

Low Power Continuous Heating Single IGBT Induction Cooker

D/N: WAS-21A1EN

Introduction

A traditional kitchen stove heats foods over an open flame while the induction cooker utilises an electromagnetic induction method to implement a heating function. In this way foods are cooked by the heat of the cookware itself. Compared to the open flame heating method, an induction cooker can increase the thermal efficiency by 90%. As a safety feature, the induction cooker will be automatically shut off if the cookware has been removed for a certain period of time. During cooking the cooktop surface temperature is much lower than a traditional kitchen stove and in addition, the induction cooker and cookware are more easily cleaned than a traditional stove.

For a traditional single-IGBT induction cooker, when being set to operate at a low power level, it needs to be active intermittently, for example active for 0.2 seconds and then stopped for 0.8 seconds to lower its average heating power. In this induction cooker solution, continuous heating at a lower power level is achieved using the drop-wave control method, which is different from the traditional intermittent control. The working principle of this will be explained in a later section of this document. With an integrated high-voltage IGBT drive circuit, the MCU program can control the IGBT driving signal as well as change the voltage rise rate, thus implementing a low power continuous heating function. This implementation method for low power continuous heating is the main feature of this induction cooker solution. Figure 1 shows the application block diagram.

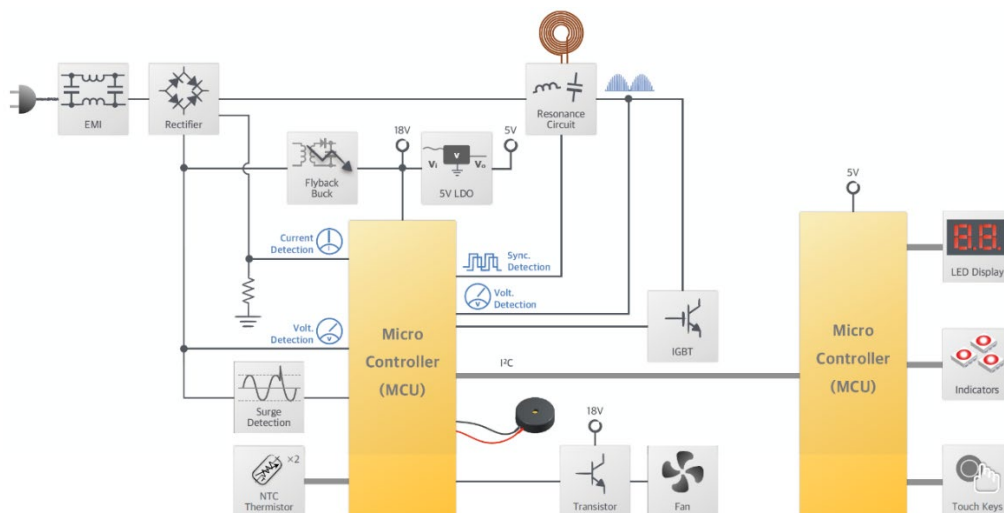


Figure 1. Application Block Diagram

Application Areas

Induction cookers, IH rice cookers, IH milk frothers and other products with low power heating requirements.

Solution Features

1. Low power continuous heating: even and efficient heating with power levels down to as low as 100W.

When the induction cooker operates at a power level below 1000W, the drop-wave control method will be used to achieve continuous heating. Situations where liquids intermittently boil in the pot will not occur. This can achieve almost the same effects as traditional stove slow cooking over a low flame and therefore provide a better user experience.

2. Highly integrated MCU: the MCU includes a high voltage driving circuit for the IGBT, a hardware frequency jittering circuit and multiple protection circuits.

The frequency jittering function can significantly reduce the IGBT V_{CE} voltage and the amount of generated EMI. The highly integrated IGBT high-voltage drive circuit, not only reduces the count of required external components and thus lowering hardware costs, but also ensures small PCB areas, resulting in less complex PCB designs. Several comparators are also integrated to allow the implementation of induction cooker over-voltage, over-current protection circuits, etc.

Operating Principles

Induction Cooker Working Principle

By using a rectifier circuit in the induction cooker, a 50/60Hz alternating current can be converted to direct current, which will pass through a resonance circuit and the IGBT switching circuit and then be converted to a 20~35kHz high-frequency voltage. This results in a high-speed varying current in the induction cooker coil which then produces a high-frequency, changing magnetic field around it. The magnetic field lines pass through the metal cookware on the cooktop surface and induce eddy currents on the bottom of the metal cookware due to electromagnetic induction. It is this which implements the heating function. The principle diagram is shown in Figure 2.

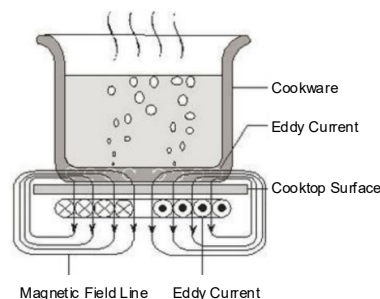


Figure 2. Induction Cooker Heating Principle Diagram

When the induction cooker operates at a power level below 1000W, which can be seen as low power operation, continuous heating can be achieved by changing the rise rate and pulse width of the IGBT drive voltages.

Low Power Continuous Heating Principles

Low power continuous heating is achieved by controlling the drop-wave number in a power cycle. Here we take 10 AC cycles as a power cycle. During a power cycle, the IGBT will be turned on by the driving waveform only in a specified number (but not all) of the AC cycles. For example, within a total of 10 AC cycles, which is taken as a power cycle, the waveform can drive the IGBT in seven cycles and then off in three cycles. The number of working cycles is set according to the required output power. By using this drop-wave control method, continuous heating under low power conditions can be achieved. Using this method will prevent intermittent boiling, which has almost the same heating effect as traditional slow cooking over a low flame. The parameters related to the drop-wave control operation in this document apply only to the hardware circuit designed for the application solution. In practice, the control effects may fluctuate due to different conditions in different applications. The settings should be adjusted according to the actual product application. Table 1 shows the drop-wave control test data. The test data is for reference only as different cookware materials will require different data. The number 10:1 in the table below indicates that there is a single IGBT on cycle within a total of 10 AC cycles.

