# SPEED CONTROL OF INDUCTION MOTOR USING TRIAC

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***Abstract: Single phase induction motor is slightly different than three phase induction motors except that it has no starting torque so we have to make some different arrangements to start. The single phase induction motor has a drawback of self starting though it is widely used in the present scenario due to the reason of low cost and reliability.***

***Index Terms - induction motor, triac, timer 555IC, diac, speed control, pulse transformer***

**INTRODUCTION**

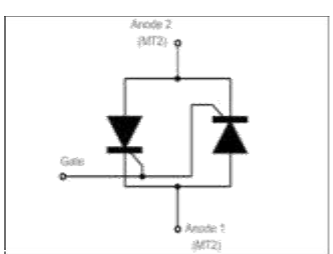
In this paper speed control of induction motor is done using various methods using triac. Different devices are use control gate terminal of triac the devices are 555 timer IC, pulse transformer and diac controlling the firing angle of triac Is done using these different devices the complete control of the circuitry depends on only one parameter that is voltage as we know that direction of the motor torque which is developed is directly proportional to the square of the voltage thus with the help of controlling the voltage in stator terminal by triac and its Gate pulse by increasing the firing angle the voltage is reduced and applied to the motor stator and due to the relation of voltage and torque, speed of the motor is controlled. Induction motor is widely used industrial drives particularly polyphase induction motor because of their property of ragged and having no brushes as a rotor present in induction motor, the power transfers from stator to the Rotor due to electromagnetic induction.

Triac is the three terminal power electronic device which works on all for switching quadrants that is forward blocking mode, forward conducting mode, reverse blocking mode, reverse conducting mode. The triac is basically known as AC voltage controller, triac is three terminal devices which are ANODE1, ANODE2 and the gate terminal. The gate terminal has control on its ON and OFF so it is known as fully controlled device. Triac is basically the to antiparallel thyristors connected which works in both the directions that is why triac is known as a bidirectional switch it has also on and off characteristics which is very much similar to thyristors but characteristics is applicable to both positive and the negative voltages but in thyristor it only is applicable for positive voltages triac works in all four quadrant operation.

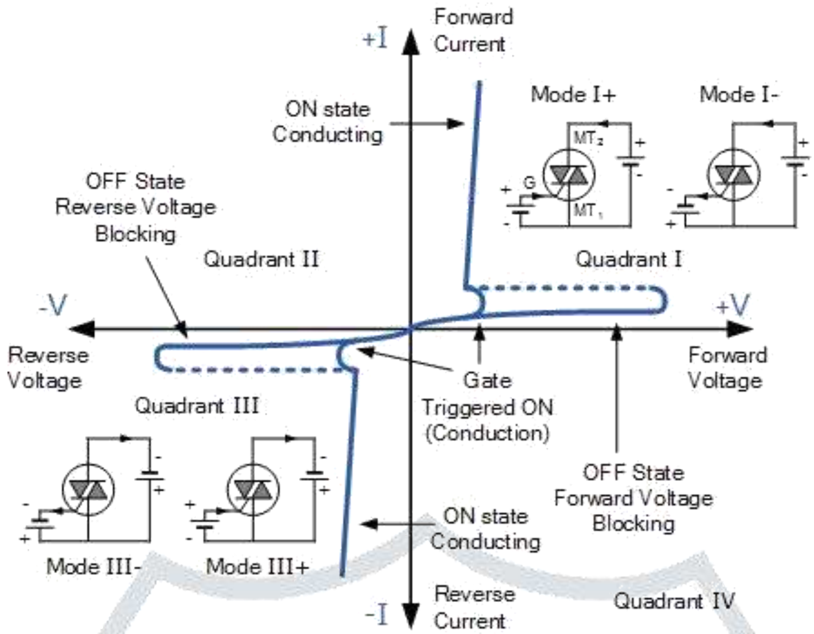
The terminal voltage across the stator winding of the motor can be varied for obtaining the desired speed control by controlling the firing angle of the semiconductor power devices (TRIAC in our project). For any firing angle „α‟ the average output voltage across a TRIAC is given by:

$$V = (2V' \cos\alpha/\pi)$$

V'= INPUT voltage




1. TRIAC SYMBOL




2. CHARACTERSTIC OF TRIAC

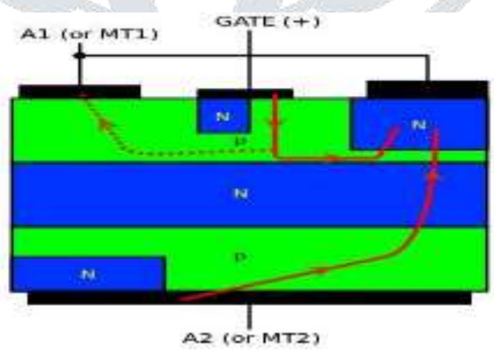
1) **Quadrant I operation: VA2 positive; VG positive**

2) **Quadrant II operation: VA2 positive; VG negative**

3) **Quadrant III operation: VA2 negative; VG negative**

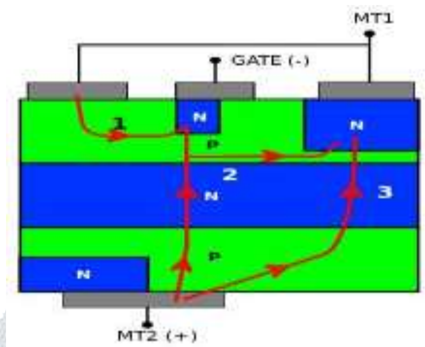
4) **Quadrant IV operation: VA2 negative; VG positive**

