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Simulation of Three Phase Sine Wave Generation for Pulse Width Modulation (PWM)

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***Abstract*- The sinusoidal pulse width modulation (SPWM) principle is widely used to control the power switches used in DC to AC inverters. In a three phase PWM inverter, three sinusoidal reference waves (each 120º out of phase) are compared with a triangular carrier wave. PWM are used in motor control and inverter application in order to control the operating state of the power switches. In this paper, three phase sine wave generation is presented in detail. It can be used as a component of PWM in 3 phase DC to AC inverters. Simulation is carried out by using PROTEUS (software).**

***Index Terms*-** SPWM, DC to AC inverter, sinusoidal reference wave, triangular carrier wave.

I. Introduction

The PWM technique is one of the most popular new techniques. Harmonics are reduced by this technique for inverter. In PWM, a triangular wave is used as carrier signal and three sine waves displaced with 120º phase difference are used as reference signals for three phase inverter. The frequency of reference signal determines the inverter output frequency and its peak amplitude controls the modulation index and output voltage [1].

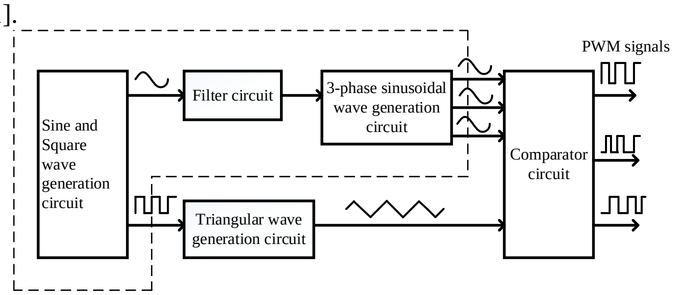

Fig.1.Block circuit diagram of 3-phase PWM control circuit

In figure 1, reference 400Hz waveform signals are generated by the sine and square wave generation circuit [2]. The sine wave signal is applied to the filter circuit to emphasize signals in certain frequency ranges. The output of the filter circuit is applied to the three phase sine wave generation circuit to produce three phase sinusoidal wave signals of 400Hz, 120º out of phase. The square waveform signal is applied to the triangular wave generation circuit to produce a synchronous triangular signal. In comparator circuit, the three phase sinusoidal signals are compared with the triangular signal and the results are PWM signals. In this paper, sine and square wave generation circuit, filter circuit and three phase sine wave generation circuit are presented in detail. Voltage controlled oscillator (VCO) ICL8038 is used in wave generation circuit and TL074 Op-amps are used in filter circuit and three phase sine wave generation circuit.

II. Three Phase Sine Wave Generation

A. Waveform Generation

The first stage is to produce waveforms. Voltage controlled oscillator (VCO) ICL8038 is used in wave generation circuit. ICL8038 is capable of producing high accuracy sine, square, triangular, sawtooth and pulse waveforms with minimum of external components [3]. Fig.2 illustrates the schematic diagram of ICL8038 for producing a sine wave signal with 400Hz.The frequency of this circuit can be selected externally from 0.001Hz to more than 300KHz.The ICL8038 output is stable over a wide range of temperature and supply voltage.

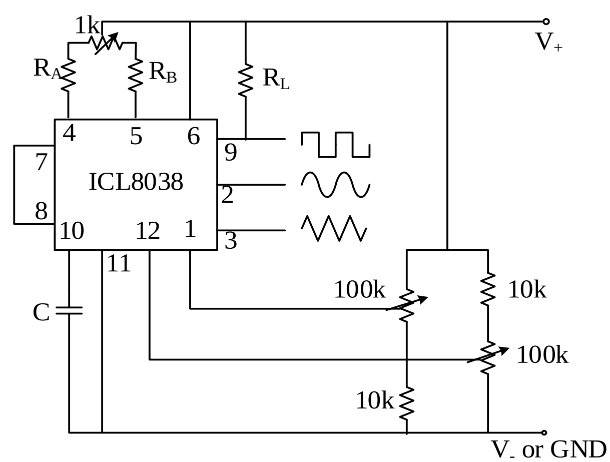

Fig.2 Schematic diagram to achieve minimum sine wave distortion

The symmetry of all waveforms can be adjusted with external timing resistors R_A and R_B. Two potentiometers can be connected to pin 12 and pin 1, this reduces sine wave distortion close to 0.5%. In this ICL8038, 50% duty cycle is achieved when $R_A = R_B$. A 1KΩ potentiometer may not allow the duty cycle to be adjusted through 50% on all devices. If a 50% duty cycle is required, a 2KΩ or 5KΩ potentiometer should be used. The output frequency of ICl8038 is [3];

