# Integrated H-bridge Motor Control with ST Automotive Smart Power

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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
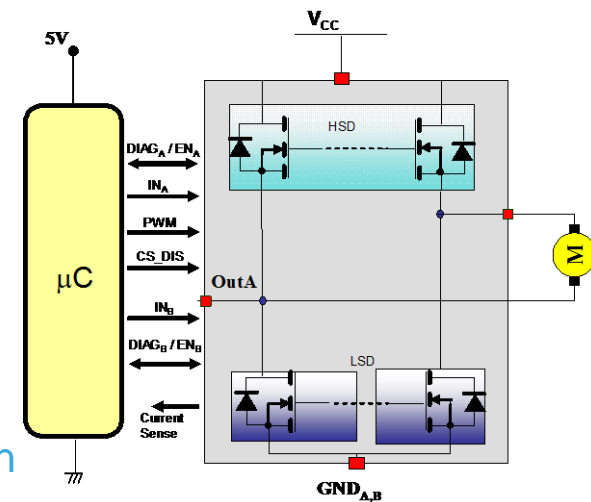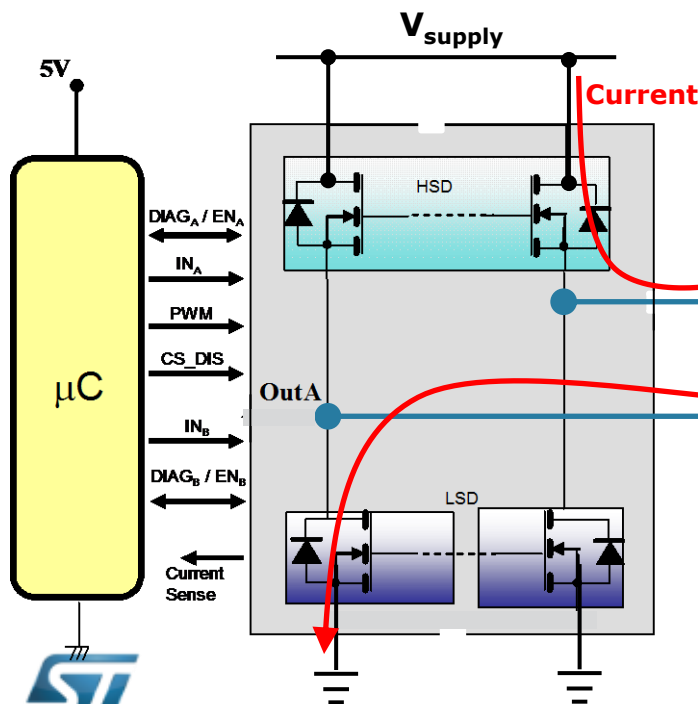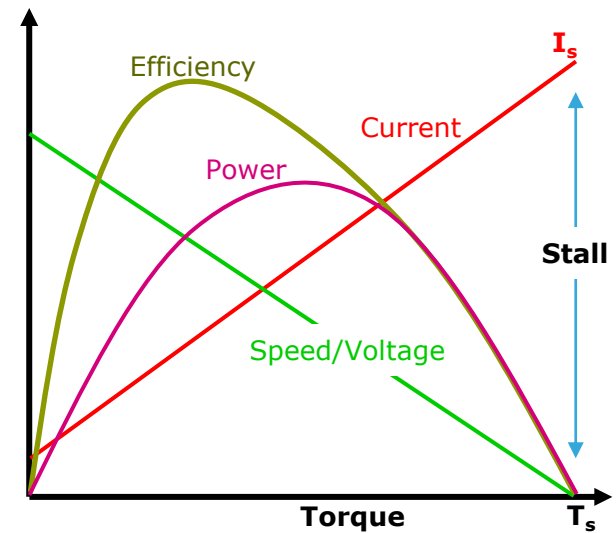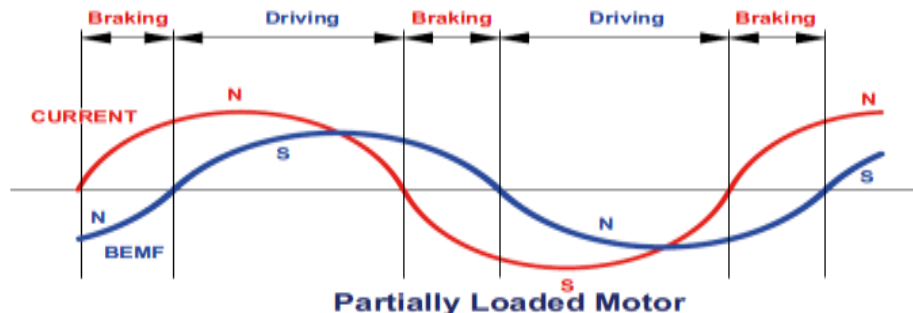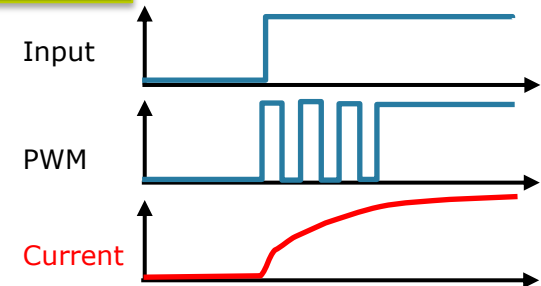
DC Motor Basics

