BROADCOM®

Data Sheet

# ACHS-7225

## Fully Integrated, Hall Effect-Based Linear Current Sensor IC with 3 $kV_{RMS}$ Isolation and Low-Resistance Current Conductor

## Description

The Broadcom® ACHS-7225 (±50A) fully integrated Hall Effect-based isolated linear current sensors are designed for AC or DC current sensing in industrial, commercial, and communications systems. Inside each of the ACHS-7225 IC is a precise, low-offset, linear Hall circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field that the Hall sensors convert into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall sensors.

A precise, proportional voltage is provided by the low-offset, chopper-stabilized CMOS Hall IC, which is programmed for accuracy after packaging. The output of the device has a positive slope (>$V_{OUT(Q)}$) when an increasing current flows through the primary copper (4-oz copper PCB for 50A) conduction path (from pins 1 and 2, to pins 3 and 4), which is the path used for current sampling.

The internal resistance of this conductive path is 0.7 mΩ typical, providing low power loss. The terminals of the conductive path are electrically isolated from the signal leads (pins 5 through 8). This performance is delivered in a compact, surface mountable, SO-8 package that meets worldwide regulatory safety standards.

| Part Number | Current Range | Sensitivity |
|---|---|---|
| ACHS-7225[a] | ±50 Apk | 26.4 mV/A |

a. Due to the SO-8 package power dissipation limitations, the rated input power of ACHS-7225 product needs to be based on 4-oz copper PCB.

## Features

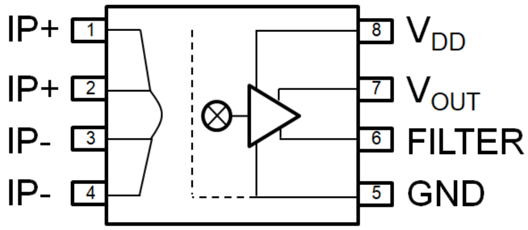
- Wide operating temperature: –40ºC to +110ºC
- Internal conductor resistance: 0.7 mΩ typ.
- Sensing current range ±50A (see the table footnote[a] under the part number table to the left)
- Output sensitivity: 26.4 mV/A
- Output voltage proportional to AC or DC currents
- Ratiometric output from supply voltage
- Single supply operation: 3.3V
- Low-noise analog signal path
- Device bandwidth is set using the new FILTER pin: 80-kHz typ. bandwidth with 1-nF filter capacitor
- Factory-trimmed for accuracy
- Extremely stable output offset voltage
- Near zero magnetic hysteresis
- Maximum total output error of ±5.5% across operating $T_A$
- >25 kV/µs common-mode transient immunity
- Small footprint, low-profile SO-8 package
- Worldwide safety approvals: UL/cUL; Isolation voltage: 3 kVrms, 1 minute

## Applications

- E-bikes
- Food processor
- Low-power inverter current sensing
- Motor phase and rail current sensing
- Solar inverters
- Chargers and converters
- Switching power supplies

**CAUTION!** Take normal static precautions in handling and assembly of this component to prevent damage, degradation, or both, which may be induced by ESD. The components featured in this data sheet are not to be used in military or aerospace applications or environments.

# Functional Diagram




**NOTE:** The connection of 1-μF bypass capacitor between pins 8 and 5 is recommended.

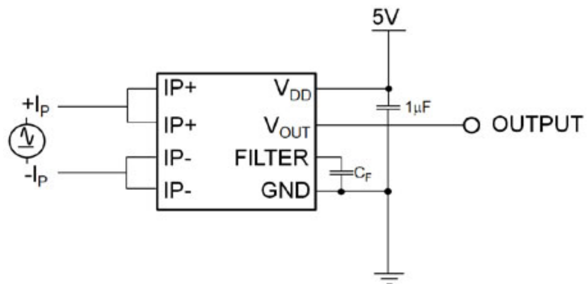
# Pin Description

| Pin | Pin Name | Description |
|---|---|---|
| 1 | $I_{P+}$ | Terminals for current being sampled; fused internally |
| 2 | $I_{P+}$ | |
| 3 | $I_{P-}$ | Terminals for current being sampled; fused internally |
| 4 | $I_{P-}$ | |

| Pin | Pin Name | Description |
|---|---|---|
| 8 | $V_{DD}$ | Supply voltage relative to GND |
| 7 | $V_{OUT}$ | Output voltage |
| 6 | FILTER | Filter pin to set bandwidth |
| 5 | GND | Output side ground |

# Typical Application Circuit

A typical application circuit for the ACHS-7225 product series consists of a bypass capacitor and a filter capacitor as additional external components. On the input side, pins 1 and 2 are shorted together, and pins 3 and 4 shorted together. The output voltage is directly measured from the $V_{OUT}$ pin.



# Ordering Information

| Part Number | Current Range | Option (RoHS) Compliant | Package | Surface Mount | Tape and Reel | UL 3 $kV_{RMS}$ 1 min. Rating | Quantity |
|---|---|---|---|---|---|---|---|
| ACHS-7225 | ±50A | -000E | SO-8 | X | | X | 100 per tube |
| | | -500E | | X | X | X | 1500 per reel |

To order, combine the part number from the Part Number column with the desired option from the Option column to form an order entry.

