# Inverter Circuit for IH Cooker

# Reference Guide

## RD206-RGUIDE-01

TOSHIBA ELECTRONIC DEVICES & STORAGE CORPORATION

Contents

# 1. Introduction

This reference guide describes the specifications, basic circuitry, and other features of the IH Cooker built using GT20N135SRA IGBT. Toshiba's IGBT (GT20N135SRA) and Holtek's MCU (HT45F0058) used in this application are designed specifically to be used with home appliance applications to provide most operational and economical efficiency. High-speed switching, High maximum junction temperature and Low saturation voltage are some key features of GT20N135SRA IGBT. The input-voltage range of this IH Cooker is from AC 200 V to 240 V at 50 Hz. This reference guide provides various design information including reference design, and contributes to the reduction of effort required in designing according to actual specifications.

# 2. Specification

## 2.1. Specification

Table 2.1 lists the general specification of this IH Cooker.

**Table 2.1 General Specification**

| No. | Item | Overview | Remarks |
|---|---|---|---|
| 1 | Mode | Voltage resonance system | |
| 2 | Basic feature | IH Cooker with coil power control (function limited) | |
| 3 | Safety Standards | Designed for IEC60355-1 standard | |
| 4 | EMI standards | Designed for CISPR14 standard | |
| 5 | Input voltage | AC 200 V ~ AC 240 V Single phase (50 Hz typical) | |
| 6 | Cooling | Uses one DC 18 V Fan | |
| 7 | Main board | Performs the main operation of controlling IGBT and coil current. | |
| 8 | Control board | Takes user input and sends to the Main board. | |
| 9 | Precautions | The voltage equivalent to the input is applied to most of the inside of this product, and touching inside may result in an electric shock or burns, so do not touch. | |

Table 2.2 lists the specifications of the main board of this IH Cooker.

**Table 2.2 Main Board Specification**

| No. | Item | Overview | Remarks |
|---|---|---|---|
| 1 | Communication with the control board | I/O port control by I2C-bus(Master) software | |
| 2 | Debugging communication | I/O port control by UART software | TX only |
| 3 | Microcontroller | Part No.: HT45F0058 (Holtek) | |
| 4 | IGBT | Part No.: GT20N135SRA (Toshiba) | |
| 5 | Resonant capacitor | MKPH 0.24 μF, 630 Vac (BM Cap) or equivalent | |

| | | | |
|---|---|---|---|
| 6 | IGBT TEMP SENSOR | For monitoring IGBT temperature<br>Thermistor type: 100 kΩ, B25/75:3964K | |
| 7 | Main temperature sensor | For monitoring IH coil temperature<br>Thermistor type | |
| 8 | 18 V power supply (+18 V) | +18 V power supply for IGBT drive and fan | |
| 9 | 5 V power supply (+5 V) | +5 V power supply for main board MCU and control board | |
| 10 | Coating of the substrate | No coating | |

Table 2.3 lists the specifications of the control board of this IH Cooker.

**Table 2.3 Control Board Specification**

| No. | Item | Overview | Remarks |
|---|---|---|---|
| 1 | Communicating with the Mainboard | Uses I2C-bus(Slave) H/W module | |
| 2 | Microcontroller | Part No.: BS86D12C (Holtek) | |
| 3 | Touch key | 7 pcs. (Electrostatic Touch Sensor) | |
| 4 | LED | 12 pcs. (1 pc. is spare) | |
| 5 | 7-Seg LED | 4 digits | |
| 9 | 5 V power supply (+5 V) | Supplied from the main board | |
| 10 | Coating of the substrate | No coating | |

## 2.2. Outline

Fig. 2.1 shows an overview of this IH Cooker components. External dimentions of IH Cooker are 350 mm x 280 mm x 60 mm.

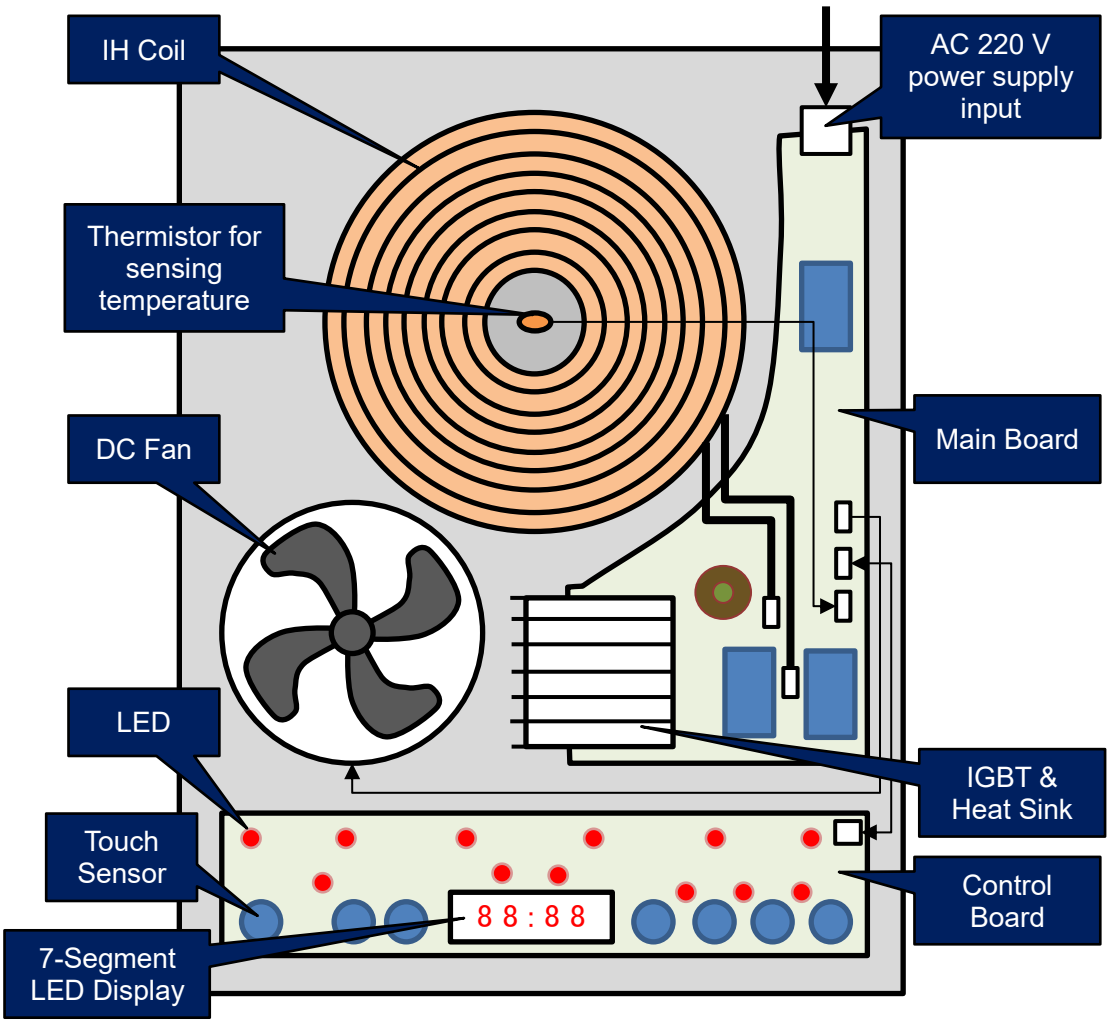


**Fig. 2.1 Overall View of IH Cooker Components**

### 2.2.1. Main Board

Fig. 2.2 shows the front side and back side of the main board.

