

REF-Hairdryer-C101-6ED user guide

SOI driver & Hairdryer application reference design kits

About this document

Scope and purpose

This user guide provides an overview of the reference board REF-Hairdryer-C101-6ED including its main features, key test results and mechanical dimensions.

The REF-Hairdryer-C101-6ED is a full-featured starter kit, turnkey motor drive designed for high-performance, high-efficiency PMSM/BLDC motor drive applications, including all of the required elements for hair dryer applications, such as IMC101T iMOTION™ controller, IGBT and 6EDL04106PT SOI three-phase gate driver.

The starter kit features and demonstrates Infineon's thin-film SOI technology and advanced motion control engine (MCE 2.0) technology for small power PMSM/BLDC motor drives up to 100 kRPM speed, and inverters up to a rating of 400 W. It is optimized for small home appliances like hairdryers, fans, pumps and other low-power motor drive applications.

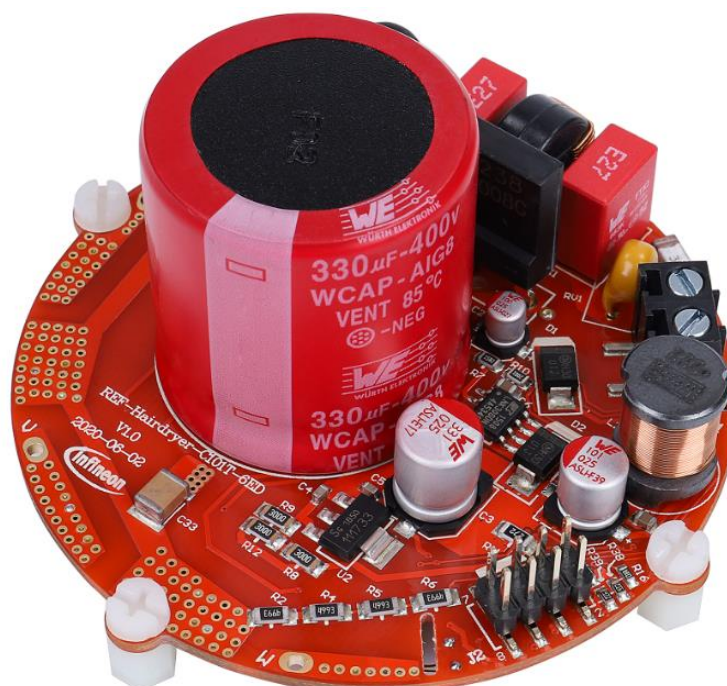
Intended audience

This document is intended for all technical specialists who are familiar with high-speed motor control and middle/high voltage electronics converters. The reference design is intended to be used under laboratory conditions only by trained specialists.

Reference Board

Products embedded on a PCB, with focus on specific applications and defined use cases that can include Software. PCB and auxiliary circuits are optimized for the requirements of the target application.

Note: Boards do not necessarily meet safety, EMI, quality standards (for example UL, CE) requirements.



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Important notice

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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>Warning: The DC link potential of this board is up to 310 V_{DC}. 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>Warning: The 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>Warning: The 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>Warning: 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>Caution: The heat sink and device surfaces of the reference board may become hot during testing. Hence, necessary precautions are required while handling the board. Failure to comply may cause injury.</p>
	<p>Caution: 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>Caution: The 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>Caution: 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>Caution: The 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>

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The board at a glance

1 The board at a glance

The REF-Hairdryer-C101-6ED is part of the SOI driver & iMOTION™ reference design kits. It is an optimized design for 100 ~ 400 W power hairdryer applications, which can be used for different voltages or different power classes, by replacing different IGBT, current-sensing resistors and by modifying DC bus capacitor. It allows fast prototyping and fast time to market.

The REF-Hairdryer-C101-6ED reference design is available through regular Infineon distribution partners as well as on Infineon's website. This document describes the main features of this board and provides information on how to enable customers to copy, modify and qualify the design for production according to their own specific requirements.

1.1 Delivery content

The REF-Hairdryer-C101-6ED board is designed to provide ready-to-use, middle and high-voltage, middle and high-speed motor drive solutions based on Infineon's thin-film SOI technology, TRENCHSTOP™ Reverse Conducting (RC) technology and advanced motion control engine (MCE 2.0) technology.

The delivery includes the finished board as shown in Figure 1 and Figure 2. It provides a single-phase AC connector, an EMI filter, input rectifier, DC bus capacitors, iMOTION™ controller IMC101T, 6 A 600 V TRENCHSTOP™ IGBT and 6EDL04I06PT three-phase gate driver with integrated bootstrap diode.

Environmental conditions were considered in the design of the REF-Hairdryer-C101-6ED, but the board is not qualified in terms of safety requirements or manufacturing and operation over the entire operating temperature range or lifetime. The boards provided by Infineon are subject to functional testing only.

1.2 Block diagram

The block diagram of the REF-Hairdryer-C101-6ED is depicted in Figure 1.

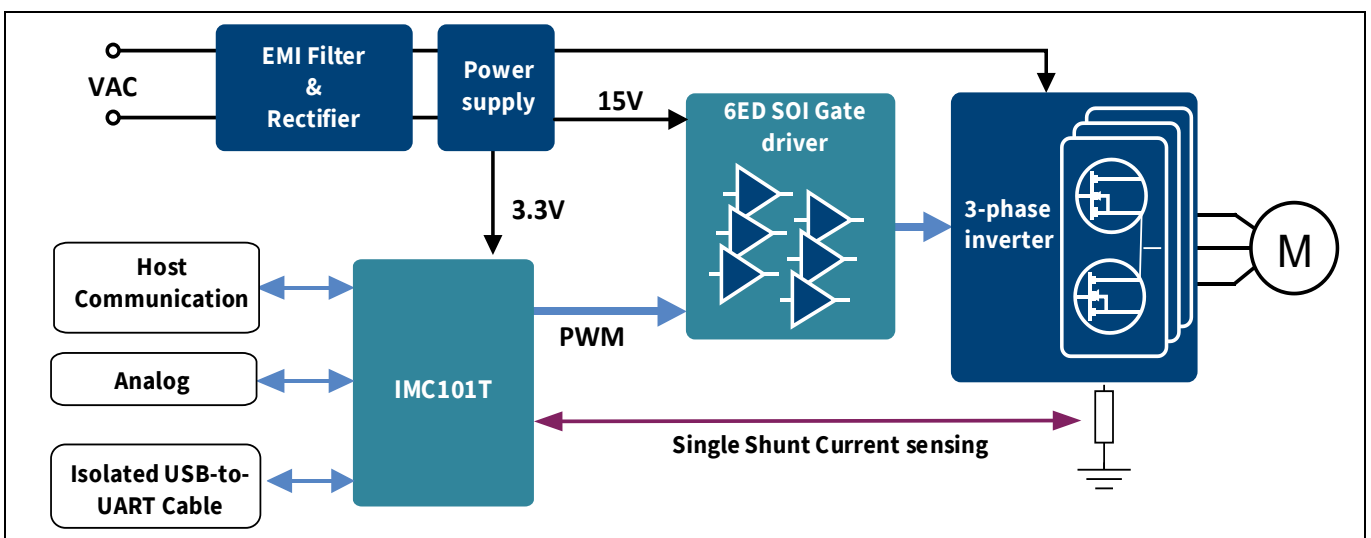


Figure 1 Block diagram of the REF-Hairdryer-C101-6ED

The board at a glance

Figure 2 points out the functional groups on the top side of the REF-Hairdryer-C101-6ED reference design.

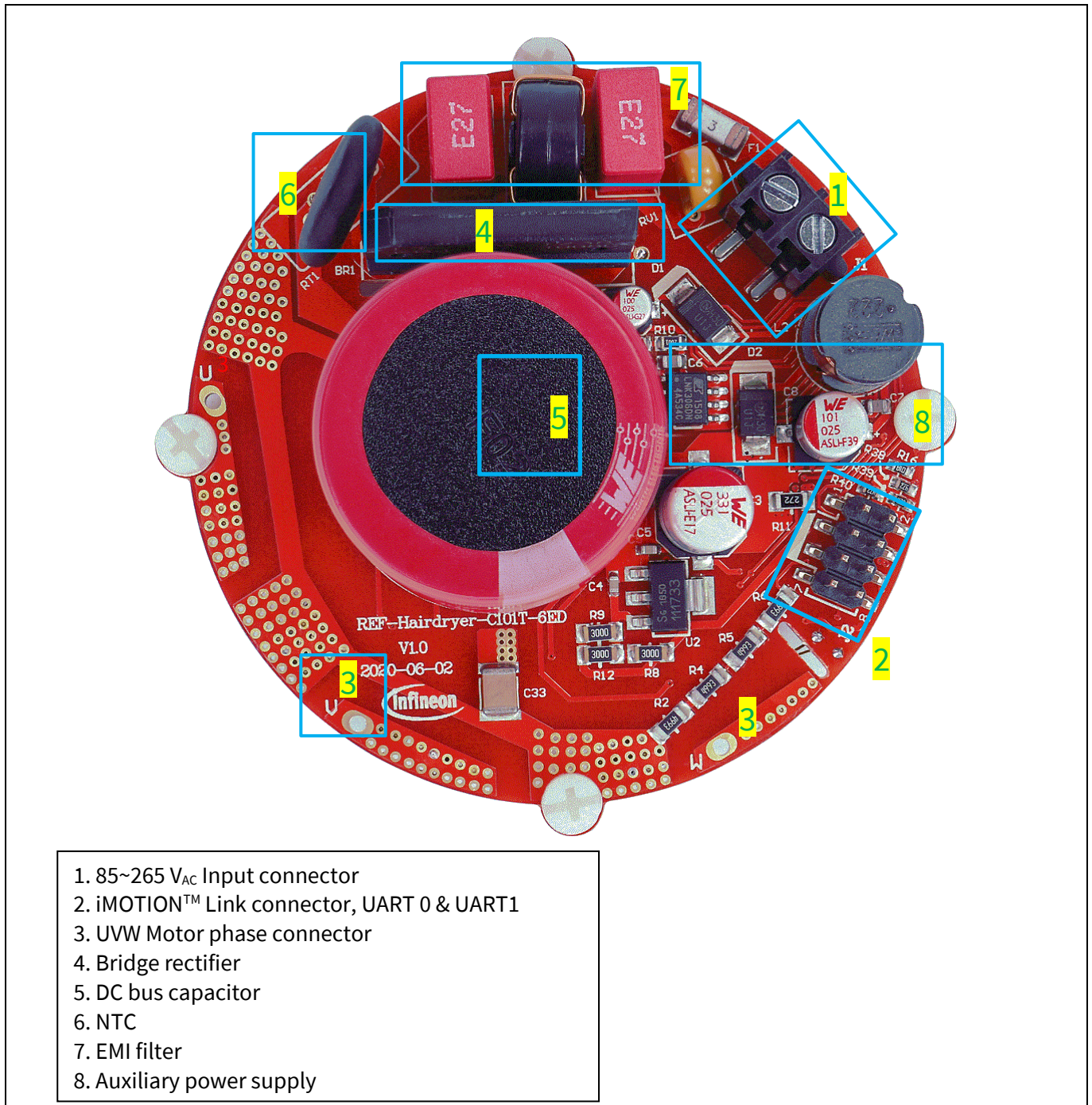


Figure 2 Functional groups of the REF-Hairdryer-C101-6ED reference design's top side

The board at a glance

Figure 3 points out the functional groups on the bottom side of the REF-Hairdryer-C101-6ED reference design.

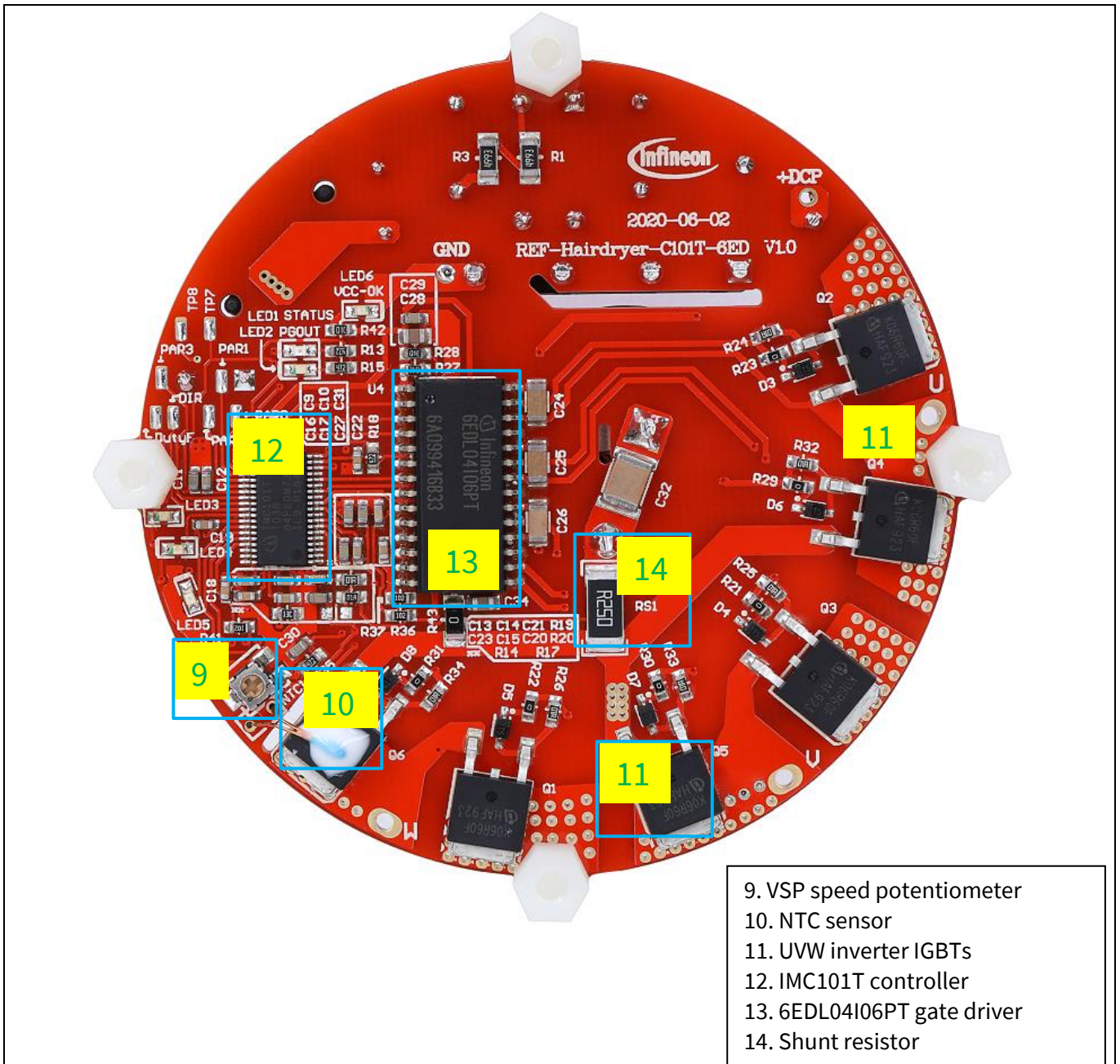


Figure 3 Functional groups of the bottom side of REF-Hairdryer-C101-6ED reference design

The board at a glance

1.3 Main features

The REF-Hairdryer-C101-6ED is a reference design for 100 ~ 240 Vac, 100 ~ 400 W motor drive applications, its characteristics include:

- Input voltage 85 ~ 265 Vac
- 400 W at 220 Vac input (with wind cooling)
- On board EMI filter
- Direct current sensing with single shunt
- VSP speed command potentiometer
- User UART for script function
- Overcurrent and over temperature protection, fault diagnostic LED output
- Auxiliary power supply with 15 V, 3.3 V
- Round PCB in diameter of 70 mm, 2 layers, 1 oz. copper
- RoHS compliant

1.4 Board parameters and technical data

Table 2 depicts the key specifications of the reference design REF-Hairdryer-C101-6ED.

