Click here for production status of specific part numbers.

MAX14914

High-Side Switch with Settable Current-Limiting, Push-Pull Driver Option and Digital Input Configuration

General Description

The MAX14914 is a high-side/push-pull driver that operates as both an industrial digital output (DO) and an industrial digital input (DI). The MAX14914 is specified for operation with supplies up to 40V. The high-side switch current is resistor settable from 135mA (min) to 1.3A (min). The high-side driver's on-resistance is 120mΩ (typ) at 125°C ambient temperature. Optional push-pull operation allows driving of cables and fast discharge of load capacitance. The output voltage is monitored and indicated through the $\overline{DOI_LVL}$ pin for safety applications.

The MAX14914 complies with Type 1, Type 2, or Type 3 input characteristics when configured for DI operation.

Applications

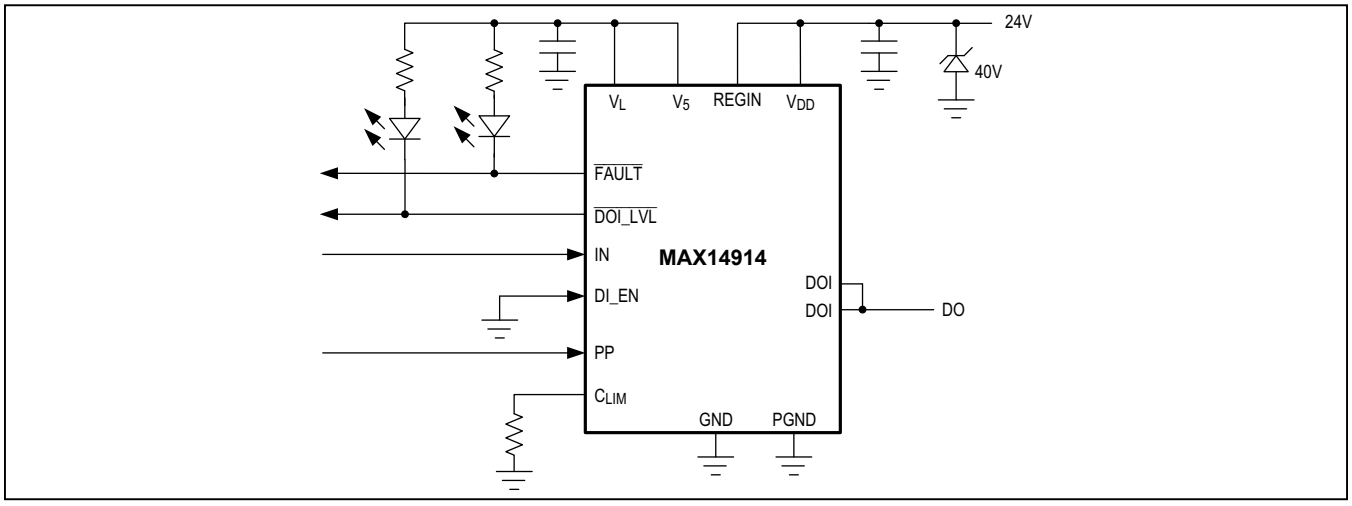
- Industrial Digital Outputs and Inputs Modules
- Configurable Digital Input/Output
- Motor Control
- Safety Systems

***Ordering Information* and *Functional Diagram* appears at end of data sheet.**

Benefits and Features

- Reduces Power and Heat Dissipation
  - 240mΩ (max) HS R_{ON} at T_A = 125°C
  - Accurate Short-Circuit Current Limit
  - Accurate Internal Current Limiter for Types 1, Type 2, and Type 3 Digital Inputs
- Enhances System Robustness
  - "Safe-Demagnetization" for Safe Turn-Off of Unlimited Inductance
  - 60V Supply Tolerance
  - Loss of GND Protection
  - Thermal Shutdown Protection
  - ±2kV IEC 61000-4-5 Surge Protection
  - ±20kV IEC 61000-4-2 Air-Gap ESD Protection
  - ±7kV IEC 61000-4-2 Contact ESD Protection
  - -40°C to +125°C Ambient Operating Temperature
- Reduces BOM Count and PCB Space
  - Small 4mm x 4mm TQFN Package
  - Internal Clamps for Fast Inductive Load Turn-Off
  - On-Chip 5V Regulator
- Provides Flexibility
  - Configurable as a Digital Input or a High-Side or Push-Pull Digital Output
  - Resistor Settable Current Limiting for the High-Side Switch (135mA - 1.3A)
  - 10V to 40V Operating Supply Range
- Improves System Speed and Throughput
  - Propagation Delay of Less Than 2µs

Typical DO Application Diagram



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Absolute Maximum Ratings

(All voltages referenced to GND)

V_{DD} .....-0.3V to +65V
REGIN .....-0.3V to lower of +65V and (V_{DD} + 0.3)V
PGND .....-0.3V to + 0.3V
DOI (V_{DD} < VDD_{OVLOTH}).....(V_{DD} - 49)V to (V_{DD} + 0.3)V
DOI (V_{DD} > VDD_{OVLOTH})..... -1V to (V_{DD} + 0.3)V
V5 ..... -0.3V to lower of +6V and (REGIN + 0.3)V
VL .....-0.3V to +6V
IN, PP, DIN_EN, $\overline{FAULT}$, CLIM .....-0.3V to +6V
$\overline{DOI_LVL}$ .....-0.3V to (VL + 0.3)V
OV_VDD.....-0.3V to lower of +65V and (V_{DD} + 0.3)V

DOI Load Current.....Internally Limited
Continuous Current (any other terminal)..... -100mA to +100mA
Continuous Power Dissipation
(T_A = +70°C, derate 28.6mW/°C above +70°C.).....2280mW
Inductive Demagnetization Energy (I_{LOAD} < 0.6A)..... Unlimited
Operating Temperature Range..... -40°C to +125°C
Junction Temperature.....Internally Limited
Storage Temperature Range..... -65°C to +150°C
Lead Temperature (Soldering, 10 sec).....+260°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions 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.

Package Thermal Characteristics (Note 1)

TQFN16
Junction-to-Ambient Thermal Resistance (θ_{JA}) .....35°C/W
Junction-to-Case Thermal Resistance (θ_{JC}).....2.7°C/W

Note 1: Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to **www.maximintegrated.com/thermal-tutorial**.

Electrical Characteristics

(V_{DD} = +10V to +40V, V5 = +4.5V to +5.5V, VL = +2.5V to +5.5V, R_{LIM} = 27kΩ to 220kΩ, T_A = -40°C to +125°C, unless otherwise noted. Typical values are at T_A = +25°C and V_{DD} = +24V, VL = +3.3V and V5 = +5V, R_{LIM} = 50kΩ) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
V_{DD} SUPPLY						
Supply Voltage	V_{VDD}	Operating Conditions	10		40	V
		Tolerant	0		60	V
Supply Current	$I_{VDD_ON_HS}$	HS mode, PP = low, IN = VL, DOI high (no switching), no load, V5 = VL = REGIN, V_{DD} = 40V		0.6	0.95	mA
	$I_{VDD_ON_PP}$	PP mode, PP = high, 10kHz switching, V5 = VL = REGIN, no load		0.85	1.4	
	$I_{VDD_ON_DI}$	DI_EN = VL, REGIN = 40V		0.13	0.3	
Undervoltage-Lockout Threshold	V_{VDD_UV}	V_{DD} rising, V5 = VL	8.5	9.1	9.7	V
		V_{DD} falling, V5 = VL	8	8.6	9	V
Undervoltage-Lockout Hysteresis	V_{VDD_UVHYST}	V5 = 5V		0.5		V
V_{DD} Overvoltage-Lockout Threshold	V_{VDD_OVLO}	V_{DD} rising, V5 = 5V	41.5	43.5	45	V
		V_{DD} falling, V5 = 5V	40.5	42.2	44	V
V_{DD} Overvoltage-Lockout Hysteresis	V_{VDD_OVHYST}	V5 = 5V		1		V
VL LOGIC INTERFACE SUPPLY						
VL Supply Voltage	V_{VL}		2.5		5.5	V
VL Supply Current	I_{VL}	All logic inputs high or low, all outputs unloaded		10	25	µA
VL POR Threshold	V_{VL_POR}	VL falling	1.12	1.27	1.52	V