Low Power Level	Drop-Wave Control
100W	10:1
300W	10:3
600W	10:5

Table 1. Drop-Wave Control Data for Low Power Levels

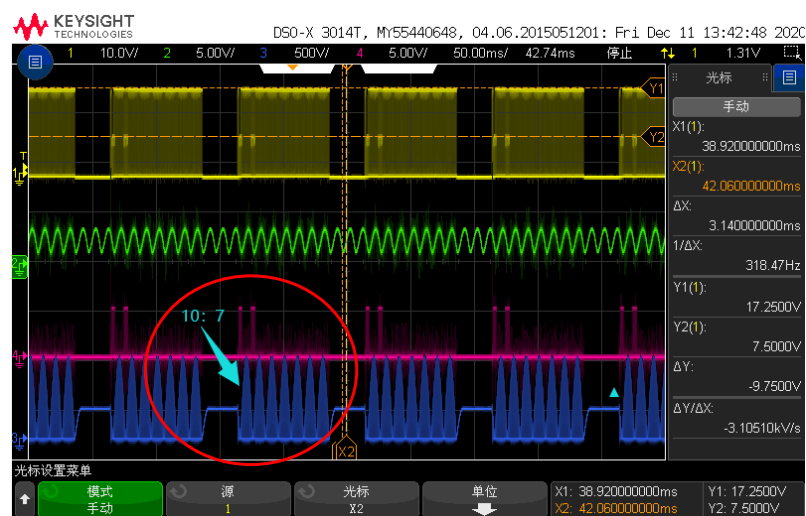


Figure 3. Drop-Wave Control Test Waveform

The implementation of low power heating is only briefly explained in this article, for more details please refer to Holtek Application Note AN0591.

Functional Description

Solution Features

- Input voltage range: AC 150V~265V 50/60Hz
- Standby power consumption: < 5W
- Communication interface: I²C – the power heating board is the software emulated master and the touch & display board is the hardware circuit slave
- Heating power: 100W~2000W continuous heating
- Protection functions: over/under voltage protection, over current protection, cooktop surface overheating protection, IGBT overheating protection, surge voltage protection
- EMI test
 - ◆ CE conducted interference test margin (2000W): > 6dB
 - ◆ DP power interference test margin (2000W): > 8dB

Solution Function

The induction cooker solution is suitable for general household and commercial small hot pot cooking. The induction cooker supports multiple cooking modes, such as fast heating, slow heating, soup, steam, porridge, hot pot and super high heating. The differences between these modes are in the different heating power, time settings and temperature control.



Figure 4. Induction Cooker

Operation Description

After the power cord is plugged in, the induction cooker enters the standby mode in which the fans remains off, the buzzer sounds once and the 7-segment display and LEDs are all on and flashing. After this, the “On/Off” LED button on the control panel starts to flash indicating that the induction cooker initialisation has completed. After pressing the “On/Off” button, the LED will remain on and the display area displays “- - -” which means that it is waiting for further operations. When an error occurs, the display area will display the error code.

Function Key	Description
Pause	Stop the current cooking mode - press again to resume the cooking mode
Smart	Press this button to switch between the following modes. ● Fast heating: 100W~2000W adjustable power continuous heating ● Slow heating: 100W/300W/600W low power continuous heating ● Soup: use the time setting to setup a heating time, ranging from 10~240 minutes in 10-minute increments. ● Steam: use the time setting to setup a heating time, ranging from 10~240 minutes in 10-minute increments. ● Porridge: the heating temperature in the pot is adjustable from 60°C~240°C in 20°C increments.
Hot Pot	100W~2000W adjustable power continuous heating
Super High Heating	2000W output power

Table 2. Solution Function Table

Error Code	Description	Error Code	Description
E0	No cookware detected	E3	IGBT overheating
E4	IGBT NTC open or short circuit has been detected	E5	Cooktop surface overheating
E6	Cooktop surface NTC open or short circuit has been detected	E7	Mains supply over current
E8	Mains supply over voltage	E9	Mains supply under voltage
EA	Communication failure	—	—

Table 3. Induction Cooker Error Code Introduction

Reference Design Description

This reference design includes a power heating board and a touch & display board. The power heating board controls the power supply for the complete system and the heating power of the induction cooker. The selection of the heating power and the induction cooker on/off state on the power heating board are adjusted according to the current heating power and other settings obtained from the touch & display board using I²C communication. The touch & display board uses touch keys and LED display functions to provide a human-machine interface (HMI) control. The touch keys can be used to select the desired operating mode while the LED display function is used to display the current selected operating mode and power setting. The induction cooker error information is also displayed on the touch & display board. In this induction cooker solution, low power heating control is achieved using the drop-wave control method.

Hardware Description

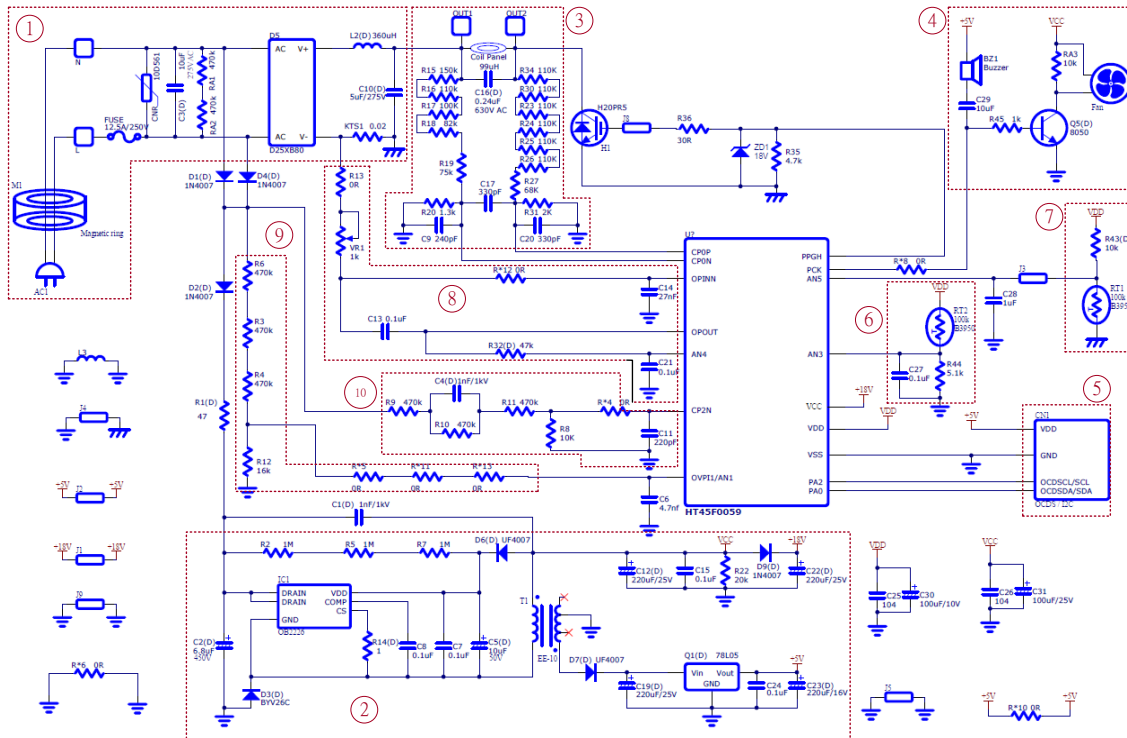


Figure 5. Power Heating Board Schematic

The AC supply for the power heating board is divided into two paths after passing through the EMI filter circuit⁽¹⁾. One path is to the switching power circuit⁽²⁾ and the other is to the resonance circuit⁽³⁾, being used as the heating main power. The switching power circuit outputs +18V and +5V. The +18V power is supplied to the fan control circuit⁽⁴⁾ and the main control MCU (HT45F0059) on the power heating board. The +5V power is supplied to the buzzer and touch & display board⁽⁵⁾. The V_{DD} output from the main control MCU is supplied to the power heating board peripherals such as the cooktop surface overheating protection circuit⁽⁶⁾ and the IGBT overheating protection circuit⁽⁷⁾. The induction cooker power control is implemented depending upon the current detection circuit⁽⁸⁾ and the voltage detection circuit⁽⁹⁾. These two circuits are used to detect the present operating current value and the voltage value, which are used to calculate the present power. The system will determine whether to increase or reduce the IGBT on time to adjust the power according to the present operating power. The measured current and voltage values are also used as the reference source for the over/under voltage protection and over current protection functions.