Table 2 REF-Hairdryer-C101-6ED board specifications

Parameter	Symbol	Conditions / comments	Value	Unit
Input voltage	V_{ac}	Optimized design for 220 V _{AC} application	85 ~ 265	V _{rms}
Maximum input current	$I_{ac(max)}$	Input 220 V _{AC} , T _a =25°C, with 1 m/s wind cooling	3	A _{rms}
Maximum output power	$P_{in(max1)}$	Input 220 V _{AC} , f _{PWM} =16 kHz 2-ph PWM, T _a =25°C, T _{IGBT} =105 °C, with 1 m/s wind, 3X AD internal gain	400	W
	$P_{in(max2)}$	Input 220 V _{AC} , f _{PWM} =16 kHz 2-ph PWM, T _a =25°C, T _{IGBT} =105 °C, self-cooling mode, 6X AD internal gain	100	W
Maximum motor current	$I_{mtr(max1)}$	Input 220 V _{AC} , f _{PWM} =16 kHz 2-ph PWM, T _a =25°C, T _{IGBT} =105 °C, with 1 m/s wind, 3X AD internal gain	1.5	A _{rms}
	$I_{mtr(max2)}$	6X AD internal gain allows maximum 1.2A motor output peak current	0.6	A _{rms}
Maximum DC bus voltage	$V_{dc(max)}$	DC bus capacitor is 400 V, 330µF	400	V
Minimum DC bus voltage	$V_{dc(min)}$	Aux power supply brown-in voltage	40	V
Shunt Resistance	R_{sh}	Direct ADC sample (without external OPA)	250	mΩ
Protections				
Motor current protection trigger level at AD internal 3X gain	I_{trip1}	Wizard setup for OC trigger level, related to AD range, shunt resistor RS1 and pull-up bias (R17 & R20)	3.6 ¹	A _{peak}

¹ For iMOTION™ IC IMCxxx, there are three types of Gatekill input source options in MCEWizard setup: Gatekill-pin, Comparator and Both. If you select “comparator” mode, the external Gatekill signal will be not used, and the signal I_Shunt will be compared by the internal comparator with the “Device overcurrent trigger level setting” value set in MCEWizard.

The board at a glance

Parameter	Symbol	Conditions / comments	Value	Unit
Motor current protection trigger level at AD internal 6X gain	I_{trip2}	Wizard setup for OC trigger level, related to AD range, shunt resistor RS1 and pull-up bias (R17 & R20)	1.2	A _{peak}
Motor current protection trigger level	I_{trip3}	Hardware comparator overcurrent protection, related to RS1 and 6EDL04I06PT's Itrip threshold (445 mV typical).	3.56	A _{peak}
Thermal protection level	$T_{protection}$	Temperature gap between junction and NTC sensor needs to be considered	105	°C

Auxiliary power supply 1 – 15 V

Output voltage	V_{out1}	Used for IGBT gate driver	15 ± 2%	V
Maximum output current	I_{out1}		100	mA

Auxiliary power supply 2 – 3.3 V

Output voltage	V_{out2}	Used for IMC controller and protection circuits	3.3 ± 1%	V
Maximum output current	I_{out2}		100	mA

PCB characteristics

Dimension		Round diameter	70	mm
Material		FR4, 1.6 mm thickness, 1oz PCB		

System environment

Ambient temperature	T_a	Non-condensing, maximum RH of 95%	0 ~ 50	°C
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2 System and functional description

2.1 Getting started with REF-Hairdryer-C101-6ED

The REF-Hairdryer-C101-6ED reference designs are shipped with embedded firmware and default parameters. This chapter provides more details on setting up the system and getting started with the iMOTION™ development platform. A 100 W 95000 RPM BLDC hairdryer motor and 400 W 2500 RPM PMSM motor are used for the default DEMO function and thermal test. Please note that motor parameters need to be double-checked in MCEWizard if a different motor is used.

iMOTION™ Link or third-party isolated USB-to-UART 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.

The iMOTION™ software tools, MCEDesigner and MCEWizard, are required to initially set up the system, as well as to control and fine-tune the system performance to match the user's exact needs. These tools are available for download via the Infineon website (<https://www.infineon.com/cms/en/product/power/motor-control-ics/digital-motor-controller-imotion/imc101t-t038/#!tools>). Please visit this page periodically to check for tool/software updates.

After downloading and installing the iMOTION™ PC tools, MCEWizard and MCEDesigner, the following steps need to be taken to run the motor. Please refer to MCEWizard and MCEDesigner documentation for more information.

Figure 4 shows the basic system connection using REF-Hairdryer-C101-6ED to run a hairdryer motor with sensorless mode:

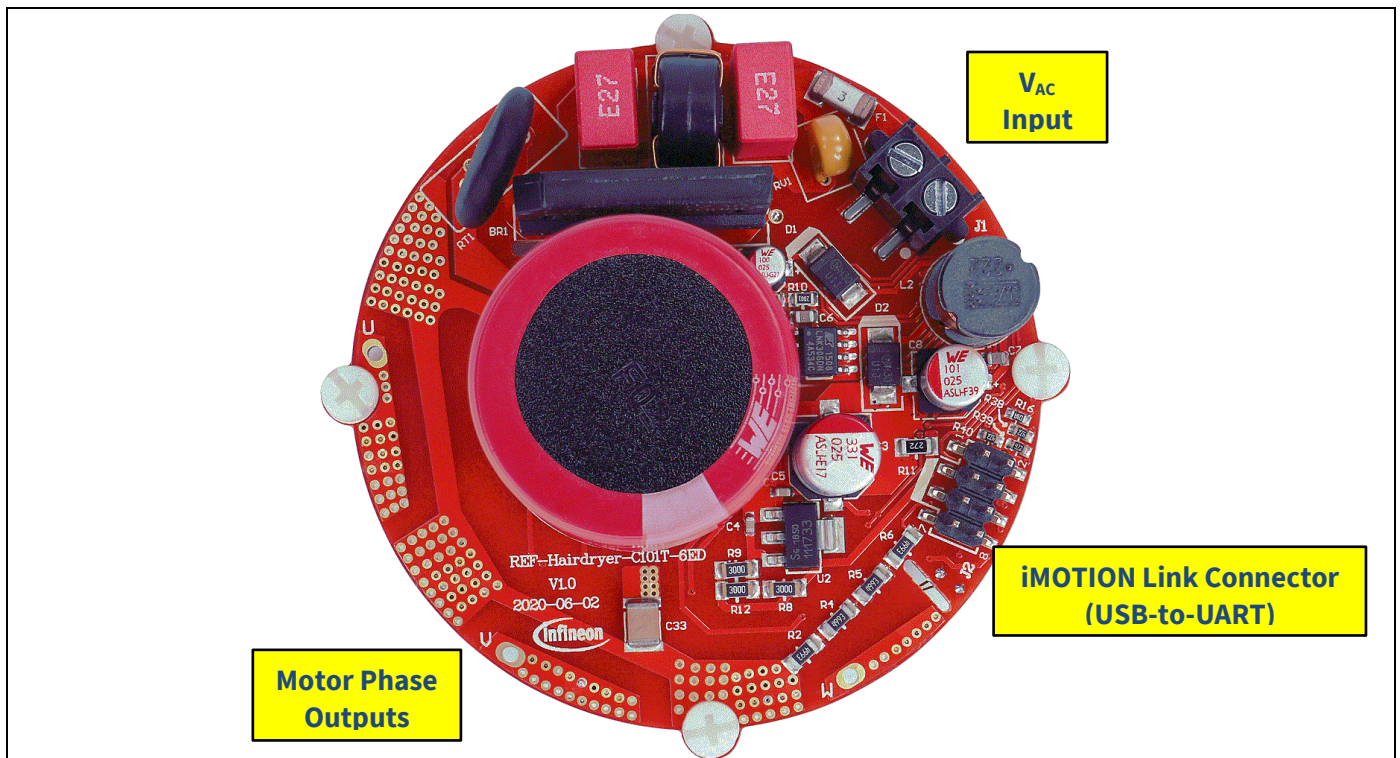


Figure 4 System connection example

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Figure 5 shows the MCEWizard welcome page and interface of MCEDesigner.

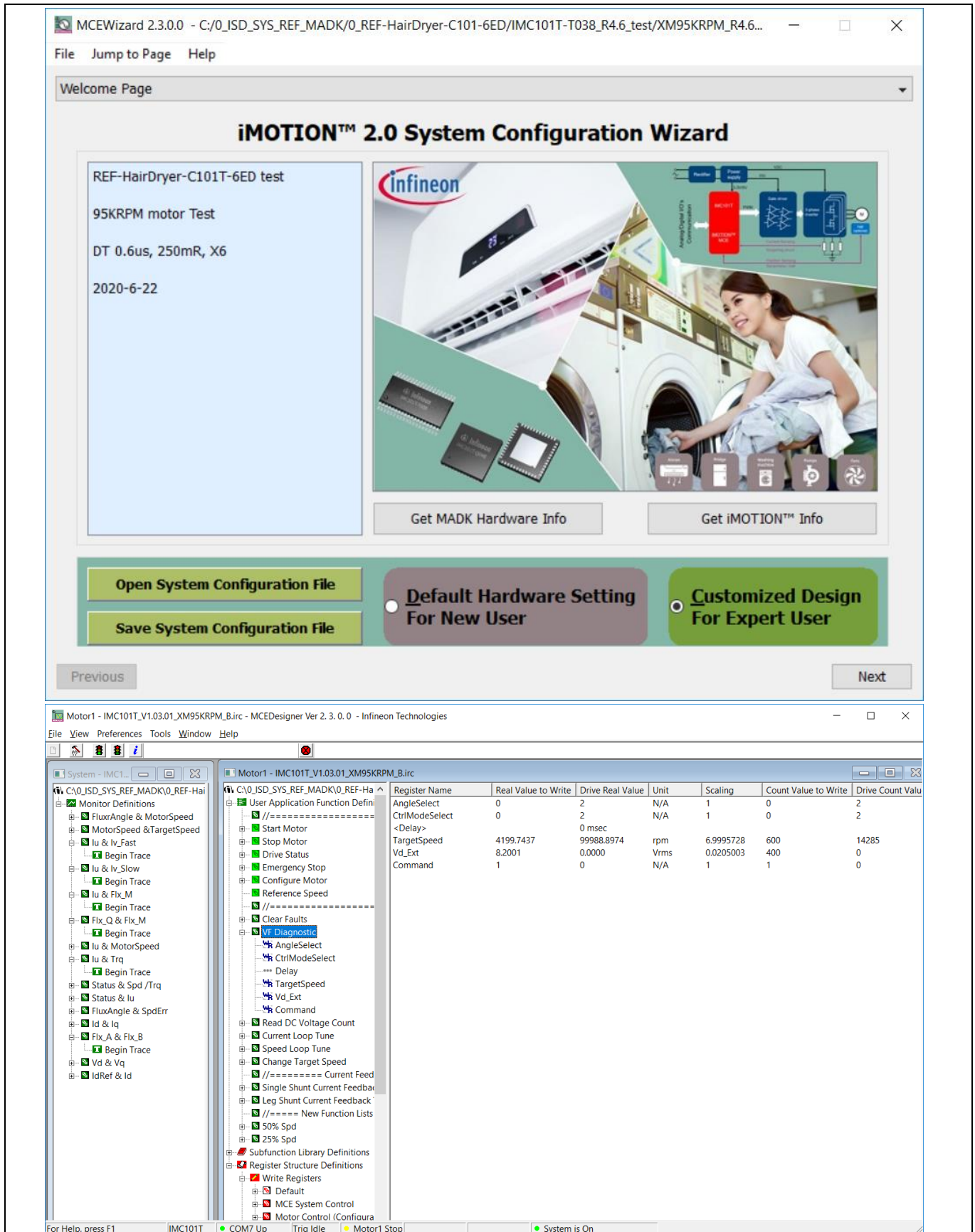


Figure 5 MCEWizard welcome page and MCEDesigner interface

Here are the steps needed to run the motor:

1. Connect iMOTION™ Link's 8-pin cable to J2 **with default pin order** (Align connector orientation markings with PCB silkscreen markings), and connect PC-USB connector to iMOTION™ Link.
2. Use MCEWizard to enter the target motor's system and operating parameters, as well as evaluation board's hardware parameters, which will then be used to calculate the digital parameter set of the controller representing the complete motor drive system.
3. After system and operating parameters are set, go to the "Verify & Save Page" and click on "Calculate Parameters" button. If no errors are reported, then save the drive parameter set into your project directory by clicking "Export to MCEDesigner file (.txt)" (Figure 6); if an error is detected, double-click on the error message (highlighted in **RED**) and adjust the related parameter. The saved drive system parameter file will be later used by the MCEDesigner in step 9.

*(Please refer to **MCEWizard_V2.3.0.0 User Guide.pdf** for more details, which is in MCE Wizard's install path)*

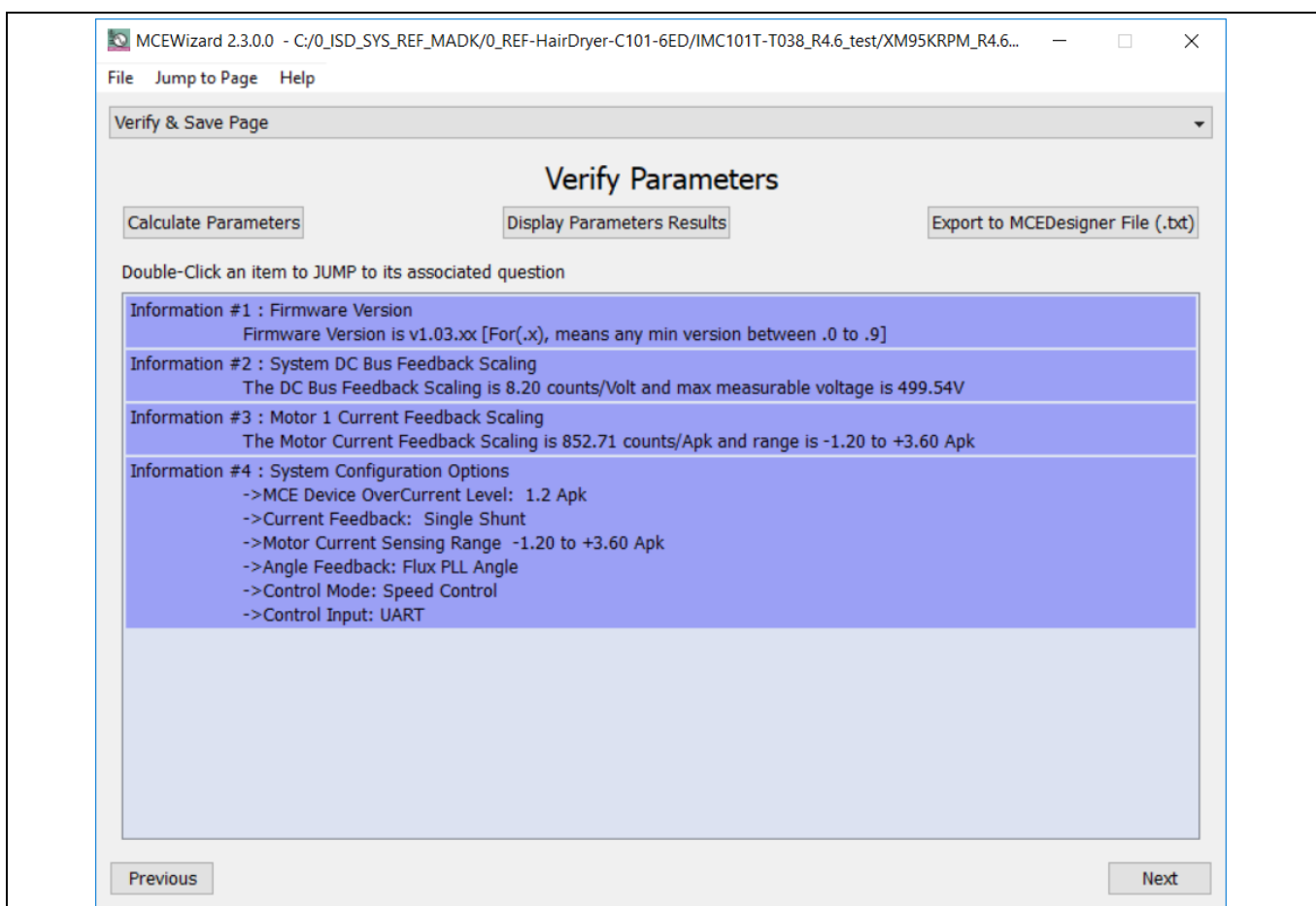


Figure 6 MCEWizard Verify and Save page

4. Connect 220 V_{AC} power supply and UVW outputs to the motor.
5. Power on 220 V_{AC}, LED1, LED2 & LED6 ON.
6. Start MCEDesigner tool and open MCEDesigner default configuration file (.irc) for IMC101T device (IMC101T_Vxxx.irc) by clicking "File" > "Open".
(IMC101T_Vxxx.irc file is included in downloaded "IMC101T MCE Software Package")
7. MCEDesigner should automatically connect to the REF-Hairdryer-C101-6ED board using default COM port *(Indicated by green circle next to "COMx Up" status in the bottom frame of the MCEDesigner GUI)*. If it cannot establish the connection due to incorrect COM port, change COM port by doing the following steps: click on

System and functional description

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.