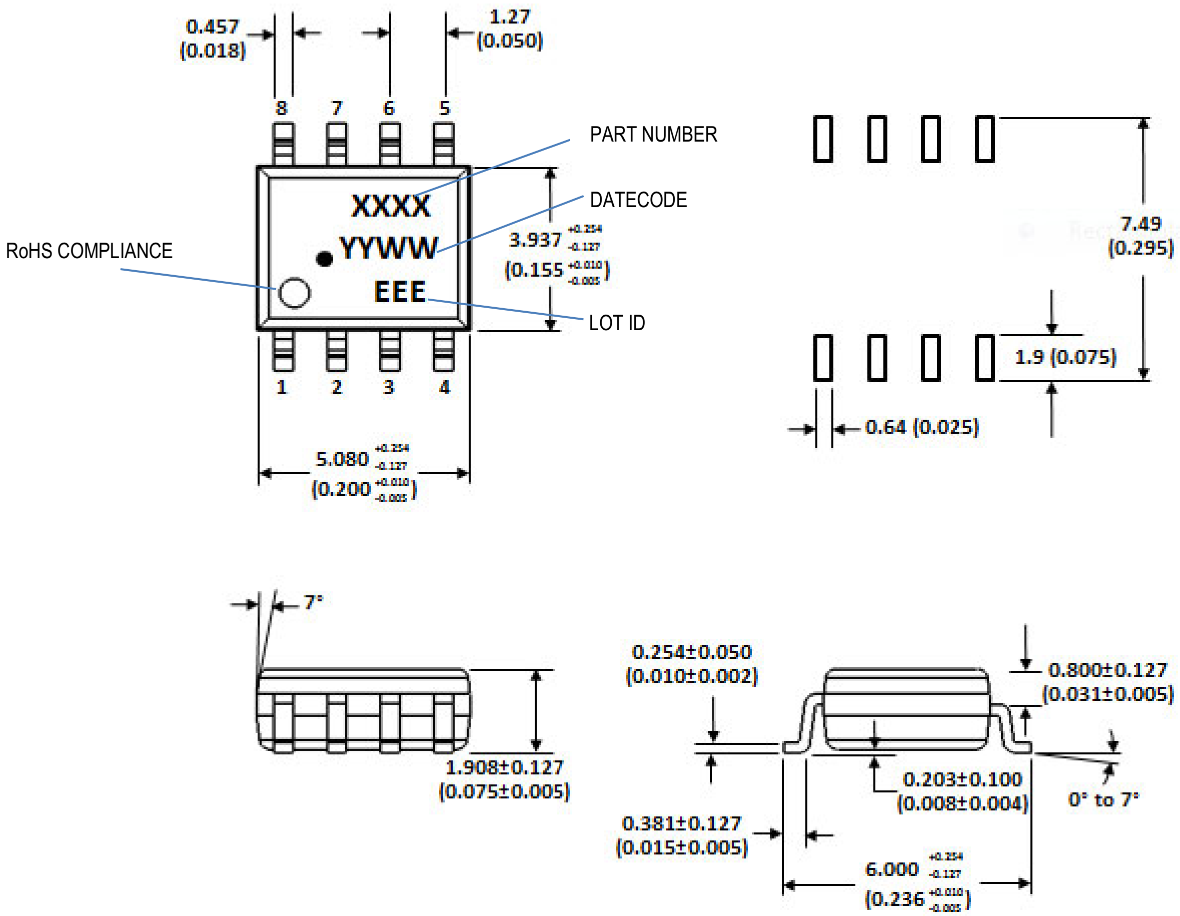
**Example:**

Select ACHL-7225-500E to order a product with ±50A, Surface Mount type in Tape-and-Reel packaging and RoHS compliance.

Option data sheets are available. Contact your Broadcom sales representative or authorized distributor for information.

# Package Outline Drawing

## ACHS-7225 SO-8, 8-Lead Surface-Mount Package




**NOTE:**

Dimensions in millimeters (inches).

Lead co-planarity = 0.100 mm (0.004 in.) maximum.

Floating lead protrusion = 0.254 mm (0.010 in.) maximum.

Mold flash on each side = 0.127 mm (0.005 in.) maximum.

# Recommended Pb-Free IR Profile

Recommended reflow condition as per JEDEC Standard, J-STD-020 (latest revision). Non-halide flux should be used.

# Regulatory Information

The ACHS-7225 ICs are approved by the following organizations:

- UL/cUL approval: UL 1577, component recognition program up to $V_{ISO}$ = 3000 $V_{RMS}$.
- Approved under IEC/EN62368-1, certified under TUV Rheinland.

