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# *Controlled Braking Method for Slip Ring Induction by Plugging With Schmitt Trigger Circuit Application*

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### *Abstract*

*This paper presents application of the technology that involves controlled breaking of slipring induction motor by use of the Schmitt-trigger circuit. These motors are used in many industries for application in machines that function only with a high initial torque. Invariably, these machines have high inertia, and while stopping, electrical braking is applied to quickly decelerate the load. The commonly used method of braking AC motors is "Plugging", if the control system fails to detect zero speed and reversing torque continues, the machine may start operating in reverse which is undesirable. Many machines have mechanical holding brakes which are applied at near-zero speed. If the mechanical brakes operate when the motor speed is high, it will lead to the brakes wearing out quickly and cause maintenance problems. Many machines use electro-mechanical speed switches, these electro-mechanical switches are prone to failure due to many moving parts, springs and coupling with motor shaft, which results in over-travel of the machine. To solve these reliability issues, it is proposed to develop an alternative system which detects zero speed of the motor by an electronic circuit.*

***Keywords:*** *-Schmitt trigger circuit, induction motor, electromechanical switches, plugging, Zero speed*

## INTRODUCTION

Slip-ring Induction motors is widely used in industries for machines which require high starting torque. Invariably, these machines have high inertia, and while stopping, electrical braking is applied to quickly decelerate the load. A slip ring is an electromechanical device that allows the transmission of power and electrical signals from a stationary to a rotating structure. A slip ring can be used in any electromechanical system that requires unrestrained, intermittent or continuous rotation while transmitting power and /or data. It can improve mechanical performance, simplify system operation and eliminate damage-prone wires dangling from movable joints. The commonly used method of braking AC motors is "Plugging", i.e., reversing any two phases of the stator supply, which creates reverse torque. This is done automatically by power contactors. However, while effecting 'plugging', the reversing torque must be withdrawn at zero speed. If the control system fails to detect zero speed and reversing torque continues, the machine may start operating in reverse which is undesirable [1].

The electronic circuit will be designed to compare the actual voltage of the rotor phases with respect to the locked rotor voltage which is given in the motor data sheets. Rotor voltage can be taken from the slip-rings of any two phases. The voltage appearing across the slip-rings varies inversely as the rotor speed. When motor is running at rated speed, slip is low and the voltage appearing across the sliprings is low- measured to be approximately 15 volts in typical cases. As the motor decelerates, the slip increases and rotor voltage also increases and approaches the locked rotor voltage [2].

To make the circuit suitable to industrial conditions, a Schmitt Trigger circuit can be utilized which can detect a varying signal between two threshold values. The effect of the threshold values will be to give the user facility to adjust the comparison parameters to match with the actual field conditions and the motor in use. This alternative system, which is based completely on electronics, will solve the reliability issues with the electromechanical speed switches presently in use, as it is will not have any moving components which might fail, and will not require any maintenance [3].

After the elapsed time, the Timer contact would switch off the contactor. This method was crude and inaccurate without taking into account the actual speed. If the machine friction is more, the motor-load combination would decelerate faster and speed would come to zero earlier than estimated. But Plugging would remain effective up to the present time [4, 5]. The motor would, then, reverse direction. This is an undesirable operation.

The above problems can be overcome by using method evolved with the development of mechanical speed switches which operated on centrifugal force. The switches are mounted on motor shaft and have contacts which close due to centrifugal force when motor shaft rotates.

***The drawbacks of the above said method are as follows:***

1. These electro-mechanical switches are prone to failure due to many moving parts, springs and coupling with motor shaft, which results in over-travel of the machine.

2. These components also require frequent maintenance. To solve these reliability issues, it is proposed to develop an alternative system which detects zero speed of the motor by an electronic circuit

**METHODOLOGY**

The Figure 1 shows “Circuit Diagram for Controlled Braking of Induction Motor Using Schmitt Trigger Circuit”. The connections are taken from any two phases of rotor, i.e., RY, YB, RB phase of rotor and this rotor voltage is stepped down by using transformer because rotor voltage can vary from 0 to 200V, but the 200V cannot be used in electronics, that is while the 1st stage step down transformer are used to reduced rotor voltage to the level of work.

