LAB 6

LAB 6: INVERTERS

Part 1. Single Phase PWM Controller

Part 2. Single Phase Inverter

SECTION NUMBER: .…………………………………

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GROUP MEMBERS : ……………………………………..
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Part 1. Single Phase PWM Controller

Inverters are called as DC to AC converters these are single phase inverters and three phase inverters.

You will understand the operating principle of single phase PWM controller, to measure the output waveforms of a single phase PWM controller, to compare the difference between square control signal and PWM control signal.

BEFORE COME TO THIS LAB, YOU SHOULD

* Read the technical background on the report.
* Make some research on Single Phase PWM Controller.

AFTER COMPLETING THIS LAB, YOU SHOULD

* Know the circuit of single phase PWM controller.
* Know the output waveforms of single phase PWM controller.

REQUIREMENTS

* DC Power Supply
* Differential Amplifier
* Reference Variable Generator
* Single Phase PWM Generator
* Oscilloscope
* Wires

TECHNICAL BACKGROUND

Chapter 5 Inverters

5-1 Introduction

Inverters are also called as dc-to-ac converters. An inverter converts a fixed dc voltage to a symmetrical ac voltage of desired frequency and amplitude. Inverters are widely used in industrial applications such as uninterruptible power supplies (UPS), induction motor and variable-speed ac servo motor drives.

5-2 Principles of Inverters

Inverters convert dc power to ac power at some desired output voltage and frequency. Inverters can be classified into two types: 1) single-phase inverters, and 2) three-phase inverters. The basic circuits of single-phase and three inverters are shown in Figures 5-1 and 5-2, respectively. The dc input voltage is fixed and may be a battery, solar cell, fuel cell, or other dc source. The switching device can use each type of controlled turn-on and turn-off devices such as thyristors, BJTs, MOSFETs, and IGBTs.

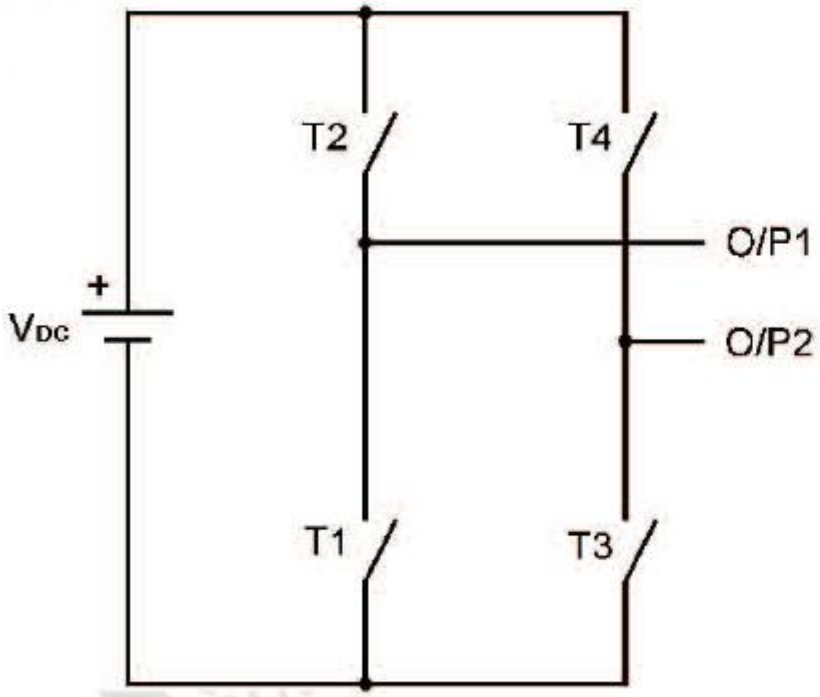


Figure 5-1 Single-phase inverter

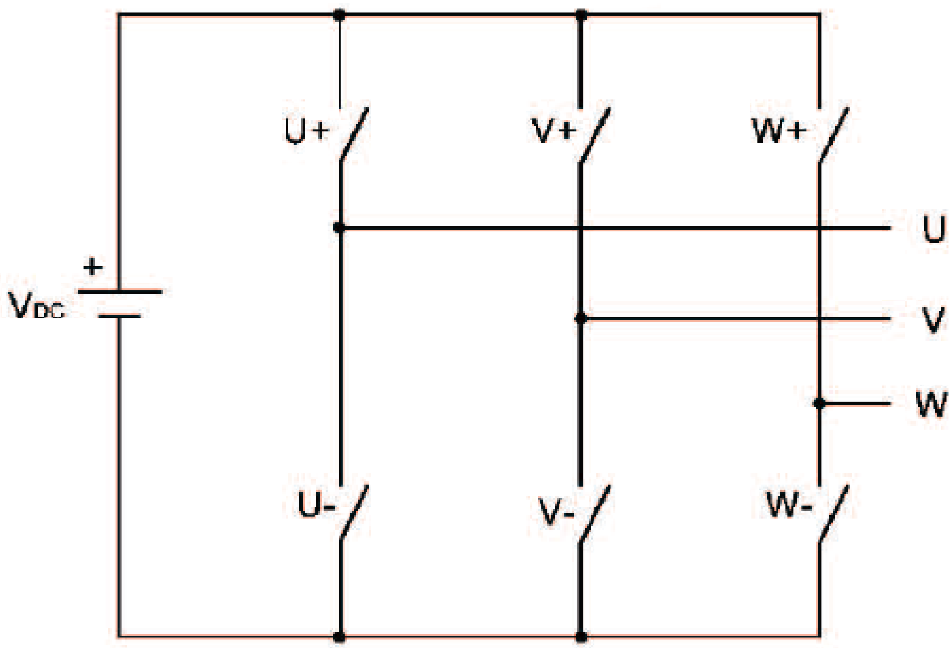


Figure 5-2 Three-phase inverter

The output of a single-phase inverter is a symmetrical ac voltage either square or sinusoidal wave. A three-phase inverter may be considered as three single-phase inverters and the output of each single-phase inverter is shifted by 120 degrees.

The switching devices of the same arm (e.g., T1 and T2, U+ and U-) can not conduct at the same time. Since the turn-off time of power switching devices is greater than turn-on time, therefore a delay called the dead time must be introduced to avoid a short circuit. The dead time depending on the turn-off time of power devices is usually specified as 2~3 times the turn-on time.

To control the on- and off-time of each switching device, a gating signal should be applied at an appropriate time. The gating signal may be square or PWM voltage. Generally the inverters are controlled by using Sinusoidal Pulse-Width Modulation (SPWM) technique. A SPWM wave is produced by comparing a sinusoidal reference signal to a higher frequency triangular carrier wave. The frequency of reference signal determines the output frequency of inverter, the peak value of reference signal controls the average output voltage, and the number of pulses per half-cycle, P, is determined by the carrier frequency. SPWM can eliminate the harmonics which are less than or equal to 2P-1-order.

The SPWM can be divided into two types: 1) unidirectional SPWM control, and 2) bidirectional SPWM control. Figure 5-3 shows the operation of unidirectional SPWM control. During the positive half cycle of sinusoidal reference wave, triangular carrier wave can only be positive. When the amplitude of sinusoidal reference wave is higher than that of triangular carrier wave, the output is high; inversely, when the amplitude of sinusoidal reference wave is lower than that of triangular carrier wave, the output is low.

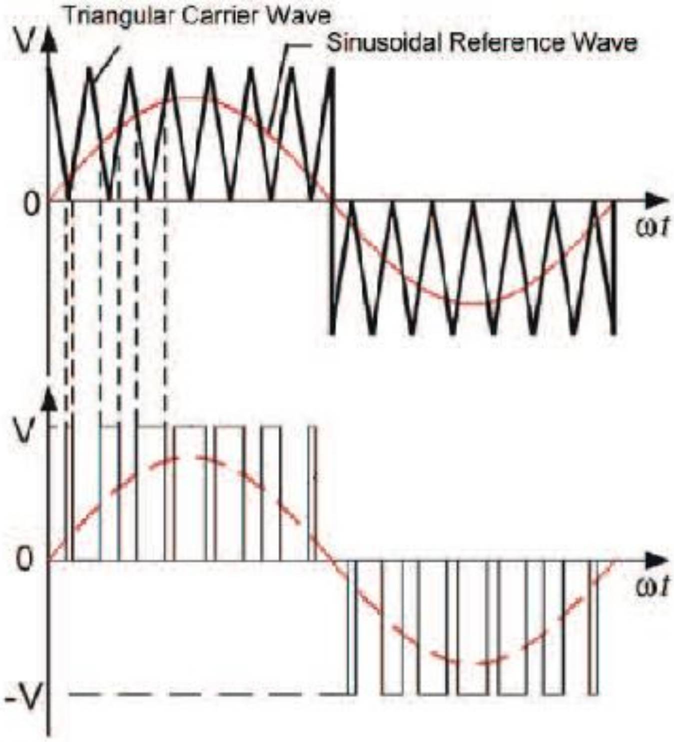


Figure 5-3 Unidirectional PWM control

The operation of bidirectional SPWM control is illustrated in Figure 5-4. In bidirectional SPWM control, triangular carrier wave may be positive and negative and the output PWM wave has positive and negative voltages.

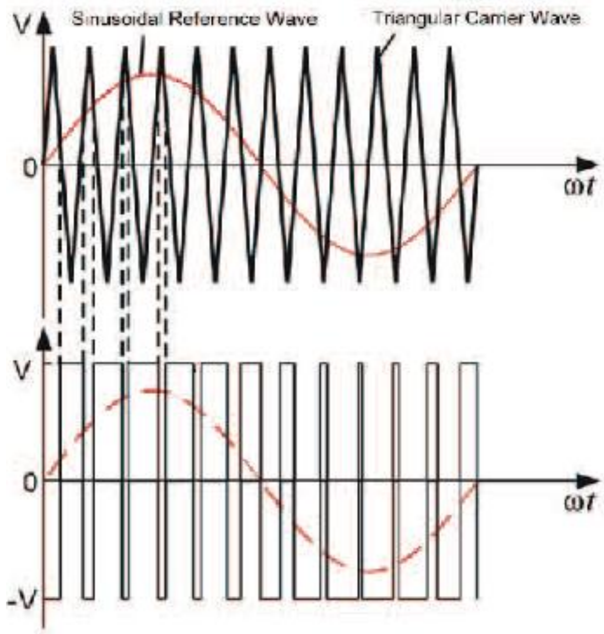
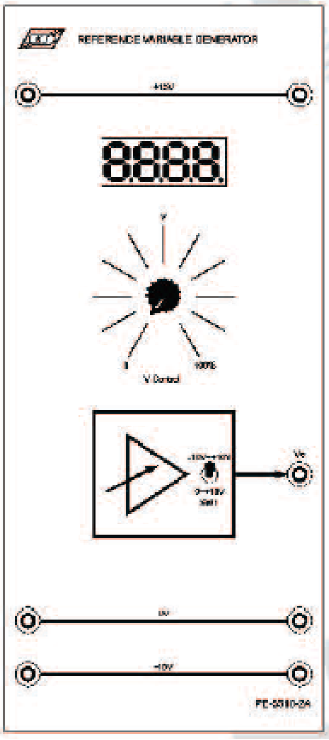


Figure 5-4 Bidirectional PWM control

5-3-2 PE-5310-2A Reference Variable Generator



Specifications

1. Vc range: 0~+10V, -10V~+10V
2. Linear scale: 0~100%
3. 7-segment display for displaying the value of output control voltage Vc.
4. Operating voltage: ±15V

Purpose

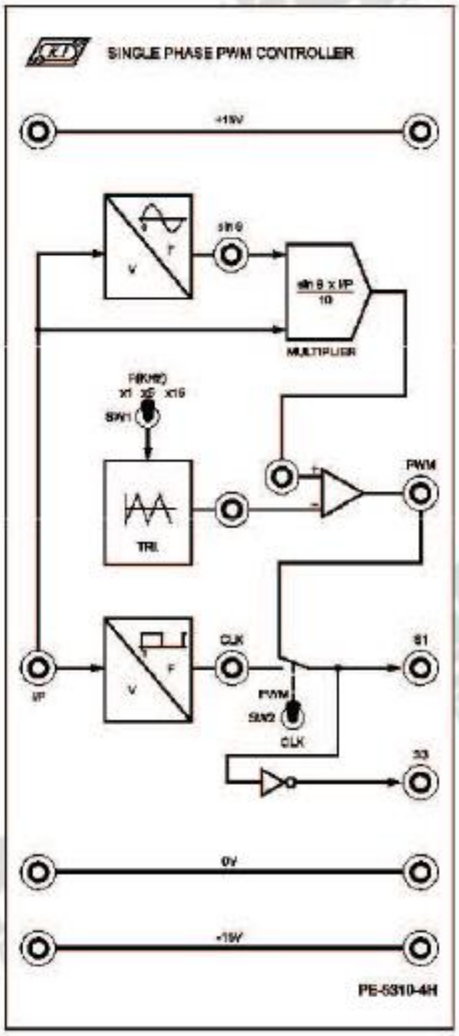
In the experiments of electronic power circuits, the output voltage Vc of this module is used as the command input voltage of the Single Phase PWM Controller or Three Phase PWM Controller module for generating the expected carrier and reference frequencies.

