

Fundamentals of Power Electronics
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Lecture - 70
Forward converter design mfile

(Refer Slide Time: 00:27)

```
1 %Design of multi-output FORWARD CONVERTER
2
3
4 %SPECIFICATIONS
5 Vc=48; %Nominal dc-link voltage
6 Vcmin=40; %Minimum dc-link voltage
7 Vcmax=60; %Maximum dc-link voltage
8 %
9 Vm=[2]; %Isolated multi output voltages
10 d=0.05; %peak to peak output voltage ripples
11 Io=[1]; %output currents
12
13 %DESIGNER'S VARIABLES
14 di=0.3*Io; %Inductor current ripple
15 fs=20e3; %switching frequency,Mz
16 Bm=0.2; %flux density, T for transformer
17 Bm=0.25; %flux density, T for inductor
18 eff=0.8; %Unlimited efficiency of the transformer
19 Dmax=0.45; %Maximum duty cycle
20 J=3e6; %current density, A/m2
21 Km=0.4; %window factor for transformer
22 Kw=0.6; %window factor for inductor
23 Vd=1.0; %diode forward drop
24 mu=0.0001; %muo - permeability of air
25 Rm=0.01; %output load resistance
26
27 %POWER CALCULATIONS
28 Pout=sum(I.*abs(Vo)/Vo).*Io);
29
30 %TURNS RATIO and DUTY RATIO
31 n=1.1*abs(Vo)/Vc; %Dmax*Vcmin);
32 Dmin=(Dmax*Vcmin)/Vcmax;
33
34 %FORWARD TRANSFORMER DESIGN
35 ap=(sqrt(Dmax)*Po*(1+(1/eff)))/(Km*J*Bm*fs));
36 ap_fir=ap;
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(Refer Slide Time: 01:49)

```
1 %Design of multi-output FORWARD CONVERTER
2
3 %SPECIFICATIONS
4
5 Vc=48; %nominal dc-link voltage
6 Vmin=48; %minimum dc-link voltage
7 Vmax=48; %maximum dc-link voltage
8 Vom=12; %isolated multi output voltage
9 d=0.05; %peak to peak output voltage
10 Io=1; %output currents
11
12 %DESIGNER'S VARIABLES
13 di=0.3*Io; %inductor current
14 fs=20e3; %switching frequency
15 Bm=0.2; %flux density, T
16 Bm1=0.25; %flux density, T
17 eff=0.8; %estimated efficiency
18 Dmax=0.45; %maximum duty cycle
19 J=30e3; %current density, A/mm^2
20 Kw=0.4; %window factor for core
21 Kw1=0.6; %window factor for diode
22 Vd=1.0; %diode forward drop
23 mu=mu0*mu_r; %mu - permeability
24 Rm=abs(Vo)/Io; %output load resistance
25
26 %POWER CALCULATIONS
27 Psum=(1.1*abs(Vo)+Vd)*Io;
28
29 %TURNS RATIO and DUTY RATIO
30 n=(1.1*abs(Vo)+Vd)/(Dmax*Vcmin);
31 Dmin=(Dmax*Vcmin)/Vcmax;
32
33 %FORWARD TRANSFORMER DESIGN
34 ap=(sqrt(Dmax)*Po*(1+(1/eff)))/(Kw*J*Bm)
35 ap1=ap;
36 [l,ap]=lsize;
37 a1=apex1;
38 cnt1;
```

core no.	Ap, mm^4	Ac, mm^2	Aw, mm^2
1	1490	31	47.8
2	3120	40	75
3	4780	55	87
4	7100	59.7	119
5	18470	131	141
6	27290	107	256
7	46590	182	256
8	60160	235	256
9	142840	266	537

It is simple for you to add as much as you want into this database.

(Refer Slide Time: 01:58)

```
1 function [wire,eth,swg]=wires(w area)
2
3 %This is a database for copper wire gauges. The calculated
4 %wire cross section area is given as parameter. The
5 %actual wire cross section area and the SMG gauge type
6 %are given as outputs.
7
8 %The SYNTAX is as follows
9 % [wire,eth,SWG] = wires(calc_area);
10
11 %All area units are in m^2.
12 % calc_area = calculated area of cross section , m^2
13 % wire = area of bare conductor, from database, m^2
14 % eth = enamel thickness to be added to bare dia, m
15 % SWG = gauge number of annealed copper
16
17 %This is a function in the "power electronic application design"
18 %toolbox designed at
19 %IITM, Indian Institute of Science, Bangalore-560 012, INDIA.
20 %Ref: Dr. I. Manandhar
21
22 %
23 error(nargchk(1, nargin));
24 % area_conv=area*1e6; % conversion from m^2 to mm^2
25
26
27 % SMG GAUGES
28
29 gauges=[ 'SWG 45';
30 'SWG 44';
31 'SWG 43';
32 'SWG 42';
33 'SWG 41';
34 'SWG 40';
35 'SWG 39';
36 'SWG 38';
37 'SWG 37';
38 'SWG 36'];
39 cnt1;
```

SWG
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(Refer Slide Time: 02:03)

