EE462L – H-Bridge Controller Circuit Lab

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Lab Overview

The H-Bridge Converter is an all-purpose power converter that can handle DC-DC, DC-AC, AC-DC, and AC-AC conversion. Most frequently the H-Bridge is used as an inverter, taking a DC input and transforming that to an AC output. Through the utilization of four power electronics switches configured in an "H" pattern, it can create a nearly sinusoidal output waveform. The H-bridge achieves this through a process called pulse width modulation. Pulse width modulation is a process where a control signal is compared to a known periodic signal, such as a square or triangle wave, and when the control signal is higher than the known periodic signal, the output waveform is high. When the control signal is lower than the known periodic signal, the output waveform is low. With a sinusoidal control signal, pulse width modulation results in square waves with different widths that are proportional to the sinusoidal control signal's amplitude. In order to achieve pulse width modulation, a known periodic signal must be created and used to compare against the control signal. The H-bridge controller circuit built in this lab provides that function and other functions such as the H-bridge switching controls.

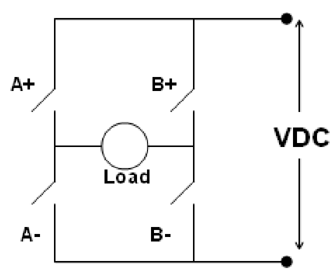


Fig. 1. H-Bridge inverter/amplifier circuit made from four MOSFET switches. Freewheeling diodes are not shown. [1]

H-Bridge Gate Control Circuit

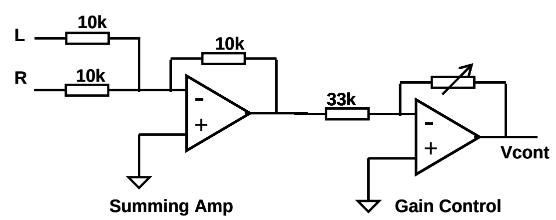
The purpose of this lab is to build and test the gate control circuit for a H-Bridge inverter/amplifier. This circuit is used to generate the gate signals for the four mosfet switches of Fig. 1. The A+ and A- mosfets are switched with a signal VA and its inverse. When VA is high A+ is on, and A- is off. Similarly, the B+ and B- mosfets are switched using a signal VB and its inverse.

The signal VA is the output generated by feeding a low frequency control signal Vcont and a high frequency triangular wave Vtri into a comparator. It is important to note that the frequency of Vtri needs to be much greater than the frequency of Vcont for proper filtering of the H-Bridge output signal. When used as an inverter, the frequency of Vcont is the desired frequency of the ac output of the H-Bridge inverter. This is typically 60 Hz. The output of the comparator used in this circuit switches between +12V and -12V.

The signal VB is similarly generated by feeding the negative -Vcont, of the control signal, and the same triangular wave to a comparator.

Fig. 1 shows a schematic of the circuit used to generate Vcont from a stereo signal. The left and righ channel signals are summed using a op amp summing amplifier. The summed signal is then attenuated or amplified further using a second op amp. The negative of Vcont (i.e. -Vcont) is generated using an op amp in inverting amplifier configuration with gain of 1.

The triangular wave is generated by using a NTE864 precision waveform generator chip. The frequency of the triangular wave is determined by a timing capacitor Cf. In this circuit a Cf of 1.5nF was used, which produced a triangular wave of frequency 139 kHz.



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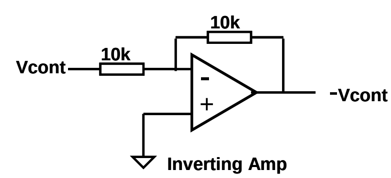

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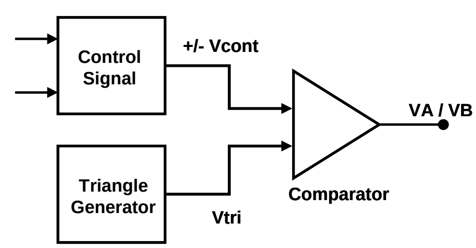


(c)

Figure. 2. (a) Schematic of circuit used to generate the control signal Vcont for the H-Bridge gate controller. (b) Schematic of circuit used to generate the negative image of Vcont. (c) Block diagram of gate drive circuit.

