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Design and Implementation of Cosine Based Firing Scheme for Single Phase Converter

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ABSTRACT

The non-linearity associated with any sort of converter has been one of the key issues when dealing with it, since it renders its control highly susceptible to even minor disturbances. The use of a synchronised cosine signal as the carrier signal to generate PWM pulses is one of the most common methods used by industries to reduce the adverse effects of nonlinearity on system stability and closed-loop response, as it linearizes the transfer characteristics between input and output. In this procedure, the negative consequences of the rectifier's intrinsic nonlinear behaviour are balanced.With the help of hardware components such as a comparator, timer, and flip-flop, describe the development and use of cosine carrier wave signals. These hardware components degrade the system's reliability and complexity while slowing down its response.... The cosine signal is obtained from and synced to the converter AC input voltage, and its phase is set to peak at the earliest possible commutation angle(i.e.α) of the related switch

1.INTRODUTION

Thyristors, also known as Silicon Controlled Rectifiers (SCRs), are commonly employed as a switching device in medium and large power applications, ranging from a few kilowatts to several megawatts at voltages ranging from a few hundred to several kilovolts. Despite having faster switching characteristics than SCRs, Bipolar Junction Transistors (BJTs) and Metal Oxide Semiconductor Field Effect Transistors (MOSFETs) are limited to medium power levels at a few hundred volts.Insulated Gate Bipolar Transistors (IGBTs) are positive-point switching devices that are superior to MOSFETs and thyristors. SCRs are still a superior choice today due to their higher cost and inability to perform at very high voltages. We have built a low-cost firing circuit for singlephase line commuted converters in this project.

1. Thyristor & its conduction

A thyristor, often known as an SCR, is a four-layer device with three junctions: J1, J2, and J3. For external connections, there are three terminals: anode, cathode, and gate, as indicated in Fig. 1 (below). Figure 1 depicts the conditions under which a thyristor will either conduct or not conduct, that is, whether it will allow current to flow or not. Regardless of whether or not a gate pulse is present, a thyristor will be in reverse blocking mode if VAK 0. When VAK > 0 in the absence of any gate pulse, the thyristor is said to be in the forward blocking mode, and some current will flow through it.When a thyristor is turned on byeither exceeding the forward break-over voltage or putting a gate pulse between the gate and the cathode, this is referred to as line commutated converters.

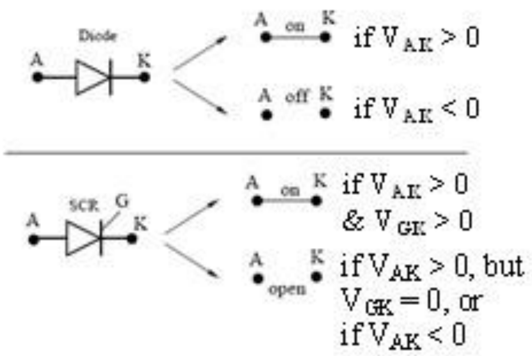


Figure 1 Symbols for Diode and Thyristor

As a result, if we want to use an SCR as a switching device , we must make sure that the gate and cathode get an acceptable gate pulse at the desired moment.

The following are some important thyristor values:
230 V is the voltage rating.
20 A is the current rating.
Time to turn on (TON) - 1 to 2 seconds
TOFF (turn-off time) - around 70 to 100 mA current
a pulse with a duration more than a TON
Conduction voltage drop is approximately 1.2V.
The firing angle, symboled as α, is the number of degrees from the start of the cycle when the SCR is gated or switched on, and the conduction angle is the number of degrees that the SCR remains conducting.

2. Line Commutated Converters

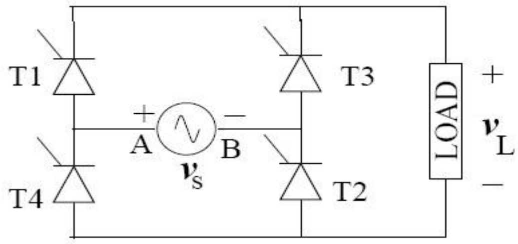


Figure 2. Fully Controlled Converter

A single phase bridge converter with four thyristors or a three-phase converter with six thyristors is used to convert line frequency (50 Hz) a.c. to d.c. Figure 2 depicts a single phase fully regulated bridge with four thyristors. Appropriate pulses between the gates and cathodes of the thyristors T1 through T2 must be provided, with the ability to change the firing angle(α)When VAB > 0 or positive, two diagonally opposing thyristors T1 and T2 are forward biased, while the other two thyristors T3 and T4 are reversed biased, as seen in the single phase converter circuit depicted in Fig. 2. As a result, at intervals (i.e. 00 to 1800), gate pulses are applied simultaneously to T1 and T2, causing them to start conducting and the load voltage VL = VAB, while T3 and T4 are reversed biased and unable to conduct at that time, and vice versa (when T3 and T4 are switched on, VL = VBA).

