

# JoVE: Science Education

## Flyback Converter

--Manuscript Draft--

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### Overview:

The objective of this experiment is to study different characteristics of a flyback converter. This converter operates like a buck-boost converter but has electrical isolation through a coupled inductor. Open-loop operation with a manually-set duty ratio will be used. An approximation of the input-output relationship will be observed.

**ATTENTION: This experiment is designed to limit the output voltage to be less than 50V DC. Only use duty ratios, frequencies, input voltage, or loads that are given here.**

### Procedure:

This experiment will utilize the DC-DC converter board provided by HiRel Systems.

<http://www.hirelsystems.com/shop/Power-Pole-Board.html>

Information about the board components, schematics, and operation are available here:

[http://www.ece.umn.edu/groups/power/labs/pe/pe\\_manual.pdf](http://www.ece.umn.edu/groups/power/labs/pe/pe_manual.pdf)

The procedure followed here applies to any simple buck converter circuit that can be built on proto boards, bread boards, or printed circuit boards.

1. Board setup:
  - 1.1 Connect the  $\pm 12$  signal supply at the DIN connector but keep S90 OFF.
  - 1.2 Make sure that the PWM control selector is in the open-loop position.
  - 1.3 Set your DC power supply at 16V. Keep its output disconnected from your board until instructed otherwise.
  - 1.4 Before connecting your load resistor, adjusted it to  $10\Omega$ .
  - 1.5 Build the circuit shown in Fig. 7.1 by using the lower MOSFET and flyback magnetic board.
    - 1.5.1 Note that the turns ratio  $N1/N2=2$ .
  - 1.6 Connect RL across V2+ and COM.
    - 1.6.1 **NEVER Disconnect your load during the experiment as the boost converter can become unstable and cause damage to the board.**
  - 1.7 Make sure the switch array for MOSFET selection (lower MOSGET), PWM selection, and other settings are correct to achieve a functional Fig. 1.

