HybridPACK™

Hybrid Kit for HybridPACK™1

Evaluation Kit for Applications with HybridPACK™1 Module

Application Note

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18	added the information for Kemet Capacitor
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31	Figure 25 updated
	Information on Pin-Fin Version added

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Last Trademarks Update 2009-10-19

Table of Contents

List of Figures

List of Tables

1 Introduction

The Hybrid Kit for HybridPACK™1 shown in **Figure 1** was developed to support customers during their first steps in designing applications with HybridPACK™1 IGBT module. The following chapters provide a detailed description of the main components and their functionality. This information is intended to enable the customers to copy, modify and qualify the design for production, according to their specific requirements.

The boards **Hybrid Kit for HybridPACK™1 Evaluation Driver Board** (further refered as **"Driver Board"**) and **Hybrid Kit for HybridPACK™1 Logic Board** (further refered as **"Logic Board"**) provided by Infineon Technologies are subjected to functional testing only.

Due to their purpose the system is not subject to the same procedures regarding Returned Material Analysis (RMA), Process Change Notification (PCN) and Product Withdraw (PWD) as regular products.

See Legal Disclaimer and Warnings for further restrictions on Infineons warranty and liability.

The current implementation of the HybridKit (e.g. electrical schematics) is for reference only. It does not cover in general all application specific requirements. For specific recommendations on how to implement design with HybridPACK™ and EiceDRIVER™, please contact local sales partner. More information is available on www.infineon.com/hybrid.

1.1 How to Order Hybrid Kit for HybridPACK™1

Hybrid Kit for HybridPACK™1 and **Hybrid Kit for HybridPACK™1 Evaluation Driver Board** (that can be ordered separately) have Infineon Technologies SAP numbers and can be ordered via Infineon Sales Partners.

- SAP ordering number for Hybrid Kit for HybridPACK™1 : **SP000806996**

Information can also be found at the Infineon Technologies web page: www.infineon.com

Figure 1 The Hybrid Kit for HybridPACK™1

1.2 Support for Hybrid Kit for HybridPACK™1

The new **Hybrid Kits for HybridPACK™1** are labeled with a serial number inside the suitcase. That provides better support for you and a better issue tracking for us. If you need any support with the hardware or software just let us known your issue and your serial number and we will try to help you as best we can. Where you can find the serial number inside the suitcase is shown on **Figure 2**.

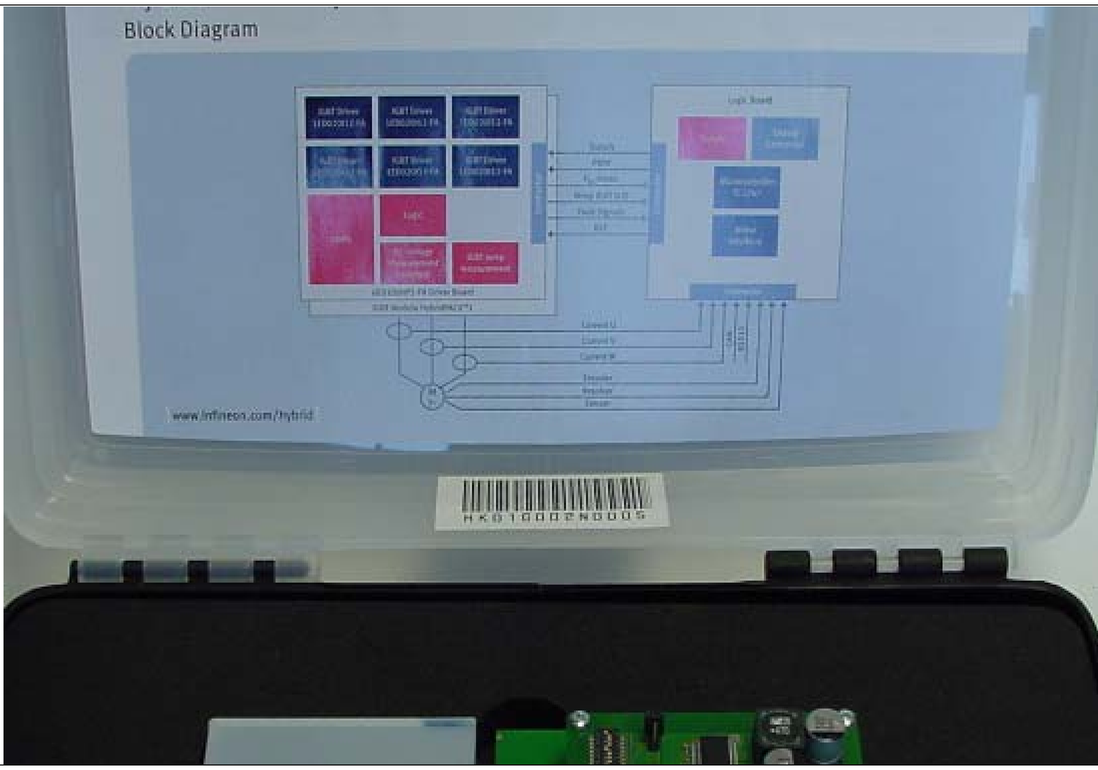

Figure 2 Serial number in the suitcase

W A R N I N G !

Please always take care of the dead-time settings of the driver (to avoid short circuit conditions on the IGBT module) and always have on mind that Hybrid Kit for HybridPACK™1 inverter has no breaking chopper or similar hardware protection to absorb the energy generated during the regenerative breaking of a motor. In any case user shall ensure that voltage, current and temperature are monitored properly, e.g. by software or additional supporting hardware.

2 Design Features

The Hybrid Kit for HybridPACK™1 is made up of two PCBs (Driver Board and Logic Board) mechanically and electrically suitable to be used with an IGBT Module HybridPACK™1 (included), a DC-link capacitor and a cooler. All these components build a complete main inverter for (H)EV applications up to 20kW.

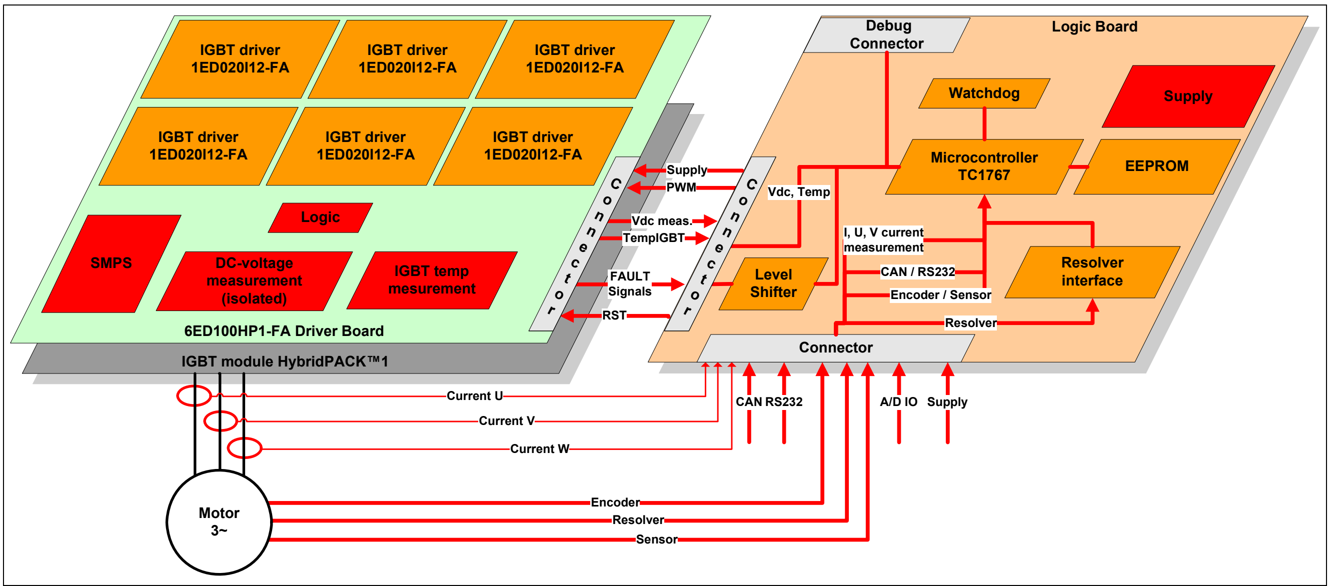

Figure 3 Block Diagram of Hybrid Kit for HybridPACK™1

Figure 3 show the complete block diagram for the system and the following sections provide an overview of the single components including main features, key data, pin assignments and mechanical dimensions.

2.1 Main Features

Complete main inverter for (H)EV applications up to 20kW.

- Automotive qualified IGBT module HybridPACK™1
  - 650V/400A IGBT & Diode chip set
- Automotive qualified Driver IC 1ED020I12-FA
  - Based on coreless transformer technology
  - Up to 1200 V and 2A driving capability
  - $V_{CE\ sat}$ - detection
- TriCore™ family 32-bit microcontroller TC1767: member of the AUDO FUTURE product family designed for automotive applications
- Possibility of different motor position interfaces: encoder, resolver and GMR (Giant Magneto resistance))

2.2 Dimensions

Figure 4 and **Figure 5** shows the dimensions of a complete Hybrid Kit for HybridPACK™1.

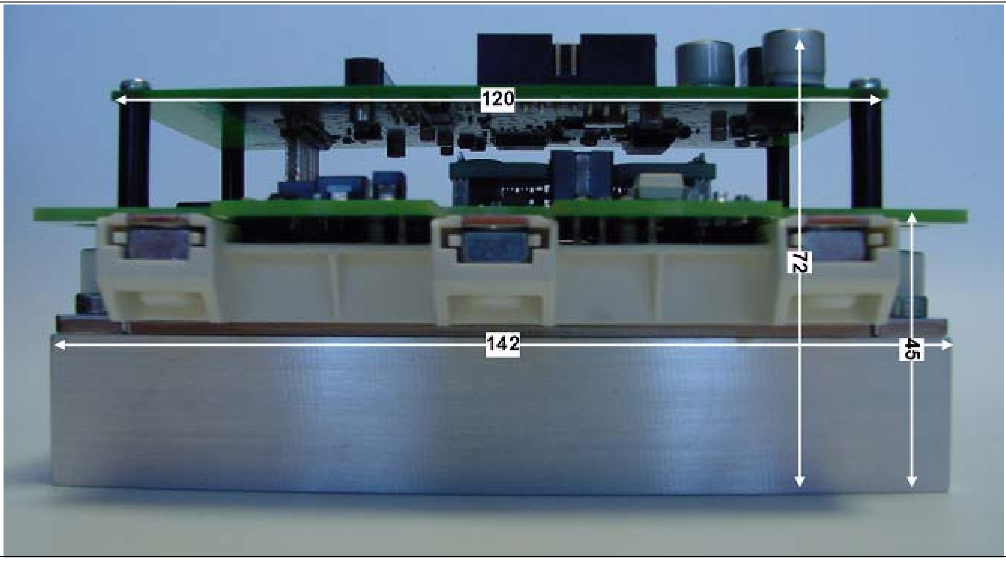

Figure 4 Dimensions of the Hybrid Kit for HybridPACK™1 - front view (all dimensions are in mm)

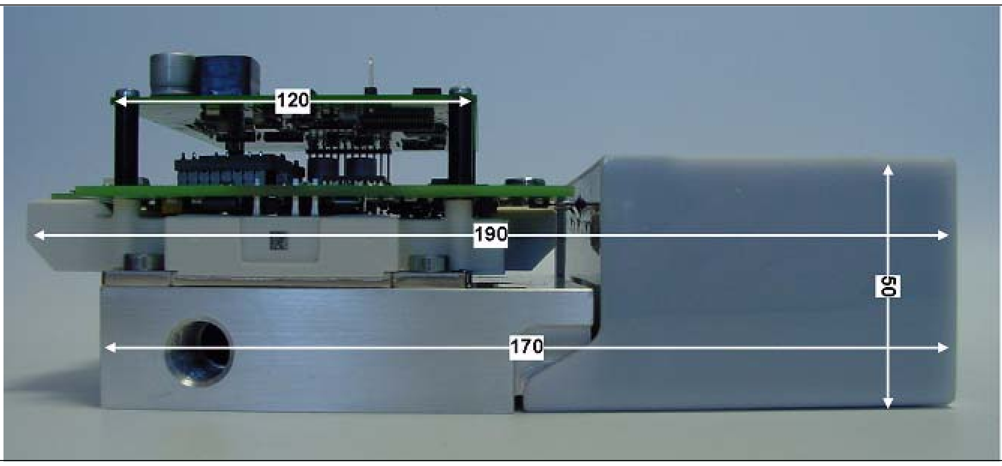

Figure 5 Dimensions of the Hybrid Kit for HybridPACK™1 - side view (all dimensions are in mm)

2.3 Key Components

For detailed technical information about the different components please refer to the different web pages on the Infineon Internet.

2.3.1 Driver Board (6ED100HP1-FA)

The 6ED100HP1-FA is a six channel IGBT driver board, specially designed for the HybridPACK™1 IGBT module. The main features and a detailed description of the board, including schematics and layout, can be found in **Chapter 3**.

2.3.2 Logic Board

The Logic Board contains all necessary components for the control of the system. Furthermore it offers the connections to the motor positioning system (encoder, resolver or GMR) and to the current measurement system. For a detailed description of the board please refer to **Chapter 3**.

2.3.3 HybridPACK™1

(see **Figure 6**) is a power module designed for mild Hybrid Electrical Vehicle (HEV) applications with a maximum supply voltage of 450 V and a power range up to 20kW. Designed for a junction operation temperature at 175°C, the module accommodates a six-pack configuration of 3rd generation Trench-Field-Stop IGBT and matching emitter controlled diodes and is rated up to 400A/650V. It is based on Infineon Technologies leading TRENCHSTOP™ IGBT Technology, which offers lowest conduction and switching losses.

HybridPACK™1 is a baseplate module and can be screwed directly to a water- or air-cooled heat sink. For a compact inverter design the driver stage PCB can easily be soldered on top of the module. All power connections are realized with screw terminals.

Figure 6 HybridPACK™1 IGBT Six-Pack Module

HybridPACK™1 is also available with a Pin - Fin baseplate for direct water cooling. As the thermal resistance is lower the module can be used for a higher power ranges (40kW). All pins and power terminals as well as the rest of the package is the same. Therefore it is necessary to have only a different heat sink design. For detailed technical information of the module refer to the datasheet and to the application note mounting instructions.

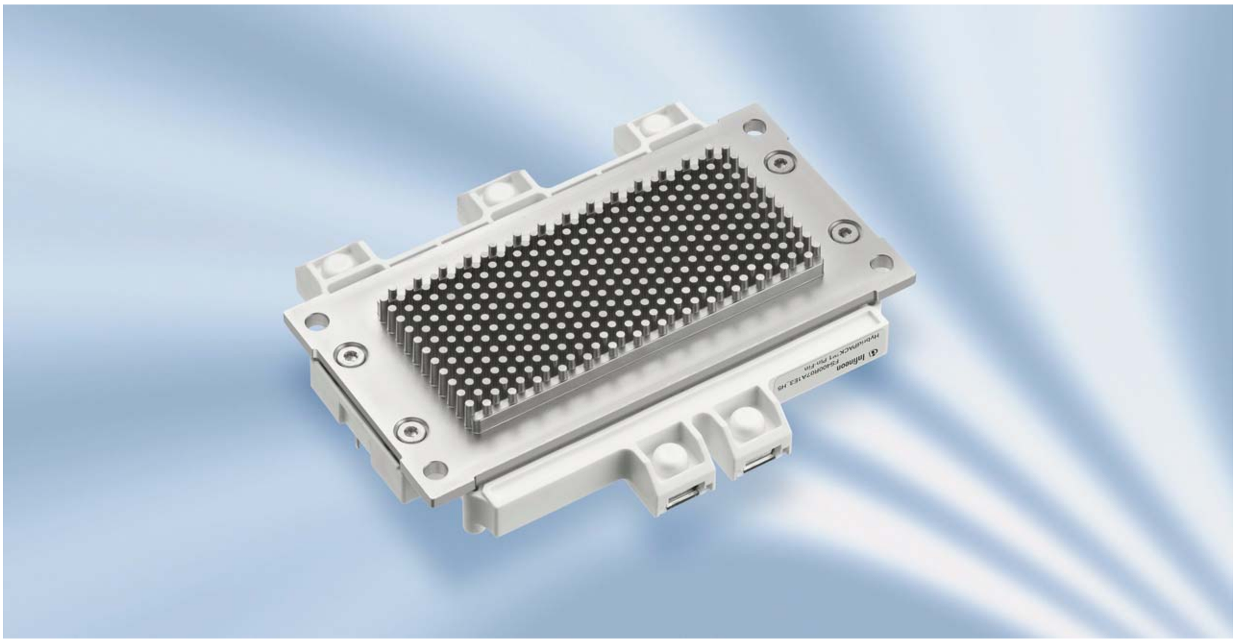

Figure 7 HybridPACK™1 Pin Fin IGBT Six-Pack Module (backside)

2.3.4 DC-Link Capacitor

The power electronic capacitor B25655J4307K from the company Epcos AG (see **Figure 8**) is strongly recommended (included). **Table 1** shows the main features of the capacitor. For dimensions of the DC-Link Capacitor have a look on **Figure 9**. Please refer to the Epcos datasheet for further details.

Figure 8 DC-Link Capacitor for HybridPACK™1

Table 1 Key Data of DC-Link Capacitor

Characteristics		Maximum ratings		Test Data	
C_R	300 µF ±10%	V_s	600 V	V_{TT}	675V DC, 10 s
V_R	450 V DC	î	1.2 kA	R_{ins} ·C	≥ 10000 s
W_R	30 Ws	I_s	4.8 kA	tan δ (50 Hz)	$\leq 8 \cdot 10^{-4}$
I_{max}	80 A	$(dV/dt)_{max}$	4 V/µs		
L_{self}	25 nH	$(dV/dt)_s$	16 V/µs		
tan δ_0	$2 \cdot 10^{-4}$				
R_s	0.8 mΩ				
Climatic Category 0/110/21(IEC 68-1/2)		**Design Data**		**Mean Life Expentancy**	
T_{min}	- 40 °C	Dimensions l × w × h	140 × 72 × 50 mm	t_{LD}	15000h
T_{max}	+ 110 °C	Approx. weight	750 g	α_{FQ}	300fit
Max. Rel. Humidity	≤ 95%	Impregnation	Resin Filled		
T_{stg}	- 45 … +110°C	Terminals	Flat Copper		
		Clearance	9 mm		
Values after Test Ca, IEC 68-2 (21 days, 40°C, 93% rel. humidity)		Creepage distance	9 mm		
ΔC/C	≤ 5%	Plastic Case			
Δtanδ	$\leq 4 \cdot 10^{-4}$				
R_{ins} ·C	≥ 3000s				

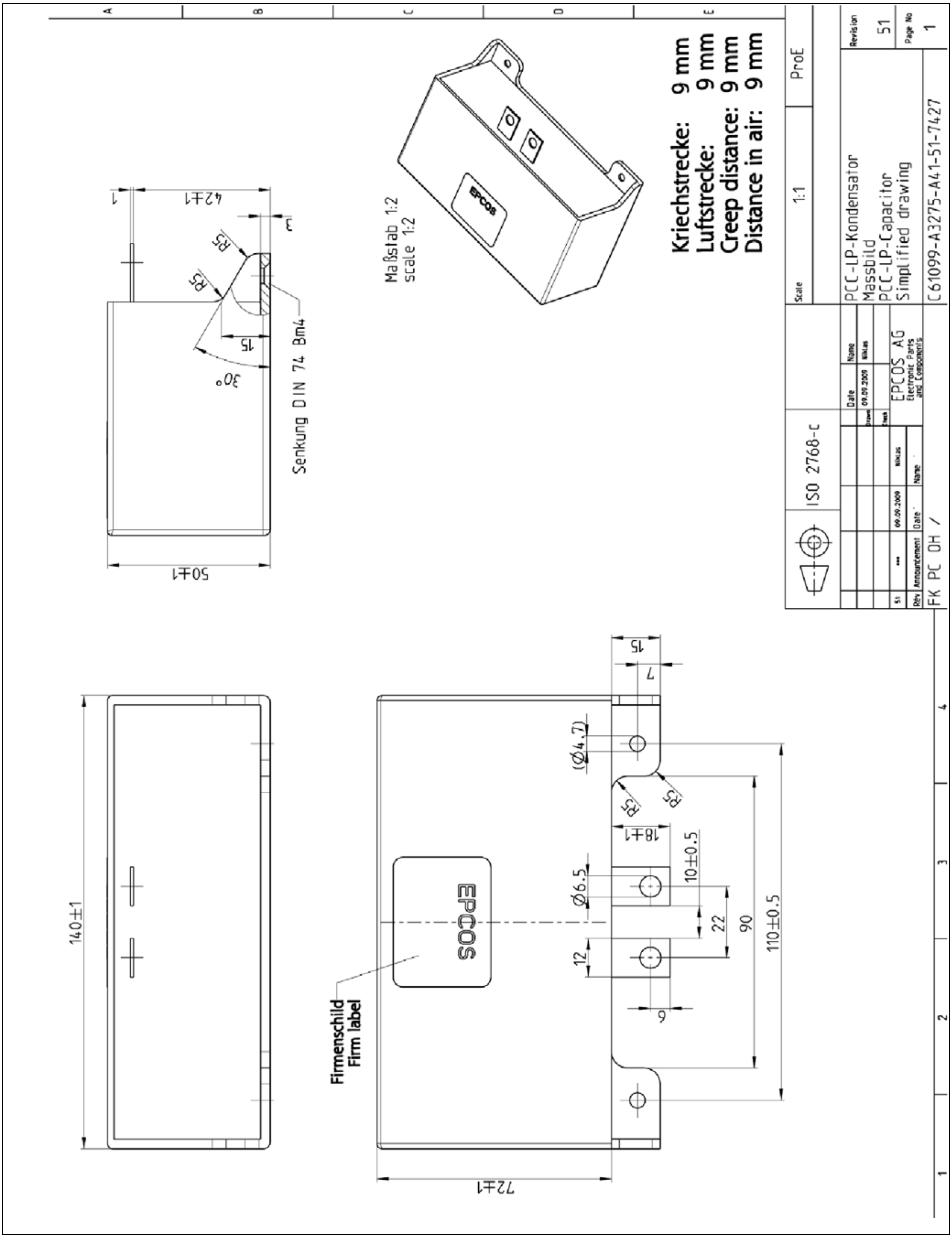

Figure 9 Technical drawing of the DC-Link Capacitor

There are also other capacitors available on the market which fit mechanicaly to the HybridPACK™1. The different capacitors are very often vary in mechanical, thermal and electrical parameters which needs to be validated for the dedicated application. The following example is a capacitor JSPXZ6300ZAA0K from Kemet Electronics, which allows different mechanical design of the cooler. Please refer to the Kemet Electronics datasheet for further details.

The power electronic capacitor JSPXZ6300ZAA0K from KEMET Electronics is a polypropylene 300µF/450V/105°C DC-Link capacitor with a low-inductive 8nH terminal. The plastic case is filled with resin for longterm humidity protection. Version-2 (see picture) is designed for optimized usage of the cooling plate surface.

Version 1 would also fit to the Hybrid Kit (current capability needs to be evaluated for the dedicated application).

Table 2 Key Data of DC-Link Capacitor (Kemet)

Electrical Performance					
C_{nom}	300 µF ±10%	@RT ±5°C,f=1kHz			
U_{Rated}	450 V DC	@105°C			
U_{peak}	650 V	for 10s			
I_{max_rms}	80 A	@10kHz;Tcase<105°C			
I_{peak}	100 A	@450VDC, 2sec.			
ESL	8 nH				
ESR	1 mΩ	@1kHz			
DF @1kHz	0,01%	Dissipation Factor			
DF @100Hz	0,001%	Dissipation Factor			
Climatic Category 40/105/56(IEC 60068-1)		**Design Data**		**Mean Life Expentancy**	
T_{min}	- 40 °C	Dimensions l × w × h	140 × 42 × 40mm	L_{exp}	15000h
T_{max}	+ 105 °C	Approx. weight	350 g	α_{FQ}	300fit
Max. Rel. Humidity	≤ 60%	Impregnation	Resin Filled		
$T_{storage}$	0… +105°C	Terminals	Flat Copper		
		Plastic Case			
Test performance					
U_{T-T}	600V DC	@25°C, 10s, Voltage test between terminals			
U_{T-C}	3000VAC	@50Hz, 1min., Voltage test between terminals to case			

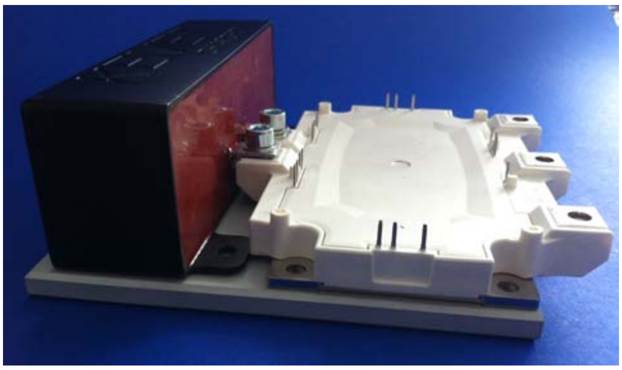

Figure 10 JSPXZ6300ZAA0K - Kemet Capacitor Version2 - thermal optimized for a cooling plate

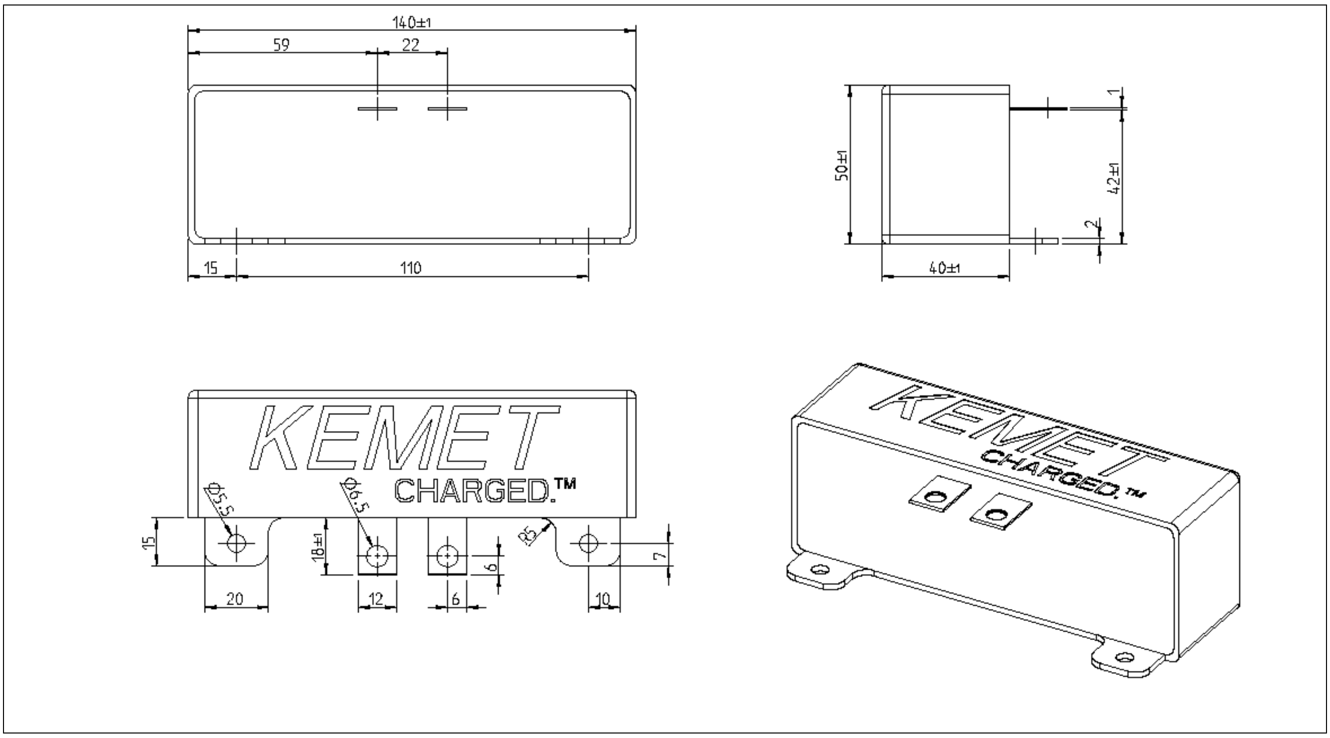

Figure 11 Kemet Capacitor Version1 - for face-surface cooling

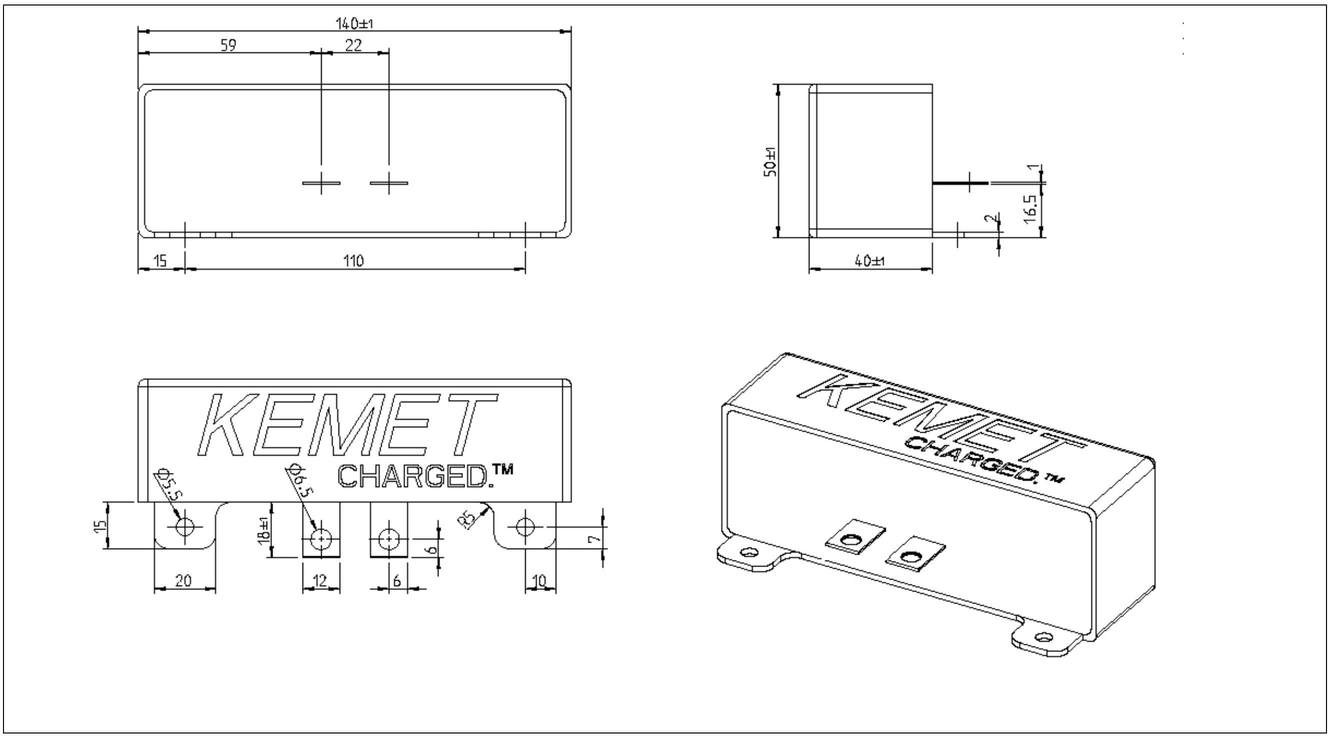

Figure 12 Kemet Capacitor Version2 - thermal optimized for a cooling plate

2.3.5 Cooling Element

For applications requiring higher power or higher operation temperature a usage of cooling element is recommended. **Figure 13** shows the low cost water cooling system that is included in the Hybrid Kit for HybridPACK™1 which is screwed directly to HybridPACK™1 - **Figure 14** shows the technical drawings of it. A heat sink for air cooling is also a possible solution, but it will be larger than this water heat sink.

Figure 13 Example of Water Cooling Element for HybridPACK™1

For a proper connection to a rubber hose a tailpiece should be used. A possible tailpiece could be the 0931 10 13 from Legris, for more detailed information please refer to the website of Legris Inc.