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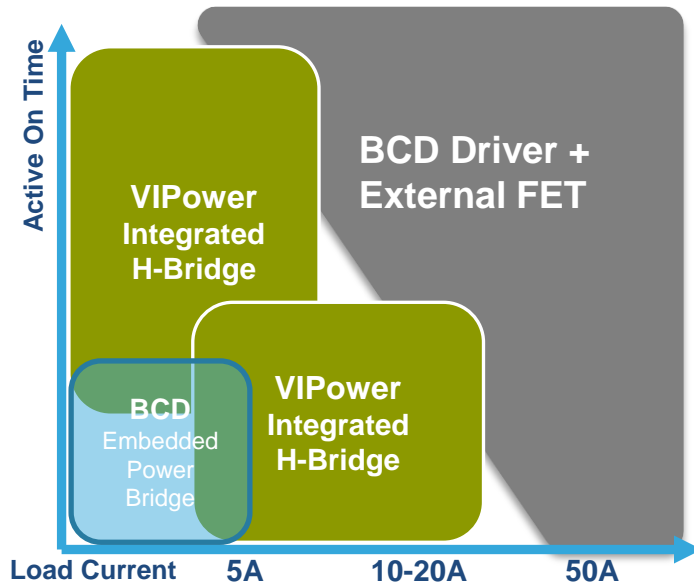 - DC Motor voltage and speed are proportional

Choosing the Right Solution:
VIPower Integrated H-bridges in the Full Suite of ST Motor Control Products

Active On Time

VIPower Integrated H-Bridge

BCD Driver + External FET

BCD Embedded Power Bridge

VIPower Integrated H-Bridge

Load Current   5A   10-20A   50A

Decision Factors Leading to VIPower

- Motor Type — DC motor, Stepper, BLDC
- System Voltage — 5V, 12V, 18V, 24V
- Load Profile — Continous 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

Robotics

Automotive

Door Locks

Seat Belt Tensioner

Throttle Valve

Front Wiper

Cooling Fan

HVAC

Sun Roof

Trunk, Tail Gate

Power Steering

Park Brake

Rear Wiper

Water Pump Oil Pump Vacuum Pump etc ..

Seat Control

Fuel Pump

Sliding Door

Power Window

Power Tools

Vending Machines

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VNH5XXXA
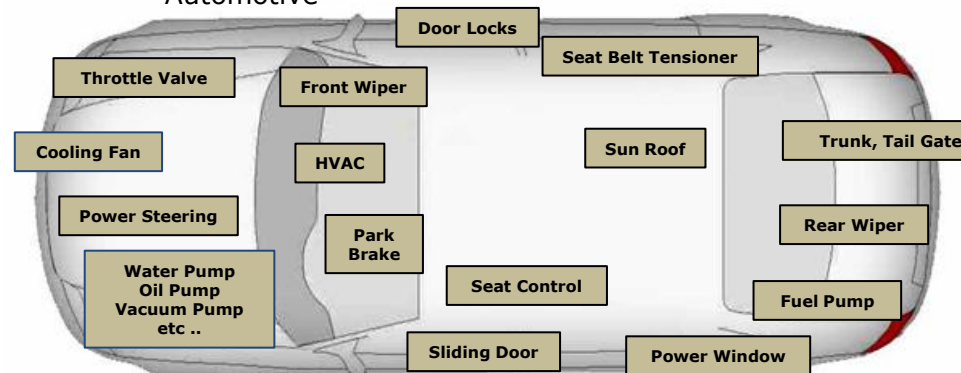
VIPower Integrated H-Bridge Motor Driver

