Induction Heater with Variable Power Output
SLG47105

This application note describes how to create an induction heating device using HVPAK. In addition, the device has four power modes which make it versatile for various tasks, whether it's heating a cup of water or scalding a bolt. The application note comes complete with design files which can be found in the Reference section.

Contents

1. Terms and Definitions

DC   Direct current

DFF   D Flip-Flop

HV   High voltage

LUT   Look-up Table

OSC   Oscillator

2. References

For related documents and software, please visit:

https://www.renesas.com/eu/en/products/programmable-mixed-signal-asic-ip-products/greenpak-programmable-mixed-signal-products/greenpak-high-voltage-programmable-mixed-signal-matrix

Download our free GreenPAK Designer software [1] to open the .gp files [2] and view the proposed circuit design. Use the GreenPAK development tools [3] to freeze the design into your own customized IC in a matter of minutes. Renesas provides a complete library of application notes [4] featuring design examples as well as explanations of features and blocks within the Renesas IC.

[1] GreenPAK Designer Software, Software Download and User Guide

[2] AN-CM-353 Induction Heater with Variable Power Output.gp, GreenPAK Design File

[3] GreenPAK Development Tools, GreenPAK Development Tools Webpage

[4] GreenPAK Application Notes, GreenPAK Application Notes Webpage

[5] SLG47105 Datasheet

3. Introduction

The main goal of this application is to design an Induction Heater device using the SLG47105V. The system is designed using the HVPAK macrocells and other internal and external components within the HVPAK to drive two powerful N-MOSFETs to control the Induction Heater.

The proposed Induction Heater has four power control modes, these modes are switched with a push button starting from the lowest power mode.

Induction heating is used in induction cooktops, many industrial processes, such as heat treatment in metallurgy, Czochralski crystal growth, and zone refining used in the semiconductor industry, and to melt refractory metals that require very high temperatures. It is also used in medicine from heating scalpels in surgery to hyperthermia for cancer treatment.

4. Operating Principle

An induction heater is a device that uses a high-frequency magnetic field to heat an iron load or any ferromagnetic metal through an eddy current.

During this process electrons inside metal are unable to move as fast as the frequency, and this leads to the rise of a reverse current in the metal termed an eddy current. This development of a high eddy current ultimately causes the iron to heat up.

The above heat is also directly proportional to the induced frequency and that's why ordinary iron stamped transformers are not used in high-frequency switching applications, instead, ferrite materials are used as cores.

The SLG47105 sets the frequency of 198 kHz of the attached coil and capacitor quite identical to a tank circuit resonant frequency ensuring a permanent resonance effect being induced across the LC circuit. The attached coil is shown in Figure 1. It has 10 turns of wire with a diameter of 2 mm. The capacitance in parallel is 660 nF. Also, the SLG47105 allows to use of other types of coils with other sizes as the frequency can be easily changed. The main thing is to correctly calculate the resonant frequency of the LC tank.
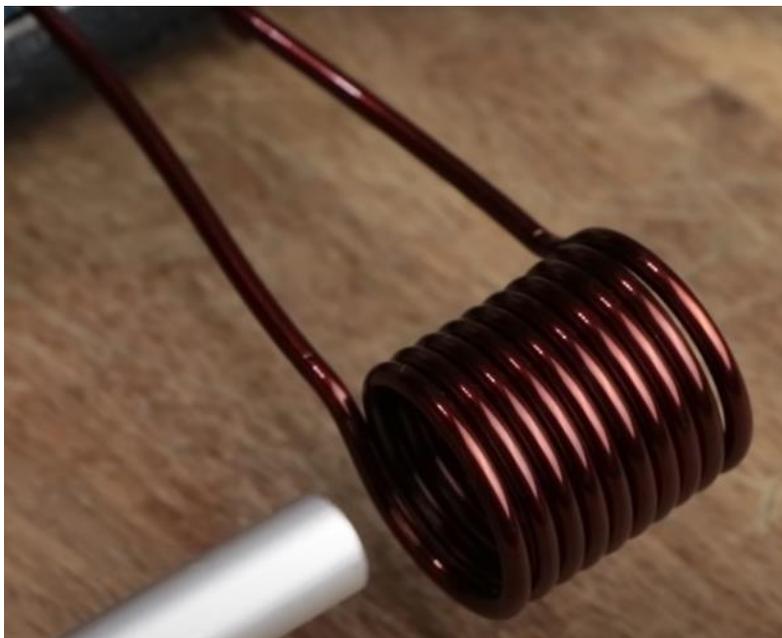
Figure 1: Main Heater Coil L1