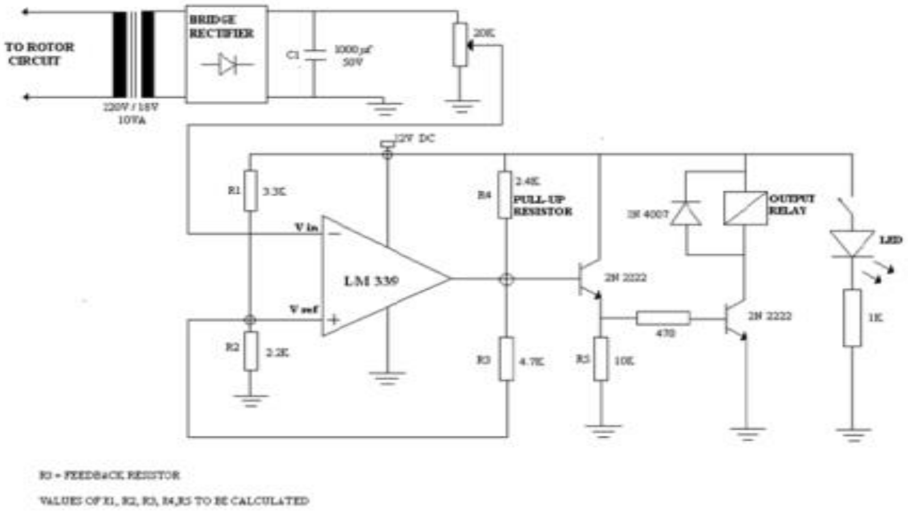


*Fig. 1: Circuit Diagram for Control Braking*

This rotor voltage is noisy and fluctuating signal. After DC rectification and filtering the voltage terminal of the comparator set as reference voltage of 8V through another potential divider circuit comprising R2 and R1. Now, during stand still condition, the rotor voltage is approximately equal to 200V, 8V comparator input and the reference voltage of 8V, the output of the comparator is 1. The comparator IC is digital it will give 0 or 1, it does not give any amplifier output. To stabilize the output and to prevent frequent transition will give a hysteresis band of within a margin of 0.7 V. The transition should not occur between 0 & 1 so that the output will not be stable. If there will be noise present the rotor voltage, rotor voltage will not be absolutely steady. There will be noise present in the rotor output voltage and fluctuation in rotor voltage, the +ve feedback is used to provide hysteresis, so that the output will not jump between 0 & 1 for minor fluctuation. So this will ensure that the comparator will get a study output and independent of noise. The output are taken from comparator is used as switching transistor, so that two stage of power transistor will be used as switch. The switching transistor will energized a relay. That relay will indicate the speed is zero, then that relay signal is used in our control circuit to remove braking.

## COMPONENTS USED IN THE ELECTRONIC CIRCUIT

The various components used in the electronic circuit are as explained below:

### *Electrolytic Capacitor*

An electrolytic capacitor is a capacitor that uses an electrolyte (an ionic conducting liquid) as one of its plates to achieve a larger capacitance per unit volume than other types, but with performance disadvantages. All capacitors conduct alternating current (AC) and block direct current (DC) and can be used, amongst other applications, to couple circuit blocks allowing AC signals to be transferred while blocking DC power, to store energy, and to filter signals according to their frequency. Most electrolytic capacitors are polarized; hence, they can only be operated with a lower voltage on the terminal marked "-" without damaging the capacitor. This generally limits electrolytic capacitors to supplydecoupling and bias-decoupling, since signal coupling usually involves both positive and negative voltages across the capacitor. The large capacitance of electrolytic capacitors makes them particularly suitable for passing or bypassing low-frequency signals and storing large amounts of energy. They are widely used in power supplies and for decoupling unwanted AC components from DC power connections.

***Voltage Regulator (LM 7812)***

The 78xx (sometimes L78xx, LM78xx, MC78xx...) is a family of self-contained fixed linear voltage regulator integrated circuits. The 78xx family is commonly used in electronic circuits requiring a regulated power supply due to their easeof-use and low cost.

