Solid-State Control for Bi-Directional Motors

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Some split-phase motors are able to operate in both forward and reverse directions as they have two windings for that purpose. The motor operates in the direction of the winding that is energized. These motors are used in applications such as washing machines, transport belts, and other kinds of dual-direction equipment. The most traditional way to control these motors is through mechanical relays but there are a lot of disadvantages which can make them ineffective.

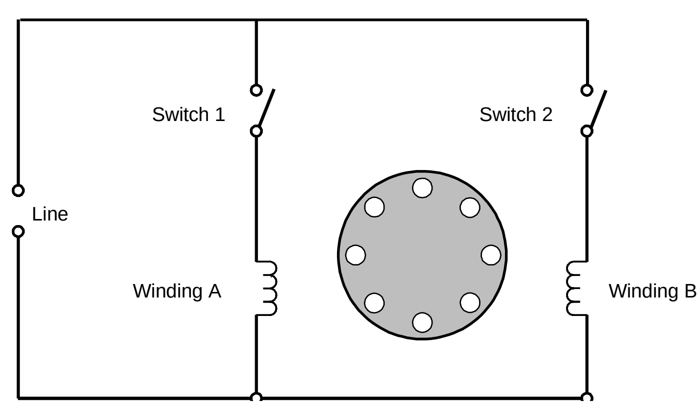
This paper shows how triacs can substitute for mechanical relays in controlling bi-directional motors with a higher level of quality and reliability. The triac is a three-terminal ac semiconductor switch that is triggered into conduction when a low energy signal is applied to its gate. Unlike the silicon controlled rectifier, or SCR, the triac will conduct current in either direction when turned on; and the triac also differs in that either a positive or negative gate signal will trigger the triac into conduction: The triac may be thought of as two complementary SCRs in parallel.

The triac offers the circuit designer an economical and versatile means of accurately controlling ac power with several advantages over conventional mechanical switches: The triac has a positive ‘on’ and a zero current ‘off’ characteristic; it does not suffer from the contact bounce or arcing inherent in mechanical switches; the switching action of the triac is very fast compared to conventional relays, giving more accurate control; a triac can be triggered by dc, ac, rectified ac or pulses; and because of the low trigger energy required the control circuit can use any of many low-cost solid-state devices such as transistors, sensitive gate SCRs and triacs, optically coupled drivers, and integrated circuits.

Definitions

The two-phase induction motor consists of a stator with two windings displaced 90 electrical degrees from each other in space and a squirrel cage rotor or the equivalent. The ac voltages applied to the two windings are generally phase displaced from each other 90° in time. When the voltage magnitudes are equal, the equivalent of a balanced two-phase voltage is applied to the stator. The resultant stator flux and motor torque speed curves are then similar to a three-phase induction motor. The two-phase control motor is usually built with a high-resistance rotor to give a high starting torque and a dropping torque speed characteristic.

