

## MAX25400

## Automotive Hi-Speed USB 2.0 Protector

### General Description

The MAX25400 device provides high-ESD and short-circuit protection for the low-voltage internal USB data and USB power line in automotive radio, navigation, connectivity, and USB hub applications. The device supports USB Hi-Speed (480Mbps), USB full-speed (12Mbps), and USB low-speed (1.5Mbps) operation. The short-circuit protection features include short-to-BUS and short-to-battery on the protected HVD+ and HVD-, and include a fault output.

The device features high-ESD protection to  $\pm 15\text{kV}$  Air Gap and  $\pm 8\text{kV}$  Contact on the protected HVD+ and HVD- outputs. The device features two low on-resistance ( $R_{ON}$ ) USB 2.0 data switches.

The MAX25400 is available in a 12-pin lead-free, TQFN-EP package and operate over the  $-40^{\circ}\text{C}$  to  $105^{\circ}\text{C}$  temperature range.

### Applications

Automotive USB Protection

### Benefits and Features

- Targeted Features for Optimized USB Performance
  - Two  $R_{ON}$   $3.3\Omega$  (typ) USB 2.0 Data Switches
  - 480Mbps, 12Mbps, or 1.5Mbps USB 2.0 Operation
  - 9ms Fault-Recovery Time
- Robust for the Automotive Environment
  - Short-to-Battery and Short-to-BUS Protection on Protected HVD+ and HVD- Outputs
  - Tested to ISO 10605 and IEC 61000-4-2 ESD
- Standards
  - 12-Pin (3mm x 3mm) TQFN-EP Package
  - $-40^{\circ}\text{C}$  to  $+105^{\circ}\text{C}$  Operating Temperature Range
  - AEC-Q100 Qualified

**Ordering Information appears at end of datasheet.**

---

**TABLE OF CONTENTS**


---

General Description . . . . .	1
Applications . . . . .	1
Benefits and Features . . . . .	1
Absolute Maximum Ratings . . . . .	4
Electrical Characteristics . . . . .	4
Typical Operating Characteristics . . . . .	8
Pin Configuration . . . . .	9
MAX25400 . . . . .	9
Pin Description . . . . .	9
Functional Diagrams . . . . .	10
Functional Block Diagram . . . . .	10
Detailed Description . . . . .	11
BUS Undervoltage Lockout (Power-On Reset) . . . . .	11
HVD+ and HVD- Overvoltage Protection . . . . .	11
FAULT Output . . . . .	11
Applications Information . . . . .	12
Power-Supply Bypass Capacitor . . . . .	12
Layout of USB Data Line Traces . . . . .	12
±25kV ESD Protection . . . . .	12
ESD Test Conditions . . . . .	12
Human Body Model . . . . .	12
IEC 61000-4-2 . . . . .	12
Human Body Test Model . . . . .	13
Human Body Current Waveform . . . . .	14
IEC 61000-4-2 ESD Test Model . . . . .	15
IEC 61000-4-2 Current Waveform . . . . .	16
Typical Application Circuits . . . . .	17
Typical Operating Circuit . . . . .	17
Ordering Information . . . . .	17
Revision History . . . . .	18

---

**LIST OF FIGURES**

---

Figure 1. Timing Diagram For UnderVoltage Lockout on BUS .....	5
Figure 2. Timing Diagram for Overvoltage Protection on HVD+, HVD-.....	6
Figure 3. On-Channel -3dB Bandwidth and Crosstalk .....	6
Figure 4. On-Capacitance .....	7
Figure 5. Propagation Delay and Output Skew .....	7
Figure 6. Human Body ESD Test Model .....	13
Figure 7. Human Body Current Waveform .....	14
Figure 8. IEC 61000-4-2 ESD Test Model .....	15
Figure 9. IEC 61000-4-2 ESD Generator Current Waveform .....	16

## Absolute Maximum Ratings

BUS, IN	-0.3V to +6V	Operating Ambient Temperature Range	-40°C to +105°C
FAULT, D+, D-	-0.3V to +6V	Maximum Junction Temperature	+150°C
D+, D- to IN	+0.3V	Storage Temperature Range	-60°C to +150°C
HVD+, HVD-	-0.3V to +18V	Lead Temperature (soldering) (10s)	+300°C
Continuous Power Dissipation 12-Pin TQFN (Four Layer Board derate 21.3mW/°C above +70°C) (TA = +70°C)	1704mW	Soldering Temperature (reflow)	+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.

## Electrical Characteristics

(V<sub>BUS</sub> = 5.0V V<sub>IN</sub> = +3.3V, T<sub>J</sub> = T<sub>A</sub> = -40°C to +105°C. R<sub>L</sub> = ∞, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C, unless otherwise noted. (Note 1))

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>POWER SUPPLY</b>						
Power Supply Range (BUS)	V <sub>BUS</sub>		4.75		5.5	V
Power Supply Range (IN)	V <sub>IN</sub>		3.0		3.6	V
BUS Input Current	I <sub>BUS</sub>	No load, no fault		125		μA
V <sub>IN</sub> Input Current	I <sub>IN</sub>	No load, no fault			12	μA
BUS Undervoltage Lockout	V <sub>UVLO</sub>	V <sub>BUS</sub> falling (Figure 1)	3.85	4.2	4.55	V
<b>USB DATA SWITCH</b>						
Analog Signal Range			0		3.6	V
Protection-Trip Threshold	V <sub>OV_D</sub>	HVD+, HVD- rises from V <sub>IN</sub> to > V <sub>IN</sub> +1V (Figure 2)			3.9	V
Protection-Recovery Time	t <sub>FPR_D</sub>	HVD+, HVD- falling to below V <sub>OV_D</sub> (Figure 2)	6	9	11	ms
Protection-Response Time	t <sub>FP_D</sub>	HVD+, HVD- rises from V <sub>IN</sub> to > V <sub>IN</sub> +1V (Figure 2)		0.5	1	μs
On-Resistance	R <sub>ON</sub>	V <sub>BUS</sub> = 5V, I <sub>L</sub> = 40mA, 0 ≤ V <sub>D</sub> ≤ 3.6V		3.3		Ω
On-Resistance Match Between Channels	ΔR <sub>ON</sub>	V <sub>BUS</sub> = 5V, I <sub>L</sub> = 40mA, V <sub>D</sub> = 1.5V, 3.0V			0.25	Ω
On-Resistance Flatness	R <sub>FLAT(ON)</sub>	I <sub>L</sub> = 40mA, V <sub>D</sub> = 0V or 0.4V			0.25	Ω
HVD+, HVD- Off-Leakage Current	I <sub>HVD_OFF</sub>	V <sub>HVD+</sub> , V <sub>HVD-</sub> = 18V, V <sub>D+</sub> , V <sub>D-</sub> = 0V			20	μA
		V <sub>HVD+</sub> , V <sub>HVD-</sub> = 18V, V <sub>D+</sub> /V <sub>D-</sub> = 0V, V <sub>IN</sub> = 0V, V <sub>BUS</sub> = 0V			20	
HVD+, HVD- On-Leakage Current	I <sub>HVD_ON</sub>	V <sub>HVD+</sub> , V <sub>HVD-</sub> = V <sub>IN</sub>			5	μA
On Channel -3dB Bandwidth	BW	R <sub>L</sub> = 50Ω, Source Impedance = 50Ω (Figure 5)		864		MHz
<b>FAULT OUTPUT</b>						
FAULT Output Low Voltage	V <sub>OL</sub>	I <sub>SINK</sub> = 500μA			0.5	V