3.Necessity of getting synchronizing pulses

Figure 3 shows a typical supply voltage waveform with the appropriate gate pulses. It is obvious from Figure 3 how the firingangle is to be fixed and measured

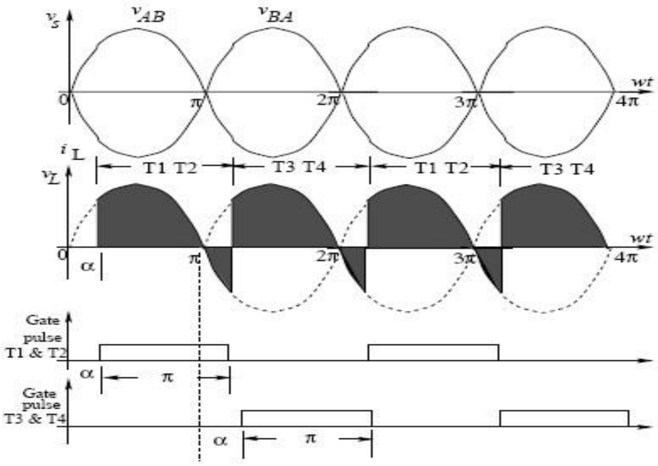


Figure 3. Typical waveforms of a single phase converter

T1 and T2 should be measured from the point where VAB is zero and increasing towards positive. Similarly, T3 and T4 are to be monitored from the point where VBA is zero to the point where it is positive. As a result, the gate pulses must be appropriately timed with the a.c. power supply for the fully controlled bridge to operate successfully. It should be remembered that each thyristor only conducts for 1800 milliseconds.

4.Using cosine control

The supply voltage Vs is first integrated to create a cosine wave in this fascinating approach, as shown in Fig. 5. A reference dc. voltage is used to compare the cosine wave (Vref). As a result, at the comparator's output terminal Y, square pulses will be created. The signal at Y is synced with the pulse and is shifted by an angle from the supply zero crossing. The value of can obviously be changed between 00 and 1800.

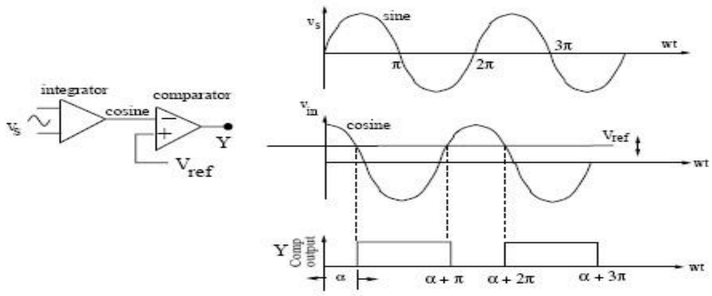
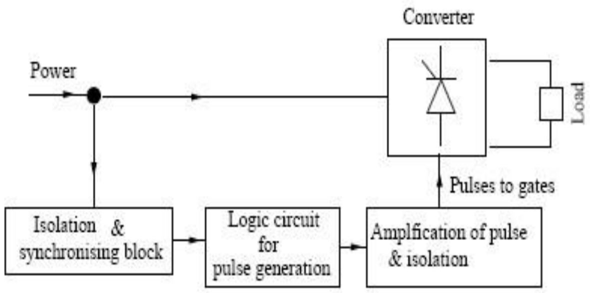


Figure 4 . Basic idea of cosine control scheme

5.Basic building blocks

Figure shows the basic blocks that will be required to execute any fire control method in a converter circuit. The picture depicts the major blocks required to generate firing pulses for any design using a single line diagram. A.c. power is used to power the converter. Because the firing pulses must be synced with the a.c. supply, the isolation and synchronisation blocks also receive a.c. power. Because the control circuit relies on it, isolation is critical.Devices with very low power consumption, such as chips, logic gates, and so on To implement a specific firing scheme, the logic circuit block employs alimited number of logic gates. Because the power of the pulse generated by logic gates may be insufficient to drive the gate of a thyristor, amplification and isolation are utilised at the final stage, as shown in Fig.



REPRESENTATION OF THE COSINE CONTROL SCHEME IN BLOCK DIAGRAM:

The implementation of a cosine control technique is the focus of this paper. We'll start with a block diagram of the plan and then go over each block in depth. Let Vab be the converter's supply voltage for which the control pulses are to be generated. Vab is converted into two power level voltages, Va0 and Vb0, using a step down centre tapped transformer. Va0 and Vb0 will be 180^0 out of phase for obvious reasons, as shown in Fig.

