Rev 1.7

DIO7960
250 mA, Ultra-Low Noise and High PSRR LDO for RF and Analog Circuits

Features

- Operating input voltage range: 1.65 V to 5.5 V
- Available in fixed voltage option: 1 V to 3.3 V
- Output current：250 mA
- Ultra-high PSRR: 95 dB at f = 1 kHz
- Ultra-low noise: 10 μV_{RMS}
- Output voltage accuracy: ±1%
- Ultra-low quiescent current : 18 μA (typ.)
- Standby current : 0.1 μA (typ.)
- Very low dropout: 100 mV at 250 mA
- Stable with a 1 μF small case size ceramic capacitor
- Quick output discharge:
  DIO7960A: available
  DIO7960B: not available
- Small package:
  WLCSP-4 (0.65 mm*0.65 mm, pitch 0.35 mm) and DFN1*1-4 packages

Descriptions

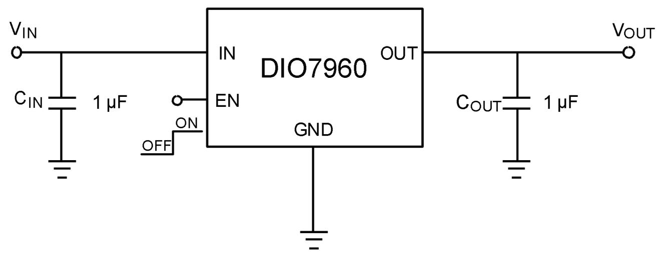
The DIO7960 series is a 250 mA, ultra-high PSRR, ultra-low noise, high-accuracy, low dropout CMOS linear regulator. The DIO7960 is designed for radio frequency and analog circuits. The device consumes low quiescent current and provides fast line and load transient performance. The DIO7960 operates over an input voltage range of 1.65 V to 5.5 V and supports fixed output voltage from 1 V to 3.3 V.

The DIO7960 is designed to work with a 1 μF input and a 1 μF output ceramic capacitor, allowing for a small overall solution size. A precision band-gap and error amplifier provides a high accuracy of ±1% (max) at 25°C. It is available in WLCSP-4 (0.65 mm*0.65 mm, pitch 0.35 mm) and DFN1*1-4 packages.

Applications

- Smartphones, tablets
- IP cameras
- RF, PLL, VCO and clock power supply
- Portable medical equipment

Typical Application



Ordering Information

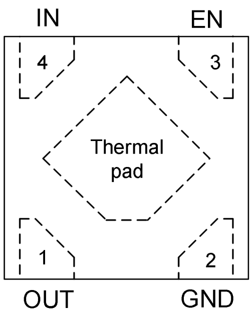
Ordering Part No.	Top Marking	Description	MSL	RoHS	T_A	Package	
DIO7960AaaWL4	W6X	Active Discharge	1	Green	-40 to 125°C	WLCSP-4	Tape & Reel, 5000
DIO7960AaaEN4	YW6X		1	Green	-40 to 125°C	DFN1*1-4	Tape & Reel,10000
DIO7960BaaWL4	W8X	Non-Active Discharge	1	Green	-40 to 125°C	WLCSP-4	Tape & Reel, 5000
DIO7960BaaEN4	YW8X		1	Green	-40 to 125°C	DFN1*1-4	Tape & Reel,10000

Output voltage options									
Option Code “**aa**”	**10**	**12**	**13**	**15**	**18**	**25**	**28**	**30**	**33**
Voltage	1.0 V	1.2 V	1.3 V	1.5 V	1.8 V	2.5 V	2.8 V	3 V	3.3 V

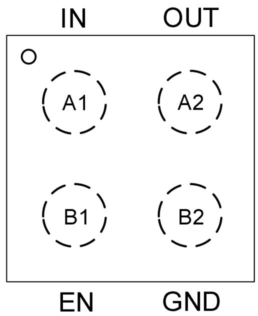
Marking definition	
W6X	W: Week code; 6: Product code
YW6X	Y: Year code; W: Week code; 6: Product code
W8X	W: Week code; 8: Product code
YW8X	Y: Year code; W: Week code; 8: Product code

Voltage code									
Option Code “X”	E	F	S	G	H	J	K	L	M
Voltage	1.0 V	1.2 V	1.3 V	1.5 V	1.8 V	2.5V	2.8 V	3 V	3.3 V

Pin Assignments



DFN1*1-4 (Top view)



WLCSP-4 (Top view)

Pin Definitions

Pin Name	Description
OUT	Regulated output voltage. The output should be bypassed with small 1 μF ceramic capacitor.
EN	Enable pin. This pin has an internal pull-down source current. A logic low reduces the supply current to less than 1 μA. Connect to logic high for normal operation.
GND	Power supply ground.
IN	Input voltage supply pin.
Thermal pad	Connect the thermal pad to a large-area GND plane to improve the thermal performance.

Absolute Maximum Ratings

Stresses beyond those listed under the Absolute Maximum Rating table may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other condition beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

<table>
<tr><th>Symbol</th><th colspan="2">Parameter</th><th>Rating</th><th>Unit</th></tr>
<tr><td>V_{IN}</td><td colspan="2">Input voltage</td><td>-0.3 to 6</td><td>V</td></tr>
<tr><td>V_{OUT}</td><td colspan="2">Output voltage</td><td>-0.3 to V_{IN} + 0.3, max.6</td><td>V</td></tr>
<tr><td>V_{EN}</td><td colspan="2">EN input voltage</td><td>-0.3 to 6</td><td>V</td></tr>
<tr><td>t_{SC}</td><td colspan="2">Output short circuit duration</td><td>unlimited</td><td>s</td></tr>
<tr><td>$T_{J(MAX)}$</td><td colspan="2">Maximum junction temperature</td><td>150</td><td>°C</td></tr>
<tr><td>T_{STG}</td><td colspan="2">Storage temperature</td><td>-55 to 150</td><td>°C</td></tr>
<tr><td rowspan="2">$R_{θJA}$</td><td rowspan="2">Thermal resistance, junction−to−air</td><td>WLCSP-4</td><td>108</td><td>°C/W</td></tr>
<tr><td>DFN1*1-4</td><td>198.1</td><td>°C/W</td></tr>
<tr><td rowspan="2">ESD</td><td colspan="2">Human body model (HBM)</td><td>±4000</td><td rowspan="2">V</td></tr>
<tr><td colspan="2">Charged device model (CDM)</td><td>±2000</td></tr>
</table>

Recommend Operating Conditions

Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. Dioo does not recommend exceeding them or designing to absolute maximum ratings.

