Ultra-Small Package, 3V to 5.5V Single Supply, Linear Hall-Effect Current Sensor with Over-Current Detection

DESCRIPTION

The MCS1826 is a linear Hall-effect current sensor IC for AC or DC current sensing. The Hall array is differential to cancel out homogeneous or gradient stray magnetic fields.

The primary conductor's low resistance (0.6mΩ) allows large currents to flow within close proximity to the integrated circuit that contains 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 that is proportional to the applied current. A spinning current technique is used for a low, stable offset.

The MCS1826 integrates fast over-current detection (OCD), which makes it simple to monitor the system for OC events.

The MCS1826's small footprint reduces board area and makes this device well-suited for space-constrained applications. The MCS1826 is available in an ultra-small TQFN-12 (3mmx3mm) package.

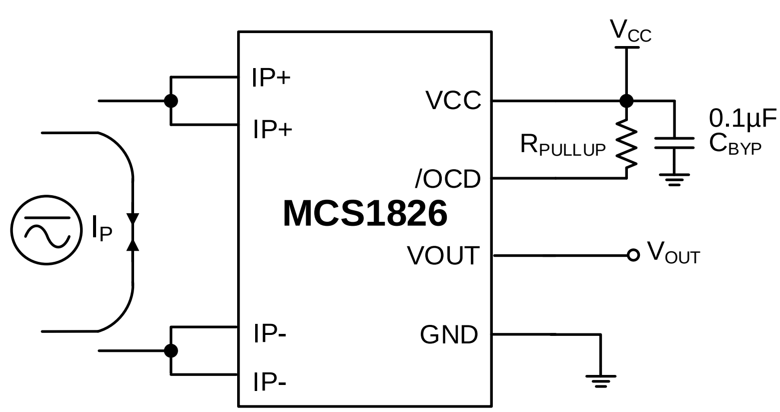
FEATURES

- 3V to 5.5V Single Supply Options
- Immune to All External Gradient Magnetic Fields by Differential Sensing
- 0.6mΩ Internal Conductor Resistance
- ±5A to ±50A Input Current Range
- 120kHz Bandwidth
- Fast OCD with 1.3µs Response Time
- Output Voltage (V_{OUT}) Proportional to AC or DC Currents
- Ratiometric V_{OUT} from VCC Supply
- Factory-Trimmed for Accuracy
- No Magnetic Hysteresis
- Available in a TQFN-12 (3mmx3mm) Package

APPLICATIONS

- Motor Controls
- Audio Driver Current Controls
- Load Detection and Management
- Switch-Mode Power Supplies
- Over-Current Fault Protection

TYPICAL APPLICATION



ORDERING INFORMATION

Part Number *, **	Rated Current Range (A)	Typ. Sensitivity (mV/A)	OCD Threshold (A)	Top Marking	MSL Rating
MCS1826GQTE-05	±5	80 x V_{CC}	±5	*BXPY*	*1*
MCS1826GQTE-10	±10	40 x V_{CC}	±10		
MCS1826GQTE-15	±15.5	27.3 x V_{CC}	±15.5		
MCS1826GQTE-20	±20	20 x V_{CC}	±20		
MCS1826GQTE-31	±31	13.6 x V_{CC}	±31		
MCS1826GQTE-40	±40	10 x V_{CC}	±40		
MCS1826GQTE-50	±50	8 x V_{CC}	±50		

* For Tape & Reel, add suffix -Z (e.g. MCS1826GQTE-15-Z).
** Contact an MPS FAE for additional variants.

PART NUMBERING (MCS1826GQTE-AA)

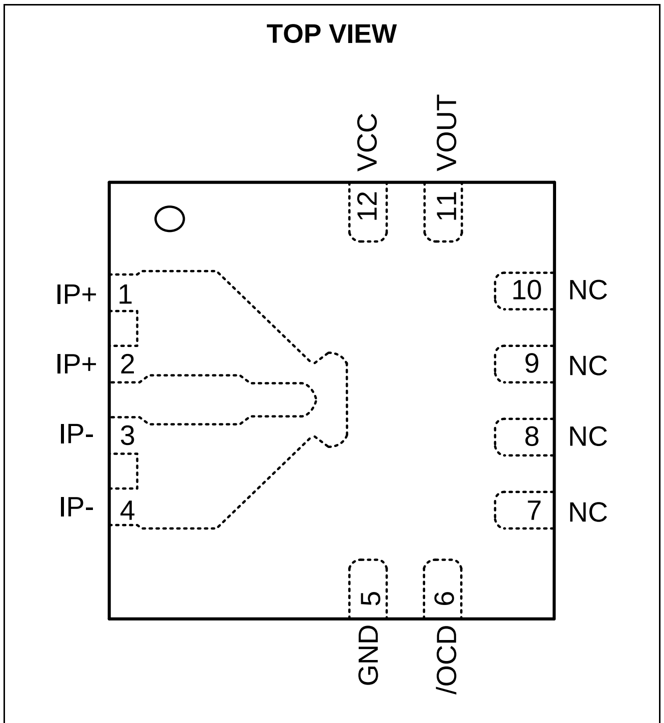
G	Operating Temperature (T_J): -40°C to +125°C
QTE	Package Code for TQFN-12
AA	Rated Primary Current