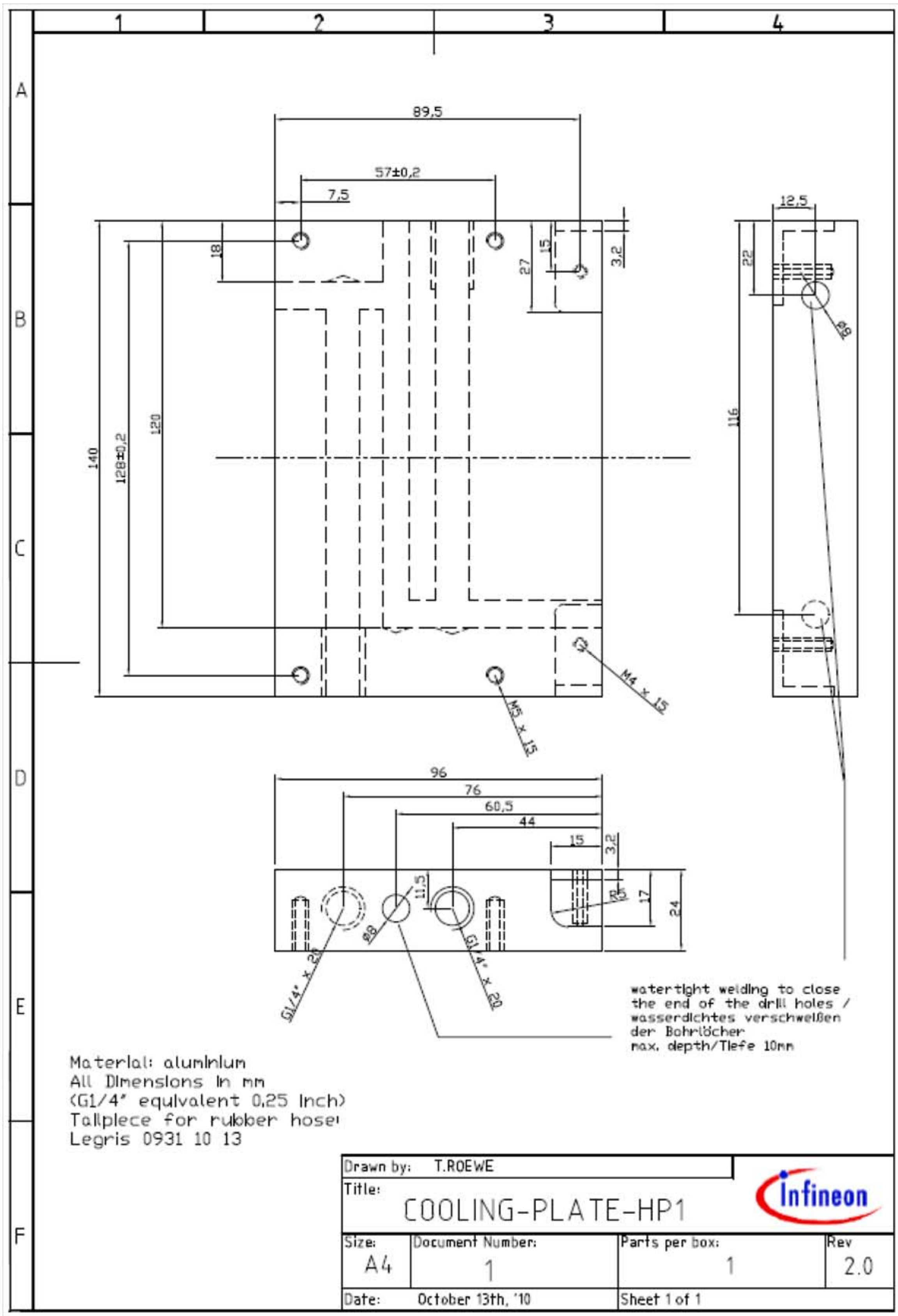

Figure 14 Water Cooling System Technical Drawings

The heat sink for the pin fin baseplate is more complex then the one for a standard baseplate. It is necessary to have a grove for a seal as well as the notch for the pin fin structure. For a optimal coolant flow through the heat sink it is recommended to follow the design from the application note mounting instructions for HybridPACK™1 Pin Fin.

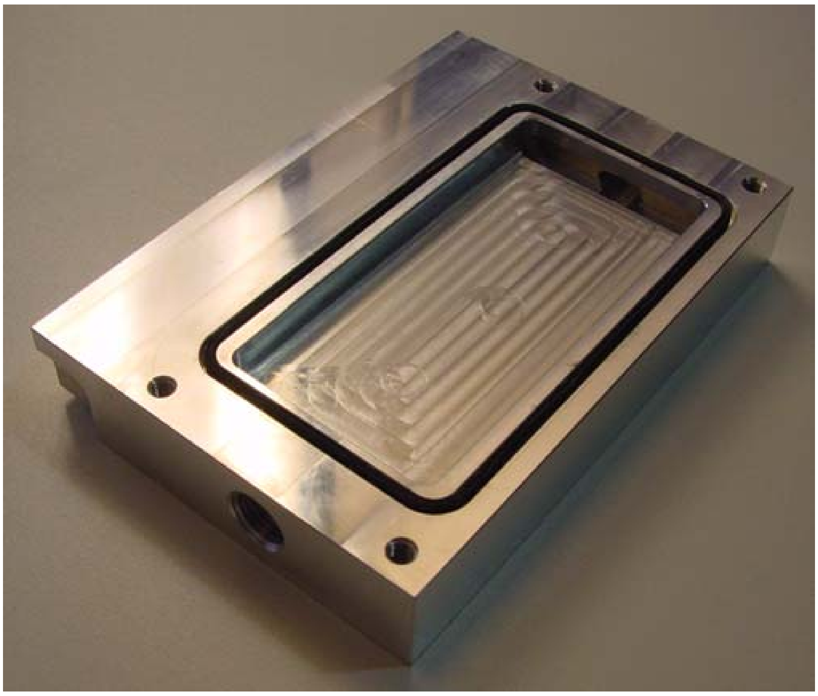

Figure 15 Example of Water Cooling Element for HybridPACK™1 Pin Fin

A seal is for the given grove already available it has the order number YA-231109-JD. The seal is available with and without knobs which avoid a loosely behavior during mounting (falling out of the grove during turning).

For the Hybrid Kit 1 with the HybridPACK™1 Pin Fin the cooler was modificated as there was not enough space left, so the inlet and outlet are not optimal.

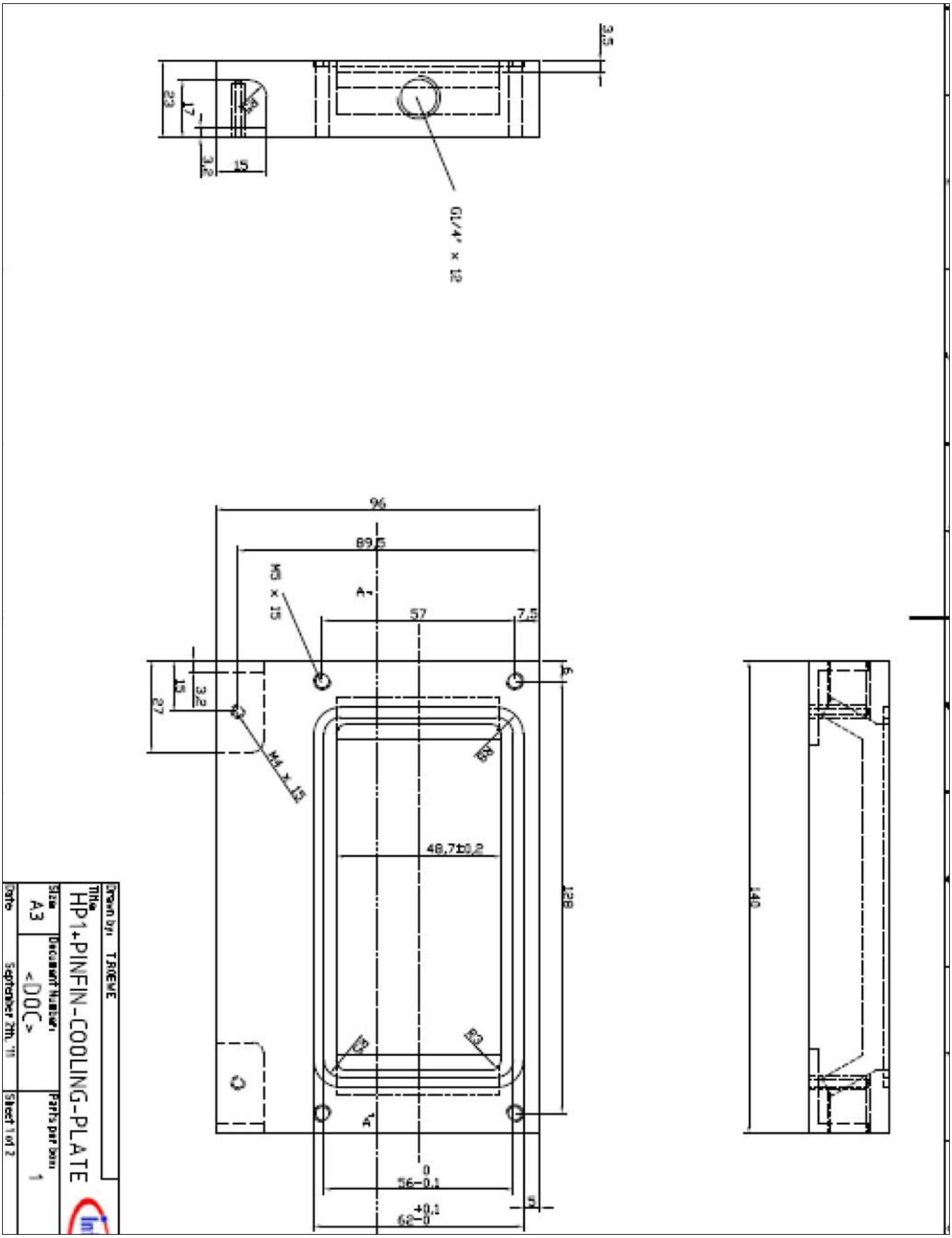

Figure 16 Water Cooling System Technical Drawings

3 Evaluation Driver Board for the HybridPACK™1

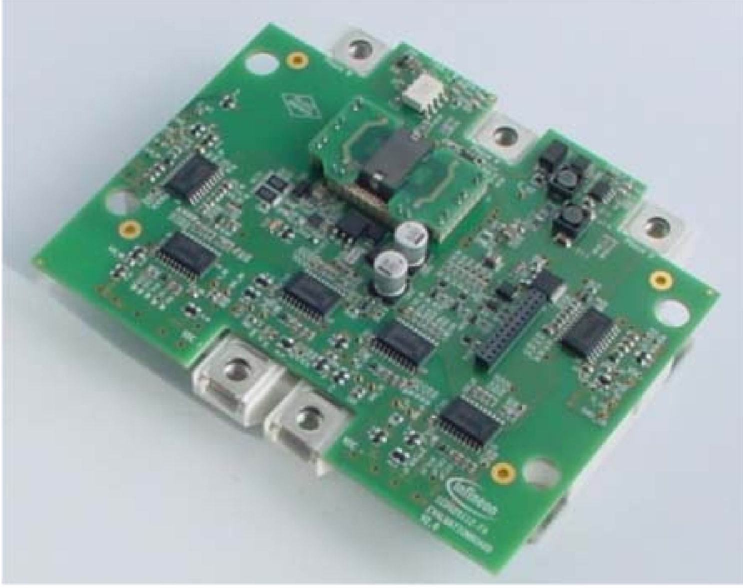

Figure 17 Driver Board Mounted on the Top of the HybridPACK™1 Module

3.1 Main Features

The Hybrid Kit for HybridPACK™1 Evaluation Driver Board offers the following features:

- Six channel IGBT driver
- Electrically and mechanically suitable for 600 V IGBT Module HybridPACK™1
- Includes DC/DC power supply
- Isolated voltage measurement
- Short circuit protection with t_{off} < 6 µs
- Under Voltage Lockout of IGBT driver IC
- Positive logic with 5 V CMOS level for PWM and Fault signals
- One fault signal for each driver (LED signaling) and their combination for each leg
- Design according to IEC-60664-1

3.2 Key Data

All values given in the **Table 3** (bellow) are typical values, measured at T_A = 25 °C

Table 3 Key Data and Characteristic Values (Typical Values)

Parameter	Value	Unit
VSUPPLY – Voltage Supply	+[8..18]	V
VPWM – PWM Signals for Top and Bottom IGBT (Active High)	0 / +5	V
VFAULT – /FAULT Detection Output (Active Low)	0 / +5	V
IFAULT – Max. /FAULT Detection Output Load Current	10	mA
VRST – /RST Input (Active Low)	0 / +5	V
ISUPPLY – Supply Current Consumption (Idle Mode) (VSUPPLY=12V)	260	mA
VOUT – Drive Voltage Level	15/-8	V
IG – Maximum Peak Output Current	±10	A
PDC/DC – Maximum DC/DC Output Power of SMPS unit	30	W
fS – Maximum PWM Signal Frequency [1)]	20	kHz
tPDELAY – Propagation Delay Time	200	ns
tPDISTO – Input to Output Propagation Distortion	15	ns
tMININ – Minimum Pulse Suppression for Turn-on and Turn-off[2)]	30	ns
VDESAT – Desaturation Reference Level	9	V
dmax – Maximum Duty Cycle	100	%
VCES – Maximum Collector – Emitter Voltage on IGBT	600	V
TOP – Operating Temperature (Design Target)[3)]	-40…+125	°C
TSTO – Storage Temperature (Design Target)	-40…+125	°C
VIORM – Maximum Repetitive Insulation Voltage [4)] (1ED020I12-FA Driver IC)	1420	VPEAK
VISODRIVER – Maximum Insulation Test Voltage[5)] (1ED020I12-FA Driver IC)	4500	Vrms
VISOBOARD – Maximum Insulation Test Voltage (Evaluation Board)	2500	Vrms

1) The max. switching frequency for the HybridPACK™1module should be calculated separately. Limiting factors are: max. DC/DC output power of 4.6W per channel and max. PCB board temperature measured around gate resistors of 75°C for used FR4 material. For detailed information see **Chapter 3.5.3**
2) Minimum value tMININ given in 1ED020I12-FA IGBT driver datasheet
3) Maximum ambient temperature strictly depends on load and cooling conditions
4) 1ED020I12-FA datasheet - complies with DIN EN 60747-5-2 (VDE 0884 Part 2): 2003-01.Basic Insulation
5) 1ED020I12-FA datasheet - complies with UL 1577

3.3 External Connector Pin Assignment

Figure 18 shows the pin assignment for the external connector (K1) on the Driver Board. The connector is a MMS-112-01-L-DV from Samtec, proper matching parts are the TW series for PCB connection or the TCMD series for cable connection. It includes all necessary signals to get the board into operation, that is, supply, control and monitoring.

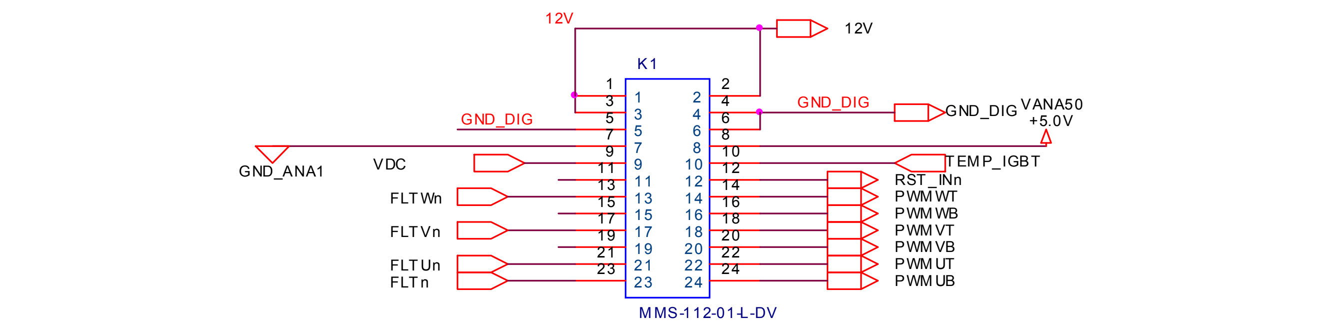

Figure 18 External Connector on the Driver Board

Pins 1 to 6 provide the power supply. The Driver Board must be supplied with an external regulated DC power supply. The input voltage must be kept between 8 V and 18 V and the current consumption will depend on different factors (Logic Board, PWM frequency, etc.). Pins 7-8 provide 5 V analogue power supply which can be used to supply different devices in case of using the Hybrid Kit for HybridPACK™1 as driver board in an inverter such as current measurement, ADC or the motor interface.

To pins 9, 10, 15 and 19 are connected monitoring signals: DC-link voltage measurement and temperature of the three different phases inside of the IGBT module.

Pins 12, 13, 14, 16, 17, 18, 20, 21, 22 and 23 contain the logic signals for controlling the 6 drivers on the board, that are the PWM signals, Fault detection and Reset signal.

3.4 Mechanical Dimensions of the Driver Board

The Driver Board has placed components on both sides of the PCB. The maximum height of the Parts and the dimensions of the PCB is shown in **Figure 19**

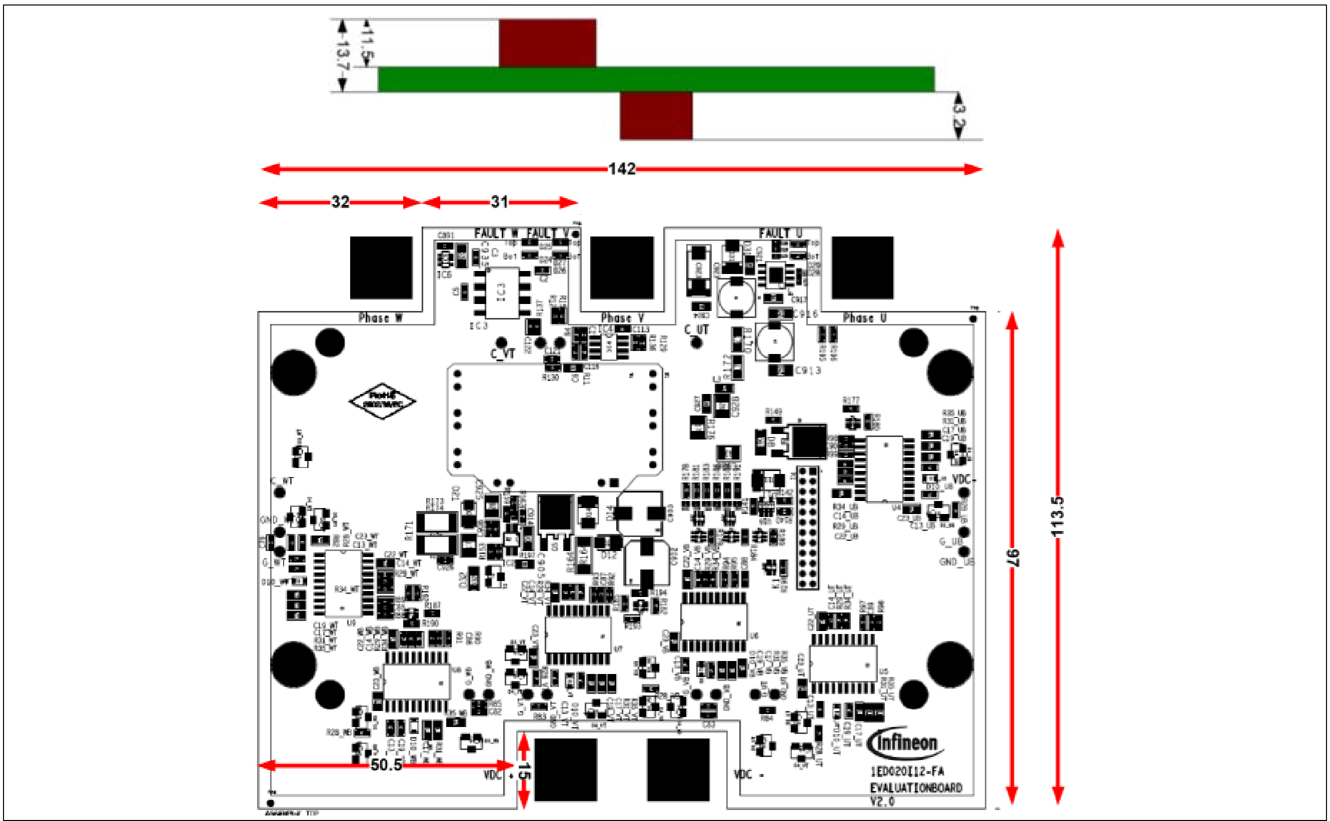

Figure 19 Dimensions of the Driver Board (in mm)

The Driver Boards should be fastened by self taping screws and soldered to the auxiliary connectors on top of the IGBT module. The contact joints (solder points) between PCB and module auxiliary contacts should be mechanically relieved in order to disburden the solder connection as far as possible. Relieve of the contact points is carried out by mounting the PCB directly onto the module at the ten mounting stand-offs (see **Figure 20**) using self-tapping screws (thread forming with 2.5mm diameter) or similar assembly material. The screws should be mounted in the sequence showed in **Figure 20**.

Figure 20 PCB Mounting Stand-offs of HybridPACK™1

3.5 Operation of the Driver Board

Figure 21 shows the block structure of the Driver Board. The following chapter describes these blocks in detail.

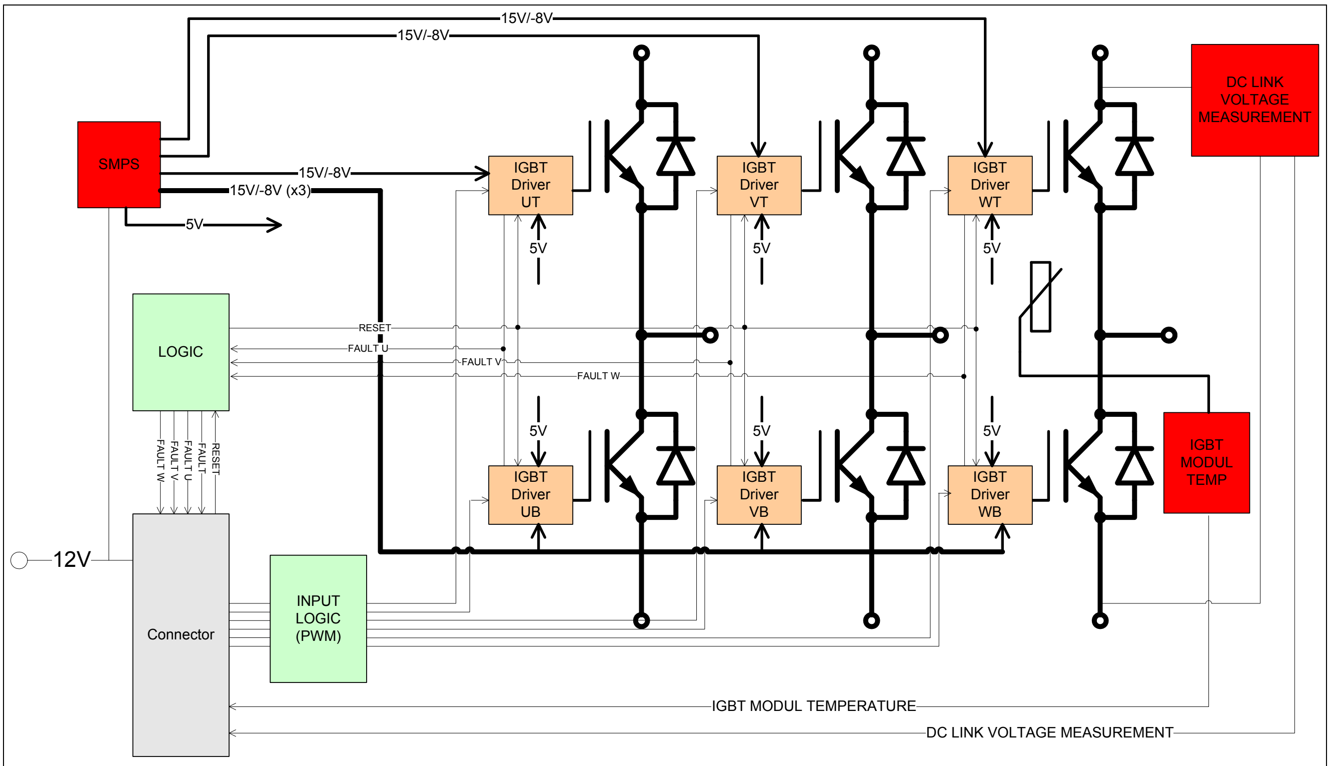

Figure 21 Hybrid Kit for the HybridPACK™1 Evaluation Driver Board Block Diagram

3.5.1 Switching Mode Power Supply (SMPS)

The Driver Board has an integrated DC/DC converter which generates the required secondary isolated unsymmetrical supply voltage of +15/-8V. Top and bottom driver voltages are independently generated by using one unipolar input voltage of 12 V.

An additional supply voltage (5V) is generated and forwarded to the external connector (K1) so it can be used to supply external components in the system (current measurement, motor interface, etc.)

For circuit details please refer to **Figure 33**.

3.5.2 Input Logic

The Driver Board is a dedicated system for a six-pack HybridPACK™1 IGBT configuration - therefore it is necessary to use 6 separated PWM signals. The schematics on **Figure 22** shows the input logic block with +5V positive logic. The block is made up of RC filters for each PWM signal in order to reduce noise. Additionally these signals are pulled-down in order to avoid unwanted switching-on of the drivers. Please have in mind that the Hybrid Kit for HybridPACK™1 does not provide dead time automatically (meaning that hardware alone provides no dead time) - it is up to the user to generate the PWM signals with the correct dead time (by means of software).

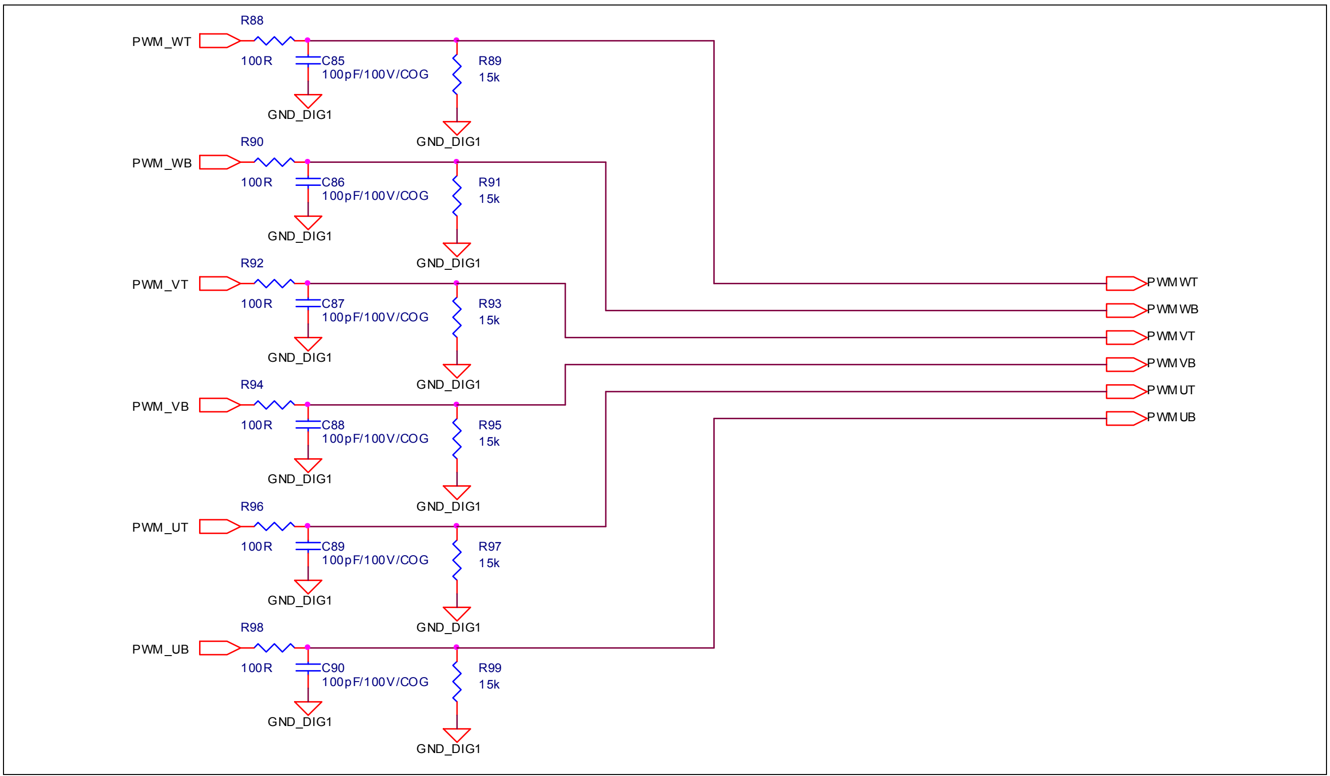

Figure 22 Schematic of the Input Logic Block of the Driver Board

3.5.3 IGBT Switch-off Behavior

Due to the stray inductances of the system a voltage overshoots occur during the switching-off the IGBT. Such overshoots are added to the DC-link voltage, so that the maximum blocking voltage of the IGBT or capacitor might be exceeded causing damages in both components (DC link capacitor and IGBT module). In order to avoid such risks an active clamping circuit is used (see **Chapter 3.5.6**).

Without such protection methods the maximum current would be limited by the DC-link voltage and the voltage overshoots at switching-off. The voltage overshoots can be minimized by increasing the gate resistor, which will reduce the di/dt value. **Figure 23** shows the maximal switch-off current at different DC-link voltages for a different values of the gate resistor. These results were obtained with the DC-link capacitor described in **Chapter 2.3.4**.

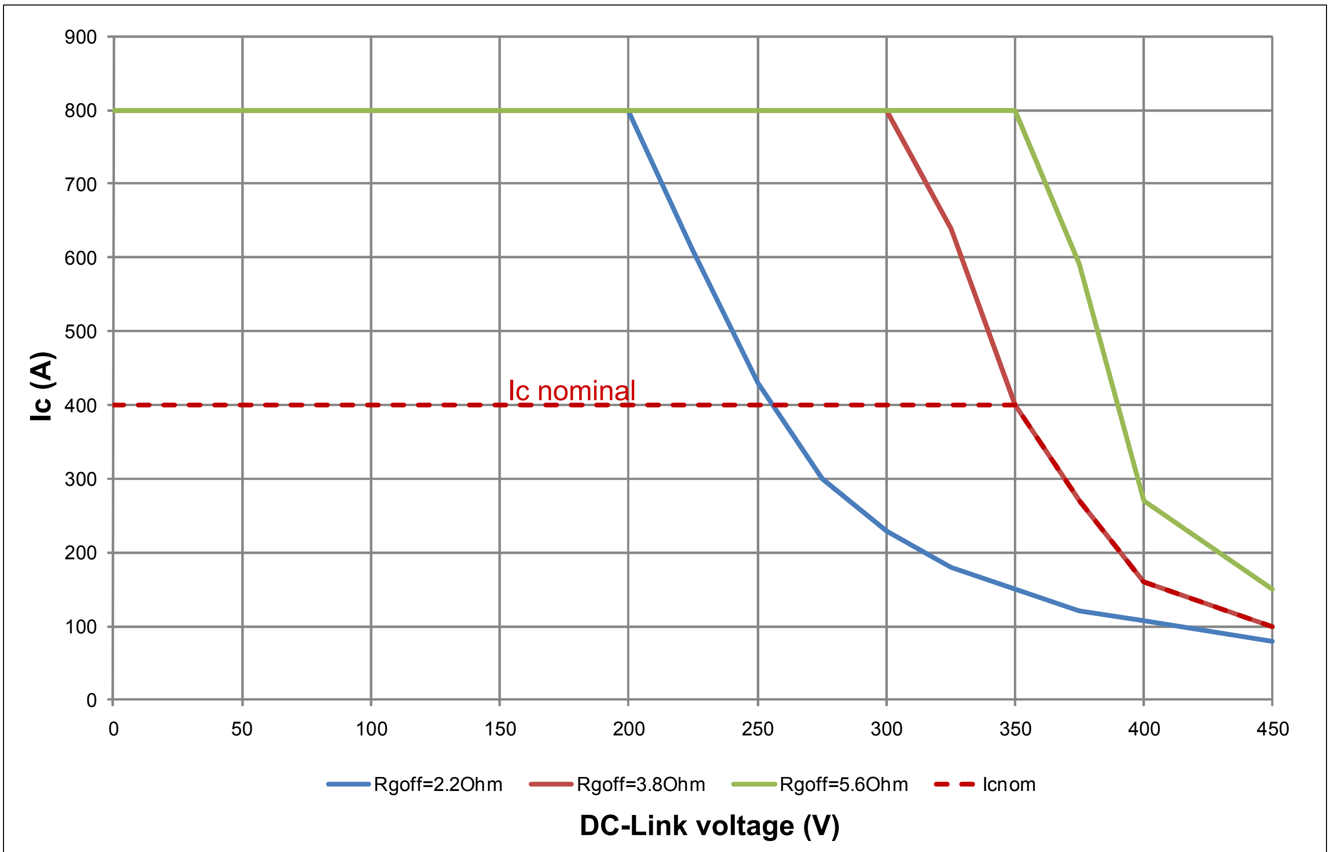

Figure 23 Maximal Switch-off Current at Different DC-Link Voltages (Gate Resistance as a Parameter)

3.5.4 Maximum Switching Frequency

The IGBT switching frequency is limited by the available power and by PCB temperature. According to theory the power losses generated in the gate resistors are a function of a gate charge, voltage step at the driver output and switching frequency. The energy is dissipated mainly through the PCB and raises the temperature around the gate resistors. When the available power of the DC/DC converter is not exceeded, the limiting factor for the switching frequency is the absolute maximum temperature for the FR4 material. The allowed operation temperature is 105 °C.