In addition to the over/under voltage protection and over current protection functions, this solution also contains a surge voltage protection circuit⁽¹⁰⁾, a cooktop surface overheating protection circuit and an IGBT overheating protection circuit, etc. When any of the above protection functions are triggered during induction cooker operation, the system determines whether to reduce power or stop heating for safety protection reasons.

Touch & display board: The power heating board provides the power supply to the touch & display board via the communication circuit. This voltage supply is regulated to a 5V voltage output by a voltage regulation filtering circuit and is supplied as the touch & display board main power. The

LED display circuit displays the current induction cooker operating mode and function. The touch keys are provided as a human-machine operating interface, with which functions can be selected. The induction cooker will then control the power heating board operation according to the selected function.

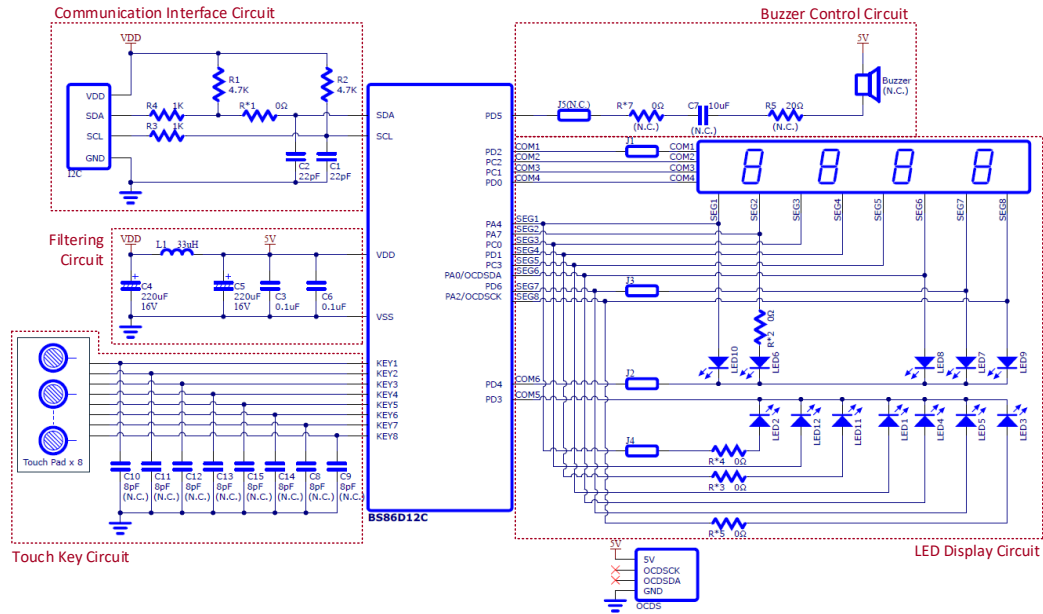


Figure 6. Touch & Display Board Schematic

Layout and Hardware Considerations

There are some important considerations for the power heating board.

1. The filter capacitors next to the MCU should be located as close to VDD and VSS as possible and the ground of the peripheral circuit should be a single point grounded to the source capacitor ground. The resonance circuit ground should be separated from other peripherals to avoid the IGBT switching interference signal influencing other peripherals. Also ensure that the routings go through a voltage regulation filter capacitor to filter out any noise.
2. Routings from the bridge rectifier to the resonance circuit should be as wide as possible as these routes carry larger currents. The resonance capacitor should be as close as possible to the induction cooker resonance coil.
3. Routings which are close to the high power area and the low power zone should be separated via a KEEPOUT layer.
4. The IGBT E pin and the ground of the bridge rectifier IC should be wide and have a single point connected via a constantan wire, which is then a single point routed to the current detection circuit.

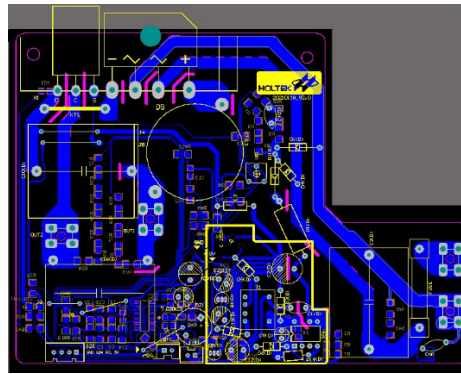


Figure 7. Power Heating Board PCB

There are some considerations for the touch MCU BS86D12C on the touch & display board.

1. The filter capacitors next to the MCU should be located as close to VDD and VSS as possible.
2. When there are multiple touch keys on the board, the MCU should be located at a central position among these keys, thus shortening the routes. Using capacitors connected between the MCU corresponding KEY pin and VSS is an effective method of adjusting the touch sensitivity. Wires can be routed from the MCU to the KEY pins on the copper floor to reduce any interference on the touch keys caused by signal wires. It should be noted that any touch key routings should be located as far away as possible from any high frequency signal paths.

