PURPOSE:
The purpose of this lab is to test the LM267X voltage regulating chip. National Semiconductor makes the LM267X chip that will be utilized in these labs. There are a couple variations available for the LM267X SIMPLE SWITCHER evaluation board; a series 3A and 5A. The series 5A will be utilized throughout this course. The series that a particular evaluation board uses is printed on the board. The LM2673S-5.0 is the chip that will be used on the board. The 3S-5.0 indicates that the chip operates at 3 amps and 5 volts. This model is a buck converter with 5V output voltage and 3A maximum load current. This lab will explore the following:

- INTRODUCTION to the LM267X series step-down voltage regulators.
- GENERAL DESCRIPTION
- PHYSICALLY TESTING

INTRODUCTION:
In this course, the important concepts of buck converters and the mathematics behind them have been extensively covered. These labs are set up to actually test a buck converter circuit and make some general observations about its characteristics. The simulations that will be performed in this lab will also reinforce your understanding of the buck converter topology.

GENERAL DESCRIPTION:
Figure 1, shown below, is a circuit diagram of the evaluation board used for this lab. Carefully inspect the board in your possession. Especially note the connection pins. Find the $V_{IN}$, $V_{OUT}$, $SW_{OUT}$ and the four GND pins on your board.
Table 2 is courtesy of the National Semiconductor website and shows a complete list of the component labels and their functions.

**TABLE 2. List of Component Labels and Functionality**

<table>
<thead>
<tr>
<th>LABEL</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1</td>
<td>LM267X Switching Regulator IC</td>
</tr>
<tr>
<td>CIN</td>
<td>Input Capacitor(s); All devices.</td>
</tr>
<tr>
<td>CINX</td>
<td>0.47(\mu)F, optional high frequency input bypass capacitor, recommended in all designs; All devices.</td>
</tr>
<tr>
<td>CB</td>
<td>Boost capacitor; All devices.</td>
</tr>
<tr>
<td>D1</td>
<td>Catch diode; All devices.</td>
</tr>
<tr>
<td>R1</td>
<td>Feedback resistor (1kΩ) for adjustable output devices and shorted, replaced by a jumper wire, with fixed output voltage devices.</td>
</tr>
<tr>
<td>R2</td>
<td>Feedback resistor for adjustable output devices and open, not connected for fixed voltage devices.</td>
</tr>
<tr>
<td>R3*</td>
<td>Current limit resistor for LM2673, LM2679; Sync input resistor (1KΩ) for LM2670 and LM2677; Not inserted for LM2676 and LM2678.</td>
</tr>
<tr>
<td>L1</td>
<td>Inductor; All devices.</td>
</tr>
<tr>
<td>CSS</td>
<td>Sync input capacitor (100(\mu)F); LM2670 and LM2677 only. Not inserted with other devices.</td>
</tr>
<tr>
<td>CSS</td>
<td>Soft start capacitor; LM2673 and LM2679 only. Not inserted with other devices.</td>
</tr>
<tr>
<td>COUTX</td>
<td>0.47(\mu)F, optional high frequency output bypass capacitor; All devices.</td>
</tr>
<tr>
<td>COUT</td>
<td>Output capacitor(s); All devices.</td>
</tr>
</tbody>
</table>

*All devices have internally preset current limits, but those with adjustable current limit capability can be used to set the current limit to any value up to the maximum preset value.*

See if you can locate all of the components (resistors, capacitors, etc.) on the board shown in this schematic.

There are other prints that may be of interest such as Figures 2, 3 and 4 that show the top, bottom and silk screen of the printed circuit board, respectively.
FIGURE 2. Top Layer Foil Pattern of Printed Circuit Board

FIGURE 3. Bottom Layer Foil Pattern of Printed Circuit Board
For this evaluation board, the LM267X-3A, all of the components are included on the board. The only variables are the input voltage and the switching speed. Everything else, including the output voltage, is fixed.

