

# REF-SHA35WRC2SYS user guide

## Ceiling fan application reference design kits

### About this document

#### Scope and purpose

This user guide provides an overview of the reference board REF-SHA35WRC2SYS including its main features, key test results and mechanical dimensions.

The REF-SHA35WRC2SYS is a full-featured starter kit, with a turnkey motor driver designed for high-performance, high-efficiency permanent magnet synchronous motor (PMSM) / brushless direct current motor (BLDC) applications, including all of the required elements for ceiling fan applications. It includes the iMOTION™ IMD112T smart driver for PFC and motor control, the IRS44273L PFC gate driver, and IKA08N65H5 DuoPack IGBTs and diodes for PFC, the TRENCHSTOP™ RC-Series IKN03N60RC2 that provides cost-effective, monolithically integrated IGBTs with diode for the inverter stage.

The starter kit features Infineon's iMOTION™ smart driver and advanced motion control engine (MCE 2.0) technology for PMSM/BLDC motor and PFC driver. It is optimized for small and major home appliances like fans, pumps, compressors and other general-purpose variable speed drives.

*Note: Please note that this product is not qualified according to the AEC Q100 or AEC Q101 documents from the Automotive Electronics Council.*

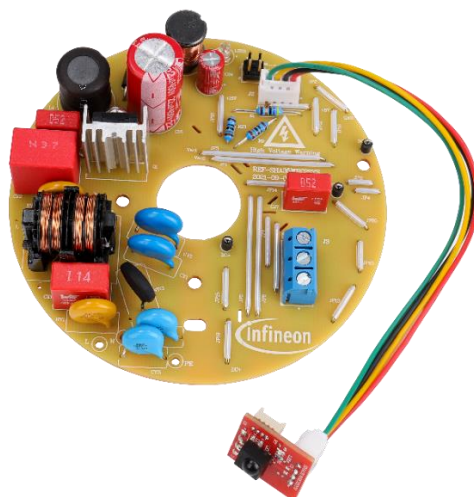
#### Intended audience

This user guide is intended for all technical specialists who are familiar with ceiling fan control and electronics converters. The reference design is intended to be used under laboratory conditions only by trained specialists.

#### Reference board/kit

Product(s) embedded on a PCB, with a focus on specific applications and defined use cases that may include software. PCB and auxiliary circuits are optimized for the requirements of the target application.

*Note: The boards do not necessarily meet the safety or quality standards requirements such as UL, CE.*



**Important notice**

**Important notice**

**“Evaluation Boards and Reference Boards” shall mean products embedded on a printed circuit board (PCB) for demonstration and/or evaluation purposes, which include, without limitation, demonstration, reference and evaluation boards, kits and design (collectively referred to as “Reference Board”).**

**Environmental conditions have been considered in the design of the Evaluation Boards and Reference Boards provided by Infineon Technologies. The design of the Evaluation Boards and Reference Boards has been tested by Infineon Technologies only as described in this document. The design is not qualified in terms of safety requirements, manufacturing and operation over the entire operating temperature range or lifetime.**

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Safety precautions

Safety precautions

Note: Please note the following warnings regarding the hazards associated with development systems.

Table 1 Safety precautions

	<p><b>Warning:</b> The DC link potential of this board is up to 1000 VDC. When measuring voltage waveforms by oscilloscope, high voltage differential probes must be used. Failure to do so may result in personal injury or death.</p>
	<p><b>Warning:</b> The evaluation or reference board contains DC bus capacitors which take time to discharge after removal of the main supply. Before working on the drive system, wait five minutes for capacitors to discharge to safe voltage levels. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.</p>
	<p><b>Warning:</b> The evaluation or reference board is connected to the grid input during testing. Hence, high-voltage differential probes must be used when measuring voltage waveforms by oscilloscope. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.</p>
	<p><b>Warning:</b> Remove or disconnect power from the drive before you disconnect or reconnect wires, or perform maintenance work. Wait five minutes after removing power to discharge the bus capacitors. Do not attempt to service the drive until the bus capacitors have discharged to zero. Failure to do so may result in personal injury or death.</p>
	<p><b>Caution:</b> The heat sink and device surfaces of the evaluation or reference board may become hot during testing. Hence, necessary precautions are required while handling the board. Failure to comply may cause injury.</p>
	<p><b>Caution:</b> Only personnel familiar with the drive, power electronics and associated machinery should plan, install, commission and subsequently service the system. Failure to comply may result in personal injury and/or equipment damage.</p>
	<p><b>Caution:</b> The evaluation or reference board contains parts and assemblies sensitive to electrostatic discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing the assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to the applicable ESD protection handbooks and guidelines.</p>
	<p><b>Caution:</b> A drive that is incorrectly applied or installed can lead to component damage or reduction in product lifetime. Wiring or application errors such as undersizing the motor, supplying an incorrect or inadequate AC supply, or excessive ambient temperatures may result in system malfunction.</p>
	<p><b>Caution:</b> The evaluation or reference board is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials that are unnecessary for system installation may result in overheating or abnormal operating conditions.</p>

## Table of contents

<b>About this document.....</b>	<b>1</b>
<b>Important notice .....</b>	<b>2</b>
<b>Safety precautions.....</b>	<b>3</b>
<b>Table of contents.....</b>	<b>4</b>
<b>1 The board at a glance.....</b>	<b>6</b>
1.1 Delivery content .....	6
1.2 Block diagram.....	7
1.3 Main features .....	9
1.4 Board parameters and technical data .....	10
<b>2 System and functional description .....</b>	<b>12</b>
2.1 Commissioning.....	12
2.1.1 Hardware connection .....	12
2.1.2 Software tools preparation.....	13
2.1.3 Firmware, parameter and script files preparation.....	13
2.1.4 Program firmware/parameters/script.....	22
2.1.5 Open-loop diagnostic .....	23
2.1.6 Closed loop run .....	24
2.1.7 Infrared control .....	26
2.2 Description of the main board functional blocks.....	26
2.2.1 EMI filter and surge protection .....	26
2.2.2 DC bus sensing and MCEWizard configuration .....	26
2.2.3 Inverter section .....	28
2.2.4 Motor current sensing and overcurrent protection .....	28
2.2.4.1 Motor current sensing.....	28
2.2.4.2 Motor overcurrent protection.....	30
2.2.5 PFC section .....	31
2.2.6 PFC current sensing and overcurrent protection .....	32
2.2.6.1 PFC current sensing .....	32
2.2.6.2 PFC overcurrent protection .....	33
2.2.7 Interface circuit of IMD112T .....	34
2.2.8 Interface circuit to XMC daughter board .....	35
2.3 Description of the daughter board functional blocks.....	35
2.3.1 Circuit of daughter board.....	36
2.3.2 Output duty signals versus buttons .....	36
<b>3 System design.....</b>	<b>38</b>
3.1 Schematics .....	38
3.2 Layout .....	38
3.2.1 Main board layout .....	38
3.2.2 Daughter board layout.....	40
3.3 Bill of material .....	42
3.4 Connector details .....	43
3.4.1 Main board connectors .....	43
3.4.2 Daughter board connectors.....	44
<b>4 System performance .....</b>	<b>45</b>
4.1 PFC iTHD at rated condition .....	45
4.2 Bus voltage ripple.....	45

**Table of contents**

4.3	PFC IGBT Vce dv/dt performance .....	46
4.4	PFC thermal performance.....	48
4.5	Inverter IGBT dv/dt performance .....	49
4.6	Inverter IGBT dead time test.....	51
4.7	Electromagnetic interference (EMI) conducted .....	52
4.8	Surge immunity test.....	53
4.9	System test with infrared control .....	54
<b>5</b>	<b>References and appendices .....</b>	<b>55</b>
5.1	Abbreviations and definitions.....	55
5.2	References .....	55
5.3	Additional information.....	55
	<b>Revision history.....</b>	<b>56</b>

**The board at a glance**

# 1 The board at a glance

The REF-SHA35WRC2SYS is a part of Infineon’s TRENCHSTOP™ IGBT, gate driver and iMOTION™ smart driver reference design kits. It is designed to provide a ready-to-use ceiling fan solution based on the above-mentioned technology as well as on the advanced motion control engine (MCE 2.0).

The REF-SHA35WRC2SYS is an optimized design for 35 W ceiling fan applications. It allows fast prototyping and a fast time to market. It is available through regular Infineon distribution partners as well as on Infineon's website. The main features of this board are described in Chapter 1.3 of this document. The remaining sections provide information for customers, enabling them to copy and modify the design for production according to their specific requirements.

Environmental conditions have been considered in the design of the REF-SHA35WRC2SYS. The design was tested as described in this document, but not qualified in terms of safety requirements or manufacturing and operation over the whole operating temperature range or lifetime. The boards provided by Infineon are subject to functional testing only.

The boards are not subject to the same procedures as regular products in terms of returned material analysis (RMA), process change notification (PCN) and product discontinuation (PD).

## 1.1 Delivery content

The scope of delivery contains the main board REF-SHA35WRC2SYS and daughter board XMC1100\_IR\_RC as shown in Figure 2 to Figure 5, one connecting cable, and remote infrared control box. The detailed ordering information is indicated in Table 2.

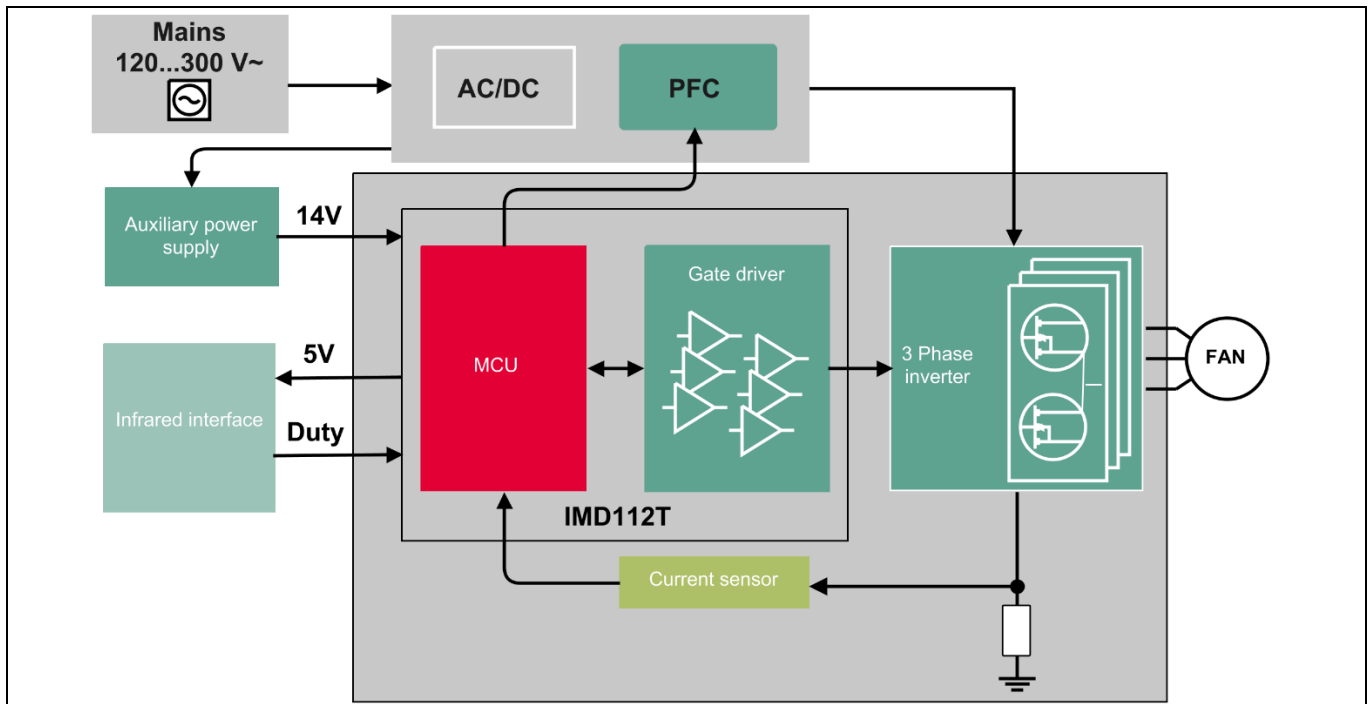
**Table 2 Delivery content**

Base part number	Package	Standard pack		Orderable part number
		Form	Quantity	
REF_SHA35WRC2SYS		Boxed	1	REFSHA35WRC2SYSTOBO1
XMC1100_IR_RC		Boxed	1	
Cable		Boxed	1	
Remote infrared control box		Boxed	1	

**The board at a glance**

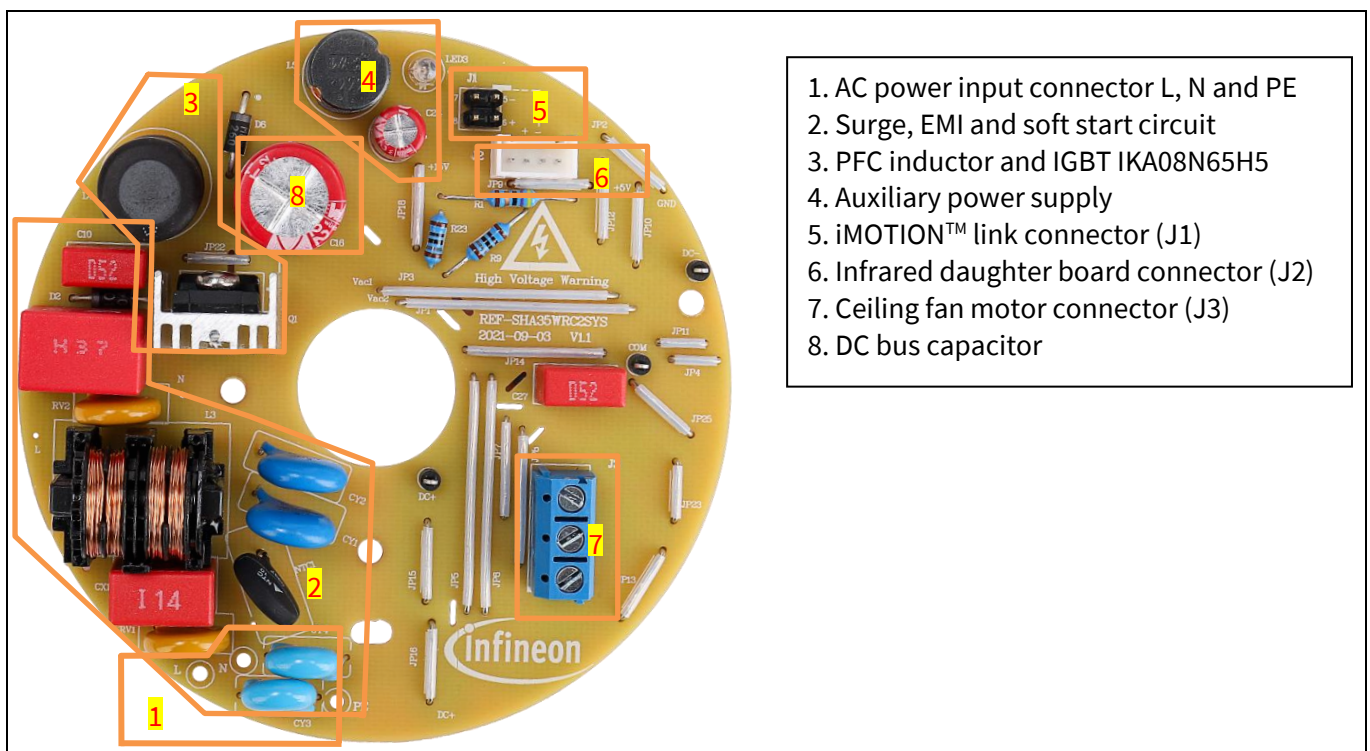
**1.2 Block diagram**

The block diagram of the REF-SHA35WRC2SYS is depicted in Figure 1.



**Figure 1 Block diagram of the REF-SHA35WRC2SYS**

Figure 2 to Figure 5 depict the functional groups of the main board REF-SHA35WRC2SYS and daughter board XMC1100\_IR\_RC.

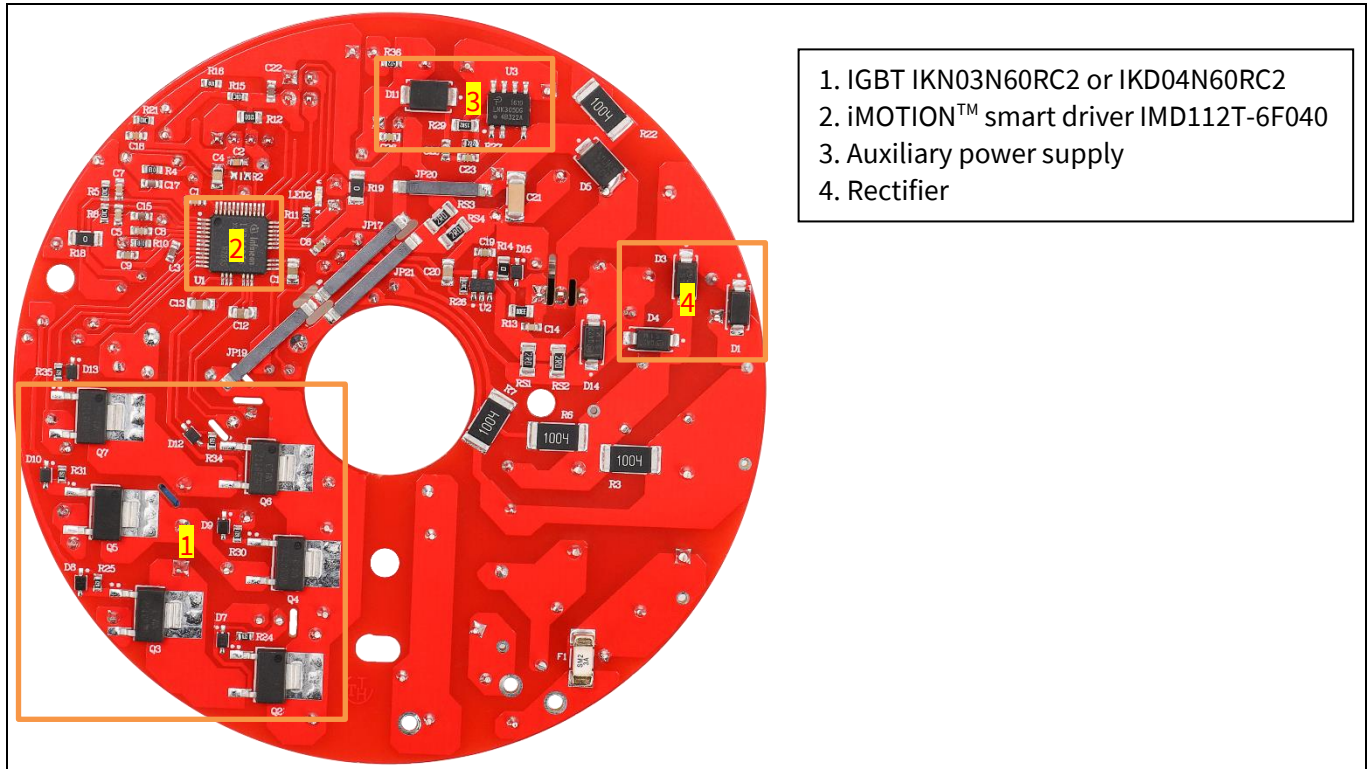


**Figure 2 Functional groups on top side of the main board REF-SHA35WRC2SYS**

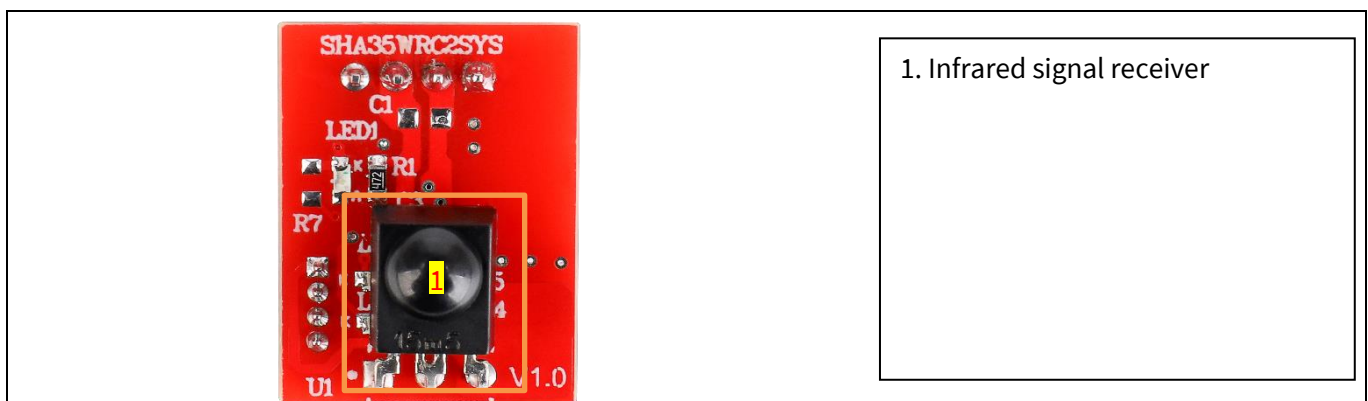
# REF-SHA35WRC2SYS user guide

## Ceiling fan application reference design kits

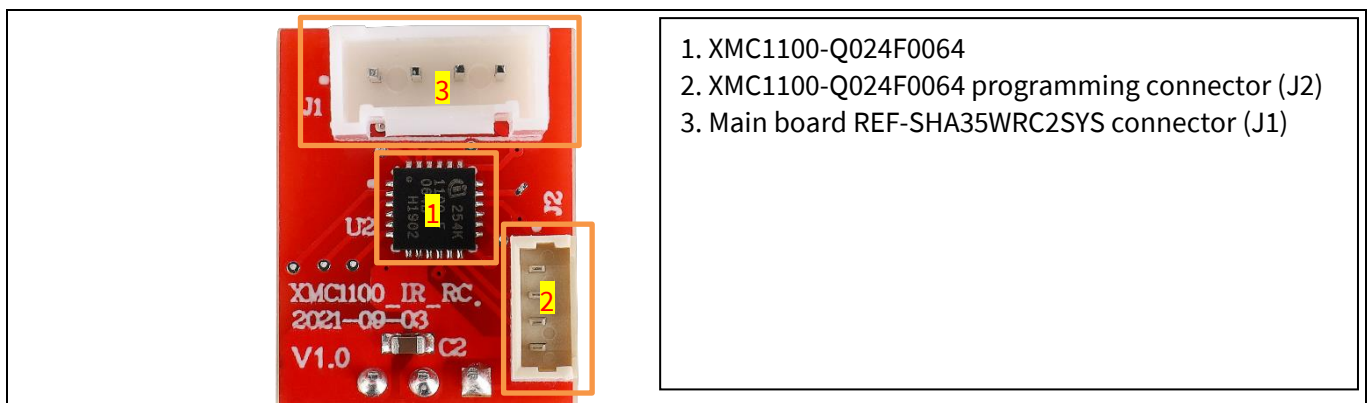
### The board at a glance



**Figure 3** Functional groups on bottom side of the main board REF-SHA35WRC2SYS



**Figure 4** Functional groups on top side of the daughter board XMC1100\_IR\_RC



**Figure 5** Functional groups on bottom side of the daughter board XMC1100\_IR\_RC



## The board at a glance

### 1.3 Main features

The REF-SHA35WRC2SYS board is an optimized reference design for 230 V<sub>rms</sub> ceiling fan applications. It contains iMOTION™ smart driver IMD112T for controller and inverter driver, TRENCHSTOP™ RC-Series cost-effective, monolithically integrated IGBT with diode IKN03N60RC2 for inverter switches, 650 V DuoPack IGBT and diode IKA08N65H5 for PFC switch, and IRS44273L for PFC gate driver.

Major REF- SHA35WRC2SYS characteristics include:

- Input voltage range 120~300 V<sub>rms</sub>, Normal input voltage 230 V<sub>rms</sub>.
- Maximum input power 35 W at T<sub>vj</sub>=25°C with input voltage range of 120~300 V<sub>rms</sub>
- PFC factor ≥ 0.9 at normal input voltage 230 V<sub>rms</sub> and maximum input power 35 W
- iTHD ≤ 10% at normal input voltage 230 V<sub>rms</sub> and maximum input power 35 W
- Surge is compliant with IEC standards IEC61000-4-5, L-N, L-PE and N-PE 4 kV
- EMI is compliant with EN55032 Class B
- 650 V DuoPack IGBT and diode for PFC switch
- Single-channel, low-side IGBT gate driver IC for PFC switch driver
- On-board 0.3 A, 10 mH PFC inductor for 60 kHz PFC operation
- The cost-effective, monolithically integrated 600 V Reverse Conducting Driver 2 for 16 kHz PWM motor control
- iMOTION™ smart driver for main control and inverter driver
- Infrared remote interface for ceiling fan speed control
- Overcurrent protection
- Auxiliary power supply with 14 V
- 5 V is supplied by on-board iMOTION™ smart driver
- Main board PCB is 90 mm diameter cycle, single layer, 1 oz. copper
- Daughter board is 15 mm x 9 mm, 2 layers, 1 oz. copper
- RoHS compliant

**The board at a glance**

**1.4 Board parameters and technical data**

Table 3 depicts the key specifications of the reference design of REF-SHA35WRC2SYS.

**Table 3 REF-SHA35WRC2SYS board specifications**

Parameter	Symbol	Conditions	Value	Unit
Input voltage	$V_{ac}$	Optimized design for 230 $V_{rms}$ applications	120 ~ 300	$V_{rms}$
Maximum input current	$I_{ac(max)}$	Input 120 $V_{rms}$ , input power = 35W, $T_a=25^{\circ}C$ , Motor $f_{PWM}=16$ kHz, PFC $f_{PWM}=60$ kHz natural cooling mode	290	$mA_{rms}$
Normal input current	$I_{ac(norm)}$	Input 230 $V_{rms}$ , input power = 35W, $T_a=25^{\circ}C$ , Motor $f_{PWM}=16$ kHz, PFC $f_{PWM}=60$ kHz natural cooling mode	155	$mA_{rms}$
Maximum input power	$P_{in(max)}$	Input 120 ~ 300 $V_{rms}$ , input power = 35W, $T_a=25^{\circ}C$ , natural cooling mode	35	W
Maximum motor current	$I_{mtr(max)}$	Input 230 $V_{rms}$ , input power = 35W, $T_a=25^{\circ}C$ , Motor $f_{PWM}=16$ kHz, PFC $f_{PWM}=60$ kHz, Natural cooling mode	130	$mA_{rms}$
<b>DC bus voltage</b>				
Maximum DC bus voltage	$V_{dc(max)}$	DC bus capacitors are 450 V, 22 $\mu F$	450	V
Minimum DC bus voltage	$V_{dc(min)}$	Aux power supply brown-in voltage	25	V
<b>Current feedback</b>				
PFC shunt resistance	RS1	Direct AD sample, two 0.25 W, 2 $\Omega$ shunt resistor paralleled	1	$\Omega$
Motor shunt resistance	RS2	Direct AD sample, two 0.25 W, 2 $\Omega$ shunt resistor paralleled	1	$\Omega$
<b>Protections</b>				
PFC current protection trigger level	$PFCI_{trip}$	IMD112T's internal comparator for cycle-by-cycle OCP, trip level can be adjusted by R15 & R16	853 <sup>1</sup>	$mA_{peak}$
Motor current protection trigger level	$Mtrl_{trip}$	Wizard setup for OC trigger level, related to AD range, shunt resistor RS3, RS4 and pull-up bias	500 <sup>2</sup>	$mA_{peak}$
<b>Auxiliary power supply1 – 14V</b>				
Output voltage	$V_{AUout1}$	Used for IPM driver	14 $\pm$ 2%	V
Maximum output current	$I_{AUout1}$		175	mA

<sup>1</sup> For iMOTION™ IC IMD112T PFC overcurrent protection, there are two options in the MCEWizard setup.

