Chapter 5

Hardware Development

5.1 Block Diagram

The block diagram of hardware development of proposed fault-tolerant structure for CHBMLI is as shown on Fig. 5.1, The block diagram is divided in three parts:

1. Software Utilities
2. Control Circuit
3. Power Circuit

1. Software Utilities

To drive the hardware STM32F407VGT6 microcontroller is used. STM32F407VGT6 is programmed by MATLAB Simulink, Simulink model consist the logic for fault-tolerant operation same as used in simulation Fig. 4.1. Output of the logic is given to the Waijung block set, that build the program and dump to the controller through ST-Link Utility.

“Waijung”, a Thai slang for "so fast", is a Simulink Block set that can be used to easily and automatically generate C code from MATLAB/Simulink simulation models for many kinds of microcontrollers. Currently, Waijung has been designed specifically to support STM32F4 family of microcontrollers. STM32 ST-Link Utility is a full-featured free software interface for programming STM32 microcontrollers.

2. Control Circuit

Control circuit consisting of STM32F407VGT6 microcontroller and driver card for IGBT. According to mode, controller provides the signal to the relay card and PWM pulses to the driver card for operation of FT-CHBMLI.

3. Power Circuit

Power circuit consisting of relay card according to circuit diagram shown in Fig. 3.1 and IGBT card of symmetrical cascaded seven level multilevel inverter.

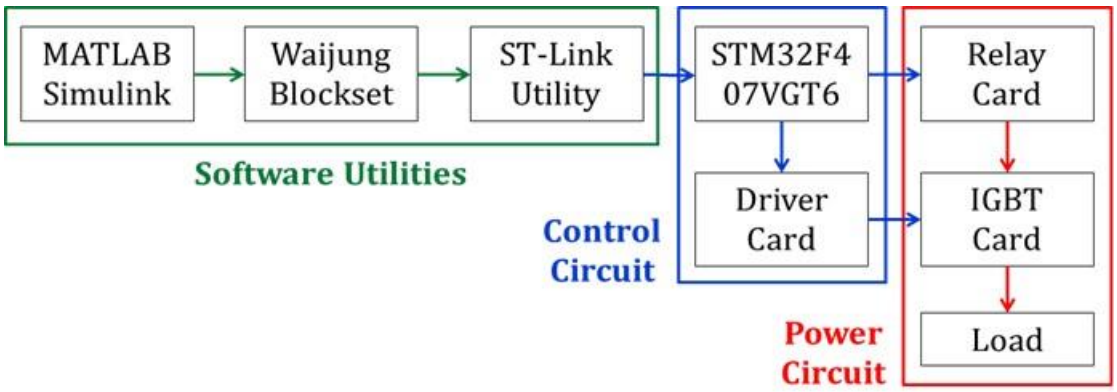

Figure 5.1 Block Diagram

5.2 STM32F407VGT6 Microcontroller

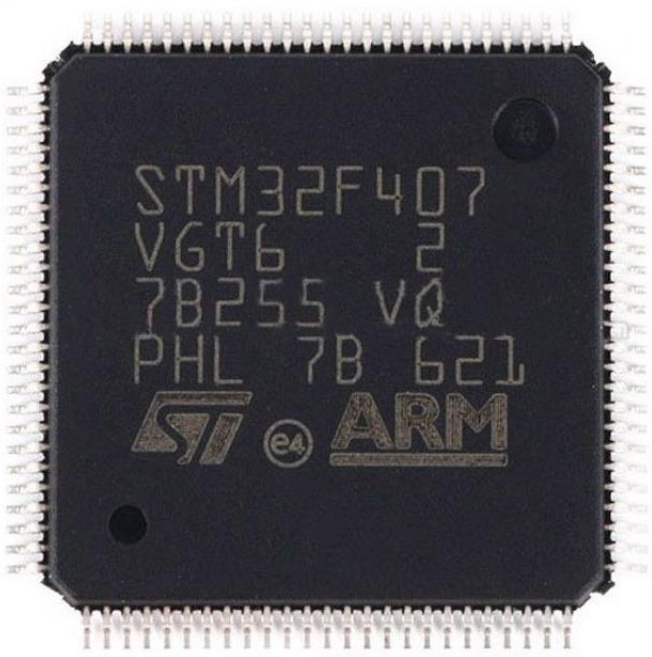

Figure 5.2 STM32F407VGT6 Microcontroller

- STM32F407xx family is based on the high-performance ARM Cortex 32-bit core operating a frequency up to 168MHz
- 1MB Flash memory, 192kB RAM
- Waijung compatible

5.3 Relay Card

Fig. 5.3 shows the circuit diagram for relay card. Relay card consisting of opto-isolators (ILQ74), NPN-transistors (BC547), SPST relays and SPDT relays. Both SPST and SPDT relays are connected as per the circuit diagram of proposed structure given in Fig. 3.1.