H-Bridge Controller Measurements

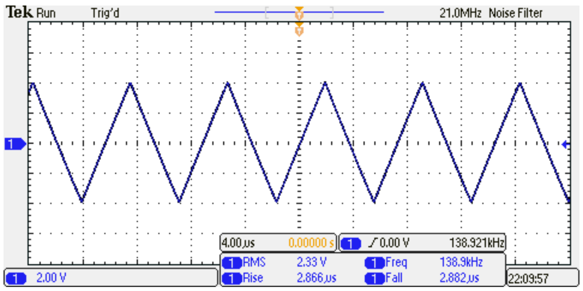


Figure. 3 Measured triangular signal Vtri. The frequency of the signal is 139 kHz.

Fig. 3 shows the measured triangular wave Vtri with a 1.5nF timing capacitor. The skewness pot of the waveform generator chip is adjusted such that the rise and fall times of Vtri are equal to the first decimal place. The ZeroDCOffset pot on the PCB is also adjusted such that the dc value of Vtri is 1 mV.

For purposes of testing, the control signal is obtained from an ac wall wart. This generates a 60Hz signal which is fed into the "left" channel of the control circuit. By adjusting the gain potentiometer shown in Fig. 2 the RMS value of Vcont is set to be 2.01V. Fig. 4 shows the measured Vcont and -Vcont waveforms.

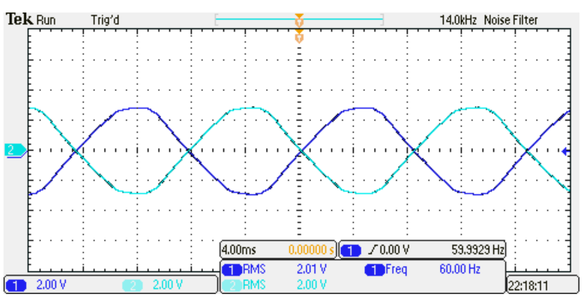
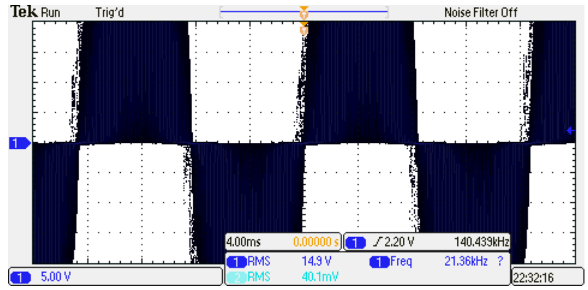


Figure 4. Measured control signals Vcont and -Vcont obtained from wall wart output. The frequency is 60Hz and the rms value is 2.01V.

As described previously, the H-Bridge gate control signals VA and VB are obtained, respectively, by feeding Vcont and Vtri and -Vcont and Vtri to a comparator.



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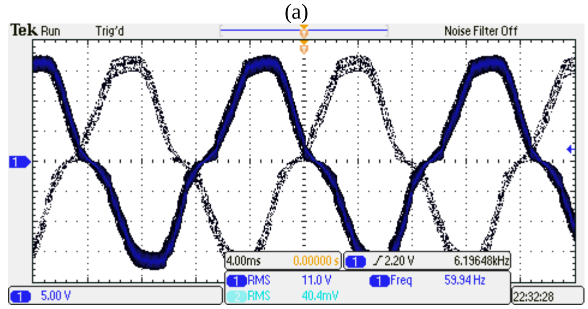
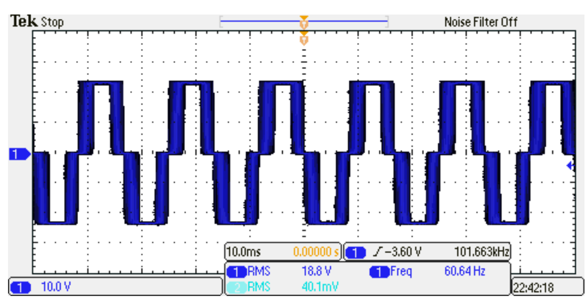


(b)

Figure 5. (a) Unfiltered waveform VAB and (b) filtered version of waveform VAB. The fundamental frequency is about 60 Hz.

Fig. 5(a) shows the resultant VAB (=VA-VB) signal. It is impossible to discern the PWM nature of the waveform at this timescale due to the very large difference in the frequencies of Vtri and Vcont, but it is evident that the signal has a fundamental frequency of about 60 Hz. Fig. 5(b) is the same signal passed through the scope filter. With the higher harmonics removed the signal begins to resemble Vcont.

Next, the effect of increasing the amplitude of Vcont to the point where it exceeds the amplitude of Vtri is examined. Fig. 6 shows the measured unfiltered and filtered VAB waveforms under these overmodulated conditions ($m_a > 1$). As expected from theory, the peaks of VAB are clipped and a shoulder appears near the zero-crossings.



