Experiment-7-8-9
DC-DC converter

Power Electronics Lab

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This manual needs to be completed before the mid-term examination. For each converter we have three setups, so plan accordingly.
Experiment No. 7

Buck Converter in Open and Closed Loop Configuration

Pre-Lab Reading

1. Chapter 5 of “Power Electronics: Circuits, Devices and Applications”, by M. H. Rashid (3e).

Objectives

On successful completion of this manual you should be able to:

1. Understand DC-DC Buck, Boost and Fly-Back converters.
2. Describe the operation of open loop and closed loop converters.
3. Understanding TL494 operation for pulse width modulation.
4. Understanding the basic concept of switch mode power supplies

Features of VSMPS-06A

1. High switching frequency.
2. Various test points to view the corresponding signals at each stage of operation.
3. Control circuit and power circuit are built in a single unit.
4. Open loop and closed loop operation of power converters can be examined.

Introduction

Power Electronics systems are employed in various fields that include rocket propulsion systems, motor control, electric vehicles, air-conditioners, high voltage direct current (HVDC) transmission systems. A power electronic system consists of one or more power electronic converters. A power electronic converter is made up of some power semiconductor devices controlled by integrated circuits. The switching characteristics of power semiconductor devices permit a power electronic converter to shape the input power of one form to output power of some other form.

Types of Power Electronics system

Diode Rectifiers: A diode rectifier circuit converts ac input voltage into a fixed DC voltage.
AC to DC converters: These convert constant AC voltage to variable DC output voltage.
DC to DC converters: A DC chopper converts fixed DC input voltage to a controllable DC output voltage.
DC to AC converters: An inverter converts fixed DC voltage to a variable AC voltage.
AC to AC converters: These convert fixed AC input voltage into variable AC output voltage.
DC-DC Converter

DC - DC converter is a device that accepts a DC input voltage and produces a DC output voltage. Typically the output produced is at a different voltage level than the input. In addition, DC-to-DC converters are used to provide noise isolation, power bus regulation, etc. The different topologies of DC-DC converter are represented below in Figure 1.

![Figure 1: Topologies of DC-DC converters]

**Non-isolated converters**: The input and output voltages share a common ground.

**Isolated converters**: The input and output voltages are isolated (i.e., different ground points)

### Non-Isolated Converters

The three basic switching power supply topologies in common use are:

1. Buck Converter
2. Boost Converter
3. Buck-Boost Converter

These topologies are non-isolated, i.e., the input and output voltages share a common ground. Each topology has unique properties, including the steady-state voltage conversion ratios, the nature of the input and output currents, and the character of the output voltage ripple. Another important property is the frequency response of the duty-cycle to output voltage transfer function.
Isolated DC-DC Converters

In many DC-DC applications, multiple isolated outputs are required. Input to output isolation may be required to meet safety standards and / or provide impedance matching. To meet the need for constant, regulated power supply modern electronic equipments and energy storage devices require transformer-coupled power conditioning equipment; these are called as isolated DC-DC converters. The conversion is efficient and power supply is small because it contains a high frequency switching power stage built with one or more semiconductor switches and operated cyclically at cut-off and saturation, which applies high voltage pulses to a transformer. The power stage commonly takes one of several forms namely:

1. Push-Pull Converter
2. Flyback Converter
3. Forward Converter

Pulse width modulation is applied to power electronics switches, with variation of either duty cycle or the frequency. The power stage configuration depends on the application and the resultant specifications like output voltage, power required, input line range, efficiency, weight and size.

Pulse Width Modulation

It is one way to control average power to the load by controlling the average voltage applied to it. The average voltage seen by the load resistor R is given as

$$ V_{avg} = \frac{I_{ON}}{T} x V_{in} $$  \hspace{1cm} (0.1)

Reducing on time of the switch reduces average output voltage. $V_{avg}$ is converter output voltage, $V_{in}$ is converter input voltage, $t_{on}$ is switch on-time, and T is the device switching time in seconds. The isolated converters are similar in with the non-isolated converters except for the isolation transformer.

Buck Converter

Buck converter is one of the basic, non-isolated DC-DC converter topology. This converter circuit provides an output voltage lesser than the input voltage with same polarity. It consists of a DC input source $V_s$, boost inductor L, controlled MOSFET switch S, filter capacitor C and load resistor, R.