*Quadrant 1*: Operation occurs when the gate and MT2 are positive with respect to MT1. The mechanism is illustrated in The gate current makes an equivalent NPN transistor switch on, which in turn draws current from the base of an equivalent PNP transistor, turning it on also. Part of the gate current (dotted line) is lost through the ohmic path across the p-silicon, flowing directly into MT1 without passing through the NPN transistor base. In this case, the injection of holes in the p-silicon makes the stacked n, p and n layers beneath MT1 behave like a NPN transistor, which turns on due to the presence of a current in its base. This, in turn, causes the p, n and p layers over MT2 to behave like a PNP transistor, which turns on because its n-type base becomes forward-biased with respect to its emitter (MT2). Thus, the triggering scheme is the same as an SCR. However, the structure is different from SCRs. In particular, TRIAC always has a small current flowing directly from the gate to MT1 through the p-silicon without passing through the p-n junction between the base and the emitter of the equivalent NPN transistor. This current is indicated in by a dotted red line and is the reason why a TRIAC needs more gate current to turn on than a comparably rated SCR. Generally, this quadrant is the most sensitive of the four. This is because it is the only quadrant where gate current is injected directly into the base of one of the main device transistors.



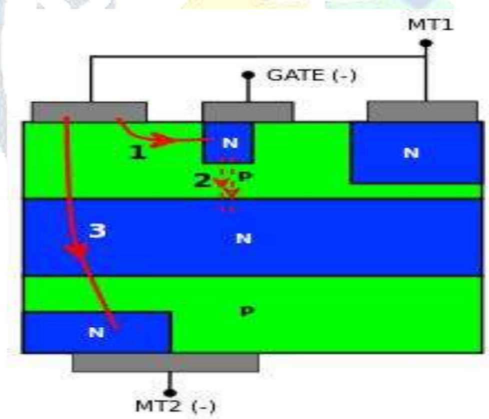

3. QUADRANT 1

*Quadrant 2*: Operation occurs when the gate is negative and MT2 is positive with respect to MT1.The turn-on of the device is three-fold and starts when the current from MT1 flows into the gate through the p-n junction under the gate. This switches on a structure composed by an NPN transistor and a PNP transistor, which has the gate as cathode (the turn-on of this structure is indicated by "1" in the figure). As current into the gate increases, the potential of the left side of the p-silicon under the gate rises towards MT1, since the difference in potential between the gate and MT2 tends to lower: this establishes a current between the left side and the right side of the p-silicon (indicated by "2" in the figure), which in turn switches on the NPN transistor under the MT1 terminal and as a consequence also the pnp transistor between MT2 and the right side of the upper p-silicon. So, in the end, the structure which is crossed by the major portion of the current is the same as quadrant-I operation.



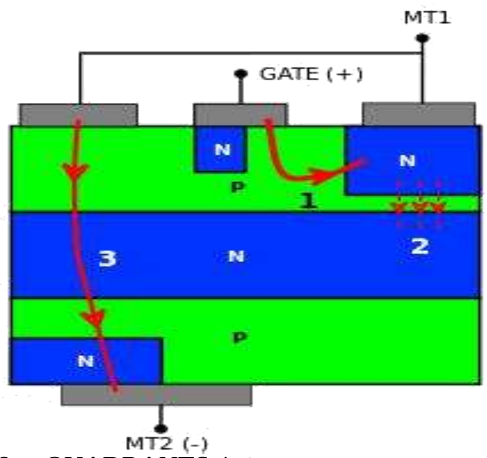

4. QUADRANTS 2

*Quadrant 3* Operation occurs when the gate and MT2 are negative with respect to MT1.The whole process is outlined in Figure 6. The process happens in different steps here too. In the first phase, the pn junction between the MT1 terminal and the gate becomes forward-biased (step 1). As forward-biasing implies the injection of minority carriers in the two layers joining the junction, electrons are injected in the p-layer under the gate. Some of these electrons do not recombine and escape to the underlying n-region (step 2). This in turn lowers the potential of the n-region, acting as the base of a pnp transistor which switches on (turning the transistor on without directly lowering the base potential is called **remote gate control**). The lower p-layer works as the collector of this PNP transistor and has its voltage heightened: actually, this p-layer also acts as the base of an NPN transistor made up by the last three layers just over the MT2 terminal, which, in turn, gets activated.




5. QUADRANTS 3

*Quadrant 4:* Operation occurs when the gate is positive and MT2 is negative with respect to MT1.Triggering in this quadrant is similar to triggering in quadrant III. The process uses a remote gate control and is illustrated in Figure 7. As current flows from the p-layer under the gate into the n-layer under MT1, minority carriers in the form of free electrons are injected into the p-region and some of them are collected by the underlying n-p junction and pass into the adjoining n-region without recombining. As in the case of a triggering in quadrant III, this lowers the potential of the n-layer and turns on the PNP transistor formed by the n-layer and the two p-layers next to it. The lower p-layer works as the collector of this PNP transistor and has its voltage heightened: actually, this p-layer also acts as the base of an NPN transistor made up by the last three layers just over the MT2 terminal, which, in turn, gets activated.




