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Digital Circuit for Power Measurement and Maintenance of Induction Heating Appliances using PIC Microcontroller

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Abstract: ***An implementation of a digital circuit that measures, in real time, the output power of medium-frequency (25–50 kHz) induction-heated cooking appliances, maintains and controls the power through GSM and potentiometer. The voltage and current are sensed using analog-to-digital converters that are inbuilt in Pic18. The power-measuring algorithm is very simple while maintaining good accuracy. We multiply the sensed current and voltage values and average them to calculate the average power. Maintaining power is done through the relay circuit connected to the Pic18.Controlling the power through GSM is possible through EUSART modules present in the PIC18. The algorithm is developed using Embedded C. Experimental results show its good performance, when tested with different saliency criteria, such as switching time , less computational time, and the combination of both.***

Keywords: GSM, Potentiometer, PIC18F46K22 , Temperature Sensor(LM35), Solid State Relay, ADC.

I.INTRODUCTION

Fig.1 shows the entire block diagram of the project, where the power of the induction heating appliance is calculated and the temperature of the circuit is controlled and maintained by using temperature sensor (LM35) , potentiometer and by GSM. Previously, there are several methods reported to measure power in resonant inverters for induction cooking appliances [1]–[3]. The most accurate method is to acquire the load voltage and current simultaneously by two analog-to-digital (A/D) converters (ADCs) with high sampling rate and resolution, and then compute the average power as sum of products over the required period.

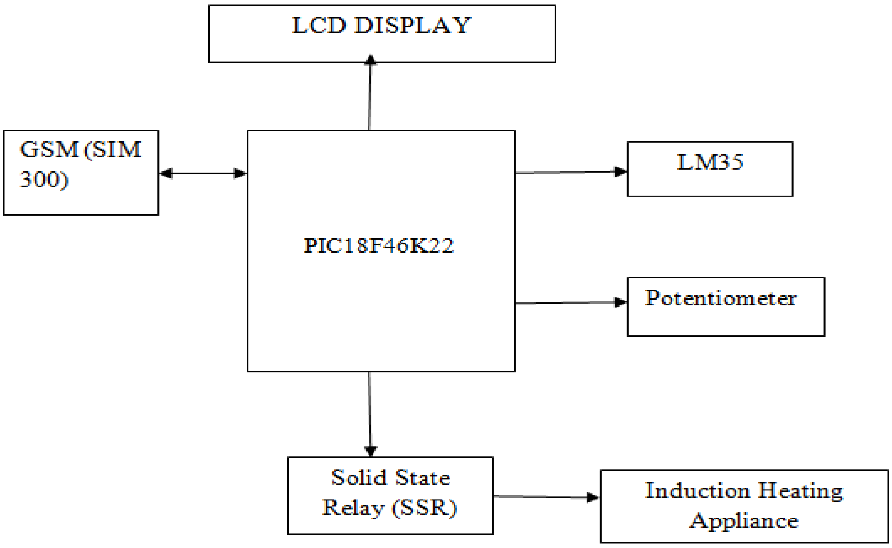

Fig.1 Block Diagram of Project

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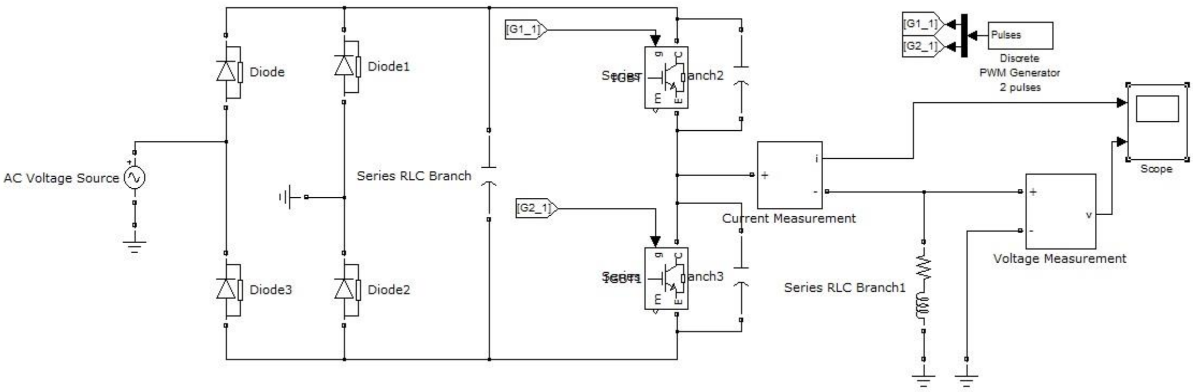