Electrical Characteristics (continued)

(V_{DD} = +10V to +40V, V5 = +4.5V to +5.5V, VL = +2.5V to +5.5V, R_{LIM} = 27kΩ to 220kΩ, T_A = -40°C to +125°C, unless otherwise noted. Typical values are at T_A = +25°C and V_{DD} = +24V, VL = +3.3V and V5 = +5V, R_{LIM} = 50kΩ) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
5V SUPPLY/LINEAR REGULATOR						
REGIN Current HS Mode	$I_{REGIN_ON_HS}$	HS mode, REGIN = 40V, IN = VL, no load on DOI, no load on V5		0.3	0.5	mA
REGIN Current PP Mode	$I_{REGIN_ON_PP}$	PP = high, REGIN = 40V, 10kHz switching, no load on DOI, no load on V5		0.35	0.6	mA
REGIN Current DI Mode	$I_{REGIN_ON_DI}$	DI_EN=VL, REGIN = 40V			0.5	mA
V5 Supply Current	I_{V5HS}	HS Mode, REGIN = V5, IN = VL, no load on DOI		0.24	0.4	mA
	I_{V5PP}	PP Mode, REGIN = V5,10kHz switching, no load on DOI		0.3	0.5	mA
	I_{V5DI}	DI Mode, DI_EN = high, REGIN = V5		0.22	0.4	mA
REGIN Undervoltage-Lockout Threshold	V_{REG_UV}	REGIN rising	6.75		7.6	V
REGIN Undervoltage-Lockout Hysteresis	V_{REG_UVHYST}			0.45		V
V5 Undervoltage-Lockout Threshold	V_{V5_UV}	V5 rising	3.8		4.2	V
V5 Undervoltage-Lockout Hysteresis	V_{V5UV_UVHYST}			0.3		V
V5 Output Voltage	V_5	0mA – 20mA external load	4.75	5.0	5.25	V
V5 Current Limit	I_{V5_CL}		25			mA
DRIVER OUTPUT (DOI)						
HS On-Resistance	$R_{DOI_ON_HS}$	PP = X, IN = high, I_{DOI} = 500mA		120	240	mΩ
LS Output Low	V_{DOI_LOW}	PP = high, IN = low, I_{DOI} = 100mA			1.2	V
DOI Clamp Voltage	V_{DOI_CL}	Relative to V_{DD}, I_{DOI} = 500mA, $V_{VDD} < V_{VDD_OVLO}$	-63	-55	-49	V
		Relative to GND, I_{DOI} = 500mA, $V_{VDD_OVLO} < V_{VDD}$ <60V	-4.5	-2.9	-1.5	V
DOI Leakage	I_{DOI_LK}	V_{DD} = 40V, PP = IN = low, DI_EN = low, 0V< V_{DOI} < V_{VDD}	-60		60	µA
		V_{DD} = 60V, PP = IN = X, DI_EN = low, 0V < V_{DOI} < V_{VDD}	-150		150	
OUTPUT DRIVER CURRENT LIMITING (DOI)						
HS Current-Limit Minimum	$I_{CLIM_HS_MIN}$	R_{LIM} = 220kΩ	135	196	255	mA
HS Current-Limit Maximum	$I_{CLIM_HS_MAX}$	R_{LIM} = 27kΩ	1.3	1.6	1.9	A
HS Current-Limit Offset Error	$I_{CLIM_HS_OE}$	(Note 3)	-25		+25	mA
HS Current-Limit Gain Error	$I_{CLIM_HS_GE}$	(Note 3)	-20		+20	%

Electrical Characteristics (continued)

(V_{DD} = +10V to +40V, V5 = +4.5V to +5.5V, VL = +2.5V to +5.5V, R_{LIM} = 27kΩ to 220kΩ, T_A = -40°C to +125°C, unless otherwise noted. Typical values are at T_A = +25°C and V_{DD} = +24V, VL = +3.3V and V5 = +5V, R_{LIM} = 50kΩ) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
CLIM Voltage	V_{CLIM}			1.21		V
CLIM Short Resistor Threshold Value	R_{LIM_SHORT}	(Note 4)	10	12.9	15	kΩ
CLIM Open Resistor Threshold Value	R_{LIM_OPEN}	(Note 5)	440		750	kΩ
LS Current Limit	I_{CLIM_LS}		150		280	mA
DIGITAL INPUT / DOI MONITOR						
DO Monitor Threshold Voltage	V_{TH_DO}	DI_EN = low, DOI rising	1.5		2.0	V
		DI_EN = low, DOI falling	1.3		1.8	
DO Monitor Hysteresis	V_{HYS_DO}	DI_EN = low		0.2		V
DI Threshold Voltage	V_{TH_DI}	DI_EN = high, DOI rising	6.7		8	V
		DI_EN = high, DOI falling	5.5		6.8	
DI Hysteresis	V_{HYS_DI}	DI_EN = high		1.2		V
DI Current Sink Type 1, 3	I_{DOI}	DI_EN = high, PP = low, 0V< V_{DOI}< 5V			2.6	mA
		DI_EN = high, PP = low, 8V< V_{DOI} < 40V V_{DOI} < V_{DD}	2.0	2.3	2.6	
DI Current Sink Type 2	I_{DOI}	DI_EN = high, PP = high, 0V < V_{DOI} < 5V	0		7.5	mA
		DI_EN = high, PP = high, 8V < V_{DOI} < 40V, V_{DOI} < V_{DD}	6.0	7.0	7.7	
LOGIC (I/O)						
Input Voltage High	V_{IH}		0.7 x V_{VL}			V
Input Voltage Low	V_{IL}				0.3 x V_{VL}	V
Input Threshold Hysteresis	V_{IHYST}			0.11 x V_{VL}		V
Input Pulldown Resistor	R_I	All logic input pins	140	200	275	kΩ
Output Logic-Low	V_{OL}	I_{LOAD} = +5mA			0.33	V
$\overline{DOI_LVL}$ Tristate Leakage	I_{LEAK}	GND < V_{DOI_LVL} < VL	-1		+1	µA
$\overline{FAULT}$ Tristate Leakage	I_{LEAK}	GND < $V_{\overline{FAULT}}$ < V5	-1		+1	µA
OV_VDD Leakage	I_{LEAK}	GND < V_{OV_VDD} < V_{DD}	-1		+1	µA
THERMAL PROTECTION						
Driver Thermal-Shutdown Temperature	T_{JSHDN}	Junction temperature rising		170		°C
Driver Thermal-Shutdown Hysteresis	T_{JSHDN_HYST}			15		°C
Chip Thermal Shutdown	T_{CSHDN}	Temperature rising		150		°C
Chip Thermal-Shutdown Hysteresis	T_{CSHDN_HYST}			10		°C

Electrical Characteristics (continued)