- 8. In case of blank IC: If the firmware has been erased from the IMC101T, a warning message will pop up saying “Target device firmware and parameters file are not programmed! Please program firmware and parameters file” (Figure 7). See step 9 on how to obtain/program firmware and parameters.

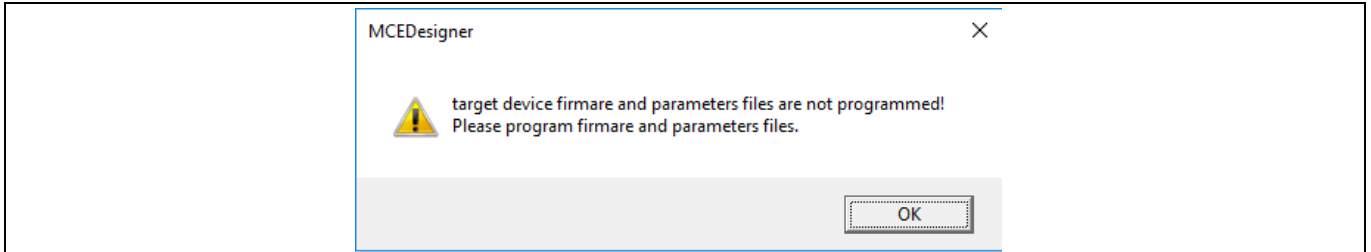


Figure 7 MCEDesigner warning message

- 9. In case of blank IC: Use the following steps to program the firmware and the parameters file into the internal Flash memory of iMOTION™ Control IC: Click on system page, click “Tools” > “Programmer” and select “Program Firmware and Parameters,” shown as Figure 8 below. The encrypted firmware is available in “IMC101T MCE Software Package,” regarding the parameters file, browse and select the .txt file in step 3.

(If blank IMC101T IC, MCE Designer will pop up information “Target device firmware and parameter files are not programmed!”) Program the MCE firmware and system parameters into the internal Flash memory of iMOTION™ IC by clicking “Tools > Programmer” in the pull-down menu, and then clicking on the “Program Firmware and Parameter” check box. Select right Parameter file and firmware file. Finally click “Start” button to program firmware and parameter. Then click YES and then the OK button to update IRC file with parameter file; finally “Save As” the IRC file to your own file name that contains COM config, Parameters & firmware file path information. (Please refer to **MCEDesigner User Guide.pdf** and **MCEDesigner_V2.3.0.0 Application Guide.pdf** for more details, which is in MCE Designer’s install path)

Red LED1 will flash on after the program is done.

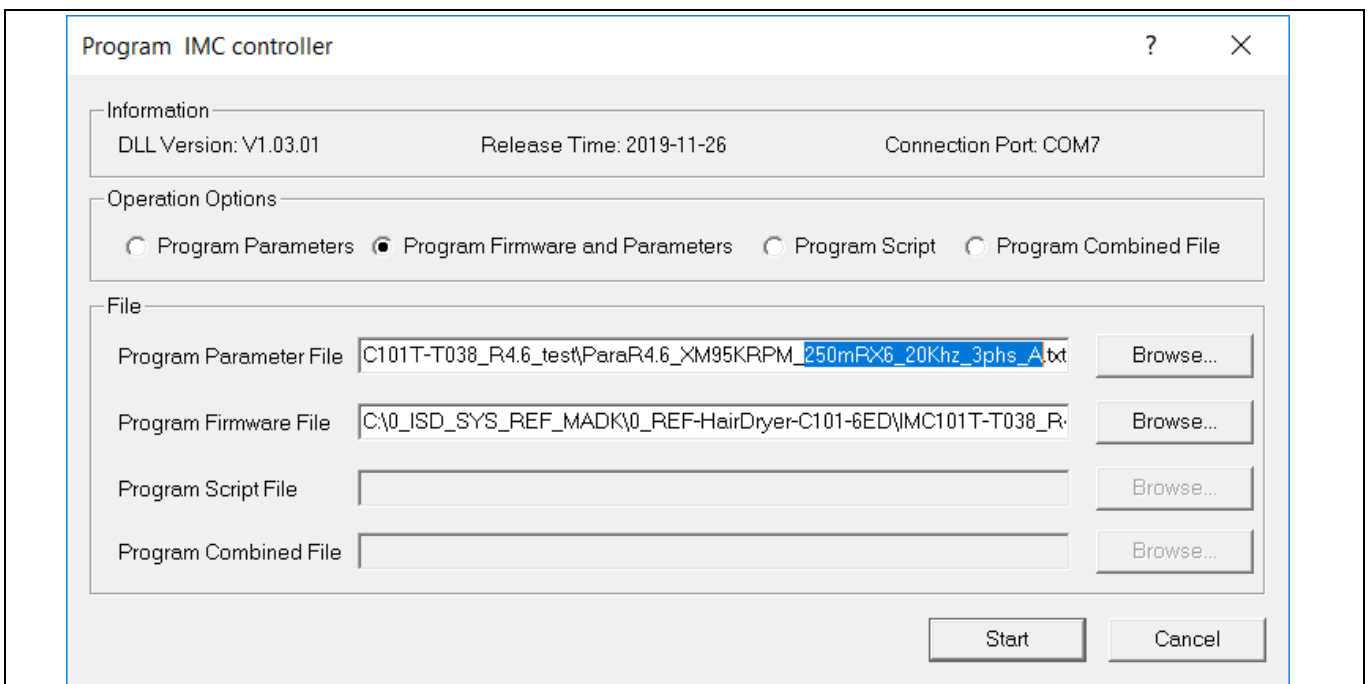


Figure 8 MCEDesigner Program message

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10. Double click “VF Diagnostic” function in motor1 page, monitor motor current with oscilloscope. If motor current is not sinusoidal, change target speed and **Vd_Ext** in VF Diagnostic sub-function, then double-click “VF Diagnostic” until oscilloscope shows a steady sinusoidal current, with amplitude of 30~50% motor rate current.

Double-click “Iu & Iv_Slow” in System page > Monitor Definitions, the motor current feedback would be very clean and sinusoidal, as shown in Figure 9, otherwise please tune “Gating Propagation Delay & Phase Shift Window Size” in MCE Wizard. The sampled motor current amplitude should be **over 300 cts ~500 cts** (corresponding to 30%~50% motor rate current); otherwise, motor current sample-related hardware and setup need tuning for better ADC range usage.

The noise and spike in traced waveforms must be less than 50 cts, or below 5% of motor current; otherwise, motor current sample-related hardware and setup need tuning.

“VF Diagnostic” sub function can verify:

- If motor is correctly connected
- If IGBT & gate driver work as expected
- If current sensing related parameters are correctly configured
- If PCB layout and DC bus decouple have been done correctly

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

Please note that motor shaft might only be vibrating during “VF Diagnostic”, which depends on target speed and **Vd_Ext** setup.

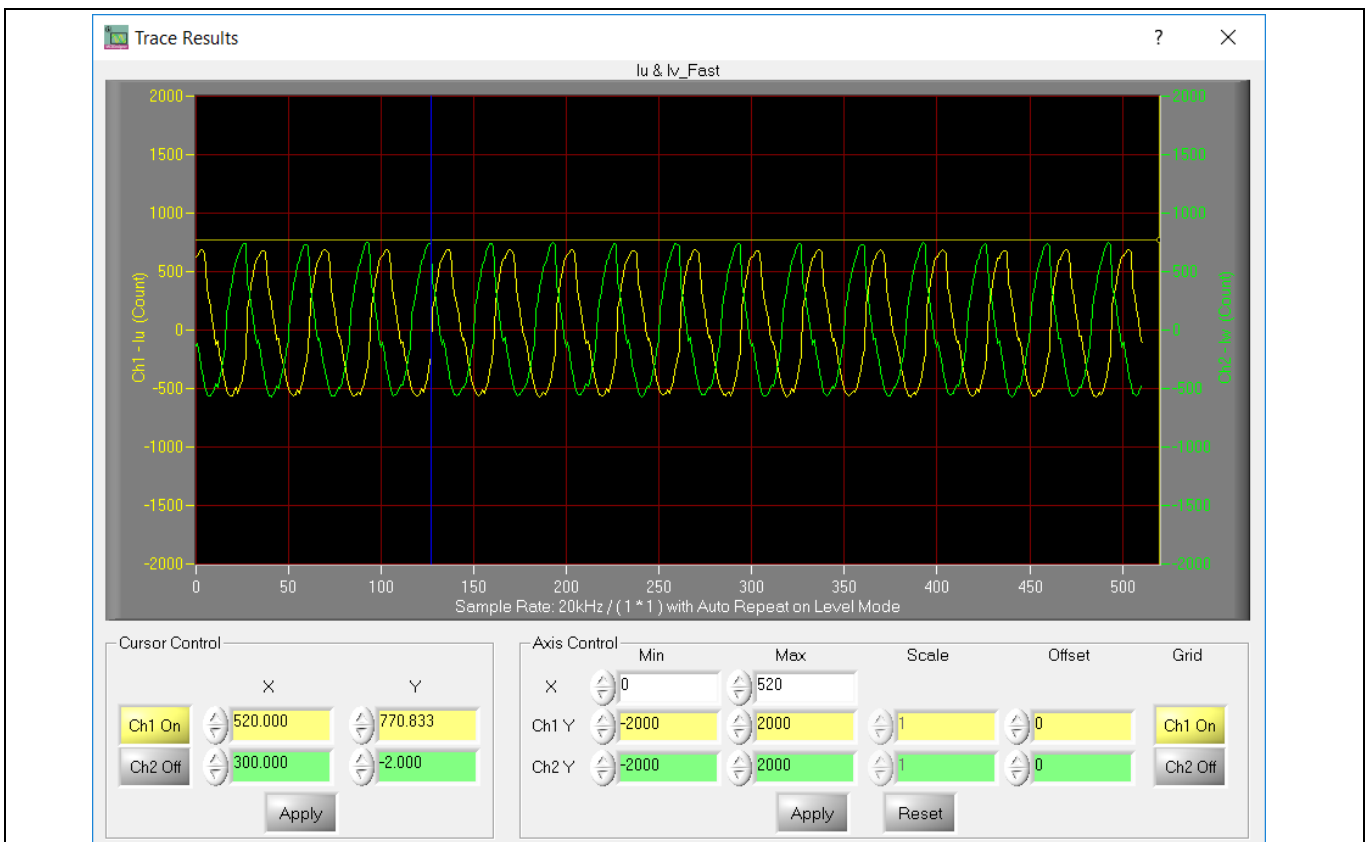


Figure 9 Trace waveform for Iu & Iv open-loop diagnostic

11. Start the motor by clicking the green traffic light button in the control bar (or double-click Start Motor sub function in Motor1 page, group of User Application Function Definitions); motor runs if above step goes well.

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12. Check motor spin direction, adjust UVW connection order or set negative target speed in MCE Designer if direction is wrong.
13. Set target speed to about 50% of speed, start “Iu & Flx_M” trace with “Auto Repeat On Level,” see Figure 10. Flx_M is better within the range of 2000~2500 (rated value is 2048), and MUST be steady and DC-like.

Then set target speed to 100% of rate speed, re-do above trace. Flx_M should be steadier and closer to 2048, as shown in Figure 11.

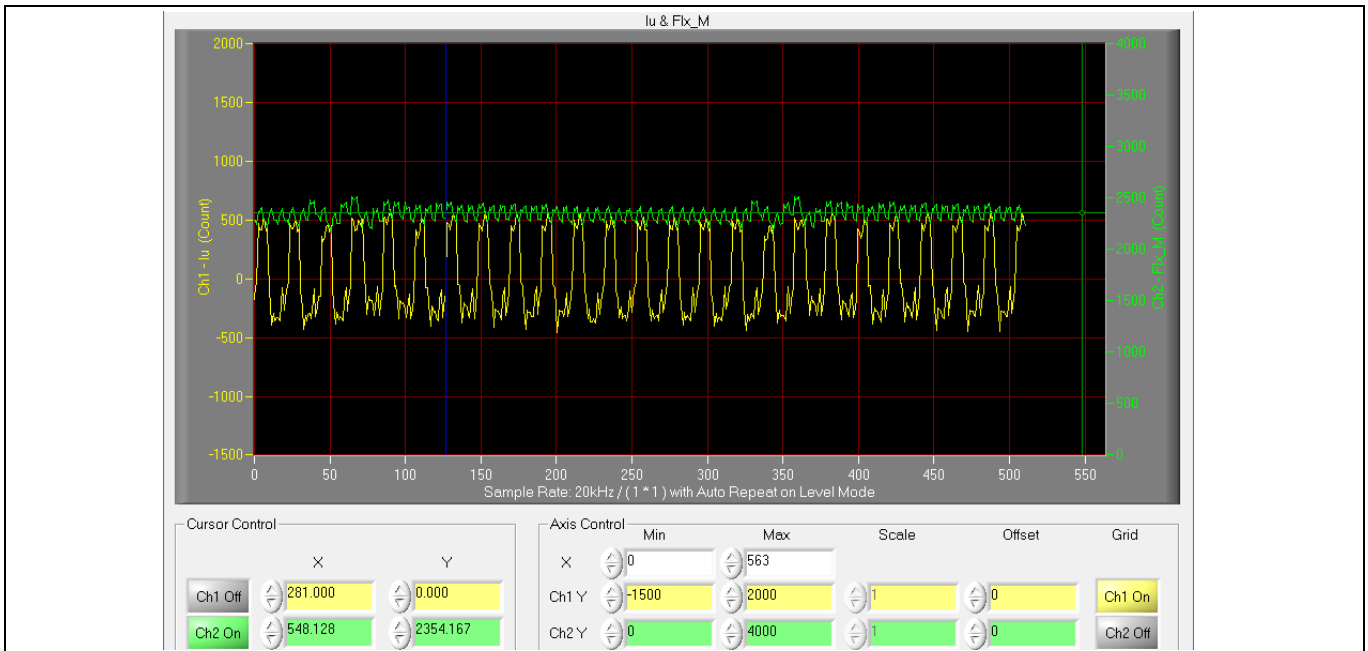


Figure 10 Trace waveform for Iu & Flx-M at 50% speed

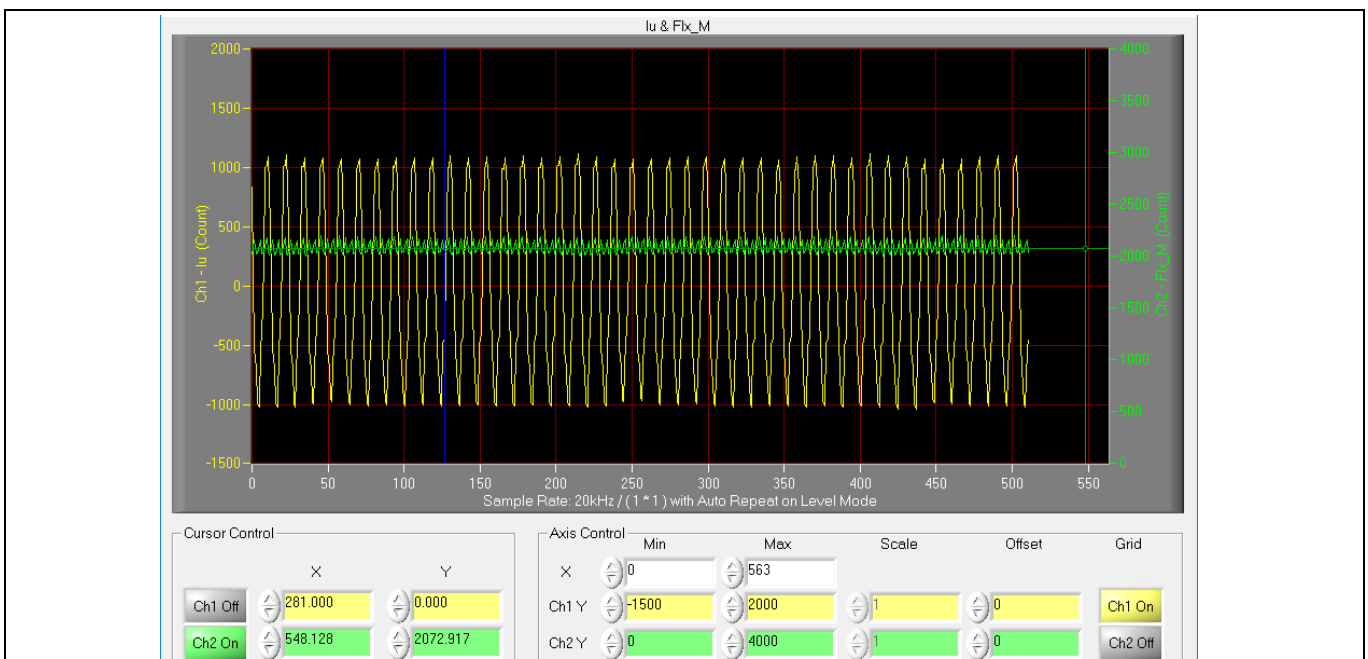


Figure 11 Trace waveform for Iu & Flx-M at rate speed

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Some key tips for better motor-performance tuning:

- If Flx_M is not steady (swinging or oscillating), double-check motor parameters, speed loop PI gain, flux Estimator time constant and PLL PI bandwidth (parameters PLLKp & PLLKi) related setup.
- If Flx_M is very noisy, double check current feedback and Vdc-related hardware and parameters (need both trace waveform and oscilloscope waveform for the modification).
- If Flx_M is far from 2048, “Motor Back EMF Constant (Ke)” needs to be adjusted in MCE Wizard.
- If Flx_M is much difference at 50% and 100% speed (say, over 20%), motor parameters (L_D , L_Q and winding resistance) need double confirm, or this motor runs in high saturation region (especially for some ultra-low cost BLDC motor).