Fig. 2 Circuit Diagram of Induction Heating Appliance

Fig. 2 shows the circuit of an inverter-fed induction-heated appliance which is simulated using MAT-LAB. The rectifier converts the ac mains voltage from the power source to dc. The capacitor (series RLC branch) allows a big voltage ripple that helps to improve the power factor of the system [4]. The inverter converts the non-smoothed dc voltage into a medium-frequency ac current (50-70 KHZS) that flows through the induction coil. By the principle of induction heating, heat will be generated in the bottom of the metal cooking pan due to induced eddy-current losses [4]. Mainly we use resonant inverters in the inverter circuit of induction heating appliances, being the half-bridge series resonant converter [4] the most common. In a first approach, the coupling between the coil and the pan can be replaced by a resistance R connected in series with an inductance L which is represented as series RLC branch1 in fig.2, where R is associated to the total power (losses and power load) provided to the inductor, and L is associated to the inductive effect of the winding coupled to the pan [5]. The capacitors across the IGBT diodes are used to get the positive and negative half cycles of voltage and current. As, the inverter converts Dc voltage to medium frequency current, power can be delivered maximum close to the resonant frequency.Usually a power reference Knob will be provided to the user to set a reference power level and then power is calculated, controlled to maintain the reference level. The measurement will be accurate by sensing output voltage and current of inverter [5] by an analog to digital converter and calculating the average power. The power calculation algorithm is coded in Embedded C programming language by MPLAB and C18 compilers. The algorithm and the flowchart of the coding are discussed. The Whole project is done using PIC18 as it contains two ADC's (8-bit and 10-bit), EUSART module for GSM communication, 5-ports to operate, enough memory and it is Cost effective. Controlling of Power through GSM is possible due to EUSART modules present in the chip. The instructions for coding GSM are available to control the power which is discussed later. The overall paper is organized as follows; Section II describes the voltage and current-sensing by ADC. Section III presents the method to calculate the output power. Section IV explains controlling the power through various modes. Section V describes how the system as a whole works. The simulated results obtained are summarized in Section VI. At the last, Section VII describes the algorithm and flowchart of the Embedded C code.

VOLTAGE AND CURRENT SENSING

For the induction heating appliance, the output voltage and current are analog in nature. They have to be converted to digital in order to calculate average power. So we use PIC18F46K22 microcontroller chip for digital conversion. PIC18F46K22 contains one 8-bit and one 10 bit ADC, where the conversion takes via successive approximation technique [6]. The reference voltage, clock source and the interrupt upon conversion is software enabled. Usually conversion takes place during the sleep mode, after conversion, interrupt will be generated to wake it up from sleep mode. The result of the ADC will be stored in ADRESL and ADRESH registers of microcontroller.

As PIC18F46K22 is optimized with ANSI C programming language, the software of ADC is coded in Embedded C.

The algorithm of the code is as follows:

1. Configure Port:
- Disable pin output driver (See TRIS register)
- Configure pin as analog
2. Configure the ADC module:
- Select ADC conversion clock
- Configure voltage reference
- Select ADC input channel
- Select result format
- Select acquisition delay
- Turn on ADC module
3. Configure ADC interrupt (optional):
- Clear ADC interrupt flag
- Enable ADC interrupt
- Enable peripheral interrupt
- Enable global interrupt
4. Wait the required acquisition time
5. Start conversion by setting the GO/DONE bit.
6. Wait for ADC conversion to complete by one ofthe following:
- Polling the GO/DONE bit
- Waiting for the ADC interrupt (interruptsenabled)
7. Read ADC Result
8. Clear the ADC interrupt flag (required if interruptis enabled).

II.POWER MEASUREMENT

Firstly, we make us of the relationship between voltage and temperature for LM35 temperature sensor used, which gives Voltage is approximately double the temperature.

V=2*T

So, when the temperature sensor senses the temperature of induction heater, by above relationship we can find the voltage. Current can be determined by equation:

I=V/R

So, Power can be calculated by equation:

Power = Voltage * Current = ((Voltage) ^2)/R, where R = Coil Resistance

The maximum power at which heater operates is 1000W and resistance of the coil is 60 ohms. The reference power can be set by varying the reference voltage through potentiometer in manual mode or through GSM in Auto mode.

