

DESCRIPTION

The MCS1801 is a Hall effect-based linear current sensor IC for AC or DC current sensing. The Hall array is differential to cancel out any stray magnetic fields.

A low-resistance primary conductor allows current flow within close proximity of an integrated circuit containing high-accuracy Hall sensors. This current generates a magnetic field, which is sensed at two different points by the integrated Hall transducers. The magnetic field difference between these two points is then converted into a voltage proportional to the applied current. Spinning current technique is used for a low stable offset.

The galvanic isolation between the pins of the primary conductive path and the sensor leads allows the MCS1801 to replace opto-isolators or other expensive isolation devices.

The MCS1801 requires a minimal number of readily available, standard external components. It is available in a SOIC-8 package. The small footprint saves board area and is ideal for space-constrained applications.

FEATURES

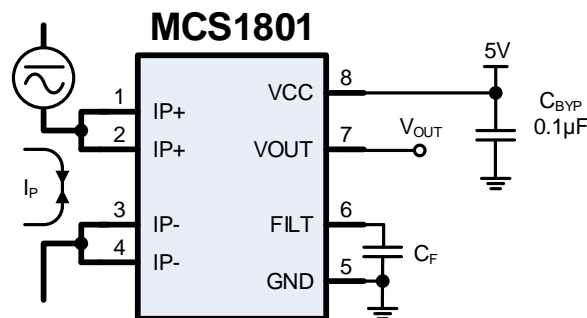
- 5V Single Supply
- Immune to External Magnetic Fields by Differential Sensing
- 200V RMS Minimum Isolation Voltage from Pins 1-4 to Pins 5-8
- Operating Temperature -40°C to +125°C
- 1.2mΩ Internal Conductor Resistance
- 12.5A to 25A Range
- Adjustable Bandwidth, Up to 100kHz
- 3.5µs Minimum Output Rise Time
- Ratiometric Output from Supply Voltage
- Output Proportional to AC or DC Currents
- Factory-Trimmed for Accuracy
- No Magnetic Hysteresis
- Integrated Shield Suppressing Capacitive Coupling from Current Conductor to Die (Up to 10V/ns)
- Available in a SOIC-8 Package

APPLICATIONS

- Motor Control
- Automotive Systems
- Load Detection & Management
- Switched-Mode Power Supplies
- Over-Current Fault Protection

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TYPICAL APPLICATION



V_{OUT} is proportional to I_P within the range specified. The noise vs. bandwidth tradeoff can be adjusted by C_F connected between FILT and GND.

ORDERING INFORMATION

| Part Number* | Optimized Primary Current Range (A) | Typ. Sensitivity (Sens) (mV/A) | Top Marking |
|--------------|-------------------------------------|--------------------------------|-------------|
| MCS1801GS-12 | ±12.5 | 110 | MC1801 |
| MCS1801GS-25 | ±25 | 55 | MC1801 |

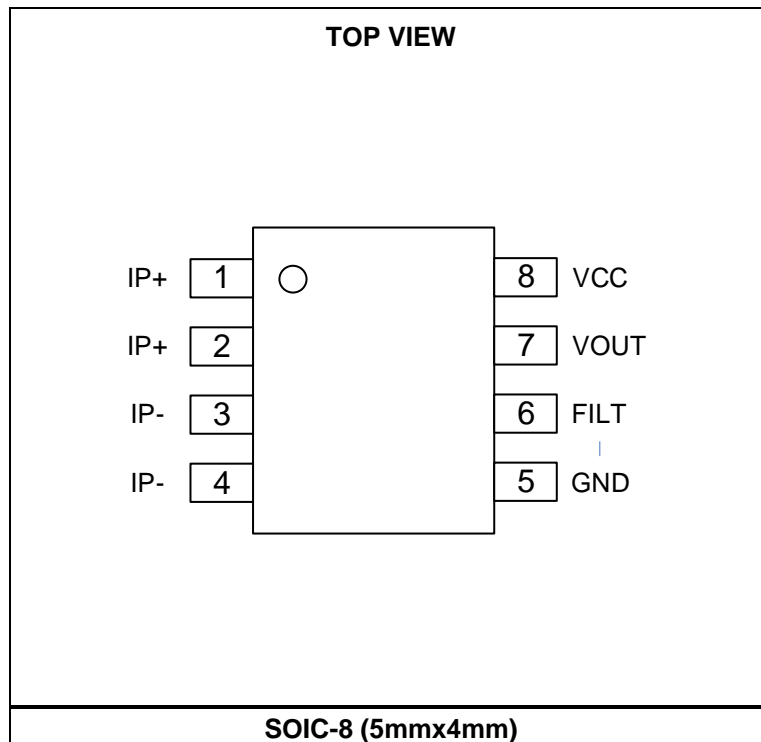
* For Tape & Reel, add suffix -Z (e.g. MCS1801GS-12-Z).

