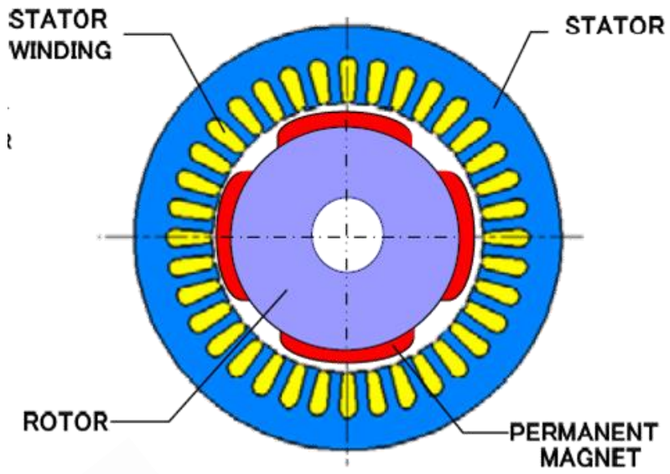
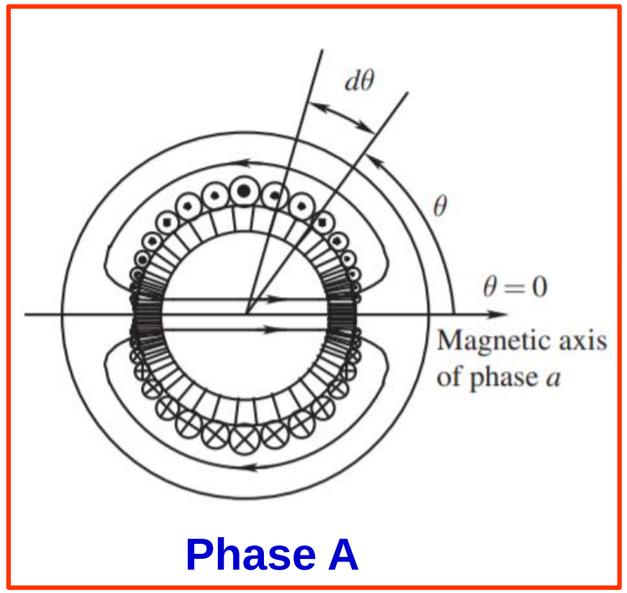
Brushless – DC Motor 4: Commutation – Sinusoidal Control

TI Precision Labs - Motor Drivers

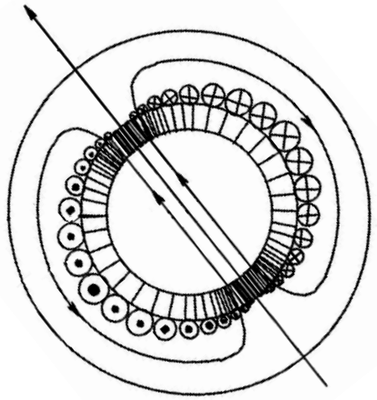
Presented and prepared by Vishnu Balaraj