```
1 *Design of multi-output FORWARD CONVERTER
2
3 *SPECIFICATIONS
4
5 Vc=40;          %Nominal dc-link voltage
6 Vmin=40;       %Minimum dc-link voltage
7 Vmax=40;       %Maximum dc-link voltage
8 Vm=12;         %Isolated multi output voltage
9 d=0.05;        %peak to peak output voltage
10 I=1;           %output currents
11
12 *DESIGNER'S VARIABLES
13 di=0.3*Io;     %inductor current
14 fs=200;        %switching frequency
15 Bm=0.2;        %flux density, T
16 Bm1=0.25;     %flux density, T
17 eff=0.8;      %estimated efficiency
18 Dmax=0.45;    %maximum duty cycle
19 J=300;         %current density, A/mm^2
20 Kw=0.4;       %window factor for core
21 Kw1=0.6;      %window factor for winding
22 Vd=1.0;       %diode forward drop
23 mu=4*pi*1e-7; %mu - permeability
24 Rm=abs(Vo)/Io; %output load resistance
25
26 *POWER CALCULATIONS
27 Pout=sum(1.1*abs(Vo)*Io); %output power
28
29 *TURNS RATIO AND DUTY RATIO
30 n=(1.1*abs(Vo)+Vd)/(Dmax*Vcmin); %turns ratio
31 Dmin=(Dmax*Vcmin)/Vcmax; %duty ratio
32
33 *FORWARD TRANSFORMER DESIGN
34 ap=(sqrt(Dmax)*Po*(1+(1/eff)))/(Kw*J*Bm) %primary area
35 ap1=firsttap; %primary area
36 I1=ap*d; %primary current
37 a1=Index*1; %primary area
38 cnt1=1; %primary current
```

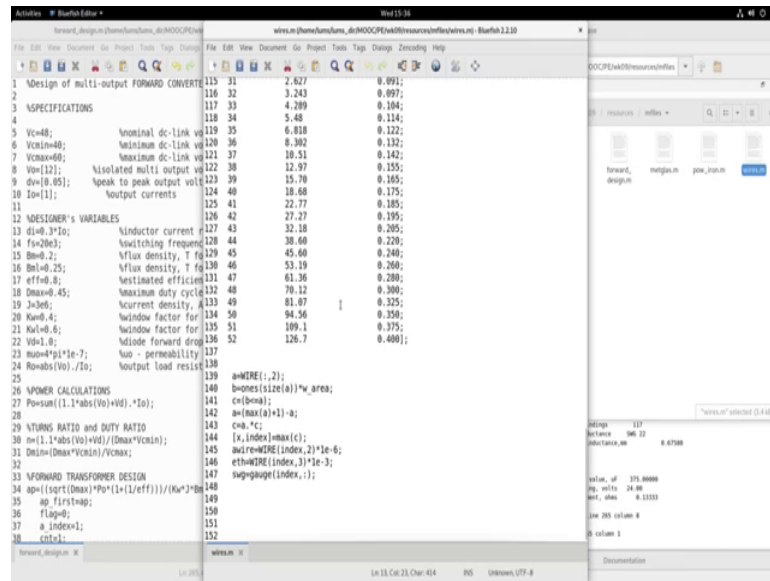
And then you say, in the wires table I am going to show you that I have included the standard wire gauges details, these are the standard wire gauges starting going down from SWG 45 number toward SWG 7.

(Refer Slide Time: 02:12)

Gauge	Bare area of conductor, mm ²	enamel thickness addition to bare dia, mm
45	0.003973	0.015
44	0.005189	0.016
43	0.006567	0.018
42	0.008107	0.018
41	0.009810	0.020
40	0.011675	0.020
39	0.013700	0.020
38	0.01624	0.025
37	0.02043	0.025
36	0.02527	0.028
35	0.03175	0.028
34	0.04289	0.035
33	0.05667	0.035
32	0.07518	0.045
31	0.09972	0.045
30	0.131	0.045
29	0.1703	0.048
28	0.224	0.048
27	0.2927	0.053

With all their bare conductor area and enamel thickness, all these things.

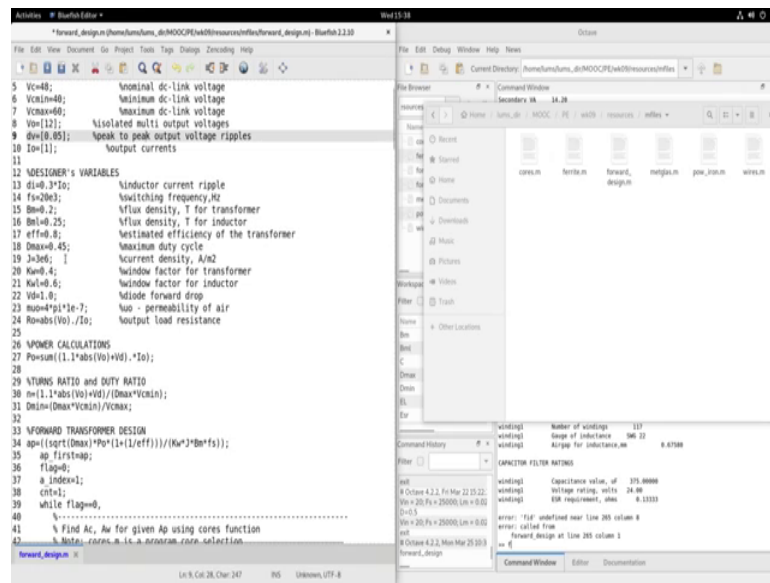
(Refer Slide Time: 02:19)



So, you have the wire gauge table and also the cores table and in forward design dot m I have included the actual design calculations. So, what is there in forward design? Look at it first the specifications, we saw the specifications we see 48, we see minimum, we see maximum calculation, you can calculate it if you have tolerance otherwise list the minimum and the maximum

Now, the change that I have done, V naught is indicated as a vector twelve volts and dv as another vector the delta v and I naught is also a vector one volte these are single a single secondary, but if you have multi secondary you just have to include comma and put in let us say, you can put in a 15 volts, you can put in a minus 15 volts so on. And accordingly the ripple for the output corresponding that vector will change and the I naught vector also will change, but now I will just bring it back into a single. So, this can be used for multi output forward converter.

(Refer Slide Time: 03:34)



