



Fig.4 illustrates a simple three-phase unipolar-operated motor that uses optical sensors (phototransistors) as position detectors. Three phototransistors PT1, PT2, and PT3 are placed on the end-plate at 120° intervals, and are exposed to light in sequence through a revolving shutter coupled to the motor shaft.

As shown in Fig.4, the north pole of the rotor now faces the salient pole P2 of the stator, and the phototransistor PT1 detects the light and turns transistor Tr1 on. In this state, the south pole which is created at the salient pole P1 by the electrical current flowing through the winding W1 is attracting the north pole of the rotor to move it in the direction of the arrow. When the north pole comes to the position to face the salient pole P1, the shutter, which is coupled to the shaft, will shade PT1, and PT2 will be exposed to the light and a current will flow through the transistor Tr2. When a current flow through the winding W2, and creates a south pole on salient pole P2, then the north pole in the rotor will revolve in the direction of the arrow and face the salient pole P2. At this moment, the shutter shades PT2, and the phototransistor PT3 is exposed to the light. These actions steer the current from the winding W2 to W3. Thus, salient pole P2 is de-energized, while the salient pole P3 is energized and creates the south pole. Hence the north pole on the rotor further travels from P2 to P3 without stopping. By repeating such a switching action in sequence given in Fig.5, the permanent magnet rotor revolves continuously.

### 10.3.2 Bipolar Drive

When a three-phase (brushless) motor is driven by a three-phase bridge circuit, the efficiency, which is the ratio of the mechanical output power to the electrical input power, is the highest, since in this drive an alternating current flow through each winding as an ac motor. This drive is often referred to as 'bipolar drive'. Here, 'bipolar' means that a winding is alternatively energised in the south and north poles.

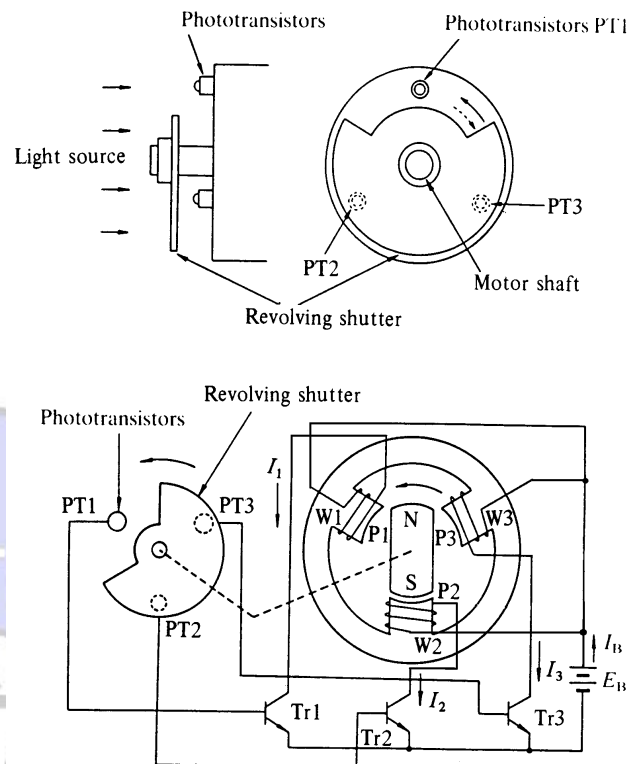


Fig.10.4 Three-phase unipolar-driven brushless dc motor (from Ref. [1] p59)

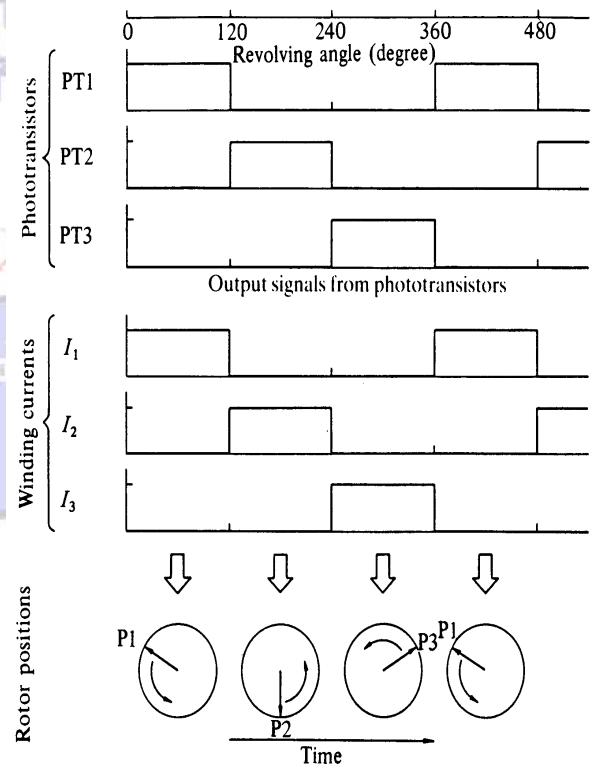


Fig.10.5 Switching sequence and rotation of stator's magnetic field (from Ref. [1] p60 Fig.4.3)



We shall now survey the principle of the three-phase bridge circuit of Fig.6. Here too, we use the optical method for detecting the rotor position; six phototransistors are placed on the end-plate at equal intervals.

