MITSUBISHI ELECTRIC

< Evaluation Board for M81748FP >

EVB-M81748FP Application Note

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WARNING

The described EVB-M81748FP evaluation board is linked to high voltages and is dangerous for life.
The operation of S1-Series NX Package 6in1 Modules is hazardous and should be performed by authorized professional and experienced persons only.
The M81748FP evaluation board is for testing purposes only.
The M81748FP evaluation board does not comply with any safety, EMI or EMC standards.
The M81748FP evaluation board does not include a dynamic braking unit and therefore if M81748FP evaluation board is used for motor drive applications requiring dynamic braking, it is recommended to add a braking circuitry to the test set-up.

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1. M81748FP Evaluation Board Concept

1-1. Applications

3 Phase Inverter applications up to 30kW 400/440V line. (Operating conditions should be verified in order to guarantee rated power operation) For a proper selection of the power module please use the latest version of MITSUBISHI ELECTRIC's power loss simulation software "MELCOSIM". Please download from www.mitsubishielectric.com

1-2. Outline and Features

The M81748FP evaluation board provides a platform for efficient testing of S1-Series NX Package 6in1 IGBT Modules of MITSUBISHI ELECTRIC driven by the dedicated HVIC M81748FP. By simple connection of a 3~AC mains voltage, a DC-link capacitor bank, a 15V single supply and control signals, a complete power stage can be realized.
The PCB contains all necessary components like half-bridge high voltage integrated circuits (HVIC) to drive and protect the IGBTs and simple bootstrap circuits to provide floating power supply voltage for P-side IGBTs. A short circuit (SC) situation is sensed via desaturation detection diodes connected to the High Side and Low Side fault protection circuitries employed in the driver, e.g. covering Low Side and High side to protect against short circuits and earth faults.
The printed circuit board utilizes a low inductive interface between the on board DC-link snubber (only one piece is populated) capacitors and the high voltage supply of the IGBTs. All power connections for the DC-link electrolytic capacitors and the 3 phase outputs are utilizing solid terminal block with internal M6 thread. The low voltage (15V) power supply and all control signals are available at a single row 2.54mm pitch pinheader.
Fig.1.1 shows EVB-M81748FP.

1-3. Product Options

EVB-M81748FP is designed to be used with MITSUBISHI ELECTRIC S1-Series NX Package 6in1 IGBT Modules. Below is a brief table to introduce the modules that can be used with the evaluation board.

Table1.1 Modules that can be used with the evaluation board

HVIC Type Name	IGBT Module Type Name	IGBT Rating (I_c)	IGBT Rating (V_{DC})
M81748FP	CM100TX-24S1	100A	1200V
M81748FP	CM150TX-24S1	150A	1200V

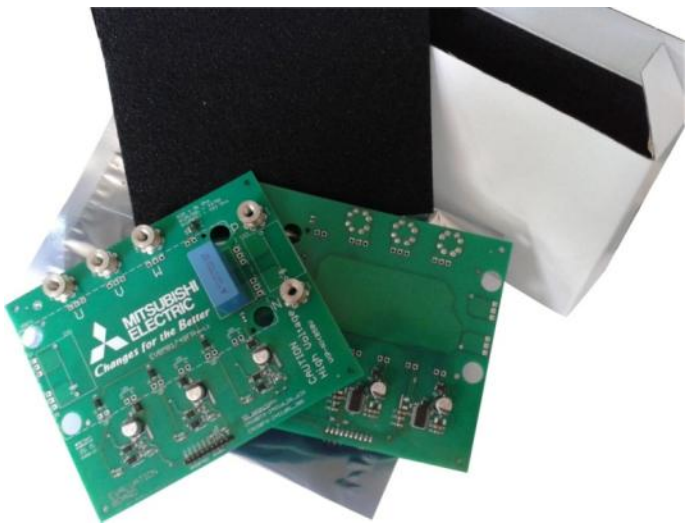

Fig.1.1 EVBM81748FP evaluation board

1-4. Connections to M81748FP Evaluation Board

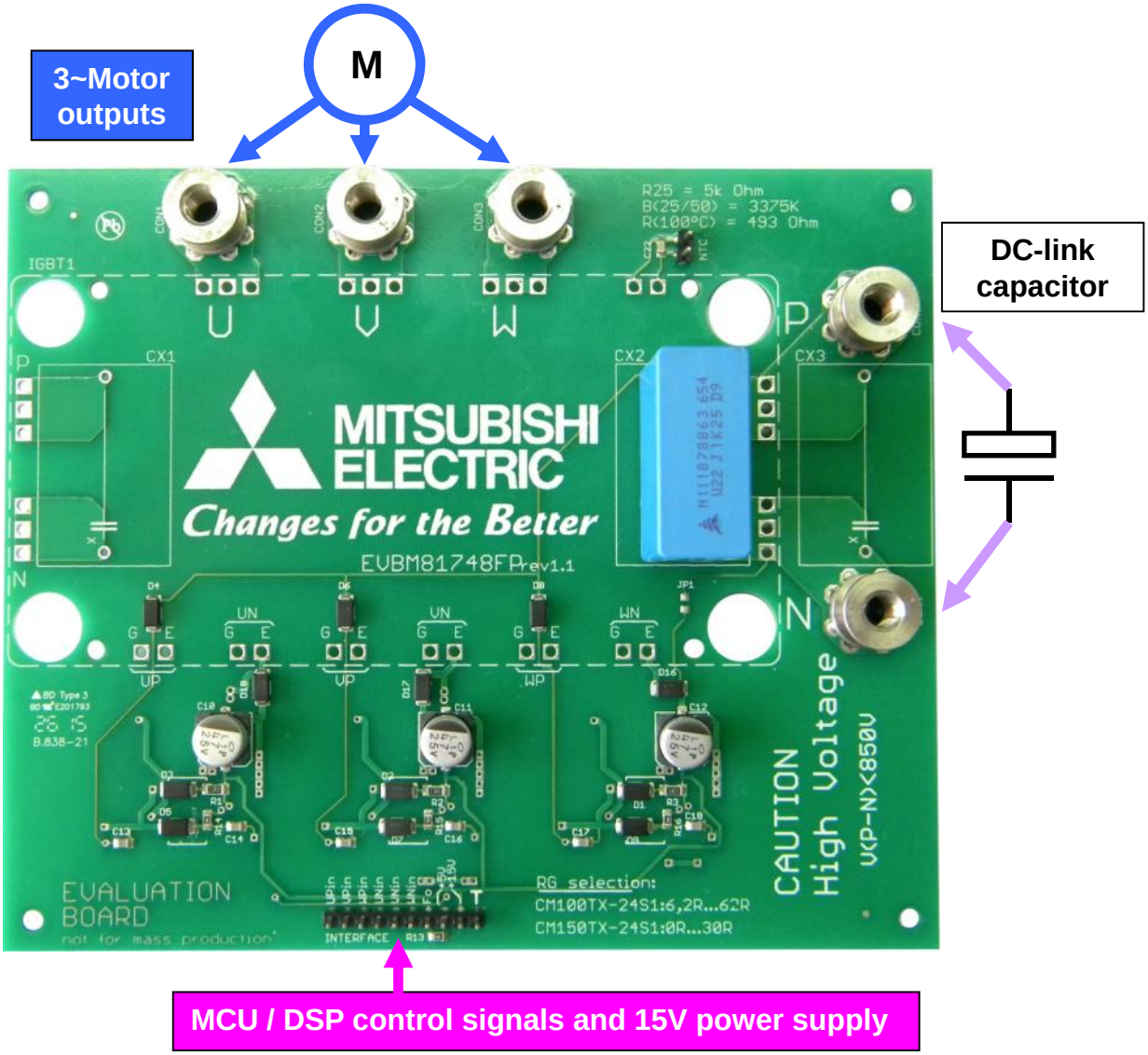

Fig.1.2 Connections to EVBM81748FP evaluation board

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2. Using HVICs to drive S1-Series NX Package 6in1 Modules

2-1. Introduction

Utilizing HVICs to drive IGBT modules efficiently and well protected in 3 phase inverter/converter applications requires certain know how about the layout of the PCB to reach low inductive structures. This application note provides a proposal for a test environment to develop setups that reliably work in industrial environments.