14. Once the firmware has been programmed, in case a new parameter file has to be programmed, follow the same instructions given in step 9. In this case, firmware programming is no longer needed, and it is possible to select the first option “Program Parameters.”

Note1: For detailed information on controller programming, refer to AN2018-33 iMOTION™ 2.0 Device Programming, MCEDesigner documentation and MCEWizard documentation.

Note2: This user guide use “Using Count Value Tune” setup for the MCE Designer trace, which shows original MCE internal data. MCEDesigner’s trace default setup is “Using Real Value Tune”.

Please check the setup with below operation: Click System page > Preferences > Tuning value Format

2.2 Description of the functional blocks

The motor inverter of REF-Hairdryer-C101-6ED reference design is implemented by the 6EDL04I06PT driver and IKD06N60RF RCD IGBT. IMC101T is used for motor control, and motor current sensing is direct AD sensing with single shunt mode.

2.2.1 Overview of 6EDL04I06PT

Figure 12 illustrates the internal block diagram of the 6EDL04I06PT, whose PWM input signal is **high true**.

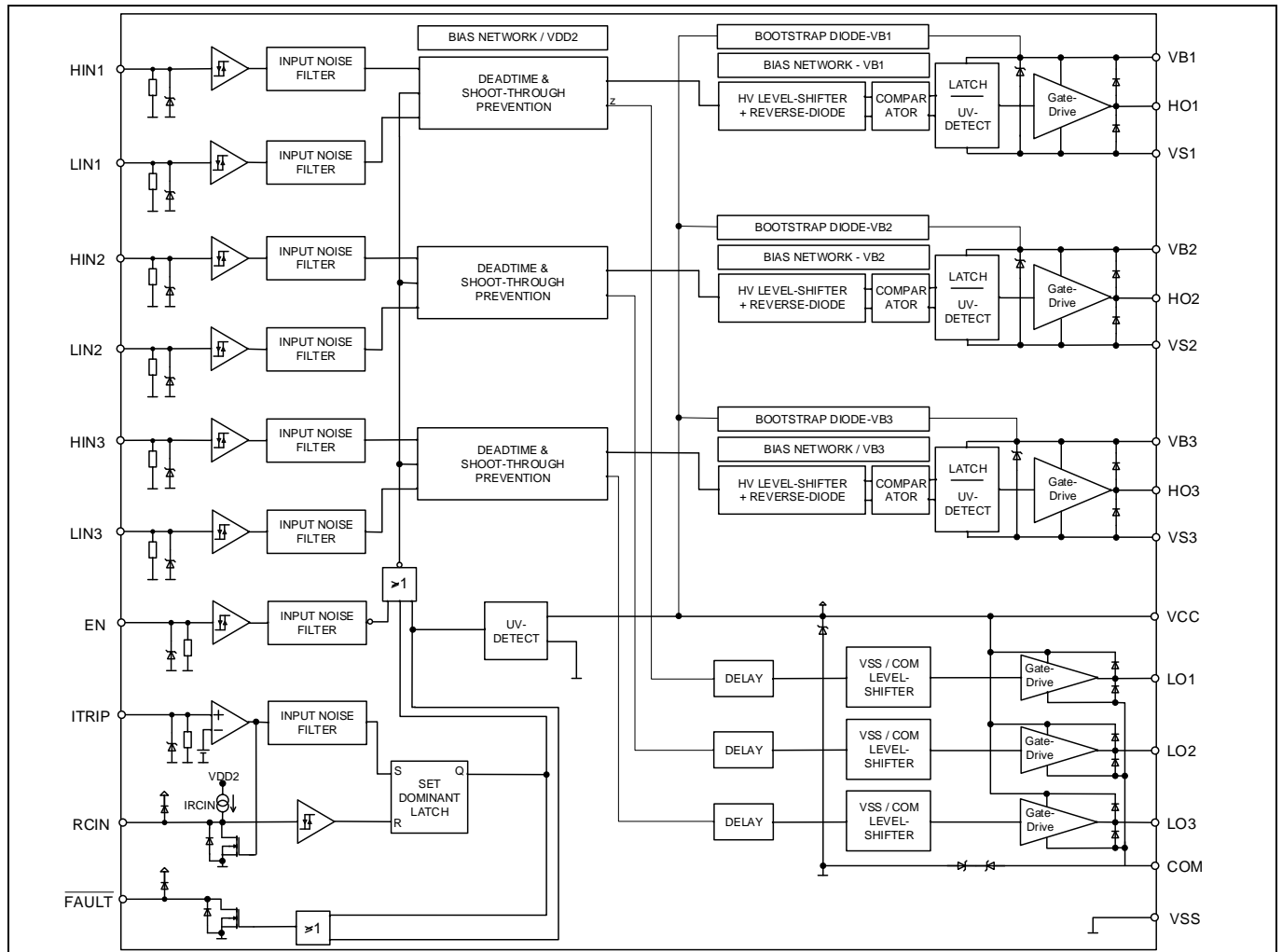


Figure 12 Block diagram of 6EDL04I06PT

6EDL04I06PT is DSO-28 package; the pin definition is the same as IRS2136 except for the active logic, as shown in Figure 13.

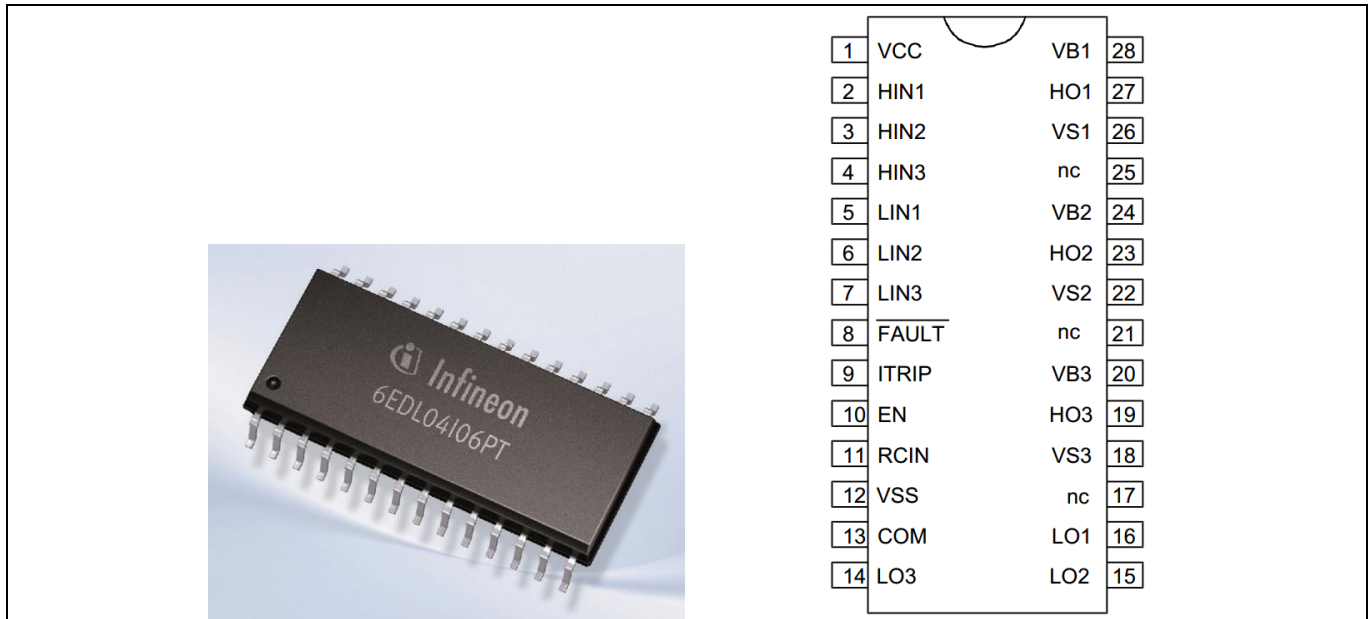


Figure 13 6EDL04I06PT lead assignments PG-DSO-28 (top view)

Main features of SOI three-phase gate driver 6EDL04I06PT include:

- Infineon thin-film SOI technology
- Fully operational to +600 V, floating channel designed for bootstrap operation
- Output peak source/sink current capability +240 mA/-420 mA
- Integrated ultra-fast, low $R_{DS(ON)}$ bootstrap diode
- Separate control circuits for six drivers
- Tolerant to negative transient voltage up to -50 V
- Overcurrent protection with 445 mV (+/-15 % tolerance) reference threshold
- Externally programmable delay for fault clear after overcurrent detection
- Shut down of all switches during error conditions
- 3.3 V, 5 V and 15 V input logic compatible
- Signal interlocking of every phase to prevent cross-conduction, Internal dead time 310 ns (typical)
- Intergrate input filter, no external filters needed to reduce noise sensitivity
- RoHS compliant

2.2.2 Overview of IMC101T

IMC101T is a member of iMOTION™ high performance motor control IC, whose main features include:

- Motion control engine as ready-to-use controller solution for sensorless and Hall-sensor motor drives
- Field-oriented control (FOC) for permanent magnet synchronous motor (PMSM/BLDC)
- Optional support for Hall sensors (analog or digital)
- Space vector PWM with sinusoidal commutation and integrated protection features
- Current sensing via single shunt or leg shunt
- Integrated analog comparators for overcurrent protection

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- Integrated scripting engine for application flexibility
- 3.3 V or 5.0 V supply voltage options for controller
- Flexible host interface options for speed commands: UART, SPI, PWM or analog signal
- Class B pre-certification (IEC60335) for MCE2.0 firmware

2.2.3 Design tips for direct current sensing

From the point view of the AD convertor, the current input scaling value is the product of the shunt resistance in milliohms and gain of external current sense amplifier for motor control design, as shown in Figure 14.

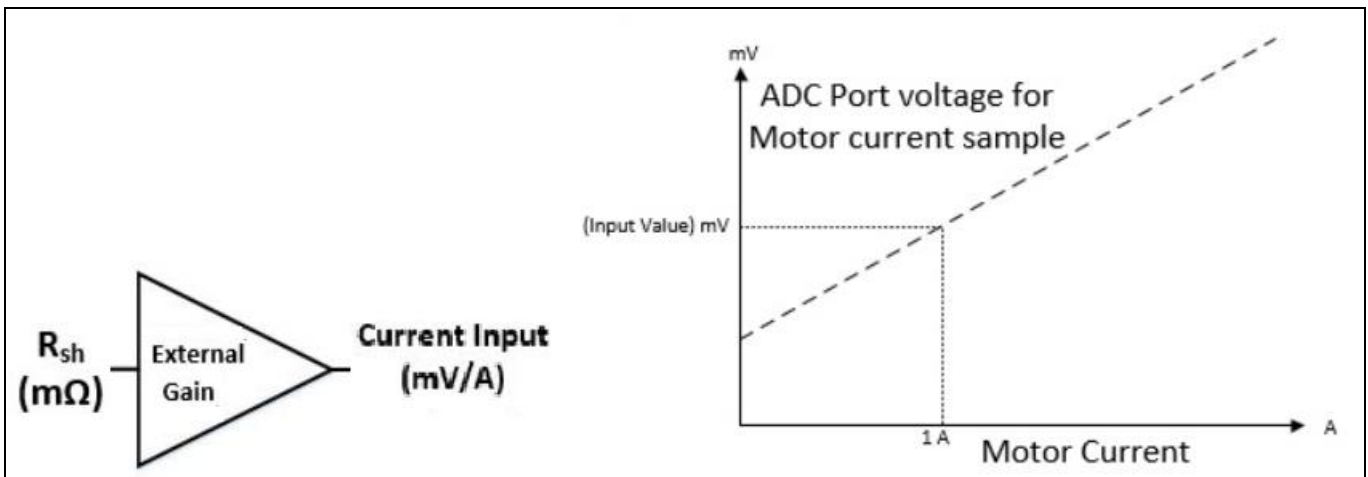


Figure 14 Current feedback scaling outside IMC101T

Direct AD sample is used in the REF-Hairdryer-C101-6ED reference design, since hairdryers are cost-sensitive applications, which means, they are without external op-amp, only RC for operational gain & bias (R17 & R20), and low pass filter (R19 & C21), as shown in Figure 15.

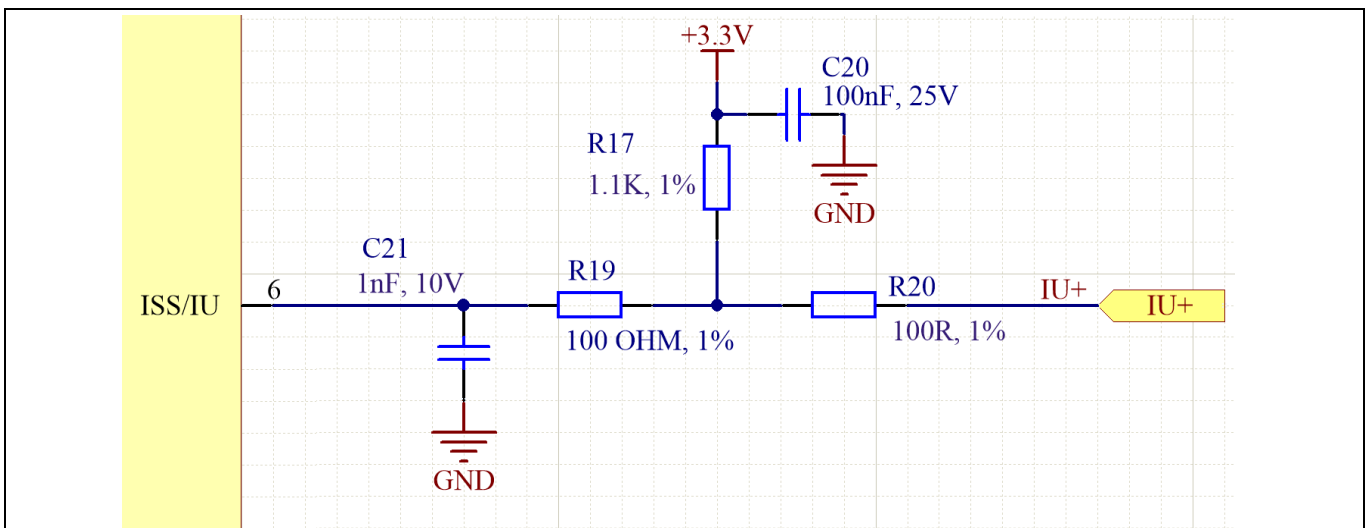


Figure 15 Direct AD sample (current feedback without external op-amp)

R19 & C21 is a low pass filter for switching noise suppression, whose time constant is about 0.1~0.5 μ s normally. The real AD input voltage is decided by the divider of R17 & R20, with bias of 275 mV and gain of 0.916:

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SOI driver & Hairdryer application reference design kits

System and functional description

$$AD\ input = \frac{R_{17}}{R_{17} + R_{20}} RS_1 * I_{bus} = \frac{1.1K}{1.1K + 0.1K} RS_1 * I_{bus} = 0.916 * RS_1 * I_{bus}$$

A 250 mOhm 2W 2512 package single shunt resistor and 1.1 k & 100 Ohm pull-up net is the default configuration for the REF-Hairdryer-C101-6ED reference design, which means 1A DC bus current produces 229 mV voltage to ADC input, MCE Wizard’s “Motor1 Current Input Scaling” needs input as 229 mV/A (250*0.916=229).