Generally the power losses generated in the gate resistors can be calculated according to **Equation (1)**:

$$P_{dis} = P_{R_{Gext}} + P_{R_{Gint}} = \Delta V_{out} \cdot f_S \cdot Q_{ge} \quad (1)$$

In **Equation (1)** f_S represents the switching frequency, ΔV_{out} represents the voltage step at the driver output, P_{dis} is the dissipated power, Q_{ge} is the IGBT gate charge value corresponding to +15V/-8V switching operation. This value can be approximately calculated from the datasheet value by multiplying it by 0.77, that is $Q_{ge} = 3.31\,\mu C$. Therefore the maximum frequency limited by the available power will be:

$$f_{Smax} = 4.6\,W/(23V \cdot 3.31\,\mu C) = 60.4\,kHz$$

Figure 24 shows experimentally determined board temperature dependencies with switching frequency (at 25 °C ambient temperature). From **Figure 24** it can be concluded that the maximum switching frequency is limited by PCB temperature.

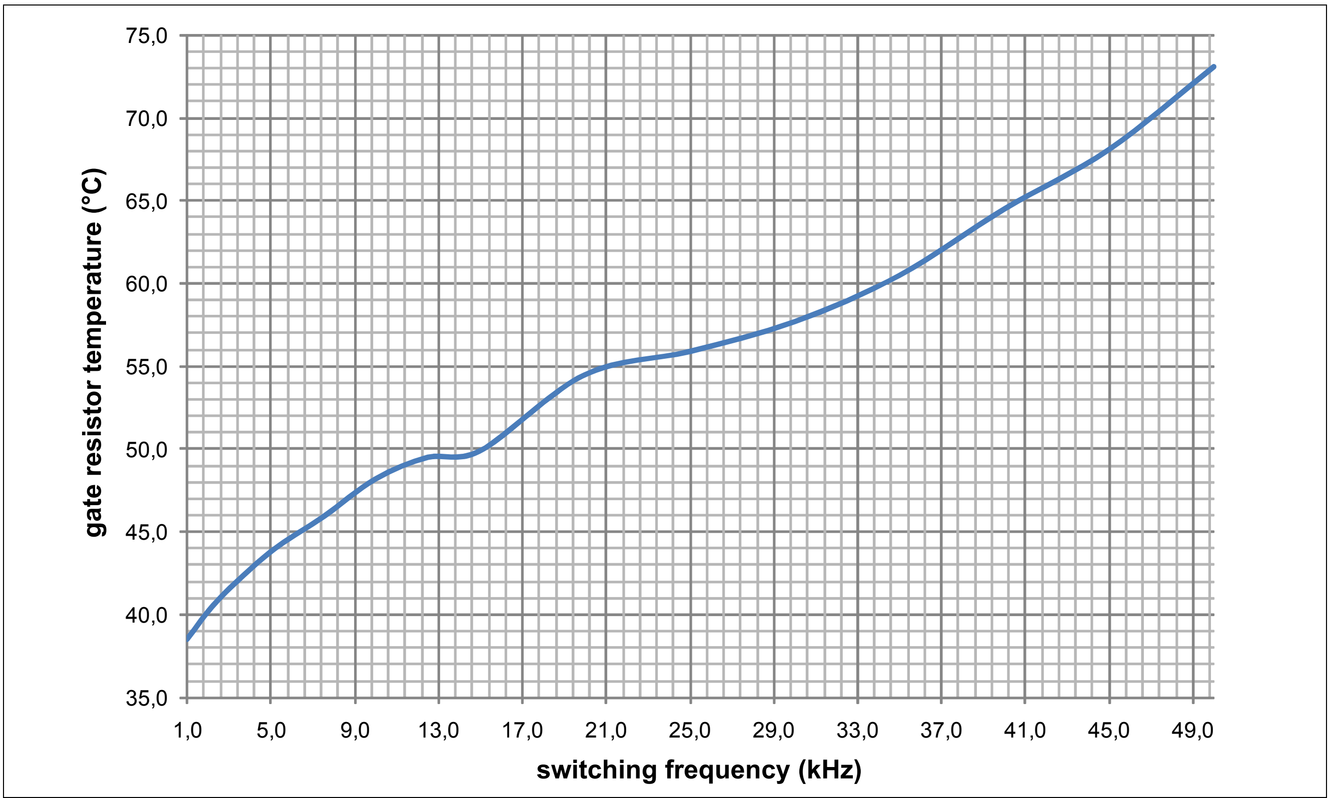

Figure 24 Temperature of Gate Resistors vs. Switching Frequency

3.5.5 Booster

Two transistors per driver IC are used to amplify the driver ICs signals. On this way the driving IGBTs are supplied with sufficient current even if driver ICs alone can't deliver enough current. One NPN transistor is used for switching the IGBT on and another PNP transistor for switching the IGBT off.

The transistors are dimensioned to have enough peak current to drive HybridPACK™1 modules. Peak current can be calculated like in **Equation (2)**:

$$I_{peak} = \frac{\Delta V_{out}}{R_{G_{int}} + R_{G_{ext}} + R_{Driver}} \qquad (2)$$

For circuit details please refer to **Figure 37**.

3.5.6 Short Circuit Protection and Clamp Function

The short circuit protection of the Driver Board basically relies on the detection of a voltage level higher as 9 V on the DESAT pin of the 1ED020I12-FA driver IC and the implemented active clamp function. Thanks to this operation mode, the collector-emitter overvoltage, which is a result of the stray inductance and the collector current slope, is limited. Depending on the stray inductance, the current and the DC voltage the voltage overshoot during turn off changes. **Figure 25** shows the parts of the circuit needed for the desaturation function and the active clamping function.

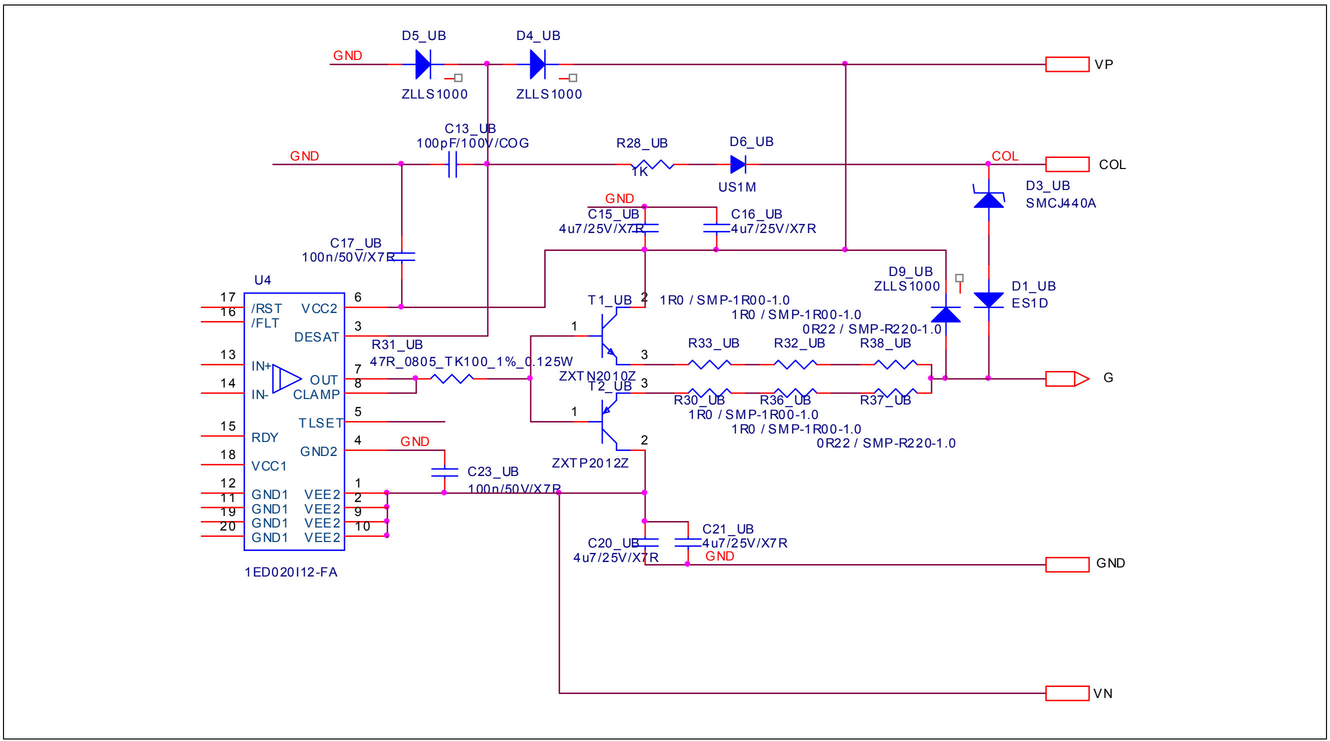

Figure 25 Desaturation Protection and Active Clamping Diodes

In the case of a short circuit the collector-emitter saturation voltage will rise and the driver detects the short circuit occurrence - to protect the IGBT it has to be turned off. As a consequence of IGBT turn-off process there will occur an voltage overshoot due to the stray inductance of the module and the DC-link. This voltage overshoot has to be lower than the maximum IGBT blocking voltage. Therefore the Driver Board has an active clamping function whereby the clamping will increase the voltage for the booster and also increase the voltage directly on the gate.

The typical turn-off waveform under short circuit condition and room temperature of a HybridPACK™1 module without any additional protective functions is shown in **Figure 26** a). Typical waveform under short circuit condition with active clamp function at room temperature is shown in **Figure 26** b). As it can be seen, the voltage overshoot without active clamping at a DC voltage of 71 V is close to the maximum IGBT blocking voltage of HybridPACK™1 (650V), which could damage the devices. With active clamping the voltage overshoot can be reduced and the DC voltage increased without damaging the IGBT module (at 280 V DC voltage can be observed voltage overshoot of approximately 596 V, **Figure 26** b). In design are implemented 440 V clamping diodes. The level of the clamping voltage must be adjusted depending on the application.

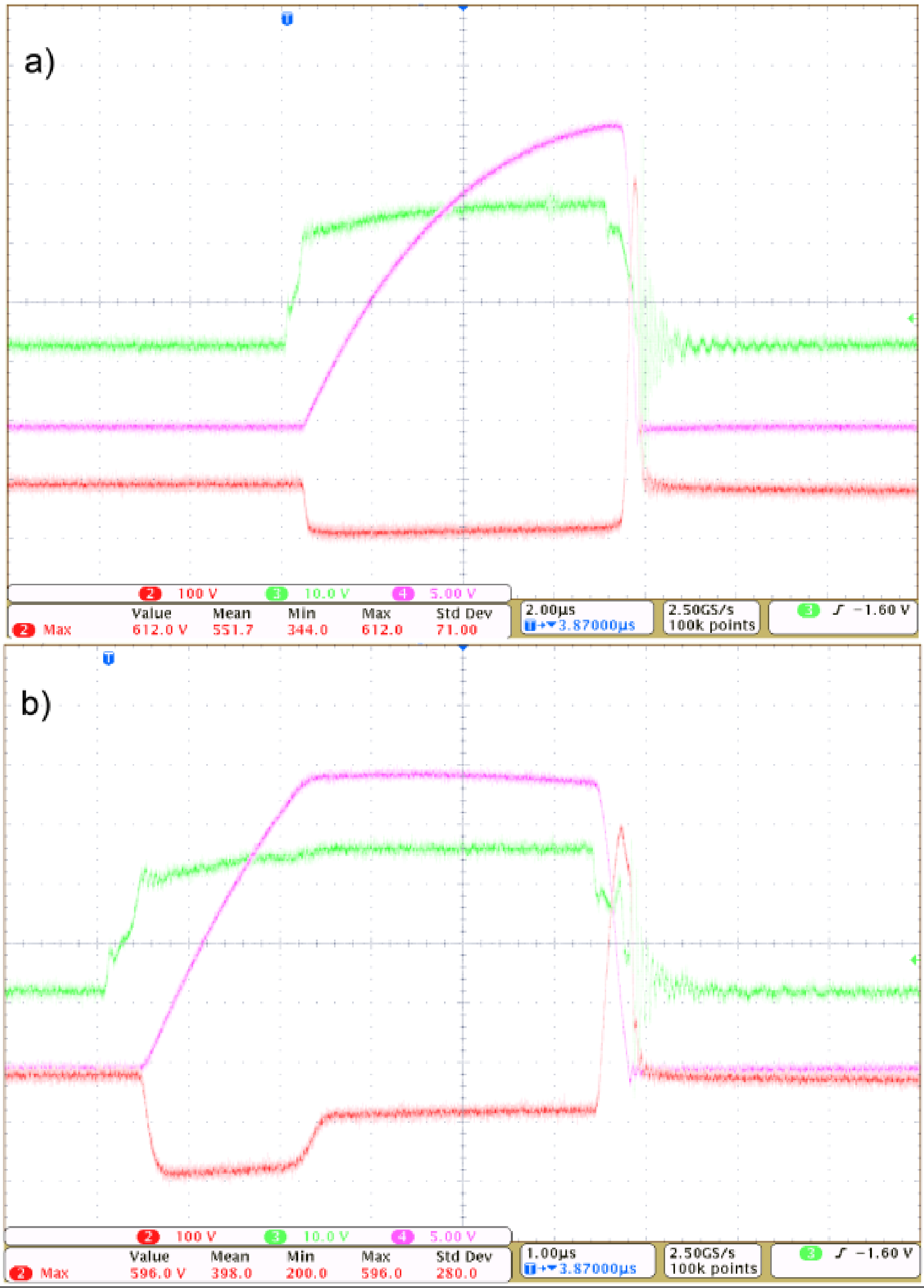

Figure 26 a) Short Circuit without Active Clamp (DC Voltage=71V, Voltage Overshoot=612V)
b) With Active Clamp Function (DC Voltage=280V, Voltage Overshoot=596V)

3.5.7 Fault Output

When a short circuit occurs the voltage V_{CE} is detected by the desaturation protection of the 1ED020I12-FA and the IGBT is switched off. The fault is reported to the primary side of the driver as long as there is no reset signal applied to the driver. The fault signal (/FLT) is active low - the schematic of design implemented in Driver Board can be seen on **Figure 27**.

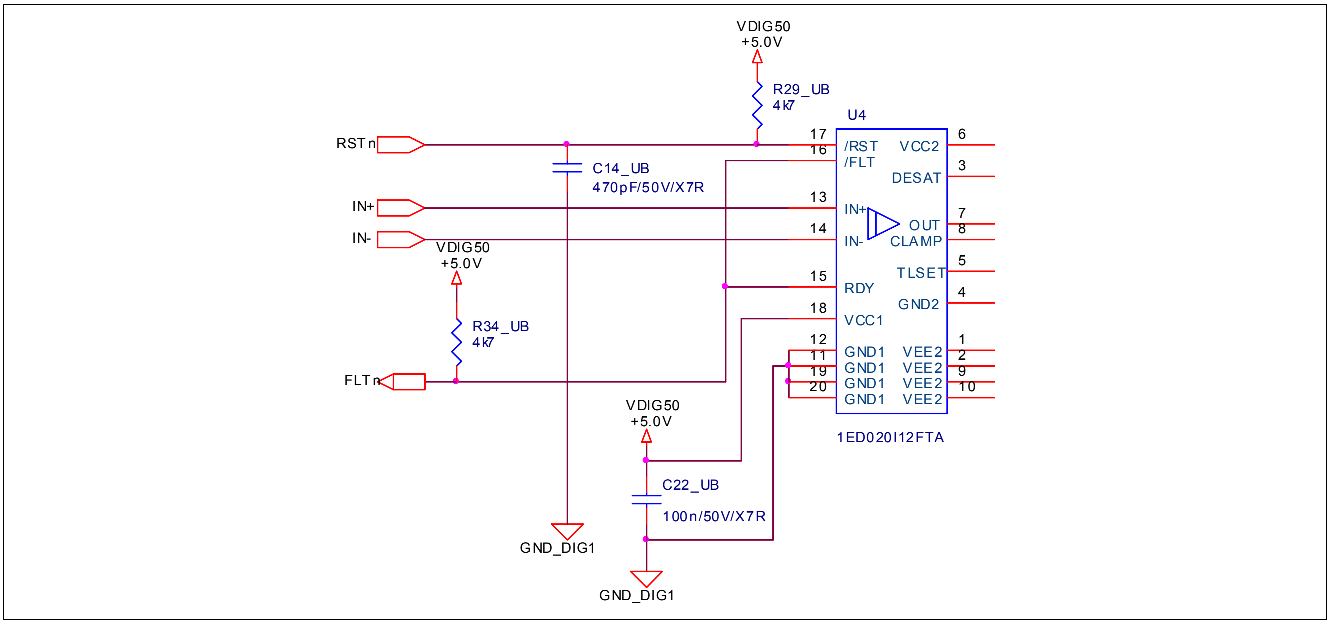

Figure 27 Fault Output of a Single Driver IC

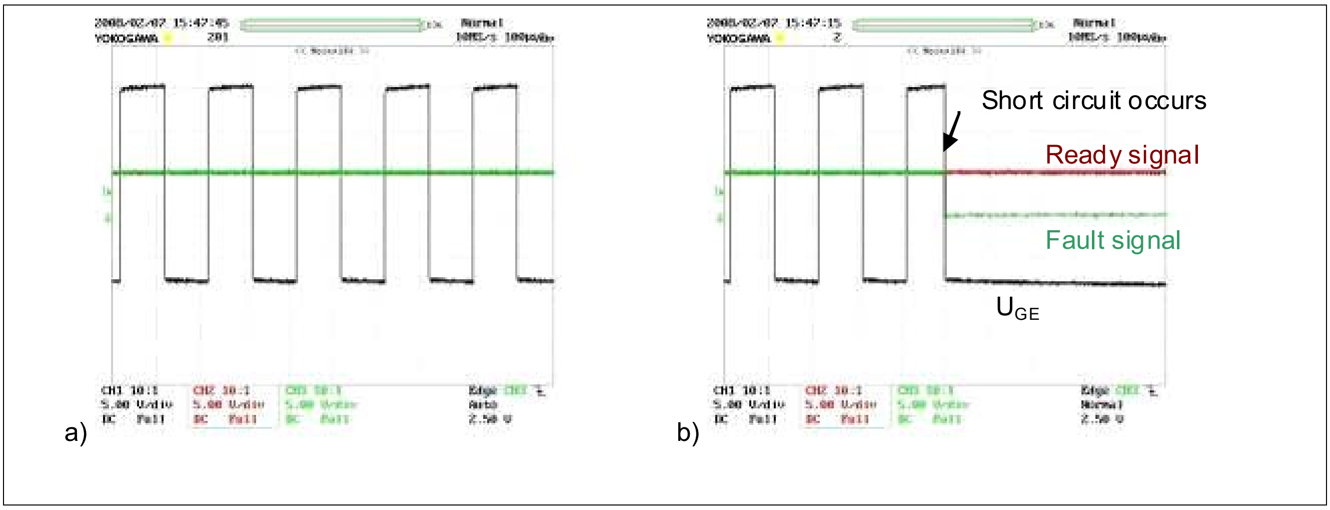

Figure 28 Fault Output During: a) Normal Operation b) Operation under Short Circuit

The fault signal (/FLT) will be in low state if a short circuit occurs until /RST signal is pulled down.

On the Driver Board each of the drivers has its own fault signal (FAULT_UTn, FAULT_UBn, FAULT_VTn, FAULT_VBn, FAULT_WTn, FAULT_WBn). As it can be seen in **Figure 35**, a LED will warn in the case of a DESAT-FAULT condition at a IGBT. The fault signals are connected to a logic circuit and the output of this are a combined fault and one fault for each phase, which is forwarded to the external connector (K1).

3.5.8 Temperature Measurement

The IGBT module HybridPACK™1 includes one integrated NTC (Negative Temperature Coefficient) sensor which simplify the thermal measurements in inverters significantly.

The NTC is located on the same ceramic substrate together with the IGBT and diode chips for the middle phase. The module is filled with silicon gel for isolation purpose and under normal operation conditions the requirements for isolation voltages are met. The NTC isolation capability is tested with 2.5kV AC in final test for 1 minute for 100% of module production.

The NTC is connected to the main connector K1 (pin 10) by means of the circuit showed in **Figure 39**. **Figure 29** shows the relationship between IGBT module base plate temperature of the three phases and output voltage of IGBT module temperature block (TEMP_IGBT, K1.10)

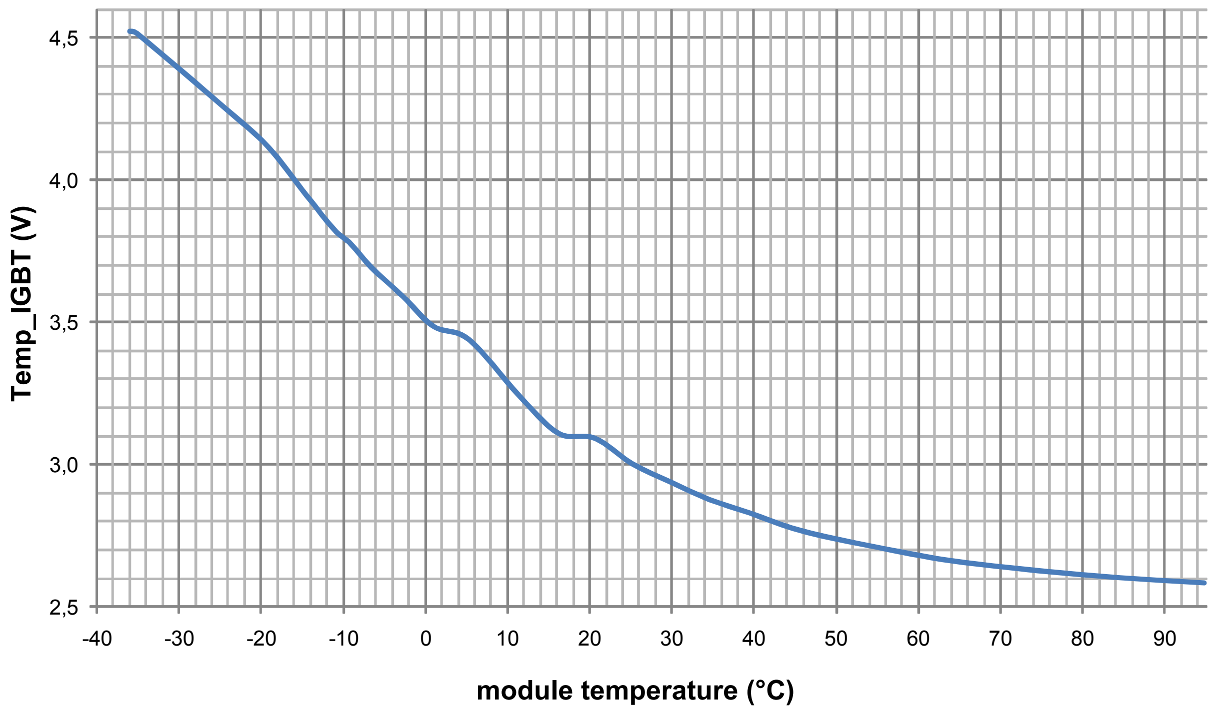

Figure 29 Characteristics of the Temperature Measurements

Note: This temperature measurement is not suitable for the short circuit or short term overload detection and should be used only for the module protection against long term overload or malfunction of the cooling system.

3.5.9 DC Voltage Measurement

On the Hybrid Kit for HybridPACK™1 the voltage at the DC link is measured by means of a isolation amplifier which offers the necessary galvanic isolation (see **Figure 39**).

The output of this circuit is connected to the external connector (Vdc, K1.9). **Figure 30** shows the relationship between DC link voltage and Vdc output signal.

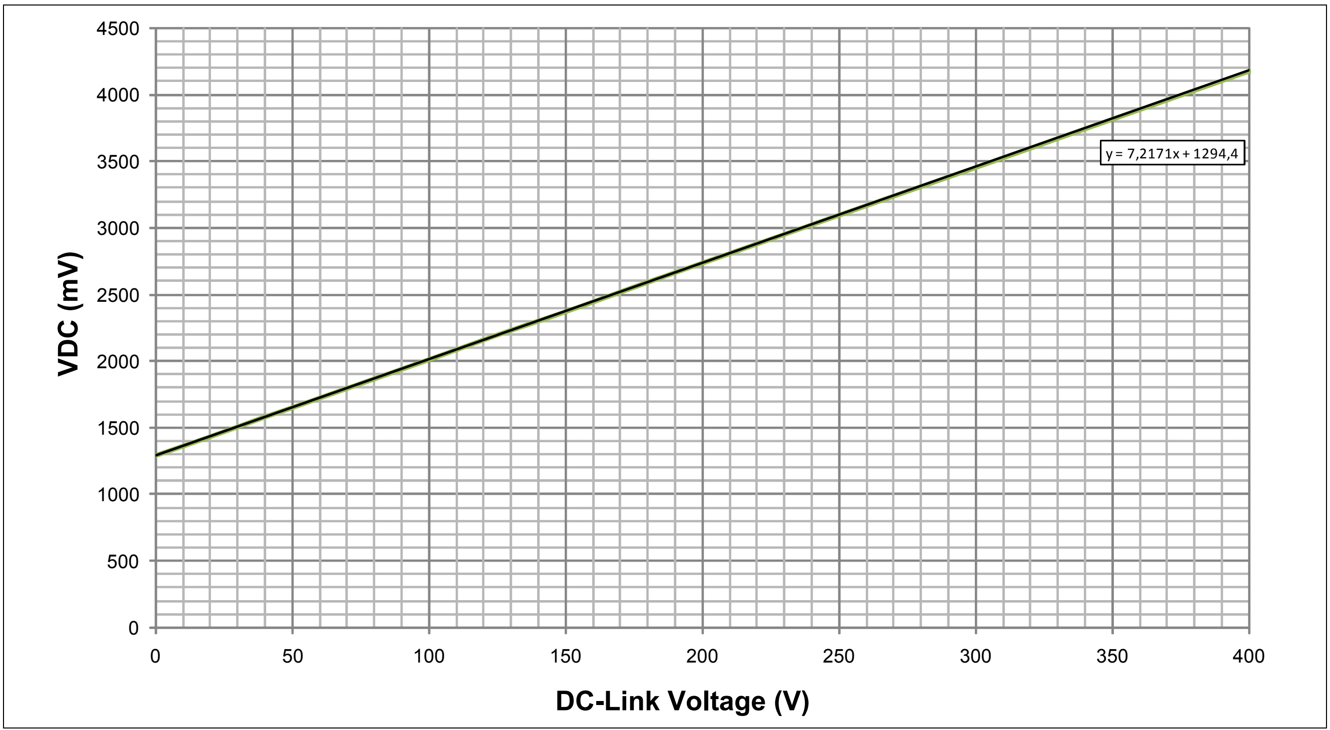

Figure 30 Characteristics of the DC Voltage Measurement

3.6 Switching Losses

Switching losses can be different comparing to the values given in the HybridPACK™1 IGBT module datasheet. Main reason for this discrepancy is that switching voltages used on the Driver Board (+15V for turn-on and -8V for turn-off) differ from HybridPACK™1 characterisation switching voltages (+15V/-15V).

Turn-on losses are expected to be close to the values of the datasheet of HybridPACK™1, but as mentioned, this will be different for the turn-off losses. In general the turn-off losses depend on the stray inductances of the DC-link and increase linear with the DC-link voltage. In the case of the Driver Board the turn-off losses do not increase linearly because of the fact that the active clamping feature increases the turn-off losses due to decrease of the di/dt.

3.7 Definition of Layers of Driver Board

The Driver Board was made keeping the following rules for the copper thickness and the space between different layers shown in **Figure 31**.

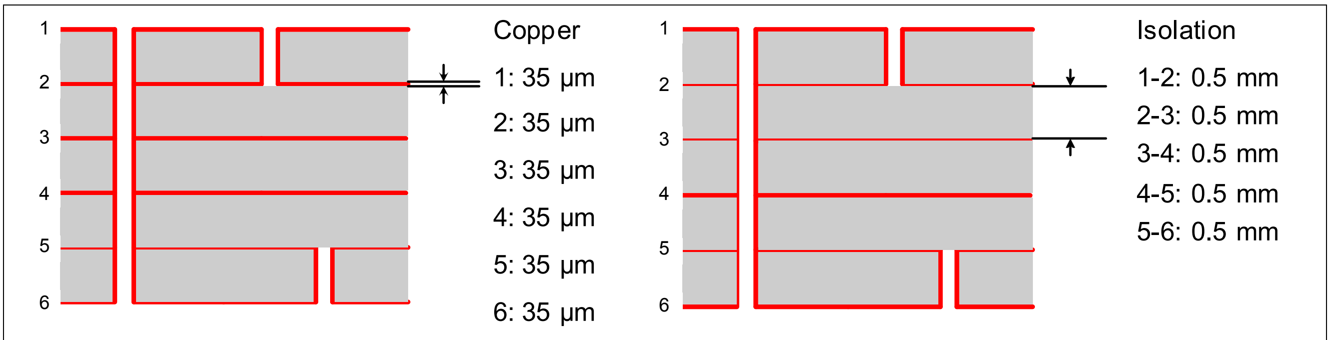

Figure 31 Copper and Isolation for Layers of Driver Board

3.8 Schematics, Layout and Bill of Material

To meet the individual customer requirements and to make the Driver Board for the HybridPACK™1 module as a platform for development or modifications, all necessary technical data like schematics, layout and components are included in this chapter.

The current implementation of the HybridKit (e.g. electrical schematics) is for reference only. It does not cover in general all application specific requirements. For specific recommendations on how to implement design with HybridPACK™ and EiceDRIVER™, please contact local sales partner. More information is available on www.infineon.com/hybrid.