6. QUADRANTS 4

**METHODOLOGY:**

The controlling circuit of triac consists of

1. Triggering circuit
2. Triac circuit
3. Power supply circuit

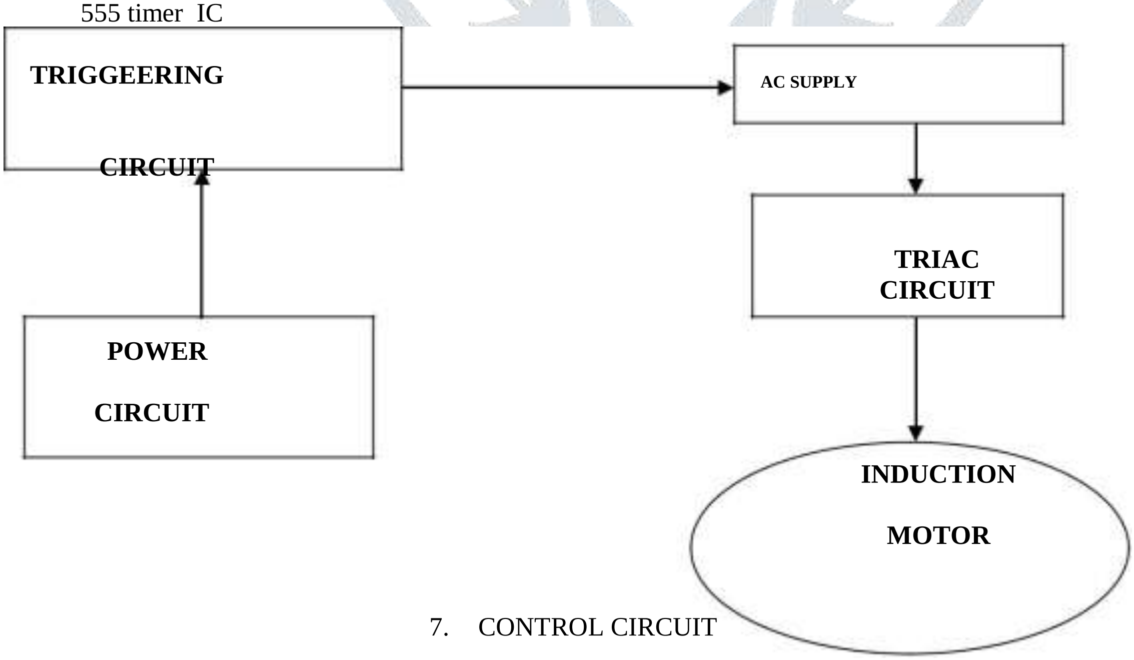
To control the speed of induction motor triac can used the triac required a triggering circuit as there are many different methods of triggering a triac.

**TRIGGERING CIRCUIT**: - Triac require a triggering to get turn ON different technique is used for it in triac control circuitry some of the methods are:-

Triggering method of triac circuit

Microprocessor Pulse transformer Diac circuit

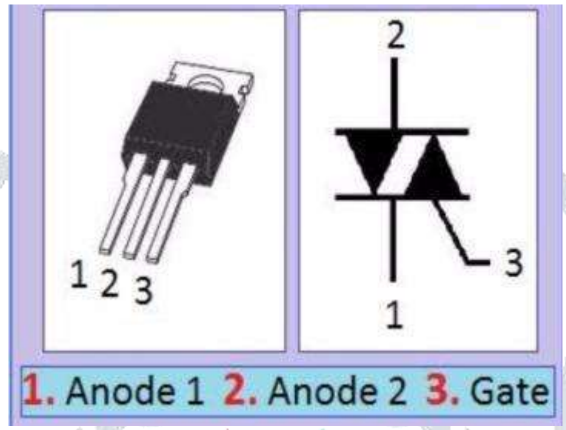
555 timer IC




7. CONTROL CIRCUIT

- **MICROPROCESSOR:-**

Conventional methods for starting and speed control of single-phase induction motor USING need often quite expensive external electrical equipment. The induction motor used here is an ac motor which requires 230V power supply but microcontroller kit used requires 5Vsupply. Hence the supply is processed by a step-down transformer which acts as full wave rectifier. The rectified output is given to voltage regulator IC7805. This IC regulates the 12V ac voltage and delivers 5V constant dc voltage which is required by the microcontroller kits. A zero crossing detector is placed across the full wave rectifier which generates pulses only when the output is zero. Hence zero voltage generates the pulses in zero crossing detectors. A diode is placed, grounded at anode, in between full wave rectifier and zero crossing detectors. If there is any voltage then the diode gets activated to make voltage zero. The 5V dc supply generated by voltage generator circuit is given to output of zero crossing detectors which is input to ATMEGA 32 microcontroller kit. This kit will be connected to LCD display where the net speed in which motor has to run on no load is set manually. The 230V, 50Hz ac supply given to step-down transformer is also given to the motor through TRIAC and opto-coupler MOC3022.