For more information, please refer to the M81748FP datasheet and the HVIC application note available on the Mitsubishi Electric semiconductor website as shown below.

- M81748FP datasheet

http://www.mitsubishielectric.com/semiconductors/php/ePartProfile.php?FILENAME=m81748fp_e_a.pdf&FOLDER=/product/icsensor/hvic/hvic_lv3/hvic_lv4

- HVIC application note

http://www.mitsubishielectric.com/semiconductors/files/manuals/hvic_application_note_e.pdf.pdf

2-2. Features of the HVIC (M81748FP)

- Floating supply voltage up to 1200V
- Low quiescent power supply current
- Sink and source current output up to ±2A (typ)
- Active Miller effect clamp up to 2A (typ)
- Input noise filters (HIN,LIN,FO)
- Desat detection and protection with output soft shutdown
- Under voltage lockout
- Synchronization signal to synchronize shutdown with other phases

2-3. Functions of the HVIC and Typical connection

Fig.2.1 shows the block diagram of the HVIC. The “HIN” input signal is transmitted to the output “HO” by a level shifter and the HDESAT fault signal is transferred to the “FO” by the reverse level shifter.

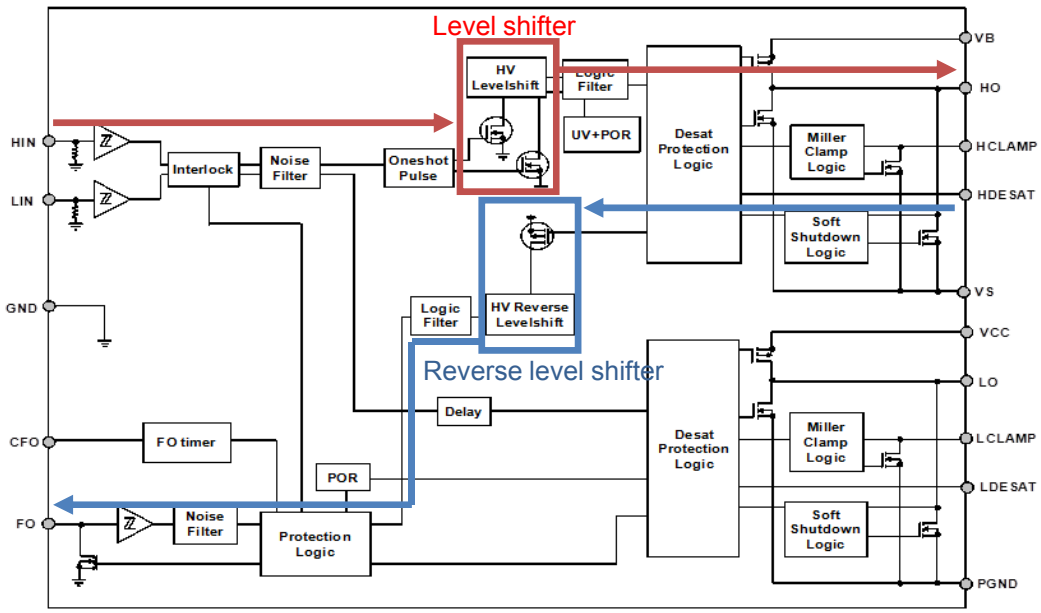

Fig.2.1 Internal Block diagram of M81748FP

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M81748FP can detect a desaturation of the connected MOSFET or IGBT at its “HDESAT” and “LDESAT” terminals respectively.

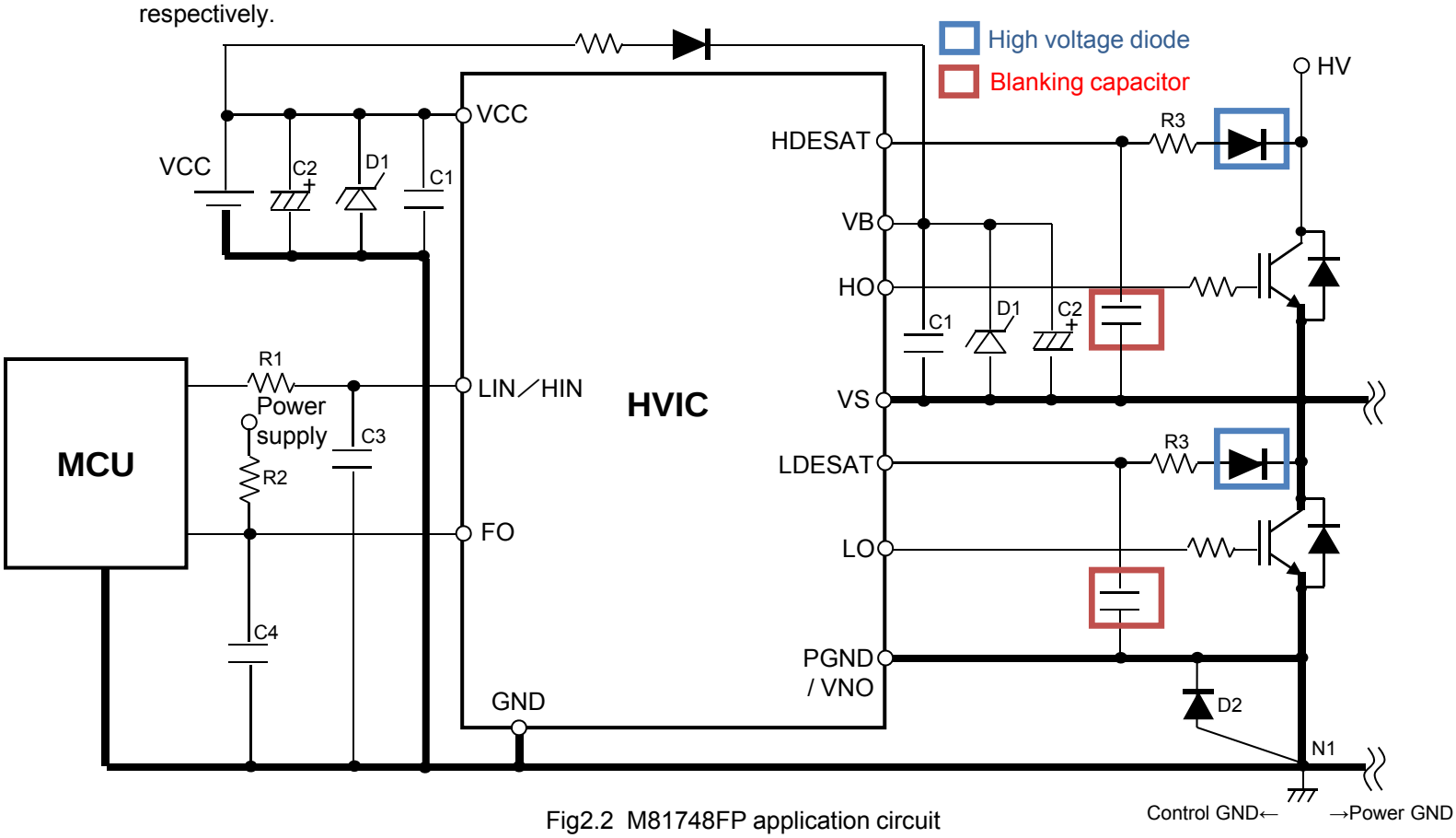

Fig2.2 M81748FP application circuit

2-4. Desaturation detection and high current protection

The terminal HDESAT(LDESAT) detects the IGBT saturation voltage. When the IGBT is turned on and the voltage at the DESAT terminal exceeds the DESAT threshold voltage, the HO(LO) output terminals will slowly turn off and hence the connected IGBT is softly turned off preventing from high di/dt occurrence. The terminal “FO output” assumes a low level to transmit the fault signal to the microcontroller. Once the fault condition is detected, all input signals are ignored during the tFO period to complete the soft shutdown.