TOP MARKING

MC1801
 LLLLLLLL
 MPSYWW

MC: MPS current sensor prefix
 1801: First four digits of the part number
 LLL: Lot number
 Y: Year code
 W: Week code

PACKAGE REFERENCE



PIN FUNCTIONS

| Package Pin # | Name | Description |
|---------------|-------|---|
| 1, 2 | IP+ | Primary current + Terminals for current being sampled; fused internally. |
| 3, 4 | IP- | Primary current - Terminals for current being sampled; fused internally. |
| 5 | GND | Ground. Signal ground terminal. |
| 6 | FILT | Filter. Terminal for the external capacitor C_F setting the bandwidth. Can be unconnected. |
| 7 | VOOUT | Analog output. |
| 8 | VCC | Voltage supply. |

ABSOLUTE MAXIMUM RATINGS ⁽¹⁾

Supply voltage (V_{CC})-0.1V to 6V
 Output voltage (V_{OUT})-0.1V to 6V
 V_{FILT} -0.1V to 6V
 Junction temperature 165°C
 Lead temperature260°C
 Storage temperature -65°C to +165°C

Recommended Operating Conditions ⁽²⁾

Supply voltage (V_{IN})4.5V to 5.5V
 Operating junction temp (T_J) -40°C to +125°C

Notes:

- 1) Exceeding these ratings may damage the device.
- 2) The device is not guaranteed to function outside of its operating conditions.

ISOLATION CHARACTERISTICS

| Parameters | Symbol | Condition | Rating | Units |
|-------------------------------------|------------|--|--------|-----------------|
| Working voltage for basic isolation | V_{WFBI} | Maximum approved working voltage for basic (single) isolation according UL60950-1 (edition 2). | 200 | VDC or V_{PK} |
| Clearance | D_{cl} | Minimum distance through air from IP leads to signal leads. | 4.2 | mm |
| Creepage | D_{cr} | Minimum distance along package body from IP leads to signal leads. | 4.2 | mm |

ELECTRICAL CHARACTERISTICS ⁽⁵⁾

 Typical values are $V_{CC} = 5V$, $C_F = 0nF$, $C_L = 1nF$, $T_J = -40^{\circ}C$ to $+125^{\circ}C$, unless otherwise noted.

| Parameters | Symbol | Condition | Min | Typ | Max | Units |
|---|-------------------|---|----------------|--------------|------|-----------------------------|
| Supply voltage | V_{CC} | | 4.5 | | 5.5 | V |
| VCC under-voltage lockout threshold | V_{CCUVLO} | V_{CC} falling | 2 | 2.5 | 3 | V |
| VCC Under-voltage lockout hysteresis | V_{CCUVLO_HYS} | | | 400 | 750 | mV |
| Operating supply current | I_{CC} | $V_{CC} = 5V$ | | 8.5 | 10 | mA |
| Output capacitance load | C_L | From VOUT to GND | | | 10 | nF |
| Output resistive load | R_L | From VOUT to GND | 4.7 | | | k Ω |
| Primary conductor resistance | R_P | | | 1.2 | | m Ω |
| Frequency bandwidth ⁽¹²⁾ | f_{BW} | FILT unconnected | | 100 | | kHz |
| Power-on time ⁽¹²⁾ | t_{PO} | $I_P = I_{P_{MAX}}$ | | 90 | | μs |
| Rise time ⁽¹²⁾ | t_r | $I_P = I_{P_{MAX}}$, FILT unconnected | | 3.5 | | μs |
| Propagation delay ⁽¹²⁾ | t_{pd} | $I_P = I_{P_{MAX}}$, FILT unconnected | | 1.7 | | μs |
| Response time ⁽¹²⁾ | $t_{RESPONSE}$ | $I_P = I_{P_{MAX}}$, FILT unconnected | | 4.2 | | μs |
| Noise density ⁽¹²⁾ | I_{ND} | Input referenced noise density | | 200 | | $\mu A_{(RMS)} / \sqrt{Hz}$ |
| Noise ⁽¹²⁾ | I_N | Input referred, 1nF on FILT (60kHz bandwidth) | | 50 | | $mA_{(RMS)}$ |
| Nonlinearity | E_{LIN} | Over full range of I_P | | 1 | | % |
| Ratiometry | K_{sens} | $V_{CC} = 4.5$ to $5.5V$ | 99 | 100 | 101 | % |
| | K_{V0} | $V_{CC} = 4.5$ to $5.5V$, $I_P = 0A$ | 99 | 100 | 101 | % |
| Zero current output voltage | $V_{OUT(Q)}$ | $I_P = 0A$ | | $V_{CC} / 2$ | | V |
| Primary Hall magnetic coupling factor ⁽¹¹⁾ | P_{MCF1} | | 1.1 | 1.2 | 1.3 | mT/A |
| Secondary Hall magnetic coupling factor ⁽¹¹⁾ | P_{MCF2} | | 0.60 | 0.65 | 0.70 | mT/A |
| Hall plate matching ⁽¹¹⁾ | M_H | | | ± 1 | | % |
| Saturation voltage ⁽⁷⁾ | $V_{OUT(H)}$ | $R_L = 4.7k\Omega$, $T_J = 25^{\circ}C$ | $V_{CC} - 0.5$ | | | V |
| | $V_{OUT(L)}$ | $R_L = 4.7k\Omega$, $T_J = 25^{\circ}C$ | | | 0.5 | V |

