75 V Common-Mode Voltage, High-Side Current-Sense Amplifier with Comparator and Reference

Features

- Common-mode voltage: -0.1 V to 75 V
- Supply voltage: 3 V to 40 V
- High accuracy
- Options for gain/bandwidth:
  - DIO2210: 20 V/V, 440 kHz
  - DIO2211: 50 V/V, 110 kHz
  - DIO2212: 100 V/V, 65 kHz
- Operating temperature: -40°C to 125°C
- Slew rate: 3 V/μs
- Latching capability
- Open-drain output
- Internal voltage reference: 0.6 V
- Quiescent current: 470 μA (typ)

Applications

- Brake systems
- Electric power steering systems
- Electronic stability control systems
- Laptops
- Battery chargers

Package Information

Part Number	Package	Body Size
DIO221X	SOIC-8	4.9 mm × 3.9 mm
	MSOP-8	3.0 mm × 3.0mm

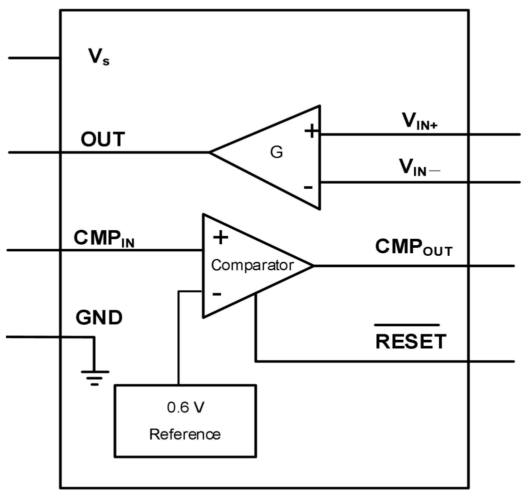
Description

The DIO221X series is a high-side current-sense amplifier with voltage output and can sense drops across shunts at common-mode voltage from -0.1 V to 75 V. The choices of gain are 20 V/V, 50 V/V, and 100 V/V, with the according bandwidths of 440 kHz, 110 kHz, and 65 kHz.

The DIO221X series is integrated with an open-drain comparator and internal reference at 0.6 V voltage. By pulling or grounding the pin, the comparator can be made transparent or latched as needed.

The DIO221X series operates from single 3 V to 40 V supply under -40°C to 125°C, with a maximum supply current of 620 μA.

Simplified Schematic



Ordering Information

Ordering Part No.	Top Marking	MSL	RoHS	T_A	Package	
DIO2210MP8	DIOBB1V	3	Green	-40 to 125°C	MSOP-8	Tape & Reel, 3000
DIO2210CS8	DIOBB1V	3	Green	-40 to 125°C	SOIC-8	Tape & Reel, 2500
DIO2211MP8	DIOBB1A	3	Green	-40 to 125°C	MSOP-8	Tape & Reel, 3000
DIO2211CS8	DIOBB1A	3	Green	-40 to 125°C	SOIC-8	Tape & Reel, 2500
DIO2212MP8	DIOBB1B	3	Green	-40 to 125°C	MSOP-8	Tape & Reel, 3000
DIO2212CS8	DIOBB1B	3	Green	-40 to 125°C	SOIC-8	Tape & Reel, 2500

If you encounter any issue in the process of using the device, please contact our customer service at marketing@dioo.com or phone us at (+86)-21-62116882. If you have any improvement suggestions regarding the datasheet, we encourage you to contact our technical writing team at docs@dioo.com. Your feedback is invaluable for us to provide a better user experience.

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1. Pin Assignment and Functions

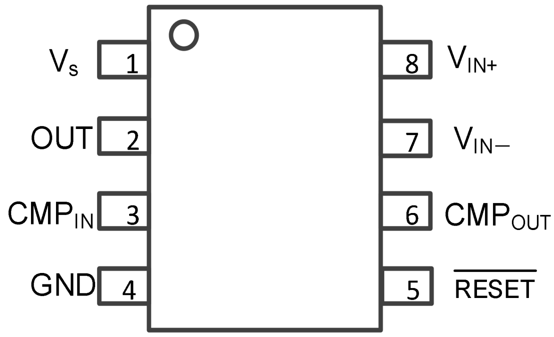


Figure 1. MSOP-8/SOIC-8 (Top view)