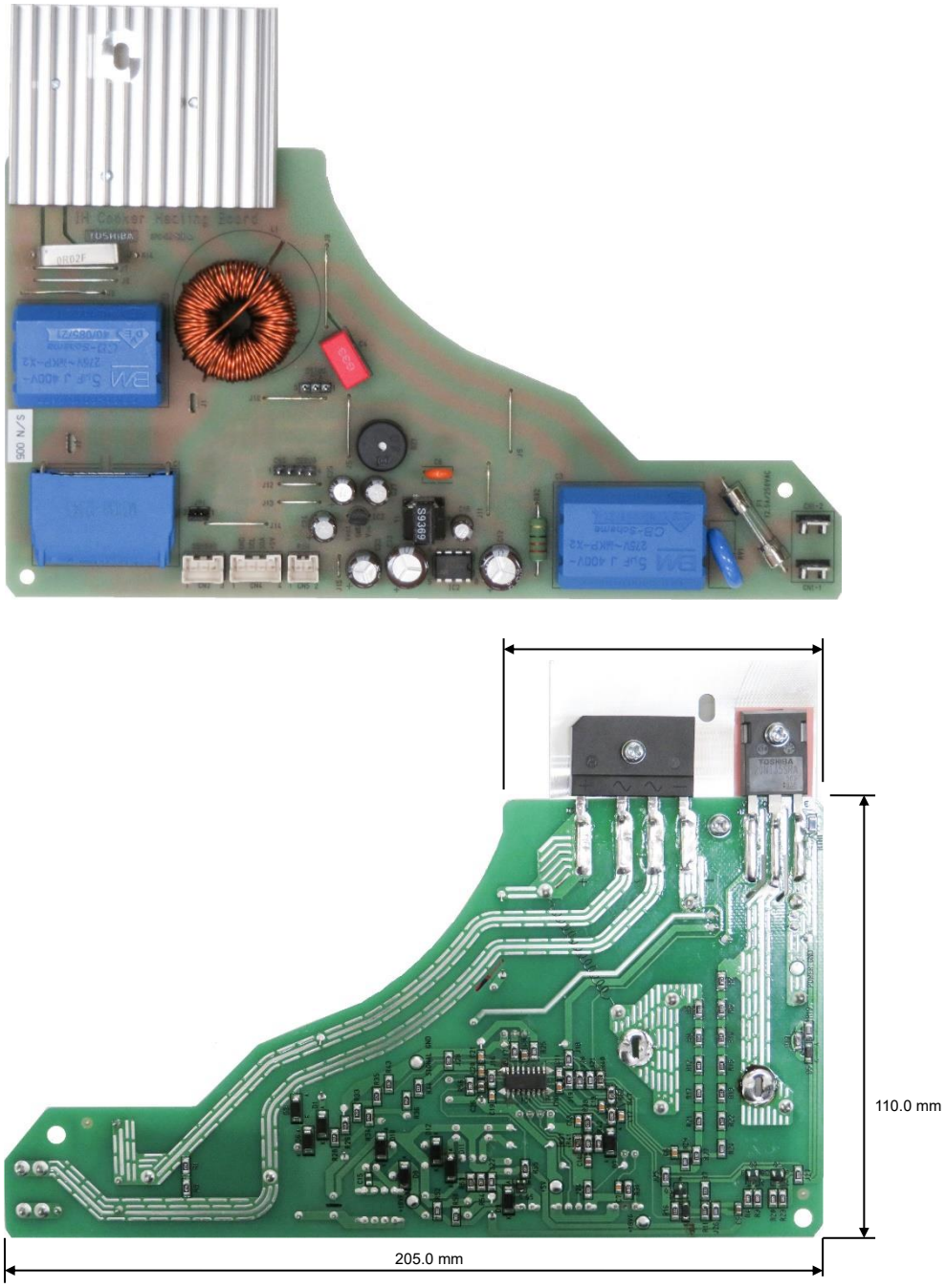


**Fig. 2.2 Front Side and Back Side View of the Main Board**

| | |
|---|---|
| Board size | 205 × 110 mm |
| Board type | CEM-3 (single side) |

Fig. 2.3 shows the connectors on the main board.

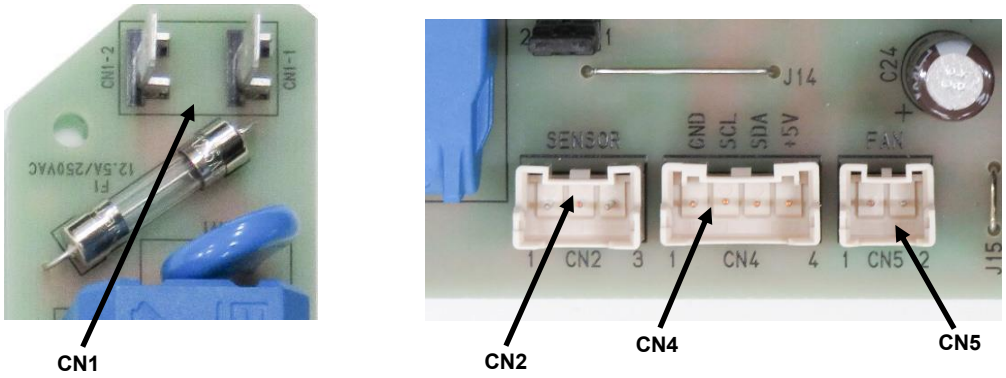


**Fig. 2.3 Connectors on the Main Board**

### (1) CN1 for AC Power Supply Input

It is a Faston terminal.

Manufacturer: KEYSTONE

Part No.: 4902

Pin map:

| Terminal board No. | Signal name | Function |
|---|---|---|
| 1 | AC1 | For Input AC |
| 2 | AC2 | For Input AC |

### (2) J1 & J2 for IH Coil Connection

Direct soldering of wires is used for this connection.

Pin map:

| Terminal board No. | Signal name | Function |
|---|---|---|
| J1 | OUT1 | For IH coil connection |
| J2 | OUT2 | |

### (3) CN2 for NTC Thermistor Connection

Manufacturer name: JST

Part No.: B03B-XASK-1

Pin map:

| Pin number | Signal name | Function |
|---|---|---|
| 1 | HTC | Main temperature sensor: Thermistor for temperature monitoring of IH coil (pot bottom). |
| 2 | - | |
| 3 | VDD | Thermistor power supply (+5 V) |

### (4) CN3 for Programming MCU

Manufacturer name: JST

Part No.: T4B-SQ(LF)(SN)

Pin map:

| Pin number | Signal name | Function |
|---|---|---|
| 1 | GND | |

| | | |
|---|---|---|
| 2 | OCDSDA | Programmer data |
| 3 | OCDSCK | Programmer clock |
| 4 | VDD | Power supply for the programmer (+5 V) |

**(5) CN4 for Control Board Connection**

Manufacturer name: JST

Part No.: B04B-XASK-1

Pin map:

| Pin number | Signal name | Function |
|---|---|---|
| 1 | GND | |
| 2 | SCL | $I^2C$-Bus SCL signals for communication with the control board |
| 3 | SDA | $I^2C$-Bus SDA signal for communication with the control board |
| 4 | VDD | Power supply for the control board (+5 V) |

**(6) CN5 for Fan Power Connection**

Manufacturer name: JST

Part No.: B02B-XASK-1

Pin map:

| Pin number | Signal name | Function |
|---|---|---|
| 1 | FAN | ON/OFF control by software |
| 2 | +18VF | Power supply for FAN (+18 V) |

**(6) CN6 for Debugging via Serial Out**

Manufacturer name: JST

Part No.: T3B-SQ(LF)(SN)

Pin map:

| Pin | Signal name | Description |
|---|---|---|
| 1 | VSS | |
| 2 | TXD | Serial output for debugging |
| 3 | VDD | Outputs +5 V |

### 2.2.2. Control Board

Description of keys available for use in this IH Cooker reference design is as follows:

- Power Key: To turn on and off the power supply of IH Cooker.
- Pause Key: To temporarily stop the heating process.
- Strong Heat Key: To start “Strong Heat” mode of heating.
- + Key: To increase the heating power.
- - Key: To decrease the heating power.