Usage

1. Using bridging plugs or connecting wires, connect terminals +15V, 0V and -15V of this module to the terminals +15V, 0V and -15V of DC Power Supply module and Single Phase PWM Controller (or Three Phase PWM Controller) module.

2. Connect the Vc terminal to the I/P terminal of Single Phase PWM Controller (or Three Phase PWM Controller) module.
3. Set the Vc Range Selector switch to a desired position 0~+10V or -10V~+10V.
4. Adjust the V control knob to vary the output voltage in percent at Vc terminal and read the output voltage from the 7-segment display.

5-3-3 PE-5310-4H Single Phase PWM Controller



Specifications

1. Operating voltages: ±15V DC
2. Input command voltage: 0 to 10V DC
3. Triangular carrier wave generator
   a. Amplitude: ±10Vp
   b. Frequency: 1KHz, 5KHz, 15KHz
4. Sinusoidal reference wave generators
   a. Amplitude: ±10Vp
   b. Frequency: 0 to 60Hz proportional to the input command voltages
5. PWM signal outputs: 2, TTL level
6. Square wave (Clock) generator
   a. Amplitude: TTL level
   b. Frequency: proportional to the input command voltage

Purpose

The Single Phase PWM Controller module is used to generate the gating signals of single-phase inverter such as the PE-5310-4F IGBT Drive Set module.

Usage

1. Using bridging plugs or connecting wires, connect terminals +15V, 0V and -15V of this module to the terminals +15V, 0V and -15V of DC Power Supply and Reference Variable Generator modules.
2. Connect the I/P terminal to the Vc output terminal of the Reference Variable Generator module.
3. Adjust the V control knob of the Reference Variable Generator to vary the command voltage (reading of 7-segment display) that determines the amplitude and frequency of the sinusoidal reference wave and the output frequency of clock generator.
4. Select the desired frequency of triangular carrier wave by setting the F(KHz) Frequency Selector switch to an appropriate position.
5. Select PWM or clock signal as the gating signals of single-phase inverter using the PWM/CLK Selector switch.

Experiment 5-1
Single-Phase PWM Controller

OBJECTIVE

1. To understand the operating principle of single-phase PWM controller.
2. To measure the output wavefoms of a single-phase PWM controller.
3. To compare the difference between square control signal and PWM control signal.

DISCUSSION

The operation of the Sinusoidal Pulse-Width Modulation (SPWM) controller is identical to the DC PWM controller discussed in Experiment 4-1, but a sinusoidal reference wave instead of the dc reference. As shown in Figure 5-1-1, the output pulse signal is generated by comparing a triangular carrier wave with a sinusoidal reference wave. Figure 5-1-1(b) shows the output pulses when the carrier wave compares with the reference wave 1 (high-amplitude). When the carrier wave compares with the reference wave 2 (low-amplitude), the output pulses are shown in Figure 5-1-1(c).

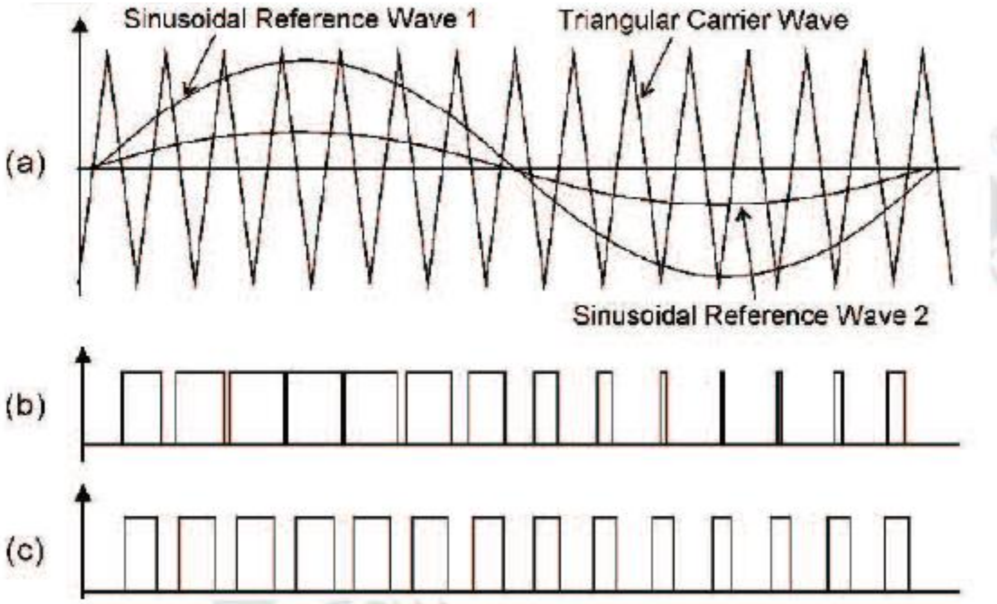


Figure 5-1-1 SPWM operation. (a) Triangular carrier and sinusoidal reference waves; (b) PWM output 1; (c) PWM output 2

The PWM output 1 is a result of comparing triangular carrier wave with sinusoidal reference wave 1. The PWM output 2 is a result of comparing triangular carrier wave with sinusoidal reference wave 2.

In the SPWM control, the widths of pulses are varied by changing the amplitude of the reference signal Ar and the number of pulses is determined by the carrier frequency fc.

The Single Phase PWM Controller module shown in Figure 5-1-2 is used to generate the gating signals of single-phase inverter such as the PE-5310-4F IGBT Drive Set module. This module mainly consists of the following functional blocks and controls:

Triangular Carrier Wave Generator provides a triangular carrier with fixed amplitude (±10V) but variable frequency to the input of the PWM signal generator (comparator). The carrier frequency is selected by using the F(KHz) Frequency Selector switch for 1KHz (x1), 5KHz (x5), and 15KHz (x15).

Sinusoidal Reference Wave Generator provides a ±10V sinusoidal wave with a frequency proportional to the input command voltage. Actually it is a voltage-to-frequency (V to F) converter. A 10V command voltage generates a ±10V, 60Hz sinusoidal wave and a 5V command voltage generates a ±10V, 30Hz sinusoidal wave.

Square Wave (Clock) Generator produces a TTL-level clock signal with a frequency proportional to the input command voltage. A 10V command voltage generates a 60Hz clock signal and a 5V command voltage produces a 30Hz clock signal.

Multiplier determines the amplitude of sinusoidal reference wave depending on the magnitude of command voltage. The fixed-amplitude sinusoidal signal ($\sin\theta$) is further converted to a variable-amplitude variable-frequency reference sinewave by the multiplier. That is, a low command voltage produces a sinusoidal reference wave with low amplitude and frequency and a high command voltage produces a high-amplitude high-frequency sinusoidal reference wave.

PWM Signal Generator produces a PWM signal by comparing the sinusoidal reference wave and the triangular carrier wave. The output PWM signal at S1 terminal is further inverted by an inverter whose output is the S3 terminal.

PWM/CLK Selector switch selects PWM or clock output as the gating signals at S1 and S3.

EQUIPMENT REQUIRED

1. PE-5310-1A DC Power Supply x1
2. PE-5310-2A Reference Variable Generator x1
3. PE-5310-2B Differential Amplifier x1
4. PE-5310-4H Single Phase PWM Generator x1
5. Digital Storage Oscilloscope (DSO) x1
6. Connecting Wires
7. Bridging Plugs

PROCEDURE

1. Put modules PE-5310-1A, PE-5310-2A, PE-5310-2B and PE-5310-4H in Experimental Frame. Place DSO on workbench.

2. Complete the connections shown in Figure 5-1-3 using bridging plugs (curved lines) and connecting wires. Connect 220V AC power to DC Power Supply and Differential Amplifier modules by plugging in the grounded 3-prong outlets.

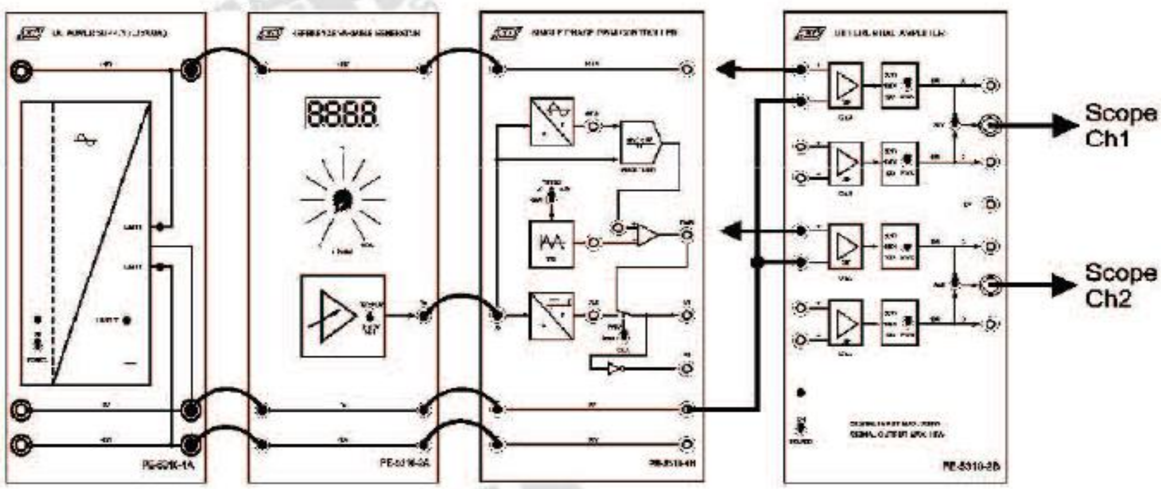


Figure 5-1-3 Wiring diagram for single phase PWM controller measurement

3. On Differential Amplifier, connect Ch.A DIF inputs to sinθ (+ to sinθ, - to 0V) and Ch.C DIF inputs to CLK (+ to CLK, - to 0V). Set V Range Selectors(SWA,SWC) to 100V and set Ch Selectors(SW1,SW2) to A and C.

4. Turn on all power. On Reference Variable Generator, set the Vc Range Selector (SW1) switch to 0~+10V, set the V control knob to 50% position to make Vc=5V. Using DSO (DC input coupling), measure and record the voltage wavefoms at sinθ and CLK outputs as shown in Figure 5-1-4. Calculate the frequency = Hz (*30Hz approximately*) and the amplitude = _________ Vpp (*Sine=20Vpp, Clock=5Vpp approximately*).