| PN	R_{DS}(ON) Path	I_{LIM}	Package	Typical Application
VNH5019A	19mΩ	30A	Multi-Power SO-30	Window Lift
VNH5050A	50mΩ	30A	PowerSSO-36	Dual Washer
VNH5180A	180mΩ	8A	PowerSSO-36	Electric Lock

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)
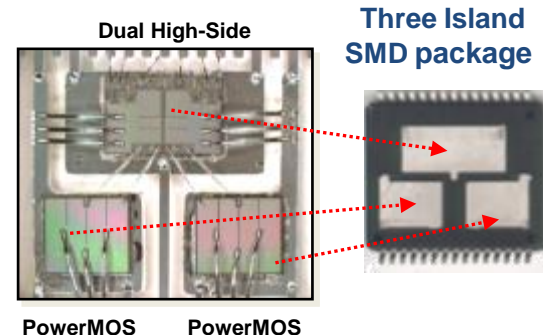- Outputs protected against Short to GND and VCC

VNHxxxxA

Three Island SMD package

Dual High-Side

PowerMOS   PowerMOS
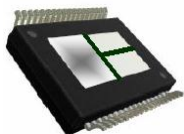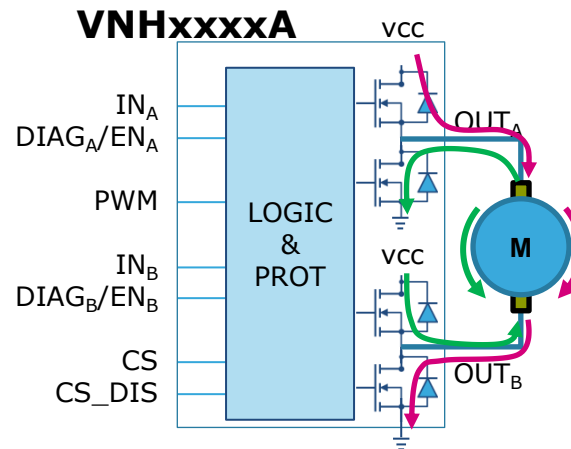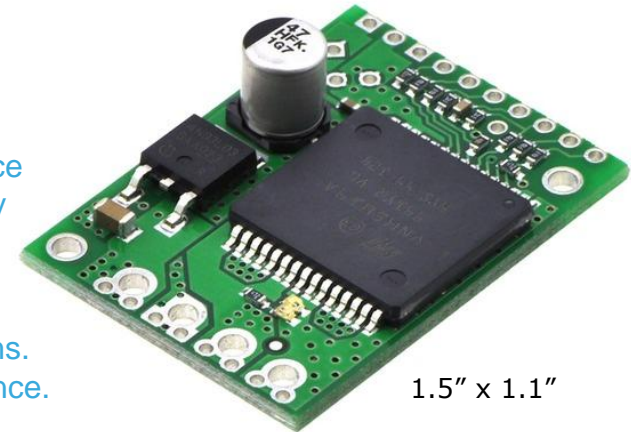
Triple Island PwSSO-36
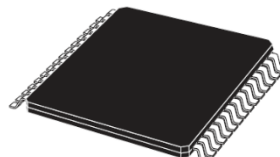
Triple Island Multipower SO-30

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.

1.5" x 1.1"

Courtesy of Pololu

- 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.

VNH5xxxA
General Application Scheme

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.