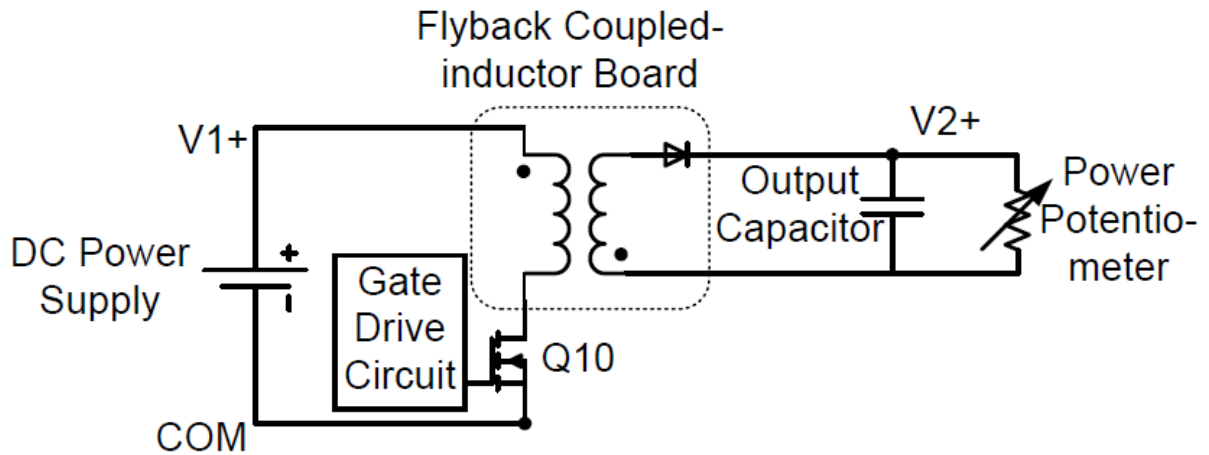


Fig. 1 Flyback converter circuit

2. Adjusting the Duty Ratio and Switching Frequency
  - 2.1 Connect the differential probe across the gate-to-source of the lower MOSFET.
  - 2.2 Turn ON S90. A switching signal should appear on the scope screen.
    - 2.2.1 Adjust the signal time axis to see two or three periods.
    - 2.2.2 Adjust the frequency potentiometer to achieve a frequency of 100 kHz (period of 10 $\mu$ s).
  - 2.3 Adjust the duty ratio potentiometer to achieve a 50% duty ratio (on-time of 5 $\mu$ s).
3. Flyback Converter Testing for Variable Input
  - 3.1 Connect your input DC power supply which you already set at 16V to V1+ and COM.
  - 3.2 Connect a regular probe to measure the input current at CS1. Make sure the ground connector is connected to COM.
    - 3.2.1 Connect the differential probe across the load.
    - 3.2.2 Capture the waveforms and measure the output voltage mean, input current peak, and input current mean.
    - 3.2.3 Record the input current and voltage readings on the DC power supply.
  - 3.3 Adjust your input voltage to 11V, 13V, and 15V.
    - 3.3.1 Repeat the above steps for each of these voltages.
  - 3.4 Disconnect your input DC supply and adjust its output to 16V.
4. Flyback Converter Testing for Variable Duty Ratio
  - 4.1 Connect a regular probe across the gate to source of the lower MOSFET.
    - 4.1.1 Connect the differential probe across the load.
  - 4.2 Connect the input DC supply to V1+ and COM.
  - 4.3 Capture the waveforms and measure the output voltage mean and on-time of the gate-to-source voltage (also the duty ratio).
    - 4.3.1 Record the input current and voltage readings on the DC power supply.

- 4.4 Adjust your duty ratio to 10%, 25%, and 40%. Repeat the above steps for each of these three duty ratios.
- 4.5 Reset your duty ratio to 50%.
- 4.6 Disconnect your input DC supply.
- 5. Flyback Converter Testing for Variable Switching Frequency
  - 5.1 Connect a regular probe at CS1 to measure the input current.
    - 5.1.1 Connect the differential probe across the load.
  - 5.2 On the second scope, observe the gate-to-source voltage using a regular probe to adjust the switching frequency as needed.
  - 5.3 Connect the input DC supply to V1+ and COM.
  - 5.4 Adjust your switching frequency to 70kHz.
  - 5.5 Capture the waveforms from the first scope and measure the input current peak and output voltage mean.
    - 5.5.1 Note down the frequency and duty ratio from the second scope but do not capture its waveform.
    - 5.5.2 Record the input current and voltage reading on the DC power supply.
  - 5.6 Adjust your switching frequency to 50kHz, 30kHz, and 10kHz (or minimum possible if you cannot reach 10kHz).
    - 5.6.1 Repeat the above steps for each of these three switching frequencies.
  - 5.7 Turn OFF the input DC supply and S90, and then disassemble your circuit.

### **Representative Results:**

Flyback converters are isolated buck-boost converters that can step up or step down the input voltage. The turns-ratio of the flyback coupled inductor or transformer aids in the stepping up or down process, and given that the switching frequency is high, the flyback transformer size is small and uses ferrite cores. If the input voltage is  $V_{in}$  and the output voltage is  $V_{out}$ ,  $V_{out}/V_{in}=(N_2/N_1)D/(1-D)$  when the converter is operating in continuous conduction mode, where  $0 \leq D \leq 100\%$ . Typically, flyback converters are not operated above 50% duty cycle to maintain energy balance in the flyback transformer. As seen in the  $V_{out}/V_{in}$  relationship,  $D$  and  $1/(1-D)$  are multiplied and which show the buck and boost capabilities, while the  $N_2/N_1$  term shows the effect of the transformer's turns ratio. Among the main factors in designing and building a flyback converter are 1) the magnetizing inductance  $L_m$  of the flyback transformer, and 2) the snubber circuit across the transformer's input side.

### **Applications:**

Flyback converters are typically used in isolated power supplies where the output side should have galvanic isolation from the input side. This is common in driving high-side power semiconductors such as MOSFETs and IGBTs whose gate drive circuits may require isolated DC supplies. Flyback converters are typically operated at high switching frequencies higher than 100 kHz, and have power ratings typically not exceeding 200 W.