Pin No.	Name	I/O	Description
1	V_S		Power supply
2	OUT	Output	Output voltage of the amplifier
3	CMP_{IN}	Input	Non-inverting input of the comparator
4	GND		Ground
5	$\overline{RESET}$	Input	Comparator reset pin. Pull the pin low to activate it.
6	CMP_{OUT}	Output	Open-drain output of the comparator
7	V_{IN-}	Input	Negative input. Connect to shunt low side
8	V_{IN+}	Input	Positive input. Connect to shunt high side

2. Absolute Maximum Ratings

Exceeding the maximum ratings listed under Absolute Maximum Ratings when designing is likely to damage the device permanently. Do not design to the maximum limits because long-time exposure to them might impact the device's reliability. The ratings are obtained over an operating free-air temperature range unless otherwise specified.

Symbol	Parameter		Rating	Unit
V_S	Supply voltage		3 to 44	V
V_{IN+}, V_{IN-}	Current-shunt monitor analog inputs	Differential (V_{IN+} ~ V_{IN-})	-18 to 18	V
		Common mode (1)	GND - 0.3 to 80	V
CMPIN and $\overline{RESET}$	Comparator analog input and reset pins (1)		GND - 0.3 to (V_S) + 0.3	V
Out	Analog output (1)		GND - 0.3 to (V_S) + 0.3	V
CMP_{OUT}	Comparator output (1)		GND - 0.3 to 40	V
	Input current into any pin (1)		5	mA
T_A	Ambient temperature		-40 to 125	°C
T_J	Junction temperature		150	°C
T_{STG}	Storage temperature		-65 to 150	°C

Note:

(1) This voltage may exceed the ratings shown if the current at that pin is limited to 5 mA.

3. Recommended Operating Conditions

Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. The ratings are obtained over an operating free-air temperature range unless otherwise specified.

Symbol	Parameter	Rating	Unit
V_{CM}	Common-mode input voltage	-0.1 to 75	V
V_S	Supply voltage	3 to 40	V
T_A	Ambient temperature	-40 to 125	°C

4. ESD Ratings

When a statically-charged person or object touches an electrostatic discharge sensitive device, the electrostatic charge might be drained through sensitive circuitry in the device. If the electrostatic discharge possesses sufficient energy, damage might occur to the device due to localized overheating.

Model	Standard	Value	Unit
Human-body model	ANSI/ESDA/JEDEC JS-001	±2000	V

5. Thermal Considerations

The thermal resistance determines the heat insulation property of a material. The higher the thermal resistance is, the lower the heat loss. Accumulation of heat energy degrades the performance of semiconductor components.

Symbol	Parameter	Value		Unit
		SOIC-8	MSOP-8	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	130	162	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	50	38	°C/W

7. Electrical Characteristics

7.1. Current-shunt monitor

The values are obtained under these conditions unless otherwise specified: The values are obtained under these conditions unless otherwise specified: T_A = 25°C, V_S = 12 V, V_{CM} = 12 V, V_{SENSE} = 100 mV, R_L = 10 kΩ to GND, and $R_{PULL\text{-}UP}$ = 5.1 kΩ connected from CMP_{OUT} to V_S, and CMP_{IN} = GND.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Input						
V_{SENSE}	Sense input voltage in full-scale	V_{SENSE} = V_{IN+} – V_{IN-}		0.15	(V_S-0.25) /G	V
V_{CM}	Common-mode input range	T_A = -40°C to 125°C	-0.1		75	V
CMR	Common-mode rejection	V_{IN+} = 0 to 80 V	80	100		dB
V_{OS}	Offset voltage, RTI	T_A = 25°C		±20	±50	µV
		T_A = -40°C to 125°C			±100	µV
dV_{OS}/dT	Offset voltage, RTI, versus temperature	T_A = -40°C to 125°C		0.3		µV/°C
PSR	Offset voltage, RTI, versus power supply	V_{OUT} = 2 V, V_{IN+} = 18 V, 2.7 V, T_A = -40°C to 125°C		±20		µV/V
I_B	Input bias current, V_{IN-} pin	T_A = -40°C to 125°C		±220		µA
Output (V_{SENSE} ≥ 20 mV)						
G	Gain	DIO2210		20		V/V
		DIO2211		50		V/V
		DIO2212		100		V/V
	Total output error (1)	V_{SENSE} = 120 mV, V_S = 16 V, T_A = -40°C to 125°C		±0.3	±1	%
C_{LOAD}	Maximum capacitive load	No sustained oscillation		0.5		nF
Voltage output						
	Output swing to the positive rail(3)	V_{IN-} = 11 V, V_{IN+} = 12 V, T_A = –40°C to 125°C		V_S - 0.12	V_S - 0.25	V
	Output swing to GND (2)	V_{IN-} = 0 V, V_{IN+} = -0.5 V, T_A = –40°C to 125°C		6	50	mV
Frequency response						
BW	Bandwidth	C_{LOAD} = 5 pF, DIO2210		440		kHz
		C_{LOAD} = 5 pF, DIO2211		110		kHz
		C_{LOAD} = 5 pF, DIO2212		65		kHz
	Phase margin (2)	C_{LOAD} = 500 pF		40		Degree

