H-Bridges Motor Drivers

FTF-IND-F0332

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MAY 2014
Agenda

- Overview of Freescale Analog Driver Group and Introduction to H-Bridge Product Portfolio (5 minutes)
- Technology Review (5 minutes)
- Motor Driver Basics (10 minutes)
- Application Examples (10 minutes)
- Portfolio Review (10 minutes)
- Power Dissipation and Thermal Analysis (5 minutes)
- Integration and Demonstration with FRDM Platform (10 minutes)
- Wrap-up and Enablements (5 minutes)
Freescale Analog
Expanding Markets

Analog Organization and Driver Products
A Global Leader in

<table>
<thead>
<tr>
<th>Five Core Product Groups</th>
<th>Four Primary Markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcontrollers</td>
<td>Automotive</td>
</tr>
<tr>
<td>Digital Networking</td>
<td>Networking</td>
</tr>
<tr>
<td>Automotive MCU</td>
<td>Industrial</td>
</tr>
<tr>
<td>Analog &amp; Sensors</td>
<td>Consumer</td>
</tr>
<tr>
<td>RF</td>
<td></td>
</tr>
</tbody>
</table>

- 50 Year Legacy
- 5,500 Engineers
- 6,100 Patent Families
Analog & Sensor Group Organizational Chart

James Bates
SVP & GM

Deena Shipman
Executive Assistant

Babak Taheri
Sensor Solutions

Eric Toulouse
Driver Products

Jaime Pla
Power Products

Patrick Morgan
Safety Systems

Jorge Salhuana
Standard Products

Erwan Hemon
Design and Test

Mark Klatt
Product Engineering

Ronen Shtayer
Program Mgmt & Technology Development

Product Team Support

Brett Whitmire
Finance

Marc Paul Denamiel
HR

James Trimble
Legal

Bob Sulski
Quality

Jill Partridge
Communications

Lisa Bradley
Corporate Marketing

Corporate Support
Freescale Analog in the World

Detroit, MI
- Design

Moscow
- Design

Austin, TX
- Fab*2

Tempe, AZ
- Design & Eng
- Fab
- Operations

Toulouse, France
- Design & Eng
- Operations

Tianjin, China
- Manufacturing
- Operations

Korea ASM
- Manufacturing
- Operations
# Analog Drivers: High Level Portfolio

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Market / Typical Application</th>
</tr>
</thead>
</table>
| **H-Bridge**                        | Automotive (engine management, throttle control, electronic gas recirculation, turbo flap control, etc.)  
                                         Industrial (DC brushed & stepper motor)  
                                         Consumer (battery operated system)                                                   |
| **3 Phase Gate Driver**             | Automotive (EPS, EGR, ETC, HVAC)  
                                         Industrial (fans, pumps, power tools, and general brushless DC motor drive)           |
| **General Purpose Low Side and High Side drivers** | Automotive (engine management, body)  
                                         Industrial (general purpose load driver)                                                   |
| **Solenoid Drivers & Controllers**  | Automotive (engine control, transmission)  
                                         Industrial (small engine control, solenoid driver)                                            |
| **Networked Motor Driver**          | Automotive (body electronic)  
                                         Industrial (gas valves, motor valves control)                                           |
SMARTMOS
Technology for Today and Tomorrow

SMOS Roadmap
SMARTMOS Technology Integration

More than driving loads

- Cost-effective high voltage (105V) power analog embedded system process platform
- Low RDS\(_{(ON)}\)*A (30 mΩ-mm\(^2\)) for thermal efficiency in high current applications
- High precision for sensor interface integrated with power applications
- Advanced isolation capability (-40V) and robust system transient ESD/EMC immunity
- Low power devices to reduce overall system power consumption
- Extreme temperature operation for harsh application environments (-40°C to +175°C)
Migration toward deep submicron processes

- **Power FET**
  - HDTMOS3 0.8µm/45V
  - HDTMOS5 0.8µm/45V
  - LFET 65/45 0.28µm/45V/65V

- **High Voltage Path**
  - SMOS 5HV+ 0.7µ/105V
  - SMOS 8MV 0.28µ/80V
  - SMOS 10HV 0.13µ/105V

- **Low Voltage Path**
  - SMOS 7LV 0.4µ/40V
  - SMOS 8LV 0.28µ/30V
  - SMOS 10W 0.13µ/30V

**New processes**

**Current processes**

**Migration toward deep submicron processes**

- 2001
- 2003
- 2007
- 2010
- 2013
SMARTMOS Evolution

<table>
<thead>
<tr>
<th>Logic Density</th>
<th>1.1K</th>
<th>2.0K</th>
<th>25.0K</th>
<th>90.0K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Capability</td>
<td>65V</td>
<td>105V</td>
<td>45/80V</td>
<td>105 V</td>
</tr>
<tr>
<td>45V Power Rdson*A</td>
<td>90 mΩ·mm²</td>
<td>67 mΩ·mm²</td>
<td>40 mΩ·mm²</td>
<td>30 mΩ·mm²</td>
</tr>
<tr>
<td>Isolation Voltage</td>
<td>65 V (Junction)</td>
<td>105 V (Junction)</td>
<td>80 V (Trench)</td>
<td>105 V (Trench + SOI)</td>
</tr>
<tr>
<td>Logic Density</td>
<td>SMOS5AP 1996 (0.8 µm)</td>
<td>SMOS5HVP 2002 (0.7 µm)</td>
<td>SMOS8MV 2006 (0.25 µm)</td>
<td>SMOS10HV 2013 (0.13 µm)</td>
</tr>
</tbody>
</table>
Motor Driver Basics

