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Developing Analog PWM Inverter for Induction Motor Control

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ABSTRACT

This switch-based power converter analog implementation is developed based on sinusoidal-PWM technique(SPWM). Center-aligned triangle is compared with 3-phase sinusoidal waves to produced SPWM signals; switching six (6) IGBTs SKM200GB123D for 3-phase induction motor inverter module. Op-amp, passive components and IR2130 bridge driver are used. The circuit is tested with slowly increased 80Vdc and manually adjustable carrier frequency capable to operate tested induction motor at rated speed. SPWM inverter has improves power efficiency of the induction motor.

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INTRODUCTION

Boris Mokritzki'spaper happened to be the earliest publication regarding PWM and ac motor that the graphical was still illustrated in handwritings (Mokrytzki 1967). This topic has been greatly discussed, improvised and taught throughout the decades. Until today, the digital generations celebrate this matured technique in various platforms; could develop system based on PWM in power converter for many applications without understand or would not be necessary to understand in detail on each of their system's component.

Practically before PWM ICs have been available in market since the late 1980s, analog design is the solution for implementation. Today, there are many powerful digital control platforms available in market such as dSpace DS1104-DS1103with 3550MHz-1GHz speed and 662-2500 MIPS that also could handle floating point number types. AlthoughDSP ProcessorBoard represents appealing solution in design and implementation due to simplicity and high computational capabilities, analog and AMS (analog-mix-signal) design is still remain valuable choice in high-frequency servo-drives that the extremely high bandwidth required for the control loops and thus the whole system need to be implemented in analog.

Typically there are three main types of PWM techniques used in power converter namely the Sinusoidal-PWM (SPWM), Space Vector-PWM (SV-PWM) and Hysteresis-PWM (Zhenyu Yu 1997). In term of performance, SPWM generated the worst Total Harmonic Distortion (THD) (K. Vinoth Kumar *et al* 2010) but relatively easy to be implemented in analog using op-amp and passive components which available easily in school and electronics shops. Thus, the total cost of developing each block of induction motor controller system is cheaper. It may trade off power efficiency and noises problem issues but this is a good approach to learn PWM inverter for motor controller hands-on.

This paper is written as part of process in developing adjustable-speed drive for induction motor. By using op-amp and passive components, the circuit is able to run the experimented linear control of induction motor at rated speed. Analysis on the system performance is made and discussed briefly in this paper.

2. Methodology:

As summarized in Fig. 2, the process is started with design and verification in software environment. In design stage, values of components are adjusted empirically based on component available. Next, actual circuit connection is made and functional test is run.

Prior to the induction motor integration, PWM signals are isolated with opto-coupler before connected with 3-phase bridge driver. Functional and timing test is run after driver is connected. Timing test is important to ensure "deadtime" event is compensated in every switching period of the 3-phase inverter's switches lag.

It may takes sometime of troubleshooting before the circuit it functioning accordingly. In this experiment, problems is occurs due to poor printing quality of PCB board and untidy circuit connections; short circuit and

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neutral point is often confused that cause numbers of ICs to burn or blow off. The building power supplies also interrupted because separated circuit breaker is not available for the experiment.