```
5 Vc=48; %Nominal dc-link voltage
6 Vcmin=48; %Minimum dc-link voltage
7 Vcmax=48; %Maximum dc-link voltage
8 Vm=[2]; %Isolated multi output voltages
9 d=0.05; %peak to peak output voltage ripples
10 Io=[1]; %Output currents
11
12 %DESIGNER'S VARIABLES
13 di=0.3*Io; %Inductor current ripple
14 fs=20e3; %Switching frequency,Hz
15 Bm=0.2; %Flux density, T for transformer
16 Bml=0.25; %Flux density, T for inductor
17 eff=0.8; %Estimated efficiency of the transformer
18 Dmax=0.45; %Maximum duty cycle
19 J=3e3; %Current density, A/mm^2
20 Kw=0.4; %Window factor for transformer
21 Kw1=0.6; %Window factor for inductor
22 Vd=1.0; %Diode forward drop
23 mu=0.012; %mu - permeability of air
24 Rload=10; %Output load resistance
25
26 %POWER CALCULATIONS
27 Pout=sum(Io.*abs(Vo)/Vo.*Io);
28
29 %TURNS RATIO AND DUTY RATIO
30 n=(1.1*abs(Vo)/Vo)/(Dmax*Vcmin);
31 Dmin=(Dmax*Vcmin)/Vcmax;
32
33 %FORWARD TRANSFORMER DESIGN
34 ap=((sqrt(Dmax)*Po*(1+(1/eff)))/(Kw*J*Bm^fs));
35 ap=first(ap);
36 flag=0;
37 a_index=1;
38 cnt=1;
39 while flag=0,
40 %.....
41 % Find A_c, A_w for given Ap using cores function
42 % find_cores.m is a program core selection
43
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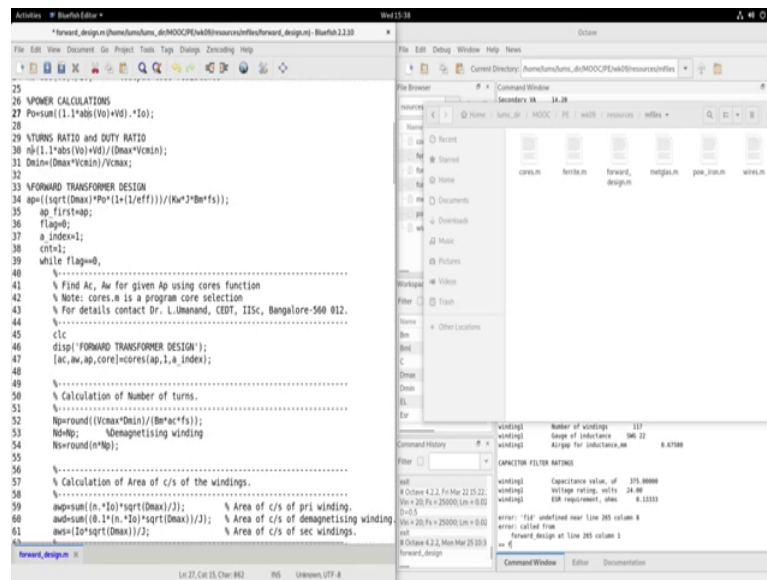
Command Window Output:

Command	Output
winding	Number of windings 117
winding	Range of inductance 366.22
winding	Range for inductance 6.6758
Filter	CAPACITOR FILTER RATINGS
ind	Capacitance value, uF 375.8668
8 Octave 4.2.2, Fri Mar 22 15:22:02	voltage rating, volts 24.88
ind	ESR requirement, ohm 6.33333
ind	error: 'if' undefined near Line 265 column 6
ind	error called from
8 Octave 4.2.2, Mon Mar 25 10:30:00	forward design at line 265 column 1
ind	ee 6

Then the designer variables delta I, I have set it at 30 percent ripple inductor current ripple can change it did that so that to reduce the core size. 20 colour switching frequency, I have given two different flux densities; one for the flux density or transformer where I am setting it as 0.2 tesla, another Bml the flux density for inductors as 0.25 tesla.

The efficiency of the transformer worst case minimum is 80 percent generally, when you design it will be much more than 80 percent. So, this is a safe lower limit to calculate the input power. Dmax are set at 0.45, J is 3 ampere mm³ ampere mm square or 3 into ten to the power of 6 ampere meter square, Kw 0.44, transformer 0.6 for inductor, Vd and all these other calculations.

(Refer Slide Time: 04:24)



```
25
26 %POWER CALCULATIONS
27 P=Vnaught*(1.1*abs(Vo)+Vd)*Io;
28
29 %TURNS RATIO and DUTY RATIO
30 n=(1.1*abs(Vo)+Vd)/(Dmax*Vcmin);
31 Dmin=(Dmax*Vcmin)/Vcmax;
32
33 %FORWARD TRANSFORMER DESIGN
34 ap=(sqrt(Dmax)*Po*(1+(1/eff)))/(Kw*J*Bm*fs);
35 ap=firstnq;
36 flag=0;
37 a_index=1;
38 cnt=1;
39 while flag=0,
40     %
41     % Find Ac, Aw for given Ap using cores function
42     % Note: cores.m is a program core selection
43     % For details contact Dr. L.Umanand, CDT, IISc, Bangalore-560 012.
44     %
45     clc
46     disp('FORWARD TRANSFORMER DESIGN');
47     [ac,aw,ap,core]=cores(ap,1,a_index);
48
49     %
50     % Calculation of Number of turns.
51     %
52     Np=round((Vnaught*Dmin)/(Bm*ac*fs));
53     Np=Np; %Demagnetising winding
54     Ns=round(n*Np);
55
56     %
57     % Calculation of Area of c/s of the windings.
58     %
59     aprimary=(n.*Io)*sqrt(Dmax)/J; % Area of c/s of pri winding.
60     asecondary=(0.1*(n.*Io)*sqrt(Dmax))/J; % Area of c/s of demagnetising winding
61     asec=[2]*sqrt(Dmax)/J; % Area of c/s of sec windings.
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```
41 % Find Ac, Aw for given Ap using core function
42 % Note: cores.m is a program core selection
43 % For details contact Dr. L.Dhanand, CDT, IISc, Bangalore-560 012.
44 %-----
45
46 disp('FORWARD TRANSFORMER DESIGN');
47 [ac,aw,ap,core]=cores(ap,1,a_index);
48
49 %-----
50 % Calculation of Number of turns.
51
52 Np=round((Vcos*Di)/(B*ac*fs));
53 Nd=Np; %Demagnetising winding
54 Ns=round(n*Np);
55
56 %-----
57 % Calculation of Area of c/s of the windings.
58
59 a=pi*(n1^2)*sqrt(Dmax/2); % Area of c/s of pri winding.
60 a2=pi*(n2^2)*sqrt(Dmax/2); % Area of c/s of demagnetising winding.
61 a3=pi*(n3^2)*sqrt(Dmax/2); % Area of c/s of sec windings.
62
63 % Find SWG of the wire to be used using the wires function
64 % Note: Wires.m is a program for wire gauge selection
65 % For details contact Dr. L.Dhanand, CDT, IISc, Bangalore-560 012.
66 %-----
67 [awp,ethp,SWGp]=wires(awp);
68 [awd,ethd,SWGd]=wires(awd);
69 SWGd=''; %Initialise to null string
70 for j=1:length(awd);
71 [awd(j),ethd(j),SWGd(j)]=wires(awd(j));
72 SWGd=strcat(SWGd,SWGd(j));
73
74
75
76 % Check for Window Area
77 %-----
```

