

USB 2.0 High-Speed, Fault-Tolerant 3:1, 4:1 Multiplexers

General Description

The MAX4899E/MAX4899AE analog multiplexers combine the low on-capacitance (C_{ON}) and low on-resistance (R_{ON}) necessary for high-performance switching applications. These devices are designed for USB 2.0 high-speed applications at 480Mbps. The MAX4899E/MAX4899AE also handle all the requirements for USB low- and full-speed signaling.

The MAX4899E is a dual 3:1 multiplexer whereas the MAX4899AE is a dual 4:1 multiplexer. The MAX4899E/MAX4899AE feature two digital inputs, C_0 and C_1 , to control the analog signal path. Typical applications include switching a USB connector between USB and other operations such as serial communications, audio, and video.

An enable input ($\overline{EN}$) is provided to disable all channels and place the device into a high-impedance (off) state, as well as reducing power consumption.

The MAX4899E/MAX4899AE operate from a 2.7V to 3.6V power-supply voltage and are protected against +5.5V shorts to COM_A- and COM_A+ . In addition, COM_A+ and COM_A- are normally connected to outside circuitry and feature $\pm 15kV$ ESD protection. The MAX4899E/MAX4899AE are available in a 3mm x 3mm, 16-pin TQFN package and operate over the $-40^\circ C$ to $+85^\circ C$ temperature range.

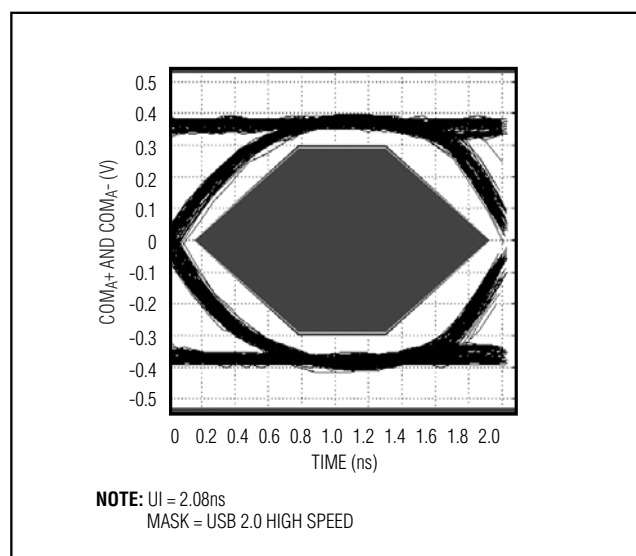
Applications

Cell Phones
Digital Still Cameras
PDAs
Digital Video Cameras
MPEG-4 Players
Portable GPS
Combination Products
KVM

Features

- ◆ Single 2.7V to 3.6V Power-Supply Voltage
- ◆ Low 4Ω (typ) On-Resistance (R_{ON})
- ◆ -3dB Bandwidth: 425MHz
- ◆ Fault Tolerant to Meet Full USB 2.0 Specification
- ◆ COM_ Protected to $\pm 15kV$ ESD Protection per Human Body Model (MIL-STD-883; Method 3015)
- ◆ Low Operating Current (200 μA), Ultra-Low Quiescent Current (3.0 μA max) in Standby Mode
- ◆ Low Threshold Eliminates the Need for Translators in 1.8V Low Voltage Systems
- ◆ Tiny 16-Pin, 3mm x 3mm, Lead-Free TQFN Package

Eye Diagram



Pin Configurations appear at end of data sheet.

Ordering Information/Selector Guide

PART	PIN-PACKAGE	MUX CONFIGURATION	TOP MARK	PKG CODE
MAX4899EETE+	16 TQFN-EP*	DUAL 3:1	AEY	T1633-4
MAX4899AEETE+	16 TQFN-EP*	DUAL 4:1	AEZ	T1633-4

Note: All devices are specified over the $-40^\circ C$ to $+85^\circ C$ operating temperature range.

+ Denotes lead-free package.

*EP = Exposed paddle.

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ABSOLUTE MAXIMUM RATINGS

(All Voltages Referenced to GND.)

V+	-0.3V to +4V
$\overline{QP}$, $\overline{EN}$, C ₀ , C ₁ , (Note 1)	-0.3V to +4V
COMA+, COMA-, USB0+, USB0-, USB1+, USB1-, USB2+, USB2-, USB3+, USB3-	-0.3V to +5.5V
Continuous Current (COMA_ to USB_)	±120mA
Peak Current (COMA_ to USB_)	±240mA
(pulsed at 1ms, 10% duty cycle)	±240mA

Continuous Power Dissipation (T_A = +70°C)

16-Pin TQFN (derate 20.8mW/°C above +70°C)	1667mW
Operating Temperature Range	-40°C to +85°C
Storage Temperature Range	-65°C to +150°C
Junction Temperature	+150°C
Lead Temperature (soldering, 10s)	+300°C

Note 1: Signals exceeding GND are clamped by internal diodes. Limit forward-diode current to maximum current rating.

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+ = +2.7V to +3.6V, T_A = -40°C to +85°C, $\overline{QP}$ = low, $\overline{EN}$ = low, unless otherwise noted. Typical values are at V+ = +3.3V and T_A = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
ANALOG SWITCH (COMA_, USB_)							
On-Resistance	RON	V+ = 2.7V, ICOMA_ = -10mA, VCOMA_ = 0V, 1.5V, QP = low	TA = +25°C	4	5	Ω	
			TA = -40°C to +85°C	6			
		V+ = 2.7V, ICOMA_ = -10mA, VCOM_ = 0V, 1.5V, 2.7V, QP = low	TA = +25°C	4	7		
			TA = -40°C to +85°C	8			
		V+ = 2.7V, ICOMA_ = -10mA, VCOMA_ = 0V, 1.5V, QP = high	TA = +25°C	8	17		
			TA = -40°C to +85°C	18			
V+ = 3.0V, ICOMA_ = -10mA, VCOMA_ = 0V, 1.5V, QP = high	TA = +25°C	4	12				
	TA = -40°C to +85°C	13					
On-Resistance Match Between Channels	ΔRON	V+ = 2.7V, ICOMA_ = -10mA, VCOMA_ = 0V, 1.5V, 2.7V	TA = +25°C	0.5	0.8	Ω	
			TA = -40°C to +85°C	1.0			
On-Resistance Flatness	RFLAT (ON)	V+ = 2.7V, ICOMA_ = -10mA, VCOMA_ = 0V, 1.5V, 2.7V		0.5	1.1	Ω	
Off-Leakage Current	IL(OFF)	V+ = 3.6V, VCOMA_ = VUSB_ = 0.3V, 3.3V	-1		+1	μA	
On-Leakage Current	IL(ON)	V+ = 3.6V, VCOMA_ = VUSB_ = 0.3V, 3.3V	-1		+1	μA	
Quiescent Supply Current	I+	V+ = 3.6V, C0 = C1 = 0 or V+	QP = low	250	600	μA	
			QP = high	3			
Fault-Protection Trip Threshold	VFP	V+ = 3.3V	3.6	3.9	4.2	V	
ESD PROTECTION							
COMA+, COMA-		Human Body Model		±15		kV	