8. TRIAC

This TRIAC and opto-coupler are used to control the firing angle of the input voltage. The firing angle will be as much less as 5mV till the load is applied. The speed of the motor shaft is sensed by photodiode. The pulses will be generated by the rotation of the rotor of the motor. These pulses are generated by timer IC 555. The timer IC 555 will be generating pulses which are read in revolutions per second (rps). The BJT circuit attached to it will convert the speed in revolution per second and then will be given as input to MC89C2051 microcontroller kit. This microcontroller MC89C2051 will calculate the pulses generated per revolution per second and will find the pulses generated per revolution per minute (rpm). We cannot directly calculate the pulses generated per revolution per minute as it is a hectic job and there is a possibility of missing some pulses generated. And also calculating pulses generated per revolution per minute will lead to harmonic distortions which will decrease the efficiency of the motor. Hence we will calculate pulses generated per revolution per second by BJT circuit and then will manually calculate the number of possible pulses generator in revolution per minute and then sent it to the ATMEGA 32 microcontroller kit as a feedback. This feedback signal received by ATMEGA 32 microcontroller kit resembles the speed of the rotating part of the motor. This current running speed of motor will be displayed on the 2x8 LCD display. The previous set speed of motor and the current speed of motor are compared by ATMEGA 32 kit and the difference between them is recorded. If the difference between them is very small and the current speed is approximately equal to set speed, then the motor is running at constant speed. If the difference is more, the ATMEGA 32 kit which is also connected to opto-coupler triggers the gate terminal of the TRIAC which varies the firing angle and increases the power of the motor as well as increases the speed of the motor. When the speed of the motor is increased the pulses generated by timer 555 varies and hence pulses per revolution per second will vary. Again pulses per revolution per minute are calculated and then it is given as feedback to the ATMEGA 32 microcontroller kit. Once again the set speed of the motor and the current speed of the motor are compared and recorded. The difference in recorded speeds will be noticed. If the difference is small, then it is proven that we have controlled the speed of the motor and hence reduced the harmonic distortions by calculating pulses in revolution per second. When the motor is loaded, the speed becomes less and when the motor is not loaded, it will be running in the set speed. Hence there is no chance of high speed than the set speed in the motor.

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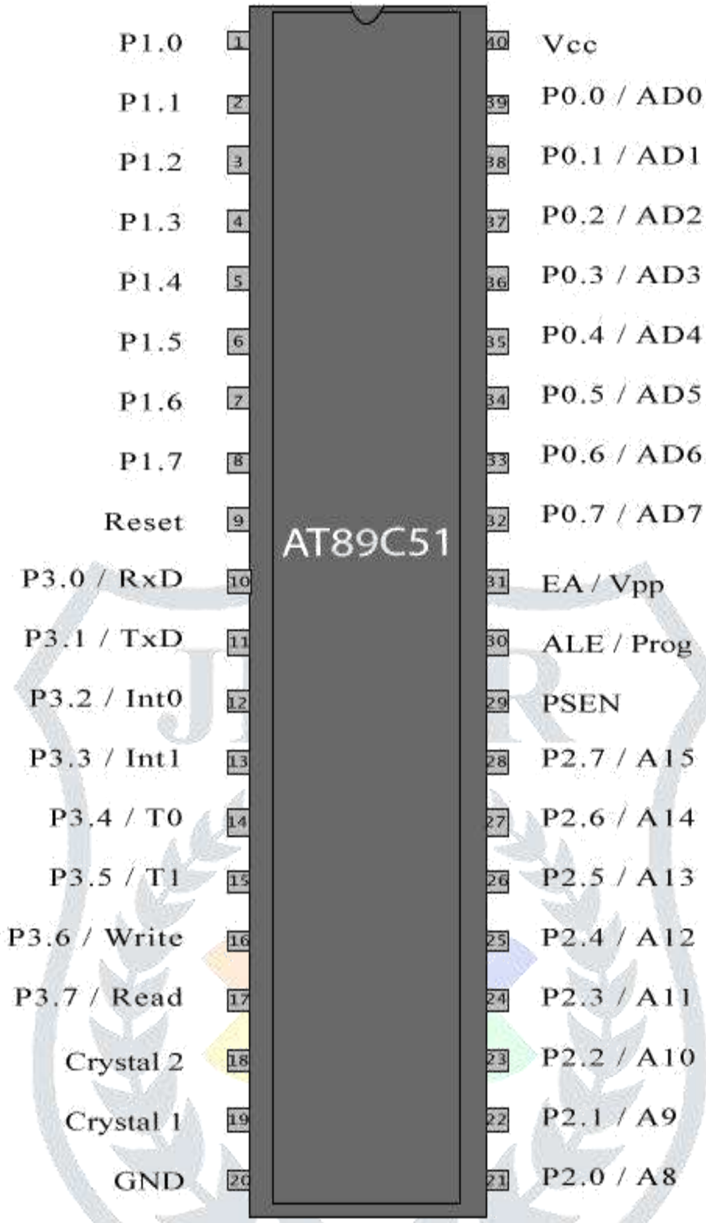
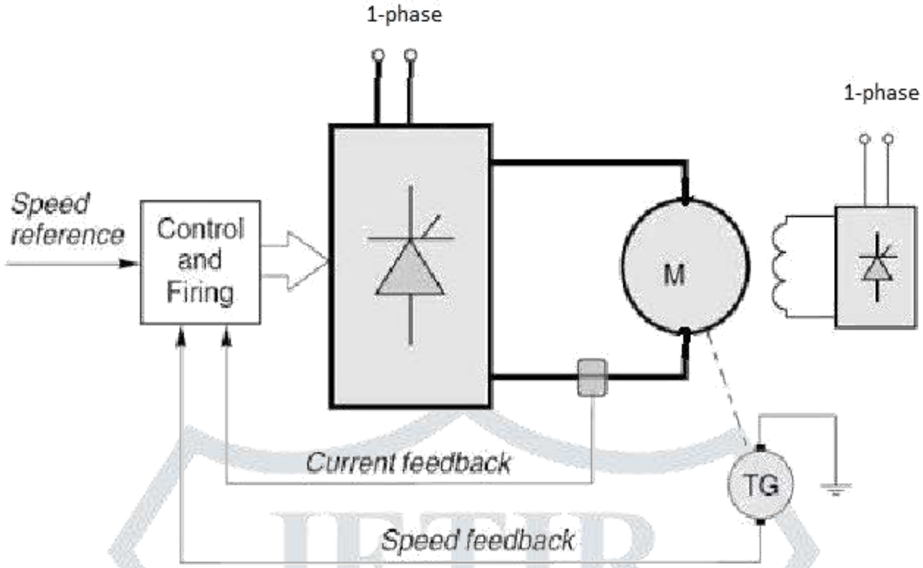
9. ATMEGA32