DC Brushed and Stepper Motor Driver review

✓ Basic operation
✓ Internal architecture
Basic Operation With Brushed DC Motor

Several types of motors

- 3-phase AC, brushless AC, DC brushed, stepper, etc.
- This presentation focus is on DC brushed and stepper motor

Important considerations for motor drivers

- Number of outputs
- Voltage & current operation range; will vary depending on load (motor)
- Low resistance path
- Switching frequency; trade-off between noise and efficiency

Freescale integrates analog and digital power MOSFETs into a turnkey solution

An H-bridge is an electronic circuit that enables a voltage to be applied across a load in either direction.
H-Bridge DC Brushed and Stepper Motor Drivers

Basic Operation With Stepper Motor

- Dual H-Bridge required for stepper motor control
- Requires sequentially switched power
DC Brushed and Stepper Motor Driver Control

Example H-Bridge Pin-out
- Inputs - typically from micro or PWM
- Outputs - motor control
- Enable
- Disable
- Status flag for errors OV, OC, UV, etc
- Current mirror output
- Powers
- Grounds

Example Dual H-Bridge Pin-out
- Dual input control from micro
- Dual output motor control
- Pin-out for external capacitors for charge pumps
- Powers
- Grounds
Bridge Fully Integrated Motor Drivers
Analog + Power + Logic MC33926 Internal Block Diagram
Application Examples

DC Brushed and Stepper Motor Portfolio for Battery, 5V and 12V Bus

- Review of device portfolio
- One pagers of device features and benefits
Portable Point of Sale Terminal

**Power Source**

- 3.6V Li-ion battery

**MC34675 LiOn battery charger IC**

**PF0100**

- 6 DC/DC
- 6 LDO
- OTP
- I²C

**CPU:**

- i.MX25
- i.MX7

**MPC17531 1.4A Dual H-Bridge Driver IC**

- Charge Pump
- Control & Monitoring
- Protection

**Connectors, System Wireless Module Audio Display**

**Paper handling stepper motors**
Brushed DC Motor Control Application (12-24V)

Applications: Tube motor, cash counter, electric rolling door, robotics, medical, etc.

MC34903 Power Management and Safety System IC

MC34931 5A H-Bridge Driver IC

Kinetis E
Robust 5V MCU

MC34903
2 LDO
Safety
CAN
SPI

12 or 24 V
CAN

12 or 24 V

Kinetis E
Cortex M0+ core
PWM
ADC

Charge Pump
Control & Monitoring
Protection

HS1
HS2
LS1
LS2

External Use | 18
Battery Powered UPS Inverter

Applications: Home or office battery back-up uninterruptible power supply (UPS), stationary and grid storage battery, battery powered vehicle

MC34903 Power Management and Safety System IC

MC33883 H-bridge gate driver IC

MM912J637 battery sensor for 12V lead acid

MC912J637

MM9Z1J638

MM56F84xxx Digital Signal Controller MCU

MC33883 Charge Pump

AC voltage

110 / 220V

External MOSFET H-bridge

External Use | 19
Brushed DC Motor Control Application (3.6V Li-ion or 5V)

Applications: Digital camera, video conference, DVD player, small robots, toys, etc.

DC Power Source (Wall charger, USB, etc.)

3.6V Li-ion battery

MC34674 LiOn battery charger IC

Vbatt or 5V

MC34933 1A dual H-bridge driver IC

Stepper motor

MC34933

Charge Pump

Control Logic

Vcc Detect

Thermal Detection

HS1

HS2

LS1

LS2

Cortex M0+ core

PWM1

PWM2

Kinetis E

Robust 5V MCU

Kinetis E

MC34674

Vin Monitor

Charge Control

Logic Control

MC34674

Vin Monitor

Charge Control

Logic Control

3.6V Li-ion battery

Vbatt or 5V

Trimmer

External Use | 20
**Multi Function Printer**

- **CPU:** i.MX6 LS1021
- **PF0100:**
  - 6 DC/DC
  - OTP
  - 6 LDO
  - I²C
- **Connectors, System**
  - 5.0V
  - 3.3V
  - 2.5V
  - 1.5V
- **MC34932:** 5A dual H-bridge driver IC
- **MC34972 switch monitoring IC**
  - Up to 22 switches
- **MC34981 low RDSon high side switch**
  - Protection, Diagnostic
  - Control
- **MC34981 switch control**
  - SPI
- **MC34972 memory DDR**
- **Printer Head**
  - Vpower
  - Load
- **Paper handling stepper motors**
  - 12 or 24 V
- **MC34981 switch control**
  - SPI
## IMM H-Bridge Design: Win and Opportunities

<table>
<thead>
<tr>
<th>Company</th>
<th>Product Description</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HUAWEI</strong></td>
<td><strong>MPC17510 LV H-Bridge Stepper Motor Driver</strong></td>
<td><strong>WIN</strong>&lt;br&gt;• Simple interface&lt;br&gt;• 1.2A, small package</td>
</tr>
<tr>
<td><strong>STILWELL BAKER</strong></td>
<td><strong>MC33926 MV H-Bridge Motor Driver</strong></td>
<td><strong>WIN</strong>&lt;br&gt;• Self protected for continuous operation</td>
</tr>
<tr>
<td><strong>A-OK</strong></td>
<td><strong>MC34931 MV H-Bridge Motor Driver</strong></td>
<td><strong>OPPORTUNITY</strong>&lt;br&gt;• Safety features&lt;br&gt;• Sleep mode</td>
</tr>
<tr>
<td><strong>FLEXTRONICS</strong></td>
<td><strong>MPC17511 LV H-Bridge Stepper Motor Driver</strong></td>
<td><strong>WIN</strong>&lt;br&gt;• Integration</td>
</tr>
<tr>
<td><strong>PHILIPS</strong></td>
<td><strong>MPC17C724 LV H-Bridge Motor Driver</strong></td>
<td><strong>OPPORTUNITY</strong>&lt;br&gt;• Integration</td>
</tr>
</tbody>
</table>

