International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2015): 6.391

Hardware System of Mono Switch Resonant Inverter for Induction Heating

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Abstract: ***This paper presents a mono switch resonant DC – AC high-frequency converter for induction heating. In this, the inverter operated with variable switching frequency. Zero Voltage Switching frequency has been implemented to achieve higher efficiency. The converter output power can be controlled by the programmable PWM switching of the mono switch. The proposed method is more reliable for low power induction heating applications than the high power heating applications. The configuration of inverter is simulated in multi-sim environment and validated with experimental results. The experimental results are good agreement with simulation results.***

Keywords: Mono switch resonant inverter, Induction heating, ZVS operation, Operational Amplifier (OPA), Touch Sense Input (TSI) and Programmable PWM

1. Introduction

Heat energy is essential for the human beings. There are several ways of obtaining this heat energy. The efficient and nonpolluting way of achieving the heat energy is through electrical power. Induction heating is the one of the electric heating among the conventional electrical heating methods. Induction heating has several applications such as induction cooking, metals heating, annealing, and hardening, etc. Induction heating requires high-frequency AC supply of 20 kHz to 400 kHz. The selection of frequency depends upon the type of application. Nowadays there have been lot developments in semiconductor technologies and converter configurations. It is enabling the use of power semiconductor devices such as MOSFETs and IGBTs for higher frequency level operations with lower power losses. In induction heating, eddy currents are generated in the load by high-frequency magnetic flux linkage with it based on Faraday's law of electromagnetic induction principle [1]. In the conventional electric heating methods, the heat transferred to the load by conduction or radiation. In induction heating, the temperature is raised directly inside the load due to the eddy currents. The depth of penetration of eddy currents is skin depth (δ) level in the load [2] given as follows

$$\delta = \sqrt{(\rho/\mu\pi f_s)} \quad (1)$$

Where ρ is electrical resistivity, μ is magnetic permeability of load material, and f_s is the switching frequency of the converter circuit.

Generally Quasi-resonant inverter, half-bridge inverter, and full-bridge inverter topologies are used in induction heating applications. Out of these, the full-bridge inverter has become the favored topology due to the supply of peak to peak voltage across the load, which is the double that of the source voltage.

2. Power Block diagram

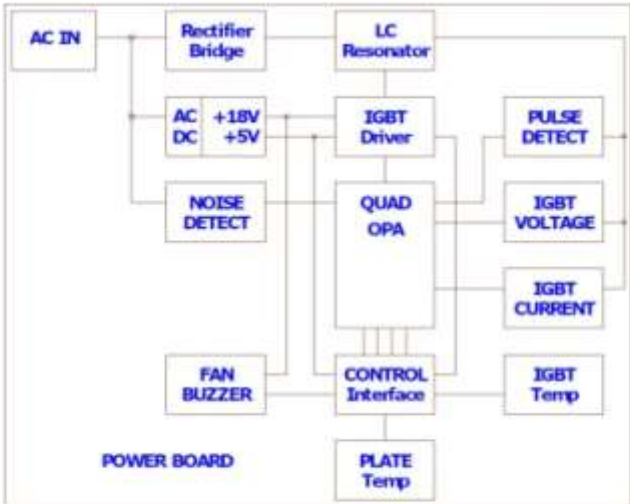

Figure 1: Power block diagram of Mono switch resonant converter

Fig.1 shows the power block diagram. On the power circuit, the AC input is converted to around +310 V by the bridge rectifier and regulated to +18 V and +5 V in the AC-DC module [8]. The LC resonator is powered from the +310 V source to generate the magnetic field for heating. +18 V is used to power the LC resonant IGBT driver circuit and the cooling fan. The +5 V is the main supply for the whole system [8]. The Operation Amplifier is used to form the loop of pulse detection, noise detection, voltage and current measuring.

3. Control Block diagram

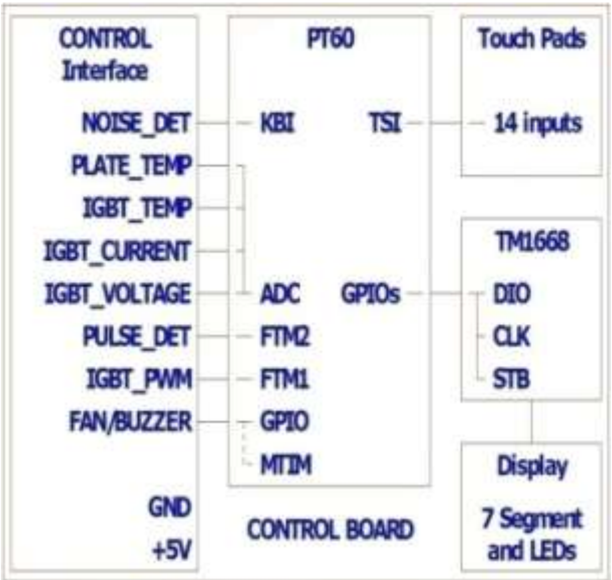

Figure 2: Control block diagram of Mono switch resonant inverter

Fig.2 Shows the Control block diagram of Mono switches resonant converter. The system is controlled entirely by a single 8-bit MCU on the control board with the following features [8]:

- Provides Touch Sense Input (TSI)
- Communicates with the display driver
- Drives the cooling fan and buzzer
- Outputs PWM to the IGBT driver
- Provides feedback from the power stage control
- Detects and measures: noise, temperature, voltage,
- and current

3.1 Temperature sensing and V or I measurement

Figure 3: Temperature sensing and voltage/current measurement as input to MCU.