3.8.1 Schematics

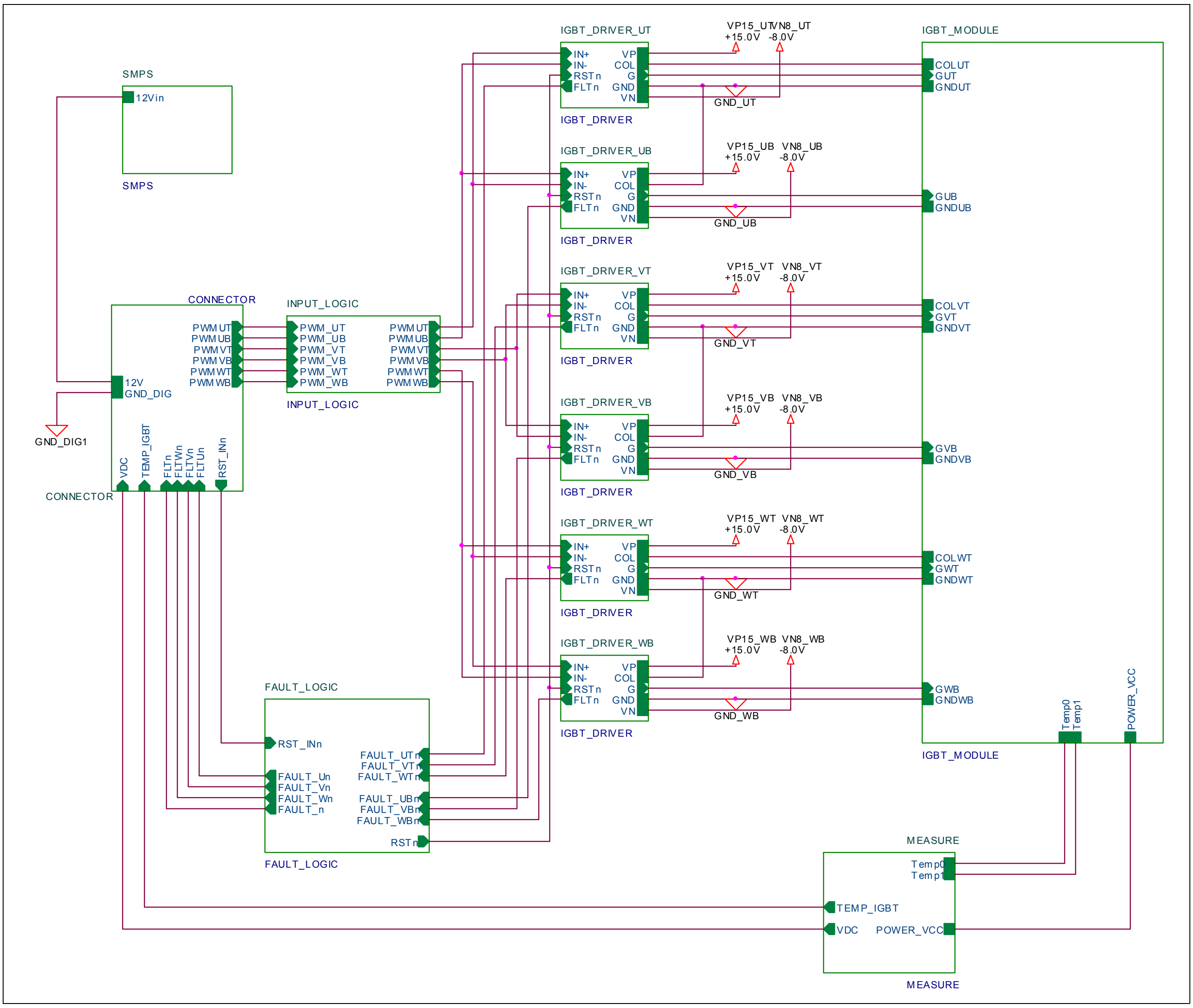

Figure 32 Schematics Block Overview

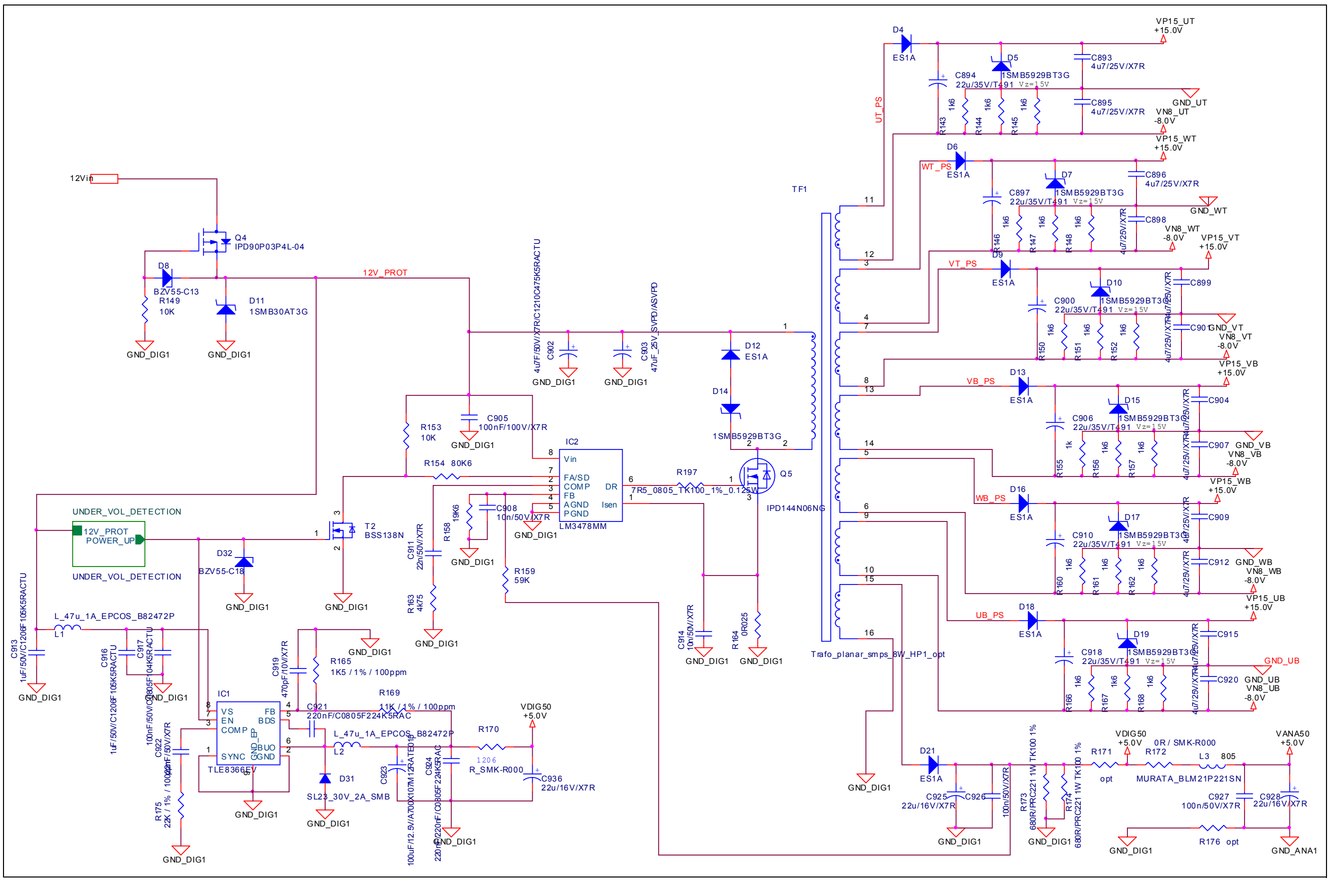

Figure 33 SMPS - Power Supply

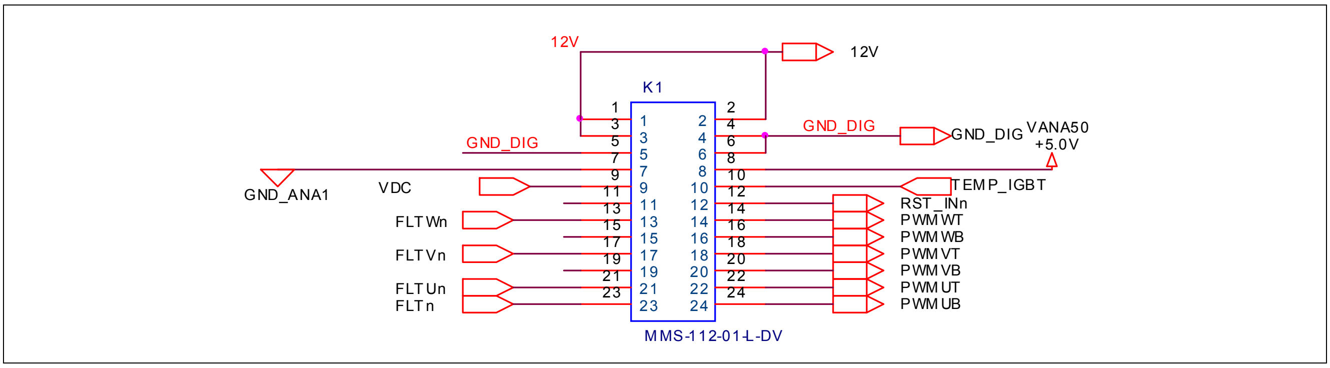

Figure 34 External Connector

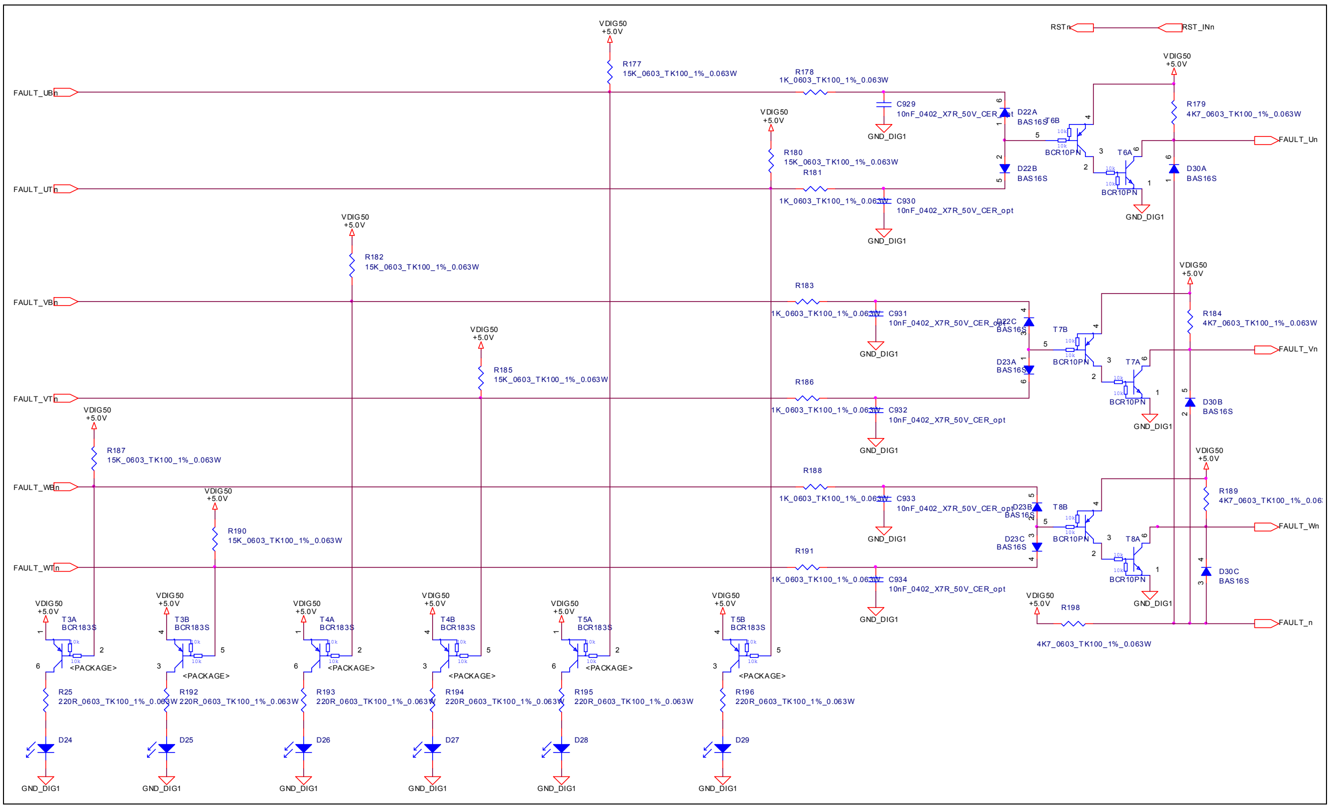

Figure 35 Fault Logic

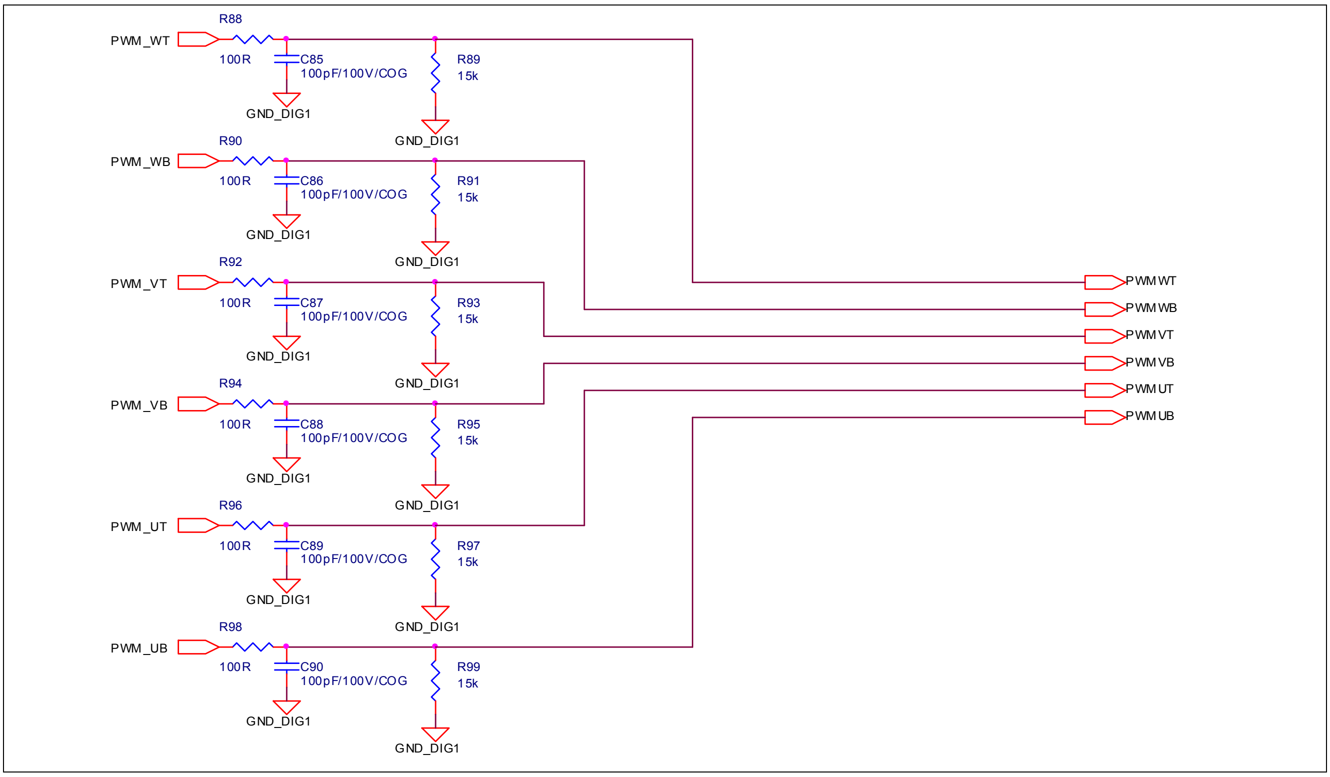

Figure 36 Input Logic

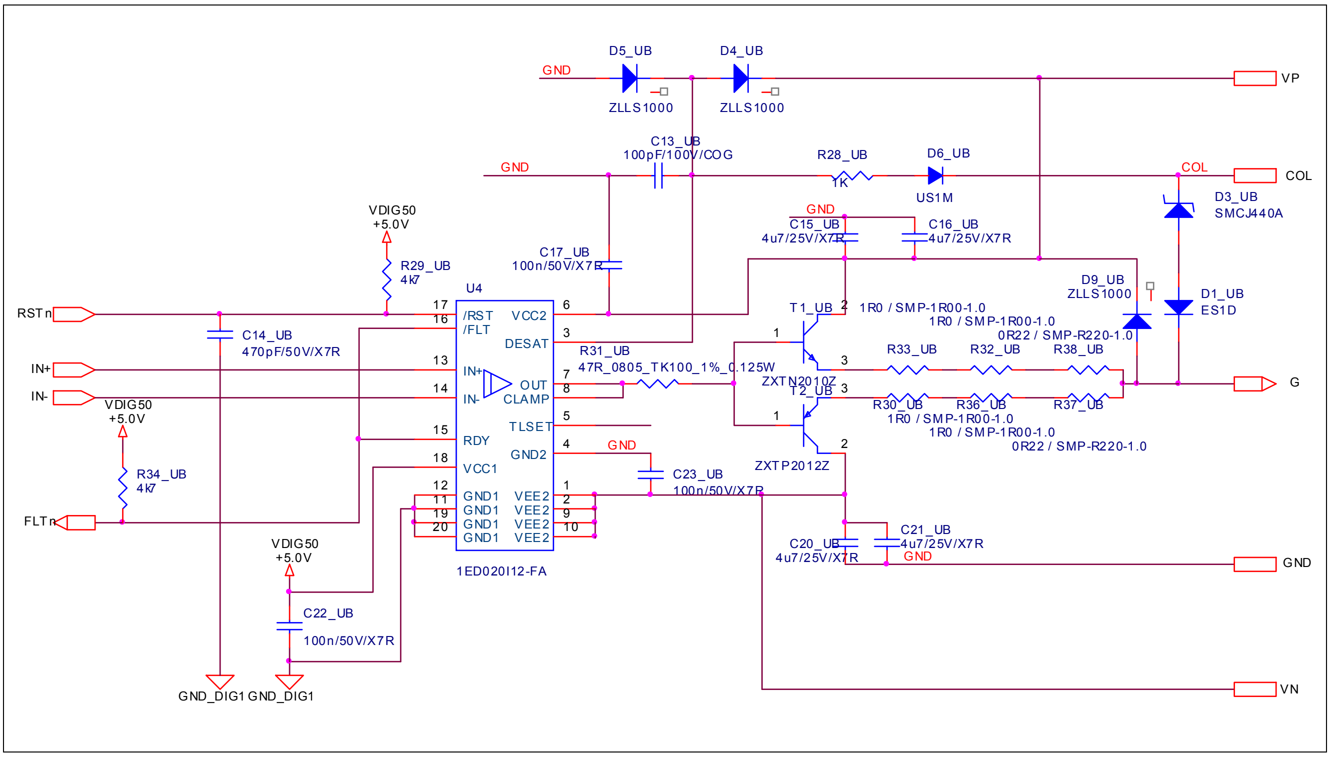

Figure 37 IGBT Driver - Bottom Transistor of Phase U

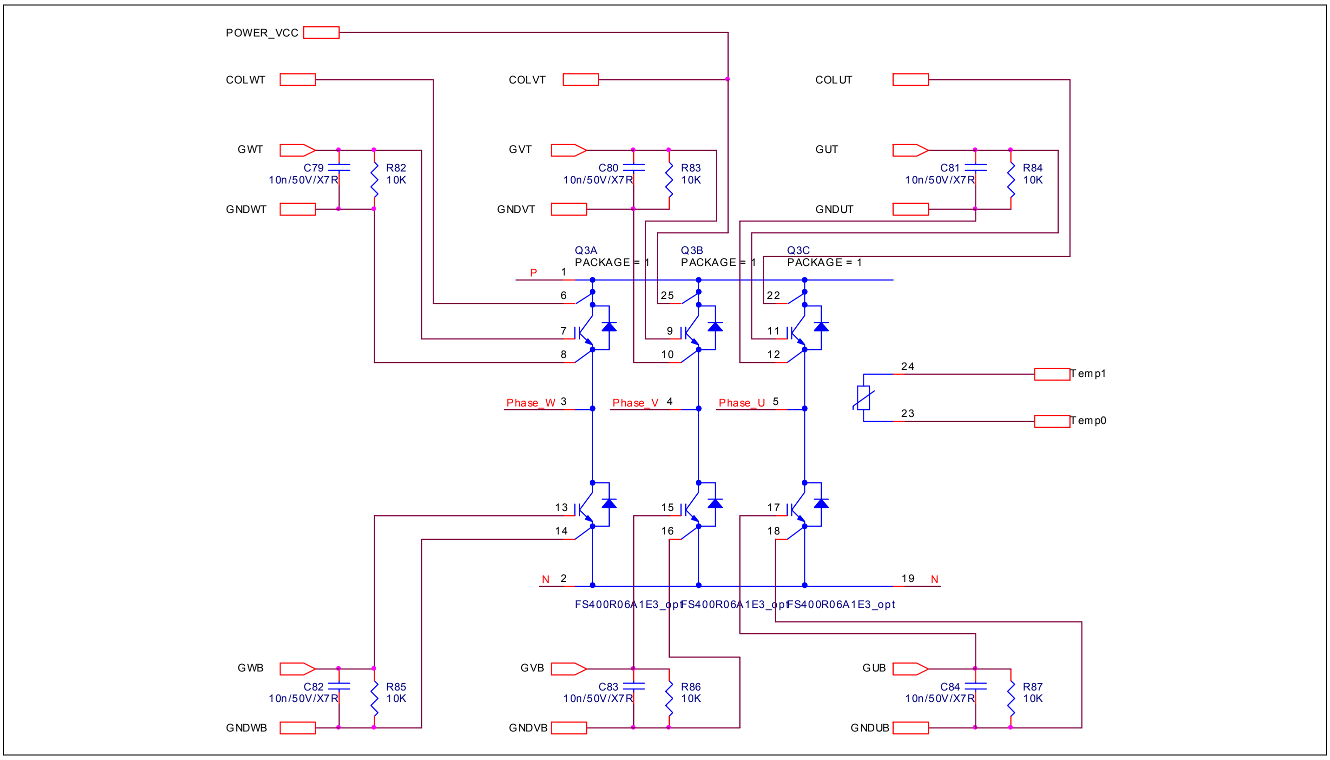

Figure 38 IGBT Module

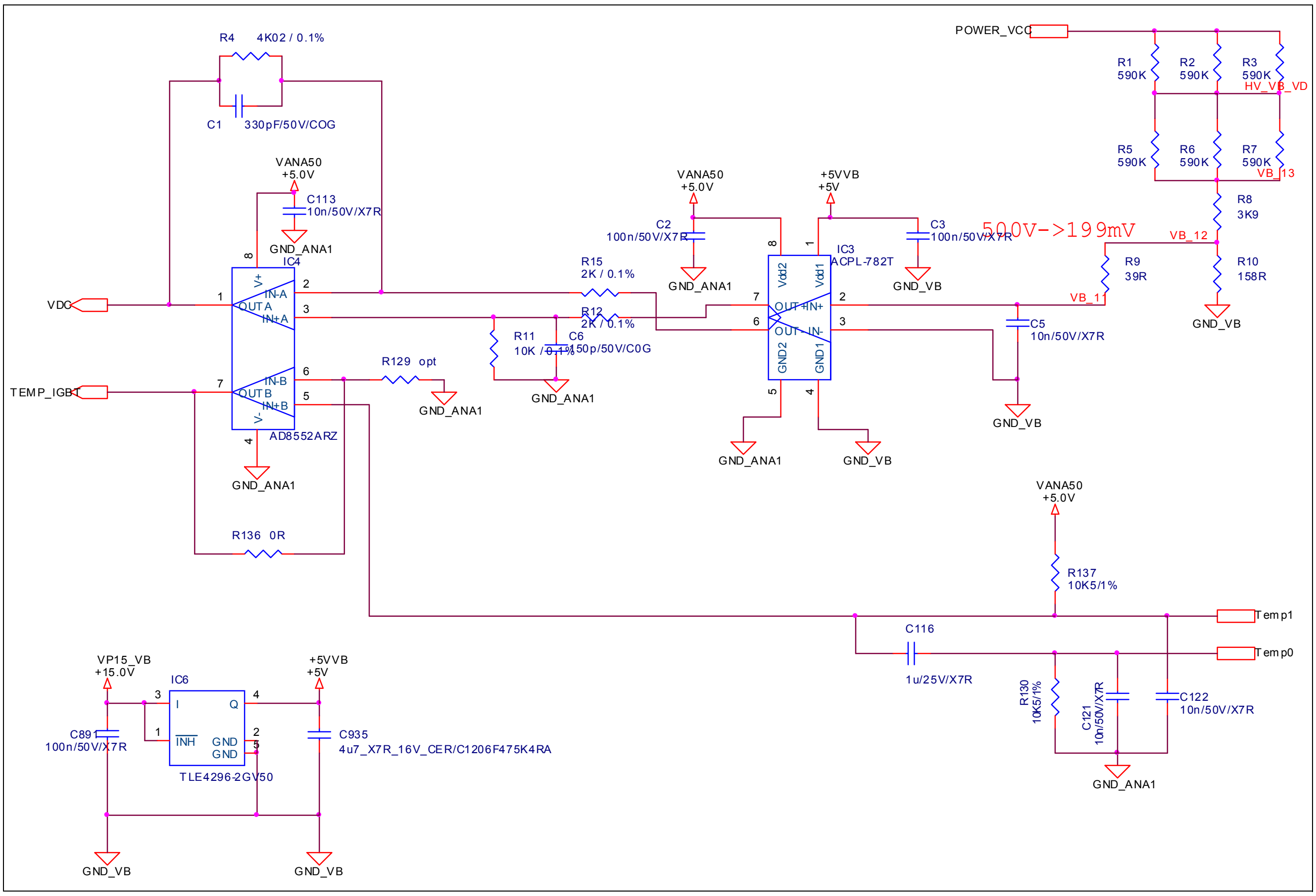

Figure 39 DC Voltage & Temperature Measurement

3.8.2 Assembly Drawing

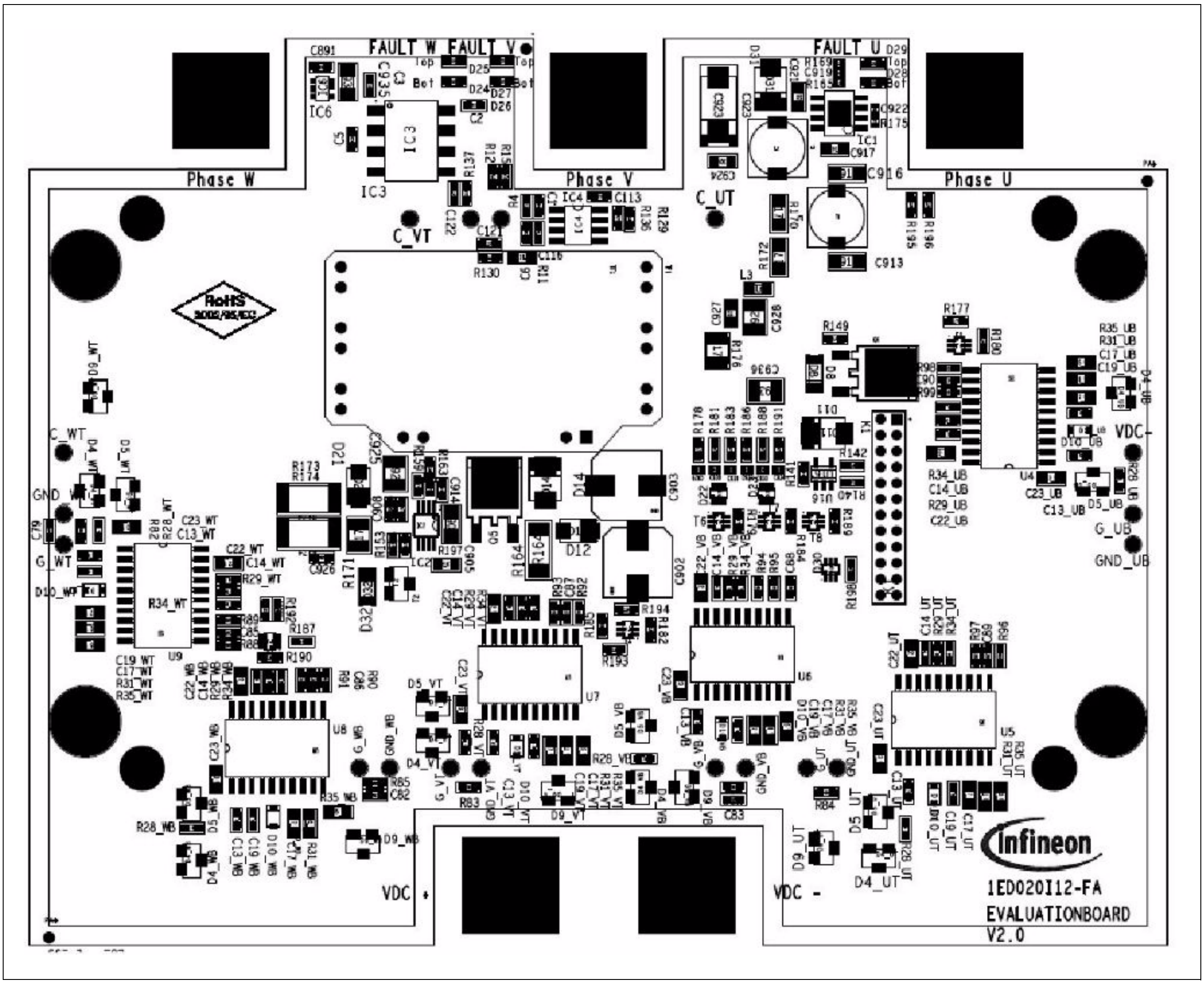

Figure 40 Assembly Drawing of the Driver Board (Top)

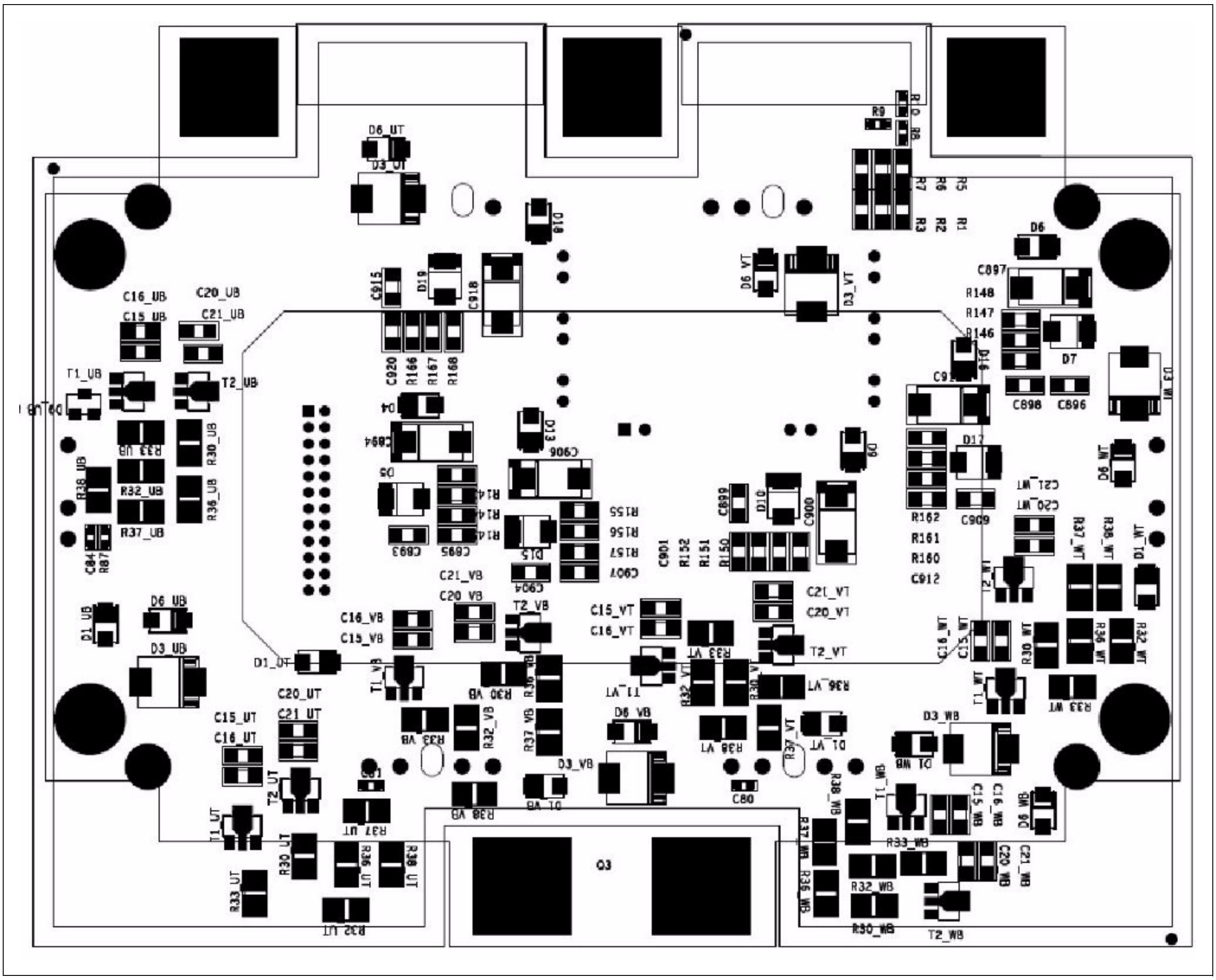

Figure 41 Assembly Drawing of the Driver Board (Bottom)

For detail information use the zoom function of your PDF viewer to zoom into the drawings on **Figure 40** and **Figure 41**.

3.8.3 Layout

Layout of the Driver Board is shown on **Figure 42** (Top Layer), on **Figure 43** (Layer-2), on **Figure 44** (Layer-3), on **Figure 45** (Layer-4), on **Figure 46** (Layer-5) and on **Figure 47** (Bottom Layer).