TOP MARKING

BXPY
LLLL

BXP: Product code of MCS1826GQTE
Y: Year code
LLLL: Lot number

PACKAGE REFERENCE



TQFN-12 (3mmx3mm)

PIN FUNCTIONS

Pin #	Name	Description
1, 2	IP+	**Primary current (+).** The IP+ pin is the positive terminal for the current being sampled. IP+ is fused internally.
3, 4	IP-	**Primary current (-).** The IP- pin is the negative terminal for the current being sampled. IP- is fused internally.
5	GND	**Ground.** The GND pin is the signal ground terminal.
6	/OCD	**Over-current detection.** The /OCD pin is an open drain, active low. Connect a 10kΩ to 500kΩ resistor from /OCD to VCC.
7, 8, 9, 10	NC	**No connection.**
11	VOUT	**Analog output signal.**
12	VCC	**Voltage supply.** Connect a 0.1µF to 1µF bypass capacitor from the VCC pin to GND.

ASOLUTE MAXIMUM RATINGS [1]

Supply voltage (V_{CC}) ....-0.3V to +6.5V
Output voltage (V_{OUT})...................-0.3V to +6.5V
$V_{/OCD}$...-0.3V to +6.5V
Junction temperature (T_J) ....165°C
Lead temperature ....260°C
Storage temperature .... -65°C to +165°C

ESD Ratings

Human body model (HBM) .... ±4kV
Charged-device model (CDM) .... ±2kV

Recommended Operating Conditions [2]

Supply voltage (V_{CC}) ....3V 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
Maximum isolation working voltage	V_{IOWM}	Maximum approved working voltage for basic isolation, according to IEC62368-1	100	V_{PK} or V_{DC}

MC1826GQTE COMMON ELECTRICAL CHARACTERISTICS

V_{CC} from 3V to 5.5V, T_J = -40°C to +125°C, typical values at T_J = 25°C, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Supply voltage	V_{CC}		3		5.5	V
V_{CC} under-voltage lockout (UVLO) threshold	V_{CC_UVLO}	V_{CC} rising	2	2.5	3	V
V_{CC} UVLO hysteresis	$V_{CC\_UVLO\_HYS}$			400	500	mV
Operating supply current	I_{CC}			8	12	mA
Output capacitance load (5)	C_L	From VOUT to GND			4.7	nF
Output resistive load (5)	R_L	From VOUT to GND	4.7			kΩ
Primary conductor resistance	R_P	Effective		0.6		mΩ
Frequency bandwidth	f_{BW}			120		kHz
Power-on time	t_{PO}	$I_P = I_{PMAX}$		60		µs
Rising time	t_R	$I_P = I_{PMAX}$		3		µs
Propagation delay	t_{PD}	$I_P = I_{PMAX}$		2		µs
Response time	$t_{RESPONSE}$	$I_P = I_{PMAX}$		4		µs
Noise density	I_{ND}	Input referred noise density		150		µA(rms) / √Hz
Noise	I_N	Input referred noise, 120kHz BW		52		$mA_{(rms)}$
Nonlinearity	E_{LIN}	Across the full I_P range		0.5		%
Ratiometry (5)	K_{SENS}	$V_{CC} = V_{CC\_MIN}$ to V_{CC_MAX}	95	100	105	%
	K_{VO}	$V_{CC} = V_{CC\_MIN}$ to V_{CC_MAX}, I_P = 0A	99	100	101	%
Zero-current output voltage	$V_{OUT(Q)}$	I_P = 0A		V_{CC} / 2		V
First Hall magnetic coupling factor	P_{MCF1}			1.15		mT/A
Second Hall magnetic coupling factor	P_{MCF2}			0.25		mT/A
Hall plate matching	M_H			±1		%
Saturation voltage (3) (5)	$V_{OUT(H)}$	R_L = 4.7kΩ, T_J = 25°C	0.1 x V_{CC}			V
	$V_{OUT(L)}$	R_L = 4.7kΩ, T_J = 25°C			0.9 x V_{CC}	V
/OCD low voltage (5)	$V_{/OCD\_L}$	/OCD triggered, R_{PULLUP} = 10kΩ			0.3	V
/OCD external pull-up resistance (5)	R_{PULLUP}	Connect from /OCD to VCC	10		500	kΩ
/OCD current hysteresis	$I_{/OCD\_HYST}$	Percentage of $I_{/OCD}$	3	12		%
/OCD error	$E_{/OCD}$		-15		+15	%
/OCD response time (5)	$t_{RESPONSE\_/OCD}$	Time from $I_P > I_{/OCD}$ to $V_{/OCD}$ below $V_{/OCD\_L}$		1.3	2	µs

