Isolated Current Sensing

Texas Instruments

Kevin Herring – Analog Field Applications Engineer
Kevin.herring@ti.com
Isolated Modulators / Amplifiers
Modern Motor Control System Architecture

- **24VDC System Power Bus**
- **Motor Drive**
  - Local Control
    - MCU
    - For fast response
  - 24VDC System Power Bus
  - 240-1700V DC BUS
- **Isolated Gate Driver**
- **Power Stage**
  - PWM Generation
  - Local position/speed/torque control
  - Multi-axis position/speed/torque control
  - Internal ADCs
  - Phase Current/Voltage Feedback
  - Temp Sense
- **CPU**
  - Industrial Ethernet PHY
  - Industrial CAN PHY
  - Industrial 485 PHY
- **PROT DC/DC Converters & LDOs**
- **Internal ADCs**
- **IGBT Gate Drivers**
- **Reinforced Isolation Barrier**
- **ISO7842 100Mbps isolated Link**
- **ISO585x Reinforced Gate-Driver**
- **AMC1304, AMC1305 Isolated Delta-Sigma ADC**
- **Safe Disturbance Management (SDM)**
- **1kV Working Voltage**
- **>8kV iso + Surge**
- **POWER BOARD DC BUS REFERRED**

(Texas Instruments Logo)
**Isolated Shunt: 0 – 100A**

- **DRV401**: Fluxgate Sensor Signal Conditioner IC
- **DRV411**: Hall Sensor Signal Conditioner IC
- **DRV421**: Fully Integrated Magnetic Fluxgate Sensor IC

**Device** | **Input Range** | **Interface**
---|---|---
AMC1304L05 | ±50-mV | LVDS
AMC1304L25 | ±250-mV | LVDS
AMC1304M25 | ±250-mV | CMOS
AMC1304M05 | ±50-mV | CMOS

**Open-loop Magnetic: 5A – 1000A**

- **ADS1208**: 1-Ch DS-Modulator for Hall Effect Sensor
- **ADS1205**: 2-Ch DS-Modulator for Hall Effect Sensor
- **ADS1209**: 2-Ch DS-Modulator for Hall Effect Sensor
- **ADS1204**: 4-Ch DS-Modulator for Hall Effect Sensor

**Closed-loop Magnetic: 10A – 1000A**

- **AMC1305L25**: LVDS Interface 20MHz CLK, ±250-mV Current Shunt, 7kV Isolation
- **AMC1305M25**: CMOS Interface 20MHz CLK, ±250-mV Current Shunt, 7kV Isolation
- **AMC1204B**: 20MHz Modulator Current Shunt 4.25kV Digital Isolation
- **AMC1200B**: 100kHz Amplifier Current Shunt 4.25kV Digital Isolation

**Low** | **High**
---|---
**Q1 Qualified** | **EXISTING** | **NEW** | **ROADMAP**
AMC1200B & AMC1100
4.25 kV<sub>PEAK</sub> Isolated Amplifiers

Features

- **Basic Isolation** (UL1577 and VDE 0884-10)
  - Working voltage: 1.2kV<sub>Peak</sub>
  - Isolation voltage: 4.25 kV<sub>PEAK</sub> / 6kV<sub>SURGE</sub>
- **Input voltage range**: ±250 mV
- Pin-to-pin performance upgrade for HCPL7800 & HCPL7840
- **Specified Temperature range**: -40 to 105°C
- **Common-Mode Transient Immunity (CMTI)**:
  - AMC1100: 2.5 kV/µs min
  - AMC1200B: 10 kV/µs min
- **Package**: SSO-8 (DWV), DIP-8 (DUB)

Benefits

- Galvanic barrier provides **EMI immunity** and robust isolation barrier lifetime
- Optimized for direct connection to shunt resistors or other low voltage level signal sources
- **Over 90% more linear, 80% less gain drift, at 50% of the power**
- Extended industrial range offers additional 20°C of fully specified performance

Applications

- Shunt-based Current measurement in:
  - Motor Control
  - Green Energy
  - Frequency Inverter Applications
  - Uninterruptible Power Supplies

Production

![Texas Instruments Logo]
AMC1305
Reinforced Isolated Delta-Sigma Modulator with LVDS and CMOS Interface

Features

- **Reinforced isolation** (UL1577 & VDE 0884-10)
  Working voltage: 1.0kV_{RMS}, 1.5kV_{DC}
  Isolation voltage: 7 kV_{PEAK} / 12kV_{SURGE}
- **CMTI**: 15 kV/μs (min.)
- **Clock**: 5-20 MHz (external)
- **Input voltage Ranges**: ±50mV_{IN} / ±250mV_{IN}
- **Superior DC performance**
  Offset /Drift: ±50uV / 1.3uV/°C
  Gain / Drift: ±0.3% / 40ppm/°C
- **CMOS** and **LVDS** interface options
- **Temperature range**: -40 to 125°C
- **SO-16 (DW) package**