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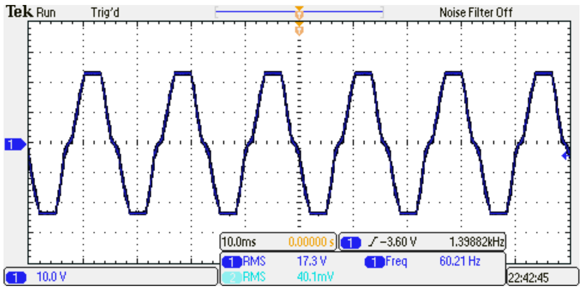


(b)

Fig. 6. (a) Unfiltered waveform VAB under overmodulation conditions and (b) filtered version.

In order to examine the frequency content of VAB an FFT of the VAB waveform was captured in the linear modulation region. Fig. 7 shows the resultant spectrum.

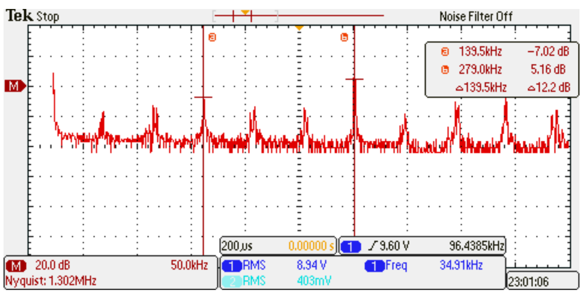
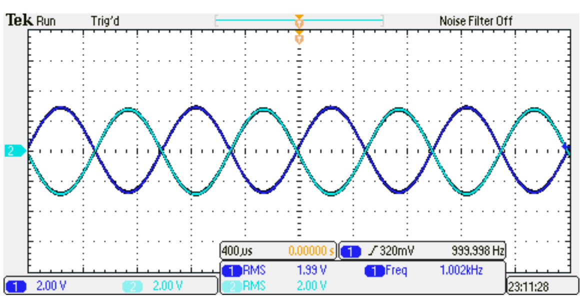


Figure 7. FFT of VAB signal in the linear region.

It can be seen from Fig. 7 that the non-ideal 139.5 kHz peak is about 12 dB below the first ideal peak at 279 kHz. That corresponds to a factor of about 4.

Lastly, the effect of increasing the frequency of the control signal Vcont is examined. Fig. 8 shows a 1 kHz Vcont control signal and the corresponding filtered VAB output waveform. Fig. 9 shows the same signals at a frequency of 10 kHZ.



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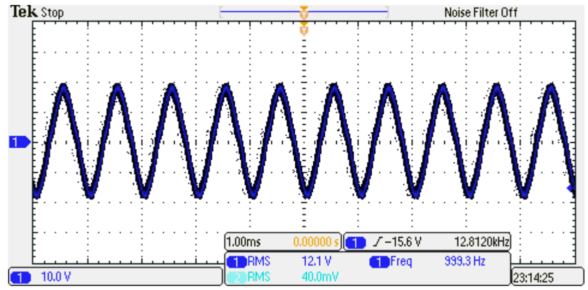

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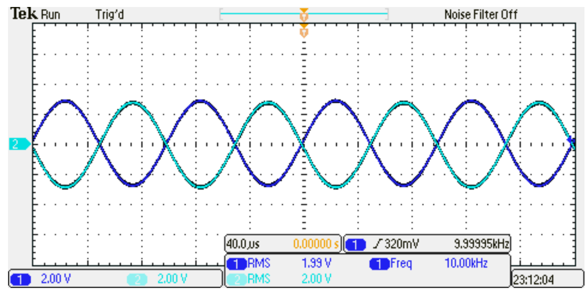
Figure 8. Vcont and VAB waveforms taken at 1 kHz frequency.



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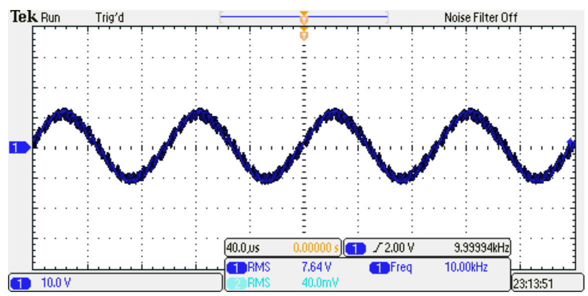


(b)

Figure 9. Vcont and VAB waveforms taken at 10 kHz frequency.