Please note that Internal Current Feedback Amplifier Gain (Question 88 for MCEWizard V2.3.0.0) is ADC’s internal gain, which defines the MAX ADC input range to $V_{cc}/Gain$. For 3.3 V power supply, the ADC sensing range is 0~1.1 V if 3X internal gain is selected, and 0~550 mV if 6X internal gain is selected, 0~275 mV if 12X internal gain is selected.

R17 & R20 also determine the ADC operational bias for current sensing, which corresponds to the motor regeneration operation range. For those applications that only work in motoring mode, the bias can be as low as possible to reserve enough ADC range for the motoring mode, since negative input would not occur.

Motor 1 Current Feedback and Sample Timing

Question 83 - Motor 1 Current Input Scaling

This parameter is the gain of the external current single/leg shunt measurement circuit.

This value is the product of the shunt resistance in milliohms and the ac gain of the offset and gain circuit:
 $G_{ext} \times R_s$.

In the circuit example, the gain calculated from analysis with $R_s \sim 0$, is given by:
 $G_{ext} = R_2 / (R_1 + R_2)$.

The input filter capacitor, C1, should be selected so that the offset and gain circuit time constant is less than 400ns to minimize the impact on current sampling.

High current applications may require an active offset and gain circuit to support low resistance shunts or to improve the measurement signal to noise ratio.

Offset & gain circuit

$V_{AD} = G_{int} (V_{off} + G_{ext} \times R_s \times I_s)$

$V_{in} = V_{off} + G_{ext} \times R_s \times I_s$

$V_s = I_s \times R_s$

Answer: mV/A

Figure 16 Current feedback configuration in MCEWizard

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System and functional description

Please note the following two design guidelines for direct AD sample:

- The external RC network's input gain is less than 1. Normally ADC internal gain needs to be configured to X3, X6 or X12 to lower the required input signal range, and reduce shunt resistor power dissipation. RS1 must be much higher than 10 mOhm to achieve enough current sensing signal-to-noise ratio (SNR) and improve control performance: For example, to achieve sufficiently high SNR, motor current sensing counts need be **over** 30~50% of AD range (traced Iu peak **over** 600 cts~1000 cts) at rate motor current, and PCB ground noise lower than 5% of total sampled signal in MCEDesigner trace result. Very low SNR might cause the motor start to fail, or not running smoothly at low power.
- There is NO common-mode noise-rejection ability, compared to external op-amp sample mode. Direct AD current-sensing mode needs to deal with the PCB GND network very carefully to reduce grounding noise as much as possible, to make shunt resistors **as close as possible** to IMC101T IC and DC bus capacitor. Please note that any voltage difference between IMC101T's ADC ground and shunt resistor ground will be considered as an "input signal" and will deteriorate control performance or increase motor audible noise.

2.2.4 Overcurrent protection and motor gatekill configuration

Figure 17 displays the overcurrent protection circuit for the IMC101T application. R17 & R20 sensed voltage is connected to ADC and internal comparators to achieve the overcurrent protection function. Only internal comparators are used for overcurrent protection.

The reference of the internal comparators is set by IMC101T's internal DAC (Sigma delta DAC, stream output), and external C23 is the low pass filter capacitor. MCEWizard calculates the DAC reference voltage based on the question input of "Device Overcurrent trigger level setting for Comparator" and "Motor1 Current Input to ADC Offset Voltage." MCEWizard's output parameter CompRef defines the DAC output voltage, which depends on the 3 items listed below, and shown in Figure 18 ~ Figure 20:

- A: Expected OC threshold
- B: Gain of external current sensing network
- C: Offset of the external op-amp or RC divider

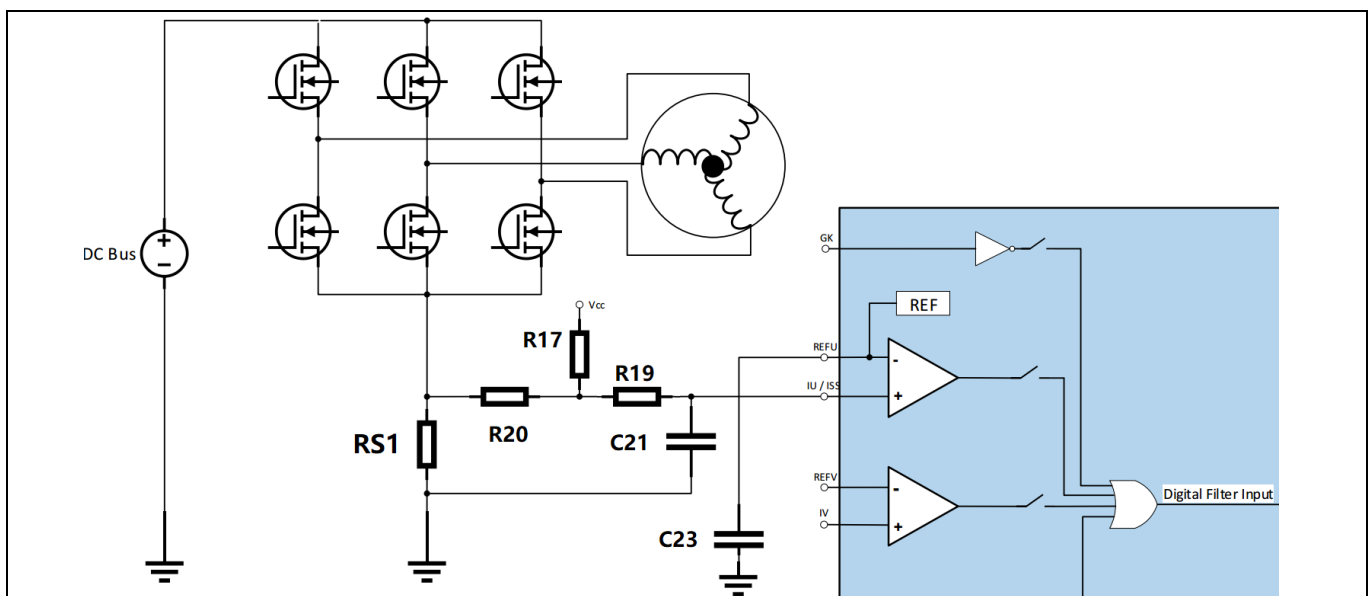


Figure 17 Overcurrent protection circuit on the REF-Hairdryer-C101-6ED reference design

Question 93 : Motor 1 Gatekill Setup - Overcurrent Trip Level for Internal GateKill Comparator

Motor 1 Gatekill Setup

Question 93 - Overcurrent Trip Level for Internal GateKill Comparator

This parameter specifies the shunt current trip level that will cause the measurement signal to exceed fault threshold level if the comparator has been selected as a Gatekill Input Source in the previous question.

The comparator fault threshold voltage is generated by an internal DAC. When the current measurement signal exceeds this level a fault signal is provided to the fault handling circuits. The comparator threshold voltage is determined from the gain and offset of the measurement circuit provided in previous questions.

Warning: Setting this value too high may lead to power device destruction or motor demagnetization.

Answer: A

Figure 18 Overcurrent protection trigger level setup in MCEWizard

Question 85 : Motor 1 Current Feedback and Sample Timing - Motor 1 Current Input to ADC Offset Voltage

Motor 1 Current Feedback and Sample Timing

Question 85 - Motor 1 Current Input to ADC Offset Voltage

This parameter is the voltage offset of the external current single/leg shunt measurement circuit.

This value is the voltage in mV at the current sense pin when the shunt current is zero.

The ADC accepts unipolar inputs only so the input signal must be offset from 0V to support bipolar measurements.

Typically the offset voltage (V_{off}) is set so the ADC input voltage at zero current is half way between VDD and 0 V. In this case the offset voltage is derived from the internal amplifier gain is:

$$V_{off} = (VDD/2)/G_{int}$$

In the circuit example, the R1 and R2 are selected so that:

$$R1 / (R1 + R2) = (Voff / VDD)$$

assuming $R_s \sim 0$.

Answer: mV

Figure 19 Offset setup in MCEWizard

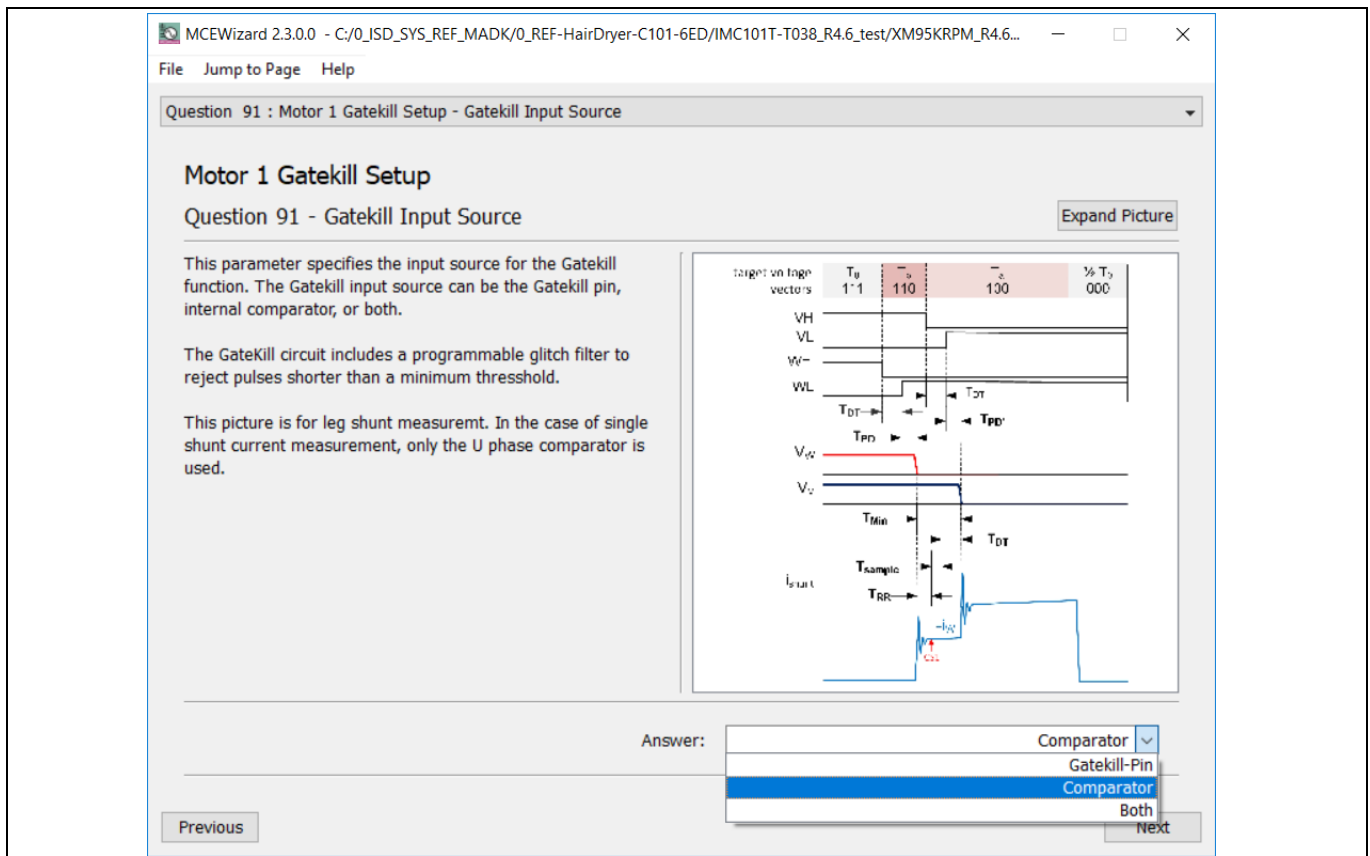


Figure 20 Gatekill input source setup in MCEWizard

Normally, it is recommended to set a value higher than the motor’s maximum peak current (maximum RMS current * 1.414) in “Overcurrent Trip Level for Internal Gatekill Comparator”, with a reserve of at least 30% margin, especially for low impedance motors, of which peak sawtooth current would trigger unwanted overcurrent fault (fake GK fault).

2.2.5 Design tips for negative transient voltage on V_S pin ($-V_S$)

A common problem in today's power switching converters is the transient response of the switch node's voltage, as the power switches transition on and off quickly while carrying a large current, as illustrated in Figure 21.

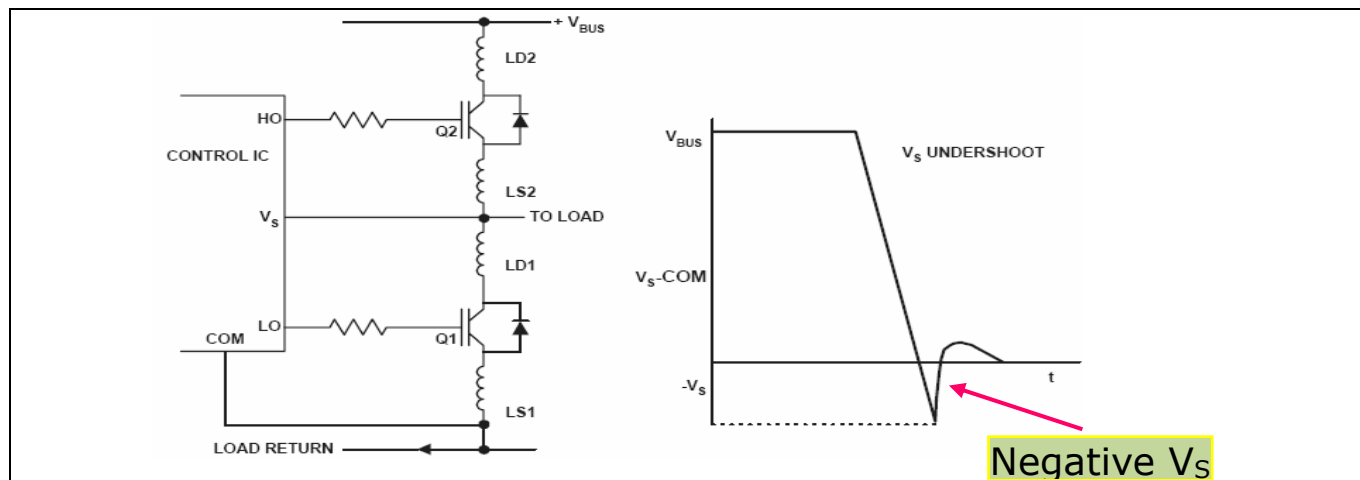


Figure 21 Negative V_S

This negative V_S voltage can cause the high side output to change state, or the device to latch up resulting in large currents or I_{QCC} shifts. A high side output transition from high to low will not damage the IC or the switch, however, a high side output transition from low to high when the low side is on can cause switch damage or unreliable motor operation.

Negative V_S excursions occur during faster switching events over long PCB traces or wiring harnesses that form a parasitic inductor. The higher the parasitic inductor value and switching frequency, the larger is the potential negative V_S voltage that is developed during a switching event.

Negative V_S immunity is a key determining factor in selecting a robust gate driver IC that will be more immune to negative V_S excursions due to inductive parasitic on the PCB or wiring harness.

In a typical motor drive system, dV/dt is typically designed to be in the range of 3-5 V/ns. The negative transient voltage can exceed this range during some events such as short-circuit and overcurrent shutdown, when di/dt is greater than in normal operation.