Sinusoidal Brushless DC Motor Construction

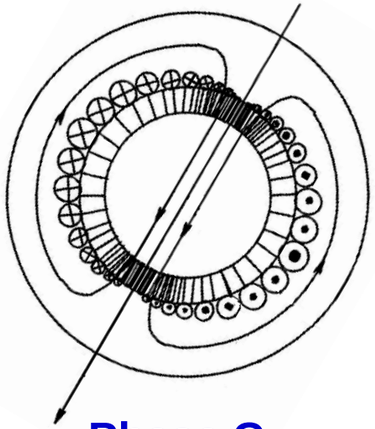




Phase A

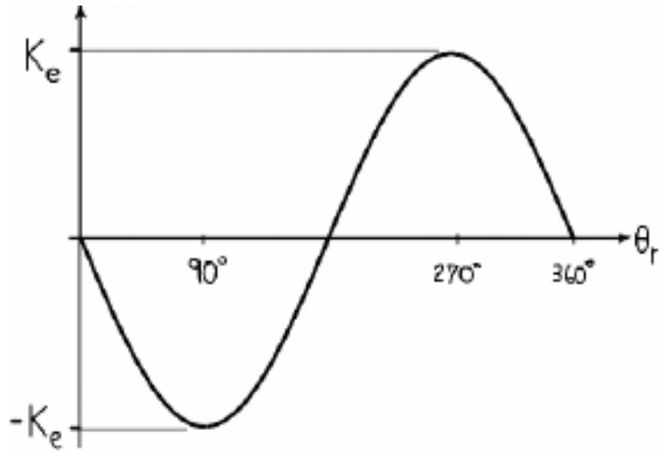


Phase B



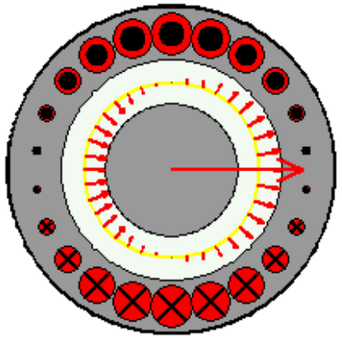
Phase C

Sinusoidal BEMF waveform

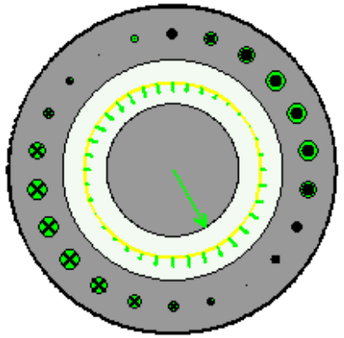


Source: Electric Drives, an Integrative Approach, by Ned Mohan, University of Minn. Printing Services, 2000

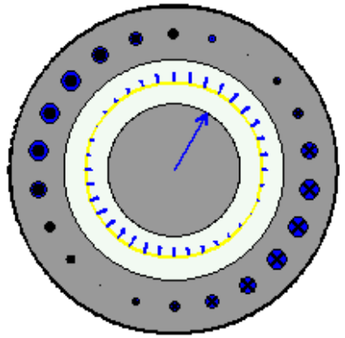
Rotating magnetic field in Sinusoidal BLDC Motors