Circuit Diagram

Circuit diagram of buck converter is shown in Figure 2.
Working Principle

**Mode 1:** From \( t = 0 \) to \( t_{on} \) (Switch Q is ON, D is OFF)
During mode 1, transistor S is turned on at \( t=0 \). The input current, which rises, flows through filter inductor L, filter capacitor C, and load resistor R.

**Mode 2:** For \( t = t_{on} \) to \( T \) (Switch Q is OFF, D is ON)
During mode 2, transistor S is off at \( t = t_{1} \). The freewheeling diode D conducts due to energy stored in the inductor, and the inductor current continues to flow through L, C, load and D. The inductor current falls until transistor S is switched on again in the next cycle. The relationship between input and output for this circuit configuration is

\[
M_v = \frac{V_o}{V_s} = D \tag{0.2}
\]

where, \( V_o \) is the converter output voltage, \( V_s \) is the converter input voltage and \( D \) is the duty cycle

**Block Diagram**

Block diagram of the setup is given in Figure 3.
Figure 3: Block diagram of buck converter

Components:

1. PWM Generator (TL 494) IC For PWM generation
2. Vcc connector (+15V) 15V DC provided internally
3. Potential divider, TR3 (10K) For carrier Triangle Frequency variation
4. Power ON/OFF IR Switch - 230V AC ON/OFF
5. Inductor (1mH)
6. Potential divider, TR4 (10K) Feedback voltage adjustment (~0 -1V)
7. Feedback voltage connector Feedback voltage (1V) from converter O/P
8. MOSFET (IRF250) Switching Device
9. PWM input connector - 16.66 KHz PWM input to opto-isolator IC
10. Open/closed loop selector switch
11. PWM output connector - 16.66 kHz PWM O/P (5V level) from TL494
12. Set voltage adjust POT (10K) 0-3V for Open loop
   1V for closed loop
   0-1V for closed loop set voltage variation

Front Panel Description

DC-DC buck converter trainer consists of PWM Generation circuit and buck converter power circuit
- The variable DC voltage input to the PWM generator circuit is provided by varying the SET VOLTAGE ADJUST POT from min to max values.
- The PWM output signal is terminated at connector P8.
- The feedback voltage from the power circuit is connected to the PWM generation circuit via connector FEEDBACK VOLT INPUT.
- The input DC voltage to the power circuit is provided by an externally connected (0-30V) regulated power supply unit through P1 and P2.
- The generated PWM input signal is fed to the gate of the MOSFET switch through a gate driver circuit.
- The feedback voltage signal is terminated at FEEDBACK VOLT O/P.
- Test points are provided to view the different control circuit and power circuit signals.
- DC output voltage is terminated across load resistance P5, P6 terminals.
- Switch SW1 controls the converter operation. Switch SW1 upward direction generates PWM signals for open loop operation and the switch SW1 downward direction generates the PWM signal for closed loop operation.
- The Power supply to the trainer module is controlled by the POWER (ON/OFF) switch.

**Test Point Details**

T1: Test point to view the PWM signal
T2: Test point to view the GND
T3: Test point to view triangular carrier signal
T4: Test point to view +5V signal
T5: GND point
T6: Test point to view feedback voltage
T7: Test point to view set voltage
T8: Test point to view +5V reference voltage
I1 & I2: Test points to view inductor current, IL1
I3 & I4: Test points to view diode current, Id
I3 & I7: Test points to view switch device current, IQ
I5 & I6: Test points to view output current, IRL
G & S: Test points to view gate source voltage, VGS

**Protection and Precautions**

- Ensure the fuses are in good condition.
- Switch ON the power.
- Ensure the PWM waveform at test points with respect to GND.
- Ensure the input supply 230V AC to the trainer module.
- Before doing connections make all switches in OFF condition.
- Make the connections as per the connection procedure and the wiring diagram.
- Switch ON the power ON/OFF switch.
- Do the experiment as per the experimental procedure.
- Don’t short input DC source positive and negative terminals.
- Don’t short output load terminals.

Connection Diagram
Step 1: PWM Signal Generation

Examine the TL494 circuit available in the trainer module for PWM generation. You have already used in your previous labs. When the set voltage POT is varied from minimum to maximum, ton time of the PWM signal varies correspondingly to a maximum value. You need a DC supply and digital oscilloscope. Connect the trainer module to the 230V, 50 Hz AC supply using PC power chord and then connect CRO between terminal T1 and GND point.

