PWM Sine AC/DC Inverter

Goal:

- Produce a 120V, 60Hz Sine output across any given load
- Must be Capable of Supplying Power Up to 250W
- Given DC Input of Approximately 170VDC Stepped Up From 12VDC

Strategy:

- Utilize Analog and Digital Components to Drive 2 or 3-Level PWM
- Use Low Level PWM Input to Switch High Voltage MOSFETS in H-Bridge Configuration
- Level Translation for MOSFETs Done With International Rectifier 2110 Integrated Circuit
- Filter Sine Wave to Minimize Contributions Above 60Hz
- Account for Voltage and Current Spikes Due to Inductive Loads Through Simple Snubber Circuit

Presented Information:

- Simulations of 2 and 3-Level Pulse Width Modulation
- Schematics of Analog Circuitry for PWM
- Information about IR2110
- H-Bridge and Output Circuit
- Snubber Design and Simulations for Inductive Loads

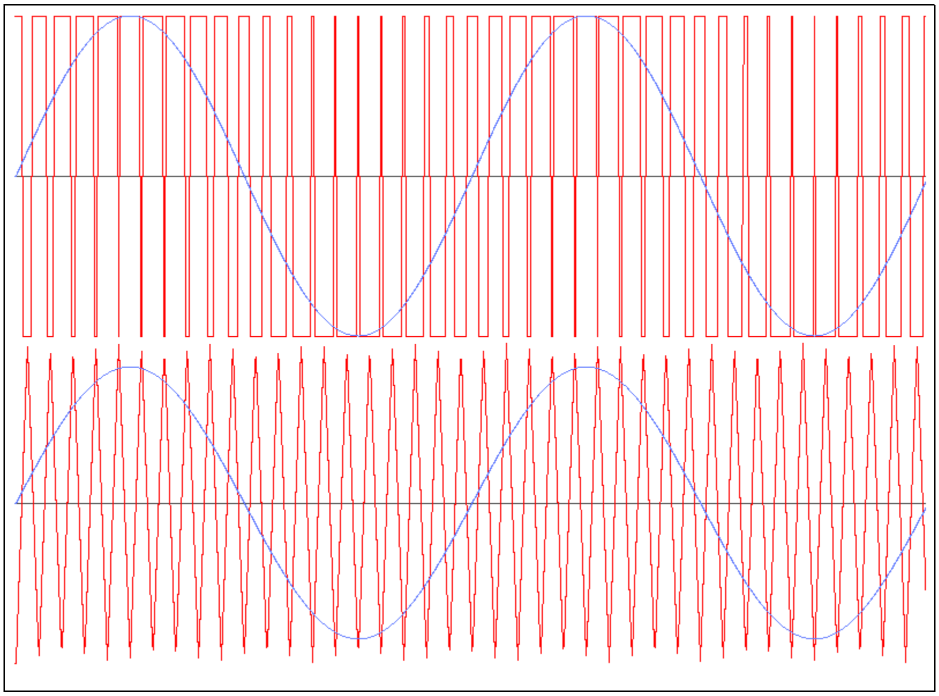

Figure 1: Bilevel PWM signal

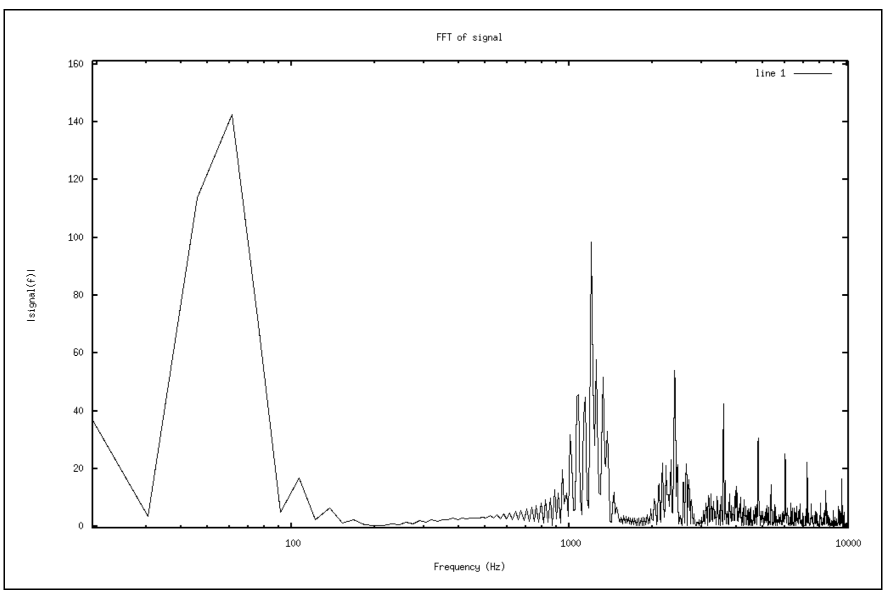

Figure 2: Bilevel PWM signal fft

These plots represent the PWM signal generated by switching the load between $\pm V_{cc}$. The drawback to this method is, as can be seen in the topmost signal, a zero output voltage is obtained with a 50% duty cycle, which means the switches are working their hardest to produce a zero output. As can be seen in the next panel, this is remedied with 3-level switching, and the fft is somewhat improved as a bonus.