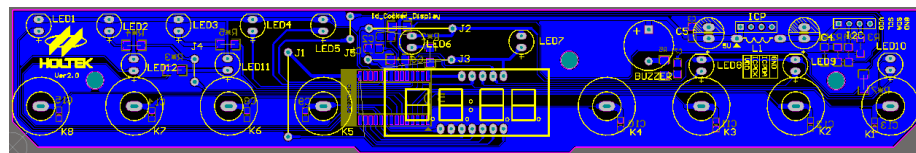


Figure 8. Touch & Display Board PCB

PCB BOM Tables

Bill of Materials				
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Source Data From: SCH_BS86D12C-B01_Common.SchDoc				
Project: Free Documents				
Variant: None				
Creation Date: 2021/10/14 14:28:33				
Print Date: 44484 44484.48421				
Footprint	Comment	LibRef	Designator	Quantity
BZ1	Bell	Bell	BUZZER	1
C0805	22pf	Cap	C1, C2	2
0805_C	104	Cap Pol2	C3	1
EC4	220UF/16V	EC	C4, C5	2
C1206	104	c	C6	1
0805_C	106	Cap Pol2	C7	1
C0603	8pf	c	C8, C9, C10, C11, C12, C13, C14, C15	8
SMG-4DISP	DISPLAY	Inductor	DISP1/Anode	1
HDR1X4	Header 4	Header 4	I2C, ICP	2
J2	Res2	Res2	J1, J2, J3	3
J1	Res2	Res2	J4, J5	2
TOUCH KEY		GYP	K1, K2, K3, K4, K5, K6, K7, K8	8
bead	Inductor	Inductor	L1	1
LEDDIP	LED1	LED1	LED1, LED2, LED3, LED4, LED5, LED6	12
R1206	4.7K	Res2	R1, R2	2
R1206	1K	Res2	R3, R4	2
1206_R	20R	Res Semi	R5	1
1206_R	0	Res Semi	R*1, R*2, R*3, R*4, R*5, R*7	6
SOP28	BS86D12C/28SC	BS86D12C	U1	1
Approved				57
Notes				

Table 4. Touch & Display Board PCB BOM Table

Bill of Materials				<Parameter Title not found>
Source Data From:		SCH_HT45F0059-A01_Common.SchDoc		
Project:		Free Documents		
Variant:		None		
Creation Date:		2021/10/14	14:19:26	
Print Date:		44483	44483.61534	
Footprint	Comment	LibRef	Designator	Quantity
BZ1	Bell	Bell	BZ1	1
C_DIP	102/1KV	Cap Pol2	C1(D), C4(D)	2
EC3_10MM	450V/6.8uF	Cap Pol1	C2(D)	1
C2_0.27UF_31MM	8uF/275V AC	CAP	C3(D)	1
EC1_5MM	50V/10uF	Cap Pol1	C5(D)	1
0805_C	4.7nf	Cap Pol2	C6	1
0805_C	104	Cap Pol2	C7, C8, C13, C15, C21, C24, C25, C26, C27	9
1206_R	240pF	Cap Pol2	C9	1
C1_5UF_26.5MM	5uF/275V AC	CAP	C10(D)	1
1206_R	211	Cap Pol2	C11	1
EC4_8mm	25V/220uF	Cap Pol1	C12(D), C22(D)	2
1206_R	27nf	Cap Pol2	C14	1
C2_0.27UF_31MM	0.33uF/630V AC	CAP	C16(D)	1
0805_C	330pF	Cap Pol2	C17	1
EC2_6.5MM	16V/220uF	Cap Pol1	C19(D), C23(D)	2
1206_R	330pF	Cap Pol2	C20	1
1206_R	105	Cap Pol2, Res Semi	C28, R2, R5, R7	4
0805_C	106	Cap Pol2	C29	1
EC2_6.5MM	10V/100uF	Cap Pol1	C30(D)	1
EC4_8mm	25V/100uF	Cap Pol1	C31(D)	1
CN2	I2C	Header 4	CN1	1
DIP_2PIN	NTC	Header 2H	CN2	1
DIP_2PIN	FAN	Header 2H	CN4	1
ZMR_10D	10D561	Res Varistor	CNR	1
DIODE_DIP+L	1N4007	Diode 1N914	D1(D), D2(D)	2
DIODE_DIP	BYV26C	Diode 1N914	D3(D)	1
DIODE_DIP	1N4007	Diode 1N914	D4(D), D9(D)	2
BRIDGE	Diode Bridge	Bridge1	D5	1
DIODE_DIP	UF4007	Diode 1N914	D6(D), D7(D)	2
FUSE	12.5A/250V	FUSE2	FUSE	1
IGBT	IGBT/H20PR5	IGBT	H1	1
0B2226	0B2226	0B2226	IC1	1
J2	Res2	Res2	J1, J3, J5	3
J1	Res2	Res2	J2, J9	2
J3	Res2	Res2	J4, J8	2
KTS	20mR	Res2	KTS	1
N	Socket	Socket	L, N	2
INDUCTANCE_2	360uH	Inductor	L2(D)	1
L4	Inductor	Inductor	L3	1
N	Pad1	Pad1	OUT1, OUT2	2
TO-92	78L05	Volt Reg	Q1(D)	1
TO-92	8050	NPN	Q5(D)	1
R1/1W	47R/2W	Res Semi	R1(D)	1
1206_R	4703	Res Semi	R3, R4, R6, R9, R10, R11	6
1206_R	103	Res Semi	R8	1
1206_R	16k	Res Semi	R12	1
1206_R	0R	Res Semi	R13, R*4, R*5, R*6, R*8, R*9, R*10, R*11, R*12, R*13	10
R3/0.25W	1R0	Res Semi	R14(D)	1
1206_R	1503	Res Semi	R15	1
1206_R	1103	Res Semi	R16, R23, R24, R25, R26, R30, R34	7
1206_R	1003	Res Semi	R17	1
1206_R	8202	Res Semi	R18	1
1206_R	7502	Res Semi	R19	1
1206_R	1301	Res Semi	R20	1
1206_R	2002	Res Semi	R22	1
1206_R	6802	Res Semi	R27	1
1206_R	202	Res Semi	R31	1
1206_R	473	Res Semi	R32	1
1206_R	472	Res Semi	R35	1
1206_R	30R	Res Semi	R36	1
1206_R	1002	Res Semi	R43	1
1206_R	5101/1%	Res Semi	R44	1
1206_R	102	Res Semi	R45	1
1206_R	474	Res Semi	RA1, RA2	2
0805_R	10K	Res Semi	RA3	1
0805_R	100K/B3950	Res2	RT1	1
transformor 1	QJ-EE10	QJ-EE10	T1	1
16NSOP	HT45F0059/16NSOP	HT45F0058_2	U1	1
VR_102	102	20K	VR1	1
1206_D	D Zener	D Zener	ZD1/18V	1
Approved				114
Notes				

Table 5. Power Heating Board PCB BOM Table

Software Description

Power Heating Board Main Program Flowchart Description

As shown in Figure 9, the power heating board main program first executes an initialisation program which includes the I/O port settings related to the induction cooker register functions, power calculation curves, etc. After initialisation, the voltage, current, IGBT temperature and cooktop surface temperature are measured using the A/D function. Protection mechanisms will be triggered if the measurement results exceed the limit range, then the corresponding flags will be set high. Then the corresponding error codes will be stored into the communication memory and be sent to the touch & display board in the next communication cycle. The induction cooker main function control includes protection mechanisms, I²C communication, power adjustment, etc.

Comparator hardware protection interrupt: The surge voltage protection and IGBT reverse voltage protection functions are implemented in hardware to achieve a faster response speed. When these protections are triggered, the system will turn off the heating function or reduce the heating power first. Further processing will be executed by software interrupt routines. If surge voltage protection is triggered, the induction cooker heating function will be turned off to protect the induction cooker from damage. If an IGBT reverse voltage protection is triggered, the induction cooker power will be reduced by hardware to avoid the IGBT from being damaged.