PN	R_{DS}(ON) Path	I_{LIM}	Package	Typical Application
VNH5019A	19mΩ	30A	Multi-Power SO-30	Window Lift
VNH5050A	50mΩ	30A	PowerSSO-36	Dual Washer
VNH5180A	180mΩ	8A	PowerSSO-36	Electric Lock

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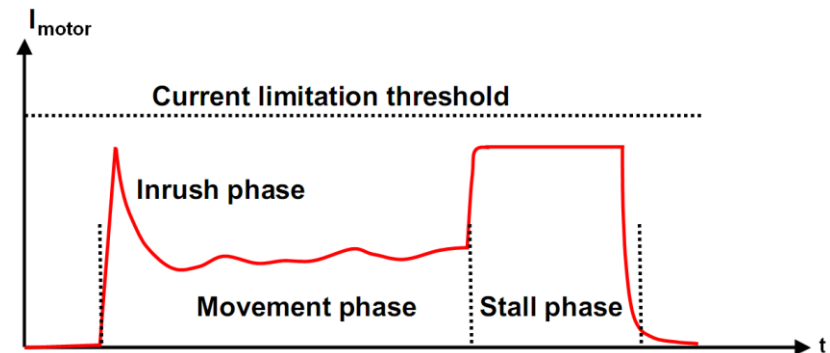
Device should be chosen to operate without current limit in all phases

VNH5xxxA Parallel Configurations

- Two identical H Bridges can be connected in parallel by combining the two outputs of each H Bridge.
  - Results in ½ RDS(ON)
  - Inputs and PWM driven in parallel
  - Diagnostic pins combined
  - Common current sense resistor

Courtesy of Pololu

- Particular attention must be paid in layout avoid asymmetry

- Energy rating is NOT doubled
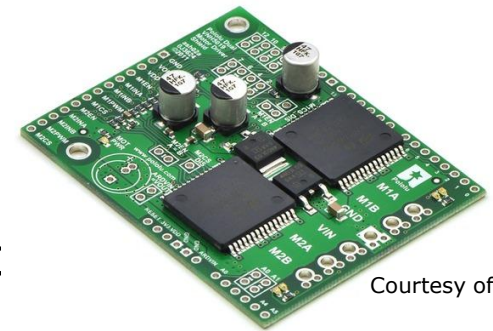
APPLICATION	Stall Current (A)	Stall Torque (Nm)	Current at max efficiency (A)	Max Efficiency (%)	Max Power (W)
Mirror Adjuster	0,2	4,2	0,08	45,0	0,5
Heating HVAC	0,3	7,6	0,1	59,0	0,7
Headrest adjusters	1,3	37,0	0,7	62,0	3,9
Washer Pump	14,0	61,0	2,8	61,0	41,0
Headlamp Washer	40,0	190,0	7,0	65,0	127,0
Child Safe Lock	4,5	32,0	0,7	63,0	11,5
Door Lock	12,0	268,0	1,9	66,0	33,0
Seat Adjustment	15,0	456,0	2,9	62,0	45,0
Power Window	30,0	418,0	5,6	61,0	77,0
Electric Parking Brake	100,0	624,0	13,0	67,0	260,0

VNH5xxxA
Diagnosis & Protection
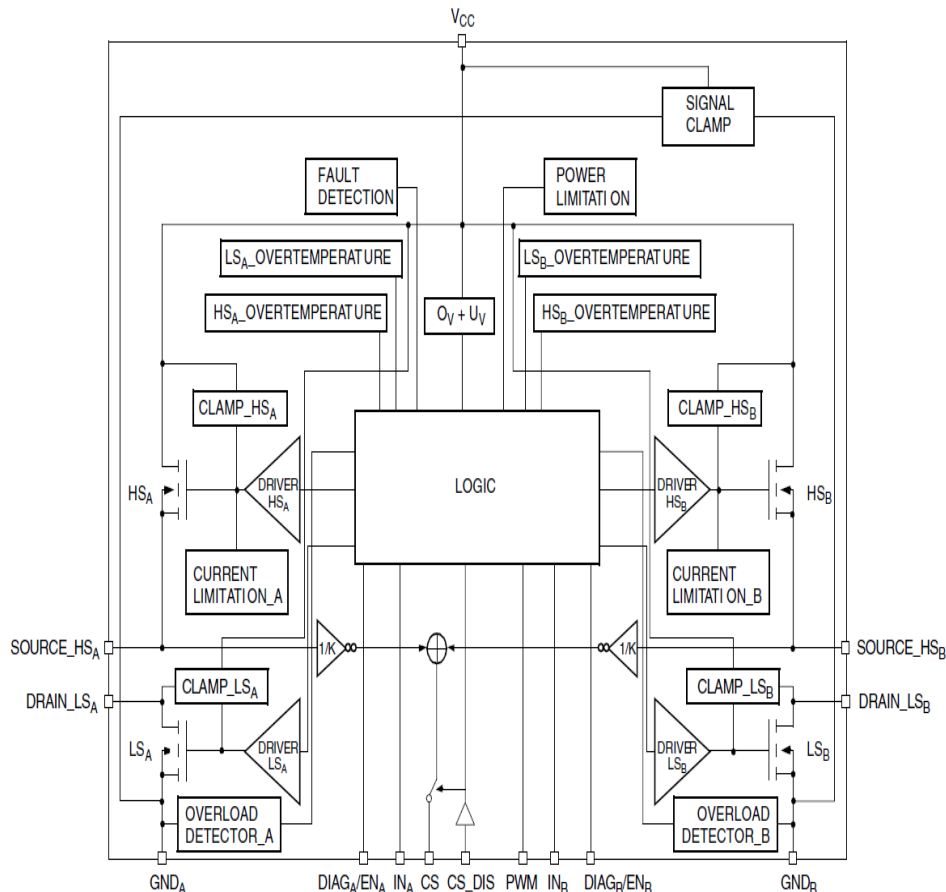
- Over-temperature

