

Description

2100W, Single plate Induction cooktop design, using iW248 single chip ASSP offers a high efficiency and high reliability performance. The design gives the flexibility to adjust the power in +/-10W steps, which allows the users to cook at simmering condition. RL78/G15 based HMI card offers low pin count, multiple matrix switch, LED Indication, and 7-Segment display. Over temperature detection using three NTCs are provided in the ASSP.

Kit Contents

- AS048INDCKTP-D-POCZ HMI Display Card
- AS048INDCKTP-P-POCZ Power Card

Features

- Integrated ASSP design offers Low cost, Low Component count system.
- AC Input, IGBT Voltage spike detection, Current sense using iW248 helps in fast protection response. It is a Digital controller with analog driver blocks using state machine offers much faster response.
- Controlled speed and soft start of the blower fan.
- Patented Low Power technology, gives adjustable to +/- 10W allows uses to cook at Simmer condition.

Evaluation Board

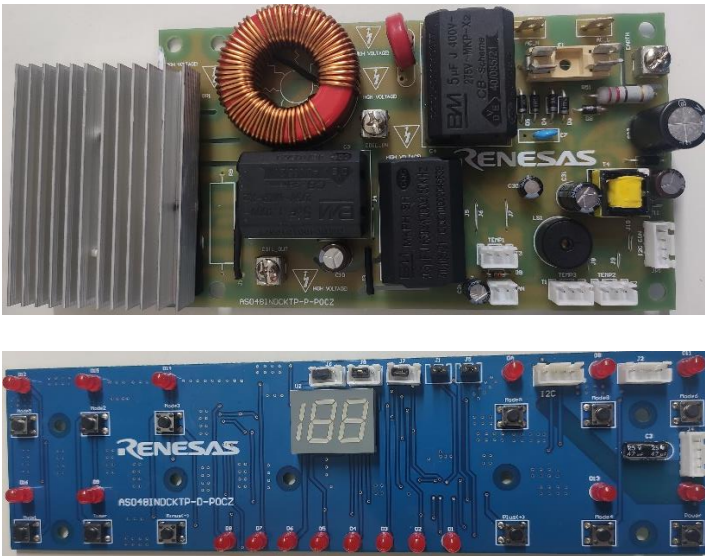


Figure 1. AS048 Energy Efficient Single Burner Induction Cooktop Board

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AS048 Overview

The block diagram below highlights the main parts of the system:

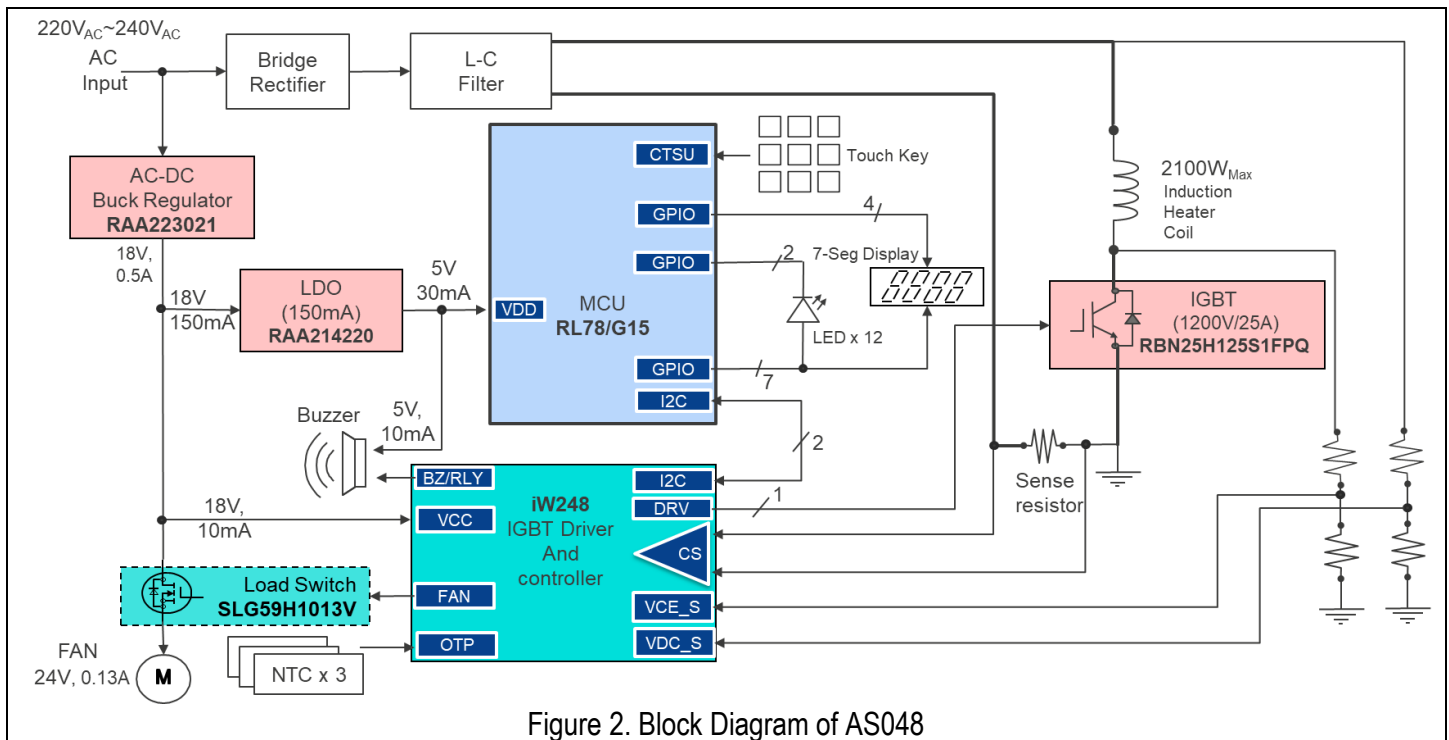


Figure 2. Block Diagram of AS048

The building blocks of the AS048 and their functionality are listed below:

1. [RAA214250](#): The RAA214250 is a low-dropout linear voltage regulator that operates from 2.5V to 20V and provide up to 500mA of output current with a typical dropout of 269mV. The output voltage is adjustable with external feedback resistors anywhere from 1.224V to 18V.
2. [RAA223021](#): The RAA223021 is a universal input AC/DC switching buck regulator with ultra-low standby power that features a 700V integrated MOSFET capable of delivering up to 12W output power. It supports output voltage as low as 5V.
3. [RBN25H125S1FPQ](#): RBN25H125S1FPQ-A0 is a Trench gate and thin wafer technology (G8H series) IGBT, which is 1250V VCE and 25A collector current in TO-247A package. It has built in fast recovery diode in one package. It has a low collector to emitter saturation voltage $V_{CE(sat)} = 1.8\text{ V typ. (at } I_C = 25\text{ A, } V_{GE} = 15\text{ V, } T_a = 25^\circ\text{C)}$. It has a short circuit withstands time (10 $\mu\text{s min.}$). The IGBT is suitable for high-speed switching.
4. [RL78/G15](#): The RL78/G15 is a general-purpose microcontroller with a 16MHz operating frequency. There is a wide lineup available, including the smallest 8-pin package in the RL78 Family, and support for a wide range of operating ambient temperatures from -40°C to 125°C . The built-in high-speed on-chip oscillator with high accuracy ($\pm 1.0\%$), the data flash, the rich serial interfaces, and the comparator make it ideal for compact applications where space comes at a premium.
5. [iW248](#): The iW248 provides a unique combination of digital controller and analog driver blocks in one IC, resulting in an optimized solution for driving induction heating elements in rice cookers and induction cooktop appliances. Integrating virtually all discrete components normally used to drive and protect IGBTs, plus an optimized state machine digital core that replaces a traditional microcontroller, the iW248 significantly reduces solution size. The iW248 also features a proprietary low-power continuous mode that allows for smooth operation at low power states and control in 10W increments for induction cooktop applications up to 2100W.

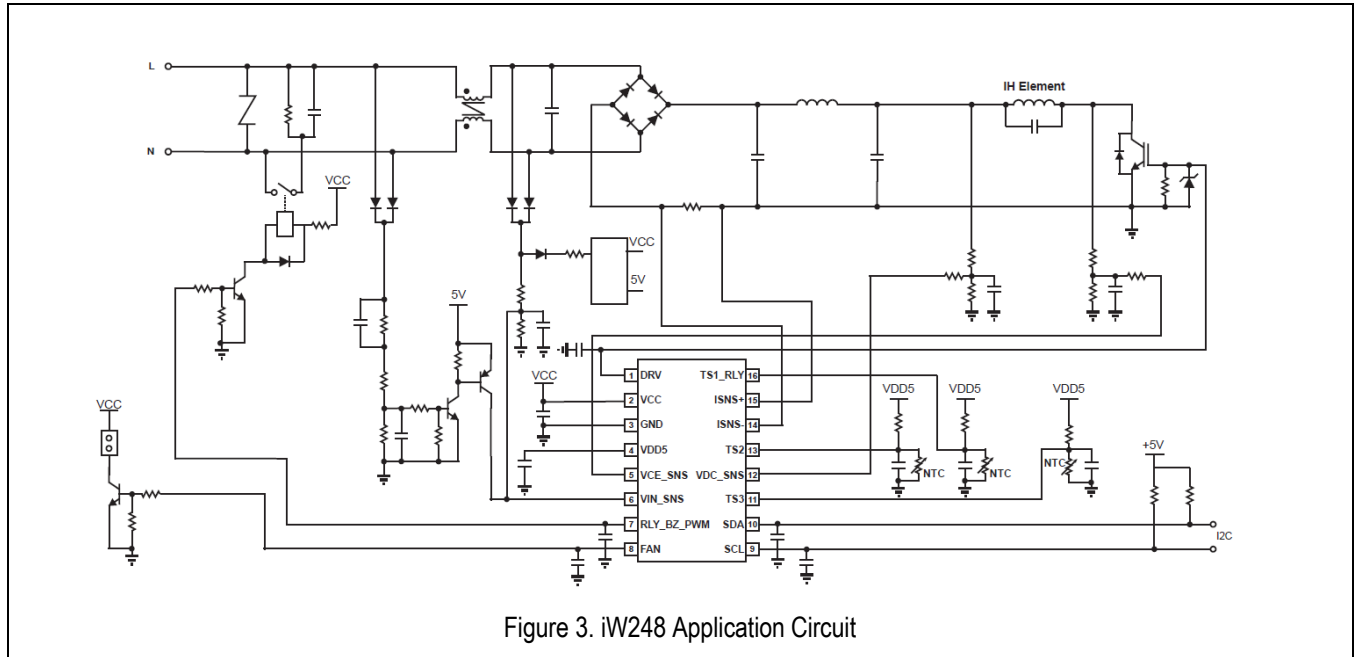


Figure 3. iW248 Application Circuit

Hardware Overview

The following block diagrams have specific applications explained below.

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 HMI board using I2C communication. The HMI display board uses tactile switch and LED display functions to provide a human-machine interface (HMI) control. The tactile switch 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.