For safety and protection, IGBT Temperature sensing, IGBT voltage, and IGBT current measurements are made as shown in Fig. 3. These measured values are input to the MCU internal Analog to Digital Converter.

RC filters are kept on the ADC inputs and placed close to the MCU which improve the EMC.

3.2 IGBT driver with pulse detection

Figure 4: IGBT driver and Pulse detection

The IGBT PWM signal is output from FTM1CH1[8], shown in Fig.4. Logical AND gate with Noise detection for noise protection used. The circuit converts the PWM signal from 5V to 18V so that the IGBT has driven appropriately.

3.3 LC Parallel resonator

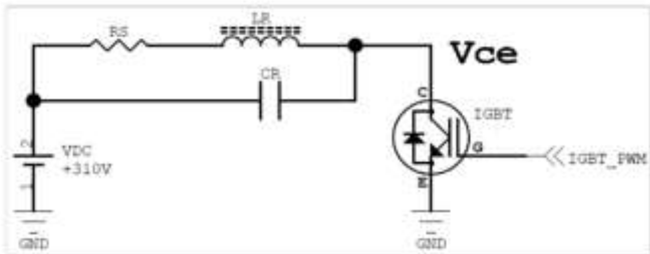

Figure 5: LC Parallel resonant equivalent circuit

A parallel LC Resonant circuit is shown in Fig. 5. As shown, the induction coil and the cookware form the equivalent Lr, and equivalent resistance Rs. This circuit resonated with resonant capacitor Cr. Proper Cr should be selected so that the LC resonant frequency ($fr = 1/(2\pi\sqrt{Lr\,Cr})$) is higher than 20 KHz to avoid audible frequency [8].

4. Specifications and circuit Parameters

Table 1: Specifications

Component	*Symbol*	*Rating*
AC input	*Vs, f*	*230V, 50Hz*
Rectified Voltage	V_{dc}	310V
Load inductance	L_r	140μH
Resonant Capacitor	C_r	0.3μF
Resonant Frequency	F_r	24.56kHz

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Operating switching frequency range	F_s	25kHz to 50kHz
IGBT	20N120R3	1200V, 20A
MCU	*S08PT*	8-bit

5. IGBT and Coil current Result waveforms

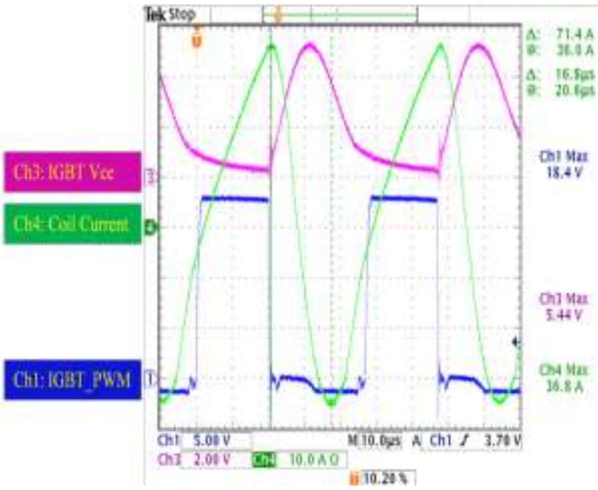

Figure 6: Switch IGBT Voltage, PWM pulse and Coil current

Fig.6 shows voltage across the mono switch Vce, switching gate pulse for load switching and the load current as coil current. The output power of the mono switch converter controlled by the pulse width of the switching gate pulse. The required PWM pulses obtained from the MCU depending upon the load requirement. The programme is loaded into the MCU for the switching pulse generation according to load requirement. The programming code not presented in this paper. When heating is in progress, the voltage of IGBT (Vce) will become higher and exceed the limit if the IGBT over drove or the load removed suddenly. Protection against this kind of situation also achieved by ADC ISR of the MCU. It stops the output of switching pulses to the IGBT driver circuit. The IGBT temperature and the load temperature are monitored continually for safety control.

6. Experimental setup

Figure 7: Experimental setup of Mono switch converter Circuit with the loaded vessel

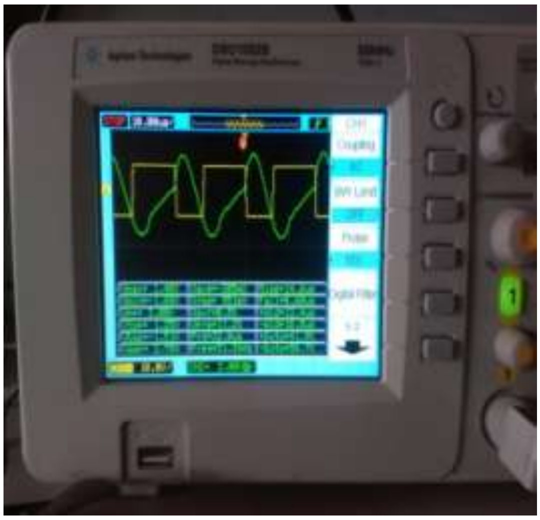

Figure 8: Experimental setup of Mono switch converter

Circuit Output Voltage and Current waveforms
Fig.7 shows the experimental setup of the proposed configuration. Fig.8 shows the inverter output voltage, and load current with ZVS. These experimental results are good agreement with simulation results.

7. Conclusion

In this paper, mono switch resonant High frequency inverter for induction heating has implemented. The proposed inverter configuration simulated in the multi-sim environment. Experimentally the inverter output power controlled using by programmable PWM of MCU for broad range control. The switching device is operated with ZVS. As the power handled by the inverter is small, and overall efficiency is not affected significantly. The simulation results are validated with the experimental results. The proposed configuration can be extended to multiple loads.

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