

# ISL54210

MP3/USB 2.0 High Speed Switch with Negative Signal Handling/Click and Pop Suppression

FN6661  
Rev 2.00  
March 18, 2010

The Intersil ISL54210 dual SPDT (Single Pole/Double Throw) switch combines low distortion audio and accurate USB 2.0 high-speed data (480Mbps) signal switching in the same low voltage device. When operated with a 2.7V to 3.6V single supply, these analog switches allow audio signal swings below-ground, allowing the use of a common USB and audio headphone connector in Personal Media Players and other portable battery powered devices.

The ISL54210 incorporates circuitry for the detection of the USB  $V_{BUS}$  voltage, which is used to switch between the audio and USB signal sources.

It has an enable pin (CTRL) to open all switches and activate the audio click/pop (C/P) circuitry. The high off-isolation and special C/P circuitry of the audio switches eliminates click and pops in the headphones when the audio CODEC drivers are powering up/down or when a headphone is inserted or removed from the jack.

It's available in a tiny 10 Ld 1.8mmx1.4mm ultra-thin  $\mu$ TQFN package and a 10 Ld 3mmx3mm TDFN package. It operates over a temperature range of  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ .

## Related Literature (see page 19)

- Technical Brief [TB363](#) "Guidelines for Handling and Processing Moisture Sensitive Surface Mount Devices (SMDs)"
- Application Note [AN1407](#) "ISL54210EVAL1Z Evaluation Board User's Manual"

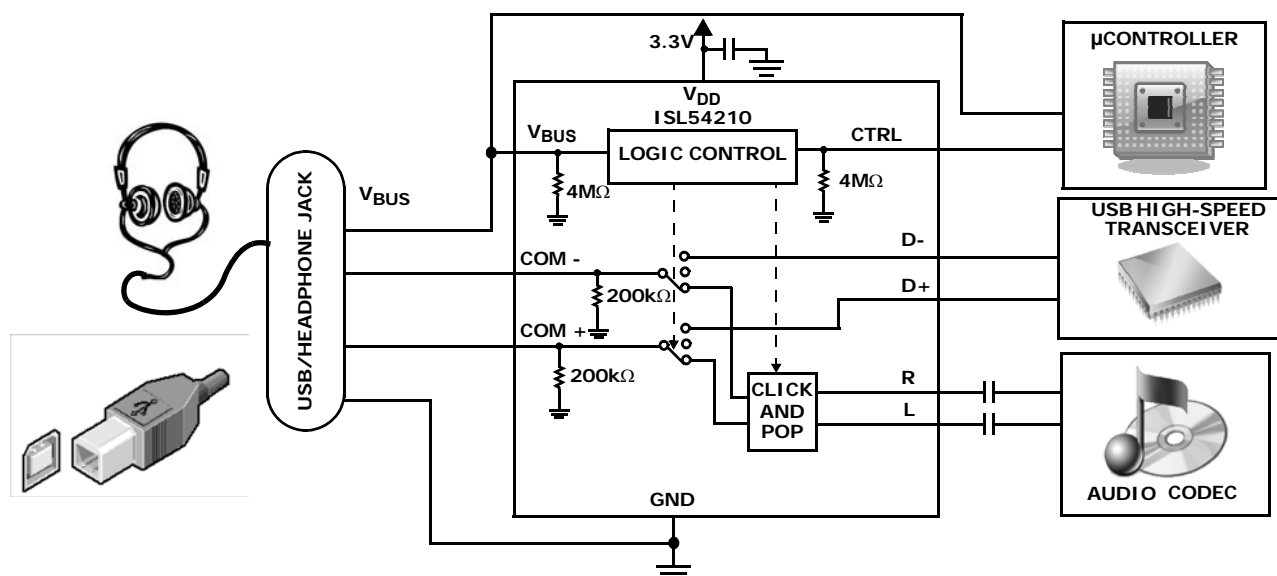
## Features

- High Speed (480Mbps) and Full Speed (12Mbps) Signaling Capability per USB 2.0
- Detection of  $V_{BUS}$  Voltage on USB Cable
- Low Distortion Negative Signal Capability
- Clickless/Popless Audio Switches
- Enable Pin to Open all Switches
- Low Distortion Headphone Audio Signals
  - 0.014% THD+N at 1mW into  $32\Omega$  Load
- 100dB Crosstalk (20Hz to 20kHz)
- 95dB Off-Isolation (20Hz to 100kHz)
- 2.7V to 3.6V Single Supply Operation ( $V_{DD}$ )
- 700MHz of -3dB Bandwidth USB Switch
- 4.2pF of low ON Capacitance @ 240MHz
- Available in  $\mu$ TQFN and TDFN Packages
- Compliant with USB 2.0 Short Circuit Requirements Without Additional External Components
- Pb-Free (RoHS Compliant)