(V_{DD} = +10V to +40V, V5 = +4.5V to +5.5V, VL = +2.5V to +5.5V, R_{LIM} = 27kΩ to 220kΩ, T_A = -40°C to +125°C, unless otherwise noted. Typical values are at T_A = +25°C and V_{DD} = +24V, VL = +3.3V and V5 = +5V, R_{LIM} = 50kΩ) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
TIMING CHARACTERISTICS						
OUTPUT DRIVER (DOI)						
Output Propagation Delay LH	t_{PD_LH}	PP = X, delay from IN to DOI rising by 1V, R_L = 5kΩ, C_L = 100pF (Figure 1)		0.4	1.5	µs
Output Propagation Delay HL	t_{PD_HL}	PP = low, delay between IN switching low to DOI falling by 1V. R_L = 5kΩ, C_L = 100pF, V_{DD} = 24V (Figure 1)		0.6	1.5	µs
		PP = high, delay between IN switching low to DOI falling by 1V. R_L = 5kΩ, C_L = 100pF (Figure 1)		0.6	1.5	
DOI Output Rise Time	t_R	PP = X, 20% to 80% VDD, R_L = 5kΩ, C_L = 100pF, (Figure 2)		0.9	2	µs
DOI Output Fall Time	t_F	PP=high, 80% to 20% VDD, VDD = 24V, R_L = 5kΩ, C_L = 100pF (Figure 2)		0.65	2	µs
		PP=low, 80% to 20% VDD, VDD = 24V, R_L = 47Ω, C_L = 100pF (Figure 2)		1		
PROPAGATION DELAY (DOI toDOI_LVL)						
Propagation Delay LH	t_{PDL_LH}	DI_EN = low, delay from DOI rising to 5V to $\overline{DOI_LVL}$ low (Figure 3)		2.7	5	µs
Propagation Delay LH DI	$t_{PDL_LH_DI}$	DI_EN = high, delay from DOI rising to 8V to $\overline{DOI_LVL}$ low		1.1		µs
Propagation Delay HL	t_{PDL_HL}	DI_EN = low, delay from DOI falling to 3.5V to $\overline{DOI_LVL}$ high		0.9	8	µs
Propagation Delay HL DI	$t_{PDL_HL_DI}$	DI_EN = high, delay from DOI falling to 5.5V to $\overline{DOI_LVL}$ high		0.9		µs
GLITCH REJECTION (IN)						
Pulse Length of Rejected Glitch	t_{FPL_GF}		0		80	ns
Glitch Filter Delay Time	t_{D_GF}			140	300	ns
FAULT DETECTION (OV_VDD, FAULT)						
OV_VDD Threshold	$V_{TH_OV_VDD}$	DI_EN = low, relative to V_{DD}		0.22		V
OVLO_VDD Debounce Time	TD_{OVLO_VDD}	DI_EN = low		200		µs
OVLO_VDD Output Leakage	$I_{LK_OV_VDD_}$	0 < I_{OV} < VDD	-1		+1	µA
FAULT Output Leakage	I_{LK_FAULT}	0 < I_{FAULT} < 5V	-1		+1	µA

Note 2: All units are production tested at T_A = +25°C. Specification over temperature are guaranteed by characterization and design.
Note 3: Specification is guaranteed by design; not production tested.
Note 4: Lower resistor values than CLIM_SHORT act like a CLIM pin short to GND.
Note 5: Higher resistor values than CLIM_OPEN act like a CLIM open circuit.

ESD and Surge Protection

PARAMETER	SYMBOL	CONDITIONS	TYP	UNITS
ESD	V_{ESD}	DOI pin contact (Note 6)	±7	kV
		DOI pin Air Discharge (Note 6)	±20	kV
		All other pins. Human Body Model	±2	kV
IEC Surge	V_{SURGE}	DOI to PGND or Earth GND per IEC 61000-4-5 (42Ω/0.5µF) (Note 7)	±2	kV

Note 6: Bypass V_{DD} pin to PGND with 1µF capacitor as close as possible to the device for high ESD protection.
Note 7: With a TVS protection on V_{DD} to PGND.