MCS1801-12 PERFORMANCE CHARACTERISTICS ⁽⁵⁾
 $V_{CC} = 5V$, $C_F = 0nF$, $C_L = 1nF$, $T_J = -40^{\circ}C$ to $+125^{\circ}C$, unless otherwise noted.

| Parameters | Symbol | Condition | Min | Typ ⁽¹³⁾ | Max | Units |
|---|---------------|--|-------|---------------------|------|-------|
| Optimized accuracy range ⁽⁸⁾ | I_P | | -12.5 | | 12.5 | A |
| Sensitivity | Sens | $-5A \leq I_P \leq 5A$, $T_J = 25^{\circ}C$ | | 110 | | mV/A |
| Sensitivity error | E_{Sens} | $I_P = 12.5A$, $T_J = 25^{\circ}C$ to $125^{\circ}C$ | | ± 3.5 | | % |
| | | $I_P = 12.5A$, $T_J = -40^{\circ}C$ to $+25^{\circ}C$ | | ± 4.5 | | |
| Offset voltage ⁽⁹⁾ | V_{OE} | $I_P = 0A$, $T_J = 25^{\circ}C$ to $125^{\circ}C$ | | 10 | | mV |
| | | $I_P = 0A$, $T_J = -40^{\circ}C$ to $+25^{\circ}C$ | | 10 | | |
| Total output error ⁽¹⁰⁾ | E_{TOT} | $I_P = \pm 12.5A$, $T_J = 25^{\circ}C$ to $125^{\circ}C$ | | ± 4.0 | | % |
| | | $I_P = \pm 12.5A$, $T_J = -40^{\circ}C$ to $+25^{\circ}C$ | | ± 5.0 | | |
| Sensitivity error lifetime drift ⁽¹²⁾ | $E_{Sens(D)}$ | | | ± 1 | | % |
| Total output error lifetime drift ⁽¹²⁾ | $E_{TOT(D)}$ | | | ± 1 | | % |

MCS1801-25 PERFORMANCE CHARACTERISTICS ⁽⁵⁾
 $V_{CC} = 5V$, $C_F = 0nF$, $C_L = 1nF$, $T_J = -40^{\circ}C$ to $+125^{\circ}C$, unless otherwise noted.

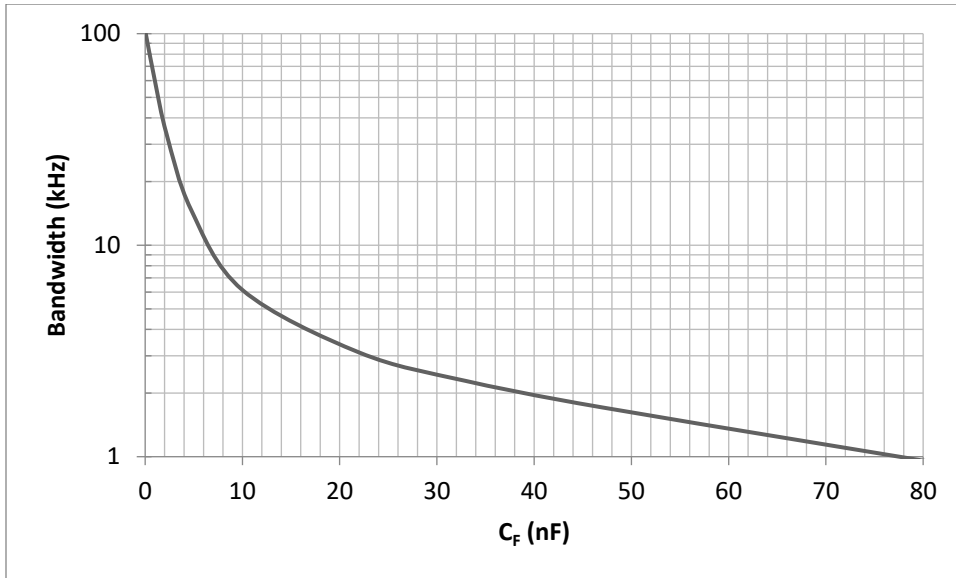
| Parameters | Symbol | Condition | Min | Typ ⁽¹³⁾ | Max | Units |
|---|---------------|--|-----|---------------------|-----|-------|
| Optimized accuracy range ⁽⁸⁾ | I_P | | -25 | | 25 | A |
| Sensitivity | Sens | $-10A \leq I_P \leq 10A$, $T_J = 25^{\circ}C$ | | 55 | | mV/A |
| Sensitivity error | E_{Sens} | $I_P = 25A$, $T_J = 25^{\circ}C$ to $125^{\circ}C$ | | ± 3.5 | | % |
| | | $I_P = 25A$, $T_J = -40^{\circ}C$ to $+25^{\circ}C$ | | ± 4.5 | | |
| Offset voltage ⁽⁹⁾ | V_{OE} | $I_P = 0A$, $T_J = 25^{\circ}C$ to $125^{\circ}C$ | | 10 | | mV |
| | | $I_P = 0A$, $T_J = -40^{\circ}C$ to $+25^{\circ}C$ | | 10 | | |
| Total output error ⁽¹⁰⁾ | E_{TOT} | $I_P = 25A$, $T_J = 25^{\circ}C$ to $125^{\circ}C$ | | ± 4.0 | | % |
| | | $I_P = 25A$, $T_J = -40^{\circ}C$ to $+25^{\circ}C$ | | ± 5.0 | | |
| Sensitivity error lifetime drift ⁽¹²⁾ | $E_{Sens(D)}$ | | | ± 1 | | % |
| Total output error lifetime drift ⁽¹²⁾ | $E_{TOT(D)}$ | | | ± 1 | | % |