As shown in Fig.2.2 high voltage diodes with low reverse-recovery charge and corresponding low reverse recovery time are connected between the “DESAT” terminals (Anode of the diode) and the IGBT’s collector terminals with the cathode of the diode. Additionally blanking capacitors filtering spikes are connected between the “DESAT” terminals and VS or GND terminals respectively providing noise immunity and a certain delay of detection. In detail the circuit operates as follows: When the High side IGBT is turned on, the current provided from the corresponding DESAT terminal flows through the Collector – Emitter path to the reference potential. Hence, the voltage level at the DESAT input can be considered low. However at a short circuit situation the IGBT is considered desaturated, and, hence, the current originating from the “DESAT” terminal flows into to the blanking capacitor since the Collector – Emitter path is blocked by the implemented diode. Once the voltage at the DESAT terminal exceeds the threshold voltage, a desaturation situation is detected initiating a soft shut down procedure inside the M81748FP. Thus, the output driver stages for low side “LO” and High-side “HO” correspondingly are shut down softly. The indication of this abnormal situation is realized by the fault output terminal “FO” becoming low to provide the information to the superimposed control system.

The desaturation fault signal on the High-side floating island is transferred to Low-side using the referred reverse level shifter as shown in Figure 2.1.

- Vce level is used to detect the desaturation

The voltage Vdesat which is monitored at the DESAT terminal is shown below (Vce:Voltage between collector and emitter of IGBT, Idesat:Current flowing from DESAT terminal, Rdesat:Resistor connected to DESAT terminal).
Vdesat=Vce+Idesat×Rdesat
Please refer to the dataseet for the DESAT threshold and Idesat. The Colledctor – Emitter voltage Vce is depending on the IGBT. Please set this Vce parameter and the Rdesat value to detect the desaturation situation according to the power semiconductor‘s requirements.

- Blanking time

A desaturation is detected when the HVIC‘s output is “high”. However, it is necesarry that a delay (blanking) time is properly set before the SC soft turn-off sequence is started to prevent malfunction. The blanking time is shown below and is mathematically a result of the following equation:

tBLANK = Cblank × Vdesat / Idesat + t0

The parameter „Cblank“ indicates the blanking capacitor in Fig.2.2. while the „t0“ blanking time is set inside the HVIC. Thus, when Cblank equals 0(pF), the blanking time is t0. Please refer to the DESAT threshold, Idesat and t0. Please set the blanking capacitor using above expression according to the blanking time that is appropriate for the IGBT or MOSFET under the actual application conditions.

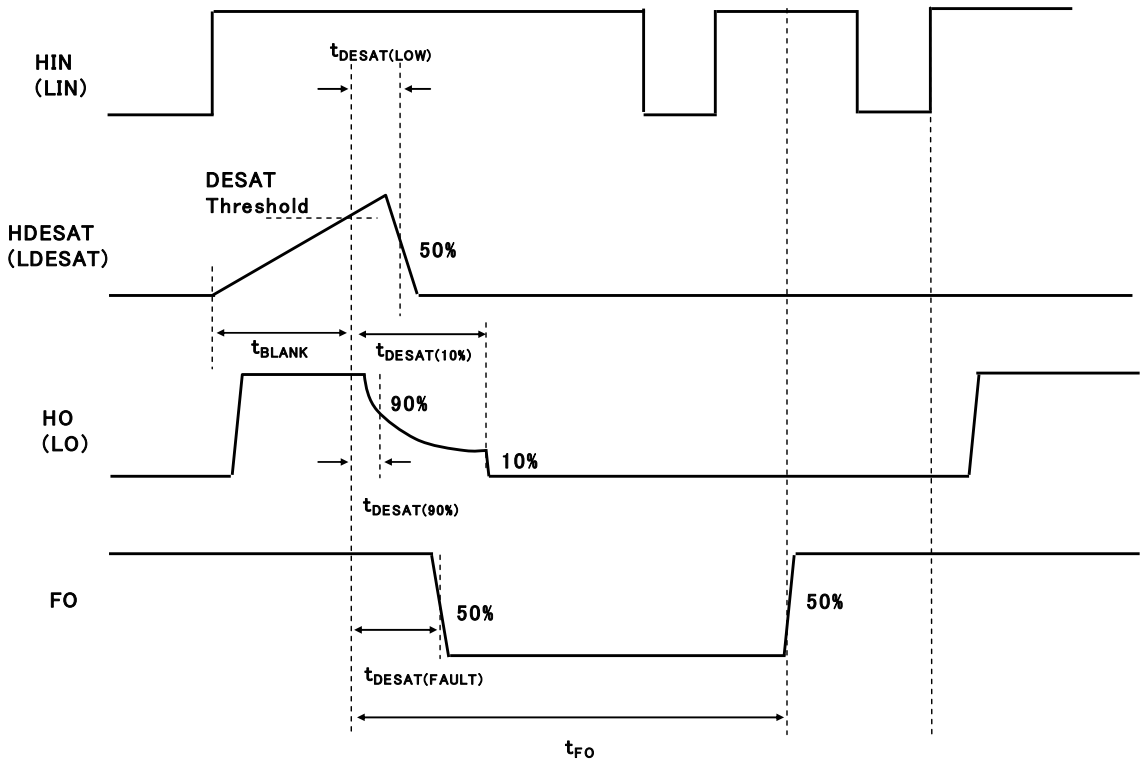

Fig.2.3 Desat detection and soft-shut down

2-5. VS undershoot

The voltage at the VS terminal can transiently be lower than the voltage at the GND terminal's reference as a result of an inductive voltage drop at turn-off in the commutation path. Such a voltage undershoot must be carefully observed to avoid a malfunction. The mechanism how this voltage undershoot is created is shown in Fig.2.4.