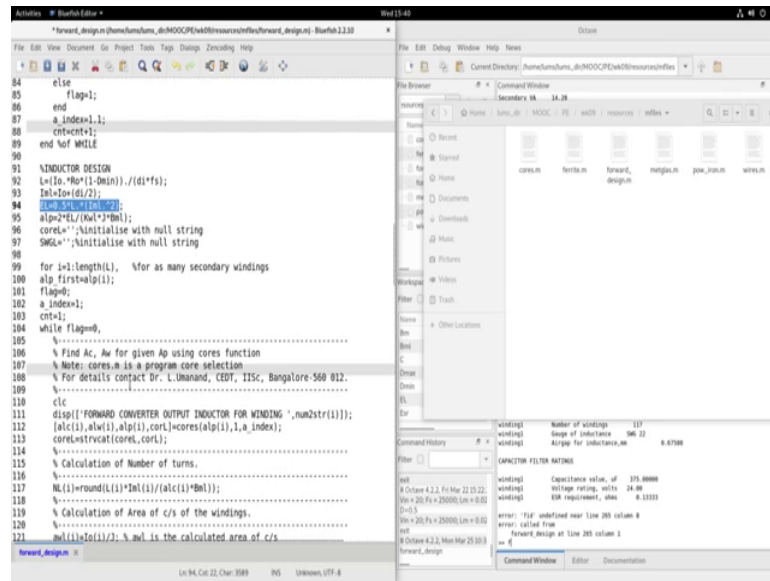
And using that N_p , N_d , N_s are calculated and then you are calculating the wire gauges here and for that I am using the wires using the wires table and the wires table will give you the aw wire cross section actual for the wires and the and the SWG, Standard Wire Gauge.

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78
79
80
81 disp(['Ap first = ',num2str(ap),' ',core,' Ap = ',num2str(ap)]);
82 disp(['Awreq = ',num2str(awreq),' Aw = ',num2str(aw)]);
83 disp('Not fitting - click again to choose bigger core');
84
85
86
87 a_index=1;
88 cnt=cnt+1;
89 end %of WHILE
90
91 %INDUCTOR DESIGN
92 [Lr,Im]=Lr(d1/2);
93 Im=Im*(d1/2);
```

Then you do the window area check if it is not fitting it will go into the next loop it will ask you which again to choose a core and so on.

(Refer Slide Time: 06:17)



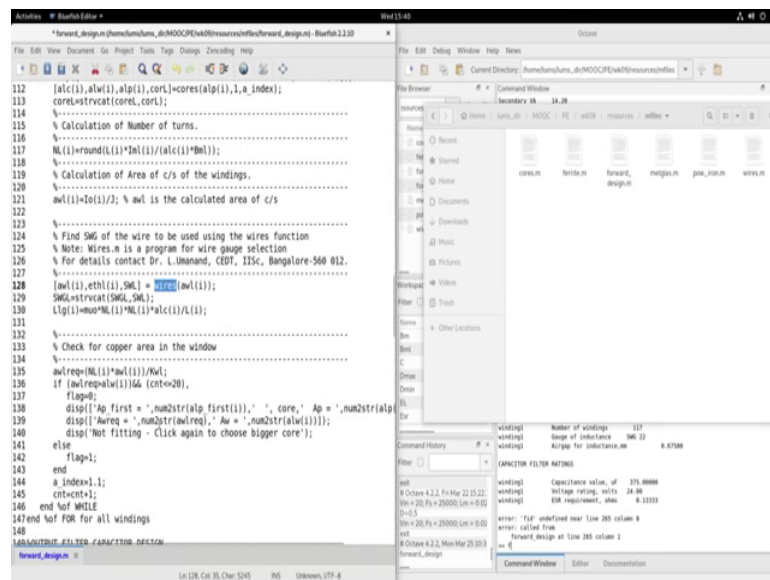
```
84 else
85     flag=1;
86 end
87 a_index=1;
88 cnt=cnt+1;
89 end not WHILE
90
91 %INDUCTOR DESIGN
92 L=[Io.*Rp*]-Dm(n)]./(di*fs);
93 In=In+(di/L);
94 L=L+(di/L);
95 alp2=L/(kwl.*Bm);
96 coreL=''; %initialise with null string
97 SWGL=''; %initialise with null string
98
99 for i=1:length(L), %for as many secondary windings
100 alp=first(alp(i));
101 flag=0;
102 a_index=1;
103 cnt=1;
104 while flag=0,
105 %-----
106 % Find A_c, A_w for given alp using cores function
107 % Note: cores.m is a program core selection
108 % For details contact Dr. L.Umanand, CEDT, IISc, Bangalore-560 012.
109 %-----
110 disp(['FORWARD CONVERTER OUTPUT INDUCTOR FOR WINDING ', num2str(i)]);
111 [al(i),alw(i),alp(i),cor]=cores(alp(i),L,a_index);
112 [al(i),alw(i),alp(i),cor]=cores(alp(i),L,a_index);
113 coreL=strcat(coreL,cor);
114 %-----
115 % Calculation of Number of turns.
116 %-----
117 N(i)=round(L.*In(i))/(al(i).*Bm);
118 %-----
119 % Calculation of Area of c/s of the windings.
120 %-----
121 aw(i)=(al(i)/2); % aw is the calculated area of c/s
122 %-----
123 %-----
124 % Find SWG of the wire to be used using the wires function
125 % Note: Wires.m is a program for wire gauge selection
126 % For details contact Dr. L.Umanand, CEDT, IISc, Bangalore-560 012.
127 %-----
128 [sw(i),eth(i),SWL]=wires(aw(i));
129 SWGL=strcat(SWGL,SWL);
130 L(i)=N(i).*N(i).*al(i).*al(i)/L(i);
131 %-----
132 %-----
133 % Check for copper area in the window
134 %-----
135 awreq=(N(i).*aw(i))/kwl;
136 if (awreq>alw(i))/46 (cnt=20);
137     flag=0;
138     disp(['ap first = ', num2str(alp first(i)), ' , core = ', num2str(alp
139         disp(['Aureq = ', num2str(awreq), ' Aw = ', num2str(alw(i))]);
140     disp('Not fitting - Click again to choose bigger core');
141 else
142     flag=1;
143 end
144 a_index=1;
145 cnt=cnt+1;
146 end not WHILE
147 end not FOR for all windings
148
149 %OUTPUT FILTER CAPACITOR DESIGN
150 forward_design
```

Command Window