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
						s
SR	Slew rate			3		V/μs
	Settling time (1%)	V_{SENSE} = 10 mV_{PP} to 100 mV_{PP}, C_{LOAD} = 5 pF		35		μs
Noise, RTI						
	Voltage noise density (2)			70		$nV/\sqrt{Hz}$

Note:

(1) Total output error includes effects of gain error, V_{OS} and non-linearity error.

(2) Guaranteed by design.

(3) Specifications subject to change without notice.

7.2. Comparator

The values are obtained under these conditions unless otherwise specified: T_A = 25°C, V_S = 12 V, V_{CM} = 12 V, V_{SENSE} = 100 mV, R_L = 10 kΩ to GND, and $R_{PULL\text{-}UP}$ = 5.1 kΩ connected from CMP_{OUT} to V_S.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Offset voltage						
	Threshold	T_A = 25°C	590	600	620	mV
		T_A = -40°C to 125°C	586		625	mV
	Hysteresis (1)	T_A = -40°C to 85°C		-8		mV
Input bias current						
	CMP_{IN} pin			1		nA
Input voltage range						
	CMP_{IN} pin	T_A = -40°C to 125°C		0 to (V_S - 1.5)		V
Output (open-drain)						
	Large-signal differential voltage gain (2)	CMP_{OUT} = 1 V to 4 V, R_L ≥ 15 kΩ connected to 5 V		200		V/mV
I_{LKG}	High-level leakage current (3) (4)	V_{ID} = 0.4 V, V_{OH} = V_S		1		nA
V_{OL}	Low-level output voltage (3)	V_{ID} = -0.6 V, I_{OL} = 2.35 mA		145	320	mV
Response time						
t_{RES}	Positive response time	$R_{PULL\text{-}UP}$ = 5.1 kΩ to 12 V, C_L = 15 pF, CMP_{IN} = 100 mV ~ 605 mV		3.5		μs
	Negative response time	$R_{PULL\text{-}UP}$ = 5.1 kΩ to 12 V, C_L = 15 pF, CMP_{IN} = 605 mV ~ 505 mV		1.5		μs

$\overline{\text{RESET}}$						
	$\overline{\text{RESET}}$ threshold [5]			1.1		V
	Logic input impedance			2		MΩ
	Minimum $\overline{\text{RESET}}$ pulse duration			0.5		μs
	$\overline{\text{RESET}}$ propagation delay			0.51		μs

Note:

(1) Hysteresis refers to the threshold (the threshold specification applies to a rising edge of a noninverting input) of a falling edge on the noninverting input of the comparator; see Figure 6.

(2) Guaranteed by design.

(3) V_{ID} refers to the differential voltage at the comparator inputs.

(4) Pulling the open-drain output to the range of 3 V to 40 V is permissible, regardless of V_S.

(5) The $\overline{\text{RESET}}$ input has an internal 2 MΩ (typical) pulldown. Leaving $\overline{\text{RESET}}$ open results in a low state, with transparent comparator operation.

(6) Specifications subject to change without notice.