When the motor is loaded, the speed is sensed by the photo-diode and due to voltage variations, pulses are generated by timer 555 IC. The speed in revolution per minute is converted to speed in revolution per second by BJT circuit which is given to microcontroller MC 89C2051 kit




10. AT89C51 MICROCONTROLLER KIT.

The pulses generated in the timer 555 IC is calculated per revolution per second and then converted manually to revolution per minute and sent as feedback to ATMEGA 32 kit. The speed in revolution per minutee is will be obviously low due to the load on the motor. This speed is noted and compared with the set speed whose difference will be large. Hence the speed of the motor on load should be increased. So the keys attached to ATMEGA 32 kit are used to increase the speed of the motor manually. Here we will increase the speed of motor manually by operating keys connected to the ATMEGA 32 microcontroller kit. Due to this increment of speed manually, the opto-coupler connected to ATMEGA 32 kit starts triggering. This allows the gate terminal of TRIAC to reduce the firing angle. The firing angle is reduced till the manually set speed is attained and then this firing angle is given to motor which increases the motor speed to the manually set speed. Once it is attained the pulses generated per revolution per second and revolution per minute will be equal to the pulses generated per revolution per second and revolution per minute at the starting, when no-load motor was running. Hence the set speed will matches the running speed and our concept is achieved.




11. BLOCK DIAGRAM OF SPEED CONTROL OF INDUCTION MOTOR

- **PULSE TRANSFORMER**:-

Among the many ways to drive a triac the pulse transformer is one of the easiest. By applying some simple rules it can be used to design an efficient triac triggering circuit without reduction of the commutation capability of the triac.

**WHY USE A PULSE TRANSFORMER**?

The use of pulse transformers in triac triggering circuits offers many advantages:

- Galvanic insulation between the power and gate drive circuit (a few kV).
- Gate drives circuit with a few components.
- Choice of the gate current polarity.
- Optimization of gate signal (single pulse or train of pulses).
- Possibility to drive several triac with only one drives circuit.

THE PULSE TRANSFORMER

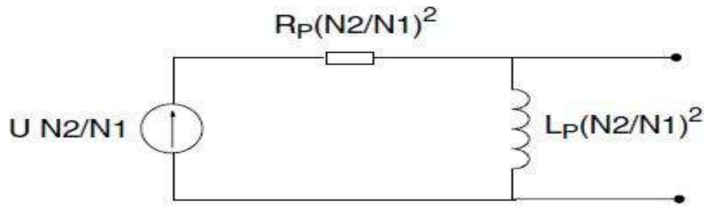
To optimize the triac and the pulse transformer in the application it is necessary to know the main characteristics of the transformer.

The transformer ratio:-It is the N2/N1 ratio, where N1 corresponds to the primary winding and N2 to the secondary.

The LP inductance:-The primary winding inductance measured at a given frequency.

The RP resistance:-The primary winding resistance.

The area of the output pulse:-For a given magnetic material the voltage. time product Vo to of the output pulse is constant. For each type of transformer the manufacturer gives the maximum voltage. time product under no load operation




12. EQUIVALENT DIAGRAM OF THE TRANSFORMER AT SECONDARY

GATE PULSE

***Peak value*:-**The transformer ratio and the power supply of the primary winding define the secondary voltage. With the equivalent diagram and triac gate characteristics it is possible to determine the output current. This has to be higher than the specified gate triggering current (IGT). To have an efficient triggering it is suitable to use a safety coefficient of 2: IG > 2 IGT

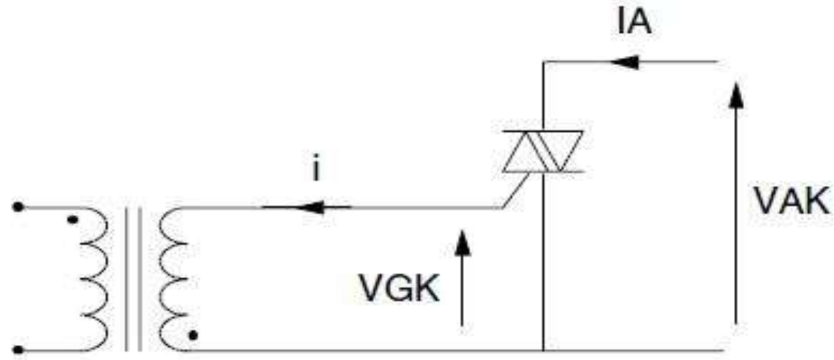
***Duration:***-The Vo.to product defines the maximum pulse duration at the output of the transformer. The anode current has to be higher than the specified latching current (IL) at the end of the gate pulse. For drives with a pulse train we can sometimes use very short pulses ( for example tp =10µs with a 15µs cycle). For proper triac triggering the gate current rise time is very important in a circuit with very high di/dt (>20 A/µs): case of resistive load.