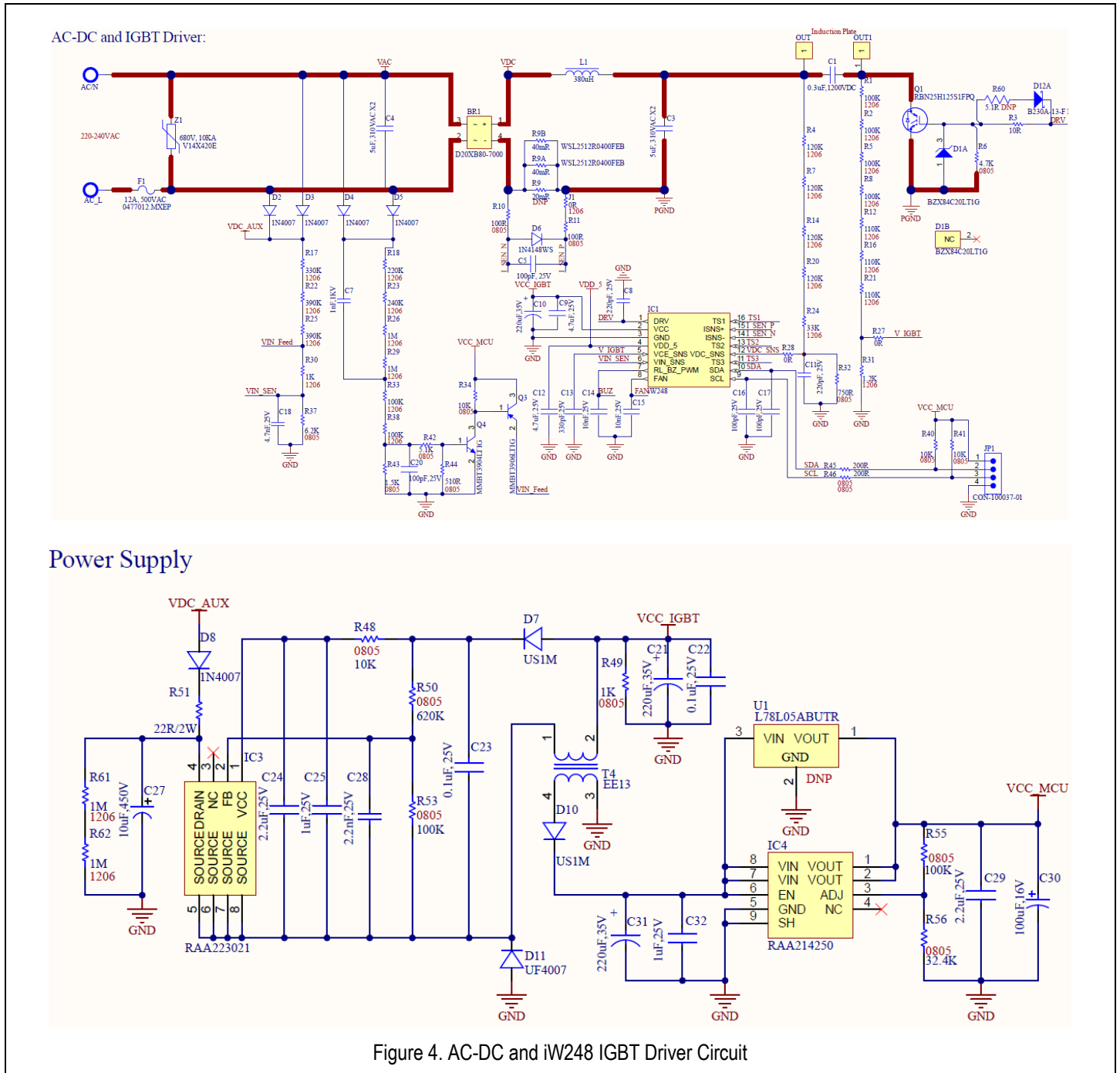


Figure 4. AC-DC and iW248 IGBT Driver Circuit

The AC supply for the power heating board is divided into two paths after passing through the EMI filter circuit. One path is to the switching power circuit and the other is to the resonance circuit (3), being used as the heating main power circuit. The mains AC line input with the Diode Bridge, Storage Capacitor(s), EMI-reduction Choke as well as safety and protection components like Fuse or Fusible Resistor, MOV and X-Capacitor. The input surge section consists of 410V MOV (Metal Oxide Varistor). Fuses are ideal candidates for overcurrent protection in SMPS because of their proven safety, reliability, low resistance, small size, and cost effectiveness. The Bridge rectifier D20XB80S is used to convert AC to DC supply to power the resonance circuit.

RAA223021 is a universal input AC/DC switching buck regulator with ultra-low standby power that features a 700V integrated MOSFET capable of delivering up to 12W output power. RAA223021 is used to power iW248 IC and the fan circuit. The RAA223021 combines constant off-time control for heavy load and Pulse Frequency Modulation (PFM) for light-load operation. Constant off-time controls switching frequency above the audible frequency around 43kHz. PFM eliminates any potential audible noises while offering superior light-load efficiency and ultra-low power consumption (<20mW at no load). The efficiency is achieved up to 80%.

The switching power circuit outputs +18V and +5V. The +18V power is supplied from RAA223021 flyback converter to the fan control circuit and the main control MCU (iW248) on the power heating board. The +5V power is supplied from RAA214250 LDO to the buzzer and HMI board. The VDD output from the main control MCU is supplied to the power heating board peripherals such as the cooktop surface overheating protection circuit and the IGBT overheating protection circuit.

The induction cooktop power control is implemented depending upon the current detection circuit and the voltage detection circuit. 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 in 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.

The iW248 is a digital controller with an integrated IGBT driver for inductive (IH) cooking applications. Once V_{CC} reaches the start-up threshold level, the controller operates in idle mode and is ready to receive instructions from the user interface MCU. Soon after the iW248 receives instructions, it starts to detect and determine the input line voltage. If the input line voltage is within the operating range, the controller enters pot detection mode. The iW248 features an innovative pot detection method by detecting the number of rings on V_{CE} of the IGBT. A pulse is sent out at DRV pin every second by default, a pot is detected if the number of rings on V_{CE} is less than nine. When a pot is detected, the iW248 goes to constant power mode operation or constant current mode according to the input line voltage. Figure 4 outlines the state machine diagram of iW248.

The iW248 drives an LC circuit comprised of an induction heating element and resonant capacitor. The controller modulates the t_{ON} time and delay time (t_{DELAY}) to maintain a constant output power requested by the user interface MCU. When the IGBT turns off, the voltage at the collector of the IGBT will quickly rise above the input voltage as the resonant capacitor charges up by the current of the inductor. The voltage at the collector of IGBT will fall from its maximum value when the polarity of the inductor changes. When the voltage on the collector of the IGBT reaches the same value as the voltage on the coil, the internal block of the controller gives the next driving pulse after it waits a programmed delay time (t_{DELAY}). This delay time can be adjusted via the digital control bus based on the system requirements. The iW248 directly monitors input voltage and current and the digital control unit inside the iW248 uses these values to calculate the on-time required as a function of requested output power.

As the output power decreases, the energy in the LC tank is insufficient to achieve zero-voltage switching. To prevent the IGBT from overheating from excessive switching loss, the VCE_SNS pin senses the VCE level for every switching cycle and counts the occurrence when the VCE doesn't reach its valley threshold.