7.3. General

The values are obtained under these conditions unless otherwise noted: T_A = 25°C, V_S = 12 V, V_{CM} = 12 V, V_{SENSE} = 100 mV, R_L = 10 kΩ to GND, $R_{PULL-UP}$ = 5.1 kΩ connected from CMP_{OUT} to V_S, and CMP_{IN} = 1 V.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Power supply						
I_Q	Quiescent current	V_{OUT} = 2 V, no load		470	620	μA
	Comparator power-on reset threshold			1.85		V

Note:

(1) Specifications subject to change without notice.

8. Typical Characteristics

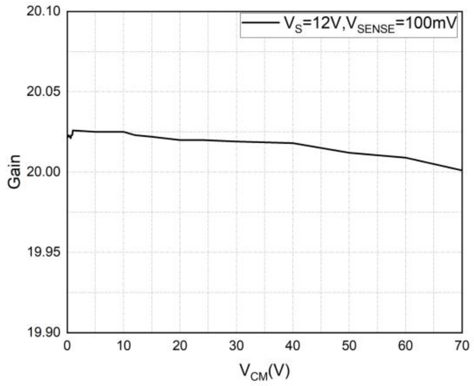


Figure 2. Gain vs. V_{CM}

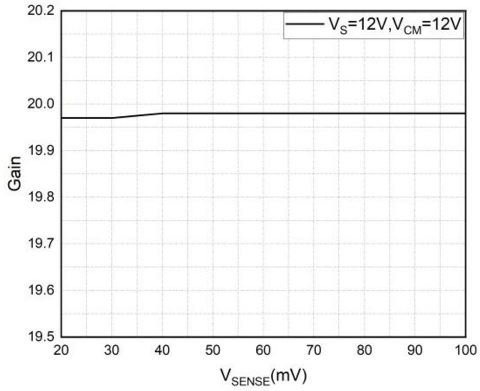


Figure 3. Gain vs. V_{SENSE}

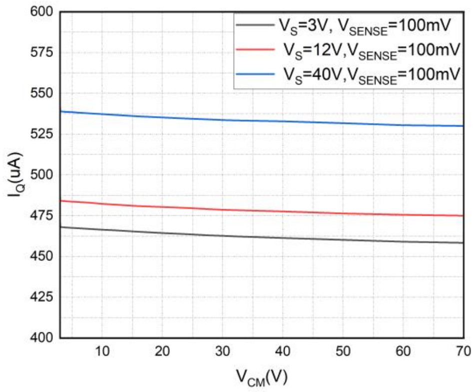


Figure 4. I_Q vs. V_{CM}

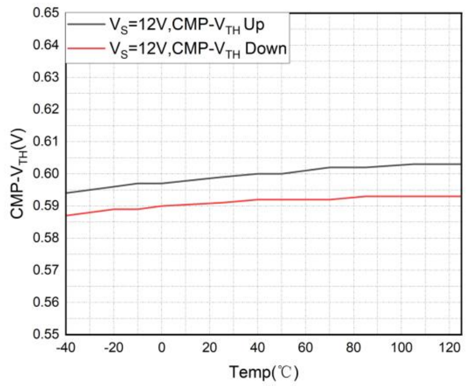


Figure 5. CMP-V_{TH} vs. Temperature

9. Function Description

9.1. Comparator hysteresis

Both the up threshold and down threshold are 0.6 V.

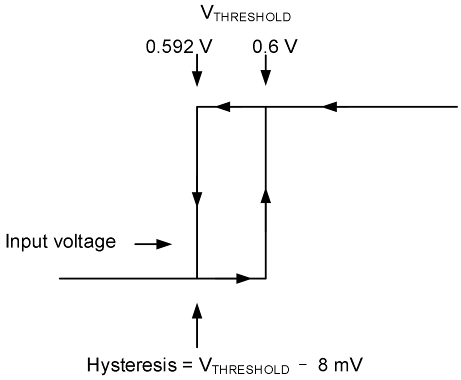


Figure 6. Comparator hysteresis

9.2. Comparator

The open-drain comparator integrated into the amplifier typically has a 3.5 μs positive response time and a 1.5 μs negative response time. The $\overline{RESET}$ pin controls the latching and resetting of the comparator output (See Figure 7).