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MAX4899E/MAX4899AE

ELECTRICAL CHARACTERISTICS (continued)

(V₊ = +2.7V to +3.6V, T_A = -40°C to +85°C, $\overline{QP}$ = low, $\overline{EN}$ = low, unless otherwise noted. Typical values are at V₊ = +3.3V and T_A = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
SWITCH AC PERFORMANCE (Note 3)						
On-Loss	ON _{LOSS}	f = 10MHz, 0 < V _{IN} < 1V, Figure 1		0.5		dB
Crosstalk	V _{CT1} , V _{DCT1}	f = 50MHz, Figure 1		-50		dB
Off-Isolation	V _{ISO}	f = 50MHz, Figure 1		-45		dB
Charge-Pump Noise	V _{QP}	COMA ₋ , USB ₋ , R _L = R _S = 50Ω (Note 4)		100		μV
Bandwidth -3dB	BW	R _S = R _L = unbalanced 50Ω		425		MHz
Off-Capacitance	C _{OFF}	f = 1MHz, COMA ₋ , USB ₋ , Figure 2		10.5		pF
On-Capacitance	C _{ON}	f = 1MHz, COMA ₋ , USB ₋ , Figure 2		15		pF
Propagation Delay	t _{PD}	R _L = R _S = 50Ω, Figure 3		200		ps
Output Skew Same Switch	t _{SK}	Skew between opposite transitions in same switch, Figure 3		100		ps
Fault-Protection Response Time	t _{FP}	V _{COMA-} = 0V to 5V to V _{USB-} = 2.5V, R _L = 50Ω, C _L = 10pF, Figure 4		1		μs
Fault-Protection Recovery Time	t _{FPR}	V _{COMA-} = 5V to 3V to V _{USB-} = 1.5V, R _L = 50Ω, C _L = 10pF, Figure 4		1		μs
Charge Injection	Q	V _{GEN} = 0, C _L = 1000pF, Figure 5		25		pC
Enable Turn-On Time	t _{ON}	V _{USB0+} = V ₊ , R _L = 50Ω, C _L = 10pF, Figure 6		2.8		μs
Enable Turn-Off Time	t _{OFF}	V _{USB0+} = V ₊ , R _L = 50Ω, C _L = 10pF, Figure 6		3		ns
Address Transition Time	t _{TRANS}	V _{USB0+} = V ₊ , R _L = 50Ω, C _L = 10pF, Figure 7		1.2		μs
Total Harmonic Distortion Plus Noise	THD+N	f = 20Hz to 20kHz, V _{COMA-} = 1Vp-p, R _L = 600Ω		0.02		%
SWITCH LOGIC ($\overline{QP}$, $\overline{EN}$, C₀, C₁)						
Logic-Input Voltage Low	V _{IL}			0.4		V
Logic-Input Voltage High	V _{IH}		1.4			V
Input Logic Hysteresis	V _{HYST}			100		mV
Input Leakage Current	I _{LEAK}	V ₊ = 3.6V, C ₀ = 0 or V ₊ , C ₁ = 0 or V ₊	-1		1	μA

Note 2: Limits at -40°C are guaranteed by design.

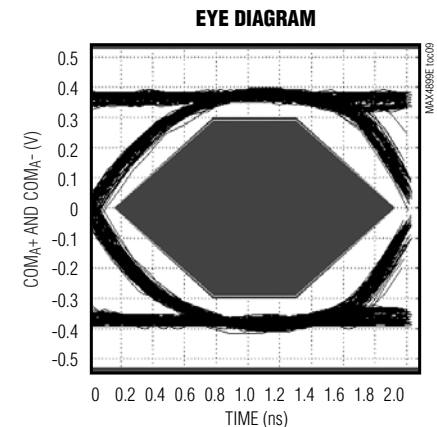
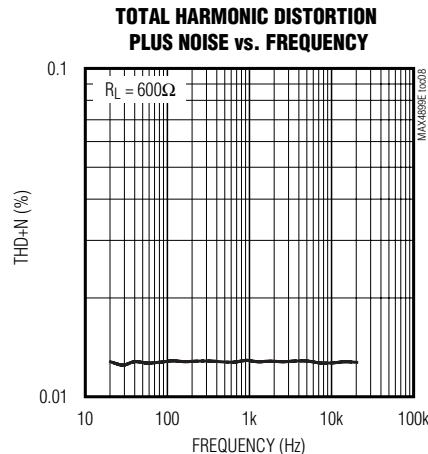
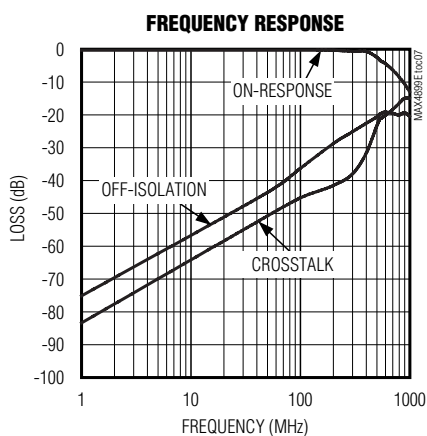
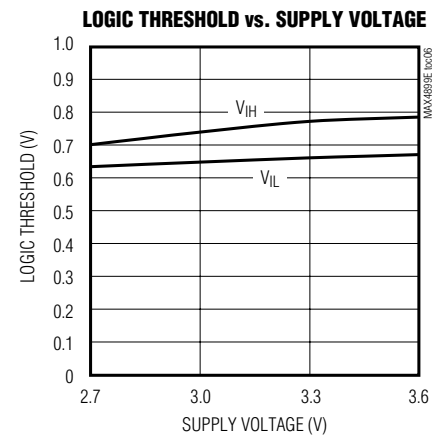
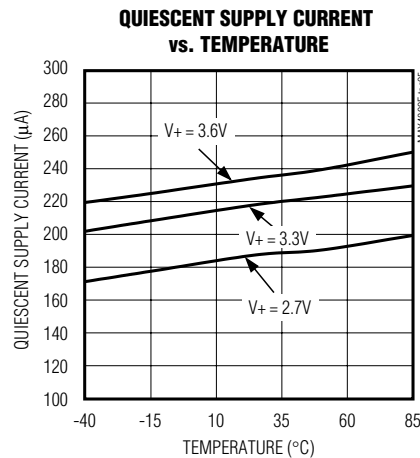
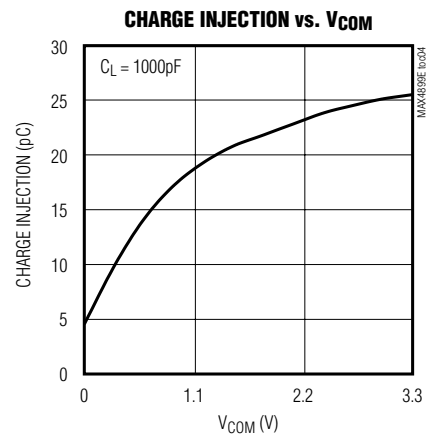
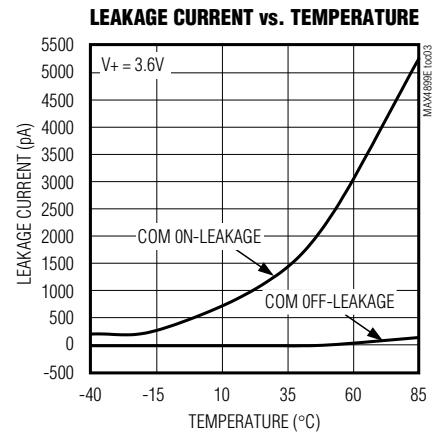
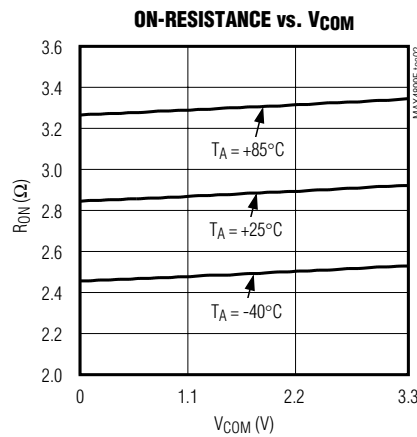
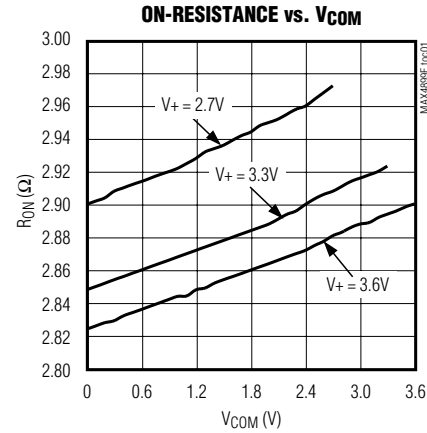
Note 3: Guaranteed by design.