If you select “Cycle-By-Cycle” mode, the PWM output immediately goes to logic LOW when the inductor current exceeds the pre-determined OCP threshold, and re-starts at the following PWM cycle.

If you select “Latch-off” mode, PFC state machine would shift from RUN state to FAULT state when the inductor current exceeds the pre-determined OCP threshold for a duration specified by parameter “PFC\_GateKillTime”, only Fault\_clear command can make it back to STOP/RUN mode.

<sup>2</sup> For iMOTION™ IC IMD112T, there is only one type of Gatekill input source in MCEWizard setup: comparator. The feedback current will be compared by the internal comparator with the “Overcurrent Trip Level for Internal GateKill Comparator” value set in MCEWizard.

**The board at a glance**

Parameter	Symbol	Conditions	Value	Unit
<b>Auxiliary power supply2 – 5V</b>				
Output voltage	$V_{AUout2}$	Supplied by IMD112T and power daughter board	$5 \pm 4\%$	V
Maximum output current	$I_{AUout2}$		10	mA
<b>PCB characteristics</b>				
Main board dimension		Diameter× height, single layer	90×65	mm
Material		FR4, 1.6 mm thickness, 1 oz. PCB		
Daughter board dimension		Length × width × height, double layer	19×15 ×11	mm
Material		FR4, 1.6 mm thickness, 1 oz. PCB		
<b>System environment</b>				
Ambient temperature	$T_a$	Non-condensing, maximum RH of 95%	0 ~ 50	°C

System and functional description

## 2 System and functional description

### 2.1 Commissioning

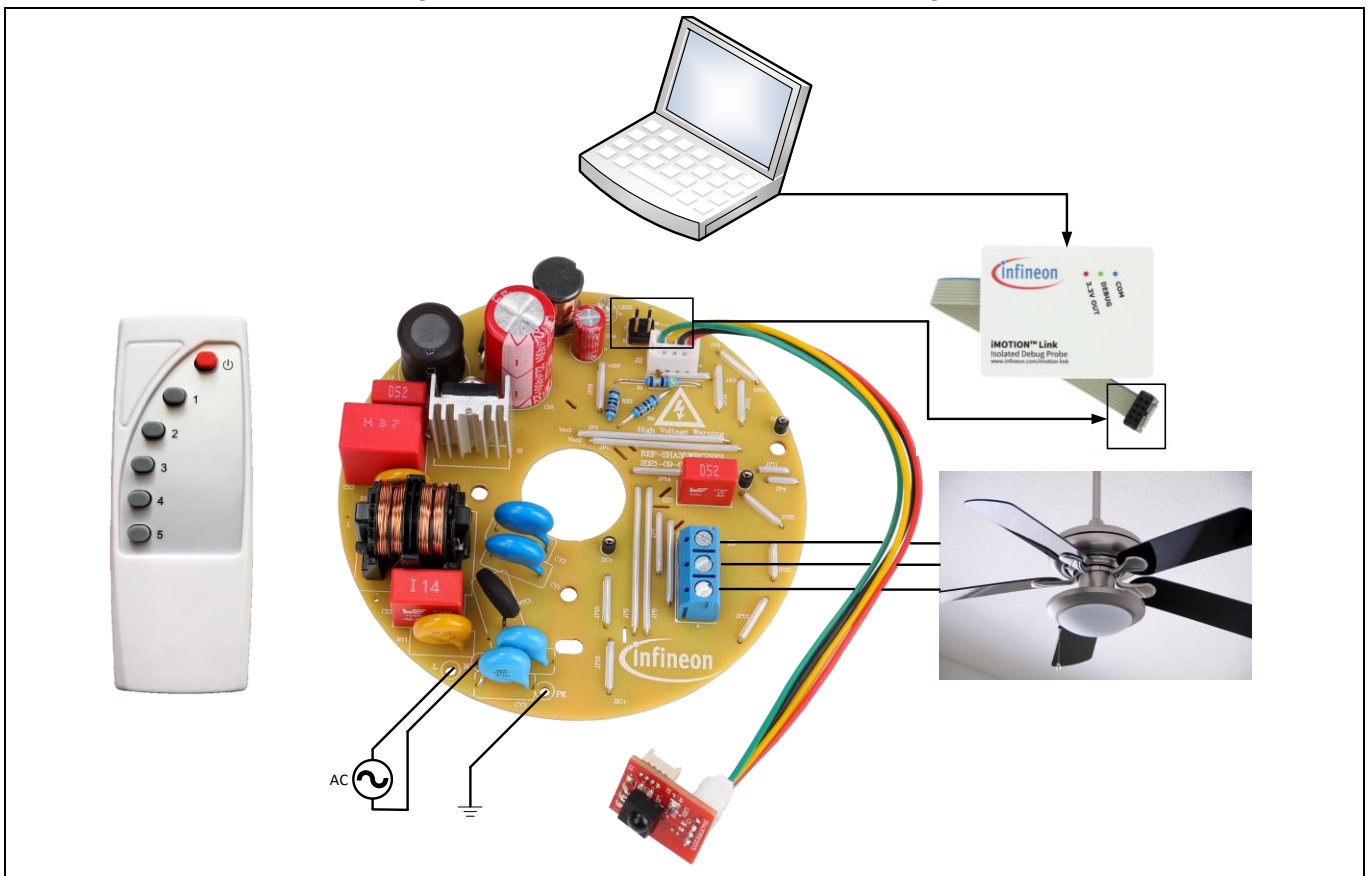
This section describes how to get the system working after the user has installed the board. The following items detail these steps. For those who are familiar with the system, or who have already run the board, some of the steps can be skipped, depending on the user's situation. For more in-depth start-up requirements, please refer to the MCE reference manual or the corresponding reference material<sup>[4][5][6]</sup>.

#### 2.1.1 Hardware connection

Figure 6 shows the hardware connection details for the reference design board.

The **iMOTION™ link** cable is needed to bridge the PC/debugger side and motor drive system (the target iMOTION™ device, hot side) with 1 kV DC galvanic isolation. Users can go to Section 5.3 for more information on the iMOTION™ link.

1. Connect iMOTION™ link's 8-pin cable to main board J1 using the default pin order (only pin 5~8 are used), and connect PC and iMOTION™ link with the USB wire.
2. Then connect AC power supply (L, N, PE) and the motor (J3).
3. Connect main board J2 to daughter board J1 by cable attached in package box.



**Figure 6** Hardware connection details

*Note:* The iMOTION™ link shown in Figure 6 is required for tuning the board firmware, but it is not included in the delivery content. It can be ordered separately according to the details in Section 5.3.

### **2.1.2 Software tools preparation**

The iMOTION™ software tools, MCEDesigner and MCEWizard, are required to set up the system, as well as to control and fine-tune the system performance to match users' needs. These tools are available for download via the Infineon website (<http://www.infineon.com/imotion-software>). Please check this page periodically for tool/software updates. Regarding the use of MCEDesigner and MCEWizard, please refer to the “MCEDesigner Application Guide” and the “MCEWizard User Guide.”

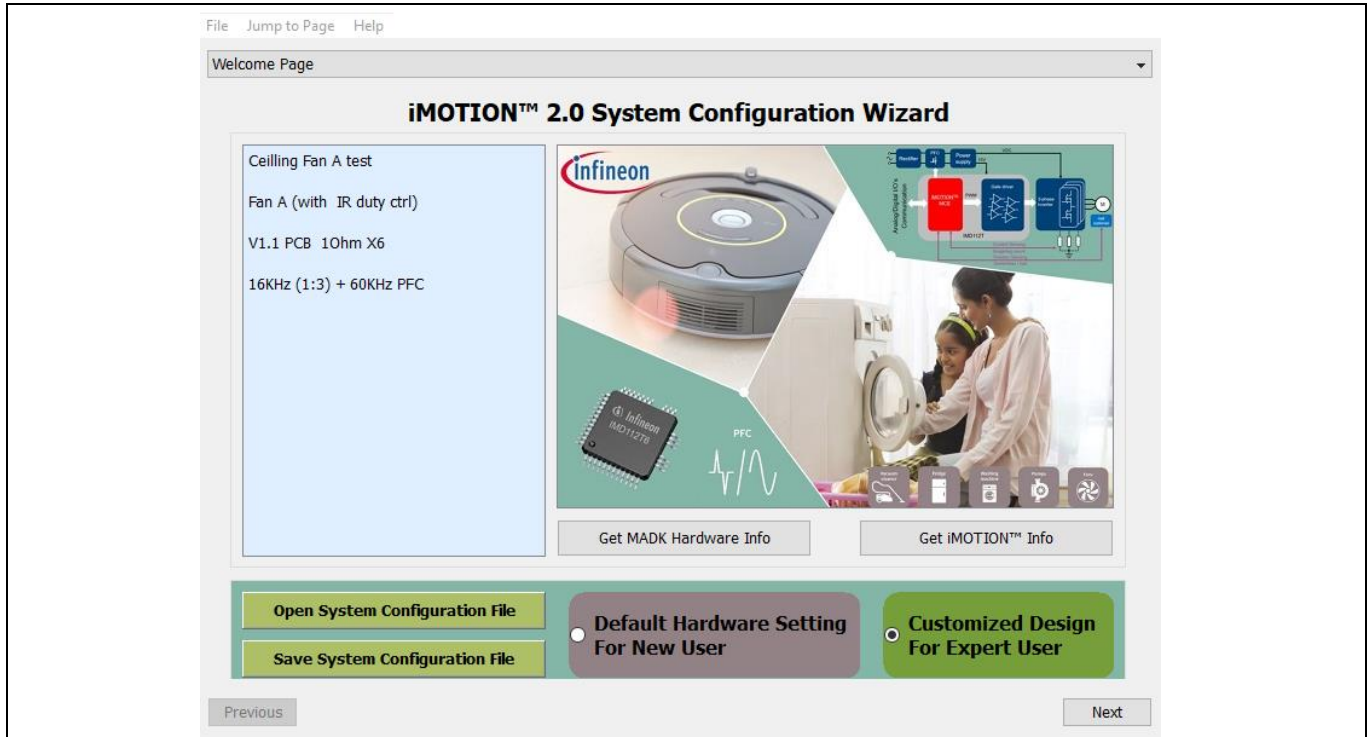
*Note: This reference board has been tested by the software tools MCEdesigner v2.3.1 and MCEWizard v2.3.1. The same performance is not guaranteed for updated software tools and MCE firmware.*

### **2.1.3 Firmware, parameter and script files preparation**

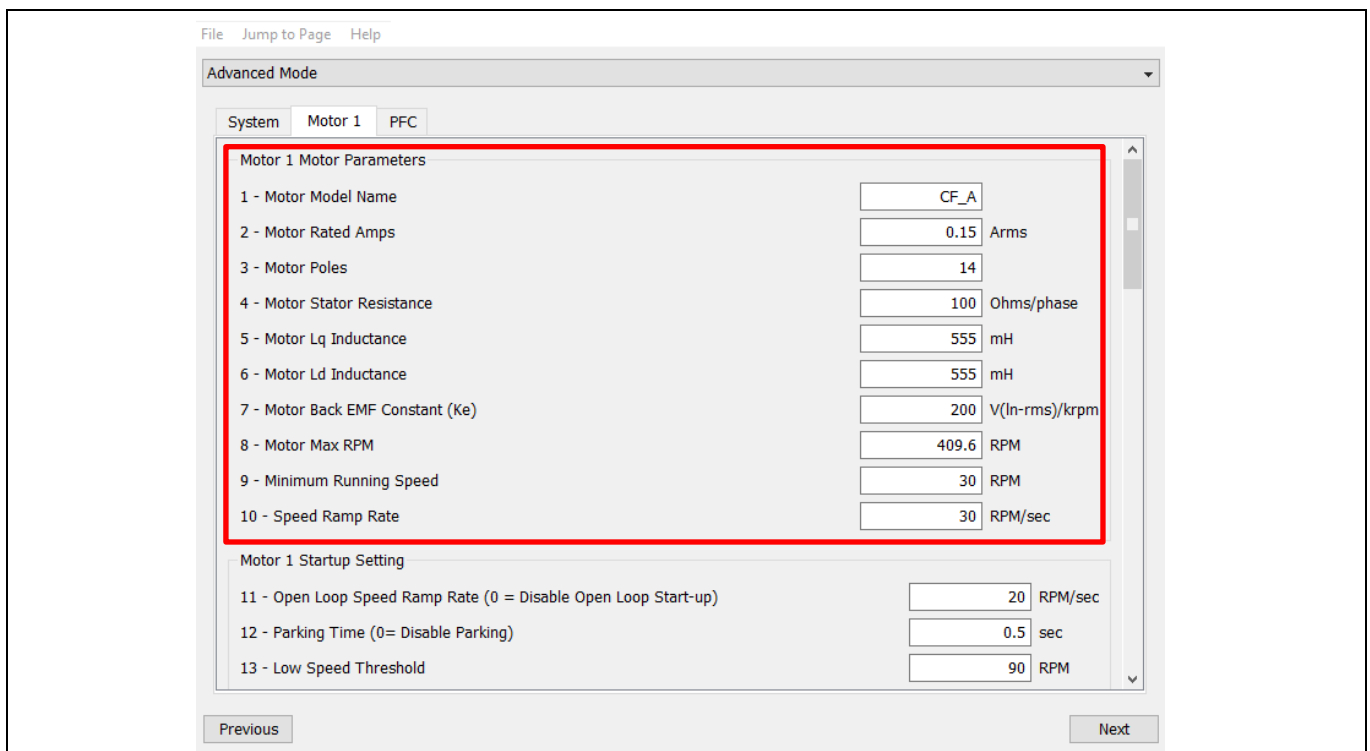
If you are not familiar with the software design of iMOTION™, you can log-in to myInfineon and download the default software package for this reference board. The package includes MCEWizard file (‘.mc2’), MCEDesigner file (‘.irc’), parameter file (‘.txt’), map file (‘.map’), MCE firmware file (‘.ldf’) and script file (‘.ldf’) for this board. In the MCEWizard file (‘.mc2’), all the parameters related to the board hardware and script code have been configured as well. To make things easier and save time, you need to modify the parameters related to your motor, and generate the parameters as described in the steps below.

*Note: There are two files for all MCEWizard file (‘.mc2’), MCEDesigner file (‘.irc’) and parameter file (‘.txt’), the one is for remote infrared control with enabled script function, and the other one is for initial open-loop diagnostic and closed-loop tuning without script function.*

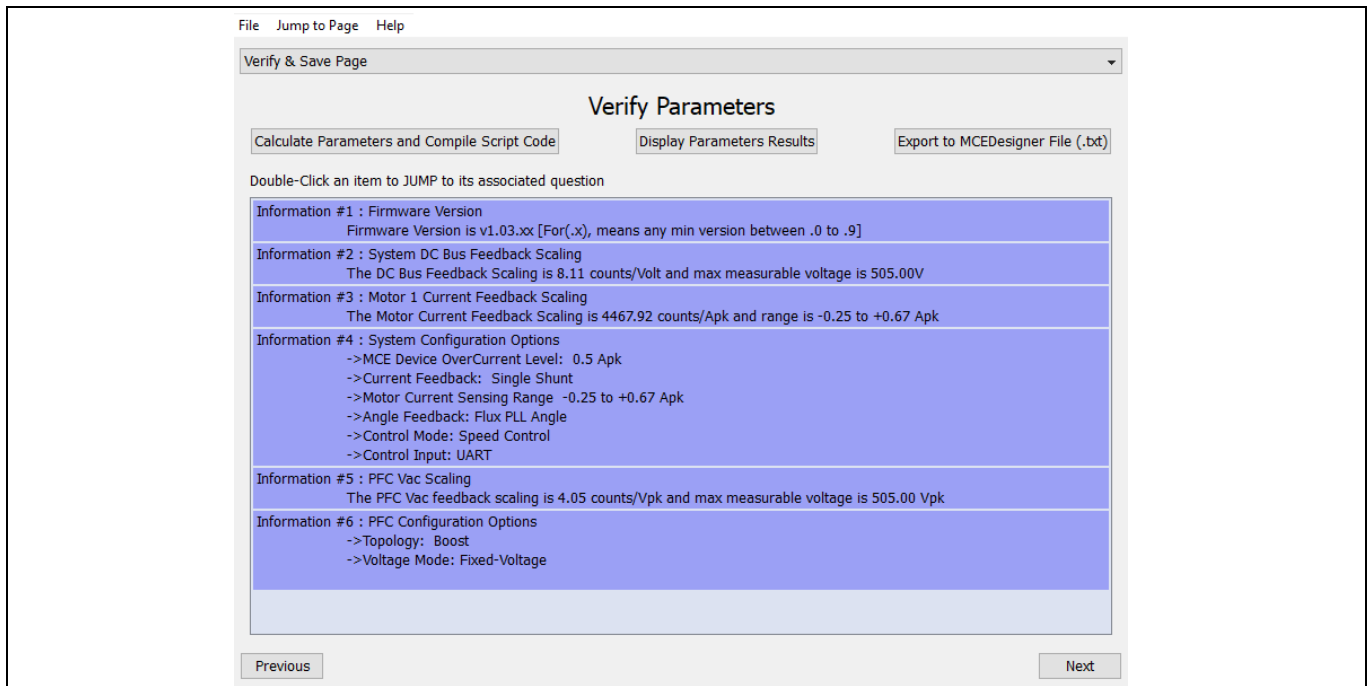
1. Use MCEWizard to open the MCEWizard file (‘.mc2’) as shown in Figure 7, then enter the target motor’s system parameters in “Advanced Mode > Motor 1” as shown in Figure 8, which will be used to calculate the controller’s digital parameter set, representing the complete motor drive system.
2. After the target motor’s system parameters are set, go to the “Verify & Save Page” and click on the “Calculate Parameters and Compile Script Code” key to enable the script function; click on “Calculate Parameters” key to disable script function. If no errors are reported, then save the drive parameters set in your project directory by clicking “Export to Designer file (.txt)” as shown in Figure 9. If errors are detected, double-click on the error message (highlighted in RED) and adjust the related parameters. The saved drive system parameter file will later be used for programmers.
3. To perfect motor running performance, the motor control parameters listed below may need to be modified to your tuning process.
  - Open loop speed ramp rate
  - Parking time
  - Low speed threshold
  - Low speed current limit
  - Current regulator bandwidth
  - Speed regulator proportional gain
  - Speed regulator integral gain



**Figure 7 Wizard welcome page**



**Figure 8 Motor parameters input**



**Figure 9 MCEWizard verify and save page (script-enabled)**

If you are familiar with the software design of iMOTION™, you can download MCE firmware via the Infineon website (<http://www.infineon.com/imotion-software>). Select the firmware package “IMD112T-F040 MCE Software Package v x.x.x.” Please check this page periodically for MCE firmware updates. Included in the package are the firmware (‘.ldf’), default parameters (‘.txt’), default map file (‘.map’), the file for the MCEDesigner(‘.irc’) and other documents. You need to modify the parameters related to your motor, but also to configure the hardware parameters according to this reference board.

*Note: This reference board has been tested by MCE firmware IMD112T-F040 MCE Software Package v1.3.3. The same performance is not guaranteed for updated software tools and MCE firmware.*

1. Use MCEWizard to enter the target motor’s system and operating parameters, as well as the reference board’s hardware parameters. Please disable the script function and check each item carefully. Here is the default list of the key configuring parameters for this reference board.
  - Motor’s system parameters as shown in Figure 8, need to be modified for your specific motor system.
  - Motor PWM frequency : 16 KHz
  - PFC PWM frequency : 60 KHz
  - Motor current shunt configuration: single shunt
  - Application control interface: UART
  - Motor control mode: speed control
  - Rotor angle calculation: flux PLL angle
  - Control supply voltage: 5.0 V
  - Maximum DC bus over-voltage: 500 V
  - DC bus over-voltage level: 440 V
  - DC bus under-voltage level: 80 V
  - DC bus critical over voltage level: 499 V
  - DC bus sensing high resistor: 1000 kOhms
  - DC bus sensing low resistor: 10 kOhms

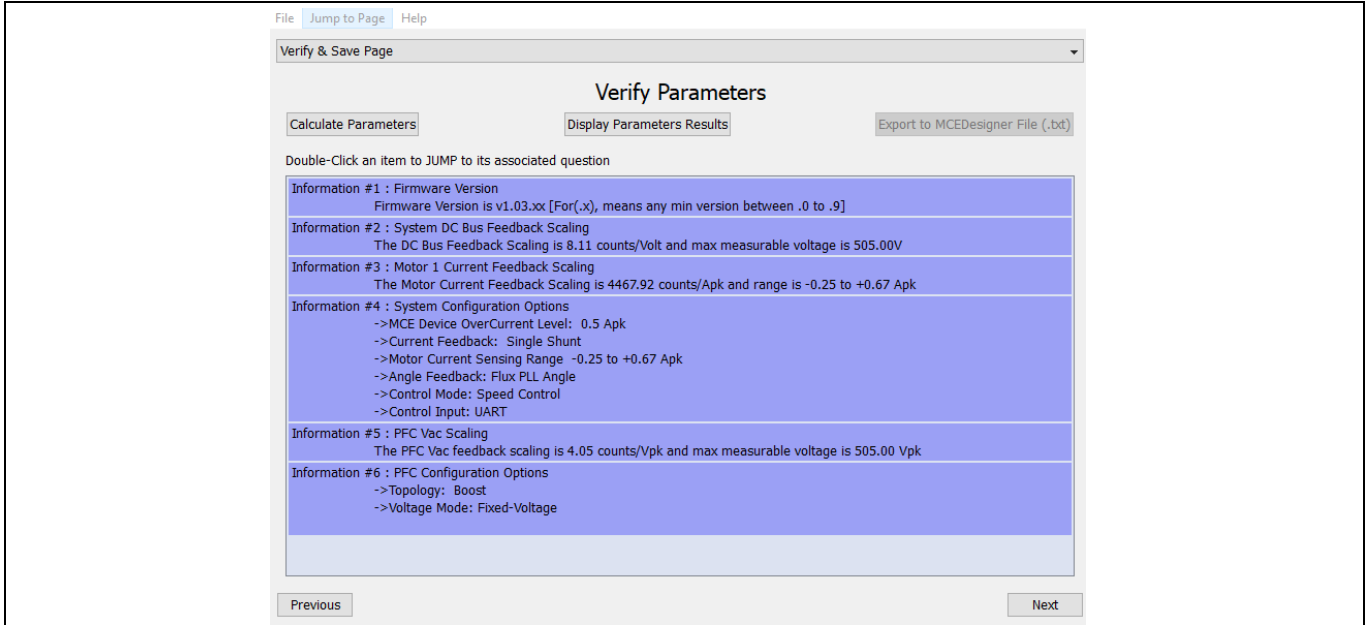
**System and functional description**

- Open loop speed ramp rate: 20 RPM/sec
- Parking time: 0.5 sec
- Low speed threshold: 90 RPM, need to be modified as your actual motor system
- Low speed current limit: 40%, need to be modified as your actual motor system
- Current regulation bandwidth: 1600 rad/sec, need to be modified as your actual motor system
- Speed regulator proportional gain: 2, need to be modified as your actual motor system
- Speed regulator integral gain: 0.8 rad/s, need to be modified as your actual motor system
- Inverter dead time: 0.6s
- Motor current input scaling: 909 mV/A
- Internal current feedback amplifier Gain: 6
- Motor current input to ADC offset voltage: 224 mV
- Gate driver propagation delay: 0.1  $\mu$ sec
- Type of single shunt current sensing: phsShift
- Enable low noise phase-shift current sensing: disable
- Phase shift window size: 3  $\mu$ sec
- Overcurrent trip level for internal gateKill comparator: 0.5 A
- Gatekill filter time constant: 0.5
- Catch spin before start: enable
- Catch spin time: 0.1  $\mu$ sec
- Target DC bus voltage initialization: 360 V
- PFC topology: boost
- PFC inductance: 7 mH
- PFC current measurement input scaling: 806 mV/A
- PFC internal current feedback amplifier gain: 6
- PFC current sensing input polarity: inverting
- AC input frequency: 50 Hz, need modify as your actual input power
- AC voltage sensing high resistor: 1000 KOhms
- AC voltage sensing low resistor: 10 KOhms
- PFC low side gate driver polarity: high
- PFC current sample delay time: -0.2  $\mu$ sec
- PFC voltage reference ramp rate: 50 v/sec
- PFC duty-feed-forward factor: 0.83
- PFC voltage regulator proportional gain: 1500
- PFC voltage regulator integral gain: 30
- PFC current regulator proportional gain: 400
- PFC current regulator integral gain: 600
- PFC over-current-protection: cycle-by-cycle
- Enable Vdc under voltage fault: enable
- Enable Vdc over voltage fault: enable
- Minimum AC input voltage fault: 100 Vrms
- Enable Vac under voltage fault: enable
- Maximum AC input voltage: 310 Vrms
- Enable Vac over voltage fault: enable
- Enable AC input frequency protection: disable



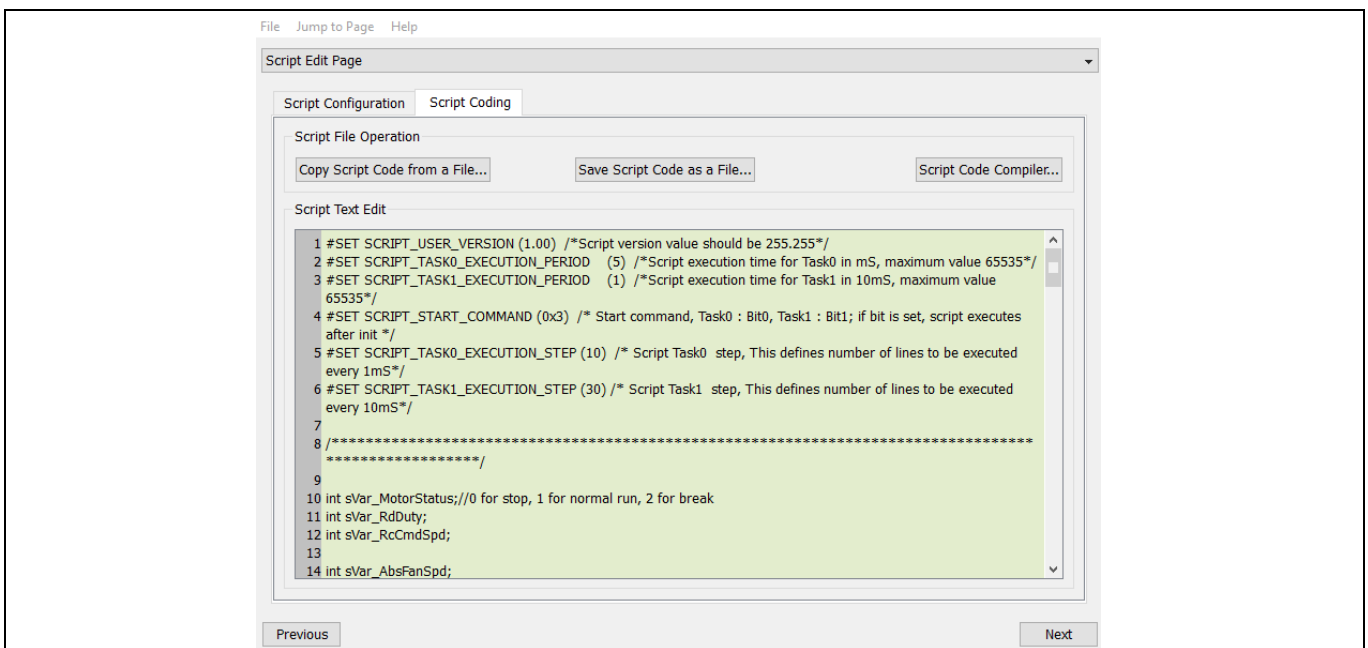
**System and functional description**

- After system and operating parameters are set, go to the “Verify & Save Page” and click on the “Calculate Parameters” key to disable script function. If no errors are reported, then save the drive parameter set in your project directory by clicking “Export to Designer file (.txt)” as shown in Figure 10. If errors are detected, double-click on the error message (highlighted in RED) and adjust the related parameters. The saved drive system parameter file will later be used for open-loop diagnostic and closed-loop tuning.