- Output shorted to ground

- Output shorted to Vcc

- Power Limitation

- Under-voltage Shutdown

- Short to Vcc latch

- Over-voltage shutdown
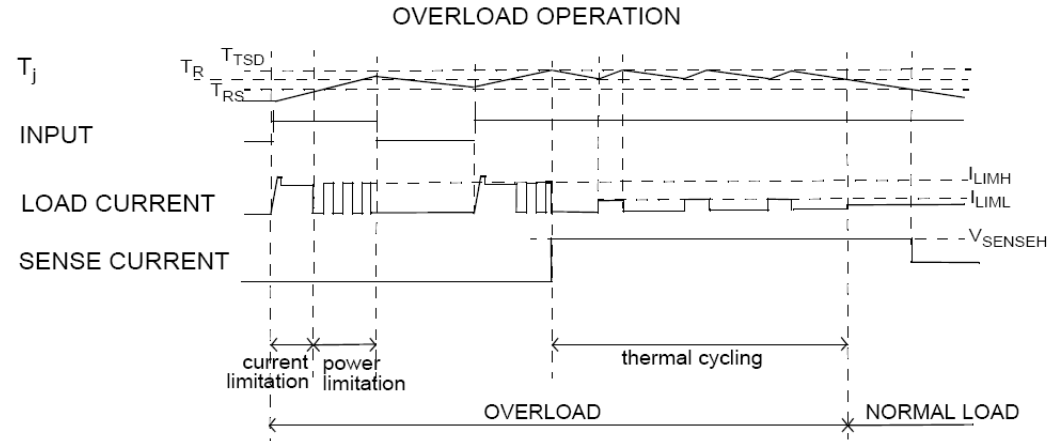
- Cross conduction protection

Overload 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

OVERLOAD OPERATION

T_j T_R T_{TSD} T_{RS}

INPUT

LOAD CURRENT I_{LIMH} I_{LIML}

SENSE CURRENT V_{SENSEH}

current limitation | power limitation   thermal cycling

OVERLOAD   NORMAL LOAD

Load short circuit event. Various protection mode

I_{SD_LS} detection ("pure" short circuit)
Test conditions
- V_{CC} = 13V
- R_L = 1.5Ω then 0Ω
- Starting T_J = 25°C
- V_{ENA}, V_{ENB} pulled-up, V_{INA} = V_{PWM} = 5V; V_{INB} = 0V
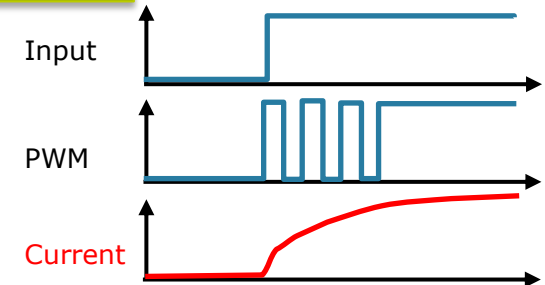
Thermal shutdown detection