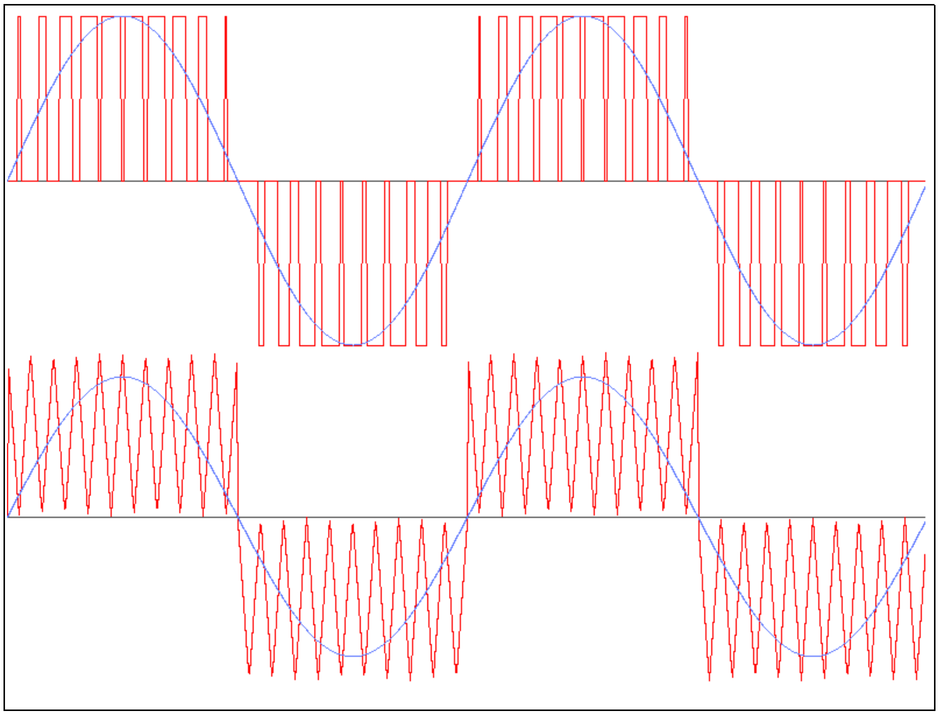

Figure 3: Trilevel PWM signal

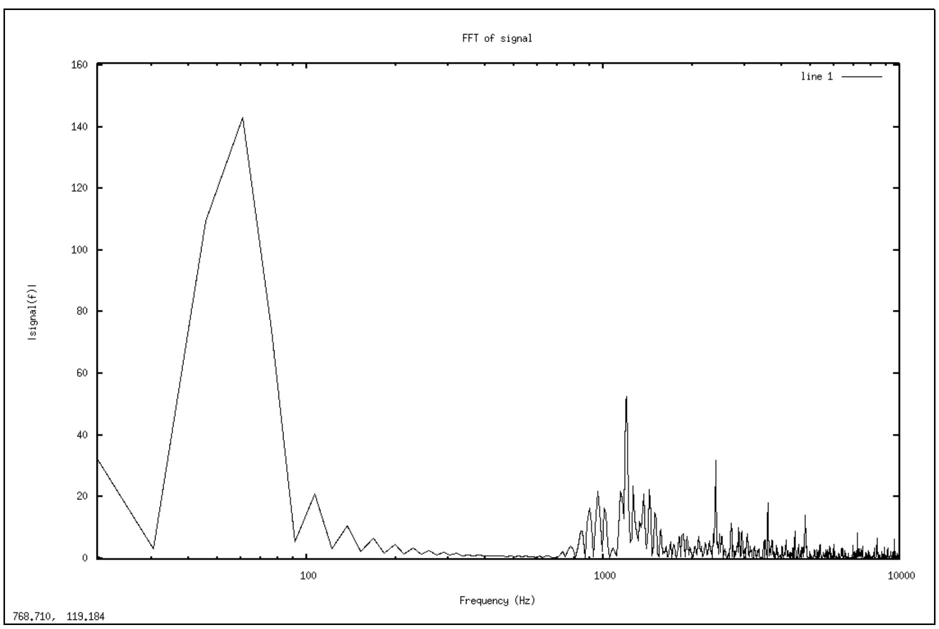

Figure 4: Trilevel PWM signal fft

These plots represent the PWM signal generated by switching the load between V_{cc} and 0 for the positive portion of the sinusoid, and switching $-V_{cc}$ and 0 for the negative portion. This attains the desired 0 % duty cycle for a zero output voltage, and decreases the switching harmonic magnitude.

