DIO7971

3.6 V, 3 A, 6.8 mΩ On-Resistance Load Switch with Adjustable Fast Turn-On and Power Good

Features

- Input voltage range from 0.65 V to 3.6 V
- Maximum continuous switch current: 3 A
- Quiescent current: 26 μA (typ.) at 3.6 V_{IN}
- Shutdown current: 1 μA (typ.) at 3.6 V_{IN}
- On-resistance
  - $R_{DS(on)}$ = 6.8 mΩ (typ.) at V_{IN} ≥ 1.8 V
  - $R_{DS(on)}$ = 11.5 mΩ (typ.) at V_{IN} = 0.65 V
- Adjustable slew rate through CT pin
- Power-good indicator after switch turn-on
- Low enable (EN) threshold of 0.9 V (V_{IH}) supports use of low voltage control logic
- Thermal shutdown
- Quick output discharge (R_{DIS}): 150 Ω (typ.)
- Package: WLCSP-8

Applications

- Industrial PCs & notebooks
- Tablets
- Computer on modules
- Optical modules
- Storage instrument

Descriptions

The DIO7971 is a single-channel space-saving load switch containing an integrated power-good indicator with a controlled and adjustable turn-on slew rate. Containing an N-channel MOSFET, the device can support a maximum continuous current of 3 A and can operate over a low input voltage range of 0.65 V to 3.6 V. The voltage drops and power loss is reduced greatly by a low on-resistance of 6.8 mΩ. On and off input (EN) controls the switch, which can interface directly with low-voltage control signals.

The DIO7971 has a fast turn-on function that can reduce the system turn-on and waiting time. The adjustable slew rate can limit the inrush current.

A power-good (PG) indicator indicates the ON state of the switch by monitoring the power-mos gate threshold internally. A 150 Ω on-chip resistor quickly discharges the output to the ground and keeps it from floating when the switch is disabled.

The DIO7971 is available in a WLCSP-8 (0.5 mm pitch) package, which is rated over the temperature range of -40°C to 105°C and integrates thermal shutdown to turn off in case of overheating.

Typical Application

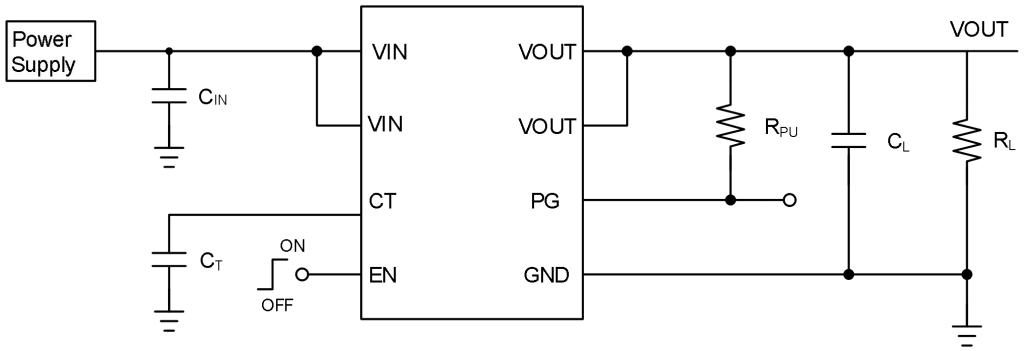


Figure 1. Typical application

Ordering Information

Ordering Part No.	Top Marking	MSL	RoHS	T_A	Package	
DIO7971WL8	GJ7A	1	Green	-40 to 105°C	WLCSP-8	Tape & Reel, 5000

Pin Assignments

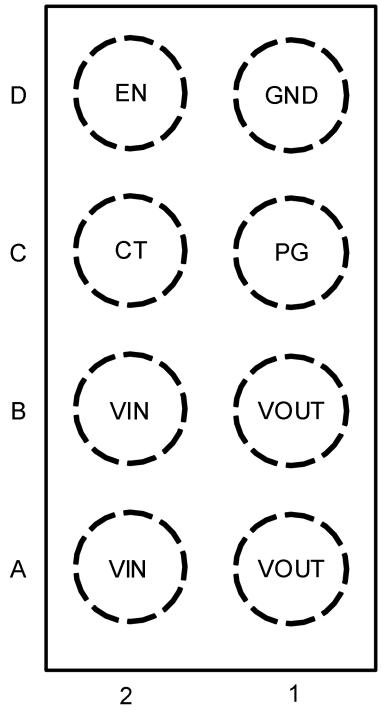


Figure 2. Pin assignment (Top view)