6EDL04I06PT has been designed for the robustness required in many of today's demanding applications. An indication of the robustness of 6EDL04I06PT can be seen in datasheet electrical parameters that shows a -50 V 500 ns immunity for negative transients on V_S node.

Even though the 6EDL04I06PT has been shown to be able to handle these large, negative transient voltage conditions, it is highly recommended that the circuit designer always limit the negative transient voltage on the V_S pin as much as possible by careful PCB layout and component use.

System design

3 System design

The REF-Hairdryer-C101-6ED reference design is an optimized design for 220 V small home appliances like hairdryers. To meet individual customer requirements and to make the REF-Hairdryer-C101-6ED board a basis for development or modification, all board design data such as schematics, Gerber and Altium design data can be found on the Infineon homepage.

3.1 Schematics

The overall schematic diagram for the IMC101T controller is provided in Figure 22.

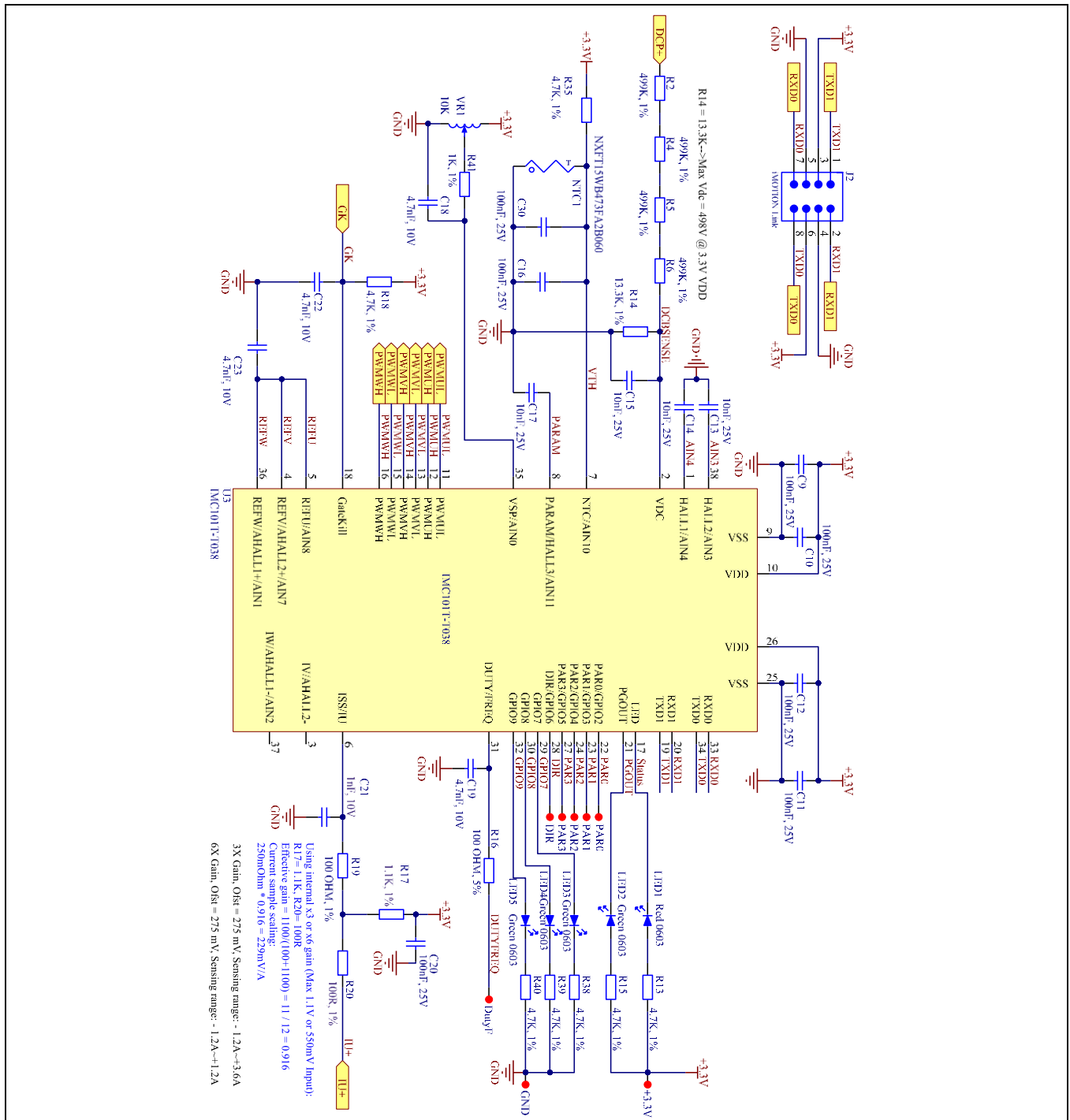


Figure 22 Schematics for REF-Hairdryer-C101-6ED: IMC101T controller

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System design

Figure 23 depicts the schematic of the auxiliary power supply for the REF-Hairdryer-C101-6ED board. A high voltage buck DC-DC for 15 V and one linear LDO used for 3.3 V power supply.

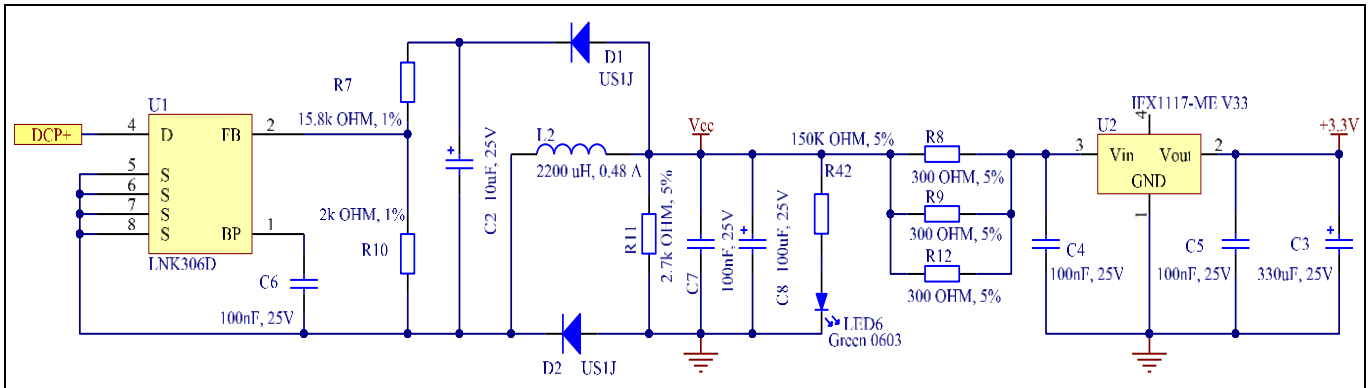


Figure 23 Power supply section of the REF-Hairdryer-C101-6ED reference design

The inverter section is implemented using 6EDL04I06PT plus IKD06N60RF as sketched in Figure 24.

6EDL04I06PT driver ability is source current +0.24 A and sink current -0.42 A; R24 & R32 are the gate resistors to control the U phase IGBT's ON time, and R24 & R32 together with R23 & R29 to set the OFF time.

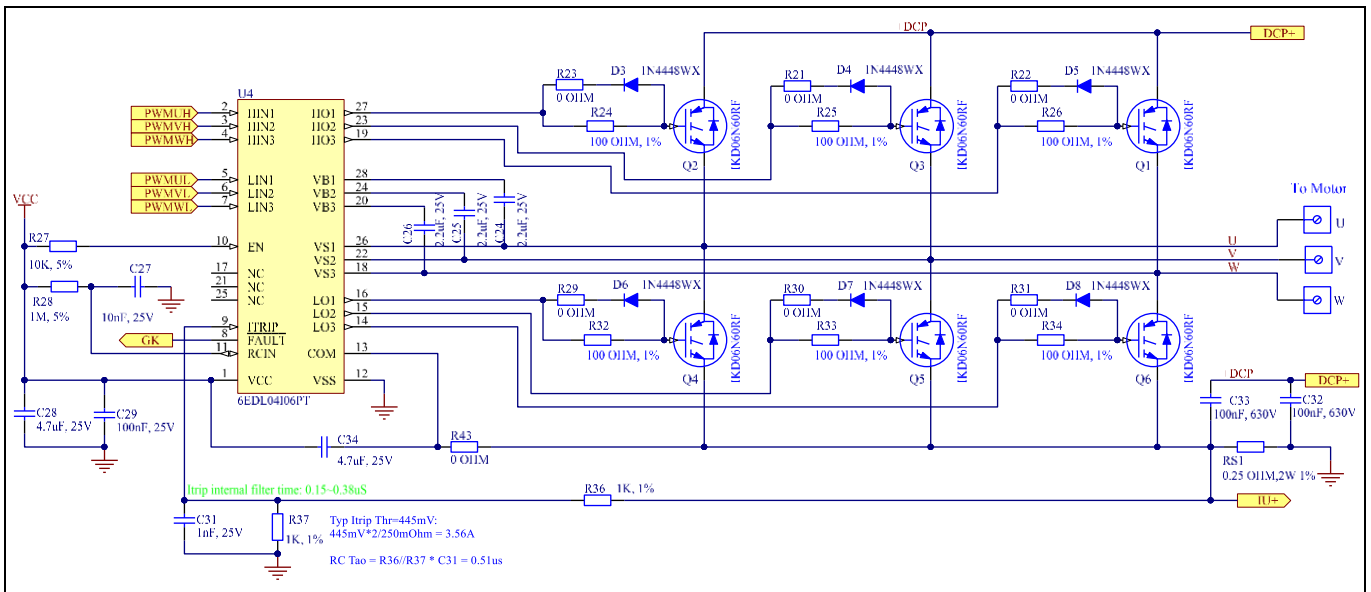


Figure 24 Inverter section on REF-Hairdryer-C101-6ED

The recommended dead time is 400~800 ns for MCEWizard setup, which represents a real ON/OFF time of 100~300 ns, as shown in Figure 25 and Figure 26 (CH1: U_{GE} for low side IGBT, CH3: motor current, CH4: U_{GE} for high side IGBT).

Note: The gate resistors and dead time setup need adjusting if new IGBTs are used, since different IGBT have different Q_g .

System design

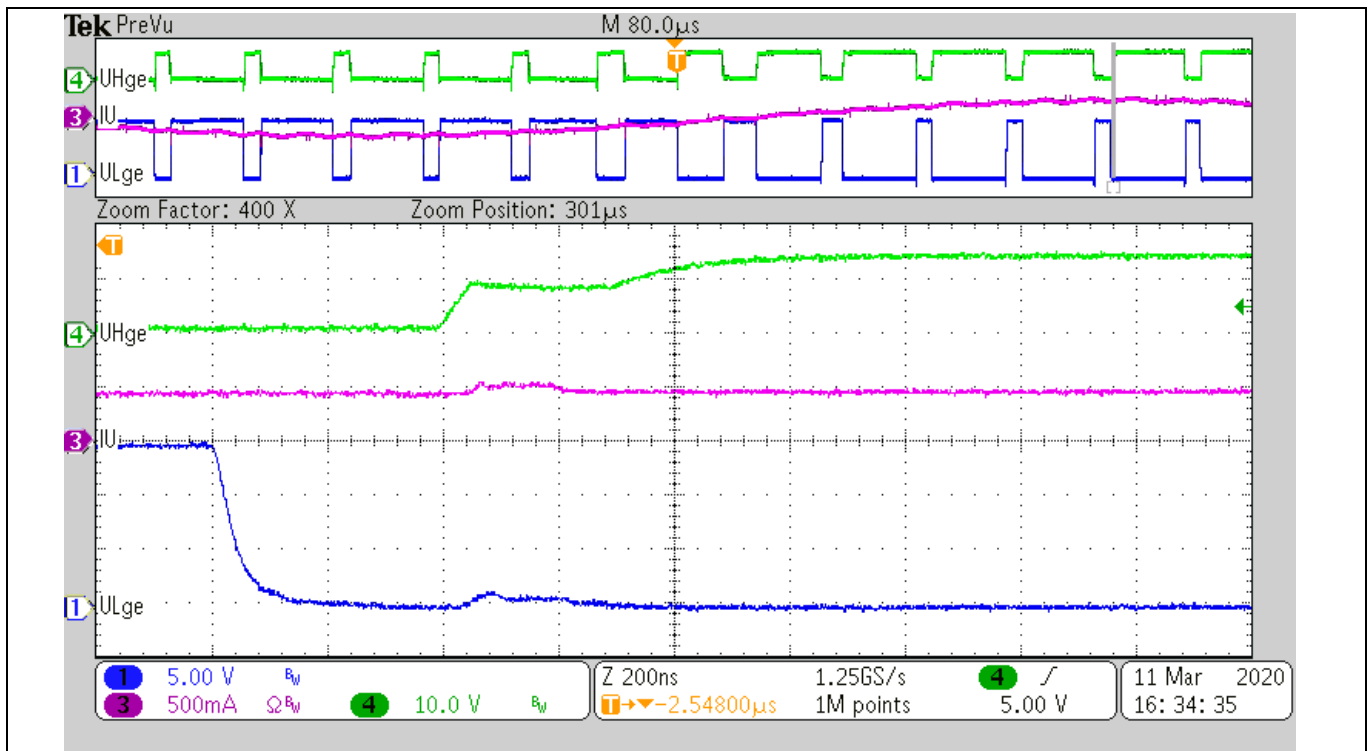


Figure 25 ON-time test waveform

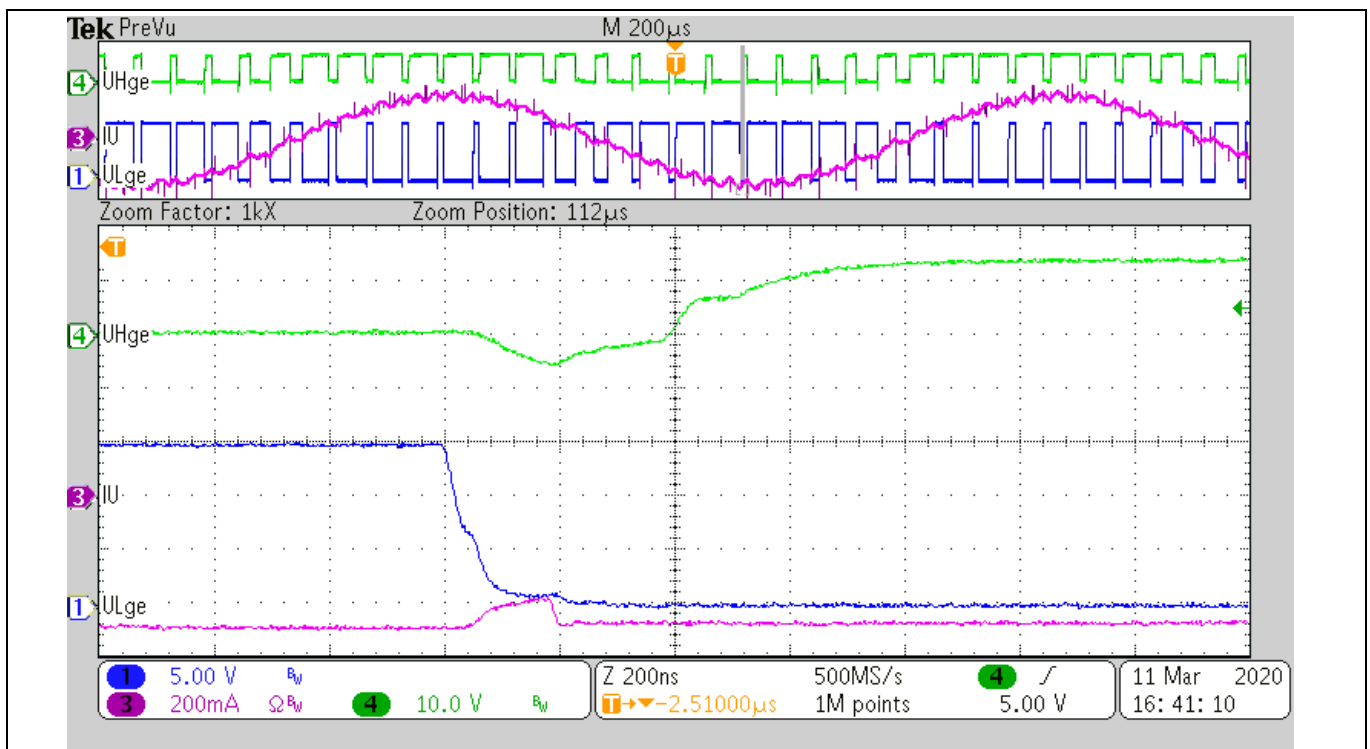


Figure 26 OFF-time test waveform

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System design

Figure 27 provides the DC bus sense resistor details on the REF-Hairdryer-C101-6ED reference design.