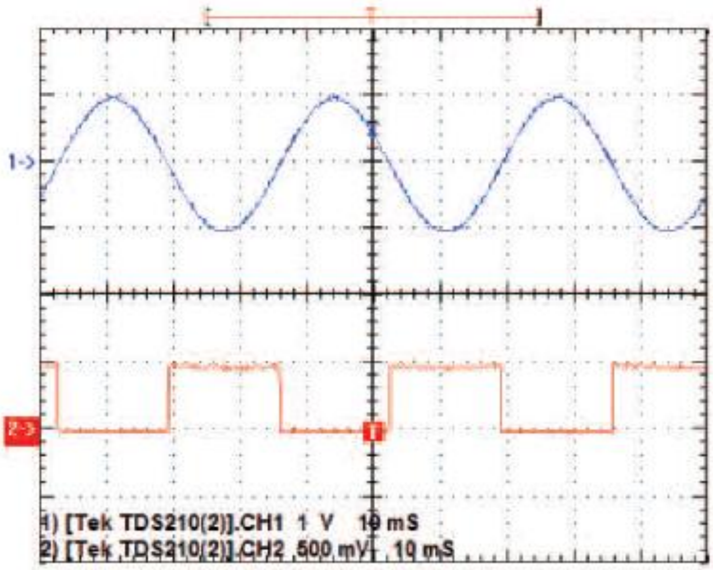


Figure 5-1-4 Measured sinθ (CH1) and CLK (CH2); Vc=5V

5. Adjust the V control knob of Reference Variable Generator to 100% position, Vc=10V approximately. Using DSO, measure and record the voltage wavefoms at sinθ and CLK outputs as shown in Figure 5-1-5. Calculate the output frequency = __________ Hz (*60Hz approximately*) and the amplitude = _______ Vpp. (*Sine=20Vpp, Clock=5Vpp approximately*)

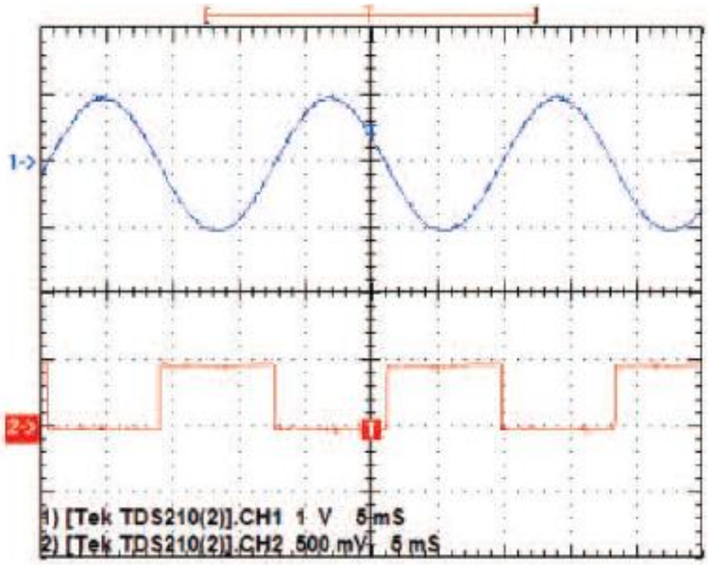


Figure 5-1-5 Measured sinθ (CH1) and CLK (CH2); Vc=10V

6. Slowly adjust the V control knob of Reference Variable Generator and set the output frequency of sinθ and CLK to 50Hz exactly. Read and record the value of Vc = ____________ V. (*8.34V approximately*)

7. Adjust the V control knob of Reference Variable Generator to set Vc=2.5V. Using DSO, measure and record the voltage waveforms at sinθ and CLK outputs as shown in Figure 5-1-6.

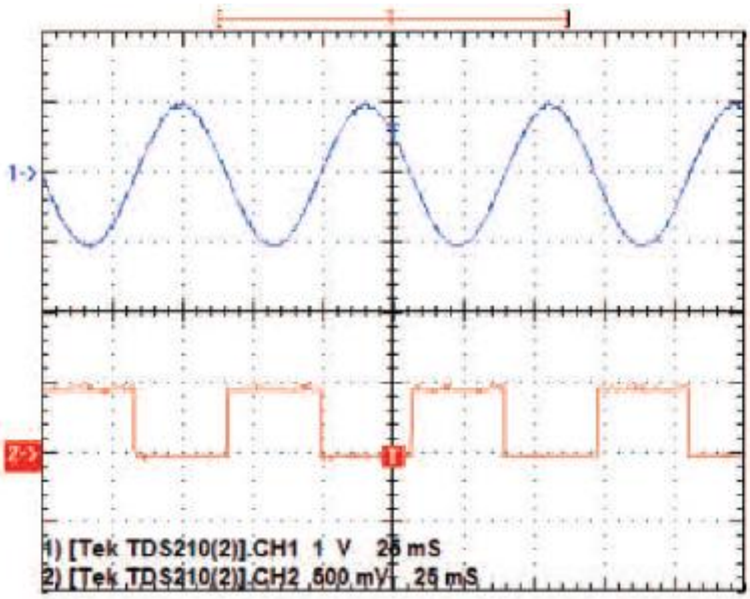


Figure 5-1-6 Measured sinθ (CH1) and CLK (CH2); Vc=2.5V

8. On Differential Amplifier, connect Ch.A DIF inputs to sinθ (+ to sinθ, - to 0V) and Ch.C DIF inputs to Multiplier output (+ to Multiplier output, - to 0V). Set V Range Selectors(SWA,SWC) to 100V and set Ch Selectors(SW1,SW2) to A and C.

9. Adjust the V control knob of Reference Variable Generator to set Vc=5V. Using DSO, measure and record the voltage waveforms at sinθ and Multiplier outputs as shown in Figure 5-1-7. Calculate the frequency = _________ Hz (*30Hz approximately*) and the amplitude = _____________ Vpp. (*Sine=20Vpp, Multiplier=10Vpp approximately*)

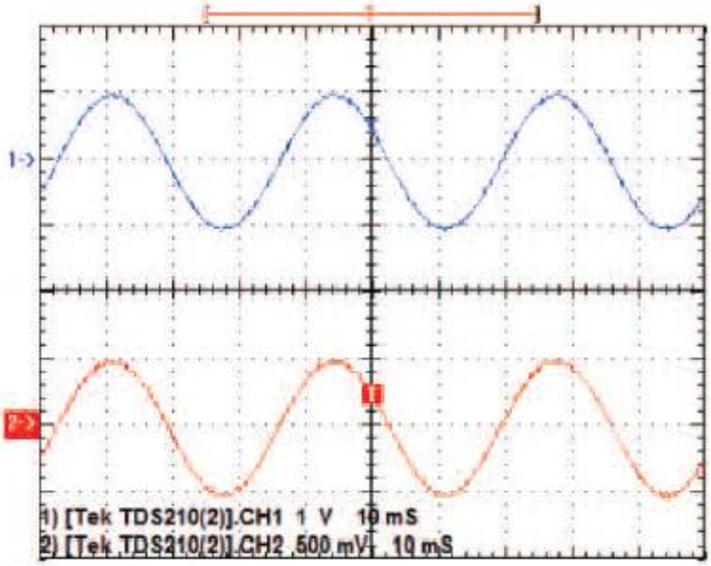


Figure 5-1-7 Measured sinθ (CH1) and Multiplier output (CH2), Vc=5V

10. Adjust the V control knob of Reference Variable Generator to 100% position, Vc=10V approximately. Using DSO, measure and record the voltage waveforms at sinθ and Multiplier outputs as shown in Figure 5-1-8. Calculate the output frequency = ____________ Hz (*60Hz approximately*) and the output amplitude = ___________ Vpp. (*Sine=Multiplier=20Vpp approximately*)

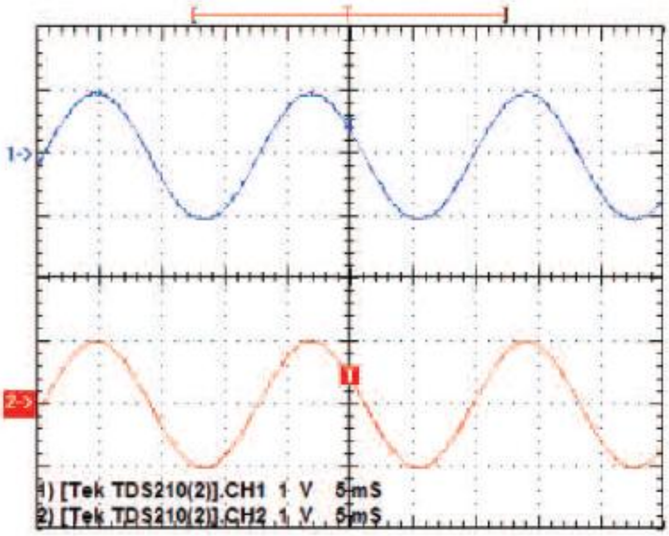


Figure 5-1-8 Measured sinθ (CH1) and Multiplier output (CH2), Vc=10V

11. On Differential Amplifier, connect Ch.A DIF inputs to S1 (+ to S1, - to 0V) and Ch.C DIF inputs to S3 (+ to S3, - to 0V). Set V Range Selectors(SWA,SWC) to 100V and set Ch Selectors(SW1,SW2) to A and C. On Single Phase PWM Controller module, set the F(KHz) Frequency Selector(SW1) switch of Triangular Carrier Wave Generator to x1 (1KHz), and set PWM/CLK Selector(SW2) switch to PWM.
12. Adjust the V control knob of Reference Variable Generator to set Vc=5V. Using DSO, measure and record the voltage waveforms at outputs S1 and S3 as shown in Figure 5-1-9.

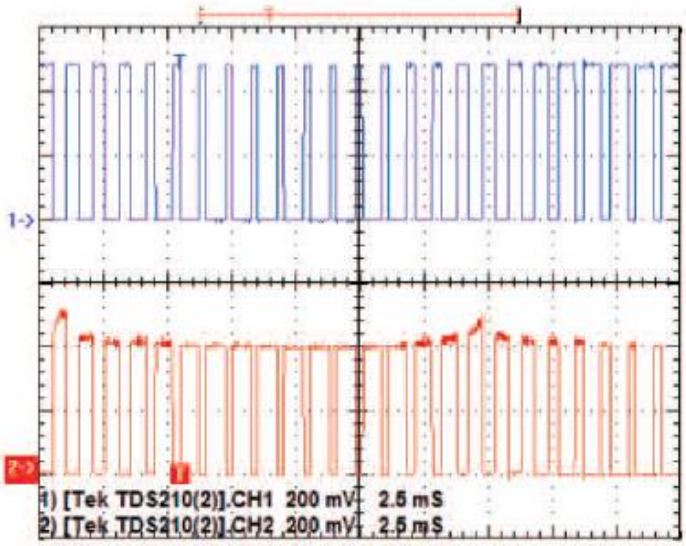
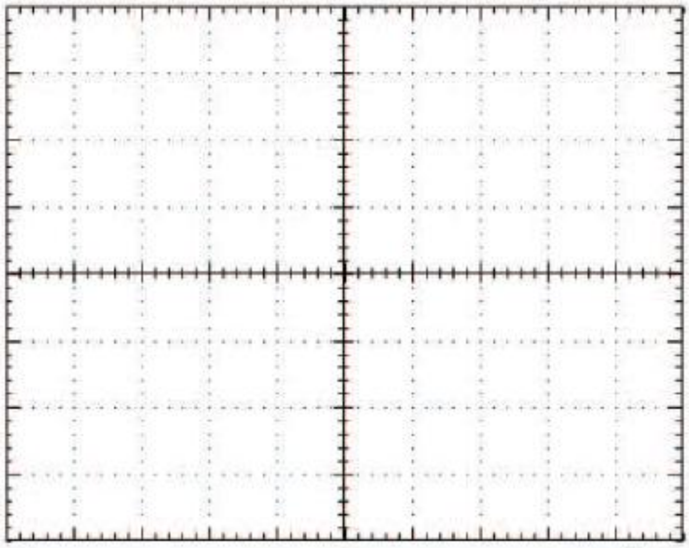


Figure 5-1-9 Measured S1 (CH1) and S3 (CH2); Vc=5V, fc=1KHz

13. Adjust the V control knob of Reference Variable Generator to set Vc=2.5V. Using DSO, measure and record the voltage wavefoms of outputs S1 and S3 in Figure 5-1-10.