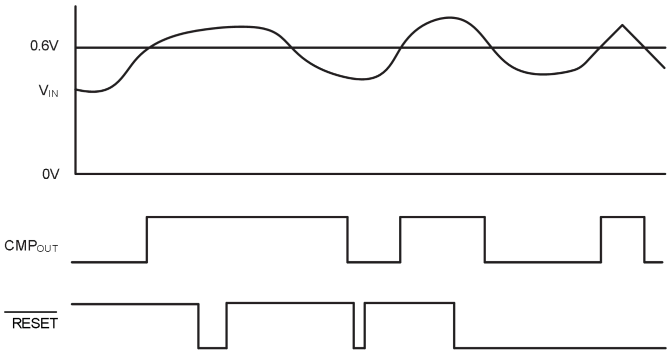


Figure 7. Comparator latching capability

9.3. Device functional mode

The DIO221X has a single functional mode and its function is guaranteed even when V_S exceeds 3 V. Note that the common-mode voltage must be between -0.1 V and 75 V. The maximum V_S is 40 V.

10. Application Information

Important notice: Validation and testing are the most reliable ways to confirm system functionality. The application information is not part of the specification and is for reference purposes only.

The DIO221X can detect overcurrent conditions and monitor current in an application through easy configuration. Designers can use the device alone to detect the overcurrent of a single threshold or pair it with other devices and circuitry to build more complex monitoring functional blocks.

10.1. Basic connections

To minimize the resistance in series with the shunt resistance, connect V_{IN+} and V_{IN-} as close as possible to the shunt resistor. Power-supply bypass capacitors can increase stability. To reject power supply noise in applications with noisy or high-impedance power supplies, add decoupling capacitors. Connect bypass capacitors close to the device pins (See Figure 8).

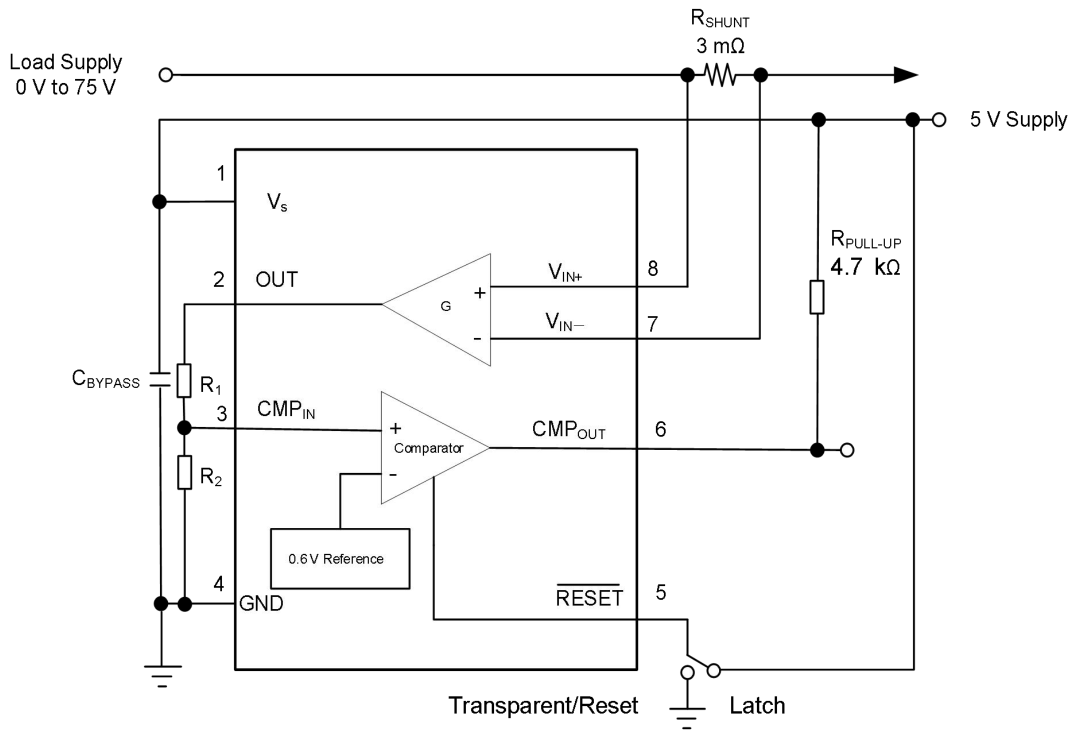


Figure 8. DIO221X basic connections

10.2. Choosing shunt resistor

The value for the shunt resistor or R_{SHUNT} varies from application to application. The higher the R_{SHUNT} value is, the smaller the offset effects are. Likewise, the lower the value is, the smaller the supply voltage loss is. Users should find a balance between maximum permissible voltage loss and the accuracy of small input signals. Normally, R_{SHUNT} with a range of 50 mV to 100 mV can help the application achieve the best performance.