The high-side resistor is 2000 kOhm (R2+R4+R5+R6) and low side resistor is 13.3 kΩ (R14), 0 ~ 499.5 V DCBUS reflecting 0 ~ 3.3 V at the ADC input pin with 3.3 V power supply.

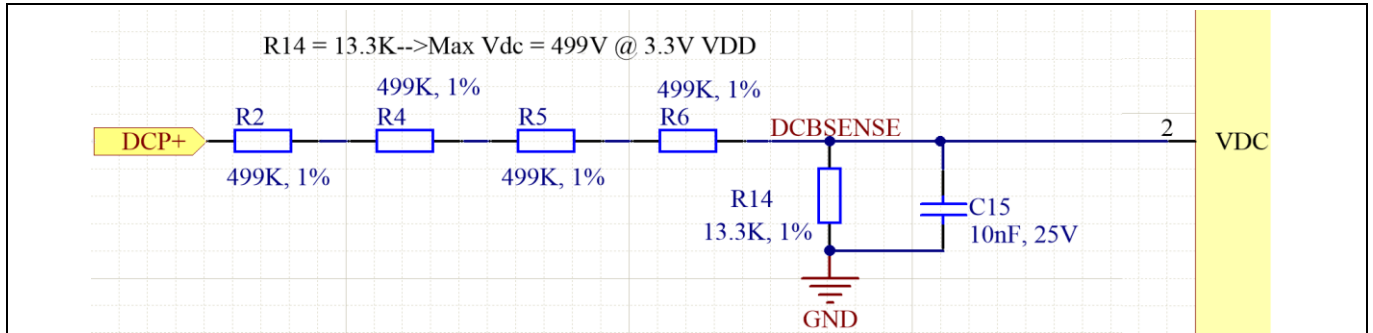


Figure 27 DC bus sense resistor on REF-Hairdryer-C101-6ED reference design

For a wider DC sensing range, R14 can be adjusted to a lower value; the hardware changes should be configured in MCEWizard, as shown in Figure 28.

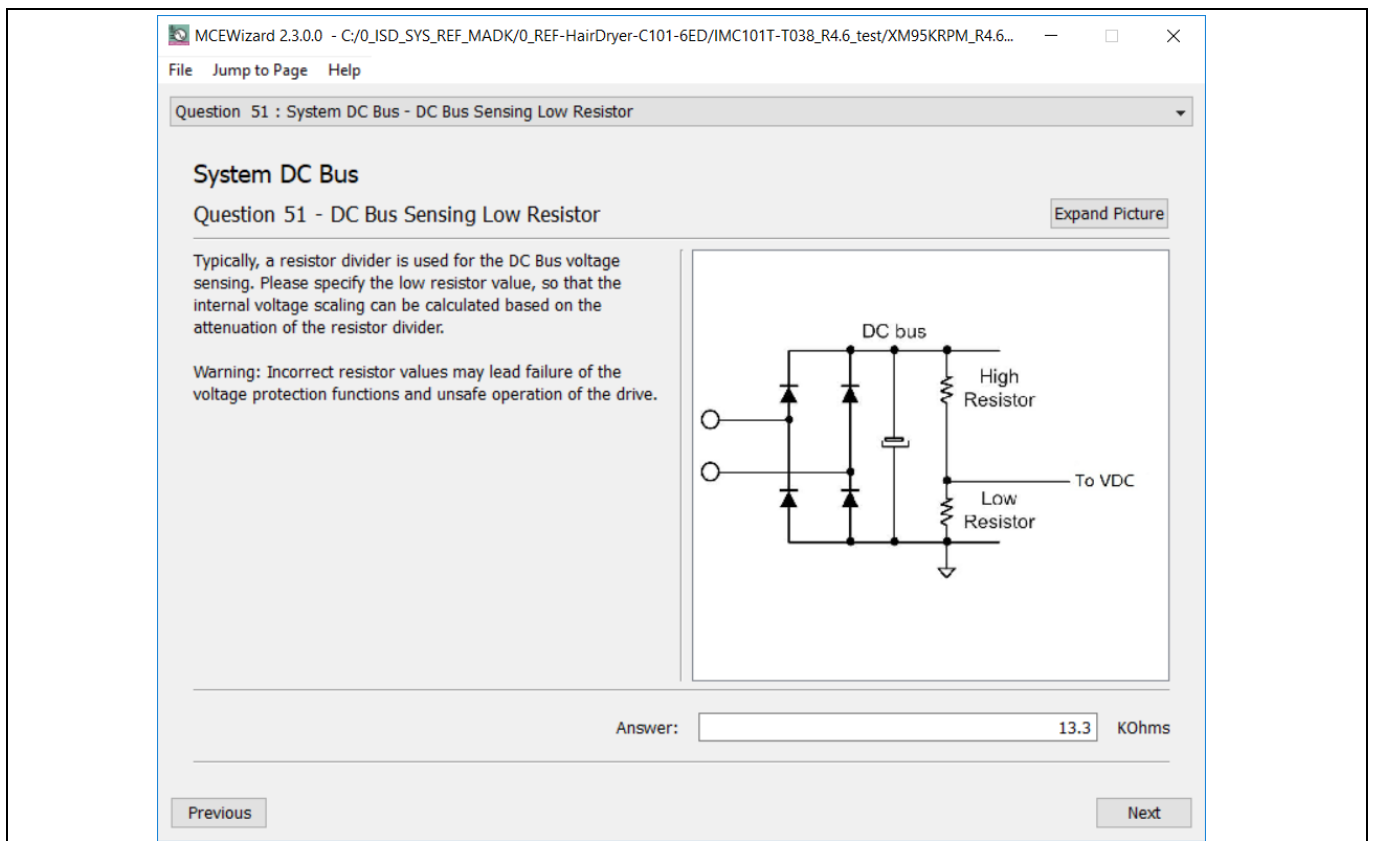


Figure 28 DC bus sensing configuration in MCEWizard

The Vdc sensing low-pass filter time constant is $(R2 \sim R6 // R14) * C15 = (2000 \text{ k} // 13.3 \text{ k}) * 10 \text{ nF} = 132 \mu\text{s}$, which is at least two times the 16 kHz PWM periods (66 μs); C15 can be adjusted to higher capacitance for clean Vdc sensing, if new motor and new IGBT cause Vdc bus sensing noise at MCEDesigner trace.

System design

3.2 Layout

This board has two electrical layers with 35 µm copper (standard). Its main part size is round 70 mm, maximum 76 mm with mounting hole, which can be put inside the hairdryer, to use the air flow to cooling this board. The PCB board thickness is 1.6 mm.

Figure 29 illustrates the top and bottom assembly print of the reference design.

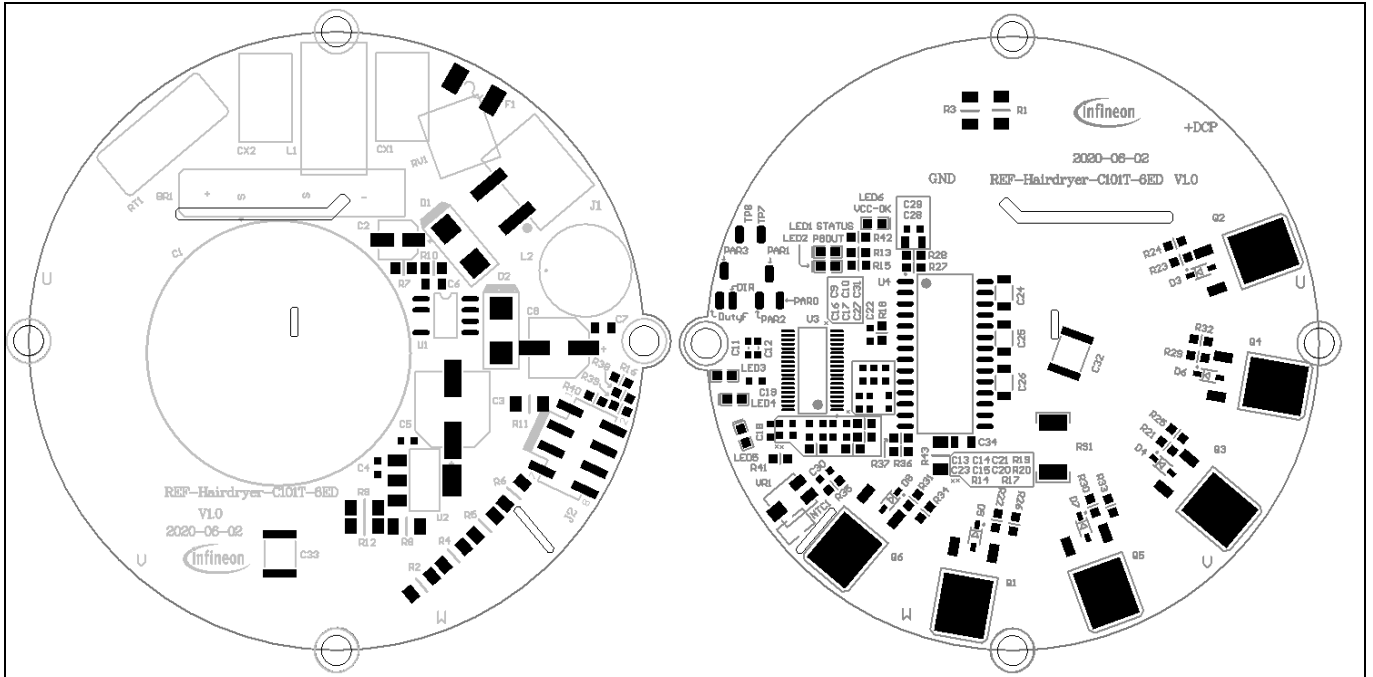


Figure 29 Top and bottom assembly print of the REF-Hairdryer-C101-6ED reference design

The top and bottom layer routing of the PCB is provided in Figure 30 .

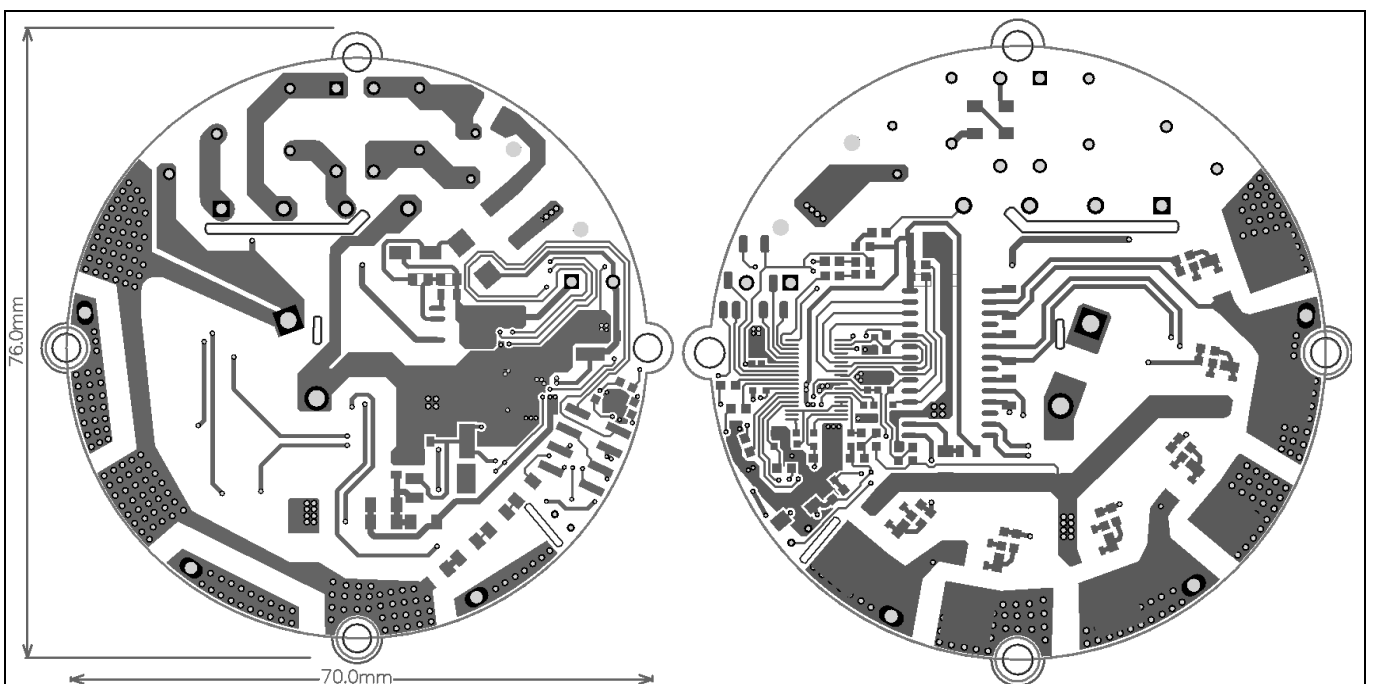


Figure 30 Top and bottom layer routing of the REF-Hairdryer-C101-6ED

System design

3.3 Bill of material

Table 3 shows the major parts of the REF-Hairdryer-C101-6ED. 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 3 BOM of the most important/critical parts of the evaluation or reference board

S. No.	Ref Designator	Description	Manufacturer P/N	Manufacturer
1	BR1	BRIDGE RECT, 800V 4A	KBJ408G	
2	C1	Aluminum Electrolytic Capacitors, 400V DC, 330uF	861011385023	Wurth Elektronik
3	F1	FUSE, 3A 250VAC, SMD	0443003.DR	
4	J1	5.00 mm Horizontal Entry SMT, 2 pin	691709710302	Wurth Elektronik
5	J2	SMT, pitch 2.54mm, Dual Row, Vertical, 8pin	61000821121	Wurth Elektronik
6	L1	Common Mode Power Line Choke, 0.5mH, 3.5A, 250V	7448013501	Wurth Elektronik
7	L2	Inductor, size 1014, 2200 uH, 0.48 A	7447480222	Wurth Elektronik
8	NTC1	THERMISTOR NTC 10KOHM 3936K BEAD	NXFT15WB473FA2B060	
9	Q1, Q2, Q3, Q4, Q5, Q6	600V TRENCHSTOP, RC IGBT	IKD06N60RF	Infineon Technologies
10	RT1	ICL 5 OHM 20% 5A 15MM	B57237S0509M000	
11	RV1	WE-VD Disk Varistor, size 5mm, 385Vrms, 505Vdc	820453811	Wurth Elektronik
12	U1	DC_DC IC, SO8	LNK306DG-TL	
13	U2	IC REG LINEAR 3.3V 1A SOT223-4	IFX1117MEV33HTMA1	Infineon Technologies
14	U3	IMC101T-T038		Infineon Technologies
15	U4	GATE DRVR IC DSO28	6EDL04I06PTXUMA1	Infineon Technologies
16	VR1	TRIMMER 10K OHM 0.125W	ST32ETB103	

System design

3.4 Connector details

General information about the connectors of the REF-Hairdryer-C101-6ED reference design is provided in this section.

Table 4 includes the details of the AC input connector.

Table 4 AC input connector

Pin	Details
J1 (1)	AC L input
J1 (2)	AC N input

Table 5 denotes the details of the UART-related connector (iMOTION™ Link connector J2)

Table 5 J2- iMOTION™ link connector

S. No.	Pin	Details
1	TXD1	User UART for script communication
2	RXD1	User UART for script communication
3 & 6	+3.3 V	On board 3.3 V supply
4 & 5	GND	Ground
7	RXD0	MCE Designer & firmware download
8	TXD0	MCE Designer & firmware download

Table 6 provides the details of the motor UVW output connector

Table 6 Motor side connector

S. No.	Pin	Details
U	U	Connected to motor phase U
V	V	Connected to motor phase V
W	W	Connected to motor phase W

System performance

4 System performance

4.1 Thermal characterization

Figure 31 shows the thermal characterizations of REF-Hairdryer-C101-6ED at natural cooling conditions. The tests reported have been performed under the following conditions: $T_{amb}=25^{\circ}\text{C}$, $V_{AC} = 220\text{ V}$, different phase current values until the IGBT case reaches 105°C , four PWM frequencies (6, 8, 16 and 24 kHz) tested, 3-phase modulation mode and 2-phase modulation.