CH1:

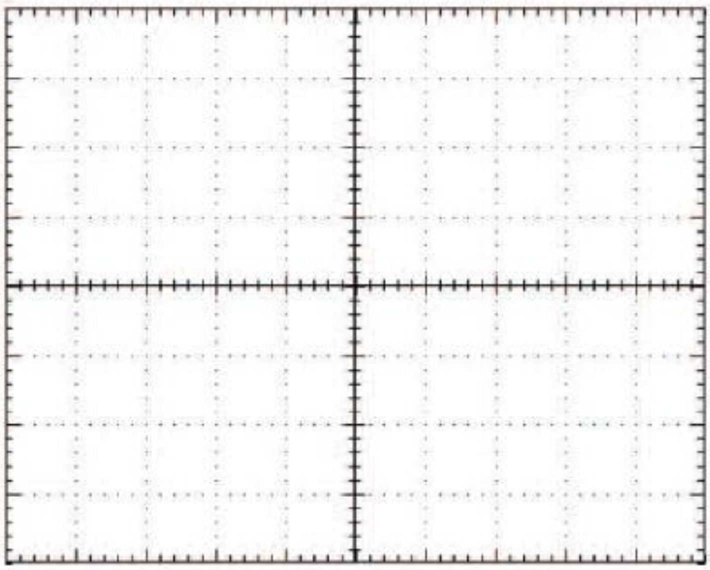
DIF AMP V Range:____
VOLTS/DIV:____
SEC/DIV:____

CH2:

DIF AMP V Range:____
VOLTS/DIV:____
SEC/DIV:____

Figure 5-1-10 Measured S1 (CH1) and S3 (CH2); Vc=2.5V, fc=1KHz

14. Adjust the V control knob of Reference Variable Generator to set Vc=7.5V. Using DSO, measure and record the voltage wavefoms of outputs S1 and S3 in Figure 5-1-11.



CH1:

DIF AMP V Range:____
VOLTS/DIV:____
SEC/DIV:____

CH2:

DIF AMP V Range:____
VOLTS/DIV:____
SEC/DIV:____

Figure 5-1-11 Measured S1 (CH1) and S3 (CH2); Vc=7.5V, fc=1KHz

15. On Differential Amplifier, connect Ch.A DIF inputs to Multiplier output (+ to Multiplier output, - to 0V) and Ch.C DIF inputs to S1 (+ to S1, - to 0V). Using DSO, measure and record the voltage waveforms at S1 and Multiplier outputs as shown in Figure 5-1-12.

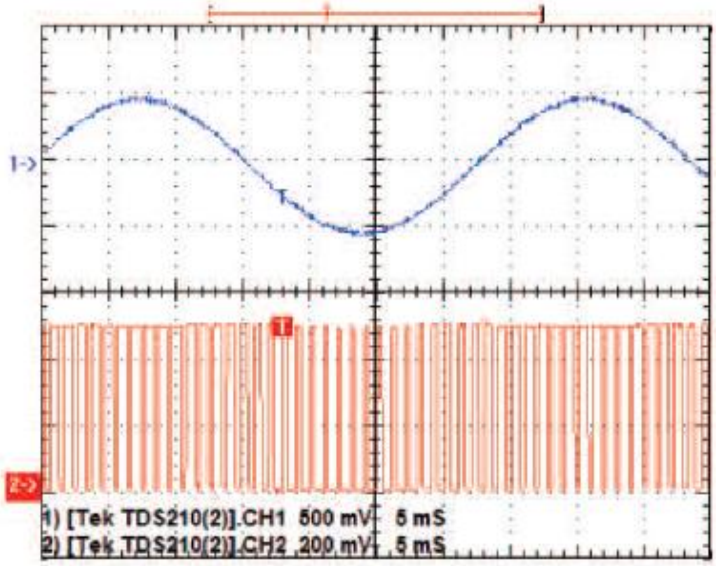


Figure 5-1-12 Measured Multiplier output (CH1) and S1 (CH2); Vc=7.5V, fc=1KHz

16. Set the F(KHz) Frequency Selector(SW1) switch of Single Phase PWM Controller module to x5 (5KHz). Using DSO, measure and record the voltage waveforms at S1 and Multiplier outputs as shown in Figure 5-1-13.

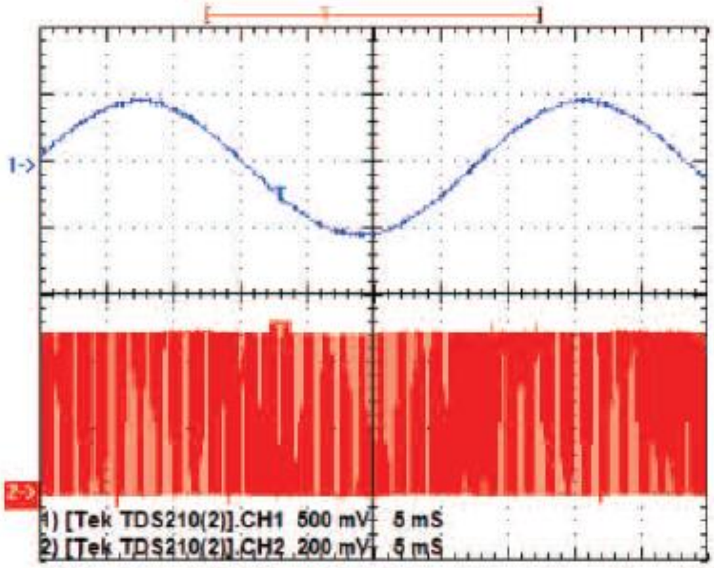
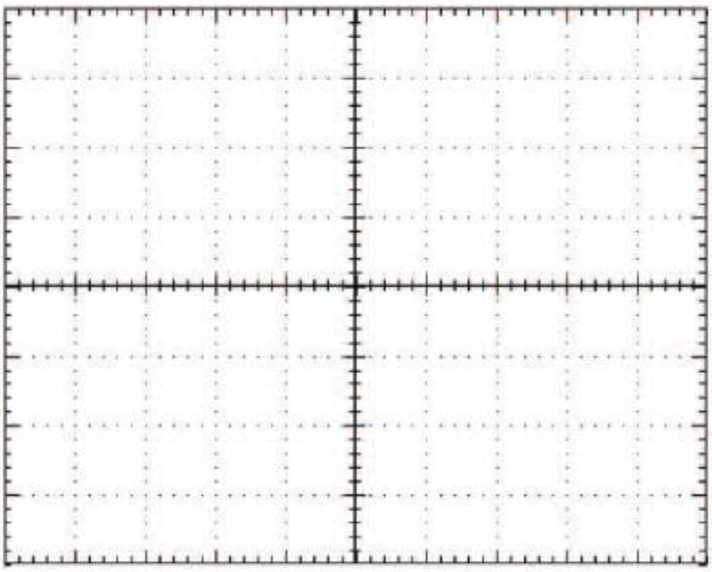


Figure 5-1-13 Measured Multiplier output (CH1) and S1 (CH2); Vc=7.5V, fc=5KHz

17. Set the F(KHz) Frequency Selector(SW1) switch of Single Phase PWM Controller module to x15 (15KHz). Using DSO, measure and record the voltage waveforms at S1 and Multiplier outputs in Figure 5-1-14.



CH1:

DIF AMP V Range:____
VOLTS/DIV:____
SEC/DIV:____

CH2:

DIF AMP V Range:____
VOLTS/DIV:____
SEC/DIV:____

Figure 5-1-14 Measured Multiplier output (CH1) and S1 (CH2); Vc=7.5V, fc=15KHz

18. Adjust the V control knob of Reference Variable Generator to 100%, Vc=10V approximately. On Single Phase PWM Controller module, set the F(KHz) Frequency Selector(SW1) switch of Triangular Carrier Wave Generator to x1 (1KHz), and set PWM/CLK Selector(SW2) switch to PWM. Using DSO, measure and record the voltage waveforms at S1 and Multiplier outputs as shown in Figure 5-1-15.

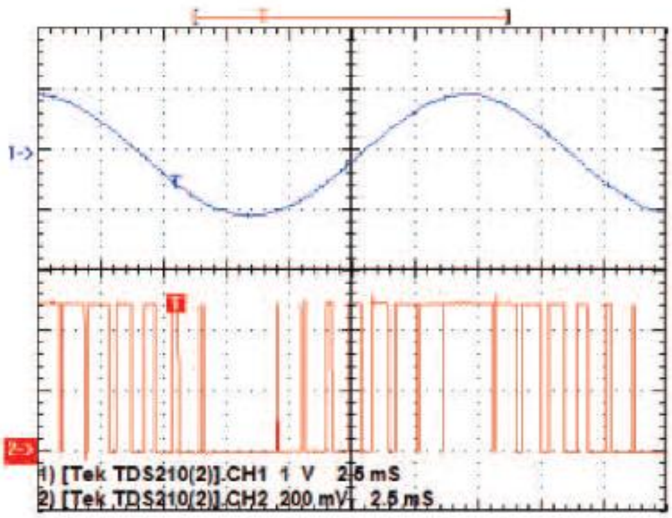


Figure 5-1-15 Measured Multiplier output (CH1) and S1 (CH2); Vc=10V, fc=1KHz

19. Set the F(KHz) Frequency Selector(SW1) switch of Triangular Carrier Wave Generator to x5 (5KHz). Using DSO, measure and record the voltage waveforms at S1 and Multiplier outputs as shown in Figure 5-1-16.

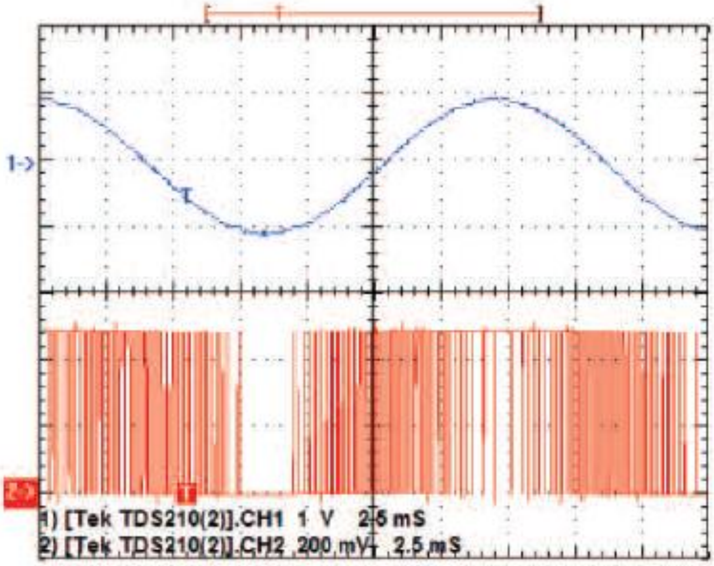


Figure 5-1-16 Measured Multiplier output (CH1) and S1 (CH2); Vc=10V, fc=5KHz

20. Set the F(KHz) Frequency Selector(SW1) switch of Triangular Carrier Wave Generator to x15 (15KHz). Using DSO, measure and record the voltage waveforms at S1 and Multiplier outputs as shown in Figure 5-1-17.