```
windings Number of windings 117
windings Range of Inductance 96.22
windings Airgap for Inductance,aw 6.67588
CAPACITOR FILTER RATINGS
err Voltage rating, uf 375.88888
err Voltage rating, volts 24.48
err ESR requirement, ohm 6.13333
err Vin = 20.Fv * 25000, Lm = 0.0
err D=0.5
err error: 'if' undefined near line 263 column 8
err error: called from
err forward_design at line 263 column 1
err = 4
forward_design
```

And then the INDUCTOR DESIGN comes in finding out the value of L for every secondary you have an inductor. So, L here will be a vector and find out the energy of the inductor and finally, you do a area product design just like we discussed.

(Refer Slide Time: 06:45)



```
112 [al(i),alw(i),alp(i),cor]=cores(alp(i),L,a_index);
113 coreL=strcat(coreL,cor);
114 %-----
115 % Calculation of Number of turns.
116 %-----
117 N(i)=round(L.*In(i))/(al(i).*Bm);
118 %-----
119 % Calculation of Area of c/s of the windings.
120 %-----
121 aw(i)=(al(i)/2); % aw is the calculated area of c/s
122 %-----
123 %-----
124 % Find SWG of the wire to be used using the wires function
125 % Note: Wires.m is a program for wire gauge selection
126 % For details contact Dr. L.Umanand, CEDT, IISc, Bangalore-560 012.
127 %-----
128 [sw(i),eth(i),SWL]=wires(aw(i));
129 SWGL=strcat(SWGL,SWL);
130 L(i)=N(i).*N(i).*al(i).*al(i)/L(i);
131 %-----
132 %-----
133 % Check for copper area in the window
134 %-----
135 awreq=(N(i).*aw(i))/kwl;
136 if (awreq>alw(i))/46 (cnt=20);
137     flag=0;
138     disp(['ap first = ', num2str(alp first(i)), ' , core = ', num2str(alp
139         disp(['Aureq = ', num2str(awreq), ' Aw = ', num2str(alw(i))]);
140     disp('Not fitting - Click again to choose bigger core');
141 else
142     flag=1;
143 end
144 a_index=1;
145 cnt=cnt+1;
146 end not WHILE
147 end not FOR for all windings
148
149 %OUTPUT FILTER CAPACITOR DESIGN
150 forward_design
```

Command Window