**Figure 10 MCEWizard verify and save page (script-disabled)**

- If the open-loop diagnostic and closed-loop are tuned up, enable the script function in the “Options Page” of MCEWizard, and copy the default script code for remote infrared control in the Code Listing 1 to “Script Edit Page >Script Coding tap” in the MCEWizard as shown in 0Figure 11. Then generate the execution file of script code for remote infrared control tuning by clicking “Script Code Compiler” in “Script Edit Page >Script Coding tap” or go to the “Verify & Save Page” and click on “Calculate Parameters.” For more information regarding script, please refer to the MCE reference manual<sup>[6]</sup>.



**Figure 11 Script edit page**

**Code Listing 1 Default script code for remote infrared control**

```
001 #SET SCRIPT_USER_VERSION (1.00) /*Script version value should be 255.255*/
002 #SET SCRIPT_TASK0_EXECUTION_PERIOD (5) /*Script execution time for Task0
in mS, maximum value 65535*/
003 #SET SCRIPT_TASK1_EXECUTION_PERIOD (1) /*Script execution time for Task1
in 10mS, maximum value 65535*/
004 #SET SCRIPT_START_COMMAND (0x3) /* Start command, Task0 : Bit0, Task1 : Bit1;
if bit is set, script executes after init */
005 #SET SCRIPT_TASK0_EXECUTION_STEP (10) /* Script Task0 step, This defines
number of lines to be executed every 1mS*/
006 #SET SCRIPT_TASK1_EXECUTION_STEP (30) /* Script Task1 step, This defines
number of lines to be executed every 10mS*/
007
008 /*****
*****/
009
010 int sVar_MotorStatus;
011 int sVar_RdDuty;
012 int sVar_RcCmdSpd;
013
014 int sVar_AbsFanSpd;
015 int sVar_ErrorCode;
016 int sVar_VacRMS_Flt;
017 int sVar_FollowPFCCmd;
018
019 int sVar_temp0;
020 int sVar_temp1;
021
022 /*
023 Read Dutycycle about 10% ~ 90% (total 664us)
024 Ton is 66us,199us,332us,465us,598us
025 */
026
027 /*Task0 init function*/
028 Script_Task0_init()
029 {
030     sVar_MotorStatus = 0;
031 }
032
033 Script_Task1_init()
034 {
035     sVar_MotorStatus = 0;
036     PllKp = 600;
037     PllKi = 100;
038     Vd_Ext=0;
039     Vq_Ext=0;
040     AngleSelect =2;
041     CtrlModeSelect =2;
042     Command = 0;
043     PFC_Command = 0;
044
045     TargetSpeed= 1600; //initial motor speed 40 rpm
046     PFC_TargetVolt = 2400; //initial PFC target voltage 296V
047 }
048
049 /*****Task0 script function*****/
050 /*****RC commnad read and deal 5ms run*****/
051 Script_Task0()
052 {
053     int ControlDutyTemp;
```

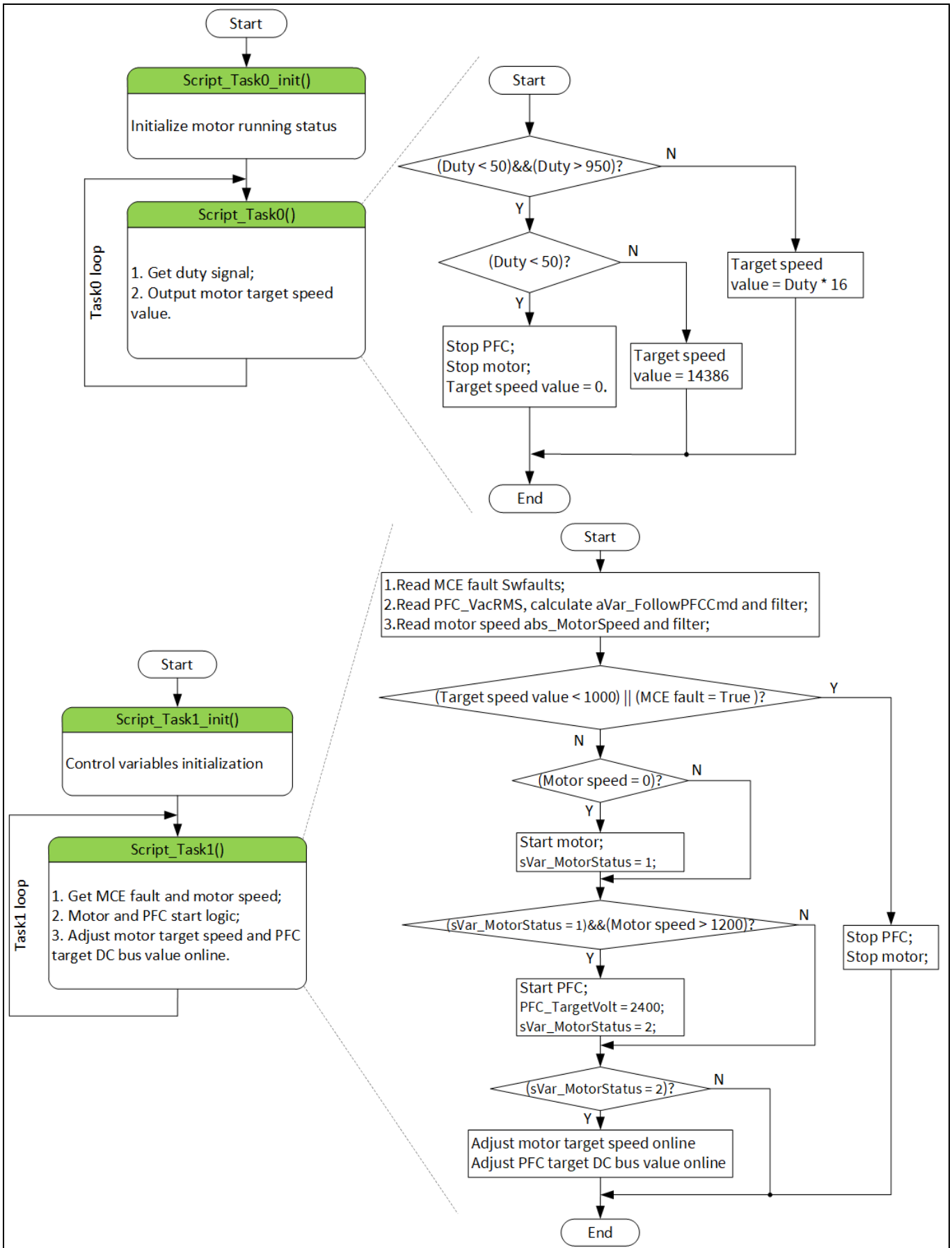
System and functional description

Code Listing 1 Default script code for remote infrared control

```
054 // Read ControlDuty: 100~900cts for 10%~90% dutycycle,update every 10 ms
055 // Input low level active
056     ControlDutyTemp = 1000 - ControlDuty;
057     if(ControlDutyTemp < 0)
058     {
059         ControlDutyTemp = 0;
060     }
061     if(ControlDutyTemp > 1000)
062     {
063         ControlDutyTemp = 1000;
064     }
065     sVar_RdDuty = (ControlDutyTemp + 7 * sVar_RdDuty + 4)>>3; //LPF for 1/8
066
067     //Stop or Wrong input, keep Stop and fix SpdCmd = 0
068     if((sVar_RdDuty > 950) || (sVar_RdDuty < 50))
069     {
070         sVar_RcCmdSpd = 0;
071         Command = 0;
072         PFC_Command = 0;
073     }
074     else
075     {
076         sVar_RcCmdSpd = sVar_RdDuty * 16; //Transfer Dutycycle to speed count
077                                     //(10% --> 1600cts)
078         if(sVar_RcCmdSpd > 14386)
079         {
080             sVar_RcCmdSpd = 14386; //limit motor speed to max speed 360 rpm
081         }
082     }
083 }
084
085 /*****Task1 script function*****/
086 /*****10ms run*****/
087 Script_Task1()
088 {
089     /*****Read and LPF*****/
090     //Read MCE fault
091     sVar_ErrorCode = SwFaults;
092
093     // LPF for Vac RMS
094     sVar_VacRMS_Flt = (7*sVar_VacRMS_Flt + PFC_VacRMS + 4)>>3;
095
096     //1.414*32= 45.248 // Vacpeak +10V
097     sVar_FollowPFCCmd = 81 + (sVar_VacRMS_Flt * 45 + 8)>>4;
098
099     // LPF for Fan ABS speed feedback
100     sVar_AbsFanSpd = (7*sVar_AbsFanSpd + abs_MotorSpeed + 4)>>3;
101
102     /*****Motor and PFC control, (0,1,2 state machine)*****/
103     // Stop PWM if CMD is too low or MCE fault
104     if (( sVar_RcCmdSpd < 1000) || (sVar_ErrorCode >0))
105     {
106         Command=0;
107         PFC_Command = 0;
108         sVar_MotorStatus = 0;
109     }
110     else // Start Motor and update Spd & TargetVolt
111     {
112         if (sVar_MotorStatus ==0) //From STOP to Start
```

**Code Listing 1 Default script code for remote infrared control**

```
113         {
114             sVar_MotorStatus = 1;           //Motor start
115             AngleSelect =2;
116             CtrlModeSelect =2;
117             TargetSpeed = sVar_RcCmdSpd;    //Normal Run Speed
118             Command = 1;                   //Start motor PWM
119         }
120
121     //Start PFC when motor start OK (speed over Minspd)
122     if((sVar_MotorStatus ==1) && (sVar_AbsFanSpd > 1200))
123     {
124         sVar_MotorStatus = 2;             //Motor started
125
126         //PFC start with a very low voltage REF to reduce power loss
127         PFC_TargetVolt = 2400;
128
129         //Start PFC PWM
130         PFC_Command=1;
131     }
132
133     //Normal PFC and motor run, update PFC and motor speed command
134     if(sVar_MotorStatus ==2)
135     {
136         TargetSpeed = sVar_RcCmdSpd;
137
138         //360RPM= 14386-->2877-->354V, 16383/5 = 3276 -->404V DCBUS
139         sVar_temp0 = sVar_AbsFanSpd/5;
140
141         if(sVar_temp0 > sVar_FollowPFCCmd)
142         {
143             //High spd & BEMF, need higher Vdcbus to support motor run
144             PFC_TargetVolt = sVar_temp0;
145         }
146         else //lower Vdcbus as possible to reduce power loss
147         {
148             //Low Spd or high Vac input, Vdc tracking Vac peak +10V
149             PFC_TargetVolt = sVar_FollowPFCCmd;
150         }
151
152         if (PFC_TargetVolt > 3244) //MAX Vdc limit: 400V *8.11 = 3244 cts
153         {
154             PFC_TargetVolt = 3244;
155         }
156     }
157 }
158 }
159 /*****End of Script*****/
```



**Figure 12** Flow chart of default script code

**System and functional description**

Figure 12 shows the flow chart of default Script code. There are two tasks: Script\_Task0 and Script\_Task1. Script\_Task0 executes every 5 ms and Script\_Task1 executes every 10 ms. Script\_Task0 is to get duty signal from the daughter board and output motor target speed value. Script\_Task1 is to get the MCE fault and motor real speed, control motor and PFC start logic and adjust motor target speed and PFC target DC bus value online.

**2.1.4 Program firmware/parameters/script**

The REF\_SHA35WRC2SYS reference design kit is shipped with pre-programmed firmware, default parameters and Script for remote infrared control, since the functional tests are performed before the shipment. Users need to program their parameters, as the users' ceiling fan motor may be different from the one under test.

Program the IMD112T-6F040 as follows:

- Program the firmware of the MCE
- Program parameter sets for system and motor
- Program customer script file (optional)

or

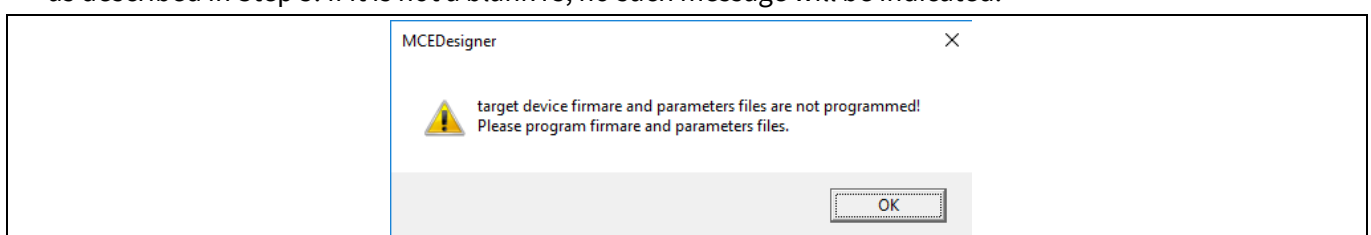
- Program the combined file, which is generated by MCEWizard, and contains all three items above. Customer script file is optional depending on whether it is available. The combined file is usually used for production, since it only needs to be programmed once.

The programming process is as follows:

1. Start the MCEDesigner tool and open MCEDesigner file (‘.irc’) for the IMD112T device prepared in Section 2.1.3 by clicking “File” > “Open.”
2. Power the iMOTION™ control IC with 3.3 V. It is recommended to program the IC with the 3.3 V isolated power supply that comes from the iMOTION™ link; there is a switch on the iMOTION™ link to enable the 3.3 V output. The iMOTION™ control IC will also be powered by the on-board auxiliary power supply after the AC source is powered. Caution must be taken in the latter case due to high voltage.

*Note: The output voltage of LDO combined in the IMD112T-6F040 is 5 V, i.e. the controller of IMD112T-6F040 is powered by 5 V. However, it is also possible to use the 3.3 V power supply in the iMOTION™ link to power the IMD112T-6F040 (for programmers).*

3. MCEDesigner should automatically connect to the board using the default COM port (indicated by the green circle next to “COMx Up” status in the bottom frame of the MCEDesigner GUI) when iMOTION™ control IC is powered. If it cannot establish the connection due to an incorrect COM port, change the COM port by doing the following: click on the “System Page” window and then click on “Preferences > Connection > Connect using” and choose one of the other available COM ports from the drop-down list.
4. In case of a blank IC: If the firmware has been erased from the IMD112T-6F040, the following warning message will pop up “Target device firmware and parameters file are not programmed! Please program firmware and parameters file” as shown in Figure 13. Then you can program the firmware and parameters as described in Step 5. If it is not a blank IC, no such message will be indicated.



**Figure 13 MCEDesigner warning message**

System and functional description

- 5. Use the following steps to program the firmware and the parameters file to the internal Flash memory of iMOTION™ Control IC as follows: click on the system page, click “Tools” > “Programmer” and select “Program Firmware and Parameters,” as shown in Figure 14 below. Regarding the firmware and parameters file, browse and select the ‘.ldf’ and ‘.txt’ file prepared in Section 2.1.2.

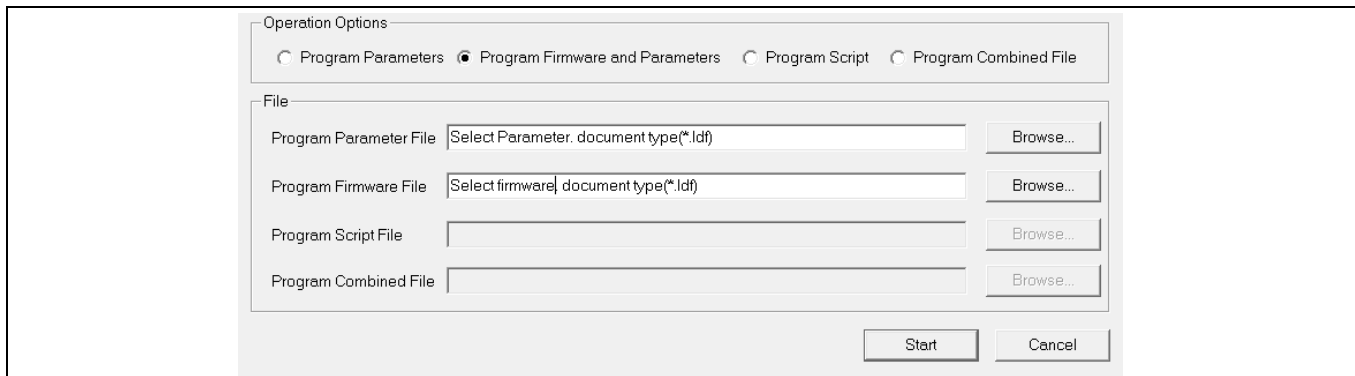


Figure 14 Program the parameters and firmware

- 6. If the script file needs to be programmed in the internal Flash memory of iMOTION™ Control IC after programmed firmware and parameters file, still click on system page, click “Tools” > “Programmer” and select “Program Script,” shown as in Figure 15 below. Regarding the Script file, browse and select the ‘xxx\_Script.ldf’ file prepared in Section 2.1.2. After programming script, please click “File” > “Import Register Map” to import script (.map) file into MCEDesigner file (.irc), and save this (.irc) file, otherwise a map error will appear.

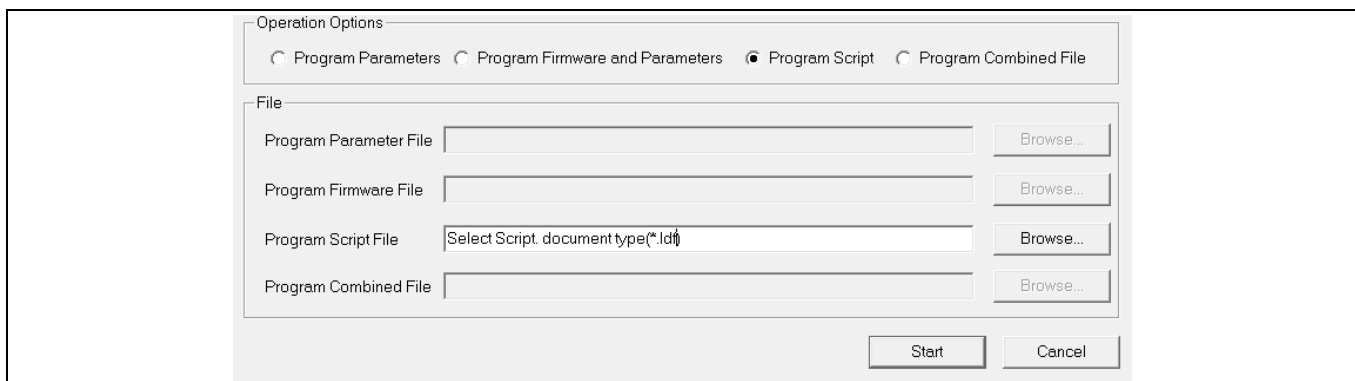


Figure 15 Program the script

Note: For detailed information on controller programming, refer to AN2018-33 iMOTION™ 2.0 device programming, MCEDesigner documentation and MCEWizard documentation.

### 2.1.5 Open-loop diagnostic

Make sure the input power is 230 Vrms, and program only the firmware and parameters file (script function disabled) without remote infrared script control.

Double-click the “VF Diagnostic” function in the window of motor1, and monitor motor current with oscilloscope. If the motor current is not sinusoidal, change register TargetSpeed and Vd\_Ext in the VF Diagnostic sub-function, then double-click “VF Diagnostic” until the oscilloscope shows a steady sinusoidal current with an amplitude of 30~50% motor rate current.

### System and functional description

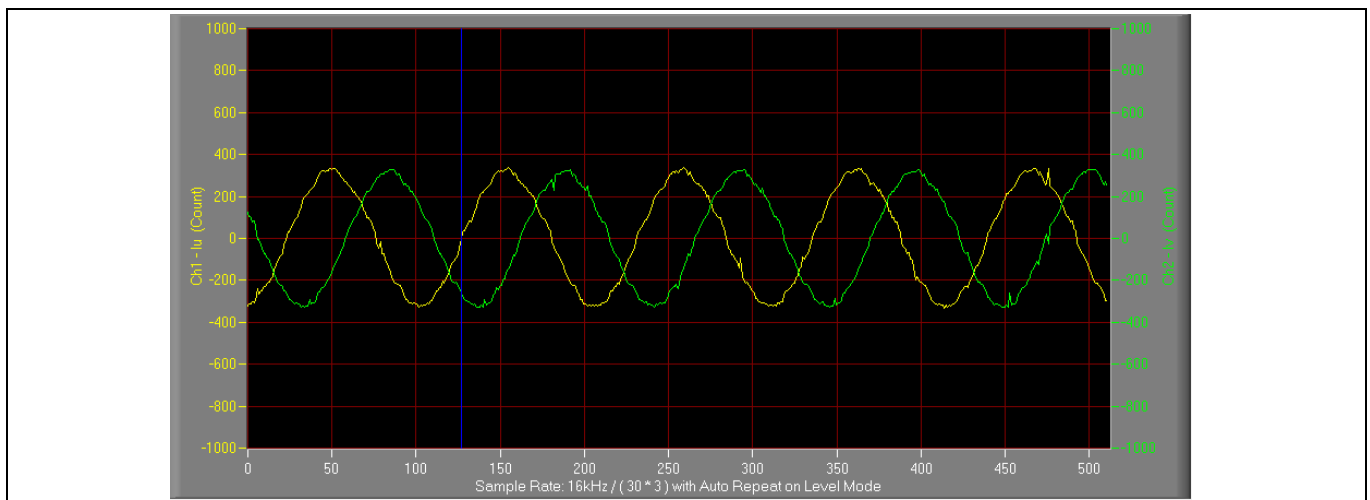
Double-click “Iu & Iv\_Slow” in “System page > Monitor Definitions.” The motor current feedback should be very clean and sinusoidal, as shown in Figure 16; otherwise please tune “Gating Driver Propagation Delay & Phase Shift Window Size” in MCEWizard.

“VF Diagnostic” sub-function can check whether:

- The ceiling fan motor is connected correctly
- The power stage works as expected
- Current-sensing related parameters are correctly configured
- The PCB layout and DC bus decoupling have been done correctly

After “VF Diagnostic” is done, click STOP button (the red traffic light button) or run the “stop motor” function to stop the motor.

*Note: Please do not start PFC in this diagnostic process.*



**Figure 16** Trace waveform for Iu & Iv open loop diagnostic

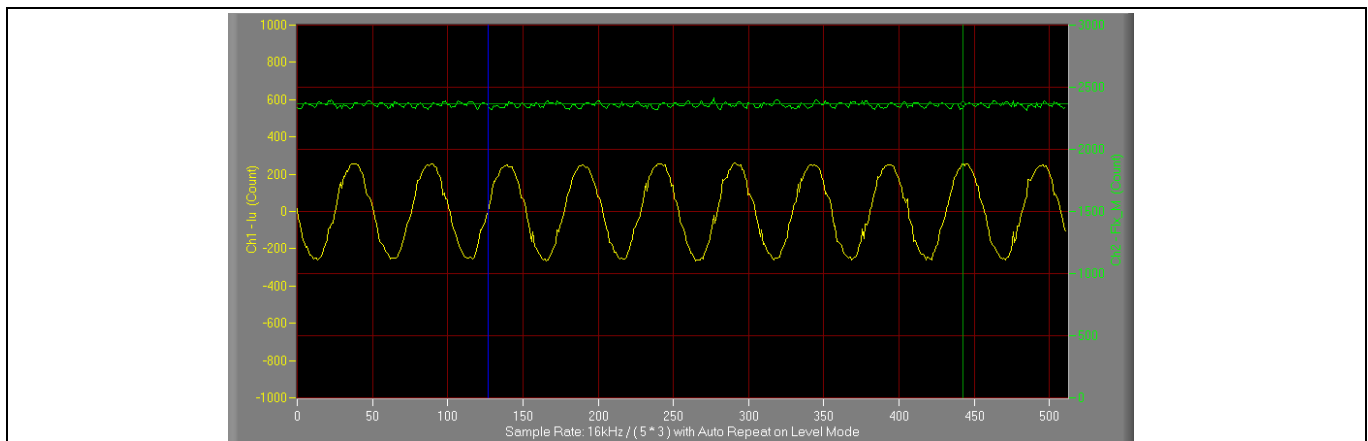
### 2.1.6 Closed loop run

Make sure the input power is 230 Vrms, and only program firmware and parameters file (script function disabled) without remote infrared script.control.

If the VF Diagnostic works correctly, the hardware circuit and signal sampling will work normally, at which point you can try to run the ceiling fan motor in a closed-loop mode. Follow the steps as listed below.

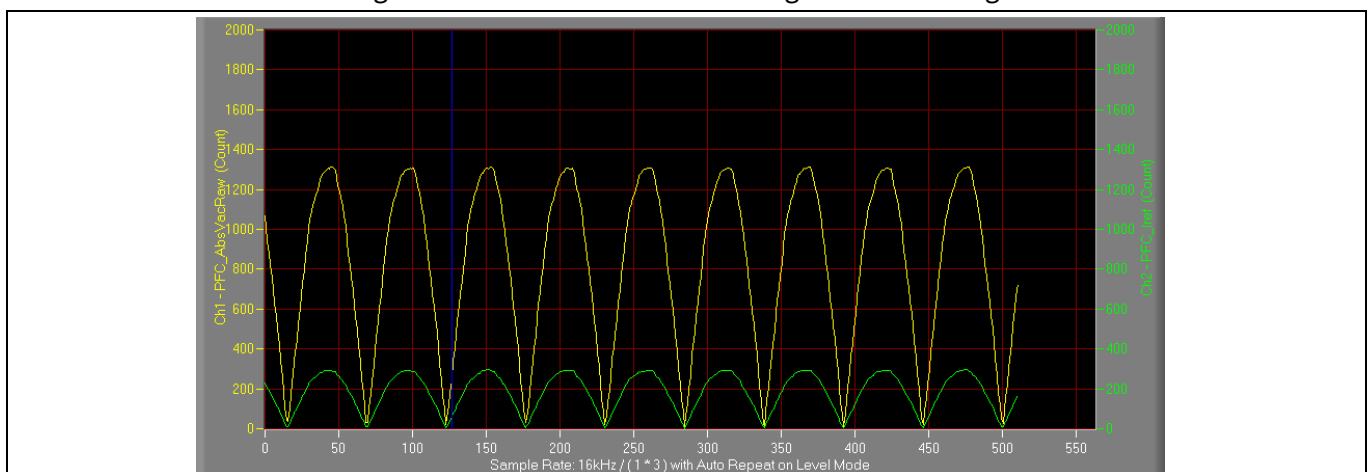
1. Start the motor by clicking the green traffic light button in the control bar (or double click Start Motor sub-function in the window of motor1, which is in the group of User Application Function Definitions). The motor will run if above step works correctly.
2. Check the motor spin direction, adjust the connection order of the motor’s winding; the motor spin direction must match the normal running direction of the ceiling fan.
3. Set TargetSpeed to about 50% of maximum speed, start “Iu & Flx\_M” trace with “Auto Repeat on Level,” see Figure 17. Flx\_M is good within the range of 2000~2500 (rated value is 2048), and must be steady and DC-like.





**Figure 17 Trace waveform for  $I_u$  &  $Flx\_M$  at 50% speed**

- If motor closed loop is tuned up, then the PFC can start when the motor is running. Starting the “PFC\_AbsVac & PFC\_Iref” trace with “Auto Repeat on Level” (see Figure 18) will show the PFC performance. The default PFC DC bus target value is set in MCEWizard “Target DC Bus Voltage Initialization.”