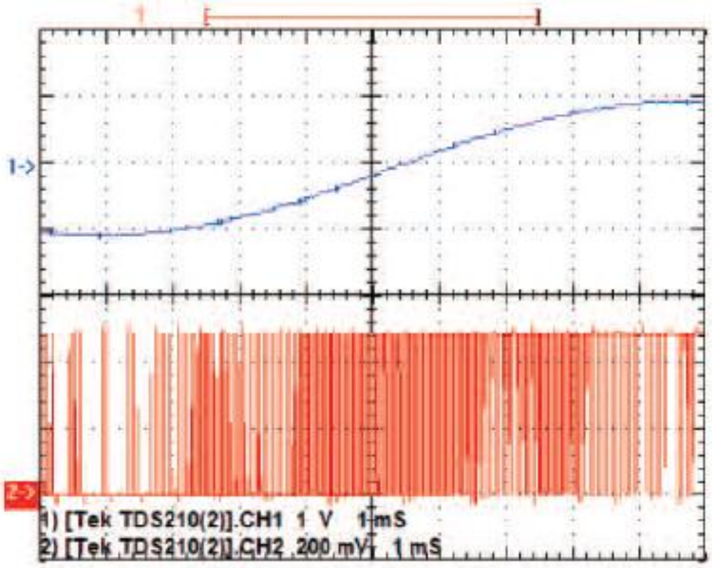


Figure 5-1-17 Measured Multiplier output (CH1) and S1 (CH2); Vc=10V, fc=15KHz

Part 2. Single Phase Inverter

You will understand the operating principle of single phase full bridge inverter, to measure the gating signals and output voltage of a single phase inverter.

BEFORE COME TO THIS LAB, YOU SHOULD

* Read the technical background on the report.
* Make some research on Single Phase Inverter.

AFTER COMPLETING THIS LAB, YOU SHOULD

* Know the circuit of single phase inverter.
* Know the output waveforms of single phase inverter with purely resistive load and also RL load.

REQUIREMENTS

* DC Power Supply
* Differential Amplifier
* Reference Variable Generator
* Single Phase PWM Generator
* Current Transducer
* Resistor and Inductive Load Unit
* IGBT Drive Set
* Three Phase Rectifier & Filter
* Fuse Set
* Isolating Transformer
* Oscilloscope
* Wires

TECHNICAL BACKGROUND

Experiment 5-2
Single-Phase Inverter

OBJECTIVE

1. To understand the operating principle of a single-phase full-bridge inverter.
2. To understand gating signals and output voltage of a single-phase inverter.
3. To measure the gating signals and output voltage of a single-phase inverter.
4. To measure the output voltage and output current of a single-phase inverter with a purely resistive load.
5. To measure the output voltage and output current of a single-phase inverter with an RL load.

DISCUSSION

The power circuit of single-phase full-bridge inverter, as shown in Figure 5-2-1(a), is the same as the four-quadrant chopper. When IGBTs T2 and T3 are turned on at the same time, the supply voltage Vs appears across the load. When IGBTs T1 and T4 are turned on simultaneously, the output voltage across the load is reversed and is –Vs.

The square gating signals and the output voltage of the single-phase inverter are shown in Figure 5-2-1(b). If the gating signals are PWM signals, the output voltage is therefore a PWM wave. With an inductive load, the output current is a sinusoidal waveform.

In this experiment, the PE-5310-4H Single Phase PWM Generator module will be used to generate the required gating signals for the single-phase inverter. The gating signals can be square or PWM and the load circuit may be either purely resistive or RL.

The output frequency of the single-phase inverter is determined by the frequency of the gating signal. The peak-to-peak output voltage is equal to 2Vs.

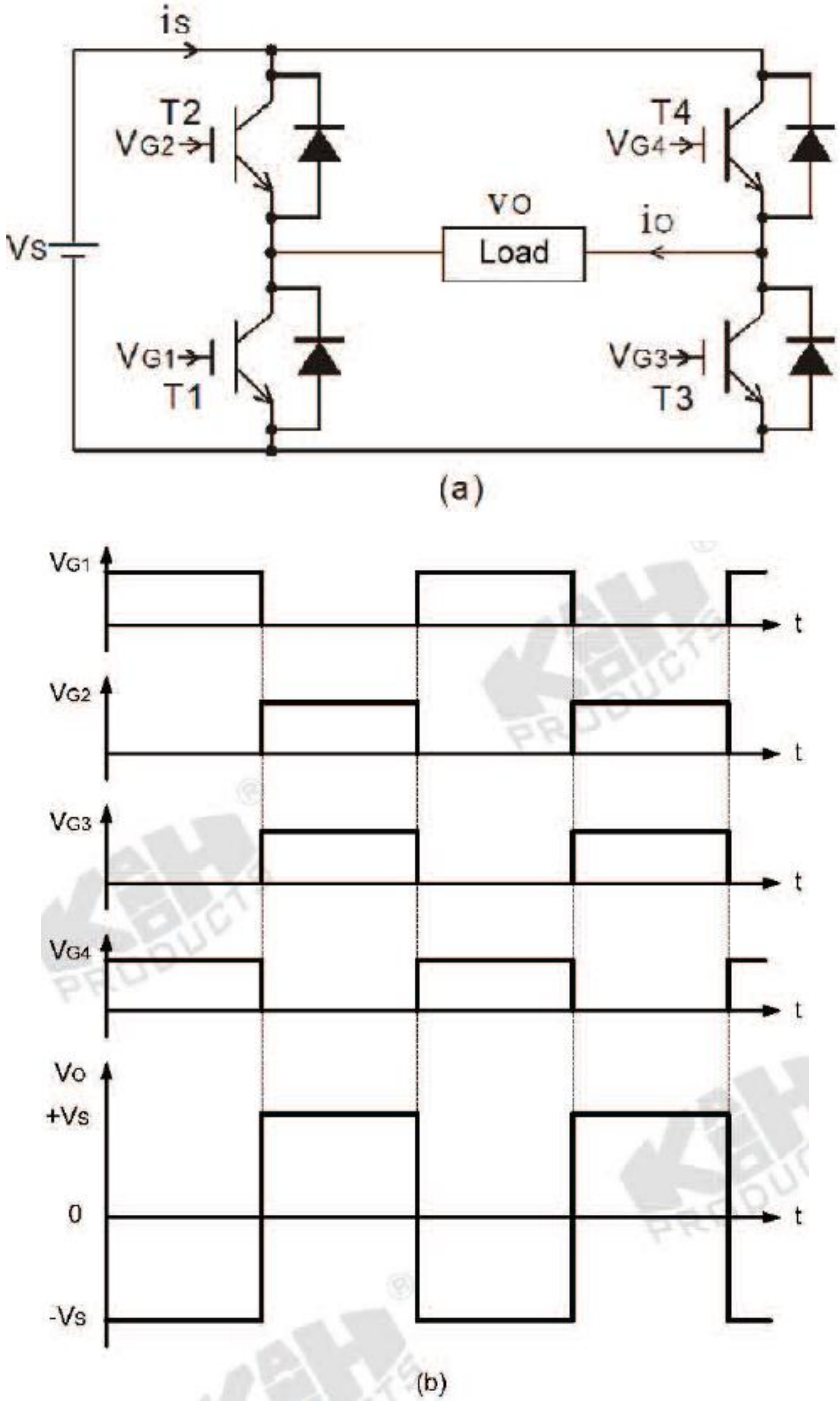


Figure 5-2-1 Single-phase full-bridge inverter. (a) Power circuit; (b) Gating signals and output voltage

EQUIPMENT REQUIRED

1. PE-5310-1A DC Power Supply x1
2. PE-5310-2A Reference Variable Generator x1
3. PE-5310-2B Differential Amplifier x1
4. PE-5310-2C Current Transducer x1
5. PE-5310-3C Resistor Load Unit x1
6. PE-5310-3E Inductive Load Unit x1
7. PE-5310-4F IGBT Drive Set x1
8. PE-5310-4H Single Phase PWM Generator x1
9. PE-5310-4J Three Phase Rectifier & Filter x1
10. PE-5310-5B Fuse Set x1
11. PE-5340-3A Isolating Transformer x1
12. Digital Storage Oscilloscope (DSO) x1
13. Connecting Wires
14. Bridging Plugs

PROCEDURE

1. Put modules PE-5310-1A, PE-5310-2A, PE-5310-2B, PE-5310-4H, PE-5310-4J, PE-5310-5B and PE-5310-4F in Experimental Frame. Place DSO, PE-5340-3A, PE-5310-3C and PE-5310-3E on workbench.

2. With power off, complete the connections shown in Figure 5-2-2 using bridging plugs (curved lines) and connecting wires. Connect 220V AC power to DC Power Supply, Current Transducer, IGBT Drive Set, and Differential Amplifier modules by plugging in the grounded 3-prong outlets.

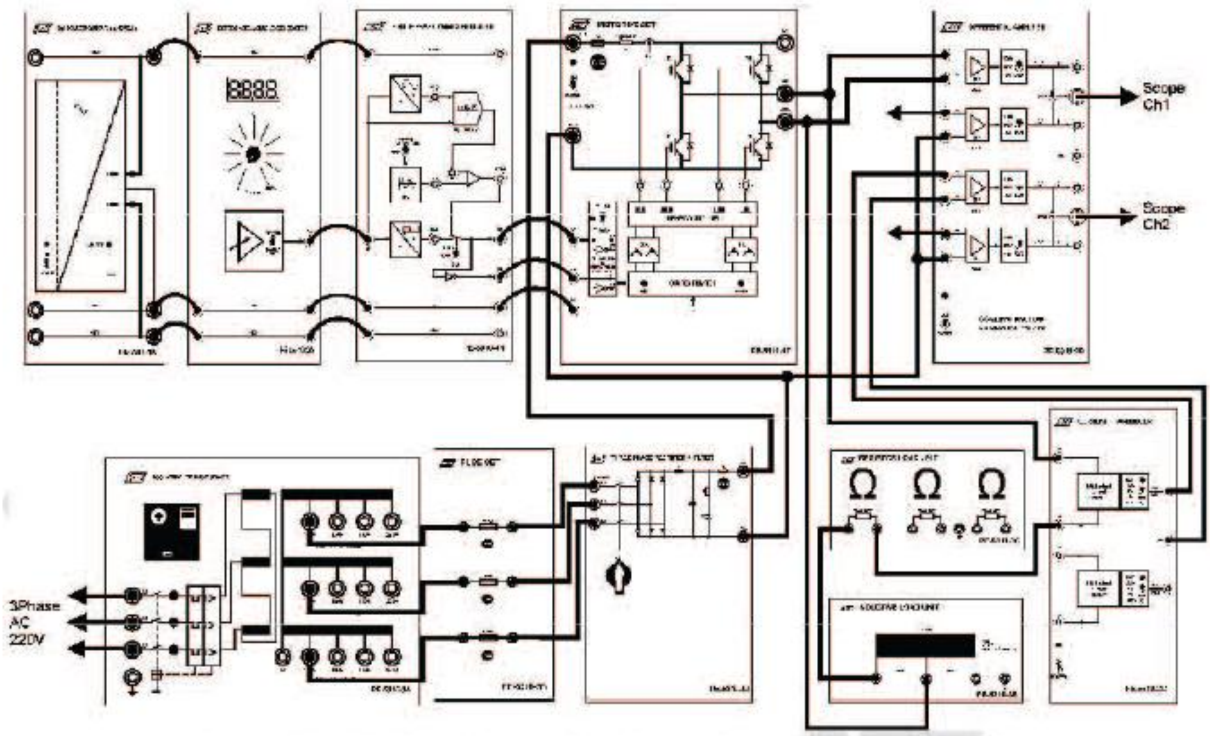


Figure 5-2-2 Wiring diagram for single-phase inverter measurement

3. Turn on the DC Power Supply. On Reference Variable Generator, set Vc Range Selector(SW1) switch to 0~+10V and turn V Control knob to set Vc=5V approximately.