For two separate timing resistors,

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$$f = \frac{1}{\frac{R_A C}{0.66}\left(1 + \frac{R_B}{2R_A - R_B}\right)} \quad (1)$$

For $R_A = R_B = R$,

$$f = \frac{0.33}{RC} \quad (2)$$

Capacitor, C should be chosen in possible range. The magnitude of the charging current is;

$$I = \frac{0.22(V_+ - V_-)}{R_A} \quad (3)$$

If I<1µA, circuit leakages will contribute significant errors at high temperature .If I>5mA, saturation voltages will contribute increasingly larger errors. Optimum performance will be obtained between 10µA and 1mA.

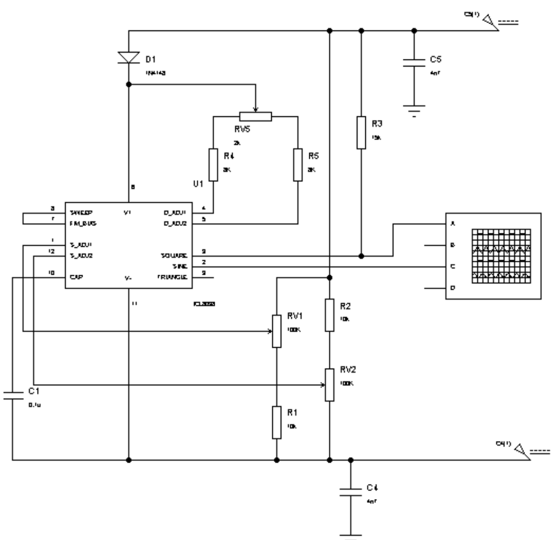

Fig 3.Simulation diagram of waveform generation circuit

B .Filter Circuit

Filters are often used in electronic systems to emphasize signals in certain frequency ranges. This allows us to completely separate signals at different frequencies from one another. There are five types of filters namely; low pass filter, high pass filter, band pass filter, band reject filter (notch filter) and all pass filter. The band pass filter is used for filtering in this paper.

Band pass filter is a combination of high pass and low pass filter [4]. It is used to separate a signal at one particular frequency, or a range of signals that lie within a certain "band" of frequencies from signals at all other frequencies.

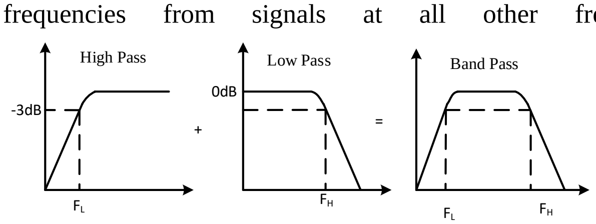

Fig 4. High pass, Low pass and Band pass filter

It can pass a band of frequencies between a lower cut-off frequency, F_L and upper cut-off frequency, F_H and rejects at other frequencies. The bandwidth is the difference between the upper and lower -3dB points.

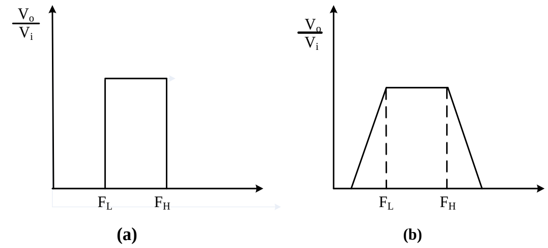

Fig 5. Frequency responses curves for band pass filter

(a) Ideal case

(b) In practical

In band pass filter circuit, TL074 op-amps are used. The TL074 op-amps are high speed JFET input single operational amplifiers [5]. These devices features are high slew rates, low input bias and offset current, low noise, low harmonic distortion and low offset voltage. The values of capacitors and resistors in the circuit are calculated from,

