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Design and Development of Gate Signal for 36 Volt 1000Hz Three Phase Inverter

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Abstract: *The sinusoidal PWM gating signals generation is most popular PWM method, which reduce harmonic reduction in output. SPWM can be generated by FPGA, micro controller and micro processor but this kind of device needs programming and coding hence avoided in using power system of aircraft. This paper present an experiment using SPWM method to generate 1000 Hz gating signals suitable for 36 Volt , 1000 Hz, 3 phase, three wire supply. Discrete components design approach is chosen to provide noise immunity at higher amplitude level of signal and a large flexibility to adjust and process various operating parameters of signals. The circuit is proved with commercial components however MIL version of components can be easily incorporated in design in later stage.*

Keywords: *aircraft, comparator,gyro, sine wave, triangular wave.*

I. INTRODUCTION

Aerospace industry is a complex field of engineering, where all the branches of science and technology have made their presence in general and specific in particular such as use of rectifier unit, rotary inverter, static inverter in power system of fighter aircraft.Though the use of Sinusoidal pulse width modulation inverter is very common in single and three phases of commercial inverters working on frequency 50 Hz/60Hz available in open market, but the article under question wherein the developed gating signal for 1000Hz,three phase for inverter of 36 volt is taken up in this paper. Other popular version of inverter in aircraft industry is 400Hz, 3 phase, 36 Volt; which is used in older version of fighter aircraft to provide power supply to gyros. In high speed aerospace vehicle such as missiles and aircraft with supersonic and hypersonic speed;inverter of 36volt, 3 phase, 1000 Hz can be used. The rigidity and degree of precession of gyro is directly depend on frequency of rotation of gyro mass. In modern aircraft, mechanical version of gyro is replaced by LRG (Laser Ring Gyro) or FOG (Fiber Optics Gyro) [3]. The 1000 Hz, 3 phase, 36 Volt supply can be used to operate gyro and synchro in modern aircraft and missiles.

II. Literature Survey

The authors have surveyed various papers published in journals and studied the features of invertors, type of SPWM method for generation and no evidence of work on 1000Hz, 3 phase, 36 Volt is found. However, for commercial power supply i.e 230 Volt, 50Hz, single phase and 400 volt, 3 phase 50 Hz;a lot of papers are found. The advantage of SPWM is clearly mentioned in [1]. Sinusoidal PWM results in lowest THD percentage as compared with other techniques like square wave PWM, trapezoidal PWM and modified sinusoidal PWM [2]. Therefore, SPWM method is chosen for design.

III. SPWM

The brief details of the SPWM are as follows:

(a) In SPWM sinusoidal signal frequency is compared with triangular carrier frequency.

(b) Sinusoidal signals {V_1 = A Sin ωt, V_2 =A Sin (ωt-120◦), V_3 = A sin (ωt+120◦)} are fed to be positive inputs of comparators and triangular signal (common to all three comparators) to the negative input of comparators.

(c) The pulse corresponding to the point whenever the instantaneous amplitude of sine signal is more than triangular signal then a pulse is generated. The width of the pulse is function of sinusoidal angular position.

(d) The pulse width varies with sinusoidal manner so that the average fundamental component frequency is the same as sinusoidal signal.

(e) It is necessary to maintain carrier frequency (triangular wave) ofat least 15 times more than the frequency of sinusoidal signal (1000 Hz). In practice, carrier frequency greater than 21 times are preferred; because, it reduces sub harmonic contentin the output of inverter.

(f) The rms value of line voltage; Vl = √3 Vs. In present case, it will be approx110 volt DC to be applied at MOSFET bridge to get 36 volts, phase to phase at inverter output. This is transformer-less design and output voltage can easily be changed by changing MOSFET bridge supply.

(g) In case synchronous operation [3] when the initial point of triangular wave coincide with sine wave then number of pulses per half cycle is N=(Fc/2Fs-1). Here design is asynchronous.
(h) Modulation index MI = Vs / Vc .