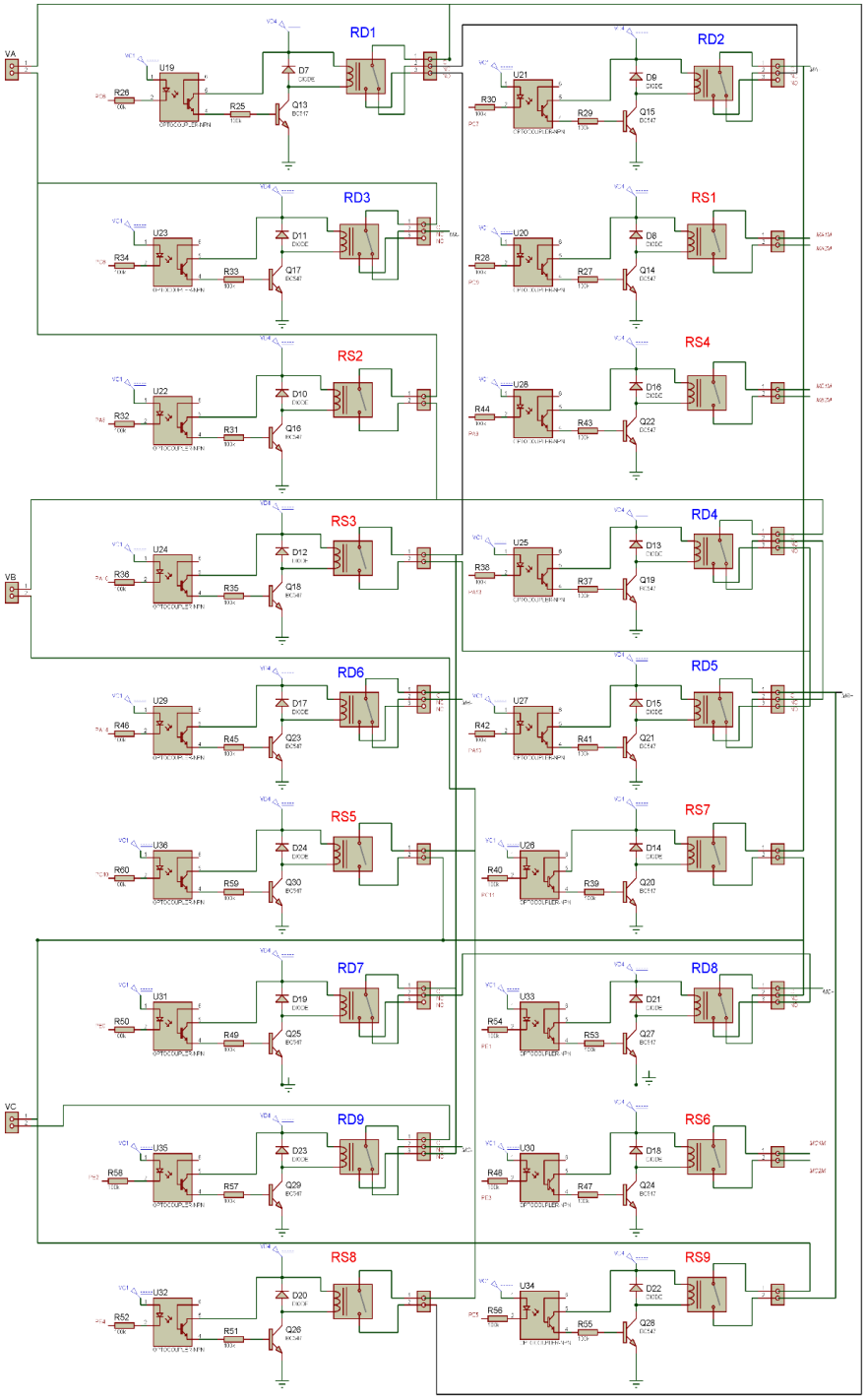

Figure 5.3 Layout of Relay Card

Output from microcontroller is given to the opto-isolator (ILQ74) to drive the relay using transistor. SPST Relays & SPDT Relays have the operating Voltage 5V DC and the output rating of 10A, 24V DC. BC547 is npn-Transistor mainly used for amplification and switching purposes. It has Collector current rating (I_C) = 100mA, Emitter-Base Voltage (V_{BE}) = 6V, Power dissipation rating = 500mW, DC Current Gain (h_{FE}) = 110 to 800 and Breakdown Voltage = 45V to 50V. Table. 5.1 shows the pin connection for relay control with controller. Fig. 5.4 shows the hardware of relay card.

Table 5.1: Pin connection for relays

Relay	Pin no.	Relay	Pin no.
RD1	PC6	RS1	PC9
RD2	PC7	RS2	PA8
RD3	PC8	RS3	PA10
RD4	PA13	RS4	PA9
RD5	PA15	RS5	PC10
RD6	PA14	RS6	PE3
RD7	PE0	RS7	PC11
RD8	PE1	RS8	PE4
RD9	PE2	RS9	PE5

5.4 Driver Card for IGBT

Fig. 5.5 shows the circuit diagram of IGBT driver card. Driver card consisting of opto-isolator (ILQ74) and driver IC (IR2101). IR2101 IC is high and low side driver IC, which automatically match the propagation delay for both channels. It has gate drive supply range from 10 to 20V and fully operational to +600 V. Output from microcontroller is given to the opto-isolator (ILQ74) and opto-isolator provides the signal to IR2101 IC for driving high side (at pin no. 2) and low side (at pin no. 3) IGBT of one leg.

Table 5.2 Pin connection for IGBT

IGBT	Pin no.	IGBT	Pin no.	IGBT	Pin no.
A1	PD13	B1	PD9	C1	PB13
A2	PD12	B2	PD8	C2	PB12
A3	PD11	B3	PB15	C3	PB11
A4	PD14	B4	PD10	C4	PB14

Pin number 7 of driver IC is connected to gate terminal of high side IGBT and pin number 6 is connected to emitter terminal of IGBT. Similarly, pin number 5 and 4

is connected to gate and emitter terminal of low side IGBT. Table. 5.2 shows the pin connection for IGBT control with controller. Fig. 5.6 shows the hardware of driver card for IGBT.