**Electrical Characteristics (continued)**

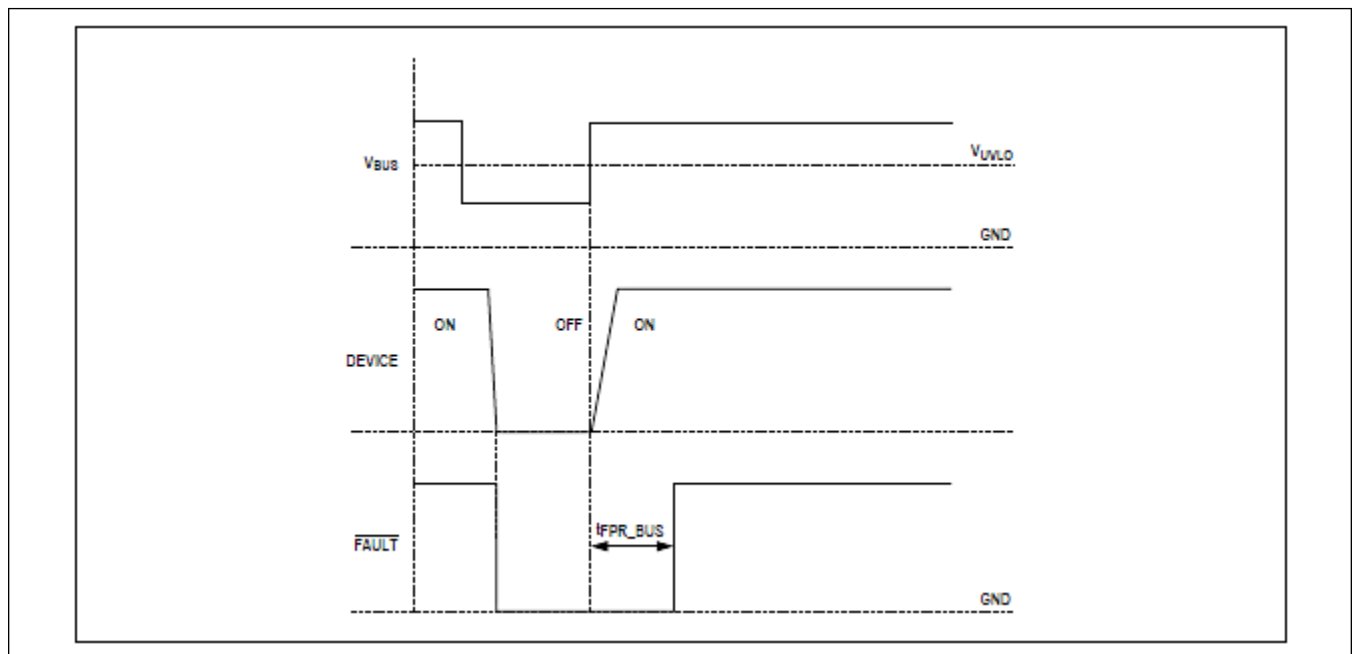
( $V_{BUS} = 5.0V$ ,  $V_{IN} = +3.3V$ ,  $T_J = T_A = -40^{\circ}C$  to  $+105^{\circ}C$ .  $R_L = \infty$ , unless otherwise noted. Typical values are at  $T_A = +25^{\circ}C$ , unless otherwise noted. (Note 1))

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
FAULT Output High Leakage Current					1	$\mu A$
FAULT Recovery Time	$t_{FPR}$	$\overline{FAULT} = V_{IN}$ (Figure 3)	6	9	11	ms
<b>ESD PROTECTION D+, D-, BUS, FAULTB, VIN</b>						
ESD Protection Level	$V_{ESD}$	Human Body Model		$\pm 2$		kV
<b>ESD PROTECTION HVD+, HVD-</b>						
ESD Protection Level	$V_{ESD}$	ISO 10605 Air Gap (330pF, 2k $\Omega$ )		$\pm 25$		kV
		ISO 10605 Contact (330pF, 2k $\Omega$ )		$\pm 8$		
		IEC 61000-4-2 Air Gap (150pF, 330 $\Omega$ )		$\pm 25$		
		IEC 61000-4-2 Contact (150pF, 330 $\Omega$ )		$\pm 8$		
<b>Thermal Protection</b>						
Thermal Shutdown				165		$^{\circ}C$
Thermal Shutdown Hysteresis				15		$^{\circ}C$

**Note 1:** Specifications with minimum and maximum limits are 100% production tested at  $T_A = +25^{\circ}C$  and are guaranteed over the operating temperature range by design and characterization. Actual typical values may vary and are not guaranteed.