Symbol	Parameter	Rating	Unit
V_{IN}	Input voltage	1.65 to 5.5	V
T_A	Operating free-air temperature	-40 to 125	°C

Electrical Characteristics

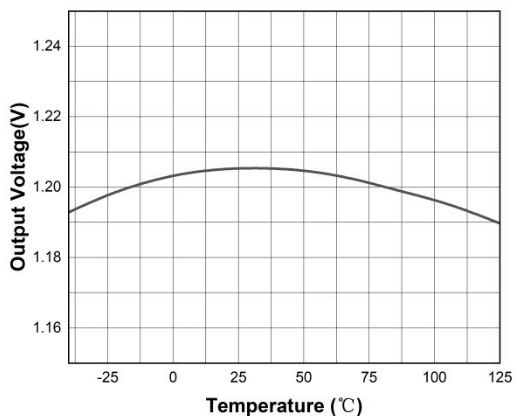
-40°C ≤ T_A ≤ 125°C; V_{IN} = $V_{OUT(NOM)}$ + 1 V; I_{OUT} = 1 mA, C_{IN} = C_{OUT} = 1 μF, unless otherwise noted. V_{EN} = 1.0 V. Typical values are at T_A = 25°C.

Symbol	Parameter	Test Conditions		Min	Typ	Max	Unit
V_{IN}	Operating input voltage			1.65		5.5	V
V_{OUT}	Output voltage accuracy	V_{IN} = $V_{OUT(NOM)}$ + 1 V, I_{OUT} = 1 mA, T_A = 25°C	V_{OUT} < 2 V	-20		20	mV
			V_{OUT} ≥ 2 V	-1		1	%
$Line_{Reg}$	Line regulation	$V_{OUT(NOM)}$ + 1 V < V_{IN} ≤ 5.5 V, T_A = 25°C				6	mV
$Load_{Reg}$	Load regulation	I_{OUT} = 1 mA to 250 mA	WLCSP-4		2		mV
			DFN1*1-4			20	mV
V_{DO}	Dropout voltage	I_{OUT} = 250 mA, WLCSP-4	$V_{OUT(NOM)}$ = 1.8 V		140	210	mV
			$V_{OUT(NOM)}$ = 2.5 V		90	130	
			$V_{OUT(NOM)}$ = 2.8 V		80	120	
			$V_{OUT(NOM)}$ = 3.3 V		70	100	
		I_{OUT} = 250 mA, DFN1*1-4	$V_{OUT(NOM)}$ = 1.8 V		160	220	
			$V_{OUT(NOM)}$ = 2.5 V		110	140	
			$V_{OUT(NOM)}$ = 2.8 V		100	125	
			$V_{OUT(NOM)}$ = 3.3 V		85	110	
I_{CL}	Output current limit	V_{OUT} = 90% $V_{OUT(NOM)}$		250	420		mA
I_{SC}	Short circuit current	V_{OUT} = 0 V			100		mA
I_Q	Quiescent current	I_{OUT} = 0 mA, T_A = 25°C			18	25	μA
I_{DIS}	Shutdown current	V_{EN} ≤ 0.4 V, V_{IN} = 4.8 V, T_A = 25°C			0.01	1	μA
V_{ENH}	EN pin threshold voltage	EN input voltage high		1			V
V_{ENL}		EN input voltage low				0.4	V
I_{EN}	EN pull-down current	V_{EN} = 4.8 V, T_A = 25°C			0.2	0.5	μA
t_{ON}	Turn-on time	C_{OUT} = 1 μF, from assertion of V_{EN} to V_{OUT} = 90% $V_{OUT(NOM)}$			250		μs
PSRR	Power supply rejection ratio	I_{OUT} = 10 mA	f = 100 Hz		91		dB
			f = 1 kHz		95		
			f = 10 kHz		75		
			f = 100 kHz		55		
			f = 1 MHz		56		
V_N	Output voltage noise	f = 10 Hz to 100 kHz	I_{OUT} = 1 mA		14		$μV_{RMS}$
			I_{OUT} = 250 mA		10		

T_{SDH}	Thermal shutdown threshold	Temperature rising		160		°C
T_{SDL}		Temperature falling		140		°C
R_{DIS}	Active output discharge resistance	V_{EN} < 0.4 V (Only for DIO7960A)		100		Ω
$Tran_{LINE}$	Line transient	V_{IN} = ($V_{OUT(NOM)}$ + 1 V) to ($V_{OUT(NOM)}$ + 1.6 V) in 30 μs, I_{OUT} = 1 mA			1	mV
		V_{IN} = ($V_{OUT(NOM)}$ + 1.6 V) to ($V_{OUT(NOM)}$ + 1 V) in 30 μs, I_{OUT} = 1 mA	-1			
$Tran_{LOAD}$	Load transient	I_{OUT} = 1 mA to 250 mA in 10 μs	-40			mV
		I_{OUT} = 250 mA to 1 mA in 10 μs			40	

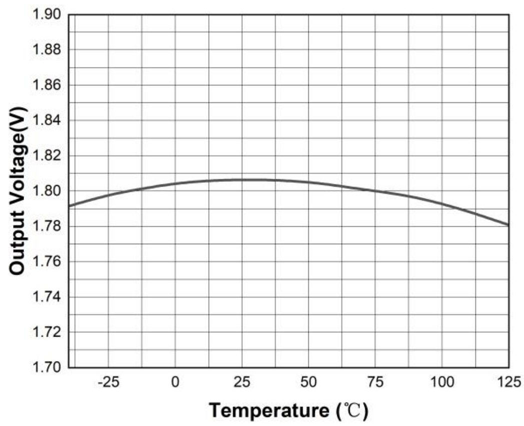
Note: Specifications subject to change without notice.

