clc

clear all

syms R1 R2 R D IL VC rC rL VD vIN

eq1=-D\*R1\*IL-(1-D)\*R2\*IL-R/(R+rC)\*VC-(1-D)\*VD+D\*vIN;

eq2=R/(R+rC)\*IL-1/(R+rC)\*VC;

DC\_operatingPoint=solve(eq1,eq2,[IL VC]);

disp('IL=')

pretty(simplify(DC\_operatingPoint.IL))

disp('VC=')

pretty(simplify(DC\_operatingPoint.VC))

%This program calculates the small signal transfer

%functions for Buck converter

R=5;

VIN=50;

rin=.1;

L=400e-6;

rL=.1;

C=100e-6;

rC=.05;

rD=.01;

VD=.7;

rds=.1;

D=.41;

R1=rin+rds+rL+R\*rC/(R+rC);

R2=rD+rL+R\*rC/(R+rC);

IL=(R+rC)\*(D\*VIN-(1-D)\*VD)/((R+rC)\*R2+R^2+D\*(R+rC)\*(R1-R2));

A=[(R2\*(D-1)-R1\*D)/L -R/(R+rC)/L;R/(R+rC)/C -1/(R+rC)/C];

B=[(VIN+VD+(R2-R1)\*IL)/L D/L;0 0];

CC=[R\*rC/(rC+R) R/(R+rC)]; %C shows the capacitance so CC is used for matrix

H=tf(ss(A,B,CC,0));

vO\_d=H(1)% transfer function between output voltage and duty ratio

vO\_vin=H(2) %transfer function between output voltage and input source

figure(1)

bode(vO\_d), grid on

figure(2)

bode(vO\_vin), grid on

% This program extracts the small signal transfer function

clc

clear all;

% Elements values

R=5; %Load resistor

VIN=50; %Input source voltage

rin=.1; %Input source internal resistance

L=400e-6;%inductor

rL=.1; %inductor series resistance

C=100e-6;%capacitor

rC=.05; %capacitor series resistance

rD=.01; %Diode series resistance

VD=.7; %Diode forward voltage drop

rds=.1; %MOSFET on resistance

D=.41; %Duty ratio

% Symbolic variables

%iL: inductor current

%vC: capacitor voltage

%vin: input voltage source

%vD: diode forward voltage drop

%d: duty cycle

syms iL vC vin vD d

%CLOSED MOSFET EQUATIONS

M1=(-(rin+rds+rL+(R\*rC/(R+rC)))\*iL-R/(R+rC)\*vC+vin)/L;%d(iL)/dt for closed MOSFET

M2=(R/(R+rC)\*iL-1/(R+rC)\*vC)/C; %d(vC)/dt for closed MOSFET

vO1=R\*(rC/(rC+R)\*iL+1/(R+rC)\*vC);

%OPENED MOSFET EQUATIONS

M3=(-(rD+rL+R\*rC/(R+rC))\*iL-R/(R+rC)\*vC-vD)/L; %d(iL)/dt for opened MOSFET

M4=(R/(R+rC)\*iL-1/(R+rC)\*vC)/C; %%d(vC)/dt for opened MOSFET

vO2=R\*(rC/(rC+R)\*iL+1/(R+rC)\*vC);

%AVERAGING

MA1= simplify(d\*M1+(1-d)\*M3);

MA2= simplify(d\*M2+(1-d)\*M4);

vO= simplify(d\*vO1+(1-d)\*vO2);

% DC OPERATING POINT CALCULATION

MA\_DC\_1=subs(MA1,[vin vD d],[VIN VD D]);

MA\_DC\_2=subs(MA2,[vin vD d],[VIN VD D]);

DC\_SOL= solve(MA\_DC\_1==0,MA\_DC\_2==0,iL,vC);

IL=eval(DC\_SOL.iL); %IL is the inductor current steady state value

VC=eval(DC\_SOL.vC); %VC is the capacitor current steady state value

%LINEARIZATION

% .

% x=Ax+Bu

%vector x=[iL;vC] is assumed. vector x is states.

%u=[vin;d] where vin=input voltage source and d=duty. vector u is system inputs.

%

A11=subs(simplify(diff(MA1,iL)),[iL vC d vD],[IL VC D VD]);

A12=subs(simplify(diff(MA1,vC)),[iL vC d vD],[IL VC D VD]);

A21=subs(simplify(diff(MA2,iL)),[iL vC d vD],[IL VC D VD]);

A22=subs(simplify(diff(MA2,vC)),[iL vC d vD],[IL VC D VD]);

A=eval([A11 A12;

A21 A22]); %variable A is matrix A in state space equation

B11=subs(simplify(diff(MA1,vin)),[iL vC d vD vin],[IL VC D VD VIN]);

B12=subs(simplify(diff(MA1,d)),[iL vC d vD vin],[IL VC D VD VIN]);

B21=subs(simplify(diff(MA2,vin)),[iL vC d vD vin],[IL VC D VD VIN]);

B22=subs(simplify(diff(MA2,d)),[iL vC d vD vin],[IL VC D VD VIN]);

B=eval([B11 B12;

B21 B22]); % variable B is matrix B in state space equation

CC1=subs(simplify(diff(vO,iL)),[iL vC d vD],[IL VC D VD]);

CC2=subs(simplify(diff(vO,vC)),[iL vC d vD],[IL VC D VD]);

CC=eval([CC1 CC2]); %variable CC is matrix C in state space equation

% variable D shows duty so DD is used.

DD11=subs(simplify(diff(vO,vin)),[iL vC d vD vin],[IL VC D VD VIN]);

DD12=subs(simplify(diff(vO,d)),[iL vC d vD vin],[IL VC D VD VIN]);

DD=eval([DD11 DD12]); % variable DD is matrix D in state space equation

% variable D shows duty so DD is used.

H=tf(ss(A,B,CC,DD));

%transfer function between input source and load resistor voltage

% ~

vR\_vin=H(1,1) % vR(s)

% ----

% ~

% vin(s)

%transfer function between duty ratio and load resistor voltage

%~

vR\_d=H(1,2) %vR(s)

%----

%~

%d(s)