**Note 2:** Guaranteed by design. Limits are not production tested.

**Note 3:** Tested in the Typical Application Circuit, as shown on the evaluation kit.



**Figure 1. Timing Diagram For UnderVoltage Lockout on BUS**

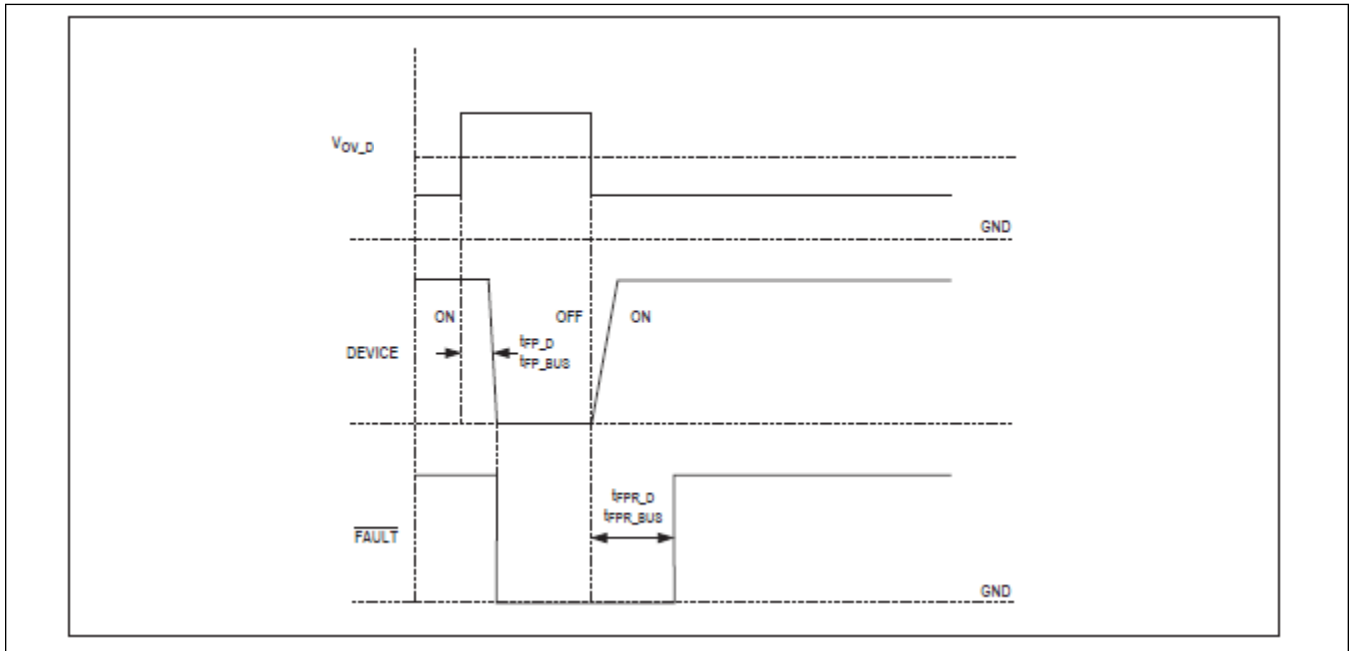


Figure 2. Timing Diagram for Overvoltage Protection on HVD+, HVD-

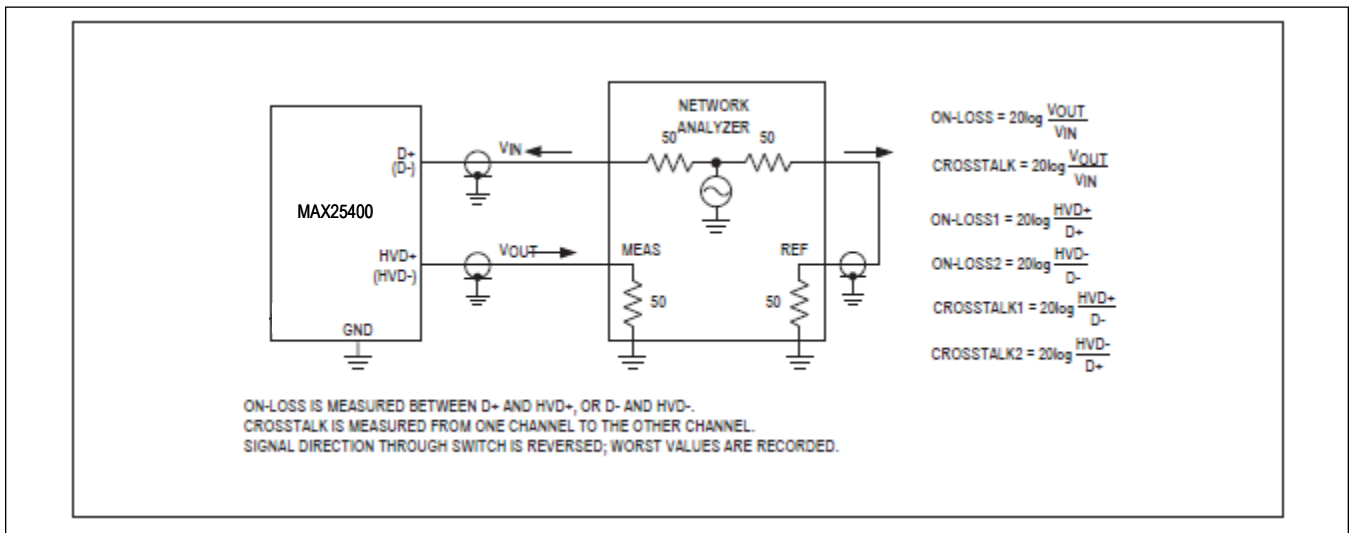


Figure 3. On-Channel -3dB Bandwidth and Crosstalk

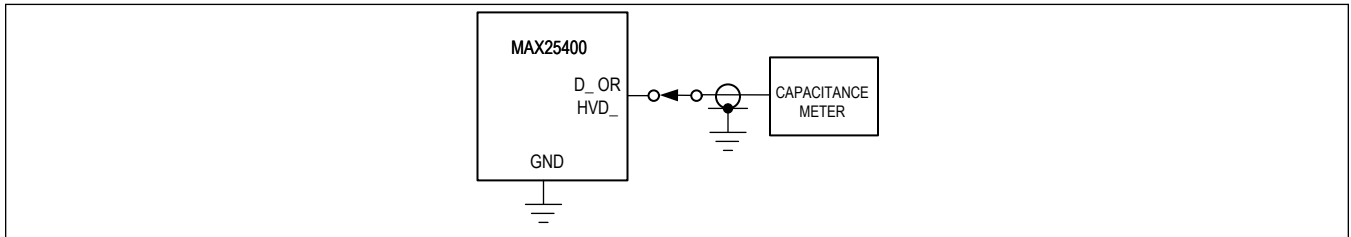


Figure 4. On-Capacitance

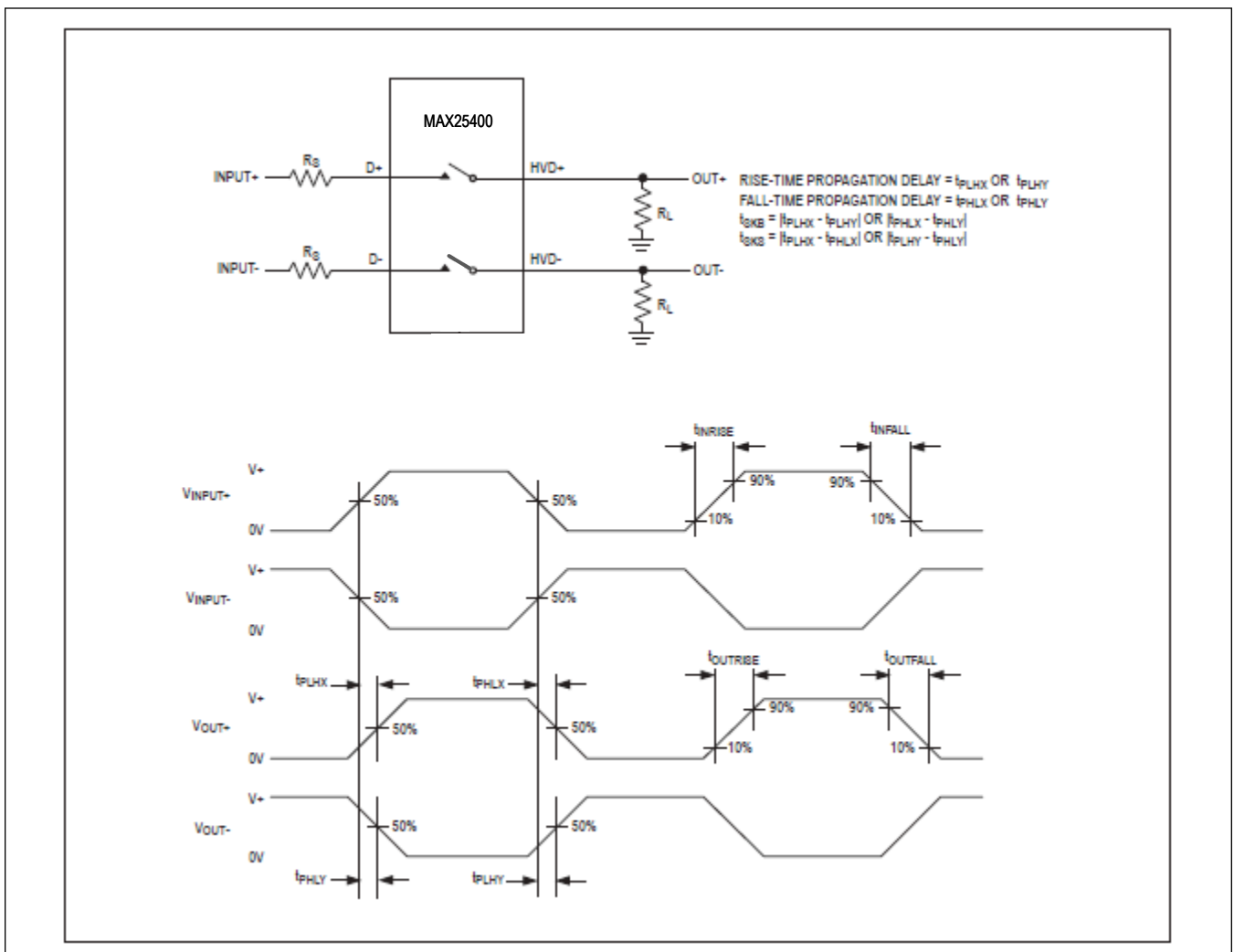
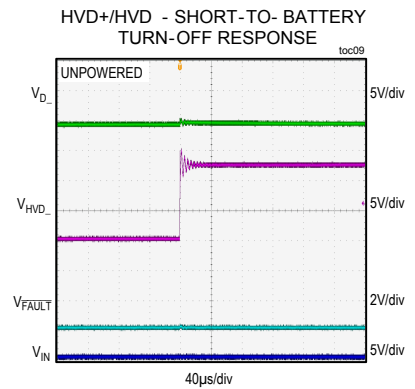
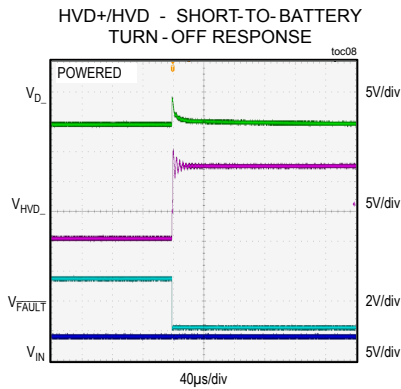