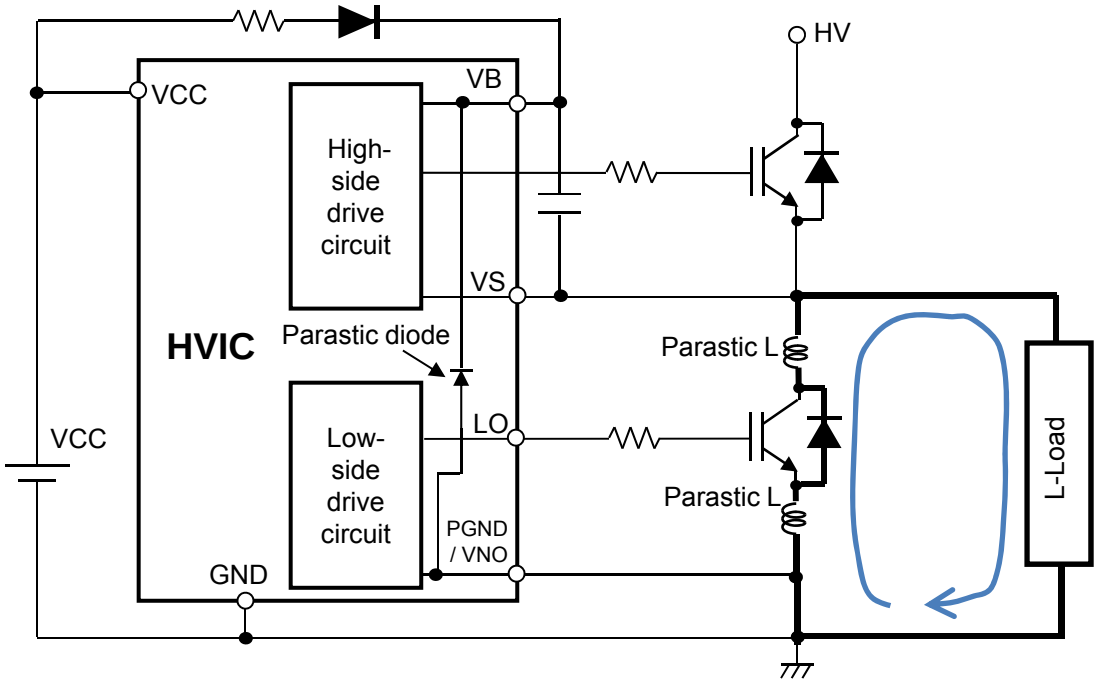

Fig.2.4 VS voltage undershoot at inductive load (L-load)

A key feature of a junction isolated HVIC is the immunity against such VS undershoot voltage. The M81748FP by its internal construction provides a high robustness to such VS voltage undershoot. A test has been carried out with a CM100TX-24S1 6in1 IGBT module and the voltage at terminal "VS" has been recorded. Fig 2.5 shows the turn-off waveforms of the IGBT module which is driven by a M81748FP. Although the voltage in this example transiently reaches a level of as low as -129V, this stress cannot destroy or create a malfunction of this tested M81748FP device.

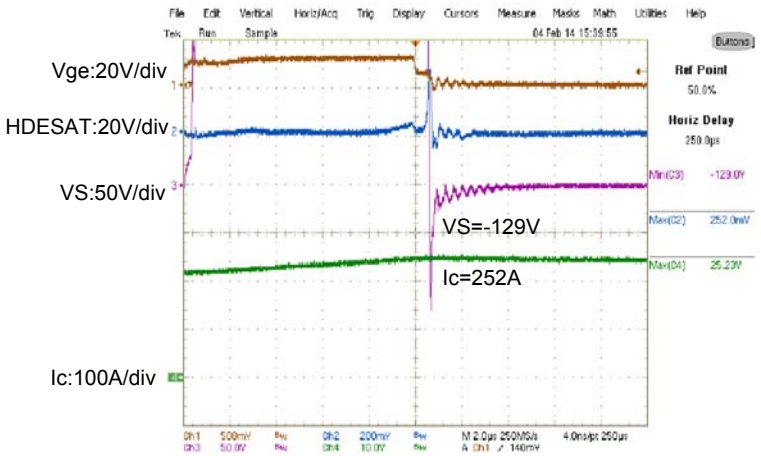

Fig.2.5 Waveforms of IGBT module during turn-off
(conditions: CM100TX-24S1, Ta=25°C, VS=900V, Rg=0ohm, VGE=15V)

3. Printed Circuit Board (PCB) Design

3-1. Schematic of the EVBM81748FP

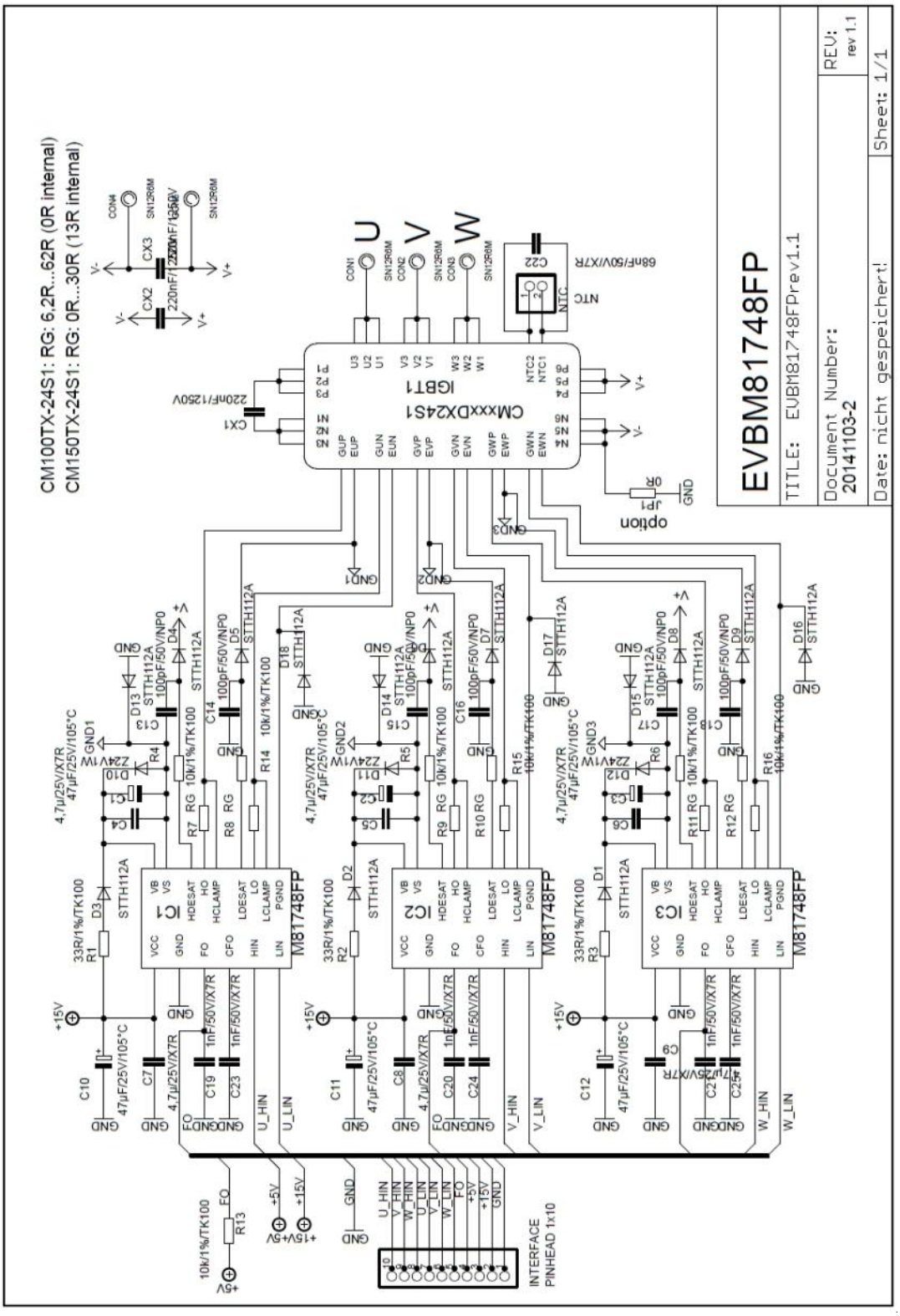

Fig.3.1 Schematic of the EVBM81748FP

3-2. General Considerations for the PCB Design

The PCB of the M81748FP evaluation board is a double layer board with an average cupper thickness of 70µm on each layer. The efficient design of the power stage and the control signal interface – realizing the design targets of low inductive connections and avoiding crossing of signal and high voltage traces – on only two layers became possible by matching pin terminal layout of the HVIC and S1-Series NX Package 6in1 IGBT modules. Suitable ground planes were realized bottom layer. For wide temperature range and robustness during the soldering process a FR4 epoxy based material has been chosen.