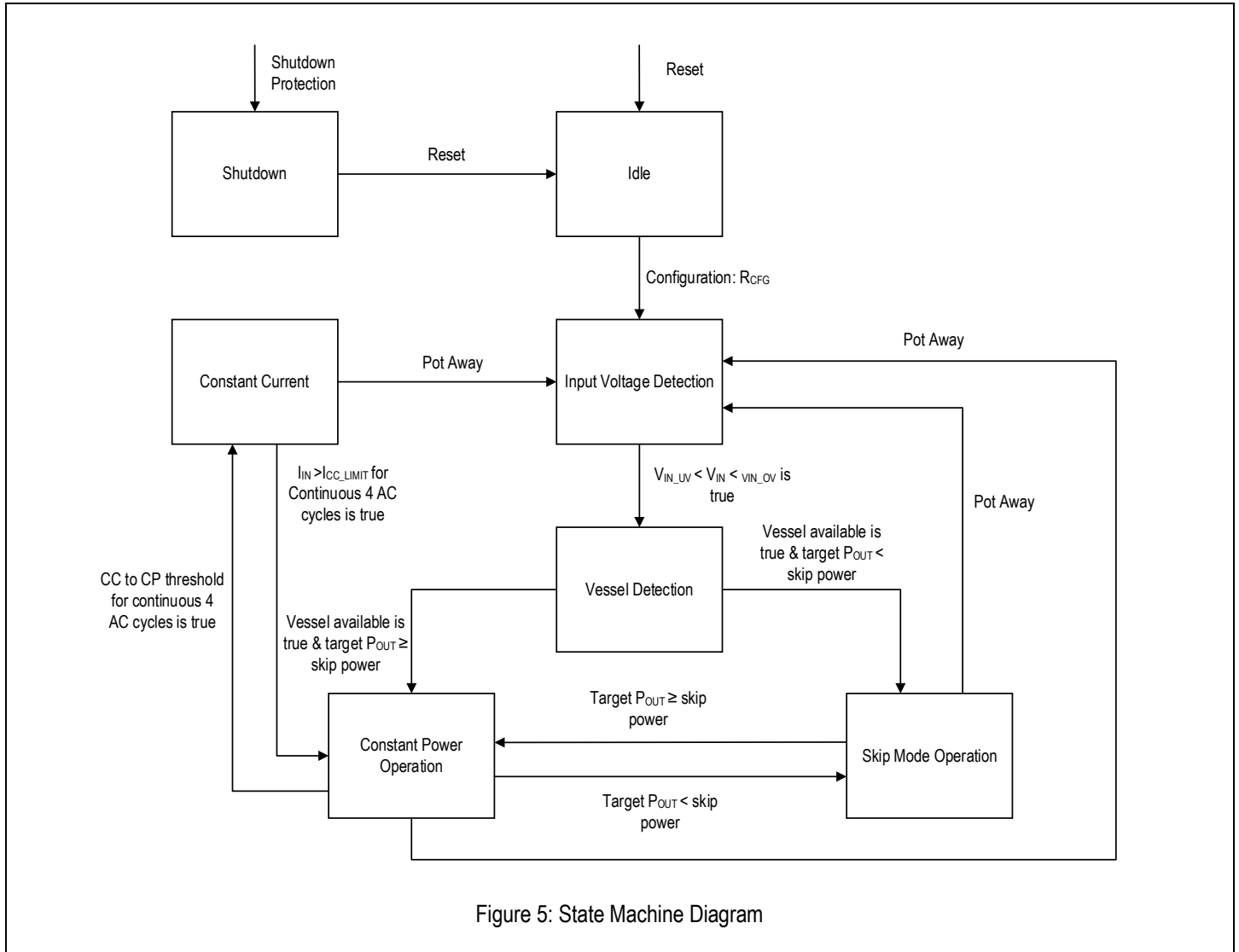
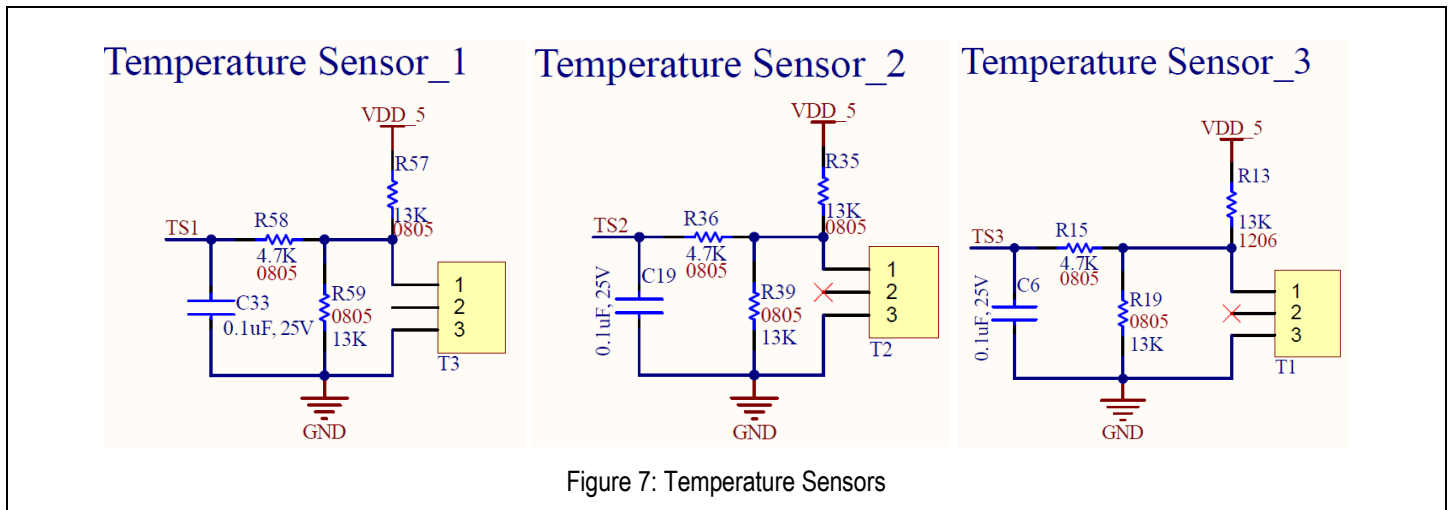
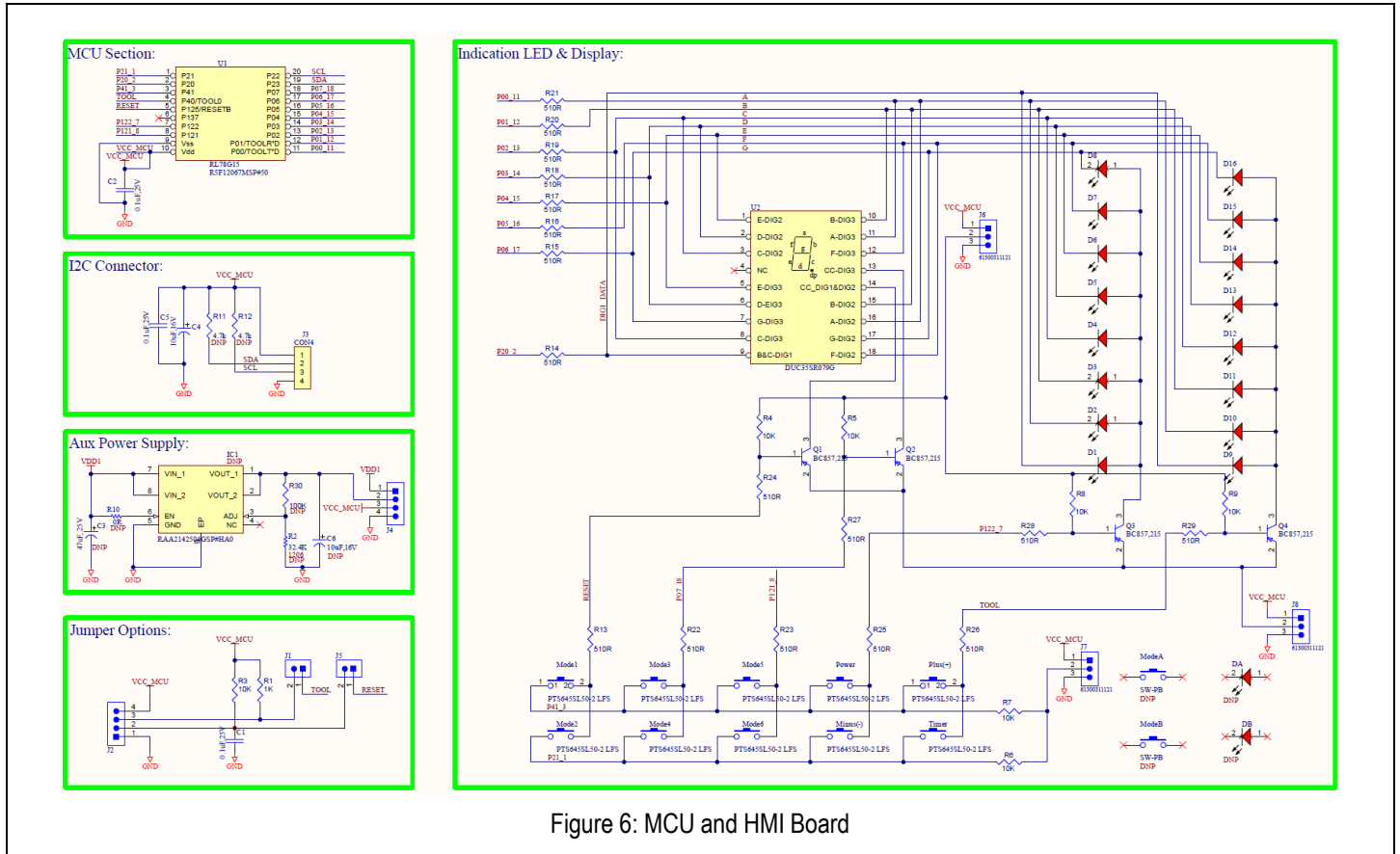


Figure 5: State Machine Diagram

HMI Board: The power board provides the power supply 5V to the HMI display board via the I2C connector. This voltage supply is regulated to a 5V voltage output by a voltage regulation filtering circuit and is supplied as the HMI display board main power. The LED's displays the current induction cooker operating mode and function. The tactile switches 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.



The TS1 works with the circuit as shown in Figure 7 and has a default over temperature threshold of 110°C and a default recovery threshold of 80°C. These are both programmable via the digital control bus.

The TS2 works with the recommended circuit shown in Figure 7 and has a default over temperature threshold of 200°C and a default recovery threshold of 170°C. These are both programmable via the digital control bus.

Software Overview

- 1) Debugging/Binary flashing:

Hardware Setup:

As per present hardware/layout hardware debugging pins of AS048 GUI board are multiplexed with switch scan functions. Renesas E2 lite emulator can be used to flash binary on to G15.

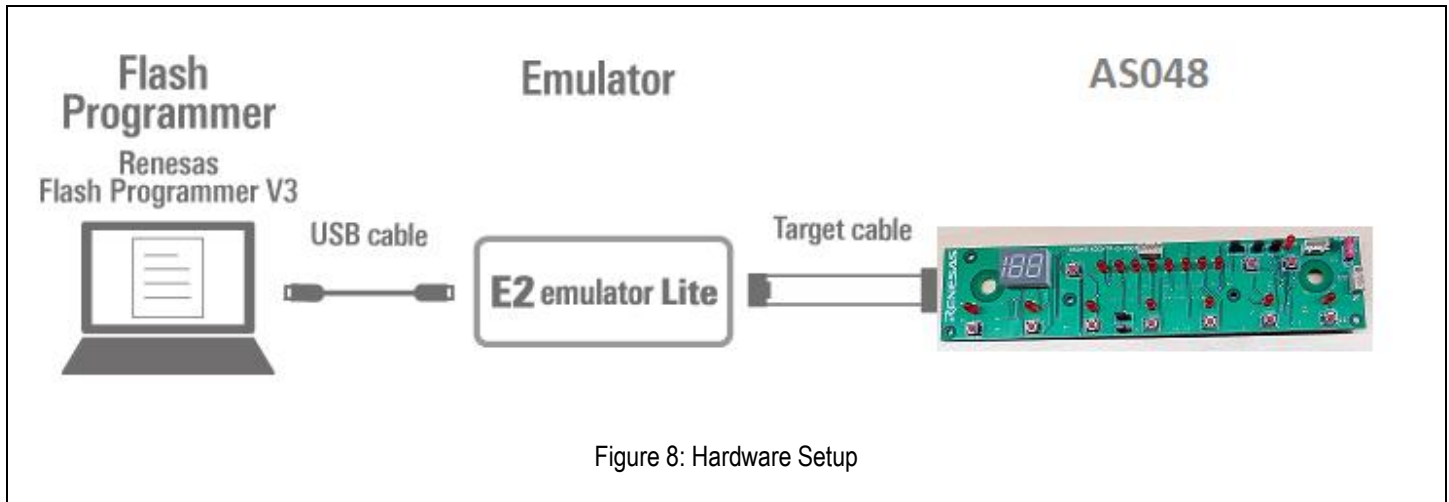


Figure 8: Hardware Setup

Flashing & Flash Programmer Settings: Tool: E2 Emulator Lite, Speed Setting: 115200

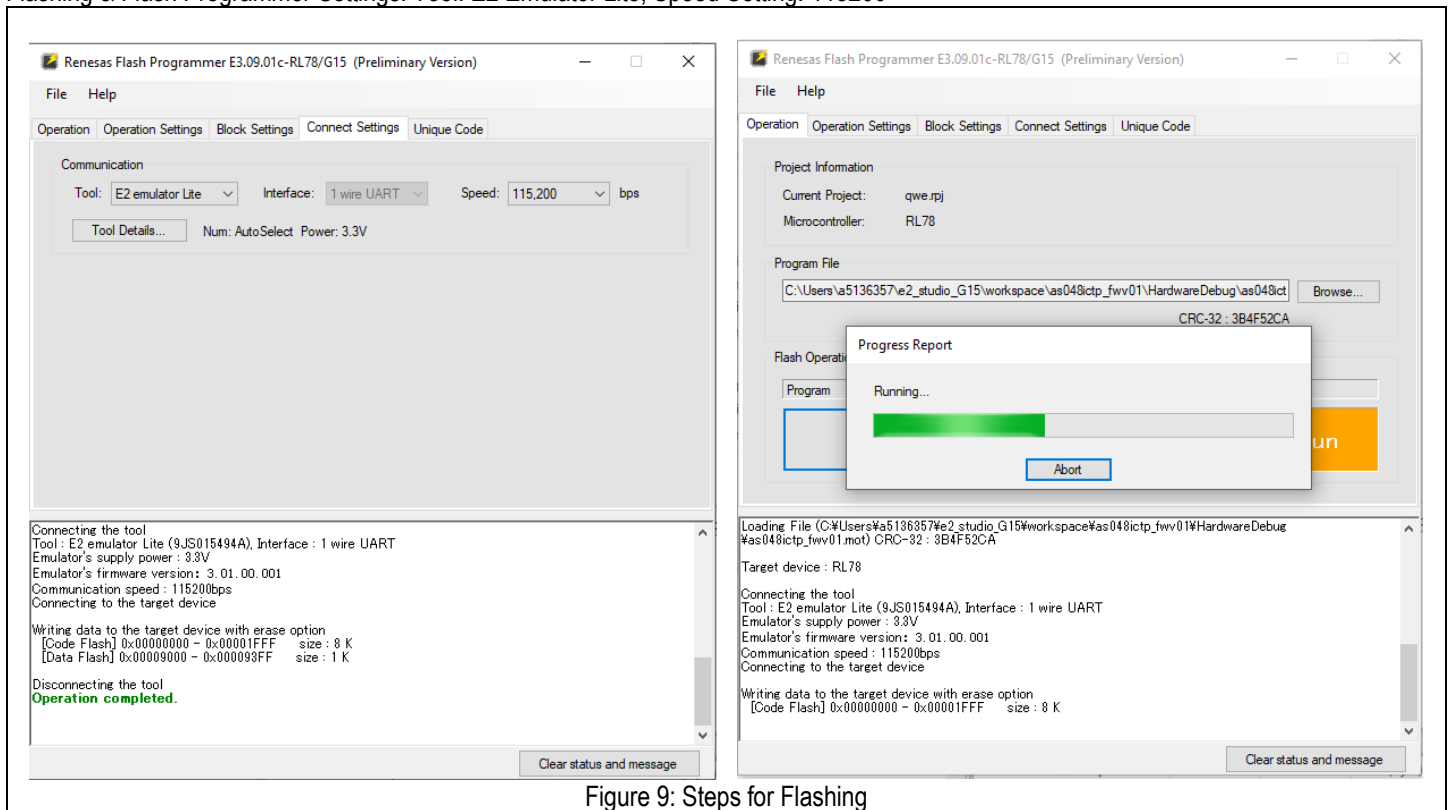


Figure 9: Steps for Flashing

2) Project settings, configuration, and Source code building:

IDE environment used for code development is e2-studio, and Toolchain is Renesas CCRL.