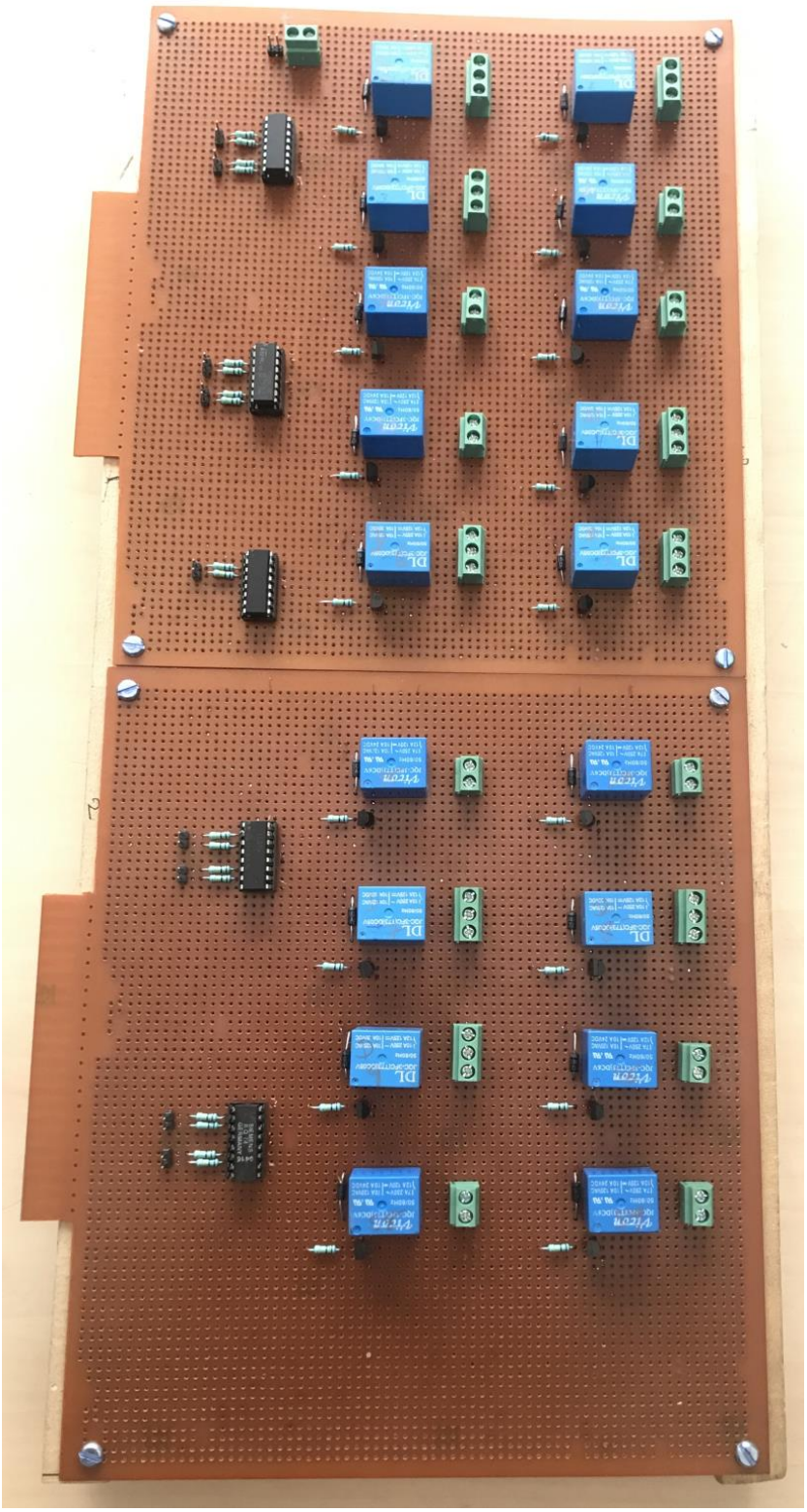

Figure 5.4 Relay Card

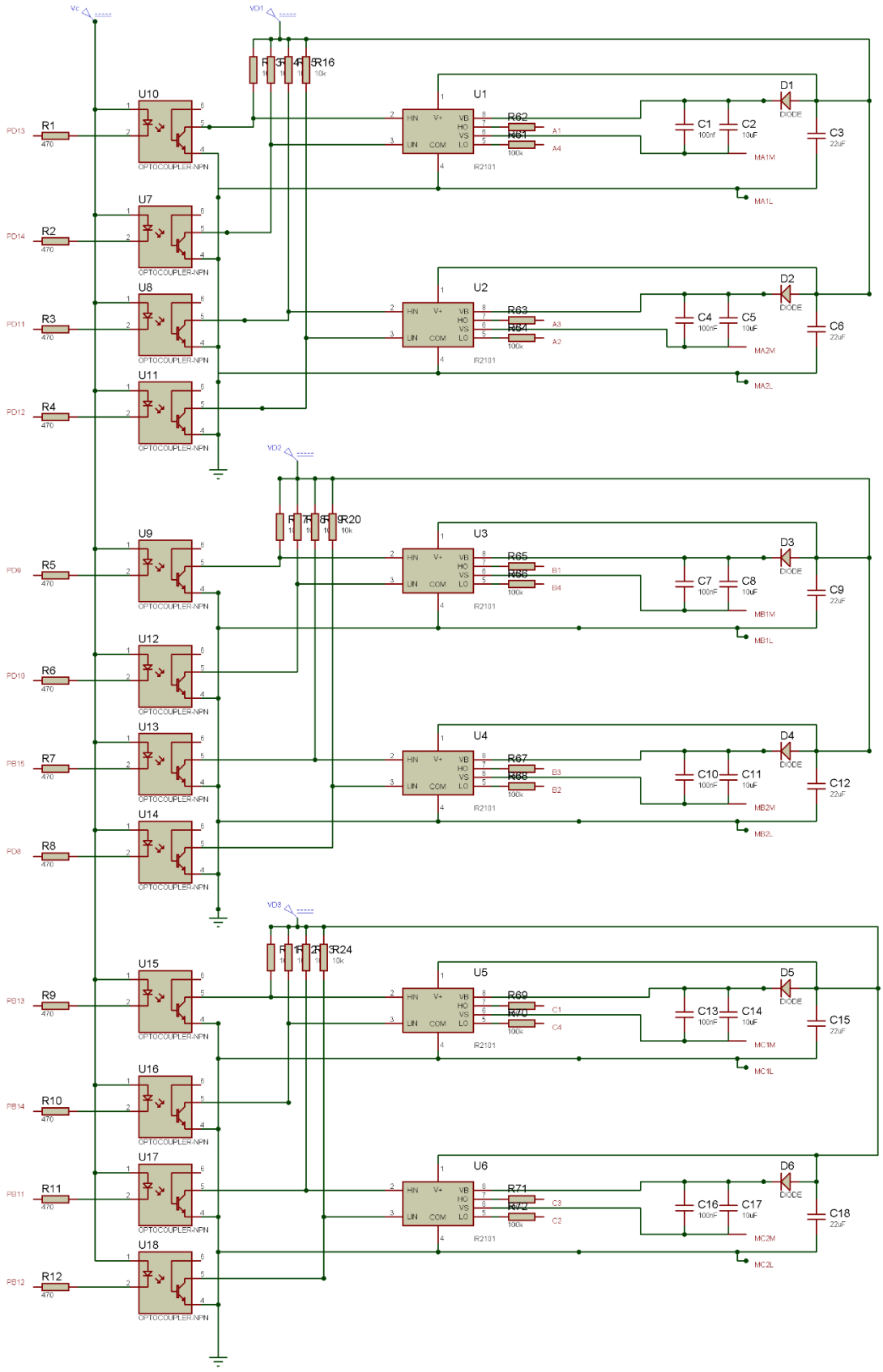

Figure 5.5 Layout of Driver Card for IGBT

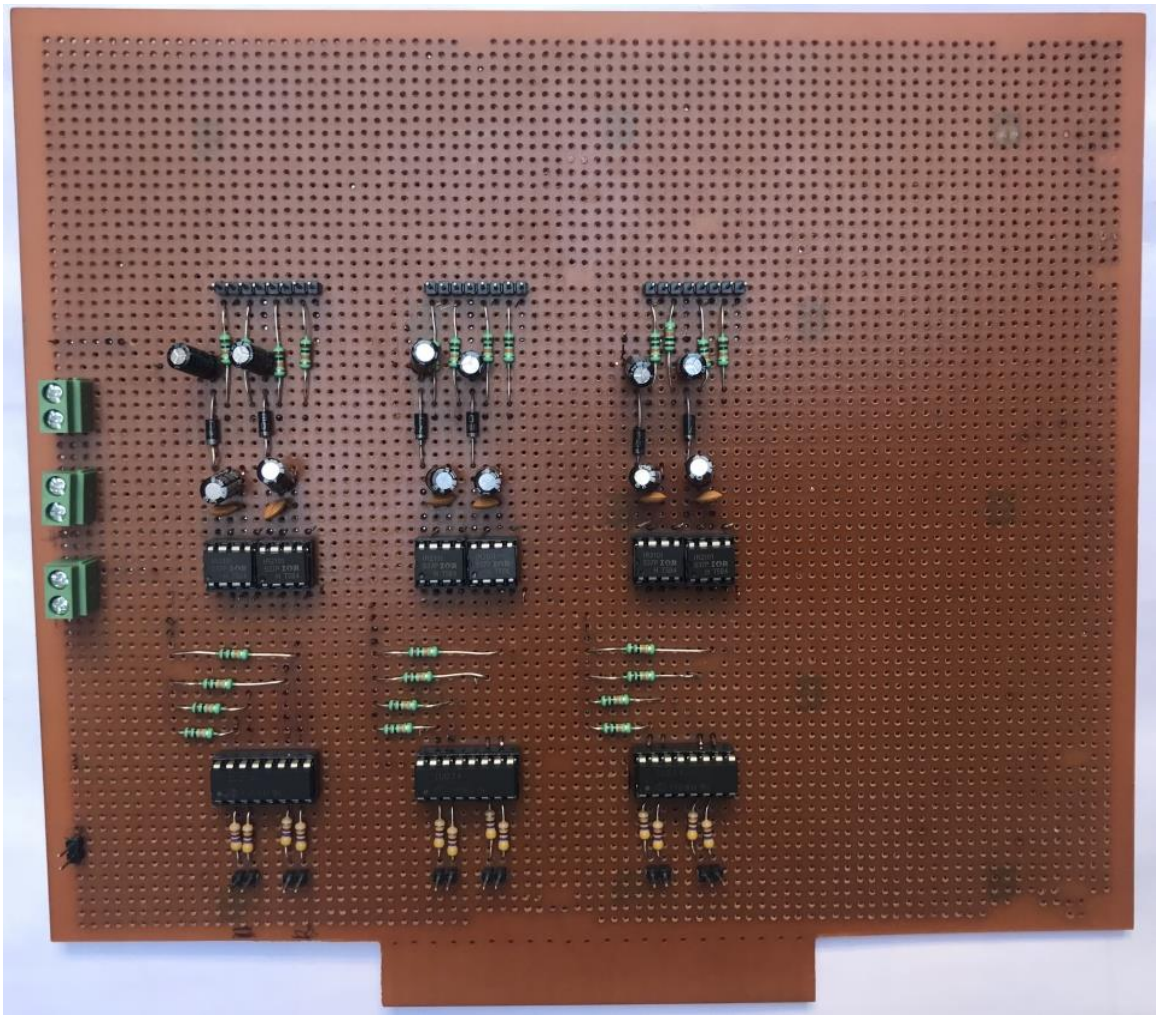

Figure 5.6 Driver Card for IGBT

5.5 IGBT Card

Fig. 5.7 shows the layout of IGBT card for symmetrical cascaded seven level multilevel inverter. GW38IH130D (33A, 1300V) IGBT is used as power switch. Fig. 5.8 shows the hardware diagram for IGBT card.

5.6 Voltage Sensing Circuit

Fig. 5.9 shows the voltage sensing circuit for fault detection in FT-CHBMLI. Voltage sensing circuit consisting single phase uncontrolled rectifier, voltage dividing resistors and filter capacitor. Output voltage of each modules are given to this circuit, which rectifies the voltage and divide the voltage in voltage sensing range of

controller's in-built ADC (3.3V). These voltages are given to the ADC pin of the controller, which convert the voltage in digital form and according to the logic (as given in Fig. 4.6) it detects the fault.