Benefits

- Galvanic barrier provides EMI immunity and robust isolation barrier lifetime
- Wide clock range for sample rate flexibility
- Reduced input voltage range enables higher shunt currents
- Extended industrial temperature range
- **Compatible to ACPL-796J (CMOS)**
- **Compatible to ACPL-798J (LVDS)**

Applications

- Shunt-based Current measurement in:
  ✓ Motor Control
  ✓ Frequency Inverter Applications
  ✓ Shunt Current Measurement

Production
AMC130x – Reference Designs

TIDA-00171
• Isolated Current Shunt and Voltage Measurement for Motor Drives
• AMC1304 with C2000™ TMS320F28377D Delfino™ microcontroller
• Integrated Sinc-Filters in MCU

TIDA-00209
• Isolated Current Shunt and Voltage Measurement Motor Drives
• AMC1304 with AM4379 Sitara™ ARM® Cortex® - A9 Processor
• Sinc-Filters on PRU-ICSS

TIDA-00080
• Shunt-Based AC/DC Current and Voltage Sensing for Smart Grid
• isolated shunt based current measurement to replace Current Transformers (CT)
Magnetic Sensing Products
Magnetic Field vs. Sensor Sensitivity

<table>
<thead>
<tr>
<th>Bio-Magnetic field</th>
<th>Natural Magnetic field</th>
<th>Industrial Magnetic field</th>
<th>Space Magnetic field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinal cord Magnetic field</td>
<td>Magnetic Storm</td>
<td>Earth Magnetic field</td>
<td>Super conducting Magnetic</td>
</tr>
</tbody>
</table>

- **pT** - nanoTesla (nT)
- **nT** - nanoTesla (nT)
- **uT** - microTesla (μT)
- **mT** - milliTesla (mT)
- **T** - Tesla (T)
- **kT** - kiloTesla (kT)
- **MT** - MegaTesla (MT)

**Hall Sensor**

**xMR Sensor**

**Fluxgate Sensor**

**SQUID**

**TI Integrated Sensor**

### Sensor Specifications

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Accuracy</th>
<th>Offset</th>
<th>Offset-drift</th>
<th>Hysteresis</th>
<th>Linearity</th>
</tr>
</thead>
<tbody>
<tr>
<td>iFG</td>
<td>Accuracy</td>
<td>Offset</td>
<td>Offset-drift</td>
<td>Hysteresis</td>
<td>Linearity</td>
</tr>
<tr>
<td>Si-Hall</td>
<td>1...3uT</td>
<td>0.02...0.03uT/K</td>
<td>0.2uT</td>
<td>0.1%</td>
<td></td>
</tr>
<tr>
<td>InSb-Hall</td>
<td>400...6000uT</td>
<td>5...16uT/K</td>
<td>0uT</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>AMR</td>
<td>400...6000uT</td>
<td>5...16uT/K</td>
<td>0uT</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>TMR</td>
<td>10...110uT</td>
<td>0.08...0.5uT/K</td>
<td>18uT</td>
<td>0.1...4%</td>
<td></td>
</tr>
<tr>
<td>GMR</td>
<td>4...100uT</td>
<td>5...16uT/K</td>
<td>0uT</td>
<td>1%</td>
<td></td>
</tr>
</tbody>
</table>

- **Offset**
- **Offset-drift**
- **Hysteresis**
- **Linearity**

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Detection Range</th>
<th>Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>iFG</td>
<td>70nT...2mT</td>
<td>2 dimensional Single chip CMOS</td>
</tr>
<tr>
<td>Si-Hall</td>
<td>500uT...1T</td>
<td>3 dimensional Single Chip CMOS</td>
</tr>
<tr>
<td>InSb-Hall</td>
<td>500uT...1T</td>
<td>3 dimensional Single Chip CMOS</td>
</tr>
<tr>
<td>AMR</td>
<td>200nT...0.8mT</td>
<td>1 dimensional Discrete component</td>
</tr>
<tr>
<td>TMR</td>
<td>100nT...1.5mT</td>
<td>2 dimensional Multi Chip</td>
</tr>
<tr>
<td>GMR</td>
<td>200nT...8mT</td>
<td>2 dimensional Multi Chip</td>
</tr>
</tbody>
</table>

- **Detection Range**
- **Integration**

**Unique Features**

- **TI Integrated Sensor**
- **2 dimensional Single Chip CMOS**
- **3 dimensional Single Chip CMOS**
- **1 dimensional Discrete component**
- **2 dimensional Multi Chip**
- **2 dimensional Multi Chip**
- **2 dimensional Single Chip CMOS with 20…30 add layers**
Closed Loop Hall Effect Driver