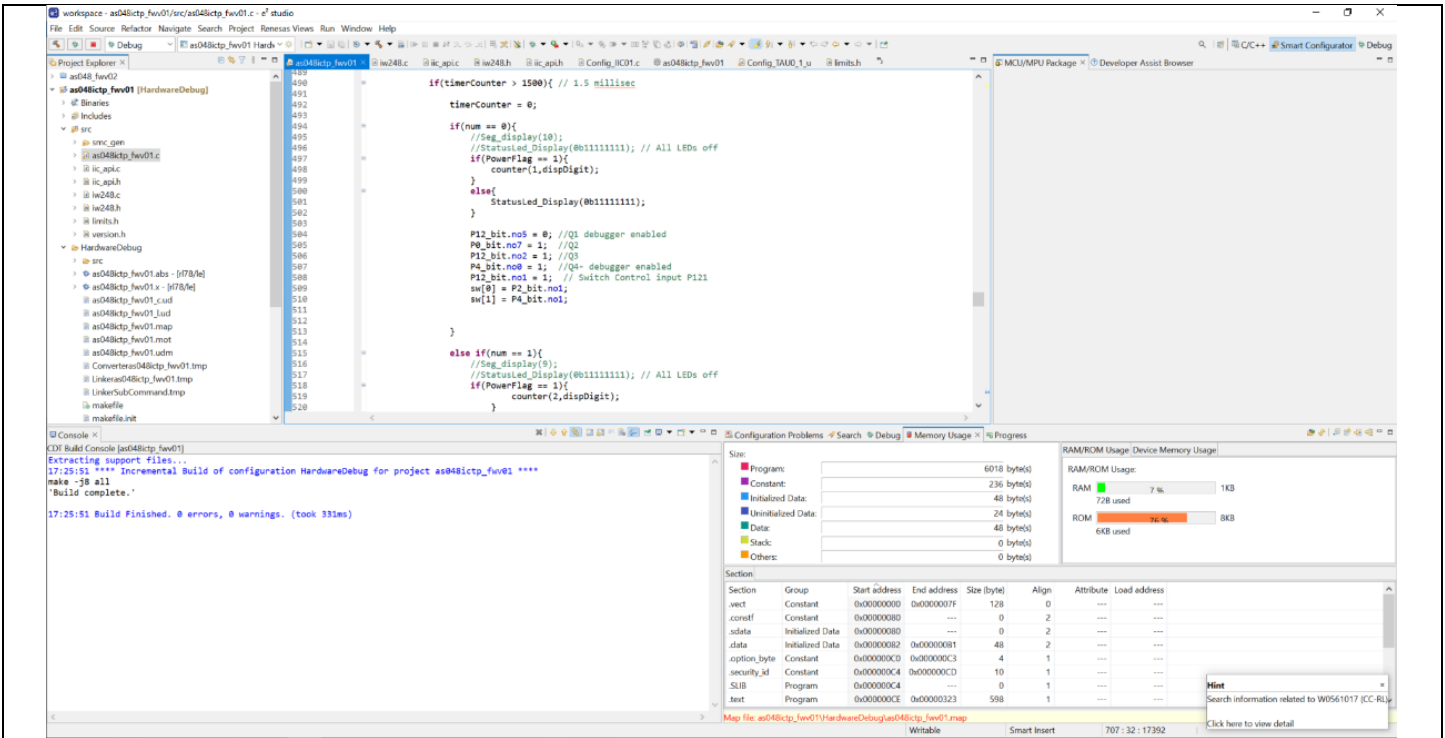


Figure 10: IDE Environment for Code Development

Smart configurator is used to configure RL78/G15 hardware configurations.

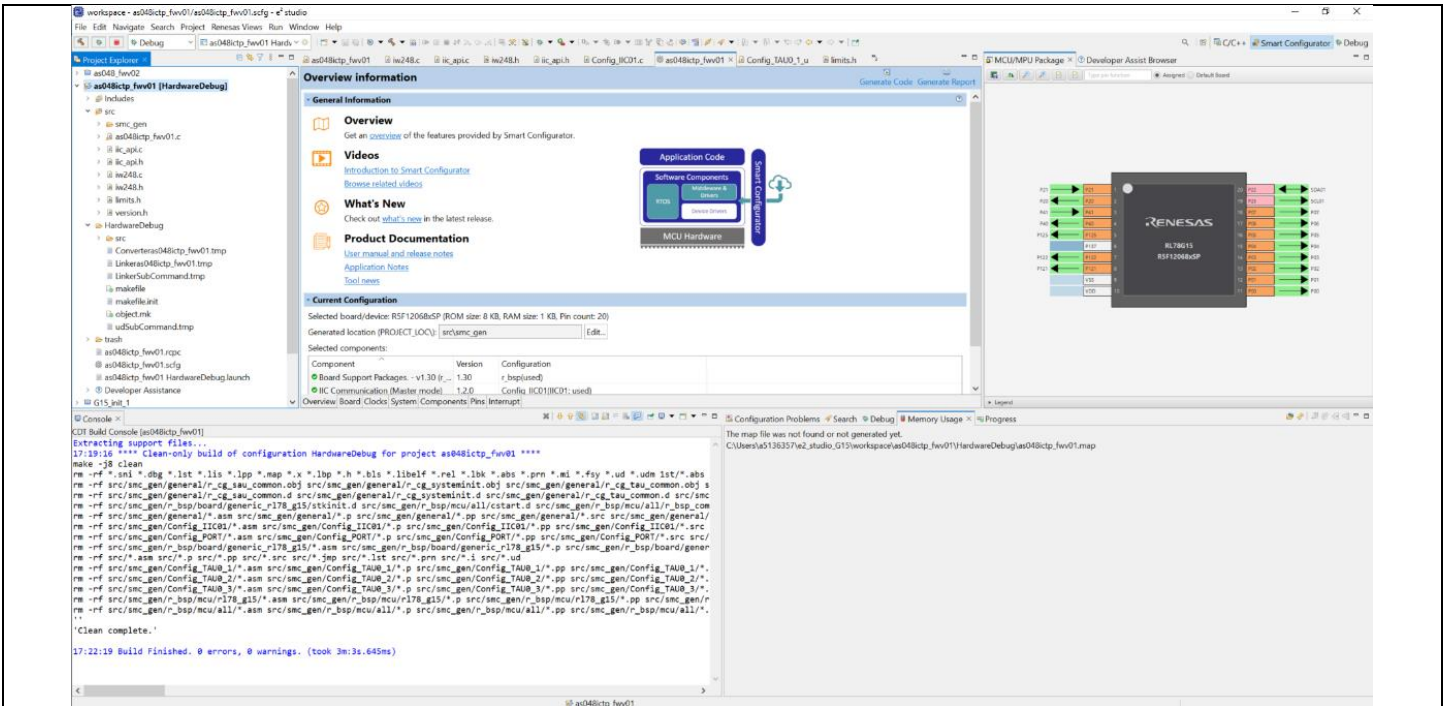


Figure 11: Smart Configurator used to Configure RL78/G15

3) Software State Diagram:

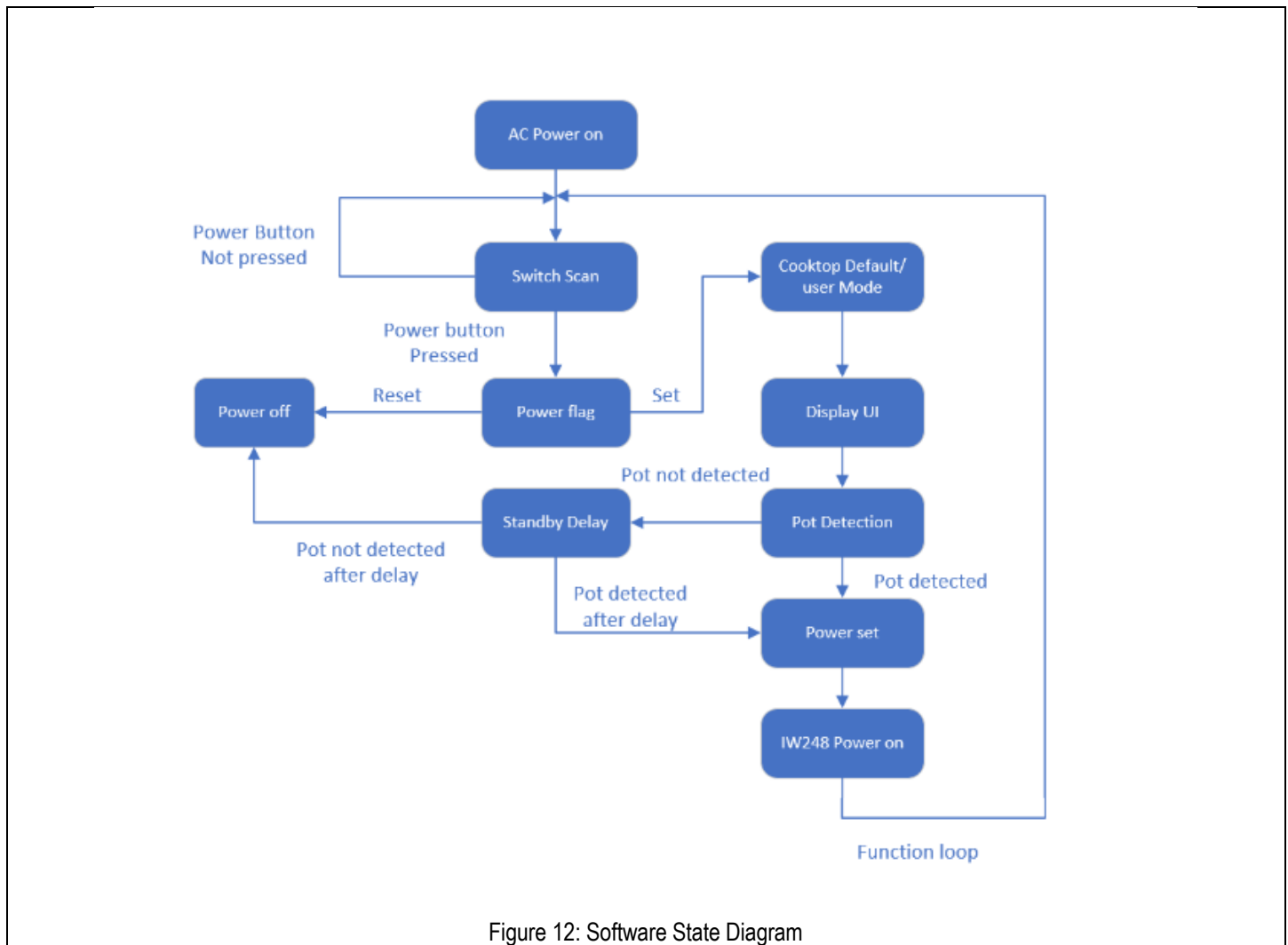


Figure 12: Software State Diagram

4) IW248 library API functions:

- IW248 Power on/off functions

```

void iW248_IIC_PowerON(void)
void iW248_IIC_PowerOFF(void)
  
```

- Fan control PWM-variable speed implementation with external voltage input for fan.

```

void iW248_IIC_FanSpeed(unsigned char spd)
  
```

- IW248 Power Control and output enable.

```

void iW248_IIC_PowerSel(unsigned char ps)
void iW248_IIC_PowerOutput(unsigned char enable)
  
```

- IW248 Buzzer call (Timing will set at initialization)

```

void iW248_IIC_Buzzer(void)
  
```

- IW248 Pot detection API.
unsigned char iW248_IIC_DetPot(void)
- IW248 Fault detection.
unsigned char iW248_IIC_GetFaultFlagH(void)
unsigned char iW248_IIC_GetFaultFlagL(void)
- IW248 Temperature sensor readings
unsigned char iW248_IIC_GetTempADC_TS1(void)
unsigned char iW248_IIC_GetTempADC_TS2(void)
unsigned char iW248_IIC_GetTempADC_TS3(void)
- IW248 Voltage sense.
unsigned int iW248_IIC_GetVinMax(void)
- IW248 IIC address (Auto Finder)
unsigned char iW248_IIC_AutoFindAddr(void)

Test Data

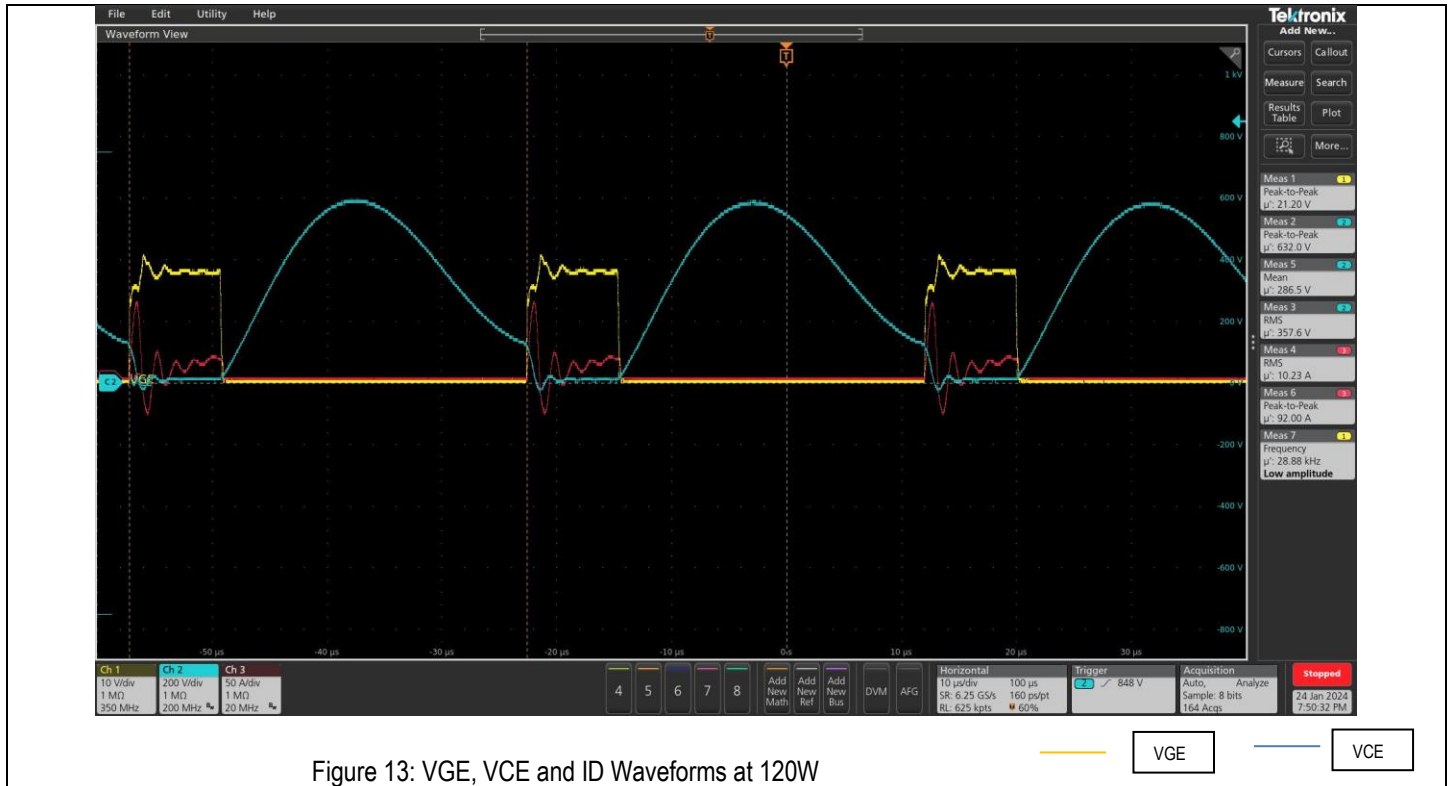


Figure 13: VGE, VCE and ID Waveforms at 120W

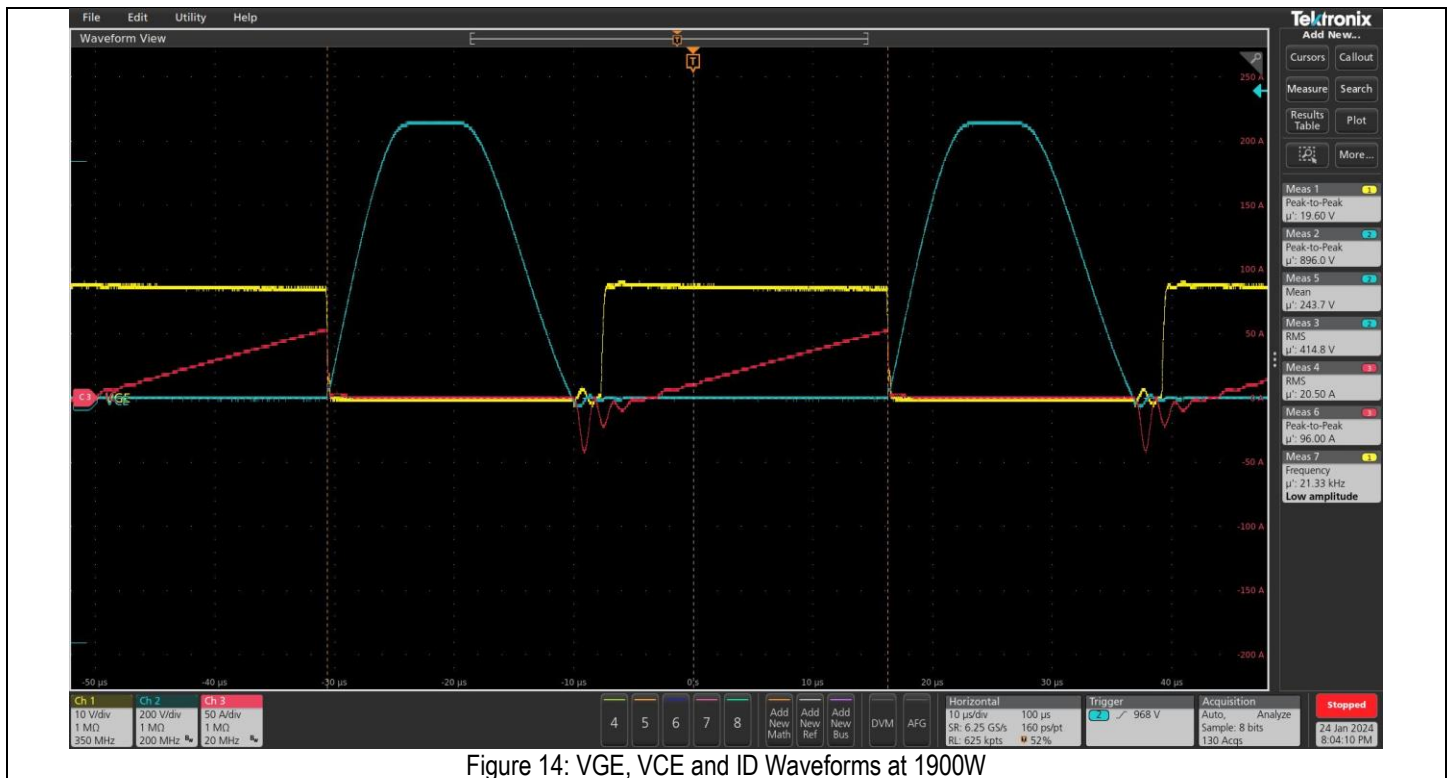


Figure 14: VGE, VCE and ID Waveforms at 1900W

Device Setup

Basic Features:

| | |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| Function | Cooking |
| Automatic Pan Detection | Yes |
| Wattage Settings | Variable wattage settings |
| Compatible Utensils | Stainless Steel Pots, Stainless Steel Rice Cookers, Cast Iron Frying Pots, Oil Boiling Pots, Stainless Steel Water Jugs, Grilling Iron Plates |
| Control Type | Button |
| Cooking Modes | 6 different intelligent cooking modes for timer and power settings |
| Indicator | Digital LED Display |
| Temperature settings | Variable Temperature settings |
| Fast Heating | Yes |

Power Supply:

| | |
|-------------------|---------------|
| Input Voltage | 220V-240V |
| Frequency | 50 Hz |
| Power Consumption | 2100 W (Max.) |

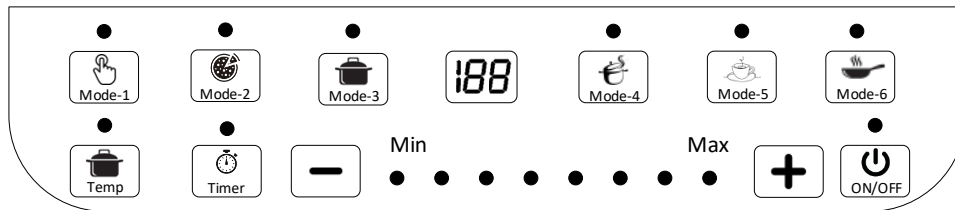


Figure 15: HMI Display with different modes

1. Press the ON/OFF button (⏻) to switch on the appliance, and the ON/OFF indicator lights up.
2. There are six preset cooking modes, which have or can be set with different time and power settings.
3. Press the desired cooking mode button, and the corresponding indicator lights up.
4. The appliance starts working in the selected mode.
5. When the cooking is finished, press the ON/OFF button (⏻) to switch off the appliance.
6. Unplug the appliance after the fan stops working.

Note:

1. During cooking, you can change the power level by pressing the Increase (+) or Decrease (-) button.
2. There is a fixed delay between changing the power or modes from one rating to another.

Getting to know the cooking modes:

Refer to the tables below for more details of different cooking modes.