Experimental Procedure

1. Switch ON the POWER ON/OFF switch.
2. View the carrier signal in the CRO at T3.
3. Set switch SW1 in upward direction.
4. View the PWM signal in the CRO at T1.
5. Vary the SET VOLTAGE ADJUST POT from min to max and note down the ton and T values.
7. Tabulate the various ton times.
8. Plot the PWM waveform.

Tabulation: Measure and record the following at f= 16.66 kHz

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Set Voltage</th>
<th>On time (u-sec)</th>
<th>PWM Signal Voltage</th>
<th>Duty Cycle</th>
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Note: Plot all the waveforms in your notebook.
Step 2: Buck Converter in Open Loop Mode

This experiment is intended to study the open loop operation of buck converter. The switching frequency is setup to 16.66 kHz. By varying the DC input supply slowly from 0 to 20V, the output voltage varies.

Apparatus Required

1. VSMPS-05A Trainer
2. Pulse patch chords
3. (0 - 20 V) DC supply
4. CRO

Connection Procedure

1. Connect P8 of PWM generator to PWM input of buck converter circuit.
2. Connect P4 of buck converter circuit to P7 of PWM generator.
3. Set switch SW1 to upward direction to select the open loop operation.
4. Connect (0-20V) DC regulated power supply across P1 and P2 terminals of the trainer module and set the voltage value at 10V.

Experimental Procedure

1. Switch ON AC power supply.
2. Switch ON the power ON \ OFF switch.
3. View the carrier signal in the CRO at T3.
4. Set switch SW1 in upward direction.
5. View the PWM signal in the CRO at T1.
6. Set the PWM signal at desired duty cycle ratio.
7. Switch ON the variable DC supply.
8. Check all the test point waveforms.
9. View the inductor current IL1 across I1 and I2.
10. View the diode D current across I3 and I4.
11. View the device current IQ across I3 and I7.
12. View device voltage across I7 and S.
13. View the gate voltage across G and S.
14. View the rectified voltage across I5 and S.
15. Connect CRO across P5 and P6 output terminals of trainer module and view the output voltage.
16. Vary the input DC voltage from 0 to20V. For each input voltage value, measure and calculate the output voltage values tabulate them.

Formula used: The calculated output voltage is given by:
where, \( V_o \) is converter output voltage, \( V_s \) is converter input voltage and \( D \) is duty cycle.

Tabulation: Measure and record the following at \( f = 16.66 \, \text{kHz} \)

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Duty Cycle (D)</th>
<th>( V_{in} ) (Volt)</th>
<th>Measured ( V_o )</th>
<th>Calculated ( V_o )</th>
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**Result:**
Step 3: Buck Converter in Closed Loop Mode

This experiment is intended to study the closed loop operation of buck converter. The set voltage to the PWM generator is set at 1V. Feedback voltage from buck converter power circuit is connected to the PWM generator circuit. On varying the DC input voltage slowly from 0 to 20V, the output voltage is measured as constant.

Equipments Required

1. VSMPS-05A Trainer
2. Pulse Patch chords
3. (0 - 30 V) DC supply
4. CRO

Connection Procedure

1. Connect P8 of PWM generator to PWM input of buck converter circuit.
2. Connect P4 of buck converter circuit to P7 of PWM generator.
3. Set switch SW1 to downward direction to select the closed loop operation.
4. Connect (0-20V) DC regulated power supply across P1 and P2 terminals of the trainer module and set the voltage value at 15V.

Experimental Procedure

1. Switch ON AC power supply.
2. Switch ON the power ON \ OFF switch.
3. View the carrier signal in the CRO at T3.
4. Set switch SW1 in downward direction.
5. View the PWM signal in the CRO at T1.
6. Set the PWM signal at desired duty cycle ratio.
7. Switch ON the variable DC supply.
8. Check all the test point waveforms.
9. View the inductor current IL1 across I1 and I2.
10. View the diode D current across I3 and I4.
11. View the device current IQ across I3 and I7.
12. View device voltage across I7 and S.
13. View the gate voltage across G and S.
14. View the rectified voltage across I5 and S.
15. Connect CRO across P5 and P6 output terminals of trainer module and view the output voltage.
16. View the feedback signal at T6.
17. For each input voltage value, tabulate the measured output voltage values.
Set Voltage = 1V

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>ON-Time ton (u-sec)</th>
<th>Input Voltage (V)</th>
<th>Output Voltage (V)</th>
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Result:

Assignment

1. Simulate buck converter in open and closed loop configuration in Multisim and attach report with this manual.
Experiment 8

Boost Converter in Open and Closed Loop Configuration

Boost converter is one of the basic, non-isolated DC-DC converter topology. This converter circuit provides an output voltage higher than the input voltage with same polarity. It consists of a DC input source $V_s$, boost inductor $L$, controlled MOSFET switch $S$, filter capacitor $C$ and load resistor, $R$.