Pin Definitions

Pin Name	NO.	Description
CT	C2	VOUT slew rate control. Adding capacitance from this pin to ground lowers the output slew Rate.
GND	D1	Ground.
EN	D2	Switch enable control input. Do not leave the pin floating.
PG	C1	Power good indication. Open drain releases when the switch is fully on.
VOUT	A1, B1	Switch output.
VIN	A2, B2	Switch input.

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. DIOO does not recommend exceeding them or designing to absolute maximum ratings.

Symbol	Parameter	Rating	Unit
V_{IN}	Input voltage	-0.3 to 4	V
V_{OUT}	Output voltage	-0.3 to 4	V
V_{EN}	EN voltage	-0.3 to 4	V
V_{PG}	PG voltage	-0.3 to 4	V
I_{MAX}	Maximum continuous switch current	≤ 3	A
I_{PLS}	Maximum pulsed switch current, pulse < 300 μs, 2% duty cycle	≤ 4	A
T_J	Maximum junction temperature	Internally limited	
T_{STG}	Storage temperature	-65 to 150	°C
ESD	Human-body model (HBM) per ESDA/JEDEC JS-001	±2000	V
	Charged-device model (CDM) per ESDA/JEDEC JS -002	±2000	V
$R_{\theta JA}$	Junction-to-ambient thermal resistance	130	°C/W
$R_{\theta JC}$	Junction-to-case thermal resistance	54	°C/W

Recommended Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications.

Symbol	Parameter	Rating	Unit
V_{IN}	Input voltage	0.65 to 3.6	V
V_{EN}	EN voltage	0 to 3.6	V
V_{OUT}	Output voltage	≤ V_{IN}	V
T_J	Operating temperature	–40 to 125	°C
T_A	Operating free-air temperature	–40 to 105	°C
V_{CT}	CT pin capacitor voltage rating	≥7	V

Note:

(1) Over operating free-air temperature range, unless otherwise noted.

Electrical Characteristics

V_{IN} = 0.65 V to 3.6 V, unless otherwise noted.

Symbol	Parameter	Test Conditions		Min	Typ	Max	Unit
V_{IH}	High-level input voltage, EN		–40°C to 105°C	0.9			V
V_{IL}	Low-level input voltage, EN		–40°C to 105°C			0.45	V
I_Q	Quiescent current	V_{OUT} = Open, Switch enabled V_{IN} > 1.2 V	–40°C to 85°C		26	65	µA
			–40°C to 105°C			75	µA
		V_{OUT} = Open, Switch enabled V_{IN} ≤ 1.2 V	–40°C to 85°C		16	50	µA
			–40°C to 105°C			55	µA
I_{SD}	Shutdown current	V_{OUT} = GND, Switch disabled V_{IN}> 1.8 V	–40°C to 85°C		1.0	15	µA
			–40°C to 105°C			36	µA
		V_{OUT} = GND, Switch disabled V_{IN} ≤ 1.8 V	–40°C to 85°C		0.9	7	µA
			–40°C to 105°C			17	µA
R_{ON}	ON-resistance	I_{OUT} = –200 mA V_{IN} ≥ 1.8 V	25°C		6.8	10	mΩ
			–40°C to 85°C			12	mΩ
			–40°C to 105°C			12	mΩ
		I_{OUT} = –200 mA V_{IN} = 1.2 V	25°C		7.8	11	mΩ
			–40°C to 85°C			13	mΩ
			–40°C to 105°C			14	mΩ
		I_{OUT} = –200 mA V_{IN} = 0.65 V	25°C		11.5	17	mΩ
			–40°C to 85°C			21	mΩ
			–40°C to 105°C			22	mΩ
R_{PD}	Output pull down	I_{OUT} = 3 mA, Switch disabled V_{IN} = 3.6 V	–40°C to 105°C		150		Ω
		I_{OUT} = 3 mA, Switch disabled V_{IN} = 0.65 V	–40°C to 105°C		3		kΩ
I_{EN}	EN input leakage	V_{ON} =0 V to 3.6 V	–40°C to 105°C			0.1	µA
$I_{PG,LK}$	Leakage current into	V_{PG} = 0 V to 3.6 V V_{EN} ≤ V_{IL}	–40°C to 105°C			5.5	µA
T_{SD}	Thermal shutdown	T_J rising			165		°C
$T_{SD,HYS}$	Thermal shutdown hysteresis	T_J falling			25		°C