At resonance frequency we can expect the amplitude of the voltage oscillating across the LC circuit to be at the maximum level, resulting in the most efficient induction.

The Full Circuit Schematic is shown in Figure 2.
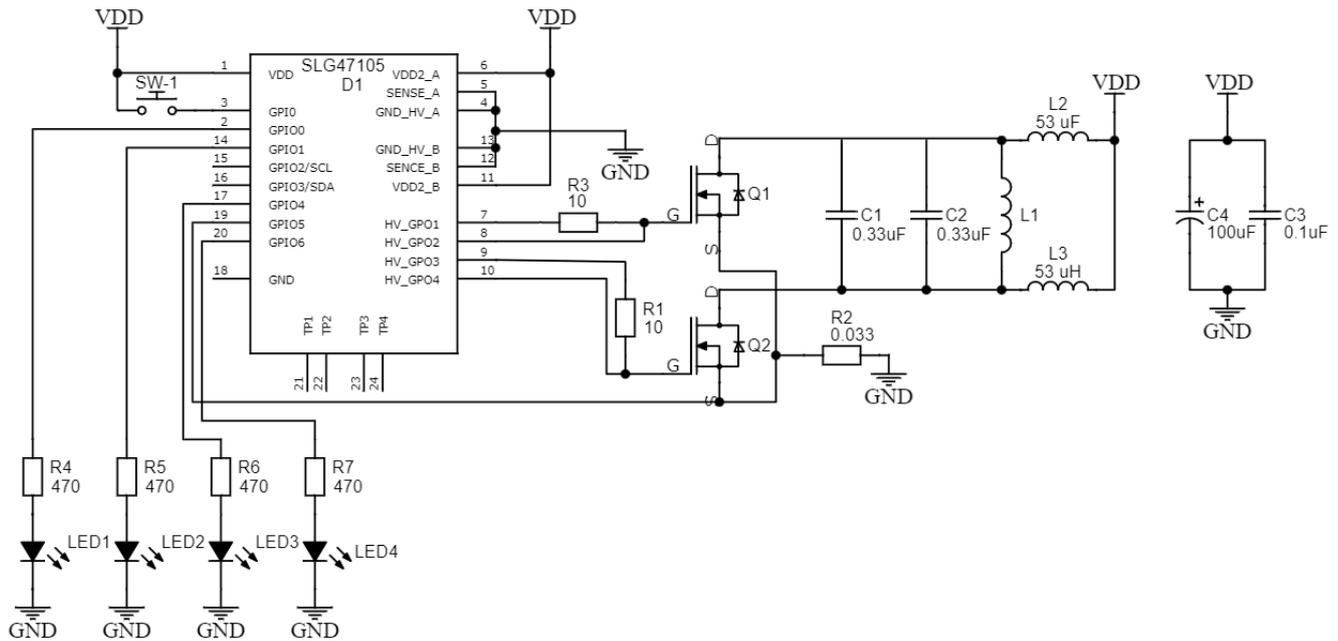
Figure 2: Full Circuit Schematic

The supply input voltage in this project is 12 V, and the current can range to 10 A depending on the load. The circuit has two states that change alternatively with a maximum transition rate. In each state, one transistor is switched on and the other is switched off. The transistors in this circuit are IRF3205 MOSFETs with heatsinks. However, any other appropriately rated N channel MOSFETs can be used, there are no specific restrictions for this.

