Power Electronics Lab (EE39006)
Autumn Semester 2021-22
Department of Electrical Engineering, IIT Kharagpur

Experiment-1
Title: STUDY OF BASIC TRANSISTOR CONVERTERS

General Instructions:

- Complete simulation model of part-A, B and C within the first 1.5 hours. Please send the simulation model with **File name: Expt1_Roll No_FirstName** in **MATLAB 2017a version** (those who are using higher version) and submit to MS Teams assignment section within 3:30 PM.
- Complete taking the readings and observation tables from the reference simulation models sent by the TAs within the next 1.5 hours and save in **pdf format** with **File name: Expt1_Roll No_FirstName** and submit to the MS Teams assignment section within 5:30 PM.
- Submit the discussion answers with a complete lab report with readings and waveforms in the MS Teams assignment section within 7 days.

Monday Batch

Part-A: Simulate the **buck converter** in MATLAB/Simulink using following parameters: Input Voltage (Vin) = 110V, Capacitance C = 4μF, Load resistance RL = 11.52Ω, Switching Frequency=50 kHz. Choose MOSFET and diode resistance as 1μΩ, and diode voltage drop as 0 V (to simulate close to an ideal converter).

I. Select the value of L such that the converter operates in CCM for the given condition. Change duty ratio in steps of 0.1 starting from 0.1 to 0.9, and tabulate calculated and measured value of the output voltage. Also, plot a graph of voltage gain (Vout/Vin) Vs duty ratio (in x-axis) for CCM operation. Note: change L value if required, but make sure that the converter operates in CCM always for the entire duty ratio(limiting inductor value for CCM and DCM at 0.1 duty ratio).

II. Now select L such that the converter operates in DCM. For the duty ratio 0.5 compare the output voltage obtained in the CCM and DCM case.

III. For a given duty ratio (say 0.5) observe and save simulated waveforms for the following variables for both CCM and DCM case: current and voltage waveforms of MOSFET, inductor, diode, and output capacitor.

Part-B: Simulate the **buck-boost converter** in MATLAB/Simulink using following parameters: Input Voltage (Vin)=57V, Inductor L = 226μH, Capacitance C = 54μF, Load resistance RL = 11.52Ω, Switching Frequency = 50 kHz, Duty Cycle =0.457. Choose MOSFET and diode resistance as 1μΩ, and diode voltage drop as 0.

Select parasitic resistance of inductor RL = 0 Ω in case (i) and RL = 5% of RL in case (ii).

Vary Duty ratio from 0.1 to 0.9 in steps of 0.1

I. Plot the voltage gain Vs duty ratio in case(i) and case(ii), and comment on the same.

II. Keeping all other parameters the same, vary the switching frequency and check at what frequency the system will be on the verge of CCM and DCM conditions for case(i) and case(ii) for D=0.457?

III. For case (i) tabulate the steady-state input and output currents for various duty ratios.

Part-C: For following operating condition (i.e. Input Voltage (Vin) = 110V, Load voltage = 48V, Inductance = 115 μH Capacitance C = 50μF, Load resistance RL = 11.52Ω, Switching Frequency=50 kHz, CCM and steady-state operation) compare the following between **buck** and **buck-boost converter**: voltage and current stress of switch and diode, inductor current ripple, output voltage ripple (save waveforms).

Discussion questions:

1. For a given duty ratio and load, voltage gain is higher in DCM or CCM? Why?
2.If all other parameters of a buck converter are kept the same, and only the switching frequency is varied, what will be its impact on converter performance?
3.If all other parameters of a buck converter are kept the same, and only the load resistance is varied, what will be its impact on converter performance?

Tuesday Batch

Part-A: Simulate the **boost converter** in MATLAB/Simulink using following parameters: Input Voltage (Vin) =24V, Inductor L = 115μH, Capacitance C = 54μF, Load resistance RL = 11.52Ω, Switching Frequency = 50 kHz, Duty Cycle = 0.5. Choose MOSFET and diode resistance as 1μΩ, and diode voltage drop as 0.

Select parasitic resistance of inductor rl = 0 in case (i) and rl = 5% of RL in case (ii).

Vary duty in range 0.1 to 0.9 in steps of 0.1

I. Plot the voltage gain Vs duty ratio in case(i) and case(ii), and comment on the same.

II. Observe the capacitor voltage and current waveforms in case (i) and calculate the rms capacitor current.D=0.5

III. For case(ii), find the inductance for which the converter falls into critical conduction mode for the specifications given above. Plot the inductor current at critical condition mode.D=0.5

IV. For case (i) with D=0.5 and initial output voltage as 0 V, observe how the inductor current, and output voltage builds up from starting to steady state. Submit a plot of inductor voltage, and a plot for capacitor current clearly identifying the transient and 'periodical' steady state zone along with your observation.