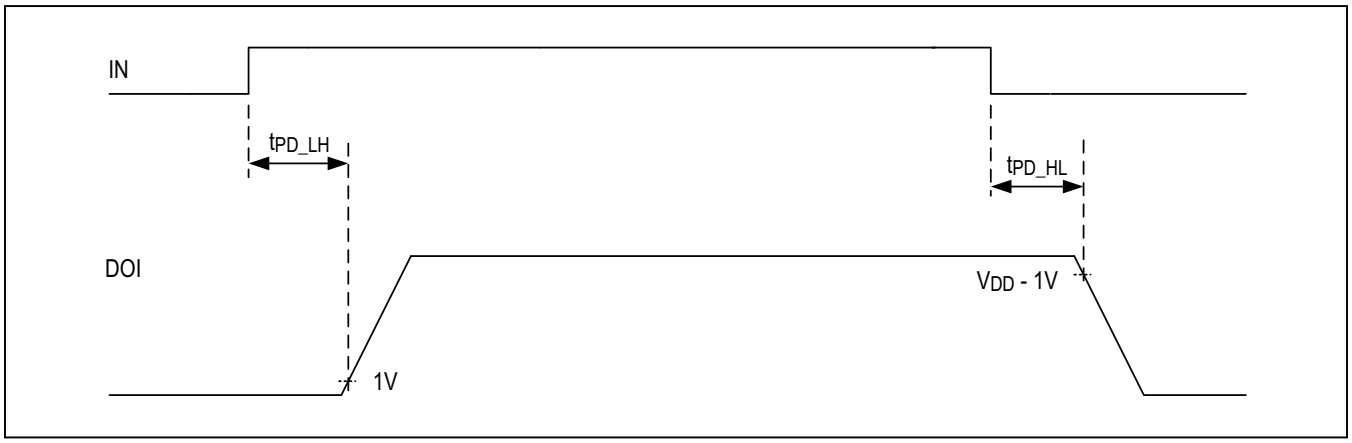


Figure 1. IN to DOI Propagation Delay

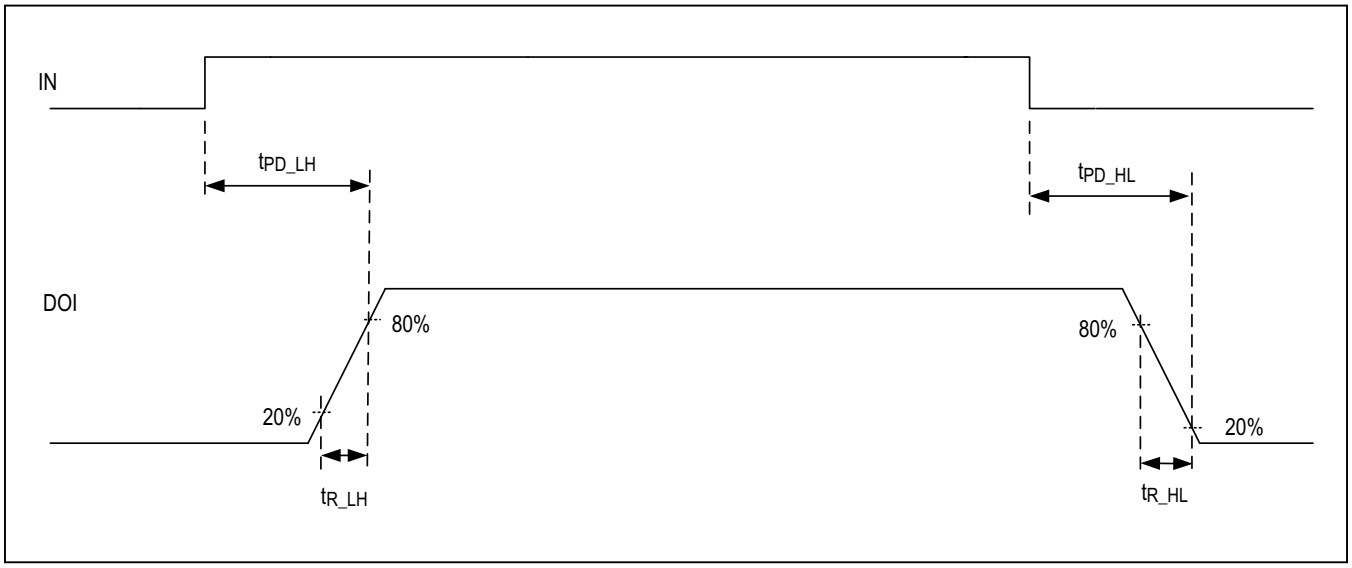


Figure 2. DOI Rise and Fall Time

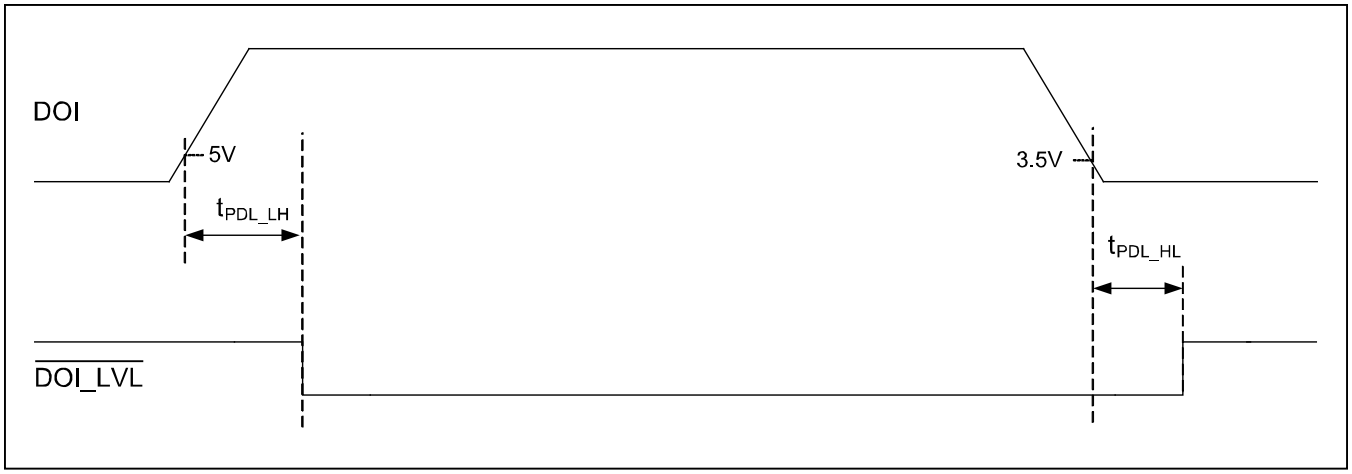
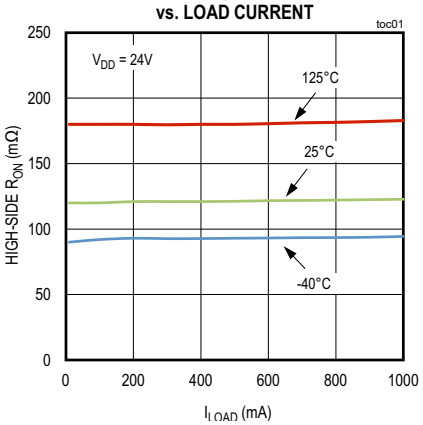


Figure 3. DOI to $\overline{DOI_LVL}$ Propagation Delay

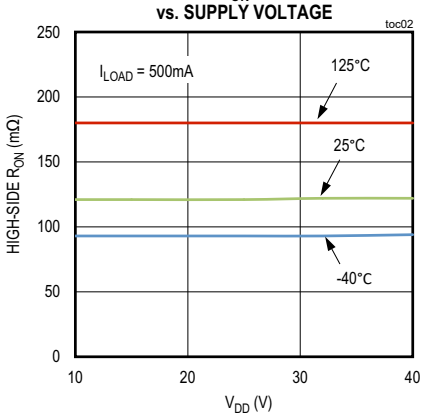
Typical Operating Characteristics

(V_{DD} = +24V, VL = +3.3V and V5 = +5V, T_A = +25°C, unless otherwise noted.)

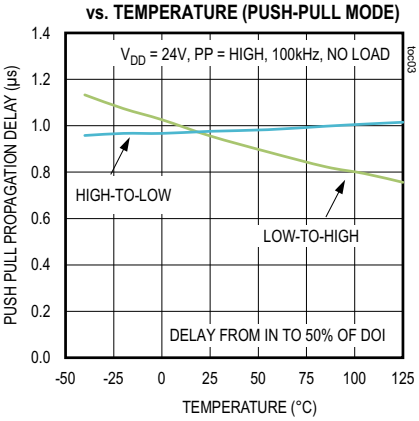
HIGH-SIDE R_{ON} RESISTANCE vs. LOAD CURRENT



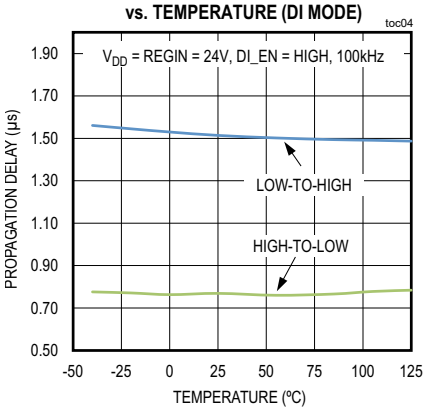
HIGH-SIDE R_{ON} RESISTANCE vs. SUPPLY VOLTAGE



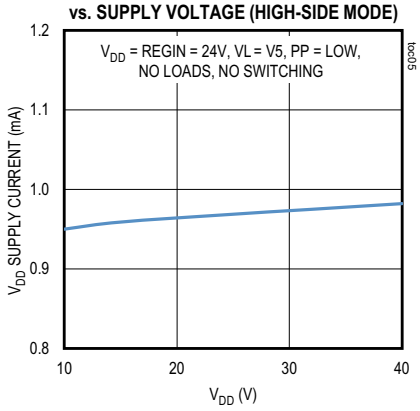
PROPAGATION DELAY vs. TEMPERATURE (PUSH-PULL MODE)



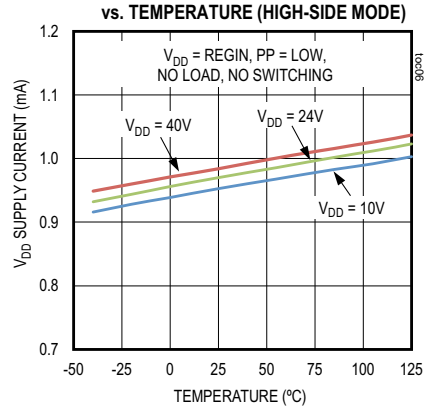
PROPAGATION DELAY vs. TEMPERATURE (DI MODE)



SUPPLY CURRENT vs. SUPPLY VOLTAGE (HIGH-SIDE MODE)



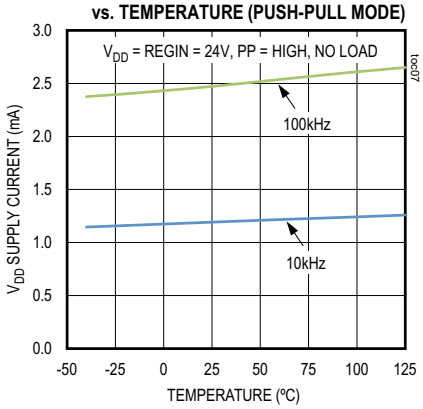
SUPPLY CURRENT vs. TEMPERATURE (HIGH-SIDE MODE)



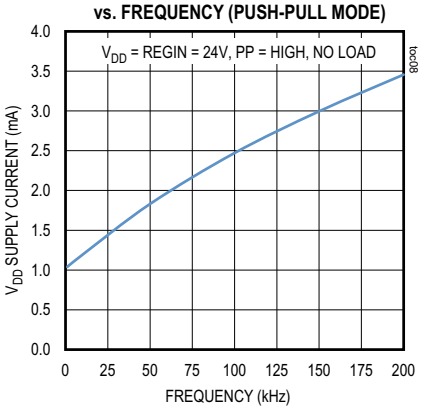
Typical Operating Characteristics (continued)

(V_{DD} = +24V, VL = +3.3V and V5 = +5V, T_A = +25°C, unless otherwise noted.)

