ACPL-333J

Fuji Electric AT-NPC 3-Level 12in1 IGBT Module

Reference Design

1. Introduction

In 2010, Fuji Electric launched a platform featuring 3-level Converter circuit. With the success, Fuji Electric released the first AT-NPC 3-Level 12-in-1 IGBT Module Series in 2013. The AT-NPC 3-level conversion circuit reduces the size of power electronic equipment by 60% and power loss by 50% as compared to conventional IGBT modules.

In a half bridge topology, a 3-level circuit uses 4 IGBTs as compared to 2 IGBTs in a 2-level circuit to produce a waveform closer to a sine wave with low harmonic distortion. The 3-level circuit also has lower conduction and switching losses and can achieve higher conversion efficiency.

As there are more IGBTs in a 3-level circuit, the complexity and number of gate drivers and IGBT protection components increase. The ACPL-333J "smart" gate drive optocoupler is suitable for driving a 3-level IGBT module because it provides isolation, drive, protection and feedback in a single chip gate drive solution. The integrated features like the short circuit protection, active Miller clamp or isolated fault feedback help to simplify 3-level Inverter IGBT gate drive design significantly, saving costs, space and design cycle.

This reference design will describe the basic operation of the Fuji Electric evaluation driver board for driving AT-NPC 3-Level 12in1 IGBT modules, 12MBI50VN-120-50, 12MBI75VN-120-50 and 12MBI100VN-120-50. It will demonstrate with waveforms how ACPL-333J is being used to drive, protect the IGBTs and provide “FAULT” signal during short circuit condition. Operation details of AT-NPC 3-level IGBT module like the switching sequence and waveforms and peripheral circuitries like DC/DC converters, signal I/O connectors and main I/O terminals can be found in Fuji Electric technical documents website :

http://www.fujielectric.com/products/semiconductor/model/igbt/technical/box/doc/pdf/module_Gate_Drive/AN-123_12in_module_Gate_Drive_Board.pdf

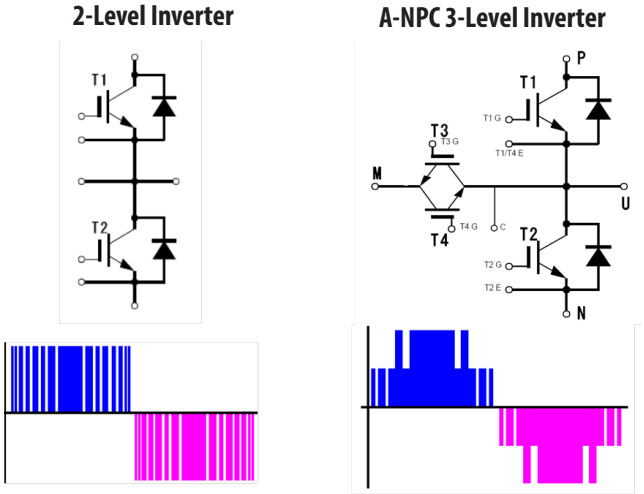


Figure 1. 2-level 3-level inverter circuitries and their output waveforms

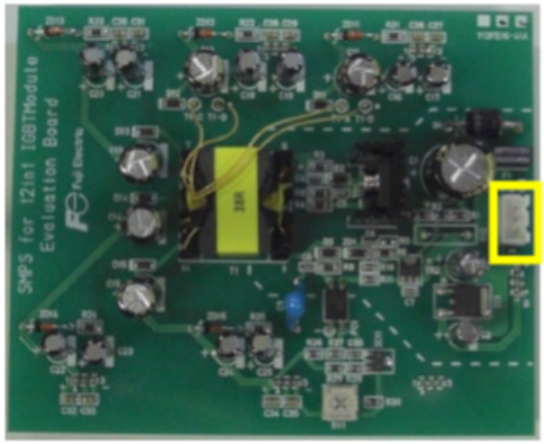


Figure 2. Evaluation driver board for AT-NPC 3-level 12in1 IGBT Module

2. DC/DC Converter and Gate Driver Board Features and Operations

The evaluation driver board consists of DC/DC converters, signal I/O connectors and the main I/O terminals to the IGBTs. The board is powered by an external 15V source to DC input connector CN1.

