Brushless-DC Motor 2: Sensored vs Sensorless Control
TI Precision Labs – Motor Drivers

Presented and Prepared by Michael Walker
Purpose of sensored and sensorless

Phase current

Phase A
Phase B
Phase C
What is sensored control?

• Stator and rotor positioning sensors:
  – Resolver
    • High resolution
    • High system cost
    • Needs digital processing
  – Encoder
    • High resolution
    • Needs digital processing
  – Hall-Effect Sensors
    • Low resolution
    • Low cost
What is sensorless control?

- Uses the “BEMF” of the motor to estimate the position of the rotor.
  - What is “BEMF”?
    - Back ElectroMotive Force
    - Faraday’s Law $V_{BEMF} = -N \frac{\Delta(B \cdot A)}{\Delta t}$

![Diagram of magnetic fields and equations](image)

**Equation:**

$V_{BEMF} = -N \frac{\Delta(B \cdot A)}{\Delta t}$

- Number of turns
- Change in magnetic field
- Area
- Change in time

**Sinusoidal BEMF and Trapezoidal BEMF Graphs**
BEMF

\[ V_{BEMF} = -N \frac{\Delta(B \times A)}{\Delta t} \]

\[ V_{BEMF} = \omega \times k_e \times \sin(\theta + \varphi) \]

- \( k_e \) = motor BEMF constant in mV/Hz
- \( \theta \) = rotor angle
- \( \omega \) = motor speed in Hz
How do you detect BEMF and position?

- Window method
How do you detect BEMF and position?

- What we know:
  - Phase voltage $U = \text{Duty cycle} \times Vm$
  - Motor Inductance $L$
  - Motor Inductance $R$
  - Motor BEMF constant $Ke$
  - $\omega$
  - $I$

- What we don’t know
  - $V_{BEMF}$
  - $\theta$
  - $I$

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

\[ V_{BEMF} = \omega \times Ke \times \sin(\theta) \]
### Types of BLDC motor applications

<table>
<thead>
<tr>
<th>Desired Output</th>
<th>Uses a motor to apply a force</th>
<th>Uses a motor to maintain a speed</th>
<th>Uses a motor to move to and hold a position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torque</td>
<td>N*m</td>
<td>RPM</td>
<td>θ</td>
</tr>
<tr>
<td>Speed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position</td>
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</tbody>
</table>
Challenges of BLDC motor applications

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Torque</th>
<th>Speed</th>
<th>Position</th>
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<tbody>
<tr>
<td>Zero/Slow speed torque</td>
<td>Withstand changes in torque</td>
<td>Position tracking</td>
<td>Zero/Slow speed torque</td>
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</tbody>
</table>

**Challenges**

- **Torque**
  - Zero/Slow speed torque

- **Speed**
  - Withstand changes in torque

- **Position**
  - Position tracking
  - Zero/Slow speed torque
## Control of BLDC motor applications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control Type</th>
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</thead>
<tbody>
<tr>
<td>Torque</td>
<td>Typically require sensored control</td>
</tr>
<tr>
<td>Speed</td>
<td>Can use either sensorless control or sensored control</td>
</tr>
<tr>
<td>Position</td>
<td>Almost always require sensored control</td>
</tr>
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</table>
Sensored vs Sensorless Control
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