Typical Performance Characteristics



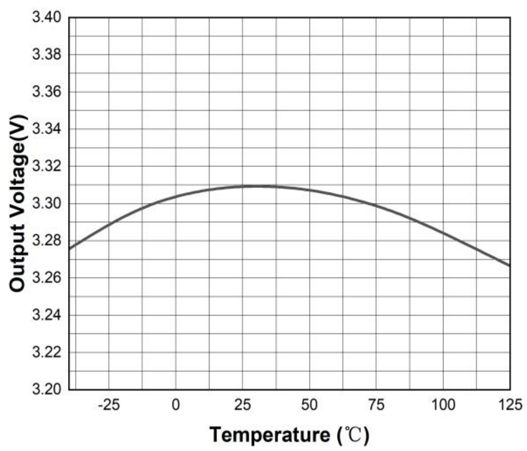
V_{OUT} = 1.2 V, C_{IN} = C_{OUT} = 1 μF, I_{OUT} = 1 mA

Figure 1. Output voltage (1.2 V) vs. Temperature



V_{OUT} = 1.8 V, C_{IN} = C_{OUT} = 1 μF, I_{OUT} = 1 mA

Figure 2. Output voltage (1.8 V) vs. Temperature



V_{OUT} = 3.3 V, C_{IN} = C_{OUT} = 1 μF, I_{OUT} = 1 mA

Figure 3. Output voltage (3.3 V) vs. Temperature

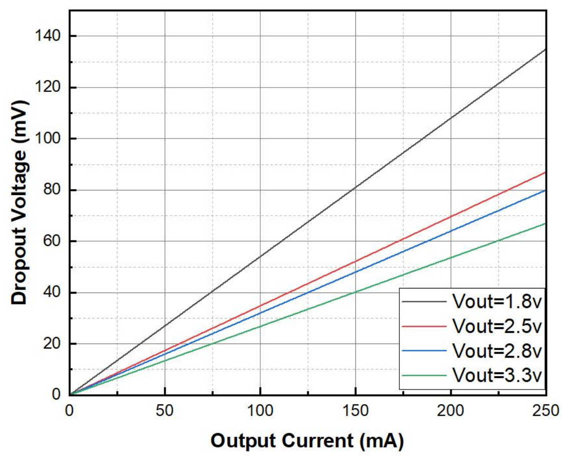
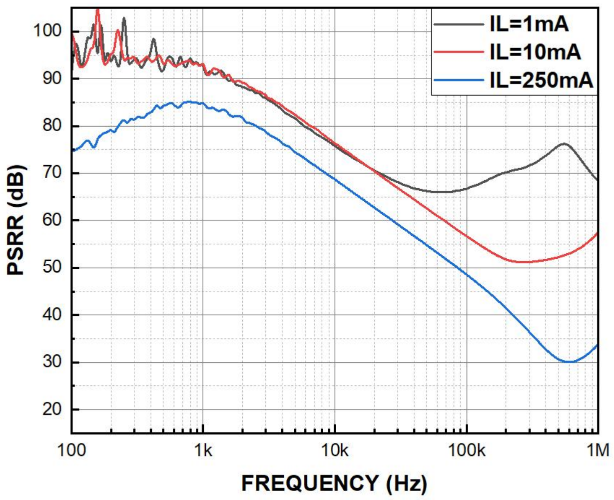
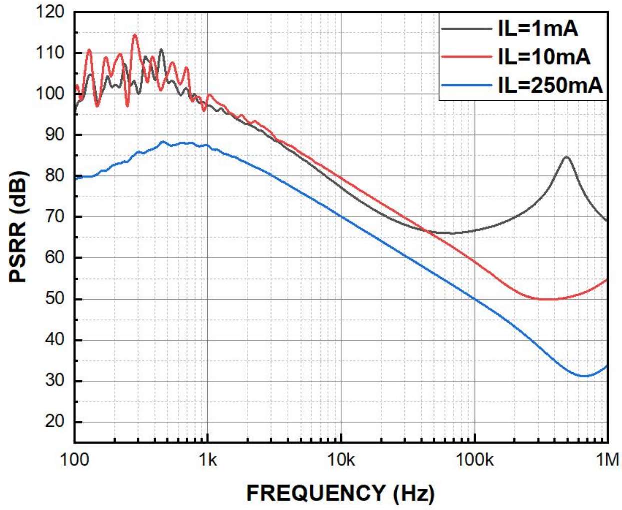


Figure 4. Dropout voltage vs. Output current



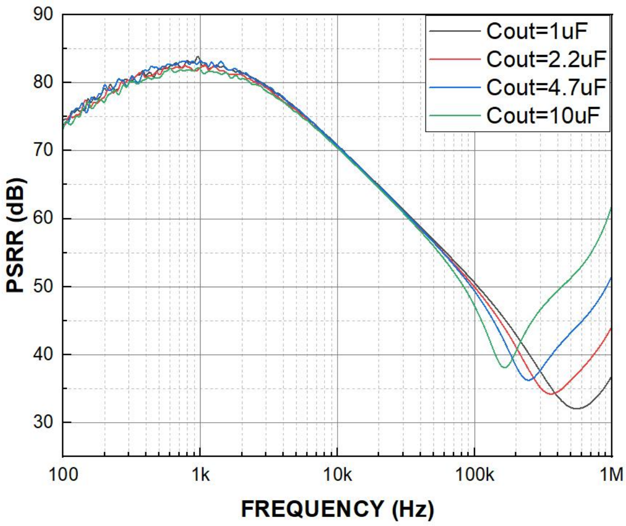
V_{IN} = 2.8 V + 200 mV_{PP}, V_{OUT} = 1.8 V, C_{OUT} = 1 μF