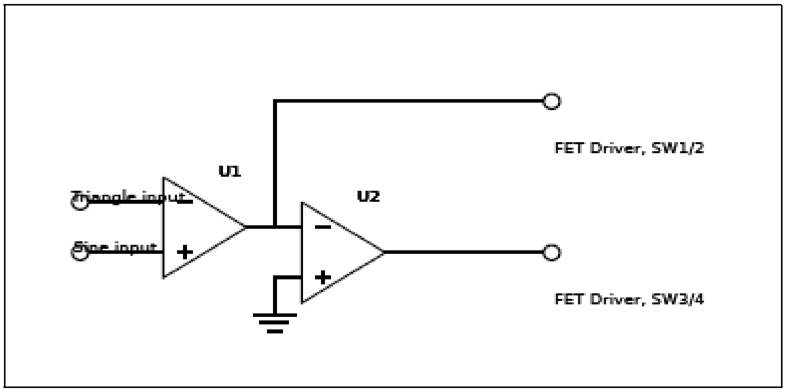

Figure 5: Bilevel PWM Controller circuit

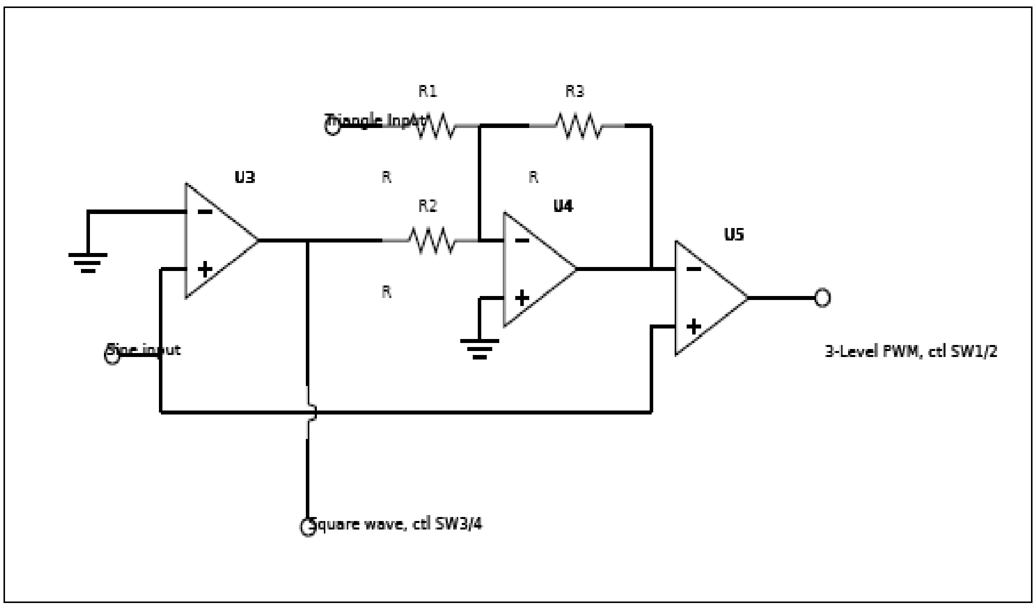

Figure 6: Trilevel PWM Controller circuit

While the bilevel circuit is self-explanatory, the trilevel one may not be. First, and opamp (U3) converts the sine input into a square wave. This square wave is added to the triangle wave input, to result in a three-level trangular wave (see three-level PWM output chart in Figure 3.) This modified triangular signal is then compared with the sine wave to obtain a trilevel PWM signal. This signal controls only two switches – the other two are controlled by the square wave generated by U3.