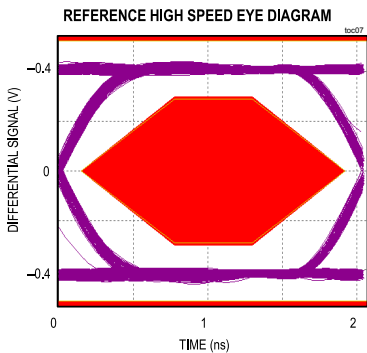
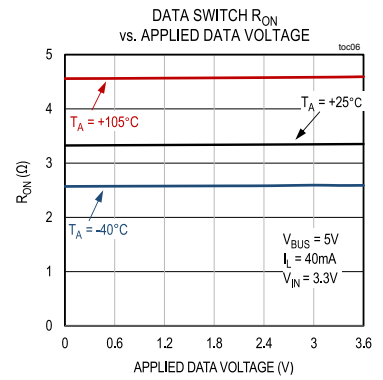
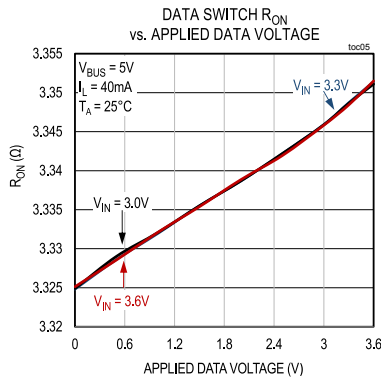
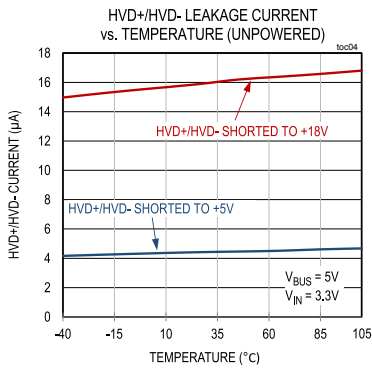
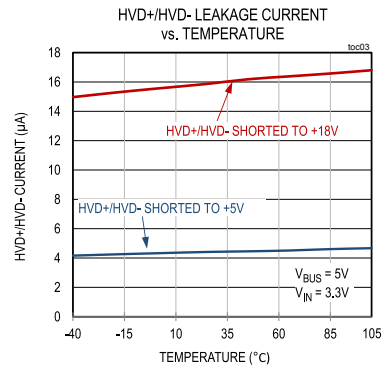
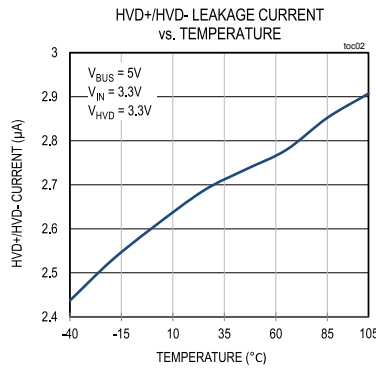
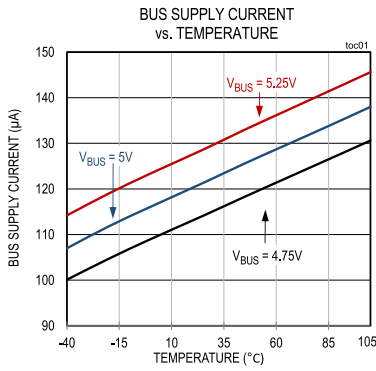


Figure 5. Propagation Delay and Output Skew

Typical Operating Characteristics

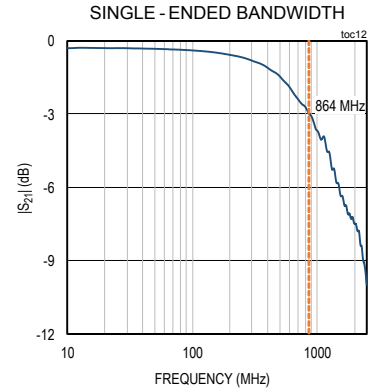
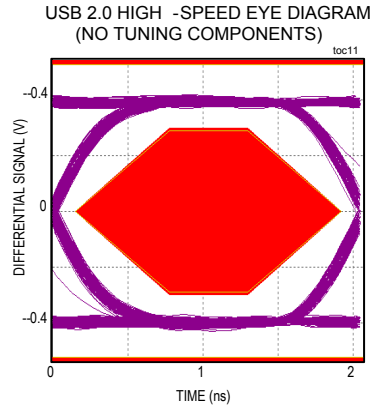
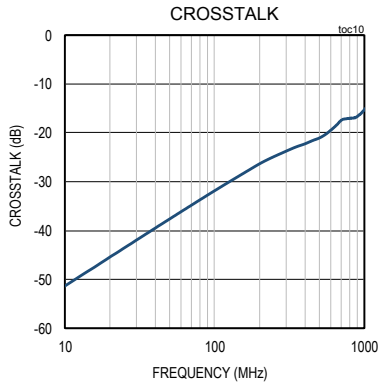
( $T_A = 25^\circ\text{C}$  unless otherwise noted)





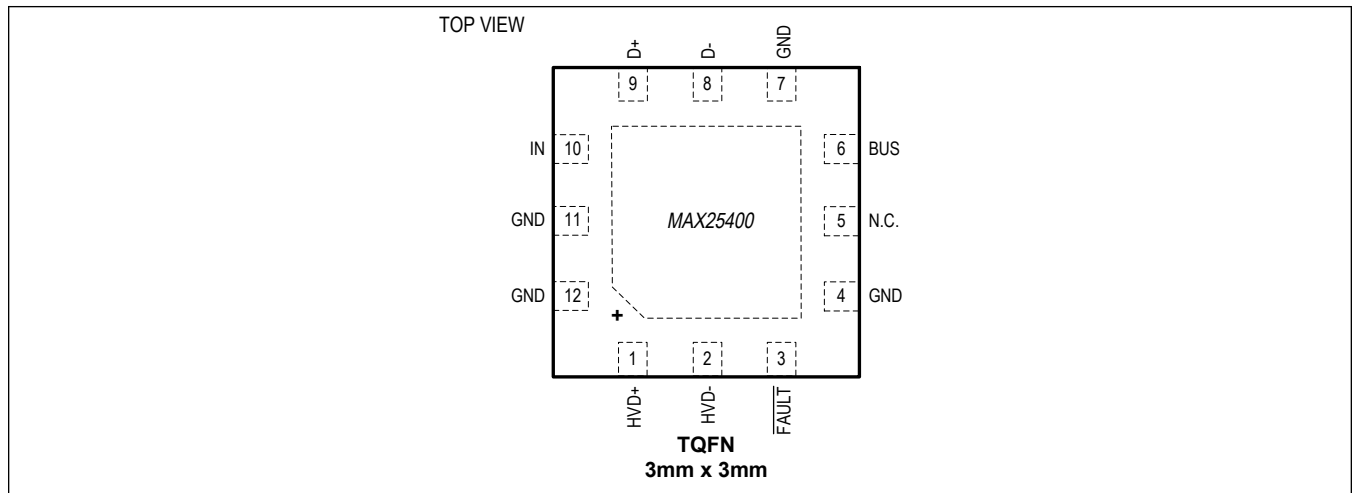
Typical Operating Characteristics (continued)