10.3. Input filtering

One possible location for filtering is at the output of the DIO221X series, in which case the output impedance of the internal buffer increases. Adding a filter at the input pins of the DIO221X series is a better option although the input impedance makes the input filtering more complicated as shown in Figure 9. To minimize the initial shift in gain and effects of tolerance, use the lowest resistor values. Equation (1) tells the effect on initial gain.

$$\text{Gain Error }\% = 100 - \left(100 \times \frac{5k\Omega}{5k\Omega + R_{FILTER}}\right) \quad (1)$$

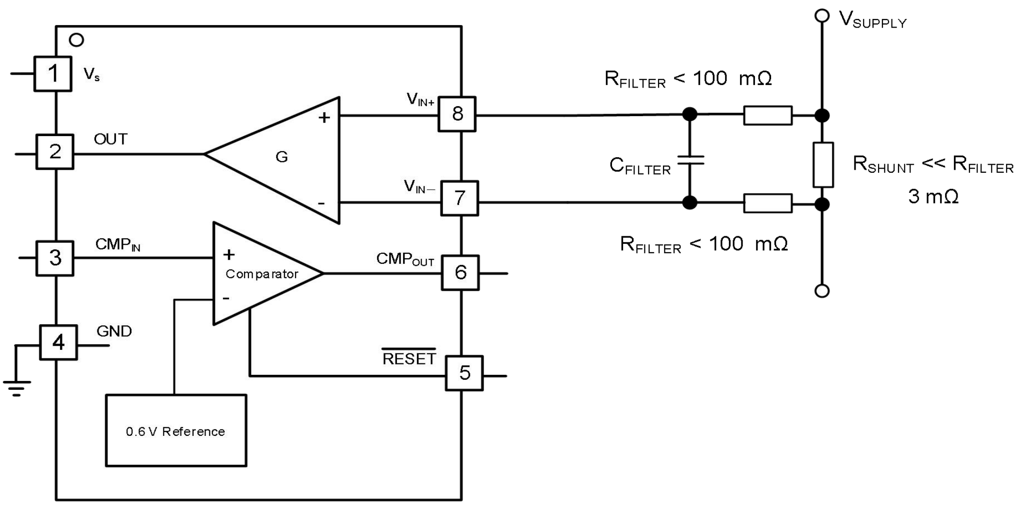


Figure 9. Input filter

Calculate the total effect on gain error by substituting the 5 kΩ term with 5 kΩ - 30% or 5 kΩ + 30%. Put the tolerance extremes of R_{FILTER} into equation (1). For instance, two resistors of 100 Ω 1% near the input pins, making a gain error of 1.96%. The worst case approach is using an internal 5 kΩ resistor and R_{FILTER} + 3%, which will offer an error gain larger than the normal value.