Inductors L2 and L3 are associated with the main heater coil (work coil). L1 is kind of a choke that helps eliminate any possible entry of the high-frequency content into the power supply. It also restricts the current to safe limits. These inductors must be built using high gauge wires for facilitating a high current range through it safely.

The Induction Heater device has four modes that are switched by a push button, SW-1. LED1-LED4 notify which mode is selected.

The resistor R2 is current feedback to avoid overcurrent.

# 5. GreenPAK Design

The GreenPAK design is shown in Figure 3.
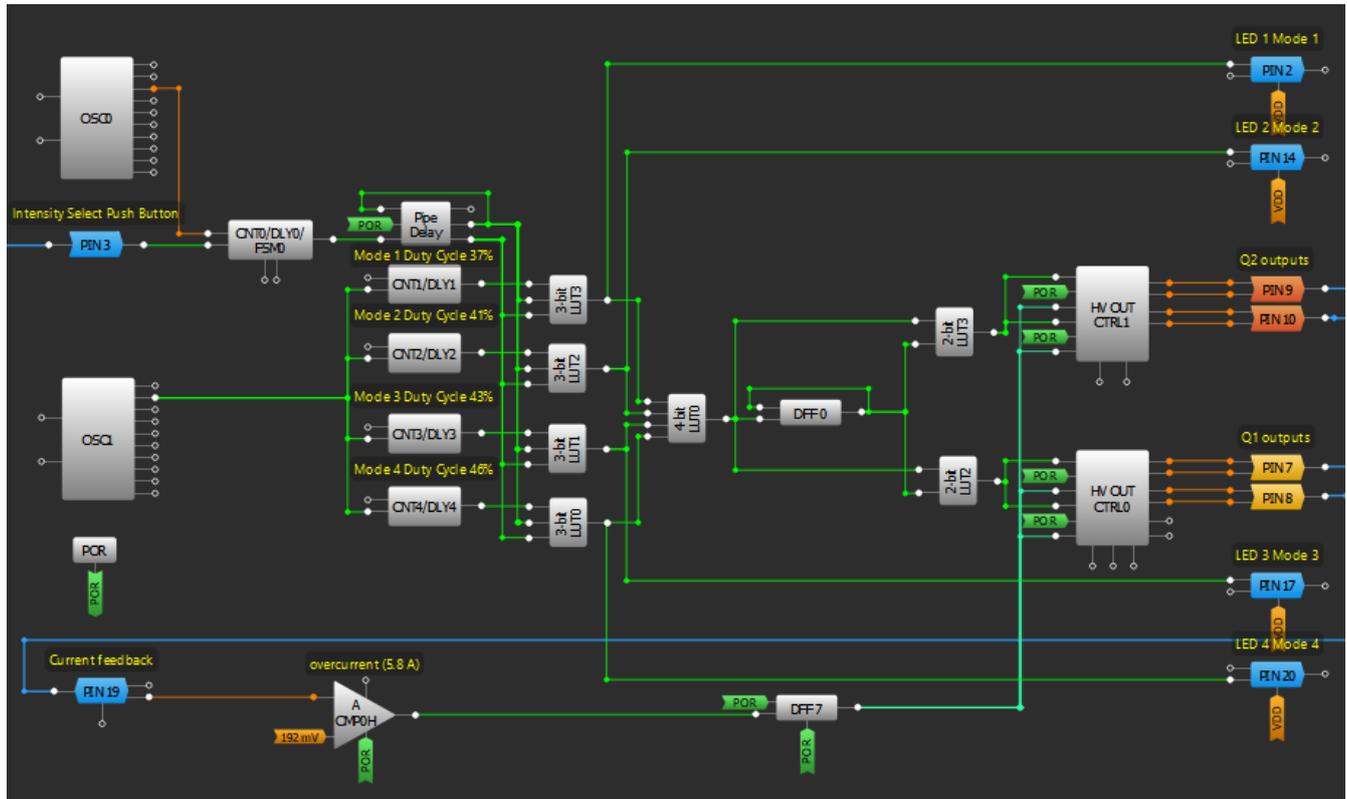
Figure 3: GreenPAK Design