**Applications:**
- PTZ Camera adjustment
- Postal Kiosk
- Tube Motor Shades
- Medicine auto-injector
- Electric Shaver
Low Voltage Portfolio
DC Brushed and Stepper Motor Portfolio for Battery, 5V and 12V Bus

✅ Review of device portfolio

✅ One pagers of device features and benefits
# Low Voltage Motor Driver Selector Guide

**Targeting Battery / 5 V / 12V Bus Applications**

<table>
<thead>
<tr>
<th>Base Part #</th>
<th>Motor type</th>
<th>Out</th>
<th>Operation Voltage (V)</th>
<th>Peak Current (A)</th>
<th>LL (V)</th>
<th>Sleep (µA)</th>
<th>Freq (kHz)</th>
<th>Temp Range (°C)</th>
<th>Package (LxW mm)</th>
<th>Footprint</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPC17510EJ</td>
<td>Brushed DC / Actuator Drive</td>
<td>2+1</td>
<td>2.0-15</td>
<td>3.8</td>
<td>4.0-5.5</td>
<td>-</td>
<td>200</td>
<td>-30 to 65</td>
<td>TSSOPW 24</td>
<td>(7.8 x 7.6)</td>
</tr>
<tr>
<td>MPC17511EP</td>
<td>Brushed DC / Actuator Drive</td>
<td>2+1</td>
<td>2.0-6.8</td>
<td>3.0</td>
<td>2.7-5.7</td>
<td>-</td>
<td>200</td>
<td>-20 to 65</td>
<td>QFN 24</td>
<td>(4 x 4)</td>
</tr>
<tr>
<td>MPC17511EV</td>
<td>Brushed DC / Actuator Drive</td>
<td>2+1</td>
<td>2.0-6.8</td>
<td>3.0</td>
<td>2.7-5.7</td>
<td>-</td>
<td>200</td>
<td>-20 to 65</td>
<td>SOIC 16</td>
<td>(5.4 x 8.1)</td>
</tr>
<tr>
<td>MC34933EP</td>
<td>Stepper / Brushed DC</td>
<td>4</td>
<td>2.0-7.0</td>
<td>1.4</td>
<td>2.7-5.5</td>
<td>-</td>
<td>200</td>
<td>-20 to 85</td>
<td>QFN 16</td>
<td>(3 x 3)</td>
</tr>
<tr>
<td>MPC17529EV</td>
<td>Stepper / Brushed DC</td>
<td>4</td>
<td>2.0-6.8</td>
<td>1.4</td>
<td>2.7-5.6</td>
<td>-</td>
<td>200</td>
<td>-20 to 65</td>
<td>SOIC 20</td>
<td>(7.4 x 8.1)</td>
</tr>
<tr>
<td>MPC17531ATEV</td>
<td>Stepper / Brushed DC</td>
<td>4</td>
<td>2.0-8.6</td>
<td>1.4</td>
<td>2.7-3.6</td>
<td>2</td>
<td>200</td>
<td>-20 to 65</td>
<td>SOIC 20</td>
<td>(7.4 x 8.1)</td>
</tr>
<tr>
<td>MPC17531ATEP</td>
<td>Stepper / Brushed DC</td>
<td>4</td>
<td>2.0-8.6</td>
<td>1.4</td>
<td>2.7-3.6</td>
<td>2</td>
<td>200</td>
<td>-20 to 65</td>
<td>QFN 24</td>
<td>(4 x 4)</td>
</tr>
<tr>
<td>MPC17533EV</td>
<td>Stepper / Brushed DC</td>
<td>4</td>
<td>2.0-6.8</td>
<td>1.4</td>
<td>2.7-5.7</td>
<td>-</td>
<td>200</td>
<td>-20 to 65</td>
<td>SOIC 16</td>
<td>(5.4 x 8.1)</td>
</tr>
<tr>
<td>MPC17C724EP</td>
<td>Stepper / Brushed DC</td>
<td>4</td>
<td>2.7-5.5</td>
<td>0.8</td>
<td>2.7-5.5</td>
<td>1</td>
<td>200</td>
<td>-20 to 85</td>
<td>QFN 16</td>
<td>(3 x 3)</td>
</tr>
</tbody>
</table>
# H-Bridge DC Motor Drivers

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Four operation modes</td>
<td>Provides control in forward, reverse, braking and tri-state for safe shut-down</td>
</tr>
<tr>
<td>200 kHz Pulse Width Modulation frequency capable</td>
<td>High slew rates provide ability to program high resolution micro-stepping and efficiency to drive micro-motors</td>
</tr>
<tr>
<td>TSWITCH output for driving an external MOSFET</td>
<td>Integrated high side driver decreases part count</td>
</tr>
<tr>
<td>Offer in 3X3 mm QFN package (MC34933 &amp; MPC17C724)</td>
<td>Ultra-small footprint for small and portable applications</td>
</tr>
<tr>
<td>Built-in shoot through current and under-voltage protection</td>
<td>Increases safety and reliability</td>
</tr>
<tr>
<td>Higher current outputs (0.8 to 3.8 Amps peak)</td>
<td>Low RDS(ON)</td>
</tr>
<tr>
<td>Offering 2 and 4 outputs H-bridge</td>
<td>For driving either DC brushed or stepper motors</td>
</tr>
<tr>
<td>Sleep mode with &lt; 1 μA current draw (MPC17C724)</td>
<td>Reduced power consumption, especially for battery applications</td>
</tr>
</tbody>
</table>
MPC17510 Monolithic H-Bridge for Portable Applications