**Figure 18 PFC\_AbsVac & PFC\_Iref**

- Once the firmware has been programmed, and only a new parameter file has to be programmed, follow the same instructions given in Section 2.1.4. In this case, the firmware programming is no longer needed, and you can select the first option “Program Parameters.”

Here are some key tips for better motor-performance tuning:

- If  $Flx\_M$  is not steady (swing or oscillation), check the following: motor parameters, speed loop PI bandwidth, current loop bandwidth, flux estimator time constant and PLL PI bandwidth (parameters  $PLLKp$  and  $PLLKi$ ) and related equipment.
- If  $Flx\_M$  is very noisy, check the following: current feedback and  $V_{dc}$  feedback related hardware and parameters.
- If  $Flx\_M$  does not come close to 2048, “Motor Back EMF Constant ( $K_e$ )” needs to be adjusted in MCEWizard.
- The PFC parameters in the software package downloaded from myInfineon are optimized for the reference board. So it is not necessary to change them.

**System and functional description**

**2.1.7 Infrared control**

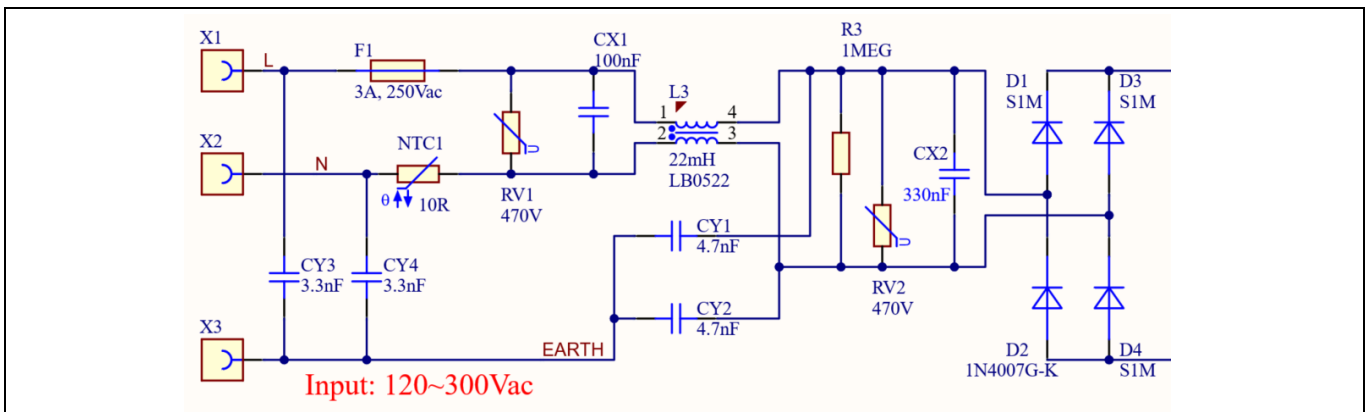
If the open-loop diagnostic and closed loop work correctly, then the infrared control can be tuned.

1. Connect the J2 of main board to J1 of daughter board by cables, as shown in Figure 6. The daughter board can receive remote infrared command from the control box.
2. Program firmware, parameters file (script function enabled), and script file for remote infrared control by iMOTION™ link. The iMOTION™ link can be removed after programming if you do not want to view the MCE variables' wave or value from MCEdeisgner.
3. The attached remote infrared control box is shown in Figure 6. There are only power, and 1, 2, 3, 4, 5 buttons. The power button is to enable or disable controller transmitting. If the controller transmitting is enabled, you can select incrementally different motor speeds with button 1, 2, 3, 4, 5. Button 5 refers to maximum motor speed. The daughter board can remember the last set speed by the control box before power button being disabled, so the motor will start at the last-used setting speed when power button is enabled.

**2.2 Description of the main board functional blocks**

**2.2.1 EMI filter and surge protection**

Figure 19 shows the diagram of the EMI filter and surge protection. The EMI stages consist of two X-capacitors of 100 nF and 330 nF respectively, two series Y-capacitors of 3.3 nF and 4.7 nF respectively, and a 22 mH common-mode inductor. The surge protection circuit consists of two stages of MOV, RV1 and RV2; their reverse break down voltage is 470 V. The conducted electromagnetic interference of this board is shown in Section 4.7.

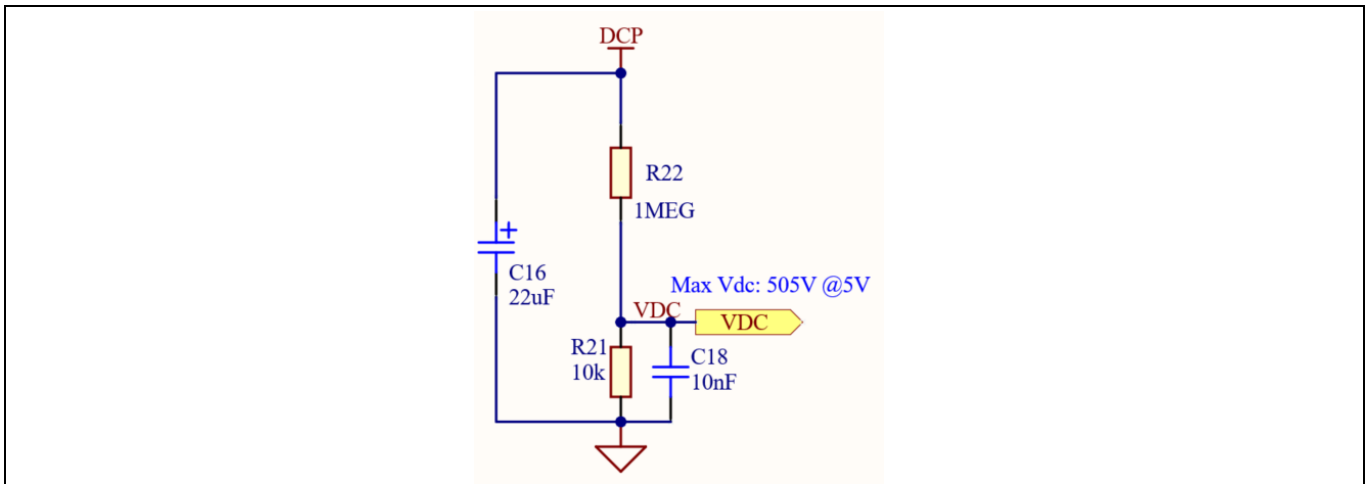


**Figure 19 EMI filter and surge protection**

**2.2.2 DC bus sensing and MCEWizard configuration**

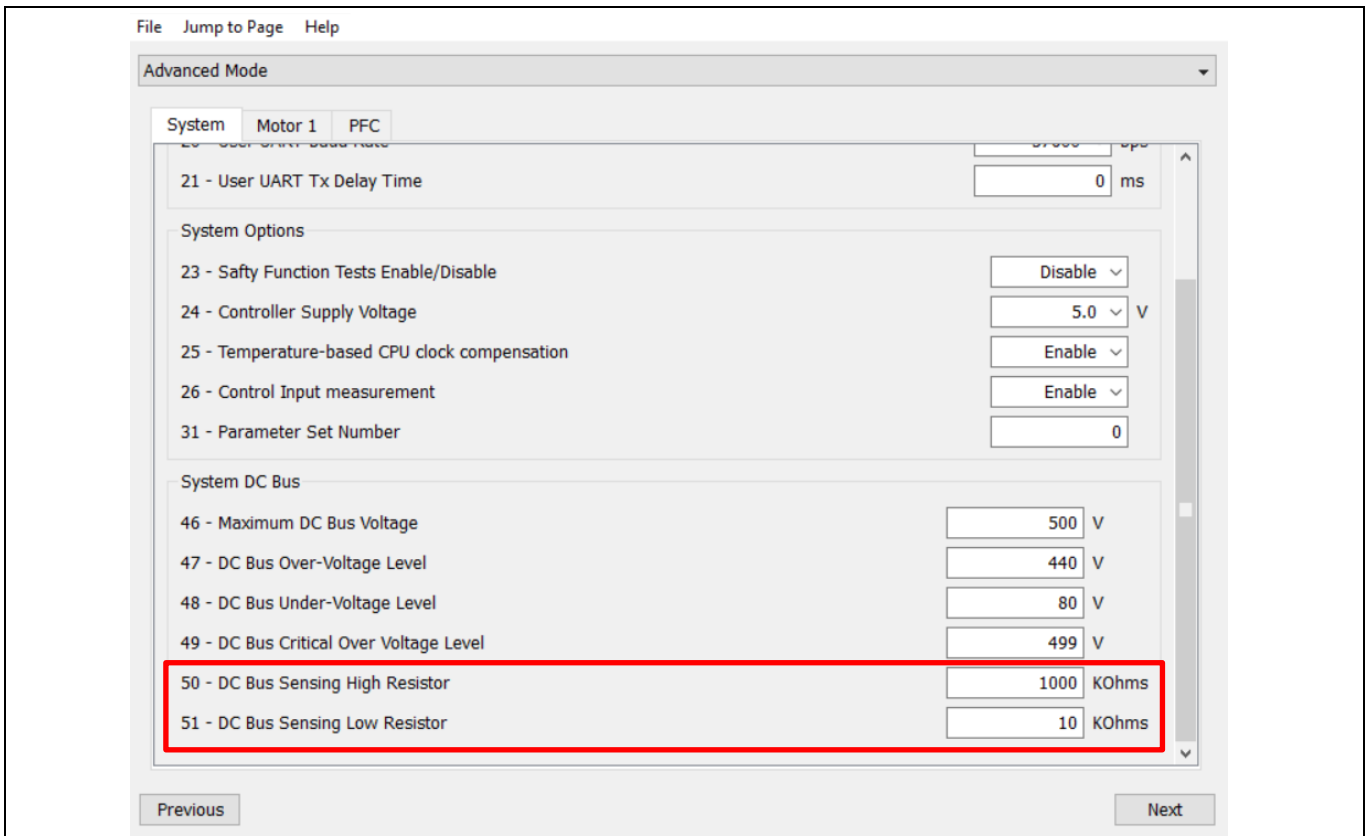
Figure 20 shows the detail of the DC bus sensing resistor divider stage.

With the values shown in the figure, the default DC bus-sense voltage results in a range of 0 V to 5 V on the ADC input of the microcontroller (MCU), reflecting an input voltage range from 0 V to 505 V.



**Figure 20 DC bus sensing**

The hardware parameters need to be configured in MCEWizard as shown in Figure 21.



**Figure 21 DC bus sensing configuration in MCEWizard**

The Vdc-sensing stage features a low-pass-filter time constant that can be calculated as:

$$\text{Time constant} = (R22//R21) * C18 = (1 \text{ M}\Omega//10 \text{ k}\Omega) * 10 \text{ nF} = 99 \mu\text{s} \quad \text{Eq. 1}$$

The value of capacitor C18 can be adjusted to improve the V<sub>dc</sub> noise rejection ratio.

**System and functional description**

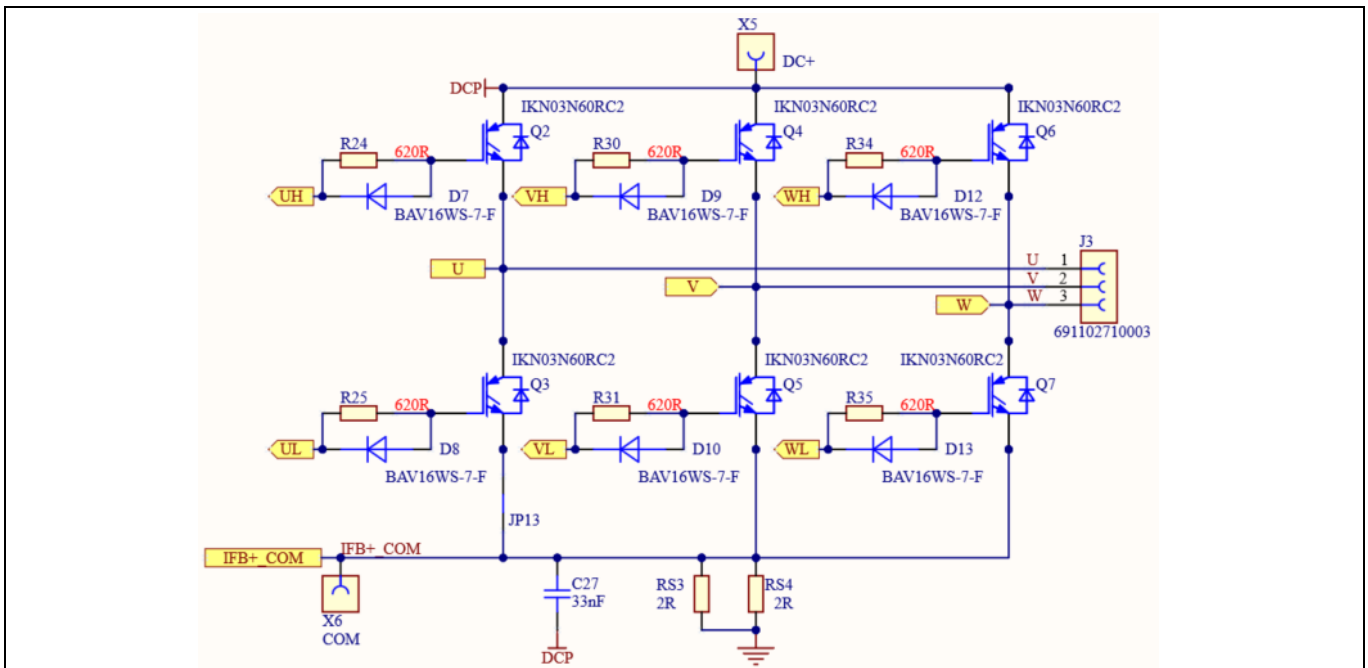
**2.2.3 Inverter section**

The inverter section is implemented with the latest generation of RC-D2 IGBT in a SOT223 package IKN03N60RC2 or in a DPAK package IKD04N60RC2. The default mounted devices are IKN03N60RC2. 600 V RC-D2 is the successor to the RC-D/DF IGBT. The latest version of the RC-D technology has several improvements compared to its older version: better price, lower power losses, and better controllability over the di/dt in order to further reduce EMI compared to RC-D/DF. These devices are also robust for high-voltage and high-humidity operations.

Features of IKN03N60RC2 and IKD04N60RC2:

- Very tight parameter distribution
- Operating range of 1 to 20 kHz
- Maximum junction temperature of 175°C
- Short-circuit capability of 3 μs
- Best-in-class current versus package size performance
- Qualified according to JEDEC for target applications
- Robust design for high-humidity operation
- Pb-free lead plating; RoHS compliant
- Complete product spectrum and PSpice Models

Figure 22 shows the diagram of the inverter and peripheral circuit.



**Figure 22 The inverter and peripheral circuit**

**2.2.4 Motor current sensing and overcurrent protection**

**2.2.4.1 Motor current sensing**

The motor current sensing on this board uses only a RC network for operational gain, bias and low-pass filter to minimize the cost. No additional operational amplifier is needed.

With reference to Figure 23, you can derive the following equation by applying the principle of Kirchhoff's voltage law, assuming that the MCU analog-to-digital converter (ADC) input port has an infinite impedance.

# REF-SHA35WRC2SYS user guide

## Ceiling fan application reference design kits

### System and functional description

$$V_{ADC} = \frac{(V_{CC} - V_{shunt})}{R_1 + R_2} * R_1 + V_{shunt} \tag{Eq. 2}$$

The equation can thus be adjusted as shown:

$$V_{ADC} = \frac{R_2 * V_{shunt}}{R_1 + R_2} + \frac{R_1 * V_{CC}}{R_1 + R_2} \tag{Eq. 3}$$

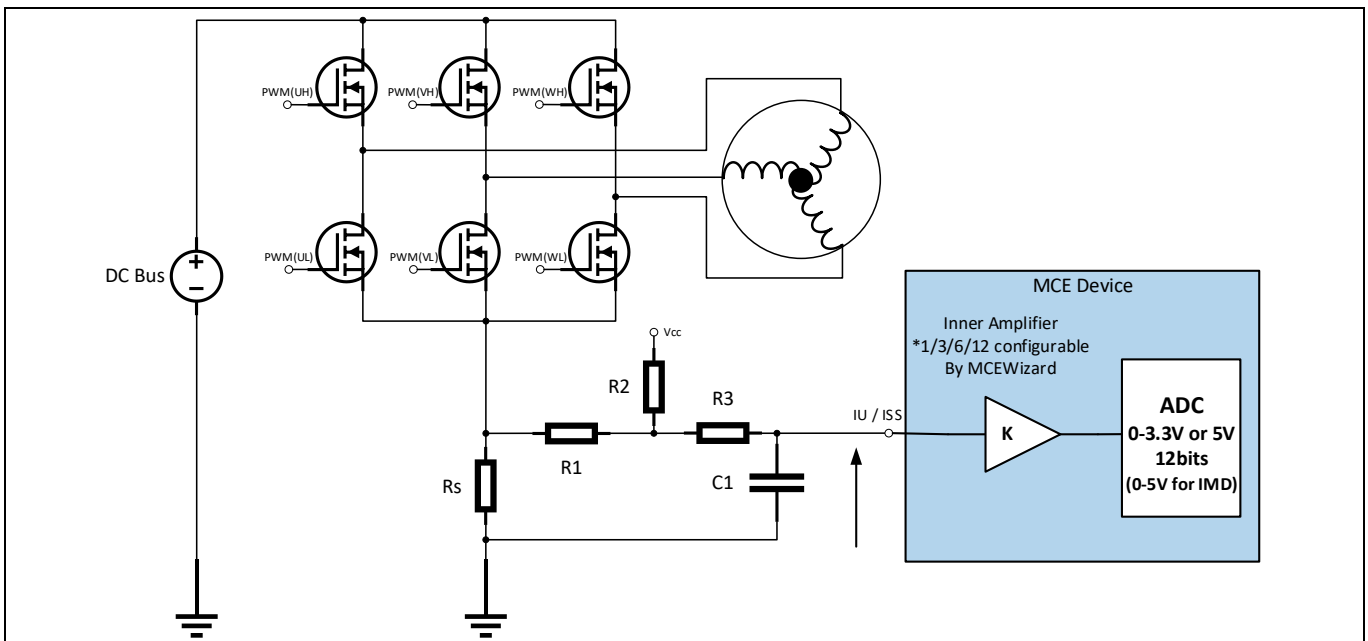
Since the impedance of the RC network is much larger than the  $R_{shunt}$ , it follows that:

$$V_{shunt} = I_{shunt} * R_{shunt} \tag{Eq. 4}$$

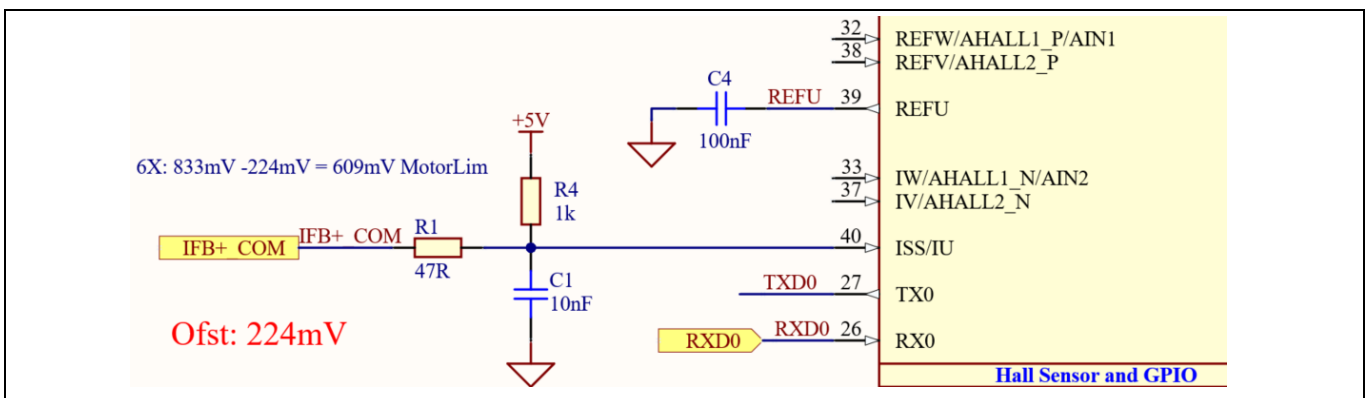
As a consequence,  $V_{ADC}$  can then be written as:

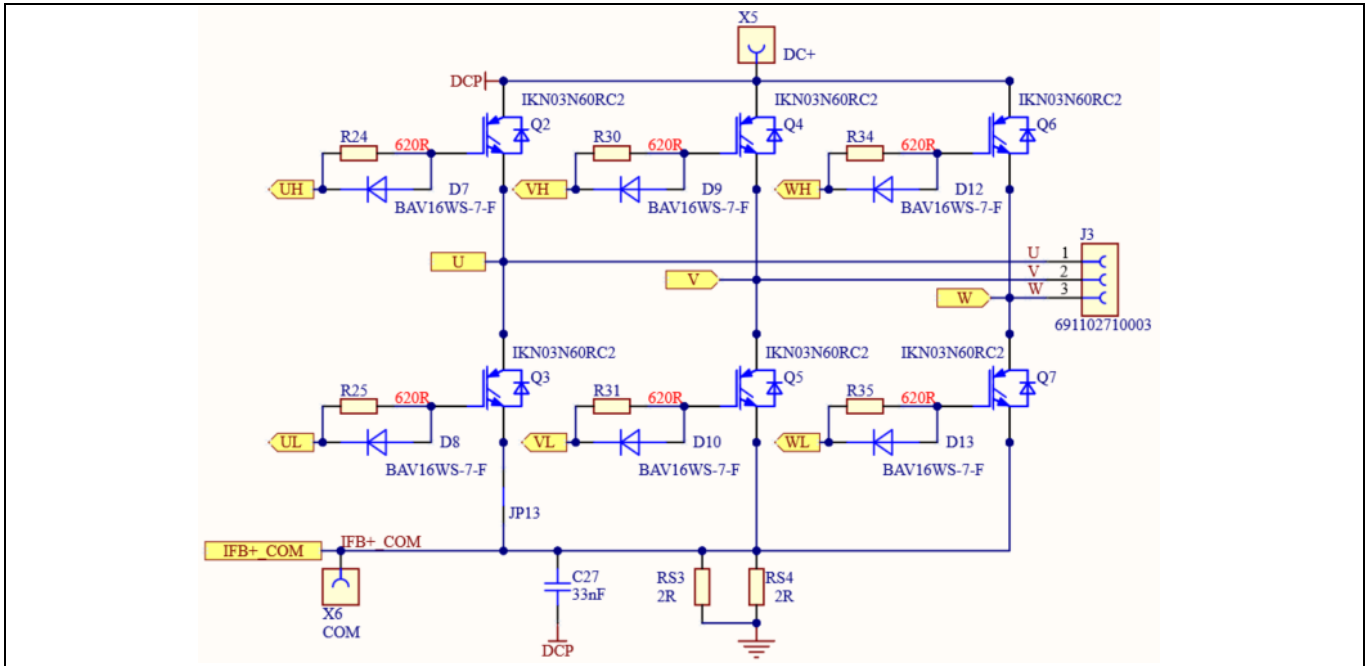
$$V_{ADC} = \frac{R_2}{R_1 + R_2} * R_{shunt} * I_{shunt} + \frac{R_1 * V_{CC}}{R_1 + R_2} \tag{Eq. 5}$$

Where  $\frac{R_1 * V_{CC}}{R_1 + R_2}$  is the offset, and the gain of the shunt current is  $\frac{R_2}{R_1 + R_2} * R_{shunt}$ .



**Figure 23 Motor current-sensing topology**





**Figure 24 Motor current-sensing circuit on the board**

As an example in Figure 24, this board has the following values:  $R_1 = R_4 = 47 \Omega$ ,  $R_2 = R_4 = 1 \text{ k}\Omega$ ,  $R_s = R_{S3}/R_{S4} = 1 \Omega$ ,  $V_{cc} = 5 \text{ V}$ . By using the formula in Eq. 5, the offset is 224 mV, and the gain is  $\frac{R_2}{R_1 + R_2} * R_{shunt} = 955 \text{ mV/A}$ . Because the amplitude attenuation of low-pass filter, the gain needs to be amended to 909 mV/A for MCEWizard configuration.

Note the following points concerning motor current sensing:

- $R_1$  and  $R_4$  in Figure 24 determine the ADC operational bias for current sensing, which corresponds to the motor regeneration operation range. For applications that do not work with a regenerative braking mode, the bias can be as low as possible to reserve enough ADC range for the drive mode, since the current in the sense resistance always flows in one direction only. In this example, the offset is 224 mV.
- Since the gain of the external RC circuit is less than 1, internal signal amplification is required to increase the current signal acquired with low shunt resistance values. MCE provides an inner current sampling amplifier with \*1, \*3, \*6 and \*12 gain selections, which can be configured in the MCEWizard. In this example, the inner current sampling amplifier is \*6, so the current sampling range is from 224 mV to 833 mV.
- There is no common mode noise suppression capability without an outer operational amplifier, so the GND network of the PCB needs to be designed very carefully, since any voltage difference between IMD112T's ADC ground and shunt resistor ground will be considered as an "input signal," and will deteriorate the control performance or increase audible noise.

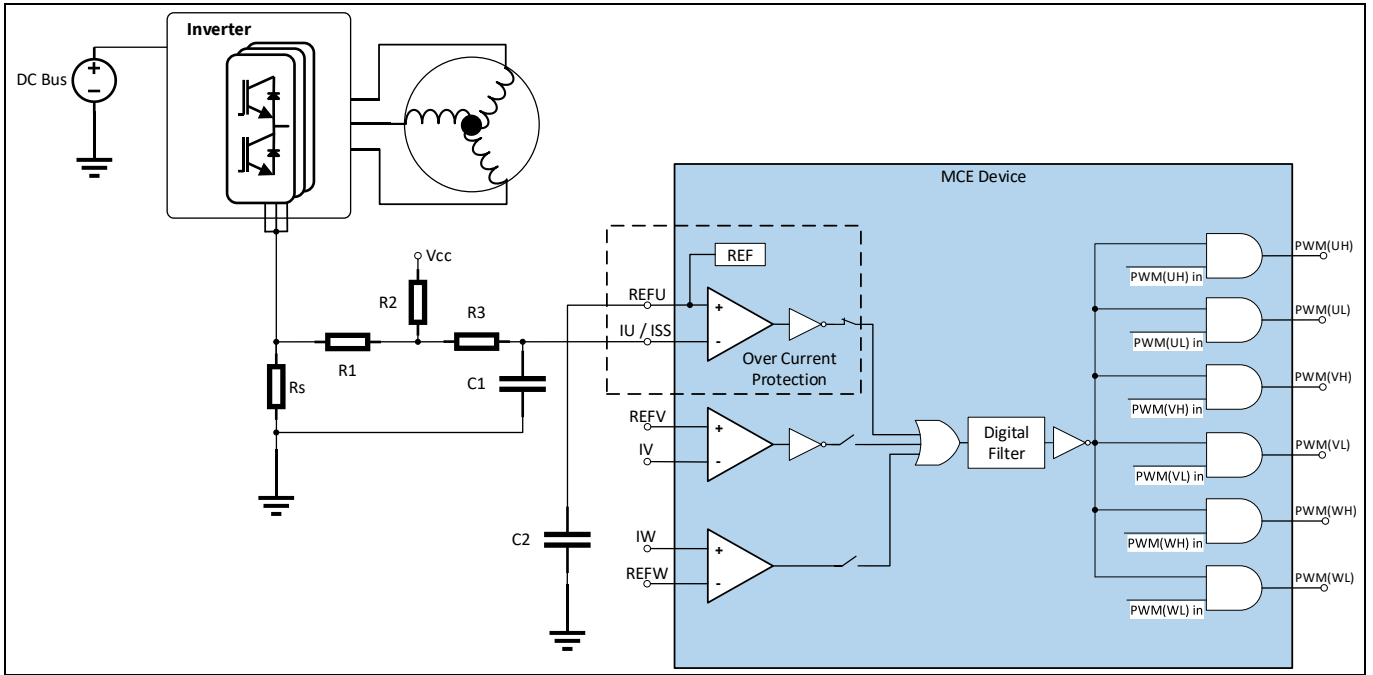
### 2.2.4.2 Motor overcurrent protection

The motor overcurrent condition can be detected by IMD112T-6F040 with internal comparator as shown in Figure 25.