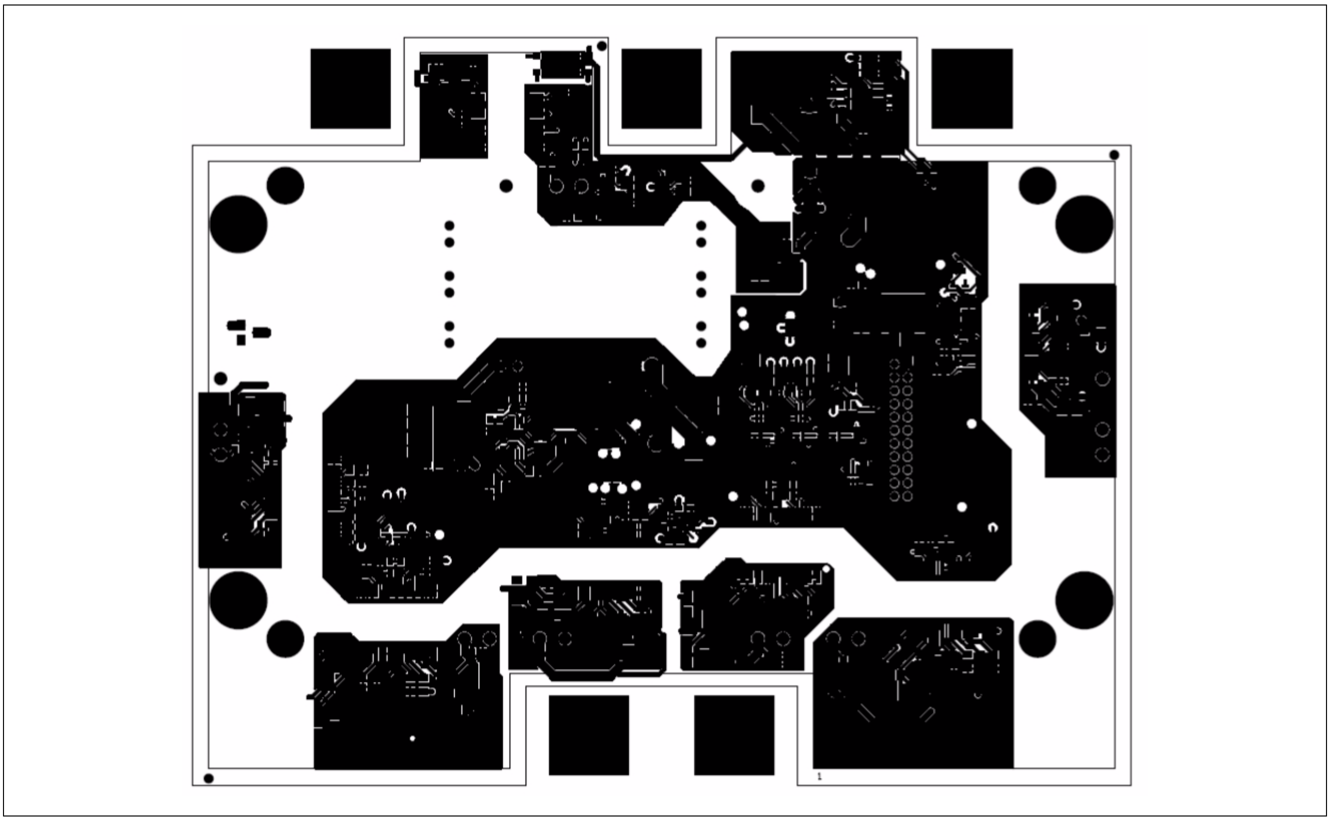

Figure 42 Driver Board - Top Layer

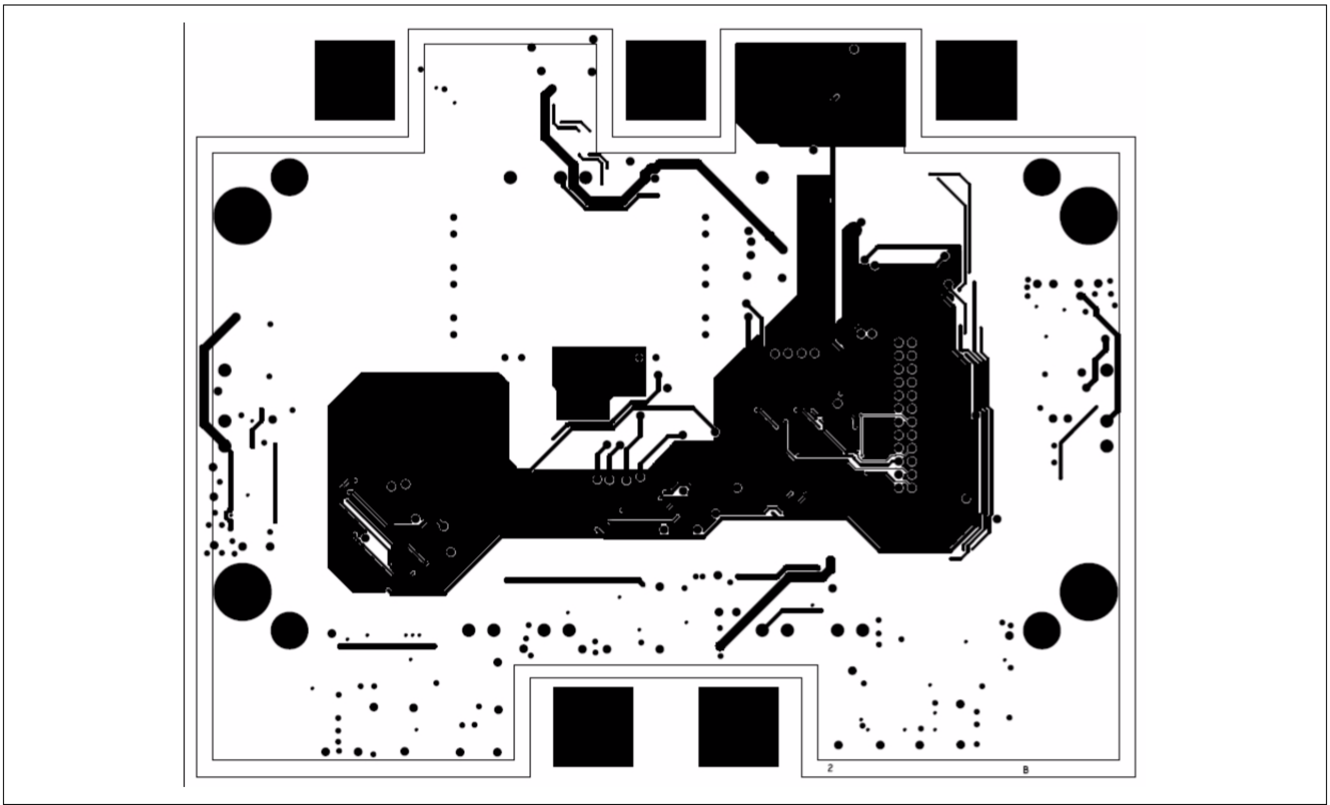

Figure 43 Driver Board - Layer-2

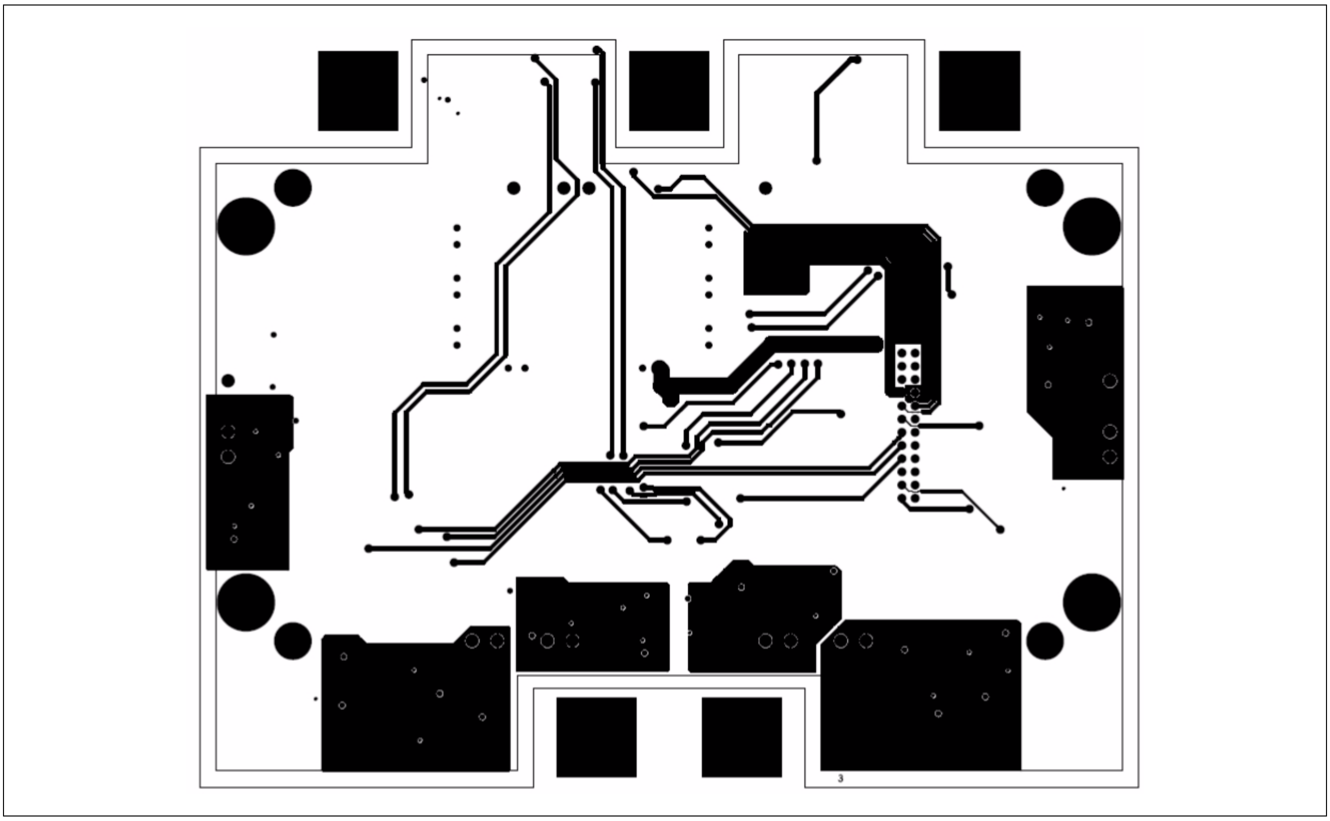

Figure 44 Driver Board - Layer-3

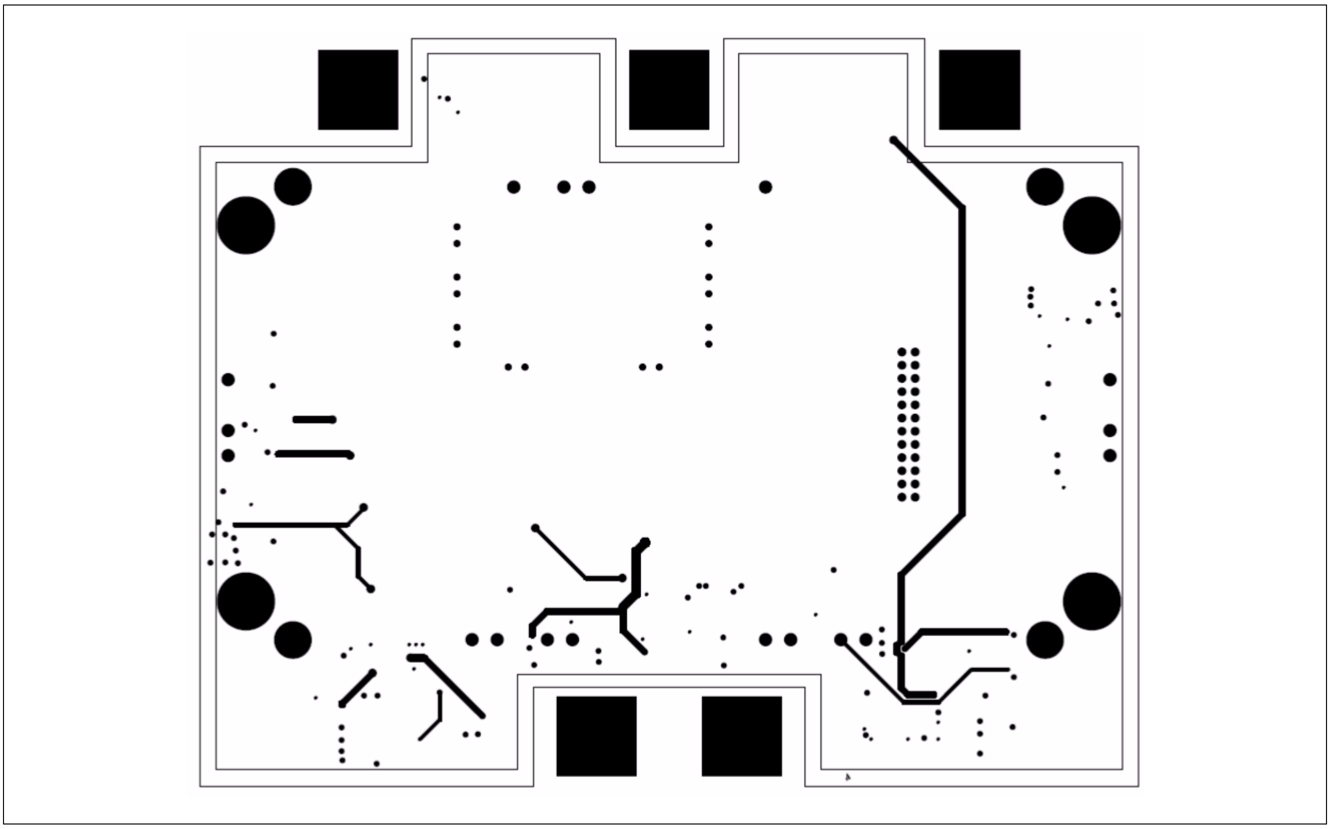

Figure 45 Driver Board - Layer-4

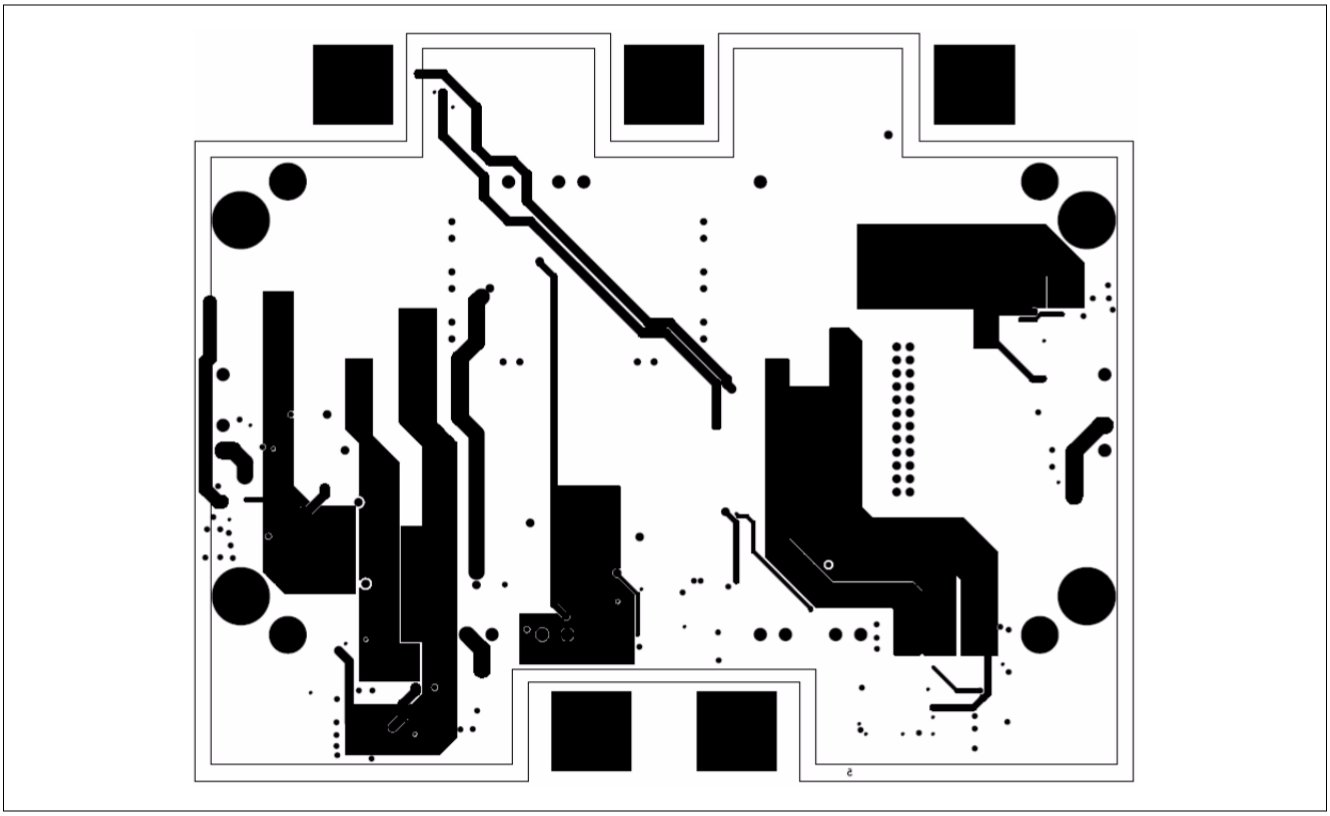

Figure 46 Driver Board - Layer-5

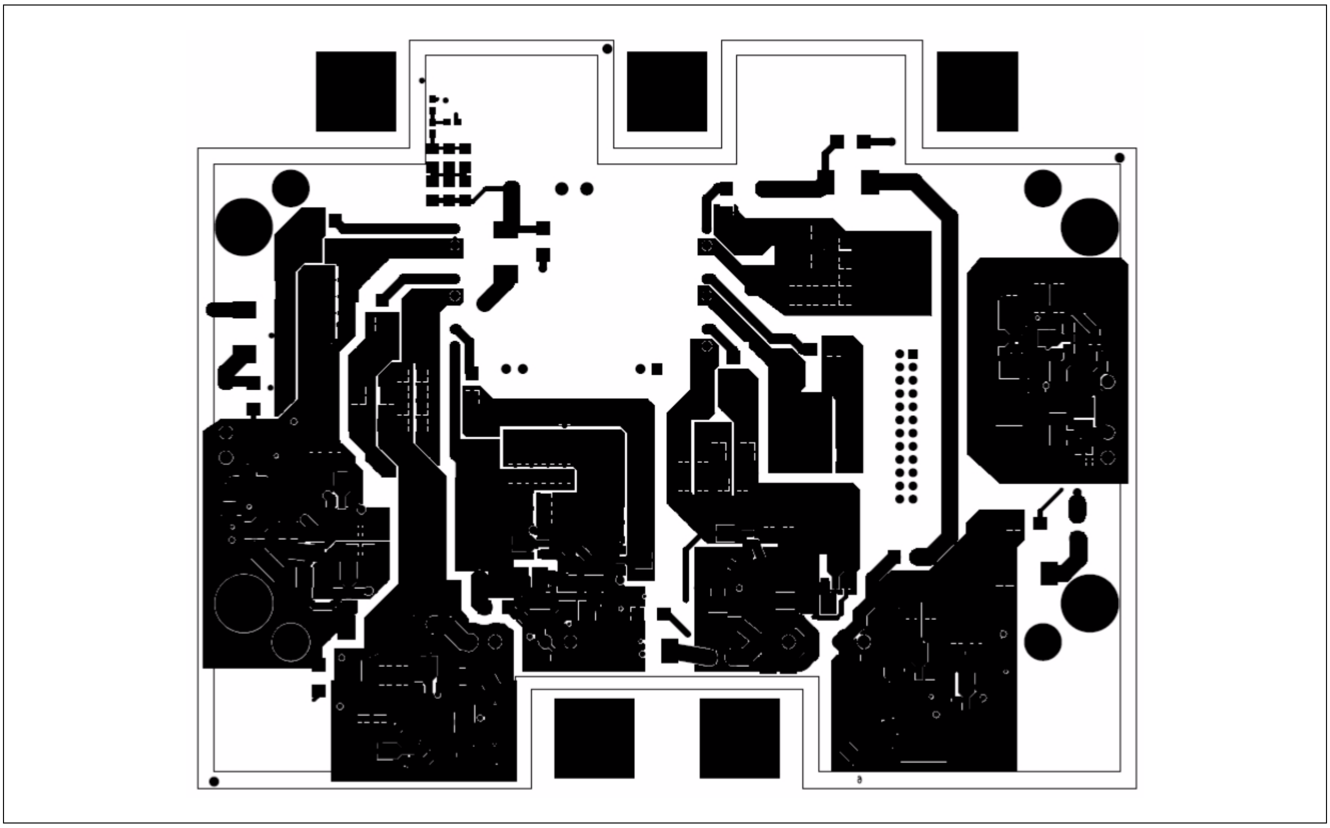

Figure 47 Driver Board - Bottom Layer

3.8.4 Bill of Materials

Table 4 Bill of Materials for Hybrid Kit for the HybridPACK™1 Evaluation Driver Board

Reference	Value / Device	Package
C1	330pF/50V/COG	C0603
C116	1u/25V/X7R	C0805
C13_WT,C13_WB,C13_VT,C13_VB,C13_UT, C13_UB,C85,C86,C87,C88,C89,C90	100pF/100V/COG	C0603
C14_WT,C14_WB,C14_VT,C14_VB,C14_UT, C14_UB	470pF/50V/X7R	C0603
C15_WT,C15_WB,C15_VT,C15_VB,C15_UT, C15_UB,C16_WT,C16_WB,C16_VT,C16_VB, C16_UT,C16_UB,C20_WT,C20_WB,C20_VT, C20_VB,C20_UT,C20_UB,C21_WT,C21_WB, C21_VT,C21_VB,C21_UT,C21_UB,C893,C89 5,C896,C898,C899,C901,C904,C907,C909,C 912,C915,C920	4u7/25V/X7R	C1206
C17_WT,C17_WB,C17_VT,C17_VB,C17_UT, C17_UB,C22_WT,C22_WB,C22_VT,C22_VB, C22_UT,C22_UB,C23_WT,C23_WB,C23_VT, C23_VB,C23_UT,C23_UB,C927	100n/50V/X7R	C0805
C19_WT,C19_WB,C19_VT,C19_VB,C19_UT, C19_UB	33pF/100V/COG	C0603
C2,C3,C891,C926	100n/50V/X7R	C0603
C5,C79,C80,C81,C82,C83,C84,C113,C121,C 122,C908,C914	10n/50V/X7R	C0603
C6	150p/50V/C0G	C0603
C894,C897,C900,C906,C910,C918	22u/35V/T491	C7343
C902	4u7/50V/X7R	C1210
C903	47uF/25V/ASVPD	C0810
C905	100nF/100V/X7R	C1206
C911,C922	22n/50V/X7R	C0402
C913,C916	1uF/50V/C1206F105K5	C1206
C917	100nF/50V/C0805F104K5	C0805
C919	470pF/10V/X7R	C0402
C921,C924	220nF/C0805F224K5RAC	C0805
C923	100uF/12.5V/A700X107M1 2RATE015	C7343
C925,C928,C936	22u/16V/X7R	C1210
C929,C930,C931,C932,C933,C934	10n/16V/X7R/optional	C0402
C935	4u7/16V/X7R/C1206F475 K4RA	C1206

Table 4 Bill of Materials for Hybrid Kit for the HybridPACK™1 Evaluation Driver Board (cont'd)

Reference	Value / Device	Package
D1_WT,D1_WB,D1_VT,D1_VB,D1_UT,D1_UB	ES1D	DO214AC
D10_WT,D10_WB,D10_VT,D10_VB,D10_UT, D10_UB	MM3Z9V1T1G/optional	SOD323
D11	1SMB30AT3G	SMB
D22,D23,D30	BAS16S	SOT363
D24,D25,D26,D27,D28,D29	SML-512UWT86	D0603
D3_WT,D3_WB,D3_VT,D3_VB,D3_UT,D3_UB	SMCJ440A	SMC
D31	SL23/30V/2A	DO214AA/SMB
D32	BZV55/C18	SOD80C
D4_WT,D4_WB,D4_VT,D4_VB,D4_UT,D4_UB,	ZLLS1000	SOT23
D4,D6,D8,D10,D11,D14,D16,D18	ES1A	DO214AC
D5,D7,D10,D14,D15,D17,D19	1SMB5929BT3G	DO214AA/SMB
D6_WT,D6_WB,D6_VT,D6_VB,D6_UT,D6_UB	GF1M	DO214AC/SMA
D8	BZV55-C13	SOD80C
IC1	TLE8366EV	SO-8-27
IC2	LM3478MM	MSOP-8
IC3	ACPL-782T	DIP-8
IC4	AD8552ARZ	SO-8
IC6	TLE4296GV50	SCT595
K1	MMS-112-01-L-DV	24POL
L1,L2	47uH/1A/B82472P	SMD 7,5x7,5
L3	MURATA_BLM21P221SN	L0805
Q3	FS400R06A1E3	HybridPACK™1
Q4	IPD90P03P4L-04	TO252
Q5	IPD144N06NG	TO252
R1,R2,R3,R5,R6,R7	590K/1%	R1206
R10	158R/1%	R0603
R11	10K 0.1%	R0603
R12,R15	2K /0.1%	R0603
R129	Optional	R0603
R130,R137	10K5/1%	R0603
R136	0R/1%	R0603
R140	226K/1%	R0603
R142	47K/1%	R0603

Table 4 Bill of Materials for Hybrid Kit for the HybridPACK™1 Evaluation Driver Board (cont'd)

Reference	Value / Device	Package
R143,R144,R145,R146,R147,R148,R150,R151,R152,R156,R157,R160,R161,R162,R166,R167,R168	1K6/1%	R1206
R154	80K6/1%	R0603
R155	1K/1%	R1206
R158	19K6/1%	R0603
R159	59K/1%	R0603
R163	4.75 kΩ/1%	R0603
R164	0R025/1%	R2010
R165	1K5/1%	R0402
R169	11kΩ/1%	R0402
R170,R172	SMK-R000	SMK (1206)
R171,R176	optional	R1210
R173,R174	1K2/PRC221/1W/1%	R2512
R175	22K/1%	R0402
R177,R180,R182,R185,R187,R190,R89,R91,R93,R95,R97,R99	15k/1%	R0603
R178,R181,R183,R186,R188,R191	1K/1%	R0603
R179,R184,R189,R198	4K7/1%	R0603
R197	7R5/1%/0.125W	R0805
R25,R192,R193,R194,R195,R196	220R/1%	R0603
R28_WT,R28_WB,R28_VT,R28_VB,R28_UT,R28_UB	1K/1%	R0603
R29_WT,R29_WB,R29_VT,R29_VB,R29_UT,R29_UB	4K7/1%	R0603
R30_WT,R30_WB,R30_VT,R30_VB,R30_UT,R30_UB,R32_WT,R32_WB,R32_VT,R32_VB,R32_UT,R32_UB,R33_WT,R33_WB,R33_VT,R33_VB,R33_UT,R33_UB,R36_WT,R36_WB,R36_VT,R36_VB,R36_UT,R36_UB	1R0 / SMP-1R00-1.0	SMP (2010)
R31_WT,R31_WB,R31_VT,R31_VB,R31_UT,R31_UB	47R/1%	R0805
R35_WT,R35_WB,R35_VT,R35_VB,R35_UT,R35_UB	0R/1%	R0805
R35_WT,R35_WB,R35_VT,R35_VB,R35_UT,R35_UB	OR/1%	R0805
R37_WT,R37_WB,R37_VT,R37_VB,R37_UT,R37_UB,R38_WT,R38_WB,R38_VT,R38_VB,R38_UT,R38_UB	0R22 / SMP-R220-1.0	SMP (2010)
R4	4K02 / 0.1%	R0603
R8	3K9/1%	R0603

Table 4 Bill of Materials for Hybrid Kit for the HybridPACK™1 Evaluation Driver Board (cont'd)

Reference	Value / Device	Package
R82,R83,R84,R85,R86,R87,R182	10K/1%	R0603
R88,R90,R92,R94,R96,R98	100R/1%	R0603
R9	39R/1%	R0603
T1_WT,T1_WB,T1_VT,T1_VB,T1_UT,T1_UB	ZXTN2010Z	SOT89
T2	BSS138N	SOT23
T2_WT,T2_WB,T2_VT,T2_VB,T2_UT,T2_UB	ZXTP2012Z	SOT89
T3,T4,T5	BCR183S	SOT363
T6,T7,T8	BCR10PN	SOT363
TF1	Planar Transformer v2.1	TH 16pin
U16	MAX6457UKD3A-T	SOT23-5
U18,U33,U34	AD8552ARZ	SO-8
U4,U5,U6,U7,U8,U9	1ED020I12-FA	PG-DSO-20

4 Logic Board for Hybrid Kit for HybridPACK™1

Figure 48 Logic Board for Hybrid Kit for the HybridPACK™1

Logic Board (**Figure 48**) contains all the components for the control of the Hybrid Kit for the HybridPACK™1. Furthermore it offers the interface for all the other elements which build a complete inverter system: motor interface (encoder, resolver, sensors), current sense interface, communication (CAN and RS232) and additional analogue (x3) and digital (x4) inputs/outputs. **Figure 49** shows the block structure of the Logic Board and the following chapters describe these blocks in detail.

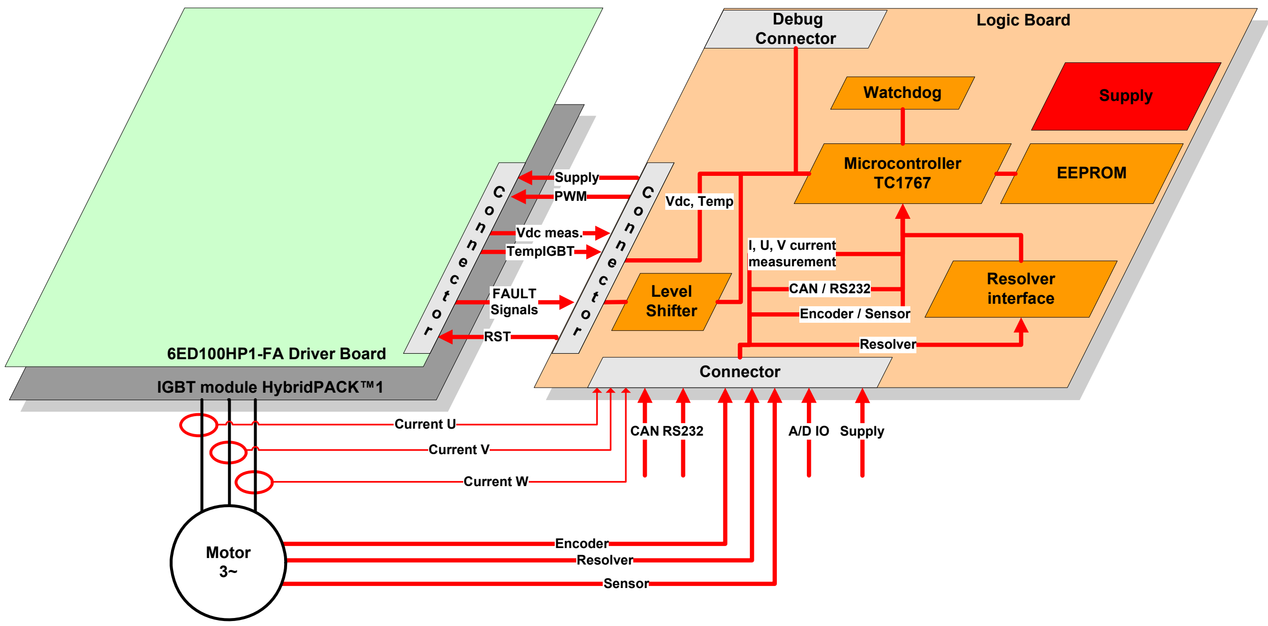

Figure 49 Block Diagram of the Logic Board

4.1 External Connector (X1-SIG1) Pin Assignment

Connector X1-SIG1 (Harwin M80-5125042P) provides the interface to all the external systems: motor (encoder, resolver, sensors), current sense, communication (CAN and RS232) and extra analogue and digital inputs/outputs. **Figure 50** shows the pin assignment of the connector X1-SIG1. For the description of the signals see **Table 5**.

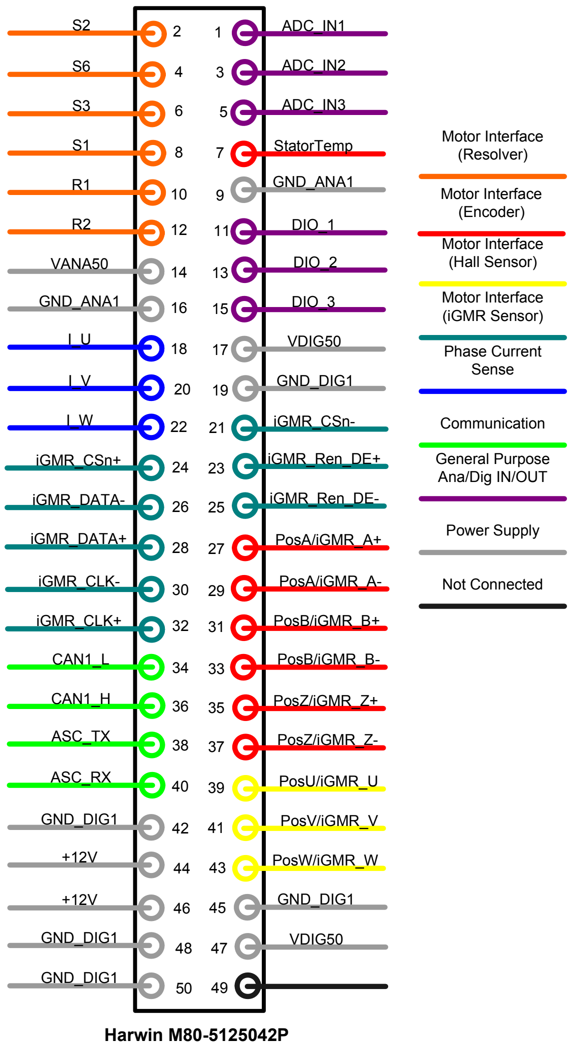

Figure 50 External Connector Pin Assignment

Table 5 External Connector Pin Assignment Logic Board v1.3b

Pin Number	Pin Name	Type	Description
1	ADC_IN1	I/O	General Purpose Analog I/O
2	S2	Input	Resolver Sine (high)
3	ADC_IN2	I/O	General Purpose Analog I/O
4	S6	Input	Resolver Sine (low)
5	ADC_IN3	I/O	General Purpose Analog I/O
6	S3	Input	Resolver Cosine (high)
7	StatorTemp	Input	Motor Temperature Measurement
8	S1	Input	Resolver Cosine (low)
9	GND_ANA1	Supply	Analog Ground
10	R1	Output	Resolver Excitation (high)
11	DIO1	I/O	General Purpose Digital I/O
12	R2	Output	Resolver Excitation (low)

Table 5 External Connector Pin Assignment Logic Board v1.3b (cont'd)

Pin Number	Pin Name	Type	Description
13	DIO2	I/O	General Purpose Digital I/O
14	VANA50	Supply	+5.0V Analog Power Supply
15	DIO3	I/O	General Purpose Digital I/O
16	GND_ANA1	Supply	Analog Ground
17	VDIG50	Supply	+5.0V Digital Power Supply
18	I_U	Input	Current Sense Phase U
19	GND_DIG1	Supply	Digital Ground
20	I_V	Input	Current Sense Phase V
21	iGMR_CSn-	Output	iGMR Chip Select (differential signal)
22	I_W	Input	Current Sense Phase W
23	iGMR_REn_DE+	Output	iGMR Read Enable (differential signal)
24	iGMR_CSn+	Output	iGMR Chip Select (differential signal)
25	iGMR_REn_DE-	Output	iGMR Read Enable (differential signal)
26	iGMR_DATA-	I/O	iGMR Data (differential signal)
27	PosA/iGMR_A+	Input	Encoder Phase A (differential signal)
28	iGMR_DATA+	I/O	iGMR Data (differential signal)
29	PosA/iGMR_A-	Input	Encoder Phase A (differential signal)
30	iGMR_CLK-	Output	iGMR SSC Clock (differential signal)
31	PosB/iGMR_B+	Input	Encoder Phase B (differential signal)
32	iGMR_CLK+	Output	iGMR SSC Clock (differential signal)
33	PosB/iGMR_B-	Input	Encoder Phase B (differential signal)
34	CAN1_L	I/O	Low line I/O CAN Signal
35	PosZ/iGMR_Z+	Input	Encoder Phase Z - index (differential signal)
36	CAN1_H	I/O	High line I/O CAN Signal
37	PosZ/iGMR_Z-	Input	Encoder Phase Z - index (differential signal)
38	ASC_TX	Output	RS-232 Transmitter Output
39	PosU/iGMR_U	Input	Hall Sensor Phase U
40	ASC_RX	Input	RS-232 Receiver Input
41	PosV/iGMR_V	Input	Hall Sensor Phase V
42	GND_DIG1	Supply	Digital Ground
43	PosW/iGMR_W	Input	Hall Sensor Phase W
44	KL_30_IN	Supply	+12.0V Power Supply
45	GND_DIG1	Supply	Digital Ground
46	KL_30_IN	Supply	+12.0V Power Supply
47	VDIG50	Supply	+5.0V Digital Power Supply
48	GND_DIG1	Supply	Digital Ground
49	NC	NC	Not Connected
50	GND_DIG1	Supply	Digital Ground

4.2 Connector to the Driver Board (K1)

See **Chapter 3.3**.