III.CONTROLLING THE OPERATION

Controlling the operation and maintaining the power of the circuit can be done through three modes:

4.1 Through temperature sensor (LM35):

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. So for a particular temperature, LM35 gives corresponding analog voltage. We use 10bit ADC in PIC18F46K22 as the maximum temperature LM35 senses is 150 Celsius that gives voltage around 300V.By using 8-bit we cannot represent 300V as the 8 bit ADC range is 0-255V.

Firstly, the EEPROM of microcontroller will be stored with the corresponding voltage value of room temperature and this value will be compared with the output of ADC. If temperature rises above reference value, solid state relay (SSR) breaks the circuit. If temperature falls below, circuit starts. The relation between voltage and temperaturein LM35 is

V = 2 * T, Where, V= voltage, T=corresponding temperature

4.2 Through GSM:

SIM 300 is the module used to interface the GSM technology with the microcontroller. Software called Terminal is used for the interfacing of GSM with the microcontroller .SIM 300 consists of 80 attention commands by which message can be sent to the microcontroller or received from the microcontroller. When the voltage value is sent through GSM, this value overwrites the threshold voltage value set manually and maintains the temperature corresponding to the voltage value. As current changes when the voltage is changed, power reference level also changes and the induction heater will be maintaining that power level with the help of Solid State Relay.

4.3 Manually through Potentiometer:

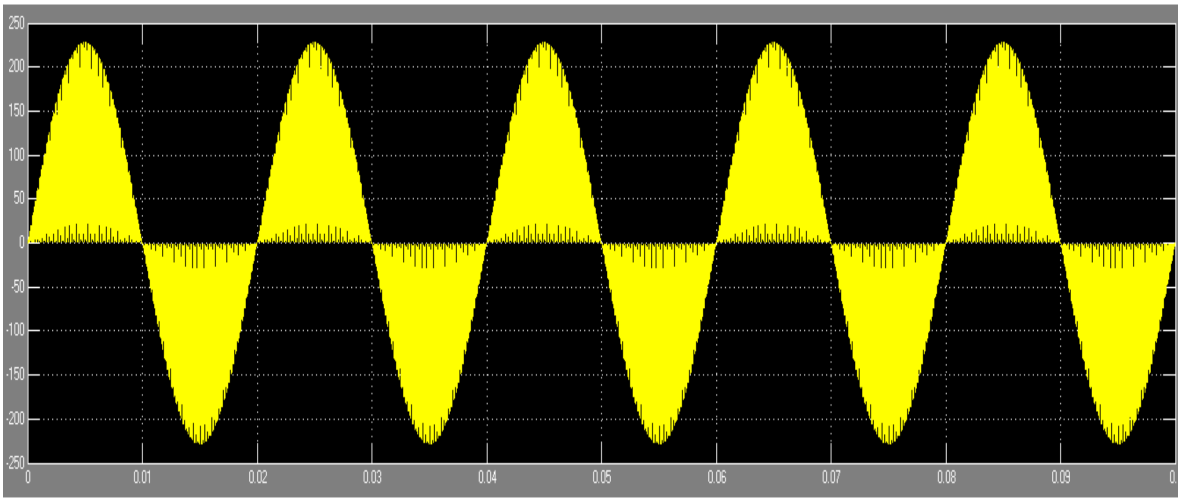
Voltage corresponding to the temperature can be obtained from the equations of the LM35.So, voltage corresponding to user reference temperature we need can be calculated and stored in EEPROM of the microcontroller. The power required for the temperature that has to be maintained is calculated through reference voltage and compared with maximum power. Through the solid state relay circuit, temperature is maintained by making and breaking of the circuit.