Circuit Diagram

Circuit diagram of boost converter is presented below in Figure 1.

![Circuit Diagram of Boost Converter](image)

Figure 1: Boost Converter

Working Principle

Mode 1: For $t = 0$ to $t_{on}$ (Switch $Q$ is ON, $D$ is OFF)

The equivalent circuit of boost converter when switch $Q$ is ON is presented below.

- Switch $Q$ is turned ON.
- ii. Input voltage is seen across inductor $L$.
- iii. Current through the inductor, $i_L$ increases from $i_{L1}$ to $i_{L2}$. 
iv. Diode D is reverse biased by the inductor negative potential.
v. Capacitor discharges to the load resistor, R.

**Mode 2:** For \( t = t_{on} \) to \( T \) (Switch Q is OFF, D is ON)
The equivalent circuit of boost converter when switch Q is OFF is presented below.

- Switch Q is turned OFF.
- Current through the inductor, \( i_L \) decreases from \( i_{L2} \) to \( i_{L1} \)
- This decreasing current forces the switch end of the inductor to swing positive and forward biases diode D.
- Now, the capacitor charges up to a voltage that is higher than the input voltage.
- Thus the output voltage is higher than the input voltage.

**At steady state,**

When Q is ON, capacitor supplies the output load current.
When Q is OFF, inductor current flows through capacitor and load.
The relationship between input and output for this circuit configuration is:

\[
V_o = \left[ \frac{1}{1 - \frac{t_{on}}{T}} \right] V_s
\]  
(0.3)

where, \( V_o \) is converter output voltage, \( V_s \) is converter input voltage, \( t_{on} \) is switch on-time, and \( T \) is device switching time.
Block Diagram

Apparatus

1. PWM Generator (TL 494) IC - For PWM generation
2. Vcc connector (+15V) - 15V DC provided internally
3. Potential divider, TR3 (10KΩ) - For carrier triangle frequency variation
4. Power ON/OFF IR Switch - 230V AC ON/OFF
5. Inductor (1mH)
6. Potential divider, TR4 (10KΩ) - Feedback voltage adjustment (~0 -1V)
7. Feedback voltage connector - Feedback voltage (1V) from converter O/P
8. MOSFET (IRF250) - Switching Device
9. PWM input connector - 16.66 KHz PWM input to opt isolator IC
10. Open/closed loop selector switch
11. PWM output connector - 16.66 KHz PWM O/P (5V level) from TL494
12. Set voltage adjust POT (10KΩ)
   - 0-3V for Open loop
   - 1V for closed loop
   - 0-1V for closed loop set voltage variation

Front Panel Description:

DC-DC Boost converter Trainer consists of
1. PWM Generation circuit
2. Boost Converter Power circuit

- The variable DC voltage input to the PWM generator circuit is provided by varying the SET VOLTAGE ADJUST POT from min to max values.
- The PWM output signal is terminated at connector P8.
- The feedback voltage from the power circuit is connected to the PWM generation circuit via connector FEEDBACK VOLT INPUT.
- The input DC voltage to the power circuit is provided by an externally connected (0-30V) regulated power supply unit through P1 and P2.
- The generated PWM input signal is fed to the gate of the MOSFET switch through PWM input.
- The feedback voltage signal is terminated at FEEDBACK VOLT O/P.
- Test points are provided to view the different control circuit and power circuit signals
- DC output voltage is terminated across load resistance P5, P6 terminals.
- Switch SW1 controls the converter operation. Switch SW1 controls the upward direction generates PWM signal generation for open loop operation and the switch SW1 in downward direction generates the PWM signal for closed loop operation.
- The Power supply to the trainer module is controlled by the POWER (ON/OFF) switch.