Figure 5. PSRR vs. Frequency



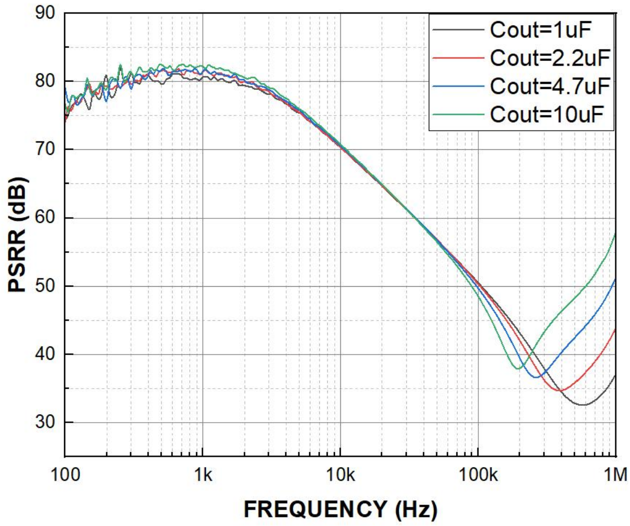
V_{IN} = 4.3 V + 200 mV_{PP}, V_{OUT} = 3.3 V, C_{OUT} = 1 μF

Figure 6. PSRR vs. Frequency



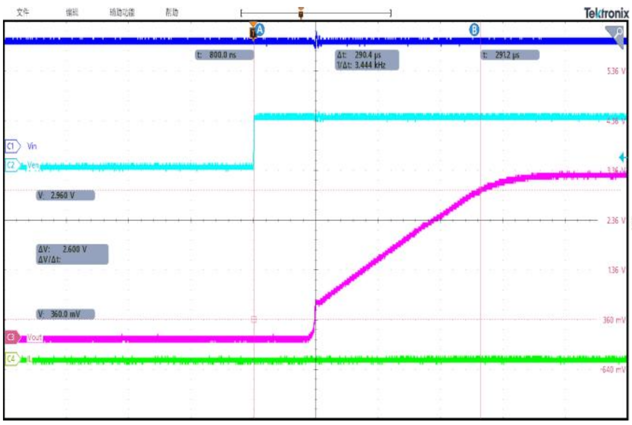
V_{IN} = 2.8 V + 200 mV_{PP}, V_{OUT} = 1.8 V, I_L= 150 mA

Figure 7. PSRR vs. Frequency



V_{IN} = 4.3 V + 200 mV_{PP}, V_{OUT} = 3.3 V, I_L= 150 mA

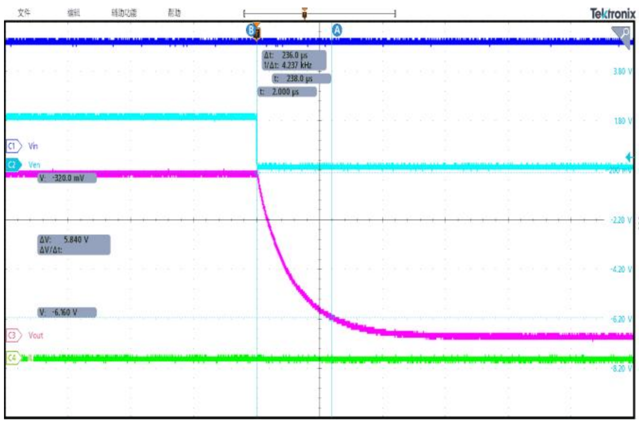
Figure 8. PSRR vs. Frequency



V_{IN} = 4.3 V, V_{OUT} = 3.3 V, C_{IN} = C_{OUT} = 1 μF, I_L = 1 mA

From assertion of V_{EN} to V_{OUT} = 90% $V_{OUT(NOM)}$

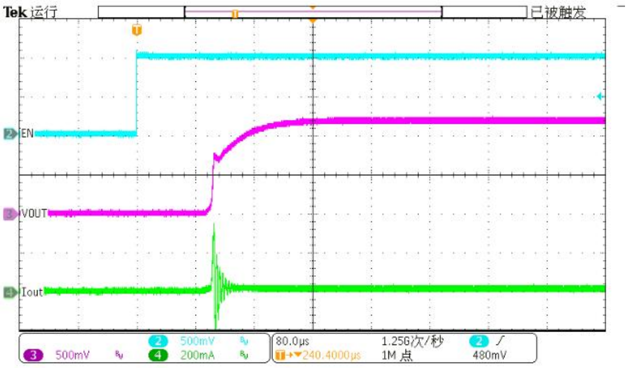
Figure 9. Turn-on time



V_{IN} = 4.3 V, V_{OUT} = 3.3 V, C_{IN} = C_{OUT} = 1 μF, I_L = 1 mA

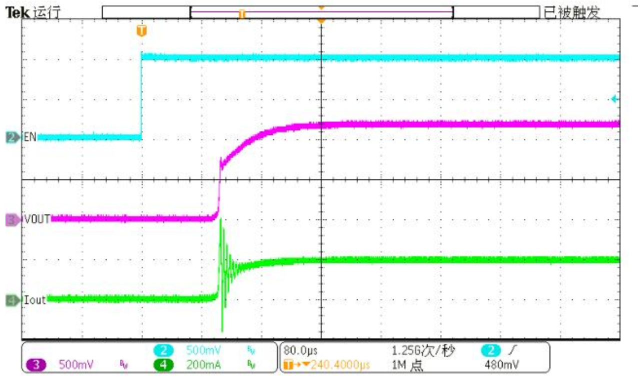
From assertion of V_{EN} to V_{OUT} = 0

Figure 10. Turn-off time



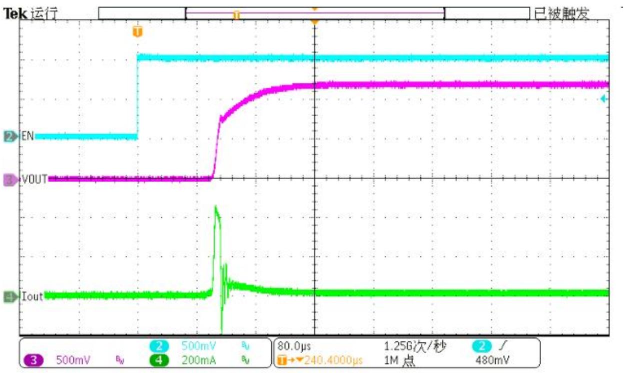
V_{IN} = 1.65 V, V_{OUT} = 1.2 V, C_{IN} = C_{OUT} = 1 μF, I_{OUT} = 10 mA