(T<sub>A</sub> = 25°C unless otherwise noted)



Pin Configuration

MAX25400



Pin Description

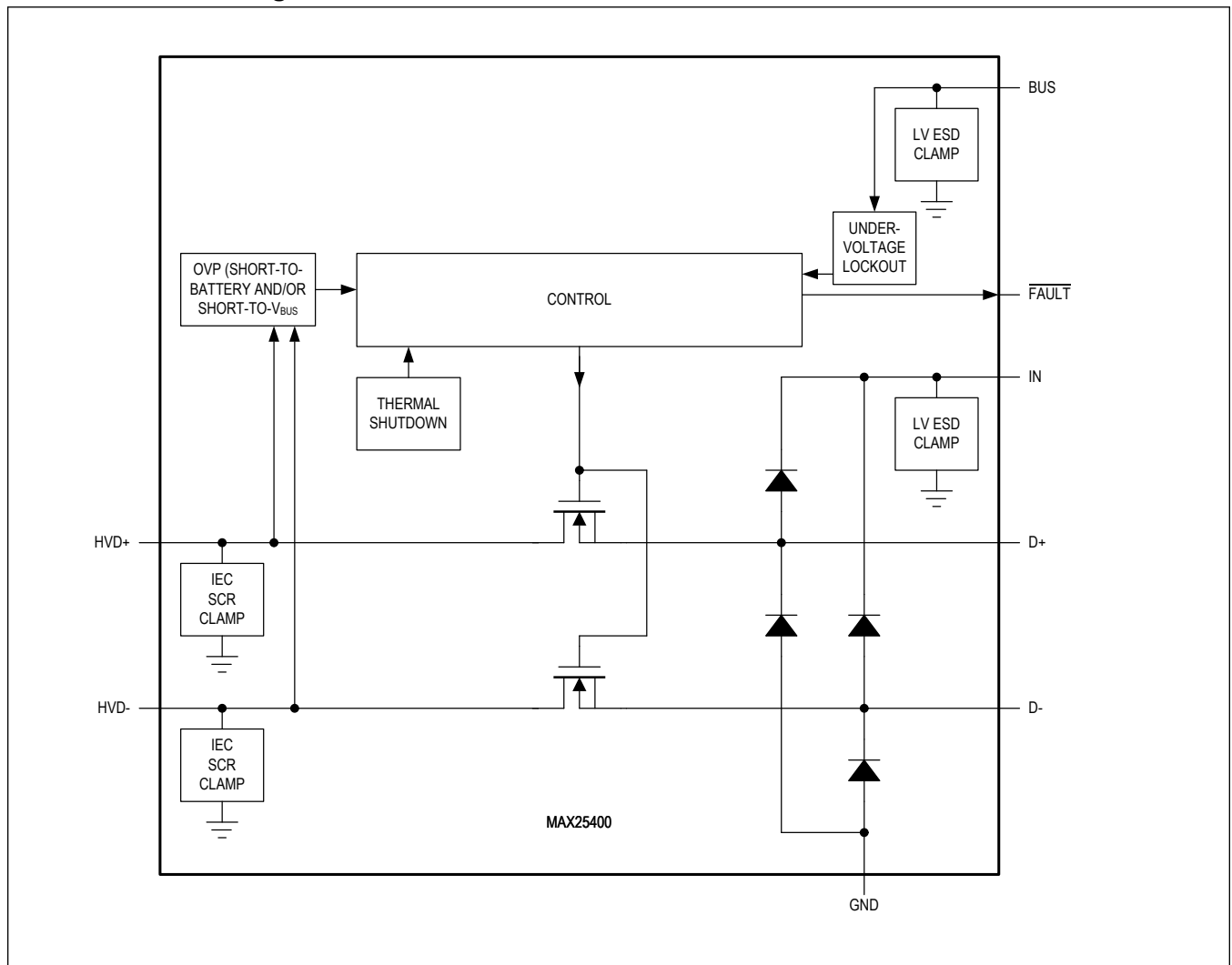
PIN	NAME	FUNCTION	REF SUPPLY
1	HVD+	High-Voltage-Protected USB Differential Data D+ Output. Connect HVD+ directly to USB connector D+.	0 to 3.6V
2	HVD-	High-Voltage-Protected USB Differential Data D- Output. Connect HVD- directly to USB connector D-.	0 to 3.6V
3	FAULT	Open-Drain Fault Condition Indicator Output.	0 to V <sub>IN</sub>
5	NC	No Connect. Internally connected to IC ground.	Float on Board

Pin Description (continued)

PIN	NAME	FUNCTION	REF SUPPLY
6	BUS	USB Power Supply. Connect BUS to USB +5V supply. Connect a 0.1μF and a 100μF, low-ESR ceramic capacitor from BUS to GND.	0 to 5.5V
8	D-	USB Differential Data D- Input. Connect D- to low-voltage USB transceiver D-.	0 to 3.6V
9	D+	USB Differential Data D+ Input. Connect D+ to low-voltage USB transceiver D+.	0 to 3.6V
10	IN	Low Voltage Supply from +3.0V to +3.6V.	0 to 3.6V
4, 7, 11, 12	GND	IC Ground	0V

Functional Diagrams

Functional Block Diagram



## Detailed Description

The MAX25400 device provides high-ESD and short-circuit protection for the USB data and USB power line in automotive radio, navigation, connectivity, and USB hub applications. The device supports USB Hi-Speed (480Mbps), USB full-speed (12Mbps), and USB low-speed (1.5Mbps) operation.

The short-circuit protection features include short-to-BUS and short-to-battery on the protected HVD+ and HVD-.

The device features high-ESD protection to  $\pm 25\text{kV}$  Air Gap Discharge and  $\pm 8\text{kV}$  Contact Discharge on all protected HVD+ and HVD- outputs.

The device features two low on-resistance ( $R_{ON}$ ), USB 2.0 switches.

### BUS Undervoltage Lockout (Power-On Reset)

The device has a 4.2V (typ) undervoltage-lockout threshold ( $V_{UVLO}$ ). When  $V_{BUS}$  is less than  $V_{UVLO}$ ,  $\overline{\text{FAULT}}$  is enabled and all the device switches are high impedance.

### HVD+ and HVD- Overvoltage Protection

The device has a 3.9V (max) overvoltage threshold ( $V_{OV\_D}$ ). When HVD+ or HVD- is greater than  $V_{OV\_D}$ ,  $\overline{\text{FAULT}}$  asserts low and all the device switches are high impedance. Note that HVD+ and HVD- do not have short-to-ground protection. Forward current is limited by the upstream transceiver.

### $\overline{\text{FAULT}}$ Output

$\overline{\text{FAULT}}$  goes low when a fault is detected on HVD+, HVD-.  $\overline{\text{FAULT}}$  indicates if any of the following conditions exist: overvoltage on HVD-, HVD+; UVLO on  $V_{BUS}$ ; or overtemperature. Connect a 100k $\Omega$  pullup resistor from  $\overline{\text{FAULT}}$  to IN.