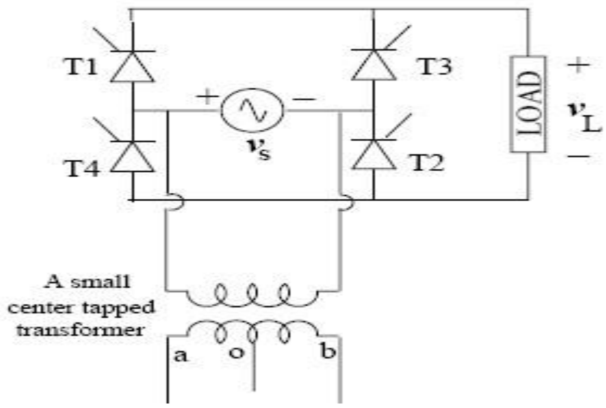


Figure 6 . Generating Va0 and Vb0

When Va0 is positive, T1 & T2 are to be fired, and when Vb0 is positive, T3 & T4 are to be fired. The firing angle for T1 and T2 should be measured from the point where Va0 is zero and increasing in the positive direction. The range of possible values for is 00 to 1800. Similarly, the firing angle for T3 and T4 should be measured starting at zero Vb0 andincreasing in the positive direction. Figures 6,7 show the basic concept for generating the requisite pulses for T1 & T2 and T3 & T4.

The signal Va0 is integrated with the help of Integrator -1 to produce a cosine wave, as seen in Fig . A comparator-1 compares this cosine wave to a variable d.c. voltage Vr.

Given that Vr is connected to the comparator-1's +ve terminal, the output of the comp-1 will be square wave, and it will go to high state as soon as Vr exceeds the cosine voltage value. The pulse width, on the other hand, will change when Vr is changed. Our initial goal will be to increase the pulse width to 180^0This is done in the following manner. The Comp-1's output is routed through a block mono-1. The mono's output will be a small-width pulse at the input square wave's positive going edge. Mono-1's output will thus produce little pulses spaced by 360^0With the help of comparator-2, the voltage Vb0 is similarly processed, i.e., it is integrated and then compared with the same variable d.c. The output of COMP-2 will be a square wave, shifted by 180^0 from the output square wave of COMP-1. This is dueto the fact that Vb0 is180^0 points behind Va0. The COMP-2's output is now routed through a block mono-2. The mono-2 output will be a small-width pulse at the positive going edge of the input square wave.Small pulses separated by 360^0 will be produced by MONO-2's output. It's crucial to note that the fixed width pulse waveforms at the output of mono-1 and mono-2, as illustrated in Fig. 9, have been moved by180^0.Mono1 and mono-2 outputs can be used in conjunction with two S-R flip flops to generate two square waves, each with a set width of$180^0$and 180^0 spacing between them.

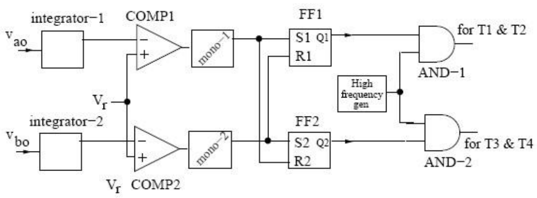
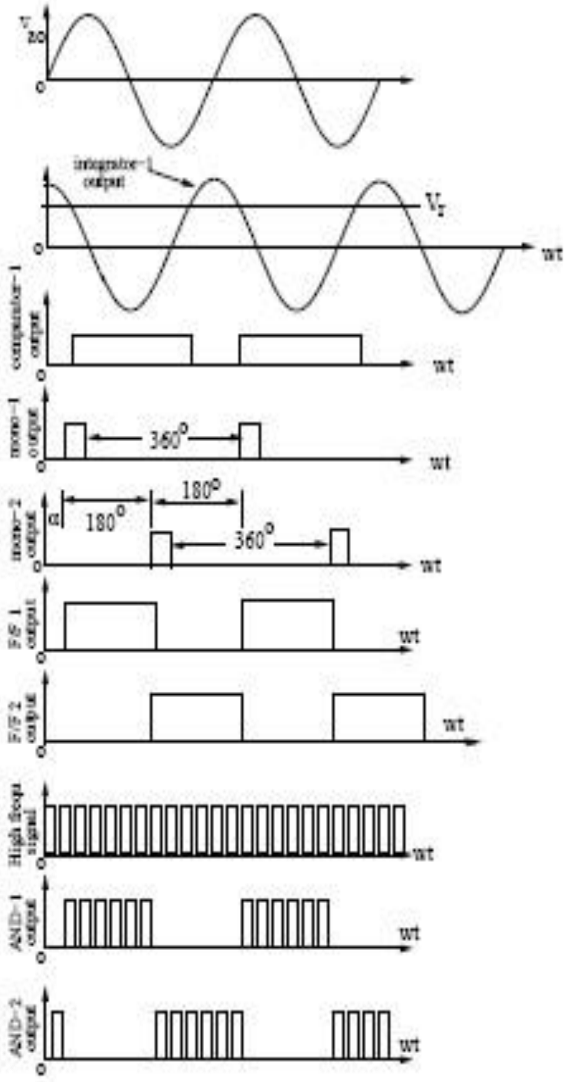


