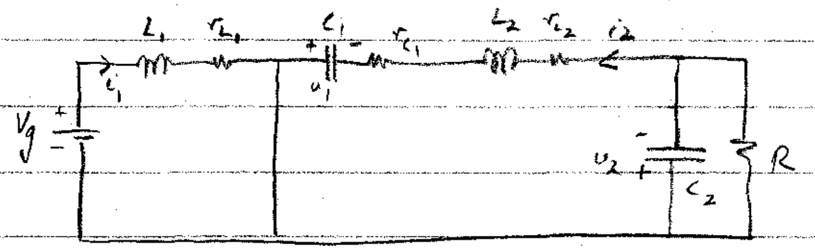
CUK CONVERTER WITH PARASITIC DAMPING



$$-V_g + L_1\frac{di_1}{dt} + r_{L_1} i_1 = 0 \Rightarrow \frac{di_1}{dt} = \frac{-r_{L_1} i_1}{L_1} + \frac{V_g}{L_1}$$

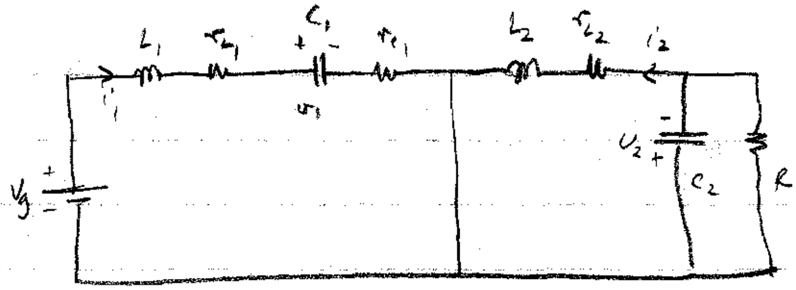
$$+v_2 + (r_{C_1} + r_{L_2}) i_2 + L_2\frac{di_2}{dt} - v_1 = 0 \Rightarrow \frac{di_2}{dt} = -\frac{(r_{C_1} + r_{L_2}) i_2}{L_2} + \frac{v_1}{L_2} - \frac{v_2}{L_2}$$

$$C_1\frac{dv_1}{dt} = -i_2 \Rightarrow \frac{dv_1}{dt} = \frac{-i_2}{C_1}$$

$$i_2 = C_2\frac{dv_2}{dt} + \frac{v_2}{R} \Rightarrow \frac{dv_2}{dt} = \frac{i_2}{C_2} - \frac{v_2}{RC_2}$$

$$\frac{d}{dt}\begin{bmatrix} i_1 \\ i_2 \\ v_1 \\ v_2 \end{bmatrix} = \underbrace{\begin{bmatrix} -\frac{r_{L_1}}{L_1} & 0 & 0 & 0 \\ 0 & -\left(\frac{r_{C_1}+r_{L_2}}{L_2}\right) & \frac{1}{L_2} & -\frac{1}{L_2} \\ 0 & -\frac{1}{C_1} & 0 & 0 \\ 0 & \frac{1}{C_2} & 0 & -\frac{1}{RC_2} \end{bmatrix}}_{A_1} \begin{bmatrix} i_1 \\ i_2 \\ v_1 \\ v_2 \end{bmatrix} + \underbrace{\begin{bmatrix} \frac{1}{L_1} \\ 0 \\ 0 \\ 0 \end{bmatrix}}_{B_1} V_g$$

$\underline{D'T_s}$



$$-V_g + L_1\frac{di_1}{dt} + \left(r_{L_1}+r_{C_1}\right)i_1 + v_1 = 0 \Rightarrow \frac{di_1}{dt} = \frac{-\left(r_{L_1}+r_{C_1}\right)i_1}{L_1} - \frac{v_1}{L_1} + \frac{V_g}{L_1}$$