## Applications Information

### Power-Supply Bypass Capacitor

If the power source has significant inductance due to long lead length, take care to prevent overshoots due to the LC tank circuit and provide protection if necessary to prevent violation of the +6V absolute maximum rating on BUS. Connect a 1 $\mu$ F low-ESR ceramic capacitor from BUS to GND. Connect a 10 $\mu$ F ceramic capacitor from IN to GND. Place these components on the same plane as the IC, close to the IN and GND pins.

### Layout of USB Data Line Traces

USB Hi-Speed requires careful PCB layout with 90 $\Omega$  controlled-impedance matched traces of equal lengths. Use LC tuning components on the data lines, as shown in the Typical Operating Circuit. The values of these components are layout and captive-cable dependent. Contact Maxim technical support for more detailed information.

### $\pm$ 25kV ESD Protection

As with all Maxim devices, ESD-protection structures are incorporated on all pins to protect against electrostatic discharges encountered during handling and assembly. The device has extra protection against static electricity. Maxim's engineers have developed state-of-the-art structures to protect against ESD of  $\pm$ 25kV at the HVD+, HVD- ports without damage. The ESD structures withstand high ESD in all states: normal operation, shutdown, and powered down. After an ESD event, the device keeps working without latchup, whereas other solutions can latch and must be powered down to remove latchup. ESD protection can be tested in various ways; this product is characterized for protection to the following limits:

- $\pm$ 2kV using the Human Body Model
- $\pm$ 25kV using IEC 61000-4-2's Air-Gap Discharge method
- $\pm$ 8kV using the Contact Discharge method specified in IEC 61000-4-2

### ESD Test Conditions

ESD performance depends on a variety of conditions. Contact Maxim for a reliability report that documents test setup, test methodology, and test results.

### Human Body Model

Figure 6 shows the Human Body Model, and Figure 7 shows the current waveform it generates when discharged into a low impedance. This model consists of a 100pF capacitor charged to the ESD voltage of interest, which is then discharged into the device through a 1.5k $\Omega$  resistor.

### IEC 61000-4-2

The IEC 61000-4-2 standard covers ESD testing and performance of finished equipment. The MAX25400 helps users design equipment that meets Level 4 of IEC 61000-4-2. The main difference between tests done using the Human Body Model and IEC 61000-4-2 is higher peak current in IEC 61000-4-2. Because series resistance is lower in the IEC 61000-4-2 ESD test model (Figure 8), the ESD withstand voltage measured to this standard is generally lower than that measured using the Human Body Model. Figure 9 shows the current waveform for the  $\pm$ 8kV, IEC 61000-4-2 Level 4, ESD Contact Discharge test. The Air-Gap Discharge test involves approaching the device with a charged probe. The Contact Discharge method connects the probe to the device before the probe is energized.