Table 1. Different default Cooking Modes



| Cooking mode | Default cooking time (minute) | Power Range (Watts) | Adjustable cooking time range (minute) |
|--------------|-------------------------------|---------------------|----------------------------------------|
| Mode-1 | 60 | 1600 | 1-180 |
| Mode-2 | 60 | 1000 | 1-180 |
| Mode-3 | 45 | 800 | 1-180 |
| Mode-4 | 60 | 1300 | 1-180 |
| Mode-5 | 120 | 1600 | 1-180 |
| Mode-6 | 60 | 1700 | 1-180 |

Table 2. Induction Cooker Error Code Introduction

| Error Code | Description |
|------------|----------------------------|
| E1 | No Cookware Detected |
| E2 | Mains supply Under Voltage |
| E3 | Mains supply Over Voltage |
| E4 | IGBT Overheating |

Using the timer:

You can use the Timer button to decide how much time you want the appliance to work at different cooking modes.

1. Press the ON/OFF () button, the ON/OFF () indicator lights up.
2. Press the desired cooking mode button, and the corresponding indicator lights up. The induction cooker starts working in the selected mode.
3. Press the Timer button and the timer indicator lights up.
4. Press the Increase (+) or Decrease (-) button to adjust the time by minute.
5. When the time has elapsed, the induction cooker turns off automatically.

AS048 Application Schematic

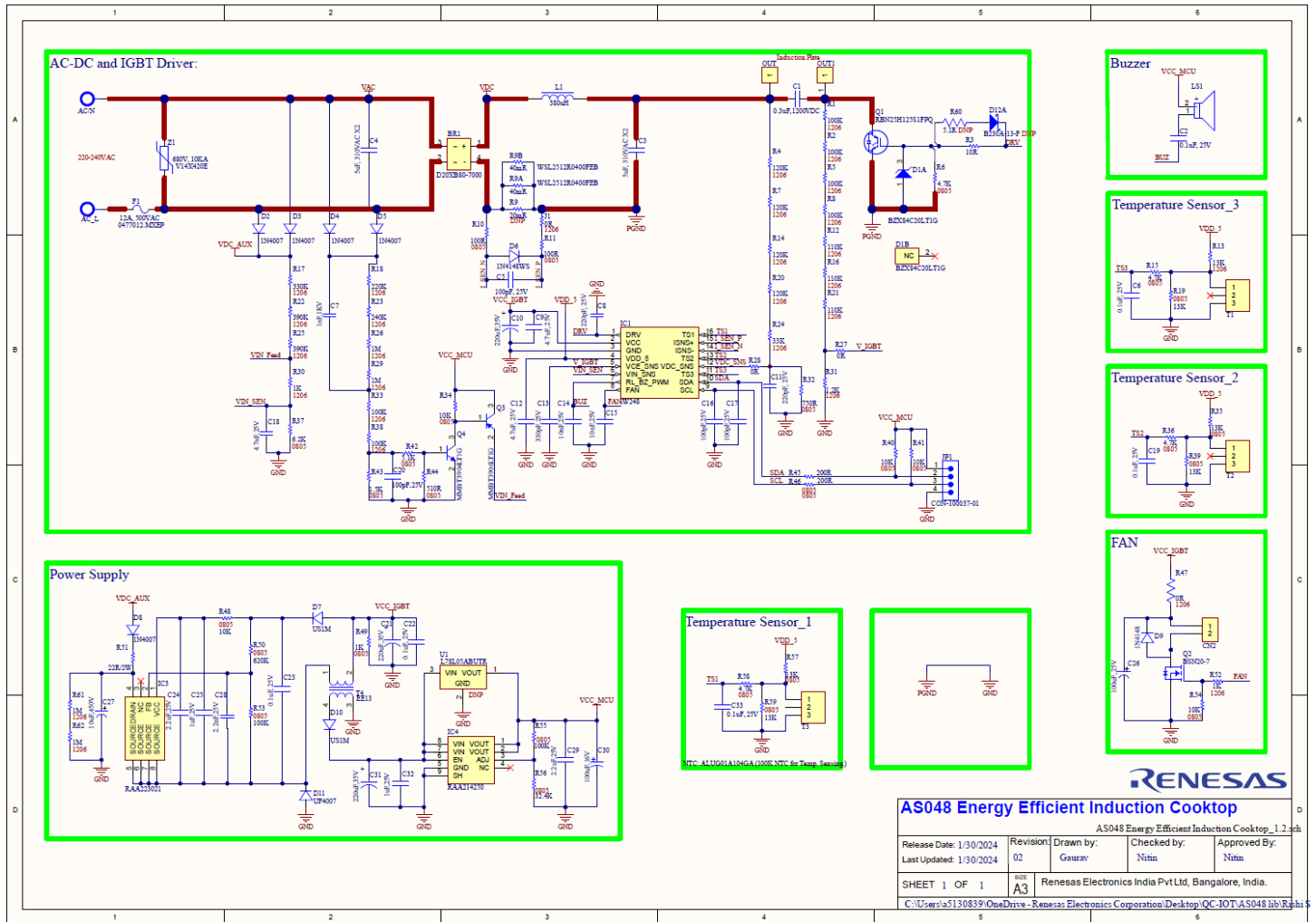


Figure 16. Power Board Schematic

AS048 Energy Efficient Induction Cooktop

AS048 Energy Efficient Induction Cooktop_1.2 sch

| | | | | |
|-------------------------------------------------------------------------------------------|--------------|------------------|-------------------|--------------------|
| Release Date: 1/30/2024 | Revision: 02 | Drawn by: Gaurav | Checked by: Nitin | Approved By: Nitin |
| SHEET 1 OF 1 | | | | |
| Renesas Electronics India Pvt Ltd, Bangalore, India. | | | | |
| C:\Users\5130839\OneDrive - Renesas Electronic Corporation\Desktop\QC-IOT\AS048.lib\Re... | | | | |

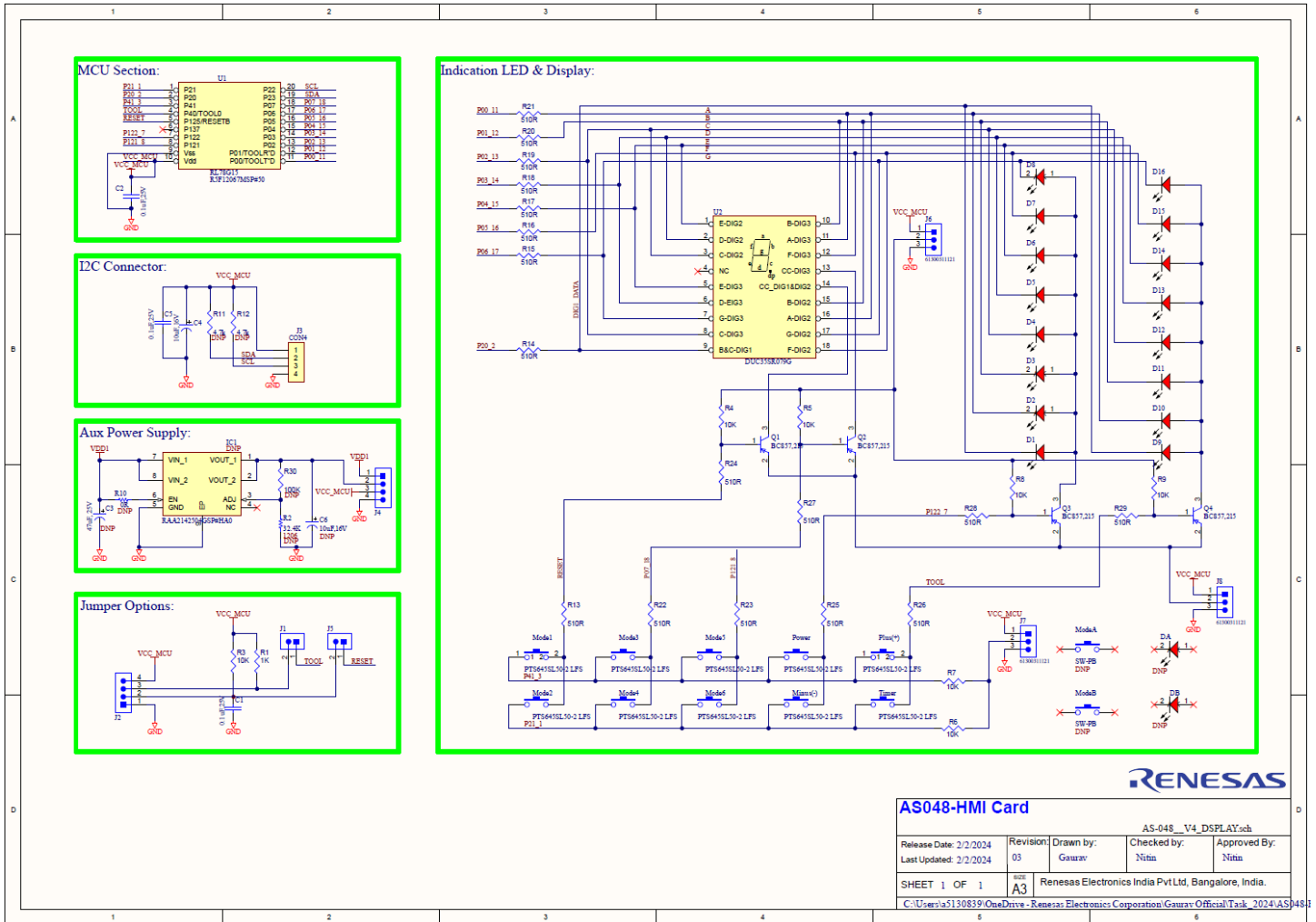


Figure 17. HMI Board Schematic

Bill of Materials (BOM)