Figure 7 . Basic blocks for cosine control scheme



DESCRIPTION OF THE EACH BLOCK:

Each block will be covered in detail in this section. The types of components employed, as well as their connections, will be discussed.

Input transformer to get V_{a0} and V_{b0}

As indicated in Fig. 1, a 220/6-0-6 V 50 Hz control transformer is used for the purpose of stepping down the 220 V supply to a level of 6-0-6 V using the centre tapped secondary.

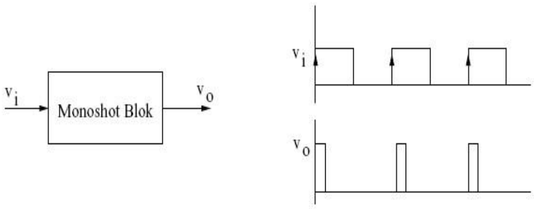


Figure 8 . Input transformer for the control circuit

Integrator to get cosine wave:

The popular IC 741 is used, along with some resistors and capacitors, to create an integrator. Figure 1 shows the values of several circuit parameters. The chip requires a 12 V d.c. supply, which is provided from a separate d.c. source. The d.c. supply's ground point is linked to the centre tapped transformer's common ground point zero (0). Signal V2
$v_2 = \int v_{ao}\, dt$ will be obtained by integrating small V1, i.e., small V2 $v_2 = \int v_1\, dt$will be obtained for our purposes.As previously stated, another identical integrator is utilised to integrate Vb0.

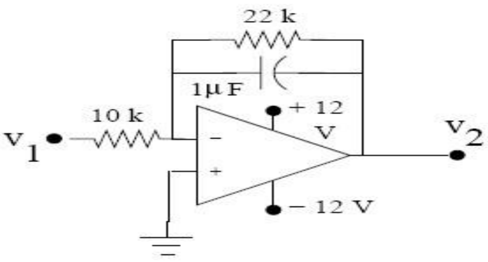


Figure 9 . Integrator using OP AMP 741

Comparator producing variable width pulse:

By inverting terminal IC 741, the variable d.c. voltage, an OP AMP (741 IC) is utilised to implement the comparator block. The cosine signal is produced from the output of the integrator block as connected when Vr is supplied to the non inverting or positive terminal. The output of a 10 K variable resistor terminal is used to power Vr. The 12 V supply is used as the pot's input, as indicated in Fig.

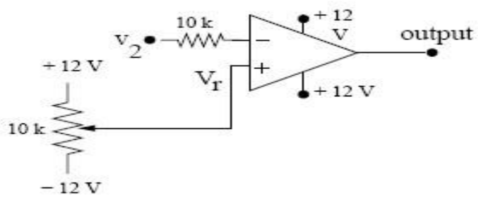


Figure 10 . Comparator using OP AMP IC 741

Monoshot block using Exclusive OR Gate:

When the input rectangular input signal Vi changes state from 0 to 1, a Monoshot block is expected to create thin pulses. In Fig. 13, a Monoshot block is depicted with input signal Vi and the required output signal V0The Monoshot is implemented in an interesting approach

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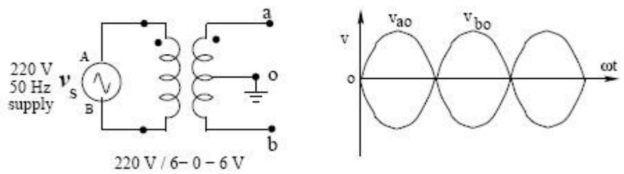
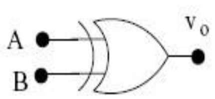


Figure 11 . Characteristics of a Monoshot

approach in this project work under this paper by employing Exclusive OR Gate. Figure 14 depicts the truth table and depiction of the Exclusive OR Gate. When one of the inputs is high (1) or oddmatching with the others, the output is high or 1, and when both inputs are the same or even nature, the output is low or 0.



A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

Figure 12. Exclusive OR Gate & its Truth Table

SR Flip flops to get 180^0 width pulse:

The variable width pulse obtained from the comparator output is converted into a train of thin pulses separated by 360^0 at the Monoshot output in Fig , as shown in the previous section.