Notes:

- 3) See below for the definitions of characteristics.
- 4) $R_{F(INT)}$ forms an RC filter with C_F via FILT pin.
- 5) The IC continues to respond to current beyond the range of I_P until the high or low saturation voltage. However, the nonlinearity in this region is worse than through the rest of the measurement range.
- 6) Device may be operated at higher primary current levels I_P and ambient temperatures T_A , provided that the maximum junction temperature T_J (MAX) is not exceeded.
- 7) Offset voltage does not incorporate any error due to external magnetic fields.
- 8) Percentage of I_P , with $I_P = I_{P_MAX}$. Output filtered.
- 9) Guaranteed by design.
- 10) Guaranteed by characterization.
- 11) Typical values with \pm are ± 3 sigma values.

TYPICAL CHARACTERISTICS

$V_{CC} = 5V$, $T_J = 25^\circ C$, unless otherwise noted.



FUNCTIONAL BLOCK DIAGRAM

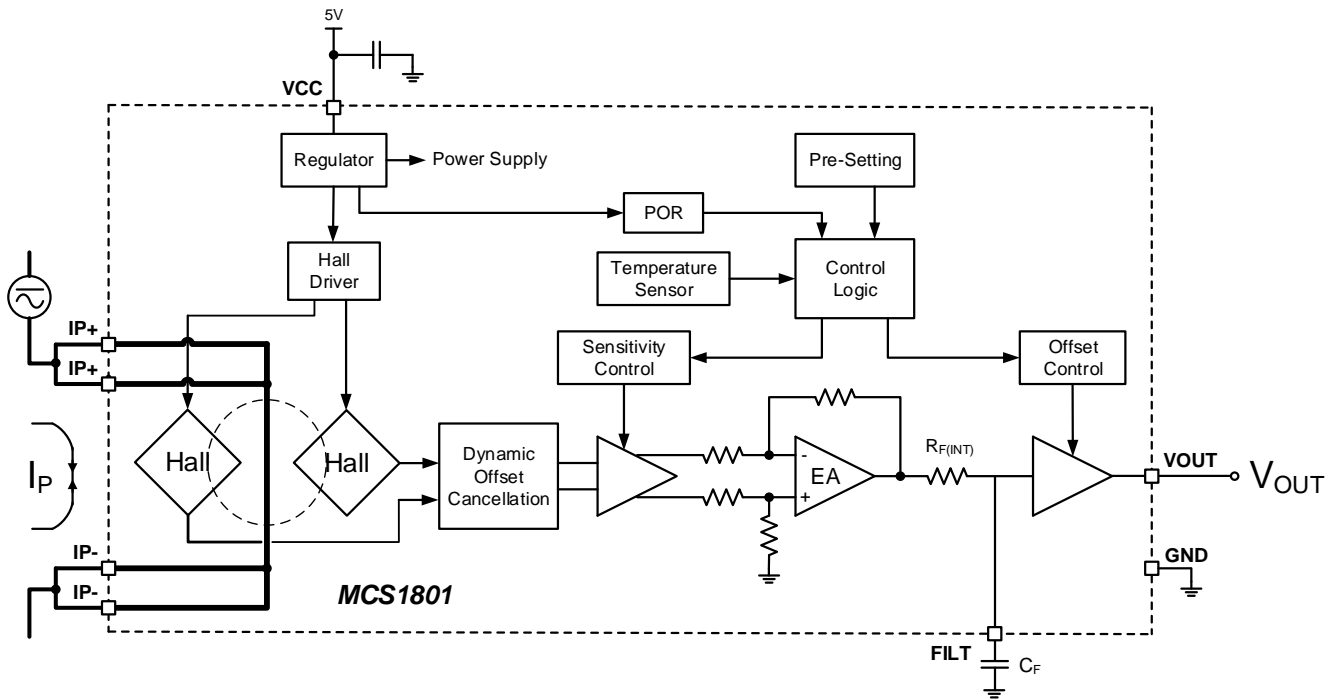


Figure 1: Functional Block Diagram

DEFINITIONS

Current Rating

$I_{P_{MAX}}$ is the rated current. The sensor output is linear as a function of the primary current (I_P), and follows the specified performances when I_P is between $-I_{P_{MAX}}$ and $+I_{P_{MAX}}$ (see Figure 2).