The DC/DC converter block, uses transformer T1 to convert the 15V input to isolated +17/-10V supplies for IGBTs gate drive at the high voltage side. The DC/DC converter board is then inserted onto the gate driver board to provide power for the low voltage primary side and high voltage secondary side for gate driving.

The microcontroller will provide the PWM signals for the high and low side of the main IGBTs and RB-IGBT using signal I/O connectors CN2. Similarly, IGBT short circuit "FAULT" signal from the ACPL-333J is fed back to the microcontroller using the same CN2. CMOS inverters IC14-19 (SN74HC04PW) are used to convert PWM voltage signal to drive the input LEDs of ACPL-333J.

The 3-level DC bus voltages are connected to P/M/N of the main DC voltage terminal. The gate driver board is then soldered on the IGBT module to apply the 3-level DC bus voltages and gate drive signal to the IGBTs. The IGBTs 3 phase outputs U/V/W will be available at the AC output terminal.

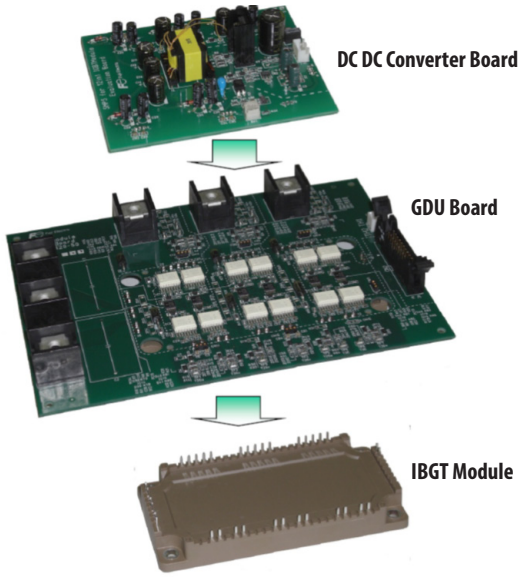


Figure 3. DC/DC Converter Board

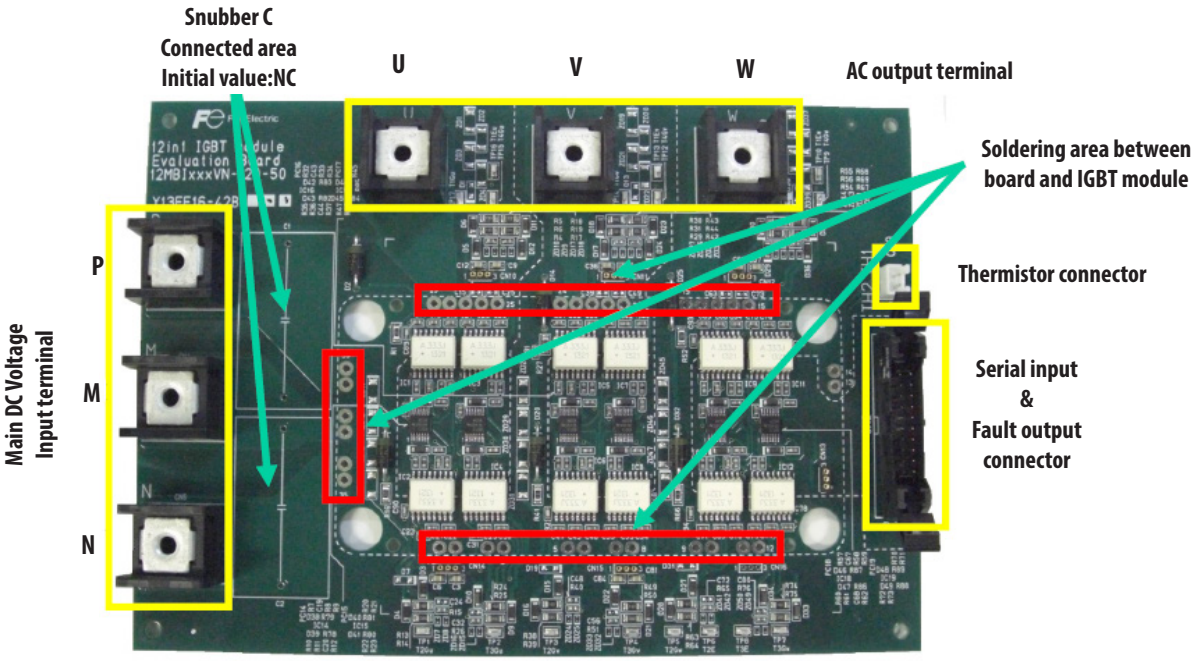