Figure 11. Inrush current



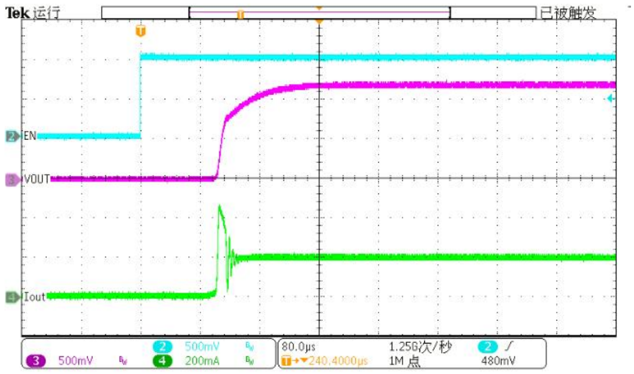
V_{IN} = 1.65 V, V_{OUT} = 1.2 V, C_{IN} = C_{OUT} = 1 μF, I_{OUT} = 200 mA

Figure 12. Inrush current



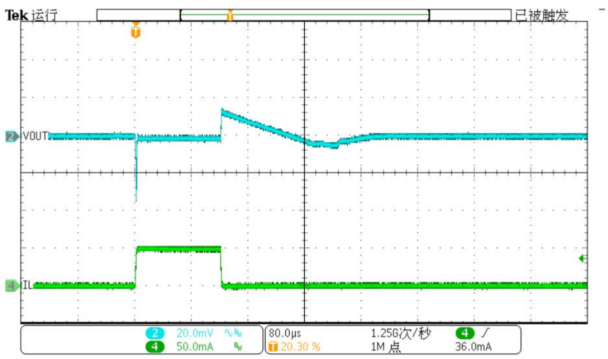
V_{IN} = 1.65 V, V_{OUT} = 1.2 V, C_{IN} = 1 μF, C_{OUT} = 4.7 μF, I_{OUT} = 10 mA

Figure 13. Inrush current



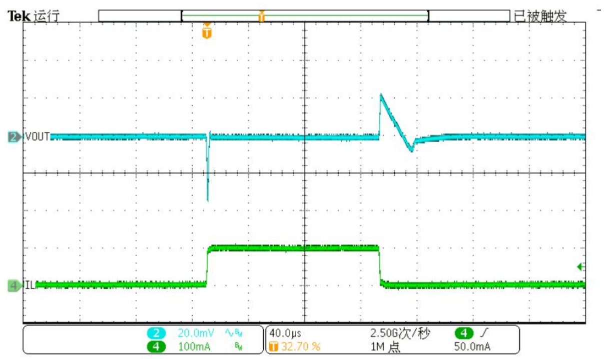
V_{IN} = 1.65 V, V_{OUT} = 1.2 V, C_{IN} = 1 μF, C_{OUT} = 4.7 μF, I_{OUT} = 200 mA

Figure 14. Inrush current



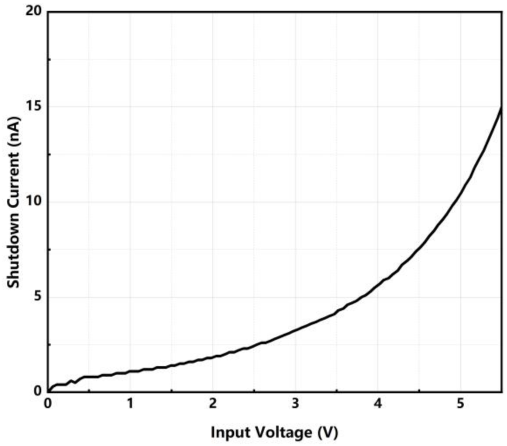
V_{IN} = 4.3 V, V_{OUT} = 3.3 V, C_{OUT} = 1 μF, I_{OUT} = 0.1 mA to 50 mA

Figure 15. Load transient response



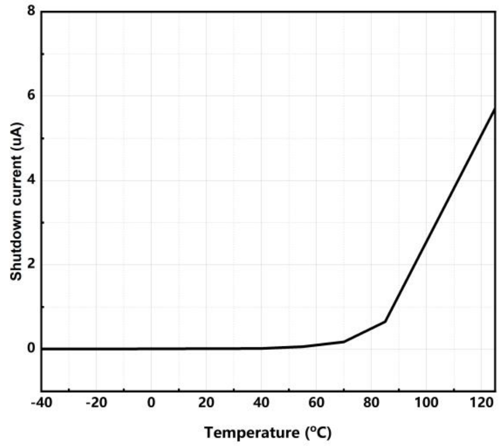
V_{IN} = 4.3 V, V_{OUT} = 3.3 V, C_{OUT} = 1 μF, I_{OUT} = 1 mA to 100 mA