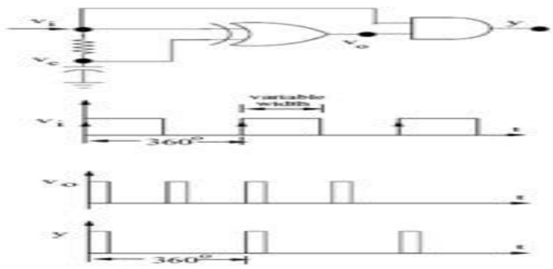


Figure 13 Final circuit for Monoshot

ANDing the rectangular pulse with frequency using 555 timer :

The complimentary rectangular voltage signals obtained from flip flops 1 and 2 are separated by 1800 as intended. The time period of the signals will be 20 ms in our situation where the supply frequency is 50 Hz, and they will be high for 10 ms and low for the remaining 10 ms. Flip flop outputs, on the other hand, cannot be directly linked to the gate and cathode of a thyristor because the output from a TTL (Transistor-Transistor-Logic) chip will not be able to give the necessary current to the gate circuit of a thyristor. Apart from that, isolationThe two aims of intensifying the pulse and providing isolation are thereby satisfied with the use of a transistor and a pulse transformer. Figure depicts the concept. between the control and power circuits is required.

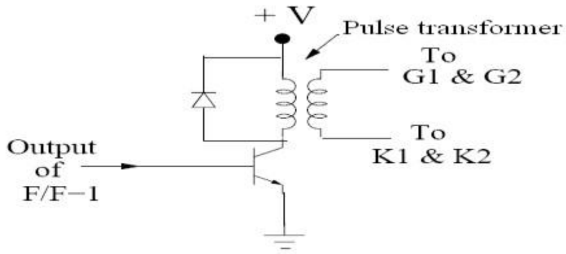


Figure 14 . Showing amplification & isolation circuit

Power supply circuit (±12 V):

In order to power the different chips employed, a 12 V d.c. power source is necessary, as can be seen from the circuit in Fig.Standard power supplies are used to make the setup self-sufficient.Chips with the IC 7812 and IC 7912 codes are utilised inin combination with a transformer with a centre tap, diode bridgecapacitors for the rectifier and filter as depicted in Fig.

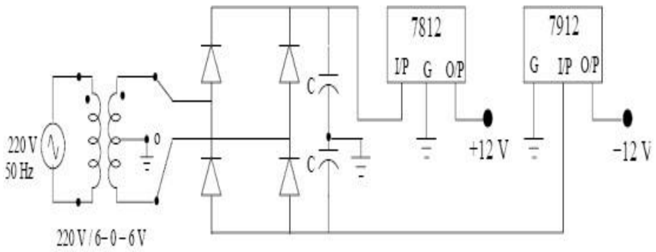


Figure 15 . Circuit for ± 12 V Power supply

Complete circuit diagram:

Putting all the blockstogether, the complete connection with circuit diagram of the circuit is shown in Fig

Practical firing Circuit :