# Insulation and Safety Related Specifications

| Parameter | Symbol | Value | Unit | Conditions |
|---|---|---|---|---|
| Minimum External Air Gap (External Clearance) | L(101) | 4.0 | mm | Measured from the input terminals to the output terminals, the shortest distance through air |
| Minimum External Tracking (External Creepage) | L(102) | 4.0 | mm | Measured from the input terminals to the output terminals, the shortest distance path along body |
| Minimum Internal Plastic Gap (Internal Clearance) | — | 0.05 | mm | Through the insulation distance, conductor to conductor, usually the direct distance between the primary input conductor and the detector IC |
| Tracking Resistance (Comparative Tracking Index) | CTI | ≥175 | V | DIN IEC 112/VDE 0303 Part 1 |
| Isolation Group | — | IIIa | — | Material Group (DIN VDE 0110, 1/89, Table 1) |
| Overvoltage Category | — | I-IV | — | Rated mains voltage ≤ 150 $V_{RMS}$ |
| | — | I-III | — | Rated mains voltage ≤ 300 $V_{RMS}$ |
| Maximum Repetitive Peak Isolation Voltage | $V_{IORM}$ | 567 | $V_{PK}$ | Internal Qualification Test |
| Maximum Transient Isolation Voltage | $V_{IOTM}$ | 4242 | $V_{PK}$ | IEC/EN62368-1 Certified<br>$V_{TEST}$ = 4242 $V_{PK}$, t = 60s (Type Tested) |

# Absolute Maximum Ratings

| Parameter | Symbol | Min. | Max. | Unit | Test Conditions |
|---|---|---|---|---|---|
| Storage Temperature | $T_S$ | –55 | +125 | °C | |
| Ambient Operating Temperature | $T_A$ | –40 | +110 | °C | |
| Junction Temperature | $T_{J(max)}$ | — | +150 | °C | |
| Primary Conductor Lead Temperature | $T_{L(ma)}$ | — | +150 | °C | Pins 1, 2, 3, or 4 |
| Supply Voltages | $V_{DD}$ | –0.5 | 5.0 | V | |
| Output Voltage | $V_{OUT}$ | –0.5 | $V_{DD}$ + 0.5 | V | |
| Output Current Source | $I_{OUT(source)}$ | — | 10 | mA | $T_A$ = 25°C |
| Output Current Sink | $I_{OUT(sink)}$ | — | 10 | mA | $T_A$ = 25°C |
| Overcurrent Transient Tolerance | $I_P$ | — | 100 | A | 1 pulse, 100 ms; $T_A$ = 25°C |
| Input Power Dissipation[a] | $P_{IN}$ | — | 1750 | mW | |
| Output Power Dissipation | $P_{OUT}$ | — | 90 | mW | |

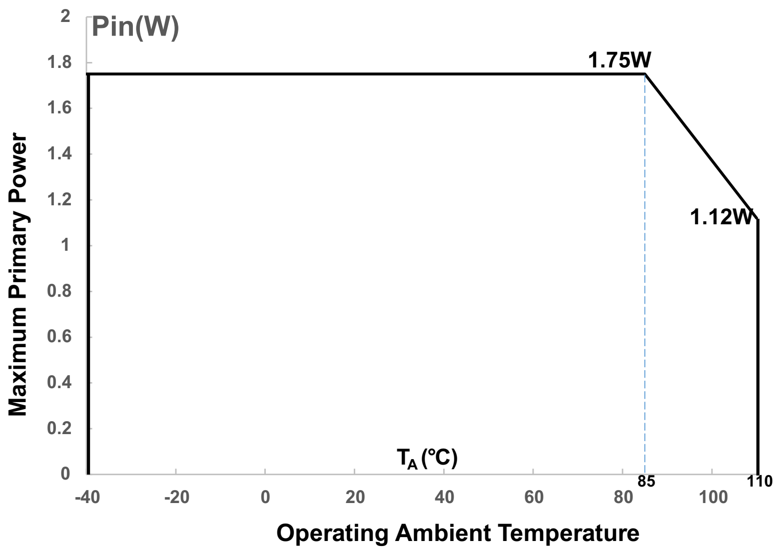
a. Absolute Maximum Input Power Dissipation is only valid if 4-oz copper PCB is used. This power is valid up to 85°C ambient temperature. For >85°C ambient, a derating factor of –25.2 mW/°C is needed.

# Recommended Operating Conditions

| Parameter | | Symbol | Min. | Max. | Unit |
|---|---|---|---|---|---|
| Ambient Operating Temperature | | $T_A$ | –40 | 110 | °C |
| $V_{DD}$ Supply Voltage | | $V_{DD}$ | 3.0 | 3.6 | V |
| Output Capacitance Load | | $C_{LOAD}$ | — | 10 | nF |
| Output Resistive Load | | $R_{LOAD}$ | 4.7 | — | kΩ |
| Input Peak Current Range | ACHS-7225[a] | $I_{pk}$ | –50 | 50 | A |

a. Due to the SO-8 package power dissipation limitations, the input peak current is valid up to 85°C ambient temperature only on 4-oz copper PCB. For >85°C ambient, derating is needed. For details, refer to Footnote *a* at Absolute Maximum Ratings. For Input Power Derating Curve, refer to the curve as shown in the following section.