Features
- 2.0V to 15V continuous operation
- Low $R_{\text{DS(ON)}}$ 450 m$\Omega$ (typ)
- Output current 1.2 A (DC), 3.8 A (peak)
- Cross-conduction suppression
- PWM control input frequency 200 kHz
- Built-in charge pump circuit

Benefits
- Simple MCU Interface
- Under voltage detection to prevent erratic operation
- TSWITCH output for driving an external MOSFET
- Low quiescent current
- Low profile package for portable designs
- Reduces design time

Applications
- Portable electronics
- Toys / robotics
- Video camera
- Digital still camera

TSSOPW 24 (7.8x7.6)
MPC17511 Monolithic H-Bridge for Portable Applications

Features
- 2.0V to 6.8V continuous operation
- Low $R_{\text{DS(ON)}}$ 460 mΩ (typ)
- Output current 1.0 A (DC), 3.0 A (peak)
- 3.0V/5.0V TTL-/CMOS-compatible inputs
- Shoot-through current protection circuit
- PWM control input frequency 200 kHz
- Built-in charge pump circuit

Benefits
- Simple MCU interface
- Under voltage detection to prevent erratic operation
- TSWITCH output for driving an external MOSFET
- Low quiescent current
- Low profile package for portable designs
- Reduces design time

Applications
- Portable electronics
- Toys / robotics
- Video camera
- Digital still camera

QFN 24 (4x4)
SOIC 16 (5.4x8.1)
MC34933EP Monolithic Dual H-Bridge for Portable Applications

**Features**
- Motor power supply - 2 to 7 V
- Low RDS(ON) 0.7 Ω (typ)
- Output current 700 mA (DC), 1.4 A (peak)
- Shoot through current protection circuit
- Thermal protected
- PWM control input frequency 200 kHz
- Built-in charge pump circuit

**Benefits**
- Simple MCU Interface
- Single or parallel H-Bridge outputs
- Under voltage detection to prevent erratic operation
- Low quiescent current
- Low profile package for portable designs
- Reduces design time

**Applications**
- Portable Electronics
- SLR Lens Shutter Control
- Optical Disc Drive (MO, DVD, CD)
- DSC, DVC

![Diagram of the MC34933EP](image)
MPC17529 Monolithic Dual H-Bridge for Portable Apps

Features

• Motor power supply - 2 to 6.8 V
• Low $R_{DS(ON)}$ 0.7 Ω (typ)
• Output current 700 mA (DC), 1.4 A (peak)
• Shoot through current protection circuit
• PWM control input frequency 200 kHz
• Built-in charge pump circuit

Benefits

• Simple MCU interface
• Single or parallel H-bridge outputs
• Under voltage detection to prevent erratic operation
• Low quiescent current
• Low profile package for portable designs
• Reduces design time

Applications

• Portable electronics
• SLR lens shutter control
• Optical disc drive (MO, DVD, CD)
• DSC, DVC

SOIC 20 (7.4x8.1)
MPC17531 Monolithic Dual H-Bridge for Portable Apps

**Features**
- Motor power supply - 2 to 8.6 V
- Low $R_{DS(ON)}$ 0.8 Ω (typ)
- Output current 700 mA (DC), 1.4 A (peak)
- Shoot through current protection circuit
- PWM control input frequency 200 kHz
- Built-in charge pump circuit

**Benefits**
- Simple MCU interface
- Single or parallel H-bridge outputs
- Under voltage detection to prevent erratic operation
- Low quiescent current
- Low profile package for portable designs
- Reduces design time

**Applications**
- Portable electronics
- SLR lens shutter control
- Optical disc drive (MO, DVD, CD)
- DSC, DVC

**Diagram**

- MPC17531A
- External Use
- Monolithic Dual H-Bridge for Portable Apps
- Motor power supply - 2 to 8.6 V
- Low $R_{DS(ON)}$ 0.8 Ω (typ)
- Output current 700 mA (DC), 1.4 A (peak)
- Shoot through current protection circuit
- PWM control input frequency 200 kHz
- Built-in charge pump circuit

**Package Options**
- SOIC 20 (7.4x8.1)
- QFN 24 (4x4)
MPC17533 Monolithic Dual H-Bridge for Portable Apps

Features
- Motor power supply - 2 to 6.8 V
- Low $R_{DS(ON)}$ 0.8 Ω (typ), 1.4 Ω (peak)
- Output current 700 mA (DC), 1.4 A (peak)
- 3.0V/5.0V CMOS-compatible inputs
- Shoot through current protection circuit
- PWM control input frequency 200 kHz
- Charge pump circuit

Benefits
- Simple MCU Interface
- Single or parallel H-bridge outputs
- Under voltage detection to prevent erratic operation
- Low quiescent current
- Low profile package for portable designs
- Reduces design time

Applications
- Portable electronics
- Lens shutter camera
- Optical disc drive

SOIC 16 (5.4x8.1)
MPC17C724 Monolithic Dual H-Bridge for Portable Apps

Features
- Motor power supply – 2.7 to 5.5 V
- $R_{DS(ON)}$ 1.0 Ω (typ), 1.5 Ω (peak)
- Output current 400 mA (DC)
- 3.0V/5.0V CMOS-compatible inputs
- Shoot through current protection circuit
- Low-voltage shutdown
- PWM control input frequency 200 kHz
- Charge pump circuit