```
windings Number of windings 117
windings Range of Inductance 96.22
windings Airgap for Inductance,aw 6.67588
CAPACITOR FILTER RATINGS
err Voltage rating, uf 375.88888
err Voltage rating, volts 24.48
err ESR requirement, ohm 6.13333
err Vin = 20.Fv * 25000, Lm = 0.0
err D=0.5
err error: 'if' undefined near line 263 column 8
err error: called from
err forward_design at line 263 column 1
err = 4
forward_design
```

And do the core you I am using cores here again, to select the cores and then wires here to select the wire gauge for the inductor and only here you also calculate the air gap and goes into an iteration.

(Refer Slide Time: 06:59)

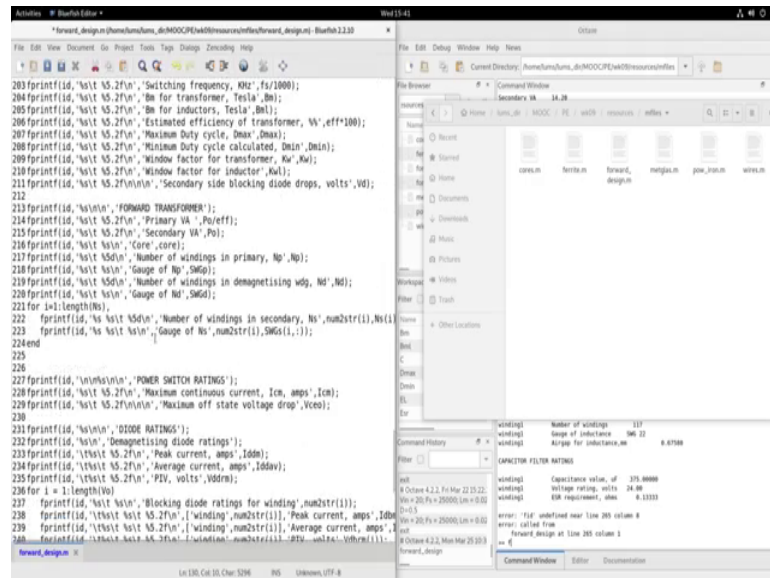
```
136 if (aw[reqpal(i)] && (cnt <= 20),
137     flag=0;
138     disp(['Ap first = ', num2str(alp first(i)), ', core = Ap = ', num2str(alp
139         disp(['Nreq = ', num2str(adreq), ' A = ', num2str(alw(i))]);
140         disp('Not fitting - Click again to choose bigger core');
141     else
142         flag=1;
143     end
144     a.index=a.index+1;
145     cnt=cnt+1;
146 end for WHILE
147 end for FOR all windings
148
149 OUTPUT FILTER CAPACITOR DESIGN
150 C=di./(0.1*V*Pfs); %design for C with 10% of allowable Vo ripple
151 Vr=2*abs(Vo);
152 Esr=(0.8*Vr)/di; %design for ESR with 80% of allowable Vo ripple
153
154 OUTPUT DIODE DESIGN
155 %demagnetising winding diode
156 Idm=sum(1.*(1-Io)*sqrt(Dmax));
157 Idav=sum(0.1*(n.*Io)*sqrt(Dmax)*(1-Dmin)/2);
158 Vdbr=2*Vcmax;
159
160 %secondary winding blocking diodes
161 Idm=Io+(di/2);
162 Idav=Idm*Dmax;
163 Vdbr=n*Vcmax;
164
165 %secondary side freewheeling diodes
166 Idm=Io+(di/2);
167 Idav=Idm*(1-Dmin);
168 Vdfr=n*Vcmax;
169
170 POWER SWITCH DESIGN
171 Inagsum(0.1*(n.*Io)*sqrt(Dmax));
172 Icmsum(n.*(1+(di/2))) + Inag;
173 Vcsw=2*Vcmax;
174
175
176 .....
177 % Display the results.
178 %
179 %
180
181 Id=I;
182
183 fprintf(id, '%s\n', 'FORWARD CONVERTER SPECIFICATIONS');
184 fprintf(id, '%s\n', 'Output Power, W, Po);
185 fprintf(id, '%s\n', 'Input DC voltage, volts, Vc);
186 fprintf(id, '%s\n', 'Minimum DC input voltage, volts, Vcmin);
187 fprintf(id, '%s\n', 'Maximum DC input voltage, volts, Vcmax);
188 for i=length(Vo),
189     fprintf(id, '%s\n', 'Output voltage, volts, V, ', num2str(i), V(i));
190 end
191 for i=length(dv),
192     fprintf(id, '%s\n', 'Output voltage ripple, volts, ', 'ripple', num2str
193 end
194 for i=length(Io),
195     fprintf(id, '%s\n', 'Output current, amps, ', I(i), num2str(i), I(i));
196 end
197 for i=length(dI),
198     fprintf(id, '%s\n', 'Inductor current ripple, amps, ', 'ripple', num2str
199 end
200
201
202 fprintf(id, '%s\n', 'DESIGNER VARIABLES');
203 fprintf(id, '%s\n', 'Switching frequency, kHz, fs/1000);
204 fprintf(id, '%s\n', 'Bm for transformer, Tesla, Bm);
forward_design.m
```

If it is not fitting and then the OUTPUT CAPACITOR FILTER DESIGN; the OUTPUT FILTER CAPACITOR DESIGN, the DIODE DESIGNS. The various diodes demagnetising diode, the secondary blocking diode in the secondary freewheeling diode POWER SWITCH all those things.

(Refer Slide Time: 07:12)

```
187 /- IOTAV IOTM*(1-DMIN);
188 Vdfr=n*Vcmax;
189
190 POWER SWITCH DESIGN
191 Inagsum(0.1*(n.*Io)*sqrt(Dmax));
192 Icmsum(n.*(1+(di/2))) + Inag;
193 Vcsw=2*Vcmax;
194
195
196 .....
197 % Display the results.
198 %
199 %
200
201 Id=I;
202
203 fprintf(id, '%s\n', 'FORWARD CONVERTER SPECIFICATIONS');
204 fprintf(id, '%s\n', 'Output Power, W, Po);
205 fprintf(id, '%s\n', 'Input DC voltage, volts, Vc);
206 fprintf(id, '%s\n', 'Minimum DC input voltage, volts, Vcmin);
207 fprintf(id, '%s\n', 'Maximum DC input voltage, volts, Vcmax);
208 for i=length(Vo),
209     fprintf(id, '%s\n', 'Output voltage, volts, V, ', num2str(i), V(i));
210 end
211 for i=length(dv),
212     fprintf(id, '%s\n', 'Output voltage ripple, volts, ', 'ripple', num2str
213 end
214 for i=length(Io),
215     fprintf(id, '%s\n', 'Output current, amps, ', I(i), num2str(i), I(i));
216 end
217 for i=length(dI),
218     fprintf(id, '%s\n', 'Inductor current ripple, amps, ', 'ripple', num2str
219 end
220
221
222 fprintf(id, '%s\n', 'DESIGNER VARIABLES');
223 fprintf(id, '%s\n', 'Switching frequency, kHz, fs/1000);
224 fprintf(id, '%s\n', 'Bm for transformer, Tesla, Bm);
forward_design.m
```

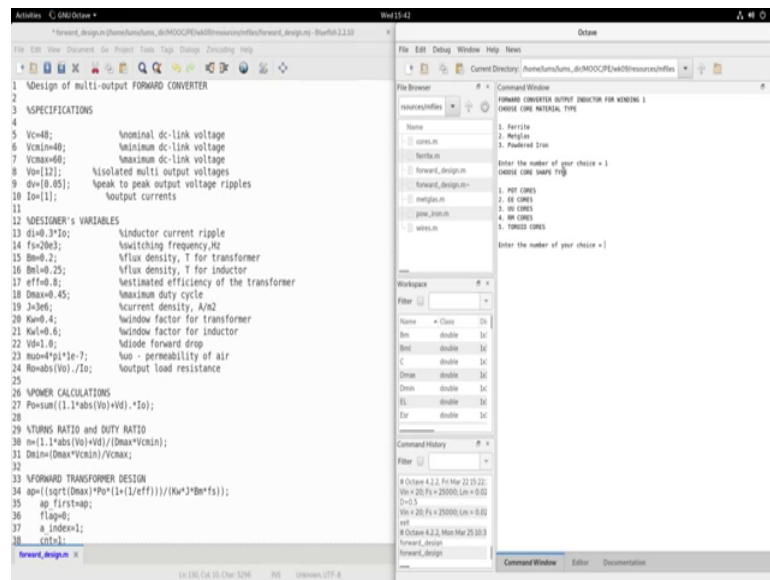
(Refer Slide Time: 07:15)