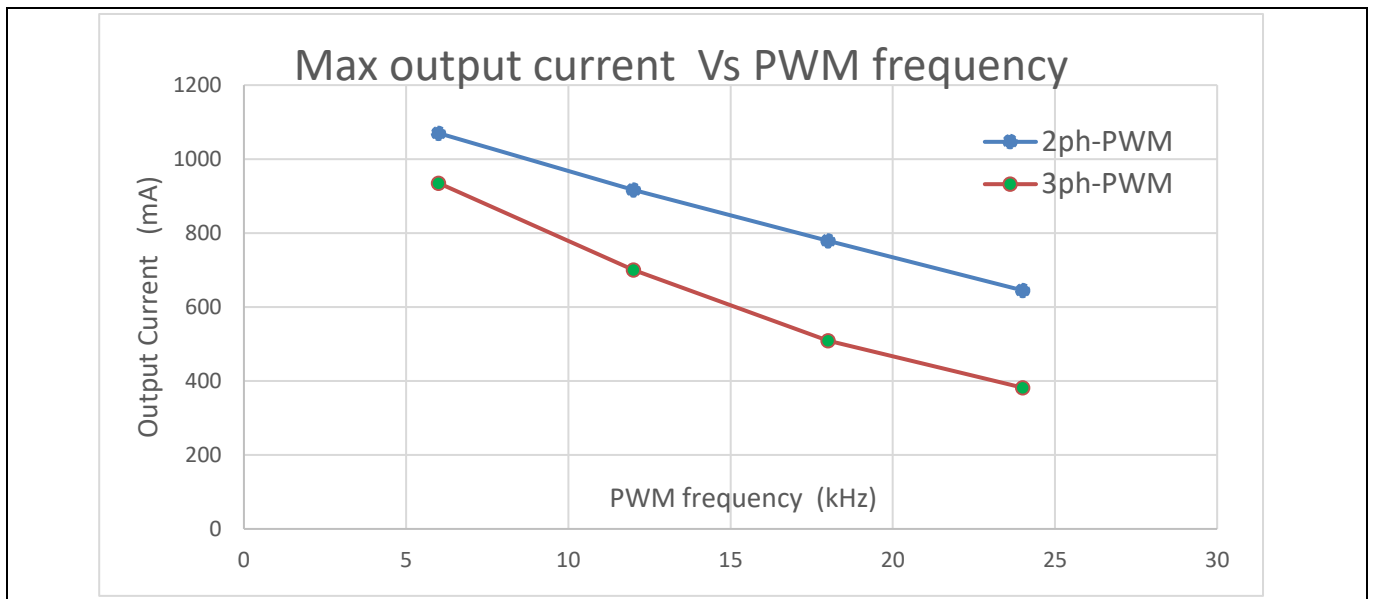


Figure 31 REF-Hairdryer-C101-6ED thermal characterization at nature cooling mode

Figure 32 shows the output ability at different cooling conditions, which are performed under the following conditions: 16 KHz PWM, $T_{amb}=25^{\circ}\text{C}$, $V_{AC} = 220\text{ V}$, different input power until the IGBT case reaches 105°C .

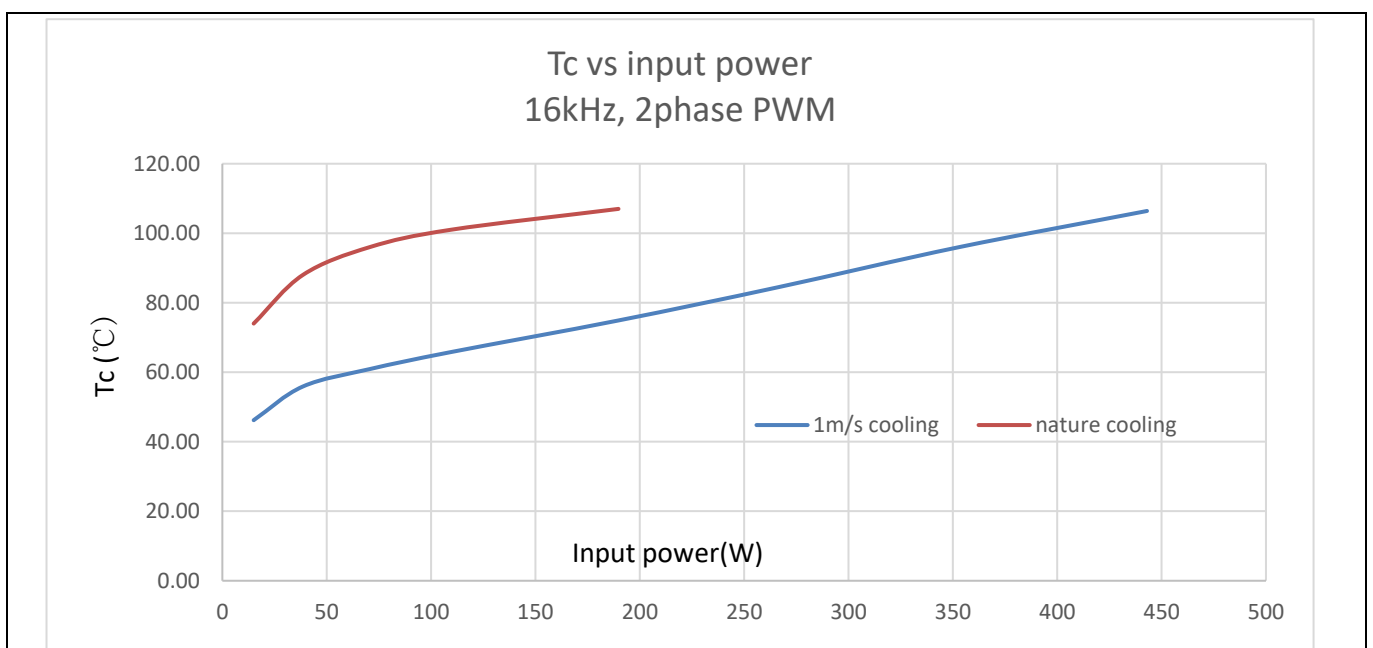


Figure 32 Output ability at different cooling modes

System performance

4.2 Test results for over-temperature protection

IMC101T’s firmware has overheat protection, Pin7 is the dedicated input of NTC temperature sensing. An external NTC thermistor is attached on the Q6.

To activate over-temperature protection, 2 setups in MCEWizard as shown in Figure 33 and Figure 35 are needed:

- Enable over-temperature shutdown function
- Set voltage for shutdown, consider the temperature difference between MOS and NTC

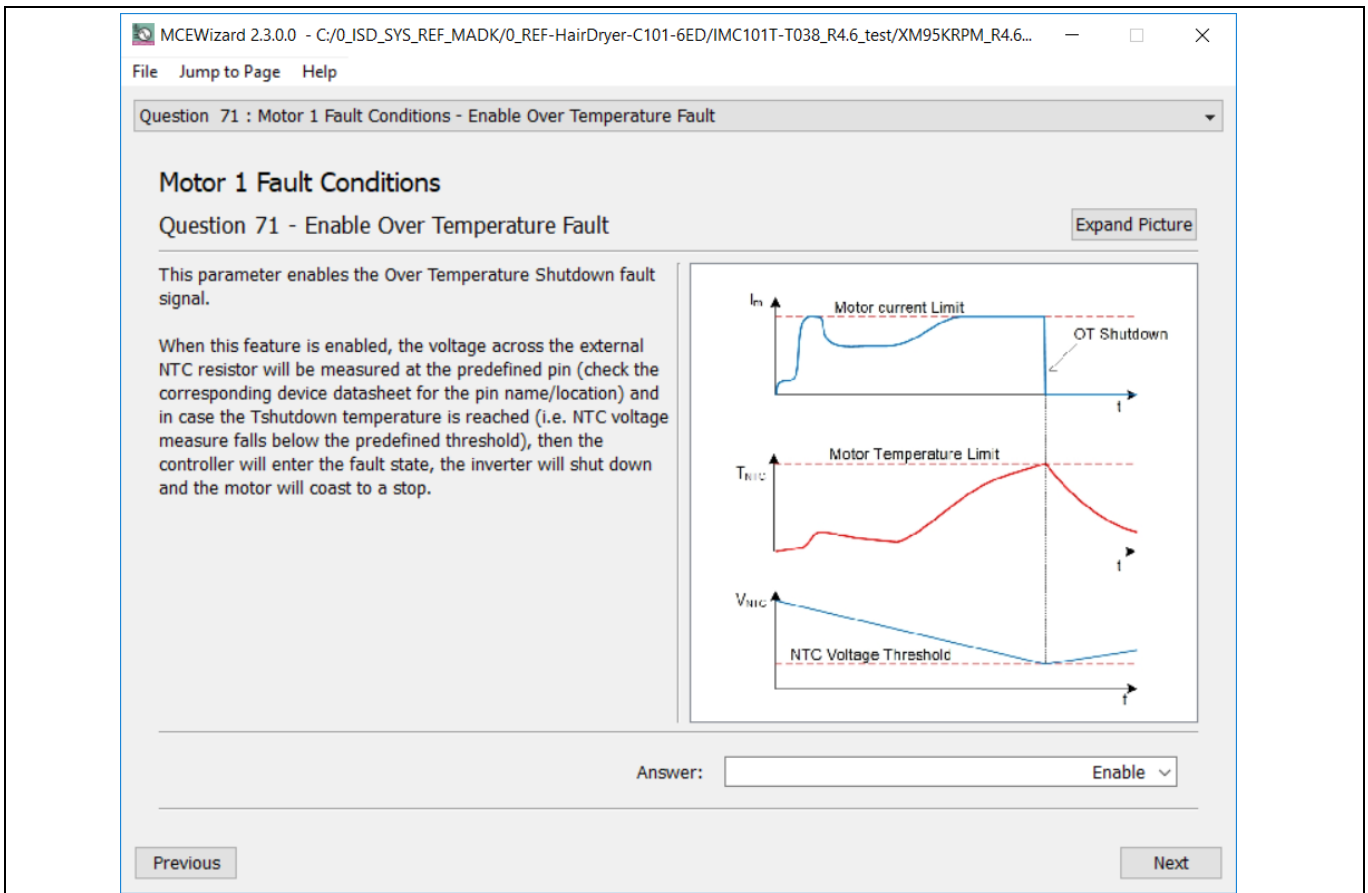


Figure 33 Over-temperature protection enabled in MCEWizard

System performance

The NXFT15WB473FA2B thermistor’s B-constant is 4050 K, typical resistance and output of temperature-sensing voltage listed in Table 7.

Table 7 NTC – Thermistor Characteristics

Temperature (°C)	Resistance (kOhm)	Vout (mV)
25	47	3000
50	16.43	2566
60	11.22	2326
70	7.818	2061
80	5.548	1787
90	4.004	1518
100	2.936	1269
110	2.184	1047
120	1.646	856
125	1.436	772

The pull-up resistor is 4.7 kOhm, and IMC101T’s temperature-related AD input voltage is shown in Figure 34.

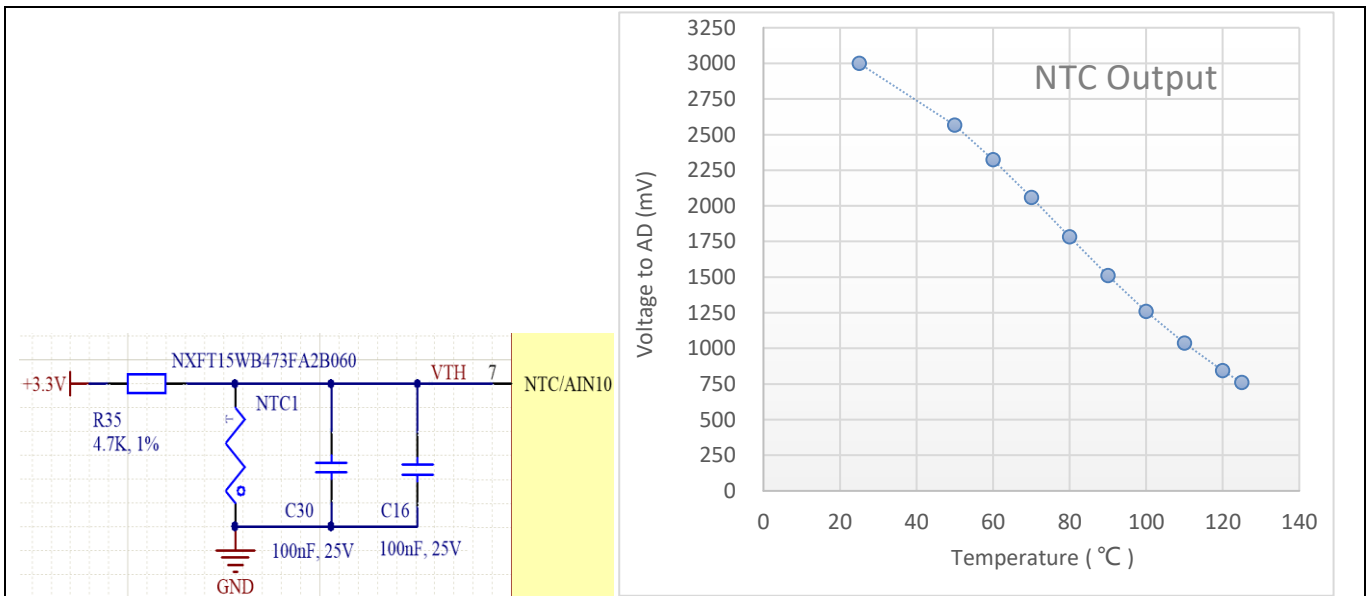


Figure 34 NTC circuit and output voltage curve

System performance

External NTC temperature shutdown value can be calculated as shown below and configured in MCEWizard as shown in Figure 35. MCEWizard default setup is 1.5 V, which sets the NTC shutdown temperature to about 90 °C.

The screenshot shows the MCEWizard 2.3.0.0 interface. The window title is "MCEWizard 2.3.0.0 - C:\0_ISD_SYS_REF_MADK\0_REF-HairDryer-C101-6ED\IMC101T-T038_R4.6_test\XM95KRPM_R4.6...". The menu bar includes "File", "Jump to Page", and "Help". The main content area is titled "Question 72 : Motor 1 Fault Conditions - NTC Over-temperature Voltage Threshold". Below this, the section "Motor 1 Fault Conditions" contains "Question 72 - NTC Over-temperature Voltage Threshold" with an "Expand Picture" button. The text explains that this parameter sets the threshold level for Over Temperature Shutdown and that a fault is detected when the voltage at the NTC input pin falls below the NTC Over-temperature Voltage Threshold Level. To the right, a graph shows three variables over time (t): Motor current Limit (blue line), Motor Temperature Limit (red line), and NTC Voltage Threshold (cyan line). A vertical dashed line marks the "OT Shutdown" point. Below the graph, the "Answer:" field is set to "1.5" V. "Previous" and "Next" buttons are at the bottom.

Figure 35 NTC shutdown temperature setup in MCEWizard

5 References and appendices

5.1 References

- [1] [Datasheet of Infineon 6EDL04I06PT](#)
- [2] [Datasheet of Infineon IMC101T](#)
- [3] [Datasheet of IKD06N60RF](#)
- [4] MCEWizard User Guide
- [5] MCEDesigner User Guide
- [6] [Infineon-MCESW-RM-User Manual](#)

5.2 Ordering information

Base Part Number	Package	Standard Pack		Orderable Part Number
		Form	Quantity	
REF-Hairdryer-C101-6ED	EVAL	Boxed	1	REFHairDryerC1016ED
IMC101T-T038	PG-TSSOP-38-9	Tape and Reel	3000	IMC101TT038XUMA1
IKD06N60RF	PG-TO252-3	Tape and Reel	2500	IKD06N60RFATMA1
6EDL04I06PT	PG-DSO-28	Tape and Reel	1000	6EDL04I06PTXUMA1

Revision history

Revision history

Document version	Date of release	Description of changes
1.0	2020-7-20	First release
1.1	2020-11-2	New UG template

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