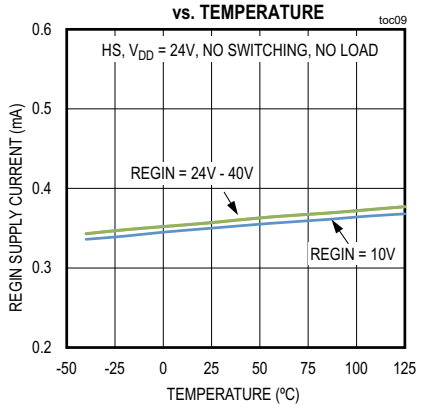
SUPPLY CURRENT vs. TEMPERATURE (PUSH-PULL MODE)



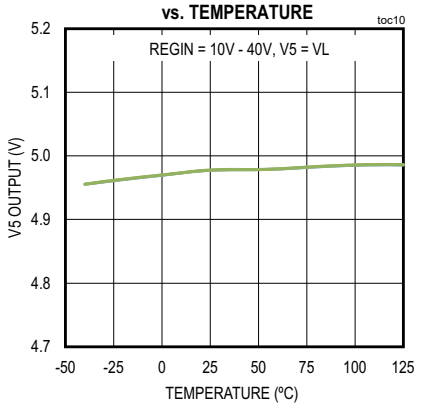
SUPPLY CURRENT vs. FREQUENCY (PUSH-PULL MODE)



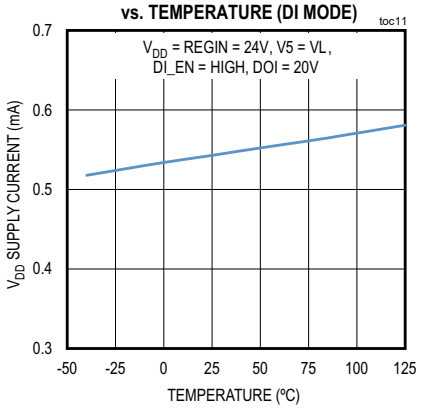
REGIN SUPPLY CURRENT vs. TEMPERATURE



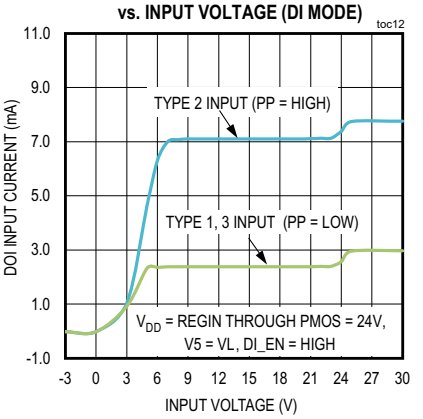
V5 OUTPUT vs. TEMPERATURE



SUPPLY CURRENT vs. TEMPERATURE (DI MODE)



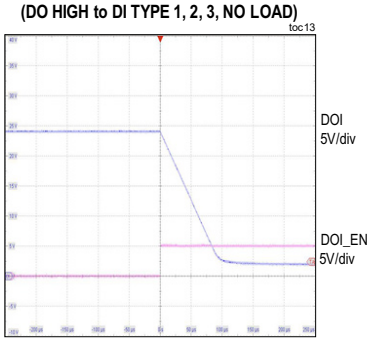
DOI INPUT CURRENT vs. INPUT VOLTAGE (DI MODE)



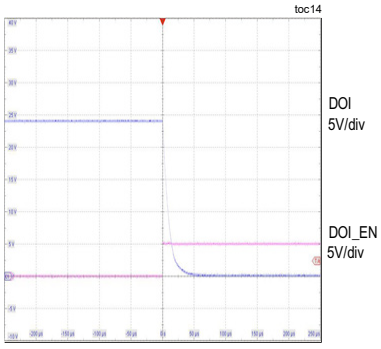
Typical Operating Characteristics (continued)

(V_{DD} = +24V, VL = +3.3V and V5 = +5V, T_A = +25°C, unless otherwise noted.)

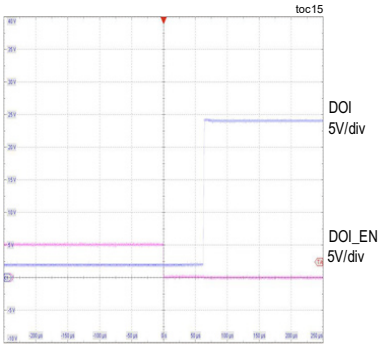
DO to DI MODE TRANSITION
(DO HIGH to DI TYPE 1, 2, 3, NO LOAD)



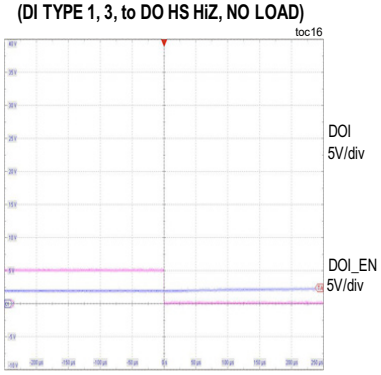
DO TO DI MODE TRANSITION
(DO HIGH TO DI TYPE 1, 2, 3, 1k LOAD)



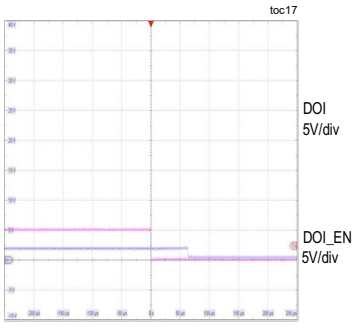
DI to DO MODE TRANSITION
(DI TYPE 1, 2, 3, to DO HIGH, NO LOAD)



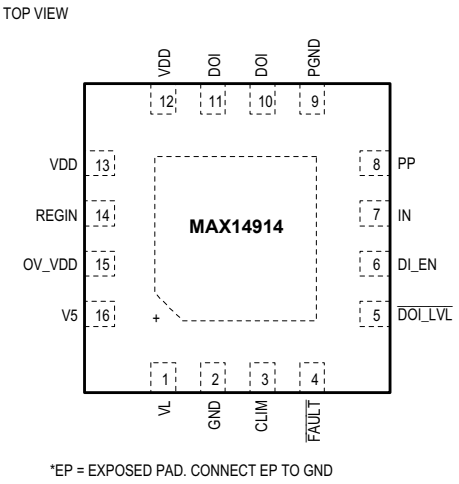
DI to DO MODE TRANSITION
(DI TYPE 1, 3, to DO HS HiZ, NO LOAD)



DI to DO MODE TRANSITION
(DI TYPE 2 to DO PP LOW, NO LOAD)