Table 2. AS048 Power Board BOM

| Quantity | Designator | Description | Manufacturer | Manufacturer Part # |
|----------|----------------------------|-----------------------------------------------------------------------------------------------------------------------|------------------------------|---------------------|
| 2 | AC_L, AC_N | 0.205" (5.21mm) Quick Connect Male Solder Connector Non-Insulated | Keystone Electronics | 1213 |
| 1 | BR1 | Rectifier Bridge Diode Single 800V 3.5A 4-Pin SIP T/R | Shindengen | D20XB80-7000 |
| 1 | C1 | 0.3uF, 1200VDC | BM Capacitors | BM 0.3uF 1200VDC |
| 6 | C2, C6, C19, C22, C23, C33 | 0.1 µF ±10% 25V Ceramic Capacitor X7R 0805 (2012 Metric) | Würth Electronics | 885012207072 |
| 2 | C3, C4 | 5µF Film Capacitor 310V Polypropylene (PP), Metallized Radial | BM Capacitors | BM 5UF 310VAC |
| 1 | C7 | 1000 pF ±20% 1000V (1kV) Ceramic Capacitor X7R 0805 (2012 Metric) | Kemet | C0805C102MDRAC7800 |
| 2 | C9, C12 | 4.7 µF ±10% 25V Ceramic Capacitor X7R 0805 (2012 Metric) | YAGEO | CC0805KKX7R8BB475 |
| 3 | C10, C21, C31 | CAP ALUM 220UF 20% 35V RADIAL | Würth Electronics | 860010574011 |
| 2 | C11, C8 | 220 pF ±10% 25V Ceramic Capacitor X7R 0805 (2012 Metric) | Würth Electronics | 885012207056 |
| 1 | C13 | 330 pF ±10% 25V Ceramic Capacitor C0G, NP0 0805 (2012 Metric) | Würth Electronics | 885012207057 |
| 2 | C14, C15 | 10nF/10000 pF ±10% 25V Ceramic Capacitor X7R 0805 (2012 Metric) | Würth Electronics | 885012207066 |
| 4 | C5, C16, C17, C20 | 100 pF ±10% 25V Ceramic Capacitor X7R 0805 (2012 Metric) | Würth Electronics | 885012207054 |
| 1 | C18 | 4700 pF ±10% 25V Ceramic Capacitor C0G, NP0 0805 (2012 Metric) | Würth Electronics | 885012207064 |
| 2 | C25, C32 | 1 µF ±10% 25V Ceramic Capacitor X7R 0805 (2012 Metric) | Würth Electronics | 885382207003 |
| 1 | C26 | Alum. Electrolytic Cap 100µF 25V 6.3mm Radial WCAP-ATG8; Lifetime 2000h +85°C | Würth Electronics | 860010473007 |
| 1 | C27 | 10uF 20% 450V Electrolytic capacitor | Würth Elektronik | 860241478003 |
| 1 | C28 | 2200 pF ±5% 25V Ceramic Capacitor C0G, NP0 0805 (2012 Metric) | Würth Electronics | 885012007042 |
| 1 | C24, C29 | 2.2 µF ±10% 25V Ceramic Capacitor X7R 0805 (2012 Metric) | Würth Electronics | 885012207079 |
| 1 | C30 | Aluminum Electrolytic Capacitor, 100 uF, +/- 20%, 16 V, 2-Pin SMD (Size Code D), -40 to 105 degC, RoHS, Tape and Reel | Würth Electronics | 865060343005 |
| 1 | CN2 | Connector Header Through Hole 2 position 0.098" (2.50mm) | JST Sales America Inc. | B2B-XH-A |
| 1 | D1 | Zener Diode 20 V 225 mW ±6% Surface Mount SOT-23-3 (TO-236) | On Semiconductor | BZX84C20LT1G |
| 6 | D2, D3, D4, D5, D8 | VR=1000V IF=1A 15pF | ON Semiconductor / Fairchild | 1N4007 |
| 1 | D6 | Diode 100 V 300mA Surface Mount SOD-123 | Diodes Incorporated | 1N4148W-13-F |
| 1 | D9 | Diode 100 V 200mA Through Hole DO-35 | onsemi | 1N4148 |
| 2 | D7, D10 | Diode Standard 1000 V 1A Surface Mount SMA | Diodes Incorporated | US1M |
| 2 | D11 | Diode Ultra-Fast Recovery Rectifier 1K Volt 1A 2-Pin DO-41 Tape and Reel | ON Semiconductor / Fairchild | UF4007 |
| 1 | F1 | 12 A 500 V AC 400 V DC Fuse Cartridge, Ceramic Through Hole 5mm x 20mm (Axial) | Littelfuse Inc. | 0477012.MXEP |
| 1 | IC1 | Integrated IGBT Driver, Optimized State Machine and Advanced Protection Features | Renesas | iW248 |

| | | | | |
|---|--------------------------|------------------------------------------------------------------------------------------------|------------------------|-----------------------|
| 1 | IC3 | 700V AC/DC Regulator with Ultra-Low Standby Power and up to 8W Output Power | Renesas | RAA2230214GSP#HA1 |
| 1 | IC4 | 20V, 500mA Linear Regulator | Renesas | RAA2142504GSP#HA0 |
| 1 | JP1 | Connector Header Through Hole 4 position 0.098" (2.50mm) | JST Sales America Inc. | B4B-XH-A |
| 1 | L1 | 380 μ H Unshielded Toroidal Inductor 6.2 A 70mOhm Max Radial, Vertical (Open) | Würth Electronics | 744156 |
| 1 | LS1 | Buzzers Piezo 5 V 2mA 4kHz Through Hole PC Pins | MikroElektronika | MIKROE-5389 |
| 2 | OUT, OUT1 | 4 Pin Screw Terminal, Power Tap M4 Through Hole | Keystone Electronics | 7797 |
| 1 | Q1 | Transistor IGBT N-Channel 1250V 25A 3-Pin TO-247A Box | Renesas | RBN25H125S1FPQ-A0#CB0 |
| 1 | Q2 | N-Channel 50 V 500mA (Ta) 600mW (Ta) Surface Mount SOT-23-3 | Diodes Incorporated | BSN20-7 |
| 1 | Q3 | General Purpose Transistor, PNP Silicon, 3-Pin SOT-23, Pb-Free, Tape and Reel | On Semiconductor | MMBT3906LT1G |
| 1 | Q4 | General Purpose Transistor, NPN Silicon, 3-Pin SOT-23, Pb-Free, Tape and Reel | On Semiconductor | MMBT3904LT1G |
| 6 | R1, R2, R5, R8, R33, R38 | 100 kOhms \pm 1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Moisture Resistant Thick Film | YAGEO | RC1206FR-07100KL |
| 1 | R3 | 10.2 Ohms \pm 1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Moisture Resistant Thick Film | YAGEO | RC1206FR-0710R2L |
| 4 | R4, R7, R14, R20 | 120 kOhms \pm 1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Moisture Resistant Thick Film | YAGEO | RC1206FR-07120KL |
| 4 | R6, R15, R36, R58 | 4.7 kOhms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-074K7L |
| 1 | R9 | 20 mOhms \pm 1% 3W Through Hole Resistor Axial Current Sense, Non-Inductive Metal Element | Ohmite | 13FR020E |
| 2 | R10, R11 | 100 Ohms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-07100RL |
| 3 | R12, R16, R21 | 110 kOhms \pm 1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Moisture Resistant Thick Film | YAGEO | RC1206FR-07110KL |
| 1 | R13 | 13 kOhms \pm 1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Moisture Resistant Thick Film | YAGEO | RC1206FR-0713KL |
| 1 | R17 | 330 kOhms \pm 1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Moisture Resistant Thick Film | YAGEO | RC1206FR-07330KL |
| 1 | R18 | 220 kOhms \pm 1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Moisture Resistant Thick Film | YAGEO | RC1206FR-07220KL |
| 5 | R19, R35, R39, R57, R59 | 13 kOhms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-0713KL |
| 2 | R22, R25 | 390 kOhms \pm 1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Moisture Resistant Thick Film | YAGEO | RC1206FR-07390KL |
| 1 | R23 | 240 kOhms \pm 1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Moisture Resistant Thick Film | YAGEO | RC1206FR-07240KL |
| 1 | R24 | 33 kOhms \pm 1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Moisture Resistant Thick Film | YAGEO | RC1206FR-0733KL |
| 2 | R27, R28 | 0 Ohms Jumper 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805JR-070RL |
| 2 | R30, R52 | 1 kOhms \pm 1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Moisture Resistant Thick Film | YAGEO | RC1206FR-071KL |
| 1 | R31 | 1.2 kOhms \pm 1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Moisture Resistant Thick Film | YAGEO | RC1206FR-071K2L |
| 1 | R32 | 750 Ohms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-07750RL |
| 5 | R34, R40, R41, R48, R54 | 10K Ohms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-1310KL |
| 1 | R37 | 6.2 kOhms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-076K2L |

| | | | | |
|---|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|------------------|
| 1 | R42 | 5.1 kOhms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-075K1L |
| 1 | R43 | 1.5 kOhms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-071K5L |
| 1 | R44 | 510 Ohms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-07510RL |
| 2 | R45, R46 | 200 Ohms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-07200RL |
| 1 | R47 | RES SMD 0 OHM JUMPER 1/4W 1206 | YAGEO | RC1206FR-070RL |
| 2 | R49 | 1K Ohms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-131KL |
| 1 | R50 | 620 kOhms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-07620KL |
| 1 | R51 | 22 Ohms \pm 5% 2W Through Hole Resistor Axial Wirewound | Ohmite | 42J22RE |
| 2 | R53, R55 | 100K Ohms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-13100KL |
| 1 | R56 | 32.4 kOhms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-0732K4L |
| 3 | T1, T2, T3 | Connector Header Through Hole 3 position 0.098" (2.50mm) | JST Sales America Inc. | B3B-XH-A |
| 1 | T4 | EE16 | SR Magnetics | EE16 |
| 1 | U1 | Positive Voltage Regulator, 5V, 4-Pin SOT-89, Tape and Reel | STMicroelectronics | L78L05ABUTR |
| 1 | Z1 | 680 V 10 kA Varistor 1 Circuit Through Hole Disc 17mm | Littelfuse Inc. | V14X420E |
| 2 | R61, R62, R26, R29 | 1 MOhms \pm 1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Thick Film | YAGEO | RE1206FRE071ML |
| 1 | D12 | 2 A Surface Mount Schottky Barrier Rectifier, 30 V, -65 to 150 degC, 2-Pin SMA, RoHS, Tape and Reel | Diodes Inc | B230A-13-F |
| 1 | R60 | Thick Film Resistors 1/8watt 5.1ohms 1% 200ppm | Vishay Dale | CRCW08055R10FNEA |
| 2 | R9A, R9B | 40 mOhms \pm 1% 1W Chip Resistor 2512 (6432 Metric) Automotive AEC-Q200, Current Sense, Moisture Resistant, Pulse Withstanding Metal Element | Vishay Dale | WSL2512R0400FEB |
| 1 | J1 | 0 Ohms Jumper Chip Resistor 1206 (3216 Metric) Automotive AEC-Q200 Thick Film | Vishay Dale | CRCW12060000Z0EA |
| 1 | T2-1 | NTC Thermistor 100k Ring Lug | Vishay Beyschlag | NTCALUG01A104GA |
| 1 | J1-1 | Wire Jumper 20A | Custom Made | Custom |

Table 3. AS048 HMI Board BOM

| Quantity | Designator | Description | Manufacturer | Manufacturer Part # |
|----------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|-------------------------------|---------------------|
| 2 | C1, C2, C5 | 0.1 μ F \pm 10% 25V Ceramic Capacitor X7R 0805 (2012 Metric) | Würth Elektronik | 885012207072 |
| 1 | C3 | Aluminium Electrolytic Capacitor, Wcap-Atg8 Series, 47 F, 20%, 25 V, 5 Mm, Radial Leaded Rohs Compliant: Yes | Würth Electronics | 860010472005 |
| 1 | C4 | Cap Alum Poly 10UF 20% 16V SMD | Würth Electronics | 875105359001 |
| 1 | C6 | Cap Alum Poly 10UF 20% 16V SMD | Würth Electronics | 875105359001 |
| 16 | D1, D2, D3, D4, D5, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16 | LED Uni-Color Red, 100 mW, 30 mA, -55 to 100 degC, 2-Pin THD, RoHS, Bulk | Paralight | LTR5LE1D127G |
| 0 | IC1 | 500mA 20V Wide Input Voltage Range LDO Linear Regulator | Renesas Electronics | RAA2142504GSP#HA0 |
| 2 | J1, J5 | THT Vertical Pin Header WR-PHD, Pitch 2.54 mm, Single Row, 2 pins, Bergstik | Würth Elektronik | 61300211121 |
| 3 | J2, J3, J4 | Connector Header Through Hole 4 position 0.098" (2.50mm) | JST Sales America Inc. | B4B-XH-A |
| 3 | J6, J7, J8 | THT Vertical Pin Header WR-PHD, Pitch 2.54 mm, Single Row, 3 pins | Würth Elektronik | 61300311121 |
| 10 | Minus(-), Mode1, Mode2, Mode3, Mode4, Mode5, Mode6, Plus(+), Power, Timer | Tactile Switch SPST-NO Top Actuated Through Hole | Omron Electronics Inc-EMC Div | B3F-1020 |
| 4 | Q1, Q2, Q3, Q4 | TRANS PNP 45V 100MA TO236AB | NXP USA Inc. | BC857,215 |
| 0 | R1 | 1 kOhms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-101KL |
| 1 | R2 | 32.4 kOhms \pm 1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Moisture Resistant Thick Film | YAGEO | RC1206FR-0732K4L |
| 7 | R3, R4, R5, R6, R7, R8, R9 | 10 kOhms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-1310KL |
| 1 | R10 | Chip Resistor, 0 Ohm, +/- 1%, 125 mW, -55 to 155 degC, 0805 (2012 Metric) | Vishay Dale | CRCW08050000Z0EAC |
| 2 | R11, R12 | Chip Resistor, 4.7 KOhm, +/- 1%, 0.125 W, -55 to 155 degC, 0805 (2012 Metric) | YAGEO | RC0805FR-074K7L |
| 17 | R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24, R25, R26, R27, R28, R29 | 510 Ohms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-07510RL |
| 1 | R30 | 100 kOhms \pm 1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film | YAGEO | RC0805FR-10100KL |
| 1 | U1 | MCU | Renesas | R5F12067GSP#50 |
| 1 | U2 | Display-7Seg | Paralight | A503SRA-NW-L9-A G/W |
| 2 | DA,DB | LED Uni-Color Red, 100 mW, 30 mA, -55 to 100 degC, 2-Pin THD, RoHS, Bulk | Paralight | LTR5LE1D127G |
| 2 | ModeA, ModeB | Tactile Switch SPST-NO Top Actuated Through Hole | Omron Electronics Inc-EMC Div | B3F-1020 |