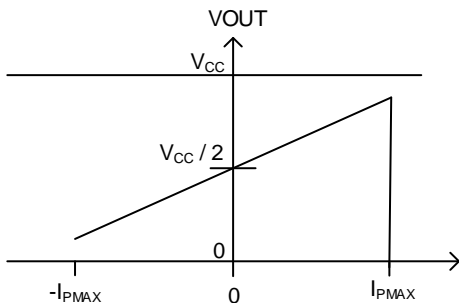


Figure 2: Sensor Output

Sensitivity (Sens)

The sensitivity (in mV/A) indicates how much the output changes when the primary current changes. It is the product of the average between the two coupling constants, P_{MCF1} and P_{MCF2} (in mT/A), and the transducer gain (in mV/mT). The gain is factory-trimmed to the sensor's target sensitivity.

Coupling Constants (P_{MCF1} and P_{MCF2})

The first and second Hall magnetic coupling factors are defined as the amount of vertical magnetic field (see arrows B_1 and B_2 in Figure 3) produced at the sensing points 1 and 2, per unit of current injected in the primary conductor. Due to the non-symmetric shape of the primary conductor, the magnetic fields generated at the two sensing points are different.

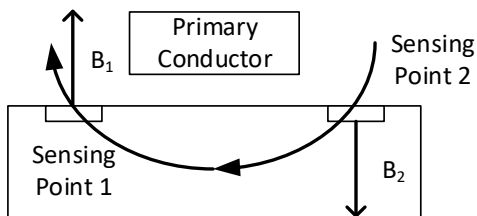


Figure 2: Schematic Cross-Section of the Sensor

Noise (V_{NOISE})

The noise is a random deviation and cannot be calibrated out. The input referred noise is the root mean square (RMS) sensor output noise (in mV) divided by the sensitivity (in mV/A). It represents the smallest current that the device is

able to resolve without any external signal treatment (it is generally accepted that the resolution is 3 times the RMS noise).

Other deviations are systematic, meaning they represent the average deviation over a large number of data points. They can be calibrated out.

Zero Current Output Voltage ($V_{OUT(Q)}$)

$V_{OUT(Q)}$ is the voltage output when the primary current is zero. The nominal value is $V_{CC} / 2$. Variation in $V_{OUT(Q)}$ from the nominal value is due to thermal drift and the resolution limits of voltage offset trimming in the factory.

Offset Voltage (V_{OE})

The offset voltage (V_{OE}) is the difference between $V_{CC} / 2$ and the zero current output. To convert this voltage into A, divide by the sensitivity.

Nonlinearity (E_{LIN})

Ideally, the primary current vs. sensor output function is a straight line. Nonlinearity is an indication of the worst deviation from this straight line.

The nonlinearity (in %) is determined with Equation (1):

$$E_{LIN} = \frac{\max(V_{out}(I_P) - V_{lin}(I_P))}{V_{out}(I_{P_{MAX}}) - V_{out}(-I_{P_{MAX}})} \times 100 \quad (1)$$

Where $V_{lin}(I_P)$ is the approximate straight line calculated by the least square method. Depending on the curvature of $V_{out}(I_P)$, E_{LIN} can be negative or positive.

Total Output Error (E_{TOT})

E_{TOT} (in %) is the relative difference between the sensor output and the ideal output at a given primary current (I_P), calculated with Equation (2):

$$E_{TOT}(I_P) = \frac{V_{out}(I_P) - V_{out\ ideal}(I_P)}{Sens \cdot I_P} \times 100 \quad (2)$$

Where $V_{out\ ideal}(I_P)$ is determined using Equation (3):

$$V_{out\ ideal}(I_P) = \frac{V_{CC}}{2} + Sens \cdot I_P \quad (3)$$

The total output error incorporates all sources of error, and is a function of I_P . At a current close to $I_{P_{MAX}}$, E_{TOT} is mainly affected by sensitivity error.

At a current close to zero, E_{TOT} is mostly due to V_{OE} . Note that when $I_P = 0$, E_{TOT} diverges to infinity because of constant offset.

Ratiometry Coefficients

Ideally, the sensor output is ratiometric, which means that the sensitivity and the zero current output scale with V_{CC} . The ratiometry coefficients measure how good this proportionality is, calculated with Equation (4) and Equation (5):

$$K_{SENS} = \frac{Sens(VCC)/Sens(3.3V)}{VCC/3.3V} \quad (4)$$

$$K_{V0} = \frac{V_{OUT}(I_P=0,VCC)/V_{OUT}(I_P=0,3.3V)}{VCC/3.3V} \quad (5)$$

Ideally, both K_{SENS} and K_{V0} are 1.

Power-On Time (t_{PO})

The power-on time (t_{PO}) reflects the time interval after power is first applied to the device until the output can be considered to correctly indicate the applied primary current. Figure 4 shows t_{PO} as the time taken between the supply reaching the minimum operating voltage $V_{CC_{MIN}}$ (t_1) and the output voltage to settling within $\pm 10\%$ of its steady state value under an applied primary current (t_2).