Note:

(1) Specifications subject to change without notice.

Switching Characteristics

All typical values are at 25°C unless otherwise noted.

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
V_{IN} = 3.6 V						
t_{ON}	Turn-on time	C_T = 0 pF		260		µs
		C_T = 2200 pF		2400		µs
t_R	VOUT rise time	C_T = 0 pF		160		µs
		C_T = 2200 pF		1800		µs
$t_{PG,ON}$	PG turn-on time	C_T = 0 pF		460		µs
		C_T = 2200 pF		2900		µs
$t_{PG,OFF}$	PG turn-off time			1.6		µs
t_{OFF}	turn-off time			4		µs
t_F	VOUT fall time	C_L = 0.1 µF, R_L = 10 Ω		3.5		µs
V_{IN} = 1.8 V						
t_{ON}	Turn-on time	C_T = 0 pF		200		µs
		C_T = 2200 pF		1400		µs
t_R	VOUT rise time	C_T = 0 pF		105		µs
		C_T = 2200 pF		950		µs
$t_{PG,ON}$	PG rurn-on time	C_T = 0 pF		375		µs
		C_T = 2200 pF		1900		µs
$t_{PG,OFF}$	PG turn-off time			1.2		µs
t_{OFF}	Turn-off time			5.5		µs
t_F	VOUT fall time	C_L = 0.1 µF, R_L = 10 Ω		3.8		µs
V_{IN} = 0.65 V						
t_{ON}	Turn-on time	C_T = 0 pF		230		µs
		C_T = 2200 pF		700		µs
t_R	V_{OUT} rise time	C_T = 0 pF		77		µs
		C_T = 2200 pF		220		µs
$t_{PG,ON}$	PG turn-on time	C_T = 0 pF		480		µs
		C_T = 2200 pF		1400		µs
$t_{PG,OFF}$	PG turn-off time			1.7		µs
t_{OFF}	Turn-off time			39		µs
t_F	V_{OUT} fall time	C_L = 0.1 µF, R_L = 10 Ω		7		µs

Note:

(1) Specifications subject to change without notice.