Figure 16. Load transient response



V_{OUT} = 3.3 V, C_{OUT} = 1 μF, EN = 0 V

Figure 17. Shutdown current vs. Input voltage



V_{IN} = 4.3 V, V_{OUT} = 3.3 V, C_{OUT} = 1 μF, EN = 0 V

Figure 18. Shutdown current vs. Temperature

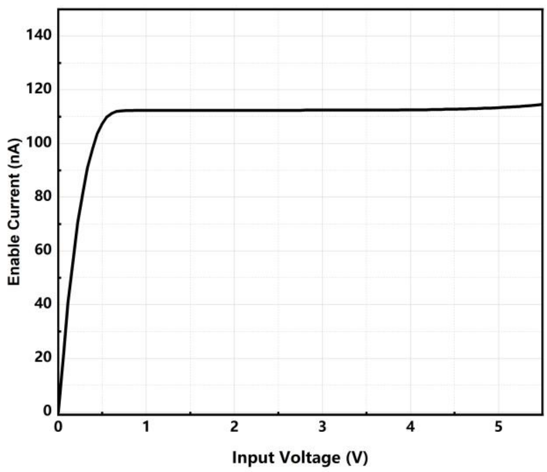
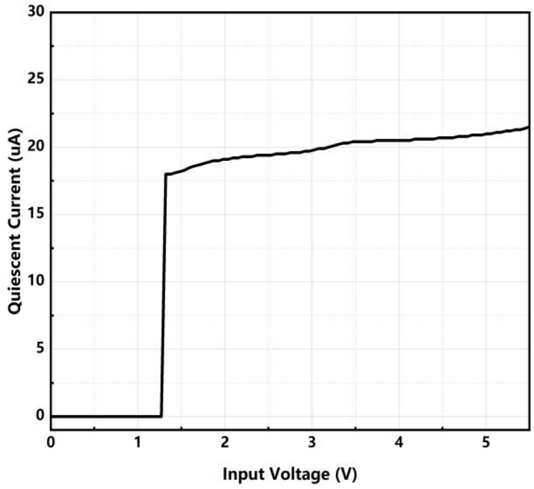
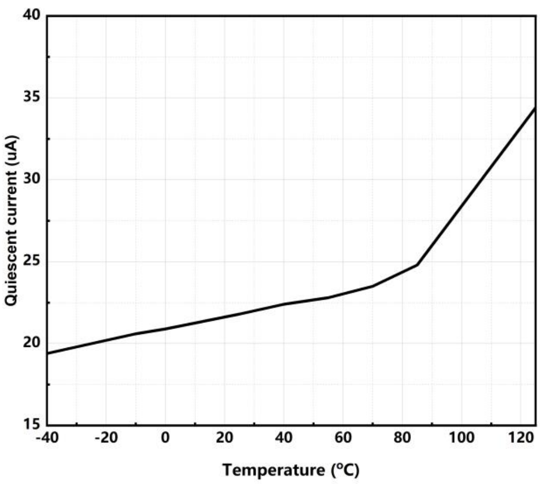


Figure 19. Enable current vs. Input voltage



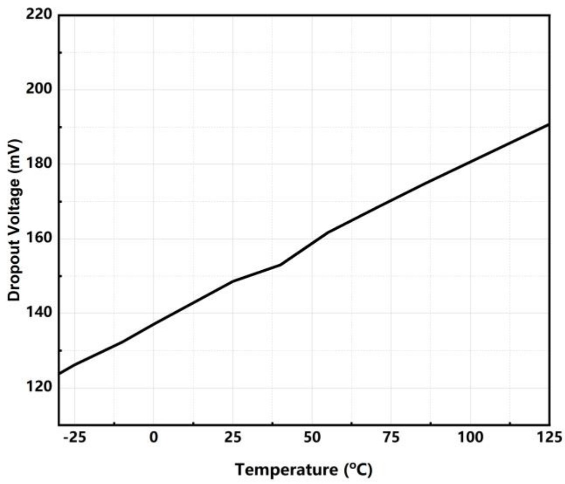
V_{OUT} = 3.3 V, C_{IN} = C_{OUT} = 1 μF, EN = 1 V

Figure 20. Quiescent current vs. Input voltage



V_{IN} = 4.3 V, V_{OUT} = 3.3 V, C_{IN} = C_{OUT} = 1 μF, EN = 1 V

Figure 21. Quiescent current vs. Temperature



V_{OUT} = 3.3 V, C_{IN} = C_{OUT} = 1 μF, EN = 1 V

Figure 22. Dropout voltage vs. Temperature

Block Diagram

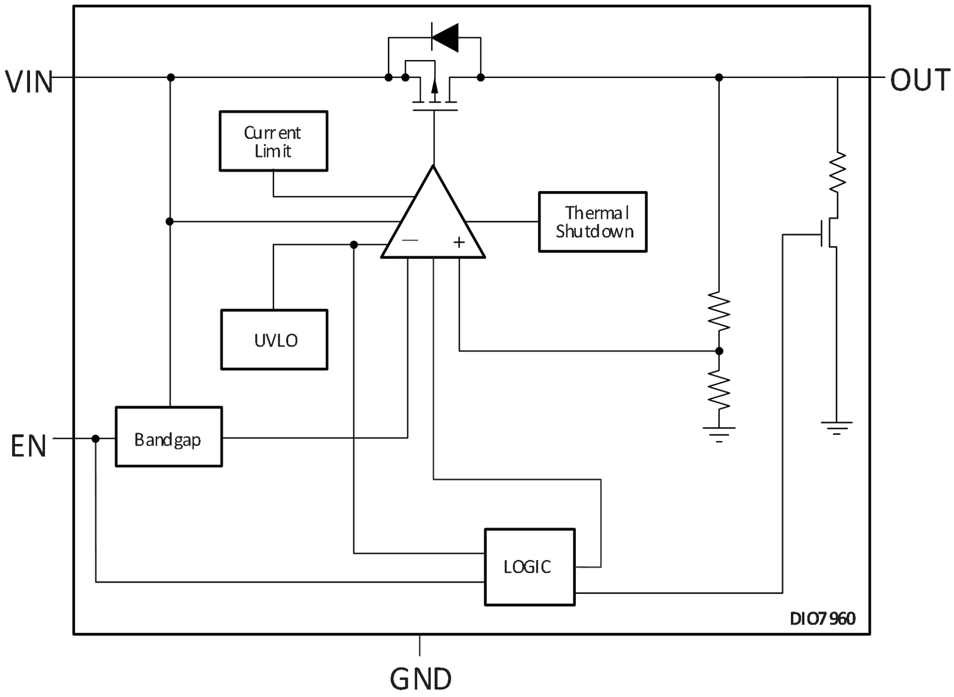


Figure 23. Block diagram

Detailed Description

Overview

The DIO7960 series of LDO linear regulators is an ultra-high PSRR and low noise LDO with excellent line and load transient performance. These LDOs are designed for power-sensitive applications. A precision bandgap and error amplifier provides overall 1% accuracy. Low output noise, very high PSRR, and low dropout voltage make this device ideal for most battery-operated handheld equipment. The DIO7960 is fully protected in case of current overload, output short circuit, and overheating.