S.C event

M5.00ms Ch4
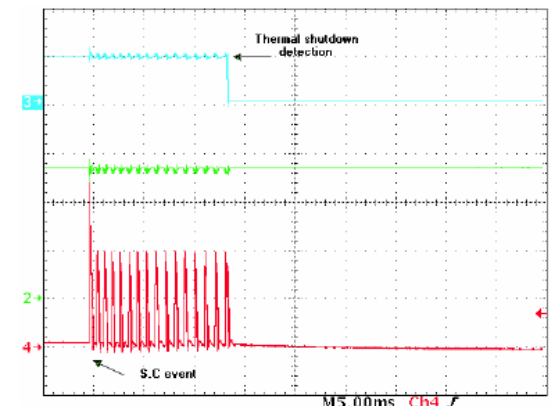
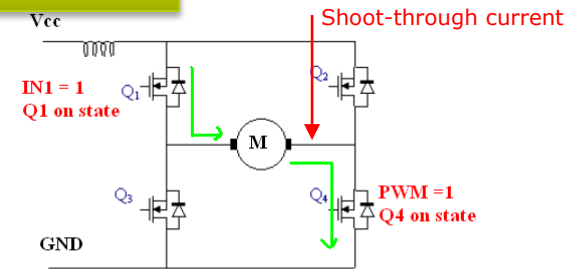*Scales:* V_{ENA} = 5V/div V_{CC}=5Vdiv, I_{CC} =20A/div,

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.
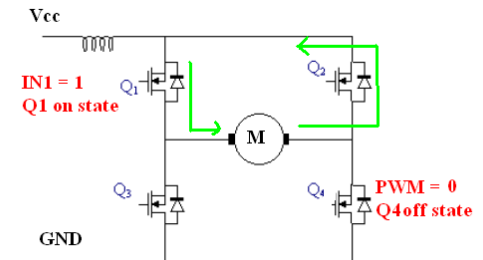
Soft Start w/ PWM

Input

PWM

Current

PWM On

Vcc

Shoot-through current

IN1 = 1
Q1 on state

Q1

Q2

M

Q3

Q4

PWM =1
Q4 on state

GND

PWM Off

Vcc

IN1 = 1
Q1 on state

Q1

Q2

M

Q3

Q4

PWM = 0
Q4 off state

GND

Reverse Battery Protection with VN5R003H

- **Stops** Reverse Battery currents in loads and devices.
- **Low Power Dissipation** in normal system operation.
  - 3 mΩ typ @ 25C, 10A
- 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.