3-3. Top Layer Design

The design of the top layer (Cu traces in red color) contains the desaturation diodes, the bootstrap circuit diodes and resistors, snubber capacitors, NTC interface pinheader along with control interface pinheader and power terminal connectors. A part of the silk screen for component placement information is shown in this view to ease the orientation.

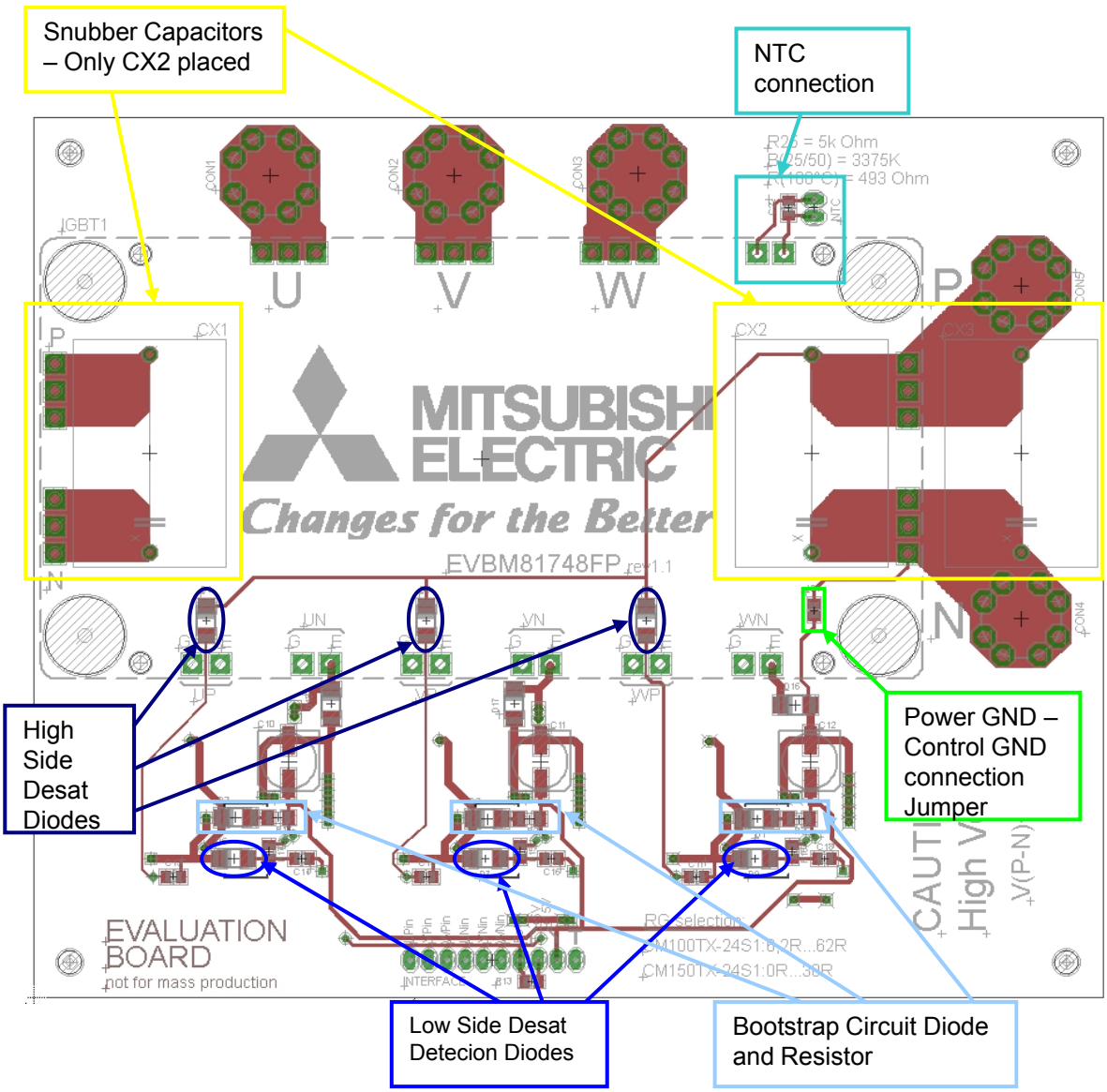

Fig.3.2 Top layer of the PCB

3-4. Bottom Layer Design

On the bottom layer (shown as blue traces), HVICs and IGBT Module Gate-Emitter traces including gate resistors, bootstrap capacitors and HVIC placement are present.