Benefits
- Simple MCU interface
- Single or parallel H-bridge outputs
- Low quiescent current
- 3 x 3mm 16-pin QFN package for small footprint
- Reduces design time

Applications
- Portable electronics
- Lens shutter camera
- Optical disc drive

QFN 16 (3 x 3)
Medium Voltage Portfolio
DC Brushed and Stepper Motor H-Bridge Motor Drivers for 5–28V Bus

- Review of device portfolio
- Review of device operations
- One pagers outlining features and benefits
# Medium Voltage Motor Driver Selector Guide

## Targeting 5-28V Applications

<table>
<thead>
<tr>
<th>Base Part #</th>
<th>Motor type</th>
<th>Tech</th>
<th>Out</th>
<th>Operation Voltage (V)</th>
<th>Peak Current (A)</th>
<th>SPI</th>
<th>Sleep (µA)</th>
<th>Freq (kHz)</th>
<th>Temp Range °C</th>
<th>Package (LxW mm) Footprint</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC33886VW</td>
<td>Brushed DC</td>
<td>SM-5</td>
<td>2</td>
<td>5-28</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>-40 to 125</td>
<td>HSOP 20 (16 x 14.4)</td>
</tr>
<tr>
<td>MC33887APVW</td>
<td>Brushed DC</td>
<td>SM-5</td>
<td>2</td>
<td>5-28</td>
<td>5</td>
<td>-</td>
<td>50</td>
<td>10</td>
<td>-40 to 125</td>
<td>HSOP 20 (16 x 14.4)</td>
</tr>
<tr>
<td>MC33887PEK</td>
<td>Brushed DC</td>
<td>SM-5</td>
<td>2</td>
<td>5-28</td>
<td>5</td>
<td>-</td>
<td>50</td>
<td>10</td>
<td>-40 to 125</td>
<td>SOICW-EP 54 (18 x 10.3)</td>
</tr>
<tr>
<td>MC33887PFK</td>
<td>Brushed DC</td>
<td>SM-5</td>
<td>2</td>
<td>5-28</td>
<td>5</td>
<td>-</td>
<td>50</td>
<td>10</td>
<td>-40 to 125</td>
<td>QFN 36 (9 x 9)</td>
</tr>
<tr>
<td>MC33899VW</td>
<td>Brushed DC</td>
<td>SM-5HV</td>
<td>2</td>
<td>5-26.5</td>
<td>4.2/5.3/6.2/9.0</td>
<td>Y</td>
<td>145</td>
<td>11</td>
<td>-40 to 125</td>
<td>HSOP 30 (16 x 14.4)</td>
</tr>
<tr>
<td>MC33926PNB</td>
<td>Brushed DC</td>
<td>SM-8</td>
<td>2</td>
<td>5-28</td>
<td>5</td>
<td>-</td>
<td>50</td>
<td>20</td>
<td>-40 to 125</td>
<td>PQFN 32 (8 x 8)</td>
</tr>
<tr>
<td>MC33931EK</td>
<td>Brushed DC</td>
<td>SM-8</td>
<td>2</td>
<td>5-28</td>
<td>5</td>
<td>-</td>
<td>50</td>
<td>11</td>
<td>-40 to 125</td>
<td>SOICW-EP 32 (11 x 10.3)</td>
</tr>
<tr>
<td>MC33931VW</td>
<td>Brushed DC</td>
<td>SM-8</td>
<td>2</td>
<td>5-28</td>
<td>5</td>
<td>-</td>
<td>50</td>
<td>11</td>
<td>-40 to 125</td>
<td>HSOP 44 (16 x 14.4)</td>
</tr>
<tr>
<td>MC33932EK</td>
<td>Brushed DC / Stepper</td>
<td>SM-8</td>
<td>4</td>
<td>5-28</td>
<td>5</td>
<td>-</td>
<td>50</td>
<td>11</td>
<td>-40 to 125</td>
<td>SOICW-EP 54 (18 x 10.3)</td>
</tr>
<tr>
<td>MC33932VW</td>
<td>Brushed DC / Stepper</td>
<td>SM-8</td>
<td>4</td>
<td>5-28</td>
<td>5</td>
<td>-</td>
<td>50</td>
<td>11</td>
<td>-40 to 125</td>
<td>HSOP 44 (16 x 14.4)</td>
</tr>
<tr>
<td>MC34931EK</td>
<td>Brushed DC</td>
<td>SM-8</td>
<td>2</td>
<td>5-28</td>
<td>5</td>
<td>-</td>
<td>18</td>
<td>11</td>
<td>-40 to 85</td>
<td>SOICW-EP 32 (11 x 10.3)</td>
</tr>
<tr>
<td>MC34932EK</td>
<td>Brushed DC / Stepper</td>
<td>SM-8</td>
<td>4</td>
<td>5-28</td>
<td>5</td>
<td>-</td>
<td>18</td>
<td>11</td>
<td>-40 to 85</td>
<td>SOICW-EP 54 (18 x 10.3)</td>
</tr>
</tbody>
</table>
# H-Bridge DC Motor Drivers