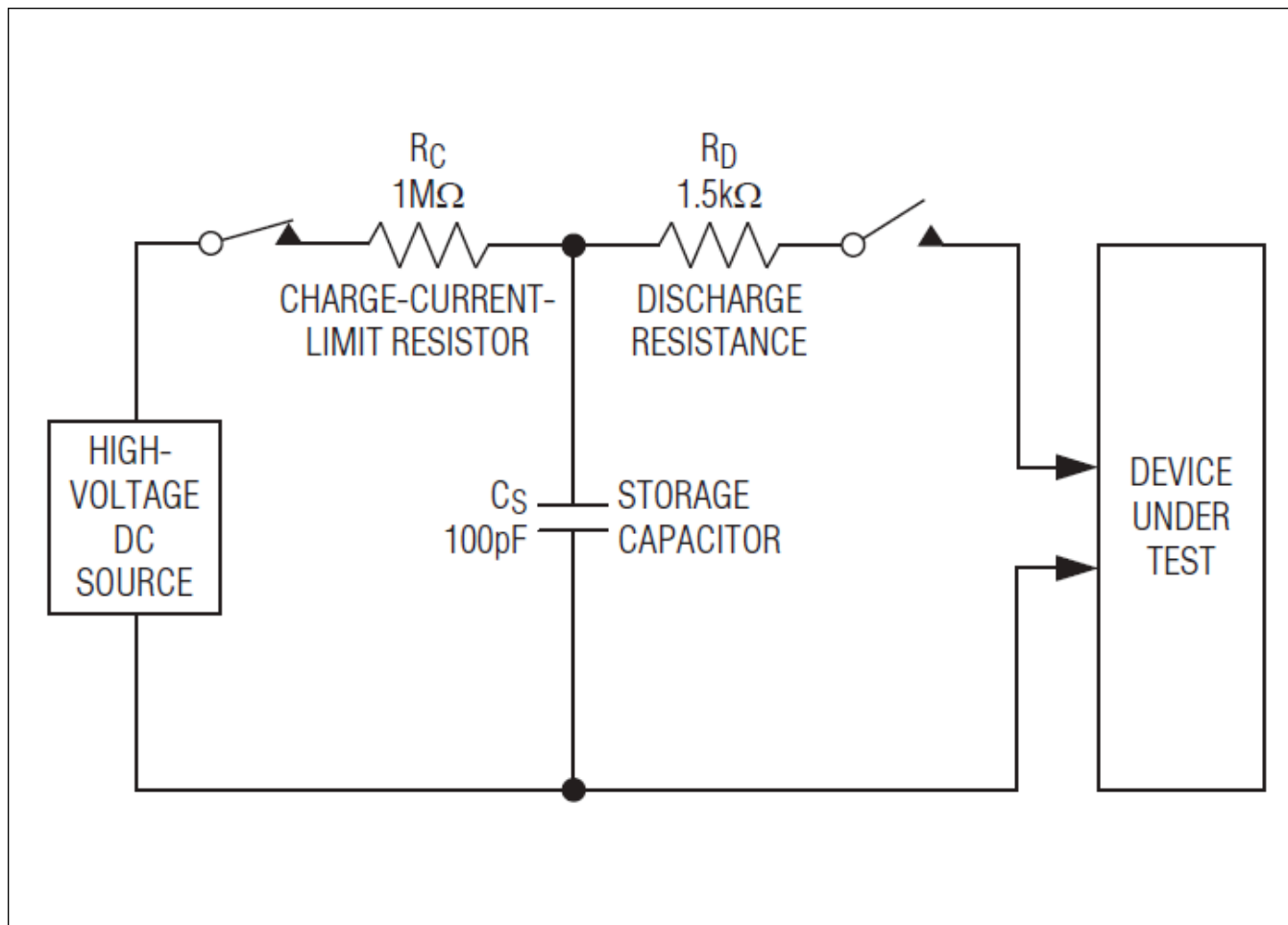
**Human Body Test Model**

Figure 6. Human Body ESD Test Model

Human Body Current Waveform

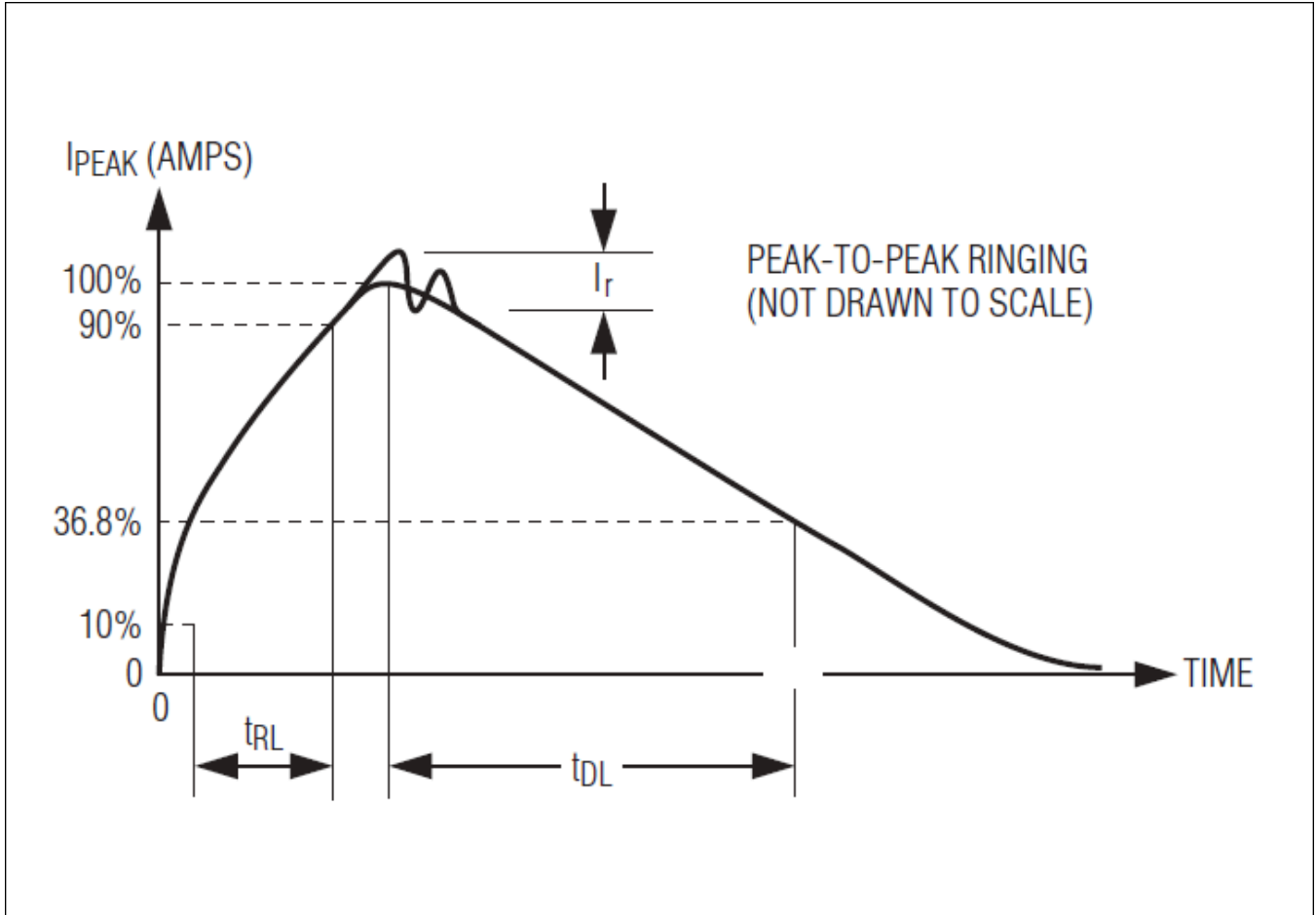


Figure 7. Human Body Current Waveform

IEC 61000-4-2 ESD Test Model

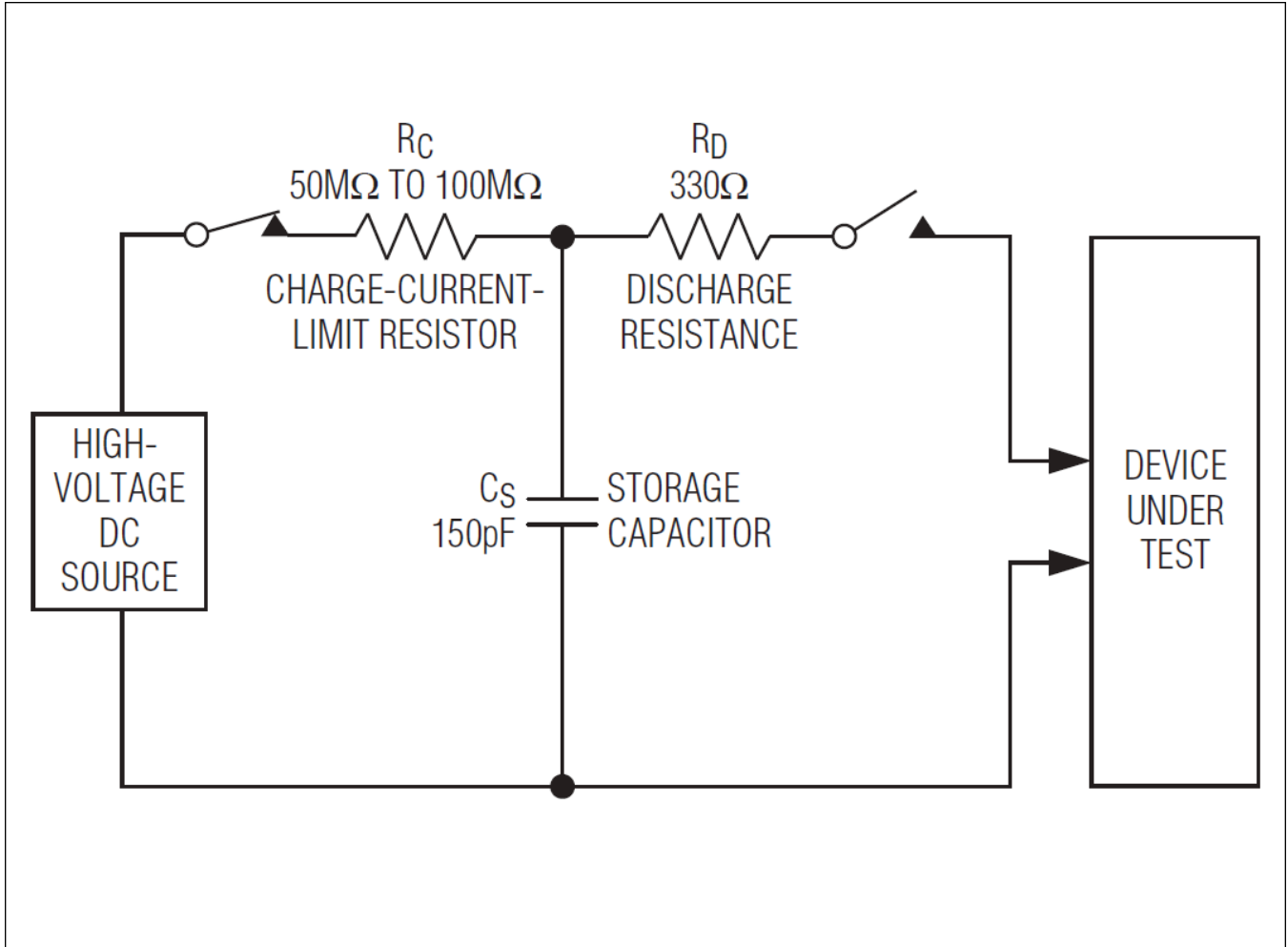


Figure 8. IEC 61000-4-2 ESD Test Model

IEC 61000-4-2 Current Waveform

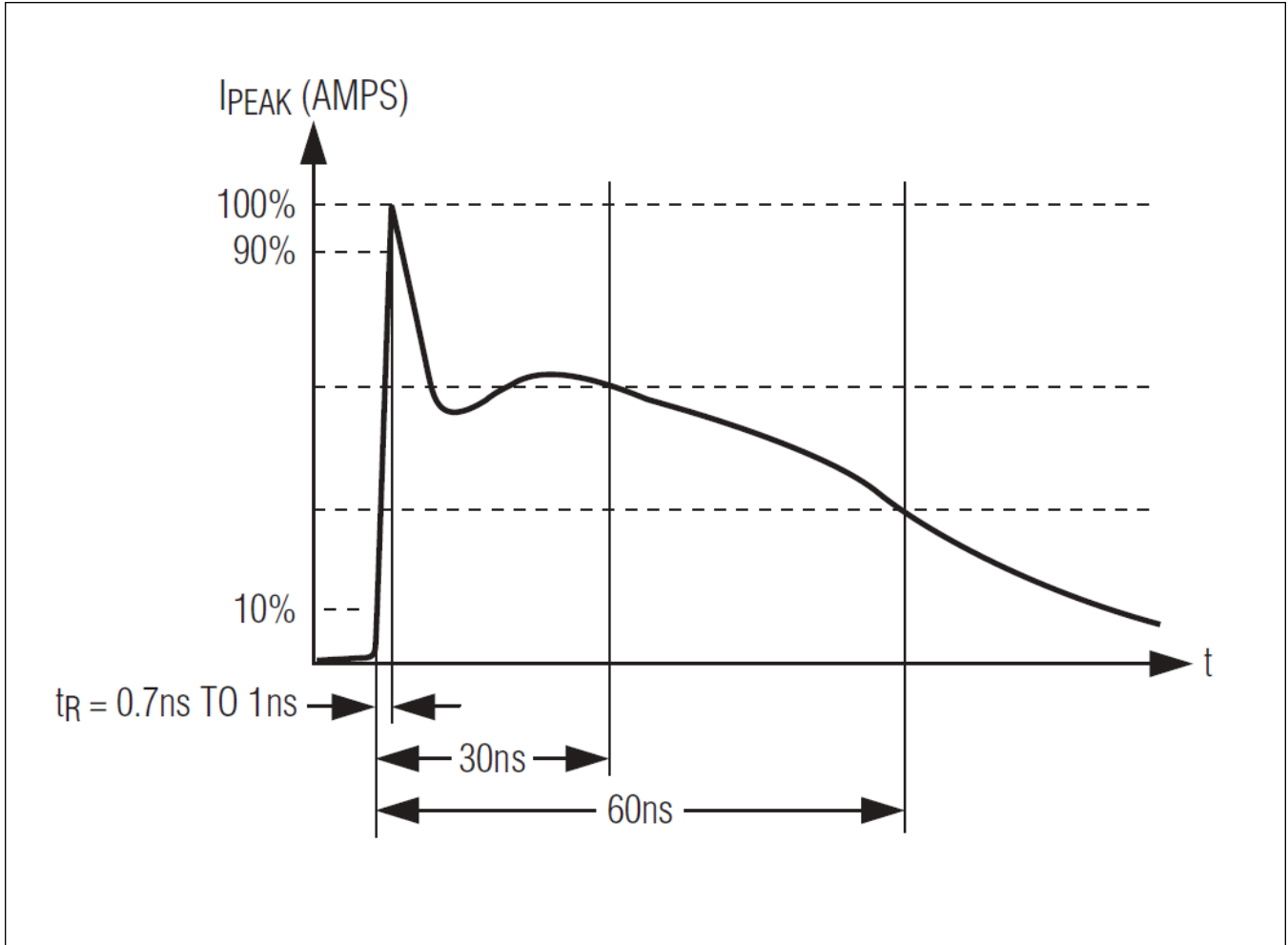
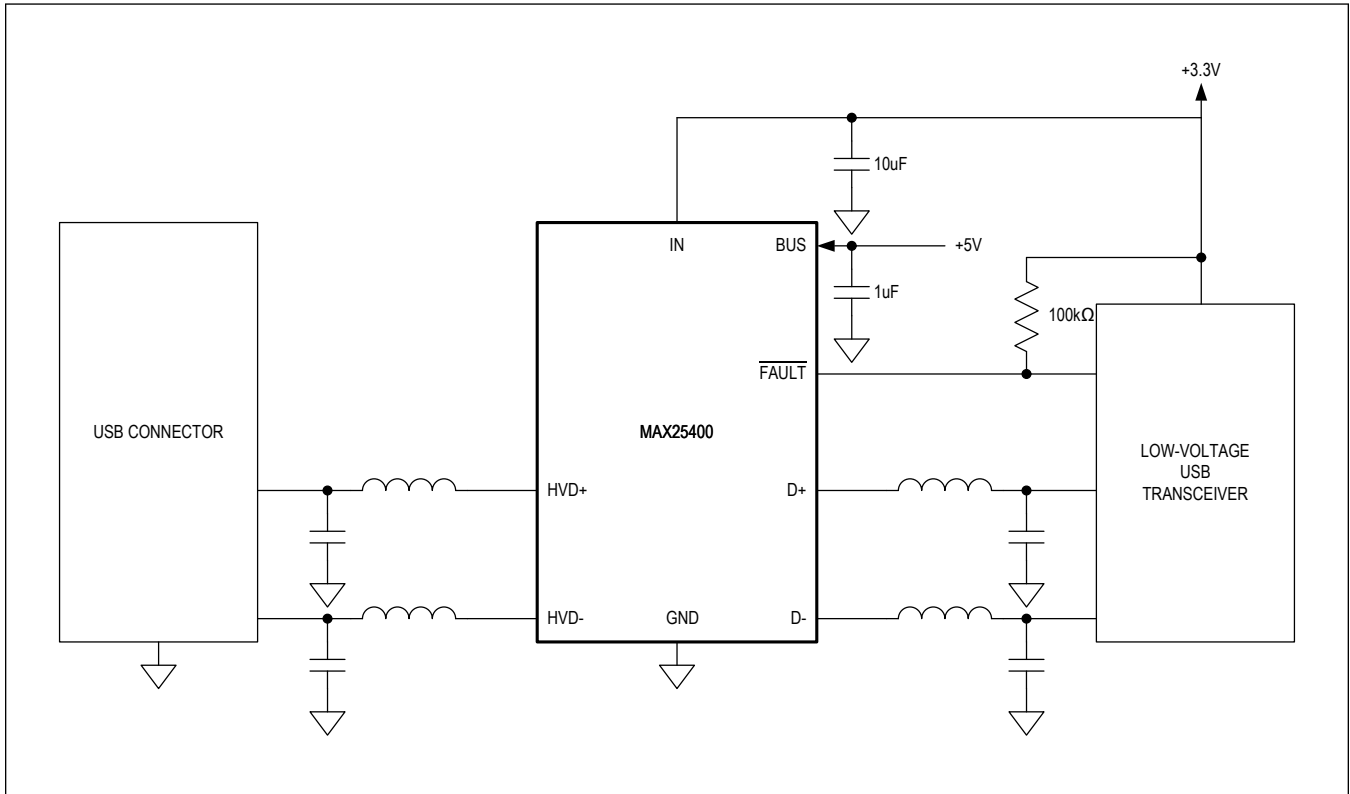


Figure 9. IEC 61000-4-2 ESD Generator Current Waveform



Typical Application Circuits

Typical Operating Circuit



Ordering Information

PART NUMBER	TEMPERATURE RANGE	PIN-PACKAGE
MAX25400GTC/V+	-40°C TO +105°C	12 TQFN-EP*

/V denotes an automotive qualified part.

+Denotes a lead(Pb)-free/RoHS-compliant package.

\*EP = Exposed pad.

## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	10/18	Initial release	—

For pricing, delivery, and ordering information, please visit Maxim Integrated's online storefront at <https://www.maximintegrated.com/en/storefront/storefront.html>.

*Maxim Integrated cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim Integrated product. No circuit patent licenses are implied. Maxim Integrated reserves the right to change the circuitry and specifications without notice at any time. The parametric values (min and max limits) shown in the Electrical Characteristics table are guaranteed. Other parametric values quoted in this data sheet are provided for guidance.*