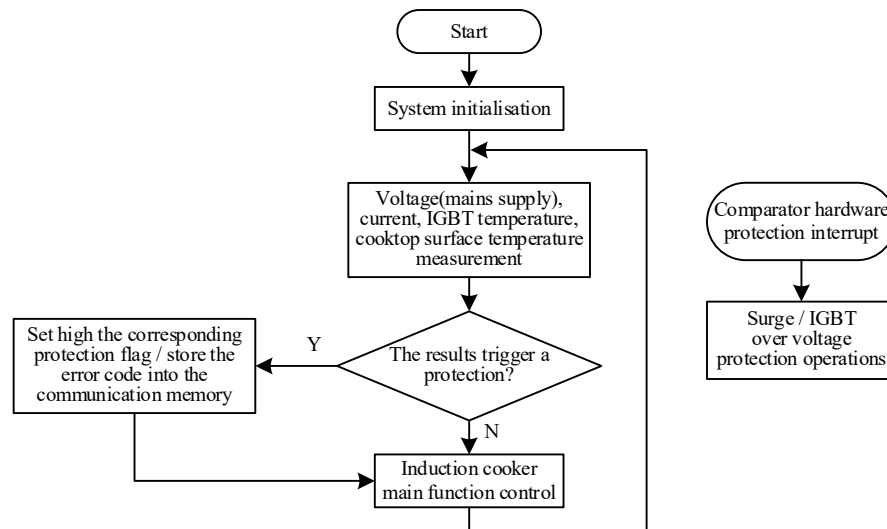


Figure 9. Power Heating Board Main Program Flowchart

Induction Cooker Main Function Control Flowchart Description

As shown in Figure 10, the induction cooker main function control flowchart executes specific functions in several fixed periods. Over current protection detection, IGBT overheating protection detection, NTC circuit detection and protection release, etc., are executed every 1s. The I²C communication, cookware detection and induction cooker power adjustment are executed every 100ms. The induction cooker On/Off and power settings, cookware removal detection as well as I²C communication time-out processing are executed every 20ms. The system will determine if the time has reached a value of 1s, 100ms and 20ms respectively every 1ms and then set high any corresponding flags. The corresponding functions will be executed according to these flags in the next process.

The system determines every second whether a mains supply over voltage or under voltage condition occurs, whether an over current condition occurs and whether the IGBT temperature or cooktop surface temperature is too high. It will then execute the corresponding protection functions, such as adjusting the power or turning off the induction cooker heating function. For the IGBT overheating protection function, when the IGBT temperature exceeds 68°C and such a condition lasts for more than 5 minutes, the system will reduce the induction cooker heating power until the IGBT temperature reduces to lower than 68°C, after which it will resume the heating power to its previous level. As the temperature protection and control is the key protection feature, an error on the temperature sensor NTC may result in the induction cooker component being damaged by an overheating condition, which is likely to lead to a dangerous situation. The NTC detection is implemented by checking if the maximum or minimum values of the read back A/D values exceed the range to determine if there is an NTC sensor open circuit or short circuit. For the protection release procedure, if the mains supply and current has triggered an induction cooker protection function, and the protection mechanism trigger condition has been eliminated for a certain period of time, the induction cooker will resume normal operation and clear the error code.

I²C communication: The power heating board acts as the master which transmits the current IGBT temperature and cooktop surface temperature A/D measurement values as well as the induction cooker status code to the touch & display board. It also receives the current selected induction cooker function from the touch & display board.

Cookware detection: The system sends a pulse signal to the coil panel through the IGBT switch and detects the number of times the Comparator 0 output state changes within a 2ms period. If the number is less than a pre-determined value, it is taken as evidence that there is cookware present, otherwise it will be taken that no cookware is present.

Power calculation and adjustment: The A/D sampled current and voltage after filtering can be converted to accurate values, AD_Vac and AD_Iac. Then the actual current and voltage values can be calculated based on the circuit design parameters to calculate the actual operating power. Then compare the calculated power with the target power. If the target power is higher or lower than the current power, then increase or decrease the PPG pulse width accordingly to obtain a power value close to the setup power.

Induction cooker on/off and power setting: Check the current induction cooker on/off state. If the induction cooker is on, users can setup the target induction cooker heating function on the touch & display board. The induction cooker heating function will adjust the PPG width according to the setup power to reach the desired power. If the power is greater than 1600W, the frequency jittering function will be turned on.

Cookware removal detection: During heating, if the current instantly decreases sharply, this will be taken as a situation where the cookware has been removed.

I²C communication time-out processing: If the I²C communication times-out, the induction cooker heating function will be disabled.