Figure 4. Gate Driver Board

3. ACPL-333J Gate Drive Optocoupler Features and Operations

The board consists of twelve ACPL-333Js to drive six main IGBTs and six RB-IGBTs in a 3phase full bridge topology. The ACPL-333J gate drive optocouplers are used to provide insulation for working voltage up to 1414VPEAK, well above the rated VCES of the IGBT of 1200V. The ACPL-333J output can provide a maximum of 2.5A peak current to direct drive the gate of the IGBT.

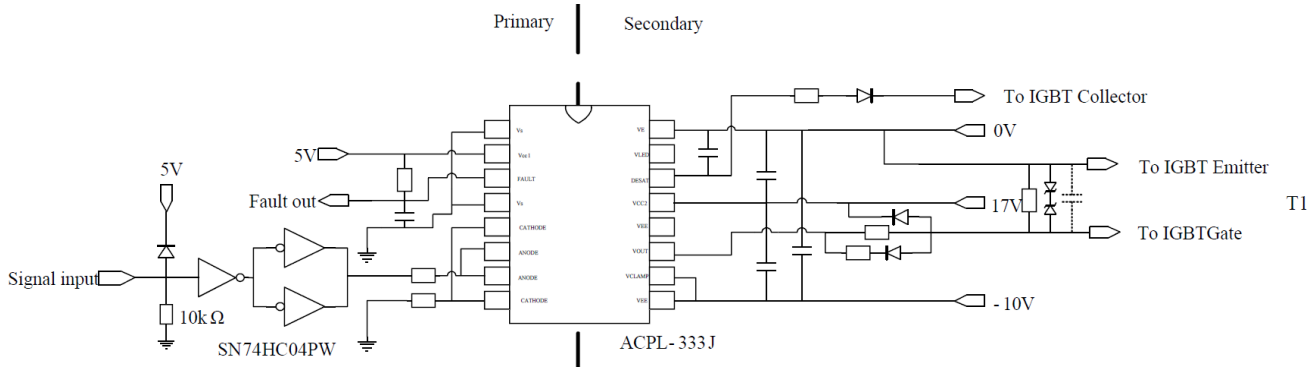


Figure 5. The schematic of ACPL-333J on the gate driver board

The main IGBT's collector-emitter voltage is monitored by ACPL-333J DESAT pin during IGBT normal operation. When short circuit occurs, IGBT comes out of saturation, into DESAT mode, causing the collector and emitter voltage to increase rapidly. Once it crosses the ACPL-333J's threshold of 6.5V, a short circuit fault is registered and soft shutdown is triggered. Lastly, the entire DESAT operation is completed by reporting the FAULT through a built-in insulated feedback path to the controller via connecter CN2.