The CNT/DLY1-CNT/DLY4 macrocells provide a 400 kHz signal with a certain duty cycle which goes to DFF0. The 3-bit LUT0-LUT3 and 4-bit LUT0 perform signal selection functions depending on the enabled mode. On the 2-bit LUT3 and 2-bit LUT2 stage, we have two ~198 kHz signals with a certain duty cycle (necessarily less than 50%) shifted in phase by half a period. Thus, we ensure that the transistors will work strictly in sequence. Then, one signal goes to the HV OUT CTRL0 and the other to the HV OUT CTRL1. They are both configured as Half Bridge. The output modes of PIN9 and PIN7 are configured as HIGH and LOW sides. These PINs are connected to gates of corresponding transistors through 10 Ω resistors. The output modes of PIN8 and PIN10 are configured as LOW sides and connected directly to gates of transistors to reduce the "switched OFF" time and to ensure that two transistors will not be ON simultaneously.

The ACMP0 compares the drop voltage on the resistor R2 (33 mΩ) with the constant Vref voltage. If the current is higher than 5.8 A then the Sleep inputs of HV OUT CTRLs are constantly HIGH and the device is cut OFF until the reload. The Vref value can be changed due to project purposes.

6. Device Testing

The following Figure 5, Figure 6, Figure 7, and Figure 8 show the resulting signals on the gates of transistors Q1 and Q2.

The current through the coil for each mode without load and with a load of a steel bolt of 6 mm (Figure 4):

Mode 1 (duty cycle 37%): current without load – 0.34 A, current with a load – 0.4 A.

Mode 2 (duty cycle 41%): current without load – 0.56 A, current with a load – 1.2 A.

Mode 3 (duty cycle 43%): current without load – 0.92 A, current with a load – 3.1 A.