Note 4: Charge-pump noise is specified as a peak-to-peak value.

USB 2.0 High-Speed, Fault-Tolerant 3:1, 4:1 Multiplexers

Typical Operating Characteristics

($V_+ = 3.3\text{V}$, $\overline{QP} = \overline{EN} = \text{low}$, $T_A = +25^\circ\text{C}$, unless otherwise noted.)



USB 2.0 High-Speed, Fault-Tolerant 3:1, 4:1 Multiplexers

Pin Description

PIN		NAME	FUNCTION
MAX4899E	MAX4899AE		
1	1	GND	Ground
2	2	COM _A +	Analog Switch Common D+ Terminal
3	3	COM _A -	Analog Switch Common D- Terminal
4	4	V+	Positive Supply-Voltage Input. Connect V+ to a 2.7V to 3.6V supply voltage. Bypass V+ to GND with a 0.1μF capacitor placed as close as possible to the device.
5	5	C ₁	Digital Control Input 1. C ₁ and C ₀ control the analog signal path as shown in the <i>Functional Diagrams</i> section.
6	6	C ₀	Digital Control Input 0. C ₁ and C ₀ control the analog signal path as shown in the <i>Functional Diagrams</i> section.
7, 8	—	N.C.	No Connection. Not internally connected.
—	7	USB3-	Analog Switch 3 D- Terminal
—	8	USB3+	Analog Switch 3 D+ Terminal
9	9	USB2-	Analog Switch 2 D- Terminal
10	10	USB2+	Analog Switch 2 D+ Terminal
11	11	USB1+	Analog Switch 1 D+ Terminal
12	12	USB1-	Analog Switch 1 D- Terminal
13	13	USB0+	Analog Switch 0 D+ Terminal
14	14	USB0-	Analog Switch 0 D- Terminal
15	15	$\overline{\text{EN}}$	Active-Low Enable Input. For normal operation, drive $\overline{\text{EN}}$ low. Drive $\overline{\text{EN}}$ high to place all channels in a high-impedance state. The internal charge pump is turned off when $\overline{\text{EN}}$ is a logic-high.
16	16	$\overline{\text{QP}}$	Active-Low Charge-Pump Enable Input. Drive $\overline{\text{QP}}$ low for normal operation. Drive $\overline{\text{QP}}$ high to disable the charge pump with the switches still active at a reduced analog signal range and higher R _{ON} .
—	—	EP	Exposed Paddle. Connect EP to GND.