MCS1826GQTE-05 PERFORMANCE CHARACTERISTICS

V_{CC} from 3V to 5.5V, T_J = -40°C to +125°C, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Rated current range (4)	I_P		-5		+5	A
Sensitivity	SENS	-5A ≤ I_P ≤ +5A, T_J = 25°C		80 x V_{CC}		mV/A
Sensitivity error	E_{SENS}	I_P = 5A, T_J = -40°C to +125°C		±4		%
Offset voltage	V_{OE}	I_P = 0A, T_J = -40°C to +125°C		±30		mV
Total output error	E_{TOT}	I_P = 5A, T_J = -40°C to +125°C		±5		%

MCS1826GQTE-10 PERFORMANCE CHARACTERISTICS

V_{CC} from 3V to 5.5V, T_J = -40°C to +125°C, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Rated current range (4)	I_P		-10		+10	A
Sensitivity	SENS	-10A ≤ I_P ≤ +10A, T_J = 25°C		40 x V_{CC}		mV/A
Sensitivity error	E_{SENS}	I_P = 10A, T_J = -40°C to +125°C		±4		%
Offset voltage	V_{OE}	I_P = 0A, T_J = -40°C to +125°C		±30		mV
Total output error	E_{TOT}	I_P = 10A, T_J = -40°C to +125°C		±5		%

MCS1826GQTE-15 PERFORMANCE CHARACTERISTICS

V_{CC} from 3V to 5.5V, T_J = -40°C to +125°C, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Rated current range (4)	I_P		-15.5		+15.5	A
Sensitivity	SENS	-15.5A ≤ I_P ≤ +15.5A, T_J = 25°C		27.3 x V_{CC}		mV/A
Sensitivity error	E_{SENS}	I_P = 15.5A, T_J = -40°C to +125°C		±4		%
Offset voltage	V_{OE}	I_P = 0A, T_J = -40°C to +125°C		±30		mV
Total output error	E_{TOT}	I_P = 15.5A, T_J = -40°C to +125°C		±5		%

MCS1826GQTE-20 PERFORMANCE CHARACTERISTICS

V_{CC} from 3V to 5.5V, T_J = -40°C to +125°C, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Rated current range (4)	I_P		-20		+20	A
Sensitivity	SENS	-20A ≤ I_P ≤ +20A, T_J = 25°C		20 x V_{CC}		mV/A
Sensitivity error	E_{SENS}	I_P = 20A, T_J = -40°C to +125°C		±4		%
Offset voltage	V_{OE}	I_P = 0A, T_J = -40°C to +125°C		±30		mV
Total output error	E_{TOT}	I_P = 20A, T_J = -40°C to +125°C		±5		%

MCS1826GQTE-31 PERFORMANCE CHARACTERISTICS

V_{CC} from 3V to 5.5V, T_J = -40°C to +125°C, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Rated current range (4)	I_P		-31		+31	A
Sensitivity	SENS	-31A ≤ I_P ≤ +31A, T_J = 25°C		13.6 x V_{CC}		mV/A
Sensitivity error	E_{SENS}	I_P = 31A, T_J = -40°C to +125°C		±4		%
Offset voltage	V_{OE}	I_P = 0A, T_J = -40°C to +125°C		±30		mV
Total output error	E_{TOT}	I_P = 31A, T_J = -40°C to +125°C		±5		%

MCS1826GQTE-40 PERFORMANCE CHARACTERISTICS

V_{CC} from 3V to 5.5V, T_J = -40°C to +125°C, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Rated current range (4)	I_P		-40		+40	A
Sensitivity	SENS	-40A ≤ I_P ≤ +40A, T_J = 25°C		10 x V_{CC}		mV/A
Sensitivity error	E_{SENS}	I_P = 40A, T_J = -40°C to +125°C		±4		%
Offset voltage	V_{OE}	I_P = 0A, T_J = -40°C to +125°C		±30		mV
Total output error	E_{TOT}	I_P = 40A, T_J = -40°C to +125°C		±5		%

MCS1826GQTE-50 PERFORMANCE CHARACTERISTICS

V_{CC} = 3.3V, T_J = -40°C to +125°C, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Rated current range (4)	I_P		-50		+50	A
Sensitivity	SENS	-50A ≤ I_P ≤ +50A, T_J = 25°C		8 x V_{CC}		mV/A
Sensitivity error	E_{SENS}	I_P = 50A, T_J = -40°C to +125°C		±4		%
Offset voltage	V_{OE}	I_P = 0A, T_J = -40°C to +125°C		±30		mV
Total output error	E_{TOT}	I_P = 50A, T_J = -40°C to +125°C		±5		%

Notes:

3) In addition to the maximum specified current range (I_{PMAX}), the current sensor continues to provide an analog output voltage proportional to the primary current until it reaches the high or low saturation voltage. However, the nonlinearity increases beyond the specified range (I_P).
4) The MCS1826 can operate at higher primary current (I_P) and ambient temperature (T_A) values as long as the maximum junction temperature (T_J (MAX)) is not exceeded.
5) Guaranteed by design and characterization.