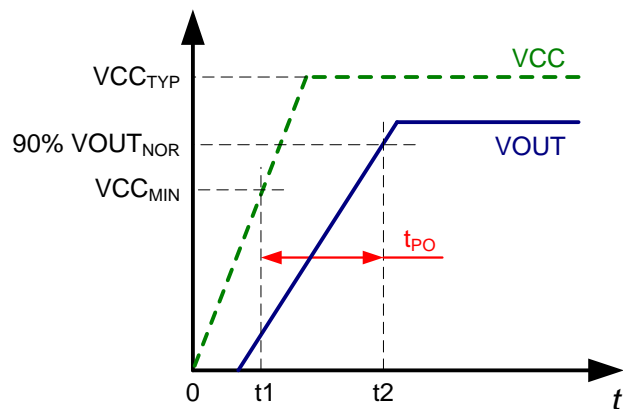


Figure 4: Power-On Time (t_{PO})

Propagation Delay (t_{pd})

Figure 5 shows the propagation delay (t_{pd}) as the time between the primary current signal reaching 20% of $I_{P_{MAX}}$ (t_1) and the device's output voltage reaching 20% of $V_{OUT_{MAX}}$ for the corresponding applied current (t_2).

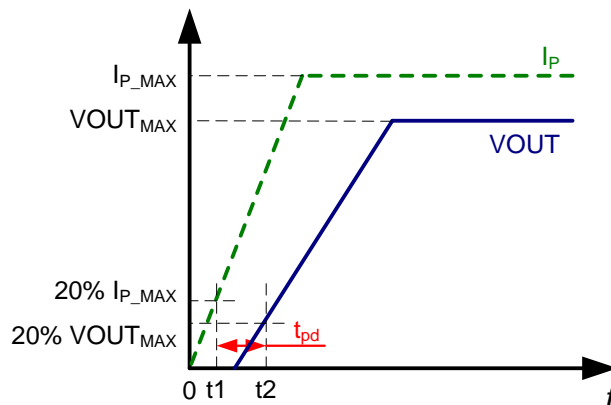


Figure 5: Propagation Delay (t_{pd})

Rise Time (t_r)

Figure 6 shows rise time (t_r) as the time interval between V_{OUT} reaching 10% of its full scale value (t_1), and it reaching 90% of its full scale value (t_2). The sensor bandwidth is defined as the 3dB cutoff frequency, and can be derived by the rise time of the response to an applied step with Equation (6):

$$f_{BW} = 0.35/t_r \quad (6)$$

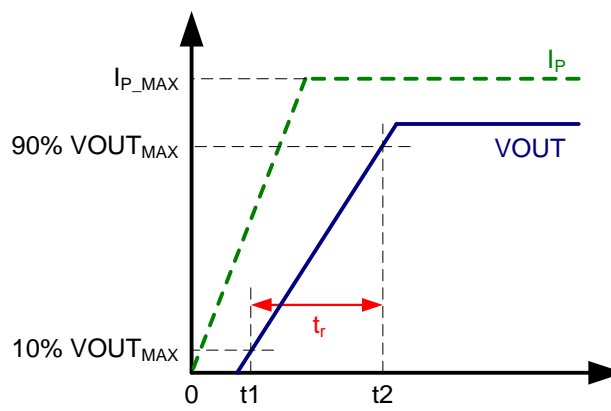


Figure 6: Rise Time (t_r)

Response Time (t_{RESPONSE})

Figure 7 shows the response time (t_{RESPONSE}) as a combination of the previously defined times. It is the time interval between the primary current signal reaching 90% of its final value (t_1) and V_{OUT} reaching 90% of its output, corresponding to the applied primary current (t_2).

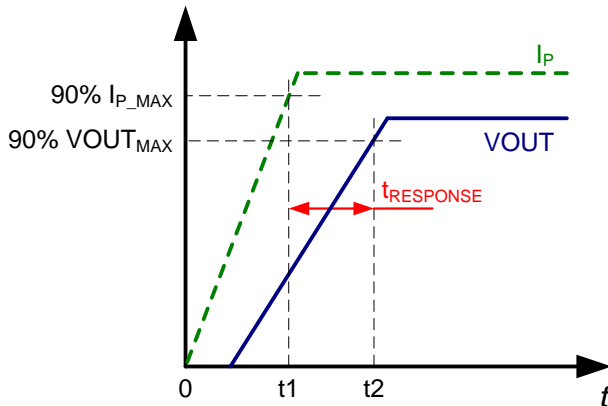


Figure 7: Response Time (t_{RESPONSE})

Both t_r and t_{RESPONSE} can be negatively affected by any eddy current losses created if a conductive ground plane is used. Cut away ground/power planes under the IC to reduce the effect of eddy currents on t_r and t_{RESPONSE} .

APPLICATION INFORMATION

Self-Heating Performance

Current flowing through the primary conductor can raise the conductor and sensor IC temperatures. Therefore, self-heating should be carefully verified to ensure the IC junction does not exceed its maximum temperature (see the absolute maximum rating table).

The device’s thermal behavior strongly depends on the thermal environment of the MCS components and its cooling capacity, especially the PCB copper area and thickness. The thermal response also depends on the profile of the current waveform, the amplitude and frequency for an AC current, and the peaks and duty cycle for a pulsed DC current.

Figure 3 shows the self-heating performance with DC current input. The test was conducted with the part mounted on the MCS180X demo board at 25°C T_A after 10 minutes of continuous current.