MAX4899E/MAX4899AE

USB 2.0 High-Speed, Fault-Tolerant 3:1, 4:1 Multiplexers

Test Circuits/Timing Diagrams

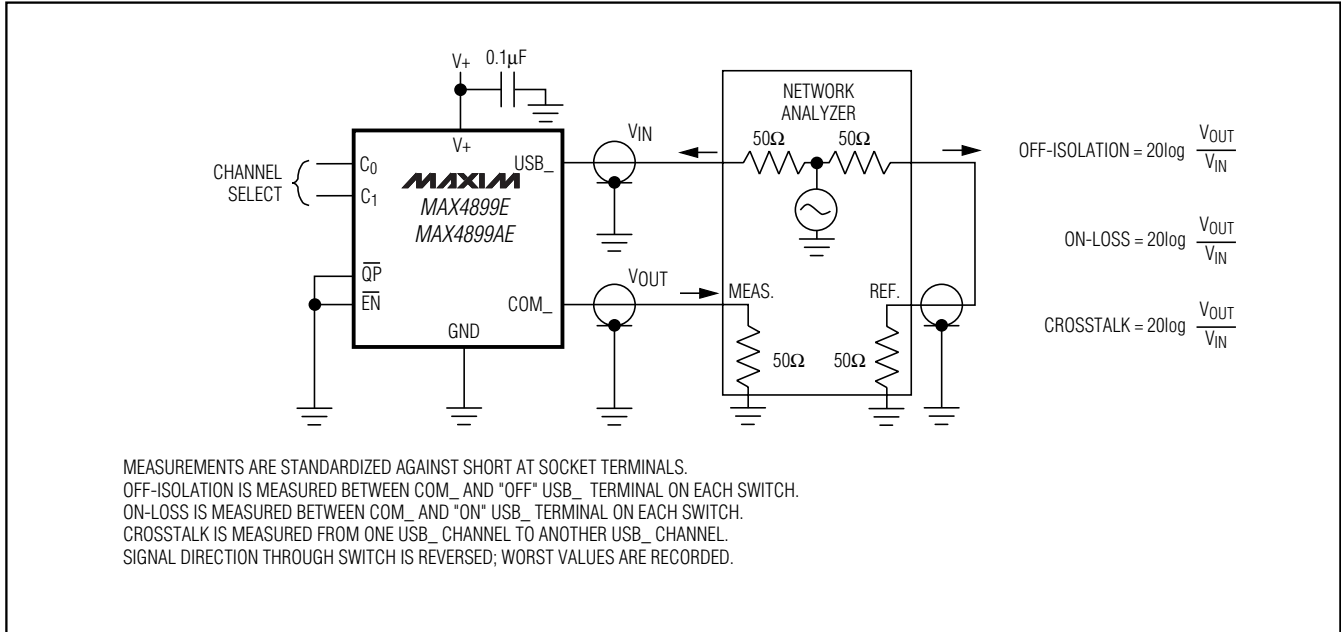


Figure 1. Off-Isolation, On-Loss, and Crosstalk

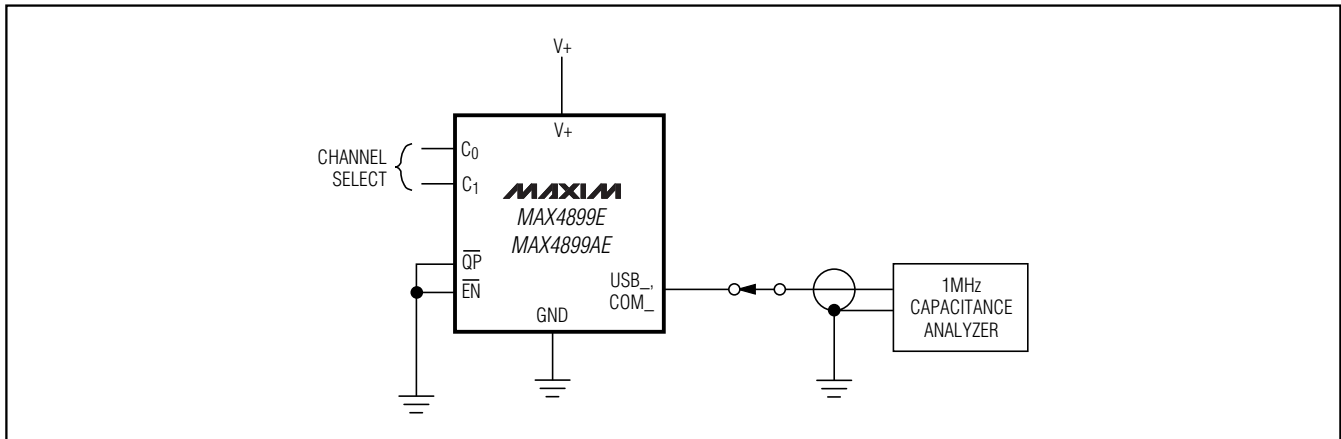


Figure 2. Channel Off-/On-Capacitance

USB 2.0 High-Speed, Fault-Tolerant 3:1, 4:1 Multiplexers

Test Circuits/Timing Diagrams (continued)

MAX4899E/MAX4899AE

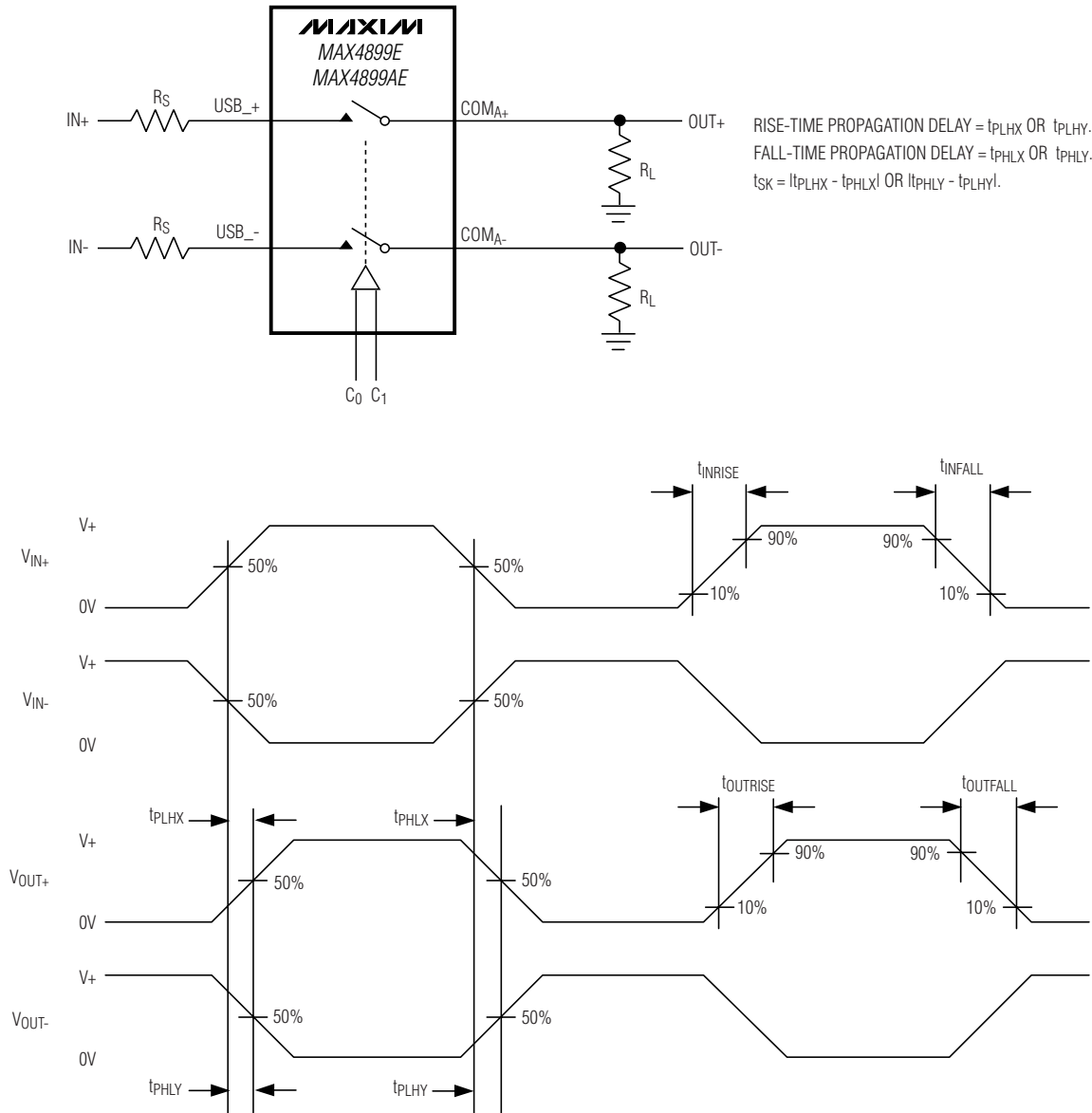


Figure 3. Propagation Delay and Output Skew

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Test Circuits/Timing Diagrams (continued)