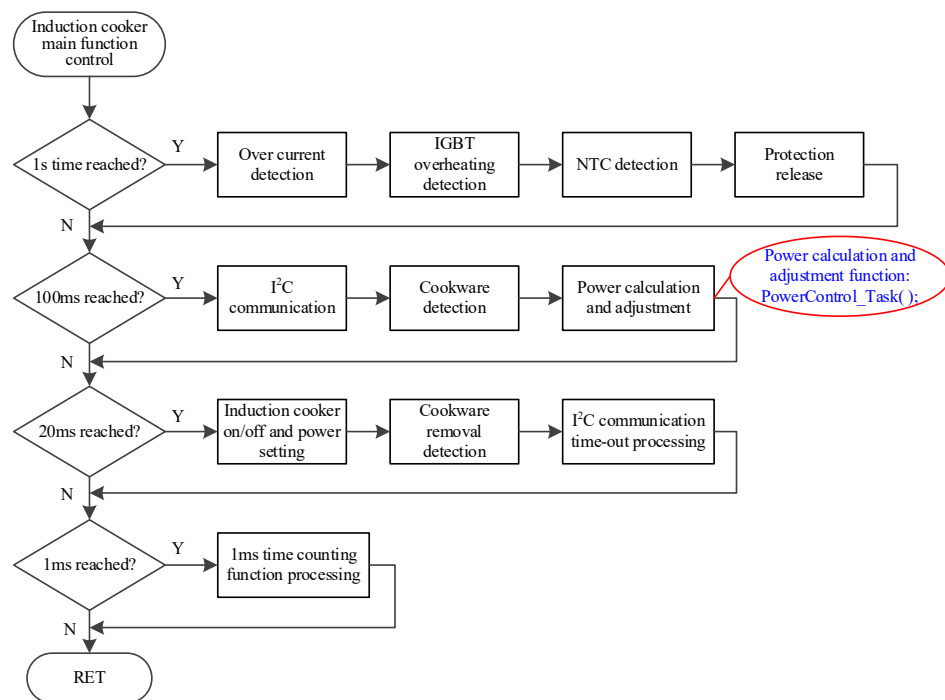


Figure 10. Induction Cooker Main Function Control Flowchart

Touch & Display Board Main Program Flowchart Description

As shown in Figure 11, the touch & display board main program flowchart executes a touch program function library initialisation and a system setting initialisation. After this, the system enters the main program, which includes “Execute key actions”, “Update LED display”, “Error code processing” and “Function menu processing”. In the “Execute key actions” procedure, it should be determined which touch key has been pressed for which the corresponding descriptions are listed in Table 6. The system executes the relevant key function according to the touch function returned value and updates the data to be transmitted for the next I²C communication to the power heating board. After this, the touch & display board updates the LED display. The “Error code processing” procedure determines if there is an error on the power heating board according to the present data acquired from the power heating board and modifies the value on the LED display panel in the next display cycle. The “Function menu processing” procedure operates in the present operating mode and may start counting if there is a preset timing function. When the time has elapsed, the system will inform the power heating board to turn off the heating function in the next communication cycle.

Function	On/Off	Super High Heating	Pause/ Resume	+ Key	- Key	Hot Pot	Smart
Returned Value	0x008	0x004	0x002	0x001	0x080	0x020	0x010

Table 6. Touch Function Returned Value Corresponding Key Function

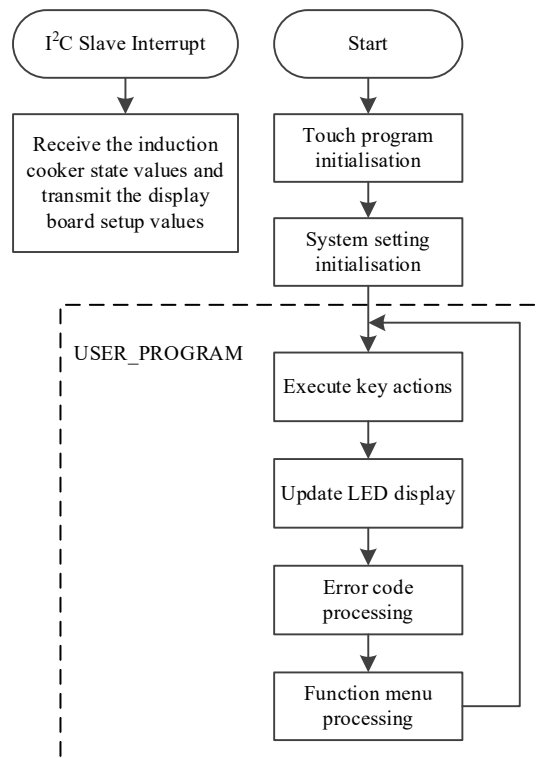


Figure 11. Touch & Display Board Main Program Flowchart

Low Power Continuous Heating (Drop-Wave) Operation Description

When using the drop-wave control method, after the specified number of IGBT off cycles, the resonant capacitor will have stored a large amount of electrical energy. Therefore it will be necessary to discharge the resonant capacitor at the beginning of IGBT on cycles. The specific discharge operation can be carried out by referring to the following figure.

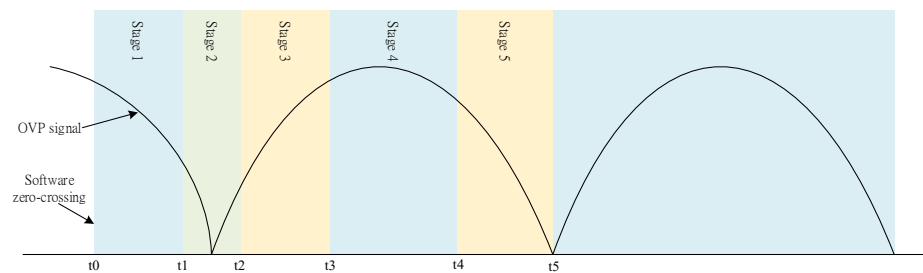


Figure 12. Resonant Capacitor Discharge Timing

- Stage 1: The PPG will be turned on after an OVP interrupt is detected by the software AC zero-crossing detect at t0. The IGBT will be driven by the PPGH output waveform where the voltage rises fast. During this period, the PPGH width is gradually increased from an initial value of 1μs to 3μs. This stage is from t0 to t1, which takes about 930μs.
- Stage 2: Stage 1 ends at time t1, at which point the IGBT is driven by the PPGH output waveform where the voltage rise slowly. The PPGH width is gradually increased from 3μs to 13μs. The duration of this stage is approximately 1.25ms from t1 to t2.

- Stage 3: The IGBT will be driven by the PPGH output waveform where the voltage rises slowly during the first half and fast during the second half. The PPGH width is gradually increased from 13μs to 17μs. The duration of this stage is approximately 3ms from time t2 to t3.
- Stage 4: The IGBT will be driven by the PPGH output waveform where the voltage rises fast. The PPGH width is 17μs during this period. The stage is from t3 to t4, which is about 5.2ms.
- Stage 5: The IGBT will be driven by the PPGH output waveform where the voltage rises slowly during the first half and fast during the second half. The PPGH waveform maintains a slow rise of 8.5μs and a fast rise of 8.5μs. The duration of this stage is approximately 1.8ms from time t4 to t5.

After stage 5, the PPGH output waveform where the voltage rises fast is maintained in each AC cycle until the IGBT is turned off due to power control. Repeat Stage 1 to Stage 5 after an OVP interrupt is triggered in the next cycle.

Solution Communication Description

The power heating board and touch & display board communicate with each other using the I²C protocol. The power heating board uses the MCU I/Os to simulate the I²C master while the touch & display board has an integrated hardware I²C slave function. The communication is executed once every 100ms. Table 7 shows the communication formats between the power heating board and the touch & display board. The “S” indicates the I²C start bit, the “Address & R/W bit” is 1-byte data, in which bit [7:1] is the I²C communication address and bit[0] is the R/W bit. Values in the Data Field are all in 1-byte format. The “Checksum” is the sum of the data values in the Data Field. The “P” indicates the I²C stop bit. Table 8 shows the data format in the power heating board data field. The “IGBT value” and “BOT Value” are temperature A/D values, the “IH Status” includes the cookware detection condition and induction cooker operating state error codes. Table 9 shows the data format in the touch & display board data field. When the power heating board transmitting data is received, the touch & display board will return its current settings which includes the induction cooker on/off state, buzzer setting, induction cooker fan setting, target heating power as well as the power heating mode setting of either continuous heating or intermittent heating. In addition, the communication data validity can be checked using two methods. One is to determine whether the checksum value is equal to the sum of the data values in the data field and the other is to determine whether the one’s complement of the IHStatus[7:5] value is equal to the IHStatus[2:0] value, or whether the one’s complement of the ControlSet[7:4] value is equal to the ControlSet[3:0] value.