Description of LEDs used in this IH Cooker reference design is as follows:

- “Power Supply LED” indicates the status of power supply.
- “Pause LED” indicates that the heating process is temporarily stopped.
- “Strong Heat LED” indicates that the “Strong Heat” mode is enabled.

**(1) CN101 for Control Board Connection**

Manufacturer name: JST

Part No.: S04B-XASK-1N-BN

Pin map:

| Pin number | Signal name | Function |
|---|---|---|
| 1 | GND | |
| 2 | SCL | $I^2C$-Bus SCLsignals for communication with the control board |
| 3 | SDA | $I^2C$-Bus SDA-signal for communication with the control board |
| 4 | VDD | Power supply to the control board (+5 V) |

**(2) CN102 for programming MCU**

Manufacturer name: JST

Part No.: T4B-SQ(LF)(SN)

Pin map:

| Pin number | Signal name | Function |
|---|---|---|
| 1 | GND | |
| 2 | OCDSDA | Programmer data |
| 3 | OCDSCK | Programmer clock |
| 4 | VDD | Power supply for the programmer (+5 V) |

**Error Indication**

Following is the list of errors, which can be handled by this IH Cooker.

| Error Code | Error Contents | Description |
|---|---|---|
| E0 | No pot | No pot on the heating surface |
| E3 | IGBT over temperature | IGBT overheat (110 °C or higher) |
| E4 | IGBT NTC open/short circuit | IGBT temperature sensor failure |
| E5 | Heating surface over temperature | Heating surface (IH coil) overheat (188 °C or higher) |
| E6 | Heating surface NTC open/short circuit | Heating surface (IH coil) temperature sensor failure |
| E7 | Mains overcurrent | AC-input overcurrent (rms 9.8 A or higher) |
| E8 | Mains overvoltage (>=270 V) | AC input overvoltage (rms value 270 V or more) |
| E9 | Mains undervoltage (<150 V) | AC input low voltage (effective value less than 150 V) |

## 2.3. Block Diagram

Fig. 2.4 shows a block diagram of this IH Cooker. Refer to RD206-SCHEMATIC-01 for the actual schematic and to RD206-BOM-01 for the bill of materials.

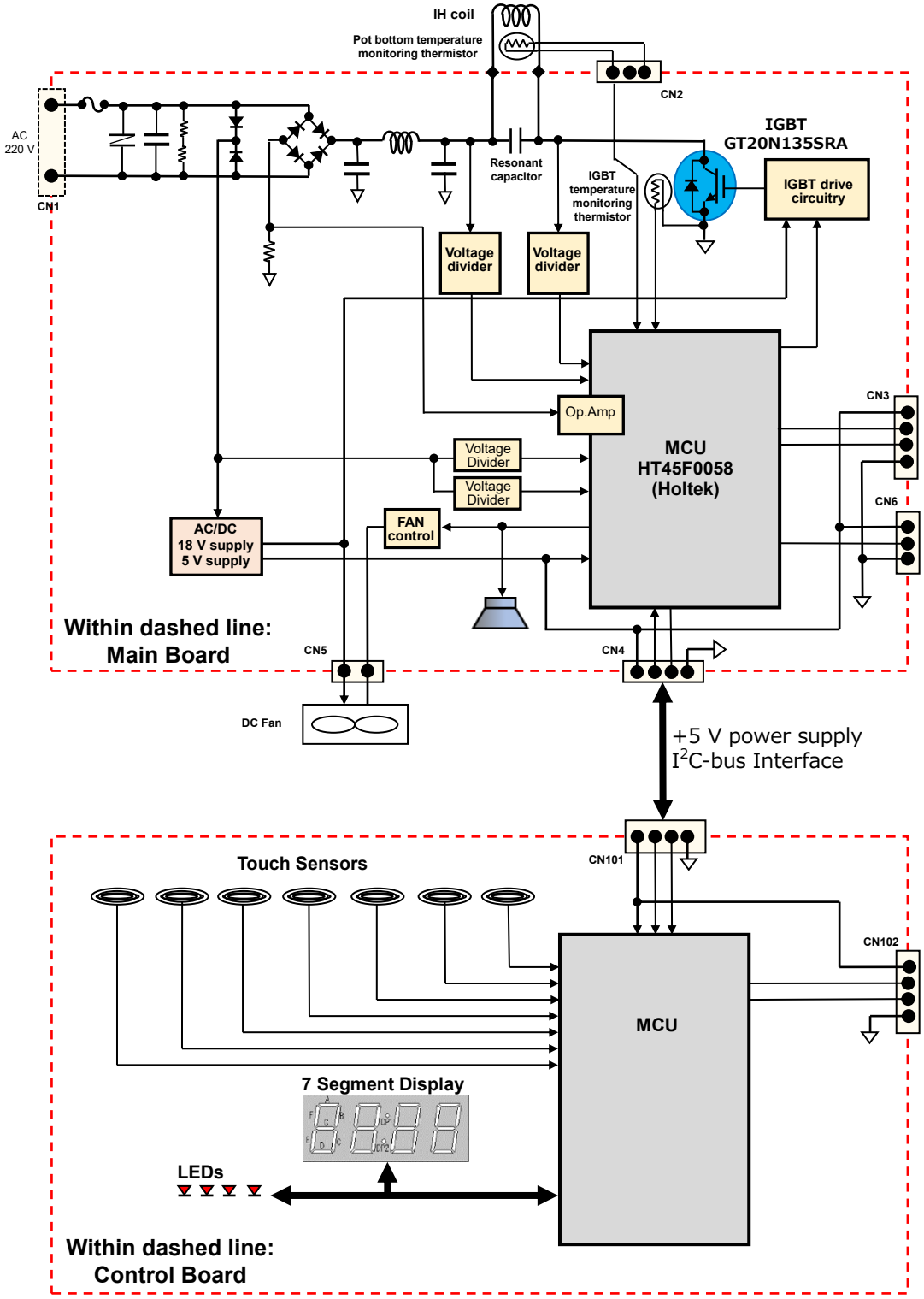


**Fig. 2.4 Block Diagram**

## 2.4. PCB Component Layout

Fig. 2.5 and Fig. 2.6 shows the layout of components on the main board PCB of this IH Cooker.