Driving High Side N-Channel MOSFETs

Difficulties:

- High Side N-Channel MOSFETS are Tied to Vcc in Our H-Bridge
- Driving these MOSFETS requires Vgs to be Higher than Vds Which is the Largest Voltage in Our System

MOSFET Drivers:

- Special IC's Designed to Achieve High Gate-to-Source Voltage
- Perform Level Shifting to Switch High Voltages with Low Voltage Control Signal
- Take output from PWM Stage and Control MOSFETS in Power Stage

IR2110 MOSFET Driver:

- MOSFET Driver Device from International Rectifier Chosen to Switch H-Bridge
- Each Chip Controls One High-Side and One Low-Side MOSFET
- Requires Use of Two Devices
- Floating Gate Drive Uses Bootstrapping Capacitor and Diode
- Operational up to 500V at Fast Switching Speeds

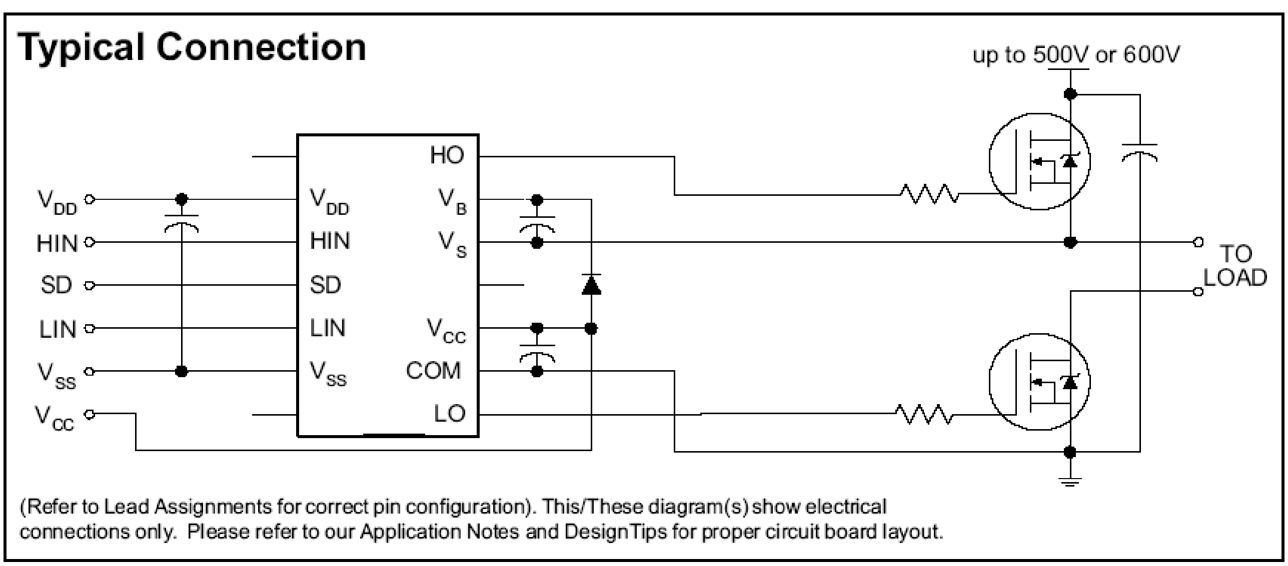

Figure 7: Typical Connection for IR2110 MOSFET Driver

H-Bridge Circuit for Output Sine Wave

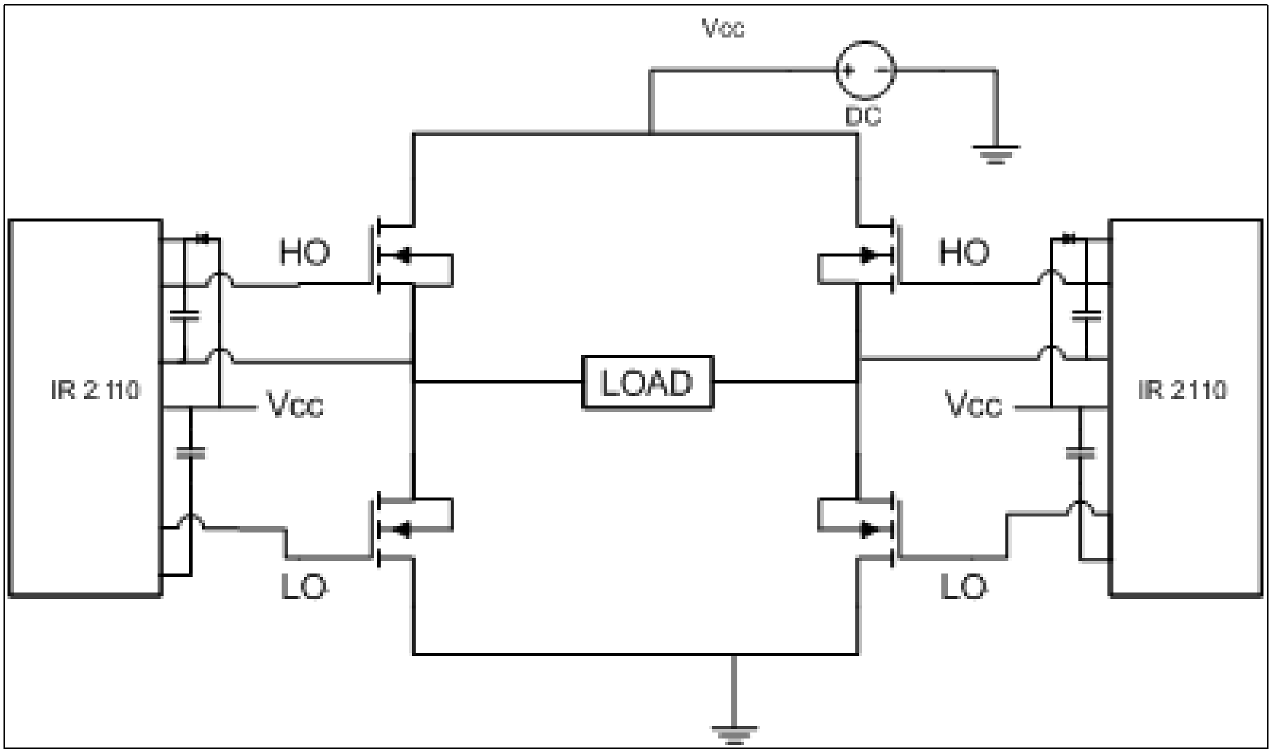

Figure 8: H-Bridge Layout Using N-Channel MOSFETs

Operation of H-Bridge Circuit:

- +170V Across Load When Switches 1 and 4 Are Driven
- 0V Across Load When Switches 1 and 2 or 3 and 4 Are Driven