DRV411
DRV411
Hall-Sensor Signal Conditioning IC for Closed-Loop Current Sensors

Features
- Spinning Current Excitation
- Compensation Coil Driver Output: 250 mA
- Precision Difference Amplifier:
  - Offset Error and Drift: ±0.1 mV max, ±1 µV/°C max
  - Gain Error and Drift: ±0.3% max, ±5 ppm/°C max
- Precision On-Chip Reference:
  - Accuracy and Drift: ±0.2% max ±50 ppm/°C max
  - Selectable Voltage: 1.65 V or 2.5 V
- Wide System Bandwidth: 200 kHz
- Wide Supply Range: 2.7 V to 5.5 V
- Wide Temperature Range: -40°C to 125°C
- Small Package: 4x4mm QFN or TSSOP-20

Benefits
- Elimination of Hall sensor offset (1/100), offset drift and low frequency noise (1/10)
- Extended current measurement range up to 500 A
- No trimming required
- Easy to use system interface with common-mode voltage $V_{CM}=2.5$ V for 5-V systems and $V_{CM}=1.65$ V for 3.3-V applications
- Applicable for DC and AC current measurement
- Extended industrial temperature range operation

Applications
- Closed-Loop, Hall-Element (InSb/GaAs) Based Current Sensor Modules
- Optimized for Symmetric Hall-Elements AKM HW-322 and HW-302
DRV411 – Advantage over Discrete Solutions

DRV411 provides …

- **Highest level of integration on the market**
  - Reduced device count
  - Less assembly cost
  - Less board space
  - Higher reliability

- **Best performance due to current spinning technique**
  - Cannot be implemented efficiently with discrete components (cost + space)
  - Hall Sensor offset voltage reduced by 100x
  - Less cost, no calibration
  - Low frequency noise reduced by 10x
New Reference Designs for DRV411

**TIPD-180**

- Complete ±50A Current Sensor using Closed-Loop Compensated Hall Element Reference Design
- 3\textsuperscript{rd} party core from Topstek (TW) available for reference (order will be possible)

**TIPD-184**

- Complete ±100A Current Sensor using Closed-Loop Compensated Hall Element Reference Design
- ±15V power supply allows higher currents to be compensated
- 3\textsuperscript{rd} party core from Topstek (TW) available for reference (order will be possible)

For more Details visit www.ti.com
Integrated Fluxgate Sensor with Closed Loop Compensation

DRV421
Closed-Loop Measurement Principle

- **Compensation coil** provides opposite magnetic field.
- **Sensor** measures the magnetic field.
- **Read-out circuit** amplifies/filters magnetic field and drives compensation coil.
- **Primary** (measured) current.
- **Magnetic core** concentrates magnetic field generated by the measured current.
- **Differential amplifier** generates output voltage proportional to the compensation current.

Components mentioned:
- DRV401
- DRV411
DRV421
Closed-Loop / Leakage Current Sense

**Features**

- **High Precision Integrated Magnetic Sensor:** 3 uT Offset max, 10 nT/°C Drift typ
- **H-Bridge Output Driver** (250 mA typ)
- **Precision Differential Amplifier**
- **Wide System Bandwidth** (>200 kHz)
- **Precision Reference** (100 ppm/°C max)
- **Over-Range and Error Flags**
- **Power Supply** 3 V to 5.5 V
- **Temperature Range:** -40 ... 125°C
- **Packages:** 4x4mm QFN

**Benefits**

- Enables 0.1% overall accuracy
- Integrated closed-loop core de-gauss
- Sensor integration for lower system cost
- The high sensor sensitivity, low offset and drift relax core requirements
- Integrated sensor reduces coil coupling, emissions and increase dynamic range
- Extended current measurement range
- DC and AC current measurement

**Applications**

- Closed-Loop Current Sensor Modules for
  - Leakage current measurement
  - Motor Control
  - Photovoltaic Inverters
  - Current Monitoring

**BLUE: Advantages of integrated fluxgate**

**Texas Instruments**
Performance Highlights

- **Measurement range of 6 decades**
- **Best in-class linearity**
- **Coupling between compensation coil and fluxgate eliminated**
- **Significantly reduced emissions from fluxgate excitation**
Success Stories: DRV421 Module
Integrated Fluxgate IC + closed-loop PCB Mounting Current Sensor Module

Where We Will Win

Who: Sumida, Japan
What: DRV421
Where: General purpose closed-loop current sensing module

Why the customer is evaluating our solution

The new integrated fluxgate technology gives the customer a new degree of freedom for the design of a CL sensor module. The sensor IC has no longer to be embedded in the module, but can sit on a PCB with the module carrying the core and compensation coil on top. The high sensitivity allows new materials like ferrite cores to be used. This all together enables Sumida to enter this product space for the first time competing with big players like LEM and VAC.
Thank You!