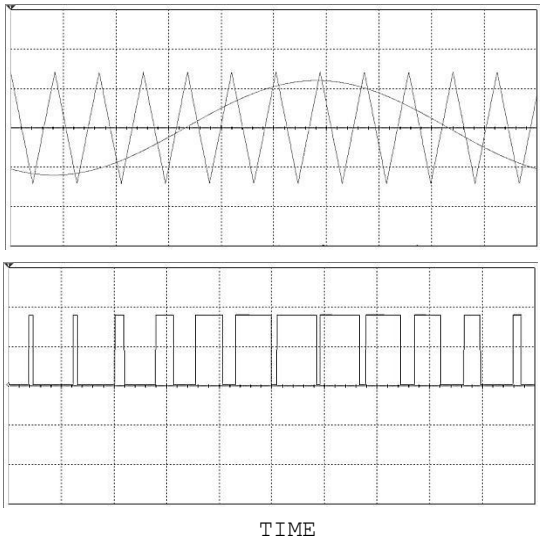


Fig. 1: Simulated PWM circuit

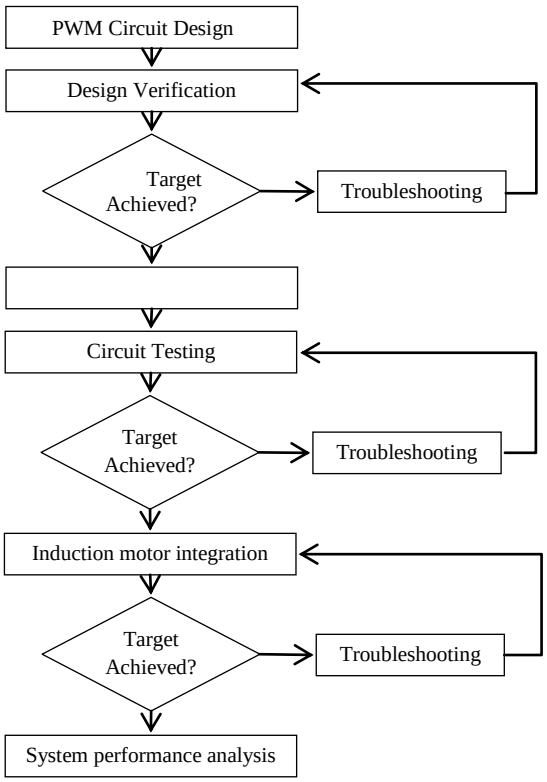
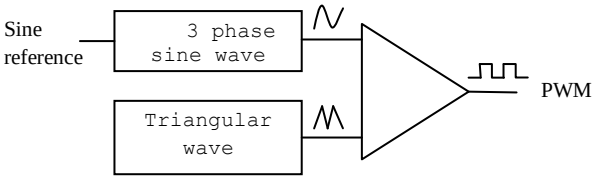


Fig. 2: Developing process

PWM Circuitry:



PWM (Pulse-Width-Modulation) circuit is designed using discrete components with NI Multisim. Singlereference phase of sinusoidal wave is buffered first to isolate the input processing circuit and source. It is the inverted back and shifted using op-amp and resistor to produce balanced 3-phase sinusoidal waves.These waves is generated with LM324 IC that consists of four (4) op-amps is used in this process based on Equation 1 to 3.

$$V_{sw1}(t) = \sin 2\pi t \quad (1)$$

$$V_{sw2}(t) = \sin(\frac{2\pi}{3}t) \quad (2)$$

$$V_{sw3}(t) = \sin(\frac{4\pi}{3}t) \quad (3)$$

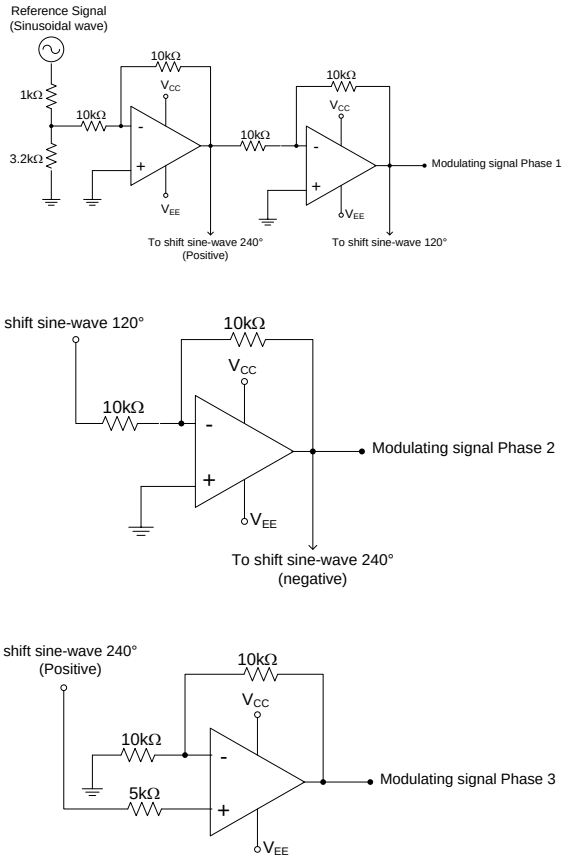


Fig. 3: 3-Phase modulating signal

Center-aligned triangle wave is generated using TL082 IC that consists of two (2) op-amps. It is derived from one phase of the sine-wave according to Equation 4.