# Primary Power Derating Curve for ACHS-7225




**NOTE:** Mounted on Broadcom's 4-oz Copper Evaluation Board as shown in Figure 18 and Figure 19.

# Common Electrical Specifications

Unless otherwise stated, all minimum/maximum specifications are over recommended operating conditions, $C_F$ = 1 nF. All typical values are based on $T_A$ = 25°C, $V_{DD}$ = 3.3V, $C_F$ = 1 nF.

| Parameter | Symbol | Min. | Typ. | Max. | Unit | Test Conditions | Figure | Note |
|---|---|---|---|---|---|---|---|---|
| Supply Current | $I_{DD}$ | — | 11.8 | 14 | mA | $V_{DD}$ = 3.3V, output open | 6, 11 | |
| Primary Conductance Resistance | $R_{PRIMARY}$ | — | 0.7 | — | mΩ | | | |
| Zero Current Output Voltage | $V_{OUT(Q)}$ | — | $V_{DD}$ / 2 | — | V | Bidirectional, $I_P$ = 0A | 7 | |
| Input Filter Resistance | $R_{F(INT)}$ | — | 1.6 | — | kΩ | | | |
| Bandwidth | BW | — | 80 | — | kHz | –3 dB | | |
| Rise Time | $t_r$ | — | 4 | — | µs | | 9 | |
| Power-on Time | $t_{PO}$ | — | 21 | — | µs | | 8 | |
| Common Mode Transient Immunity | CMTI | 25 | — | — | kV/µs | $V_{CM}$ = 1000V | | a |

a. Common Mode Transient Immunity is tested by applying a fast rising/falling voltage pulse across pin 4 and pin 5 (GND). The output glitch observed is less than 0.2V from the average output voltage for less than 1 µs.

# Electrical Specifications

Unless otherwise stated, all minimum/maximum specifications are over recommended operating conditions, $C_F$ = 1 nF. All typical values are based on $T_A$ = +25°C, $V_{DD}$ = 3.3V, $C_F$ = 1 nF.

| Parameter | Symbol | Min. | Typ. | Max. | Unit | Test Conditions | Figure | Note |
|---|---|---|---|---|---|---|---|---|
| Optimized Accuracy Range | $I_P$ | –50 | — | +50 | A | | | a |
| Sensitivity | Sens | — | 26.4 | — | mV/A | $-50A \le I_P \le +50A$ | 1 | b |
| Sensitivity Error | $E_{SENS}$ | –3 | — | 3 | % | $T_A$ = 25°C | 3 | b |
| | | –5 | — | 5 | | $T_A$ = –40°C to 110°C | | |
| Offset Output Error | $V_{OE}$ | –20 | — | 20 | mV | $T_A$ = 25°C | 2 | b |
| | | –30 | — | 30 | | $T_A$ = –40°C to 110°C | | |
| Total Output Error | $E_{TOT}$ | –3.5 | — | 3.5 | % | $T_A$ = 25°C | 4 | b, c |
| | | –5.5 | — | 5.5 | | $T_A$ = –40°C to 110°C | | |
| Output Noise | $V_{N(RMS)}$ | — | 1.8 | — | mV | BW = 2 kHz | 10 | d |
| Nonlinearity | NL | — | 0.1 | — | % | $T_A$ = 25°C | 5 | e |
| Sensitivity Error Lifetime Drift | $E_{SENS\_DRIFT}$ | — | ±2 | — | % | $T_A$ = 25°C | | |
| Total Output Error Lifetime Drift | $E_{TOT\_DRIFT}$ | — | ±2 | — | % | $T_A$ = 25°C | | |

a. The device may be operated at higher primary current levels, $I_P$, provided that the Maximum Junction Temperature, $T_{J(MAX)}$ is not exceeded. Due to the SO-8 package power dissipation limitations, the input RMS or DC current of 50A product must be derated above 85°C ambient at –25.2 mW/°C on 4-oz copper PCB.

b. See the Definition of Electrical Characteristics in this data sheet.

c. Total Output Error definition: $E_{TOT} = E_{SENS} + 100 \times V_{OE}/(Sens \times I_P) + NL$; $I_P$ = ±50A = 100A full range.

d. Output Noise is the noise level of ACHS-7225 expressed in root mean square (RMS) voltage.

e. Nonlinearity is defined as half of the peak-to-peak output deviation from the best-fit line, expressed as a percentage of the full-scale output voltage. See the Definition of Electrical Characteristics section of this data sheet for the complete definition and formula.