***Transistor (2N 2222)***

The 2N2222 is a common NPN bipolar junction transistor used for general purpose low-power amplifying or switching applications. It is designed for low to medium current, low power, medium voltage, and can operate at moderately high speeds. Divider is used, to derive an input signal.

***Comparator IC (LM 339):***

A dedicated voltage comparator chip such as LM339 is designed to interface with a digital logic interface (to a TTL or a CMOS). The output is a binary state often used to interface real world signals to digital circuitry (see analog to digital converter). The LM339 accomplishes this with an open collector output. When the inverting input is at a higher voltage than the non inverting input, the output of the comparator connects to the negative power supply. When the non inverting input is higher than the inverting input, the output is 'floating' (has a very high impedance to ground).

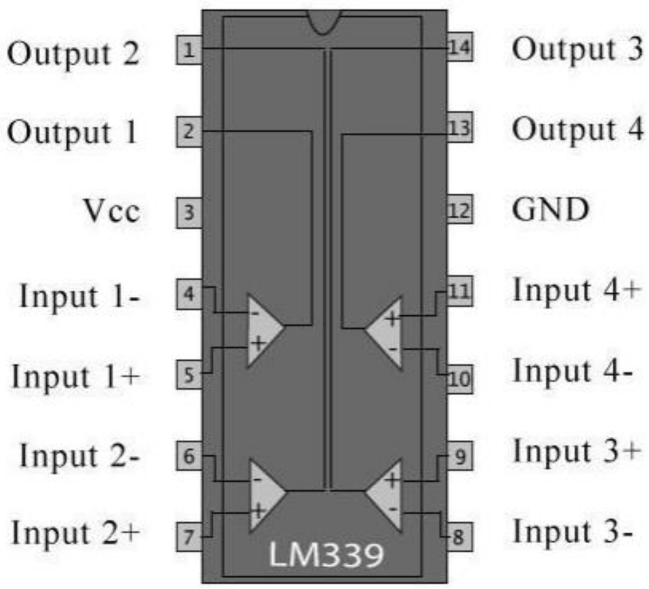


***Fig. 2: Comparator IC (LM 339)***

***Step Down Transformer:***

Step down transformers is designed to reduce electrical voltage. Their primary voltage is greater than their secondary voltage. This kind of transformer "steps down" the voltage applied to it. For instance, a step down transformer is needed to use a 110 v product in a country with a 220 v supply. Step down transformers convert electrical voltage from one level or phase configuration usually down to a lower level. They can include features for electrical isolation, power distribution, and control and instrumentation applications.

***Diode 1N 4007***

The most common function of a diode is to allow an electric current to pass in one direction (called the diode's forward direction), while blocking current in the opposite direction (the reverse direction). Thus, the diode can be viewed as an electronic version of a check valve. This unidirectional behavior is called rectification, and is used to convert alternating current to direct current, including extraction of modulation from radio signals in radio receivers ,these diodes are forms of rectifiers.

***Bridge Rectifier***

A diode bridge is an arrangement of four (or more) diodes in a bridge circuit configuration that provides the same polarity of output for either polarity of input. When used in its most common application, for conversion of an alternating current (AC) input into a direct current (DC) output, it is known as a bridge rectifier. A bridge rectifier provides full-wave rectification from a two-wire AC input, resulting in lower cost and weight as compared to a rectifier with a 3- wire input from a transformer with a center-tapped secondary winding.

***Relay***

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.

**DESIGN PROCEDURE OF THE ELECTRONIC CIRCUIT**

The comparator or op-amps in general is one of the breakthroughs in the integrated circuit development as this tiny smart circuit has tremendous applications in electronics industries. Therefore understanding of how the comparator work will help you take the advantage of this amazing circuit in your next electronics or embedded system project.

V+ voltage upper threshold (VUT) to make the Vout voltage to swing to ground could be calculated as this following formula:

We assume the $V_{out}$ equal to $V_{cc}$ when the output is high then we could have this following formula:

$V_{UT} = (R2 / (R2 + R1||R3)) \times V_{cc}$

And R1||R3 = (R1 x R3) / (R1 + R3). Substituting the R1||R3 (R1 parallel R3) inside this equation we will get this following formula:

$V_{UT}$ = (Vcc x R2 x (R1 + R3)) / (R1 x R2 + R1 x R3 + R2 x R3).