4.3 Power Supply

The complete system (Driver Board and Logic Board) must to be supplied with and external regulated DC power supply connected to connector X1-SIG1 (+12.0V on pins 44 and 46 and GND_DIG1 on pins 48 and 50) on the Logic Board. The input voltage should be kept between 8 V and 18 V and the current consumption will vary depending on different factors, i.e. PWM frequency.

This supply line will be forwarded to the Driver Board through the connector K1. On both boards a protection circuit will avoid damages in case of overvoltage or wrong polarity (see **Figure 51**).

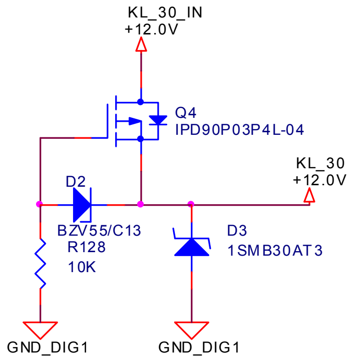

Figure 51 Overvoltage and Wrong Polarity Protection Circuit

The supply block (see **Figure 58**) generates all the necessaries supplies for the components on the logic board (5V, 3.3 V and 1.5 V). Furthermore the 5 V (analogue and digital) are connected to the external connector (X1-SIG1) for supplying external systems (i.e. current sensor).

The Logic Board use the Infineon Technologies TLE7368E Micro Controller Power Supply IC. After applying the main power supply the IC13 will be switched-on. As soon as 5 V/3.3V/1.5V power supplies reached their correct values the signal POWERrstn (RO_1 and RO_2 outputs of IC12) will be activated waking-up the microcontroller. For further details of the TLE7368E please refer to the datasheet.

4.4 Microcontroller

The microcontroller block (uC block in overview given in **Figure 57**) contains following elements:

- TC1767 (**Figure 67**) is a 32-Bit Microcontroller member of the Infineon Technologies AUDO FUTURE product family designed for automotive applications. TriCore^{TM} CPU providing high-end microcontroller performance combined with sophisticated DSP capabilities (please refer to datasheet for further details)
- Input filter (see **Figure 66**): passive filters for digital and analogue signals and voltage dividers for voltage level adaptation
- EEPROM (**Figure 68**): 256kB Electrically-Erasable Programmable Read-Only Memory optimized for use in automotive applications where low-power and low-voltage operations are essential (for more details refer to AT25256A-10TQ-2.7 datasheet). The communication with the microcontroller is done through SSC0 interface (high-speed synchronous serial interface, SPI-compatible)
- RS-232 & CAN Transceivers (see **Figure 65**)

4.4.1 Configuration of TC1767

The TC1767 can be configured with the respect to the different boot modes and with the respect to the different interfaces (serial/parallel) to the resolver and iGMR position sensors.

4.4.1.1 Boot Configuration of TC1767

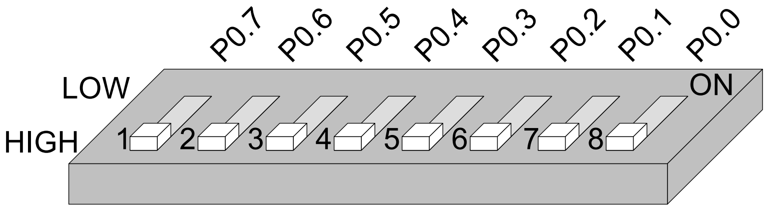

Figure 52 HW Boot Configuration of TC1767 DIP-Switch

The picture above (**Figure 52**) shows the definition of the boot HW configuration switch (DIP-Switch SW1 on **Figure 67**). The meaning of the switches will be described in the following **Table 6**.

The ON position of the switch is equal to a logical LOW at the dedicated pin.

Table 6 User Startup Modes for TC1767

CFG[7...0]	Type of Boot TC1767	1[1)]	2	3	4	5	6	7	8
11XXX11X[2)]	Internal Start from Flash	OFF	OFF	X[3)]	X	X	OFF	OFF	X
010XX110	Bootstrap Loader Mode, Generic Bootloader at CAN pins	ON	OFF	ON	X	X	OFF	OFF	ON
10101110	Bootstrap Loader Mode, ASC Bootloader	OFF	ON	OFF	ON	OFF	OFF	OFF	ON
10100110	Alternate Boot Mode, ASC Bootloader on fail	OFF	ON	OFF	ON	ON	OFF	OFF	ON
1011X11X	Alternate Boot Mode, Generic Bootloader at CAN pins on fail	OFF	ON	OFF	OFF	X	OFF	OFF	X
All others	Reserved; don't use this combination								

1) 1 to 8 are the DIP-Switch numbers

2) The shadowed line indicates the default settings.

3) 'x' represents the don't care state.

4.4.1.2 Selecting Serial/Parallel Interface

DIP-4 switch (SW2 on **Figure 65**) is used to select serial/parallel interface for the communication with resolver or iGMR position sensor - please refer to **Table 7**.

Table 7 Selecting Serial/Parallel Interface

SW2[4...1]	Inetrface to the Resolver/iGMR	4[1)]	3	2	1
0000[2)]	iGMR enabled (SPI and Incremental mode) Resolver in Parallel Mode	OFF[3)]	OFF	OFF	OFF
1111	Resolver in Serial Mode iGMR disabled	ON	ON	ON	ON
All others	Reserved; don't use this combination				

1) 1 to 4 are the DIP-Switch numbers

2) 0 is equal to open switch, "1" is equal to closed switch

3) 'x' represents the don't care state.

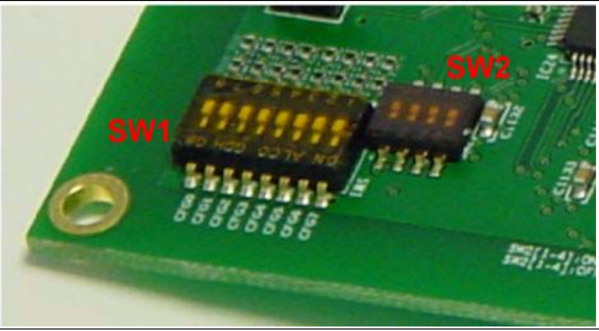

Figure 53 The Boot Configuration Switch (SW1) and Serial/Parallel Interface Select Switch (SW2)

4.5 Watchdog

The Logic Board contains a pin-selectable watchdog timer that supervises the microcontroller activity and signalizes when the system is operating improperly. During normal operation, the microcontroller (GPTA39) should repeatedly toggle the watchdog input (WDI, see **Figure 61**) before the selected watchdog time-out period elapses to report that the system is processing code properly. If this does not occurs, the supervisor asserts a watchdog output ($\overline{WDO}$) which will reset the microcontroller via PORSTn (external power-on hardware reset).

The state of the three logic control pins (SET0, SET1 and SET2) determines watchdog timing characteristics (see table in **Figure 61**). The jumper J1 allows disabling the watchdog functionality in a very easy way.

4.6 Phase Current Sensing

Phase current sensing signals should be connected to the Logic Board connector X1-SIG1 to the pins I_U, I_V and I_W (**Figure 66**). The Logic Board is designed to work with current transducers (not provided with the Hybrid Kit) with voltage output proportional to the current (usually deploying Hall effect - like LEM sensors). User can take +5V (analog) available on the X1-SIG1 pins to supply current transducers. The exact type of current transducer will depend on many parameters in application, but usually the most important is the motor current consumption. Please notice that if you control 3-phase balanced synchronous system it is enough to measure just 2 phases, since the 3rd phase current can be calculated as algebraic combination out of the 2 measured currents. The microcontroller is able to convert synchronously two phase currents, it's recommended to do an accurate current measurement.

4.7 Temperature Sense

The Logic Board includes a temperature sensor (IC54, LM50-CIM3) which is located on the bottoside of the board. With the sensor it is possible to measure the ambient temperature between Logic Board and Driver Board. For schematics and output voltage values of the circuit see **Figure 70**. If you need any further information about the device please refer to the data sheet.

4.8 Resolver Interface

The Logic Board includes a 12-Bit Resolver-to-digital converter (meaning A/D converter) which integrates an on-board programmable sinusoidal oscillator that provides sine wave excitation for resolvers (pins R1 and R2 on connector X1-SIG1). For more details please refer to the data sheet of the component (AD2S1200YST) and the schematics of the circuit see **Figure 62**. With resistors (R155, R156, R157, R158, R159 and R160) user can trim the LMH6672 (dual op-amp) output voltage values (resolver excitation). On the Logic Board is given additional possibility to trim the resolver excitation with potentiometers (R483, R484, R485 - not populated, user should solder them if needed). Please refer to data sheet of used resolver to trim this values properly. The resolver response should be connected between pins S1 and S3 (sine) and S2 and S6 (cosine) on the connector X1-SIG1.

4.9 Encoder Interface

If encoder is used as a sensor for the motor position/speed sensing the following pins on connector X1-SIG1 should be connected: the phase A should be connected between pins PosA/iGMR_A+ and PosA/iGMR_A-, the phase B should be connected between pins PosB/iGMR_B+ and PosB/iGMR_B- and phase Z (index or zero marker) should be connected between pins PosZ/iGMR_Z+ and PosZ/iGMR_Z- .

4.10 Hall Sensor Interface

If Hall sensor is used as a sensor for the motor position/speed sensing the following pins on connector X1-SIG1 should be connected: the phase U should be connected to pin PosU/iGMR_U, the phase V should be connected to pin PosV/iGMR_V and phase W should be connected to pin PosW/iGMR_W .

4.11 GMR Interface

As mentioned on the beginning of the **Chapter 4**, the Logic Board supports GMR interface by means of a bi-directional SSC (SPI compatible), encoder (or incremental) and Hall sensor interface. It is explicitly recommended to use Infineon Technologies TLE5012 GMR-based angular sensor for rotor position sensing. The TLE 5012 is a 360° angle sensor that detects the orientation of a magnetic field. This is achieved by measuring sine and cosine angle components with monolithic integrated Giant Magneto Resistance. For more details about TLE5012 please refer to the data sheets on Infineon Technologies internet pages.

4.11.1 GMR SSC Interface Mode

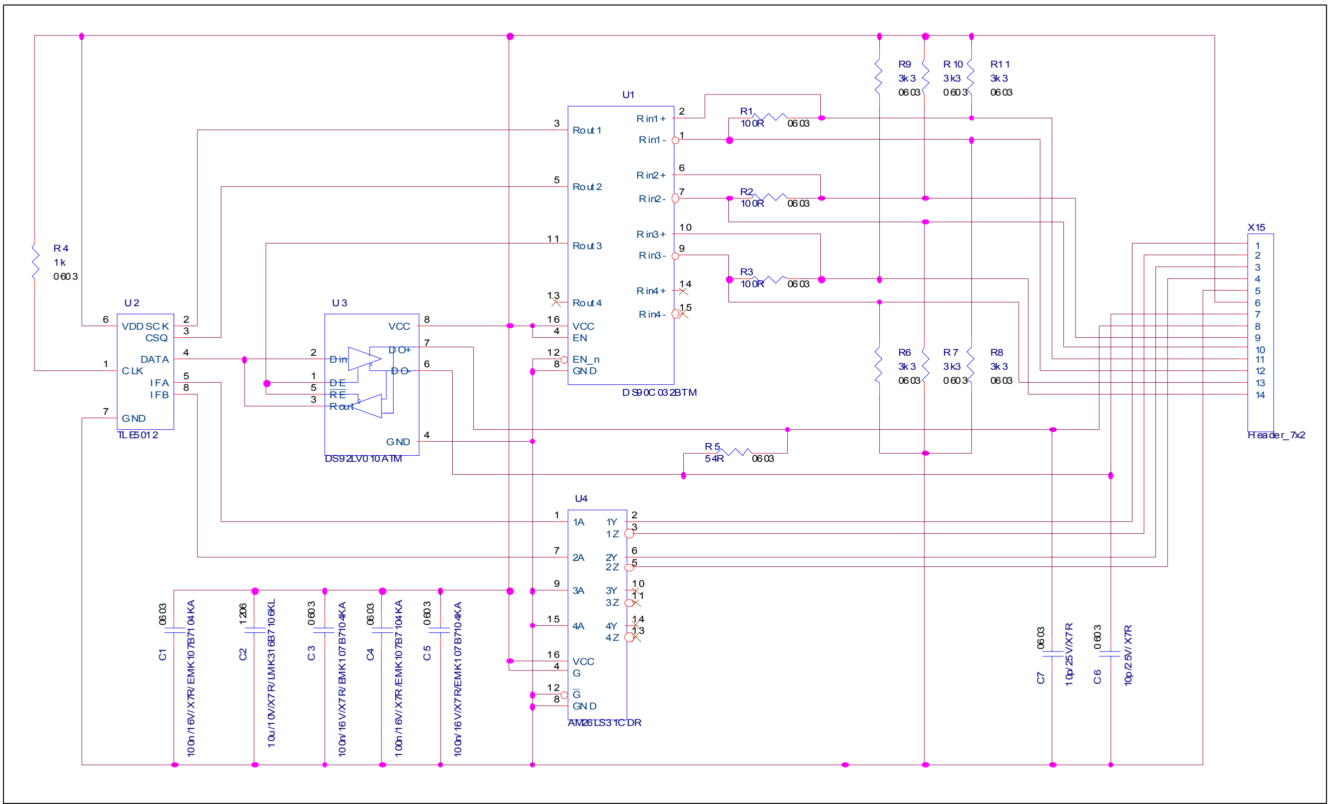

Figure 54 GMR SSC Interface - Proposal Using TLE5012

The schematics of SSC interface on the Logic Board is shown on **Figure 69**. Signals on connector X1-SIG that are used for SSC interface are: iGMR_CSn+/iGMR_CSn- (Chip Select, differential signals), iGMR_REn_DE+/iGMR_REn_DE- (Read Enable, differential signals), iGMR_DATA+/iGMR_DATA- (Serial Data, differential signals) and iGMR_CLK+/iGMR_CLK- (SSC Clock, differential signals) - all signals are listed in **Table 5**. On **Figure 54**is presented the schematics of possible technical solution (implemented by Infineon Technologies System Engineering) for usage of TLE5012. The PCB with TLE5012 and a few additional components is mounted perpendicular to the electric motor shaft - just as shown on **Figure 55**.

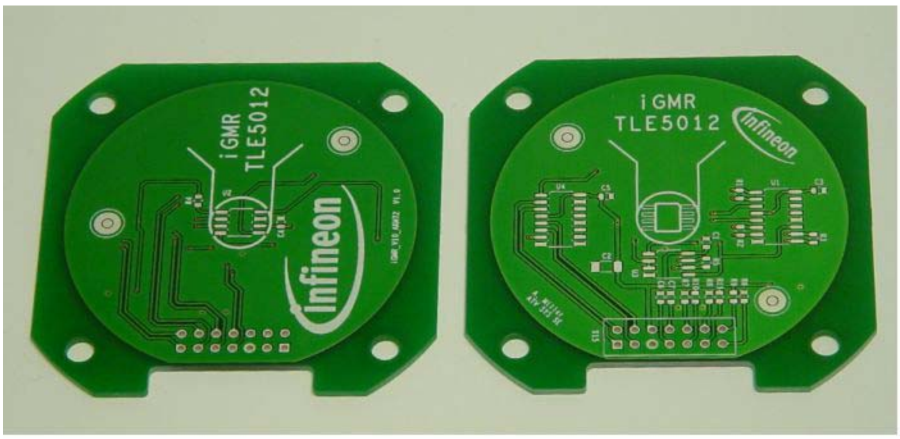

Figure 55 Picture of Possible Physical Implementation of the GMR Sensor

4.11.2 GMR Encoder Interface Mode

Infineon Technologies iGMR sensor TLE5012 can be used with encoder interface as well. This working mode is referred as IIF Interface mode in theTLE5012 data sheet. To avoid signal integrity and EMC problems, within Hybrid Kit it is expected that the 2 phase signals (A and B) and zero (index) signal are provided differentially. On the connector X1_SIG (**Figure 50**) encoder inputs are: PosA/iGMR_A+ and PosA/iGMR_A (phase A), PosB/iGMR_B+ and PosB/iGMR_B (phase B) and PosZ/iGMR_Z and PosZ/iGMR_Z (phase Z - index) - please refer to the **Table 5**. Please refer to the TLE5012 data sheet to get iGMR sensor running in incremental mode.

4.11.3 GMR Hall Sensor Interface Mode

TLE5012 supports Hall sensor interface mode as well (iGMR emulates Hall sensor mode). For this purpose to the connector X1-SIG inputs PosU/iGMR_U (phase U), PosV/iGMR_V (phase V) and PosW/iGMR_W (phase W) should be connected. Please notice (on **Figure 66**) that the pull-up resistors to 3.3 V (R491, R492 and R493) are already provided on the Logic Board. For more details on Hall sensor mode please refer to the TLE5012 data sheet.

4.12 Definition of Layers for the Logic Board

The Logic Board was made keeping the following rules for the copper thickness and the space between different layers shown in **Figure 56**.

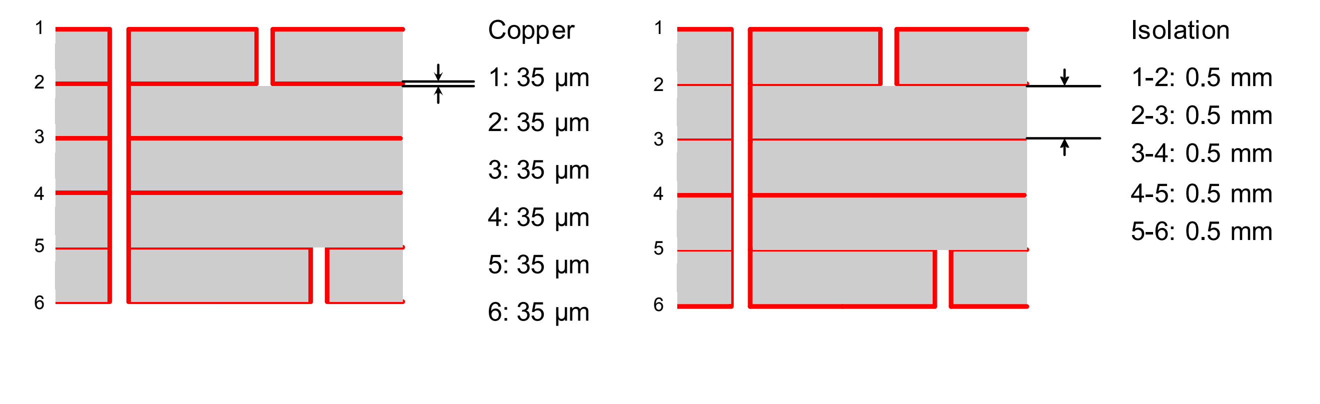

Figure 56 Definition of the Layers for the Logic Board

4.13 Schematics, Layout and Bill of Materials

To meet the individual customer requirements and to make the Logic Board for the HybridPACK™1 module as a platform for development or modifications, all necessary technical data like schematics, layout and components for the Logic Board are included in this chapter.

4.13.1 Schematics

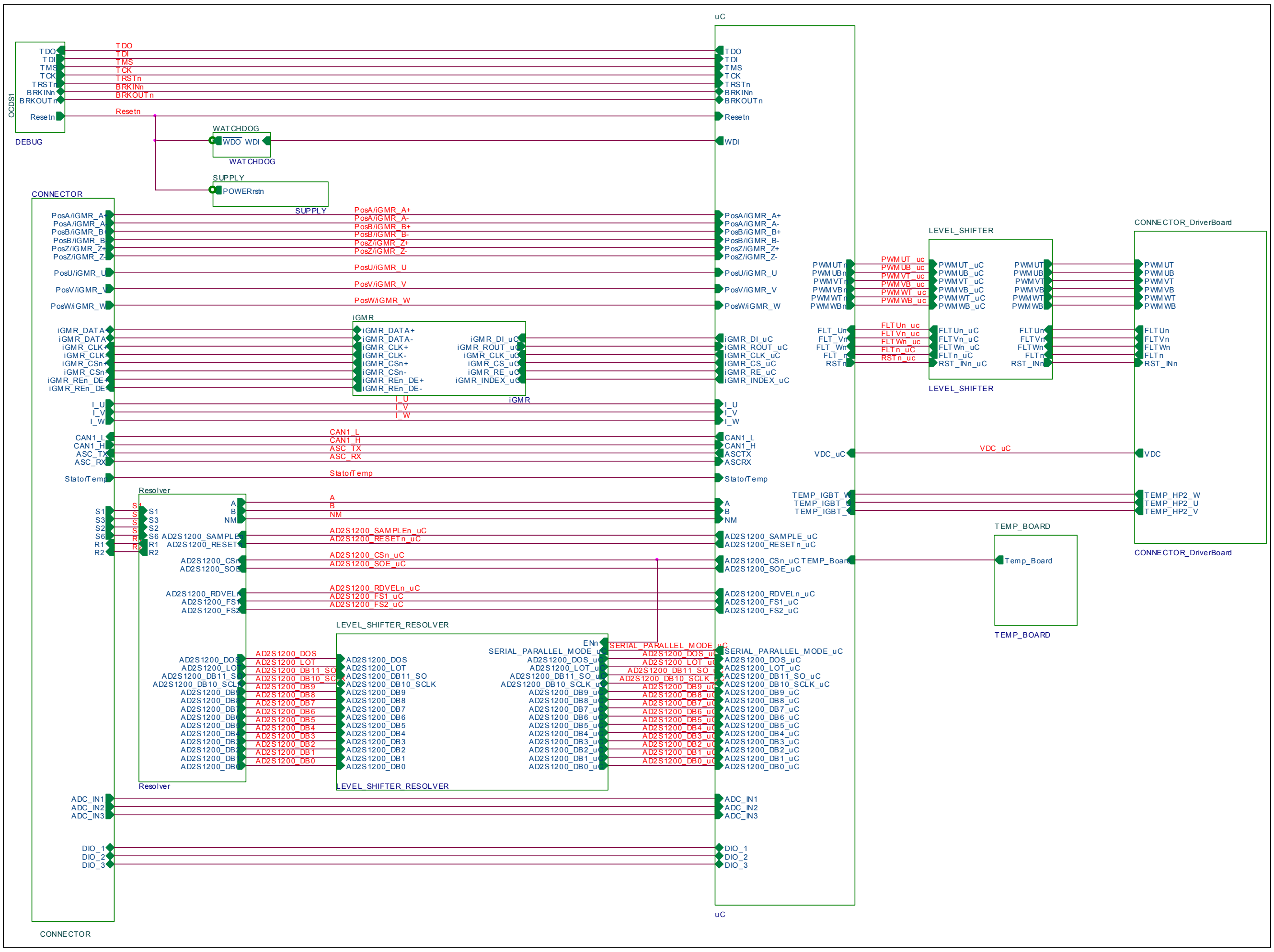

Figure 57 Schematics Block Overview

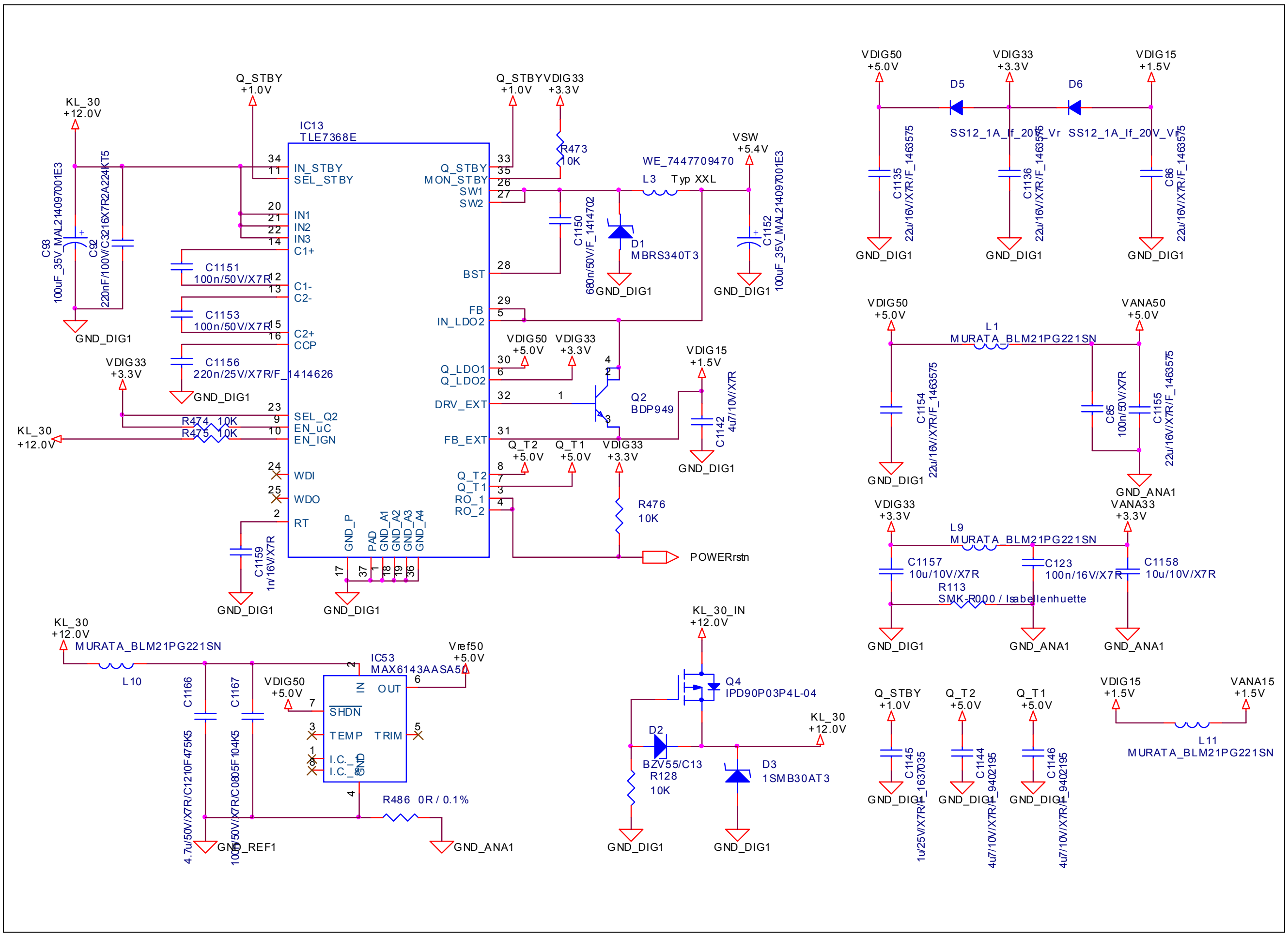

Figure 58 Power Supply

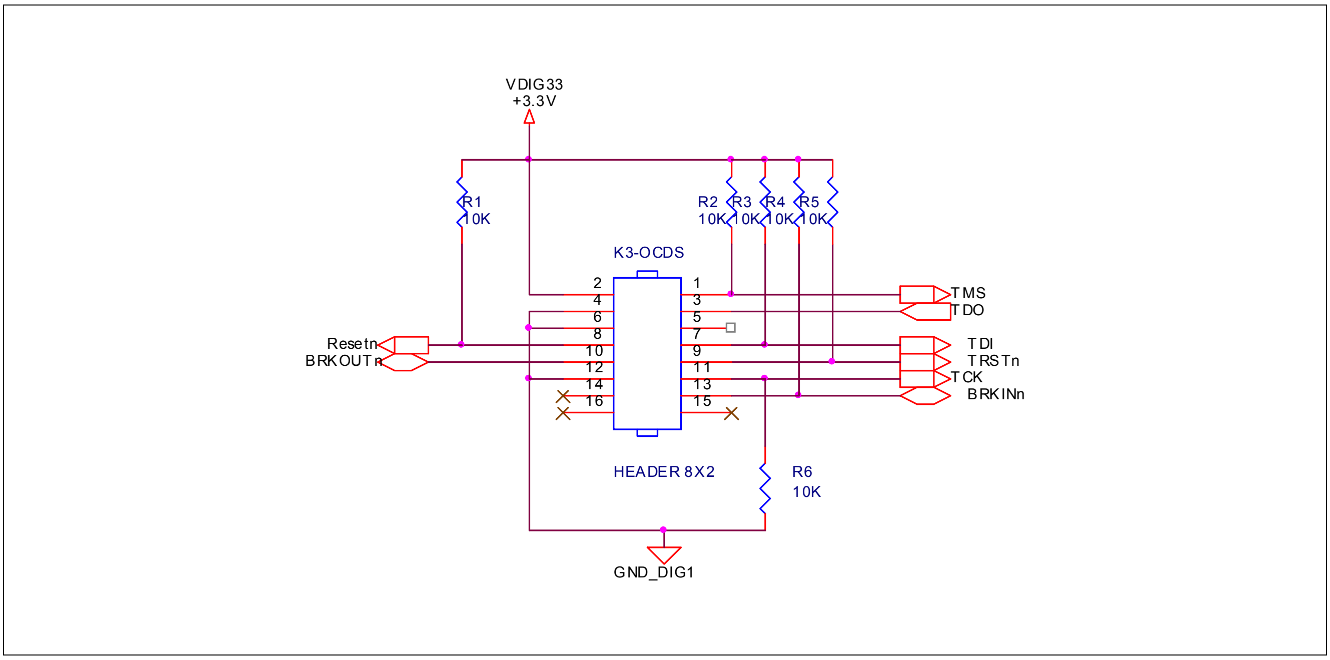

Figure 59 JTAG Debug Connector

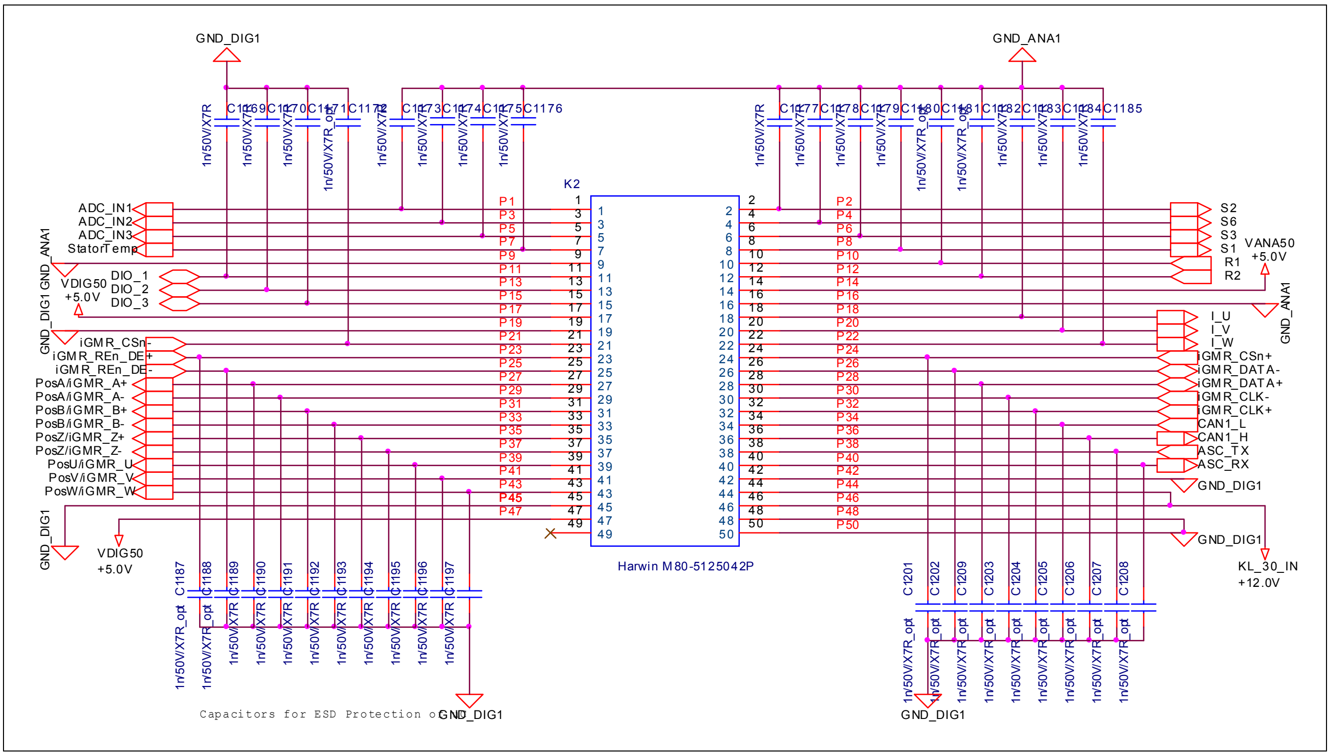

Figure 60 Connector (external)