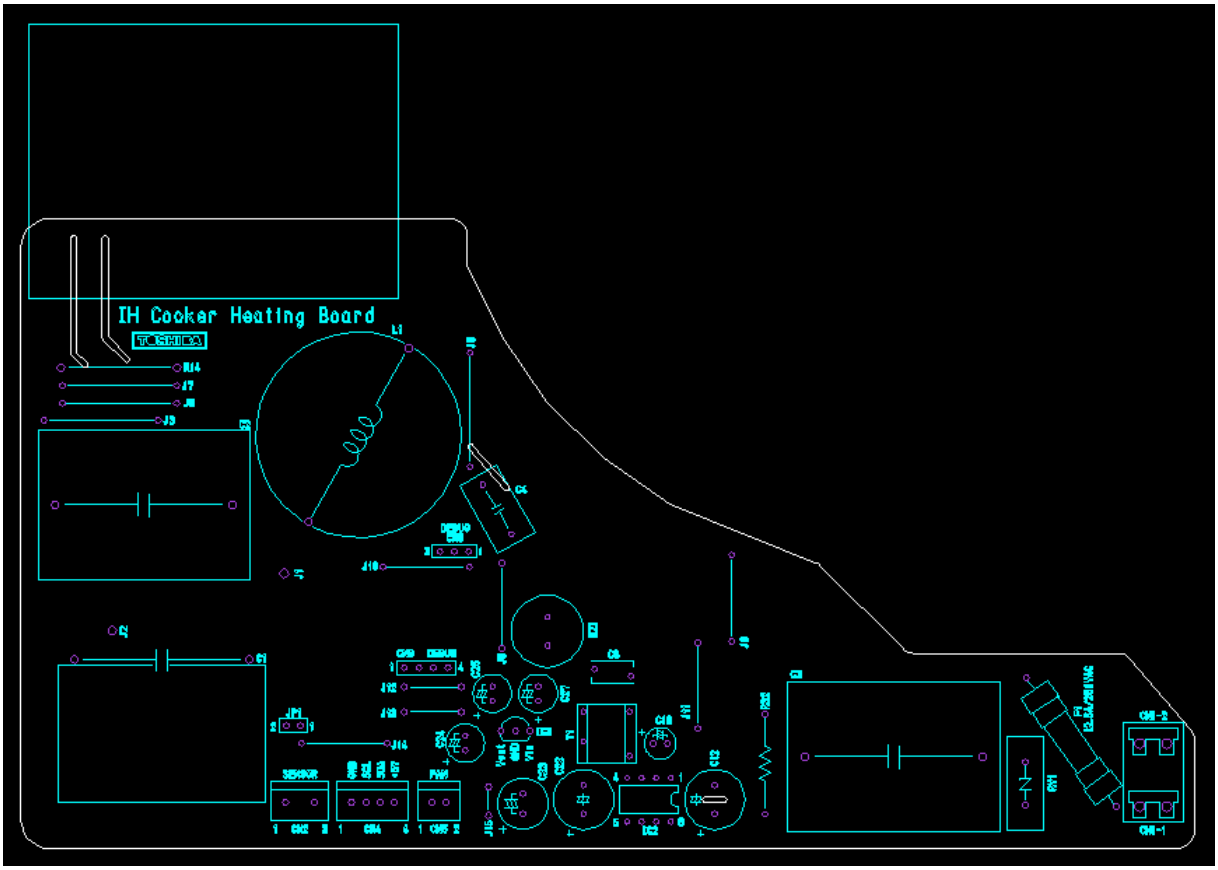


**Fig. 2.5 Main Board PCB Component Layout (Front Side)**

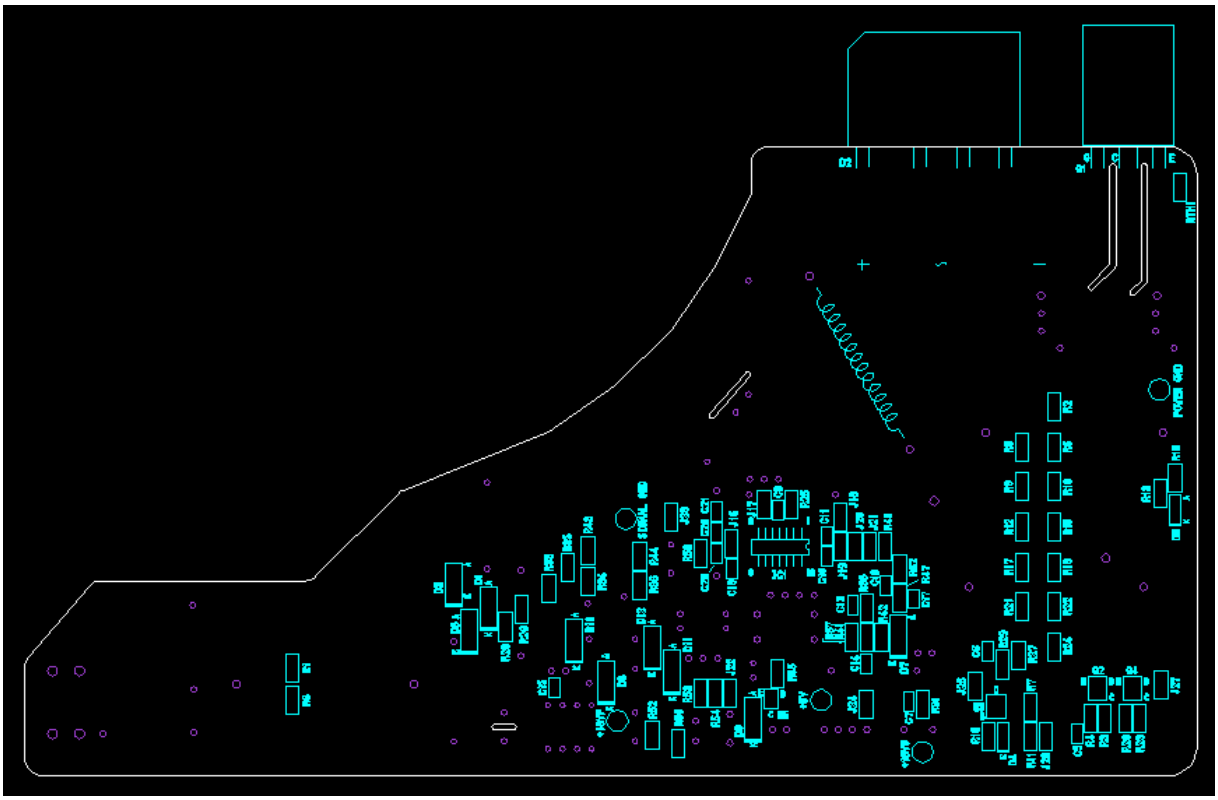

**Fig. 2.6 Main Board PCB Component Layout (Back Side)**

## 2.5. PCB Pattern

PCB design data of this IH Cooker is compatible with various EDA (Electronic Design Automation) tools. Please refer to webpage for more information.

Main Board PCB of this reference design is single sided. The Bottom Layer of the Main Board PCB is shown in Fig. 2.7.