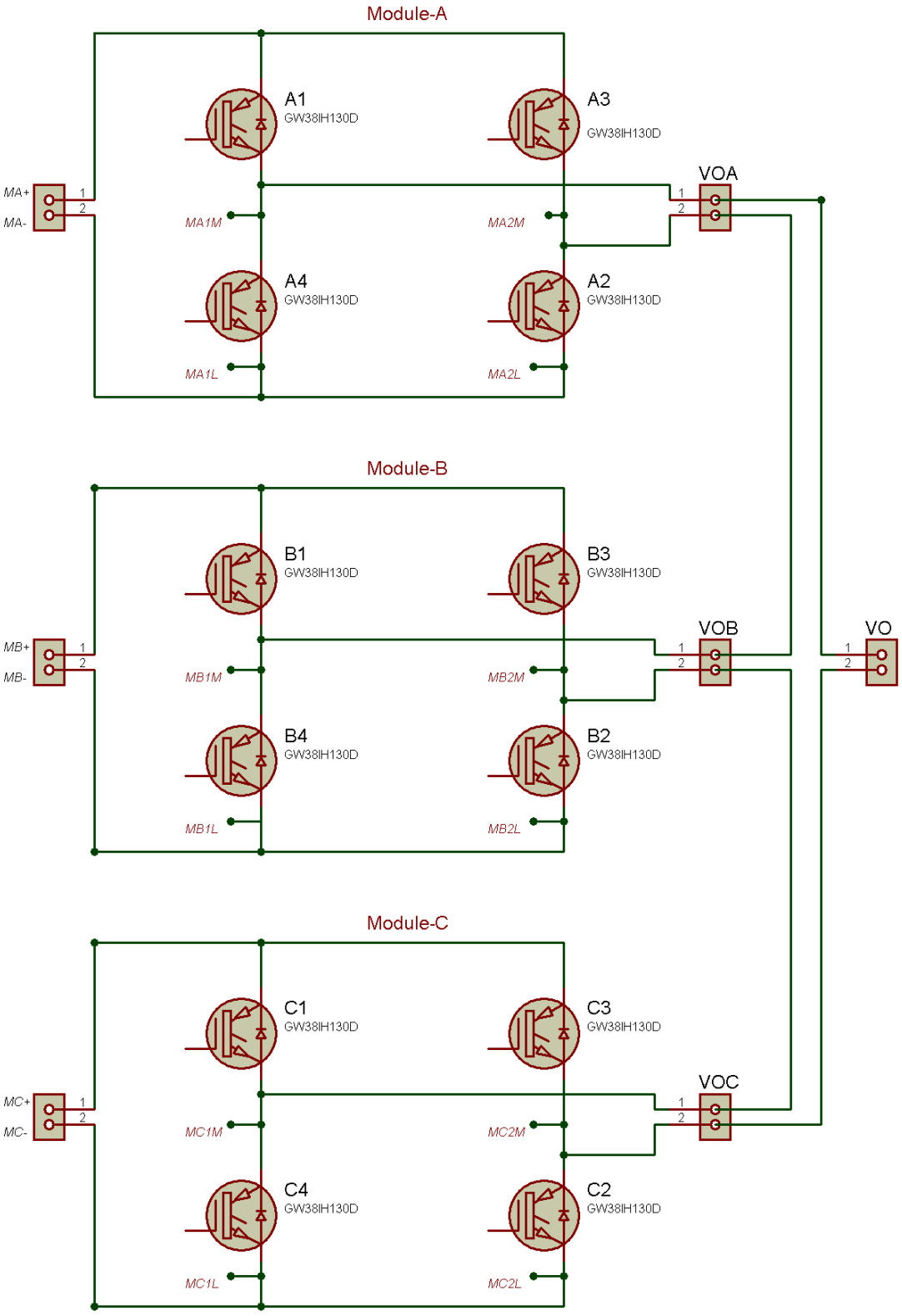

Figure 5.7 Layout of IGBT Card

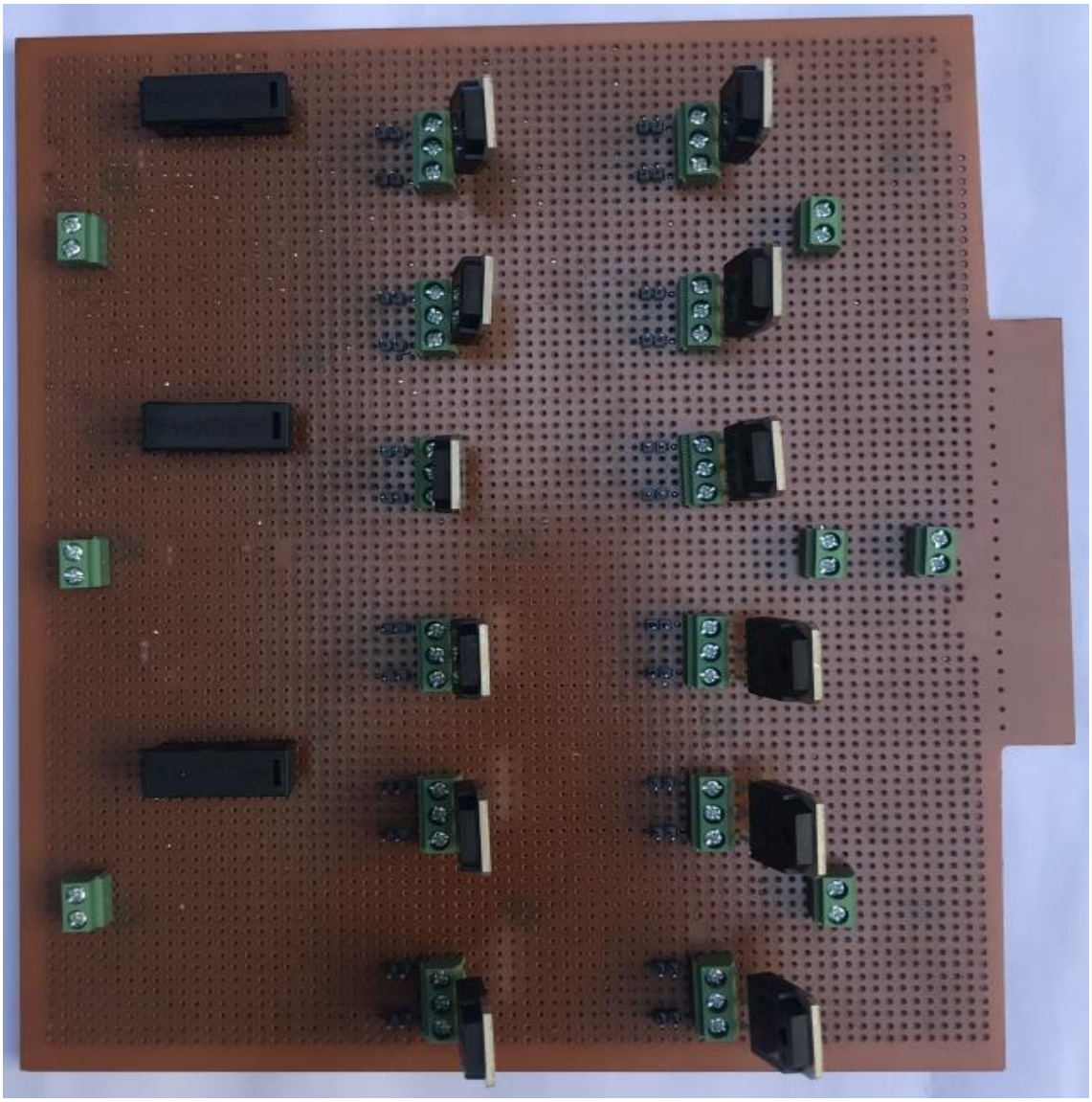

Figure 5.8 IGBT Card

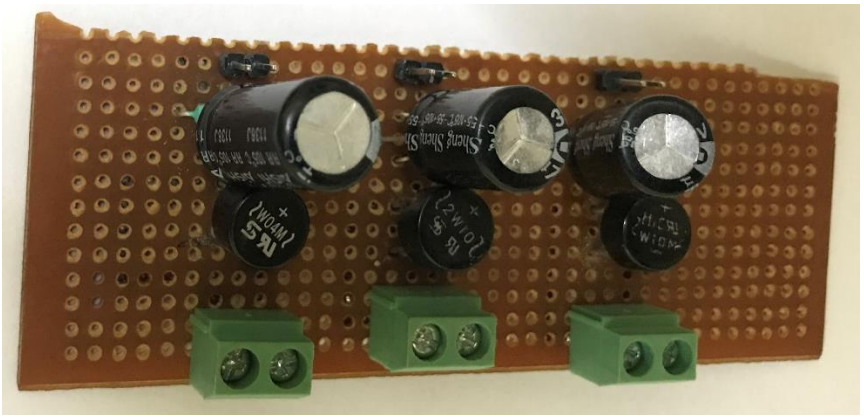

Figure 5.9 Voltage sensing circuit

5.7 Hardware Setup

Fig. 5.10 shows the entire hardware setup for proposed fault-tolerant structure for 7-level cascaded H-bridge multilevel inverter.

