AN-443
Application Note

DIRECTION AND SPEED CONTROL FOR SERIES, UNIVERSAL AND SHUNT MOTORS

Prepared by
G. V. Fay
Applications Engineering

A simple circuit containing few components allows control of both speed and direction of rotation of dc motors. The use of thyristors provides continuous driver control through the speed range without compromising the torque characteristics of the motors.

MOTOROLA Semiconductor Products Inc.

DIRECTION AND SPEED CONTROL FOR SERIES, UNIVERSAL AND SHUNT MOTORS

INTRODUCTION

The speed of a dc motor is dependent on the voltage applied to it. For a series-wound motor, the speed is directly proportional to the applied voltage. For a shunt motor, a constant voltage should be applied to the shunt field to maintain constant field flux so that the armature reaction has negligible effect. When constant voltage is applied to the shunt field, the speed is a direct function of the armature voltage and the armature current. If the field is weak, then the armature reaction may counterbalance the voltage drop due to the brushes, windings and armature resistances, with the net result of a rising speed-load characteristic.

The speed of a shunt-wound motor can be controlled with a variable resistance in series with the field or the armature. Varying the field current for small motor provides a wide range of speeds with good speed regulation. However, if the field becomes extremely weak, a rising speed-load characteristic results. This method cannot provide control below the design motor speed. Varying the resistance in series with the armature results in speeds less than the designed motor speed; however, this method yields poor speed regulation, especially at low speed settings. This method of control also increases power dissipation and reduces efficiency and the torque since the maximum armature current is reduced. Neither type of resistive speed control is very satisfactory. Thyristor drive controls, on the other hand, provide continuous control through the range of speed desired, do not have the power losses inherent in resistive circuits, and do not compromise the torque characteristics of motors.

Although a series-wound motor can be used with either dc or ac excitation, dc operation provides superior performance. A universal motor is a small series-wound motor designed to operate from either a dc or an ac supply of the same voltage. In the small motors used as universal motors, the winding inductance is not large enough to produce sufficient current through transformer action to create excessive commutation problems. Also, high-resistance brushes are used to aid commutation. The characteristics of a universal motor operated from alternating current closely approximate those obtained for a dc power source up to full load; however, above full load the ac and dc characteristics differ. For a series motor that was not designed as a universal motor, the speed-torque characteristic with ac rather than dc is not as good as that for the universal motor. At light loads, the speed for ac operation may be greater than for dc since the effective ac field strength is smaller than that obtained on direct current. At any rate, a series motor should not be operated in a no-load condition unless precautions are taken to limit the maximum speed.

SERIES-WOUND MOTORS

The circuit shown in Figure 1 can be used to control the speed and direction of rotation of a series-wound dc motor. Silicon controlled rectifiers Q1–Q4, which are connected in a bridge arrangement, are triggered in diagonal pairs. Which pair is turned on is controlled by switch S1 since it connects either coupling transformer T1 or coupling transformer T2 to a pulsing circuit. The current in the field can be reversed by selecting either SCRs Q2 and Q3 for conduction, or SCRs Q1 and Q4 for conduction. Since the armature current is always in the same direction, the field current reverses in relation to the armature current, thus reversing the direction of rotation of the motor.

A pulse circuit is used to drive the SCRs through either transformer T1 or T2. The pulse required to fire the SCR is obtained from the energy stored in capacitor C1. This capacitor charges to the breakdown voltage of zener diode D5 through potentiometer R1 and resistor R2. As the capacitor voltage exceeds the zener voltage, the zener conducts, delivering current to the gate of SCR Q5. This turns Q5 on, which discharges C1 through either T1 or T2 depending on the position of S1. This creates the desired triggering pulse. Once Q5 is on, it remains on for the duration of the half cycle. This clamps the voltage across C1 to the forward voltage drop of Q5. When the supply voltage drops to zero, Q5 turns off, permitting C1 to begin charging when the supply voltage begins to increase.

The speed of the motor can be controlled by potentiometer R1. The larger the resistance in the circuit, the longer required to charge C1 to the breakdown voltage of zener D5. This determines the conduction angle of either Q1 and Q4, or Q2 and Q3, thus setting the average motor voltage and thereby the speed.

SHUNT-WOUND MOTORS

If a shunt-wound motor is to be used, then the circuit in Figure 2 is required. This circuit operates like the one shown in Figure 1. The only differences are that the field is placed across the rectified supply and the armature is placed in the SCR bridge. Thus the field current is unidirectional but armature current is reversible; consequently the motor's direction of rotation is reversible. Potentiometer R1 controls the speed as explained previously.

