ACPL-339J

Fuji Electric AT-NPC 3-Level 4in1 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 4-in-1 IGBT Module Series in 2011. 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-339J "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, and 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 4in1 IGBT modules, 4MBI300VG-120R-50 and 4MBI400VG-060R-50. It will demonstrate with waveforms how ACPL-339J 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-125_4in1_module_Gate_Drive_Board.pdf

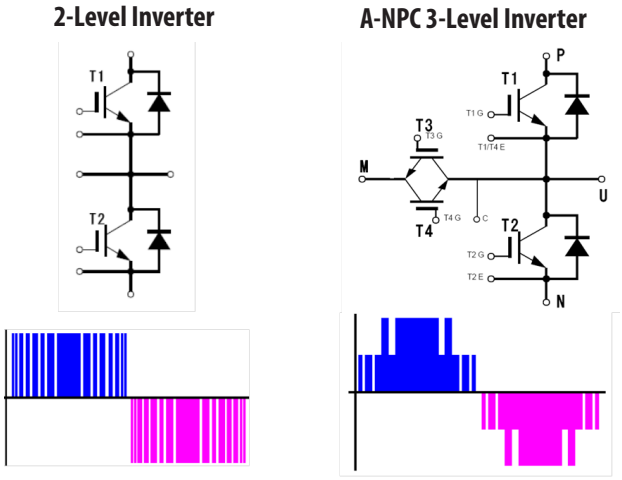


Figure 1. 2-level 3-level inverter circuitries and their output waveforms

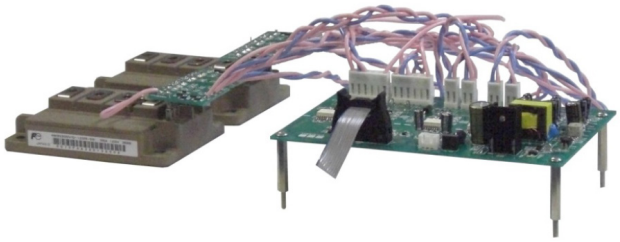


Figure 2. Evaluation driver board for AT-NPC 3-level 4in1 IGBT Module

2. Evaluation 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 CN101.

The DC/DC converter block, uses transformer T1 to convert the 15V input to isolated +15/-10V supplies for IGBTs gate drive at the high voltage side.

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 CN1. Similarly, IGBT short circuit "FAULT" signal from the ACPL-339J is fed back to the microcontroller using the same CN1. CMOS inverter IC1 and IC2 are used to convert PWM voltage signal to drive the input LEDs of ACPL-339J.

The slew rate of the gate signal to control switching of the IGBTs to prevent switching losses or ringing is controlled by the gate resistors T1-4 Rgon/Tgoff. The board can be used to drive up to 2 modules in parallel by connecting the common mode choke.

Finally, the driver board is connected to the IGBTs using drive output connector T1 to T4.