Pin Configuration



*EP = EXPOSED PAD. CONNECT EP TO GND

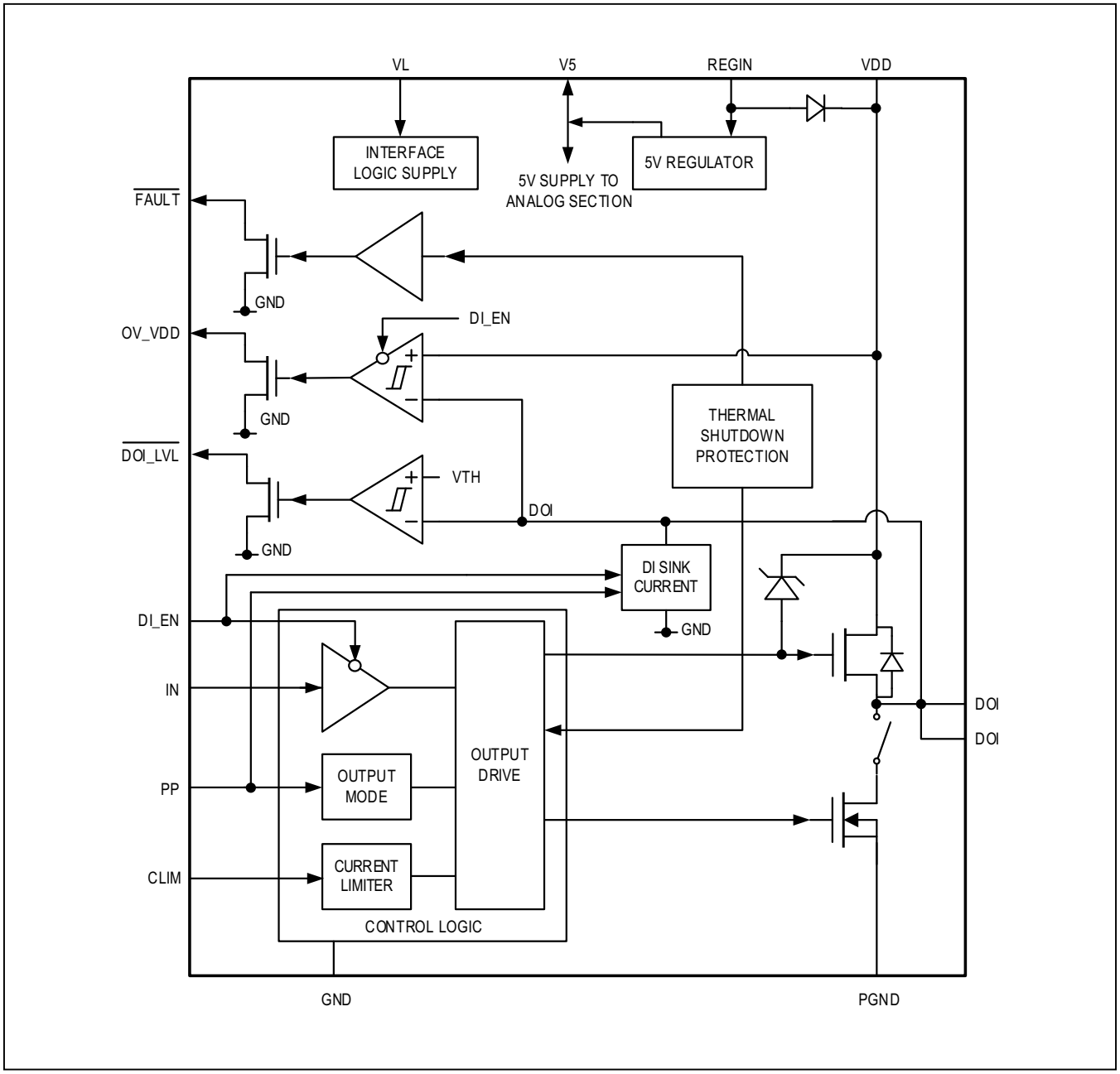
Pin Description

PIN	NAME	FUNCTION
1	VL	Logic Supply Input. VL defines the levels on all I/O logic interface pins. Bypass VL to GND through a 100nF ceramic capacitor.
2	GND	Analog Ground.
3	CLIM	Current Limit Set Input. Connect a resistor from CLIM to GND to set the current limit. See *Detailed Description* for further information.
4	$\overline{\text{FAULT}}$	Open-Drain Fault Output. The $\overline{\text{FAULT}}$ transistor turns on when a fault condition (driver thermal shutdown or loss of ground) occurs. Connect a pullup to VL or V5.
5	$\overline{\text{DOI_LVL}}$	Open-Drain DOI Level Output. $\overline{\text{DOI_LVL}}$ is logic-low when the DOI voltage is higher than the threshold voltage. $\overline{\text{DOI_LVL}}$ is logic-high when the DOI voltage is lower than the threshold voltage. The threshold voltage depends on DI_EN.
6	DI_EN	Digital Input Mode Logic Enable Input. Set DI_EN high to enable digital input operation on the DOI pin, which enables the internal current sink and sets Type 1, Type 2, or Type 3 thresholds on $\overline{\text{DOI_LVL}}$. Select between Type 1 and 3 and Type 2 DI characteristics through the PP input.
7	IN	Switch Control Input. Drive IN high to close the HS switch; drive IN low to open the HS switch and close the LS switch (when PP = low).
8	PP	Push-Pull DO or DI Type Select Input. In DO mode, set PP high to enable push-pull mode operation of the DO driver. In DI mode, set PP low for IEC Type 1/3 input characterisitcs and set high for Type 2 input characteristics.
9	PGND	Power Ground
10,11	DOI	High-Side/Push-Pull Output (DI_EN = low) or Digital Input (DI_EN = high). Connect both DOI pins together externally.
12, 13	VDD	Supply Voltage, Nominally 24V. Bypass V_{DD} to GND through a 1µF capacitor.
14	REGIN	5V Regulator Input. Connect REGIN to V_{DD} when using the internal 5V regulator. Connect REGIN to V5 when powering V5 from an external regulator.
15	OV_VDD	Open-Drain Overvoltage Output. The OV_VDD transistor turns off when: 1) a device configured for DI operation; 2) DOI level is higher than V_{DD}
16	V5	Analog Supply Voltage/LDO Output. The MAX14914 requires a 5V supply for normal operation, which can come from the internal linear regulator (REGIN connected to VDD) or from an external regulator (REGIN connected to V5).

Table 1. Operation Truth Table

MODE	DI_EN	IN	PP	DOI	DOI_LVL
DO High-Side	0	0	0	Three-state	1/0
	0	1	0	1	0
DO Push-Pull	0	0	1	0	1
	0	1	1	1	0
DI Type 1, 3	1	X	0	0	1
	1	X	0	1	0
DI Type 2	1	X	1	0	1
	1	X	1	1	0

Functional Diagram



Detailed Description

The MAX14914 is a high-side/push-pull driver that operates as an industrial digital output and can also operate as an industrial digital input. The MAX14914 is specified for operation with supplies up to 40V. The high-side switch current limiting is resistor settable from 135mA (min) to 1.3A (min). The high-side driver's on-resistance is 120mΩ (typ) and 240mΩ (max) at +125°C ambient temperature. Optional push-pull operation allows driving of cables and fast discharge of load capacitance. A separate digital $\overline{DOI_LVL}$ allows supervision of the DOI voltage in DO mode for safety applications. The MAX14914 complies with IEC Type 1, Type 2, or Type 3 input characteristics when configured for digital input operation.

5V Supply and Regulator

The MAX14914 requires a 5V supply on the V5 pin for normal operation. This 5V supply can come from an external supply or from the internal 5V linear regulator. Connect REGIN pin to V_{DD} to enable the internal regulator. Connect REGIN pin to V5 pin to disable the internal regulator, when an external 5V is used. The internal 5V regulator also can power the external loads/circuits with of up to 20mA.

Logic Interface

The logic interface features flexible logic levels, allowing interfacing to a wide range of common logic. The VL supply input defines the logic levels and can be set in the range of 2.5V to 5.5V. Connect a 0.1µF capacitor to VL.

Digital Output Operation

The driver can be configured for high-side (PP pin is driven low) or push-pull (PP pin is driven high) operation. In DO high-side mode, the DOI output voltage is high (V_{DD}) when the logic level on IN pin is high, and three-state (Hi-Z), when the logic level on IN pin is low. In DO push-Pull mode, the DOI output voltage follows the logic level on IN pin. The high-side driver has 240mΩ (max) on-resistance at 500mA and T_A = 125°C. The DOI voltage can go below ground, as will occur during inductive load demagnetization. An internal clamping diode limits the negative excursion to (V_{DD} - V_{CL}). See *Driving Inductive Loads* for details. The low-side (LS) switch speeds up the discharge of RC loads in Push-Pull mode.

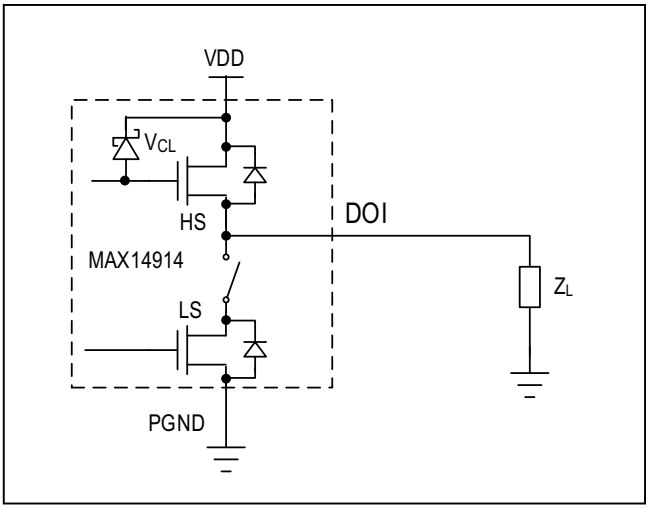


Figure 4. Digital Output Driver

Current Limit Adjustment

The MAX14914 has a settable current limiting of the HS switch. The load current is limited to between 135mA (min) and 1.3A (min), depending on the value of the resistor used at the CLIM pin. A short-circuit or overcurrent generally creates a temperature rise in the chip; both the HS and LS FET's temperatures are continuously monitored. When any switch temperatures exceed 170°C, the DOI output is put in Hi-Z until the temperature falls by 15°C. Connect a resistor (R_{LIM}) from CLIM to GND to set the required current limit. The current is given by:

$$I_{LIM} = K \times V_{LIM}/R_{LIM}$$

where, V_{LIM} = 1.21V and K = 35.6 x 10^3

If no resistor is connected to CLIM (i.e., CLIM is kept floating) or R_{LIM} is more than 440k, the I_{LIM} is internally set to 1.1A (typ). If the R_{LIM} resistor is less than 12.9k (typ), the output is turned off. CLIM is short-circuit protected.