# REF-SHA35WRC2SYS user guide

## Ceiling fan application reference design kits

### System and functional description



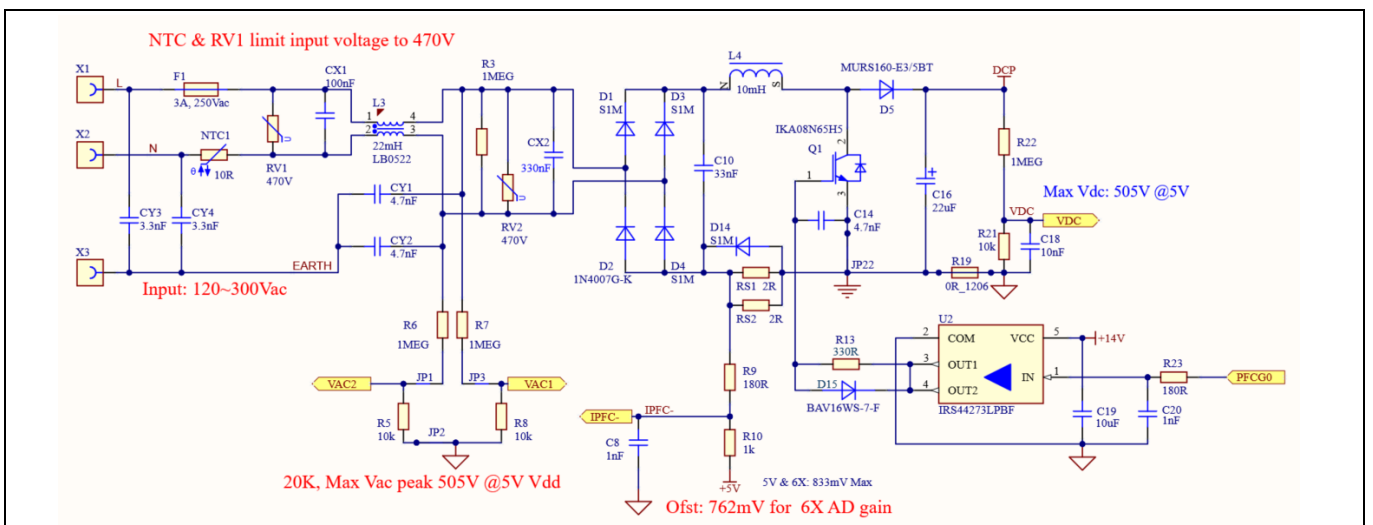
**Figure 25** Motor overcurrent protection topology

For more details about motor overcurrent protection (OCP) in the IMD112T, please see the chapter about motor overcurrent protection in the reference material [6].

The internal comparator's reference level is set by the internal digital-to-analog converter (DAC) so the level can be set in the MCEWizard by "Overcurrent Trip Level for Internal Gatekill Comparator" and "Motor1 current input to ADC offset voltage." The DAC output pin REFU needs to be connected to a capacitor to improve noise rejection (e.g. a 100 nF/25 V capacitor is used on the board as shown in Figure 24).

### 2.2.5 PFC section

Figure 26 provides the PFC MOSFET driver and peripheral circuit.



**Figure 26** The PFC and peripheral circuit

- An IRS44273L is used for the PFC MOS drive. C14, R13 & R14 select the PFC MOSFET switching du/dt; trade-off between switching noise and power loss is required.

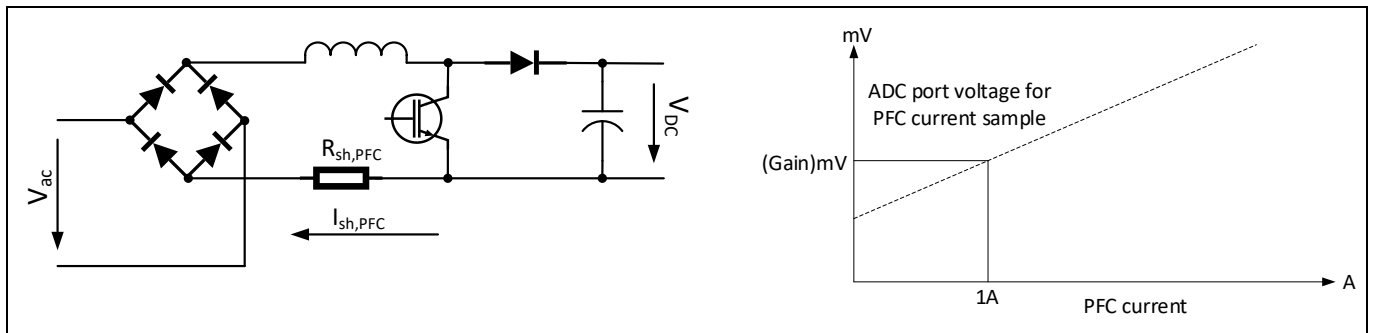
**System and functional description**

- The bypass diode D14 is designed to bypass the surge current during surge voltage input.
- Two resistors (1% tolerance, 2 Ω, 0.25 W) are used for PFC current sensing.
- 10 mH 0.3 A inductor is used for PFC.
- 650 V DuoPack IGBT with diode IKA0N65H5 is used for the PFC switch. IKA0N65H5 belongs to the high-speed switching series of the fifth generation, and has best-in-class efficiency in hard switching and resonant topologies.

**2.2.6 PFC current sensing and overcurrent protection**

**2.2.6.1 PFC current sensing**

The PFC current sensing on this board uses an RC network for operational gain, bias and low-pass filter to minimize the cost. No additional operational amplifier is needed. The PFC current-sensing topology is as shown in Figure 27. From the point view of the AD converter, the current input scaling value is the product of the voltage of PFC shunt resistor and the gain of RC network.



**Figure 27 PFC current-sensing topology**

As shown in Figure 26, two resistors RS1 and RS2 (paralleled) with 1% tolerance, 2 Ω, and 0.25 W are used for the PFC shunt resistor in this reference board. The real AD input voltage can be calculated as below according to the principle of Kirchhoff's voltage law:

$$V_{IPFC\_} = \frac{R_{10}}{R_9 + R_{10}} * R_{sh,PFC} * I_{sh,PFC} + \frac{R_9 * V_{CC}}{R_9 + R_{10}} \quad \text{Eq. 6}$$

$$V_{IPFC\_} = \frac{1K\Omega}{180\Omega + 1K\Omega} * 1\Omega * I_{sh,PFC} + \frac{180\Omega * 5V}{180\Omega + 1K\Omega} = 0.847(mV/A) * I_{sh,PFC} + 762 mV$$

So the offset of PFC current sampling is 762 mV, and the gain is 847 mV/A. Because of the amplitude attenuation of the low pass filter, the gain needs to be amended to 806 mV/A for MCEWizard configuration.

Note the following points concerning PFC current sensing:

- Since the gain of the external RC circuit is less than 1, internal signal amplification is required to increase the current signal acquired with low shunt resistance values. MCE provides an inner current sampling amplifier with \*1, \*3, \*6 and \*12 gain selections, which can be configured in the MCEWizard. In this example, the inner current sampling amplifier is \*6, so the maximum input PFC current-sampling voltage should range from 0 mV to 833 mV (5V/6).
- In this reference board design, the voltage level on the PFC current-sensing resistor is negative with reference to ground, so an ADC operational bias is needed, and PFC current-sensing input polarity should select “inverting” in MCEWizard. R9 and R10 in Figure 26 determine the ADC operational bias for current-



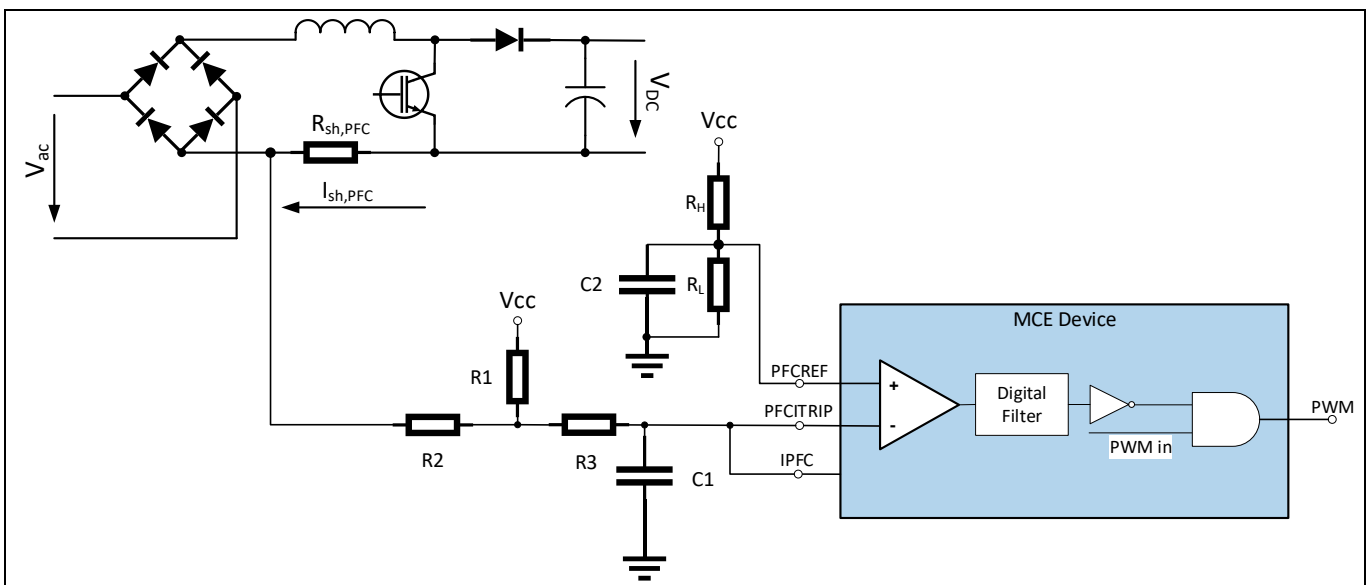
**System and functional description**

sensing; the bias value is 762 mV, so the real AD sampling range for the PFC current-sampling voltage ranges from 0 mV to 762 mV.

- There is no common mode noise suppression capability without an outer operational amplifier, so the GND network of the PCB needs to be designed very carefully. Any voltage difference between IMD112T’s ADC ground and shunt resistor ground will be considered as an “input signal,” and deteriorate the PFC performance and increase harmonic distortion.

**2.2.6.2 PFC overcurrent protection**

The PFC current-sensing signal feedback to IMD112T-6F040 goes via two pins, the IPFC for PFC control, and the PFCITRIP for PFC overcurrent protection. The PFC overcurrent condition can be detected by IMD112T-6F040 with internal comparator as shown in Figure 25. The overcurrent threshold is designed by the voltage value at input pin PFCREF.

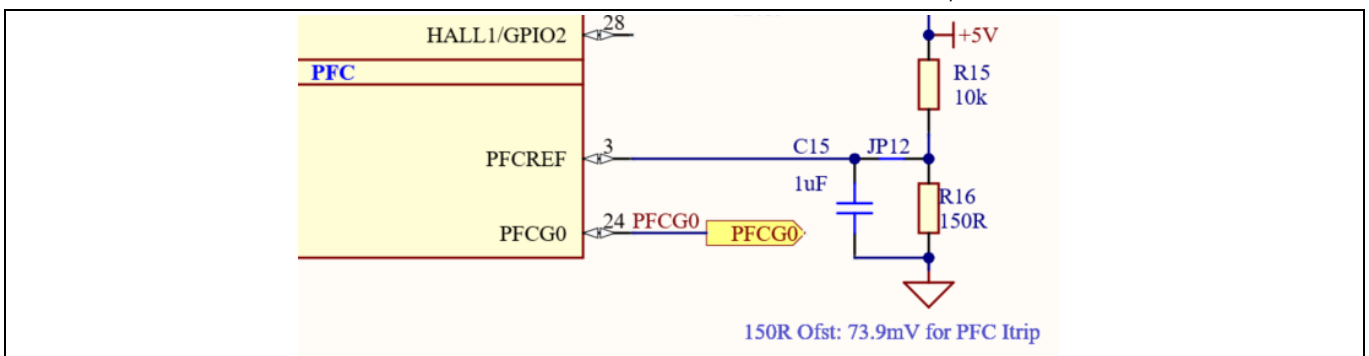


**Figure 28 PFC overcurrent protection topology**

For more details about the PFC overcurrent protection (OCP) in the IMD112T, please refer to the relevant chapter in the reference material [6].

Note the following points concerning PFC overcurrent protection:

- The PFC overcurrent threshold of this board is designed by R15 and R16, and the threshold value is  $\frac{150 \Omega}{10 K\Omega + 150 \Omega} * 5 V = 73.6 mV$ . That means the PFC overcurrent is  $\frac{762 mV - 73.9 mV}{806 mV/A} = 854 mA$ .



**Figure 29 PFC overcurrent threshold design on the board**

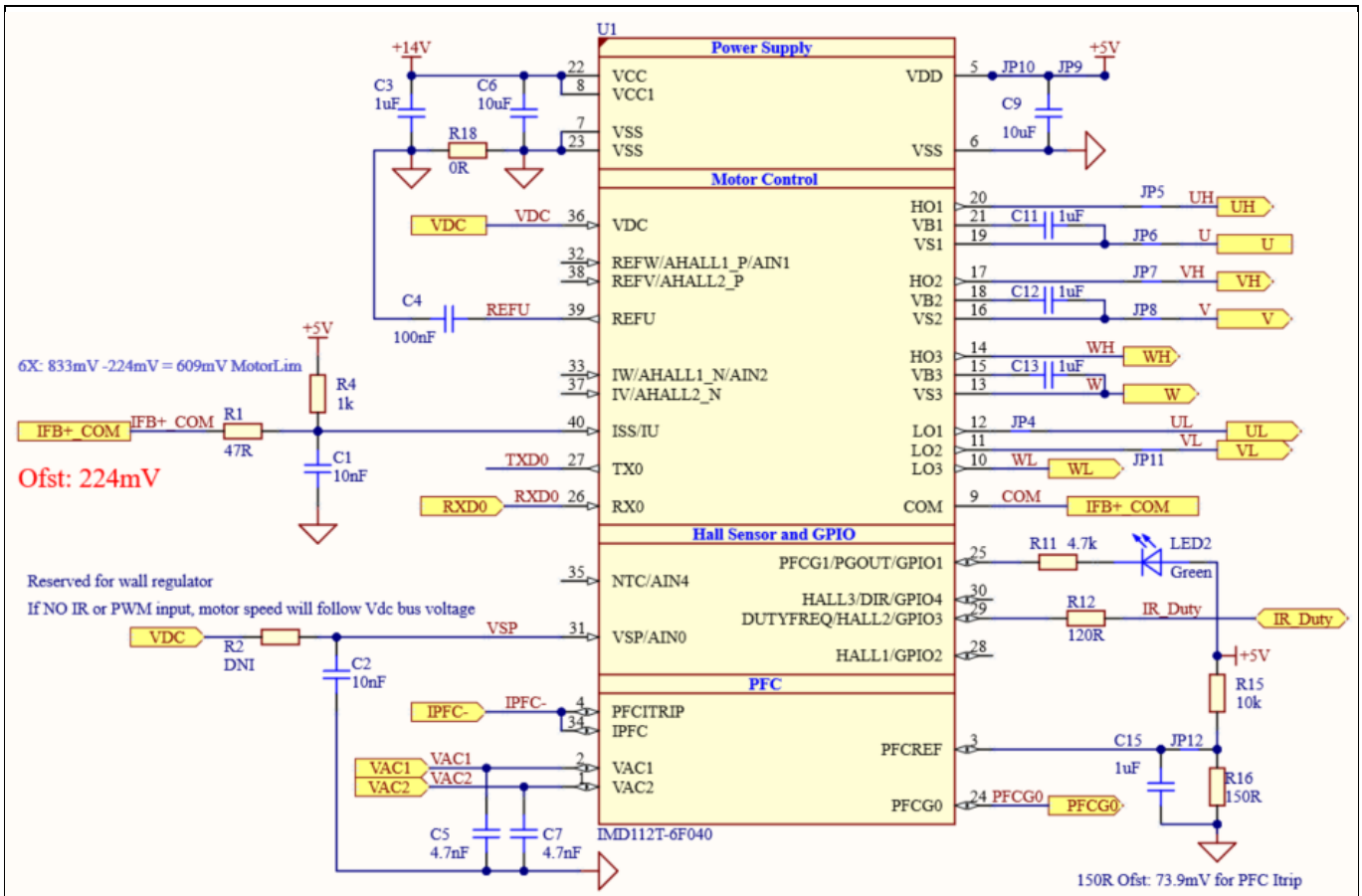
# REF-SHA35WRC2SYS user guide

## Ceiling fan application reference design kits

### System and functional description

- The PFC overcurrent has two available modes: latch-off and cycle-by-cycle. This reference board uses cycle-by-cycle mode. For more details about the two PFC overcurrent protection mode, please refer to the relevant section in the reference material [6].

### 2.2.7 Interface circuit of IMD112T



**Figure 30 Interface circuit of IMD112T**

Figure 30 shows the interface circuit of IMD112T:

- The power of IMD112T is 14V and 5 V power generated by internal LDO in IMD112T
- UH, UL, VH, VL, WH, WL provide driver for inverting circuit
- IFB+COM is the motor current sensing signal
- IPFC- is the PFC current sensing signal
- VAC1 and VAC2 are AC input voltage sensing signals for PFC
- PFCG0 is the PFC driver
- PFCREF is the threshold input of PFC overcurrent protection
- VDC is the bus voltage sensing signal
- LED2 is the indicator light of IMD112T power on
- IR\_Duty is the duty input signal from the daughter board
- VSP function is only reserved for a wall regulator, and is not enabled in this board
- RX0 and TX0 are debugging and programming communication channels to MCEDesigner

## 2.2.8 Interface circuit to XMC daughter board

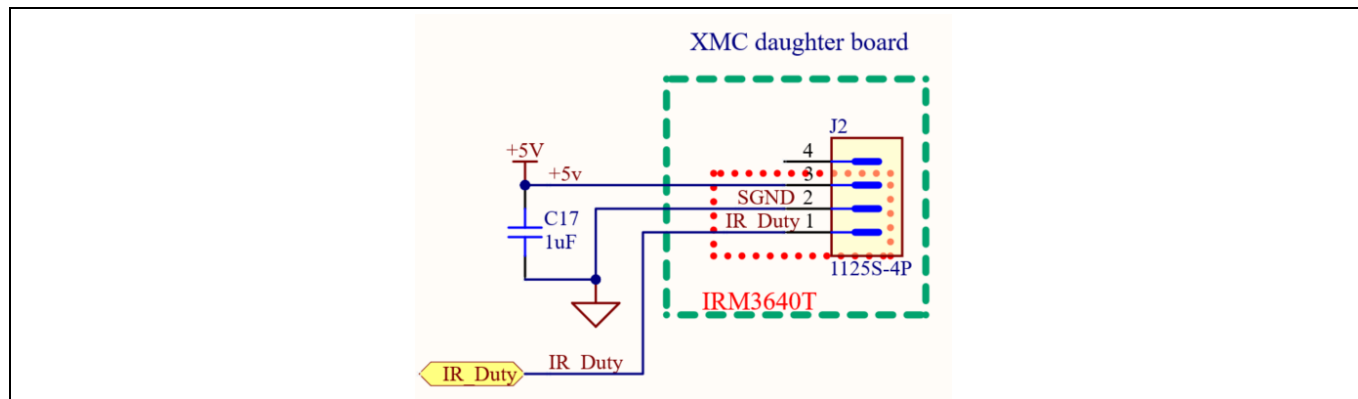


Figure 31 Interface circuit to XMC daughter board

Figure 30 shows the interface circuit to the XMC daughter board. Its function is to power 5 V for the XMC daughter board and receive the duty signal translated from the remote infrared control box.

*Note:* For the firmware version V1.03.03 of IMD112T, the infrared signal needs to be translated to duty signal by the XMC1100 on the XMC daughter board. The IR\_Duty signal is the translated duty signal from the XMC daughter board.

*Note:* The future updated firmware version of IMD112T, will be able to translate the infrared signal, so the IR-Duty signal can connect to the infrared receiver directly, and does not need to be translated by XMC1100.

## 2.3 Description of the daughter board functional blocks

This section depicts the XMC daughter board, which receives signals from the remote infrared control box and translates them to duty signal to control the motor speed of the ceiling fan.

### 2.3.1 Circuit of daughter board

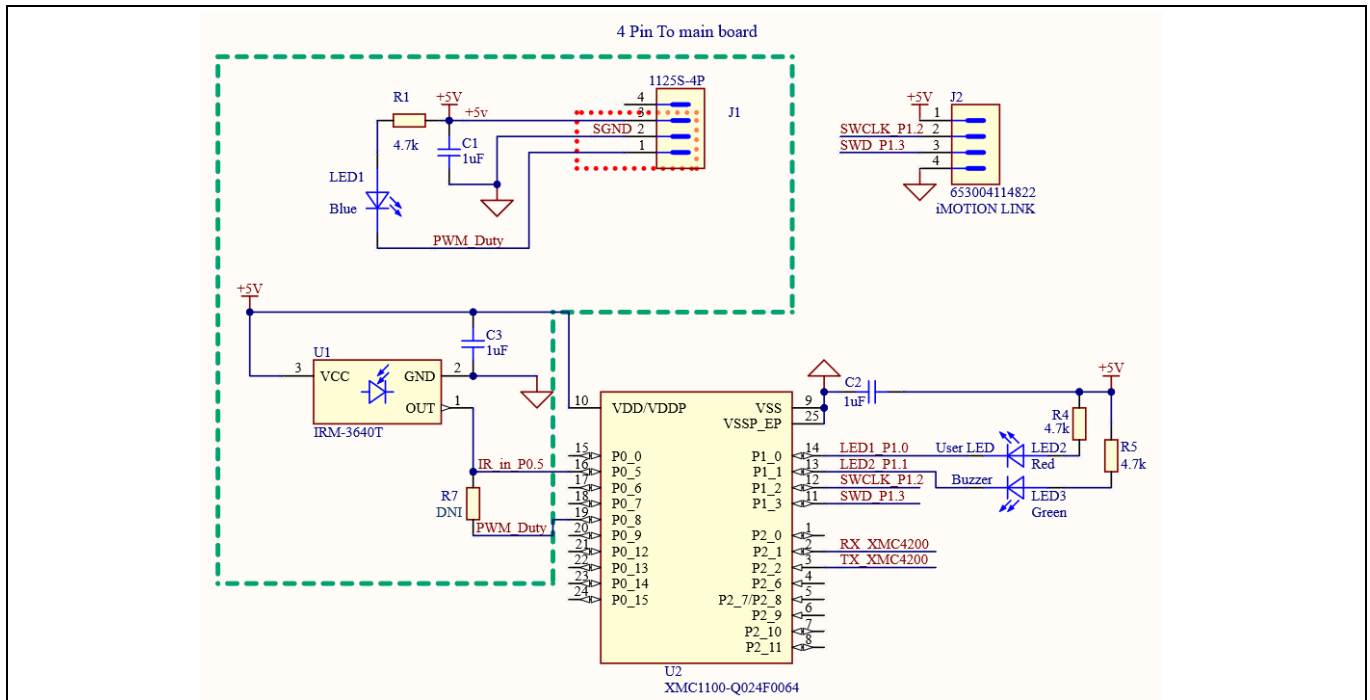


Figure 32 Circuit of daughter board

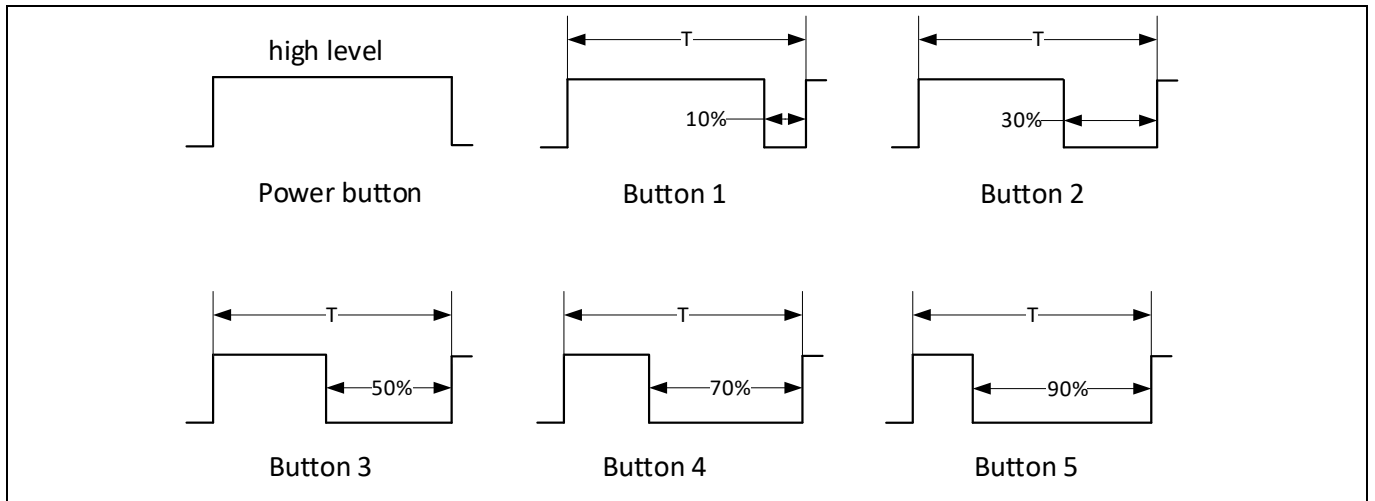
As shown in Figure 32, the IRM-3640T receives signals from the remote infrared control box, and XMC1100 translates them to duty signals. The LED1 indicates the width of the output duty and becomes brighter as the width narrows. LED2 and LED3 indicate that XMC1100 has received infrared signals, but their logic is contrary. LED2 lights up (is normally off) and LED3 goes off (is normally lit up) when the XMC1100 has received infrared signal.

The J2 is for programming XMC1100, which was programmed before leaving the factory.

*Note: The future updated firmware version of IMD112T will be able to translate the infrared signal, so the IR-Duty signal can connect to the infrared receiver directly, and does not need to be translated by XMC1100. Only the components in the green frame need to be mounted. Remember to mount R7, which is not needed in the present application.*

### 2.3.2 Output duty signals versus buttons

Figure 33 depicts the output duty signals from the remote infrared control box. When the power button is disabled, the output signal is at high level and all other buttons are inactive. When the power button is enabled, all other buttons on the control box are active, and the daughter board will output the last used signal immediately. Then you can select button 1 ~ 5 for different motor speed. Please note that all the duty cycle output from daughter board is low level active.



**Figure 33** Output duty signals versus buttons

System design

### 3 System design

This section provides the complete details of the schematics, layout and connectors. Please note that the schematics, routing and Gerber files are done in Altium® Designer. Users who are interested in the original project files or pdf files can visit the website [www.infineon.com](http://www.infineon.com) and log-in to myInfineon and download on the board's web page.