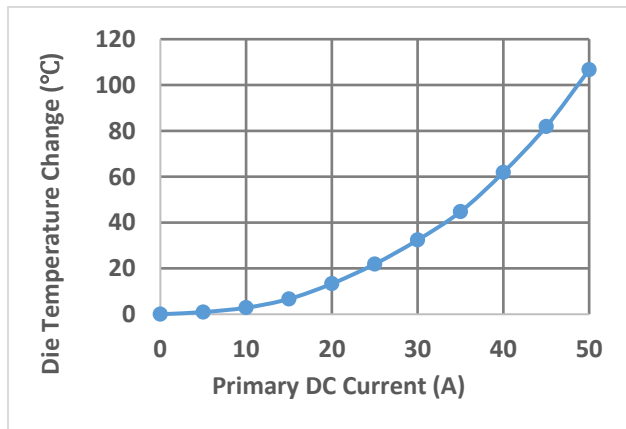


Figure 3: Self-Heating Performance with DC Current Input

Figure 4 shows the top and bottom layers of the MCS180X demo board. The board includes in total 2200mm², 4oz (139µm) copper connected to the primary conductor by the IP+ and IP- pins. The copper covers both the top and bottom side, with thermal vias connecting the two layers.

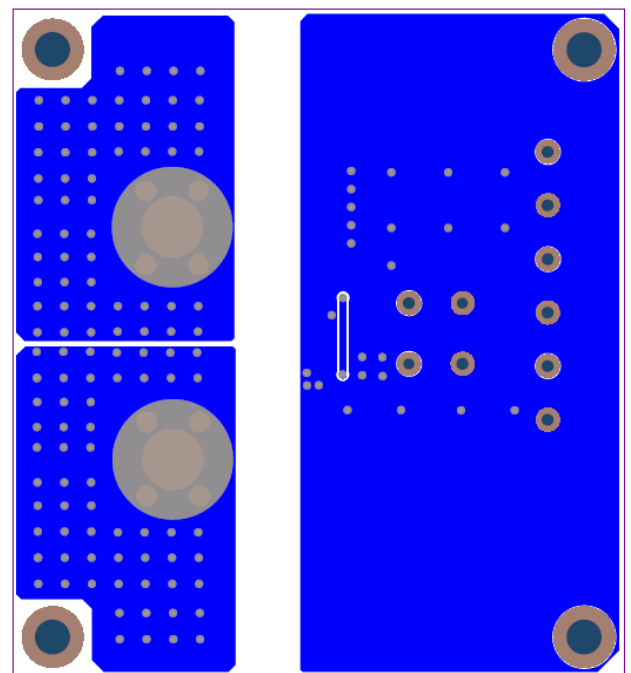
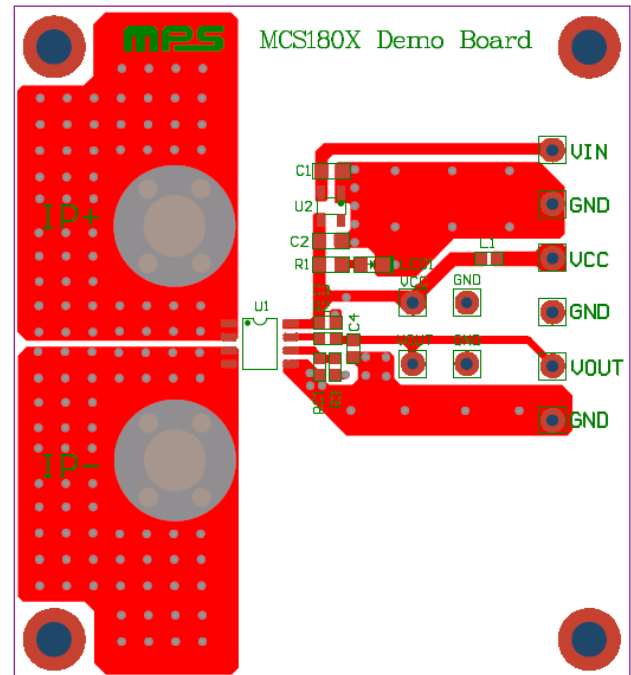