THE COMMUTATION

The use of a triac with a pulse transformer needs some precautions in order not to decrease the commutation capability.

***The commutation***:-Review: during the conduction a certain quantity of charges is injected into the triac. During the fall of the current most of them disappear by recombination. If the current decreases too fast the charges do not have time to recombine and some charge stays in the gate area. This can provoke a spurious firing. The parameter which characterizes the commutation is the anode current slope (di/dt)c, that is to say the slope of current before zero crossing.

Case of a triac triggered by a transformer:-When the triac is on, a voltage of about 0.6V appears across the gate and cathode. This voltage is either positive or negative depending on the anode current polarity. A current i can flow through the secondary winding of the transformer




13. USE OF A TRIAC WITH A PULSE TRANSFORMER

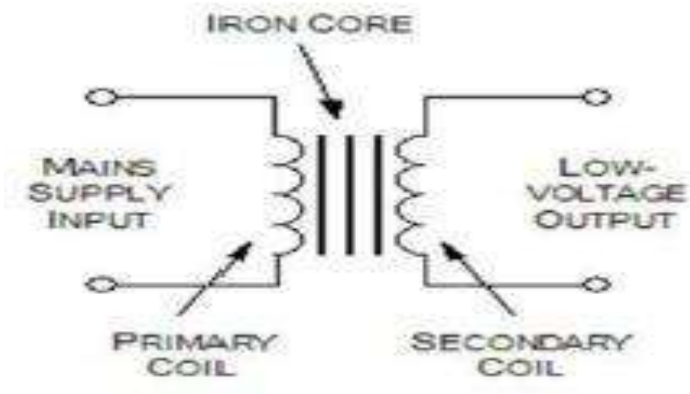
In practice the area of the pulse has to be lower than 60 or 70% of the maximum voltage. Time product Vo to. The maximum pulse duration in the output is: These two formulas allow us to define the pulse transformer according to the triac sensitivity.

- **555 TIMER IC**: -

  In this case of 555 timer used for triggering of triac consist of an entire self control circuit The functioning of the entire triggering circuit can be studied in five parts Transformer

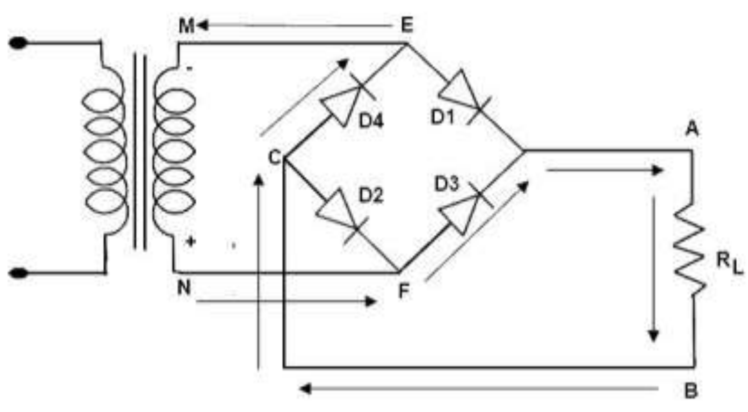
  Rectifier Comparator 555 timer AND gate

*1)* ***Transformer:-***The transformer in our circuit is a step down transformer this transforms the 220V input sinusoidal voltage to 30V at 1 amp output voltage. It acts as an isolation device between the ac mains and the electronic circuit.




14. STEP DOWN TRANSFORMER

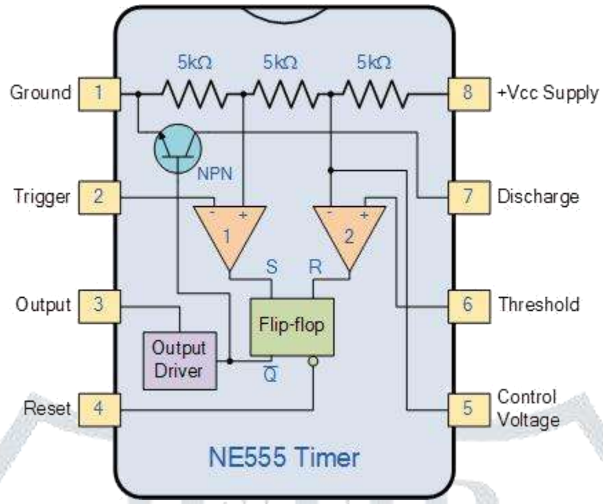
2) ***Rectifier: -*** There are two bridge rectifiers used in the circuit to rectify the 30V AC. The output from one of the rectifier is filtered using the appropriate capacitors and is used as an input to positive terminal of the comparator. The output of the remaining rectifier acts as the reference to the comparator. The rectifiers used in the circuit are MIC DB107.