FUNCTIONAL BLOCK DIAGRAM

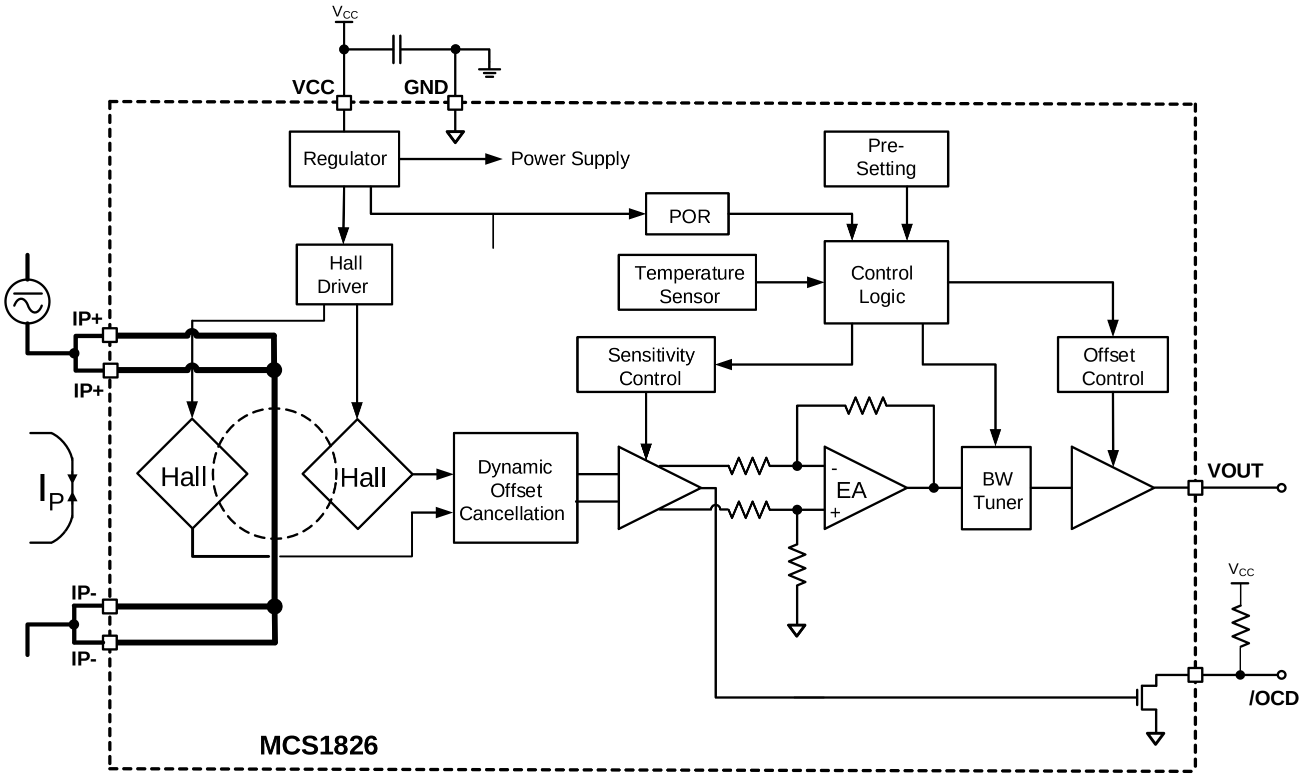


Figure 1: Functional Block Diagram

DEFINITIONS

Current Rating

I_{PMAX} is the rated current. The sensor's output is linear, as a function of the primary current (I_P), and the output current (I_{OUT}) follows the specified performance(s) when I_P is between its minimum (I_{PMIN}) and I_{PMAX}.

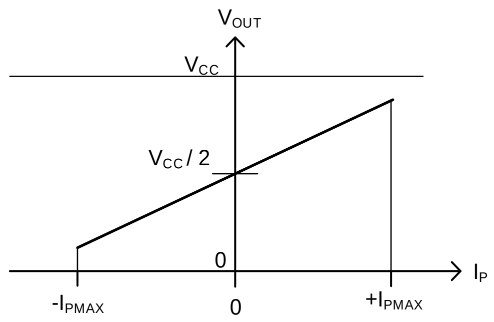


Figure 2: Sensor Output Function

Sensitivity (SENS)

The sensitivity (SENS, in mV/A) indicates how much the output voltage (V_{OUT}) changes when I_P 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})

Figure 3 shows a cross-section of the sensor. The first and second Hall magnetic coupling factors are defined as the amount of vertical magnetic field (denoted as the 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 primary conductor's asymmetrical shape, the magnetic field generated in the two sensing points are different (see Figure 3).