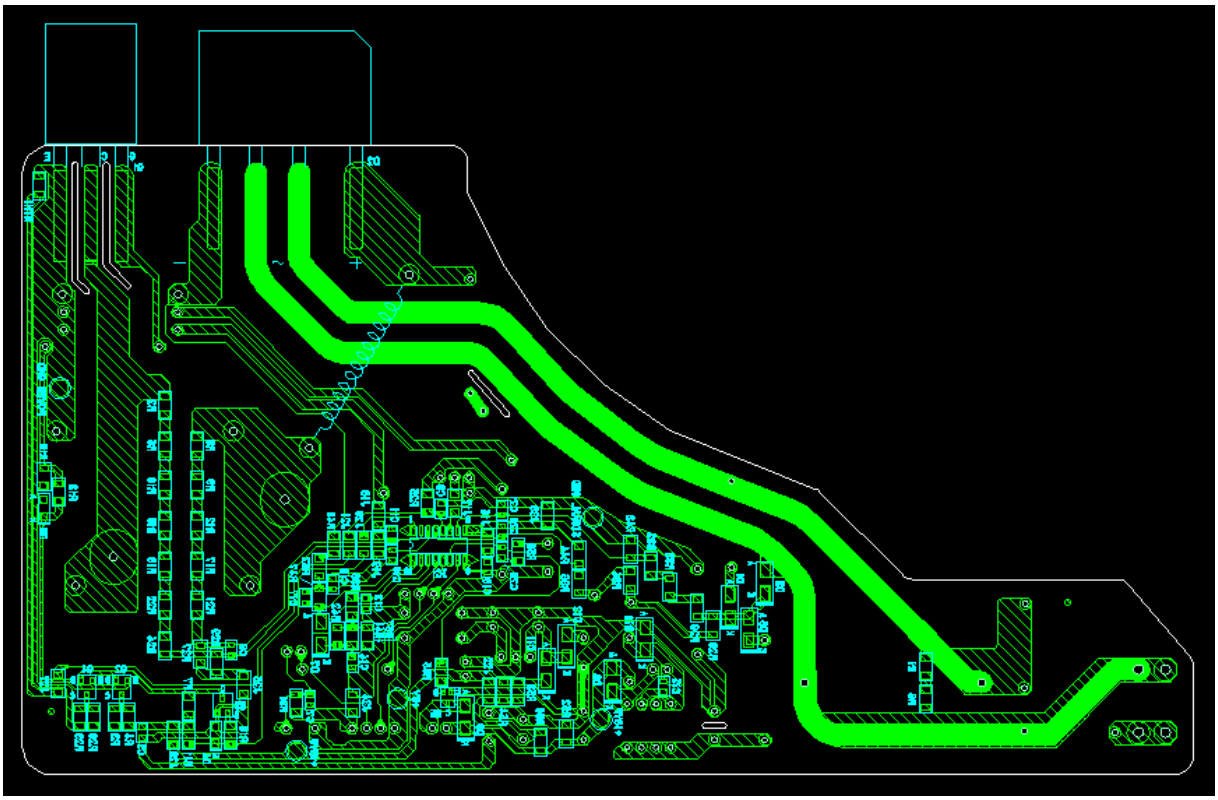

**Fig. 2.7 Bottom Layer**

# 3. Operating Procedure

This section describes the operting procedure of this IH Cooker.

## 3.1. External Connection

Connect the power cord of this IH Cooker to the AC 220 V power supply.

## 3.2. Start Procedure

- Connect IH Cooker to external AC power supply.
  - Buzzer sounds when AC power is supplied.
  - “Power LED” starts blinking.
- Touch the “Power Key” to turn on the IH Cooker.
  - “Power LED” turns on.
  - “-----“ is displayed on 7-Seg LED Display.
- Touch the “Strong Heat Key” to turn on the heating.
  - “Strong Heat LED” turns on.
  - “2000” is displayed on the 7-Seg LED display. (Initial value is 2000 W).
- Touch “+ Key” or “- Key” to change the electric power setting.
  - Electric power can be set to 2000 W, 1800 W, 1600 W, 1400 W, 1200 W, 1000 W, 600 W, 300 W or 100 W.
  - 2000 W – 1000 W is continuous heating.
  - 600 W – 100 W is intermittent heating.

## 3.3. Stop Procedure

- Touch the “Power Key” while the power is on to turn off the IH Cooker.
  - Heating operation stops if it was in progress.
  - All LEDs except “Power LED” turns off and the “Power LED” starts blinking.

## 3.4. Precautions for Evaluation (To Prevent Electric Shock, Burn Injury, etc.)

Even after this IH Cooker is stopped, there is a risk of electric shock due to the residual charge present in various capacitors. Before touching the any component inside, check that the voltage of each component has decreased sufficiently.

In addition, semiconductors, coils, etc. of this IH Cooker generate heat according to the load current. Fig. 3.1 shows the components with high heat generation with red broken line frames. This IH Cooker uses a fan to provide air-cooling to ensure that the temperature of these components remain within the rated temperature range at high loads. Also, do not touch these components while the power supply is running, as there is a risk of burns.

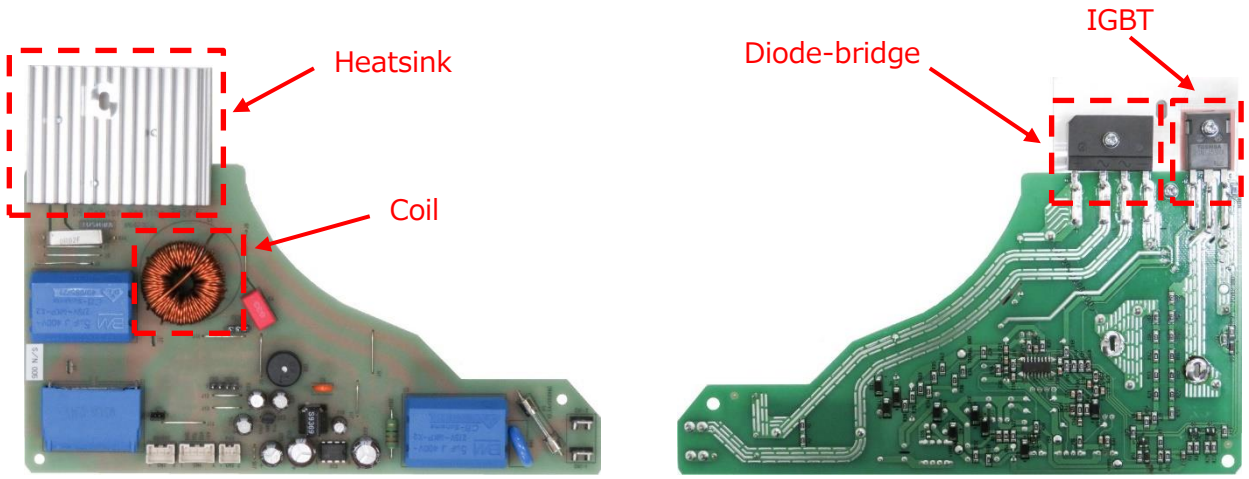


**Fig. 3.1 Components with High Heat Generation**

# 4. Power Consumption

The power consumption of this IH Cooker depends on the power supply voltage and the power setting.

The operation at 600 – 100 W is intermittent operation. The power measurement values for these are measured when heating is on.

The power consumption measurement data of this IH Cooker is shown in table below.

**Table 4.1 Power Consumption Data**

| Input Voltage | Item On / Off | Power Setting (W) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 100 | 300 | 600 | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 |
| 220 V | Power Consumption (W) | 1080 | 1080 | 1080 | 1080 | 1210 | 1416 | 1592 | 1795 | 2020 |
| | Heating Pattern | 2.5 s / 7.5 s | 4 s / 6 s | 7 s / 3 s | Always On | Always On | Always On | Always On | Always On | Always On |
| 240 V | Power Consumption (W) | 1076 | 1076 | 1076 | 1076 | 1182 | 1407 | 1586 | 1785 | 1945 |
| | Heating Pattern | 2.5 s / 7.5 s | 4 s / 6 s | 7 s / 3 s | Always On | Always On | Always On | Always On | Always On | Always On |

: This property indicates the initial value.
Power consumption is a reference value and varies depending on the position of the pot and the operating environment.

# 5. EMI radiation noise

IH-cookers are generally required to comply with CISPR14-1 Ed 7.0 standard. Table 5.1 shows the margin values for the emission standard when this design is operated at a maximum output of 2 kW. In addition, the radiated emission standard margin for IGBT (Q1) equipped with our conventional product (GT40RR21) and equivalent products from other companies is also shown. Fig. 5.1 to 5.6 show reference measured radiation emission spectrum when each IGBT is mounted. GT20N135SRA is designed to reduce radiated emissions and has been found to comply with the emission standards specified in CISPR14-1 Ed 7.0 in Quasi-Peak of all frequency bands, even without any special EMI counter-measure implementation on the set-side.

Note: In CISPR14-1 Ed 7.0, radiated emissions from 30 MHz to 1 GHz are specified by the 10 m method, but this time we performed measurements using the 3 m method to clarify differences due to differences in the mounted elements. The standard value in the tables and figures uses the value obtained by distance conversion of the standard value of 10 m method.