Test Point Details

T1 : Test point to view the PWM signal
T2 : Test Point to view the GND
T3 : Test Point to view triangular carrier signal
T4 : Test Point to view +5V signal
T5 : GND Point
T6 : Test Point to View Feedback Voltage
T7 : Test Point to View Set Voltage
T8 : Test Point to View +5V Reference Voltage
I1 & I2 : Test Points to view inductor Current, IL1
I3 & I4 : Test Points to view Diode current, Id
I3 & I7 : Test points to view switch device current, IQ
I5 & I6 : Test points to view output current, IRL
G & S : Test points to view Gate Source voltage, VGS

Protection and Precautions

- Ensure the fuses are in good condition.
- Switch ON the power.
- Ensure the PWM waveform at test points with respect to GND.
- Ensure the input supply 230V AC to the Trainer module.
Before doing connections make all switches in OFF condition.
Make the connections as per the connection procedure and the wiring diagram.
Switch ON the power ON/OFF switch.
Do the experiment as per the experimental procedure.
Don’t short input DC source positive and negative terminals.
Don’t short output load terminals.

Connection Diagram
Part 1: PWM Signal Generation

In this experiment, PWM generation for open loop operation is studied. When the set voltage POT is varied from minimum to maximum, ton time of the PWM signal varies correspondingly to a maximum value.

Apparatus Required

1. VSMPS-06A module
2. CRO

Connection Procedure

1. Connect the trainer module to the 230V, 50 Hz AC supply using PC power chord.
2. Connect CRO positive terminal to T1 and negative terminal to the GND point.

Experimental Procedure

1. Switch ON the POWER ON/OFF switch.
2. View the carrier signal in the CRO at T3.
3. Set switch SW1 in upward direction.
4. View the PWM signal in the CRO at T1.
5. Vary the SET VOLTAGE ADJUST POT from min to max and note down the t on and T values.
6. Tabulate the various ton times.
7. Plot the PWM waveform.

Tabulation: Measure and record the following at f = 16.66 kHz

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Set Voltage</th>
<th>On time (u-sec)</th>
<th>PWM Signal Voltage</th>
<th>Duty Cycle</th>
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Plot all the waveforms in your note book.
Part 2: Boost Converter in Open Loop Mode

This experiment is intended to study the open loop operation of boost converter. The switching frequency is setup 16.66 kHz. By varying the DC input supply slowly from 0 to 30V, the output voltage varies.

Apparatus Required

1. VSMPS-06A Trainer
2. Pulse Patch chords
3. (0 - 30 V) DC supply
4. CRO

Connection Procedure

1. Connect P8 of PWM generator to PWM input of boost converter circuit.
2. Connect P4 of boost converter circuit to P7 of PWM generator.
3. Set switch SW1 to upward direction to select the open loop operation.
4. Connect (0-30V) DC regulated power supply across P1 and P2 terminals of the trainer module and set the voltage value at 15V.

Experimental Procedure

1. Switch ON AC power supply.
2. Switch ON the power ON \ OFF switch.
3. View the carrier signal in the CRO at T3.
4. Set switch SW1 in upward direction.
5. View the PWM signal in the CRO at T1.
6. Set the PWM signal at desired duty cycle ratio.
7. Switch ON the variable DC supply.
8. Check all the test point waveforms.
9. View the inductor current IL1 across I1 and I2.
10. View the diode D current across I3 and I4.
11. View the device current IQ across I3 and I7.
12. View device voltage across I7 and S.
13. View the gate voltage across G and S.
14. View the rectified voltage across I5 and S.
15. Connect CRO across P5 and P6 output terminals of trainer module and view the output voltage.
16. Vary the input DC voltage from 0 to15V. For each input voltage value, measure and calculate the output voltage values tabulate them.

Tabulation: Measure and record the following at f = 16.66 kHz
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Duty Cycle (D)</th>
<th>Vin (Volt)</th>
<th>Measured Vo</th>
<th>Calculated Vo</th>
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Result:
Part 3: Boost Converter in Closed Loop Mode

This experiment is intended to study the closed loop operation of boost converter. The set voltage to the PWM generator is set at 1V. Feedback voltage from boost converter power circuit is connected to the PWM generator circuit. On varying the DC input voltage slowly from 0 to 15V, the output voltage is measured as constant.

Equipments Required:

1. VSMPS-06A Trainer
2. Pulse Patch chords
3. (0 - 30 V) DC supply
4. CRO

Connection Procedure:

1. Connect P8 of PWM generator to PWM input of Boost converter circuit.
2. Connect P4 of Boost converter circuit to P7 of PWM generator.
3. Set switch SW1 to downward direction to select the closed loop operation.
4. Connect (0-30V) DC regulated power supply across P1 and P2 terminals of the trainer module and set the voltage value at 15V.