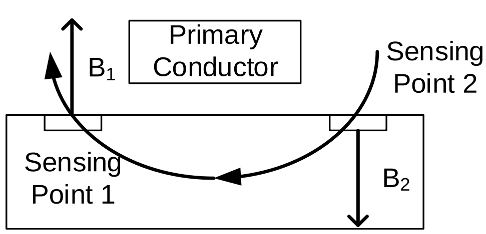


Figure 3: Cross-Section of the Sensor

Noise (I_N)

The noise (I_N) is a random deviation that cannot be removed by calibrating the device. The input's referred noise is the root mean square (rms) of the sensor's output noise (in mV), divided by SENS (in mV/A). I_N represents the smallest current that the device can resolve without any external signal treatment.

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

$V_{OUT(Q)}$ is the output voltage when I_P is zero. The typical value is V_{CC} / 2.

Offset Voltage (V_{OE})

The offset voltage (V_{OE}) is the difference between the zero current output's typical value and $V_{OUT(Q)}$. The variation is due to thermal drift, as well as the factory's resolution limits related to voltage offset trimming. To convert this voltage into amperes, divide V_{OE} by SENS.

Nonlinearity (E_{LIN})

I_P and the sensor's V_{OUT} should have a linear relationship, indicated by a straight line. A line that is not straight indicates nonlinearity, which is a deviation.

Nonlinearity (in %) can be estimated with Equation (1) :

$$E_{LIN} = \frac{Max(V_{OUT}(I_P) - V_{LIN}(I_P))}{V_{OUT}(I_{PMAX}) - V_{OUT}(-I_{PMAX})} \times 100 \quad (1)$$

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 positive or negative.

Total Output Error (E_{TOT})

The total output error (E_{TOT}, in %) is the relative difference between the sensor's output and the ideal output at a given I_P. E_{TOT} can be estimated with Equation (2):

$$E_{TOT}(I_P) = \frac{V_{OUT}(I_P) - V_{OUT\_IDEAL}(I_P)}{SENS_{\_TYP} \times I_P} \times 100 \quad (2)$$

Where V_{OUT_IDEAL} can be calculated with Equation (3):

$$V_{OUT\_IDEAL}(I_P) = \frac{V_{CC}}{2} + SENS \times I_P \quad (3)$$

E_{TOT} incorporates all error sources, and is a function of I_P. At currents close to I_{PMAX}, E_{TOT} is affected mainly by the sensitivity error. At currents close to 0A, E_{TOT} is mostly caused by the offset voltage (V_{OE}). Note that when I_P = 0A, E_{TOT} diverges to infinity due to the constant offset.

Ratiometry Coefficients

For ratiometric options, the sensor's output is ratiometric. This means that the sensitivity and the zero-current output scale with the supply voltage (V_{CC}). The ratiometry coefficients (K_{SENS} and K_{VO}) measure whether the sensitivity and zero-current output are proportional.

K_{SENS} can be estimated with Equation (4):

$$K_{SENS} = \frac{SENS(V_{CC}) / SENS(V_{CC\_TYP})}{V_{CC} / V_{CC\_TYP}} \quad (4)$$

K_{VO} can be calculated with Equation (5):

$$K_{VO} = \frac{V_{OUT}(I_P = 0, V_{CC}) / V_{OUT}(I_P = 0, V_{CC\_TYP})}{V_{CC} / V_{CC\_TYP}} \quad (5)$$

Where V_{CC_TYP} = 3.3V.

Ideally, both K_{SENS} and K_{VO} are equal to 1.

Power-On Time (t_{PO})

The power-on time (t_{PO}) is the time interval from when power is first applied to the device until the output can correctly indicate the applied I_P. t_{PO} is defined as the time between the following moments:

1. t1: The supply reaches the minimum operating voltage (V_{CC_UVLO}).
2. t2: V_{OUT} settles to 90% of its final value under an applied I_P (see Figure 4).

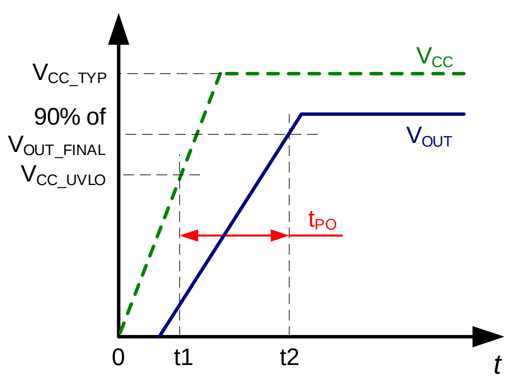


Figure 4: Power-On Time (t_{PO})

Propagation Delay (t_{PD})

The propagation delay (t_{PD}) represents the internal latency between an event that has been measured and the sensor's response. t_{PD} is defined as the time between the following moments:

1. t1: I_P reaches 20% of its final value.
2. t2: V_{OUT} reaches 20% of its final value, as it corresponds to the applied I_P (see Figure 5).