#### 3.1 Schematics

The major function blocks are introduced in Section 2.2 and Section 2.3 . Users who are interested in further details can download the design files after logging in to the myInfineon account on the board's web page.

#### 3.2 Layout

##### 3.2.1 Main board layout

The main board is designed in a single layer and has a ring shape, with dimensions of 90 mm (D) × 65 mm (H). The main board is manufactured with a copper thickness of 1 oz. (35 µm).

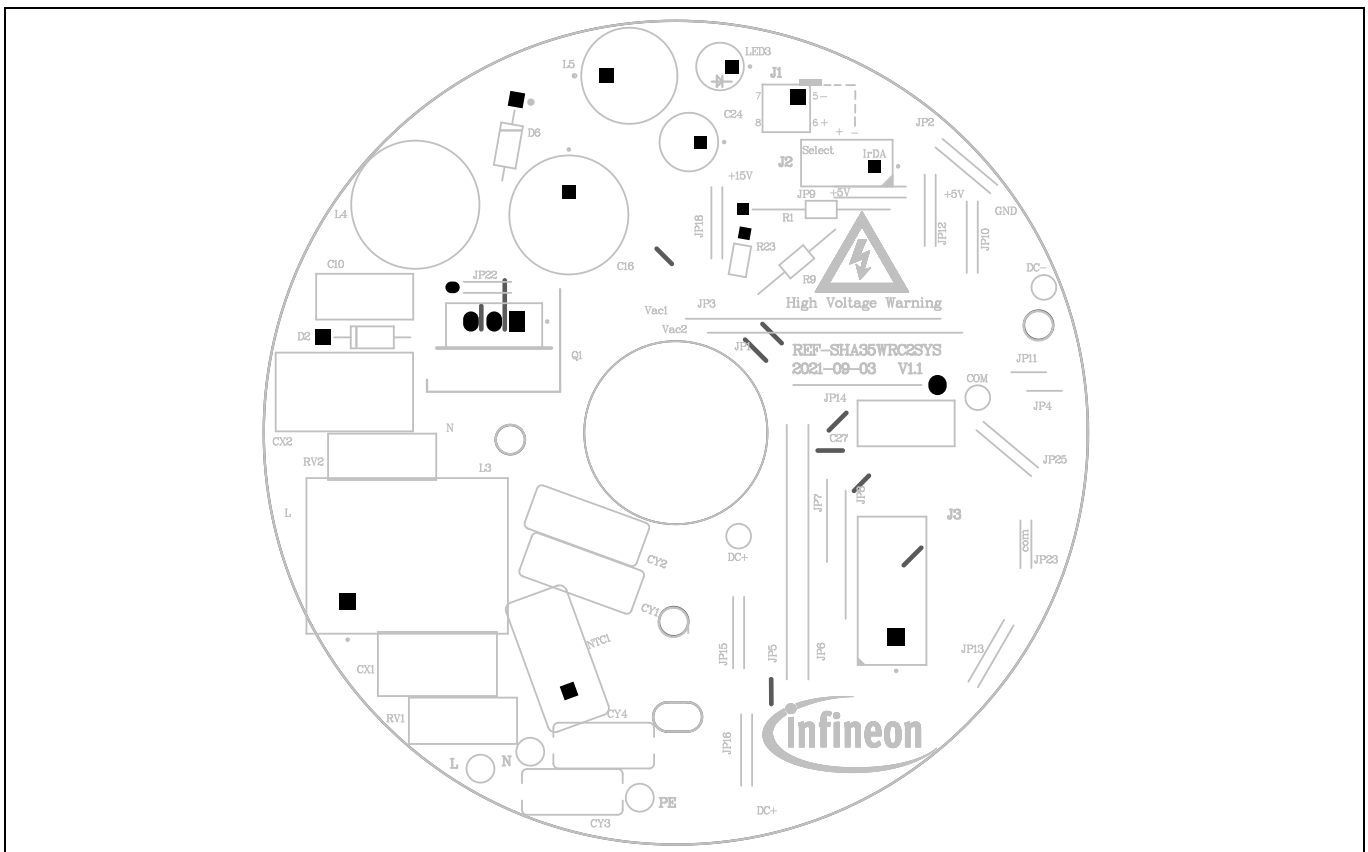


Figure 34 Top assembly print of the main board

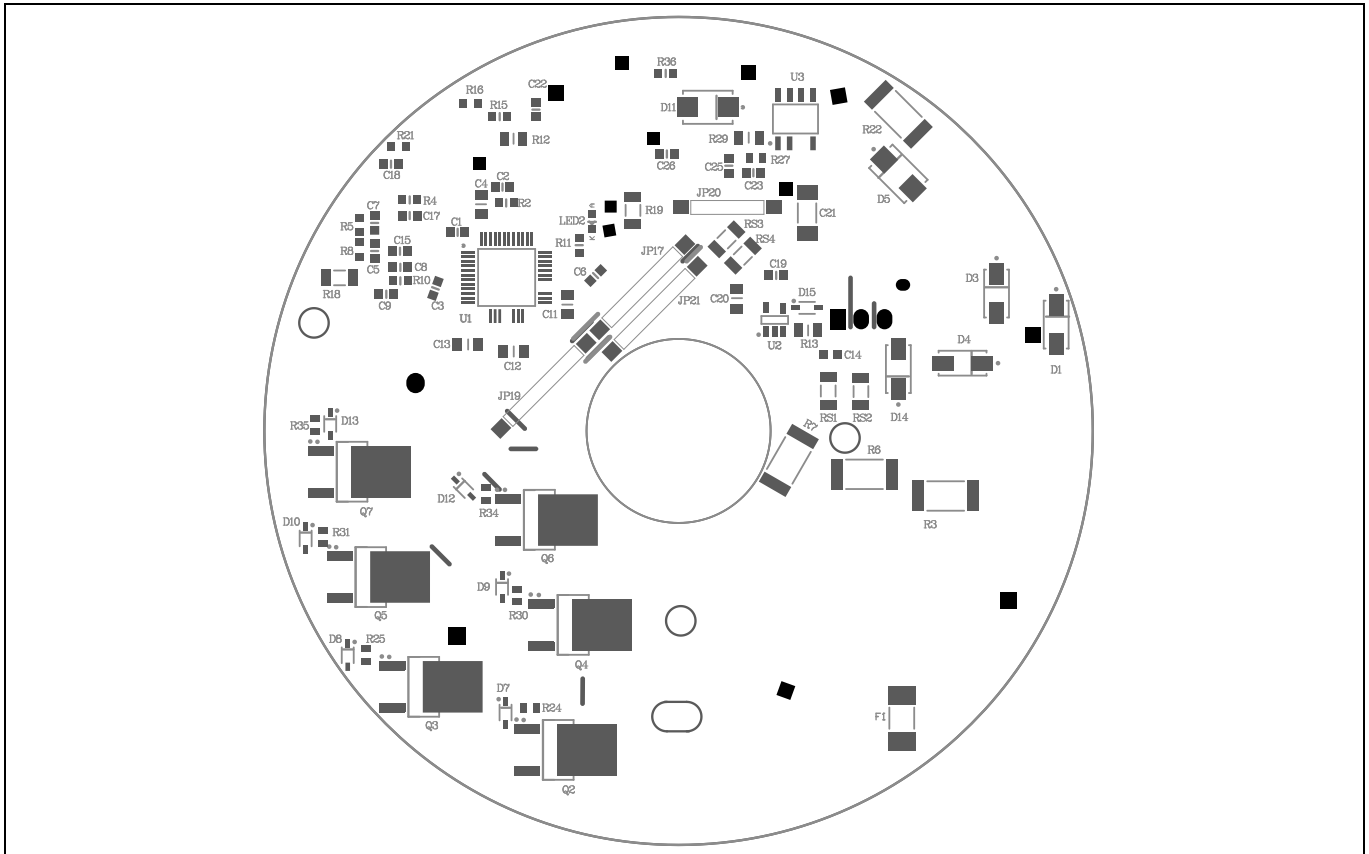


Figure 35 Bottom assembly print of the main board

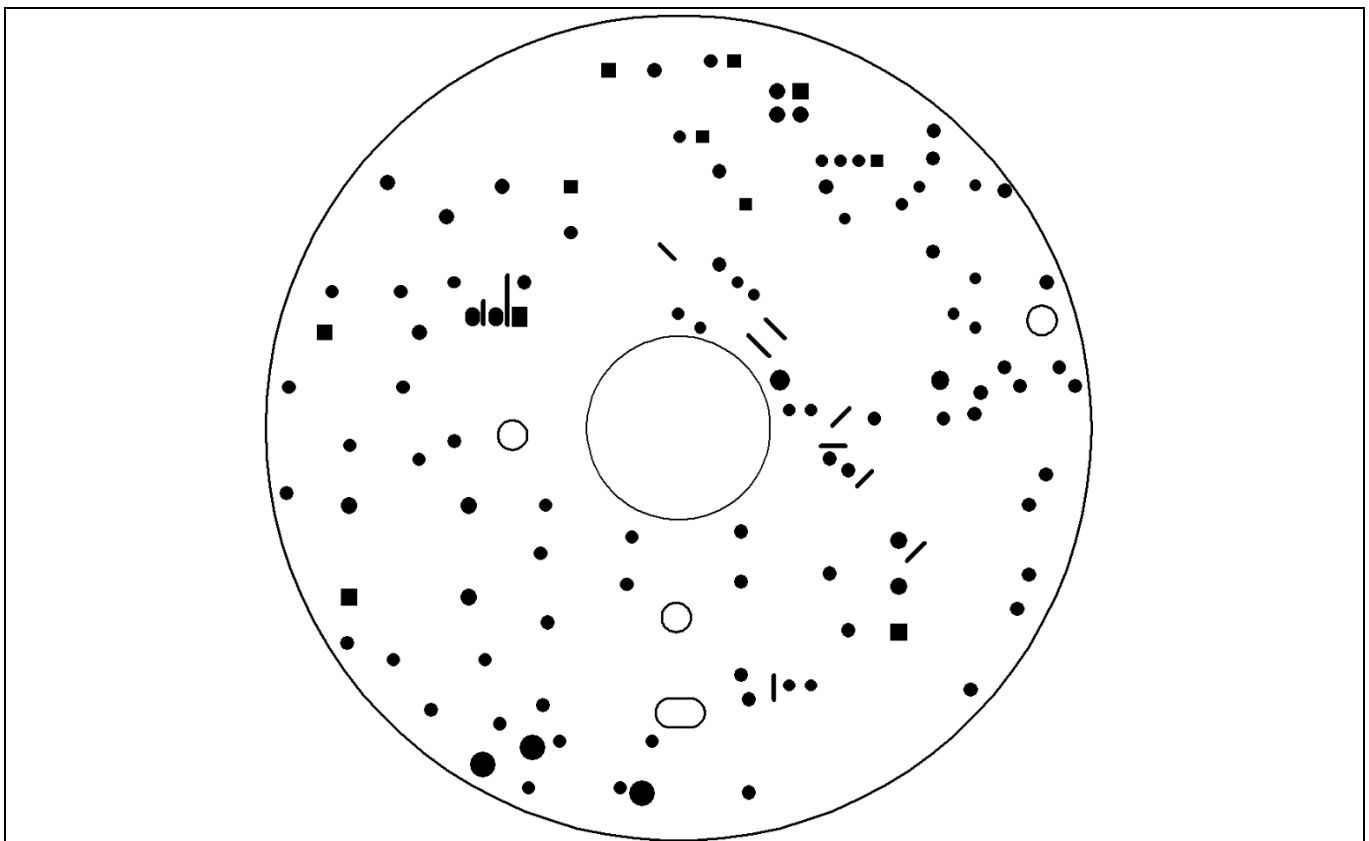


Figure 36 Top layer of the main board

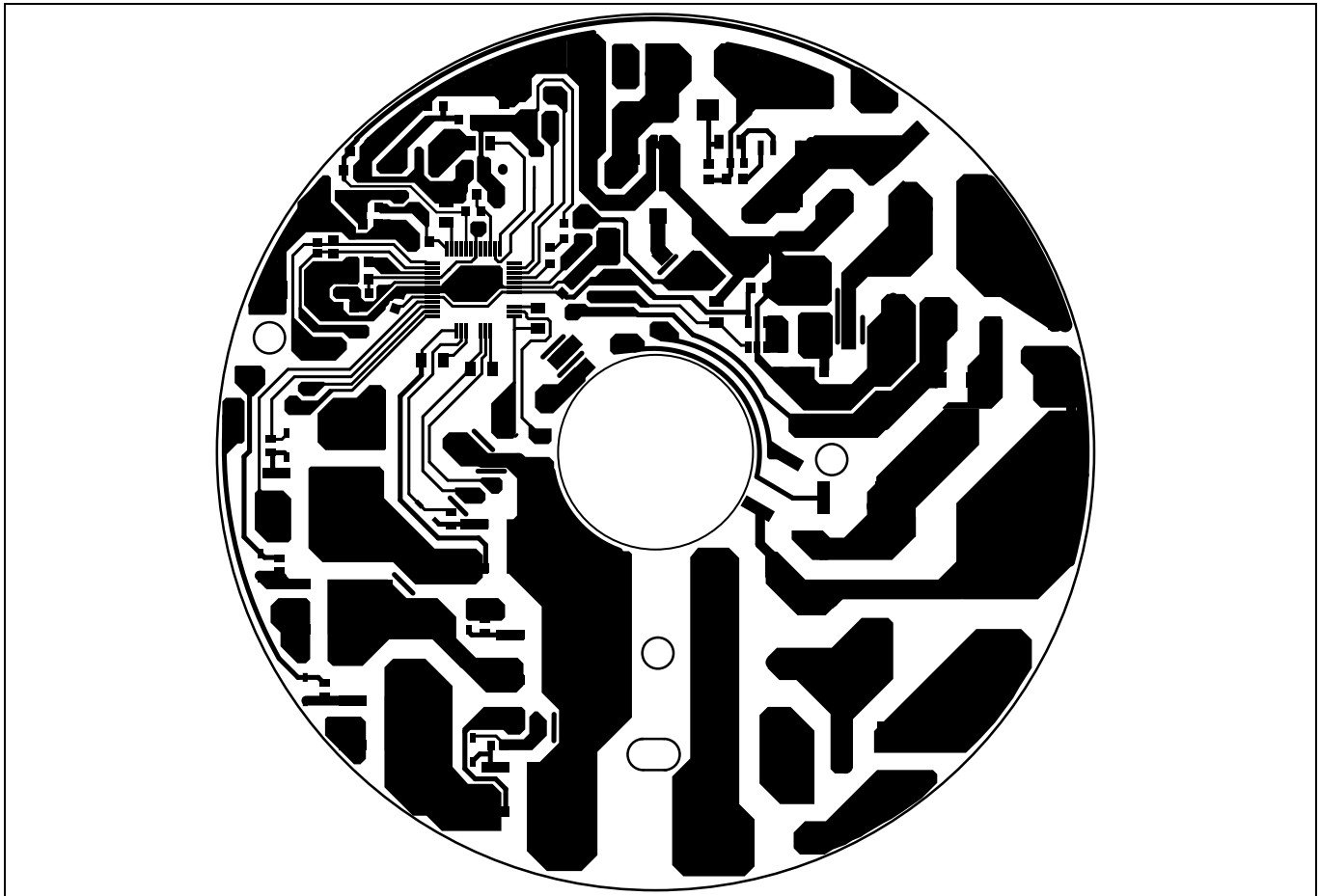


Figure 37 Bottom layer of the main board

### 3.2.2 Daughter board layout

The daughter board is designed in double layers and has a square shape, with dimensions of 19 mm (L) × 15 mm (W) × 16 mm (H). The daughter board is manufactured with a copper thickness of 1 oz. (35 μm).

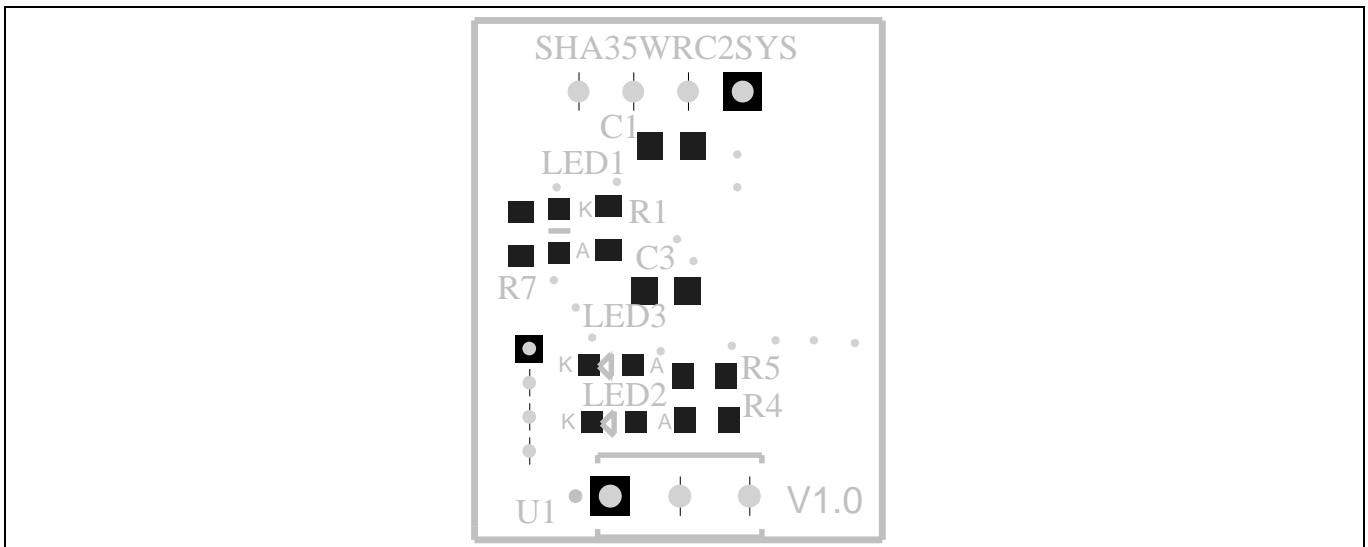


Figure 38 Top assembly print of the daughter board



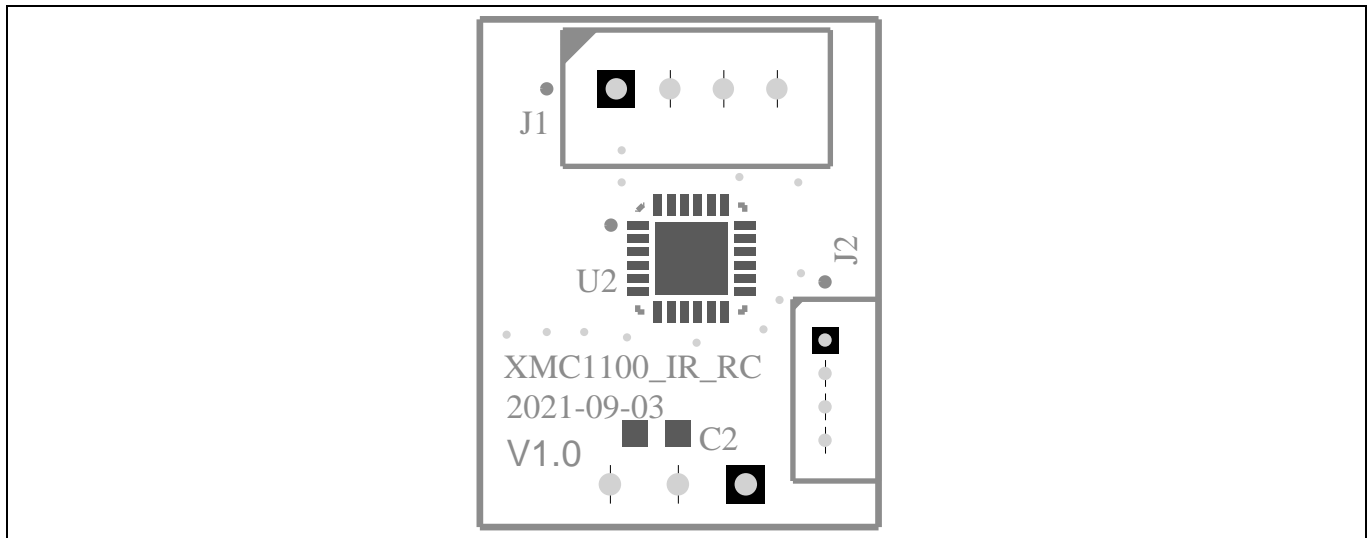


Figure 39 Bottom assembly print of the daughter board

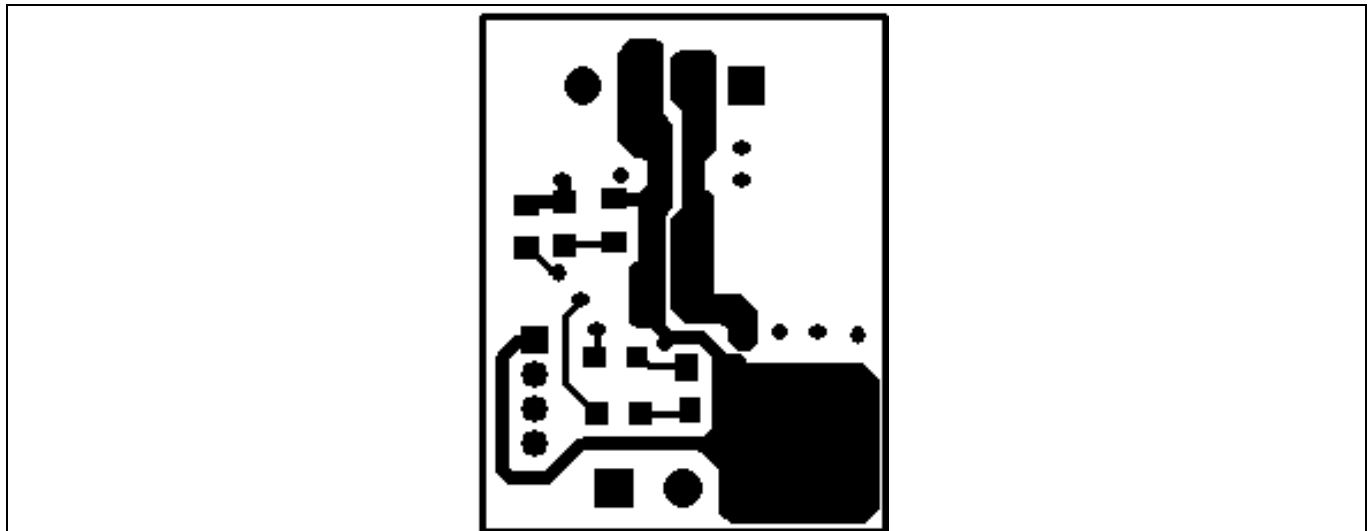


Figure 40 Top layer of the daughter board

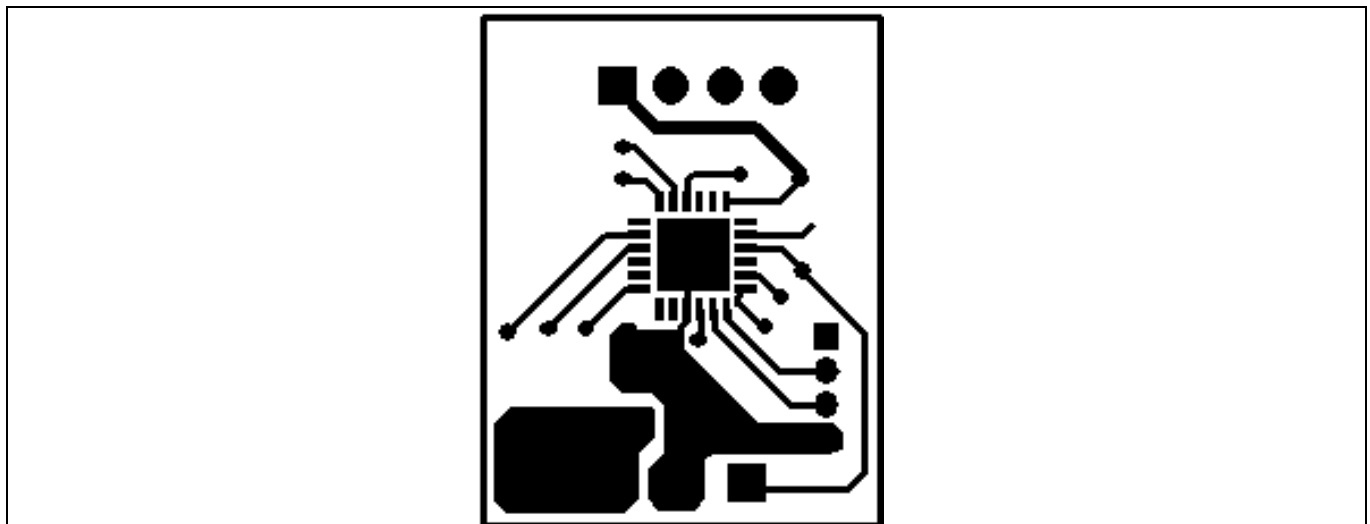


Figure 41 Bottom layer of the daughter board

**System design**

**3.3 Bill of material**

The complete bill of material is available on the download section of the Infineon homepage. A log-in is required to download this material.

**Table 4 BOM of the most important/critical parts of main board**

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
1	C16	CAP/ELCO/22 $\mu$ F/450 V/20%/Aluminium electrolytic/-25°C to 105°C/5.00 mm C X 0.60 mm W 13.00 mm Dia X 26.50 mm H	Würth Elektronik	860241478004
2	CX1	CAP/FILM/100 nF/10%/MKP (Metallized Polypropylene)/-40°C to 105°C / 10.00 mm C X 0.60 mm W 13.00 mm L X 7.00 mm T X 13.50 mm H	Würth Elektronik	890324023023
3	CX2	CAP/FILM/330 nF/275 V/10%/MKP (Metallized Polypropylene)/-40°C to 105°C/12.50 mm C X 0.60 mm W 15.00 mm L X 8.50 mm T X 14.50 mm H	Würth Elektronik	890324024003
4	CY1, CY2	CAP/CERA / 4.7 nF/2.6 kV/20%/Y5U (EIA)/-40°C to 125°C/10.00 mm C X 0.55 mm W 13.00 mm L X 5.00 mm T X 17.00 mm H	Kemet	C961U472MZWDBA7317
5	CY3, CY4	CAP/CERA/3.3 nF/2.6 kV/20%/Y5U (EIA)/-40°C to 125°C/10.00 mm C X 0.55 mm W 11.00 mm L X 5.00 mm T X 15.00 mm H	Kemet	C941U332MZWDBA7317
6	D1, D3, D4, D14	General purpose rectifier	ON Semiconductor	S1M
7	D2	1 A, 50 V – 1000 V glass passivated rectifier	Taiwan Semiconductor	1N4007G-K
8	Q1	High speed 5 IGBT in TRENCHSTOP 5 technology copacked with RAPID1 fast and soft antiparallel diode	Infineon Technologies	IKA08N65H5
9	Q2, Q3, Q4, Q5, Q6, Q7	Cost effective monolithically integrated IGBT with diode	Infineon Technologies	IKN03N60RC2
10	Q2', Q3', Q4', Q5', Q6', Q7' *	TRENCHSTOP RC-Series for hard switching applications, VCE 600V, IC 4A	Infineon Technologies	IKD04N60RC2
11	U1	Motor controller with integrated high-voltage gate	Infineon Technologies	IMD112T-6F040

System design

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
		driver, Integrated script engine for application control customization, thin-film-SOI-technology with negative transient robustness, built-in temperature sensor		
12	U2	Single low-side driver IC, application general purpose gate driver, DC-DC converters, plasma display panel (PDP) applications	Infineon Technologies	IRS44273LTRPBF
13	U3	Lowest component count, energy-efficient off-line switcher IC, 175 mA MDCM in 230 V <sub>rms</sub>	Power Integrations	LNK305DG

\* Q2', Q3', Q4', Q5', Q6', Q7' are alternatives of Q2, Q3, Q4, Q5, Q6, Q7, and Q2, Q3, Q4, Q5, Q6, Q7 are mounted by default.