**MC33926R2 (PQFP)**  
MC33931EK & MC34931EK (SOIC) Single  
MC33932EK & MC34932EK (SOIC) Dual

<table>
<thead>
<tr>
<th><strong>Features</strong></th>
<th><strong>Benefits</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic thermal back-off at high die temperatures</td>
<td>Maintains operation at reduced current for continuous operation</td>
</tr>
<tr>
<td>Load current mirroring provides a proportional current output (0.24% of the load current)</td>
<td>Provides feedback to a microcontroller for control or protection</td>
</tr>
<tr>
<td>Robust thermally enhanced eSOIC or PQFN package</td>
<td>Choice between smaller footprint or visual fillet inspection</td>
</tr>
<tr>
<td>MC33926 provides selectable slew rate control</td>
<td>Allows tradeoff between higher efficiency or better EMC</td>
</tr>
<tr>
<td>Automatic maximum current regulation via pre-determined MOSFET shut-off times</td>
<td>Reduces safety and reliability risks</td>
</tr>
<tr>
<td>Integrated fault detection and interrupt flag for under-voltage, over-current, and over-temperature</td>
<td>Saves board space over discrete solution</td>
</tr>
<tr>
<td>Industrial parts with sleep mode &lt; 12 μA current draw</td>
<td>Reduced power consumption in standby mode</td>
</tr>
<tr>
<td>5.0V to 28V continuous operation, 40V transient</td>
<td>Wide range of applications</td>
</tr>
</tbody>
</table>
H-Bridge DC Motor Drivers

Product Differentiation

Most thermally efficient 28V/5A H-bridge DC motor driver featuring real-time load current monitoring and automatic thermal current back-off for high availability operation in demanding high current, high temperature automotive and industrial applications

Thermal Efficiency
- **Thermally efficient package**: 2X lower thermal impedance
- **Automatic thermal back-off** limits current at high temperatures to ensure continuous operation
- **Low RDS(ON)** for high efficiency operation
- **Automotive grade SMARTMOS process for** proven reliability with millions of application hours

Flexibility with Simplicity
- **Current mirror** for speed control, overload protection or diagnostics
- **Large input voltage range** for applications requiring 5 to 28 V
- **Output short-circuit protection**
- **Over-current, over-voltage, over-temperature fault flag interrupt**
- **Selectable slew rate** for improved EMC or increased efficiency on 926

Integration
- **Integrated** control, protection, fault detection, charge pump and MOSFETs in monolithic die
- **Automatic fault flag interrupt** for under-voltage, over-current, and over-temperature fault conditions
- **Sleep mode** automatic default with low current draw < 12 μA (each half with inputs floating or set to match default logic states on 34 series)
**Features**

- -40°C to 125°C temperature range
- Vcc operating voltage range from 5.5V up to 55V
- Vcc2 operating voltage range from 5.5V up to 28V
- 1.0 A peak gate drive current
- Built-in high side charge pump
- CMOS/LSTTL compatible I/O
- Global enable with <10 µA sleep mode
- Supports PWM up to 100 kHz

**Typical Applications**

- Sine wave inverters
- Uninterruptable power supplies
- Motor control

**Product Options**

**Availability**

- Samples: Now
- Production: Now

**MC33883 H-Bridge Gate Driver IC**
MC33926 Monolithic Single H-Bridge Motor Driver

Differentiating Points

- Over temperature protection – current fold back at 165°C
- Current mirror – 1/400 out from current flowing in MOSFET
- Selectable slew rate control
- Ultra-low thermal resistance < 1°C/Watt, for superior heat dissipation
- 235 mΩ maximum @ Tj=150°C, 120 mΩ typical RDS(ON) @ Tj=25°C (for each H-bridge MOSFET)
- Over current limiting (regulation) via internal constant-off-time PWM
- Output short circuit protection (short to VPWR or ground)
- Temperature dependent current limit threshold reduction
- 3 and 5V TTL/CMOS logic compatible inputs

Features

- H-bridge configuration for bi-directional motors
- 5 to 28 Volt continuous; to 40 V transient operation
- 5 Amp peak output current
- Protected against common failure conditions
MC33931/MC34931 Monolithic Single H-Bridge Motor Driver

Differentiating Points

• Over temperature protection – current fold back at 165ºC
• Current mirror – 1/400 out from current flowing in MOSFET
• Ultra-low thermal resistance < 1ºC/Watt for superior heat dissipation
• Sleep mode current typical < 12 μA
• 235 mΩ maximum @ Tj=150ºC, 120 mΩ typical RDS(ON) @ Tj=25ºC (for each H-bridge MOSFET)
• Over current limiting (regulation) via internal constant-off-time PWM
• Output short circuit protection (short to VPWR or ground)
• Temperature dependent current limit threshold reduction
• 3 and 5V TTL/CMOS logic compatible inputs

Features

• H-bridge configuration for bi-directional motors
• 5 to 28 Volt continuous; to 40 V transient operation
• 5 Amp peak output current
• Protected against common failure conditions
MC33932/MC34932 Monolithic Dual H-Bridge Motor Driver

Differentiating Points

• Over temperature protection – current fold back at 165°C
• Current mirror – 1/400 out from current flowing in MOSFET
• Ultra-low thermal resistance < 1°C/Watt for superior heat dissipation
• Sleep mode current typical < 12 μA
• 235 mΩ maximum @ Tj=150°C, 120 mΩ typical RDS(ON) @ Tj=25°C (for each H-bridge MOSFET)
• Over current limiting (regulation) via internal constant-off-time PWM
• Output short circuit protection (short to VPWR or ground)
• Temperature dependent current limit threshold reduction
• 3 and 5V TTL/CMOS logic compatible inputs

Features

• H-bridge configuration for bi-directional motors
• 5 to 28 Volt continuous; to 40 V transient operation
• 5 Amp peak output current
• Protected against common failure conditions
MC33899 Programmable Single H-Bridge Motor Driver

