Integrated H-bridge Motor Control with ST Automotive Smart Power
Introduction and Agenda

- In recent years there has been a huge increase in the number of DC motors used for automotive and other portable electronic applications.
  - Improved efficiency
  - Environmental regulations
  - Reduced system cost
  - More flexible control, and better diagnostics and protection

- DC motor technology, control architectures, and control strategies have also evolved to provide the most efficient, most reliable, and safest operation in these applications and ST motor control product families are key enablers to this technology migration

- This certification training will overview
  - ST integrated H-bridge product family
  - Application engineering and control strategies for efficient and safe DC motor control using integrated H-Bridges
DC Motor Basics

- Basic DC Motor Concepts and Relationships
  - DC motor converts electrical energy into mechanical energy.
  - DC Motor current and torque are proportional
  - DC Motor voltage and speed are proportional

[Diagram of DC Motor and related concepts]
Choosing the Right Solution:
VIPower Integrated H-bridges in the Full Suite of ST Motor Control Products

Decision Factors Leading to VIPower
- **Motor Type**
  - DC motor, Stepper, BLDC
- **System Voltage**
  - 5V, 12V, 18V, 24V
- **Load Profile**
  - Continuous or Pulsed
- **Load Current**
  - Low, Medium, High
- **PWM**
  - <20kHz, >20kHz
- **Inrush Current**
  - High or Low
- **Ambient Temp.**
  - 85°C, 105°C, 140-150°C
- **Number of loads**
  - Multibridge or Singlebridge
- **Control**
  - SPI or Direct
- **Diagnostic**
  - Full, Current Sense, None

Applications
- **Automotive**
  - Door Locks
  - Seat Belt Tensioner
  - Trunk, Tail Gate
  - Sun Roof
  - Rear Wiper
  - Fuel Pump
  - Power Window
- **Vending Machines**
- **Robotic Tools**
- **Power Tools**
- **Cooling Fan**
- **Power Steering**
- **Throttle Valve**
- **Front Wiper**
- **Water Pump**
- **Oil Pump**
- **Vacuum Pump** etc.
- **HVAC**
- **Seat Control**
- **Sliding Door**
- **Rear Wiper**
- **Fuel Pump**
- **Power Window**
- **Seat Belt Tensioner**
**VIPower Integrated H-Bridge Motor Driver**

**Key Features**

- **VCC Max:** 41V
- **Operating Supply Voltage:** 5.5V to 18V (24V VNH5019A)
- **$R_{DS(on)}$ @ 25°C:** 19/50/180mΩ per leg
- **PWM to 20kHz**
- **Current sense and Digital diagnostic feedback**
- **Undervoltage and overvoltage shutdown**
- **Current and Power Limitation**
- **Thermal shutdown protection**
- **Cross-conduction protection**
- **Very low stand-by power consumption**
- **Charge pump output for reverse polarity protection** (VNH5019A)
- **Outputs protected against Short to GND and VCC**

<table>
<thead>
<tr>
<th>PN</th>
<th>$R_{DS(on)}$ Path</th>
<th>$I_{LIM}$</th>
<th>Package</th>
<th>Typical Application</th>
</tr>
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<tbody>
<tr>
<td>VNH5019A</td>
<td>19mΩ</td>
<td>30A</td>
<td>Multi-Power SO-30</td>
<td>Window Lift</td>
</tr>
<tr>
<td>VNH5050A</td>
<td>50mΩ</td>
<td>30A</td>
<td>PowerSSO-36</td>
<td>Dual Washer</td>
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<tr>
<td>VNH5180A</td>
<td>180mΩ</td>
<td>8A</td>
<td>PowerSSO-36</td>
<td>Electric Lock</td>
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</table>

**Triple Island PwSSO-36**

**Triple Island Multipower SO-30**

**Three Island SMD package**

**Dual High-Side**

**PowerMOS**

**PowerMOS**
Solid State Integrated H-Bridge
VIPower Competitive Advantages

- Technology
  - As semiconductor technology advances, component costs are lowered

- Environmental/Legislative Mandates
  - Solid state electronics provide control, protection, quality and performance reliability to meet emissions standards and safety features as required by law

- Lifetime
  - Integrated H-Bridge seldom fails and has almost no wear out mechanisms.
  - Shock, vibration, and altitude have almost no affect on reliable performance.

- Quiet Operation
  - No moving parts and operate silently, with bounce-free switching.

- Smaller and Lighter
  - Big savings on PCB real-estate and weight.

- Load and System Protection
  - Short circuit protection, overvoltage and under voltage protection, current limit protection, power limit protection.

- Diagnostics
  - Normal operation feedback and fault condition detection and communication.

- Direct drive from microcontroller
  - No need for coil driver.

- Lower EMI.
  - Relay contact arching and bouncing causes much higher EMI signature.
Design Considerations

- **MCU I/Os protection:**
  - Add series resistor to prevent latchup in negative transient

- **INA & INB:**
  - Used to select the motor direction and braking

- **PWM:**
  - Controls the speed of the motor via control of the LSD
  - Operation to ≤20 KHz.

- **DIAGX/ENX:**
  - Open drain input in normal operating condition and must be pulled high.
  - In overload condition, the faulted leg of the bridge is latched off and the corresponding DIAGX/ENx pin is pulled low to indicate the fault.
  - Branch must be reset.