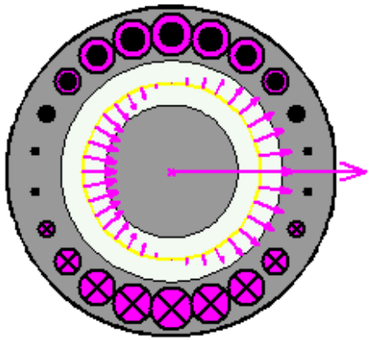
Phase A



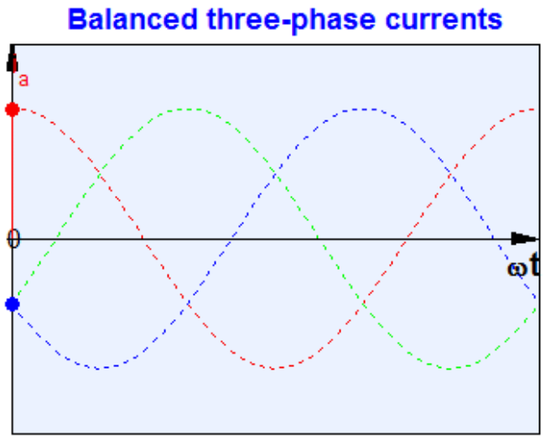
Phase B

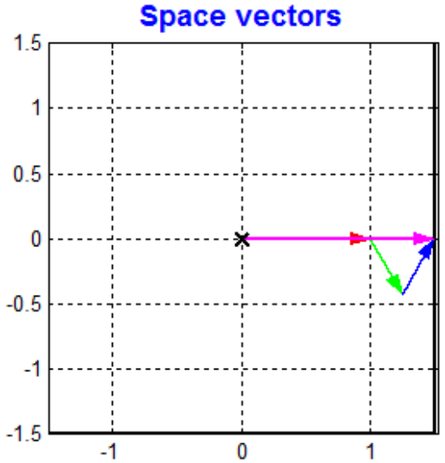


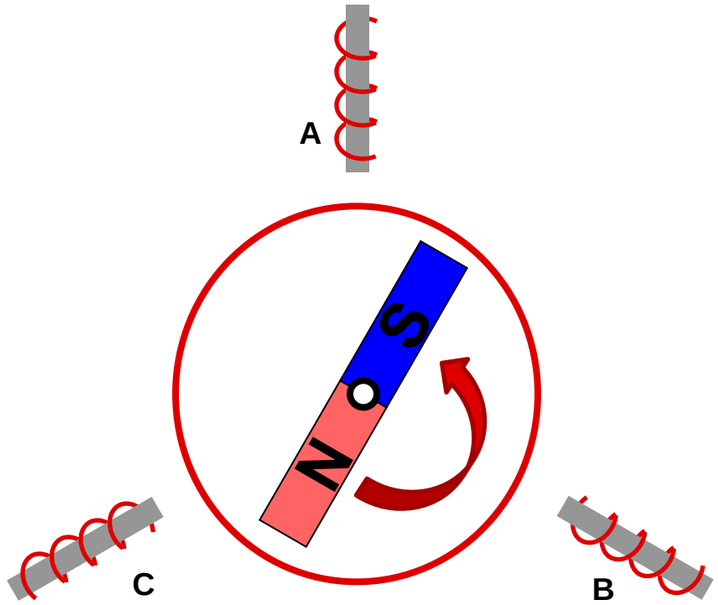
Phase C



Resultant

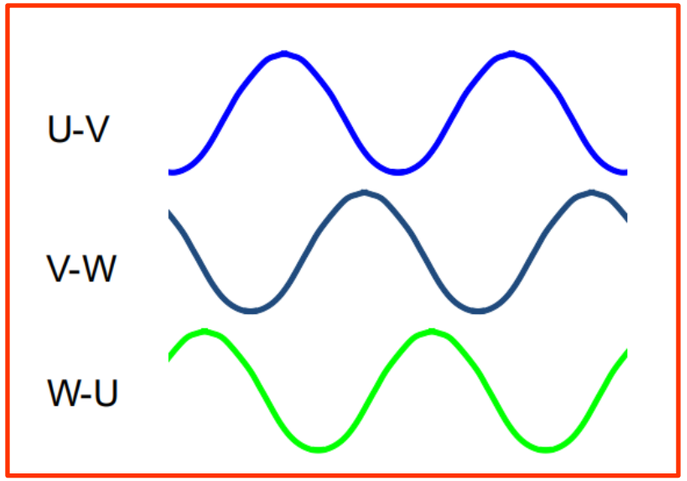


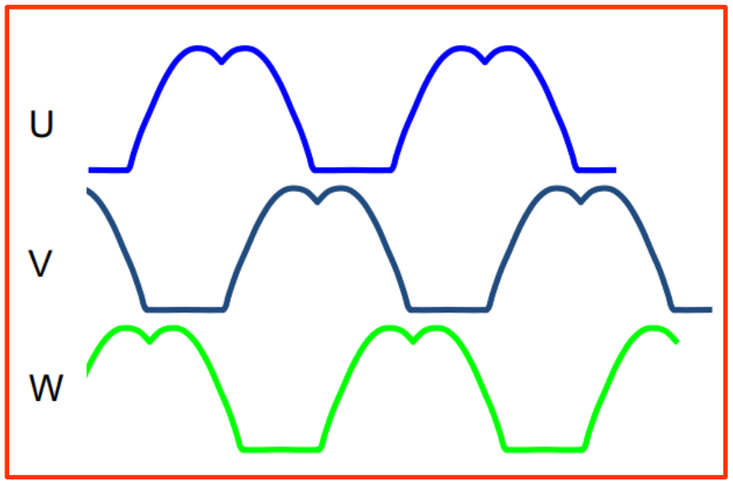




Source: http://people.ece.umn.edu/users/riaz/animations/abcvec.html

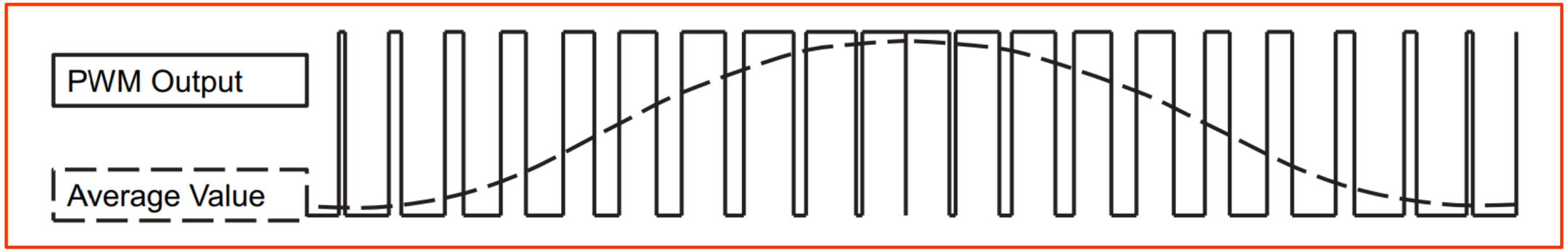
How to generate sinusoidal current?