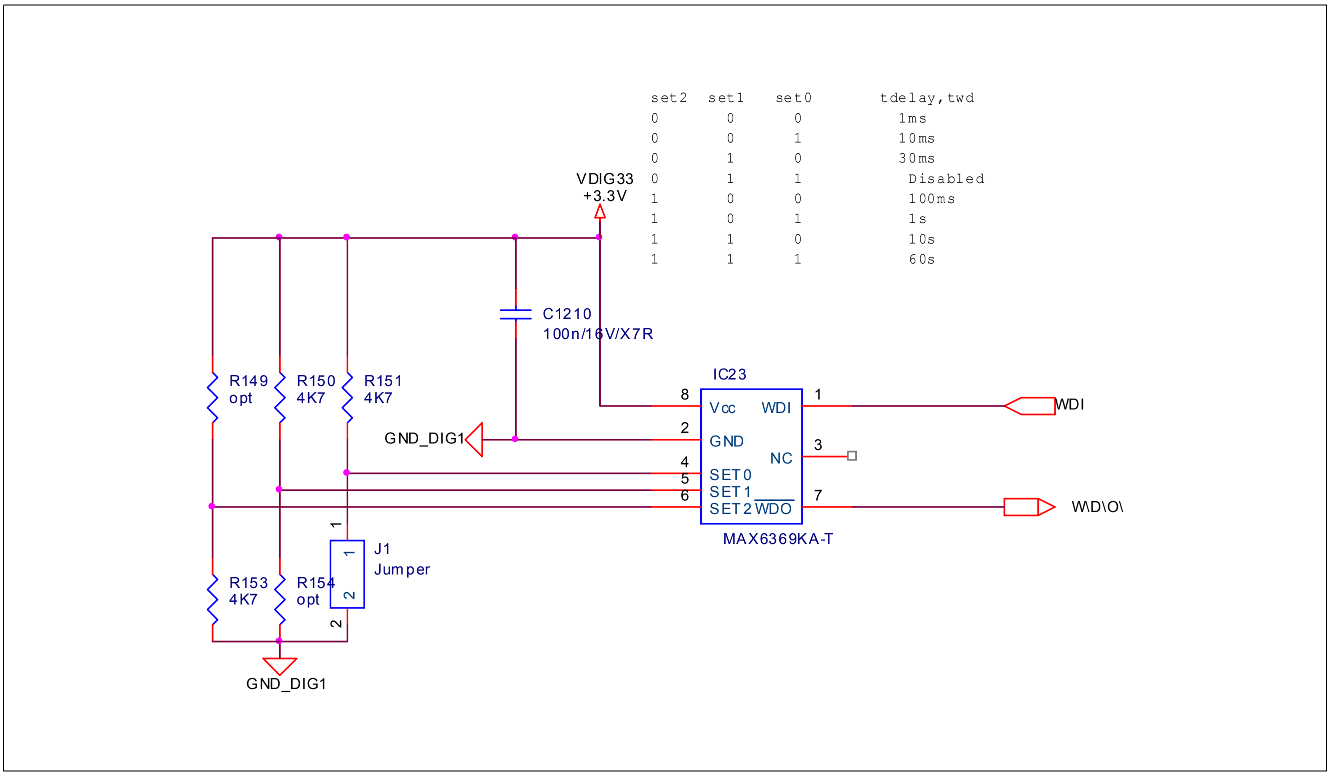

Figure 61 Watchdog

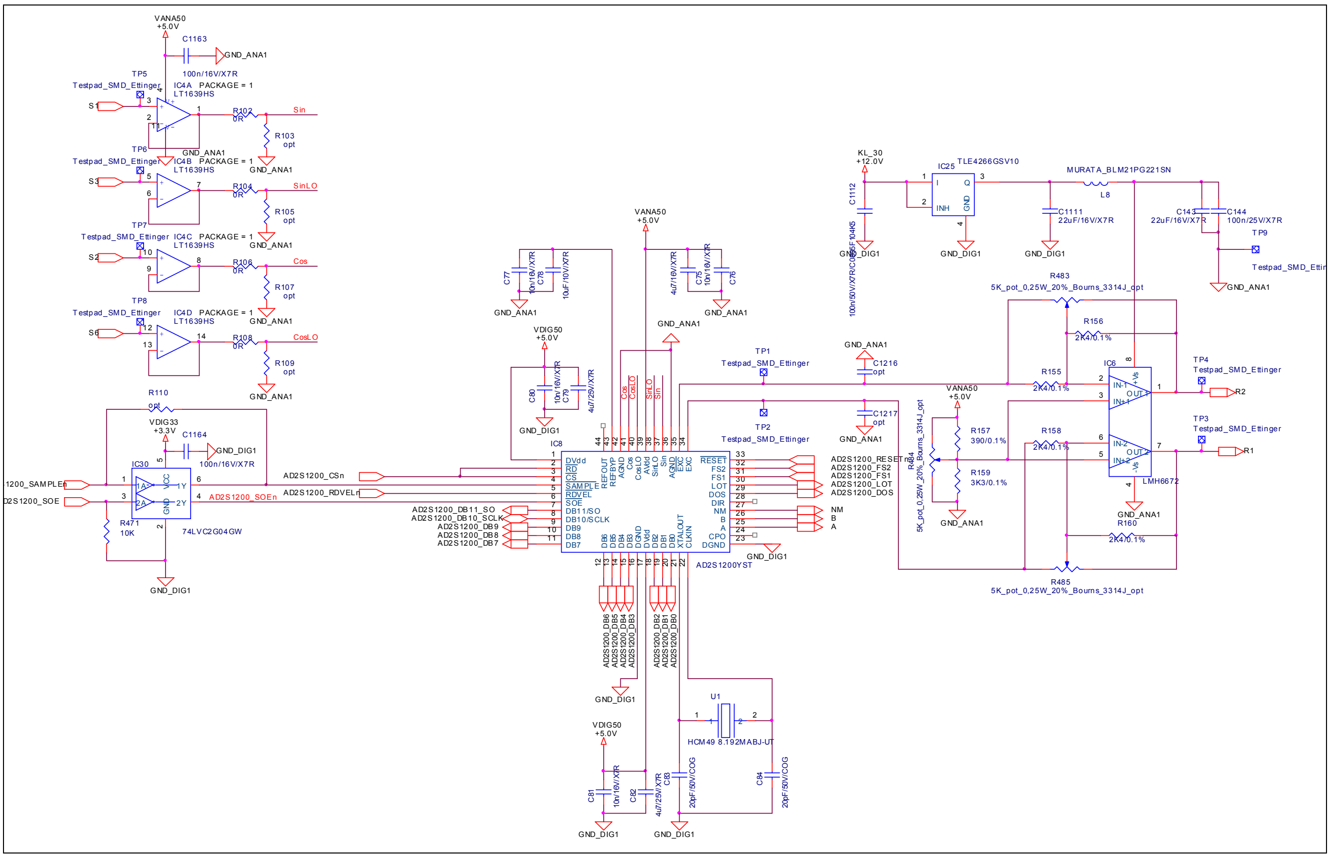

Figure 62 Resolver Interface

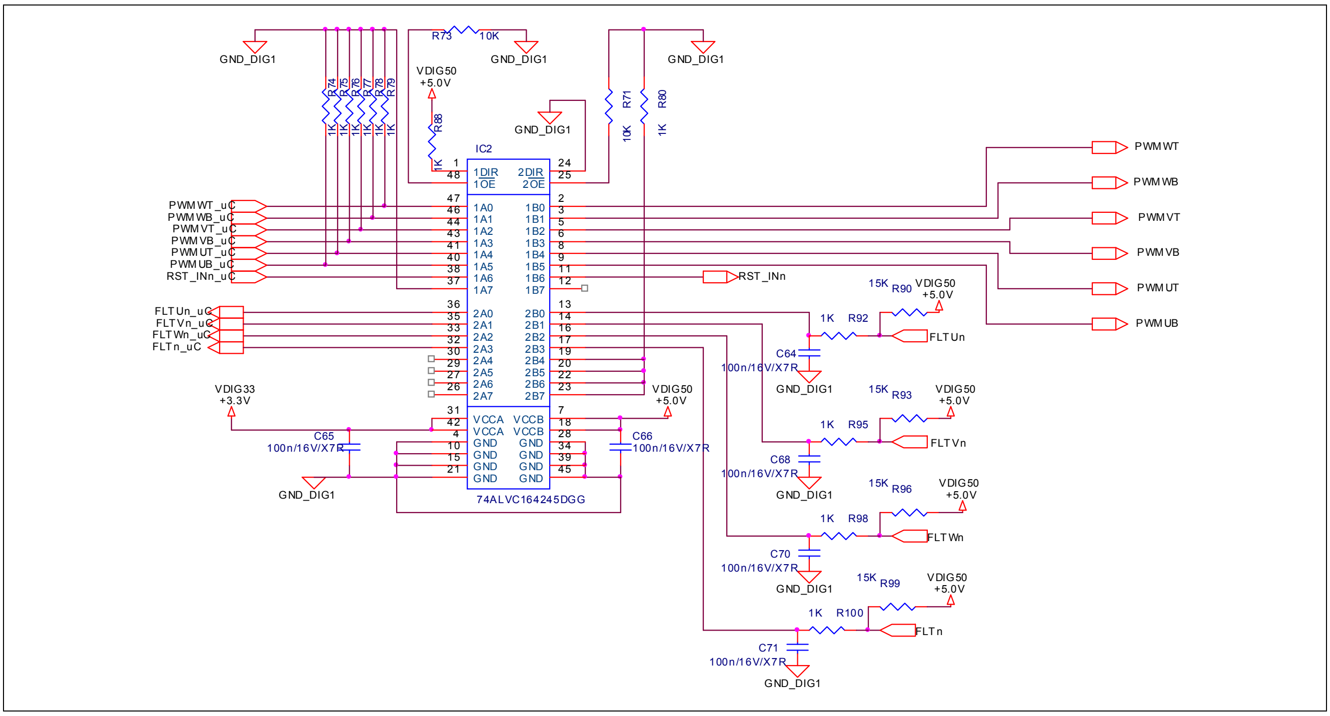

Figure 63 Level Shifter for Adapting Logic Levels for Driver Board

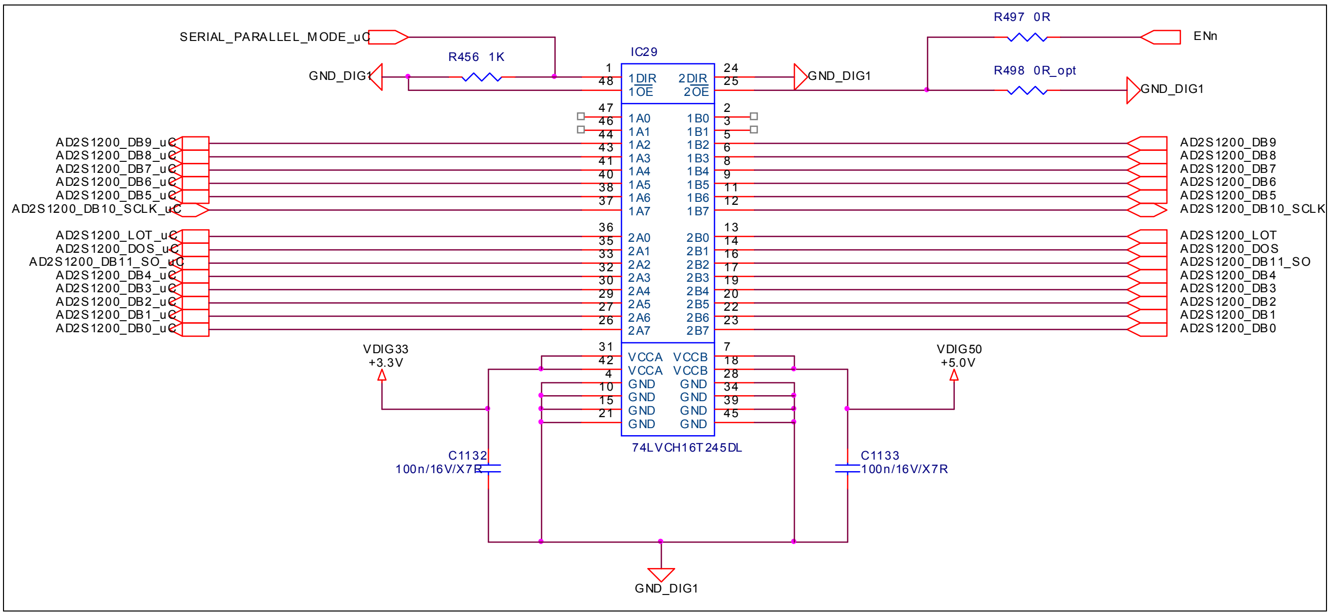

Figure 64 Level Shifter for Adapting Logic Levels for Resolver IC

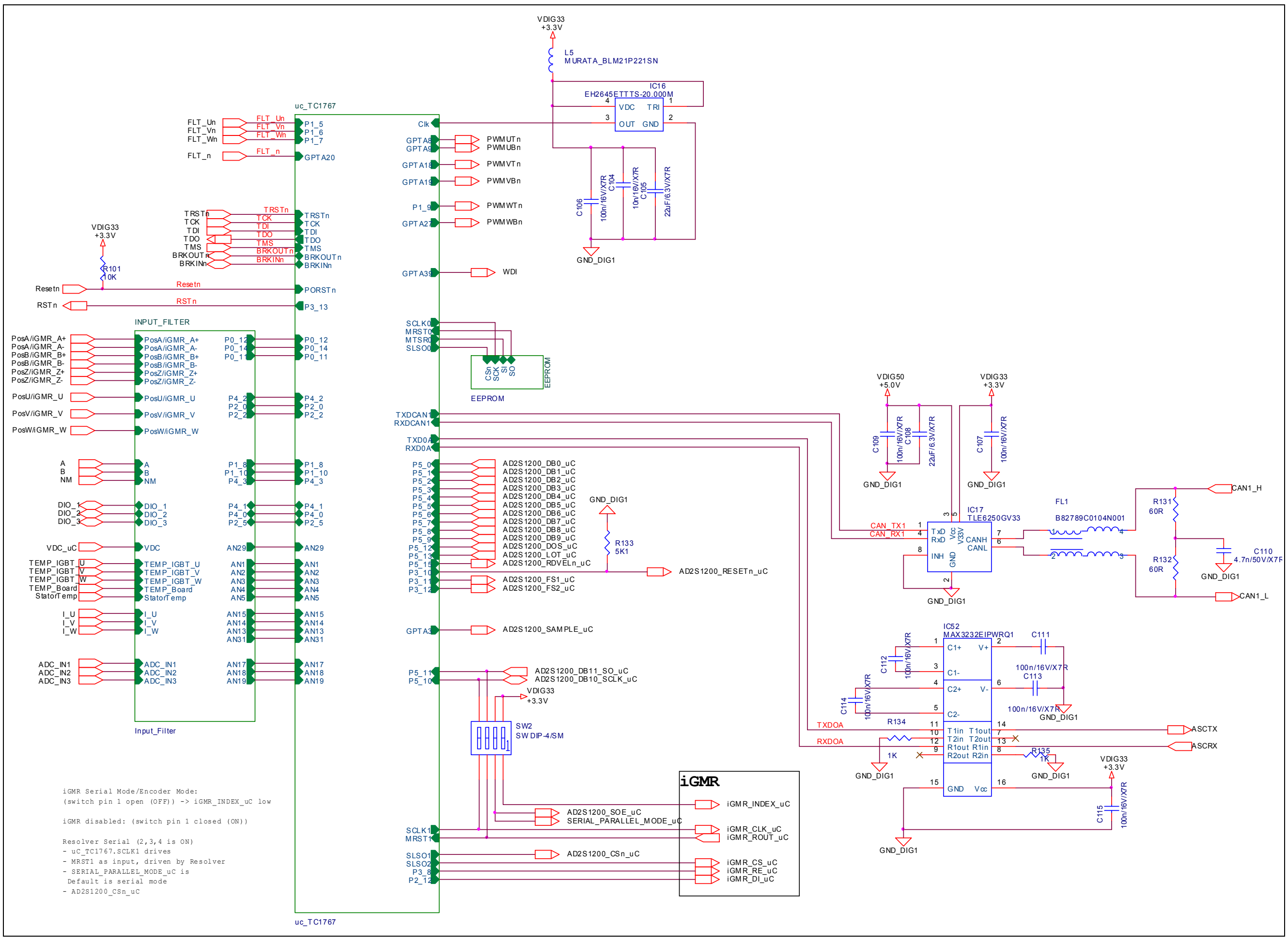

Figure 65 Microcontroller

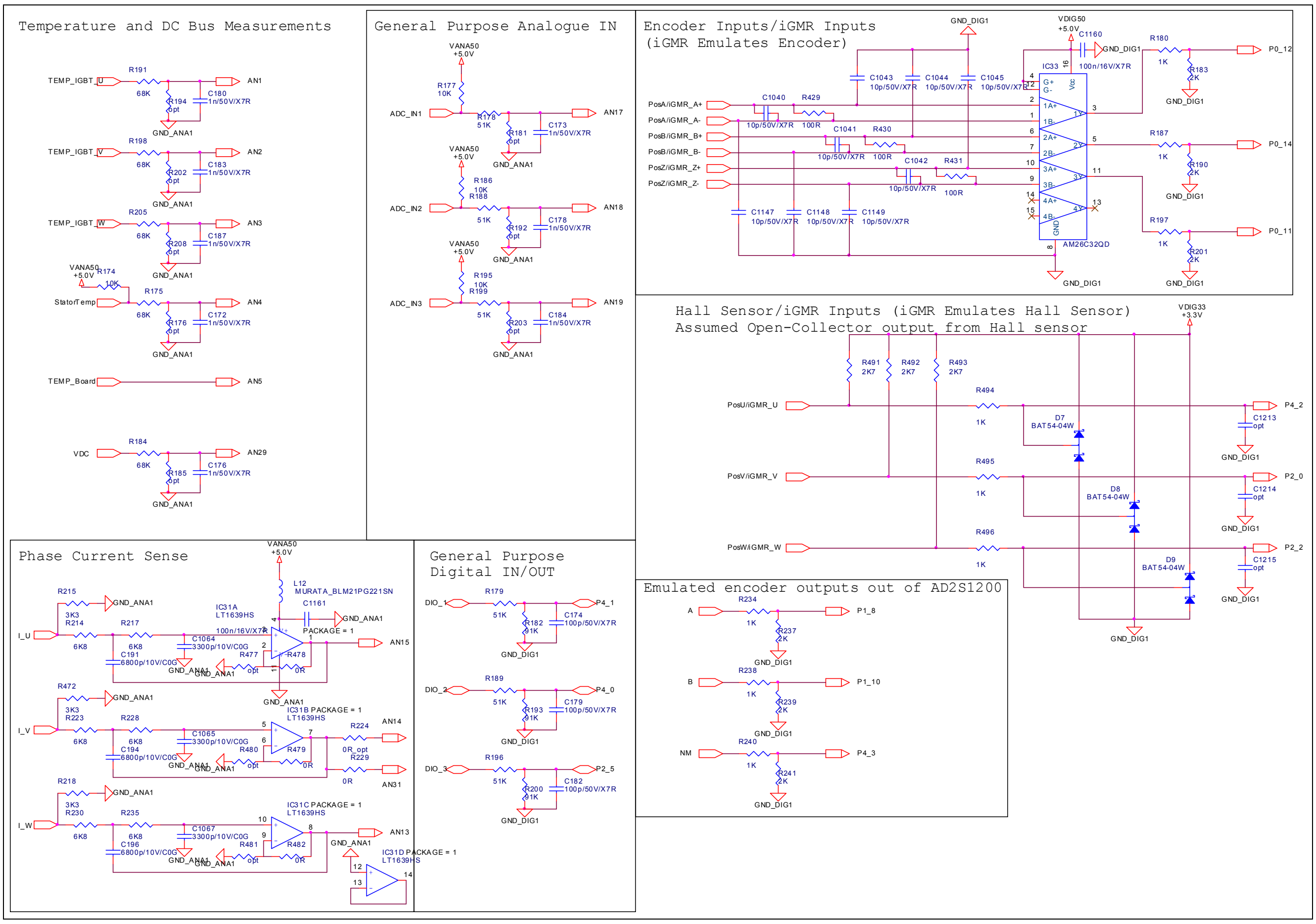

Figure 66 Input Filter

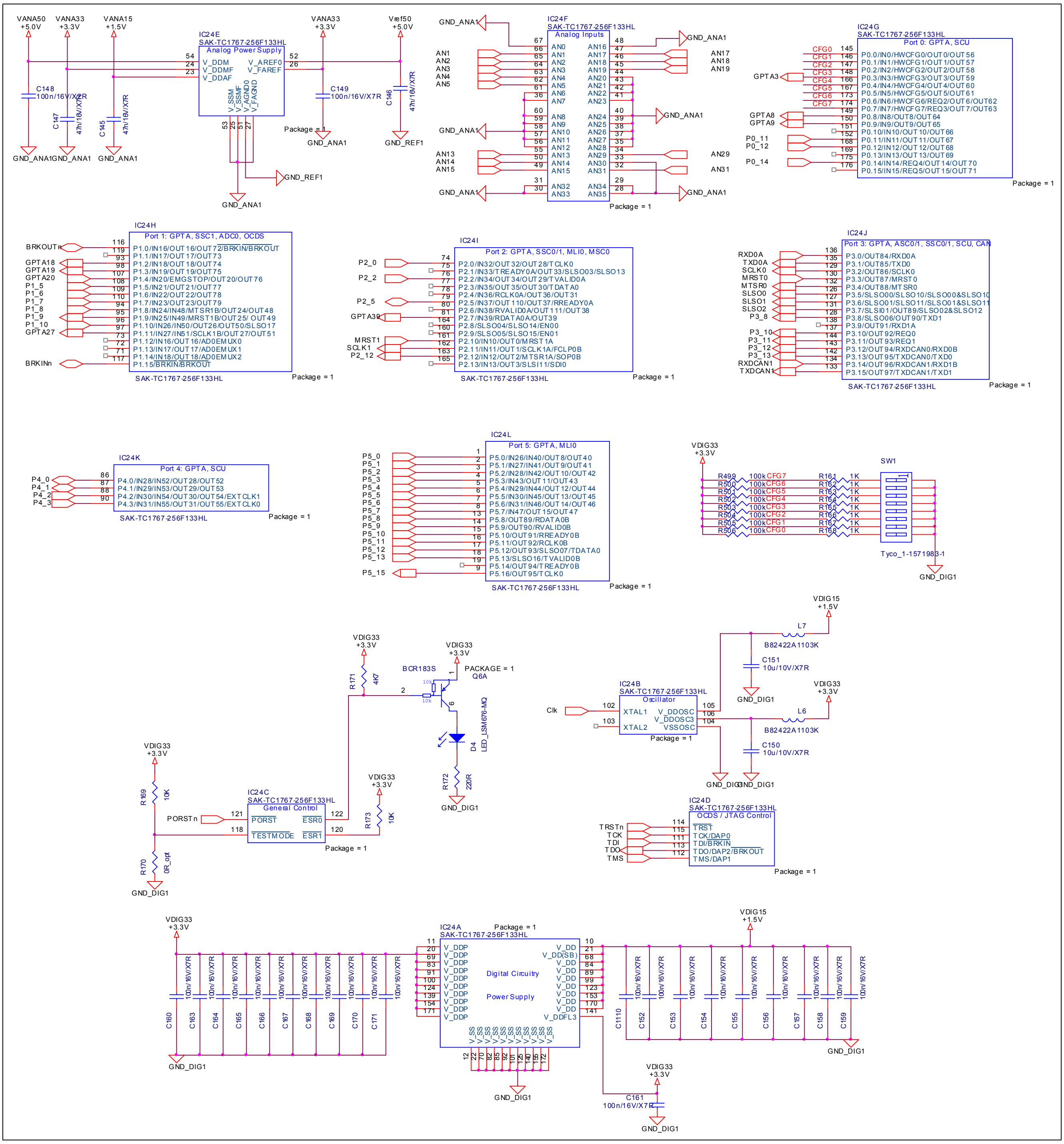

Figure 67 Microcontroller TC1767 Pin Assignment

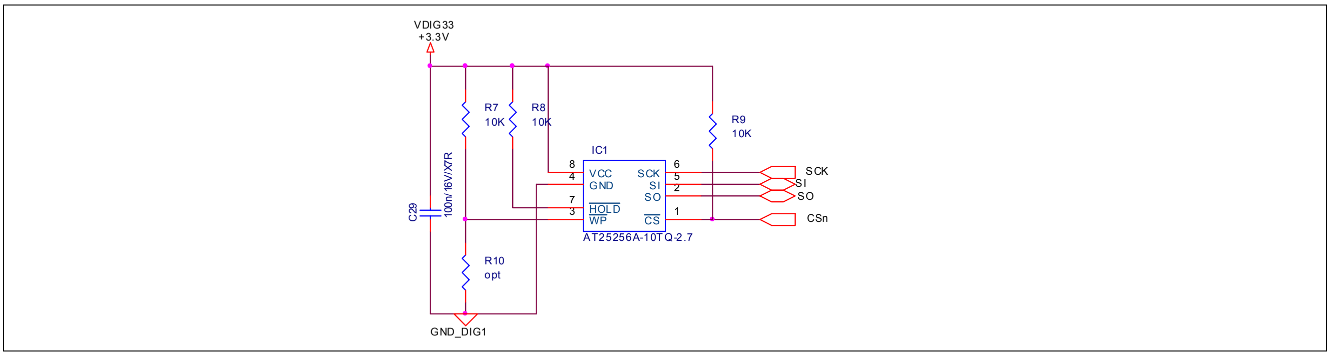

Figure 68 EEPROM

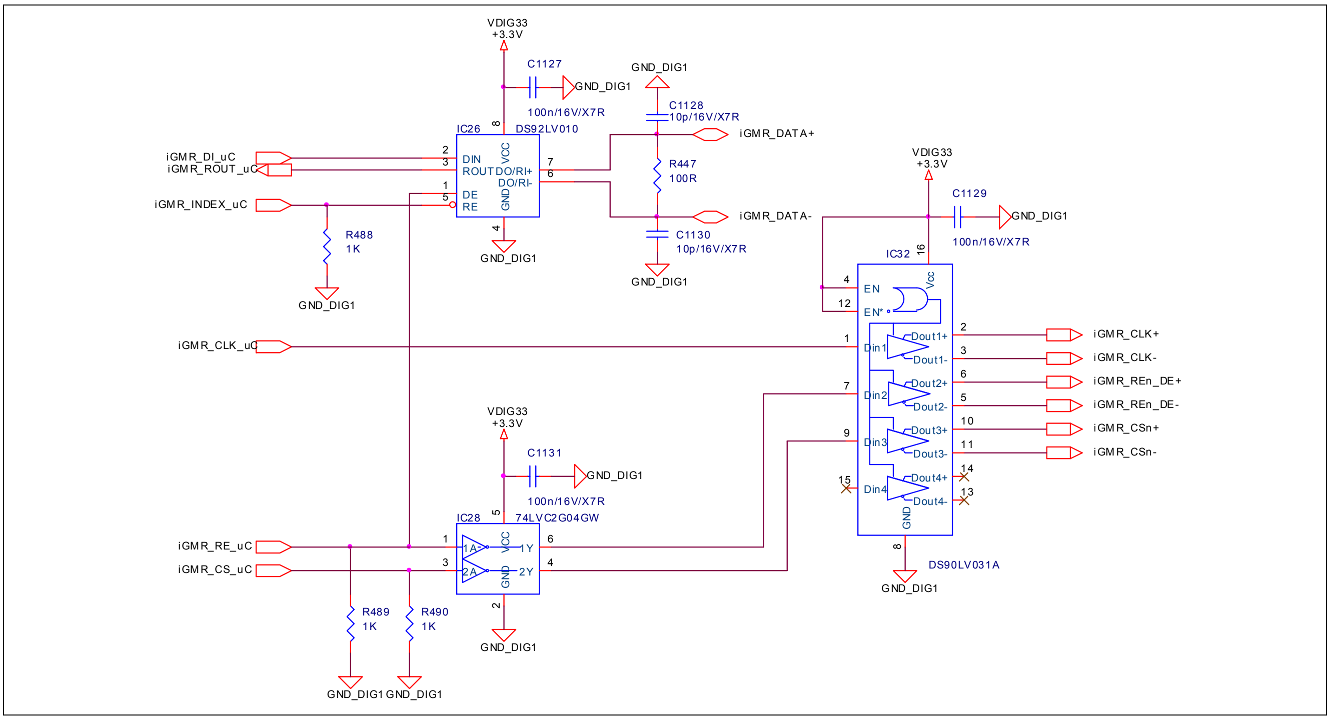

Figure 69 GMR SSC Interface

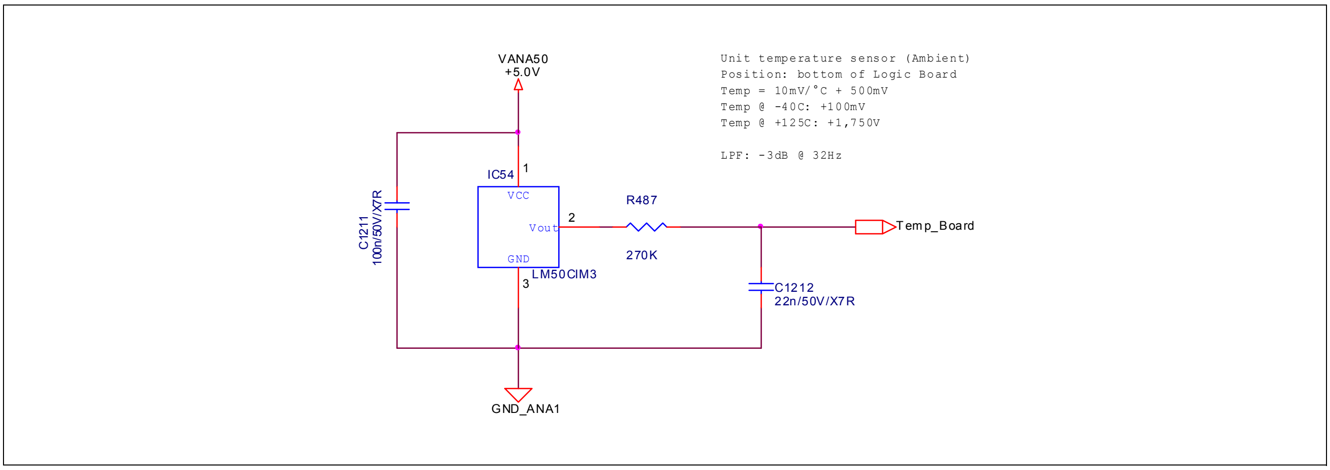

Figure 70 Temperature Sense of the Logic Board

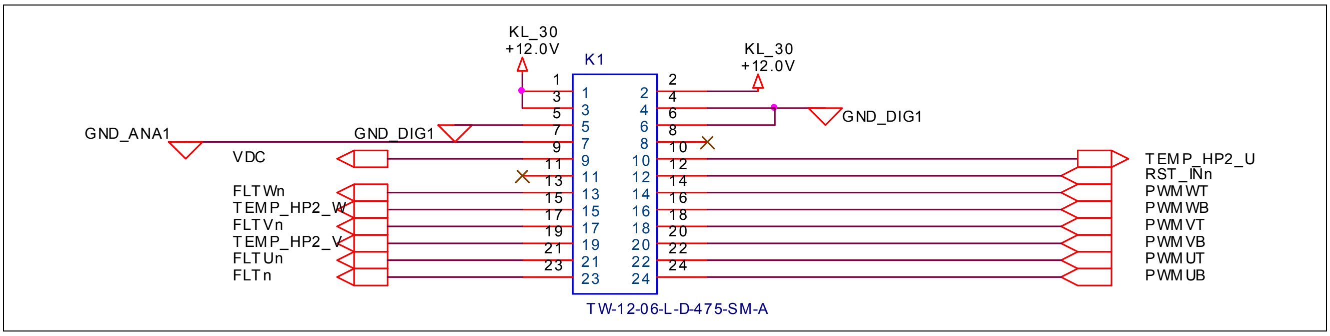

Figure 71 Connector to the Driver Board

4.13.2 Assembly Drawing

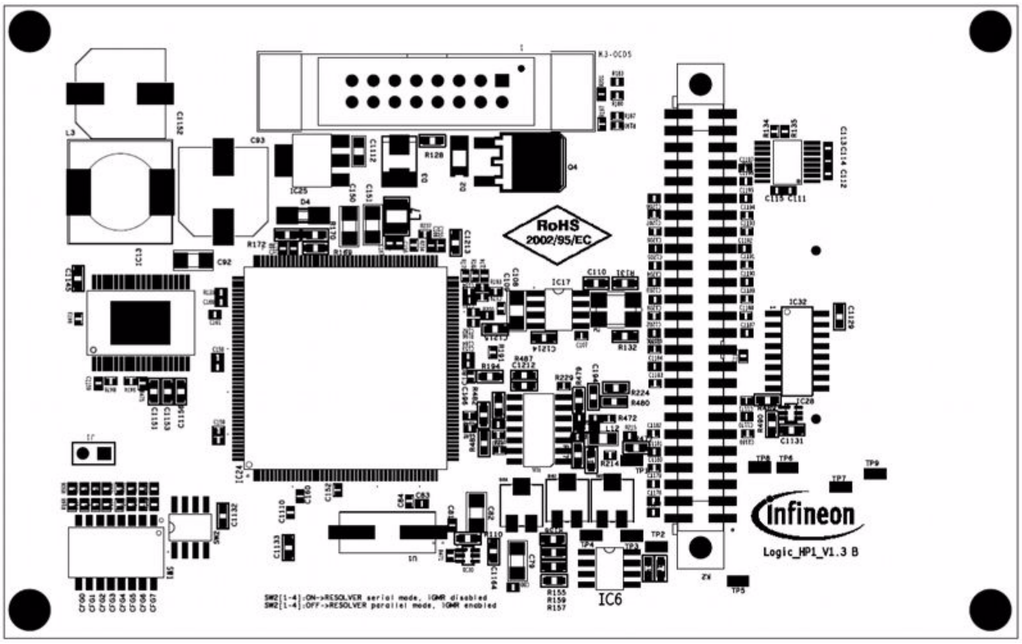

Figure 72 Assembly Drawing of the Logic Board (Top)

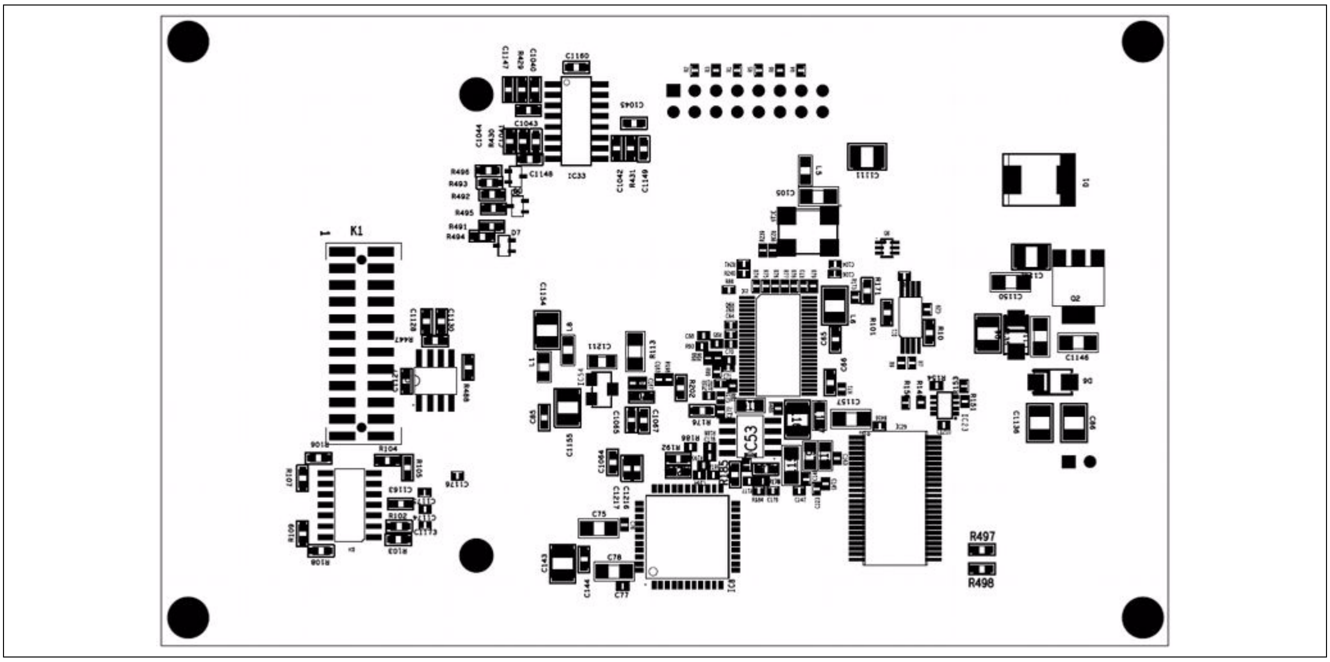

Figure 73 Assembly Drawing of the Logic Board (Bottom)

For detail information use the zoom function of your PDF viewer to zoom into the drawings on **Figure 72** and **Figure 73**.