**Table 5 BOM of the most important/critical parts of daughter board**

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
1	U1	Remote receiver sensor, 40.0 kHz 14m Through Hole	Everlight	IRM-3640T
2	U2	XMC1000 industrial microcontrollers ARM® Cortex®-M0 32-bit processor core	Infineon Technologies	XMC1100-Q024F0064

### 3.4 Connector details

#### 3.4.1 Main board connectors

**Table 6 X1, X2, X3 AC input connectors**

PIN	Label	Function
X1	L	AC line input
X2	N	AC neutral input
X3	EARTH	Earth connector

**Table 7 J1- iMOTION™ link connector**

PIN	Label	Function
5	GND	Ground
6	+5 V	On board 5 V supply
7	RXD0	MCEDesigner & firmware download
8	TXD0	MCEDesigner & firmware download

**Table 8 J2 - Daughter board connector**

System design

PIN	Label	Function
1	IR Duty	Duty signal from daughter board
2	GND	Ground
3	+5 V	On board 5 V supply
4	Reserved	Reserved

### 3.4.2 Daughter board connectors

**Table 9 J1 – Main board connector**

PIN	Label	Function
1	IR Duty	Duty signal to main board
2	GND	Ground
3	+5 V	On board 5 V supply
4	Reserved	Reserved

**Table 10 J2 – XMC1100 programming connector**

PIN	Label	Function
1	+5 V	On board 5 V supply
2	SWCLK	SWCLK pin of serial wire debug (SWD)
3	SWD	SWD pin of serial wire debug (SWD)
4	GND	Ground

System performance

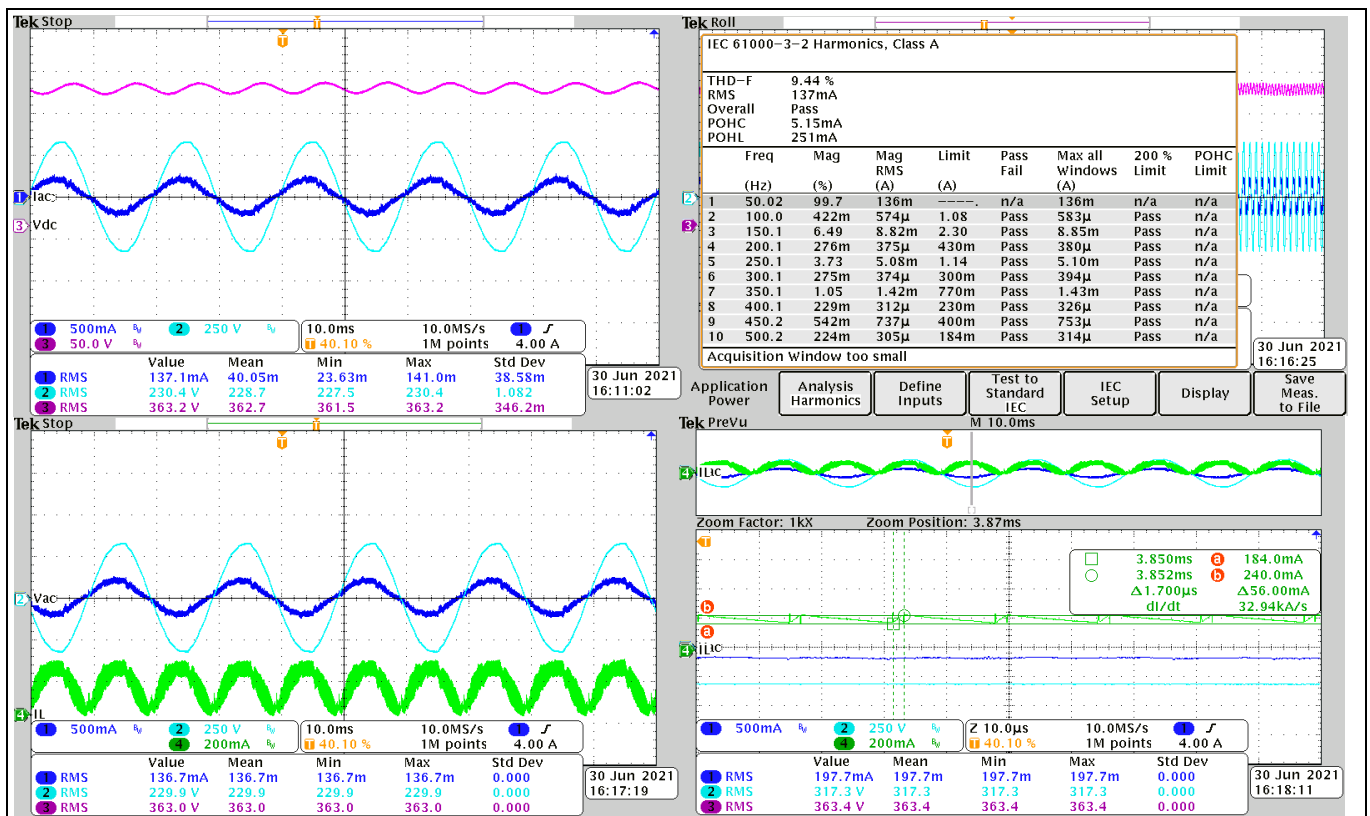
## 4 System performance

### 4.1 PFC iTHD at rated condition

PFC performance is tested at a rated input voltage of 230 Vrms and output rated power of ceiling fan motor.

**Table 11 PFC iTHD at rated condition**

Input voltage (Vrms)	Input current (A)	PFC DC target (V)	Input power(W)	Power factor	iTHD(%)
230	0.137	360	33.2~34.0	0.968~0.974	9.33~9.74
<b>Legend</b>	CH1: Iac, CH2: Vac, CH3: Vdc, CH4: IL				
<b>Condition</b>	<ul style="list-style-type: none"> <li>Typical PWM setup for: 60 kHz PFC and 16 kHz motor PWM, 3-phase only mode, motor speed: 360 rpm.</li> <li>PFC control parameters: Kpl= 400, Kxl=600, Kpv= 1500, KxV=30</li> </ul>				



**Figure 42 PFC iTHD at rated condition**

### 4.2 Bus voltage ripple

The bus voltage ripple test of input voltage is from 120 Vrms to 270 Vrms. The maximum bus voltage is 395 V.

**Table 12 Bus voltage ripple**

Input voltage (Vrms)	PFC DC target (V)	Ripple voltage (V)	(%)
120	302	8	2.6
150	305	8	2.6
230	360	7	1.92

System performance

270	395	7.5	1.89
<b>Legend</b>	CH1: Iac, CH2: Vac, CH3: Vdc		
<b>Condition</b>	<ul style="list-style-type: none"> <li>Typical PWM setup for: 60 kHz PFC and 16 kHz motor PWM, 3-phase only mode, motor speed: 360 rpm.</li> </ul>		

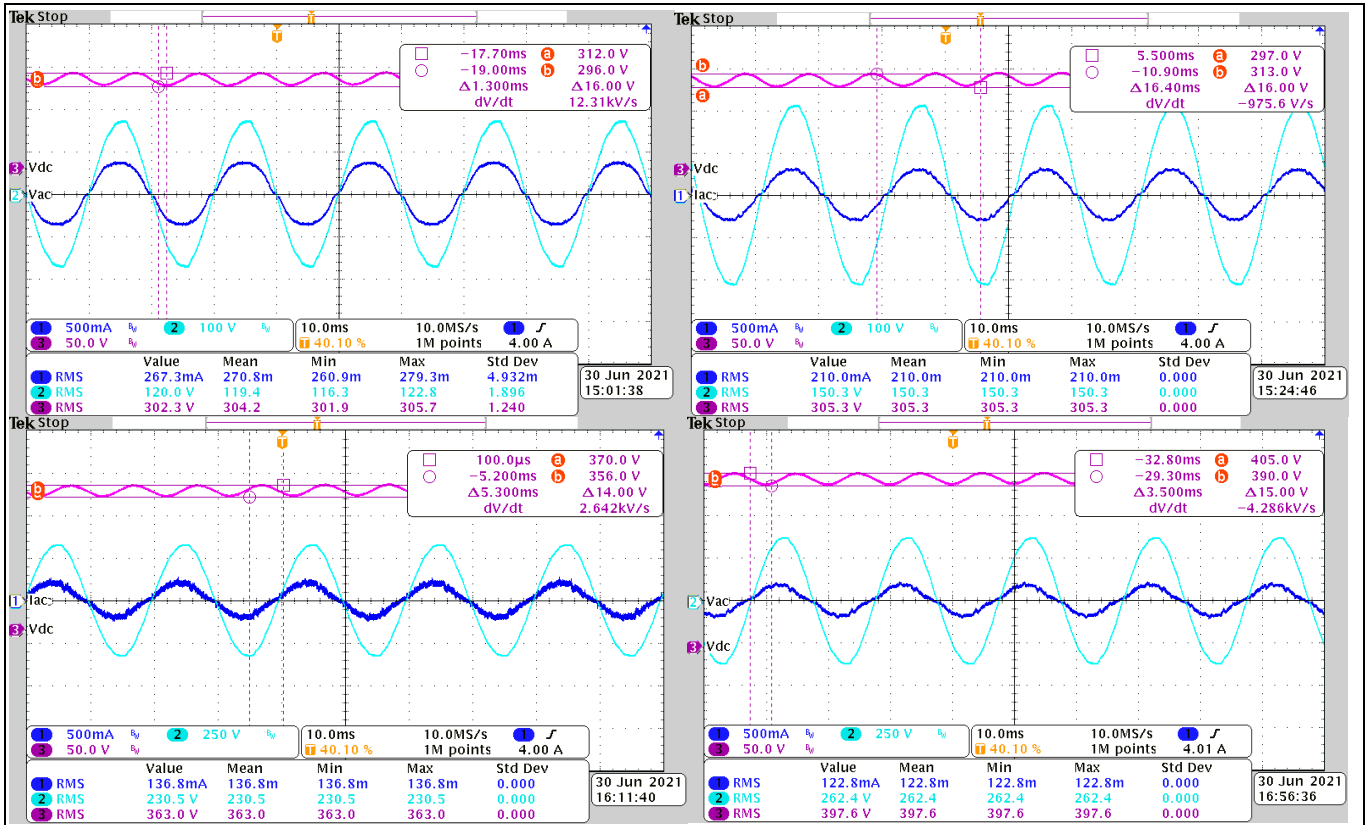


Figure 43 Bus voltage ripple at input voltage: 120 Vrms, 150 Vrms, 230 Vrms, 270 Vrms

### 4.3 PFC IGBT Vce dv/dt performance

Table 13 PFC IGBT Vce dv/dt performance

Input voltage (V)	Input power (W)	Input current (A)	PFC DC target (V)	Power factor	dv/dt of Vce (V/ns)
120	34.2	0.283	260	1	4.280 ~ 3.344
230	33.9	0.154	360	0.974	4.306 ~ 2.897

<b>Legend</b>	CH2: Vce, CH3: Vge, CH4: Ic
<b>Condition</b>	<ul style="list-style-type: none"> <li>Typical PWM setup for: 60 kHz PFC and 16 kHz motor PWM, 3-phase only mode, motor speed: 360 rpm.</li> </ul>

System performance

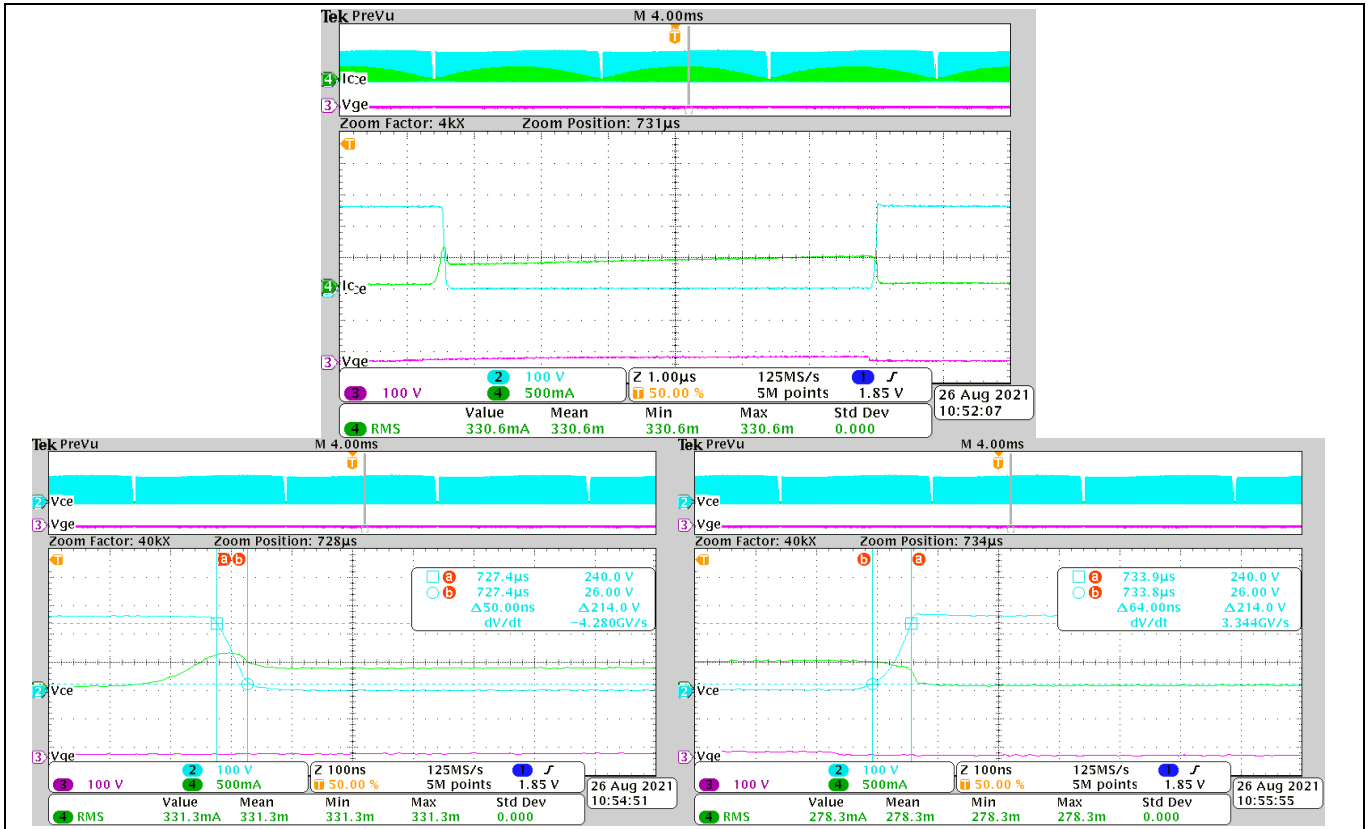


Figure 44 PFC IGBT Vce dv/dt performance at input voltage = 120 V

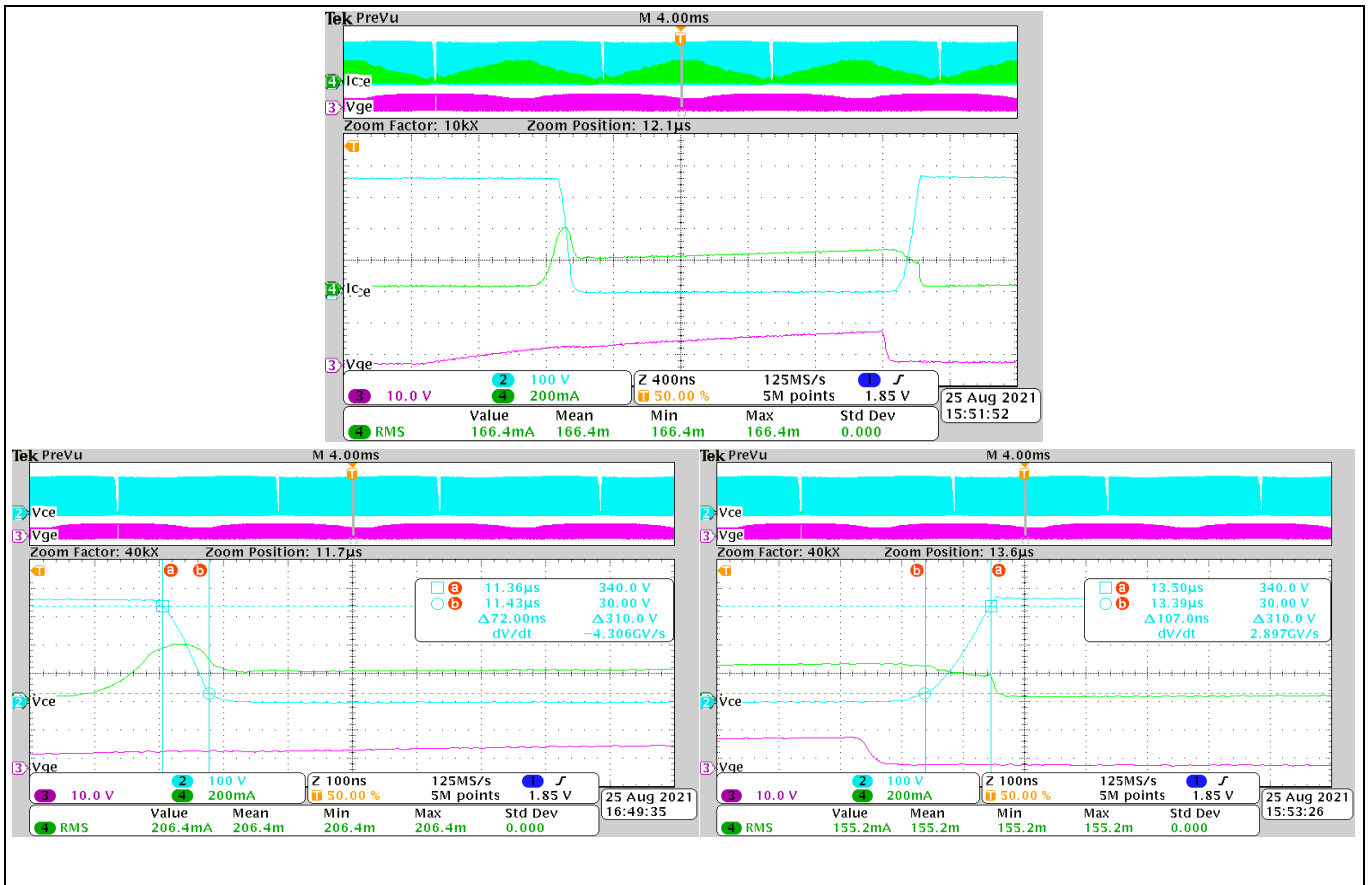


Figure 45 PFC IGBT Vce dv/dt performance at input voltage = 230 V

System performance

4.4 PFC thermal performance

Table 14 PFC thermal performance

Input voltage (V)	Input power (W)	Input current (A)	PFC DC target (V)	Power factor	Component with max temperature	$\Delta T(^{\circ}C)$
120	34.2	0.283	300	1	PFC IGBT	61.2
150	33.9	0.146	300	0.947	PFC IGBT	52.8
230	34.4	0.146	360	0.978	Motor IGBT	61.5
270	35.7	0.136	394	0.965	Motor IGBT	71.2

**Condition**

- PWM setup for: 60 kHz PFC and 16 kHz motor PWM, 3-phase only mode, motor speed: 360 rpm.
- PFC control parameters: Kpl= 400, Kxl=600, KpV= 1500, KxV=30.

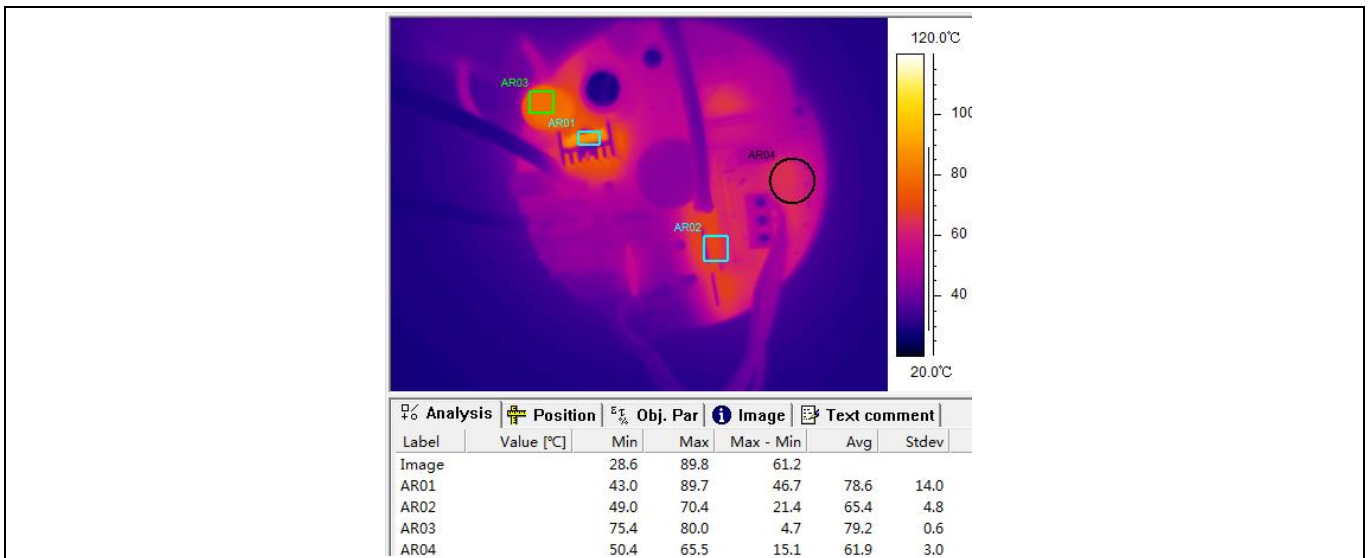


Figure 46 Input voltage = 120 V

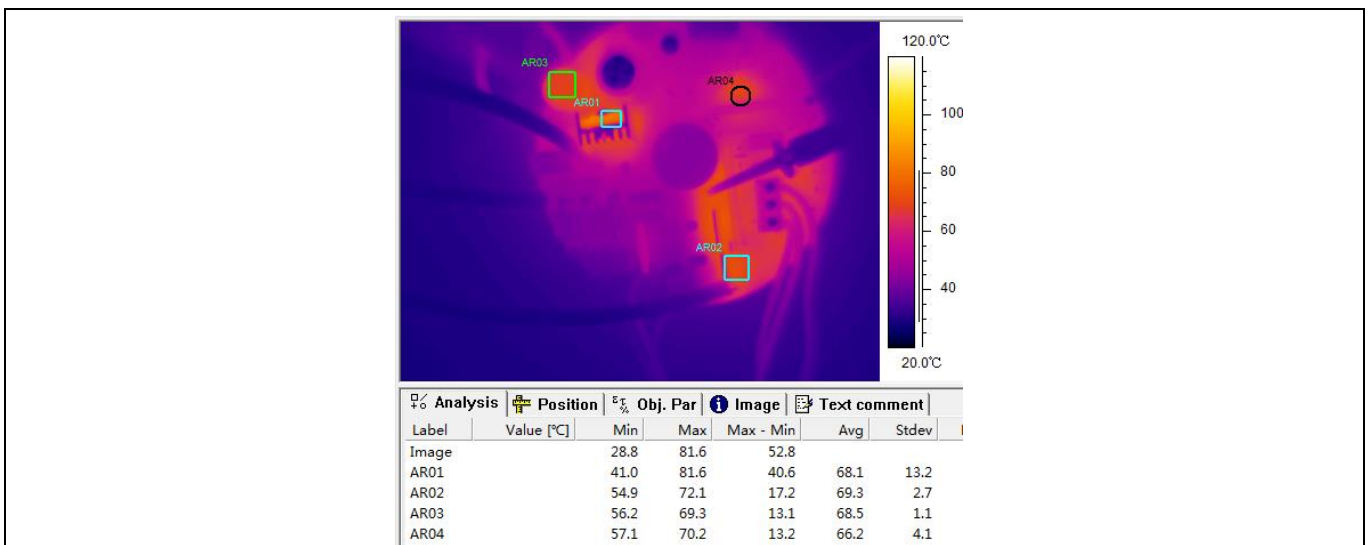


Figure 47 Input voltage = 150 V



System performance

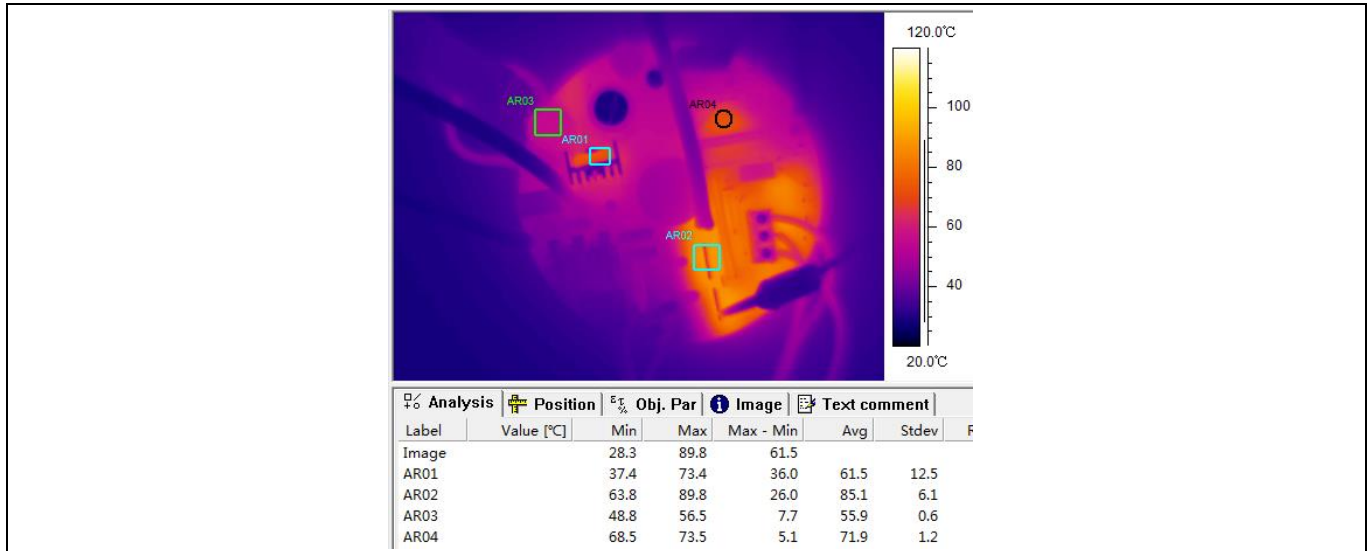


Figure 48 Input voltage = 230 V

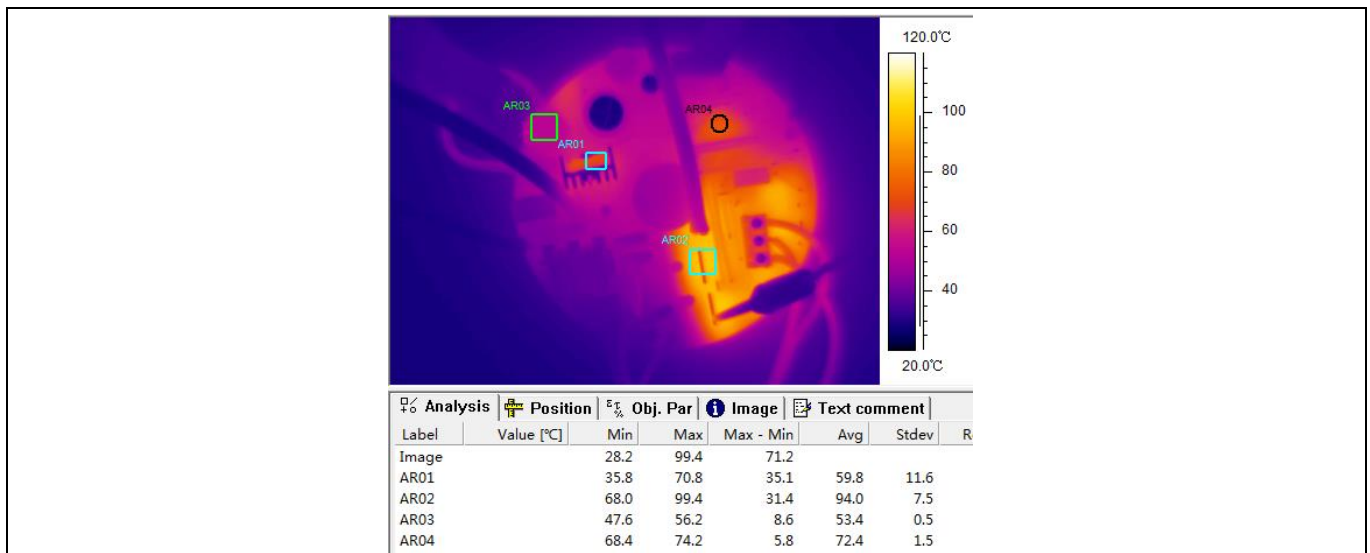


Figure 49 Input voltage = 270 V

### 4.5 Inverter IGBT dv/dt performance

IKN03N60RC2 is used here for the inverter IGBT dv/dt performance test.