$$f = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}} \quad (4)$$

$$\text{And } A_V(dB) = 40\log_{10}\left(\frac{V_O}{V_i}\right) \quad (5)$$

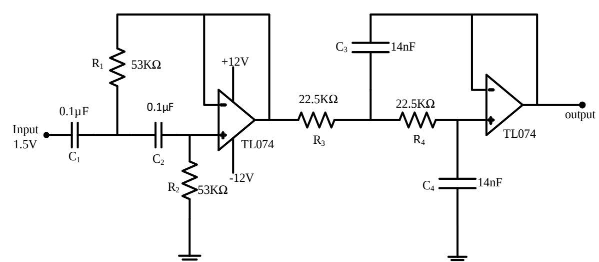

Fig.6 Second order band pass filter

C .Three Phase Sine Wave Generation

All pass filters can be used to generate three phase sinusoidal signals that are 120° out of phase. These output signals are compared with the triangular signal to produce PWM signals. All pass filter let all frequencies pass and their amplitude is unity for all frequencies. Each frequency has a certain phase shift at the output, compared with the input signal. The phase response of all pass filters can be changed between 0° and 360° as necessary.

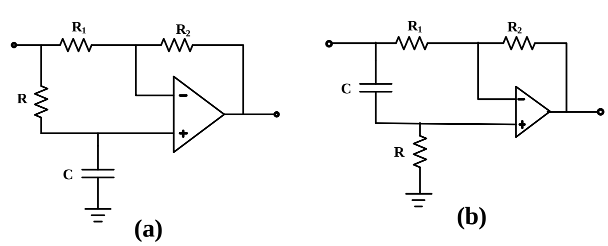

Fig 7.All pass filter

(a)For phase shift from 0° to +180°

(b)For phase shift from -180° to 0°

Resistor and capacitor can be calculated from this equation [6],

$$\Phi = \tan^{-1}\left(\frac{\frac{2\omega}{RC}}{\omega^2 - \left(\frac{1}{RC}\right)^2}\right) \qquad (6)$$

Where; $\omega = 2\pi f$

ϕ = Phase shift in degree

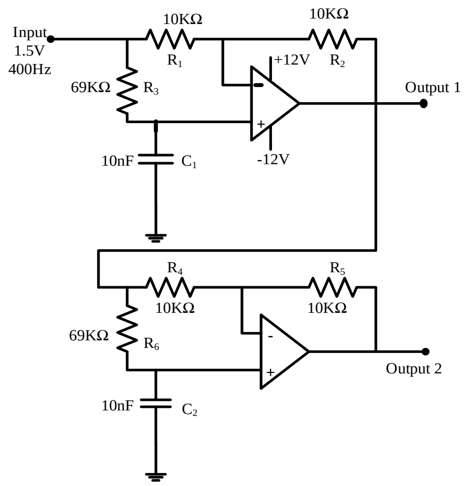

Fig .8 Three phase sine wave generation circuit

III. Simulation and Results

Figure.9 shows the simulation result diagram from waveform generation circuit and fig.10 is the simulation result diagram for band pass filter and Fig.11 illustrates the frequency response curve for band pass filter. In any case, the pass band limits are usually assumed to be the frequencies where the gain has dropped by 3dB. These frequencies are therefore called -3dB or the cut-off frequencies. From the simulation result curve, the maximum is -16.4dB. So, the cut-off frequency is -19.4dB and the pass band range is between 270Hz and 590Hz. Fg.13 is the simulation result diagram for three phase sine wave generation circuit and fig.14 shows the cascading diagram of waveform generation, filter and phase shift circuits.