Experimental Procedure:

1. Switch ON AC power supply.
2. Switch ON the power ON \ OFF switch.
3. View the carrier signal in the CRO at T3.
4. Set switch SW1 in downward direction.
5. View the PWM signal in the CRO at T1.
6. Set the PWM signal at desired duty cycle ratio.
7. Switch ON the variable DC supply.
8. Check all the test point waveforms.
9. View the inductor current IL1 across I1 and I2.
10. View the diode D current across I3 and I4.
11. View the device current IQ across I3 and I7.
12. View device voltage across I7 and S.
13. View the gate voltage across G and S.
14. View the rectified voltage across I5 and S.
15. Connect CRO across P5 and P6 output terminals of trainer module and view the output voltage.
16. View the feedback signal at T6.
17. For each input voltage value, tabulate the measured output voltage values.
Tabulation: Measure and record the following at $f = 16.66$ kHz, when set voltage = 1V

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>ON-Time ton (μ-sec)</th>
<th>Input Voltage (V)</th>
<th>Output Voltage (V)</th>
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Result:

ASSIGNMENT

1. Simulate boost converter in open and closed loop configuration in Multisim and attach report with this manual.
Experiment 9

DC-DC Fly-Back Converter in Open and Closed Loop Configuration

The Flyback converter is a negative output step-up converter. It is an isolated version of the buck-boost converter. The inductor of the buck-boost converter has been replaced by a Fly-back transformer. The input DC source $V_s$ and switch $Q$ are connected in series with the transformer primary. The diode $D$ and the RC output circuit are connected in series with the secondary of the Fly-back transformer.

- $i_p$ - Current in the primary of the high frequency Fly back Transformer
- $i_s$ - Current from the secondary of the high frequency Fly back Transformer
- $i_c$ - Capacitor Current
- $i_o$ - Output Current

**Working Principle**

**Mode 1:** For $t = 0$ to $t_{on}$ (Switch $Q$ is ON, Diode $D$ is OFF)

The equivalent circuit of the converter when the switch $Q$ is closed is shown below.

i. When supply is given to the circuit, it magnetizes the core of the transformer.
ii. The primary current $i_p$ increases from $i_{pl}$ to $i_{ph}$
iii. Due to current flow, an emf, $V1$ is induced in the primary that is equal and opposite to the supply voltage, $V_s$. 

$V_s$ $i_p$ $N1$ $D$ $N2$ $i_s$ $D$ $i_c$ $i_o$ $V_o$ $R$ $C$ $V_s$ $i_p$ $V_1$ $V_2 = V_s \times (N2/N1)$ $V_Q = 0V$
iv. An emf, $V_2$ is induced in the secondary and is equal to $VS \times (N2/N1)$

v. The diode, $D$ prevents the current flow in the secondary winding.

**Mode 2:** For $t = ton$ to $T$ (Switch $Q$ is OFF, diode $D$ is ON)

The equivalent circuit of Flyback converter when the switch $Q$ is open is shown below.

![Diagram](image)

i. The source is cut off.

ii. The primary current drops to zero,

iii. The core demagnetizes rapidly

iv. A negative emf $V_1$ is induced in the primary.

v. A negative emf $V_2$ is induced in the secondary.

vi. The diode allows the secondary current to flow, thus demagnetizing the core.

vii. The secondary current is decreases from $is_h$ to $is_l$ with $is_h = iph \times (N1/N2)$

viii. The output voltage $V_o = V_2$

ix. Hence, By transformer action $V_1 = -V_o \times (N1/N2)$

x. And, the switch voltage $V_Q = VS + V_o \times (N1/N2)$

The relationship between input and output for this circuit configuration is

$$V_o = V_s \left( \frac{D}{1-D} \right) \left( \frac{N_2}{N_1} \right)$$

(1)

where, $V_o$ is converter output voltage, $V_s$ is converter input voltage, $N2/N1$ is transformer turns ratio, $D$ is the duty cycle ratio ($ton / T$), $ton$ is the switch on-time and $T$ is device switching time.
Block Diagram