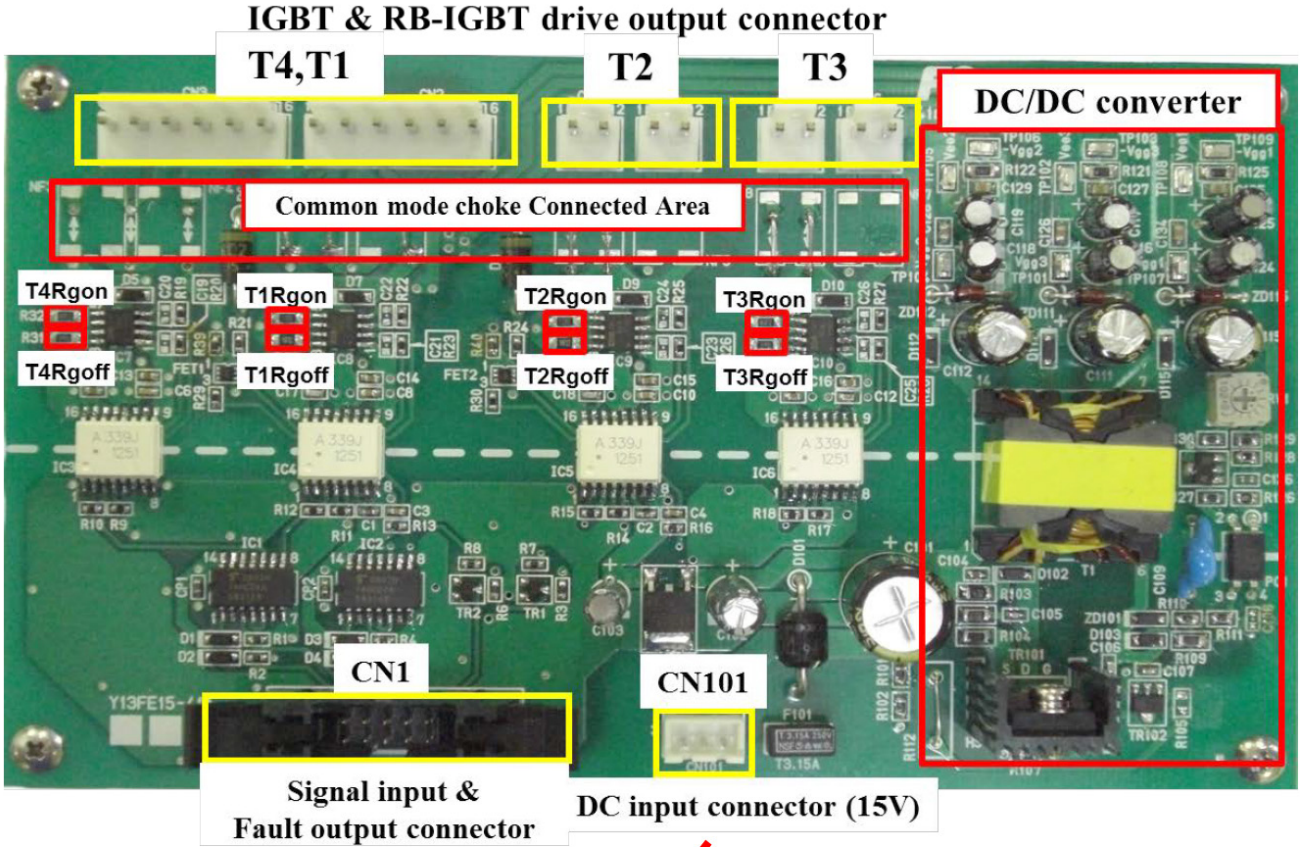


Figure 3. Main features of evaluation driver board

3. ACPL-339J Gate Drive Optocoupler Features and Operations

The board consists of four ACPL-339Js to drive two main IGBTs and two RB-IGBTs in a half bridge topology. The ACPL-339J gate drive optocouplers are used to provide insulation for working voltage up to 1414VPEAK, well above the rated VCES of the IGBT of 1200V. At the same time, the dual outputs with active timing control, drive the P and NMOS mosfet pairs of IRF7343 (IC7, IC8, IC9, IC10) to provide up to 10A peak current to the gate of the IGBTs.