$$V_{tw}(t) = \frac{8}{\pi^2}\sum_{k=0}^{\infty} -1^k \frac{sin((2k+1)t)}{(2k+1)^2} \quad (4)$$

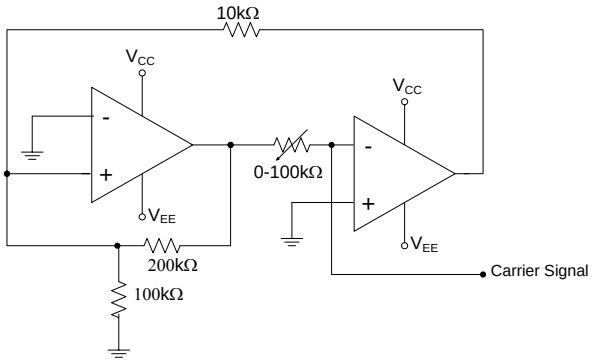
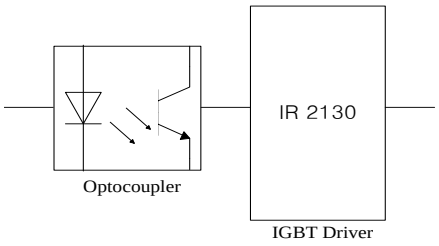


Fig. 4: Carrier Signal

Finally, the sinusoidal waves (modulating signal) and triangle wave (carrier signal) are compared using LM311 IC to generate 3-Phase PWM signals. Fig. 1 shows the single-phase SPWM signal of the designed circuit simulated in multisim.

Induction Motor Integration:



Six (6) IGBTs implemented using three (3) units of SEMIKRON SKM200GB123D arranged by pairs as shown in Fig. 5 is connected with PWM circuit through opto-coupler MCT2E and IR2130 3-phase bridge driver. The center on each lag of IGBT is tapped to be connected to each phase of induction motor.

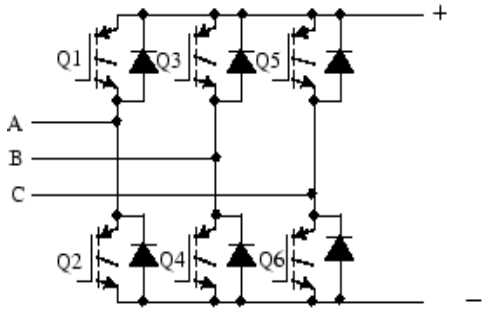


Fig. 5: 3-Lags of IGBT configuration in power inverter

RESULT AND DISCUSSION

Experimental Result:

Although circuit analysis is not covered in this paper, it is obvious that resistive and inductive element of induction motor produces noises especially at starting point. This effect could be observed as PWM circuit is connected to the load. Carrier signal is disturbed. Hence, adjustment to maintain V/Hz ratio of carrier and modulating signal is necessary to be made in real time. Table 1 summarized induction motor parameter obtained from typical motor tests; dc-test, no-load test and block rotor test.

Table 1: Induction motor Parameters

Induction motor ratings	1HP, 240V,50Hz, 1.86A, 1450rpm, 4-pole, 3-Phase, Y-connected
Induction motor parameters	R_s=12.85Ω R_r=265.67Ω, X_m=j77.47Ω, X_{ls}=j6.69Ω, X_{lr}=j10.01Ω