Typical Performance Characteristics

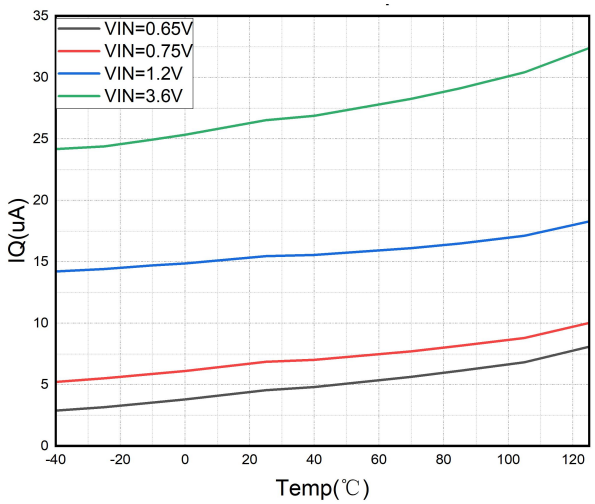


Figure 3. I_Q vs. Temperature

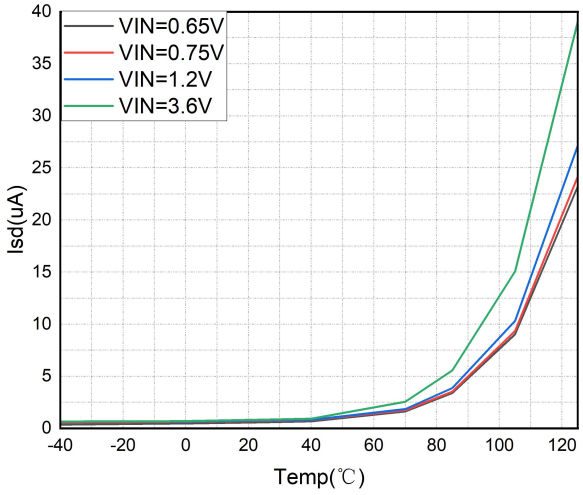
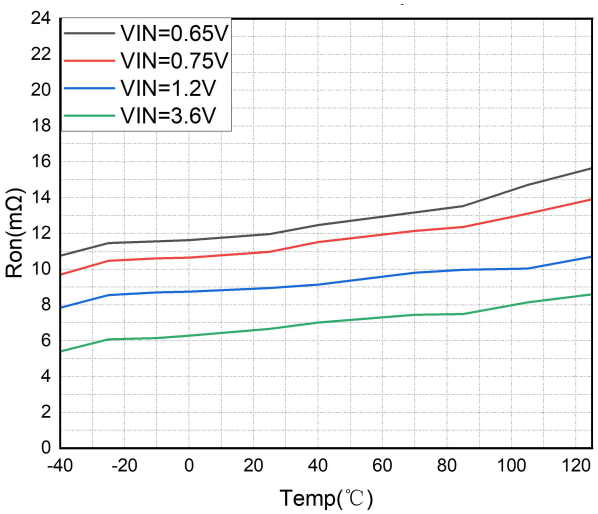