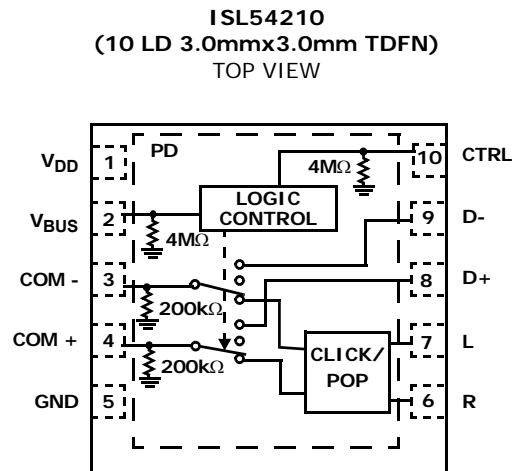
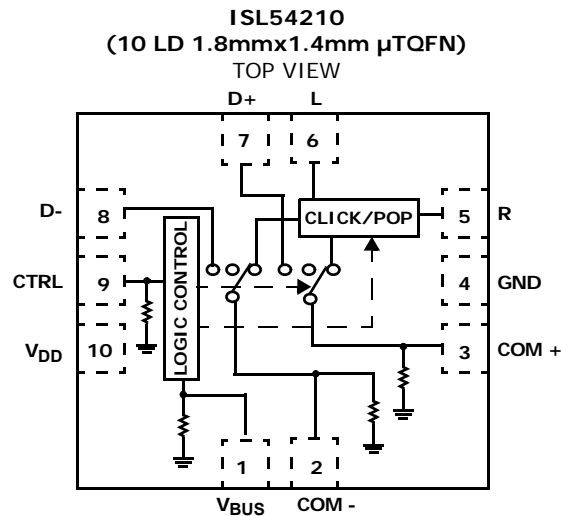
## Applications\* (see page 19)

- MP3 and other Personal Media Players
- Cellular/Mobile Phones
- PDA's
- Audio/USB Switching

## Application Block Diagram



Pin Configurations (Note 1)



NOTE:

1. Switches Shown for  $V_{BUS}$  = Logic "0" and CTRL = Logic "1".

Truth Table

ISL54210			
$V_{BUS}$	CTRL	L, R	D+, D-
0	0	OFF	OFF
0	1	ON	OFF
1	X	OFF	ON

CTRL: Logic "0" when  $\leq 0.5V$  or Floating, Logic "1" when  $\geq 1.4V$

$V_{BUS}$ : Logic "0" when  $\leq V_{DD} + 0.2V$  or Floating, Logic "1" when  $\geq V_{DD} + 0.8V$

Pin Descriptions

ISL54210			
$\mu$ TQFN	TDFN	NAME	FUNCTION
1	2	$V_{BUS}$	Digital Control Input
2	3	COM-	Voice and Data Common Pin
3	4	COM+	Voice and Data Common Pin
4	5	GND	Ground Connection
5	6	R	Audio Right Input
6	7	L	Audio Left Input
7	8	D+	USB Differential Input
8	9	D-	USB Differential Input
9	10	CTRL	Digital Control Input (Audio Enable)
10	1	$V_{DD}$	Power Supply
-	PD	PD	Thermal Pad. Tie to Ground or Float

## Ordering Information

PART NUMBER (Note 5)	PART MARKING	TEMP. RANGE (°C)	PACKAGE (Pb-Free)	PKG. DWG. #
ISL54210IRTZ (Note 3)	4210	-40 to +85	10 Ld 3mmx3mm TDFN	L10.3x3A
ISL54210IRTZ-T (Notes 2, 3)	4210	-40 to +85	10 Ld 3mmx3mm TDFN	L10.3x3A
ISL54210IRUZ-T (Notes 2, 4)	0	-40 to +85	10 Ld 1.8mmx1.4mm $\mu$ TQFN	L10.1.8x1.4A
ISL54210EVAL1Z	Evaluation Board			