Board Layout

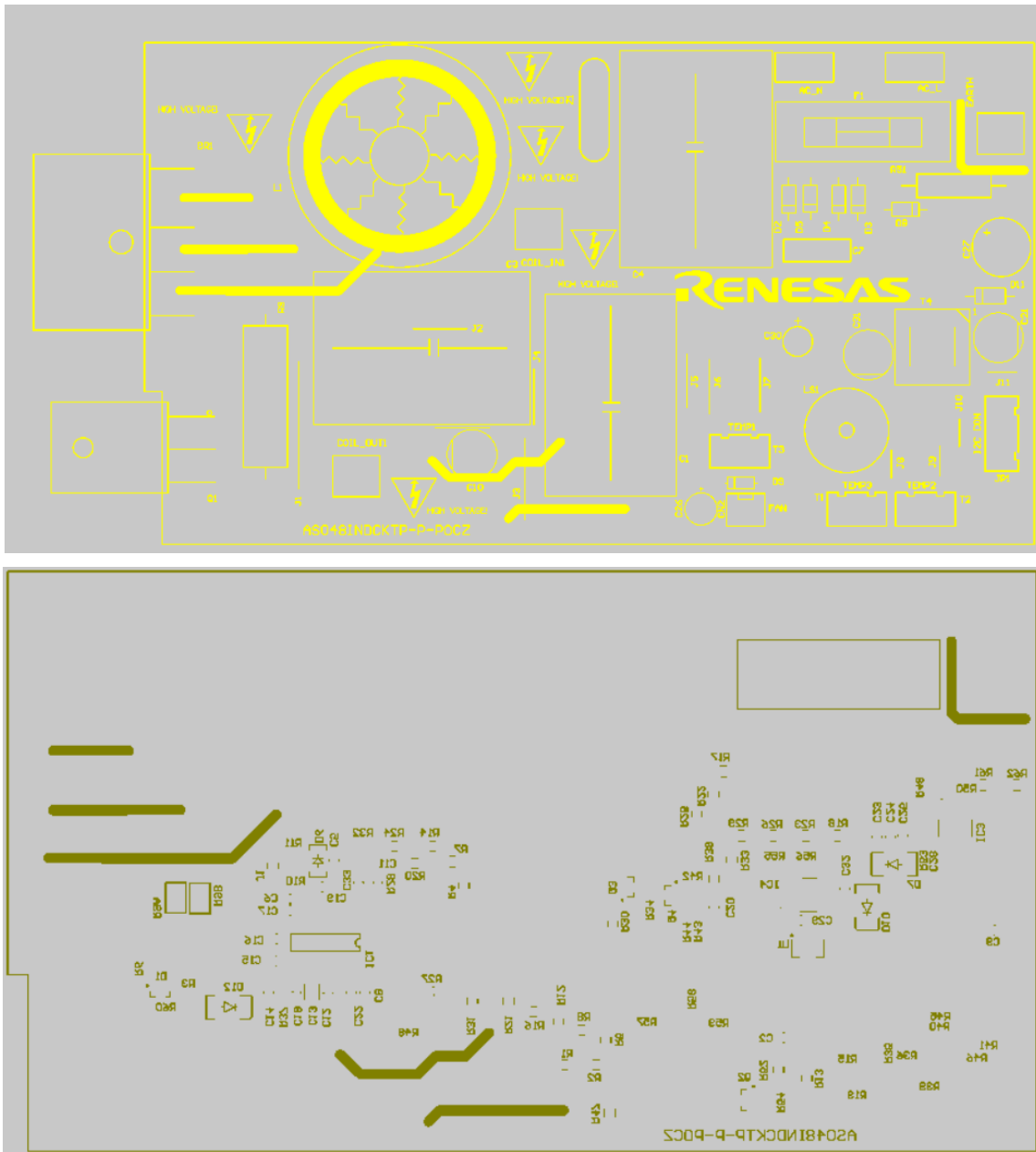


Figure 18. Silkscreen Top and Silkscreen Bottom (Power Card)

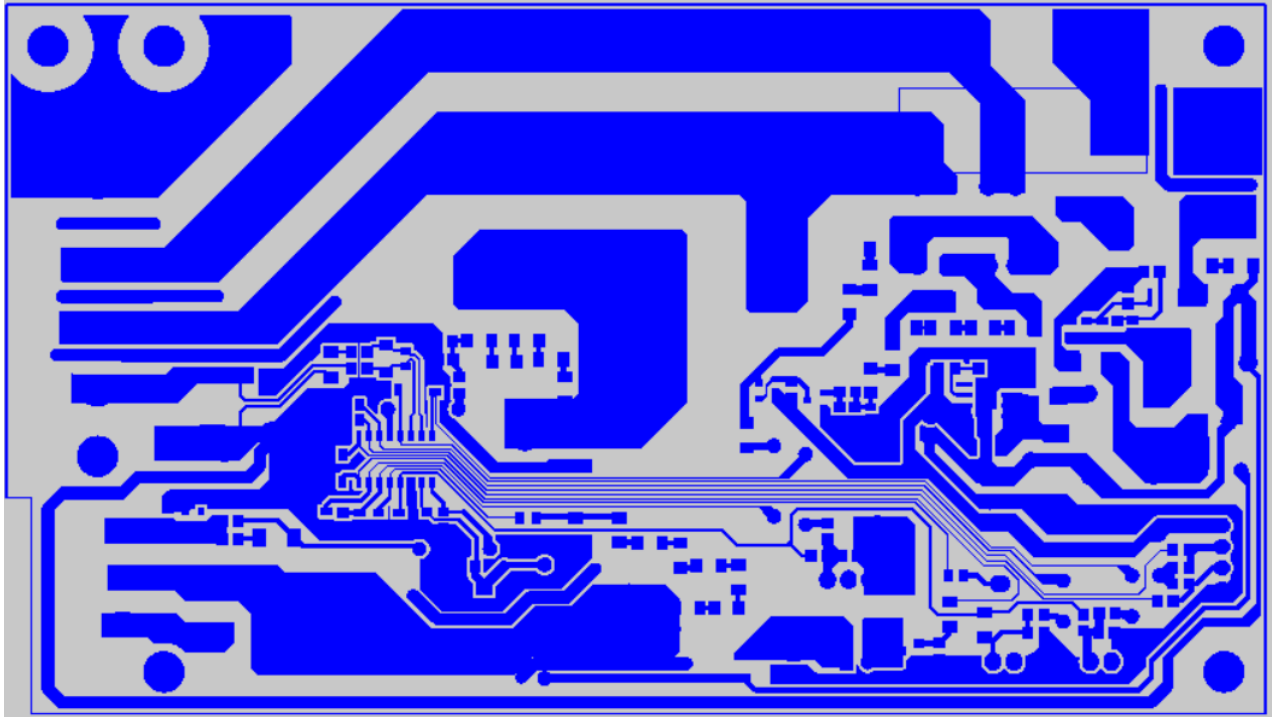


Figure 19. Copper Bottom (Power Card)

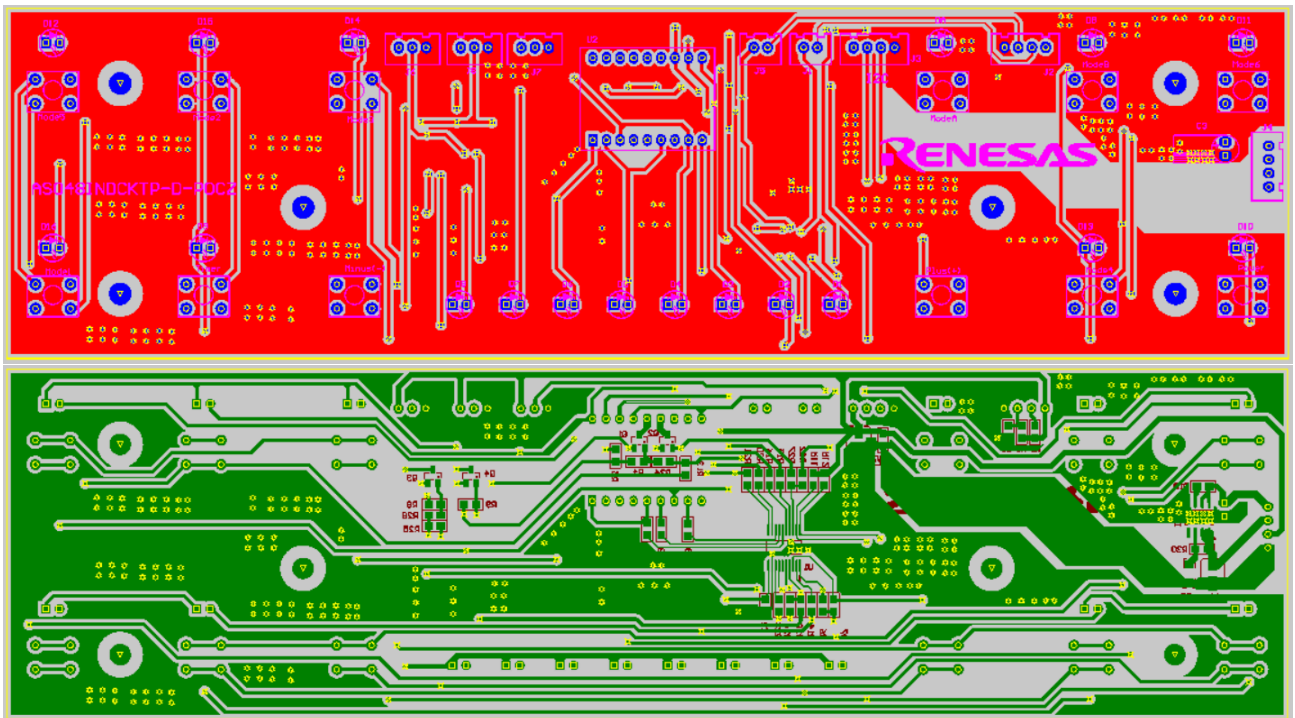


Figure 20. HMI Card