Figure 4. I_{SD} vs. Temperature



Load current = 200 mA

Figure 5. R_{ON} vs. Temperature

Block Diagram

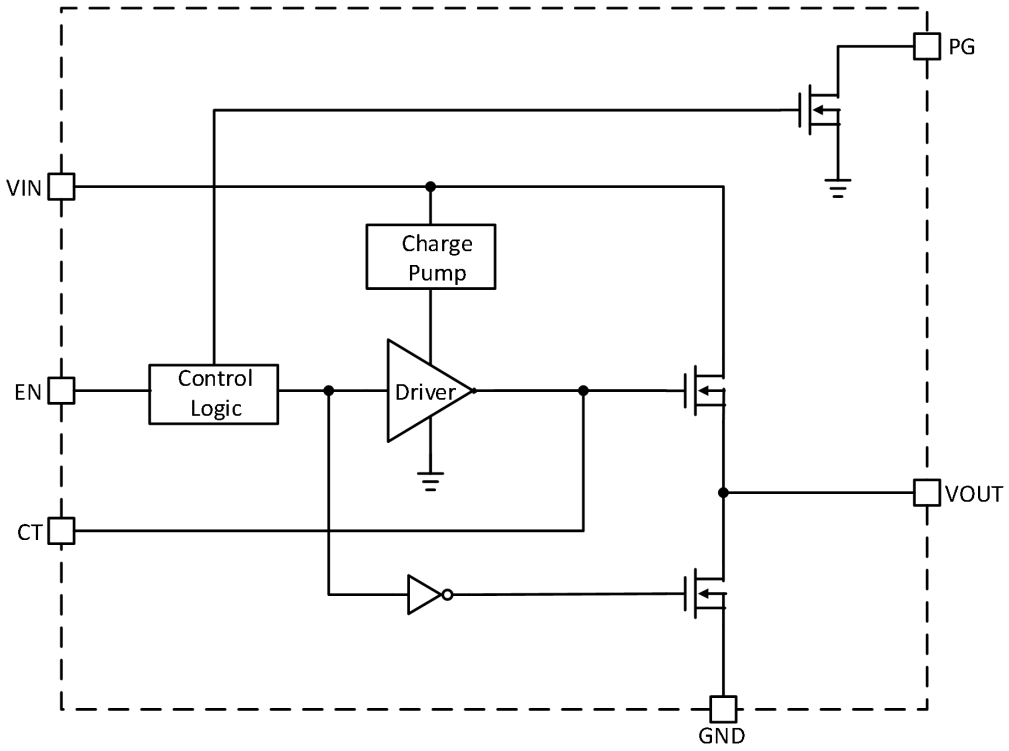


Figure 6. Block diagram

Feature Description

Overview

The DIO7971 is a single channel 3 A load switch in a small, space-saving WLCSP-8 package. This device contains a controlled rise time with a low resistance N-channel MOSFET to limit the inrush current for certain needs.

The inrush current caused by large bulk load capacitance for DIO7971 is minimized by the controlled rise time, thus minimizing or eliminating power supply droop. The design flexibility to trade off the inrush current and power-up timing requirements is provided by the adjustable slew rate. The status of the load switch is notified by the integrated PG indicator to facilitate seamless power sequencing.

The DIO7971 is designed to have a very low leakage current during the OFF state to avoid downstream circuits from pulling high standby current from the supply. The need for additional external components is eliminated by integrated control logic, driver, power supply, and output discharge FET, which reduces solution size and bill of materials (BOM) count.

On and off control

The state of the switch is controlled by the EN pin, by asserting EN high can enable the switch. EN can interface with low-voltage signals for its low threshold. The EN pin is compatible with any microcontroller with 1.2 V, 1.8 V, 2.5 V, or 3.3 V GPIOs. This pin cannot be left floating for proper functionality for it does not have an internal bias.

Controlled turn-on

For inrush current control, the DIO7971 has controlled turn-on, and the slew rate is adjusted by a capacitor to GND on the CT pin. For a given input voltage and desired slew rate.

Power good (PG)

The power good (PG) output signal of the device can indicate the gate of the pass FET is driven high and the switch is fully on (full load ready). The signal is an active high and open drain output that can be connected to a voltage source through an external pull-up resistor, R_{PU}. This voltage source can be V_{OUT} from the DIO7971 or another external voltage.

Quick output discharge (R_{DIS})

The DIO7971 has a R_{DIS} feature included. A discharge resistor is connected between V_{OUT} and GND when the switch is disabled, this resistor prevents the output from floating while the switch is disabled and has a typical value of 150 Ω.

Device functional modes

The Functional Table lists the functional modes for the DIO7971.

Functional table

DIO7971			
EN Pin	**V_{IN} to V_{OUT}**	**V_{OUT} to GND**	**PG to GND**
Below V_{IL}	OFF	ON	ON
Above V_{IH}	ON	OFF	OFF