**Table 5.1 Radiation emission standard margins (Quasi-Peak) for this design**

| Frequency | Product used in this Design GT20N135SRA | TOSHIBA Conventional Product GT40RR21 | Equivalent Product from Other Companies |
|---|---|---|---|
| Fundamental wave (23 kHz) | 3.5 dB@ 23.080 kHz (Z-axis) | 2.7 dB@ 23.120 kHz (Z-axis) | 2.1 dB@ 22.986 kHz (Z-axis) |
| 2nd(46 kHz) | 14.7 dB@ 46.210 kHz (Z-axis) | 14.8 dB@ 46.470 kHz (Z-axis) | 14.6 dB@ 46.180 kHz (Z-axis) |
| 3rd(69 kHz) | 31.6 dB@ 69.280 kHz (Z-axis) | 29.4 dB@ 69.740 kHz (Z-axis) | 30.1 dB@ 69.300 kHz (Z-axis) |
| 4th(92 kHz) | 27.1 dB@ 92.390 kHz (Z-axis) | 25.8 dB@ 93.030 kHz (Z-axis) | 26.8 dB@ 92.410 kHz (Z-axis) |
| 5th(116 kHz) | 22.1 dB@ 115.600 kHz (Z-axis) | 20.6 dB@ 116.400 kHz (Z-axis) | 21.8 dB@ 115.700 kHz (Z-axis) |
| 6th(139 kHz) | 20.8 dB@ 38.900 kHz (Z-axis) | 19.6 dB@ 139.560 kHz (Z-axis) | 20.6 dB@ 138.900 kHz (Z-axis) |
| Between harmonics (158 kHz) | 9.5 dB@ 158.210 kHz (Z-axis) | 99 dB @ 157.800 kHz (Z-axis) | 9.1 dB@ 159.300 kHz (Z-axis) |
| Between harmonics (1.29 MHz) | 25.3 dB@ 1.287 MHz (Z-axis) | 26.2 dB@ 1.298 MHz (X-axis) | 26.0 dB@ 1.288 MHz (Z-axis) |
| 30 MHz | 8.2 dB@ 30.044 MHz (vertical) | -1.3 dB@ 30.040 MHz (vertical) | -1.0 dB@ 30.250 MHz (vertical) |
| 40 MHz | 11.6 dB@ 40.543 MHz (vertical) | 2.2 dB@ 40.570 MHz (vertical) | 4.9 dB@ 40.080 MHz (vertical) |
| 99 MHz | 14.6 dB@ 99.643 MHz (vertical) | 11.7 dB@ 98.890 MHz (vertical) | 11.2 dB@ 99.447 MHz (horizontal) |
| 115 MHz | 13.3 dB@ 115.587 MHz (horizontal) | 9.0 dB@ 115.587 MHz (horizontal) | 10.4 dB@ 115.560 MHz (horizontal) |
| 192 MHz | 8.7 dB@ 193.685 MHz (horizontal) | 9.0 dB@ 191.431 MHz (horizontal) | 8.3 dB@ 191.684 MHz (horizontal) |

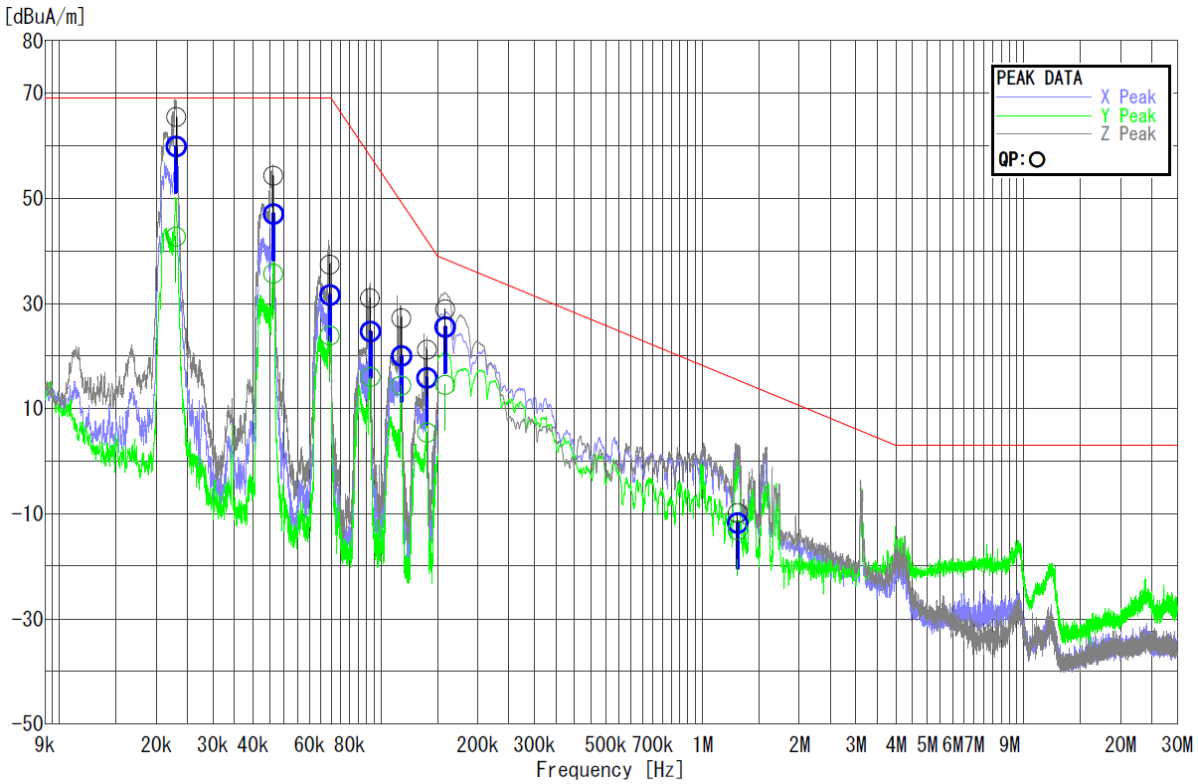


**Fig. 5.1 Example of Radiation Emission Spectrum when Equipped with the Product (GT20N135SRA) used in this Design (30 MHz or Lower)**