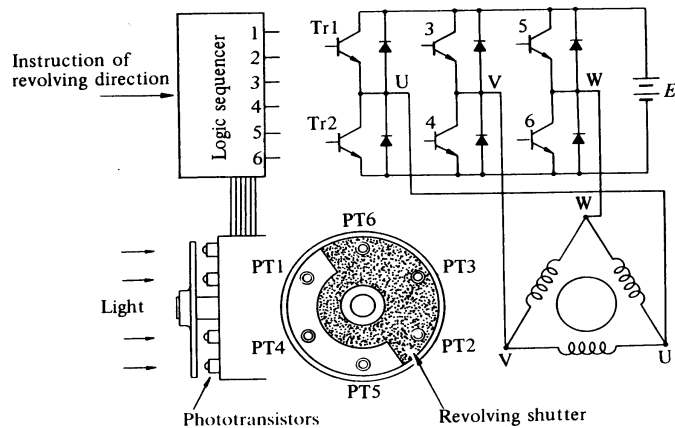


Fig.10.6 Three phase bipolar-driven brushless motor (from Ref. [1] p61, Fig.4.4)

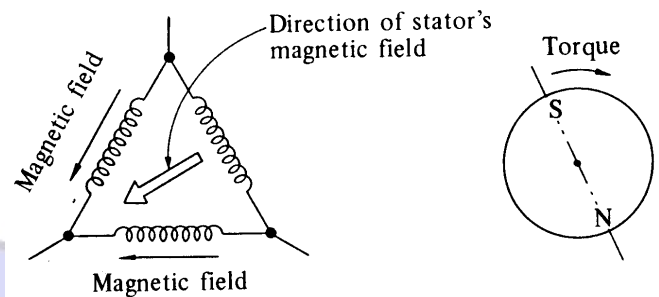


Fig.10.7 Stator's magnetic field in the shutter state of Fig.6, and the direction of torque (from Ref. [1] p62, Fig.4.5)

ON-OFF sequence	1	2	3	4	5	6
Tr 1	0	1	1	1	0	0
2	1	0	0	0	1	1
3	1	1	0	0	0	1
4	0	0	1	1	1	0
5	0	0	0	1	1	1
6	1	1	1	0	0	0

Tr 1	1	1	1	0	0	0
2	0	0	0	1	1	1
3	0	0	1	1	1	0
4	1	1	0	0	0	1
5	1	0	0	0	1	1
6	0	1	1	1	0	0

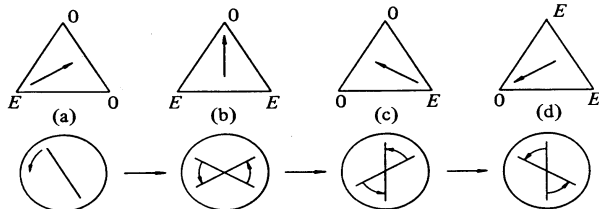


Fig.10.9 Counter-clockwise revolutions of the stator's magnetic field and rotor (from Ref. [1] p63 Fig.4.7)

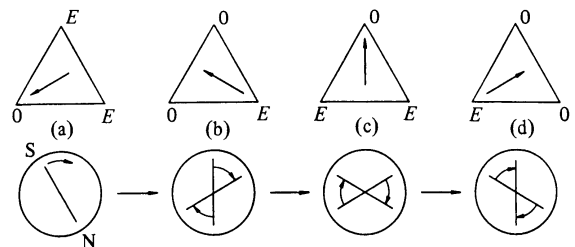


Fig.10.8 Clockwise revolutions of the stator's magnetic field and rotor (from Ref. [1] p63 Fig.4.6)

Since a shutter is coupled to the shaft, these photo elements are exposed in sequence to the light emitted from a lamp placed in the left of the figure. Now the problem is the relation between the ON/OFF state of the transistors and the light detecting phototransistors. The simplest relation is set when the logic sequencer is arranged in such a way that when a phototransistor marked with a certain number is exposed to light, the transistor of the same number turns ON. Fig.6 shows that electrical currents flow through Tr1, Tr4, and Tr5, and terminals U and W have the battery voltage, while terminal V has zero potential. In this state, a current will flow from terminal U to V, and another current from W to V as illustrated in Fig.7. We may assume that the solid arrows in this figure indicate the directions of the magnetic fields generated by the currents in each phase. The fat arrow in the centre is the resultant magnetic field in the stator. The rotational direction may be reversed by arranging the logic sequencer in such a way that when a photodetector marked with a certain number is exposed to light, the transistor of the same number is turned OFF. On the other hand, when a phototransistor is not exposed to light, the transistor of the same number is turned ON.