4. On Single Phase PWM Generator, set PWM/CLK Selector(SW2) switch to CLK (clock) and set the F(KHz) Frequency Selector(SW1) switch of triangular wave to x1 (1KHz).

5. Turn on IGBT Drive Set. Place Trigger Selector(SW1) switch in T1...T4 position. On Differential Amplifier, set V Range Selectors(SWB,SWD) of Ch.B and Ch.D to 100V and place Ch Selectors(SW1,SW2) in B and D. Connect Ch.B DIF inputs to T1 (+ to T1, - to DC-) and connect Ch.D DIF inputs to T2 (+ to T2, - to DC-). Using DSO, measure and record the gating signals of IGBTs T1 and T2 as shown in Figure 5-2-3.

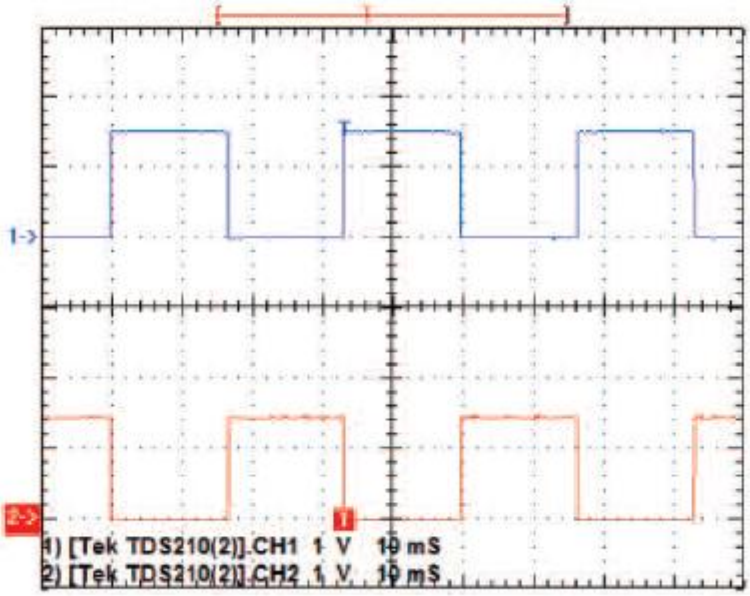


Figure 5-2-3 Measured T1 (CH1) and T2 (CH2); Vc=5V, fc=1KHz, CLK

6. Adjust the SEC/DIV knob of DSO to view the gating signals T1 and T2 as shown in Figure 5-2-4. Measure and record the dead time = ___________ μs. (*about 3μs*)

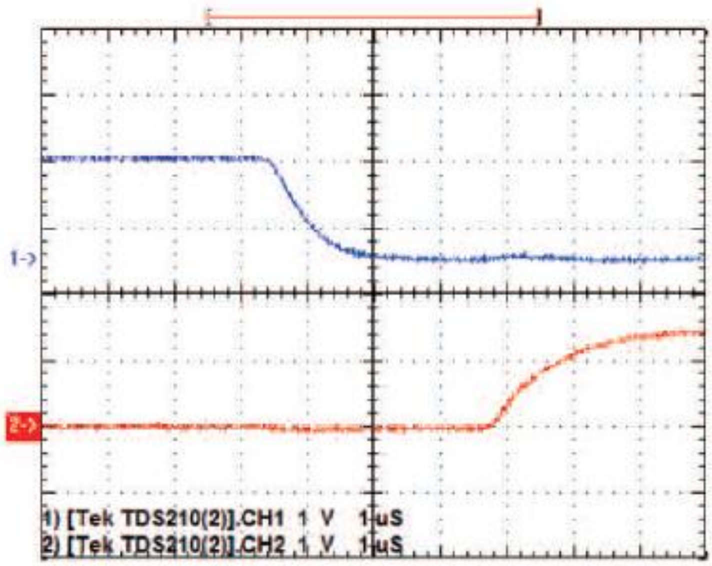
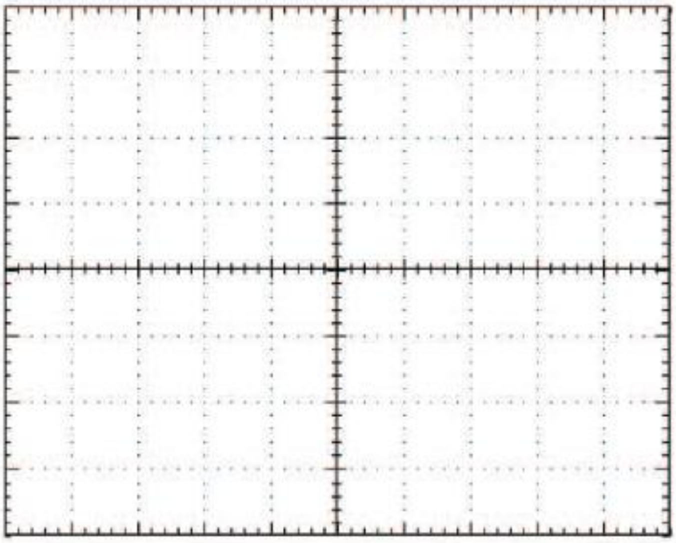


Figure 5-2-4 Measured T1 (CH1) and T2 (CH2); Vc=5V, fc=1KHz, CLK

7. Connect Ch.B DIF inputs to T3 (+ to T3, - to DC-) and connect Ch.D DIF inputs to T4 (+ to T4, - to DC-). Using DSO, measure and record the gating signals of IGBTs T3 and T4 in Figure 5-2-5.



CH1:

DIF AMP V Range:____
VOLTS/DIV:____
SEC/DIV:____

CH2:

DIF AMP V Range:____
VOLTS/DIV:____
SEC/DIV:____

Figure 5-2-5 Measured T3 (CH1) and T4 (CH2); Vc=5V, fc=1KHz, CLK

8. Repeat Step 6. Measure and record the dead time = ______________ μs.

9. Connect Ch.B DIF inputs to T1 (+ to T1, - to DC-) and connect Ch.D DIF inputs to T4 (+ to T4, - to DC-). Using DSO, measure and record the gating signals of IGBTs T1 and T4 as shown in Figure 5-2-6.

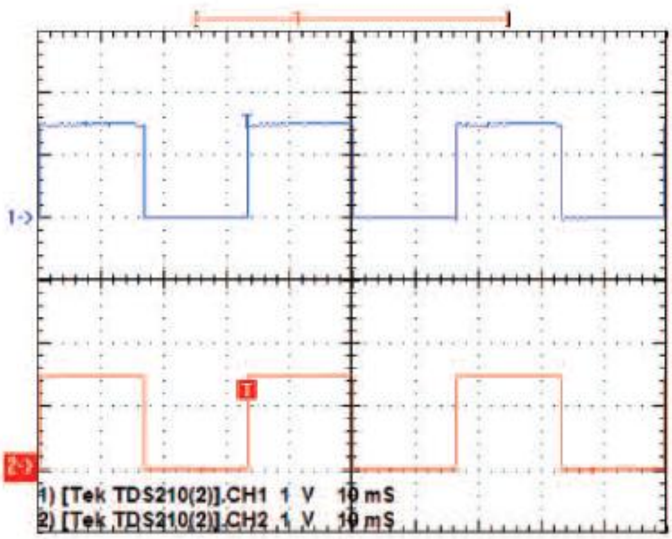
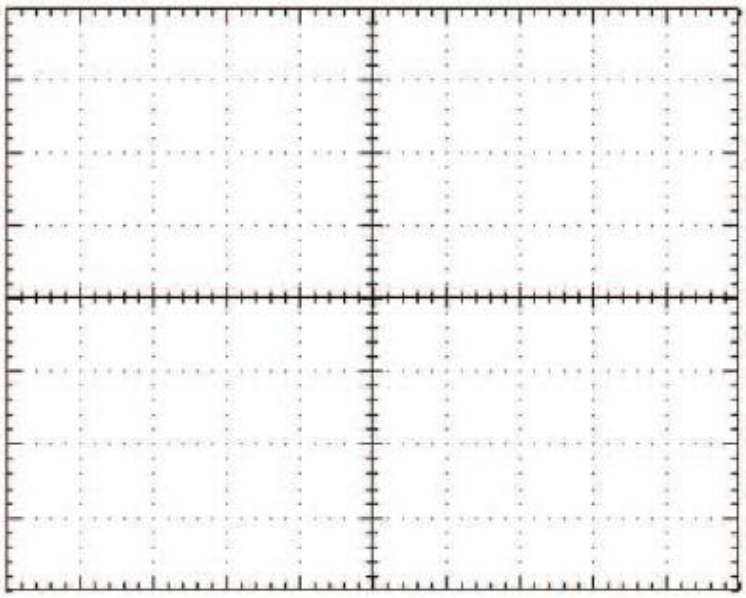


Figure 5-2-6 Measured T1 (CH1) and T4 (CH2); Vc=5V, fc=1KHz, CLK

10. Connect Ch.B DIF inputs to T2 (+ to T2, - to DC-) and connect Ch.D DIF inputs to T3 (+ to T3, - to DC-). Using DSO, measure and record the gating signals of IGBTs T2 and T3 in Figure 5-2-7.



CH1:

DIF AMP V Range:____
VOLTS/DIV:____
SEC/DIV:____

CH2:

DIF AMP V Range:____
VOLTS/DIV:____
SEC/DIV:____

Figure 5-2-7 Measured T2 (CH1) and T3 (CH2); Vc=5V, fc=1KHz, CLK

11. On Reference Variable Generator, set Vc Range Selector(SW1) switch to 0~+10V and set V Control knob to 100% (Vc=10V approximately). On Single Phase PWM Generator, set PWM/CLK Selector(SW2) switch to PWM.

12. Connect Ch.B DIF inputs to T1 (+ to T1, - to DC-) and connect Ch.D DIF inputs to T2 (+ to T2, - to DC-). Using DSO, measure and record the gating signals of IGBTs T1 and T2 as shown in Figure 5-2-8.

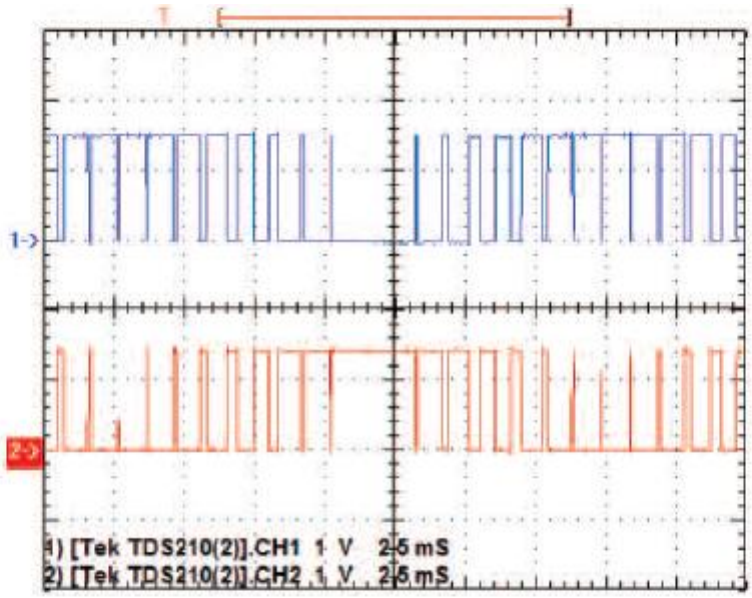


Figure 5-2-8 Measured T1 (CH1) and T2 (CH2); Vc=10V, fc=1KHz, PWM

13. Connect Ch.B DIF inputs to T1 (+ to T1, - to DC-) and connect Ch.D DIF inputs to T4 (+ to T4, - to DC-). Using DSO, measure and record the gating signals of IGBTs T1 and T4 as shown in Figure 5-2-9.