IV.WORKING OF WHOLE DIGITAL CIRCUIT

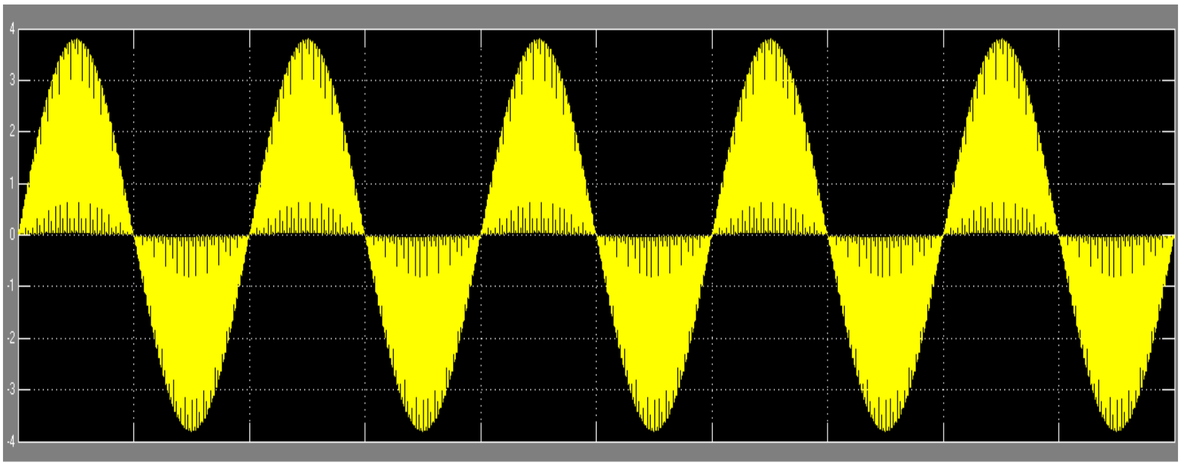
Firstly, after connecting the circuit as per the block diagram in fig 1, controller displays the maximum power taken by the heater through LCD display. Then we need to select the mode of operation (either Auto or Manual)through the on/off switch which is connected to one of the peripheral port of microcontroller. If the mode is 'AUTO' then LCD displays the mode and the reference voltage that is sent through the message via GSM and calculates the power associated with the reference voltage. Then compares it with maximum power and either breaks or makes the connection with the heater through Solid State Relay. If the mode of operation is Manual, then with the help of potentiometer, the reference voltage in the EEPROM will be overwritten and corresponding reference voltage is calculated and compared with the maximum power for maintaining the temperature of the heater through solid state relay. The whole process of changing the voltage is achieved through the temperature sensor and its voltage and temperature relationship. As temperature sensor, potentiometer gives analog output, ADC's in the controller are used to digitalization of it and for effective power calculation.

For the programming of the digital circuit, Embedded C with MPLAM and C18 compiler is used, the algorithm and flow chart of code are described below. For the interfacing of the GSM block (SIM 300), terminal software and the attention commands associated with it for applications like sending and receiving the message are used.