Figure 5.10: Hardware Setup

5.8 Hardware Results for Mode-0

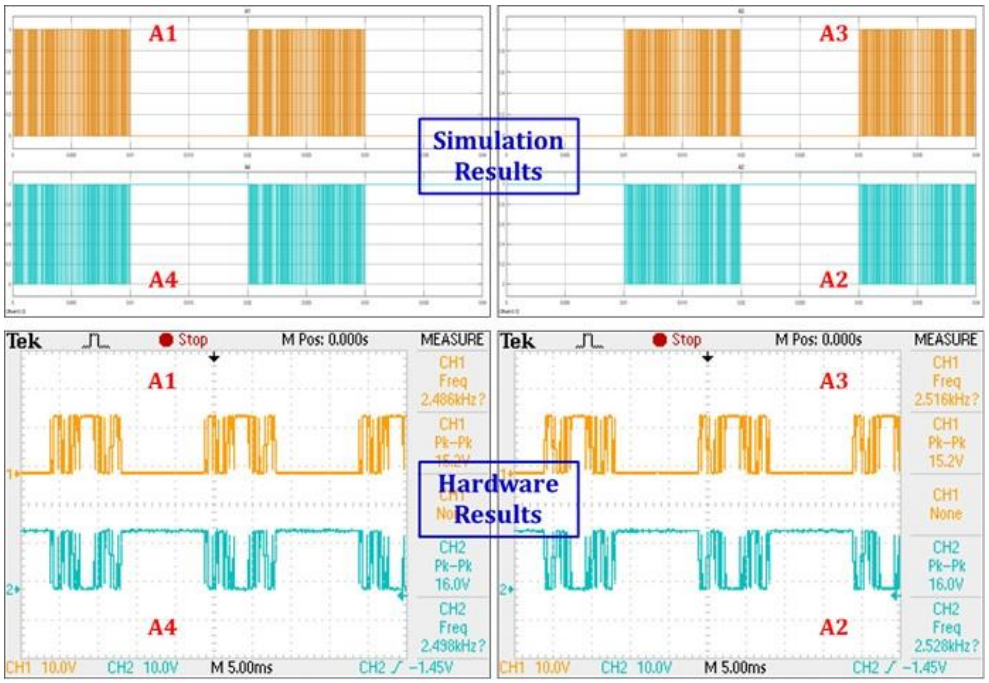

Figure 5.11 Gate Pulses for IGBT of Module-A in Mode-0

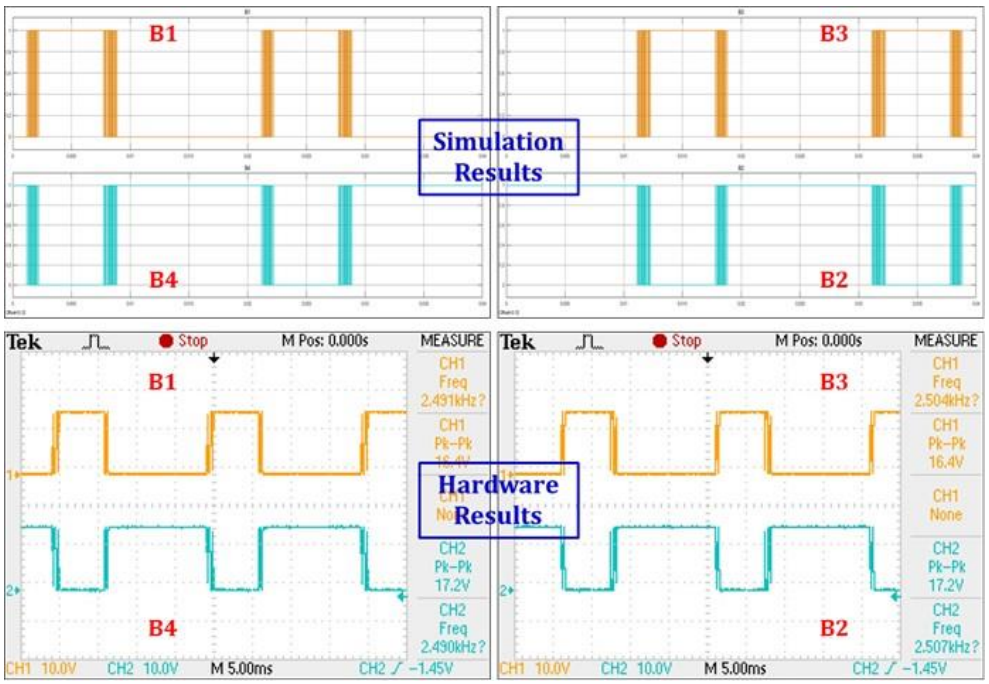

Figure 5.12 Gate Pulses for IGBT of Module-B in Mode-0

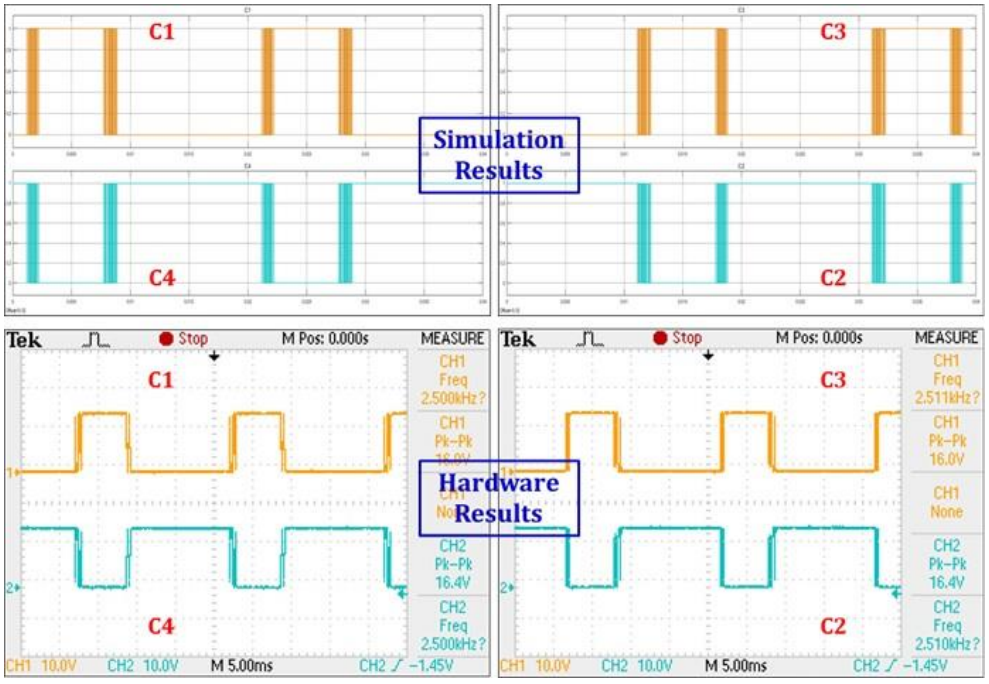

Figure 5.13 Gate Pulses for IGBT of Module-C in Mode-0

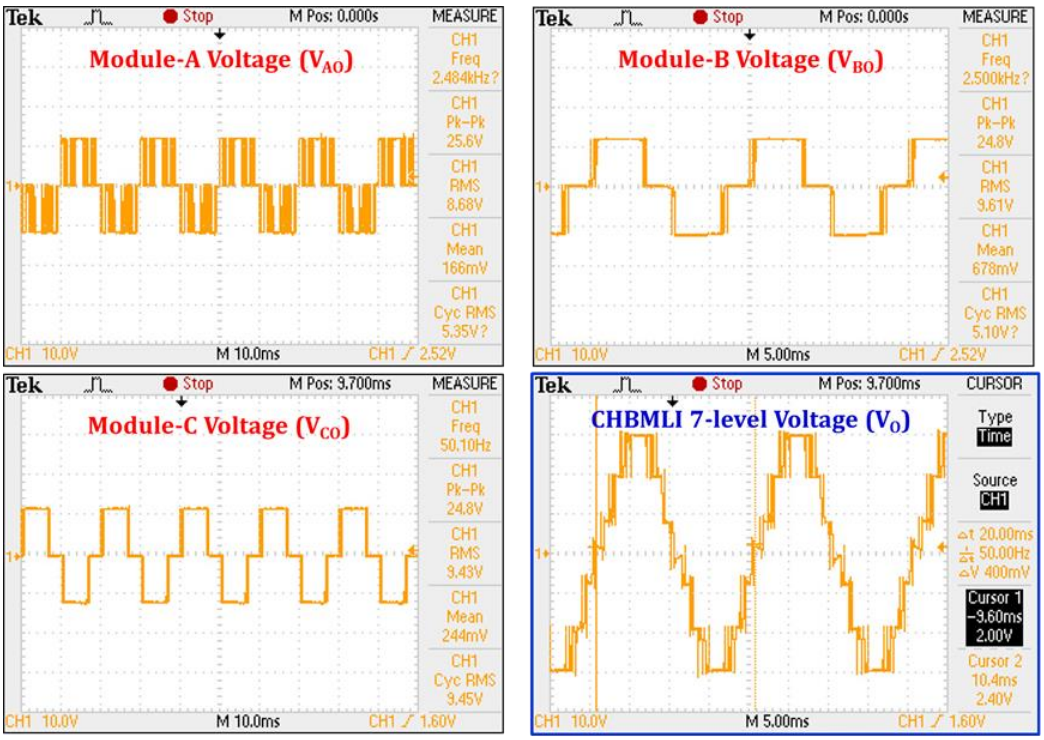