Components

1. PWM Generator (TL 494) IC - For PWM generation
2. Vcc connector (+15V) - 15V DC provided internally
3. Potential Divider, TR3 (10KΩ) - For carrier Triangle Frequency variation
4. Power ON/OFF IR Switch - 230V AC ON/OFF
5. Inductor (1mH)
6. Potential Divider, TR4 (10KΩ) - Feedback voltage adjustment (∼0 -1V)
7. Feedback voltage connector - Feedback voltage (1V) from converter O/P
8. MOSFET (IRF250) - Switching Device
9. PWM input connector - 16.66 KHz PWM input to opt isolator IC
10. Open/closed loop selector switch
11. PWM output connector - 16.66 KHz PWM O/P (5V level) from TL494
12. Set voltage adjust POT (10KΩ)
   - 0-3V for Open loop
   - 1V for closed loop
   - 0-1V for closed loop set voltage variation

Front Panel Description

DC-DC Boost converter trainer consists of

1. PWM Generation circuit
2. Flyback Converter Power circuit

- The variable DC voltage input to the PWM generator circuit is provided by varying the SET VOLTAGE ADJUST POT from min to max values.
- The PWM output signal is terminated at connector P8.
- The feedback voltage from the power circuit is connected to the PWM generation circuit via connector FEEDBACK VOLT INPUT.
- The input DC voltage to the power circuit is provided by an externally connected (0-30V) regulated power supply unit through P1 and P2.
- The generated PWM input signal is fed to the gate of the MOSFET switch through PWM input.
- The feedback voltage signal is terminated at FEEDBACK VOLT O/P.
- Test points are provided to view the different control circuit and power circuit signals
- DC output voltage is terminated across load resistance P5, P6 terminals.
- Switch SW1 controls the converter operation. Switch SW1 controls the upward direction generates PWM signal generation for open loop operation and the switch SW1 in downward direction generates the PWM signal for closed loop operation.
- The Power supply to the trainer module is controlled by the POWER (ON/OFF) switch.

Test Point Details

T1 : Test point to view the PWM signal
T2 : Test Point to view the GND
T3 : Test Point to view triangular carrier signal
T4 : Test Point to view +5V signal
T5 : GND Point
T6 : Test Point to View Feedback Voltage
T7 : Test Point to View Set Voltage
T8 : Test Point to View +5V Reference Voltage
I1 & I2 : Test Points to view inductor Current, I_IN
I3 & I4 : Test Points to view Diode current, I_d
I5 & I6 : Test points to view load current, I_L
I7 & I8 : Test points to view Drain current, I_Q
G & S : Test points to view Gate Source voltage, V_GS

Protection and Precautions

DO’s
i. Ensure the fuses are in good condition.
ii. Switch ON the power.
iii. Ensure the PWM waveform at test points with respect to GND.
iv. Ensure the input supply 230V AC to the Trainer module.
v. Before doing connections make all switches in OFF condition.
vi. Make the connections as per the connection procedure and the wiring diagram.
vii. Switch ON the power ON/OFF switch.
viii. Do the experiment as per the experimental procedure.
ix. Don’t short input DC source Positive and negative terminals.
x. Don’t short output load terminals.

Connection Diagram
Part 1: PWM Signal Generation

In this experiment, PWM generation for open loop operation is studied. When the set voltage POT is varied from minimum to maximum, ton time of the PWM signal varies correspondingly to a maximum value.

Apparatus Required

1. VSMPS-09A module
2. CRO

Connection Procedure

1. Connect the trainer module to the 230V, 50 Hz AC supply using PC power chord.
2. Connect CRO positive terminal to T1 and negative terminal to the GND point.

Experimental Procedure

1. Switch ON the POWER ON/OFF switch.
2. View the carrier signal in the CRO at T3.
3. Set switch SW1 in upward direction.
4. View the PWM signal in the CRO at T1.
5. Vary the SET VOLTAG ADJUST POT from min to max and note down the t on and T values.
6. Tabulate the various ton times.
8. Plot the PWM waveform.

Tabulation: Measure and record the following at f=33 kHz

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Set Voltage</th>
<th>On time (u-sec)</th>
<th>PWM Signal Voltage</th>
<th>Duty Cycle</th>
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Result:
Draw all the waveforms in your notebook.
Part 2: Fly-Back Converter in Open Loop Mode

This experiment is intended to study the open loop operation of Flyback converter. The switching frequency is setup 33 KHz. By varying the DC input supply slowly from 0 to 30V, the output voltage varies.