Mode 4 (duty cycle 46%): current without load – 1.15 A, current with a load – 5.4 A.
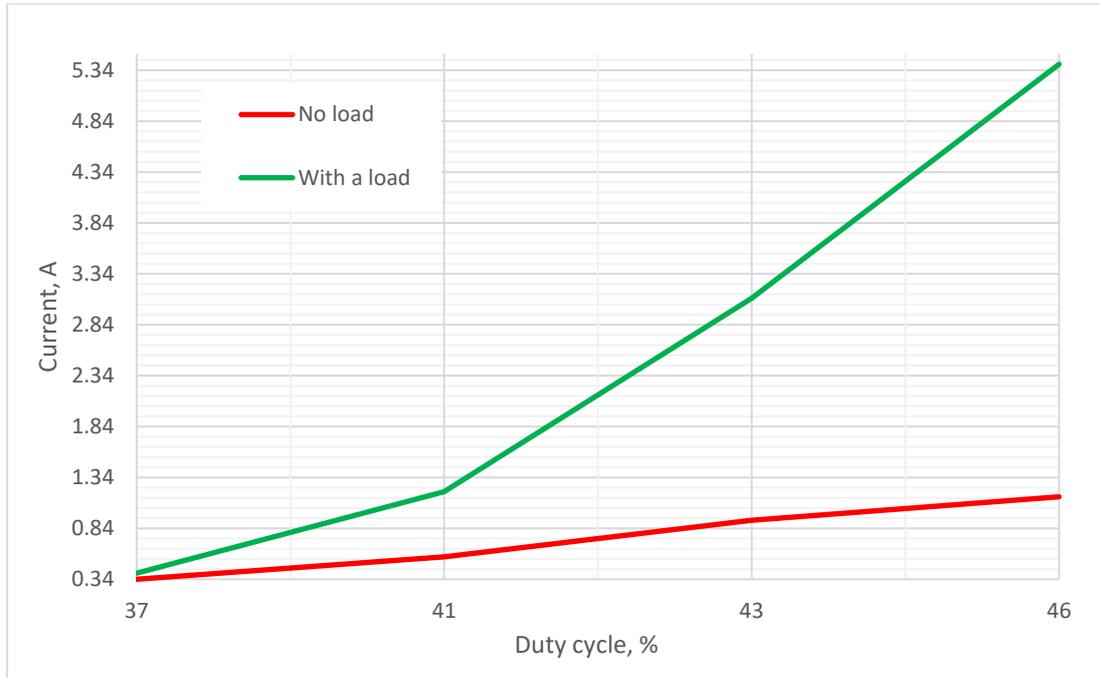
Figure 4: Current vs. Duty Cycle
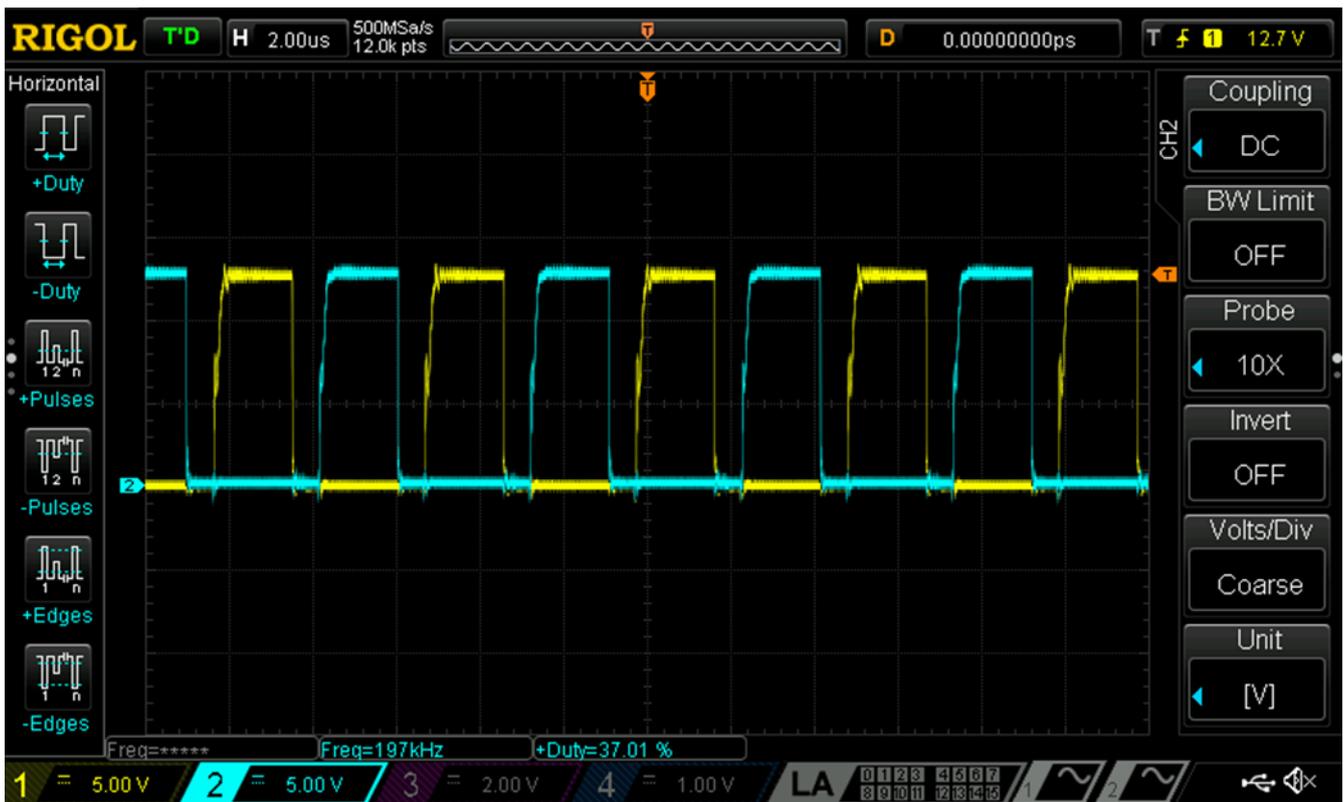
Figure 5: Mode 1 Duty cycle ~ 37%
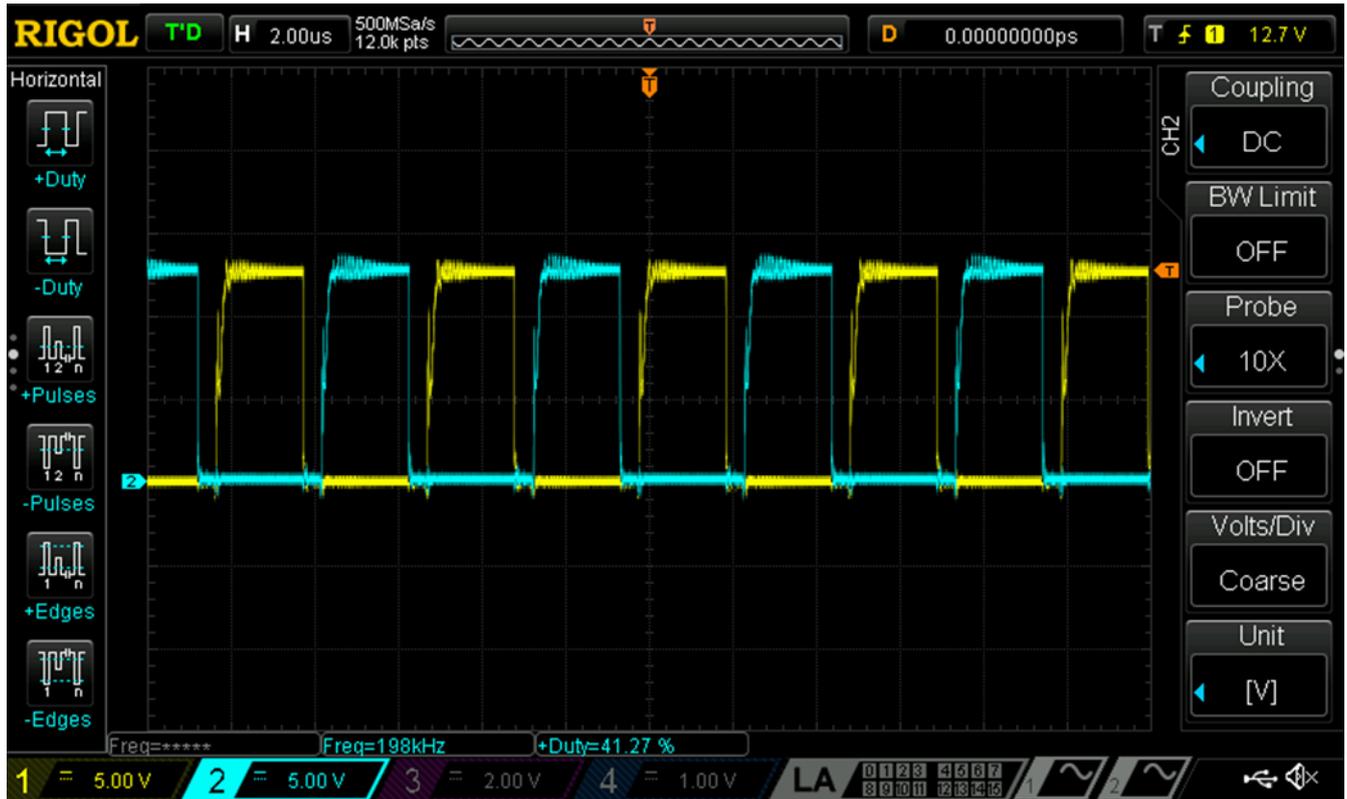