- -170V Across Load When Switches 2 and 3 Are Driven

Logical Control of Switches:

- Right Side of Bridge Driven by Output of Square Wave PWM Stage
  - Determines Polarity of Output Sine Wave
  - Switched at Approximately 60 Hz

- Left Side of Bridge Driven by PWM Signal Generated
  - Determines Amplitude of Output Sine Wave
  - Switched at >> 60 Hz

Inductive Load Issues

Problem:

- When inductive loads are used the sudden turn off can cause problems with the switch
- High dV/dt, dI/dt, V and I associated with inductive loads can hurt the switch and effect its running

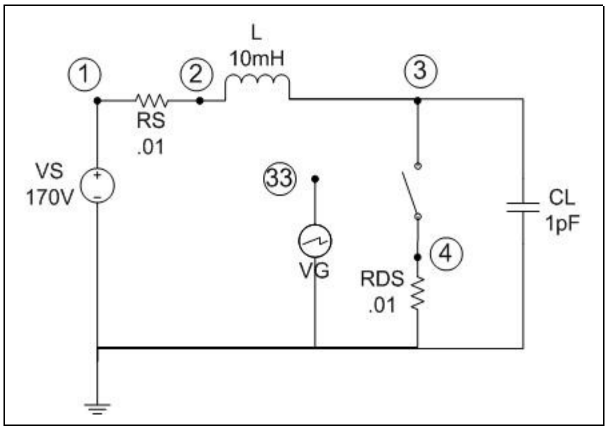

Figure 9 : Inductive Load Circuit

Example Situation:

- A power drill or vacuum cleaner is plugged into the inverter
- If unplugged while still on can cause an electric arc and if no snubber is present then a large current is run through the switches causing damage

Solution:

- A snubber circuit is simply a resistor and capacitor placed in series across a switch
- The snubber assists in reducing the transient dV/dt and dI/dt values as well as any large Voltage or currents

