
muo=4*pi*le	7; %uo - permeability of air						
Ro=abs(Vo).	To; %output load resistance						
POWER CALCI	ILATIONS						
Po=sum((1.1*	<pre>sabs(Vo)+Vd).*Io);</pre>						
TURNS RATIO	and DUTY RATIO						
n=(1.1*abs()	<pre>/o)+Vd)/(Dmax*(Vcmin-0.1*Vcmax));</pre>						
Dmin=(Dmax*)	/cmin)/Vcmax;			"halfbrid	ge_design.m'	selected (9.6 kB)	
HALFBRIDGE	TRANSFORMER DESIGN			Command W	indow E	ditor Documen	tation
in al	Int. In a PPILL class and a P. L.						
	Octave 🔻 Tab Width: 8 👻 Ln 163, C	xl4 ▼ INS					

Likewise, I have the half bridge design m file, you can look into that also. I have kept the same specifications and so, that you can compare. Slightly I have changed the output specs, but otherwise I have essentially kept the same simplification.

(Refer Slide Time: 09:06)

Activities	🗐 Text Ed	litor 🕶		Sun	22:43	•				en▼ 〒40 ∄▼
Open 💌	Ð	halfbridge_design.m	Save	Ξ	x			Octav	e	×
TURNS RAT	FIO and D s(Vo)+Vd)	UTY RATIO /(Dmax*(Vcmin-0.1*Vcmax));				urces	/ mfiles 🔻	۹ ::	▼ Ξ X	,
Dmin=(Dma)	(*Vcmin)/	Vcmax;							and a second sec	5 ×
HALFBRIDG ap=(Po*(sc ap_firs flag=0; a_index cnt=1; while f	<pre>5E TRANSF art(2)+(1 st=ap; ; c=1; flag==0,</pre>	ORMER[DESIGN /eff)))/(4*Kw*}*Bm*fs);				je_ .m	halfbridge_ design.m	metglas.m	pow_iron.m	
% Fj % No % Fc % clc disp [ac,	ind Ac, A ote: core or detail o('HALFBR ,aw,ap,co	<pre>w for given Ap using cores function s.m is a program core selection s contact Dr. L.Umanand, CEDT, IISC, B IDGE TRANSFORMER DESIGN'); re]=cores(ap,1,a_index);</pre>	angalore-	560 0	12.					
% % Ca % Np=r Ns=r	alculatio round((Vc round(n*N	n of Number of turns. max)/(8*Bm*ac*f5)); p); % centre tap to end								
\$ \$ Ca	alculatio	n of Area of c/s of the windings.								
awp= winding.	sum((n.*	Io)/J); % Area o	f c/s of	pri		L	"halfbr	idge_design.m"	selected (9.6 kB)	
aws=	=(Io*sqrt	(Dmax))/J; % Area of c/s of	sec wind	ings.						
	ind CHG o	f the wire to be used using the wires. Octave - Tab Width: 8 - Ln 8,	, Col 6	•	INS	-	Command	Window E	ditor Documen	tation

Here also everything is same except for the half bridge transformer design, the area product which this equation will change just like as I have listed shortly a while back.

(Refer Slide Time: 09:24)



So, you can execute this design like I did for the pushpull and try to find out the design values.

(Refer Slide Time: 09:25)

Activities 🌔 GNU Octa	ve 🔻		Sun 22:44 •	en 🔻 🔶 I	10 🖸 🔻
Open 🔻 🖪	halfbridge_design.m	Save		Octave	×
fprintf(id,' current, amps',Idbav	<pre>//// t%s\t %s\t %5.2f\n',['winding',num2s (i));</pre>	tr(i)],'/	File Edit Debug	Window Help News	,
<pre>(print(ld, volts',Vdbrm(i)); end fprintf(id,'\n\n%s\n fprintf(id,'%s\t %s\ fprintf(id,'%s\t %s\ fprintf(id,'%s\t %s\ fprintf(id,'%s\t %s\ indings',M(i));</pre>	<pre>(test(wsi(wsi2)(n',[winding',num2st \n','INDUCTOR DESIGN'); t %10.5f\n',['winding',num2str(i)],'I t %s\n',['winding',num2str(i)],'Gree' t %5d\n',['winding',num2str(i)],'Numb t %s\n',['winding',num2str(i)],'Gauge</pre>	nductance ,coreL(i, er of	File Browser 5 ×	Command Window WALFBRIDGE CONVERTER SPECIFICATIONS Output Power, M. 26:25 Input CD vollage, volls 325:00 Minimum CD input vollage, volls 326:00 Output vollage, volls Vol 15:00 Output vollage, volls Vol 10:00 Output vollage, volls Vol 00:00 Output vollage, vol 00:00 Output vol 00:00 O	ð ×
<pre>fprintf(id,'%s\t %s\ inductance,mm',Llg(i end</pre>	<pre>//, *10.5f\n\n',['winding',num2str(i)],)*1e3);</pre>	'Airgap 1	Filter	Inductor current ripple, amps ripple1 0.10 Inductor current ripple, amps ripple2 [0.05 DESIGNER VARIABLES	
<pre>fprintf(id,'%s\n\n', for i=1:length(C), fprintf(id,'%s\t %s\ uF',C(i)*le6); fprintf(id,'%s\t %s\ wolts' Ver(i));</pre>	<pre>'CAPACITOR FILTER RATINGS'); t %10.5f\n',['winding',num2str(i)],'C t %5.2f\n',['winding',num2str(i)],'Vo</pre>	apacitan ltage rat	Bm doi Bml doi C doi	Switching frequency, KHz 40,00 Bm for transformer, Tesla 0.20 Bm for inductors, Tesla 0.25 Estimated efficiency of transformer, NK 80,00 Maximum Duty cycle, Dmax 0.45 Minimum Duty cycle aclulated, Dmin 0.25	
<pre>volts.vcr(1)); fprintf(id,'%s\t %s\ ohms',Esr(i)); end fprintf(id,'%s\n\n', fprintf(id,'%s\t %10 forintf(id':%s\t %10 forintf(id':%s\t %10</pre>	<pre>t %10.5f\n\n',['winding',num2str(i)], 'FLUX WALKING CAPACITOR RATINGS'); .5f\n','Capacitance value, UF',CW*1e6 2f\n','Wolten rating, vuls', Vfo):</pre>	'ESR requ	Filter S ×	Mindow factor for transformer, Kw. 0.40 Window factor for inductor 0.40 Secondary side blocking diode drops, volts 1.00 HALFBRIDGE TRANSFORMER E-less(f)ormand, (b)mak, (g)mit	
	,			Command Window Editor Documentation	
	Octave 🔻 Tab Width: 8 👻 🛛 Ln 34,	Col 42			

I will just run it through half bridge converter design, it goes in the same fashion I will choose Ferrite E CORES again Ferrite EE CORE Ferrite for the inductor Ferrite inductors. So, you can you will get the mm design values, you can read through the values later on and here in the case of the half bridge I am also calculating the flux working capacitor ratings for so, that if you want to use the flux walking prepare

prevention using capacitors you can use it, for small powers this is really fine. In a similar way I have also with me here the full bridge design mfile.

So, very very similar except for the area product. The area product in the case of the half bridge and the full bridge are same. So, even those equations remain the same. You just have to run full bridge and do the same process of selecting the core, selecting the shape and go through the process of selecting the core for the inductor shape, inductor 2 shape and then you get the results.

So, just walk through the design values, you will probably get a hang of the numbers for the a typical design of this specification. So, I will allow you to play around with the specs and get try to get more insight into the design of the converters using this mfile as a template.