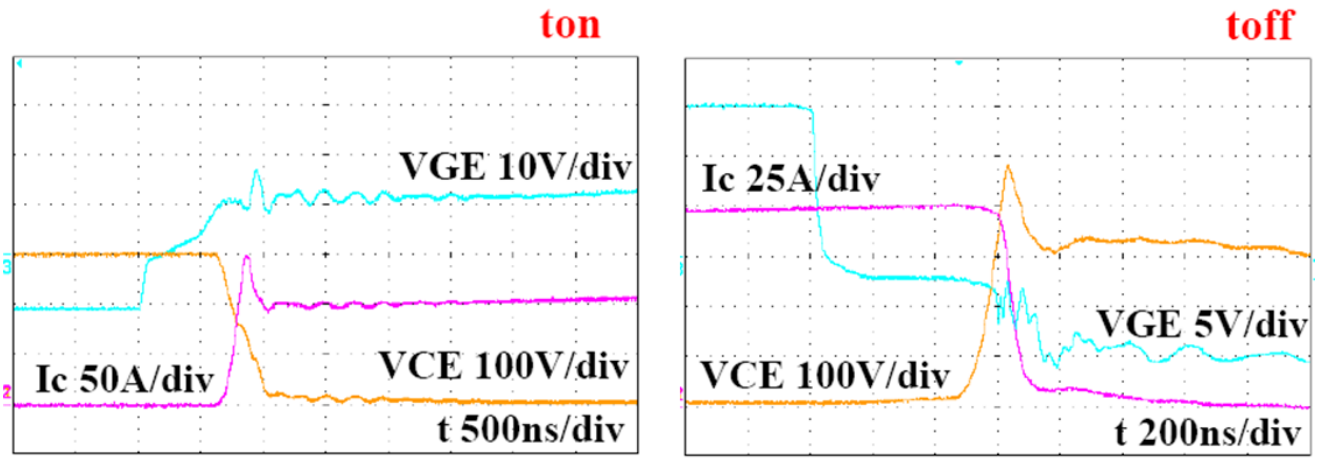


Figure 6. Switching waveforms of the main IGBTs

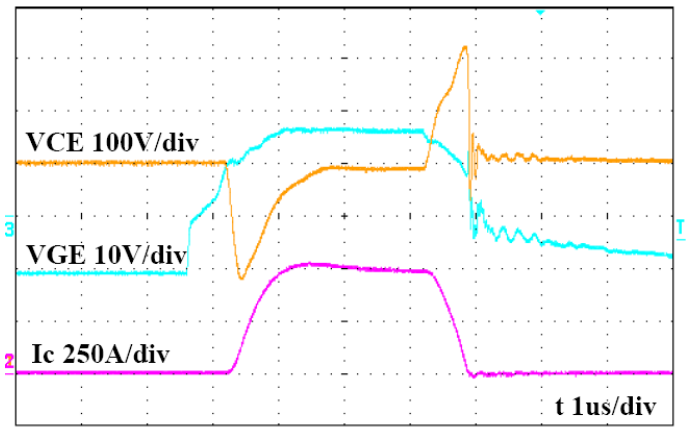


Figure 7. ACPL-333J soft shut the IGBT during short circuit

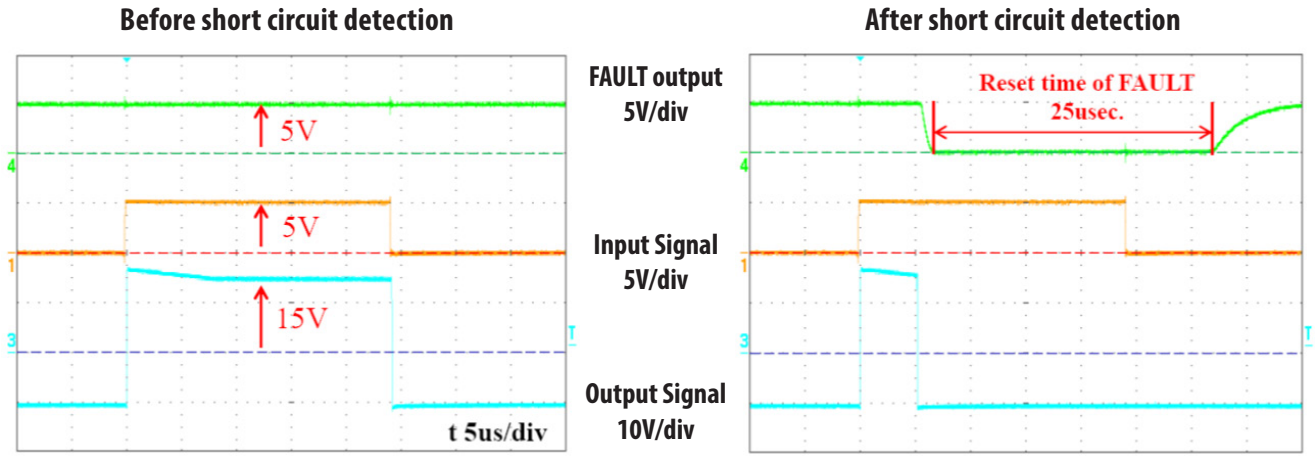