Use the formulas below to validate the accuracy range

$$I_{LIM_MAX} = I_{LIM} \times (1 + |I_{CLIM_HS_GE}|/100) + |I_{CLIM_HS_OE}|$$

$$I_{LIM_MIN} = I_{LIM} \times (1 - |I_{CLIM_HS_GE}|/100) - |I_{CLIM_HS_OE}|$$

Low-Side Current Limit

The low-side transistor has fixed-current limiting, when enabled in push-pull mode (PP driven high). The low-side driver limits current at 200mA (typ). The load current is actively controlled and the low-side switch only turns off if the driver temperature has fallen by the hysteresis value.

Short Circuit Protection

Short circuits at the DOI output will generate high transient current until the active current limiting kicks in. In order to protect the MAX14914 against high currents that can be seen over an extended time, especially if the output is switching at a high rate into a short circuit, the MAX14914 enters a protect mode. When the MAX14914 detects that the DOI current is over 3x higher than the set current limit, the driver is switched to protect mode with reduced turn-on slew rate of the rising and falling edges for a duration of 4ms. The $\overline{FAULT}$ signal does not become active and the chip operates normally, but with reduced slew rate. If the cause for the short circuit is not removed, the protect mode will remain for an additional 4ms until the short circuit is removed.

Overvoltage Lockout

When the V_{DD} supply voltage exceeds the OVLO threshold voltage of 42.2V (typ), for a time duration larger than 200µs, the high-side and low-side switches automatically turn off. They remain off until V_{DD} is reduced to below the threshold OVLO voltage minus hysteresis. When V_{DD} is above the OVLO threshold, the OV_VDD output goes active.

Undervoltage Lockout

When the V_{DD}, V5, or VL supply voltages are under their respective UVLO thresholds the DOI driver is turned off (three-stated). DOI will automatically turn back on, once V_{DD}, V5, and VL rise above their UVLO threshold.

Driving Capacitive Loads

When charging/discharging purely capacitive loads with a push-pull driver, the driver dissipates power that is proportional to the switching frequency. The power can be estimated by $P_D \sim C \times V_{DD}^2 \times f$, where C is the load capacitance, V_{DD} is the supply voltage, and *f* is the switching frequency. For example, in an application with a 10nF load and 10kHz switching frequency, the driver dissipates 130mW at V_{DD} = 36V. Therefore, switching a higher capacitance can induce thermal shutdown and that limits the operational frequency.

Driving Inductive Loads

The DOI pins can be pulled below ground potential when the high-side transistor is off. The MAX14914 has an internal clamping diode from V_{DD} to DOI that limits the negative voltage excursion to (V_{DD} - 55V) typ. Turning off the current flowing in ground-connected inductive loads will result in a negative voltage at DOI pin that is limited to V_{DOI_CL} below V_{DD} by the internal clamping diodes. The MAX14914 features SafeDemag, meaning that there are no limits for load inductance that it can demagnetize, for load currents of up to 600mA.

Turn-off of large inductive loads with currents larger than 600mA requires an external clamping diode, as shown in Figure 5. The clamping (breakdown) voltage of such diode needs to be less than V_{DOI_CL}: $V_Z < V_{DOI_CL}$. Ensure that the Zener diode is able to dissipate the energy.

Monitoring of the DOI Output

The driver output (DOI) is monitored in both high-side and push-pull modes and corresponding logic level can be seen through the inversed $\overline{DOI_LVL}$ logic output. The threshold voltage for the $\overline{DOI_LVL}$ comparator is between 1.5V and 2.0V. This feature is useful for functional safety applications.

Digital Input Operation

The MAX14914 can operate as an industrial digital input. Drive the DI_EN pin high to enable digital input operation. The 2.3mA/7mA internal current sink on DIO is then enabled and the $\overline{DOI_LVL}$ logic output presents the inverse of the DOI logic, with threshold voltages compliant with IEC61131-2 Type 1, Type 2, or Type 3 levels.

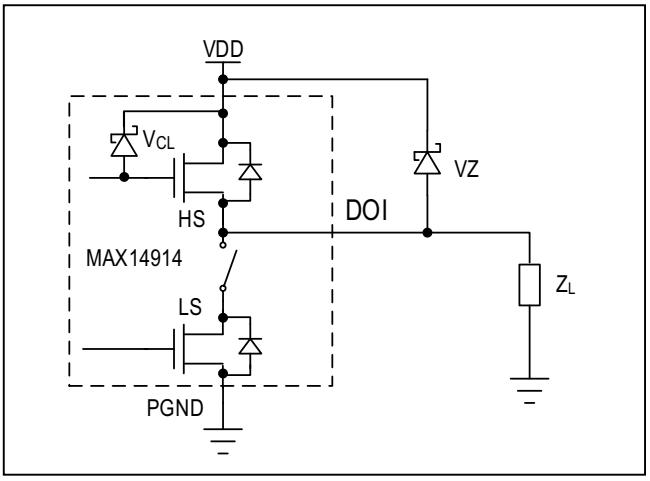


Figure 5. External Inductive Load Clamping

IN DI mode, the PP input allows selection between IEC Type 1/3 and Type 2 input characteristics. Set PP low for Type 1/3 compatibility and set PP high for Type 2 compatibility.

In order to allow the DOI input voltage to go above the V_{DD} supply voltage and preventing race condition, an external Schottky diode can be placed in series with the V_{DD} supply, as shown in Figure 6. Alternatively, an external PMOS transistor can be placed in series with the 24V supply, as shown in Figure 7, to allow the DOI voltage to exceed V_{DD}. The gate of the PMOS can be driven by the open drain OV_VDD output. When DI_EN = high, the OV_VDD pin turns the PMOS off permanently.

Therefore, V_{DD} is one forward diode voltage (of the PMOS) below the external 24V field supply, when the DOI voltage is less than the field supply voltage. The MAX14914 is parasitically powered by the external DOI input, when the DOI voltage is higher than the V_{DD} supply.

Note that the power dissipation increases strongly when Type 2 DI mode is selected (PP = high), particularly with high DOI input voltages due to the 7mA (typ) current sink. When the VDOI voltage exceeds 42.5V (typ) the sink current is automatically decreased from 7mA (typ) to 2.3mA (typ) to reduce the power dissipation.