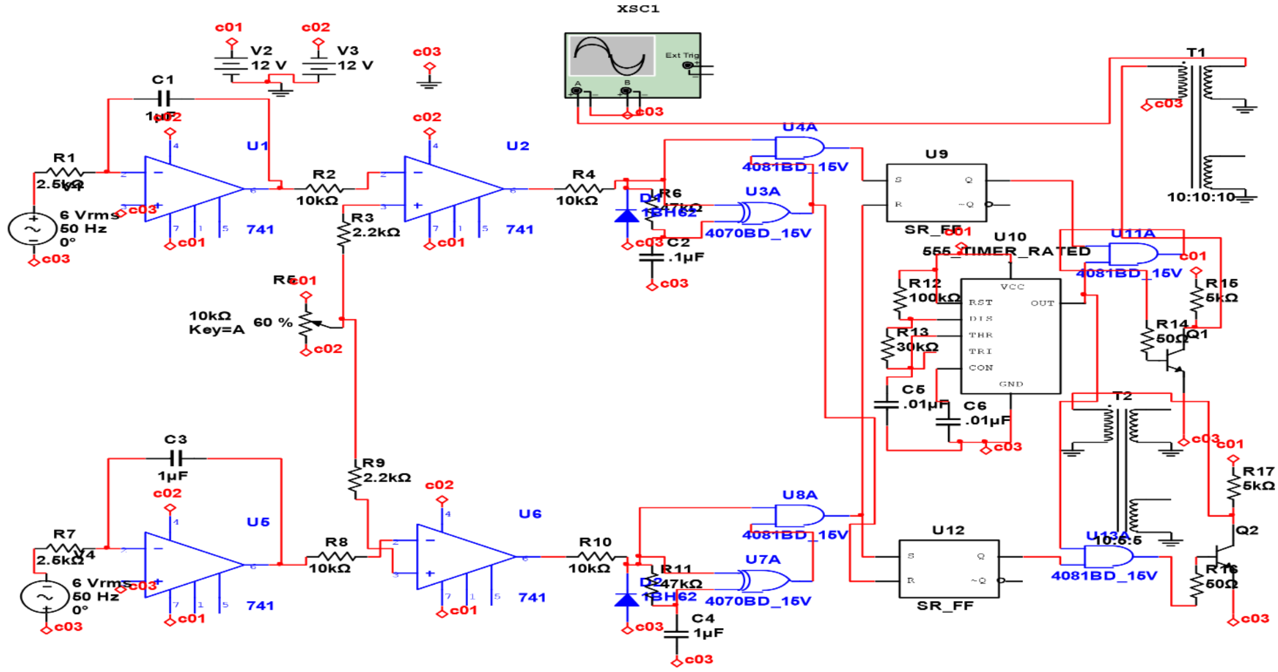


Figure 16 . complete circuit diagram

Components used:

The circuit is made up of the following components:

i. Two center - tapped transformers: 220 V/ 6-0-6 V
ii. Two IC 741 OP AMPs for two integrators, one of which corresponds to Va0 and the other to Vb0.
iii. Two IC 741 OP AMPs for two integrators one of which corresponds to Va0 and the other to Vb0..
iv. For two comparators, two IC 741 OP AMP
v. A single IC 4070 with four EX-OR gates. v. A single IC 4081 with four AND gates.
vi. A single IC 4043containing four SR flip flop gates
vii. One 555 timer for high frequency pulse generation.
viii. The number of resistors and capacitors in various configurations As indicated in the circuit, the values are as follows.
ix. A few diodes to create a 12 V power supply and to clip the negative half of the rectangular pulse obtained at the comparator's output.
x. One 10 Kohms pot to control the d.c. voltage Vr. For changeable d.c. voltage Vr.
xi. For a 12 V supply, two rectangular power supply chips with the numbers For a 12 V supply, there are two rectangular power supply chips numbered IC 7812 and IC 7912...

Hardware Results:

Firing pulses using Cosine control is implemented on hardware. The experimental results at different stages are discussed.