### Differentiating Points
- Designed to drive a DC motor in both forward and reverse shaft rotation under PWM control of speed and torque
- SPI selectable current limit typical: 4.2 / 5.3 / 6.2 / 9.5 Amp
- SPI selectable slew rate
- SPI diagnostic reporting: open circuit, short-circuit to PWR, short-circuit to GRN, die temperature range, and under-voltage
- Current mirror output signal (gain selectable via external resistor)
- Short-circuit current limiting
- Over-temperature shutdown

### Features
- 5 to 28 Volt operation
- 5 Amp peak current
- Low RDS(ON) outputs at high junction temperature (< 165mΩ @ TA = 125°C, VIGNP = 6.0V)
- Internal charge pump circuit for the internal high side MOSFETs
- Outputs can be disabled to high-impedance state
- PWM-able up to 11 kHz @ 3.0A
- Outputs survive shorts to -1.0V
Power Dissipation and Thermal Analysis Tools

- Power dissipation and thermal estimation with simulation
- Power dissipation and thermal estimation with experimentation
Factors Determining Power Dissipation

There are two cases: Steady state and dynamic.

<table>
<thead>
<tr>
<th>Steady state</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>(without switching)</td>
<td>(with switching/PWM)</td>
</tr>
<tr>
<td>• Type of load and current</td>
<td>• Type of load and current</td>
</tr>
<tr>
<td>• Change in $R_{DS(ON)}$</td>
<td>• Change in $R_{DS(ON)}$</td>
</tr>
<tr>
<td>• Body diode forward voltage drop</td>
<td>• Rise/fall time to the system voltage</td>
</tr>
<tr>
<td></td>
<td>• Body diode forward voltage drop</td>
</tr>
</tbody>
</table>
$R_{DS(ON)}$ Vs Junction Temperature [$^\circ$C]
Estimation of Power Dissipation

PD_HS2 over T [W] = I_{OUT}^2 * R_{dson}

PD_LS1 over T1 [W] = 0.5 * (V_{PWR} + V_D - I_{OUT} * R_{dson}) * I_{OUT} * T_1 * F_{SW}

PD_LS1 over T2 [W] = I_{OUT}^2 * R_{dson} * T_2 * F_{SW}

PD_LS1 over T3 [W] = 0.5 * (V_{PWR} + V_D - I_{OUT} * R_{dson}) * I_{OUT} * T_3 * F_{SW}

PD_HS1 over T4 [W] = I_{OUT}^2 * R_{dson} * T_4 * F_{SW}

Total Power Dissipation on the Die [W] = I_{OUT}^2 * R_{dson} + 0.5 * (V_{PWR} + V_D - I_{OUT} * R_{dson}) * I_{OUT} * T_1 * F_{SW} + I_{OUT}^2 * R_{dson} * T_2 * F_{SW} + 0.5 * (V_{PWR} + V_D - I_{OUT} * R_{dson}) * I_{OUT} * T_3 * F_{SW} + I_{OUT}^2 * R_{dson} * T_4 * F_{SW}
Junction Temperature Estimation

Junction temperature ($T_J$) depends primarily on the following factors:

- Ambient temperature ($T_A$)
- Thermal resistance from junction to ambient ($R_{\theta JA}$) which depends on:
  - Number of layers in PCB
  - Amount of copper used on each layer
  - Thermal via size and number of vias
  - Type of solder used
  - Heat sink efficiency
  - Interface material
  - IC packaging
- Power dissipated on the die ($P_D$)

Mathematically : $T_J = T_A + P_D \times R_{\theta JA}$
# Thermal Specifications for MC33931EK

## THERMAL RATINGS

<table>
<thead>
<tr>
<th>Storage Temperature</th>
<th>$T_{STG}$</th>
<th>-65 to 150</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Temperature&lt;sup&gt;(6)&lt;/sup&gt;</td>
<td>$T_A$</td>
<td>-40 to 125</td>
<td>°C</td>
</tr>
<tr>
<td>Junction</td>
<td>$T_J$</td>
<td>-40 to 150</td>
<td>°C</td>
</tr>
<tr>
<td>Peak Package Reflow Temperature During Reflow&lt;sup&gt;(7),(8)&lt;/sup&gt;</td>
<td>$T_{PFRT}$</td>
<td>Note 8</td>
<td>°C</td>
</tr>
<tr>
<td>Approximate Junction-to-Case Thermal Resistance&lt;sup&gt;(9)&lt;/sup&gt;</td>
<td>$R_{θJC}$</td>
<td>&lt;1.0</td>
<td>°C/W</td>
</tr>
</tbody>
</table>

### Table 6. Table of Thermal Resistance Data

<table>
<thead>
<tr>
<th>Rating</th>
<th>Value</th>
<th>Unit</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction to Ambient Natural Convection</td>
<td>Single Layer board (1s)</td>
<td>$R_{θJA}$</td>
<td>92</td>
</tr>
<tr>
<td>Junction to Ambient Natural Convection</td>
<td>Four layer board (2s2p)</td>
<td>$R_{θJA}$</td>
<td>26.6</td>
</tr>
<tr>
<td>Junction to Board</td>
<td></td>
<td>$R_{θJB}$</td>
<td>7.0</td>
</tr>
<tr>
<td>Junction to Case (bottom / flag)</td>
<td></td>
<td>$R_{θJC}$ (bottom)</td>
<td>0.62</td>
</tr>
<tr>
<td>Junction to Case (top)</td>
<td></td>
<td>$R_{θJC}$ (top)</td>
<td>23.3</td>
</tr>
<tr>
<td>Junction to Package Top</td>
<td>Natural Convection</td>
<td>$Ψ_{JT}$</td>
<td>2.7</td>
</tr>
</tbody>
</table>
Transient Thermal Response (From Datasheet)
Thermal Analysis Tools