Figure 4: Top and Bottom Layers of MCS180X Demo Board

TYPICAL APPLICATION CIRCUITS

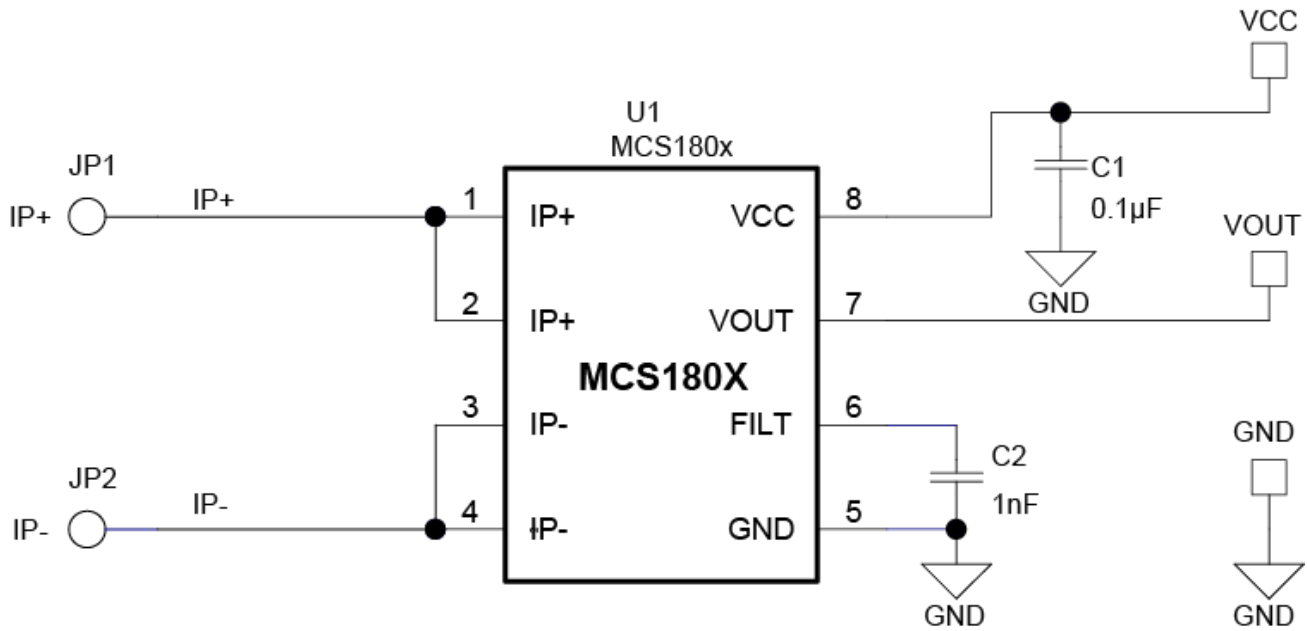
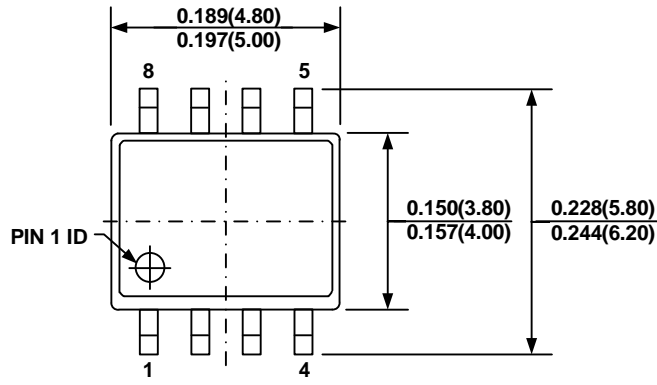


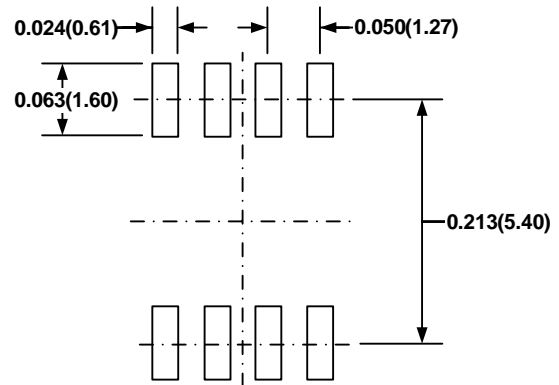
Figure 10: Application Circuit

PACKAGE INFORMATION

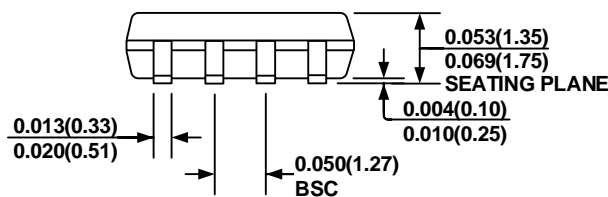
SOIC-8



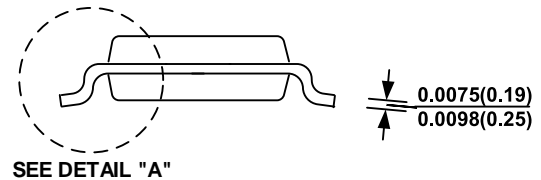
TOP VIEW



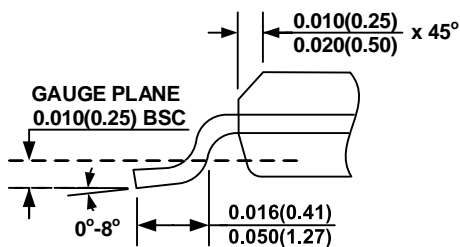
RECOMMENDED LAND PATTERN



FRONT VIEW



SIDE VIEW



DETAIL "A"

NOTE:

- 1) CONTROL DIMENSION IS IN INCHES. DIMENSION IN BRACKET IS IN MILLIMETERS.
- 2) PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS, OR GATE BURRS.
- 3) PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.
- 4) LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.004" INCHES MAX.
- 5) DRAWING CONFORMS TO JEDEC MS-012, VARIATION AA.
- 6) DRAWING IS NOT TO SCALE.

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