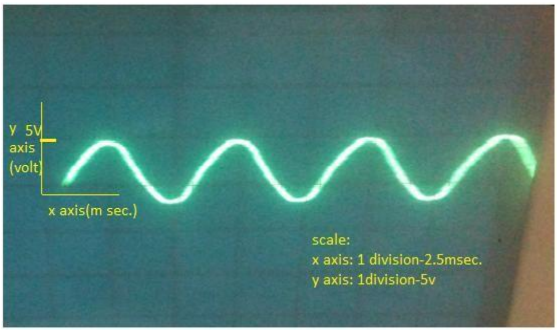


Figure 17 . (a) Waveform of Va0

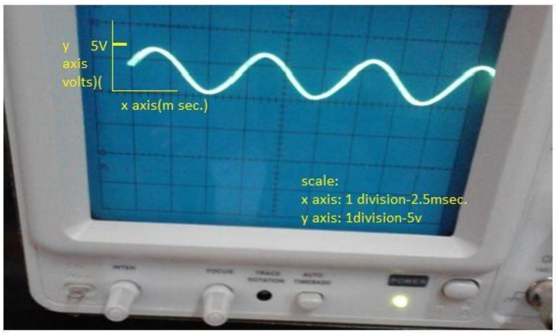


Figure 18 (b) cosine wave generator1

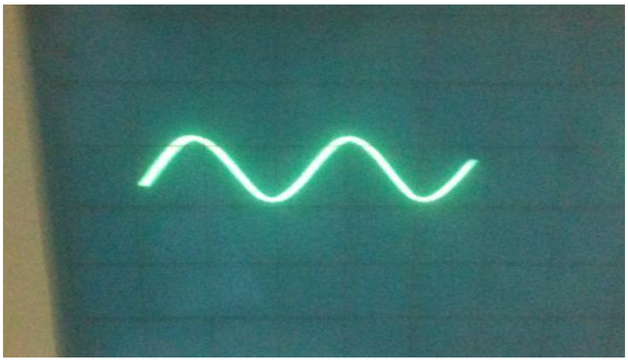


Figure 19 . (c) Waveform of Vb0

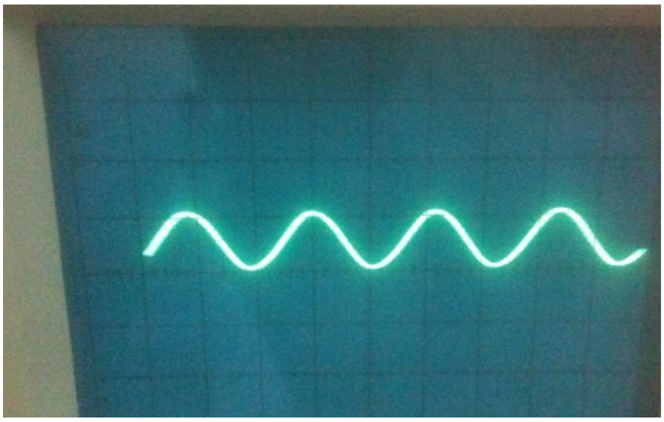


Figure 20 . (d) Waveform of cosine wave gegerator-2

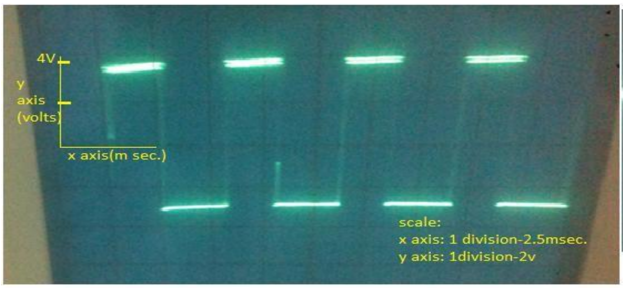


Figure 21 . (e) Waveform of comparator-1

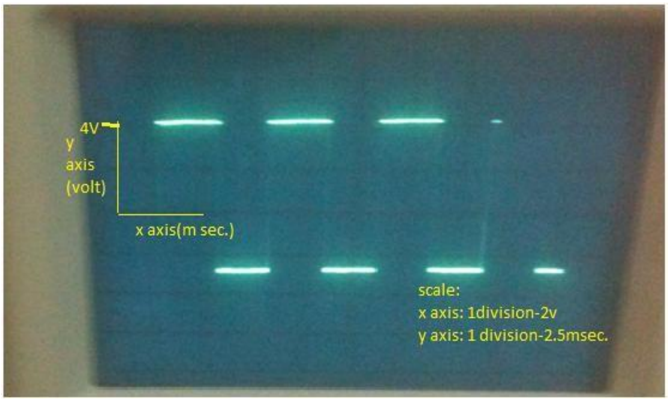


Figure 22 . (f) Waveform of comparator-2

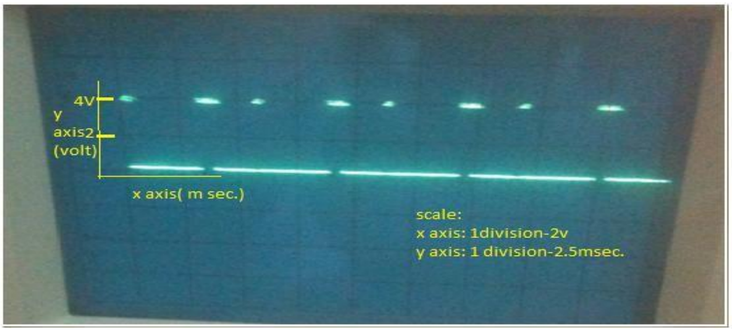


Figure 22 .(g) Waveform of EX-OR gate-1

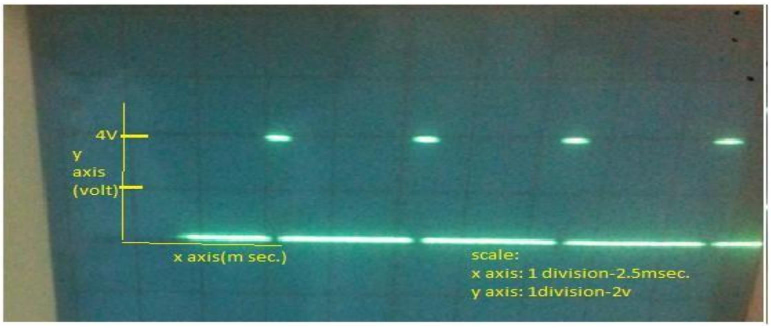


Figure 23 . (h) Waveform of EX-OR gate-2

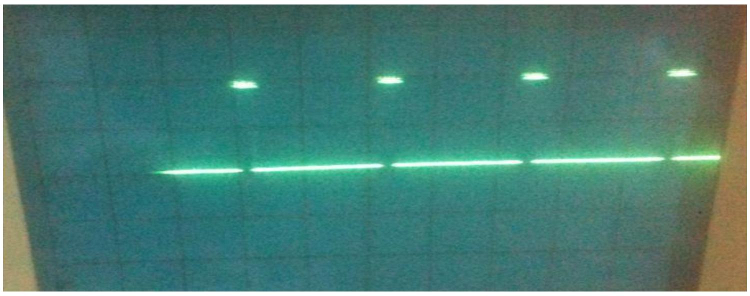


Figure 24 . (i). Waveform of first AND gate of monoshot block-1

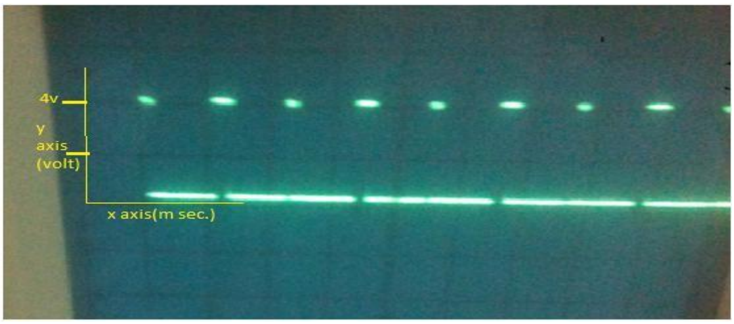


Figure 25 . (j). Waveform of first AND gate of monoshot block-2