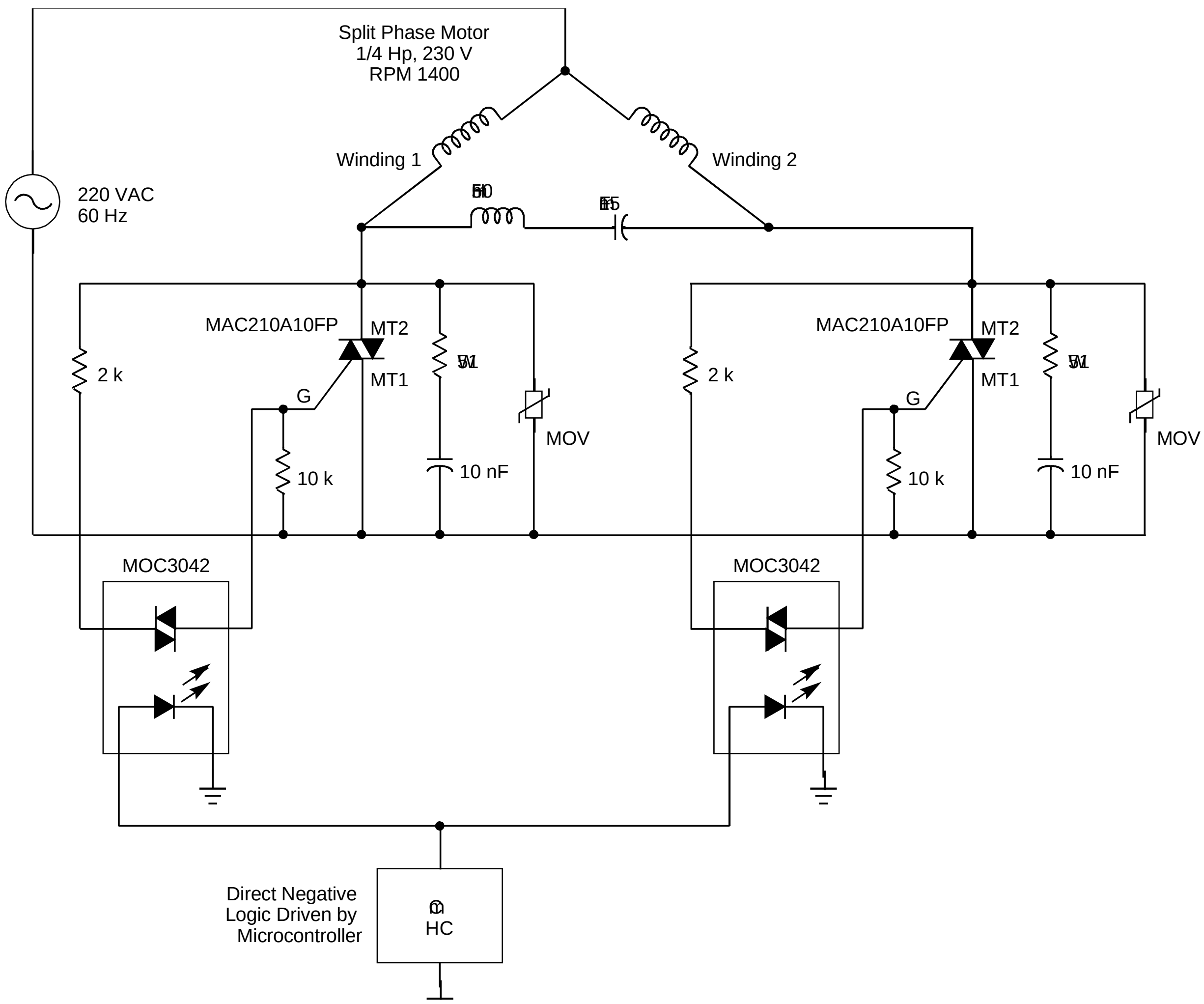
The following schematic diagram shows an ac split-phase motor:



With switch 1 closed there is rotation in one direction; if switch 2 is closed there is rotation in the other direction. Since torque is a function of the voltage supply changing it changes the developed motor torque. The stalled torque is assumed to be proportional to the rms control-winding voltage.

It is common to add a resonant L-C circuit between the motor windings to damp the energy stored by each motor winding's inductance, avoiding damage to the switches when the transition from one direction to the other occurs. In addition, this resonant L-C circuit helps motor torque performance each time it changes its rotation.

The following schematic diagram shows how two triacs can control the rotation of a split-phase motor depending on which winding is energized. In this case the motor selected for analysis is 230 V rms, 1.9 A rms, 0.25 hp, 60 Hz, 1400 rpm.



The microcontroller triggers the triacs through optocouplers (MOC3042); these protect the control circuitry (the microcontroller, logic, etc.) if a short-circuit condition should occur on the power side. The MOVs protect the triacs against high voltage transients caused by motor rotation changes -- an important protection element for the triacs. The snubber arrangement provides protection against dV/dt conditions occurring within the application circuit, and the resonant L-C circuit connected between the windings, as noted earlier, improves the torque of the motor when it changes rotation.

In a case where the motor locks-up due to a mechanical problem, the maximum current peak flowing through the triacs would be 7.2 A (5.02 A rms) but the triacs (MAC210A10FP) would not be damaged since they are able to handle up to 12 A rms. Nevertheless, it is recommended that an overload protector is added in the power circuit of the motor to protect the motor itself.

In conclusion, it has been shown how triacs can substitute for mechanical relays to control bi-directional motors, offering many important advantages like reliable control, quiet operation, longer life, smaller size, lighter weight, and faster operation. The total cost of the electronic circuitry does not exceed the cost of conventional mechanical relays.

An important consideration is that extreme temperatures could affect the functionality of the electronics; if operation under extreme ambients is needed the designer must take into consideration the parameter variations in the devices used to establish if any kind of circuit adjustment is needed. Another important item to be considered is that the triacs have to be mounted on a satisfactory heatsink to ensure that the case temperatures do not exceed the datasheet specifications.