IV. Experiment Setup For Generating Spwm

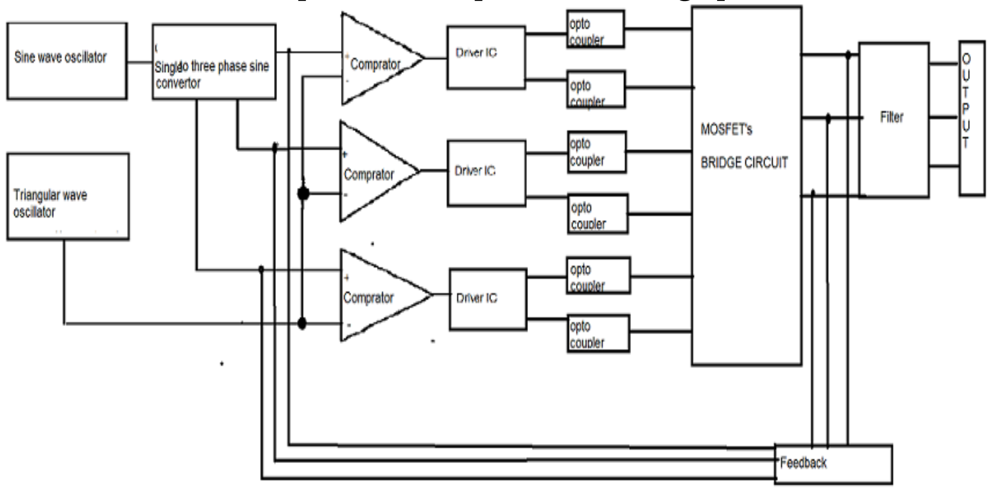

Figure 1. Block Diagram of Experiment setup

Experiment setup
SPWM generation involves four blocks of circuits namely generation, feedback, comparator, driver, opto-coupler gate driver. The brief of design and the voltage and frequency level are as follows:
(a) Each of the above levels of circuit is tested on bread board and then complete setup is assembled on PCB .
(b) Sine wave generation: Sine wave is generated through bipolar square wave of frequency 1000 Hz.
(i) Frequency = 1000 Hz ± 10 Hz
(ii) Voltage level: 1.8 to 2.5 Volts peak to peak at generation level and 8.2 to 13 Volt at comparator level selectable through potentiometer on PCB.

(c) Single phase to three phase conversion: This is obtained through three op-amp circuits and output are V_1 = A Sin ωt, V_2 =A Sin (ωt-120◦), V_3 = A sin (ωt+120◦). A is peak amplitude.
(d) Triangular wave generator: Triangular wave obtained through Op-amp circuits
(i) Frequency = 15KHZ to 25 KHZ adjustable by potentiometer.
(ii) Amplitude = 10 Volt to 13 Volt peak to peak adjustable by potentiometer.
(e) Comparator: One per phase precession comparators LM111 are used to get 3 phase PWM.
(f) Bipolar driver: One per phase bipolar driver IR 2108 is used to get normal and inverted signal
(g) Opto-couplar: Two per phase opto-couplar FOD 3120 are used to drive gate signal of normal and inverted signal.

(h) Power Supply: The circuit is tested with following external power supply, however in aircraft it will be supplied through Rectifier unit and through DC to DC convertor
(i) + 5 volt at 500 mA.
(j) – 12 volt , + 12 Volt at 500 mA.
(k) Bridge voltage supply as per voltage requirement of invertors in present case it is -55 Volt, +55 Volt and ground.
(l) Feedback: Negative Feedback is externally provided at comparator through signal generator at frequency 1000 Hz sine wave to vary signal strength of input signal at the comparator by 1000 mV.

V. Parameters Studied

Gernerally, for analysis of any wave form; shape of pulses, amplitude, rise time, fall time and duty cycle are important parameters. But, in case of three phase inverter, 120 degree apart, three separate train of pulses with their inverted form should be available on the output of gate signal circuit. Accordingly the following sets of reading are taken in laboratory and results are analyzed.

Sine wave generation: Frequency 1000 Hz amplitude 8.3 volt peak to peak.