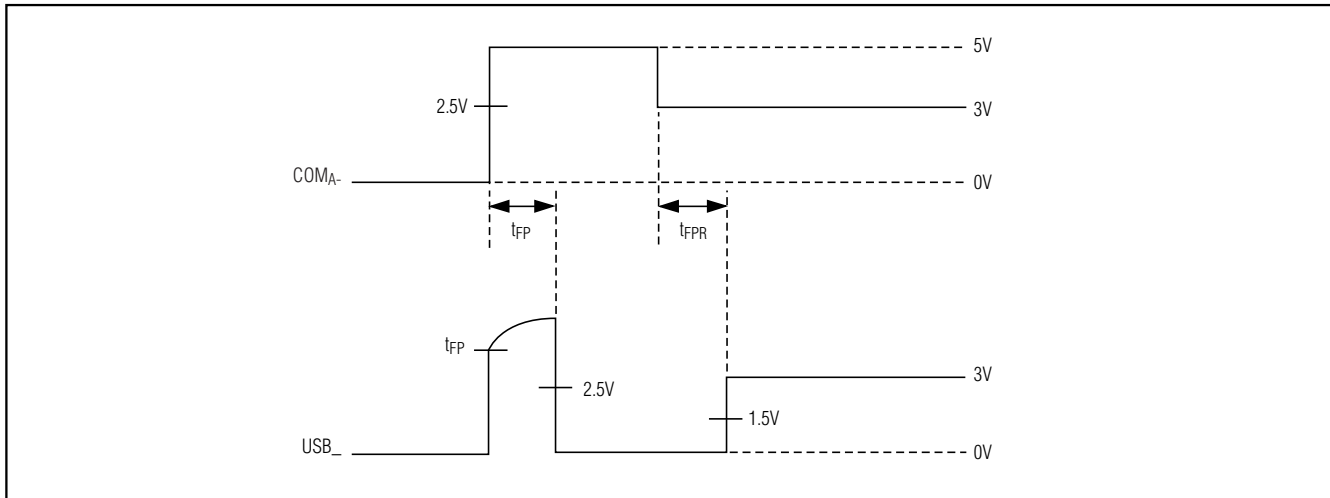


Figure 4. Fault-Protection Response/Recovery Time

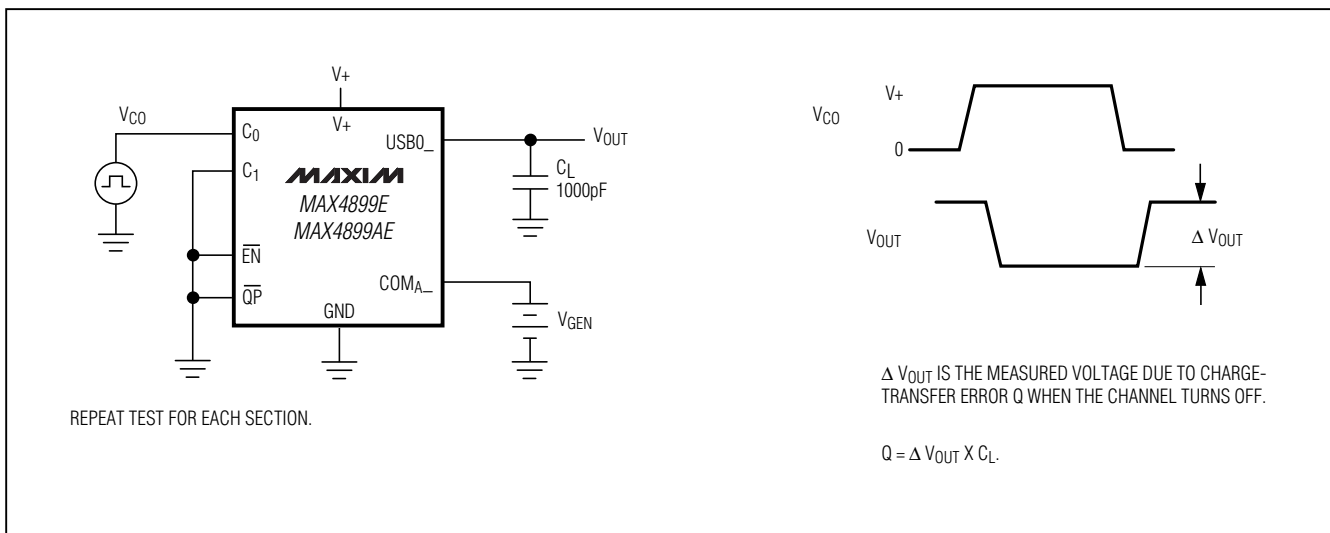


Figure 5. Charge Injection

USB 2.0 High-Speed, Fault-Tolerant 3:1, 4:1 Multiplexers

Test Circuits/Timing Diagrams (continued)