Figure 6: Mode 2 Duty cycle ~ 41%
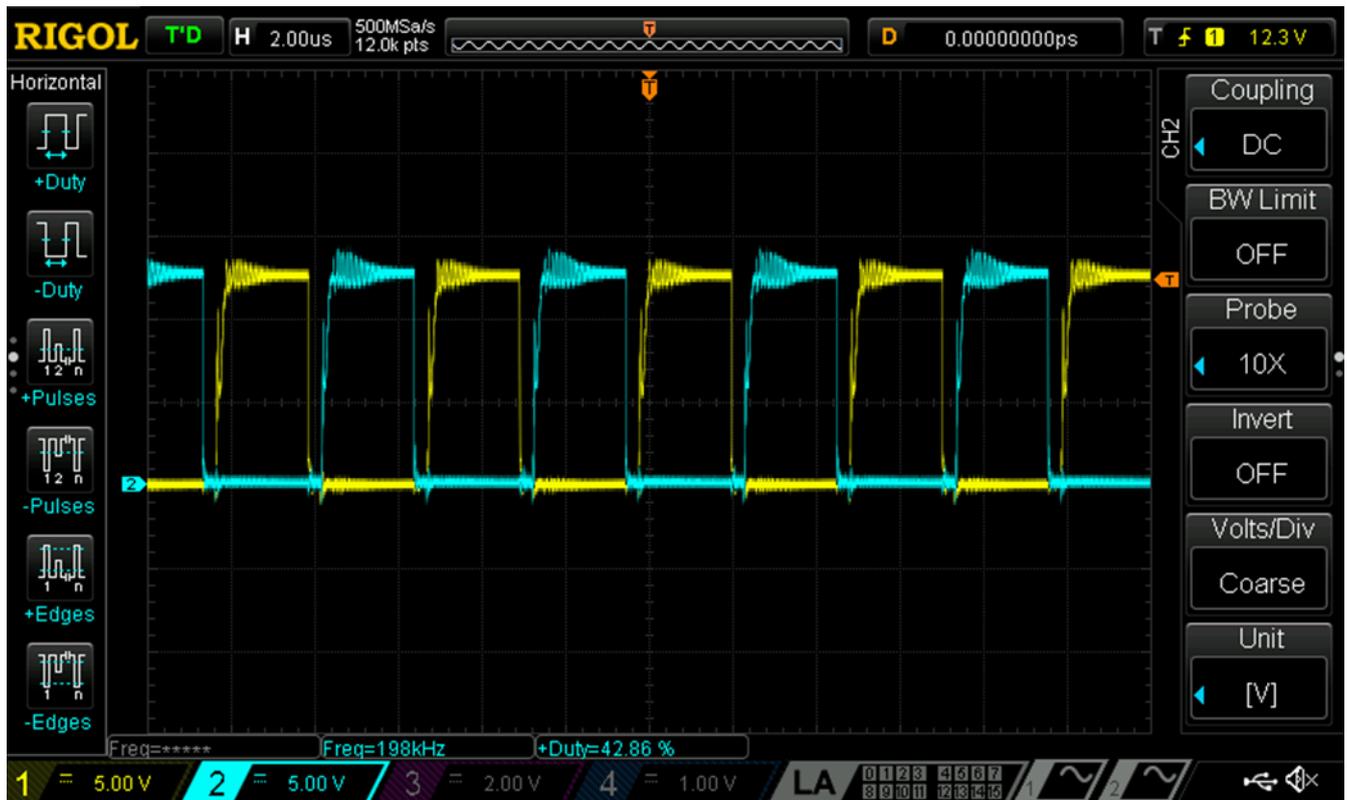
Figure 7: Mode 3 Duty cycle ~ 43%
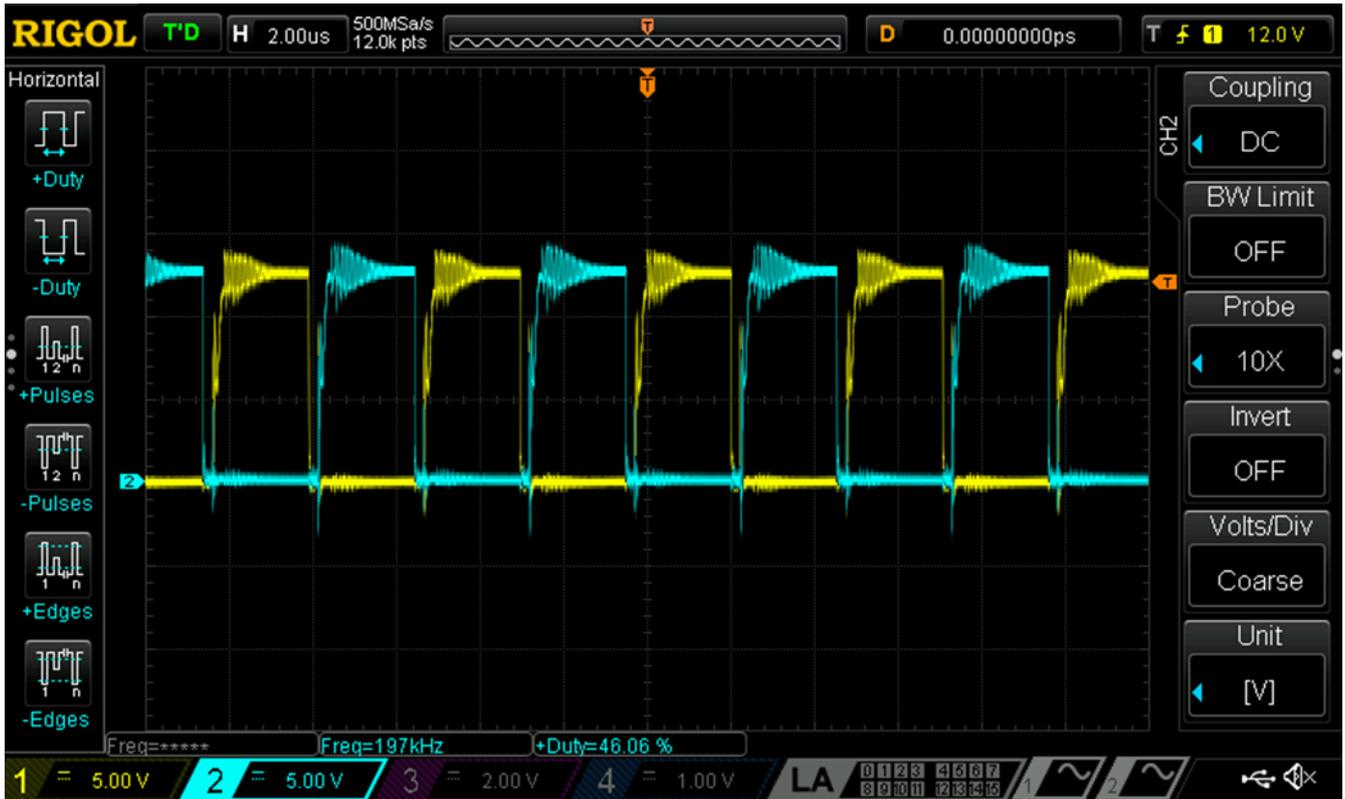
Figure 8: Mode 4 Duty cycle ~ 46%

7. Conclusion

The application note describes how to configure the HVPAK to create an Induction Heater. The results prove that the circuit works as expected, and the HVPAK is capable of acting as the control module for the powerful N-MOSFETs.

The Induction Heater has four modes for selecting the desired power of a device.

The HVPAK's internal resources, including the HV, oscillators, logic, and GPIOs are easy to configure to implement the desired functionality for this design.

8. Revision History

Revision	Date	Description
1.00	Oct 3, 2022	Initial release.

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