Input capacitor selection (C_{IN})

The DIO7960 is specifically designed to work with a standard ceramic input capacitor. Input capacitor connected as close as possible is necessary to ensure device stability. The X7R or X5R capacitor should be used because of its minimal variation in value and equivalent series resistance (ESR) over temperature. The value of the input capacitor should be 1 μF or larger to ensure the best dynamic performance. This capacitor will provide a low impedance path for unwanted AC signals or noise modulated onto constant input voltage. There is no requirement for the ESR of the input capacitor but it is recommended to use ceramic capacitors for their low ESR and ESL. A good input capacitor will limit the influence of input trace inductance and source resistance during sudden load current changes.

Output capacitor selection (C_{OUT})

The DIO7960 requires an output capacitance, and the value of the input capacitor should be 1 μF or larger for stability. Use X5R-type and X7R-type ceramic capacitors because of its minimal variation in value and equivalent series resistance (ESR) over temperature. Select a minimum effective capacitance of 0.7 μF for C_{OUT}, considering capacitance changes with temperature, DC bias and package size. A capacitance of 0.7 μF or higher can satisfy the requirement of all levels of VIN, VOUT, and load.

Larger output capacitors and lower ESR could improve the load transient response or high frequency PSRR. It is not recommended to use tantalum capacitors on the output due to their large ESR. The equivalent series resistance of tantalum capacitors is also strongly dependent on the temperature, increasing at low temperatures.

Enable operation

The DIO7960 uses the EN pin to enable/disable its device and discharge function (just for DIO7960A). If the EN pin voltage is pulled below 0.4 V the device is guaranteed to be disabled. The active discharge transistor at the devices with active discharge feature is activated and the output voltage V_{OUT} is pulled to GND through an internal circuitry with effective resistance about 100 Ω.

If the EN pin voltage is higher than 1.0 V, the device is guaranteed to be enabled. The internal active discharge circuitry is switched off and the desired output voltage is available at output pin. In case the enable function is not required, the EN pin should be connected directly to the input pin.

Output current limit

The DIO7960 internal current limit helps to protect the regulator during fault conditions. Output current is internally limited within the IC to a typical 420 mA. During current limit, the output sources a fixed amount of current that is largely independent of the output voltage. In such a case, the output voltage is not regulated, and is $V_{OUT} = I_{CL} \times R_{LOAD}$. The PMOS pass transistor dissipates $(V_{IN} – V_{OUT}) \times I_{CL}$ until thermal shutdown is triggered and the device turns off. As the device cools down, it is turned on by the internal thermal shutdown circuit. If the fault condition continues, the device cycles between current limit and thermal shutdown.

Short circuits protection

The DIO7960 has integrated internally the function of short circuit protection for the device. When the output is shorted, the short circuit protection will limit the output current to a typical 100 mA, which is called short circuit limit (I_{SC}). When a short circuit occurs, the PMOS pass transistor dissipates $(V_{IN} – V_{OUT}) \times I_{SC}$ until the thermal shutdown is triggered and the device turns off. As the device cools down, it is turned on by the internal thermal shutdown circuit.

Thermal shutdown

When the chip temperature exceeds the thermal shutdown point (T_{SD} = 160°C typical) the device goes to disabled state and the output voltage is not delivered until the die temperature decrease to 140°C. The thermal shutdown feature provides a protection from a catastrophic device failure at accidental overheating. This protection is not intended to be used as a substitute for proper heat sinking.

Dropout voltage

The DIO7960 uses a PMOS pass transistor to achieve low dropout. When $(V_{IN} – V_{OUT})$ is less than the dropout voltage (V_{DO}), the PMOS pass device is in the linear region of operation and the input-to-output resistance is the $R_{DS(on)}$ of the PMOS pass element. V_{DO} scales approximately with output current because the PMOS device behaves as a resistor in dropout.

Power dissipation and heat sinking

The maximum power dissipation supported by the device is dependent upon board design and layout. Mounting pad configuration on the PCB, the board material, and the ambient temperature affect the rate of junction temperature rise for the part. The maximum power dissipation the DIO7960 device can handle is given by Equation (1).

$$P_{D(MAX)} = \frac{[T_{J(MAX)} - T_A]}{R_{\theta JA}} \quad (1)$$

The power dissipated by the DIO7960 device for given application conditions can be calculated from Equation (2).

$$P_D \approx V_{IN} \times I_{GND} + I_{OUT}(V_{IN} - V_{OUT}) \quad (2)$$

Power supply rejection ratio

The DIO7960 features very high power supply rejection ratio to meet the requirements of RF and analog circuits. If desired, the PSRR at higher frequencies in the range 100 kHz ~ 1 MHz can be tuned by the selection of C_{OUT} capacitor and proper PCB layout.

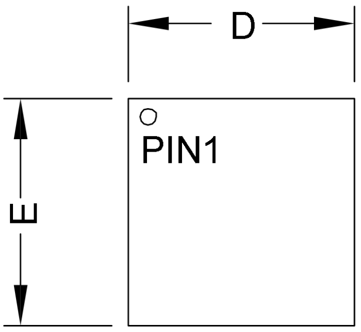
Turn−on time

The turn−on time is defined as the time period from EN assertion to the point in which V_{OUT} will reach 90% of its nominal value. This time is dependent on various application conditions such as $V_{OUT(NOM)}$, C_{OUT}, T_A.

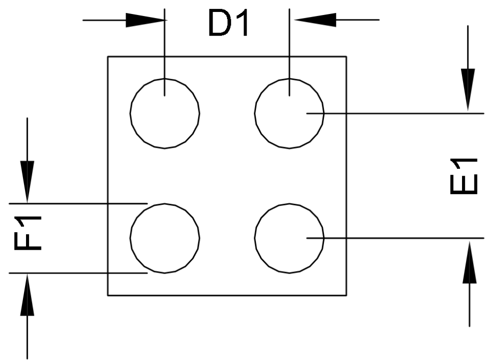
PCB layout recommendations

An optimal layout can greatly improve transient performance, PSR, and noise. To obtain excellent performance and good regulation characteristics, place C_{IN} and C_{OUT} capacitors close to the device pins and make the PCB traces wide. Place ground return connections to the input and output capacitors. Larger copper area connected to the pins will also improve the device thermal resistance. Exposed pad can be tied to the GND pin for improvement power dissipation and lower device temperature.