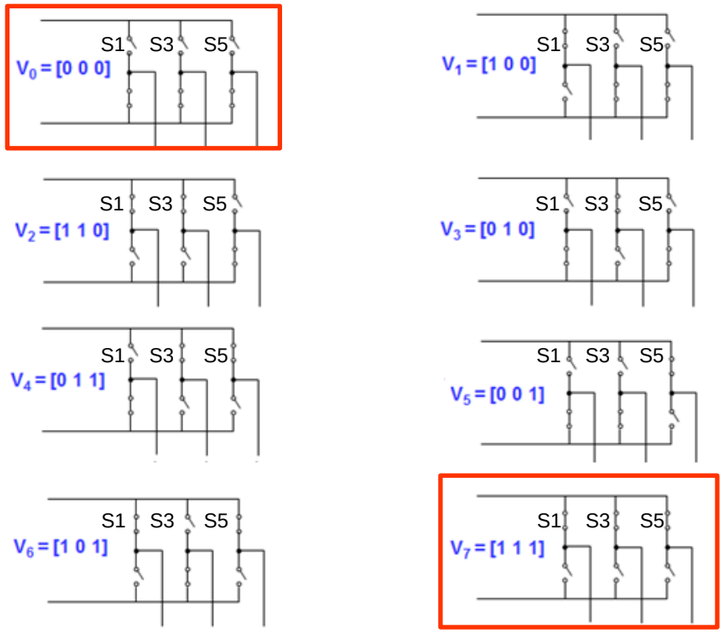
Sinusoidal Voltage from phase to Phase

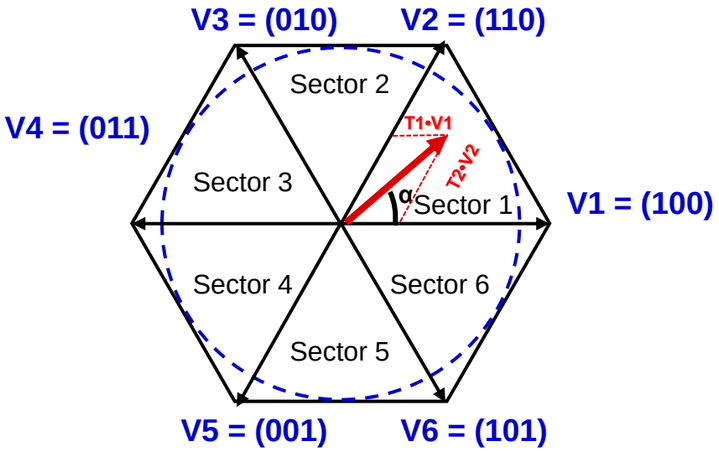
Sinusoidal Voltage with Third-Order Harmonics from Phase to GND