6.4mm

9.4mm

Application Diagram

Power Dissipation @ 10A Schottky vs VN5R003

$I_F = 10A$

VN5R003H

Charge Pump

$\overline{IN}$

D

$P = V_F * I$

$P = \underline{\textbf{8W}}$

$P = I^2 * R_{DS}(ON_{max})$

$P = \underline{\textbf{½ W}}$

VN5R003H

Charge Pump

R

R

$\overline{IN}$

S

Vcc

D

V_{BATT}

-

+

μC

5V

DIAG_A / EN_A

IN_A

PWM

CS_DIS

Out A

IN_B

DIAG_B / EN_B

Current Sense

HSD

M

LSD

GND_AB

ICC (-VBATT)
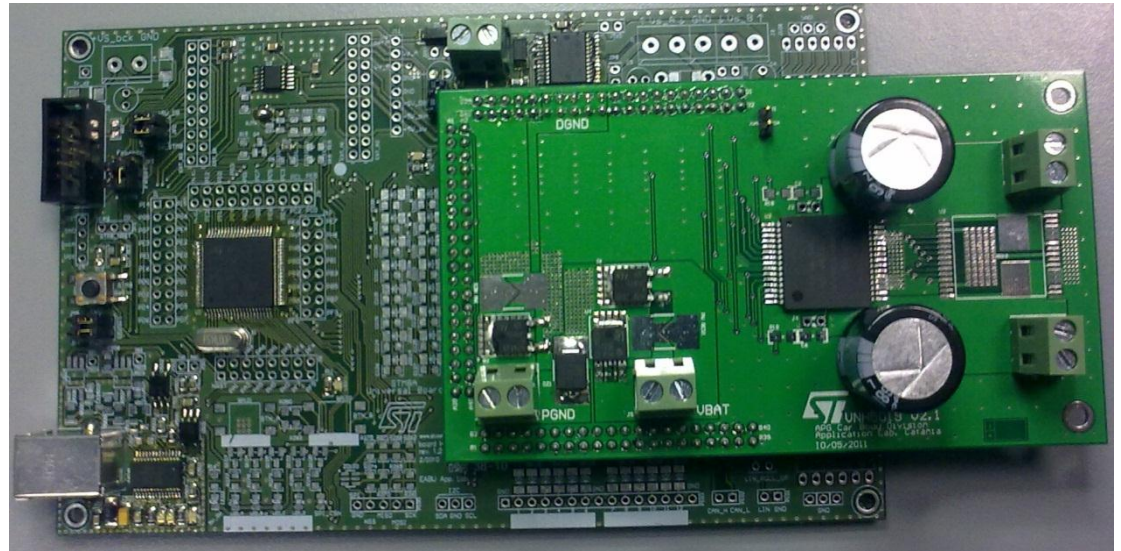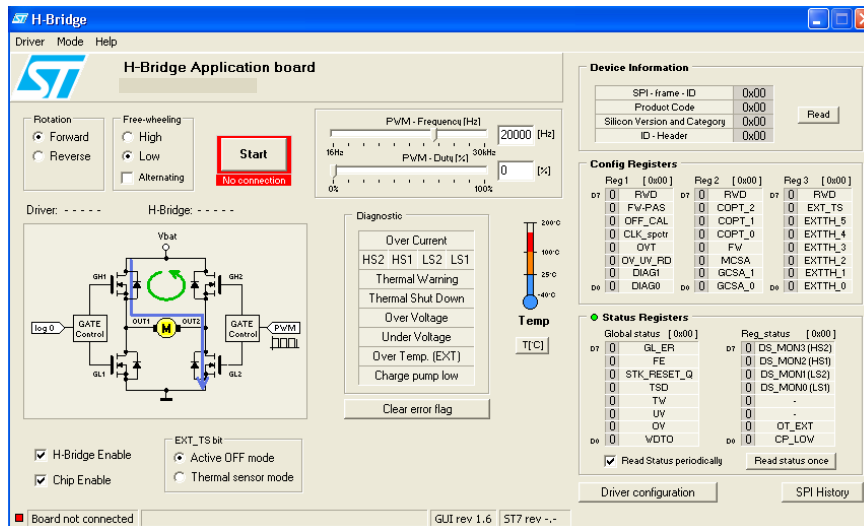
VNH5xxxA
System Development Support

Supporting VIPower M0-5 Integrated H-bridges

- VNH5019A
- VNH5050A
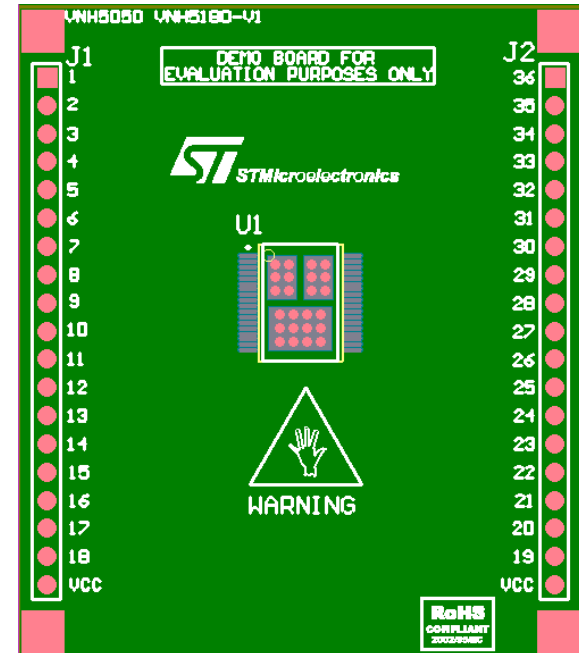- VNH5180A

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

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

Easyboards make product evaluation simpler and cut the development cost!

These products on the web @
http://www.st.com/internet/automotive/subclass/1039.jsp