Table 15 Inverter IGBT dv/dt performance

Current position	Input voltage (V)	Input power (W)	PFC DC target (V)	Power factor	dv/dt (V/ns)
At positive current	230	34.5	360	0.976	0.576 ~ 1.38
Near zero current	230	34.5	360	0.976	0.514 ~ 1.518
At negative current	230	34.5	360	0.976	0.36 ~ 1.325
<b>Legend</b>	CH1: Vge for low side, CH4: Vge for high side ,CH3: phase output current, CH2: Vce for low side				
<b>Condition</b>	<ul style="list-style-type: none"> <li>● PWM setup for: 60 kHz PFC and 16 kHz motor PWM, 3-phase only mode, motor speed: 360 rpm.</li> <li>● PFC control parameters: Kpl= 400, Kxl=600, KpV= 1500, KxV=30.</li> </ul>				

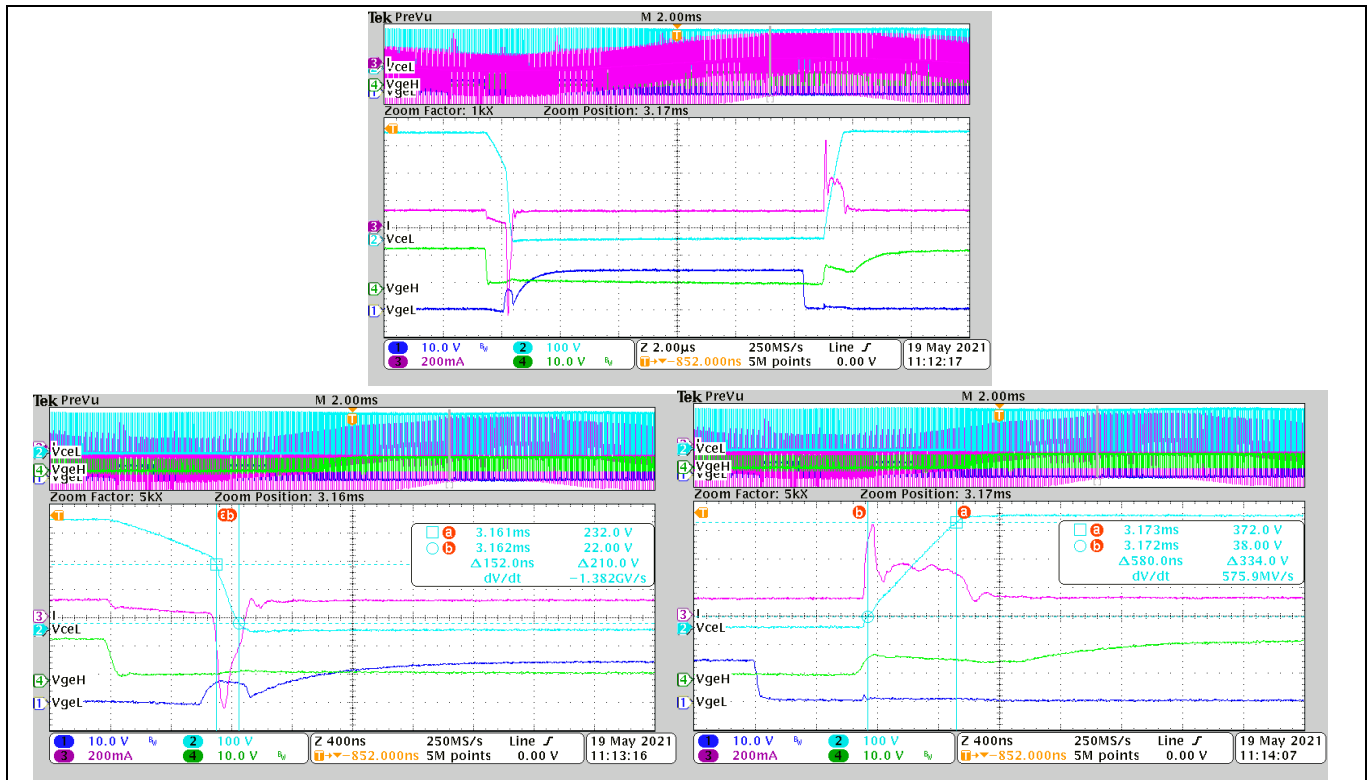


Figure 50 At positive current

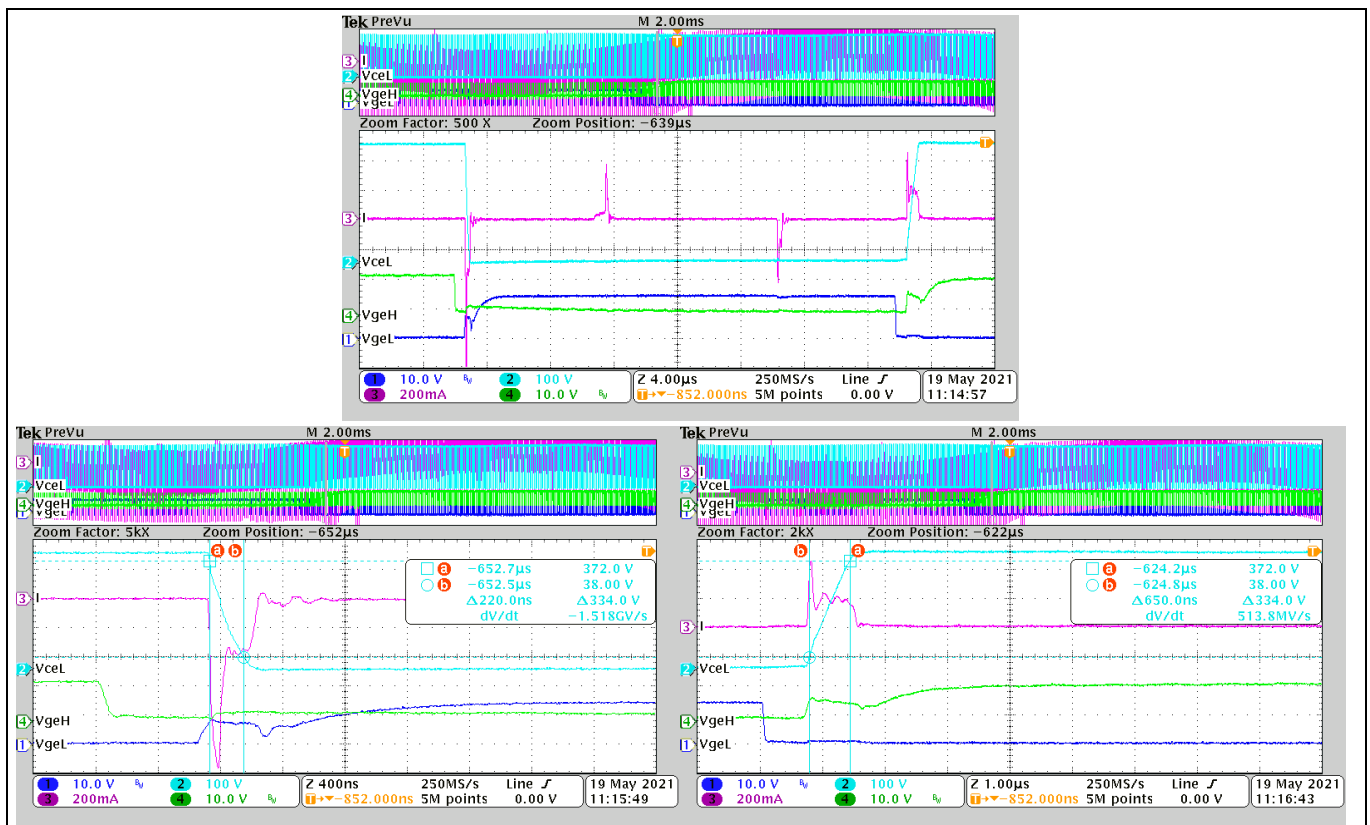


Figure 51 Near zero current

System performance

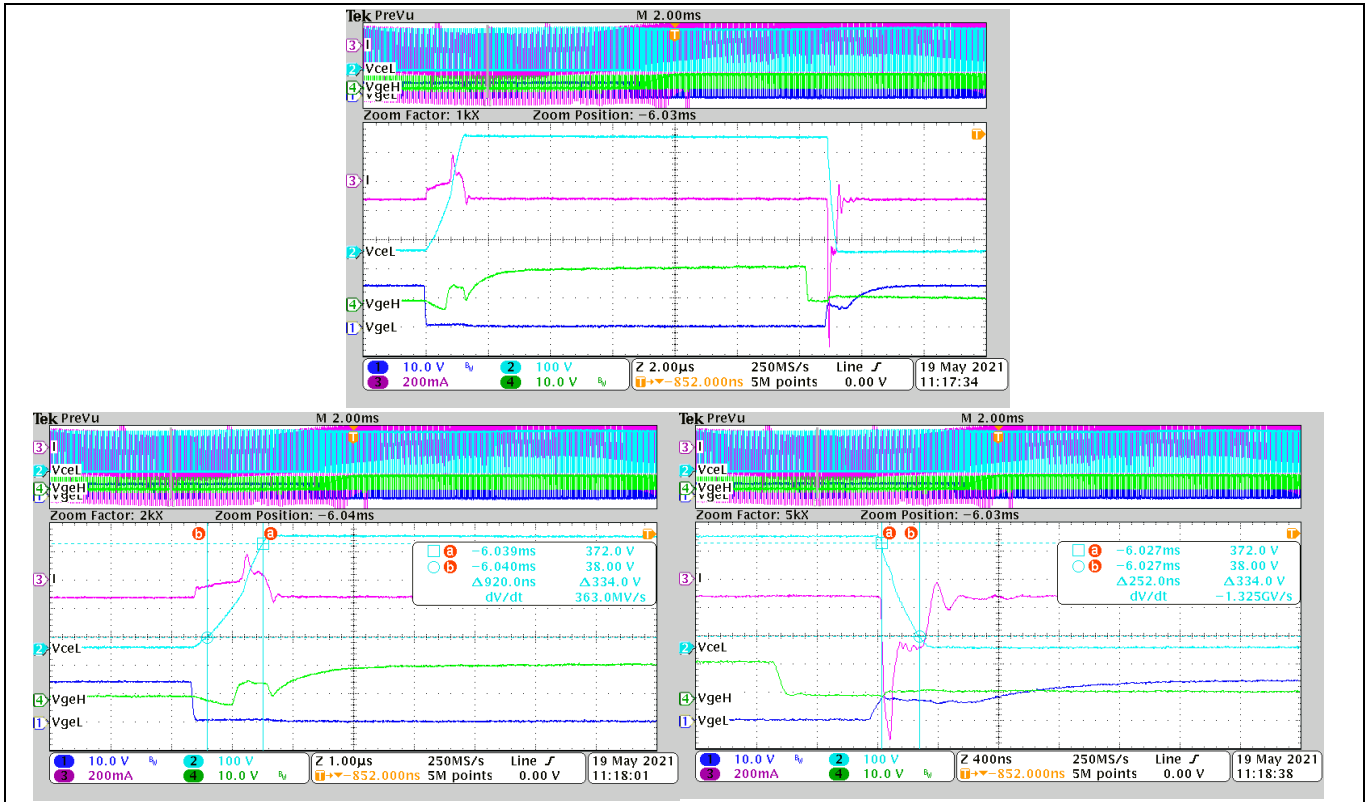


Figure 52 At negative current

### 4.6 Inverter IGBT dead time test

IKN03N60RC2 is used here for the inverter IGBT dead time test.

Table 16 Inverter IGBT dead time

Input voltage (V)	Input power (W)	PFC DC target (V)	Power factor	Tdon+Tr (ns)	Tdoff+Tf (ns)	Min dead time (ns)
120	35.8	260	1	84	512	428

**Legend** CH1: Vge for Low side, CH2: Vce for low side, CH3: phase output current.

**Condition**

- PWM setup for: 60 kHz PFC and 16 kHz motor PWM, 3-phase only mode, motor speed: 360 rpm.
- PFC control parameters: Kpl= 400, Kxl=600, KpV= 1500, KxV=30.

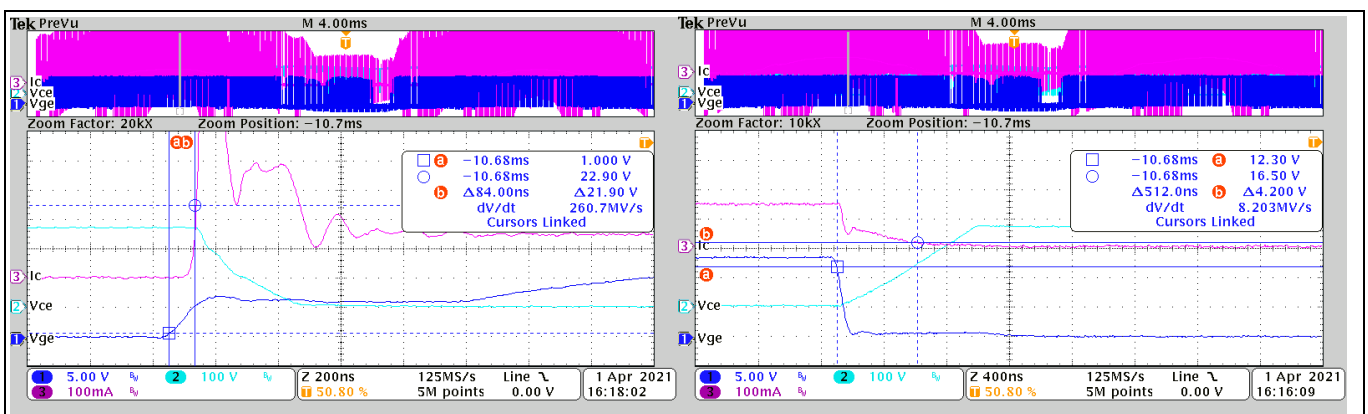


Figure 53 Inverter IGBT dead time

System performance

### 4.7 Electromagnetic interference (EMI) conducted

This section shows the conducted EMI of REF-SHA35WRC2SYS. Test limits follow the EN 55032: conducted disturbance at the mains ports of class B ITE (information technology equipment).

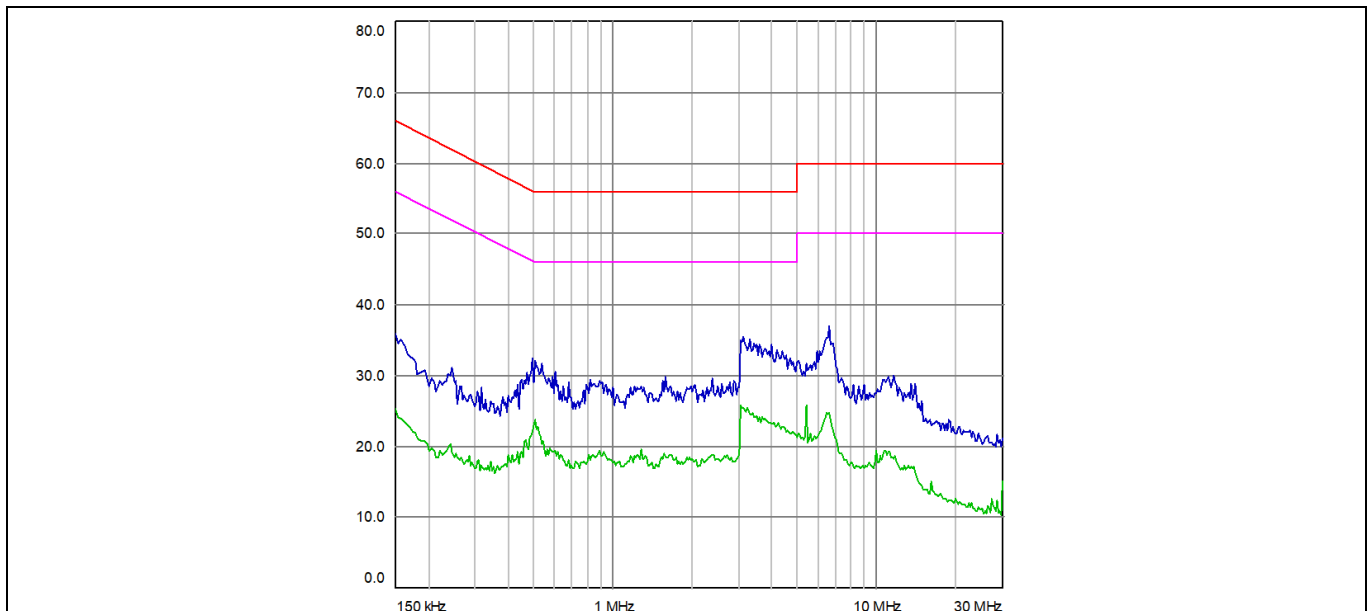
**Table 17 Limits for conducted disturbance at the mains ports of class B ITE**

Frequency range (MHz)	Limits (dB(μV))	
	Quasi-peak	Average
0.15 to 0.5	66 to 56	56 to 46
0.5 to 5	56	46
5 to 30	60	50

- Note:
1. The lower limit applies at the transition frequencies
  2. The limit decreases linearly with the logarithm of the frequency in the range 0.15 MHz to 0.50 MHz

**Table 18 EMI test result**

Operation	Phenomenon
Standby mode	Pass
Motor and PFC run	Nearly pass
<b>Condition</b>	<ul style="list-style-type: none"> <li>● Motor runs at 360 RPM without load</li> <li>● L=10 mH, CM =22 mH, X =100 nF(CX1) + 330 nF(CX2), Two stage Y = 3.3 nF(CY3, CY4)+4.7 nF(CY1, CY2), PFC Rg =330 Ohm, motor Rg = 620 Ohm</li> </ul>



**Figure 54 Standby mode**

System performance

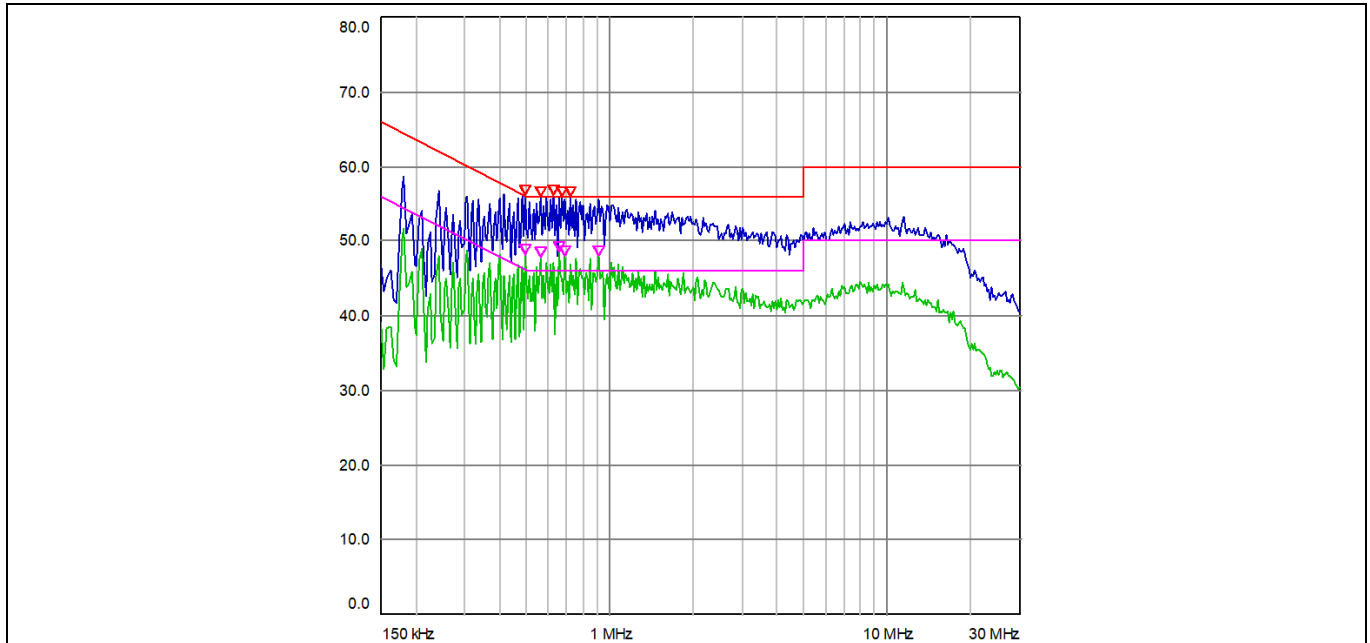


Figure 55 Motor and PFC run

Note: The short and strong PE connecting line is very important for reducing conducted disturbance at the mains ports of class B ITE

### 4.8 Surge immunity test

This test is compliant with IEC standards: IEC61000-4-5; the specification is L to N 4 kV.

Add surge pulse from 0.5 kV to 4 kV on L-N. PFC runs normally, and motor runs at 360 RPM without load.

Table 19 Surge pulse condition

Pulse voltage	Basic voltage	Connection	Waveform	Coupling impedance	ASYNC/ SYNC Angle	Interval times /Total times
0.5 ~ 4 kV	230 Vrms	L-N	1.2/50 $\mu$ s	18 $\mu$ F	ASYNC	60s / 5 times
					SYNC-0°	60s / 5 times
					SYNC-90°	60s / 5 times
					SYNC-180°	60s / 5 times
					SYNC-270°	60s / 5 times
0.5 ~ 4 kV	230 Vrms	L-PE/N-PE	1.2/50 $\mu$ s	9 $\mu$ F + 10ohm	ASYNC	60s / 5 times
					SYNC-0°	60s / 5 times
					SYNC-90°	60s / 5 times
					SYNC-180°	60s / 5 times
					SYNC-270°	60s / 5 times

1~2 kV motor & PFC work fine, with only slighy disturbance; 2~4 kV surge trigger overvoltage fault; system can go back to work after clearing the fault or re-powering on.

System performance

### 4.9 System test with infrared control

This test connects the main board and daughter board with cables provided, and uses the script code in Section 2.1.3 Code Listing 1 for remote infrared control as shown in Figure 6. The test result is shown in Table 20.

**Table 20 System test result**

Gear	Input voltage (Vrms)	Motor speed (rpm)	PFC DC target (V)	iTHD(%)	Input power (W)	Power factor	Input current (mA)
1	120	39	168	56.5%	1.8	0.811	21.7
2		119	168	24.3%	3.5	0.924	33.1
3		199	196	9.12%	8.7	0.961	77.4
4		279	275	5.18%	19.7	0.989	164.7
5		360	350	6.37%	36.5	0.998	298
1	150	39	211	70.8%	2.1	0.731	25.54
2		119	211	34.6%	3.8	0.897	32.55
3		199	209	17.40%	8.5	0.943	63.67
4		279	275	5.63%	19	0.981	128.2
5		360	354	4.02%	34.8	0.996	260
1	200	39	281	76.8%	3	0.662	25.46
2		119	281	59.1%	4.8	0.817	31.32
3		199	281	24.00%	9.6	0.938	52.43
4		279	279	11.30%	18.9	0.957	100.3
5		360	354	4.93%	34.3	0.987	174.1
1	250	39	354	75.9%	4.1	0.643	28.59
2		119	352	70.4%	5.9	0.748	33.86
3		199	350	35.00%	10.8	0.913	48.31
4		279	349	17.40%	19.4	0.956	83.2
5		360	354	8.06%	33.1	0.968	137.7
1	300	39	PFC stopped, Bus=419	139.0%	5.3	0.409	45.5
2		119	PFC stopped, Bus=417	151.0%	6.9	0.436	54.91
3		199	PFC stopped, Bus=416	162.0%	11.8	0.479	84.5
4		279	PFC stopped, Bus=413	159.0%	21	0.511	134
5		360	PFC stopped, Bus=408	154.0%	34.4	0.528	241.7

## 5 References and appendices

### 5.1 Abbreviations and definitions

**Table 21** Abbreviations

Abbreviation	Meaning
CE	Conformité Européenne
EMI	Electromagnetic interference
UL	Underwriters Laboratories
RC-D2	Reverse-conducting drive 2

### 5.2 References

- [1] Infineon Technologies AG. Datasheet of IKN03N60RC2 (2021) V1.0 [www.infineon.com](http://www.infineon.com)
- [2] Infineon Technologies AG. Datasheet of IMD112T-6F040 (2020) V1.0 [www.infineon.com](http://www.infineon.com)
- [3] Infineon Technologies AG. Datasheet of IRS44273L (2021) V1.0 [www.infineon.com](http://www.infineon.com)
- [4] Infineon Technologies AG. MCEWizard\_V2.3 User Guide (2019) [www.infineon.com](http://www.infineon.com)
- [5] Infineon Technologies AG. MCEDesigner\_V2.3 Application Guide (2019) [www.infineon.com](http://www.infineon.com)
- [6] Infineon Technologies AG. iMOTION™ Motion Control Engine Software Reference Manual (2021) V1.34 [www.infineon.com](http://www.infineon.com)

### 5.3 Additional information

In order to initiate testing, customers are advised to order the iMOTION™ link; detailed information is listed in Table 22.

The Infineon components on the board are listed in Table 22 as well. The customers can visit the corresponding webpage for more information.

**Table 22** Additional information on tools and Infineon components

Base part number	Package	Standard pack		Orderable part number
		Form	Quantity	
<a href="#">iMOTION™ link</a>		Container	1	IMOTIONLINK
<a href="#">IMD112T-6F040</a>	PG-LQFP-40	Tape and reel	1500	IMD112T6F040XUMA1
<a href="#">IKD04N60RC2</a>	PG-TO252-3	Tape and reel	2500	IKD04N60RC2ATMA1
<a href="#">IKN03N60RC2</a>	PG-SOT223-3	Tape and reel	2500	IKN03N60RC2ATMA1
<a href="#">IRS44273L</a>	PG-SOT23-5	Tape and reel	3000	IRS44273LTRPBF
<a href="#">IKA08N65H5</a>	PG-TO220-3	Tube	500	IKA08N65H5XKSA1
<a href="#">XMC1100-Q024F0064 AB</a>	PG-VQFN-24	Tape and reel	6000	XMC1100Q024F0064ABXUMA1



**Revision history**

**Revision history**

<b>Document version</b>	<b>Date of release</b>	<b>Description of changes</b>
V 1.0	10/29/2021	Initial version