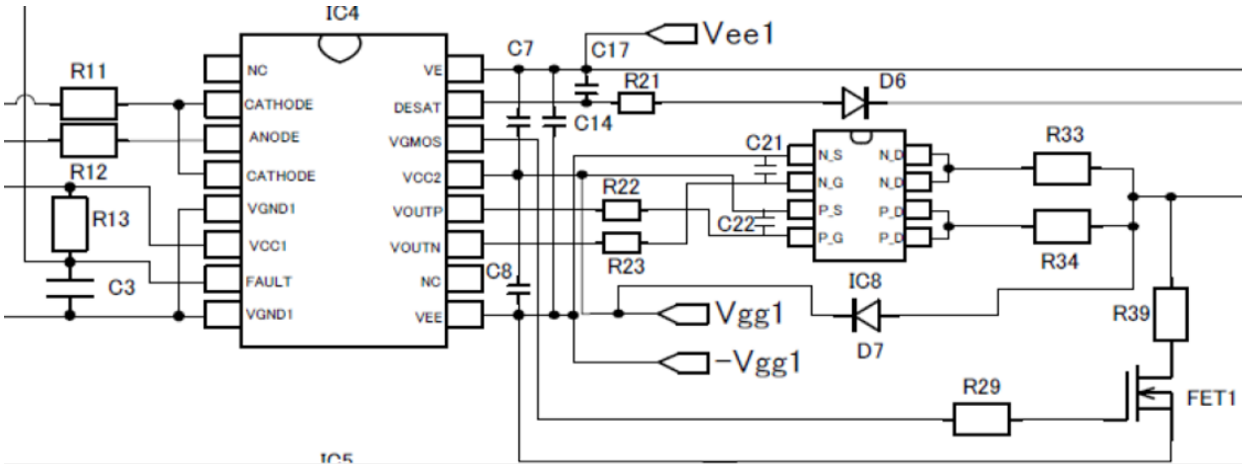


Figure 4. The schematic of ACPL-339J on the evaluation driver board

The main IGBT's collector-emitter voltage is monitored by ACPL-339J 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-339J's threshold of 8V, a short circuit fault is registered and soft shutdown is triggered. The ACPL-339J's VGMOS pin will switch on MOSFET FET1 or FET2 to slowly discharge the gate of the IGBT to achieve the soft shut effect. The rate of the soft shutdown can be adjusted by the size of the FET1/FET2 and resistors R39 and R40 to minimize the overshoot at the IGBT. Lastly, the entire DESAT operation is completed by reporting the FAULT through a built-in insulated feedback path to the controller via connecter CN1.