Apparatus Required

1. VSMPS-09A Trainer
2. Pulse Patch chords
3. (0 - 30 V) DC supply
4. CRO

Connection Procedure

1. Connect P8 of PWM generator to PWM input of Flyback converter circuit.
2. Connect P4 of Flyback converter circuit to P7 of PWM generator.
3. Set switch SW1 to upward direction to select the open loop operation.
4. Connect (0-30V) DC regulated power supply across P1 and P2 terminals of the trainer module and set the voltage value at 30V.

Experimental Procedure

1. Switch ON AC power supply.
2. Switch ON the power ON \ OFF switch.
3. View the carrier signal in the CRO at T3.
4. Set switch SW1 in upward direction.
5. View the PWM signal in the CRO at T1.
6. Vary the SET VOLTAGE ADJUST POT from min to max and note down the t on and T values
7. Set the PWM signal at desired duty cycle ratio.
8. Switch ON the variable DC supply.
9. Check all the test point waveforms.
10. View the DC input current across I2 and I1.
11. View the device current IQ across I7 and I8.
12. View the diode D current across I3 and I4.
13. View device voltage across I8 and S.
14. View the PWM and the device voltage at T1 and across I8 & S.
15. View the device gate voltage signal across G and S.
16. View the transformer primary voltage across I2 & I7.
17. View the transformer secondary voltage across I3 & I11.
18. View the rectified voltage across I5 and I11.
19. Connect CRO across P5 and P6 output terminals of trainer module and view the output voltage.

20. Vary the input DC voltage from 0 to 30V. For each input voltage value, measure and calculate the output voltage values tabulate them.

Formula used: The calculated output voltage is given by:

\[ V_o = V_{in} \left( \frac{N_2}{N_1} \right) D \]  \hspace{1cm} (0.4)

where, \( V_o \) is output voltage, \( V_{in} \) is input voltage, \( N_2/N_1 \) is transformer turns ratio (1:1), and \( D \) is the duty cycle ratio, \( t_{on} / T \).

**Tabulation:** Measure and record the following at \( f = 33 \text{ kHz} \)

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Duty Cycle (D)</th>
<th>Vin (Volt)</th>
<th>Measured Vo</th>
<th>Calculated Vo</th>
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Result:
Part 3: Fly-Back Converter in Closed Loop Mode

This experiment is intended to study the closed loop operation of Flyback converter. The set voltage to the PWM generator is set at 1V. Feedback voltage from Flyback converter power circuit is connected to the PWM generator circuit. On varying the DC input voltage slowly from 0 to 30V, the output voltage is measured as constant.

Equipments Required:

1. VSMPS-09A Trainer
2. Pulse Patch chords
3. (0 - 30 V) DC supply
4. CRO

Connection Procedure:

1. Connect P8 of PWM generator to PWM input of Flyback converter circuit.
2. Connect P4 of Boost converter circuit to P7 of PWM generator.
3. Set switch SW1 to downward direction to select the closed loop operation.
4. Connect (0-30V) DC regulated power supply across P1 and P2 terminals of the trainer module and set the voltage value at 30V.

Experimental Procedure:

1. Switch ON AC power supply.
2. Switch ON the power ON \ OFF switch.
3. View the carrier signal in the CRO at T3.
4. Set switch SW1 in downward direction.
5. View the PWM signal in the CRO at T1.
6. Vary the SET VOLTAGE ADJUST POT from min to max and note down the t on and T values.
7. Set the PWM signal at desired duty cycle ratio.
8. Switch ON the variable DC supply.
9. Check all the test point waveforms.
10. View the DC input current across I2 and I1.
11. View the device current IQ across I7 and I8.
12. View the diode D current across I3 and I4.
13. View device voltage across I8 and S.
14. View the PWM and the device voltage at T1 and across I8 & S.
15. View the device gate voltage signal across G and S.
16. View the transformer primary voltage across I2 & I7.
17. View the transformer secondary voltage across I3 & I11.
18. View the rectified voltage across I5 and I11.
19. Connect CRO across P5 and P6 output terminals of trainer module and view the output voltage.
20. View the feedback signal at T6.
21. For each input voltage value, tabulate the measured output voltage values.

Tabulation: Measure and record the following at $f = 33 \text{ kHz}$, $D = \%$
Set Voltage = 1V

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>ON-Time ton (u-sec)</th>
<th>Input Voltage (V)</th>
<th>Output Voltage (V)</th>
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Result

ASSIGNMENT

1. Simulate Fly-Back converter in open and closed loop configuration in Multisim and attach report with this manual