# Package Characteristics

| Parameter | Symbol | Min. | Typ. | Max. | Unit | Test Conditions | Note |
|---|---|---|---|---|---|---|---|
| Input-Output Momentary Withstand Voltage | $V_{ISO}$ | 3000 | — | — | $V_{RMS}$ | RH < 50%, t = 1 min., $T_A$ = 25°C | a, b, c |
| Resistance (Input-Output) | $R_{I-O}$ | — | $10^{14}$ | — | Ω | $V_{I-O}$ = 500 $V_{DC}$ | c |
| Capacitance (Input-Output) | $C_{I-O}$ | — | 1.2 | — | pF | f = 1 MHz | c |
| Junction-to-Ambient Thermal Resistance (due to primary conductor) | $R_{\theta 12}$ | — | 35 | — | °C/W | Based on the Broadcom evaluation board | d |
| Junction-to-Ambient Thermal Resistance (due to IC) | $R_{\theta 22}$ | — | 22 | — | °C/W | Based on the Broadcom evaluation board | d |

a. In accordance with UL/cUL, each device is proof-tested by applying an insulation test voltage = 3600 $V_{RMS}$ for 1 second.

b. The Input-Output Momentary Withstand Voltage is a dielectric voltage rating that should not be interpreted as an input-output continuous voltage rating.

c. This is a two-terminal measurement: pins 1 through 4 are shorted together and pins 5 through 8 are shorted together.

d. The Broadcom evaluation board has 650 $mm^2$ (total area including top and bottom copper minus the mounting holes) of 4-oz copper connected to pins 1 and 2 and pins 3 and 4. See the Thermal Consideration section in this data sheet for additional information on thermal characterization.

# Typical Performance Plots

All typical plots are based on $T_A$ = 25°C, $V_{DD}$ = 3.3V, $C_F$ = 1 nF, unless otherwise stated.