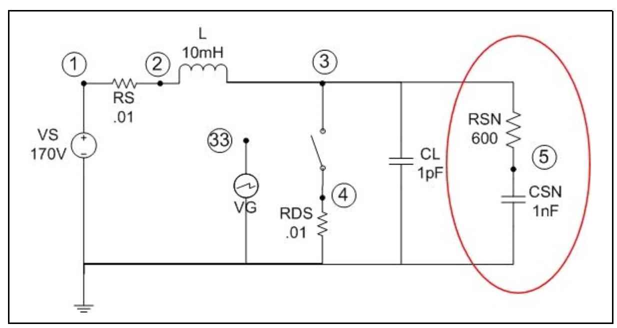

Figure 10 : Inductive Load Circuit with Snubber

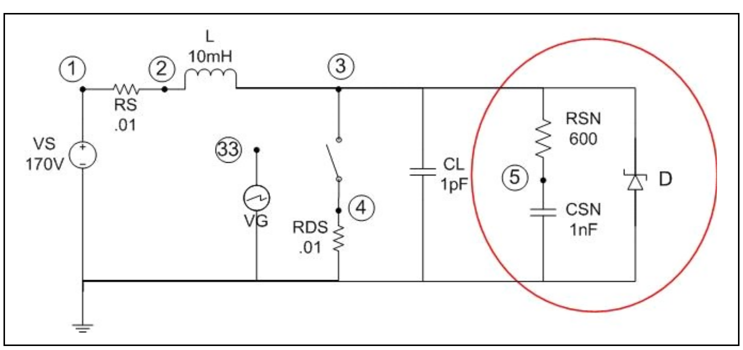

Figure 11 : Inductive Load Circuit with Snubber and Zener Diode

Even Further:

- If a Zener Diode is placed across the switch as well with a value greater then Vs it will assist even further in reducing harmful values

Simulations with and Without Snubber

These graphs come from a simulation of a switch with and without a snubber, the switching frequency set at 100kHz, and using the circuits shown under Inductive Load Issues

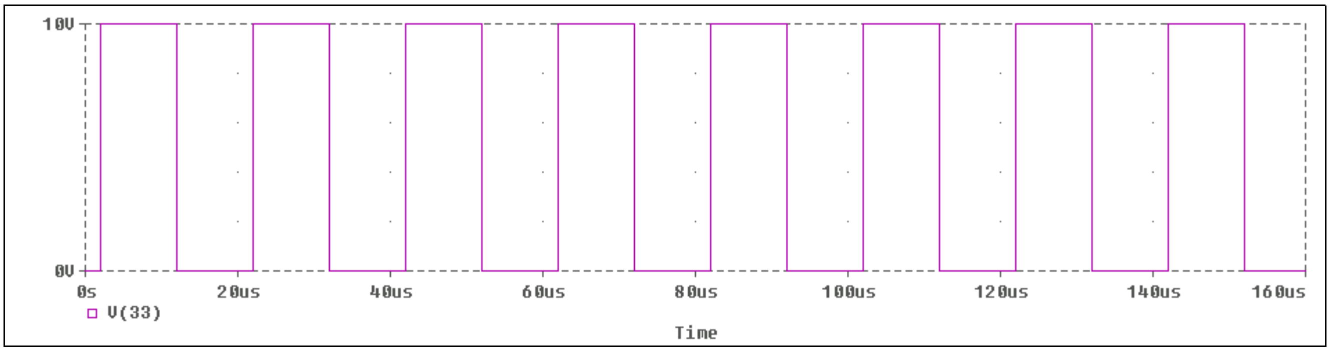

Figure 12: Switching Frequency

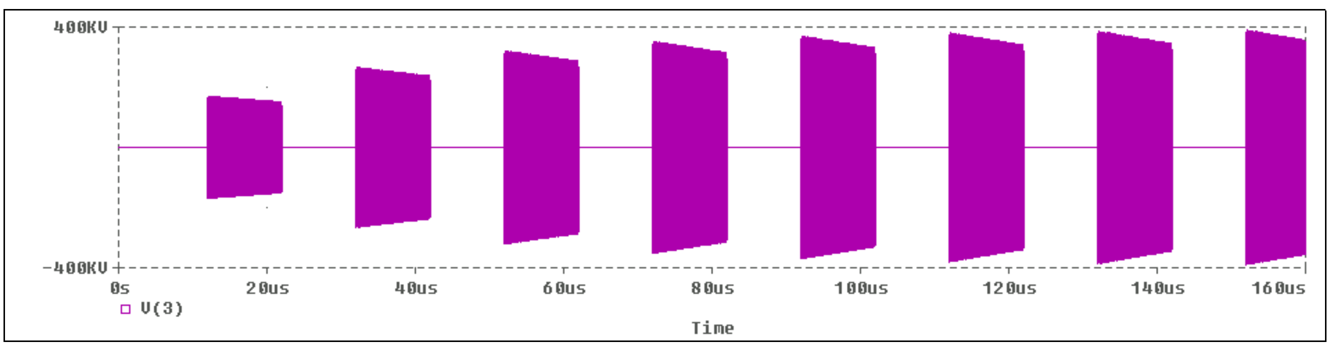

Figure 13: Voltage Across Switch (w/o snubber)