4.13.3 Layout

Layout of the Logic Board is shown on **Figure 74** (Top Layer), on **Figure 75** (Layer-2), on **Figure 76** (Layer-3), on **Figure 77** (Layer-4), on **Figure 78** (Layer-5) and on **Figure 79** (Bottom Layer).

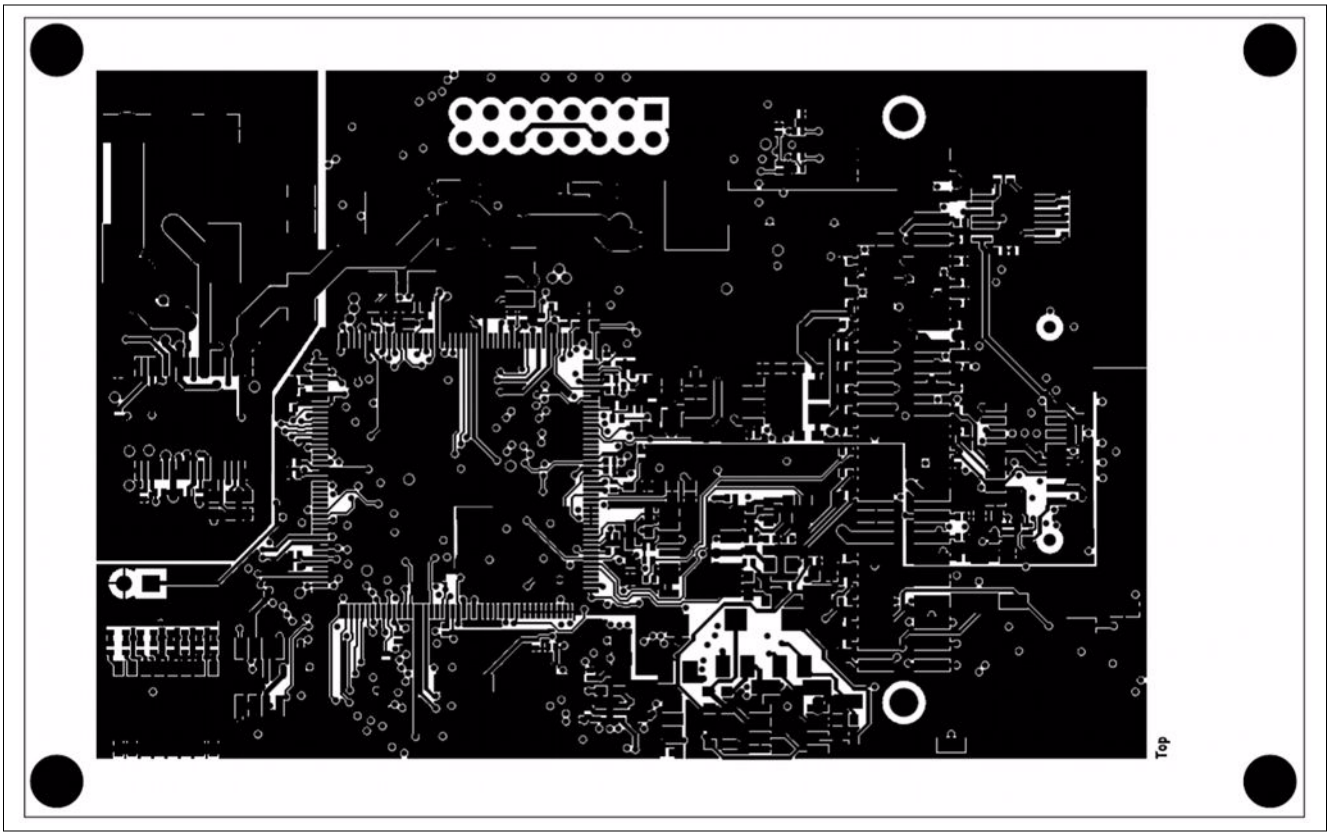

Figure 74 Logic Board - Top Layer

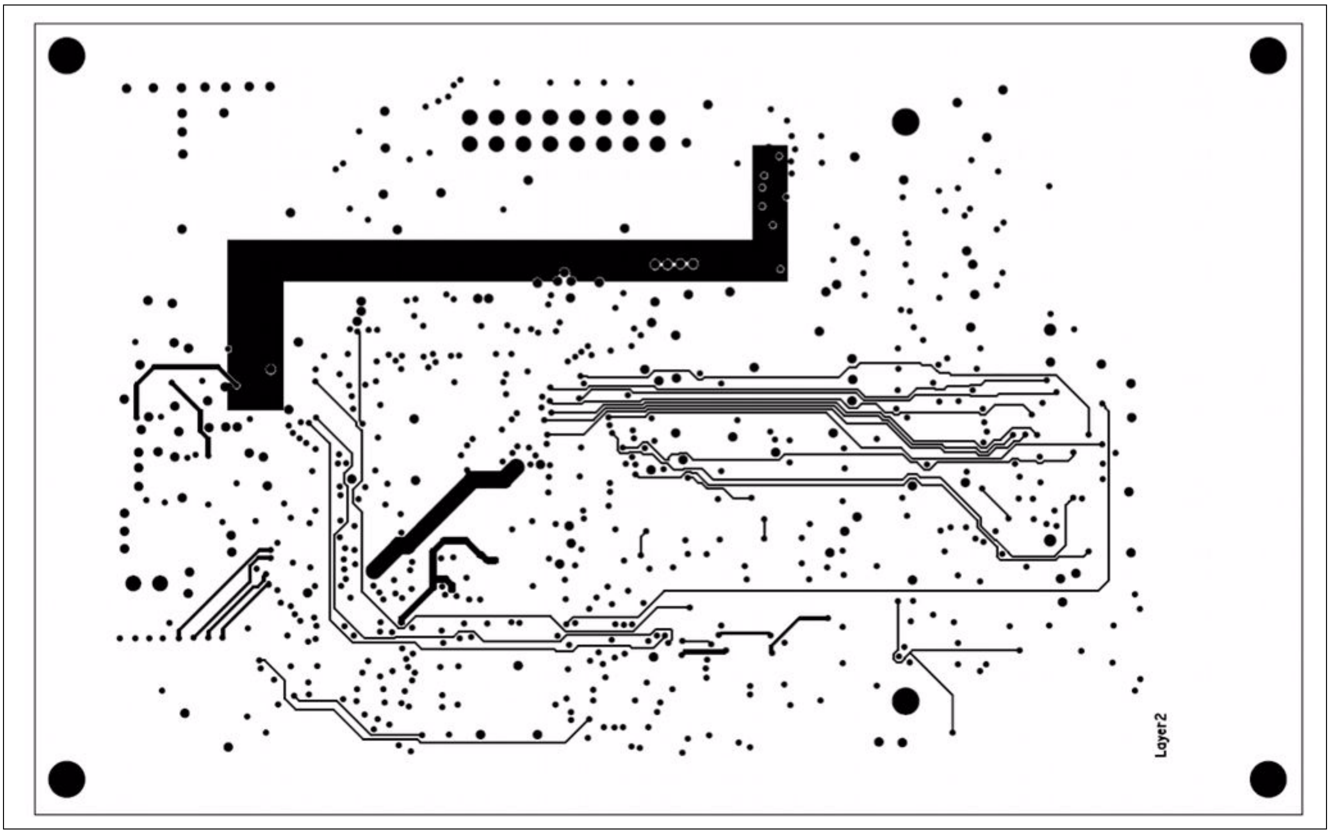

Figure 75 Logic Board - Layer-2

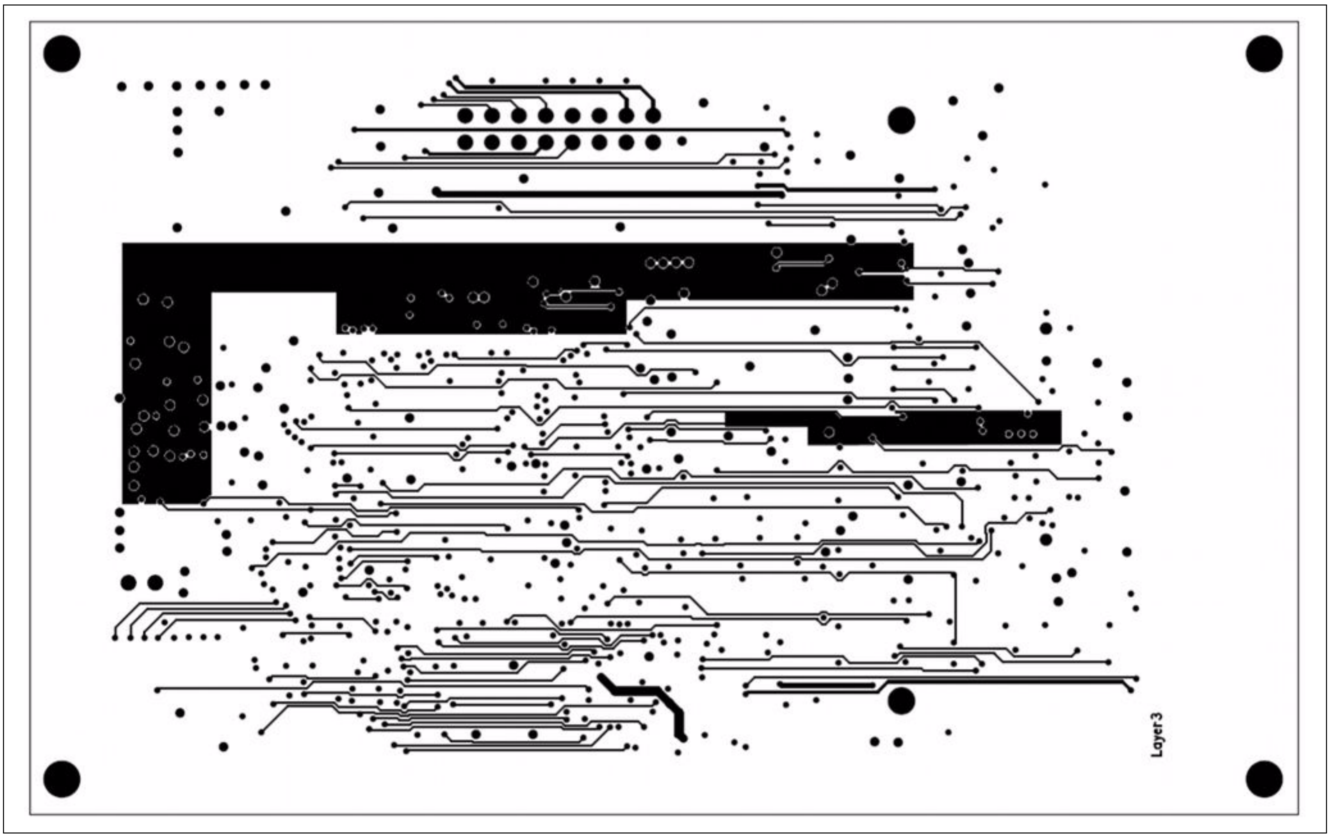

Figure 76 Logic Board - Layer-3

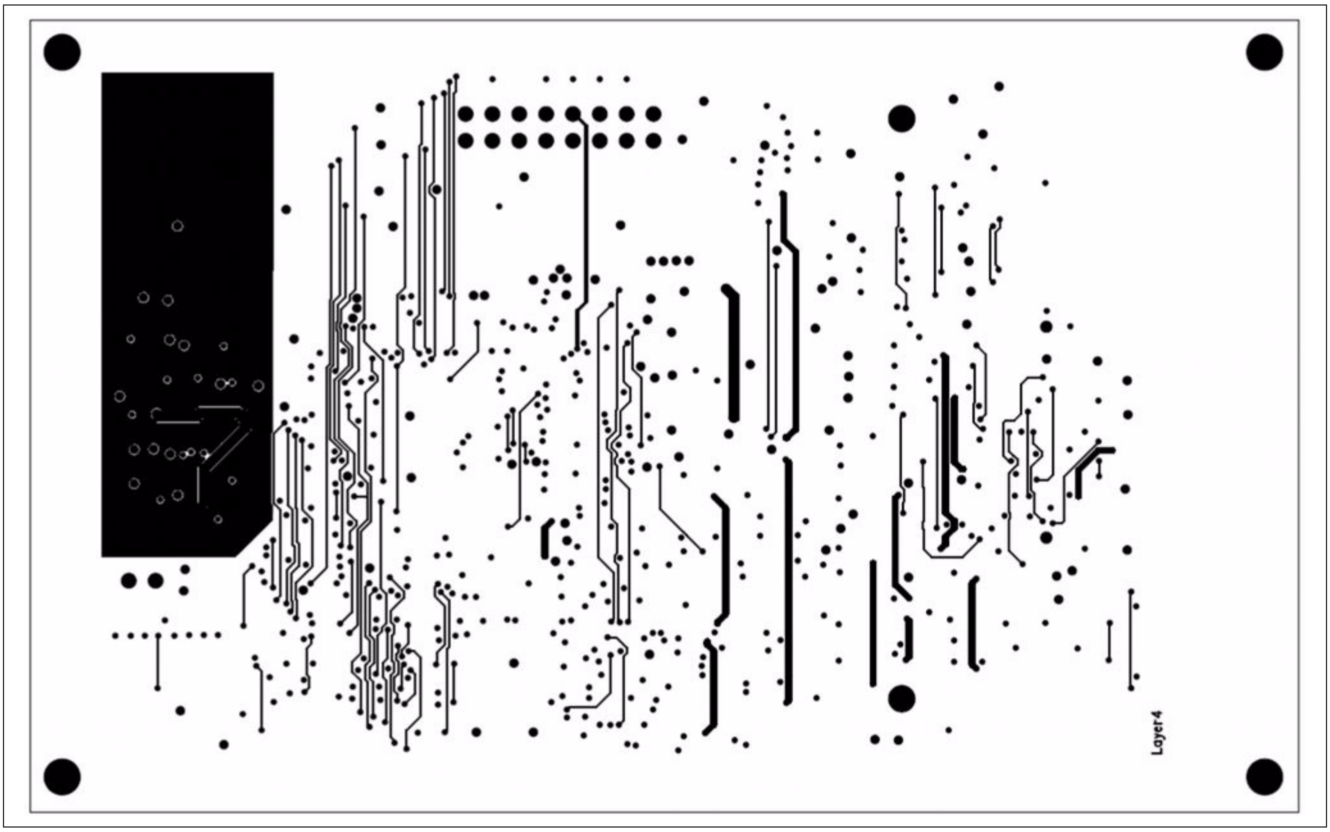

Figure 77 Logic Board - Layer-4

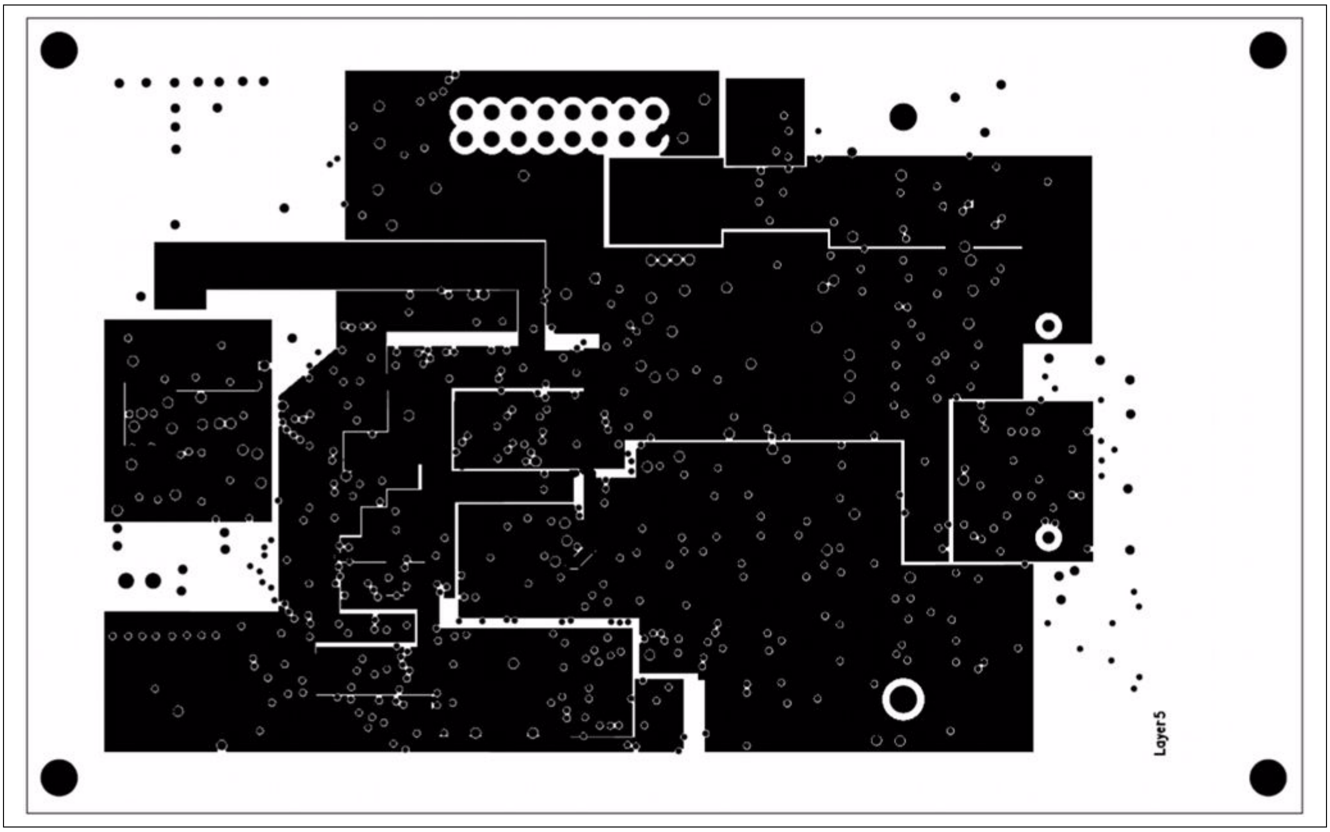

Figure 78 Logic Board - Layer-5

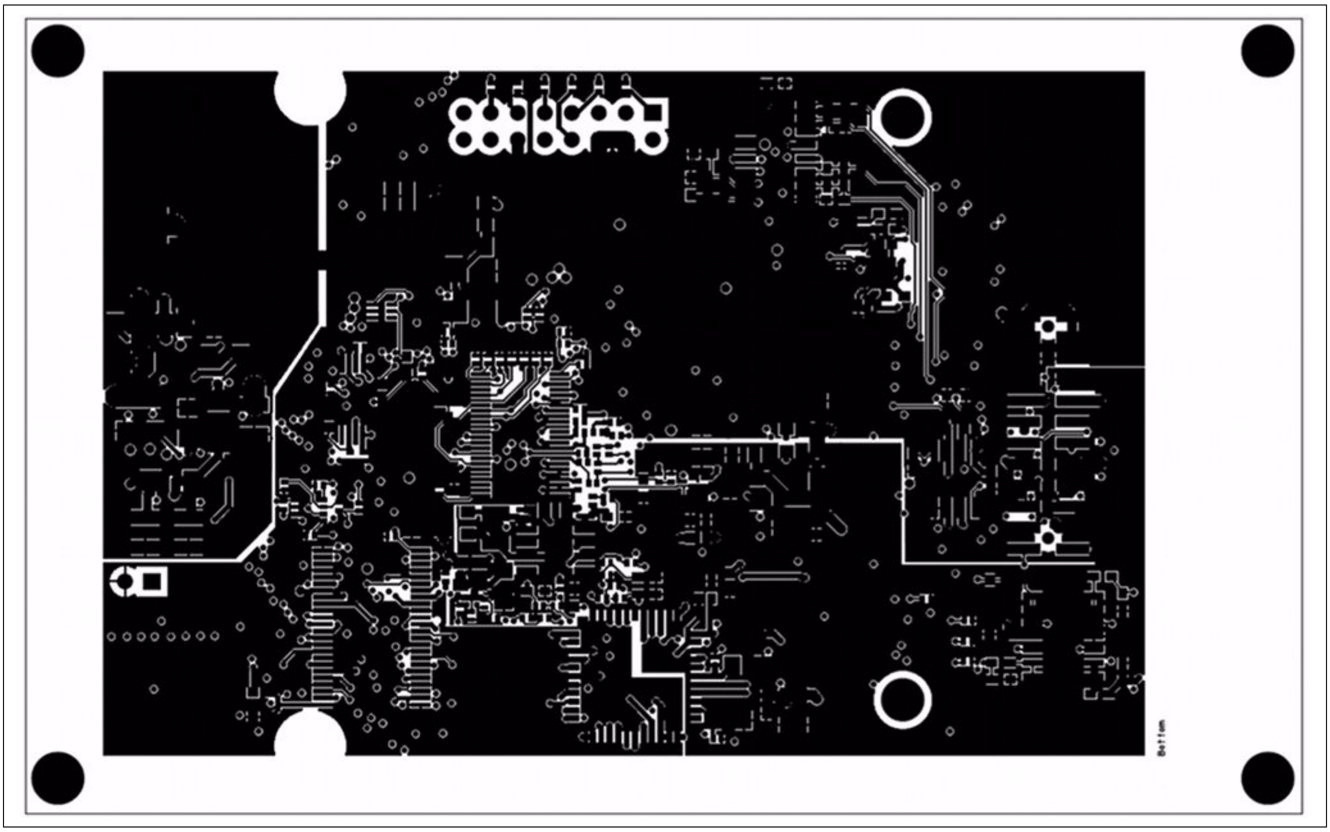

Figure 79 Logic Board - Bottom Layer

4.13.4 Bill of Materials

Table 8 Bill of Materials for Logic Board for Hybrid Kit for HybridPACK™1

Reference	Value / Device	Package
C29,C64,C68,C70,C71,C106,C107,C109,C111,C112,C113,C114,C115,C123,C148,C149,C152,C153,C154,C155,C156,C157,C158,C159,C160,C161,C163,C164,C165,C166,C167,C168,C169,C170,C171,C1110,C1210	100n/16V/X7R	C0402
C65,C66,C1127,C1129,C1131,C1132,C1133,C1160,C1161,C1163,C1164	100n/16V/X7R	C0603
C75	4u7/16V/X7R	C1206
C76,C77,C80,C81,C104	10n/16V/X7R	C0402
C78	10uF/10V/X7R	C1206
C79,C82	4u7/25V/X7R	C1206
C83,C84	20pF/50V/COG	C0402
C85,C1151,C1153	100n/50V/X7R	C0603
C86,C1135,C1136,C1154,C1155	22u/16V/X7R/F_1463575	C1210
C92	220nF/100V/C3216X7R2A224KT5	C1206
C93,C1152	100uF_35V_MAL214097001E3	C1010_CAP_Pin1_Plus
C105,C108	22uF/6.3V/X7R	C1206
C110	4.7n/50V/X7R	C0603
C143,C1111	22uF/16V/X7R	C1210
C144	100n/25V/X7R	C0603
C145,C146,C147	47n/16V/X7R	C0402
C150,C151,C1157,C1158	10u/10V/X7R	C1206
C172,C173,C176,C178,C180,C183,C184,C187,C1169,C1170,C1171,C1173,C1174,C1175,C1176,C1177,C1178,C1179,C1180,C1183,C1184,C1185,C1189,C1190,C1191,C1192,C1193,C1194,C1195,C1196,C1197	1n/50V/X7R	C0402
C174,C179,C182	100p/50V/X7R	C0402
C191,C194,C196	6800p/10V/C0G	C0603
C1040,C1041,C1042,C1043,C1044,C1045,C1147,C1148,C1149	10p/50V/X7R	C0603
C1064,C1065,C1067	3300p/10V/C0G	C0603
C1112,C1167	100n/50V/X7R/C0805F104K5	C0805
C1128,C1130	10p/16V/X7R	C0603
C1142	4u7/10V/X7R	C1210

Table 8 Bill of Materials for (cont'd)**Logic Board for Hybrid Kit for HybridPACK™1**

Reference	Value / Device	Package
C1144,C1146	4u7/10V/X7R/F_9402195	C1206
C1145	1u/25V/X7R/F_1637035	C0603
C1150	680n/50V/F_1414702	C1206
C1156	220n/25V/X7R/F_1414626	C0603
C1159	1n/16V/X7R	C0402
C1166	4.7u/50V/X7R/C1210F475K5	C1210
C1172,C1181,C1182,C1187,C1188,C1201,C1202,C1203,C1204,C1205,C1206,C1207,C1208,C1209	1n/50V/X7R_opt	C0402
C1211	100n/50V/X7R	C0805
C1212	22n/50V/X7R	C0603
R10,R103,R105,R107,R109,R110,R176,R181,R185,R192,R194,R202,R203,R208,R477,R480,R481,C1213,C1214,C1215,C1216,C1217	Opt	R0603
D1	MBRS340T3	SMC
D2	BZV55/C13	SOD80C_Pin1_Cathode
D3	1SMB30AT3	SMB
D4	LED_LSM676-MQ	Vishay_TLMK2300
D5,D6	SS12_1A_If_20V_Vr	DO214AC_SMA_Pin1_Cathode
D7,D8,D9	BAT54-04W	SOT323
FL1	B82789C0104N001	EPCOS_B82789C0
IC1	AT25256A-10TQ-2.7	TSSOP8
IC2	74ALVC164245DGG	TSSOP48
IC4,IC31	LT1639HS	SO14
IC6	LMH6672	SO8
IC8	AD2S1200YST	LQFP44_P0_8
IC13	TLE7368E	SO36-38
IC16	EH2645ETTTS-20.000M	Ecliptek_EH2645
IC17	TLE6250GV33	SO8
IC23	MAX6369KA-T	SOT23-8
IC24	SAK-TC1767-256F133HL	LQFP176_p0_50
IC25	TLE4266GSV10	SOT223
IC26	DS92LV010	SO8
IC28,IC30	74LVC2G04GW	SOT363
IC29	74LVCH16T245DL	SSOP48
IC32	DS90LV031A	SO16-1
IC33	AM26C32QD	SO16-1
IC52	MAX3232EIPWRQ1	TSSOP16

Table 8 Bill of Materials for (cont'd)**Logic Board for Hybrid Kit for HybridPACK™1**

Reference	Value / Device	Package
IC53	MAX6143AASA50	SO8
IC54	LM50CIM3	SOT23
J1	Jumper	Jumper_2way
K1	TW-12-06-L-D-475-SM-A	Samtec_TW-12-06-L-D-475-SM-A
K2	Harwin M80-5125042P	Harwin_M80-5125042P
K3-OCDS	HEADER 8X2	tyco_1761686-6
L1,L8,L9,L10,L11,L12	MURATA_BLM21PG221SN	L0805
L3	WE_7447709470	WE-PD_744770
L5	MURATA_BLM21P221SN	L0805
L6,L7	B82422A1103K	L1210
Q2	BDP949	SOT223
Q4	IPD90P03P4L-04	TO252-3
Q6	BCR183S	SOT363
R1,R2,R3,R4,R5,R6,R7,R8,R9,R71,R73,R173,R174,R177,R186,R195,R471,R473,R474,R475,R476	10K	R0402
R74,R75,R76,R77,R78,R79,R80,R88,R92,R95,R98,R100,R134,R135,R161,R162,R163,R164,R165,R166,R167,R168,R180,R187,R197,R234,R238,R240,R456	1K	R0402
R90,R93,R96,R99	15K	R0402
R101,R128,R169	10K	R0603
R102,R104,R106,R108,R478,R479,R482,R497	0R	R0603
R113	SMK-R000 / Isabellenhuette	R1206
R131,R132	60R	R0603
R133	5K1	R0402
R149,R154	Opt	R0402
R150,R151,R153	4K7	R0402
R155,R156,R158,R160	2K4/0.1%	R0603
R157	390/0.1%	R0603
R159	3K3/0.1%	R0603
R170,R224,R498	0R_opt	R0603
R171	4K7	R0603
R172	220R	R0603
R175,R184,R191,R198,R205	68K	R0402
R178,R179,R188,R189,R196,R199	51K	R0402
R182,R193,R200	91K	R0402
R183,R190,R201,R237,R239,R241	2K	R0402

Table 8 Bill of Materials for (cont'd)**Logic Board for Hybrid Kit for HybridPACK™1**

Reference	Value / Device	Package
R214,R217,R223,R228,R230,R235	6K8	R0402
R215,R218,R472	3K3	R0402
R229	0R	R0402
R429,R430,R431,R447	100R	R0603
R483,R484,R485	5K_pot_0,25W_20%_Bourns_3314J_opt	Bourns_3314J
R486	0R / 0.1%	R0402
R487	270K	R0603
R488,R489,R490,R494,R495,R496	1K	R0603
R491,R492,R493	2K7	R0603
R499,R500,R501,R502,R503,R504,R505,R506	100k	R0402
SW1	Tyco_1-1571983-1	Tyco_1-1571983-1
SW2	SW DIP-4/SM	SO8
TP1,TP2,TP3,TP4,TP5,TP6,TP7,TP8,TP9	Testpad_SMD_Ettinger	Ettinger_12_18_815_testpad
U1	HCM49 8.192MABJ-UT	Citizen_HCM49

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