Power Heating Board transmitting data format (I ² C Master)						
S	Address & R/W bit	Data Field			Checksum	P
		IGBT Value	BOT Value	IH Status	Checksum	P
Touch & Display Board transmitting data format (I ² C Slave)						
S	Address & R/W bit	Data Field			Checksum	P
		ControlSet	PowerStep		Checksum	P

Table 7. Solution Communication Format

Power Heating Board transmits the operating state, IGBT temperature and cooktop surface temperature A/D sampled values								
Data Field Parameter	Data Content							
IGBT Value	IGBT temperature A/D sampled value							
BOT Value	Cooktop surface temperature A/D sampled value							
IH Status (Operating state)	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	Checksum			Cookware detection	Power heating board operating state error code			
	One's complement of the bit[2:0] value of the power heating board operating state error code			0: Cookware present 1: No Cookware present	0000: Normal operation 0011: IGBT overheating 0100: IGBT temp. sensor fault 0101: Cooktop surface overheating 0110: Cooktop temp. sensor fault 0111: Resonance over current 1000: Mains supply over voltage 1001: Mains supply under voltage			

Table 8. Power Heating Board Data Field Format

Touch & Display Board transmits induction cooker control settings								
Data Field Parameter	Data Content							
ControlSet	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	Checksum				ON/OFF	BUZ[1:0]		FAN
	One's complement of the ControlSet[3:0] value				On/Off 0: Off 1: On	Buzzer 00: No sound 01: Sounds for 200ms 10: Sounds twice 11: Sounds for 1s		Fan control 0: Off 1: On
PowerStep	PowerStep is used for both power and temperature settings. Values 1~9 are for temperature setting, values 10~100 are for power setting value M. The setup power can be calculated by the equation: P=M×20, in which P is the induction cooker target heating power. For example, when M value is 50, the setup heating power is 1000W.							

Table 9. Touch & Display Board Data Field Format

Function Library Description

Power Heating Board Function	Description
PowerCalculation_Init()	Power calculation curve initialisation
PowerControl_Task()	Power control function

Table 10. Power Heating Board Function Library

Touch & Display Board Function	Description
void GET_KEY_BITMAP()	Read the touch key state and output the corresponding value in bitmap form

Table 11. Touch & Display Board Function Library

In the power heating board, the power calculation curve initialisation and the power calculation and adjustments are implemented using a function library. The descriptions for these functions, including the input, output and function description are listed in the following tables.

1. PowerCalculation_Init()

Function Name	PowerCalculation_Init()
Task	Power calculation curve initialisation
Input	NULL
Output	NULL
Description	Initialise the relevant variables of power control

Table 12. PowerCalculation_Init() Function Description

2. PowerControl_Task()

Function Name	PowerControl_Task()
Task	Power control
Input	AD_Iac, AD_Vac, PowerStep, bPowerStepChanged
Output	PPGTA_copy
Description	1. The target power can be adjusted either by the user setting on the touch & display panel or by a value modification caused by a triggered protection. 2. Calculate the actual power according to the voltage and current A/D values. 3. Compare the actual power with the target power and adjust the PPG variable PPGTA_copy. 4. Variable descriptions: AD_Iac: operating current A/D value AD_Vac: operating voltage A/D value PowerStep: target power intermediate variable, target power = PowerStep × 20 bPowerStepChanged: target power changed flag

Table 13. PowerControl_Task() Function Description

In the touch & display board, the touch key state reading function in the touch function library is used. It can be determined which key was pressed by the user via the return value of the touch key state reading function.

3. GET_KEY_BITMAP()

Function Name	GET_KEY_BITMAP()
Task	Read the touch key state and output the corresponding value in bitmap form
Input	NULL
Output	DATA_BUF[0] = KEY8(MSB) ~ KEY1(LSB) DATA_BUF[1] = KEY12(MSB) ~ KEY9(LSB) (0=released; 1=pressed)
Description	Use this function to read the touch key state to determine whether the touch key is pressed or not.

Table 14. GET_KEY_BITMAP() Function Description

Test Data

Power Test

Setup Power	Actual Power	Error
100W	103W	3.00%
300W	312W	4.00%
600W	615W	2.50%
1000W	1012W	1.20%
1200W	1225W	2.08%
1400W	1438W	2.71%
1600W	1582W	1.13%
1800W	1789W	0.61%
2000W	1997W	0.15%

Table 15. Power Test Table

DP Test

The following shows the test results in low power (100W\300W\600W) continuous heating mode.