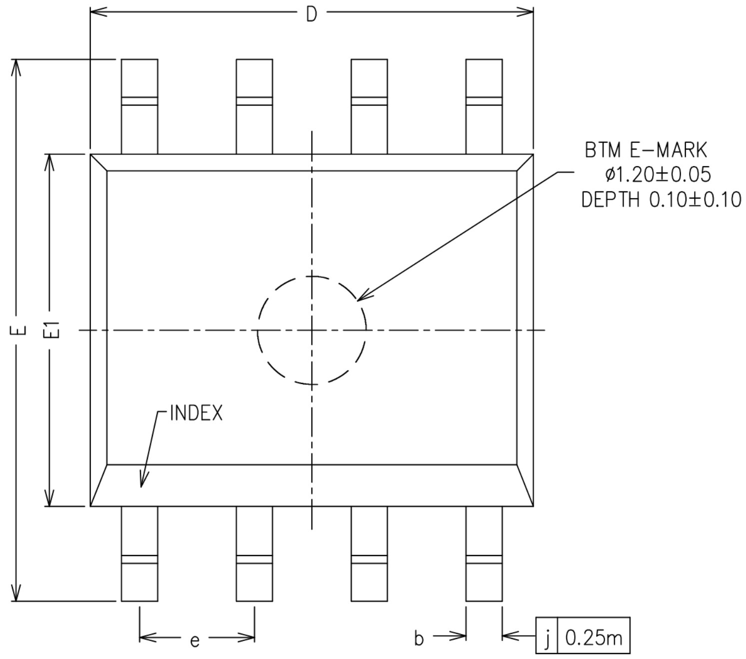
The specified accuracy of the DIO221X is another important factor to consider apart from these tolerances. Geometric-mean and root-sum-square mean are another two recommended ways to calculate the variations of accuracy.

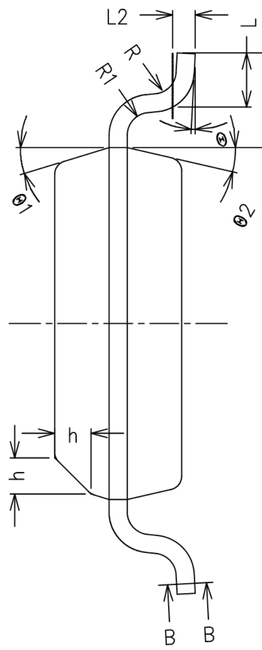
11. Layout

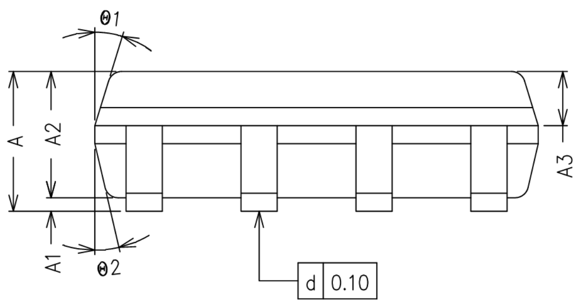
Use four wire connection, also known as Kelvin connection, to connect the input pins and the sensing resistor together so as to ensure only the current sensing resistance is detected. Inappropriate layout often results in additional resistance between the input pins, causing erroneous measuring. Locate the power-supply bypass capacitor, 0.1 μF recommended, as close as possible to the V_S and GND pins. Use an additional decoupling capacitor to lessen the impacts of noisy or high-impedance power supplies.