**Figure 1: Sensitivity vs. Temperature**

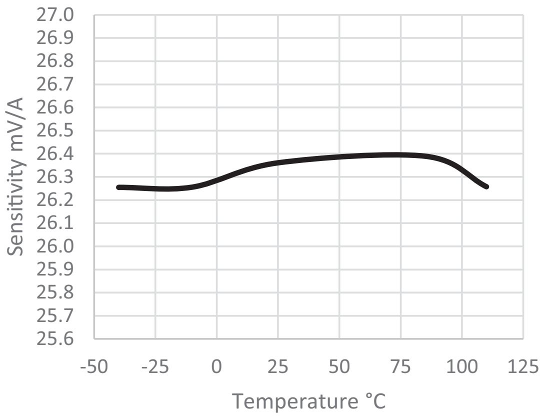



**Figure 2: Offset Voltage vs. Temperature**

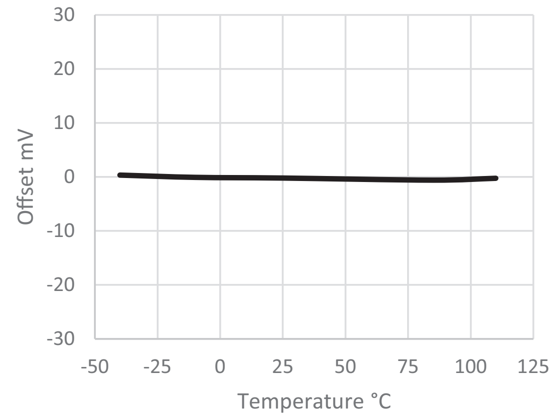



**Figure 3: Sensitivity Error vs. Temperature**

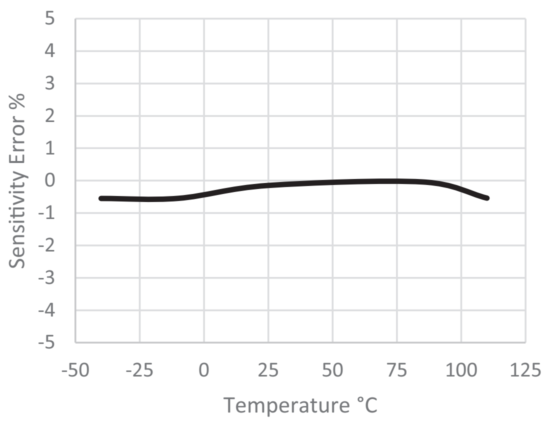



**Figure 4: Total Output Error vs. Temperature**

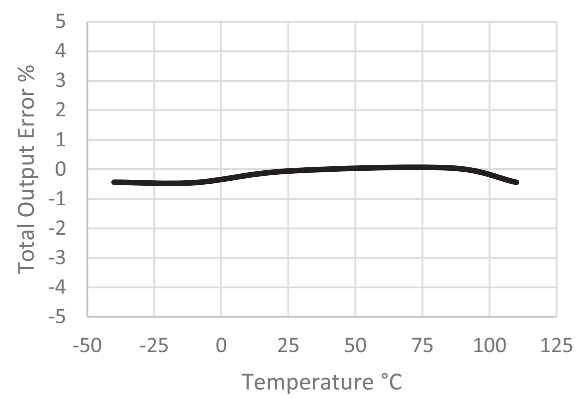



**Figure 5: Nonlinearity vs. Temperature**

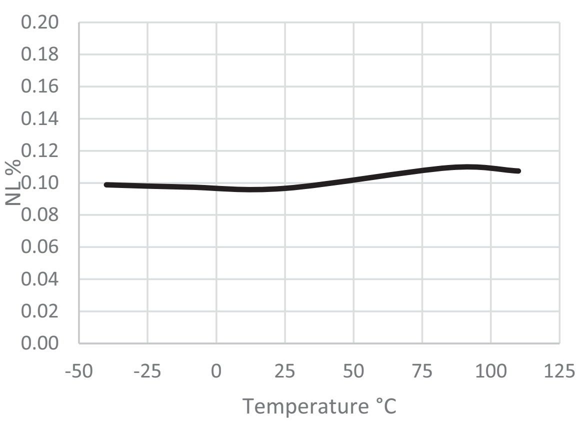



**Figure 6: Supply Current vs. Supply Voltage**

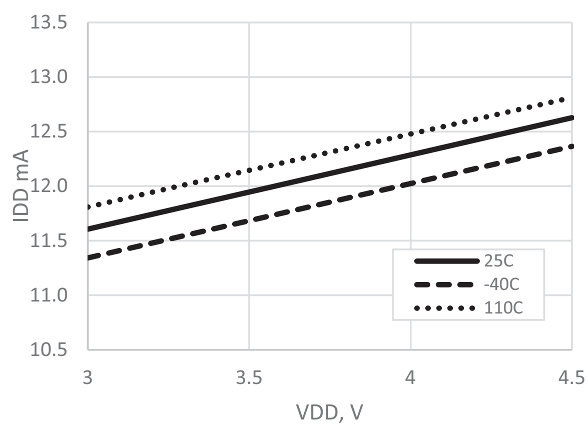


**Figure 7: Output Voltage vs. Sensed Current**

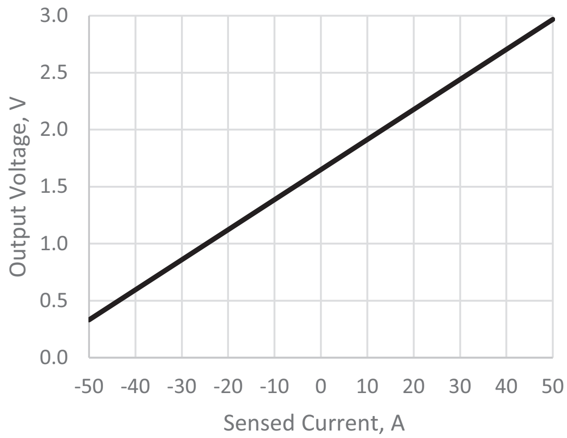



**Figure 8: Power-On Time vs. External Filter**

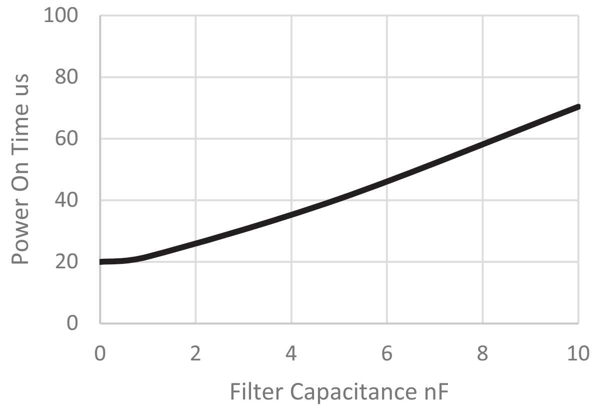



**Figure 9: Rise Time vs. External Filter**

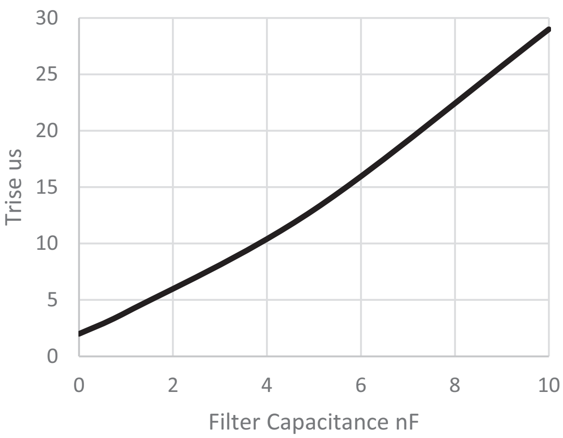



**Figure 10: Output Noise vs. External Filter**

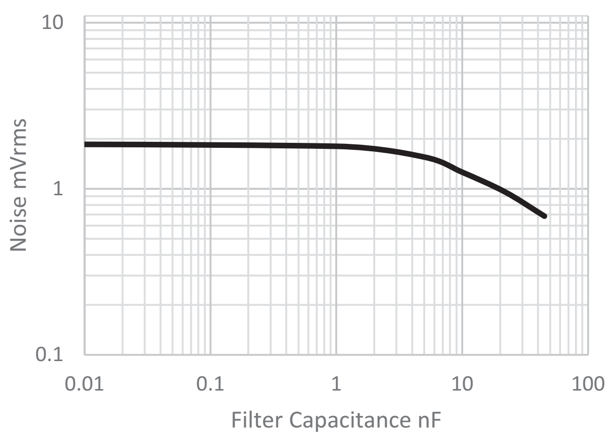
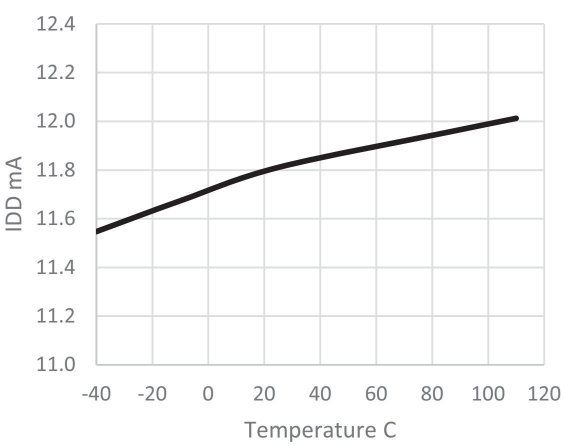