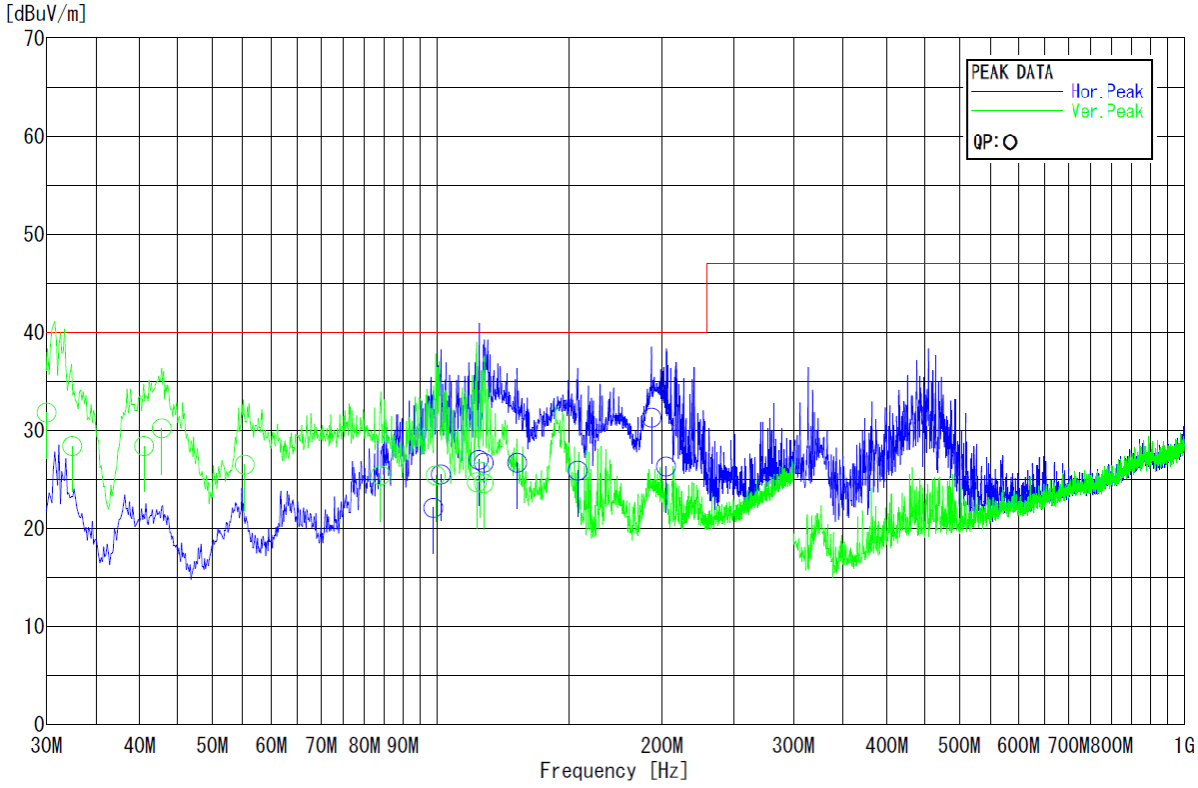


**Fig. 5.2 Example of Radiation Emission Spectrum when Equipped with the Product (GT20N135SRA) used in this Design (30 MHz or Higher)**

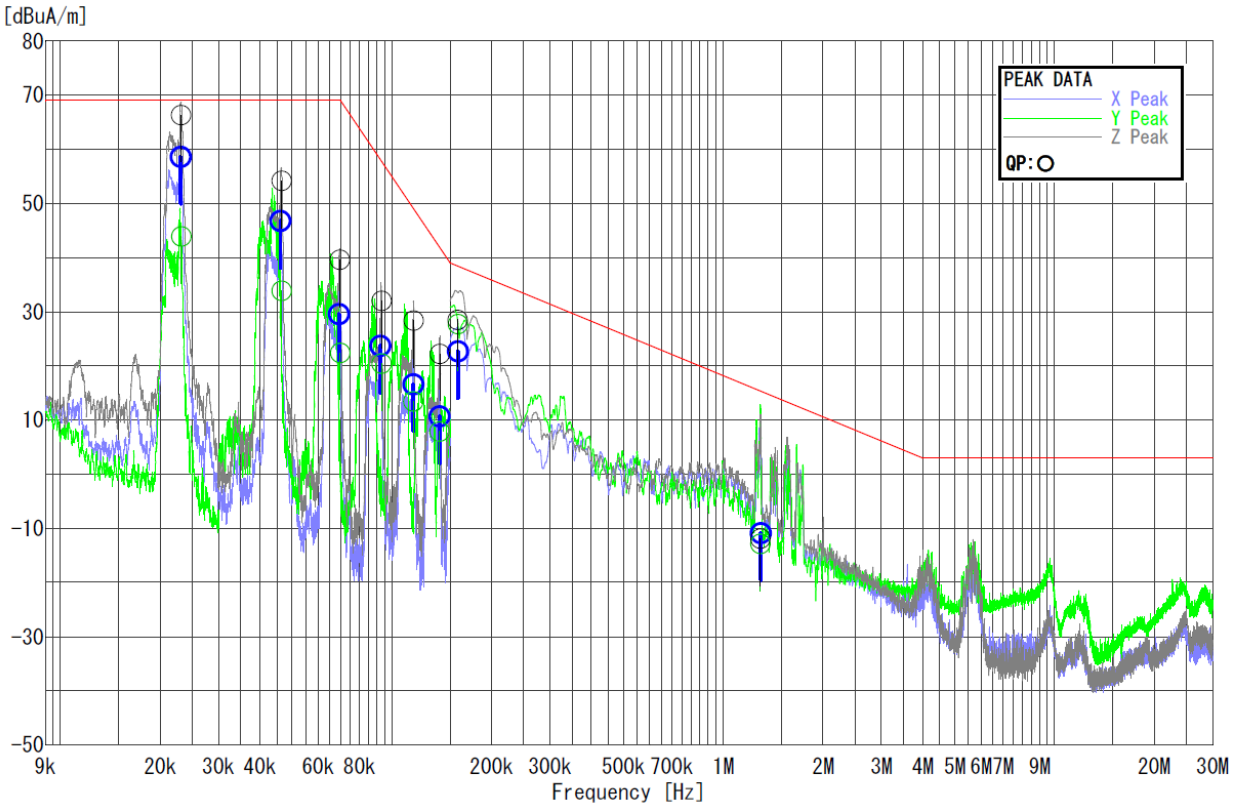


**Fig. 5.3 Example of Radiation Emission Spectrum when Equipped with Toshiba's Conventional Product (GT40RR21) (30 MHz or Lower)**

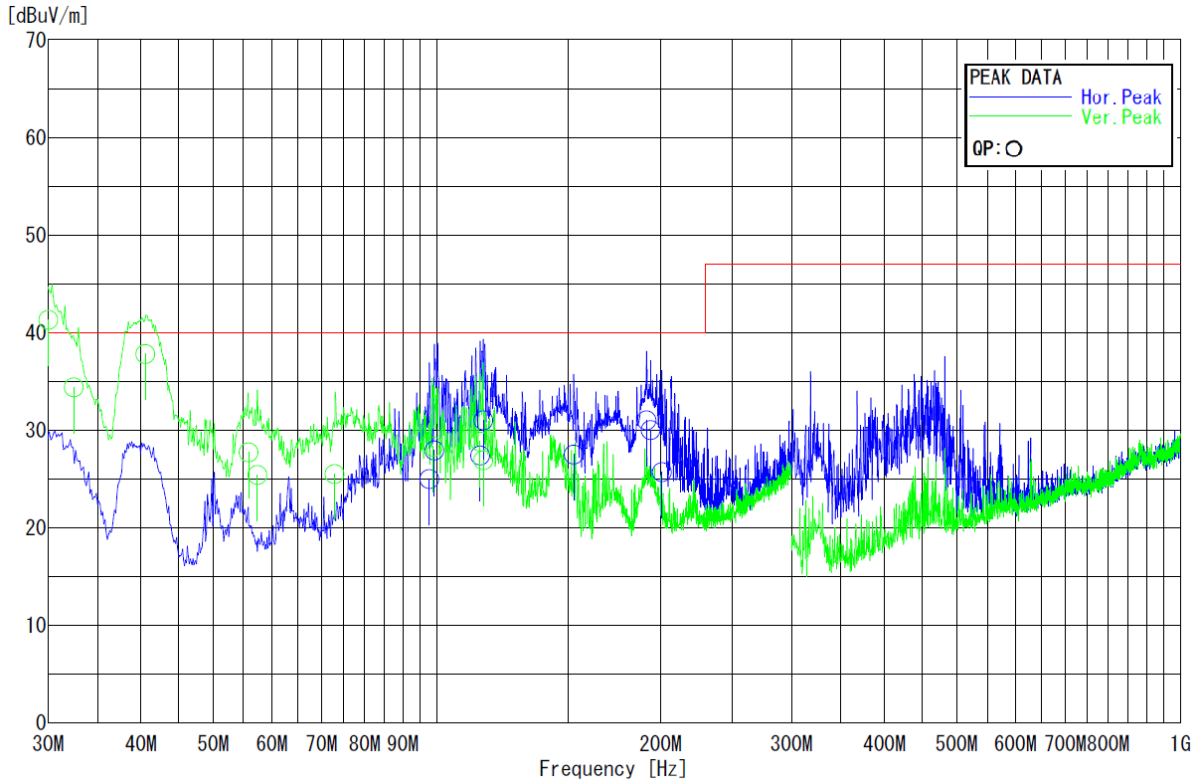


**Fig. 5.4 Example of Radiation Emission Spectrum when Equipped with Toshiba's Conventional Product (GT40RR21) (30 MHz or Higher)**