● 100W

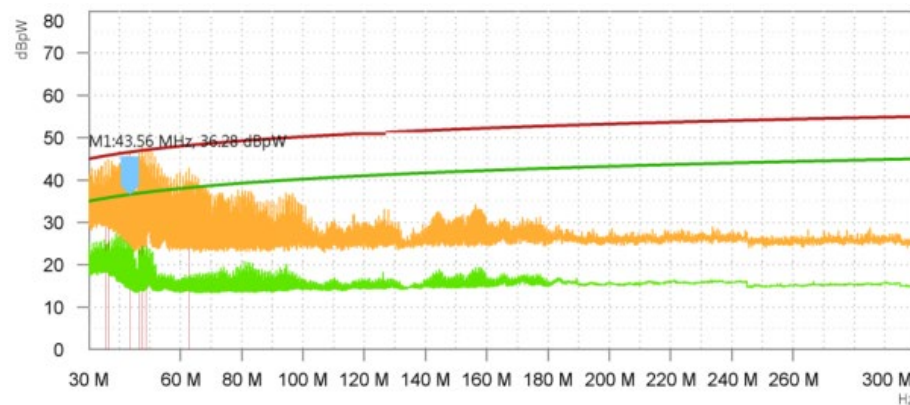


Figure 13. DP Test Frequency Spectrum at 100W Power

● 300W

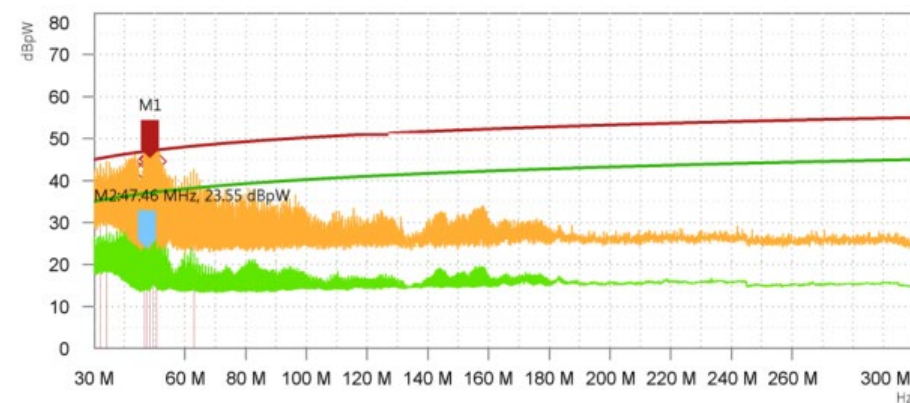


Figure 14. DP Test Frequency Spectrum at 300W Power

● 600W

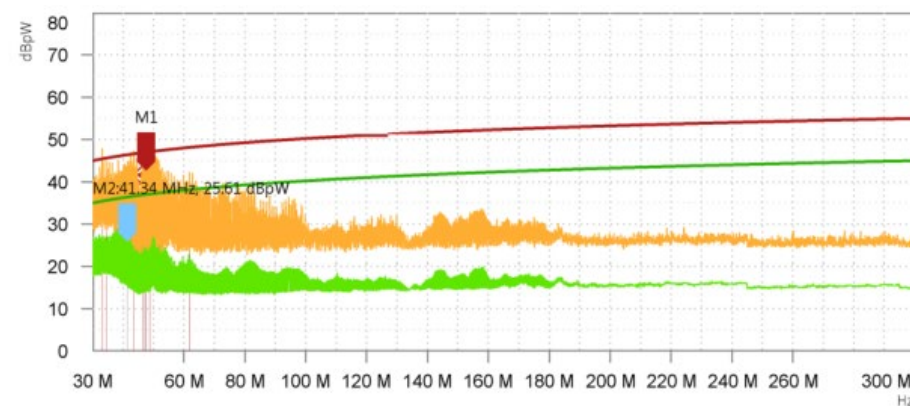


Figure 15. DP Test Frequency Spectrum at 600W Power

CE Test

The following shows the test results in low power (100W\300W\600W) continuous heating mode.

● 100W

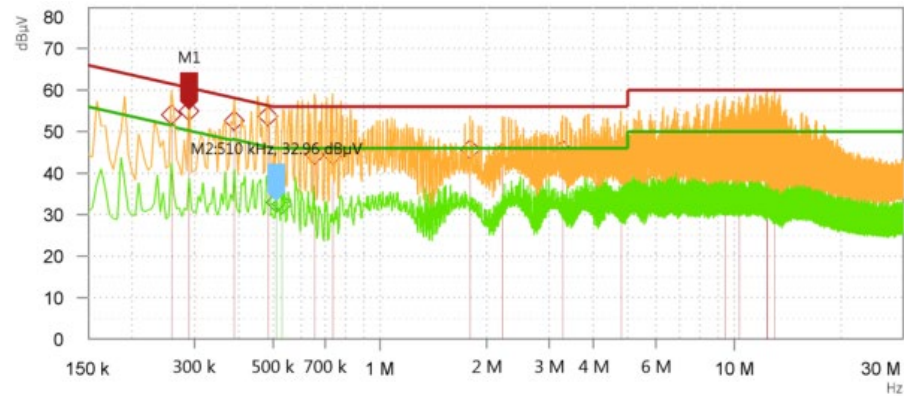


Figure 16. CE Test Frequency Spectrum at 100W Power

● 300W

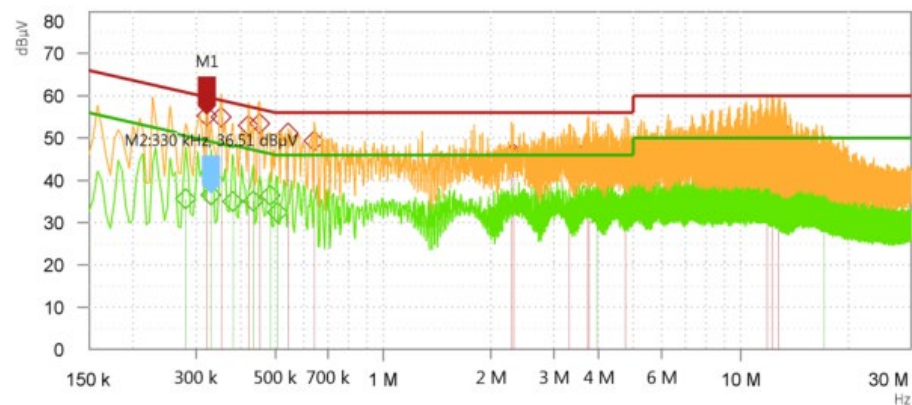


Figure 17. CE Test Frequency Spectrum at 300W Power

● 600W

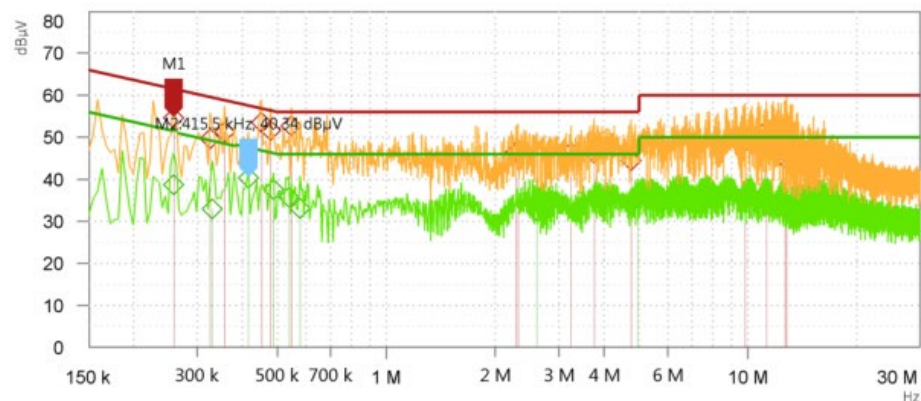


Figure 18. CE Test Frequency Spectrum at 600W Power

Solution Comparison

Compared with traditional solutions, the HT45F0059 low power continuous heating solution reduces hardware costs and simplifies the PCB layout wiring for the same functional conditions. Compared with traditional low power continuous heating methods, this solution provides higher heating efficiency and can achieve slow cooking or holding effects.

	Traditional Solution	HT45F0059 Solution
IGBT driving	External circuit	Internal circuit in IC
Low power heating	Heating intermittently	Heating continuously

Table 16. Solution Comparison Table

Conclusion

This document has provided a low power continuous heating induction cooker solution and has introduced the single-IGBT induction cooker power heating board and touch & display board operating principles and hardware description as well as communication protocols. When the induction cooker operates at a low power level, the drop-wave control method is adopted to implement continuous heating for low power conditions. This can further improve the heating efficiency when compared with traditional intermittent heating methods. In addition, this method can reduce IGBT thermal losses, extend the service life and greatly improve the user experience.

Reference Material

Reference files: HT45F0059, BS86D12C Datasheet.

For more details consult the Holtek website at <http://www.holtek.com/>.

Version and Modification Information

Date	Author	Release	Modification
2023.01.04	曾增祥	V1.10	Update Figure 1. Application Block Diagram
2021.10.18	蔡健文	V1.00	First version

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