### NOTES:

- Please refer to [TB347](#) for details on reel specifications.
- These Intersil Pb-free plastic packaged products employ special Pb-free material sets, molding compounds/die attach materials, and 100% matte tin plate plus anneal (e3 termination finish, which is RoHS compliant and compatible with both SnPb and Pb-free soldering operations). Intersil Pb-free products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC J STD-020.
- These Intersil Pb-free plastic packaged products employ special Pb-free material sets; molding compounds/die attach materials and NiPdAu plate - e4 termination finish, which is RoHS compliant and compatible with both SnPb and Pb-free soldering operations. Intersil Pb-free products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC J STD-020.
- For Moisture Sensitivity Level (MSL), please see device information page for [ISL54210](#). For more information on MSL please see techbrief [TB363](#).

## Absolute Maximum Ratings

$V_{DD}$ to GND	-0.3V to 5.5V
Input Voltages	
D+, D-, L, R (Note 6)	-2V to $((V_{DD}) + 0.3V)$
$V_{BUS}$ (Note 6)	-2V to 5.5V
CTRL (Note 6)	-0.3V to $((V_{DD}) + 0.3V)$
Output Voltages	
COM-, COM+ (Note 6)	-2V to $((V_{DD}) + 0.3V)$
Continuous Current (Audio Switches)	$\pm 150\text{mA}$
Peak Current (Audio Switches)	
(Pulsed 1ms, 10% Duty Cycle, Max)	$\pm 300\text{mA}$
Continuous Current (USB Switches)	$\pm 40\text{mA}$
Peak Current (USB Switches)	
(Pulsed 1ms, 10% Duty Cycle, Max)	$\pm 100\text{mA}$
ESD Rating:	
Human Body Model, COM Pins	>6kV
Human Body Model, All Pins	>4kV
Machine Model	>300V
Charged Device Model	>1.5kV
Latch-up Tested per JEDEC; Class II Level A	at +85°C

## Thermal Information

Thermal Resistance (Typical)	$\theta_{JA}$ (°C/W)	$\theta_{JC}$ (°C/W)
10 Ld $\mu$ TQFN Package (Notes 8, 10)	160	105
10 Ld 3x3 TDFN Package (Notes 7, 9)	55	18
Maximum Junction Temperature (Plastic Package)	+150°C	
Maximum Storage Temperature Range	-65°C to +150°C	
Pb-free Reflow Profile	see link below	
	<a href="http://www.intersil.com/pbfree/Pb-FreeReflow.asp">http://www.intersil.com/pbfree/Pb-FreeReflow.asp</a>	

## Operating Conditions

Temperature Range	-40°C to +85°C
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**CAUTION:** Do not operate at or near the maximum ratings listed for extended periods of time. Exposure to such conditions may adversely impact product reliability and result in failures not covered by warranty.

### NOTES:

- Signals on D+, D-, L, R, COM-, COM+, CTRL,  $V_{BUS}$  exceeding  $V_{DD}$  or GND by specified amount are clamped. Limit current to maximum current ratings.
- $\theta_{JA}$  is measured in free air with the component mounted on a high effective thermal conductivity test board with "direct attach" features. See Tech Brief TB379.
- $\theta_{JA}$  is measured with the component mounted on a high effective thermal conductivity test board in free air. See Tech Brief TB379 for details.
- For  $\theta_{JC}$ , the "case temp" location is the center of the exposed metal pad on the package underside.
- For  $\theta_{JC}$ , the "case temp" location is taken at the package top center.