Figure 5.14 Output Voltages under Mode-0

5.9 Hardware Results for Mode-1

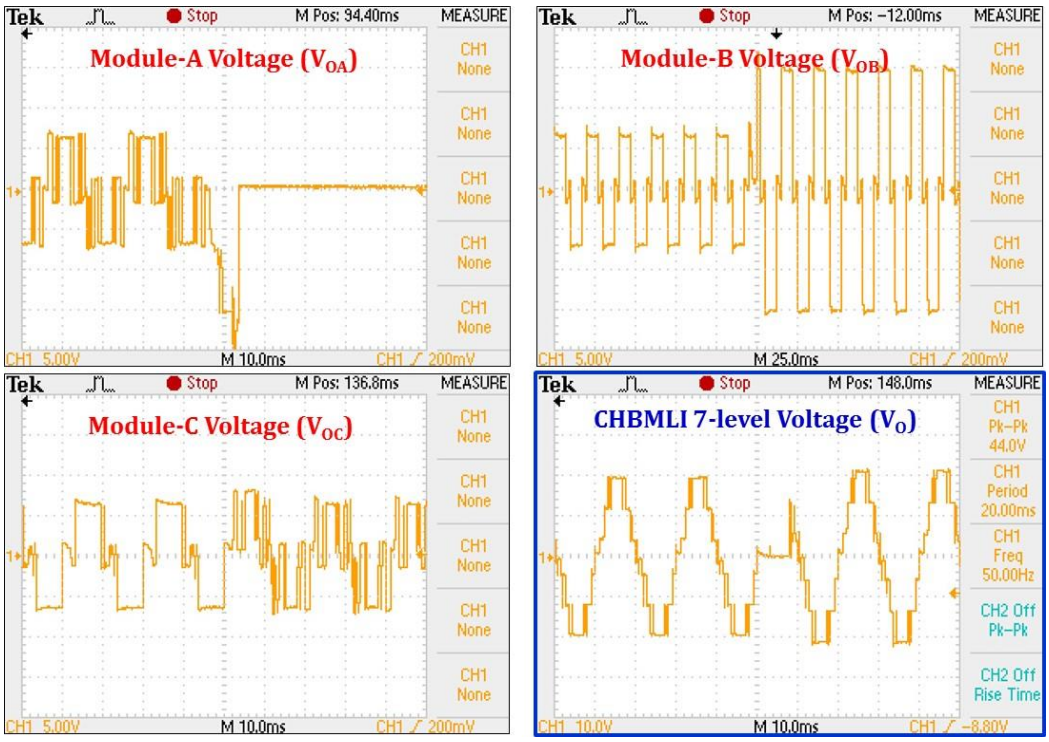

Figure 5.15 Output Voltages under Mode-1

5.10 Hardware Result for Mode-2

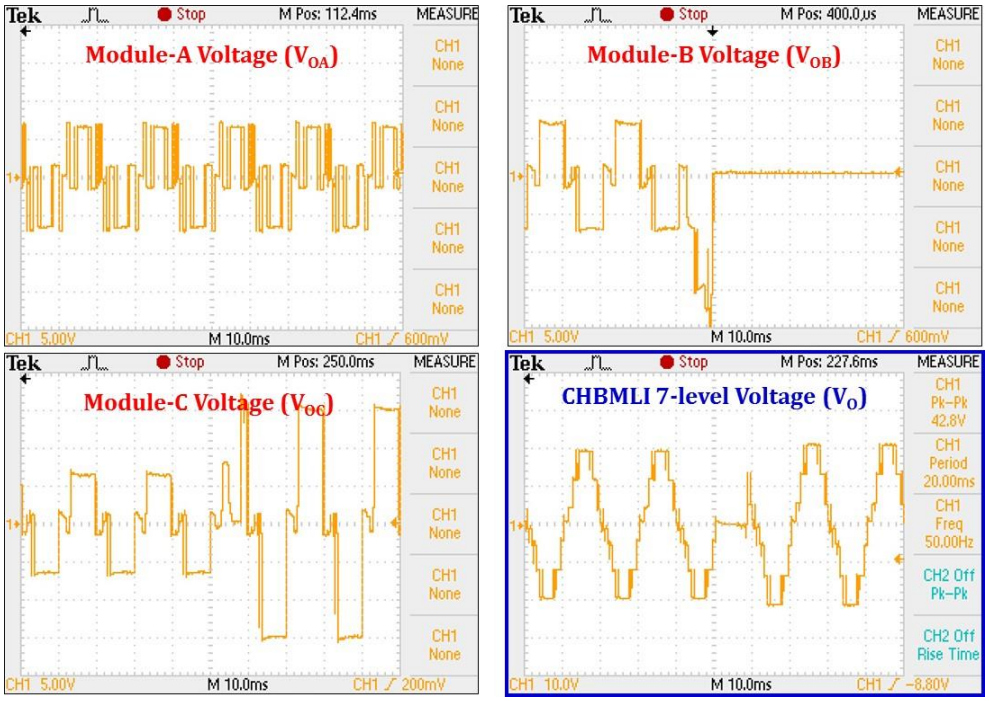

Figure 5.16 Output Voltages under Mode-2

5.11 Hardware Result for Mode-3

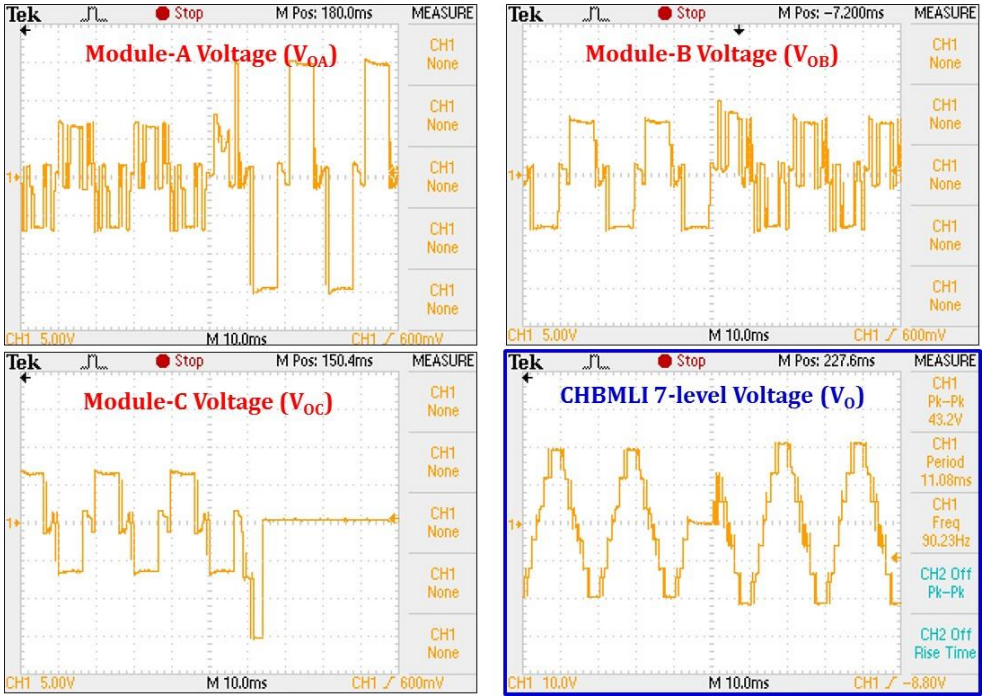