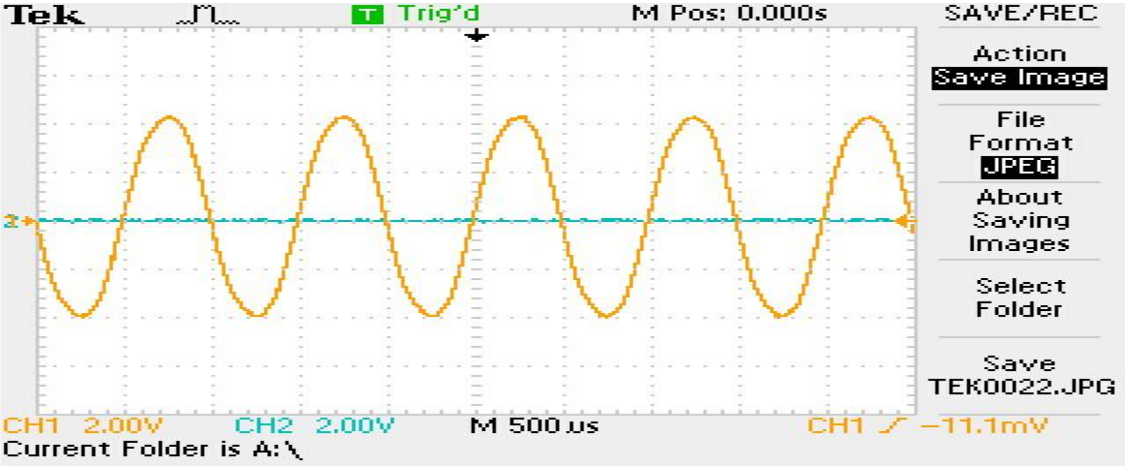

Figure 2. Sine wave generation

Triangular Wave Generation: Amplitude 12.5 Volt peak to peak, frequency 21.27 KHz.

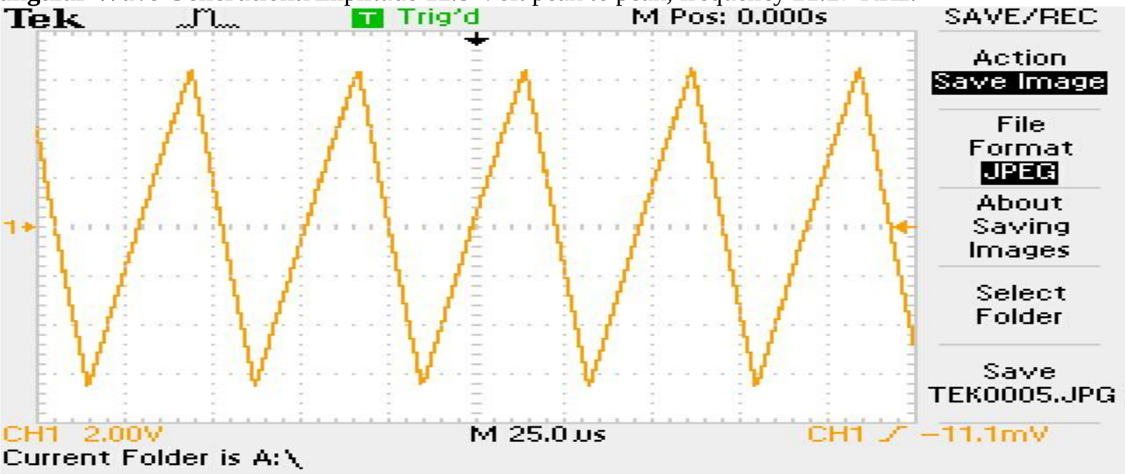

Figure 3. Triangular wave generation

Modulation Index Calculation: Sine wave amplitude 8.2 volt peak to peak triangular amplitude 13 Volt peak to peak modulation index 8.2/13 is equal to0.63.