**Figure 11: Supply Current vs. Temperature**



# Definition of Electrical Characteristics

The ACHS-7225 product series is a Hall-Effect current sensor that outputs an analog voltage proportional to the magnetic field intensity caused by the current flowing through the input primary conductor. Without the magnetic field, the output voltage is half of the supply voltage. The sensor can detect both DC and AC current.

## Ratiometric Output

The output voltage of the ACHS-7225 series is ratiometric or proportional to the supply voltage. The sensitivity (Sens) of the device and the quiescent output voltage changes when there is a change in the supply voltage ($V_{DD}$). For example, for ACHS-7225 when the $V_{DD}$ is increased by +10% from 3V to 3.3V, the quiescent output voltage will change from 1.5V to 1.65V, and the sensitivity will also change from 24 mV/A to 26.4 mV/A.

## Sensitivity

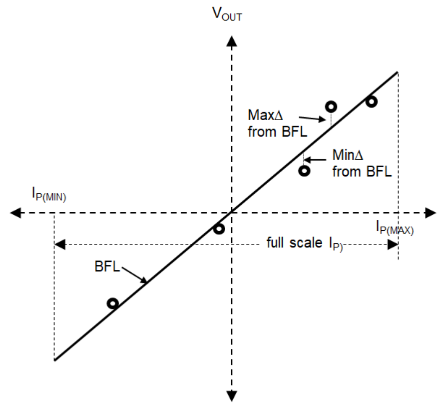
The output sensitivity (Sens) is the ratio of the output voltage ($V_{OUT}$) over the input current ($I_P$) flowing through the primary conductor. It is expressed in mV/A. When an applied current flows through the input primary conductor, it generates a magnetic field that the Hall IC converts into a voltage. The proportional voltage is provided by the Hall IC, which is programmed in the factory for accuracy after packaging. The output voltage has a positive slope when an increasing current flows through the pins 1 and 2 to pins 3 and 4. Sensitivity error ($E_{SENS}$) is the difference between the measured sensitivity and the ideal sensitivity expressed as a percentage (%).

## Nonlinearity

Nonlinearity is defined as half of the peak-to-peak output deviation from the best-fit line (BFL), expressed as a percentage of the full-scale output voltage. The full-scale output voltage is the product of the sensitivity (Sens) and full-scale input current ($I_P$).

$$NL\ (\%) = \frac{[(Max\Delta \text{ from BFL} - Min\Delta \text{ from BFL}) / 2]}{Sens \times \text{full scale } I_P} \times 100\%$$

**Figure 12: Nonlinearity Calculation**




## Zero Current Output Voltage

Zero current output voltage is the output voltage of the ACHS-7225 when the primary current is zero. Zero current output voltage is half of the supply voltage ($V_{DD}/2$).

## Zero Current Output Error

Zero current output error is the voltage difference between the measured output voltage and the ideal output voltage ($V_{DD}/2$) when there is no input current to the device.

## Total Output Error

The total output error in percentage is obtained by adding the sensitivity error plus offset error:

$$E_{TOT} = E_{SENS} + 100 \times V_{OE}/(Sens \times I_P) + NL$$

## Power-On Time

Power-on time is the time required for the internal circuitry of the device to be ready during the ramping of the supply voltage. Power-on time is defined as the finite time required for the output voltage to settle after the supply voltage reaches its recommended operating voltage.

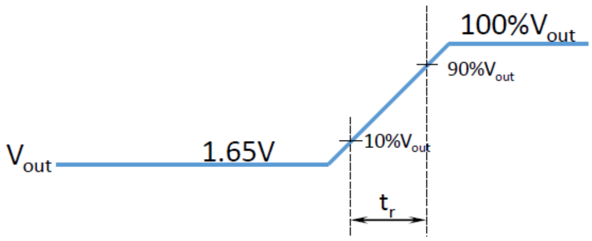
## FILTER Pin

The ACHS-7225 has a FILTER pin for improving the signal-to-noise ratio of the device. This eliminates the need for external RC filter to the $V_{OUT}$ pin of the device, which can cause attenuation of the output signal. A ceramic capacitor, $C_F$, can be connected between the FILTER pin to GND.

## Rise Time ($t_r$)

Rise time is the time interval between when the sensor IC output rises from 10%, and when it reaches 90% of its full-scale output value, as shown in Figure 13.