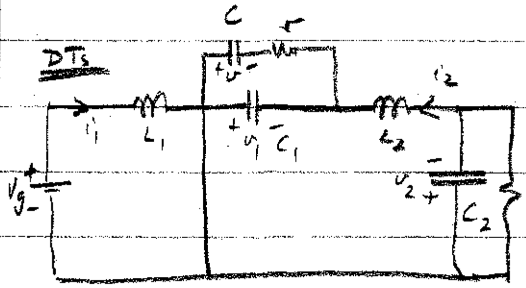
$$v_2 + r_{L_2} i_2 + L_2\frac{di_2}{dt} = 0 \Rightarrow \frac{di_2}{dt} = -\frac{r_{L_2} i_2}{L_2} - \frac{v_2}{L_2}$$

$$C_1\frac{dv_1}{dt} = i_1 \Rightarrow \frac{dv_1}{dt} = \frac{i_1}{C_1}$$

$$i_2 = C_2\frac{dv_2}{dt} + \frac{v_2}{R} \Rightarrow \frac{dv_2}{dt} = \frac{i_2}{C_2} - \frac{v_2}{RC_2}$$

$$\frac{d}{dt}\begin{bmatrix} i_1 \\ i_2 \\ v_1 \\ v_2 \end{bmatrix} = \underbrace{\begin{bmatrix} \frac{-\left(r_{L_1}+r_{C_1}\right)}{L_1} & 0 & -\frac{1}{L_1} & 0 \\ 0 & -\frac{r_{L_2}}{L_2} & 0 & -\frac{1}{L_2} \\ \frac{1}{C_1} & 0 & 0 & 0 \\ 0 & \frac{1}{C_2} & 0 & -\frac{1}{RC_2} \end{bmatrix}}_{A_2} \begin{bmatrix} i_1 \\ i_2 \\ v_1 \\ v_2 \end{bmatrix} + \underbrace{\begin{bmatrix} \frac{1}{L_1} \\ 0 \\ 0 \\ 0 \end{bmatrix}}_{B_2} V_g$$

CUK CONVERTER WITH LOSSLESS DAMPING



$$-V_g + L_1 \frac{di_1}{dt} = 0 \Rightarrow \frac{di_1}{dt} = \frac{V_g}{L_1}$$

$$v_2 + L_2 \frac{di_2}{dt} - v_1 = 0 \Rightarrow \frac{di_2}{dt} = \frac{v_1}{L_2} - \frac{v_2}{L_2}$$

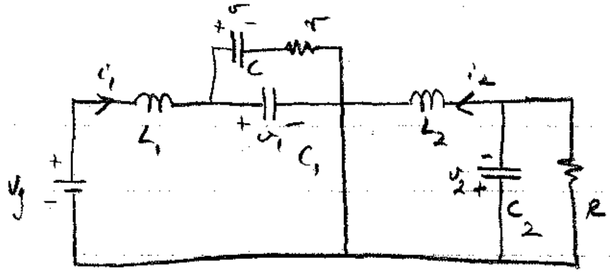
$$i_2 = C_2 \frac{dv_2}{dt} + \frac{v_2}{R} \Rightarrow \frac{dv_2}{dt} = \frac{i_2}{C_2} - \frac{v_2}{RC_2}$$

$$C \frac{dv}{dt} = \frac{v_1}{r} - \frac{v}{r} \Rightarrow \frac{dv}{dt} = \frac{v_1}{rC} - \frac{v}{rC}$$

$$C_1 \frac{dv_1}{dt} = -i_2 - \frac{v_1}{r} + \frac{v}{r} \Rightarrow \frac{dv_1}{dt} = \frac{-i_2}{C_1} - \frac{v_1}{rC_1} + \frac{v}{rC_1}$$

$$\frac{d}{dt}\begin{bmatrix} i_1 \\ i_2 \\ v_1 \\ v_2 \\ v \end{bmatrix} = \underbrace{\begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{L_2} & -\frac{1}{L_2} & 0 \\ 0 & -\frac{1}{C_1} & -\frac{1}{rC_1} & 0 & \frac{1}{rC_1} \\ 0 & \frac{1}{C_2} & 0 & -\frac{1}{RC_2} & 0 \\ 0 & 0 & \frac{1}{rC} & 0 & -\frac{1}{rC} \end{bmatrix}}_{A_1} \begin{bmatrix} i_1 \\ i_2 \\ v_1 \\ v_2 \\ v \end{bmatrix} + \underbrace{\begin{bmatrix} \frac{1}{L_1} \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}}_{B_1} V_g$$