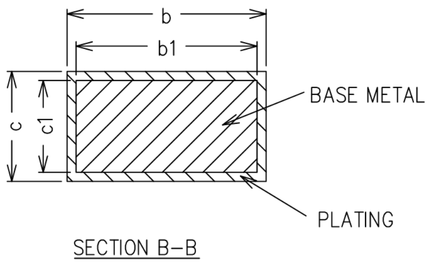
12. Physical Dimensions

12.1. SOIC-8



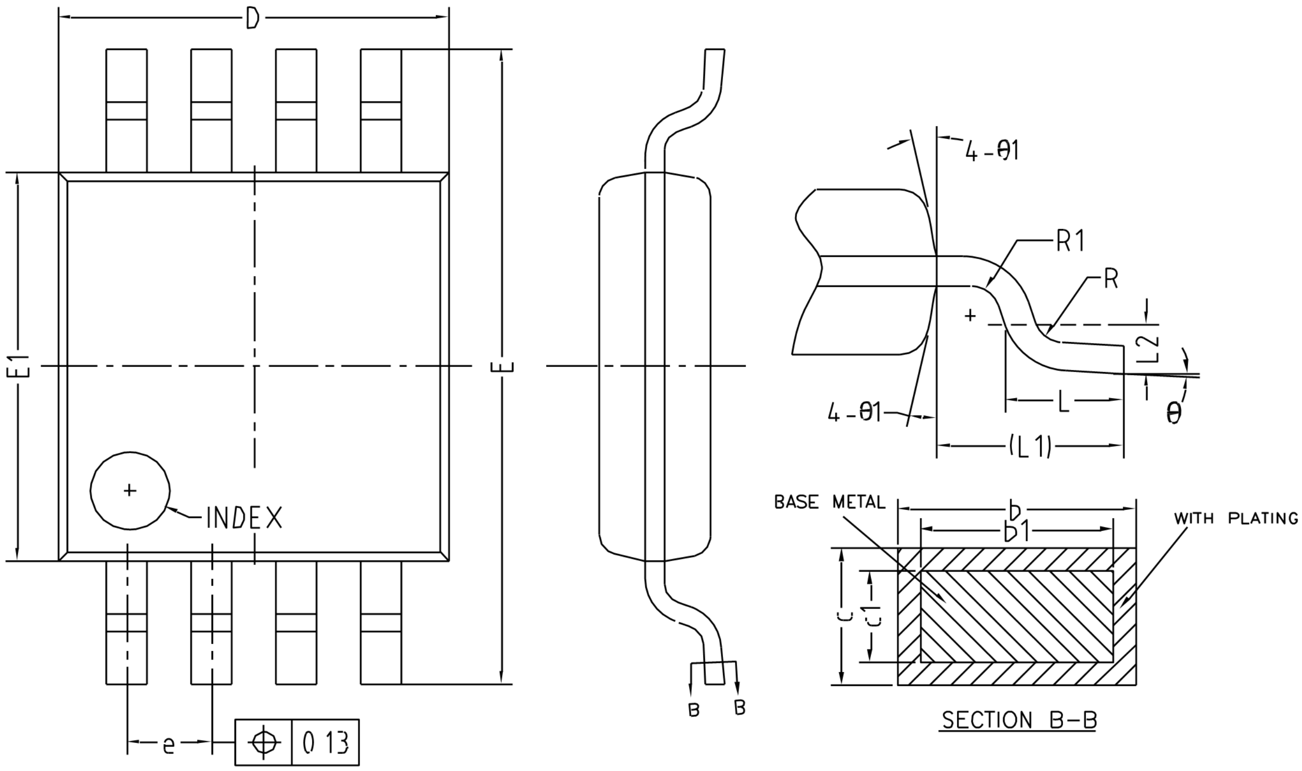


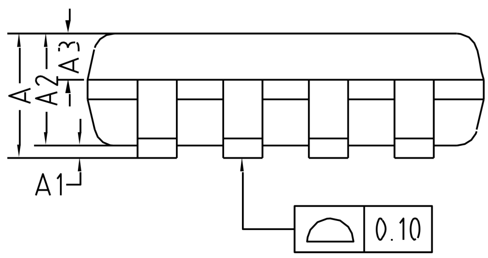




Common Dimensions (Units of measure = Millimeter)			
Symbol	Min	Nom	Max
A	1.35	1.55	1.75
A1	0.10	-	0.25
A2	1.30	1.40	1.50
A3	0.50	0.60	0.70
b	0.38	-	0.47
b1	0.37	0.40	0.43
c	0.17	-	0.25
c1	0.17	0.20	0.23
D	4.80	4.90	5.00
E	5.80	6.00	6.20
E1	3.80	3.90	4.00
e	1.17	1.27	1.37
L	0.45	0.60	0.80
L1	1.04 REF		
L2	0.25 BSC		
R	0.07	-	-
R1	0.07	-	-
h	0.30	0.40	0.50
θ	0°	-	8°
θ1	15°	17°	19°
θ2	11°	13°	15°

12.2. MSOP-8





Common Dimensions (Units of measure = Millimeter)			
Symbol	**Min**	**Nom**	**Max**
A	-	-	1.10
A1	0.05	0.10	0.15
A2	0.75	0.85	0.95
A3	0.30	0.35	0.40
b	0.25	-	0.38
b1	0.24	0.30	0.33
c	0.15	-	0.20
c1	0.14	0.15	0.16
D	2.90	3.00	3.10
E	4.75	4.90	5.05
E1	2.90	3.00	3.10
e	0.55	0.65	0.75
L	0.40	0.55	0.70
L1	0.95 REF		
L2	0.25 BSC		
R	0.07	-	-
R1	0.07	-	-
θ	0°	-	8°
θ1	9°	12°	15°

Disclaimer

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