RESULTS

Excellent results were obtained when these circuits were used to control 1/15 hp, 115 V, 5,000 r/min motors. This circuit will control larger, fractional-horsepower motors provided the motor current requirements are within the semiconductor ratings. Higher current devices will permit control of even larger motors, but the operation of the motor under worst case must not cause anode currents to exceed the ratings of the semiconductor.

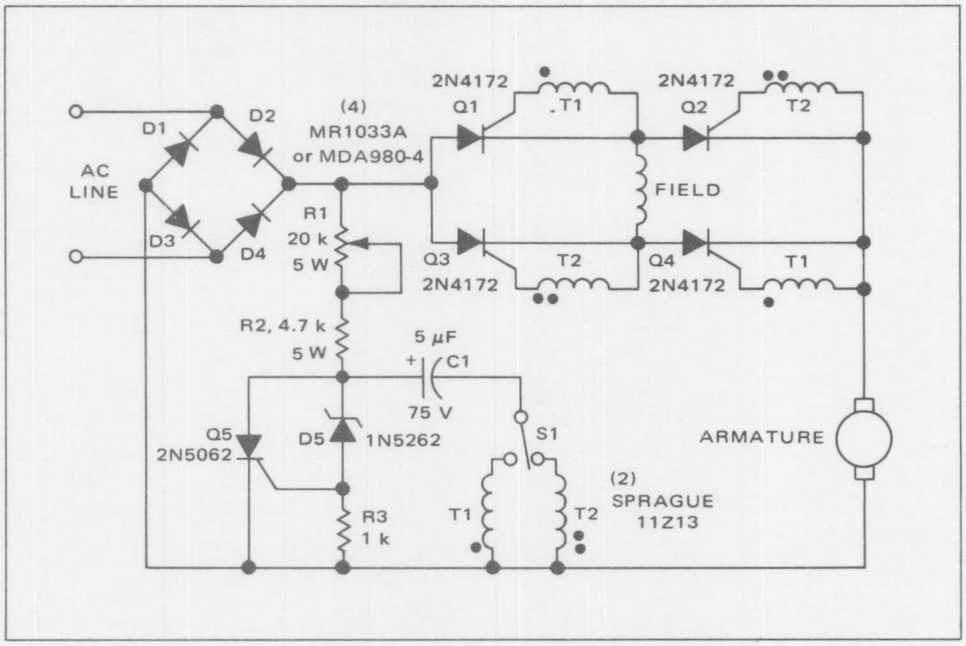

FIGURE 1 – Direction and Speed Control for Series-Wound or Universal Motor

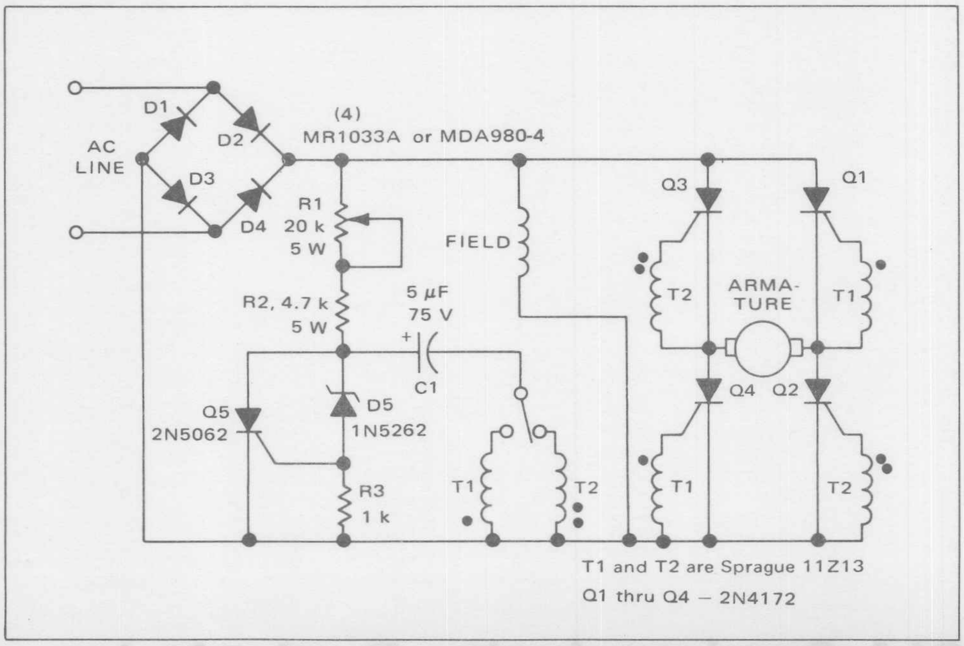

FIGURE 2 – Direction and Speed Control for Shunt-Wound Motor

MOTOROLA Semiconductor Products Inc.

Printed in Switzerland