```
203 fprintf('s\t %5.2f\n', Switching frequency, kHz, fs/1000);
204 fprintf('s\t %5.2f\n', Bm for transformer, Tesla, Bm);
205 fprintf('s\t %5.2f\n', Bm for inductors, Tesla, BmI);
206 fprintf('s\t %5.2f\n', Estimated efficiency of transformer, W, eff*100);
207 fprintf('s\t %5.2f\n', Maximum duty cycle, Dmax, Dmax);
208 fprintf('s\t %5.2f\n', Minimum duty cycle calculated, Dmin, Dmin);
209 fprintf('s\t %5.2f\n', Window factor for transformer, Kw, Kw);
210 fprintf('s\t %5.2f\n', Window factor for inductor, KwI, KwI);
211 fprintf('s\t %5.2f\n', Secondary side blocking diode drops, Vd);
212
213 fprintf('s\n', 'FORWARD TRANSFORMER');
214 fprintf('s\t %5.2f\n', Primary VA, 'Po/eff');
215 fprintf('s\t %5.2f\n', Secondary VA, 'Po');
216 fprintf('s\t %s\n', 'Core', core);
217 fprintf('s\t %5d\n', Number of windings in primary, Np, Np);
218 fprintf('s\t %s\n', 'Gauge of Np, SWG');
219 fprintf('s\t %5d\n', Number of windings in demagnetising wdg, Nd, Nd);
220 fprintf('s\t %s\n', 'Gauge of Nd, SWG');
221 for i=1:length(Ns)
222     fprintf('s\t %5d\n', Number of windings in secondary, Ns, num2str(i), Ns(i));
223     fprintf('s\t %s\t %5d\n', 'Gauge of Ns, num2str(i), SWG(i, :));
224 end
225
226
227 fprintf('s\n', 'POWER SWITCH RATINGS');
228 fprintf('s\t %5.2f\n', Maximum continuous current, Icm, amps, Icm);
229 fprintf('s\t %5.2f\n', Maximum off state voltage drop, Vceo);
230
231 fprintf('s\n', 'DIODE RATINGS');
232 fprintf('s\t %s\n', 'Demagnetising diode ratings');
233 fprintf('s\t %5.2f\n', Peak current, amps, Idpm);
234 fprintf('s\t %5.2f\n', Average current, amps, Idavg);
235 fprintf('s\t %5.2f\n', PIV, volts, Vdpm);
236 for i = 1:length(Vo)
237     fprintf('s\t %s\n', 'Blocking diode ratings for winding, num2str(i));
238     fprintf('s\t %5.2f\n', [winding, num2str(i)], Peak current, amps, Idpm);
239     fprintf('s\t %5.2f\n', [winding, num2str(i)], Average current, amps, Idavg);
240     fprintf('s\t %5.2f\n', [winding, num2str(i)], PIV, volts, Vdpm(i));
end
forward_design %
```

Then comes the display section where you display all the area details. So, let me just run this for you for this specification.

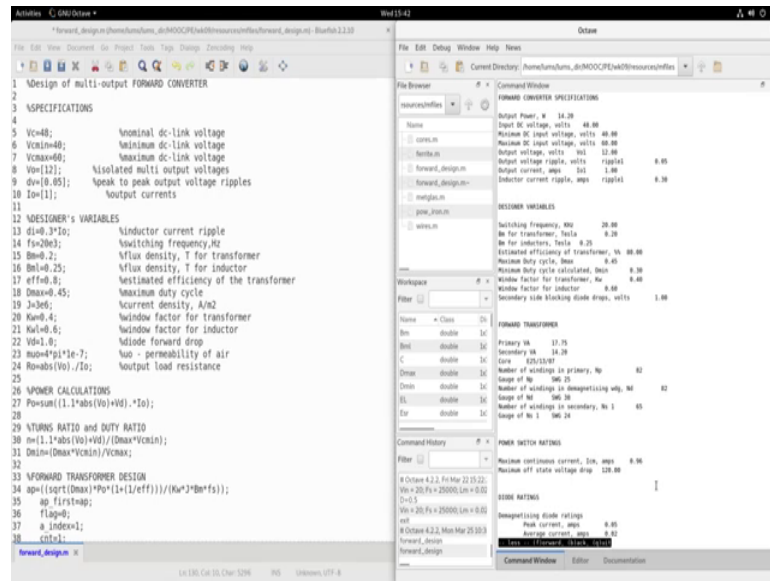
(Refer Slide Time: 07:23)