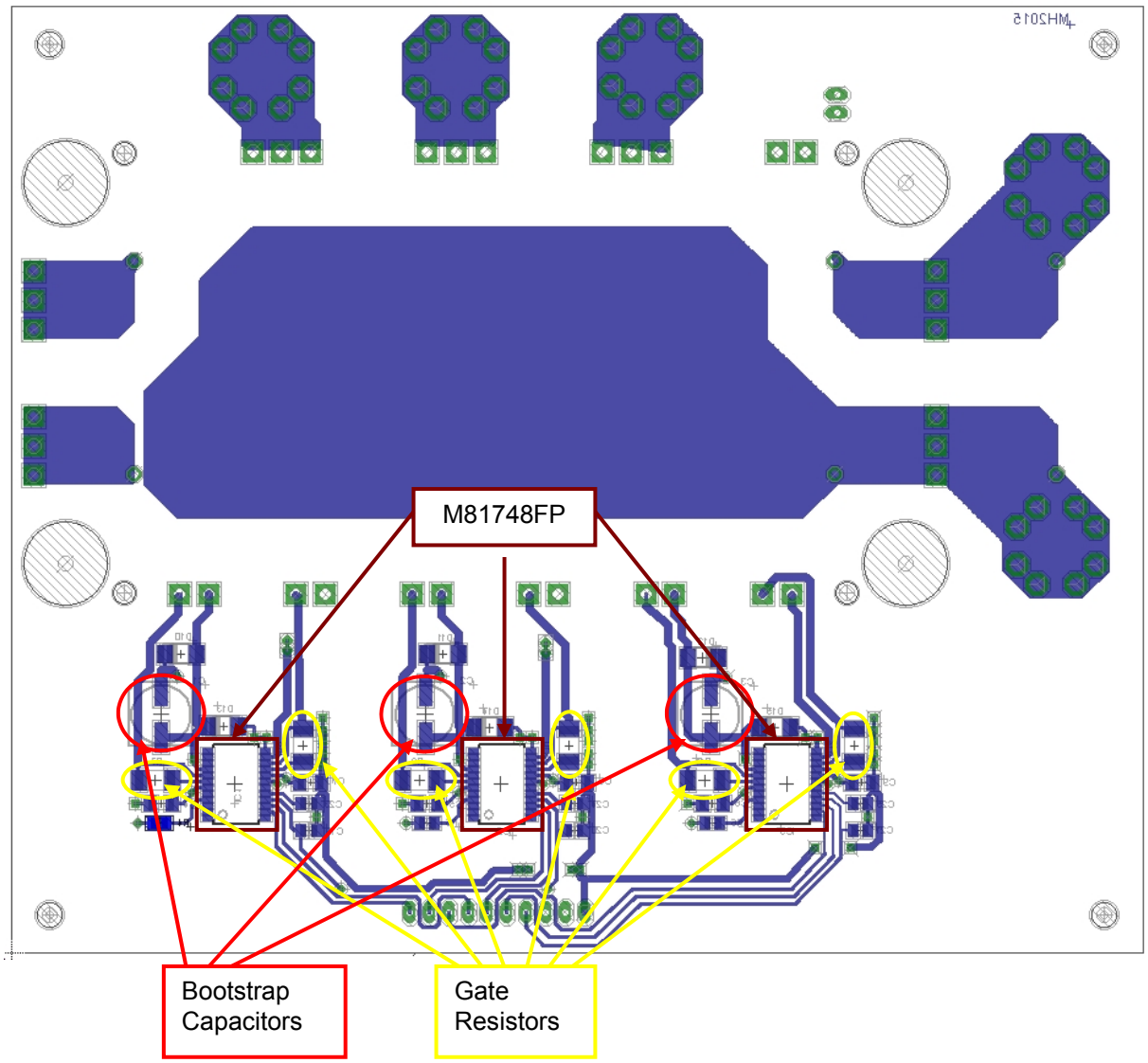

Fig.3.3 Bottom layer of the PCB

3-5. Placement diagram

The placement diagram indicates the position of components placed from top and bottom side of the PCB, their reference according to the bill of material (BOM) and their orientation in case of diodes, electrolytic capacitors and integrated circuits and holes for the mounting of through hole components.

The following resistors (2010) are not placed : R7, R8, R9, R10, R11, R12

The following resistor (0805) is not placed : JP1

The following capacitors are not placed : CX1, CX3

IGBT1 is the 6in1 IGBT module and it is not placed. After determination of the right type/size of module by the simulation software MELCOSIM the S1-Series NX Package 6in1 IGBT Module should be placed from the bottom side and should be soldered from the top side respecting the handling precautions for ESD sensitive components. Further instructions can be found in 6.1th Gen. S1 SERIES NX TYPE / 6th Gen. S SERIES NX TYPE Application note by using the following link:

http://www.mitsubishielectric.com/semiconductors/files/manuals/igbt_nx_note_e.pdf

The pin assignment of interface and NTC pinheaders, control signal terminals of the inverter and the NTC interface respectively, are printed on the PCB silk screen top layer. The placement diagram references to components shown in the schematic (ref: chapter 3.1) and the bill of material (BOM) (ref: chapter 3.6).

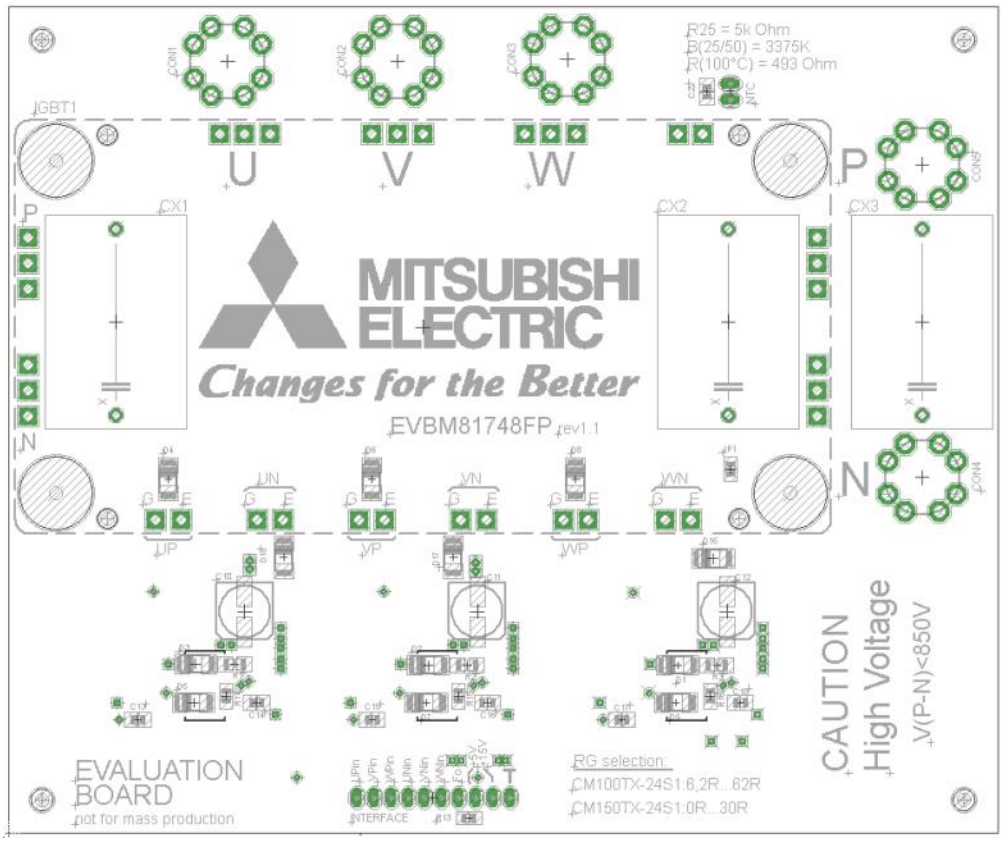

Fig.3.4 Top Component layer (“silk screen” - top)