**Figure 13: Rise Times**




# Application Information

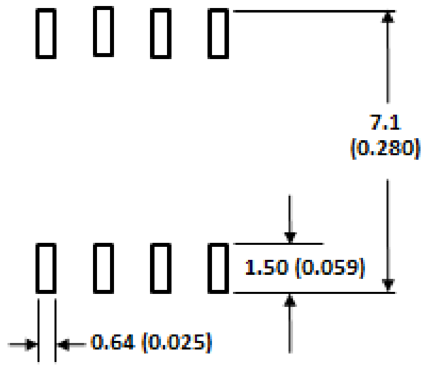
## PCB Layout

The design of the printed circuit board (PCB) should follow good layout practices, such as keeping bypass capacitors close to the supply pin and use of ground and power planes. A bypass capacitor must be connected between pins 5 and 8 of the device. The layout of the PCB can also affect the common mode transient immunity of the device due to stray capacitive coupling between the input and output circuits. To obtain maximum common mode transient immunity performance, the layout of the PCB should minimize any stray coupling by maintaining the maximum possible distance between the input and output sides of the circuit and ensuring that any ground or power plane on the PCB does not pass directly below or extend much wider than the body of the device.

## Land Pattern for 4-mm Board Creepage

For applications that require PCB creepage of 4-mm between input and output sides, the land pattern in Figure 14 can be used.

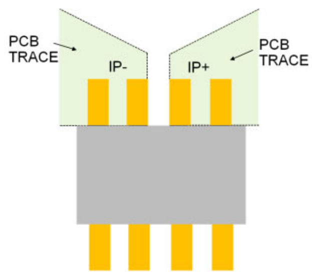
**Figure 14: Land Pattern for 4-mm Creepage**




## Effect of PCB Layout on Sensitivity

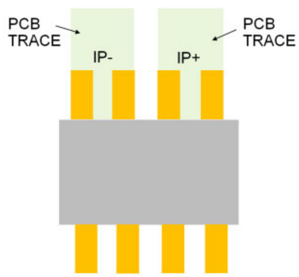
The trace layout on the input pins of ACHS-7225 affects the sensitivity. It is recommended that the PCB trace connection to the input pins covers the pins fully as shown in Figure 15.

**Figure 15: Recommended Trace Layout on the Input Pins**



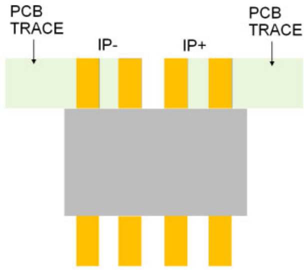

When the connection to the input pin only covers the vertical portion of the input pin, there is a sensitivity variation of about –0.6% versus recommended PCB trace layout as shown in Figure 16.

**Figure 16: Vertical Portion Connection**



When the connection to the input pin only covers the horizontal portion of the input pin, there is a sensitivity variation of about +1.2% versus the recommended PCB trace layout as shown in Figure 17.

**Figure 17: Horizontal Portion Connection**




## Thermal Consideration

The evaluation board used in the thermal characterization is shown in Figure 18. The inputs IP+ and IP- are each connected to input plane of 4-oz. copper with at least 650 $mm^2$ total area (including top and bottom planes, minus the screws mounting holes). The output side GND is connected to a ground plane of 4-oz. copper with 460 $mm^2$ total area (including top and bottom planes). The 4-oz. copper enables the board to conduct higher current and achieve good thermal distribution in a limited space.

**Figure 18: Broadcom Evaluation Board – Top Layer (sharing the same PCB with ACHS-712x).**

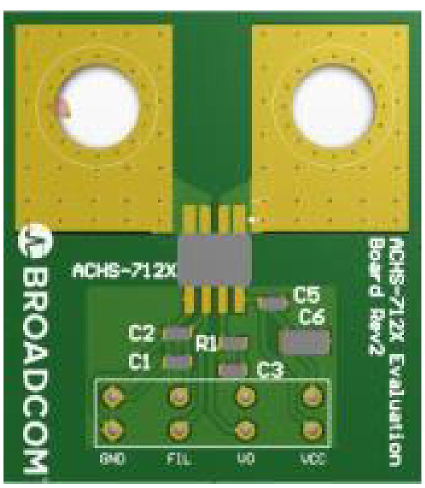
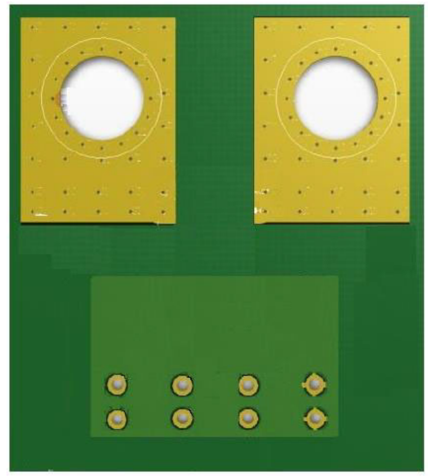



**Figure 19: Broadcom Evaluation Board – Bottom Layer**



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