Parameter measurement information

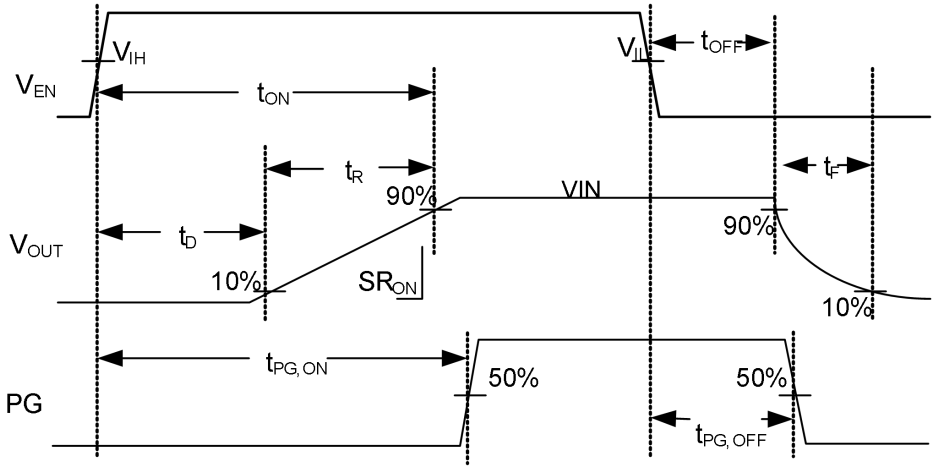


Figure 7. TAC timing waveform

Applications Information

Typical applications

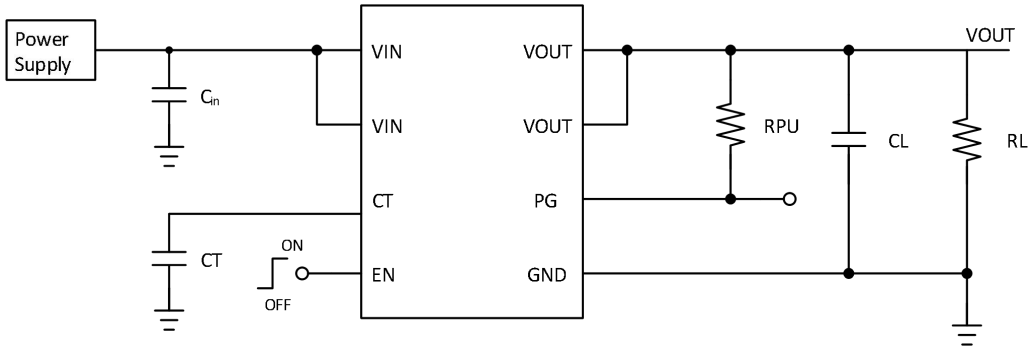


Figure 8. Typical application

Thermal consideration

Limiting the junction temperature (T_J) below 125°C is recommended. Use Equation (1) as a guideline to calculate the maximum allowable dissipation $P_{D(max)}$ for a given output current and ambient temperature.

$$P_{D(max)}=\frac{T_{J(max)}-T_A}{\theta_{JA}} \quad (1)$$

where

- $P_{D(max)}$ is maximum allowable power dissipation
- $T_{J(max)}$ is maximum allowable junction temperature
- T_A is ambient temperature of the device
- θ_{JA} is junction to air thermal impedance. See the Absolute Maximum Ratings section. This parameter is highly dependent upon board layout

PG pull up resistor

The PG output is an open drain signal connected to a voltage source through a pull-up resistor R_{PU}. The PG signal can drive the enable pins of downstream devices, EN. PG is active high, and its voltage is given by Equation (2).

$$V_{PG} = V_{OUT} - (I_{PG,LK} + I_{EN,LK}) \times R_{PU} \quad (2)$$

where

- V_{OUT} is the voltage where PG is tied to
- $I_{PG,LK}$ is the leakage current into PG pin
- $I_{EN,LK}$ is the leakage current into the EN pin driven by PG
- R_{PU} is the pull-up resistance

V_{PG} needs to be higher than $V_{IH,MIN}$ of the EN pin to be treated as logic high. The maximum R_{PU} is determined by Equation (3).

$$R_{PU,\ MAX}=\frac{V_{OUT}-V_{IH,MIN}}{I_{PG,LK}+I_{EN,LK}} \quad (3)$$

When PG is disabled, with 1 mA current into PG pin (I_{PG} = 1 mA), $V_{PG.OL}$ is less than 0.2 V and treated as logic low as long as $V_{IL,MAX}$ of the EN pin is greater than 0.2 V. The minimum R_{PU} is determined by Equation (4).

$$R_{PU\_MAX} = \frac{V_{OUT}}{I_{PG}+I_{EN,LK}} \quad (4)$$

Power sequencing

The DIO7971 has an integrated power good indicator which can be used for power sequencing.