- Tools to assist analyzing power dissipation and thermal performance include:
  - MC33887 Power Dissipation.xls
  - MC33899 Power Dissipation.xls
  - MC339xx H-Bridge Power Dissipation.xls
  - MC339xx H-Bridge PWM Response.xls

- Available on the Freescale “Compass” site
  http://compass.freescale.net/livelink/livelink?func=ll&objId=208509673&objAction=browse&viewType=1
Integration with FRDM Platform

Review and demonstration of evaluation boards
Freescale FRDM-KL25Z

MKL25Z128VLK4
MCU Features

- 48 MHz
- 128 KB flash
- 16 KB SRAM
- Capacitive touch “slider”
- MMA8451Q accelerometer
- Tri-color LED
- Easy access to MCU I/O
- Supports multiple IDE tools
  - CodeWarrior
  - IAR
  - Keil
  - Atollic
  - Rowley
  - Arrow Cloud Connect
  - mbed
FRDM Board Connectivity with H-Bridge EVBs

FRDM Board

- FRDM Interface Connectors
- Board ID Pins
- Motor & Sensor Power Connector
- Motor Connector
- Motor Current Sense Jumpers
- Sensor Connector
- Motor Control & Output Pins
- Test Pins

FRDM Board Connectivity with H-Bridge EVBs
GUI Interface

GUI Digital I/O to FRDM (via USB)

Sample GUI

EVB Ready
Fault
Motor
Brushed
Stepper
Mode
Auto
Manual

Channel 1 Control

Set max. current
5.0 A

Enabling/Disabling

EN/D2_b
EN/D1

Direction/Braking

Fwd/Rev
Coast/Dyn

PWM Frequency

Duty Cycle

Current Display Ch1
3.67 A

Channel 2 Control

Set max. current
3.0 A

Enabling/Disabling

EN/D2_b
EN/D1

Direction/Braking

Fwd/Rev
Coast/Dyn

PWM Frequency

Duty Cycle

Current Display Ch2
2.5 A
Enablements

Tools and Evaluation Boards
KIT33887EKEVBE: Evaluation Kit – 33887

Evaluation Kit Includes
The MC33887 monolithic power IC comprising control logic, charge pump, gate drive, and low RDS(on) MOSFET output H-bridge circuitry contained in a small surface mount package.

Features
- Fully specified operation 5.0 V to 28 V
- Limited operation with reduced performance up to 40 V
- 120 mΩ RDS(ON) typical H-bridge MOSFETs
- TTL/CMOS compatible inputs
- PWM frequencies up to 10 kHz
- Active current limiting (regulation)
- Fault status reporting
- Sleep mode with current draw ≤50 μA (inputs floating or set to match default logic states)

- KIT33887EKEVBE
The Evaluation Kit features the 33926, which is a monolithic H-Bridge Power IC designed primarily for automotive electronic throttle control, but is applicable to any low-voltage DC servo motor control application within the current and voltage limits stated.

**Features**

- 8.0V to 28V continuous operation (transient operation from 5.0 V to 40 V)
- 225 mΩ maximum RDS(ON) @ 150°C (each H-bridge MOSFET)
- 3.0 V and 5.0 V TTL / CMOS Logic compatible inputs
- Overcurrent limiting (regulation) via internal constant-off-time PWM
- Output short circuit protection (short to VPWR or ground)
- Temperature-dependant current-limit threshold reduction
- All inputs have an internal source/sink to define the default (floating input) states
- Sleep mode with current draw < 50 µA (with inputs floating or set to match default logic states)

This Evaluation kit may be used with the KITUSBSPIDGLEVME.

The MC33926 is a SafeAssure functional safety solution

KIT33926PNBEVBE
KIT33932VWEVBE: Evaluation Kit – 33932

The Evaluation Kit for the 33932 is a monolithic H-bridge power IC in a robust thermally enhanced package.

Features

• 8.0 to 28V continuous operation (transient operation from 5.0 to 40 V)
• 235 mΩ maximum RDS(ON) @ 150°C (each H-bridge MOSFET)
• 3.0 V and 5.0 V TTL / CMOS logic compatible inputs
• Over-current limiting (regulation) via internal constant-off-time PWM
• Output short-circuit protection (short to VPWR or GND)
• Temperature-dependent current-limit threshold reduction
• All inputs have an internal source/sink to define the default (floating input) states
• Sleep mode with current draw < 50 µA (each H-bridge)

This Evaluation kit may be used with the KITUSBSPIDGLEVME.
The Evaluation Kit for the MC33932EK is a monolithic H-bridge power IC in a robust thermally enhanced package. The 33932 has two independent monolithic H-bridge power ICs in the same package.

**Features**

- 8.0 to 28V continuous operation (transient operation from 5.0 to 40 V)
- 235 mΩ maximum RDS(ON) @ 150 °C (each H-Bridge MOSFET)
- 3.0 V and 5.0 V TTL / CMOS logic compatible inputs
- Overcurrent limiting (regulation) via internal constant-off-time PWM
- Output short-circuit protection (short to VPWR or GND)
- Temperature-dependant current-limit threshold reduction
- All inputs have an internal source/sink to define the default (floating input) states
- Sleep mode with current draw < 50 μA (each H-bridge)