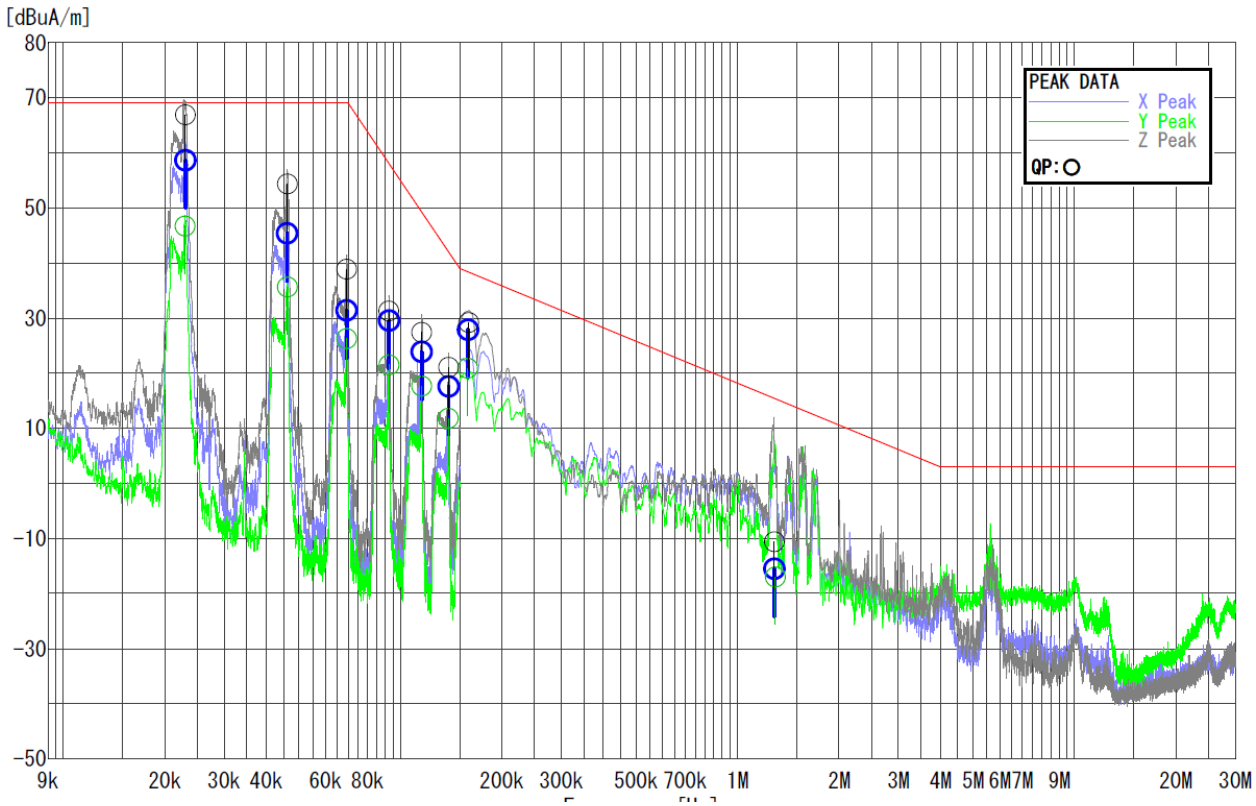


**Fig. 5.5 Example of Radiation Emission Spectrum when Equipped with an Equivalent Product from Other Manufacturers (30 MHz or Lower)**

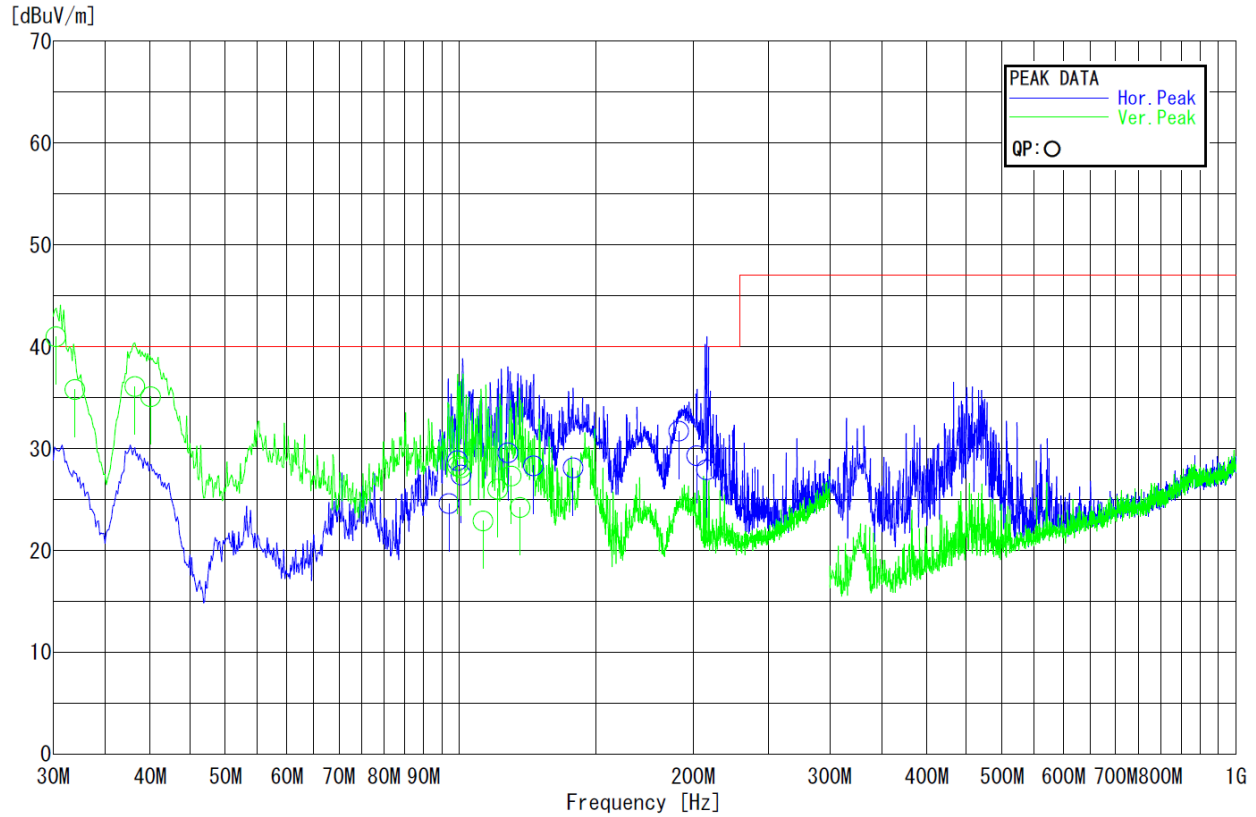


**Fig. 5.6 Example of Radiation Emission Spectrum when Equipped with an Equivalent Product from Other Manufacturers (30 MHz or Higher)**

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