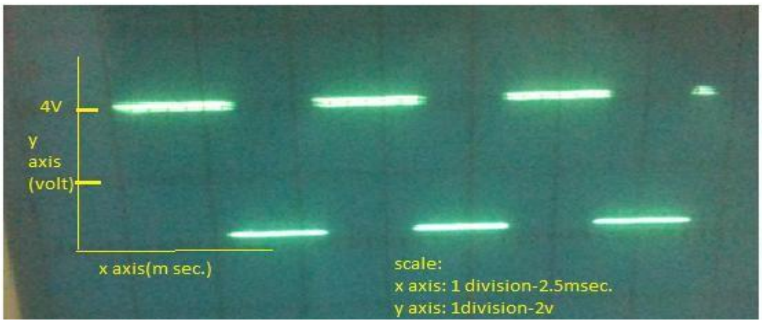


Figure 26 . (k). Waveform of SR flip-flop-1

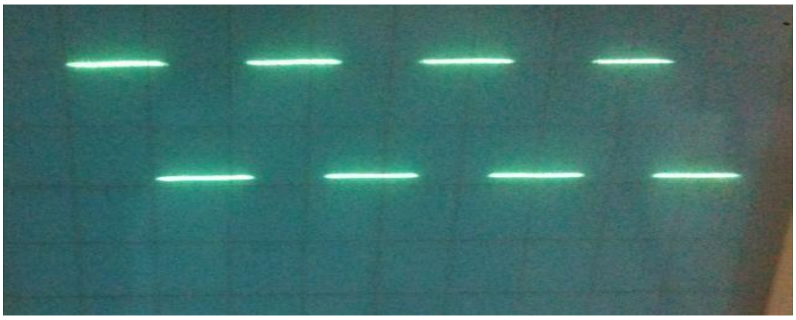


Figure 27 . (l). Waveform of SR flip-flop-2

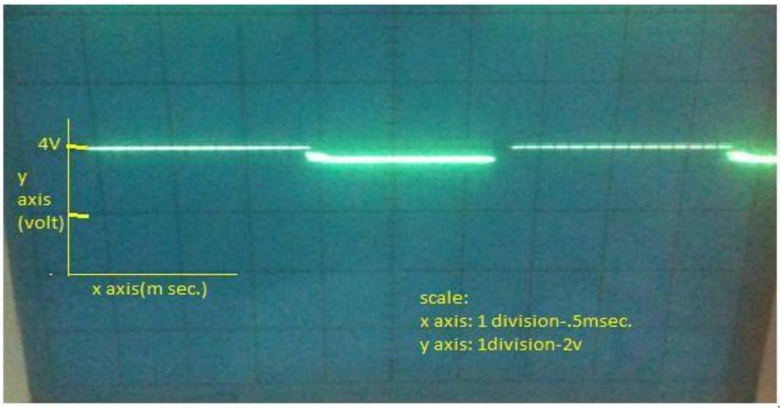


Figure 28 . (m) Waveform of 555 timer

CONCLUSION

Resistors, capacitors, and IC chips are used in this project to construct the firing circuit on a PCB board. We are trying to complete the job while the firing circuit is being tested in part.This document includes the results of the partial experiment as well as the anticipated outcomes of the entire output. After the project is finished, the firing circuit can be used to regulate single phase rectifier/converters with full control for resistive or inductive loads that require changeable DC voltage

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