Assume R1=3.3 k ohm
4 = (12*R2*R3) / (3.3k*R2+3.3k*R3+R2*R3)

By solving this equation, we obtain
13.2*R2+13.2*R3-11*R2*R3=0……………………. (2)

The difference between the upper and lower threshold voltage is called the hysteresis voltage: $V_H = V_{UT} – V_{LT}$

Therefore by applying the upper and lower threshold formula, we could get the hysteresis voltage as follow:
VH = 4.7-4 =0.7

Therefore, by solving Eqn. (1) and (2) R2=2.01 k ohm and R3=4.7 k ohm

The comparator ranges maximum up to 12V, input signal is less than 12V, so using transistor and voltage divider the comparator input voltage is step down to less than 8V.The input and reference voltage of comparator is set to get a stable output.

$V_H$ = (Vcc x R1 x R2) / (R1 x R2 + R1 x R3 + R2 x R3).

To insure that Vout will swing between Vcc and ground we have to choose:
R3 > R pull-up and R pull-up < R load
Calculate the upper and lower threshold voltage as follow:

$V_{UT} = 2/3\ V_{cc}$ and VLT = 1/3 Vcc

The different between the upper and lower threshold is called the hysteresis voltage:

$V_H = 1/3\ V_{cc}$

The common way to represent the hysteresis graph instead of using two graphs as shown on the above picture is by assigning the Vout on the Y axis and V- (in) on the X axis, now we could get this following picture:

Therefore, by shifting the V+ voltage with the R3 feedback resistor we could compensate the comparator output to become more immune to the noise signal. This hysteresis comparator circuit also could be used as a Schmitt Trigger with the adjustable threshold point by just changing the value of R1, R2 and R3 resistors respectively. One of the interesting usages of this hysteresis behavior is to use the comparator as the pulse generator or oscillator; where you could easily make a simple LED blinker as shown on model. Again to analyze this circuit first we assume the Vout is high, this will turn on the TR1 transistor and the LED will be ON. In order to meet this condition the V- should be less than V+ (V- almost zero) or we could say that the C1 is now being charged through the R4 resistor. Now, the V- will slowly increase and because of the voltage shift provided by the R3 feedback resistor on the V+ input; this will make the Vout rapidly swing to the logical low (LED OFF) and this time the C1 will discharge its energy through Working with the Comparator Circuit.

The R4 resistor and the V- will decrease; when it reaches bellow the V+ then the process will repeat again. You could easily change the LED blink rate by changing the R4 and C1 value respectively. The output frequency could be calculated using this following formula (taken from AN-74: National Semiconductor Application Note 74): Where R4 is the resistance in Ohm, C1 is the capacitance in Farad and freq. is the pulse frequency in Hertz. Therefore using this formula, we could calculate the frequency of the LED blinker.

1 / Freq. = 2 (0.694) x 470000 x 0.0000001 = 0.65236

Frequency = 1 / 0.65236 = 1.53 Hz

By using different R4 and C1 values on each comparator in the LM339 package (four comparators) you could assembly four independent LED blinker with each of them have a different blink rate. By hooking up to 4 LEDs on each 2N2222 transistor you could get a very nice random LED blink effect similar to the main computer panel shown on many scifi movies.

## EXPERIMENTAL SETUP

The Figure 3 Shows circuit design of the proposed controlled braking of the slip ring induction motor using Schmitt trigger circuit. The input power supply are taken from auto transformer instead of slip ring induction motor of any two phases of rotor, i.e., RY, YB, RB phase of rotor, and this rotor voltage is stepped down by using transformer of rating 230 V to 18 V, because rotor voltage can vary from 0 to 200 V, but the 200 V cannot be used in electronics, so that the 1st stage step down transformer are used to reduce rotor voltage to 18 V. This rotor voltage is noisy and fluctuate the transformer output signal. So that Bridge Rectifier and 1000 Micro Farad Capacitor is used, after DC rectification and filtering the voltage divider is used to derive an input signal.