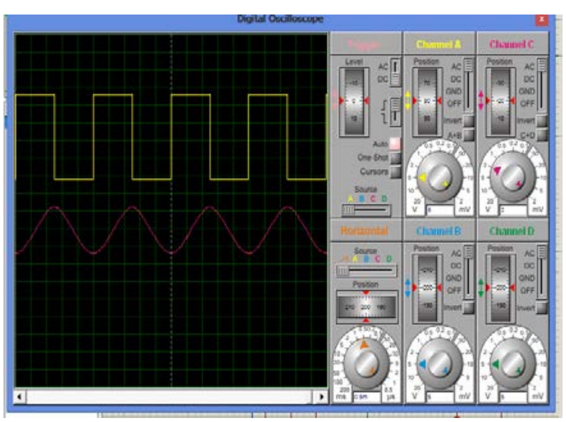

Fig. 9 Simulation result for waveform generation circuit

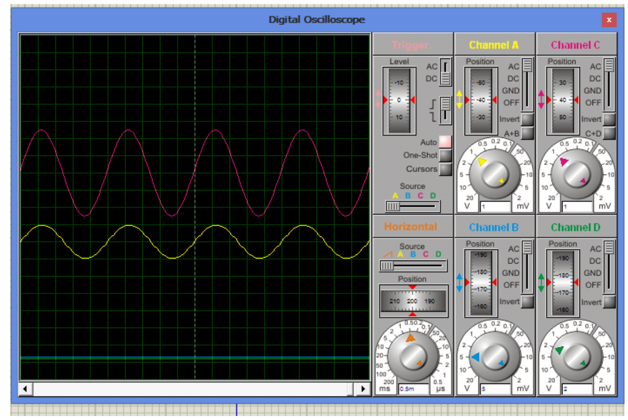

Fig. 10 Simulation for band pass filter

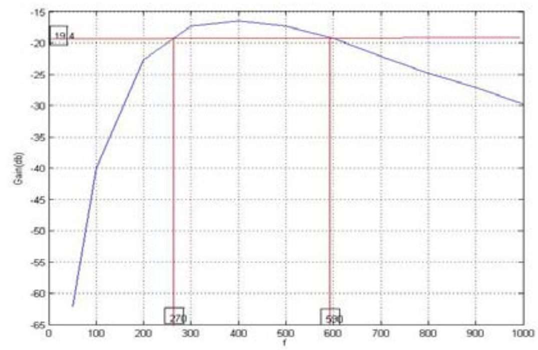

Fig. 11 Frequency response curve (frequency versus gain)

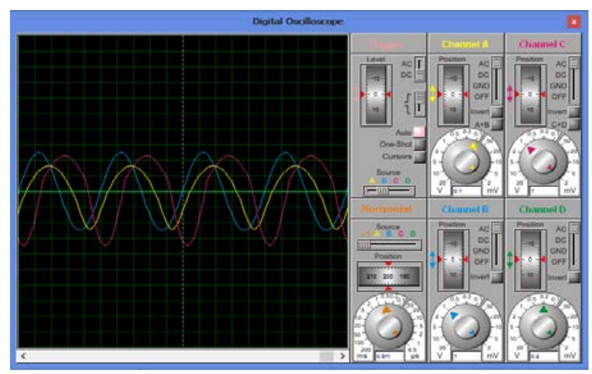

Fig. 12 Simulation result from phase shift circuit for the former design

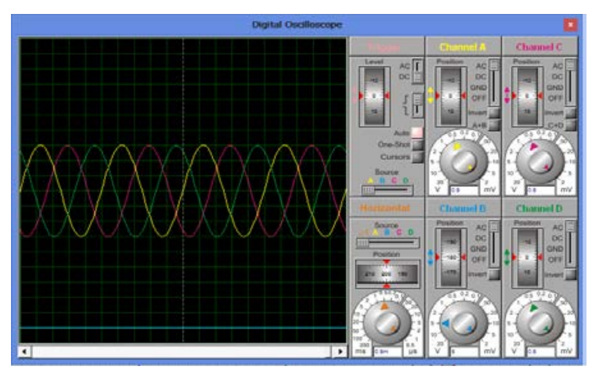

Fig.13 Simulation result for three phase sine wave generation with all pass filter

IV. CONCLUSION

Simple RC passive filters can be used for filter circuits. The main disadvantage of passive filter is that the amplitude of the output signal is less than that of the input signal, i.e., the gain is never greater than unity and the load impedance affects the filter characteristics. Active filters contain active components such as Op-amps, transistors or FETs within their circuit design. These active components draw their power from an external power source and use it to boost or amplify the output signal. Active filters are generally much easier to design than passive filters, they produce good performance characteristics, very good accuracy with a steep roll-off and low noise. Active filters use an op-amp for amplification and gain control.

The low pass filter passes all frequency below its cut-off frequency and attenuates all frequency above. The high pass filter passes only those frequencies that lie above designated cut-off frequency. The band pass filter passes only those frequencies lying within a range specified by upper and lower cut-off limits. So the band pass filter is suitable for filtering a range of signal/frequency.

For phase shift transformation, other phase shift circuits can also be used. But 120 degree cannot be provided definitely by these circuits and the output amplitude is not unity. All pass filters are suitable for any phase shift and their amplitude is unity for all frequencies. It can get definitely degree as necessary. It has simple design and easy to use.

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