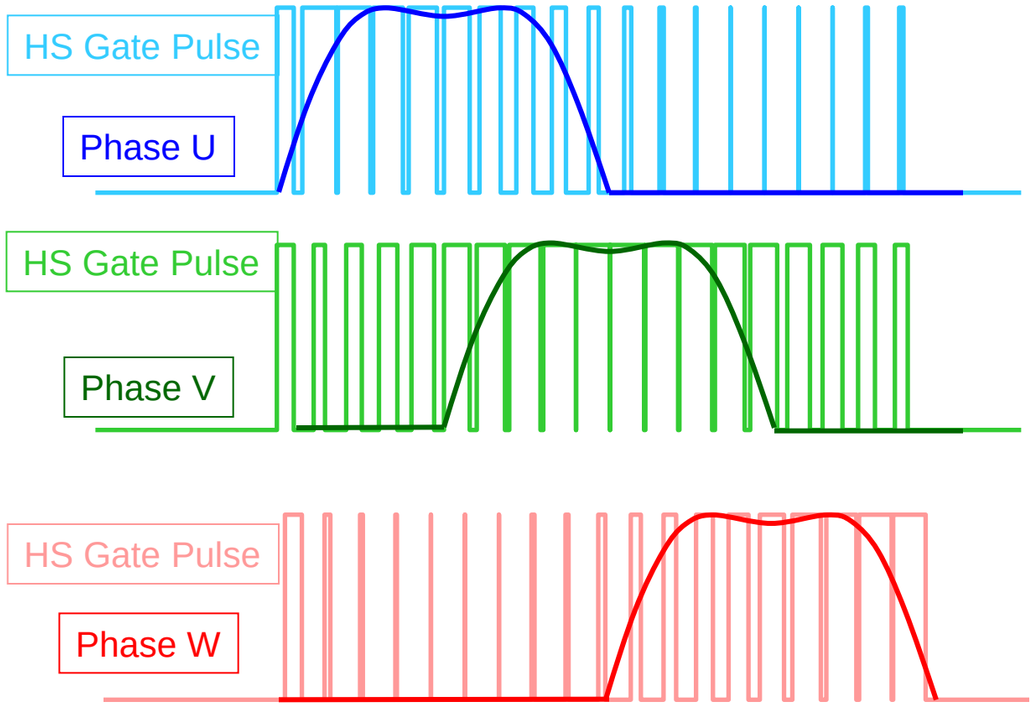
PWM output and the average value

Space Vector Modulation



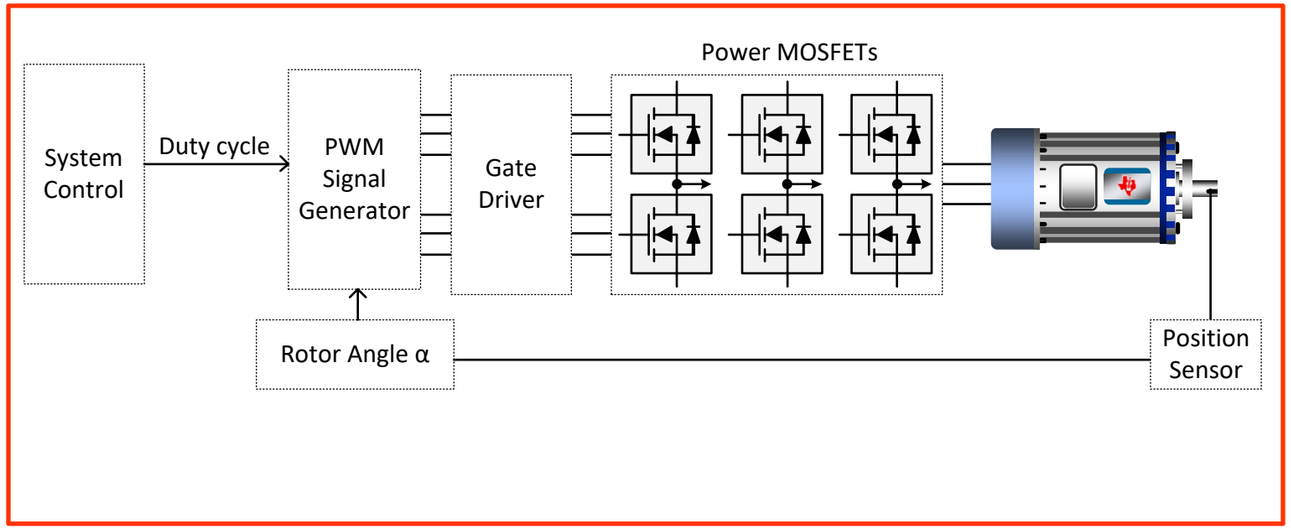


Sector	Switching Time Equation of S1, S3 and S5
1	S1 = $T_1+T_2+T_0/2$ S3 = $T_2+T_0/2$ S5 = $T_0/2$
2	S1= $T_1+T_0/2$ S3= $T_1+T_2+T_0/2$ S5= $T_0/2$
3	S1= $T_0/2$ S3= $T_1+T_2+T_0/2$ S5= $T_2+T_0/2$
4	S1= $T_0/2$ S3= $T_1+T_0/2$ S5= $T_1+T_2+T_0/2$
5	S1= $T_2+T_0/2$ S3= $T_0/2$ S5= $T_1+T_2+T_0/2$
6	S1= $T_1+T_2+T_0/2$ S3= $T_0/2$ S5= $T_1+T_0/2$

