Brushless – DC Motor 4: Commutation – Sinusoidal Control

TI Precision Labs - Motor Drivers

Presented and prepared by Vishnu Balaraj
Sinusoidal Brushless DC Motor Construction

Source: Electric Drives, an Integrative Approach, by Ned Mohan, University of Minn. Printing Services, 2000
Rotating magnetic field in Sinusoidal BLDC Motors

Source: http://people.ece.umn.edu/users/riaz/animations/abcvec.html
How to generate sinusoidal current?

Sinusoidal Voltage from phase to Phase

Sinusoidal Voltage with Third-Order Harmonics from Phase to GND

PWM output and the average value
Space Vector Modulation

<table>
<thead>
<tr>
<th>Sector</th>
<th>Switching Time Equation of S1, S3 and S5</th>
</tr>
</thead>
</table>
| 1      | S1 = T1 + T2 + T0/2  
         | S3 = T1 + T2 + T0/2  
         | S5 = T0/2          |
| 2      | S1 = T1 + T2/2  
         | S3 = T1 + T2 + T0/2  
         | S5 = T0/2          |
| 3      | S1 = T0/2  
         | S3 = T1 + T2 + T0/2  
         | S5 = T0/2          |
| 4      | S1 = T0/2  
         | S3 = T1 + T2 + T0/2  
         | S5 = T0/2          |
| 5      | S1 = T0/2  
         | S3 = T1 + T2 + T0/2  
         | S5 = T0/2          |
| 6      | S1 = T1 + T2 + T0/2  
         | S3 = T0/2          
         | S5 = T1 + T2 + T0/2 |

\[ T_1 = T \times \text{Duty cycle} \times \sin(60 - \alpha) \]
\[ T_2 = T \times \text{spd\_cmd} \times \sin \alpha \]
\[ T_0 = T - T_1 - T_2 \]

Duty cycle – ratio of phase voltage over supply voltage
\( \alpha \) – Rotor angle
\( T \) – PWM switching frequency
Sensored and Sensorless Sinusoidal Commutation

Sensored sinusoidal commutation

Sensorless sinusoidal commutation
BEMF Voltage and Rotor angle Estimation

• What we know:
  – Applied phase voltage \( U = \text{Duty cycle} \times Vm \)
  – Motor Inductance \( L \)
  – Motor Resistance \( R \)
  – Motor BEMF constant \( Ke \)
  – Motor speed \( \omega \)

• What we don’t know
  – \( V_{BEMF} \)
  – Rotor angle \( \alpha \)
  – Phase current \( I \)

\[
V_{BEMF} = Vm - I \times R - L \times \frac{di}{dt}
\]

\[
V_{BEMF} = \omega \times Ke \times \sin(\alpha)
\]
Advantages and Disadvantages

• Advantages
  – Ultra quiet
  – Highly efficient for sinusoidal motors
  – Low torque ripple

• Disadvantages
  – More switching losses
  – Poor speed and torque regulation for dynamic loads.
  – Increased complexity as it involves solving complex mathematical equations to estimate rotor angle.
To find more Motor Driver technical resources and search products, visit ti.com/motor-drivers.