MAX4899E/MAX4899AE

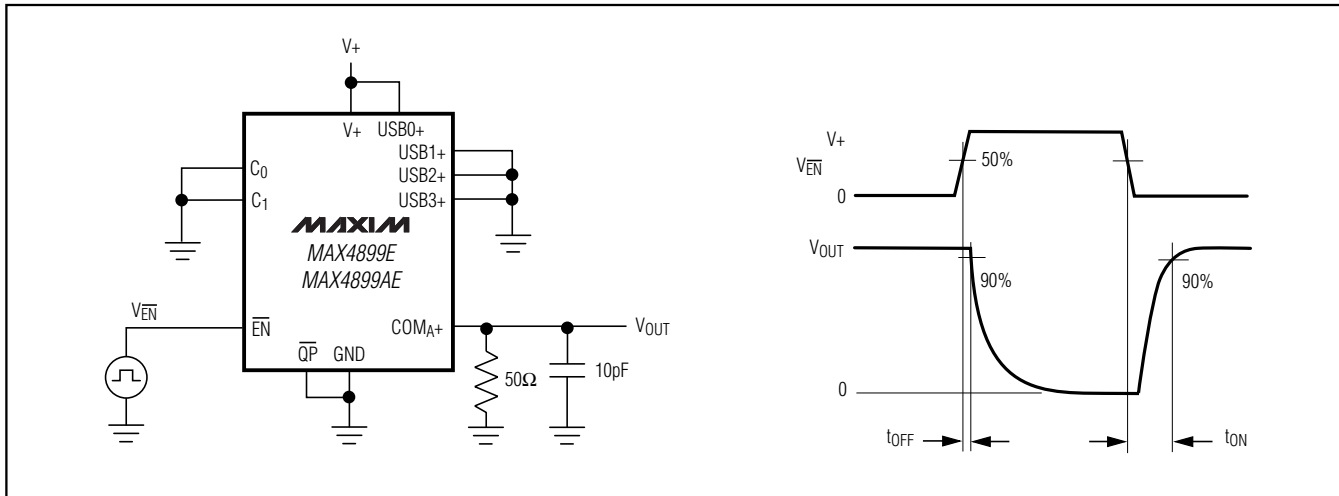


Figure 6. Enable Switching Times

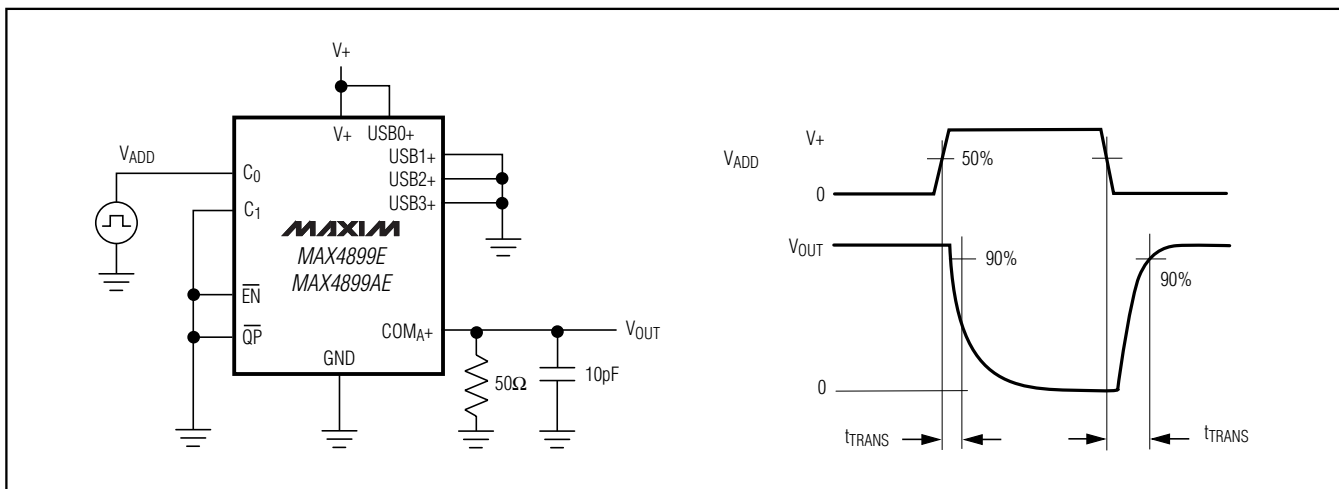


Figure 7. Address Transition Time

USB 2.0 High-Speed, Fault-Tolerant 3:1, 4:1 Multiplexers

Detailed Description

The MAX4899E/MAX4899AE analog multiplexers combine the low on-capacitance (C_{ON}) and low on-resistance (R_{ON}) necessary for high-performance switching applications. These devices are designed for USB 2.0 high-speed applications at 480Mbps. The MAX4899E/MAX4899AE also handle all the requirements for USB low- and full-speed signaling. In the case of USB low/full speed, these devices can function normally even if the supply voltage is 2.7V, even though the USB signal may be higher than the supply voltage.

The MAX4899E is a dual 3:1 multiplexer, whereas the MAX4899AE is a dual 4:1 multiplexer. The MAX4899E/MAX4899AE feature two digital inputs, C_0 and C_1 , to control the analog signal path. Typical applications include switching a USB connector between USB and other operations such as serial communications, audio, and video.

An enable input ($\overline{EN}$) is provided to disable all channels and place the device into a high-impedance (off) state, as well as shutting off the charge pump for minimum power consumption. The MAX4899E/MAX4899AE feature an additional charge-pump enable input ($\overline{QP}$) to disable the charge pump. The switches remain active at a lower analog signal range and higher R_{ON} .

The MAX4899E/MAX4899AE operate from a 2.7V to 3.6V power-supply voltage and are current-limit protected against +5.5V shorts to COM_{A-} and COM_{A+} .

Digital Control Inputs (C_0 , C_1)

The MAX4899E/MAX4899AE provide two digital control inputs (C_0 , C_1) to select the analog signal path between the COM_{A-} and USB_{-} channels. The truth tables for the MAX4899E/MAX4899AE are shown in the *Functional Diagrams*. Since the MAX4899E only has three USB_{-} channels, the code $C_1:C_0 = 1:1$ can be used to place all channels into a high-impedance state. This is particularly useful for eliminating the extra control line to the $\overline{EN}$ input that is normally used for disabling all channels. Driving C_0 and C_1 rail-to-rail minimizes power consumption.

Enable Input ($\overline{EN}$)

The MAX4899E/MAX4899AE feature an enable input ($\overline{EN}$) that when driven high places all channels into a high-impedance state, as an all-off feature. The internal charge pump is also disabled when $\overline{EN}$ is high, thus minimizing the quiescent supply current. For normal operation, drive $\overline{EN}$ low.

Charge-Pump Enable Input ($\overline{QP}$)

The charge-pump input ($\overline{QP}$) disables and enables the internal charge pump. Drive $\overline{QP}$ high to disable the charge pump and reduce the quiescent supply current.

With the charge pump disabled, the MAX4899E/MAX4899AE still function normally; however, the analog signal range is reduced and the switch on-resistance (R_{ON}) is increased. The analog signal range with the charge pump disabled is 0V to 1.5V. For normal operation, drive $\overline{QP}$ low.

Analog Signal Levels

Signals applied to COM_{A+} are routed to the USB_{+} terminals, and signals applied to COM_{A-} are routed to the USB_{-} terminals. These multiplexers are bidirectional, allowing COM_{A-} and USB_{-} to be configured as either inputs or outputs. The D+ and D- notation in the *Pin Description* table is arbitrary and can be interchanged. For example, USB D+ signals can be applied to COM_{A-} and are routed to the USB_{-} terminals. Additionally, these multiplexers can be used for non-USB signals. COM_{A+} and COM_{A-} are normally connected to outside circuitry and are ± 15 kV ESD protected.

The MAX4899E is a dual 3:1 multiplexer, allowing COM_{A+} to be routed to one of three USB_{+} channels, and COM_{A-} to be routed to one of three USB_{-} channels. The MAX4899AE is a dual 4:1 multiplexer, allowing COM_{A+} to be routed to one of four USB_{+} channels, and COM_{A-} to be routed to one of four USB_{-} channels.

Overvoltage Fault Protection

The MAX4899E/MAX4899AE feature +5.5V fault protection to COM_{A+} and COM_{A-} . When a fault occurs between 4.5V to 5.5V, the switch automatically goes into a current-limiting mode that limits current to less than 2mA. Fault protection prevents these switches and downstream devices from being damaged due to shorts to the USB bus voltage rail.

Applications Information

USB Switching

The MAX4899E/MAX4899AE analog multiplexers are fully compliant with the USB 2.0 specification. The low on-resistance and low on-capacitance of these multiplexers make them ideal for high-performance switching applications. The MAX4899E/MAX4899AE are ideal for routing USB data lines and for applications that require switching between different data types (see Figure 8).

Board Layout

High-speed switches require proper layout and design procedures for optimum performance. Keep design-controlled impedance PC board traces as short as possible. Ensure that bypass capacitors are placed as close to the device as possible and use large ground planes where possible.

USB 2.0 High-Speed, Fault-Tolerant 3:1, 4:1 Multiplexers

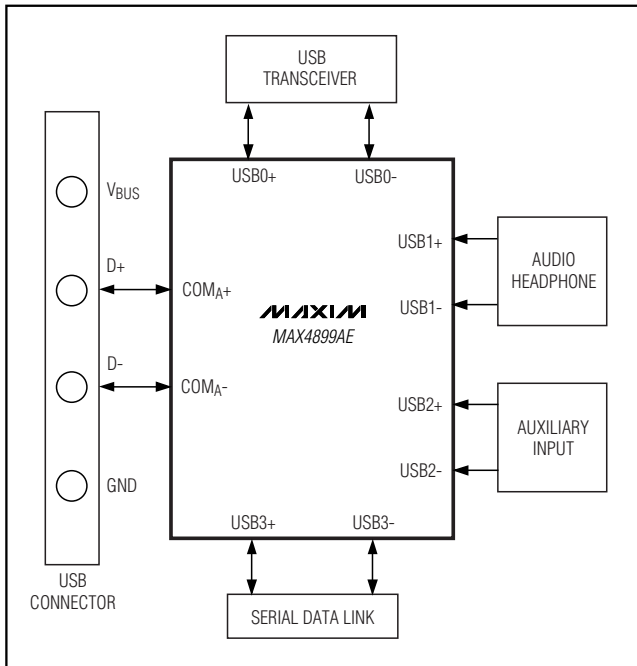


Figure 8. MAX4899AE Multiplexing Four Data Types

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 COMA+ and COMA- lines have extra protection against static electricity. Maxim's engineers have developed state-of-the-art structures to protect these pins against ESD of $\pm 15\text{kV}$ without damage. The ESD structures withstand high ESD in all states: normal operation, tri-state output mode, and powered down. After an ESD event, Maxim's E-versions keep working without latch-up, whereas competing products can latch and must be powered down to remove latch-up.