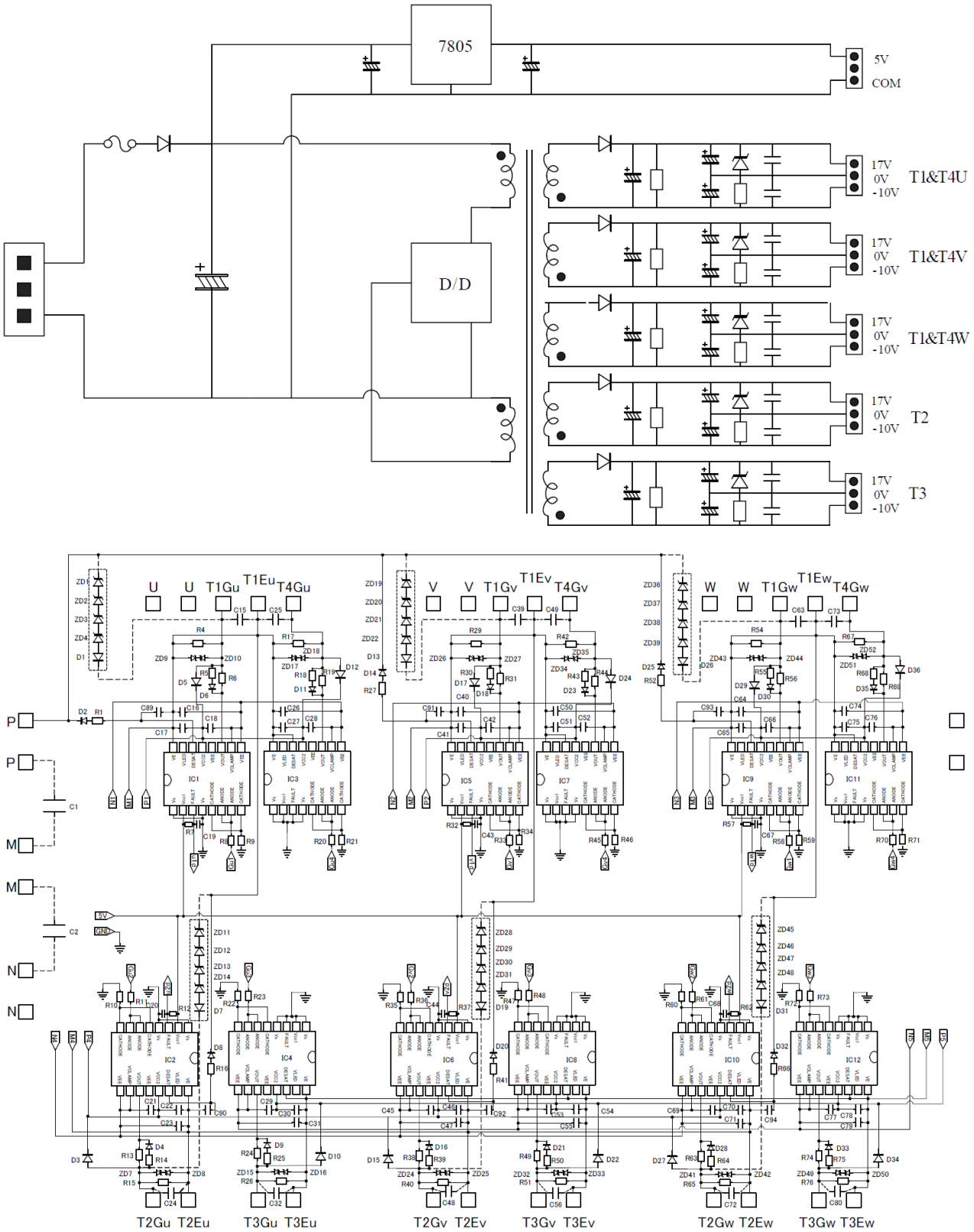


Figure 8 . FAULT output feedback signal before and after short circuit detection

4. Schematic of the Evaluation Driver Board



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