- **Blocking capacitor:**
  - 500μF per 10A load current is recommended.

- **Analogue current sense:**
  - Delivers a current proportional to the load current
  - Converted to a voltage through an external sense resistor

- **CS_DIS:**
  - Allows sharing the sense resistance and the ADC channel among different devices.
Load and Device Compatibility

• Non appropriate selection of the device has influence operational behavior and its lifetime.

• Current and power limitation protection should not be used to intentionally underestimate the choice of the device.

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**Inrush phase**: Motor driver can deliver current above nominal current for short term to provide peak torque and start the motor.

**Movement phase**: Moving motor draws less current. Motor steady state operation phase.

**Stall phase**: The motor loses its movement speed and current becomes maximum.

Device should be chosen to operate without current limit in all phases.
VNH5xxxA Parallel Configurations

- Two identical H Bridges can be connected in parallel by combining the two outputs of each H Bridge.
  - Results in \( \frac{1}{2} \) RDS(ON)
  - Inputs and PWM driven in parallel
  - Diagnostic pins combined
  - Common current sense resistor

- Particular attention must be paid in layout to avoid asymmetry

- Energy rating is NOT doubled

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>Stall Current (A)</th>
<th>Stall Torque (Nm)</th>
<th>Current at max efficiency (A)</th>
<th>Max Efficiency (%)</th>
<th>Max Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mirror Adjuster</td>
<td>0.2</td>
<td>4.2</td>
<td>0.08</td>
<td>45.0</td>
<td>0.5</td>
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<tr>
<td>Heating HVAC</td>
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<td>7.6</td>
<td>0.1</td>
<td>59.0</td>
<td>0.7</td>
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<td>Headrest adjusters</td>
<td>1.3</td>
<td>37.0</td>
<td>0.7</td>
<td>62.0</td>
<td>3.9</td>
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<tr>
<td>Washer Pump</td>
<td>14.0</td>
<td>61.0</td>
<td>2.8</td>
<td>61.0</td>
<td>41.0</td>
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<td>Headlamp Washer</td>
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<td>127.0</td>
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<td>Child Safe Lock</td>
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<td>63.0</td>
<td>11.5</td>
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<tr>
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<td>268.0</td>
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<td>33.0</td>
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<tr>
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<td>456.0</td>
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<td>45.0</td>
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<td>61.0</td>
<td>77.0</td>
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<td>Electric Parking Brake</td>
<td>100.0</td>
<td>624.0</td>
<td>13.0</td>
<td>67.0</td>
<td>260.0</td>
</tr>
</tbody>
</table>
VNH5xxxA

Diagnosis & Protection

- Over-temperature
- Output shorted to ground
- Output shorted to Vcc
- Power Limitation
- Under-voltage Shutdown
- Short to Vcc latch
- Over-voltage shutdown
- Cross conduction protection
Overload conditions

- Output short to ground
- Output shorted to VCC
- Short circuit across the motor
- Overtemperature
- Power Limitation

Overload Protection and Diagnostics

- Power Limitation
- Current Sense
- Digital Diagnostics
PWM and Cross Current Protection

- Speed control and soft start is controlled via the Low Side drivers via PWM.
- Due to their faster switching times a high frequency to ≤20 kHz can be reached.
- PWM should be as fast as possible to avoid motor noise and vibrations.
- During the off phase of the period the current of the motor freewheels through the body diode of the High Side.
- When changing motor direction Cross Conduction protection prevents the both HSD from being on at the same time.
- Shoot-through protection is provided by optimized gate charge and a suitable internal dead time.
Reverse Battery Protection with VN5R003H

- **Stops** Reverse Battery currents in loads and devices.
- **Low Power Dissipation** in normal system operation.
  - $3 \, \text{m}\Omega \, \text{typ} @ 25\,\text{C}, 10\,\text{A}$
- Can be shared by multiple circuits.
- Works with switched or non-switched battery systems.
  - Automatic switch-off in Reverse Battery
- **Small and thermally efficient** package.

Power Dissipation @ 10A

**Schottky vs VN5R003**

- $I_F = 10\,\text{A}$
- $P = V_F \times I = 8\,\text{W}$
- $P = I^2 \times R_{DS(\text{ON}_{\text{max}})} = \frac{1}{2} \, \text{W}$

Application Diagram

- 6.4mm
- 9.4mm
Supporting VIPOWER M0-5 Integrated H-bridges

- VNH5019A
- VNH5050A
- VNH5180A

GUI general view

- Full development kit and ready-to-use application for DC motor applications.
- Motherboard/Daughterboard Concept with automatic daughter board identification by USB
- Graphical User Interface (GUI) to monitor the Motor characteristics in real time under different conditions
- All diagnostic and control features available
- PWM to 20kHz
- Reference design (to assure EMC immunity) for potential customers
- Application example with STM8A µC
Coming Soon:
EZ-Boards for VIPOWER VNHxxxA

• The easiest and smartest way to evaluate and develop your application,
• Cut evaluation cost.
• Reducing resources
• Excellent thermal performance (large copper coverage and thermal vias)
• Orderable on ST.com
  http://www.st.com/internet/evalboard/subclass/1580.jsp?WT.ac=auto_m0-5_ezboard

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