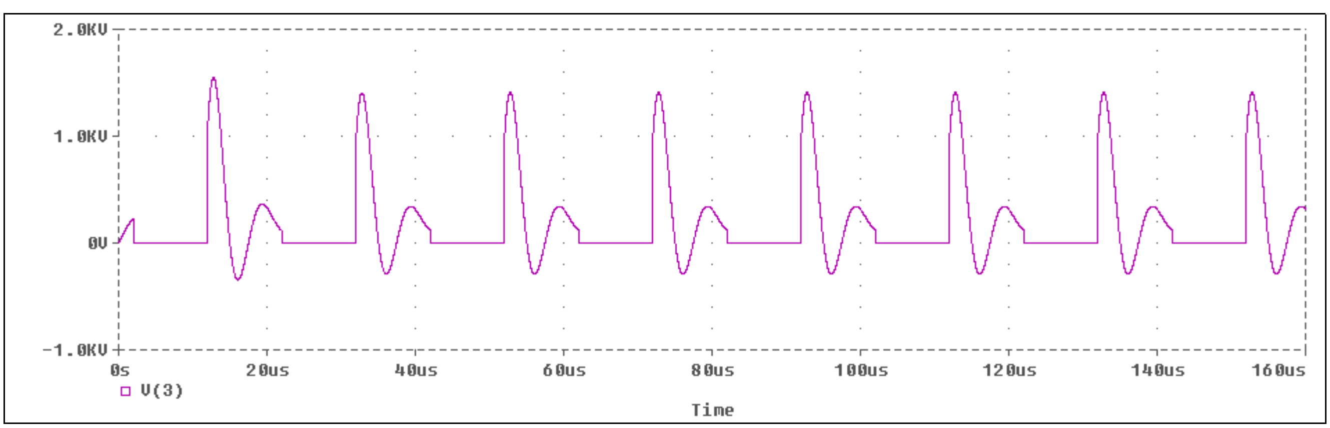

Figure 14: Voltage Across Switch (w/ snubber)

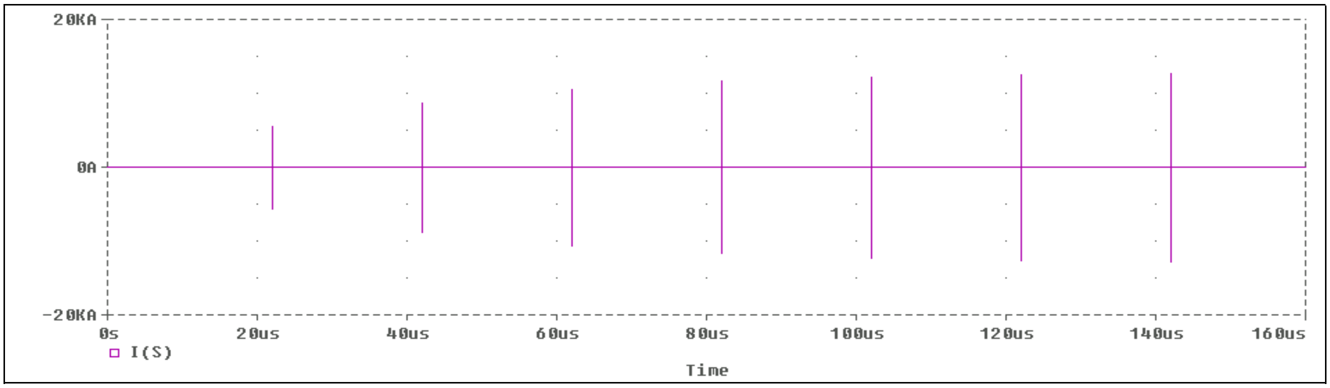

Figure 15: Current Through Switch (w/o snubber)