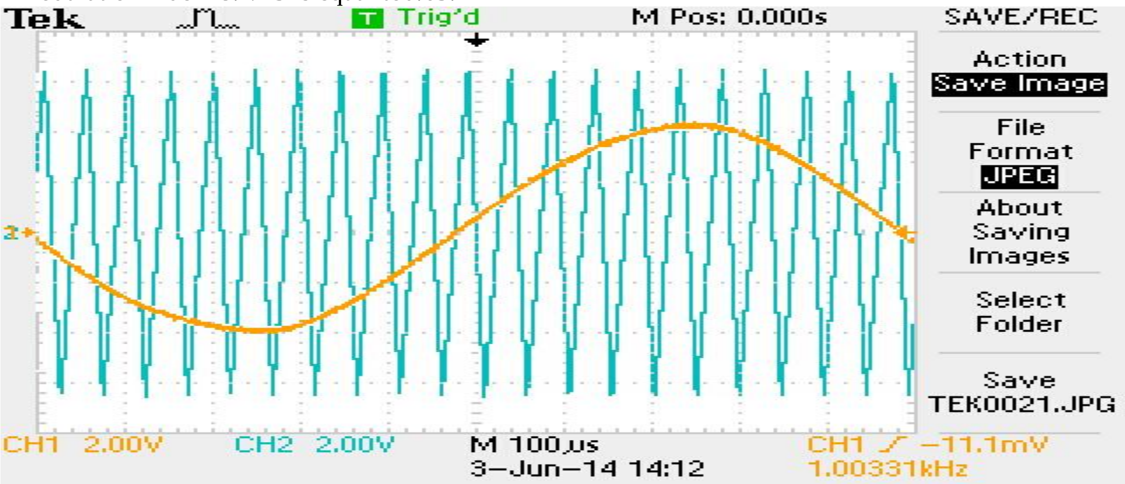

Figure 4. Modulationindex calculation

Shape and amplitude of pulses: Rectangular shape trains of pulses are obtained. The top level almost flat.
Rise time & fall time: Rise time noticed is between 80 to 83 nano second Fall time between 82 to 84 second

switching time 47 micro second so obtain rise time and fall time will suit the performance.

Duty cycle: Duty cycle cannot be calculated with certainty because SPWM is of asynchronous nature, accordingly inter space between pulses and width of pulse is varied continuously during the 500 microsecond (Half period corresponding to 1000Hz) time period so switch ON time and OFF time recorded have no certainity to which portion of wave it belong. Even for same voltage& frequency level of carrier and sinusoidal wave at different instant of time wave recorded are found different,should be same but it is not. This is because at different instant of time different portion of modulation is recorded in oscilloscope.Half period corresponding to 1000Hz is 500 micro second.

Number of pulses of PWM on various modulations index levels: Modulation index [4] is calculated on different level of carrier frequency ans recorded below:-

Table 1

Sl. No.	Modulation Index MA	Number of pulses obtained asynchronous	Carrier Frequency f_c (KHz)	Sinusoidal Frequency f_s (KHz)	No. of pulses calculated N= $(f_c / 2 f_s) - 1$ synchronous
1.	0.63	7.27	15	1	6.5
2.	0.73	10.2	21	1	9.5
3.	0.84	12.1	25	1	11.5

As in present case of asynchronous design number of pulses obtained is more than synchronous pulses calculated.

Conformation of generation of normal & inverted signal for each phase:

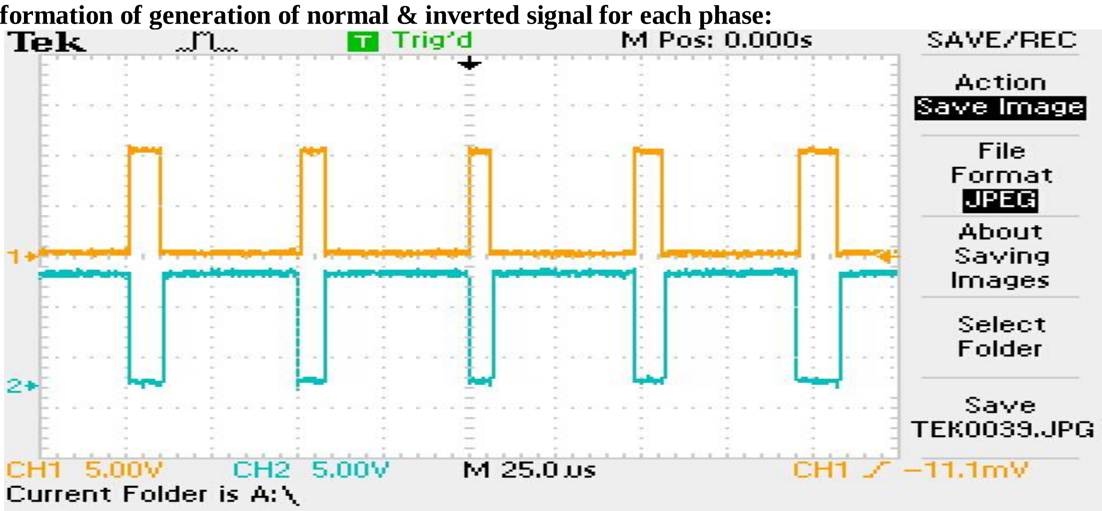

Figure 5. Phase A and inverted phase A

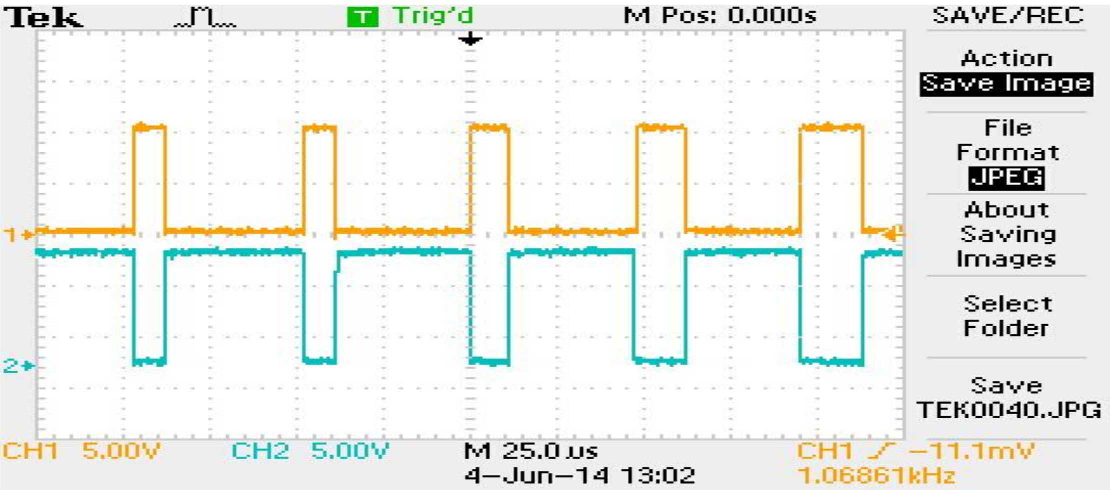

Figure 6. Phase B and inverted phase B

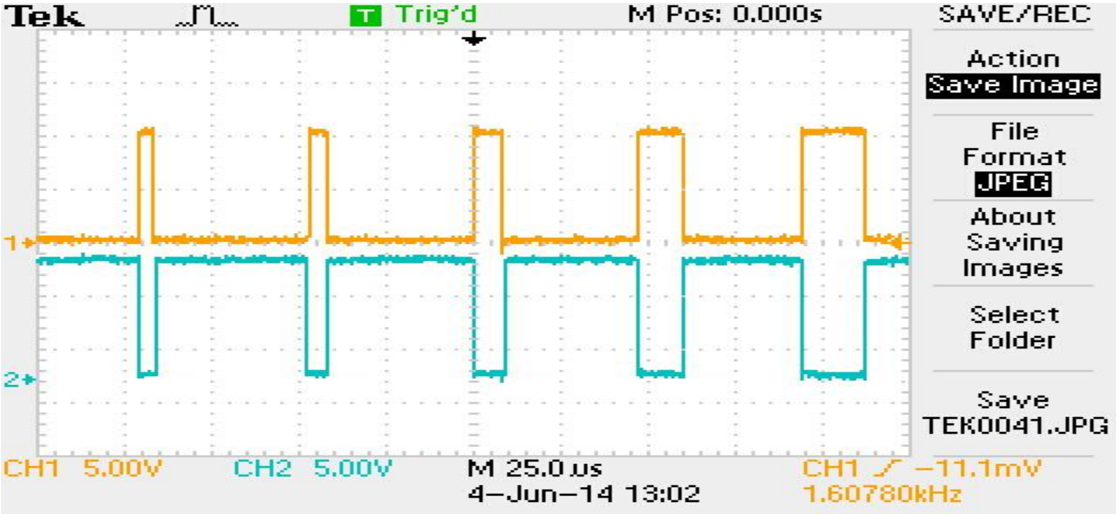

Figure 7. Phase C and inverted phase C.

It is evident from above figure no. 4, 5, 6 that normal signal and inverted signal are available for each of three phase.