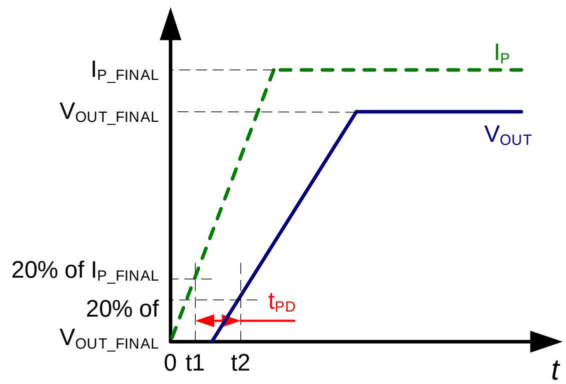


Figure 5: Propagation Delay (t_{PD})

Rising Time (t_R)

The rising time (t_R) is defined as the time between the following moments:

1. t1: The sensor's V_{OUT} reaches 10% of its full-scale value.
2. t2: The sensor's V_{OUT} reaches 90% of its full-scale value (see Figure 6).

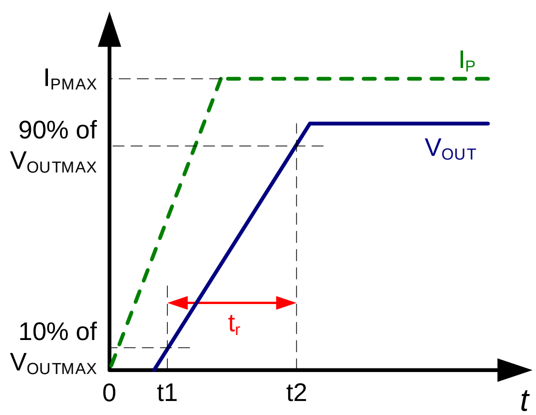


Figure 6: Rising Time (t_R)

The sensor bandwidth (f_{BW}) is defined as the 3dB cutoff frequency. Using the rising time, f_{BW} can be estimated with Equation (6):

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

Response Time ($t_{RESPONSE}$)

The response time ($t_{RESPONSE}$) is defined as the time between the following moments:

1. <u>t1</u>: I_P reaches 90% of its final value.
2. <u>t2</u>: V_{OUT} reaches 90% of its final value, as it corresponds to the applied I_P (see Figure 7).

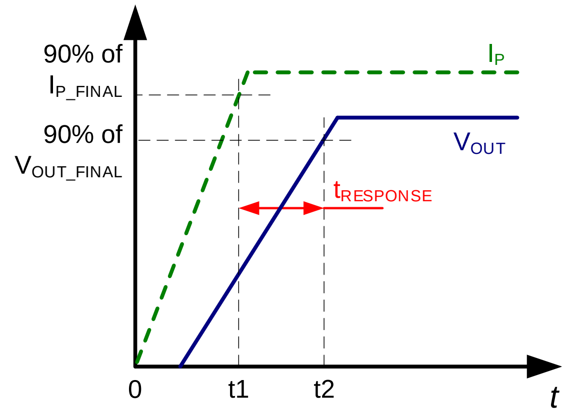


Figure 7: Response Time ($t_{RESPONSE}$)

APPLICATION INFORMATION

Over-Current Detection (OCD)

The MCS1826 integrates fast over-current detection (OCD) using the /OCD pin. If I_P exceeds the current limit ($I_{/OCD}$), a high-speed detection circuit triggers an OCD event within the OCD response time ($t_{RESPONSE\_/OCD}$). $I_{/OCD}$ is 100% of the rated $\pm I_{PMAX}$. If an OCD event is triggered, the MCS1826 implements non-latch /OCD pin output modes.

Figure 8 shows the OCD timing. If I_P reaches the $I_{/OCD}$ and stays at this value for longer than $t_{RESPONSE\_/OCD}$, the /OCD pin's voltage ($V_{/OCD}$) pulls down to $V_{/OCD\_L}$. When I_P goes below $I_{/OCD}$-$I_{/OCD\_HYST}$ over another $t_{RESPONSE\_/OCD}$, $V_{/OCD}$ starts to rise. $t_{/OCD\_RISE}$ is the $V_{/OCD}$ rising time from logic low to logic high, and it is dependent on the pull-up resistor (R_{PULLUP}) value and the capacitance from the /OCD pin to GND. A small resistor-capacitor (RC) results in a faster rise time.

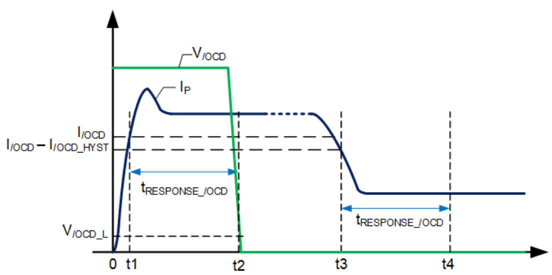


Figure 8: /OCD Timing

Self-Heating Performance

Current flowing through the primary conductor can raise the conductor and the sensor IC temperature. Therefore, self-heating should be carefully verified to ensure that the MCS1826's junction temperature (T_J) does not exceed the maximum value (165°C).