The output signal VAB at these frequencies are reasonably similar to the respective control signals. At 10 kHz there is some evidence of high frequency harmonics even in the time domain data of Fig. 9(b). This could be due to mixing of Vcont and Vtri since their frequencies are now less separated than in the other cases and also possibly due to the oscilloscope filter not having a sharp enough cut-off.

Conclusions

The H-Bridge controller circuit provides all the necessary components for the H-bridge to properly function, except for the MOSFETs themselves and the direct MOSFET support circuitry. The controller circuit takes the input control signal, inverts it and uses both the original and inverted signal compared to a triangle signal to provide the pulse width modulation for the H-bridge. These pulses directly correspond to certain MOSFETs being turned on or off will provide the load with a sinusoidal like signal with harmonics in high frequencies that can be eliminated by using a low pass filter. Without pulse width modulation, the harmonics would not be pushed out to higher frequencies and it would be difficult to filter out the harmonics without losing the fundamental signal.

	Rounok	Jonathan
Circuit Build	50%	50%
Circuit Testing	50%	50%
Lab Report	50%	50%

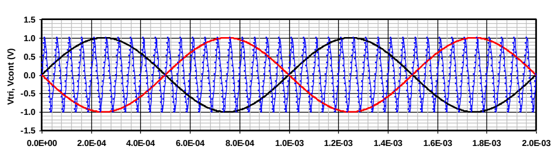
References

[1] M. Flynn, "_Lab_Week_9_EE462L_PWM_Inverter_Control_Circuit.pdf", The University of Texas at Austin, Austin, TX, EE 462L: Power Electronics Laboratory course, Spring 2015, slide 15. [Online]. Available: https://utexas.instructure.com/courses/1129504

APPENDIX

In order to better study the generation of the complex PWM gate drive signals and the properties of the H-Bridge output signal, an Excel spreadsheet was constructed. By changing the inputs in this spreadsheet the ideal theoretical relations between the various signals can be observed more closely.

Since Excel does not have a built-in triangular function, Vtri was constructed by summing the first 9 sine wave harmonics of a periodic triangular signal.



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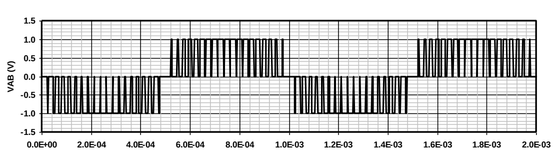

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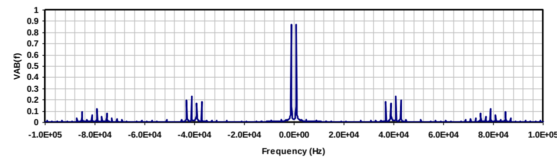

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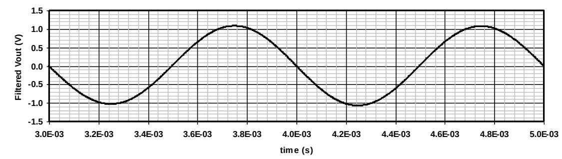

(d)

Figure 10. Various H-Bridge waveforms as simulated in Excel. (a) The triangular wave (20kHz) and the sinusoidal control signals (1 kHz). (b) The difference VAB between the comparator outputs from the positive and negative control signals. (c) The double-sided FFT of VAB. (d) Inverse FFT after passing VAB through a low-pass filter with 1.1kHz cut-off frequency.

Fig. 10 shows the various simulated waveforms. For the results shown a frequency of 20 kHz was used for the triangular wave and 1 kHz for the control signal. Equal amplitudes were used for both triangular and control voltage signals (i.e. modulation index = 1). The simulation was performed till 8.2 ms with a timestep of 2 μs. Excel's built-in Fourier Analysis tool was used to observe the harmonics of VAB, as shown in Fig. 10(c). A 2-sided FFT is shown. As expected from theory, there is a strong signal at 1 kHz which is the frequency of Vcont in this simulation, plus harmonic clusters around even multiples of the triangular wave frequency.

The frequency domain signal was passed through an ideal low-pass filter with a cut-off frequency of 1.1 kHz. Phase of the filter transfer function was ignored to keep the simulation simple. Taking the inverse FFT of the filtered signal results in a very clean output that is a replica of the control sine wave in time domain, as shown in Fig. 10(d). By increasing the DC voltage supply to a H-Bridge the amplitude of VAB can be increased, which will result in an amplified version of the control signal at the output.