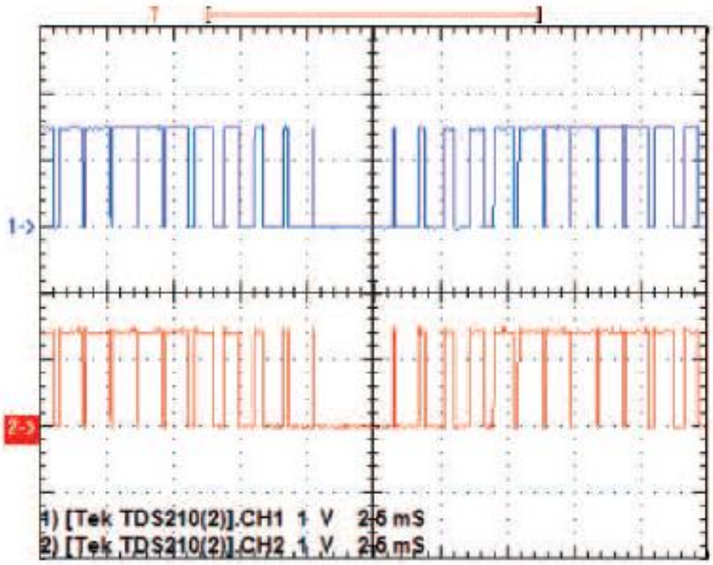


Figure 5-2-9 Measured T1 (CH1) and T4 (CH2); Vc=10V, fc=1KHz, PWM

14. Connect Ch.B DIF inputs to T2 (+ to T2, - to DC-) and connect Ch.D DIF inputs to T3 (+ to T3, - to DC-). Using DSO, measure and record the gating signals of IGBTs T2 and T3 as shown in Figure 5-2-10.

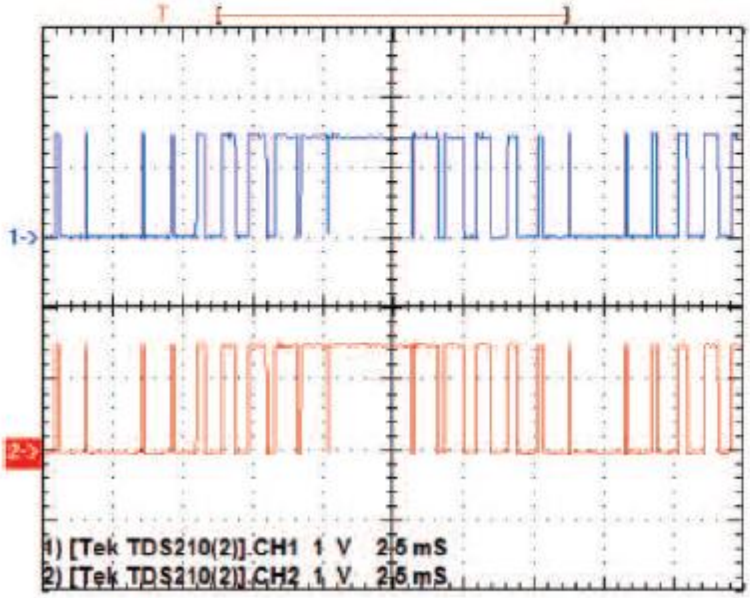


Figure 5-2-10 Measured T2 (CH1) and T3 (CH2); Vc=10V, fc=1KHz, PWM

15. Connect Ch.B DIF inputs to T3 (+ to T3, - to DC-) and connect Ch.D DIF inputs to T4 (+ to T4, - to DC-). Using DSO, measure and record the gating signals of IGBTs T3 and T4 as shown in Figure 5-2-11.

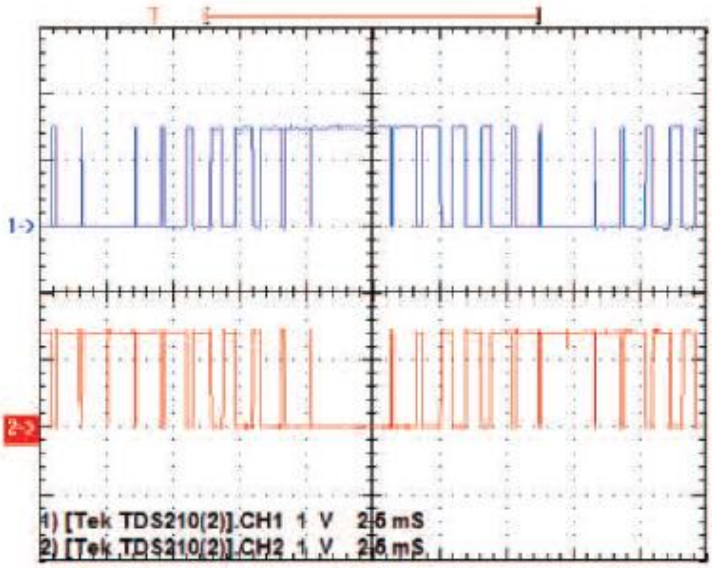


Figure 5-2-11 Measured T3 (CH1) and T4 (CH2); Vc=10V, fc=1KHz, PWM

16. Recover the connections of Figure 5-2-2. Short out the load inductor by placing a connecting wire directly across the 50mH inductor terminals. This constructs a purely resistive load circuit (100Ω) across output terminals O/P1 and O/P2.

17. On Differential Amplifier, set V Range Selector(SWA) of Ch.A to 500V and set V Range Selector(SWC) of Ch.C to 100V, place Ch Selectors(SW1,SW2) in A and C. On Current Transducer module, set I Range Selector to 5Ap. On Single Phase PWM Generator, set PWM/CLK Selector(SW2) switch to CLK. Turn on all power.

18. Slowly adjust the V control knob of Reference Variable Generator to set Vc=5V. Using DSO, measure and record the load voltage V_L and load current I_L waveforms as shown in Figure 5-2-12. Calculate and record the output frequency = __________ Hz (*30Hz approximately*).

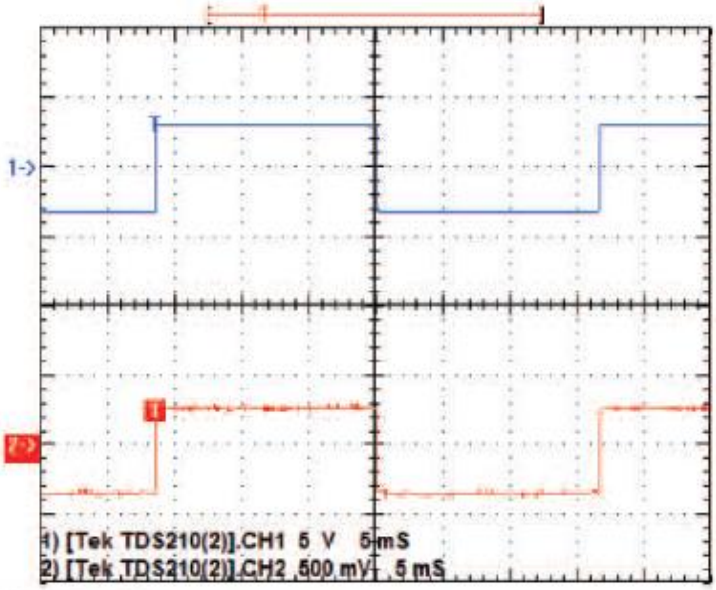


Figure 5-2-12 Measured V_L (CH1) and I_L (CH2); Vc=5V, fc=1KHz, CLK

19. Adjust the V control knob of Reference Variable Generator to set Vc=10V approximately. Using DSO, measure and record the load voltage and load current waveforms as shown in Figure 5-2-13. Calculate and record the output frequency = __________ Hz. (*60Hz approximately*)

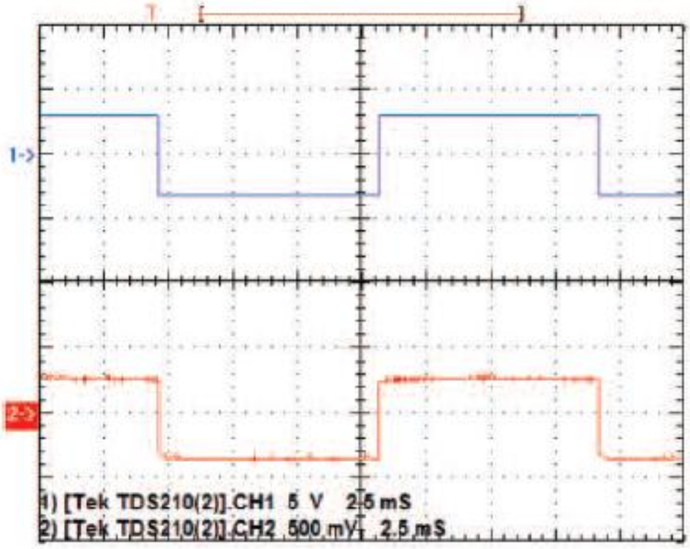


Figure 5-2-13 Measured V_L (CH1) and I_L (CH2); Vc=10V, fc=1KHz, CLK

20. Turn power off. Recover the load inductor by removing the connecting wire from inductor terminals. This modifies the purely resistive load to an RL load (100Ω in series with 50mH). Turn power on. Slowly adjust the V control knob of Reference Variable Generator to set Vc=10V approximately. Using DSO, measure and record the load voltage and load current waveforms as shown in Figure 5-2-14.

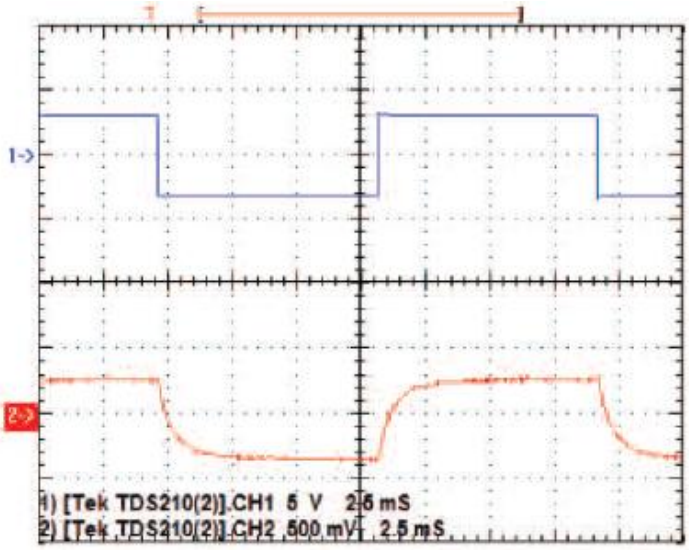


Figure 5-2-14 Measured V_L (CH1) and I_L (CH2); Vc=10V, fc=1KHz, CLK

21. Slowly adjust the V control knob of Reference Variable Generator to set Vc=5V. Using DSO, measure and record the load voltage and load current waveforms as shown in Figure 5-2-15.