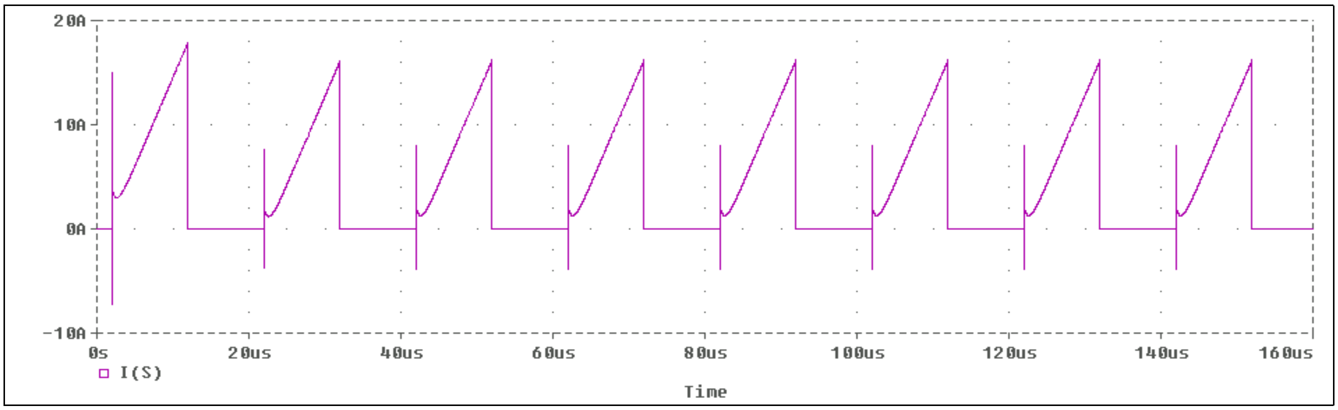

Figure 16: Current Through Switch (w/ snubber)

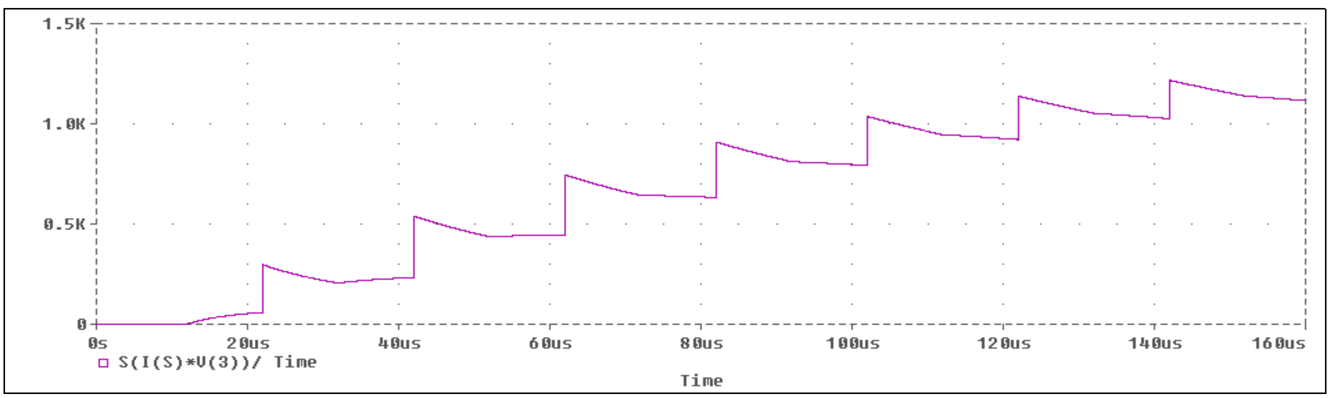

Figure 17: Average Power Dissipated in Switch over Time (w/o snubber)

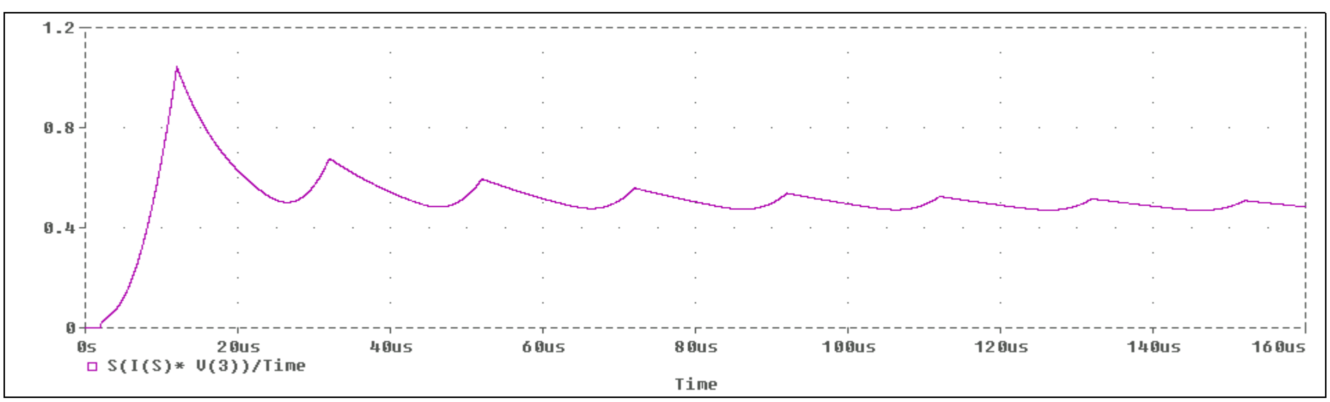

Figure 18: Average Power Dissipated in Switch over Time (w/ snubber)