Human Body Model

The MAX4899E/MAX4899AE COMA+ and COMA- pins are characterized for $\pm 15\text{kV}$ ESD protection using the Human Body Model (MIL-STD-883, Method 3015). Figure 9a shows the Human Body Model and Figure 9b 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 $1.5\text{k}\Omega$ resistor.

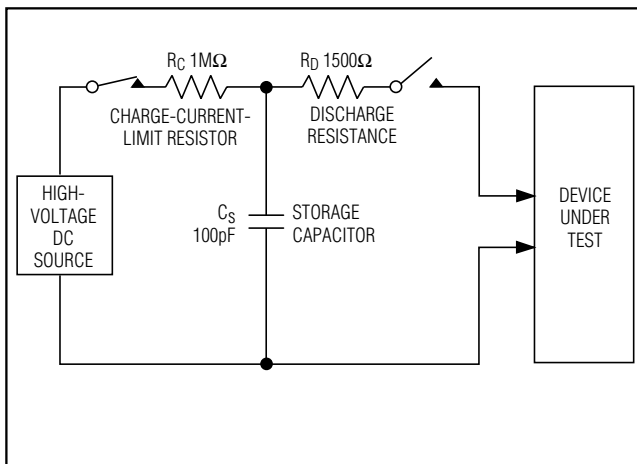


Figure 9a. Human Body ESD Test Model

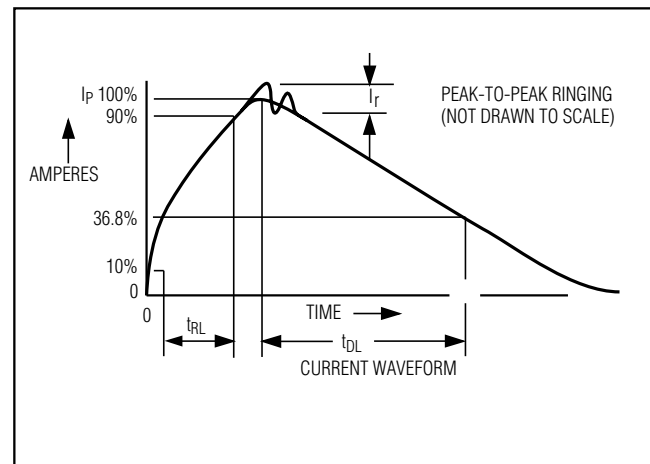


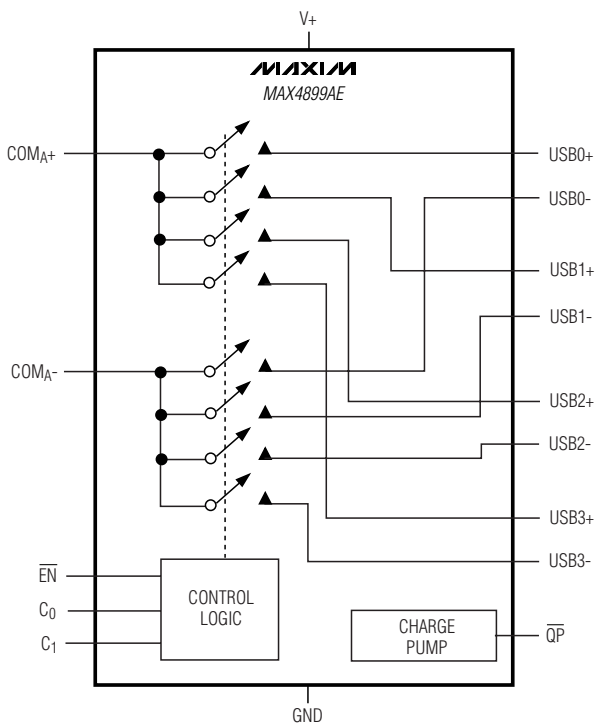
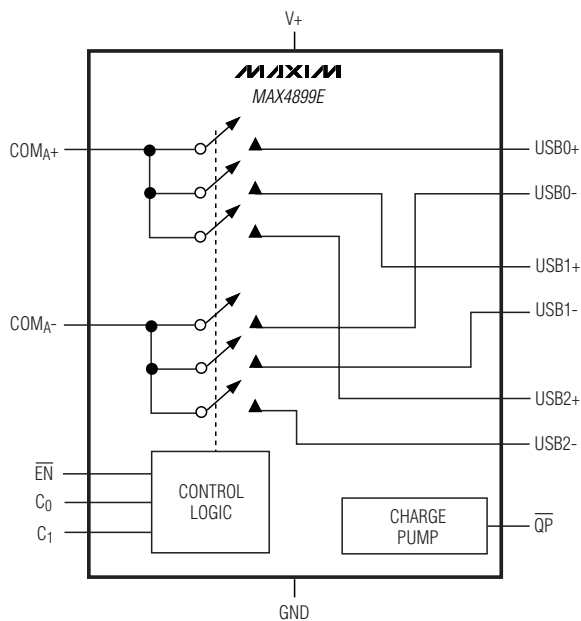
Figure 9b. Human Body Model Current Waveform