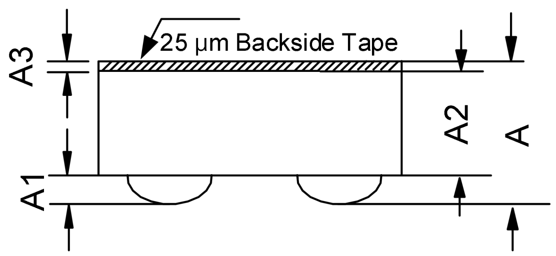
Physical Dimensions: WLCSP-4



TOP VIEW
Ball Down



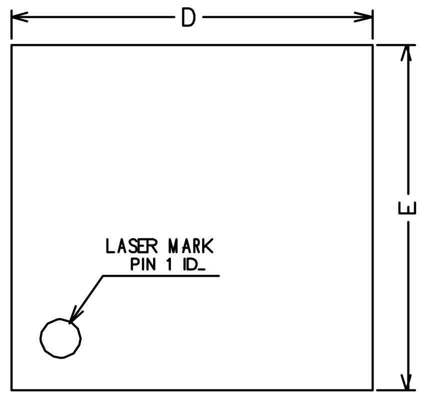
BOTTOM VIEW
Ball Up

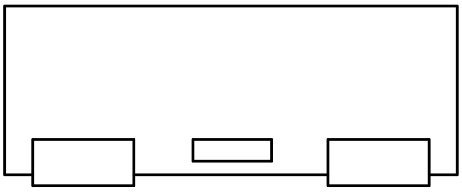


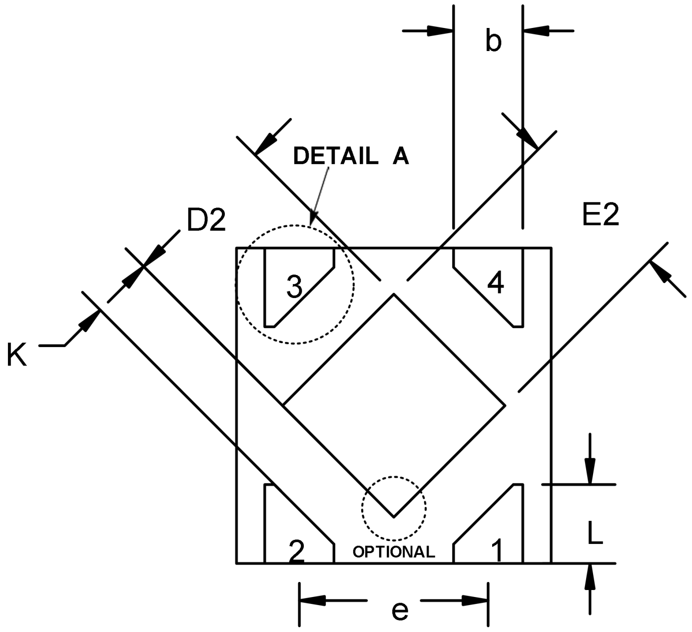
SIDE VIEW

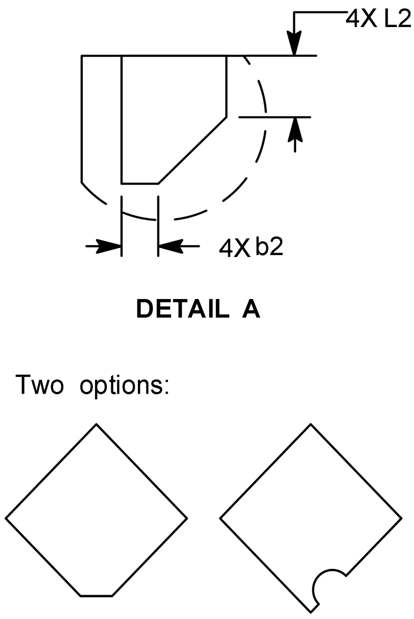
Common Dimensions (Units of measure = Millimeter)			
Symbol	Min	Nom	Max
A	0.270	0.300	0.330
A1	0.050	0.060	0.070
A2	0.200	0.215	0.230
A3	0.020	0.025	0.030
D	0.620	0.645	0.670
E	0.620	0.645	0.670
F1	0.189	0.195	0.201
D1	0.350 BSC		
E1	0.350 BSC		

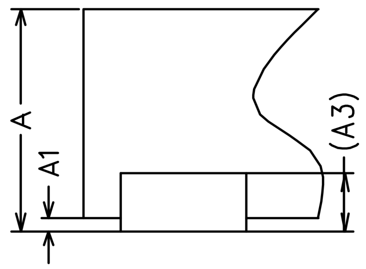
Physical Dimensions: DFN1*1-4

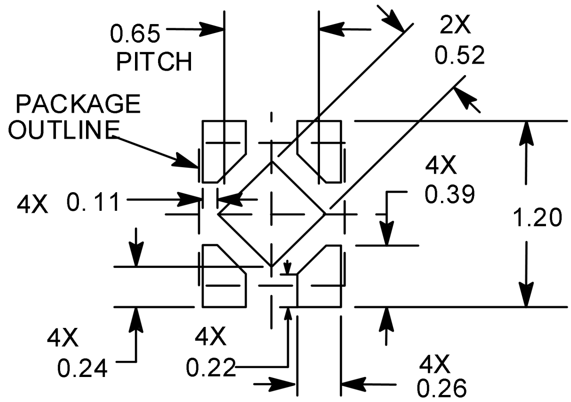












RECOMMENDED LAND PATTERN (Unit: mm)

Common Dimensions (Units of measure = Millimeter)			
Symbol	Min	Nom	Max
A	0.34	0.37	0.40
A1	0	0.02	0.05
A3	0.10 REF		
b	0.17	0.22	0.27
D	0.95	1.00	1.05
E	0.95	1.00	1.05
D2	0.43	0.48	0.53
E2	0.43	0.48	0.53
L	0.20	0.25	0.30
e	0.60	0.65	0.70
K	0.15	-	-
L2	0.07	0.12	0.17
b2	0.02	-	0.12

CONTACT US

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For additional product information or full datasheet, please contact our sales department or representatives.