The thermal behavior strongly depends on the thermal environment of the MCS1826's components and its cooling capacity, such as the PCB copper area and thickness. The thermal response also depends on the profile of the current waveform (e.g. the amplitude and frequency for an AC current), as well as the peaks and duty cycle for a pulsed DC current.

Figure 9 shows the self-heating performance with the DC current input. The data is collected with the part mounted on the MCS1826's evaluation board after 10 minutes of continuous current at T_A = 25°C.

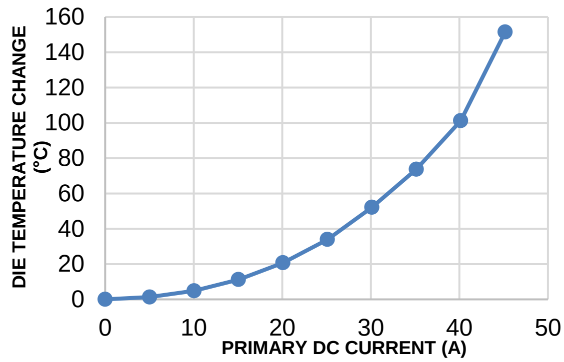
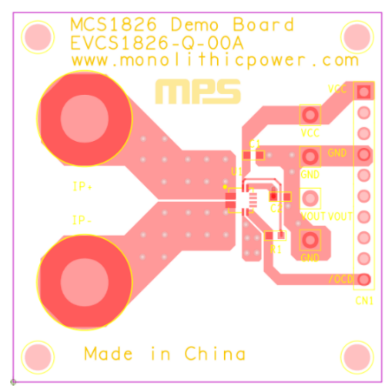
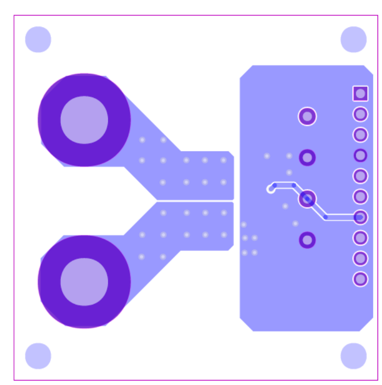


Figure 9: Self-Heating Performance with DC Current Input

Figure 10 shows the top and bottom layers of the MCS1826's evaluation board. The board includes in total 570mm^2, 2.5oz (87µm) copper connected to the primary conductor by the IP+ and IP- pins. The copper covers both the top and bottom sides with thermal vias connecting the two layers.



Top Layer



Bottom Layer

Figure 10: MCS1826 Evaluation Board

TYPICAL APPLICATION CIRCUIT

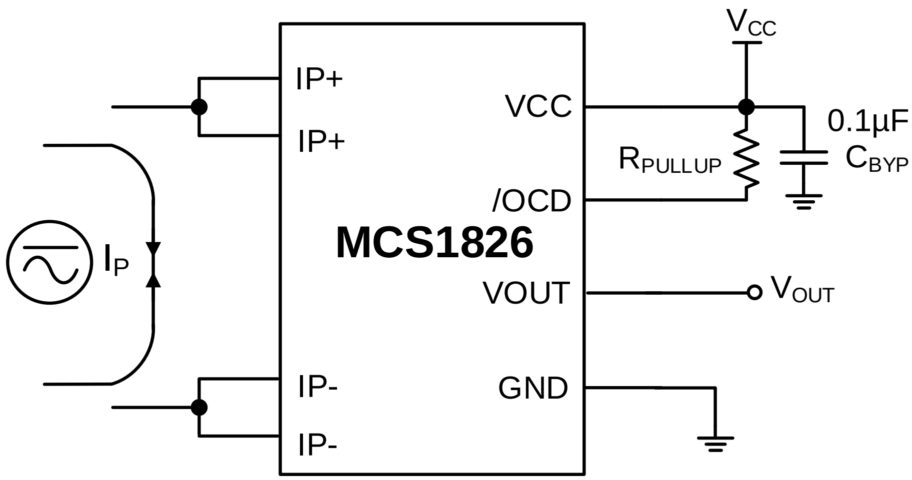
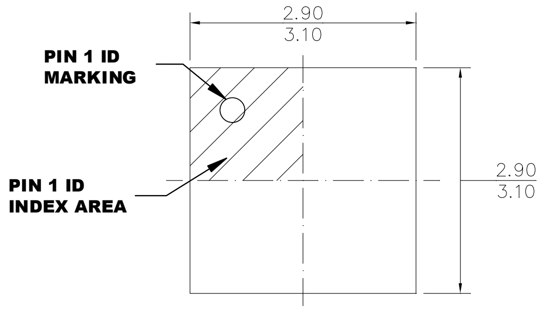