Three phase 120 degree apart signals

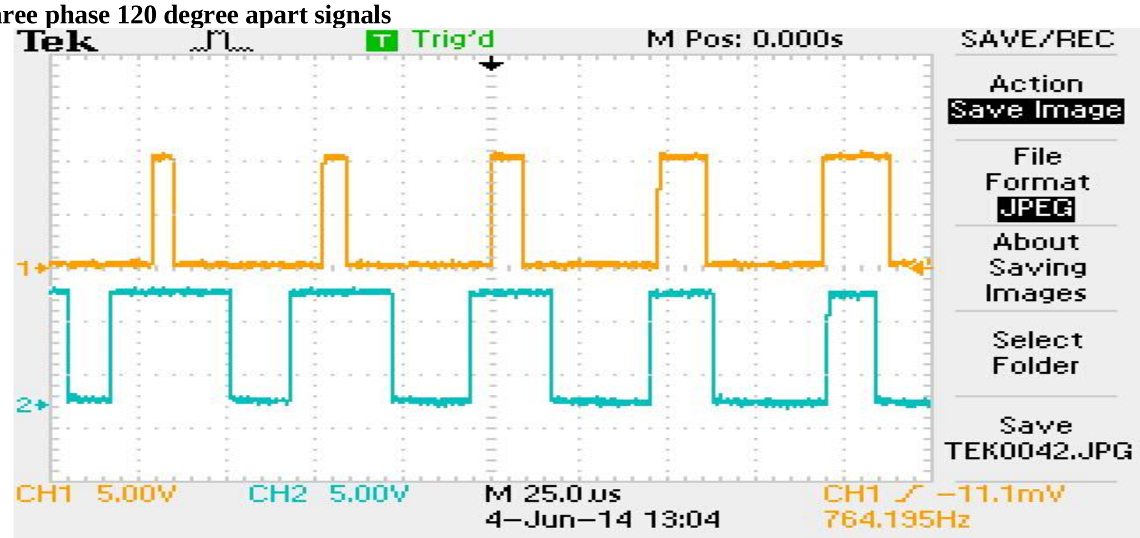

Figure 8. Phase A and phase B

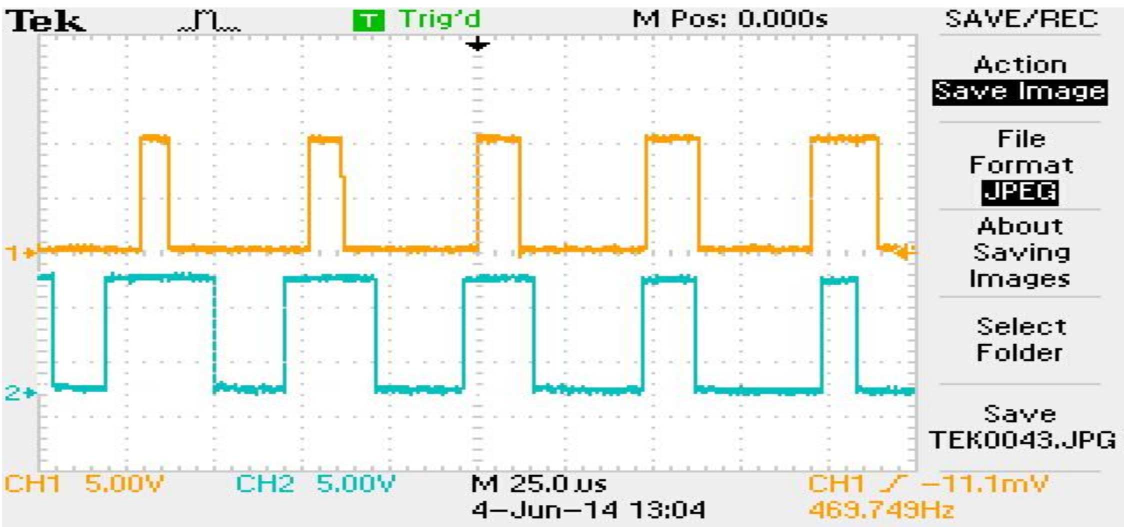

Figure 9. Phase B and phase C

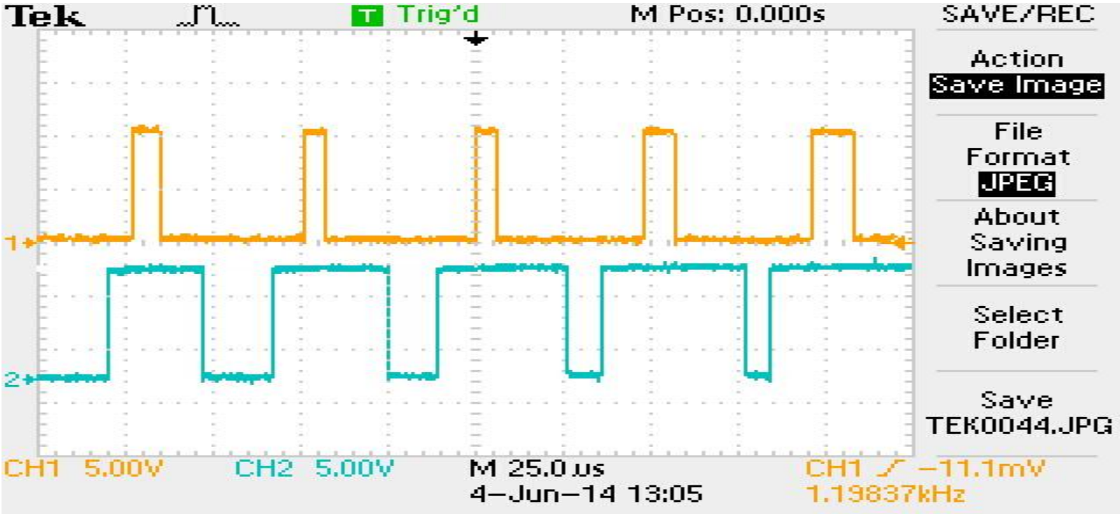

Figure 10. Phase C and phase A

VI. CONCLUSION

Based on the actual measurement of different parameters on three phases,1000 Hz, 36 Volt gatting signal setup; the following are concluded:

1. PWM signals and their inverted signals of 12 voltsmagnitude are available at the output of gate signal PCB. The shape, amplitude, rise time, fall time, phase difference among three phases and their inverted signal are found to be satisfactory. Hence, these arefit to be integrated with next stage of MOSFET bridge.
2. Limitation to calculate duty cycle from the recorded signal is noticed, however, it will not effect theoutput performance of inverter.
3. In SPWM, switching losses are higher due to large switchingfrequency of MOSFET in bridge, but this disadvantage is not considered in comparison to the quality output obtained with low THD.

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