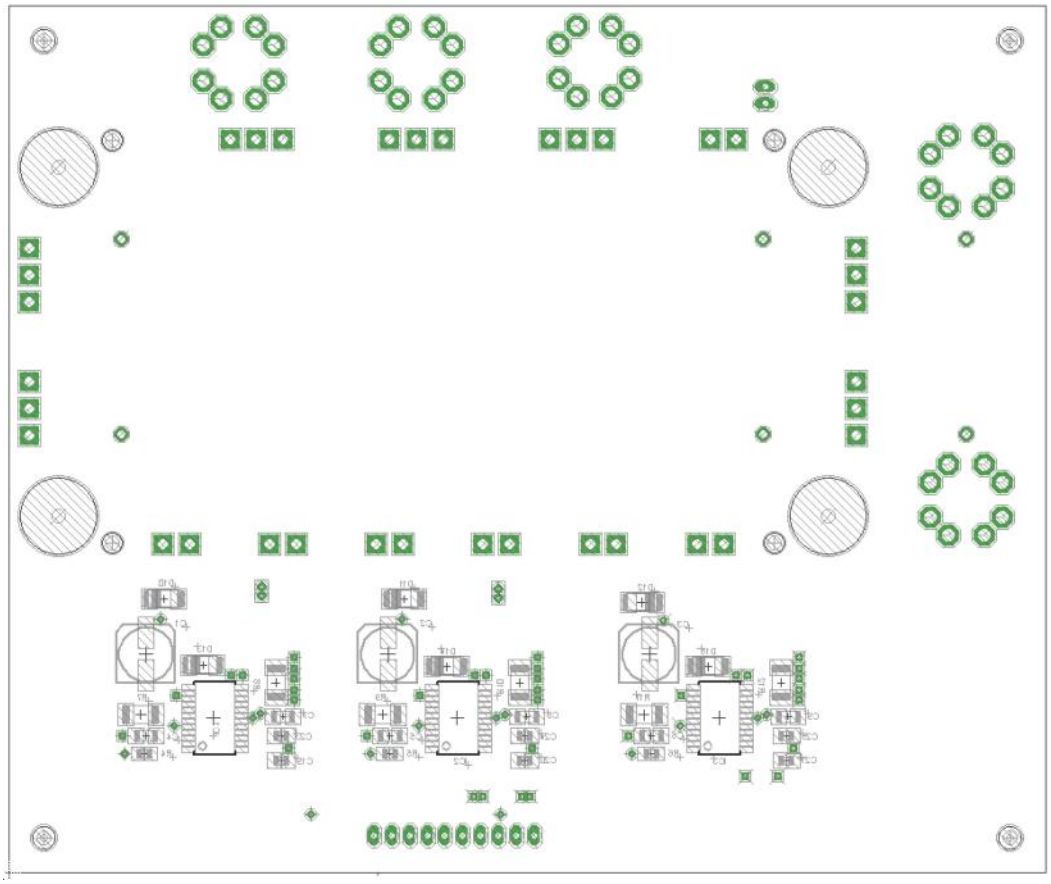

Fig.3.5 Bottom Component layer (“silk screen” - bottom)

3-6. Bill of Material (BOM)

Table 3.1 Bill of Material (BOM)

Part	Value	Package /Part No. /Comment	Manufacturer
C1	47µF/25V/105℃	UUX1E470MCL1GS	Nichicon
C2	47µF/25V/105℃	UUX1E470MCL1GS	Nichicon
C3	47µF/25V/105℃	UUX1E470MCL1GS	Nichicon
C4	4,7µ/25V/X7R	CL31B475KAHNNNE	Samsung
C5	4,7µ/25V/X7R	CL31B475KAHNNNE	Samsung
C6	4,7µ/25V/X7R	CL31B475KAHNNNE	Samsung
C7	4,7µ/25V/X7R	CL31B475KAHNNNE	Samsung
C8	4,7µ/25V/X7R	CL31B475KAHNNNE	Samsung
C9	4,7µ/25V/X7R	CL31B475KAHNNNE	Samsung
C10	47µF/25V/105℃	UUX1E470MCL1GS	Nichicon
C11	47µF/25V/105℃	UUX1E470MCL1GS	Nichicon
C12	47µF/25V/105℃	UUX1E470MCL1GS	Nichicon
C13	100pF/50V/NP0	C0805	
C14	100pF/50V/NP0	C0806	
C15	100pF/50V/NP0	C0807	
C16	100pF/50V/NP0	C0808	
C17	100pF/50V/NP0	C0809	
C18	100pF/50V/NP0	C0810	
C19	1nF/50V/X7R	C0811	
C20	1nF/50V/X7R	C0812	
C21	1nF/50V/X7R	C0813	
C22	68nF/50V/X7R	C0814	
C23	1nF/50V/X7R	C0815	
C24	1nF/50V/X7R	C0816	
C25	1nF/50V/X7R	C0817	
CON1	SN12R6M	SN12R6M	Broxing
CON2	SN12R6M	SN12R6M	Broxing
CON3	SN12R6M	SN12R6M	Broxing
CON4	SN12R6M	SN12R6M	Broxing
CON5	SN12R6M	SN12R6M	Broxing
CX1	220nF/1250V	not populated	
CX2	220nF/1250V	B32654A7224J000	TDK
CX3	220nF/1250V	not populated	
D1	STTH112A	DO-214AC	STMicroelectronics
D2	STTH112A	DO-214AC	STMicroelectronics
D3	STTH112A	DO-214AC	STMicroelectronics
D4	STTH112A	DO-214AC	STMicroelectronics
D5	STTH112A	DO-214AC	STMicroelectronics
D6	STTH112A	DO-214AC	STMicroelectronics
D7	STTH112A	DO-214AC	STMicroelectronics
D8	STTH112A	DO-214AC	STMicroelectronics
D9	STTH112A	DO-214AC	STMicroelectronics
D10	BZG05C24TR	DO-214AC	Vishay
D11	BZG05C24TR	DO-214AC	Vishay
D12	BZG05C24TR	DO-214AC	Vishay
D13	STTH112A	DO-214AC	STMicroelectronics
D14	STTH112A	DO-214AC	STMicroelectronics
D15	STTH112A	DO-214AC	STMicroelectronics
D16	STTH112A	DO-214AC	STMicroelectronics
D17	STTH112A	DO-214AC	STMicroelectronics
D18	STTH112A	DO-214AC	STMicroelectronics

Table 3.1 Bill of Material (BOM) (Continue)

Part	Value	Package /Part No. /Comment	Manufacturer
IC1	M81748FP	SSOP4-300-0.8	Mitsubishi Electric
IC2	M81748FP	SSOP4-300-0.8	Mitsubishi Electric
IC3	M81748FP	SSOP4-300-0.8	Mitsubishi Electric
IGBT1	CMxxxDX24S1	not populated	
INTERFACE	PINHEAD 1x10	1X10	
JP1	0R	not populated	
NTC	NTC	1X02	
R1	33R/1%/TK100	R1206	
R2	33R/1%/TK100	R1206	
R3	33R/1%/TK100	R1206	
R4	10k/1%/TK100	R0805	
R5	10k/1%/TK100	R0805	
R6	10k/1%/TK100	R0805	
R7	RG	not populated	
R8	RG	not populated	
R9	RG	not populated	
R10	RG	not populated	
R11	RG	not populated	
R12	RG	not populated	
R13	10k/1%/TK100	R0805	
R14	10k/1%/TK100	R0805	
R15	10k/1%/TK100	R0805	
R16	10k/1%/TK100	R0805	

5. Test results of EVB-M81748FP

Tests of the performance and the robustness of the M81748FP has been carried out on EVB-M81748FP with S1-Series NX package 6in1 IGBT modules.
Fig.4.1, 4.2, 4.3 and 4.4 show switching test results of this experimental test setup using a sample of a 100A and 1200V rated IGBT module the CM100TX-24S1 IGBT module. Fig.4.1 and 4.2 show a “normal” operation switching waveform but to up to around 250A Collector current which is already 50A beyond the specified Safe operating Area (SOA) limit of the CM100TX-24S1. Even in this extreme operation point being out of the specified limits no destruction and no malfunction has occurred neither in High-side nor on Low-side during this test at VDC= 600V, Ta=25°C and Rg=0Ω.
Fig.4.3 and 4.4 show a soft shutdown waveform after a successful detection of the desaturation at a short circuit situation: The oscillograph shows that after the desaturation signal is detected, the HO/LO output is softly shut down and a FO fault signal is generated.