```
1 %Design of multi-output FORWARD CONVERTER
2
3 %SPECIFICATIONS
4
5 Vc=48; %Nominal dc-link voltage
6 Vcmin=48; %Minimum dc-link voltage
7 Vcmax=60; %Maximum dc-link voltage
8 Vo=[12]; %Isolated multi output voltages
9 d=[0.05]; %peak to peak output voltage ripples
10 Io=[1]; %Output currents
11
12 %DESIGNER'S VARIABLES
13 di=0.3; %Inductor current ripple
14 fs=20e3; %Switching frequency, Hz
15 Bm=0.2; %Flux density, T for transformer
16 BmI=0.25; %Flux density, T for inductor
17 eff=0.8; %Estimated efficiency of the transformer
18 Dmax=0.45; %Maximum duty cycle
19 Ju=3e6; %Current density, A/m2
20 Kw=0.4; %Window factor for transformer
21 KwI=0.6; %Window factor for inductor
22 Vd=1.0; %Diode forward drop
23 muo=4*pi*1e-7; %muo - permeability of air
24 Rm=abs(Vo)/Io; %Output load resistance
25
26 %POWER CALCULATIONS
27 Pout=sum(1.1*abs(Vo)+Vd).*Io);
28
29 %TURNS RATIO AND DUTY RATIO
30 n=[1.1*abs(Vo)+Vd]/(Dmax*Vcmin);
31 Dmin=(Dmax*Vcmin)/Vcmax;
32
33 %FORWARD TRANSFORMER DESIGN
34 ap=(sqrt(Dmax)*Po)/(1+(1/eff)))/(Dk*3*Bm*fs));
35 ap, firstNap;
36 flag=0;
37 a, index=1;
38 ... (c);
forward_design %
```

So, I will go into octave I am already in that folder you see that you see forward design and the other m files

(Refer Slide Time: 08:15)



So, let me type in forward convert FORWARD DESIGN and then you execute that it will ask you to choose a core material, I will choose Ferrite which is 1. I will choose ferrite and then within ferrite it will ask you to choose POT CORES, EE CORES this is the data which I have entered. A minimal set of data you can always increase if you can add your own set of new cores and cores shapes.

Let me choose EE CORE now, second and then see that it may then it is asking for the INDUCTORS and I will again choose this one again EE CORE. And that is it the design is done and it will get printed you see the specifications and the DESIGN VARIABLES, FORWARD TRANSFORMER see, choice of E25 13 0 7, the primary windings, the Gauges, Demagnetizing Winding Gauge so on, the POWER RATING of the switch.

(Refer Slide Time: 08:35)

```
1 %Design of multi-output FORWARD CONVERTER
2
3 %SPECIFICATIONS
4
5 Vc=48; %nominal dc-link voltage
6 Vcmin=48; %minimum dc-link voltage
7 Vcmax=48; %maximum dc-link voltage
8 Vm=[12]; %isolated multi output voltages
9 dm=[0.05]; %peak to peak output voltage ripples
10 Io=[1]; %output currents
11
12 %DESIGNER'S VARIABLES
13 di=0.3*Io; %inductor current ripple
14 fs=20e3; %switching frequency,Hz
15 Bm=0.2; %flux density, T for transformer
16 Bm1=0.25; %flux density, T for inductor
17 eff=0.8; %estimated efficiency of the transformer
18 Dmax=0.45; %maximum duty cycle
19 J=30e3; %current density, A/m2
20 Kw=0.4; %window factor for transformer
21 Kw1=0.6; %window factor for inductor
22 Vd=1.0; %diode forward drop
23 mu0=4*pi*1e-7; %mu0 - permeability of air
24 Rload=(Vm)/Io; %output load resistance
25
26 %POWER CALCULATIONS
27 Pout=sum(1.1*abs(Vm)+Vd).*Io);
28
29 %TURNS RATIO AND DUTY RATIO
30 n=(1.1*abs(Vm)+Vd)/(Dmax*Vcmin);
31 Dmin=(Dmax*Vcmin)/Vcmax;
32
33 %FORWARD TRANSFORMER DESIGN
34 ap=(sqrt(Dmax)*Po*(1+(1/eff)))/(Kw*J*Bm*fs));
35 ap=firstnap;
36 [l1]p=;
37 a_index=1;
38 cnt=1;
```

The Command Window displays the following results:

Secondary No	Secondary VA	Core
1	12.00	E25/13/47
2	24.00	
3	36.00	
4	48.00	

POWER SWITCH RATINGS

Parameter	Value
Maximum continuous current, I _{cs} , rms	0.36
Maximum off state voltage drop	128.88

DIODE RATINGS

Parameter	Value
Demagnetizing diode ratings	
Peak current, amps	0.85
Average current, amps	0.82
PS, volts	128.88
Blocking diode ratings for winding 1	
winding1 Peak current, amps	1.13
winding1 Average current, amps	0.52
winding1 PS, volts	47.33
Freewheeling diode ratings for winding 1	
winding1 Peak current, amps	1.13
winding1 Average current, amps	0.88
winding1 PS, volts	47.33

INDUCTOR DESIGN

Parameter	Value
winding1 Inductance value, mH	1.48888
winding1 Core	E25/13/47
winding1 Number of windings	117
winding1 Gauge of Inductance	366.22
winding1 Airgap for Inductance,mm	0.47588

CAPACITOR FILTER RATINGS

Parameter	Value
winding1 Capacitance value, uF	375.86888
winding1 Voltage rating, volts	24.88
winding1 ESR requirement, ohm	0.13333

error: FileSize: Invalid stream number = 1
error: called from
= forward_design at line 283 column 1

And the DIODE RATINGS, Demagnetizing, Blocking, Freewheeling, INDUCTOR DESIGN all these things are calculated and you see the output. I will allow you to explore this and leave it to you fine tune it and try to understand this forward design m file.