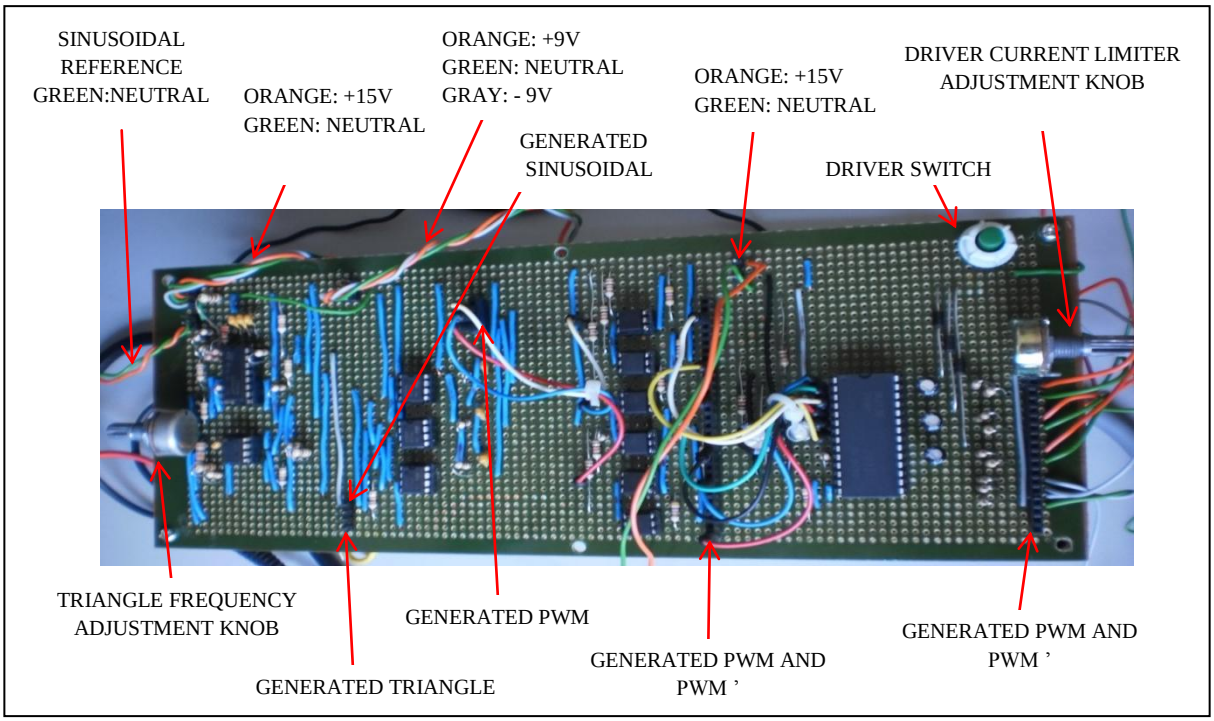


Fig. 5: SPWM circuit

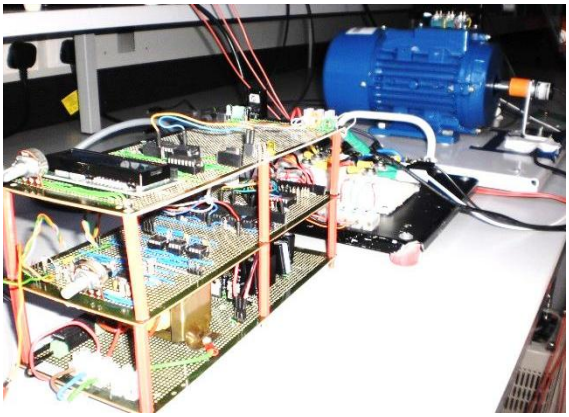


Fig. 6: Tested PWM circuit for 3-phase induction motor inverter

DC-Link that supplies power to the inverter made of rectifier with filtering unit. Carrier signal is adjusted manually to maintain $f_c/f_m = 3K$ ($K \in N$) modulation index is at 0.86. Maximum 5A current is limited at the DC-link and this induction motor could run at $80V_{dc}$ at synchronous speed.

Conclusion:

SPWM controller has been designed and implemented for induction motor. The cost of implementation is low as compared to digital implementation. It is also help for better understanding of power converter in machinery application. This system could be applied into application that requirement of precise speed control is not crucial.

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