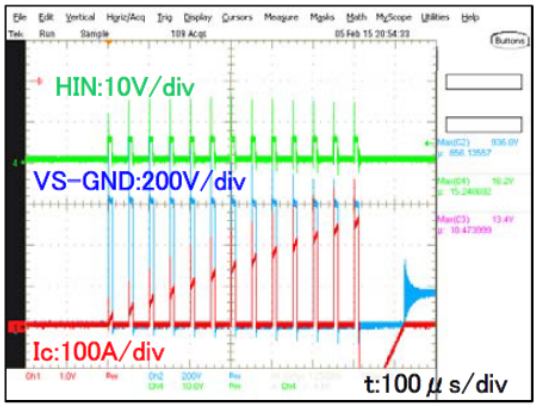

Fig.4.1 High-side switching waveform

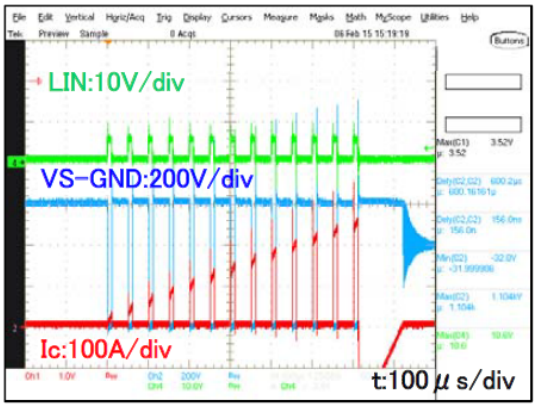

Fig.4.2 Low-side switching waveform

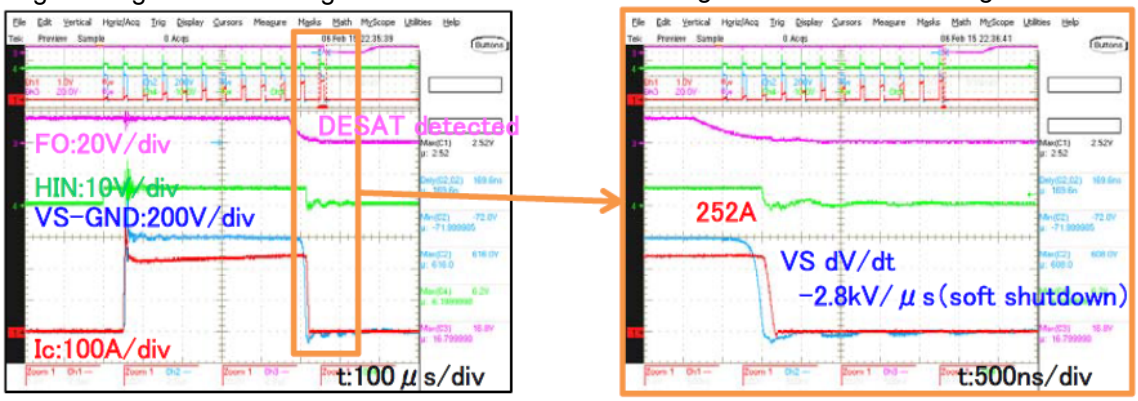

Fig.4.3 High-side soft shutdown waveform

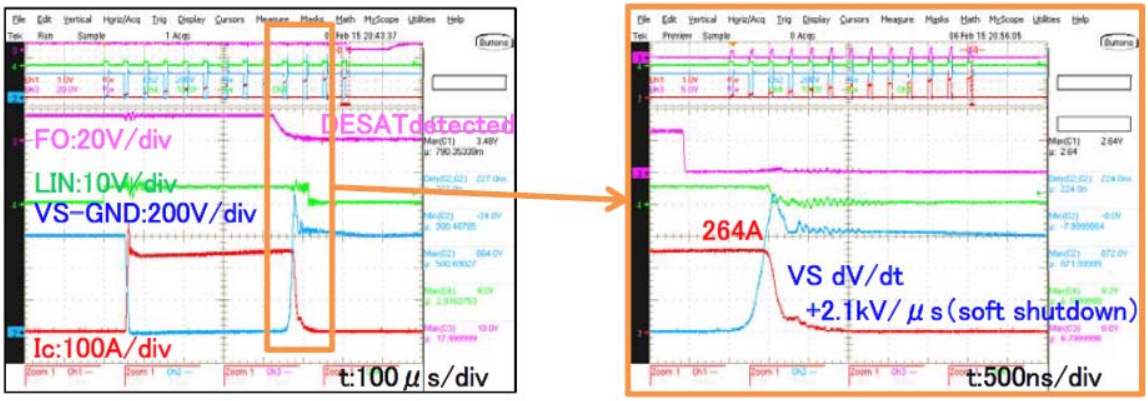

Fig.4.4 Low-side soft shutdown waveform

3. Notes for handling

■ Using the HVIC safely

The processes related to the HVIC are focusing on reliability and quality especially in the development stage of the HVIC product (Hereafter, it is called “unit”) and with the best degree of care during the manufacturing process. The reliability of the unit is greatly influenced not only by a factor peculiar to the unit but also the application conditions that it is used in. Please read carefully the notes below to ensure correct handling and utilization of this unit.

⚠ **Cautions**	
Packaging	The packing box and the interior material of the unit shipped by our company come to be able to endure a constant environment and the condition. However when the packing box is exposed to the outside impact, rain water and pollution, the packing box and the interior material might break and the unit is exposed. Please note handling enough.
Carry	・ Please put the packing box on the correct direction while transporting it. It keeps inverted, and it leans it. And then unnatural power might join, and it breaks. (This side up) ・ If it throw out or it drop, the unit might break. (Fragile attention) ・ It is necessary not to get wet by the water. Please note that it is wetting for the transportation at the rainfall snow. (Water wet attention) ・ When another of the above-mentioned point is transported, a mechanical vibration and the impact are reduced as much as possible. Please note the way. The unit might break.
Keeping	・ The temperature and the humidity of the place where the unit is kept as a standard with 5-30℃ and about 40-60% Normal temperature is preferable, and avoid each of the temperature and humidity too far apart, please. Moreover, keep it in the place where the temperature changes drastically, the dew of moisture happens in the surface of the unit and the lead part. Thus keep it in the place where the temperature change is a little as much as possible, please. ・ Keeping by the place where causticity gas generates, an organic solvent or explosiveness dust, etc. exists causes corrosion, the malfunction, and destruction of the units. Thus avoid these places. ・ You must do not pile up the packing box high, and put the heavy one on the packing box. As a result, the packing box breaks, the cargo collapses, and it is dangerous.
Long storage	If you need long storage, you must do not open the wrapping box. Moreover, if you use the units kept at putting on a very bad environment and a long term is passed, you must confirm it without the wound, dirt or rust.
Ratings characteristics	Absolute maximum ratings defines that our company guarantees maximum ratings. If you use unit beyond this ratings, it brings its reliability, damage or destroy. To avoid these phenomena and realized on the interfacial devices high reliably, we recommend that unit is operated within the ratings and the regulations. And then it makes unit operate effectively for the characteristic and economical point views.
Ambient temperature	Temperature ratings have two ratings. One is operation temperature rating. Another is storage temperature rating. Please use within range of the temperature decided respectively. If it used the exceeding ratings of the operation and storage temperature, it becomes deterioration or destruction of the unit.
Noise	This device is composed of junction isolation structure. Therefore when I/O potential of the unit is less than -0.5V by external noise etc, a parasitic unit operates. Therefore, adjacent transistors inside of the unit cannot isolate, and becoming causes of the decrease in the circuit malfunction and no output and the destruction of the device, etc.
Flame resisting	It is not nonflammability though 94-V0 recognition goods of the UL standard are used for the epoxy molding resin material of this unit.
Electrostatic protection	It is necessary to note static electricity especially in the semiconductor unit. It is preferable to suppress the static electricity level of the working environment to 100V or less, and the mind for which do not use insulation thing (especially, artificial fiber and plastics product) it that humidifies at a dry period, avoids the state of low humidity, and uses the one of electro conductive (electro conductive mat, electrostatic work wear, and Mitibidencts) is injuring necessary for that.

Main Revision for this Edition

No.	Date	Revision	
		Pages	Points
A	Oct 2015	-	New making

Keep safety first in your circuit designs!

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