15. CIRCUIT DIAGRAM AND WAVEFORM OF RECTIFIER

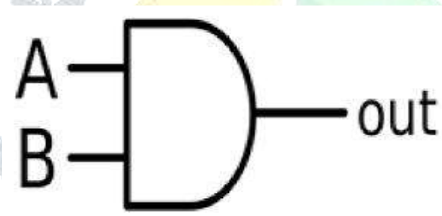
3) ***Comparator:*** - The comparator used in the circuit is LM741.The comparator compares the rectified voltage at the positive terminal with the filtered input voltage at the negative terminal which acts as a reference and hence generates a square wave. The magnitude of the square wave is equal to the saturation value, and its magnitude is positive when the input voltage is greater than the reference voltage and vice versa. The resultant output wave forms the input to the AND gate.

4) ***555 Timers*: -** The pin The pin diagram, internal diagram and 555 timer pin diagram are shown below: The 555 timer used in the circuit is in the a stable mode. The resistors R1 and R2 help in varying the frequency of the output from the comparator .This helps in generating a pulse train used to trigger the gate of the triac used. The biasing voltage used in the circuit is 5V. Frequency of generated pulse (f) = 1/[(R1+2R2)*C*ln(2)]




16. Pin Diagram, Internal Diagram

5***) AND gate*: -** The AND gate used in the circuit is 7408N. The input of the gate is derived from the output of the comparator and that of the 555 timer. The AND gate is used to eliminate the negative pulse train. The output of the AND gate is shown below. These are train of pulses and are used for triggering the TRIAC. Thereby by the TRIAC will be conducting and the supply is connected to the induction motor.

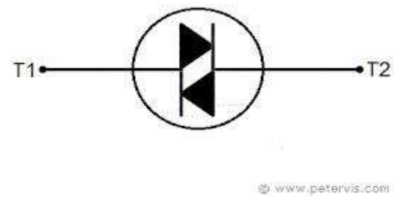



17. AND GATE

- **DIAC: -**

The DIAC is a diode that conduct electrical energy only after its break over voltage, VBO, has been reached momentarily. The term is an acronym of diode for alternating current. When breakdown occurs, the diode enters a region of negative dynamic resistance, leading to a decrement in the voltage drop in the diode, usually a sharp increase in current through the diode. The diode remains in conduction until the current through it drops below a value characteristic for the device, called the holding current IH. Below this value, the diode switches back to high resistance, non-conducting state. This behavior is bidirectional meaning typically the same for both directions of current. Most DIACs have a three layer structure with break over voltage of approximately 30V. Their behavior is similar to that of a neon lamp, but it can be more precisely controlled and takes place at a lower voltage. DIACs have no gate electrode, unlike some other thyristors that they are commonly used to trigger, such as

TRIACs, like quadrics, contain a built in series with the TRIAC"s Gate terminal for this purpose.




18. DIAC

Here are the four different ways to trigger a triac this all different methods are very reliable to trigger a triac for this methods are very efficient to trigger.

**MODELING & SIMULATION**:

In both induction and synchronous motor the AC power supplied to the motors stator creates a magnetic field that rotates in synchronism with the AC oscillations. Whereas a synchronous motor's rotor turns at the same rate as the stator field, an induction motor's rotor rotates at a somewhat slower speed than the stator field. The induction motor stator's magnetic field is therefore changing or rotating relative to the rotor. This induces an opposing current in the induction motor's rotor, in effect the motor's secondary winding, when the latter is short-circuited or closed through external impedance. The rotating magnetic induces currents in the windings of the rotor; in a manner similar to currents induced in a transformer's secondary winding(s).The induced currents in the rotor windings in turn create magnetic fields in the rotor that react against the stator field. Due to Lenz's Law, the direction of the magnetic field created will be such as to oppose the change in current through the rotor windings. The cause of induced current in the rotor windings is the rotating stator magnetic field, so to oppose the change in rotor-winding currents the rotor will start to rotate in the direction of the rotating stator magnetic field. The rotor accelerates until the magnitude of induced rotor current and torque balances the applied mechanical load on the rotation of the rotor. Since rotation at synchronous speed would result in no induced rotor current, an induction motor always operates slightly slower than synchronous speed. The difference, or "slip," between actual and synchronous speed varies from about 0.5% to 5.0% for standard Design B torque curve induction motors. The induction motor's essential character is that it is created solely by induction instead of being separately excited as in synchronous or DC machines or being self-magnetized as in permanent. For rotor currents to be induced, the speed of the physical rotor must be lower than that of the stator's rotating magnetic field otherwise the magnetic field would not be moving relative to the rotor conductors and no currents would be induced. As the speed of the rotor drops below synchronous speed, the rotation rate of the magnetic field in the rotor increases, inducing more current in the windings and creating more torque. The ratio between the rotation rate of the magnetic field induced in the rotor and the rotation rate of the stator's rotating field is called "slip". Under load, the speed drops and the slip increases enough to create sufficient torque to turn the load. For this reason, induction motors are sometimes referred to as "asynchronous motors". An induction motor can be used as an induction generator or it can be unrolled to form a linear induction motor which can directly generate linear motion

***Synchronous speed***

An AC motor's synchronous speed, is the rotation rate of the stator's magnetic field,