Figure 5.17 Output Voltages under Mode-3

5.12 Hardware Result for Mode-4

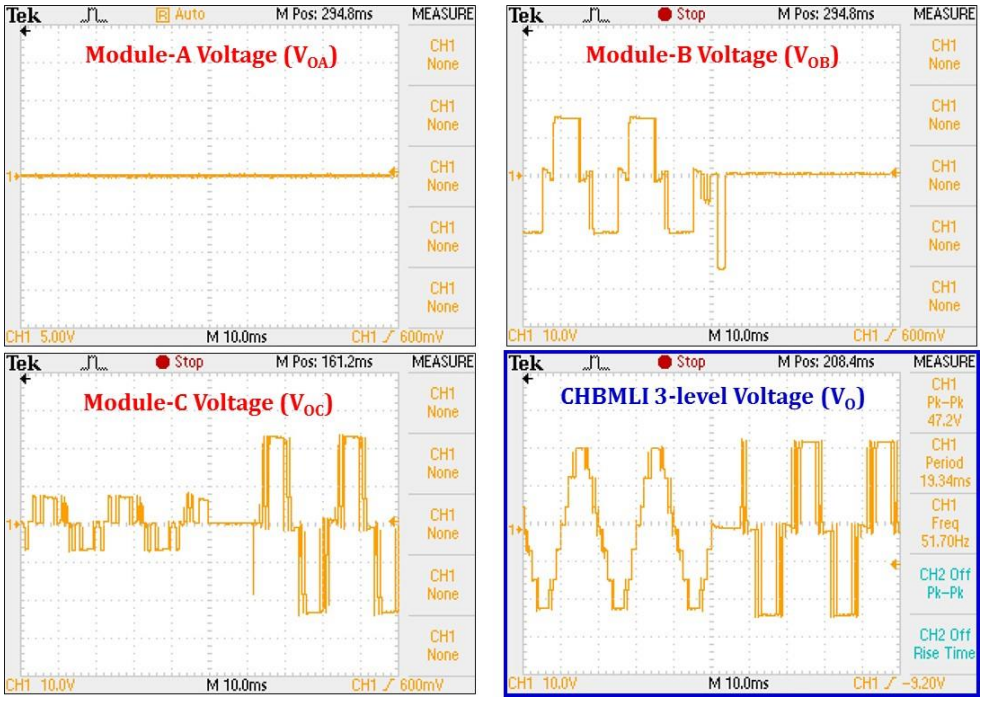

Figure 5.18 Output Voltages under Mode-4

5.13 Hardware Result for Mode-5

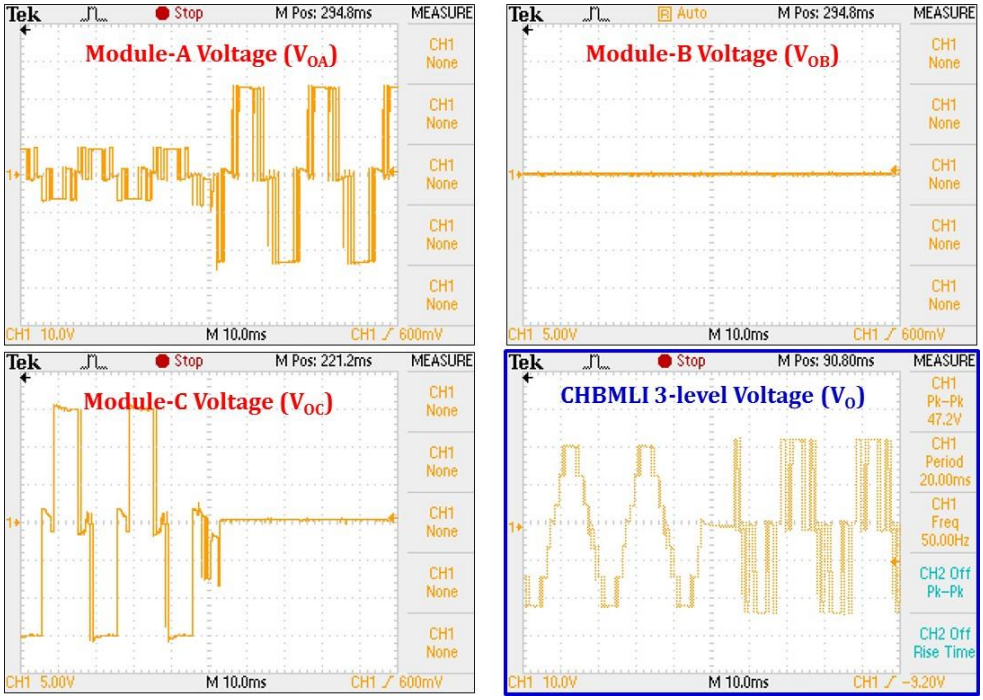

Figure 5.19 Output Voltages under Mode-5

5.14 Hardware Result for Mode-6

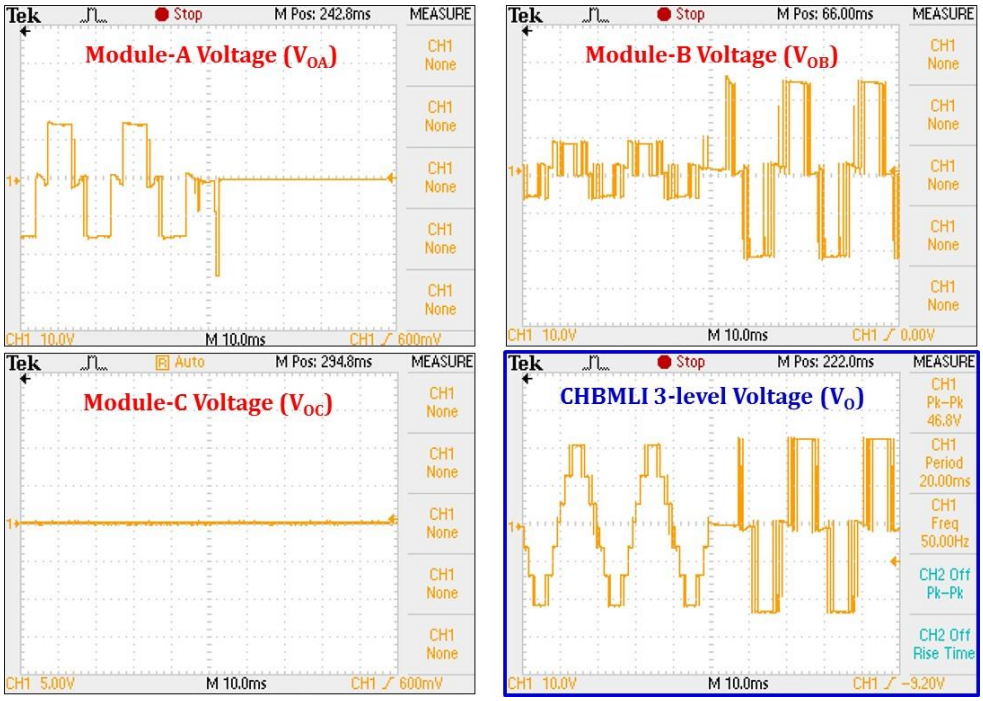

Figure 5.20 Output Voltages under Mode-6