V. For case i) Vary the load between 0.2 PU to 1 PU in steps of 0.1 for the rated input and output voltage, and Plot the load vs efficiency (y-axis) characteristics.

Part-B: Simulate the **buck-boost converter** in MATLAB/Simulink using following parameters: Input Voltage (Vin)=57V, Inductor L = 226μH, Capacitance C = 54μF, Load resistance RL = 11.52Ω, Switching Frequency = 50 kHz, Duty Cycle =0.457. Choose MOSFET and diode resistance as 1μΩ, and diode voltage drop as 0.

Select parasitic resistance of inductor RL = 0 Ω in case (i) and RL = 5% of RL in case (ii).

Vary Duty ratio from 0.1 to 0.9 in steps of 0.1

I. Plot the voltage gain Vs duty ratio in case(i) and case(ii), and comment on the same.

II. Keeping all other parameters the same, vary the switching frequency and check at what frequency the system will be on the verge of CCM and DCM conditions for case(i) and case(ii) for D=0.457?

III. For case (i) tabulate the steady-state input and output currents for various duty ratios.

Part-C: For following operating condition (i.e. Input Voltage (Vin) = 57V, Duty Cycle =0.457, Inductance = 115 μH Capacitance C = 50μF, Load resistance RL = 11.52Ω, Switching Frequency=50 kHz, CCM and steady-state operation) compare the following between **boost** and **buck-boost converter**: voltage and current stress of switch and diode, inductor current ripple, output voltage ripple (save waveforms).

Discussion questions:

1. Comment on the comparison of overall (both core and copper loss) loss of the inductor when the inductance is changed from specified value in CCM to critical inductance value. Assume inductor resistance has not changed.

2.Assuming ideal boost converter, compare the theoretical and simulated value of Vout for duty ratio=1, and write down your observations.

3. For a given duty ratio and load, voltage gain is higher in DCM or CCM? Why? (Consider ideal Boost Converter)

Wednesday Batch

Part-A: Simulate the **buck converter** in MATLAB/Simulink using following parameters: Input Voltage (Vin) = 110V, Capacitance C = 4μF, Load resistance RL = 11.52Ω, Switching Frequency=50 kHz. Choose MOSFET and diode resistance as 1μΩ, and diode voltage drop as 0 V (to simulate close to an ideal converter).

I. Select the value of L such that the converter operates in CCM for the given condition. Change duty ratio in steps of 0.1 starting from 0.1 to 0.9, and tabulate calculated and measured value of the output voltage. Also, plot a graph of voltage gain (Vout/Vin) Vs duty ratio (in x-axis) for CCM operation. Note: change L value if required, but make sure that the converter operates in CCM always for the entire duty ratio(limiting inductor value for CCM and DCM at 0.1 duty ratio).

II. Now select L such that the converter operates in DCM. For the duty ratio 0.5 compare the output voltage obtained in the CCM and DCM case.

III. For a given duty ratio (say 0.5) observe and save simulated waveforms for the following variables for both CCM and DCM case: current and voltage waveforms of MOSFET, inductor, diode, and output capacitor.

Part-B: Simulate the **boost converter** in MATLAB/Simulink using following parameters: Input Voltage (Vin) =24V, Inductor L = 115μH, Capacitance C = 54μF, Load resistance RL = 11.52Ω, Switching Frequency = 50 kHz, Duty Cycle = 0.5. Choose MOSFET and diode resistance as 1μΩ, and diode voltage drop as 0.

Select parasitic resistance of inductor rl = 0 in case (i) and rl = 5% of RL in case (ii).

I. Plot the voltage gain Vs duty ratio in case(i) and case(ii), and comment on the same.

II. Observe the capacitor voltage and current waveforms in case (i) and calculate the rms capacitor current.

III. For case(ii), find the inductance for which the converter falls into critical conduction mode for the specifications given above. Plot the inductor current at critical condition mode.

Part-C: For same operating condition (i.e. Duty cycle = 0.436, Load voltage = 48V, Inductance = 230 μH Capacitance C = 4μF, Load resistance RL = 11.52Ω, Switching Frequency=50 kHz, CCM and steady-state operation) compare the following between **buck** and **boost converter**: voltage and current stress of switch and diode, inductor current ripple, output voltage ripple(save waveforms).

Discussion questions:

1. What is the effect of load variation on the inductor current ripple amplitude?
2. Write down 5 key aspects which are unique to buck-boost converter in comparison to both buck and boost converters.
3. Comment on the difference in efficiency results for boost converter obtained for two switching frequencies.