**PHYSICALLY TESTING:**
In order to produce the graphical data required for this lab, you will need to use the following equipment:

- Agilent Infinium Oscilloscope
- DC power supply
- Multimeter
- Waveform generator
- Three sets of leads
- One probe for the oscilloscope
- One of each: 10Ω, 100Ω and a 1kΩ resistor
- A floppy disk (to record oscilloscope images)

The first step is to set up all of the equipment mentioned above. If necessary, review equipment manuals for proper set up.
Oscilloscope: Record the output voltage from Channel 1.

DC Power Supply: Connect the leads to +25V and Ground. Initially set the voltage to +10V.

Multimeter: Configure to record current readings.

Waveform Generator: Set for a square wave with an amplitude of 1V and a frequency of 1 kHz.

The next step will be to prepare the circuit for testing. First, connect the oscilloscope to record the voltage between the V\text{OUT} pin and ground. Next, connect the positive lead of the waveform generator to the SW\text{OUT} pin and the negative to a GND pin. Finally, connect the positive lead from the DC power supply to the V\text{IN} pin and the negative lead to a GND pin. \textbf{This is extremely important. The maximum input voltage for this circuit is 16V so do not, under any circumstances, let the DC power supply exceed that voltage to the evaluation board, as it may cause irreversible damage.}

You will notice that there are several GND pins, but they are all, electrically speaking, the same point in the circuit. To make things easier, spread out the ground connections to several different GND pins. You are now ready to test your circuit.
QUESTIONS:

1) With all the variables set, as mentioned above, record the $V_{\text{MAX}}$, $V_{\text{MIN}}$, $V_{\text{P-P}}$ and the output frequency from the oscilloscope. Include a screenshot from the oscilloscope with these values displayed.

2) Now adjust $V_{\text{IN}}$. Set the DC power supply to +15V and record your observations. Did increasing the $V_{\text{IN}}$ change $V_{\text{OUT}}$? Include a screenshot from the oscilloscope with the same values displayed. Now set $V_{\text{IN}}$ back to +10V. Keep decreasing $V_{\text{IN}}$ until $V_{\text{OUT}}$ changes. At what voltage of $V_{\text{IN}}$ did $V_{\text{OUT}}$ change and how did $V_{\text{OUT}}$ change?

3) Now adjust the input frequency. With $V_{\text{IN}}$ reset to +10V, increase the frequency of the waveform generator until $V_{\text{OUT}}$ changes. At what maximum frequency did $V_{\text{OUT}}$ change and how did $V_{\text{OUT}}$ change? Now, decrease the frequency of the waveform generator until $V_{\text{OUT}}$ changes. At what minimum frequency did $V_{\text{OUT}}$ change and how did $V_{\text{OUT}}$ change?

4) Now, turn all of the equipment off and connect the $V_{\text{OUT}}$ pin and a GND pin to your circuit board with your resistor completing the circuit. Reset $V_{\text{IN}}$ to +10V and the frequency to 1 kHz (on the SWOUT pin). Connect the multimeter to measure the current flowing through the resistor. Before you actually run the experiment, what current would you expect to see with the 10Ω resistor connected in the circuit? The 100Ω resistor? The 1kΩ resistor? Now, repeat the experiment with the 10Ω resistor connected in the circuit. What is the output current with the 10Ω load resistor? Now, repeat the experiment with the 100Ω resistor connected in the circuit. What is the output current with the 100Ω load resistor? Now, repeat the experiment with the 1kΩ resistor connected in the circuit. What is the output current with the 1kΩ load resistor? Did the experimental results match your predictions? Explain any differences you might see.
5) Based on the data you have accrued, what can you say about this circuit regarding the output voltage and the maximum load current? ________________________________

6) Think like an engineer. Your company has ordered 10,000 of the LM2673S-5.0 simple switcher chips (the same chip used in this lab) to develop prototypes to show the investors. However, when the technician begins testing the chips, he finds that the output voltage was registering at approximately 3V and the load current at approximately 5A. Obviously, the manufacturer had mislabeled the chips and sent you the wrong ones. Assuming the chip is in the LM267X family, which chip do you think the manufacturer actually sent out? ________________________________

WRITTEN REPORT:
When writing the report, answer all questions posed throughout this lab.
Written Report shall include:

- Cover page
- Purpose
- Answers to questions – show all work!
- All oscilloscope snapshots
- Conclusion