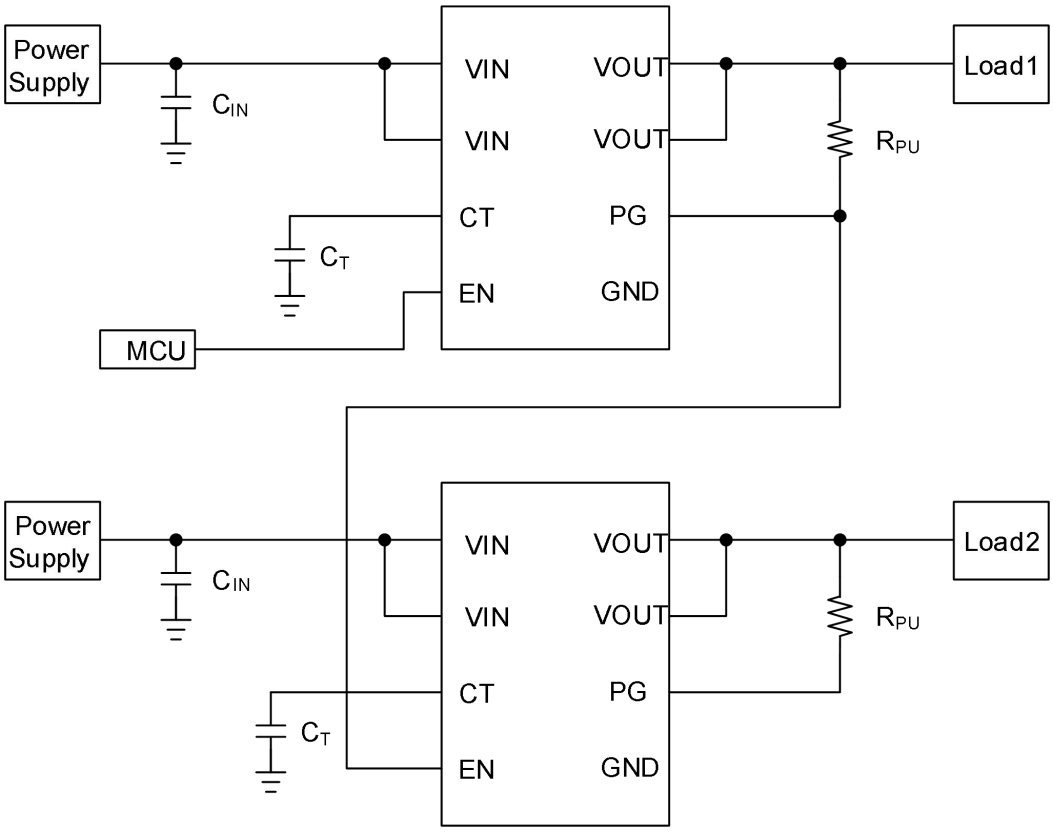


Figure 9. Power sequencing

Design requirements

For this design example, below, use the input parameters shown in the table below.

Design Parameter	Example Value
V_{IN}	3.6 V
I_{LOAD}	10 mA
Load Capacitance	33 µF
Maximum voltage drop	1%
Maximum inrush current	600 mA

Maximum voltage drop and on-resistance

The DIO7971 has a typical R_{ON} of 6.8 mΩ at 3.6 V input voltage with a maximum voltage drop tolerance of 1%. The rail is supplying 10 mA of current; the voltage drop for a rail is calculated based on Equation (5).

$$\Delta V = R_{ON} \times I_{LOAD} \quad (5)$$

$$\Delta V = 0.068\ mV \quad (6)$$

The maximum voltage drop is 1%, which is 36 mV. The voltage drop caused by the load current across the on resistance is 0.068 mV.

Managing inrush current

The output capacitors must be charged up from 0 V to V_{IN} when the switch is enabled. This charge arrives in the form of an inrush current. Given a load capacitance (C_L) of 33 µF, an input voltage (V_{IN}) of 3.6 V, and a maximum inrush (I_{INRUSH}) of 600 mA, use Equation (7) and Equation (8) to solve for Slew Rate (S_R).