Chip Information

PROCESS: BiCMOS

USB 2.0 High-Speed, Fault-Tolerant 3:1, 4:1 Multiplexers

Functional Diagrams



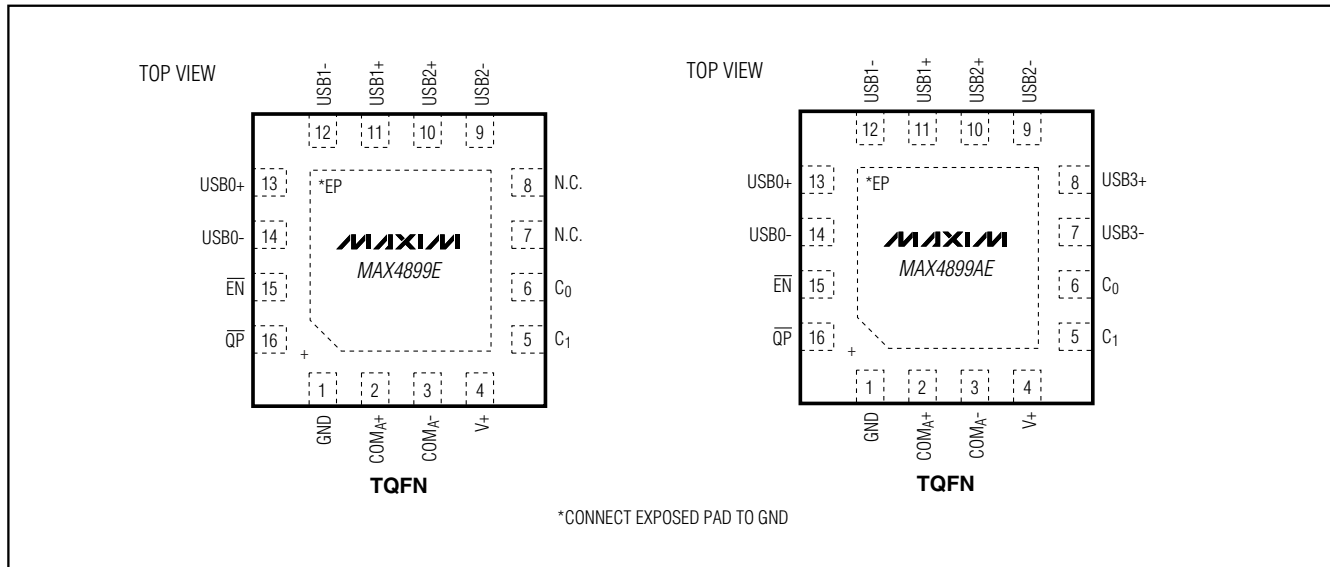
MAX4899E					
QP	EN	C1	C0	FUNCTION	COMMENT
0	0	0	0	COMA+ →USB0+ COMA- →USB0-	NORMAL OPERATION
0	0	0	1	COMA+ →USB1+ COMA- →USB1-	NORMAL OPERATION
0	0	1	0	COMA+ →USB2+ COMA- →USB2-	NORMAL OPERATION
0	0	1	1	HIGH-Z	ALL OFF
0	1	X	X	HIGH-Z	ALL OFF
1	1	X	X	HIGH-Z	ALL OFF
1	0	0	0	COMA+ →USB0+ COMA- →USB0-	LARGER RON
1	0	0	1	COMA+ →USB1+ COMA- →USB1-	LARGER RON
1	0	1	0	COMA+ →USB2+ COMA- →USB2-	LARGER RON
1	0	1	1	HIGH-Z	ALL OFF

MAX4899AE					
QP	EN	C1	C0	FUNCTION	COMMENT
0	0	0	0	COMA+ →USB0+ COMA- →USB0-	NORMAL OPERATION
0	0	0	1	COMA+ →USB1+ COMA- →USB1-	NORMAL OPERATION
0	0	1	0	COMA+ →USB2+ COMA- →USB2-	NORMAL OPERATION
0	0	1	1	COMA+ →USB3+ COMA- →USB3-	NORMAL OPERATION
0	1	X	X	HIGH-Z	ALL OFF
1	1	X	X	HIGH-Z	ALL OFF
1	0	0	0	COMA+ →USB0+ COMA- →USB0-	LARGER RON
1	0	0	1	COMA+ →USB1+ COMA- →USB1-	LARGER RON
1	0	1	0	COMA+ →USB2+ COMA- →USB2-	LARGER RON
1	0	1	1	COMA+ →USB3+ COMA- →USB3-	LARGER RON

X = 1 or 0.

USB 2.0 High-Speed, Fault-Tolerant 3:1, 4:1 Multiplexers

Pin Configurations

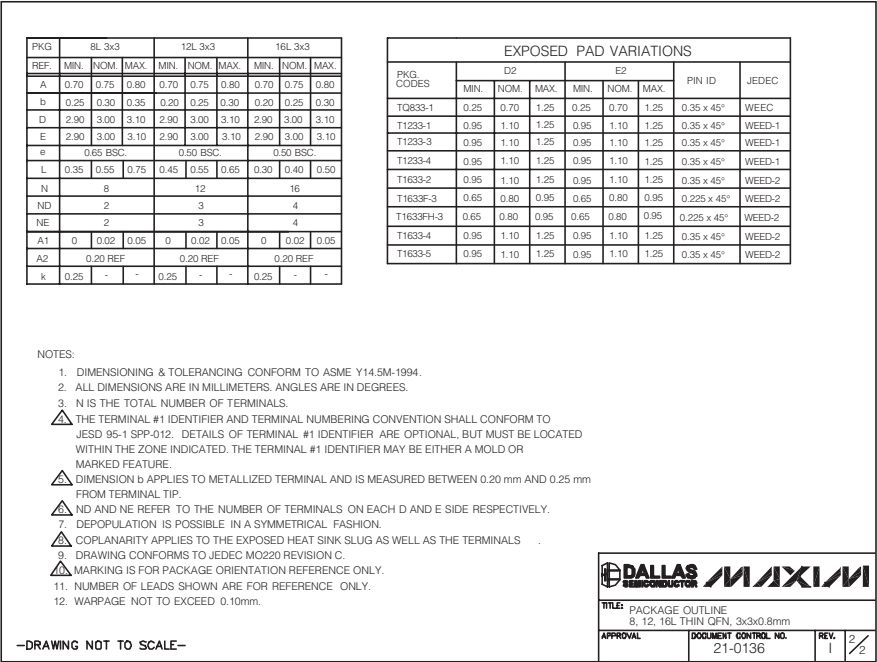
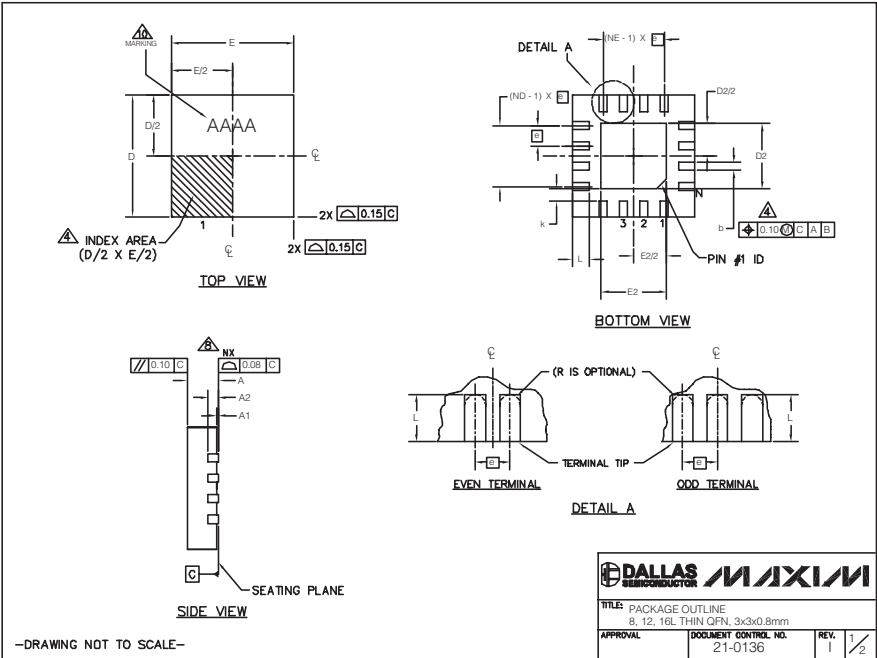


MAX4899E/MAX4899AE

USB 2.0 High-Speed, Fault-Tolerant 3:1, 4:1 Multiplexers

Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to www.maxim-ic.com/packages.)



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