$\underline{\underline{D'T_s}}$



$$-V_g + L_1 \frac{di_1}{dt} + v_1 = 0 \quad \Rightarrow \quad \frac{di_1}{dt} = -\frac{v_1}{L_1} + \frac{v_g}{L_1}$$

$$v_2 + L_2 \frac{di_2}{dt} = 0 \quad \Rightarrow \quad \frac{dv_2}{dt} = -\frac{v_2}{L_2}$$

$$v_2 = C_2 \frac{dv_2}{dt} + \frac{v_2}{R} \quad \Rightarrow \quad \frac{dv_2}{dt} = \frac{v_2}{C_2} - \frac{v_2}{RC_2}$$

$$C_1 \frac{dv_1}{dt} = i_1 + \frac{v}{r} - \frac{v_1}{r} \quad \Rightarrow \quad \frac{dv_1}{dt} = \frac{i_1}{C_1} + \frac{v}{rC_1} - \frac{v_1}{rC_1}$$

$$C \frac{dv}{dt} = \frac{v_1}{r} - \frac{v}{r} \quad \Rightarrow \quad \frac{dv}{dt} = \frac{v_1}{rC} - \frac{v}{rC}$$

$$\frac{d}{dt}\begin{bmatrix} i_1 \\ i_2 \\ v_1 \\ v_2 \\ v \end{bmatrix} = \underbrace{\begin{bmatrix} 0 & 0 & -\frac{1}{L_1} & 0 & 0 \\ 0 & 0 & 0 & -\frac{1}{L_2} & 0 \\ \frac{1}{C_1} & 0 & -\frac{1}{rC_1} & 0 & \frac{1}{rC_1} \\ 0 & \frac{1}{C_2} & 0 & -\frac{1}{RC_2} & 0 \\ 0 & 0 & \frac{1}{rC} & 0 & -\frac{1}{rC} \end{bmatrix}}_{A_2} \begin{bmatrix} i_1 \\ i_2 \\ v_1 \\ v_2 \\ v \end{bmatrix} + \underbrace{\begin{bmatrix} \frac{1}{L_1} \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}}_{B_2} V_g$$

```
% This m file demonstrates how to use the "margin" command
% to obtain loop gain plots. A Cuk converter (with lossless damping)
% is used below.

close all;      % close all figures
clear all;      % clear all variables in the workspace

%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% parameters
Vg = 12;        % input voltage
R = 12;         % load resistance
L1 = 100e-6;    % input inductor
L2 = 800e-6;    % output inductor
C1 = 100e-6;    % input capacitor
C2 = 800e-6;    % output capacitor

C = 500e-3;    % damping capacitor
r = 1;          % damping resistance
D = 0.6;        % duty ratio

%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% State matrices
% These are the correct matrices for a Cuk converter with
%   lossless damping across the center capacitor

A1 = [0     0       0          0           0;
      0     0      1/L2      -1/L2         0;
      0  -1/C1  -1/(r*C1)      0         1/(r*C1);
      0   1/C2      0       -1/(R*C2)      0;
      0     0     1/(r*C)      0        -1/(r*C)];

A2 = [0     0      -1/L1       0           0;
      0     0        0       -1/L2         0;
    1/C1    0   -1/(r*C1)      0       1/(r*C1);
      0   1/C2      0       -1/(R*C2)      0;
      0     0    1/(r*C)       0       -1/(r*C);];

B1 = [1/L1 ; 0 ; 0 ; 0 ; 0];
B2 = [1/L1 ; 0 ; 0 ; 0 ; 0];
C_1 = [0 0 0 1 0];
C_2 = [0 0 0 1 0];
E1 = 0;
E2 = 0;


%  SSA Model
A = D*A1 + (1-D)*A2;
B = D*B1 + (1-D)*B2;
C = D*C_1 + (1-D)*C_2;
X = -A\B*Vg;
Bd = (A1-A2)*X + (B1-B2)*Vg;
Ed = (C_1-C_2)*X + (E1-E2)*Vg;
sys_ss = ss(A, Bd, C, Ed);  % construct a state space (ss) model

Gc = tf(0.05*[1/2 1], [1/20  1]);  % an arbitrary compensator
sys_loop = sys_ss * Gc;  % Note: ss model can be multiplied by a tf

% use this, if you want control of the frequencies w:
figure(1)
w = logspace(1, 5, 1000);
[mag, ph] = bode(sys_loop, w);
margin(mag, ph, w);

%  or just this otherwise:
figure(2)
margin(sys_loop);
```