$$S_R = \frac{I_{INRUSH}}{C_L} \quad (7)$$

$$S_R = 0.0182\ V/\mu s \quad (8)$$

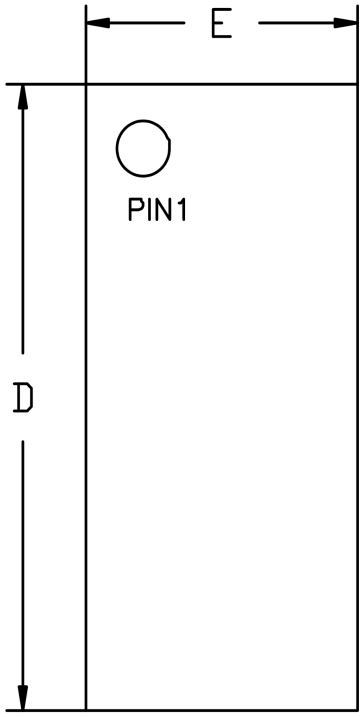
Power supply recommendations

The DIO7971 is designed to operate from a V_{IN} range of 0.65 V to 3.6 V. The V_{IN} power supply must be well regulated and placed as close to the device terminal as possible and must be able to withstand all transient load current steps. Normally, using an input capacitance of 1 µF is sufficient to prevent the supply voltage from dipping when the switch is turned on. The additional bulk capacitance may be required on the input in cases where the power supply is slow to respond to a large transient current or large load current step. The requirements for larger input capacitance can be mitigated by adding additional capacitance to the CT pin. This may slow the load switch from turning on, this reduces transient inrush current as well as gives the power supply more time to respond to the load current step.

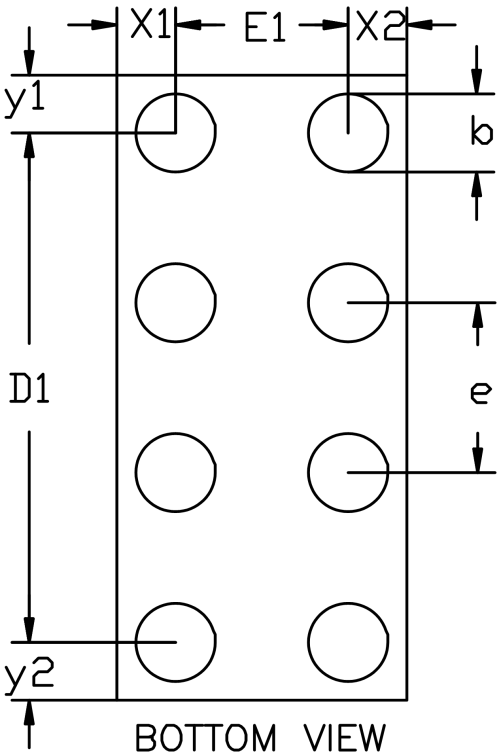
Layout

All traces should be as short as possible for best performance. To be most effective, the input and output capacitors should be placed close to the DIO7971 to minimize the effects that parasitic trace inductances may have on normal and short circuit operation. Using wide traces for VIN, VOUT, and GND helps minimize the parasitic electrical effects along with minimizing the case to ambient thermal impedance.

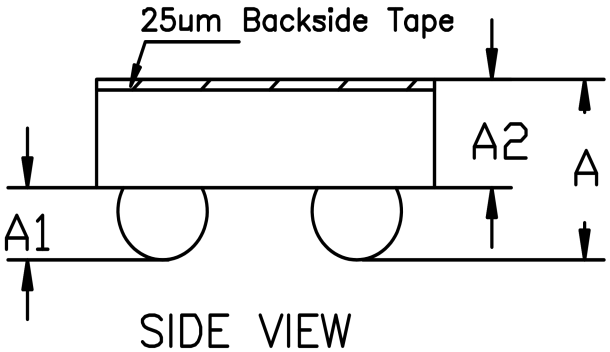
Physical Dimensions: WLCSP-8



TOP VIEW
(MARK SIDE)



BOTTOM VIEW
(BALL SIDE)



SIDE VIEW

Common Dimensions (Units of measure = Millimeter)			
Symbol	**Min**	**Nom**	**Max**
A	0.385	0.425	0.465
A1	0.150	0.170	0.190
A2	0.235	0.255	0.275
D	1.810	1.840	1.870
D1	1.500 BSC		
E	0.810	0.840	0.870
E1	0.500 BSC		
b	0.210	0.230	0.250
e	0.500 BSC		
x1	0.170 REF		
x2	0.170 REF		
y1	0.170 REF		
Y2	0.170 REF		

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