V.SIMULATION RESULTS



Voltage vs time
Voltage peak: 230V



Current vs time
current peak: 3.8Amps

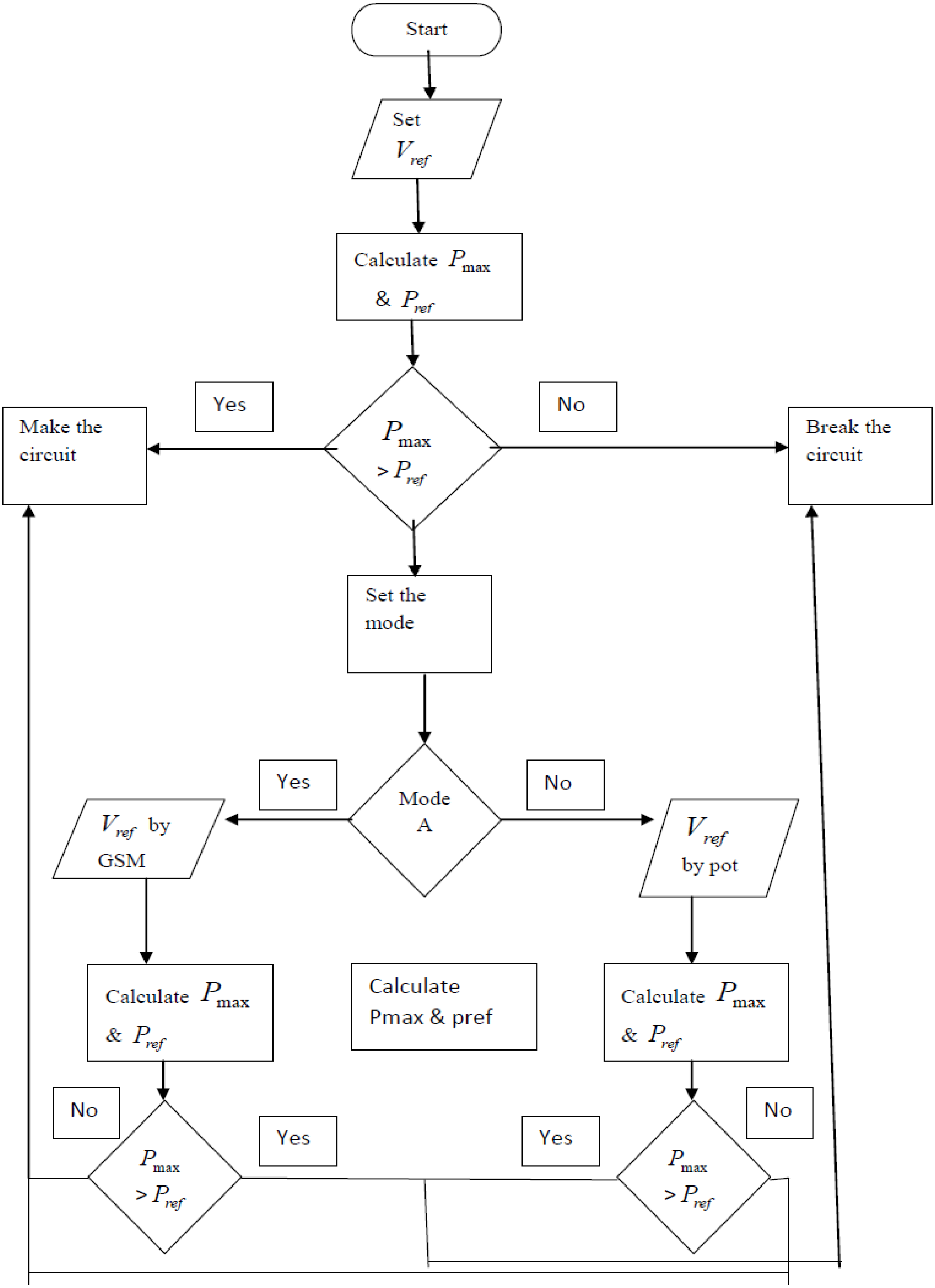
The above two graphs(Voltage vs. time, current vs. time respectively) shows the simulated outputs of the induction heating appliance circuit. The results are not noise free, there are harmonics noise in the result but those noises doesn't affect the digitalization of the voltage or current. The ideal circuit shows the maximum power to be 1000w with coil resistance as 60 ohms and inductance of 0.2milli Henry and the frequency of the circuit is 60KHzs.But when coming to hardware implementation the total circuit is inbuilt in the induction heater.

VI.ALGORITHM AND FLOW CHART

The basic algorithm of the code:

1. Set the reference voltage in the EEPROM of the microcontroller.
2. Calculate the maximum power and the reference power.
3. Check if maximum power is greater than reference power for making and breaking of circuit.
4. Check for the mode of operation of the circuit.
5. If mode is 'AUTO', reference voltage existing in EEPROM is overwritten by voltage sent through GSM; else it is overwritten by voltage set by potentiometer.
6. Again calculate reference power and check with maximum power for making and breaking of the circuit.

Flow Chart of the Embedded C code:


Start
Set V_{ref}
Calculate P_{max} & P_{ref}
$P_{max} > P_{ref}$
Yes
No
Make the circuit
Break the circuit
Set the mode
Mode A
Yes
No
V_{ref} by GSM
V_{ref} by pot
Calculate P_{max} & P_{ref}
Calculate Pmax & pref
Calculate P_{max} & P_{ref}
No
Yes
Yes
No
$P_{max} > P_{ref}$
$P_{max} > P_{ref}$

VII.CONCLUSION

A digital circuit has been designed and implemented into a PIC18F46K22 that measures in real-time the power transferred to the load in induction-heated cooking appliances. The voltage and current are sensed using Successive Approximation ADCs. The power measuring algorithm does not require many multiplications as the number of multiplications is highly reduced. The circuit has been described in Embedded C that allows flexibility, reusability, and technology independence. Besides, the design can be used as a peripheral module of a global induction-heating controller implemented into an ASIC. The induction appliance circuit has been simulated using MAT-LAB simulinksimulation tool. This simulation has allowed performing analysis of parameters like capacitor and resistor values, diode forward voltages, etcin the measurement accuracy. The efficiency of the circuit in power calculation is 88.2%. This whole project can be applicable to various household appliances like controlling the temperature of Air Conditioners, used in smart home applications, etc.

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