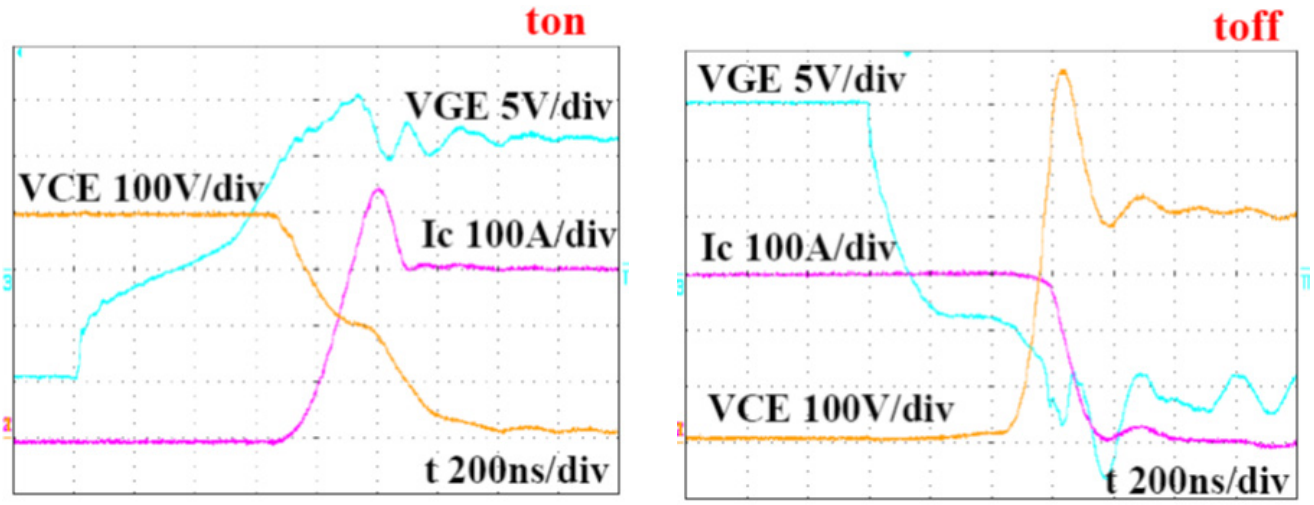


Figure 5. Switching waveforms of the main IGBTs

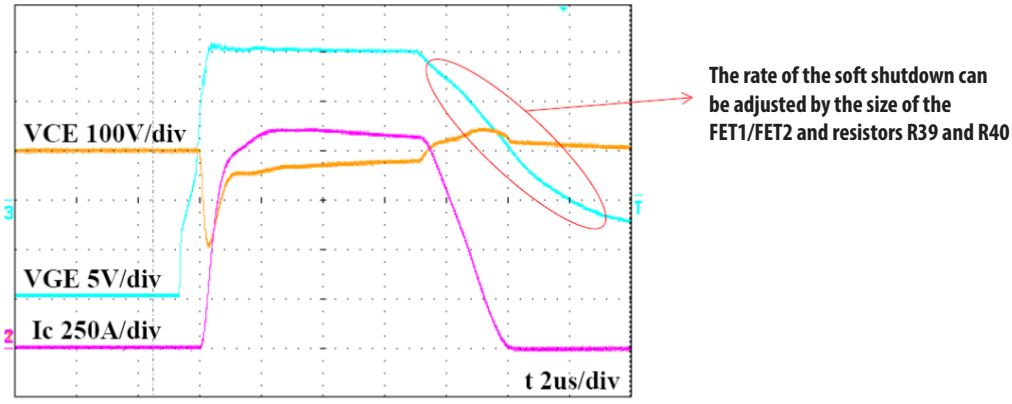


Figure 6. ACPL-339J soft shut the IGBT during short circuit

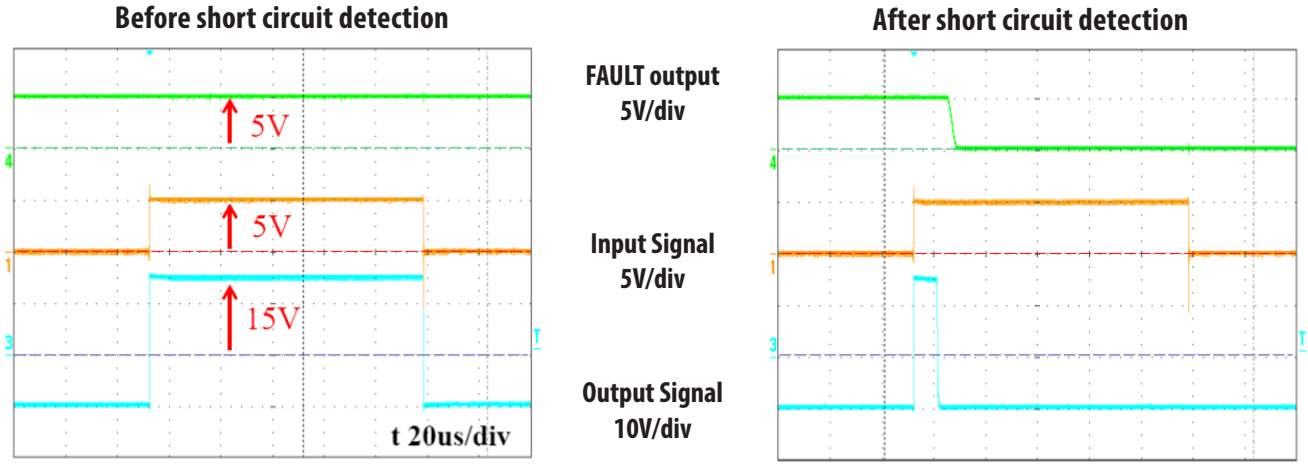
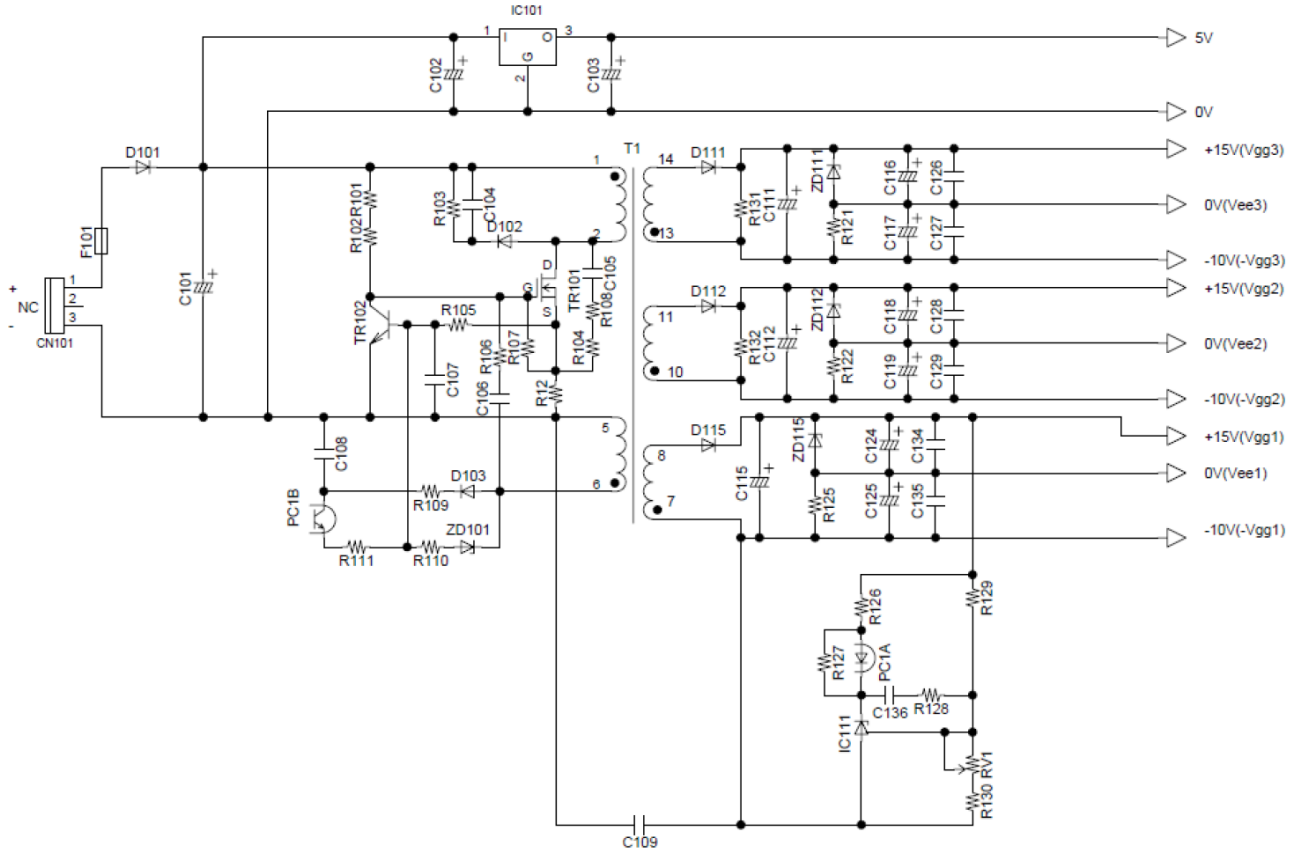
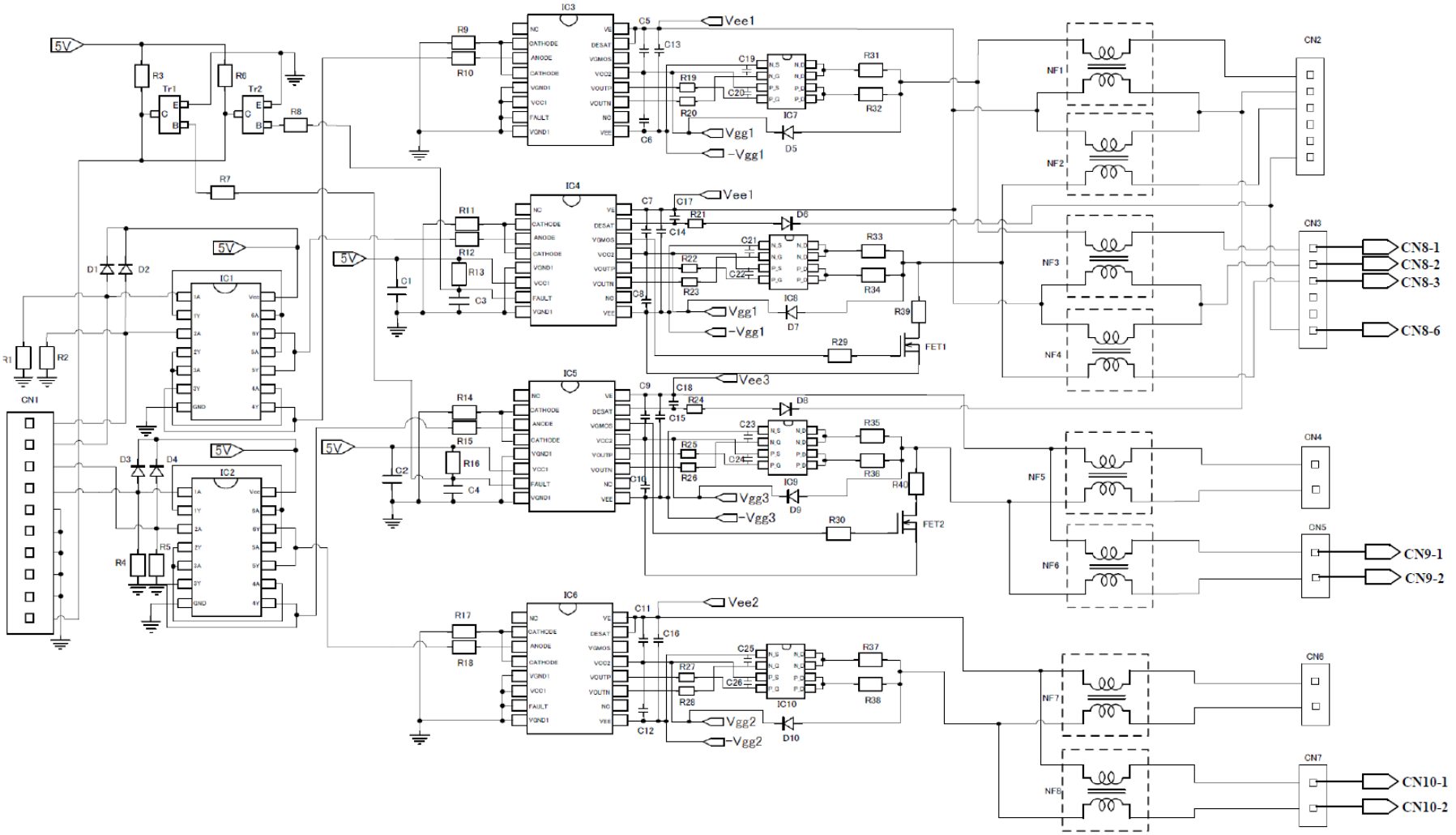


Figure 7. FAULT output feedback signal before and after short circuit detection

4. Schematic of the Evaluation Driver Board




5V
Tr1
Tr2
R3
R6
R8
R7
D1
D2
D3
D4
R1
R2
CN1
IC1
IC2
R4
R5
IC3
IC4
IC5
IC6
R9
R10
R11
R12
R13
R14
R15
R16
R17
R18
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
C12
C13
C14
C15
C16
C17
C18
Vee1
Vee3
Vee2
Vgg1
-Vgg1
Vgg3
-Vgg3
Vgg2
-Vgg2
R19
R20
R21
R22
R23
R24
R25
R26
R27
R28
C19
C20
C21
C22
C23
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D5
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R29
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R31
R32
R33
R34
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R36
R37
R38
R39
R40
FET1
FET2
NF1
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