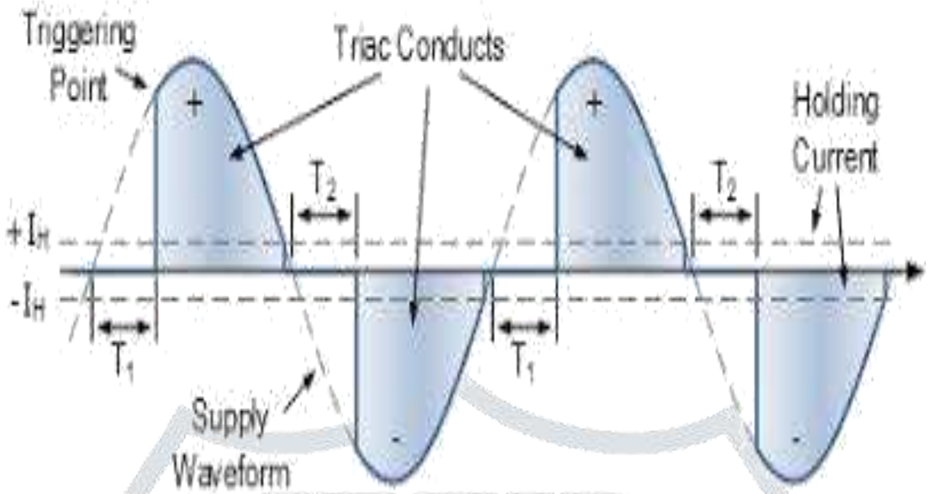
$$\mathbf{Ns=120F/P}$$

WHERE NS = SYNCHRONOUS SPEED, F= FREQUENCY, P= POLES

The triggering circuit, supply, TRIAC and virtual load has to be connected and pre-executed in the software for checking the correctness of the entire circuit. For this purpose we have used software called "Multisim software". In it we have connected the entire circuit including a virtual load. The circuit comprises of the triggering circuit and TRIAC, supply and virtual load connections. First lets discuss about the triggering circuit, as explained in previous chapters there are important parts in the triggering circuit and are transformer, diode bridge rectifier, op-amp,555 timer and AND gate. As it is simulation there is no need of the transformer. We can direct get the required levels of voltages. Next is diode bridge rectifier it is used for conversion of ac to dc. The 555 timer is used for producing square wave pulses of higher frequency and the op-amp that is comparator used for generating square wave pulses of lower frequency when compared to the 555 timer .And finally they are given to AND gate as the 2 inputs. As the AND gate output is high when only both the input are at logic 1, the obtained waveform from the AND gate will be a square wave but of only logic 0 and logic 1 that is it negative part of the voltage and eliminated. This is how the pulses are generated and are given to the TRIAC as the gate pulses. These pulses will trigger the TRIAC and provides a conducting path from supply or source to load. So supply is connected to load if the triggering pulses are applied else not connected. And this how is reduced voltage is applied to the load.

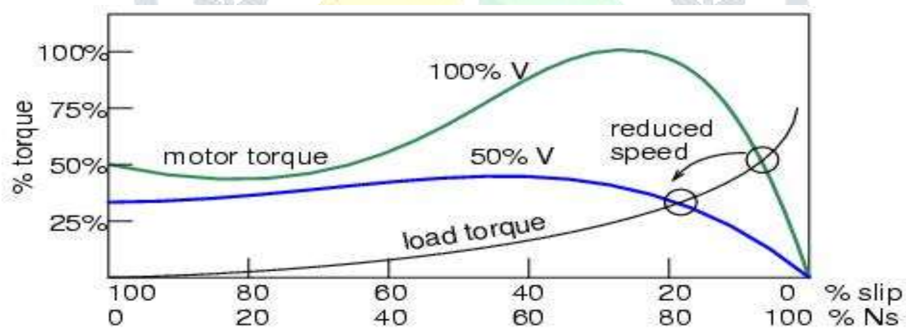
**RESULT AND WAVEFORM:**

The TRIAC output is same as the output of the AC voltage controller. Depending on the potentiometer value, the firing angle to the TRIAC's gate is controlled and thus the output of the TRIAC is in the form of chopped wave that is reduced in value. Therefore the reduced voltage is applied to the induction motor. The output voltage waveform of the TRIAC is shown in the figure below:




19. TRIAC OUTPUT WAVEFORM

From the above observation and analysis the following result is obtained. The speed of the motor is maximum at minimum firing angle (α). As we increase the firing angle (α) the speed of the single-phase induction motor decreases. When the firing angle (α) reaches its peak value the speed of single-phase induction motor is controlled. As firing angle is increasing, speed of the induction motor is decreasing. By varying TRIAC and setting firing angle, we are bringing the speed of motor to be approximately constant. By checking the pulses in revolution per second we are reducing the harmonic distortions going to be occurred, if we start calculating pulses in revolution per minute. By maintaining speed approximately constant, we are achieving the good efficiency of the motor. Speed of the single phase Induction motor can be controlled and maintained as shown in figure below.




20. SPEED TORUE CHARACTERSTIC OF IM

**CONCLUSION & FUTURE SCOPE**:

It is clear that we can change or vary the speed of induction motor by varying gate firing angle. If we increase the firing angle then speed will be decrease that means we can vary the voltage as well as speed of induction motor using TRIAC. In electrical regulator by using resistance the output voltage is varied simultaneously the speed is varied. But to reduce the energy losses in the resistor, electronic regulator is introduced, which uses TRIAC to vary the output voltage by varying the firing angle and avoids loss of energy in resistor. This model of speed control of the fan (single phase induction motor) is already existing technology. The speed control of the fan is only an prototype for the existing technology .The existing technology can be improved by doing modifications in the speed adjustment of the fan through controlling the TRIAC triggering pulses with micro-controller and the work is been going for the more efficient and automatic speed control of the single phase induction motor.

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