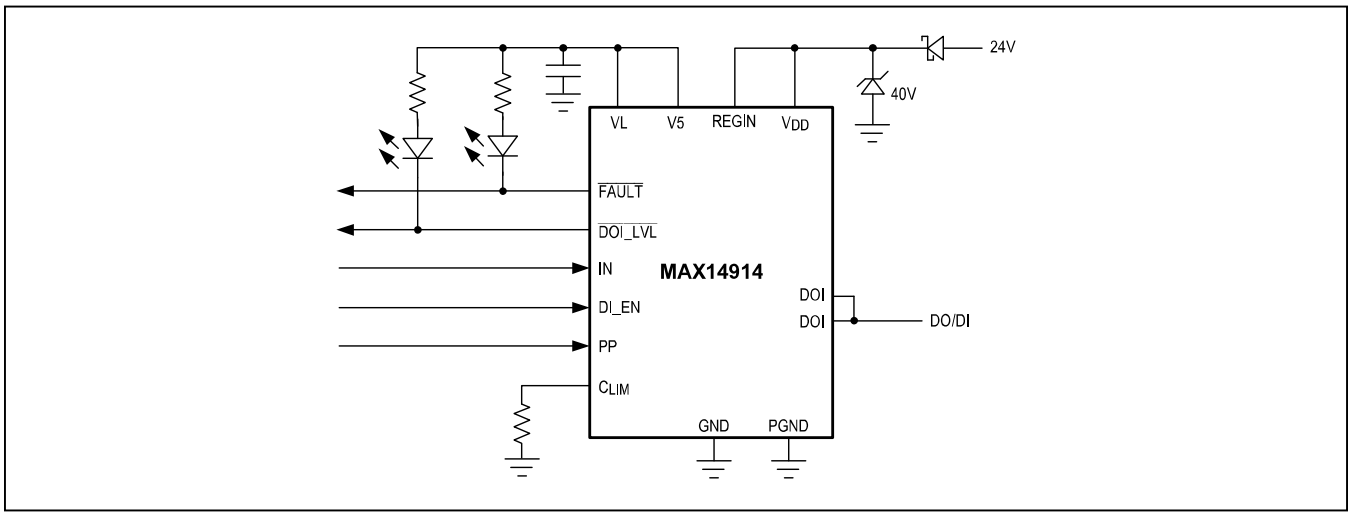


Figure 6. DO/DI Configuration with External Schottky Diode

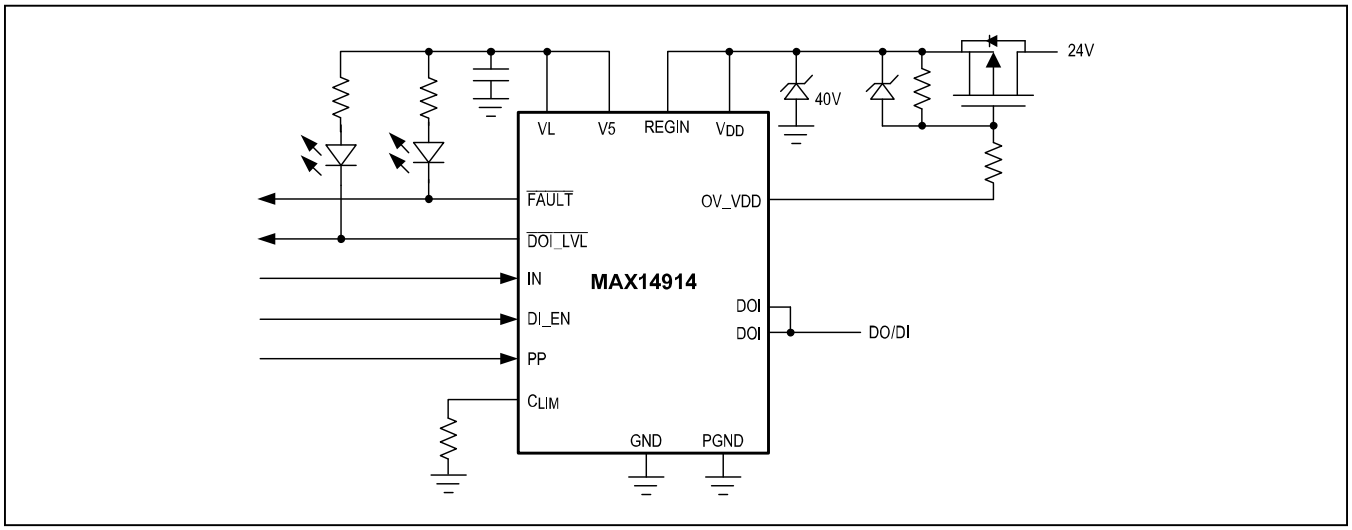


Figure 7. DO/DI Configuration with External pMOSFET

Diagnostics and FAULT Conditions

Thermal Shutdown Fault

The driver's temperature is constantly monitored while V_{DD} > V_{DD_UV}. If the temperature of the driver rises above the thermal shutdown threshold of 170°C (typ), the channel is automatically turned off for protection.

After the temperature drops below 150°C, the drivers will be turned on again.

Both high-side and low-side drivers are thermally protected.

The V5 regulator is also thermally protected and it is switched off if chip temperature rises above the thermal shutdown threshold of150°C (typ). When the driver turns off due to thermal shutdown a fault is indicated through the global $\overline{FAULT}$ output.

FAULT Conditions

The $\overline{FAULT}$ pin is a pulldown open-drain output. The pulldown transistor is turned on ($\overline{FAULT}$ goes low) as soon as any of the following conditions becomes true:

- Driver Thermal-protection activated ($\overline{DOI_LVL}$ low)
- Chip thermal-protection activated ($\overline{DOI_LVL}$ low)
- Loss of ground event ($\overline{DOI_LVL}$ high)

During a loss of ground event with large inductive load, the inductor energy might be partially dissipated by V_{DD} TVS diode. To avoid stress on TVS diode set IN pin low when Loss of ground event fault is detected.

$\overline{FAULT}$ does not go active for any other conditions, like over- or under-voltage. Therefore, monitoring both FAULT and $\overline{DOI_LVL}$ by microcontroller is recommended.

Applications Information

Power Supply Requirement

If the MAX14914 is powered from a single 24V power supply, then the REGIN pin must be connected to the V_{DD} pin. In this case, the MAX14914 will be powered from the internal +5V voltage regulator. It is also possible to power the device from an external 5V supply. In this case, the REGIN pin should be connected to V5 pin, allowing the external power supply to power the chip through the V5 pin and bypassing the internal regulator.

In both cases, the VL pin should be provided with the appropriate logic level. All three supply pins (V_{DD}, V5, and VL) should be bypassed with at least 0.1µF low-ESR ceramic capacitor to ground.

Layout Considerations

The PCB designer should follow some critical recommendations in order to get the best performance from the design.

- Keep the input/output traces as short as possible. Avoid using vias to make low-inductance paths for the signals.
- Have a solid ground plane underneath the high-speed signal layer.

A suppressor/TVS diode should be used between V_{DD} and PGND to clamp positive-surge transients on the V_{DD} supply input and surges from DOI. The standoff voltage should be higher than the maximum operating voltage of the device while the breakdown voltage should be below 65V.

As long field-supply cables can generate large voltage transients on the V_{DD} supply due to large dI/dt, it is recommended to add a large 10µF capacitor on V_{DD} at the point of field supply entry.

Surge Protection

DOI is protected against ±2kV/42Ω surge pulses as per IEC61000-4-5. Thus, no external surge suppression is needed on DOI. A suppressor/TVS diode (SMBJ40A, for example) should be used between V_{DD} and PGND to clamp high-surge transients on the V_{DD} supply input and surges from DOI. The breakdown voltage of TVS should be higher than the maximum operating voltage of the equipment, while the maximum clamping voltage should be below 70V.

Conducted RF Immunity

To insure that the DOI driver, configured for HS mode with the switch turned off, is not turned on during IEC61000-4-6 RF immunity testing, a 10nF capacitor should be applied between the DOI output and PGND. For PP mode a capacitor on DOI is not needed.

Reverse Current into DOI

Reverse current flow into DOI pin in DO mode will heat up the device and can destroy it thermally. The allowed reverse current depends on V_{DD}, the ambient temperature and the thermal resistance. At 25°C ambient temperature the continuous reverse current into DOI pin should be limited to 250mA at V_{DD} = 40V and 400mA at V_{DD} = 24V.

Using a PMOS transistor or a Schottky diode (as shown in Figure 6 and Figure 7) removes the reverse current flow path into the 24V field supply.

Ordering Information

PART	PACKAGE	BODY SIZE	PIN PITCH	TEMP RANGE (°C)
MAX14914ATE+	TQFN16	4mm x 4mm	0.65mm	-40 to +125
MAX14914ATE+T	TQFN16	4mm x 4mm	0.65mm	-40 to +125

+Denotes a lead (Pb)-free/RoHS-compliant package
T = Tape and Reel

Chip Information

PROCESS: BiCMOS

Package Information

For the latest package outline information and land patterns (footprints), go to **www.maximintegrated.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

PACKAGE TYPE	PACKAGE CODE	OUTLINE NO.	LAND PATTERN NO.
16 TQFN	T1644-4C	**21-0139**	**90-0070**

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	12/16	Initial release	—
1	7/17	Corrected pin number in *Pin Description* section and updated various typos	1, 10, 13
2	12/17	Updated *Electrical Characteristics* global specifications	2–5
3	6/18	Updated *Electrical Characteristics* table, Typical Operating Characteristics section, Pin Description table, Funcation Diagram, and Figures 4 and 5	5, 9, 10, 12–14

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