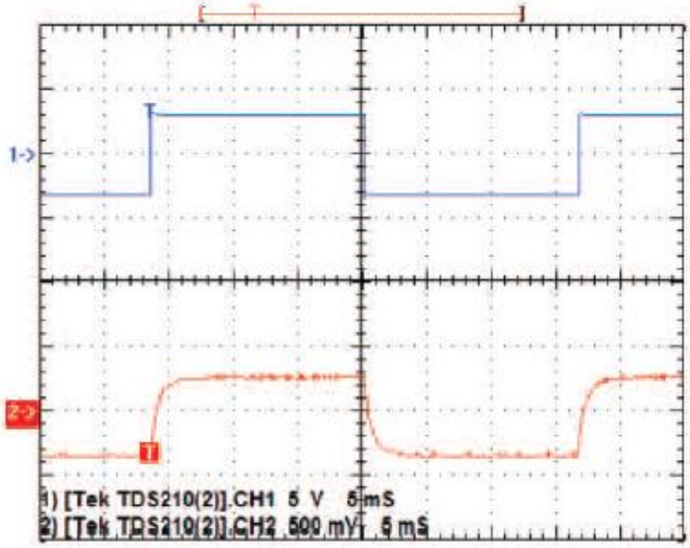


Figure 5-2-15 Measured V_L (CH1) and I_L (CH2); Vc=5V, fc=1KHz, CLK

22. On Single Phase PWM Generator module, place the PWM/CLK Selector(SW2) switch in PWM position and set the F(KHz) Frequency Selector(SW1) switch of triangular wave to x1 (1KHz). Short out the load inductor by placing a connecting wire directly across the 50mH inductor terminals. This constructs a purely resistive load circuit (100Ω).

23. Slowly turn the V control knob of Reference Variable Generator to set Vc=10V approximately. Using DSO, measure and record the load voltage and load current waveforms as shown in Figure 5-2-16.

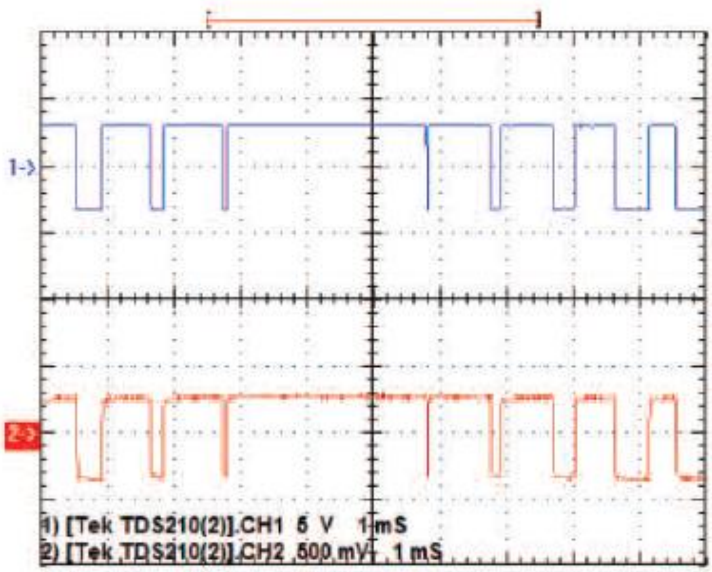
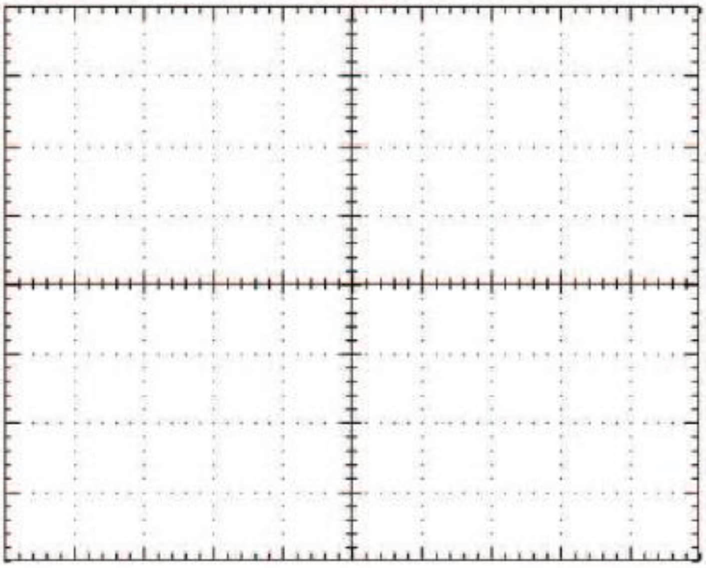


Figure 5-2-16 Measured V_L (CH1) and I_L (CH2); Vc=10V, fc=1KHz, PWM

24. Slowly turn the V control knob of Reference Variable Generator to set Vc=5V approximately. Using DSO, measure and record the load voltage and load current waveforms in Figure 5-2-17.



CH1:

DIF AMP V Range:____
VOLTS/DIV:____
SEC/DIV:____

CH2:

DIF AMP V Range:____
VOLTS/DIV:____
SEC/DIV:____

Figure 5-2-17 Measured V_L (CH1) and I_L (CH2); Vc=5V, fc=1KHz

25. Recover the load inductor by removing the connecting wire from inductor terminals. This modifies the purely resistive load to an RL load (100Ω in series with 50mH). Slowly adjust the V control knob of Reference Variable Generator to set Vc=10V approximately. Using DSO, measure and record the load voltage across 100Ω and load current waveforms in Figure 5-2-18.

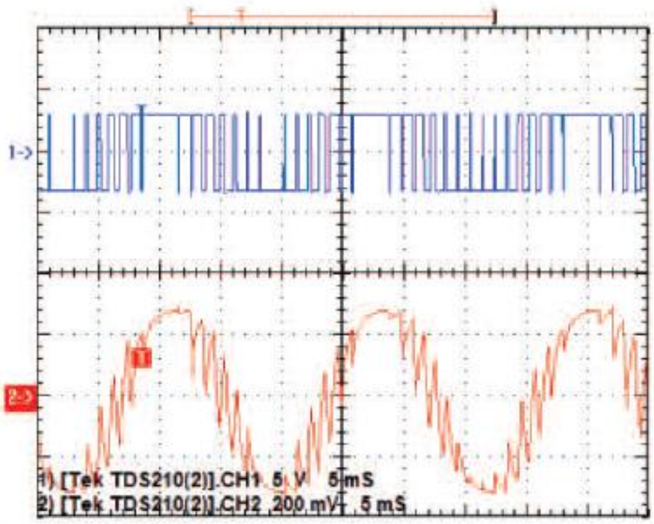


Figure 5-2-18 Measured V_L (CH1) and I_L (CH2); Vc=10V, fc=1KHz, PWM

26. Slowly adjust the V control knob of Reference Variable Generator to set Vc=5V approximately. Using DSO, measure and record the load voltage across 100Ω and load current waveforms in Figure 5-2-19.

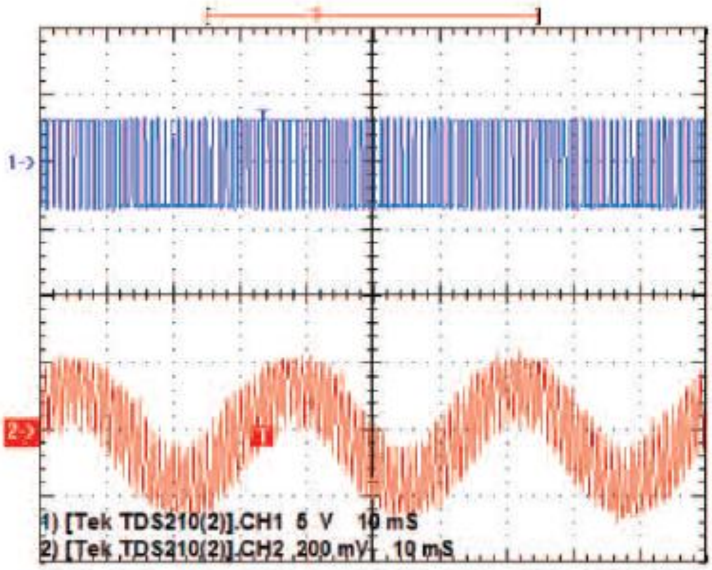


Figure 5-2-19 Measured V_L (CH1) and I_L (CH2); Vc=5V, fc=1KHz, PWM

27. On Single Phase PWM Controller, set F(KHz) Frequency Selector(SW1) switch of triangular wave to x5 (5KHz). Slowly turn the V control knob of Reference Variable Generator to set Vc=10V approximately. Using DSO, measure and record the load voltage and load current waveforms as shown in Figure 5-2-20.

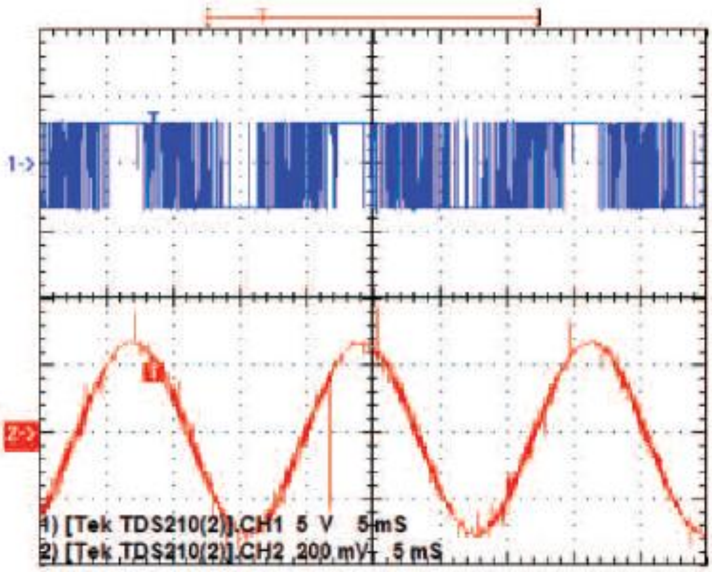


Figure 5-2-20 Measured V_L (CH1) and I_L (CH2); Vc=10V, fc=5KHz, PWM

28. On Single Phase PWM Controller, set F(KHz) Frequency Selector(SW1) switch of triangular wave to x15 (15KHz). Using DSO, measure and record the load voltage and load current waveforms as shown in Figure 5-2-21.

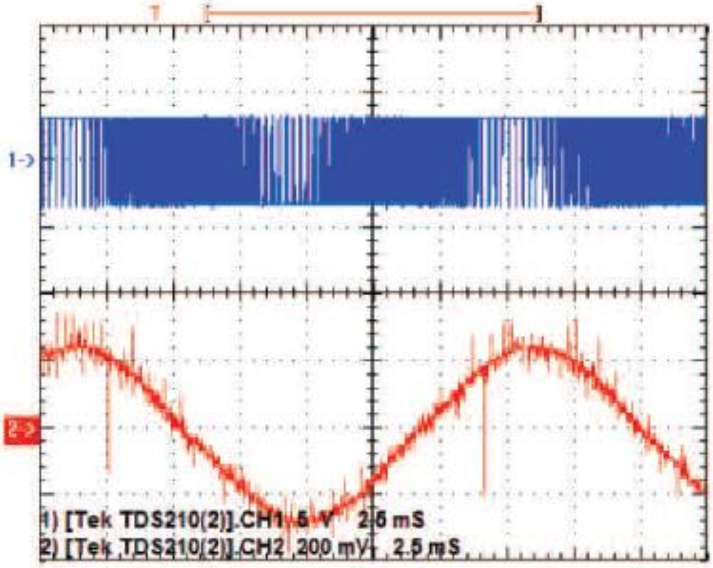


Figure 5-2-21 Measured V_L (CH1) and I_L (CH2); Vc=10V, fc=15KHz, PWM

Laboratory Report:

- Laboratory Report must include, Your own oscilloscope figures for all required experiment steps.
- The main title will be “Experimental Waveforms”
- Clarify which figures belongs to which sections.
- The MS Word document that includes the figures will be printed and attached to this manual.