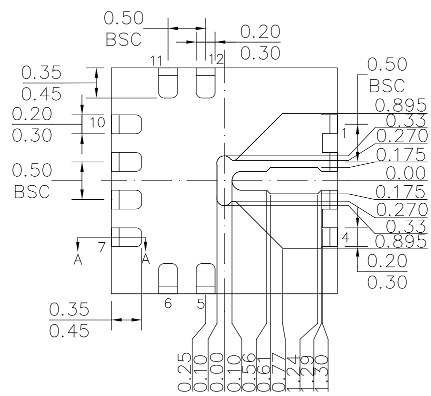
Figure 11: Typical Application Circuit

PACKAGE INFORMATION

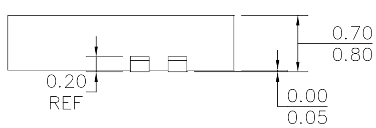
TQFN-12 (3mmx3mm)



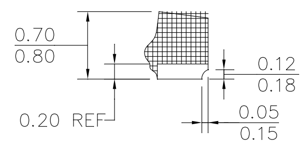
TOP VIEW



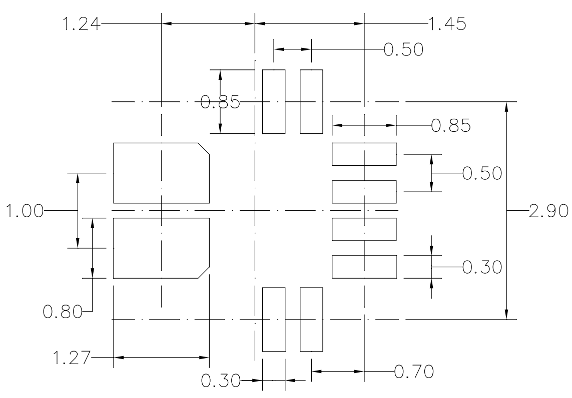
BOTTOM VIEW



SIDE VIEW



SECTION A-A

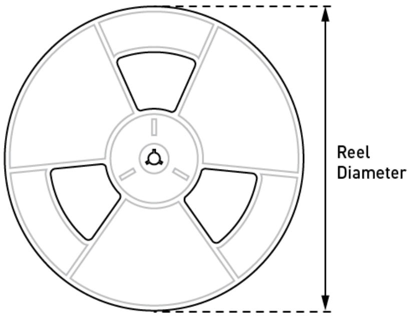


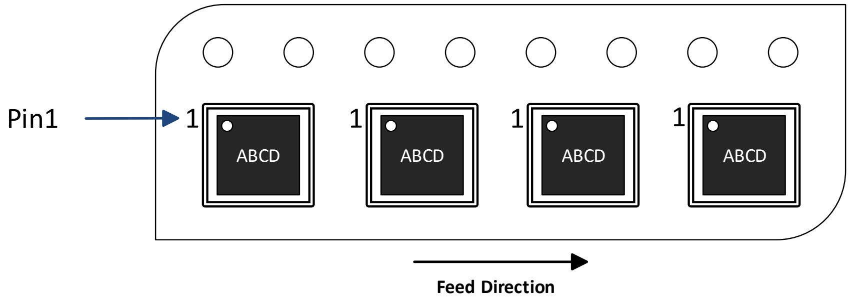
RECOMMENDED LAND PATTERN

NOTE:

1)THE LEAD SIDE IS WETTABLE.
2) ALL DIMENSIONS ARE IN MILLIMETERS.
3) LEAD COPLANARITY SHALL BE 0.08 MILLIMETERS MAX.
4) JEDEC REFERENCE IS MO-220.
5) DRAWING IS NOT TO SCALE.

CARRIER INFORMATION





Part Number	Package Description	Quantity/ Reel	Quantity/ Tube	Quantity/ Tray	Reel Diameter	Carrier Tape Width	Carrier Tape Pitch
MCS1826GQTE-05-Z	TQFN-12 (3mmx3mm)	5000	N/A	N/A	13in	12mm	8mm
MCS1826GQTE-10-Z	TQFN-12 (3mmx3mm)	5000	N/A	N/A	13in	12mm	8mm
MCS1826GQTE-15-Z	TQFN-12 (3mmx3mm)	5000	N/A	N/A	13in	12mm	8mm
MCS1826GQTE-20-Z	TQFN-12 (3mmx3mm)	5000	N/A	N/A	13in	12mm	8mm
MCS1826GQTE-31-Z	TQFN-12 (3mmx3mm)	5000	N/A	N/A	13in	12mm	8mm
MCS1826GQTE-40-Z	TQFN-12 (3mmx3mm)	5000	N/A	N/A	13in	12mm	8mm
MCS1826GQTE-50-Z	TQFN-12 (3mmx3mm)	5000	N/A	N/A	13in	12mm	8mm

REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	7/28/2023	Initial Release	-