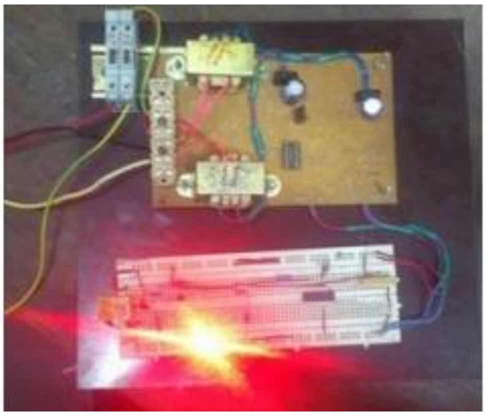

***Fig. 3: Top View of Controlled Braking of the Slip Ring Induction Motor using Schmitt Trigger Circuit Design***

The 220 V AC supply is given to the transformer to step-down to 18 V. The step-down voltage is given to the bridge rectifier for DC rectification and filtering. After rectification the voltage is given to the IC 7812, it will give a 12 V regulated fixed output voltage. This +12 v dc output supply is given to the comparator LM 339 instead of regulated DC Power supply

The Comparator Vcc supply is 12 v DC. The input voltage is adjusted to 8V DC with the help of potentiometer, this is given to –ve input of the comparator, the +ve terminal of the comparator set as reference voltage of 8V through another potential divider circuit comprising R2 and R1. Then R3 acts as positive feedback, because the comparator basically is an uncompensated high gain operational amplifier, therefore this could make the comparator to start oscillate or continuously giving high and low output, and R4 acts as pull up resistor are used in electronic logic circuits to introduce high impedance.

Now, during stand still condition, the rotor voltage is approximately equal to 200 V, 8 V comparator input and the reference voltage is of 8 V, and the output of comparator is 1. The comparator IC is digital it will give 0 or 1, it does not give any amplifier output. The output is taken from comparator which is used as switching transistor i.e., transistor 2 N 2222, so that two stage of power transistor will be used as switch. The switching transistor will energize a relay, which indicates the speed status, and then the LED will be ON according to it, and then relay signal is used to remove braking in the proposed control circuit. The upper threshold voltage is adjusted to 200 V, which corresponds to locked rotor voltage. The lower threshold voltage is set at 130 V at which the relay picks up. At 130 Volts, motor is at midpoint of acceleration. The relay picks up and it is ready for Plugging. When motor forward command is withdrawn, Plugging starts and motor decelerates. Rotor voltage increases to 200 V when motor speed is nearly zero. 200 V corresponds to motor standstill condition when the relay drops out to withdraw plugging.

## ADVANTAGES

1. Low Cost.
2. Practically zero-maintenance.
3. Easy to adapt to any drive. No mechanical adapters, couplings etc. are required. The unit can be kept inside the control room and rotor voltage can be tapped from connections of rotor contactors.

***Table 1: Output Result.***

| S. No | Input Supply In volt | Step Down Voltage in Volt | Comparator Input | Comparator Output (Digital) | Result |
|---|---|---|---|---|---|
| 1. | 220V | 18V | 8V | 1 | LED ON |

## CONCLUSION

Although the circuit was developed to be adapted for a slip-ring induction motor, it can be used in many other industrial applications where two voltage, that is rotor phase with respect to locked rotor voltage signals are to be compared which is given in motor data sheet to initiate an action. In industrial conditions, a Schmitt Trigger circuit can be utilized, which can detect a varying signal between two threshold values. The effect of the threshold values will be to give the user facility to adjust the comparison parameters to match with the actual field conditions and the motor in use. Due to plugging, this results in the production of negative torque, which continuously decreases the speed. At an instant speed is zero, the torque reaches to zero. At this instant slip is equal to unity and rotor will be blocked. The adaptation of hysteresis makes it suitable for industrial environments where signals have noise. Hysteresis is reliable and can be applied predictably using small amounts of positive feedback. The voltage follower at the output gives in-built high output impedance so that any type of relay, or lamp, even with a different voltage level can be used.

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