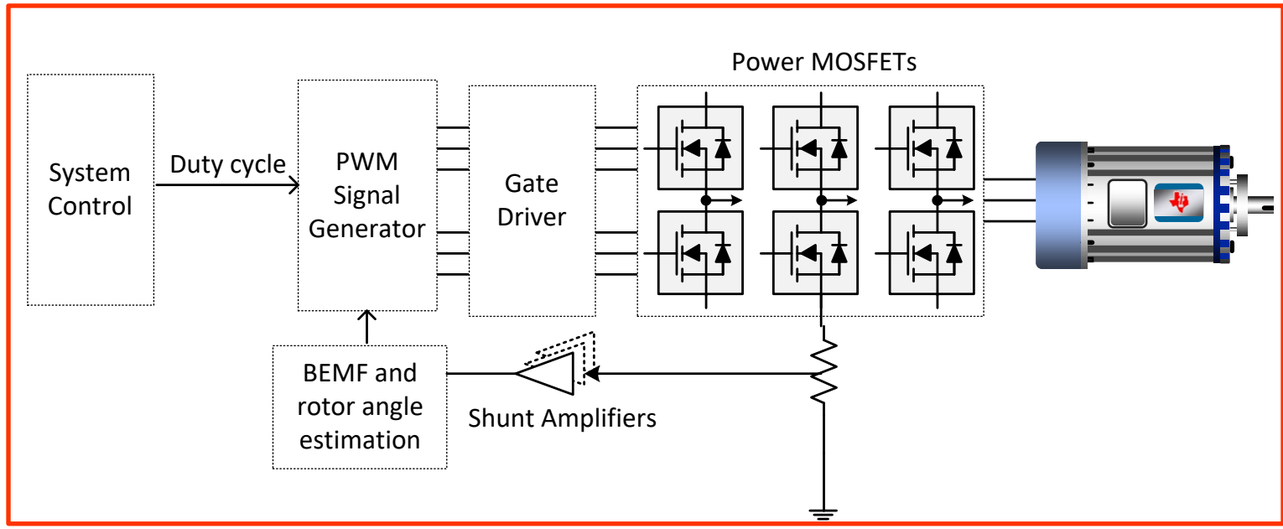


$$T_1 = T \times Duty\ cycle \times \sin(60 - \alpha)$$
$$T_2 = T \times spd\_cmd \times \sin\alpha$$
$$T_0 = T - T_1 - T_2$$
$$Duty\ cycle - ratio\ of\ phase\ voltage\ over\ supply\ voltage$$
$$\alpha - Rotor\ angle$$
$$T - PWM\ switching\ frequency$$

Sensored and Sensorless Sinusoidal Commutation



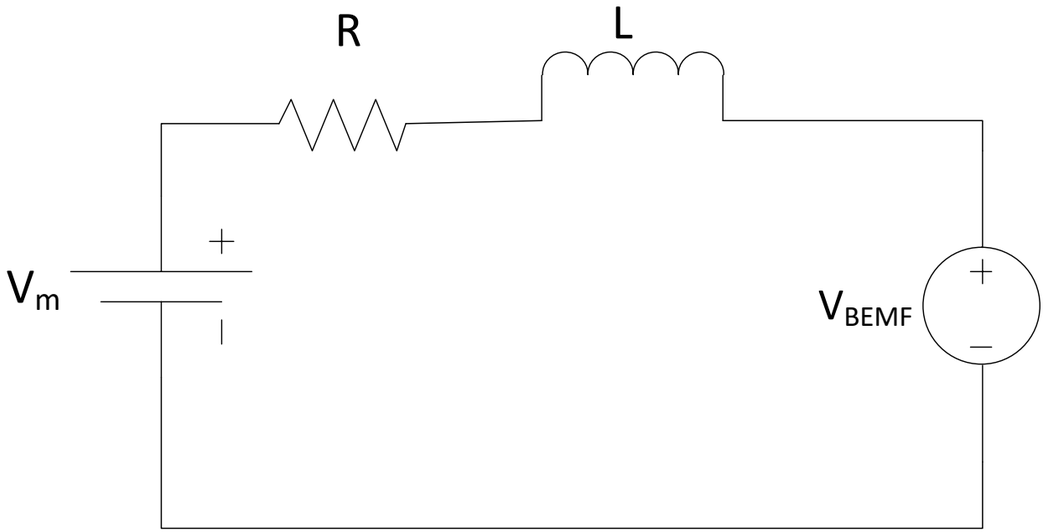
Sensored sinusoidal commutation



Sensorless sinusoidal commutation

BEMF Voltage and Rotor angle Estimation

- What we know:
  - Applied phase voltage $U = Duty\ cycle * Vm$
  - Motor Inductance L
  - Motor Resistance R
  - Motor BEMF constant Ke
  - Motor speed ω
- What we don't know
  - V_{BEMF}
  - Rotor angle α
  - 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.

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ti.com/motor-drivers.