## Electrical Specifications - 2.7V to 3.6V Supply

Test Conditions:  $V_{DD} = +3.0V$ , GND = 0V,  $V_{BUSH} = 3.8V$ ,  $V_{BUSL} = 3.2V$ ,  $V_{CTRLH} = 1.4V$ ,  $V_{CTRL} = 0.5V$ , (Note 11), Unless Otherwise Specified.  
**Boldface limits apply over the operating temperature range, -40°C to +85°C.**

PARAMETER	TEST CONDITIONS	TEMP (°C)	MIN (Notes 12, 13)	TYP	MAX (Notes 12, 13)	UNITS
<b>ANALOG SWITCH CHARACTERISTICS</b>						
<b>Audio Switches (L, R)</b>						
Analog Signal Range, $V_{ANALOG}$	$V_{DD} = 2.7V$ to $3.6V$ , $V_{BUS} = \text{float}$ , CTRL = 1.4V	Full	<b>-1.5</b>	-	<b>1.5</b>	V
ON-Resistance, $r_{ON}$	$V_{DD} = 3.0V$ , $V_{BUS} = 3.2V$ , CTRL = 1.4V, $I_{COMx} = 40\text{mA}$ , $V_L$ or $V_R = -0.85V$ to $0.85V$ (see Figure 2, Note 15)	+25	-	2.4	2.8	$\Omega$
		Full	-	-	<b>3.8</b>	$\Omega$
$r_{ON}$ Matching Between Channels, $\Delta r_{ON}$	$V_{DD} = 3.0V$ , $V_{BUS} = 3.2V$ , CTRL = 1.4V, $I_{COMx} = 40\text{mA}$ , $V_L$ or $V_R = \text{Voltage at max } r_{ON} \text{ over signal range of } -0.85V \text{ to } 0.85V$ (Notes 15, 16)	+25	-	0.1	0.32	$\Omega$
		Full	-	-	<b>0.4</b>	$\Omega$
$r_{ON}$ Flatness, $R_{FLAT(ON)}$	$V_{DD} = 3.0V$ , $V_{BUS} = 3.2V$ , CTRL = 1.4V, $I_{COMx} = 40\text{mA}$ , $V_L$ or $V_R = -0.85V$ to $0.85V$ , (Notes 14, 15)	+25	-	0.02	0.06	$\Omega$
		Full	-	-	<b>0.07</b>	$\Omega$
Insertion Loss, $G_{ON}$	$V_{DD} = 3.0V$ , $V_{BUS} = 0V$ , CTRL = $V_{DD}$ , $R_{LOAD} = 32\Omega$	+25	-	-0.78	-	dB
Insertion Loss, $G_{ON}$	$V_{DD} = 3.0V$ , $V_{BUS} = 0V$ , CTRL = $V_{DD}$ , $R_{LOAD} = 15\Omega$	+25	-	-1.5	-	dB

**Electrical Specifications - 2.7V to 3.6V Supply** Test Conditions:  $V_{DD} = +3.0V$ ,  $GND = 0V$ ,  $V_{BUSH} = 3.8V$ ,  $V_{BUSL} = 3.2V$ ,  $V_{CTRLH} = 1.4V$ ,  $V_{CTRL L} = 0.5V$ , (Note 11), Unless Otherwise Specified.  
**Boldface limits apply over the operating temperature range, -40°C to +85°C. (Continued)**

PARAMETER	TEST CONDITIONS	TEMP (°C)	MIN (Notes 12, 13)	TYP	MAX (Notes 12, 13)	UNITS
Discharge Pull-Down Resistance, R <sub>L</sub> , R <sub>R</sub>	V <sub>DD</sub> = 3.6V, V <sub>BUS</sub> = 3.2V, CTRL = 0.5V, V <sub>COM-</sub> or V <sub>COM+</sub> = -0.85V, 0.85V, V <sub>L</sub> or V <sub>R</sub> = -0.85V, 0.85V, V <sub>D+</sub> and V <sub>D-</sub> = floating; measure current through the discharge pull-down resistor and calculate resistance value.	+25	-	40	-	Ω
USB Switches (D+, D-)						
Analog Signal Range, V <sub>ANALOG</sub>	V <sub>DD</sub> = 2.7V to 3.6V, V <sub>BUS</sub> = 5.0V, CTRL = 0V or V <sub>DD</sub>	Full	0	-	V <sub>DD</sub>	V
ON-Resistance, r <sub>ON</sub>	V <sub>DD</sub> = 3.3V, V <sub>BUS</sub> = 4.4V, CTRL = 1.4V, I <sub>COMx</sub> = 1mA, V <sub>D+</sub> or V <sub>D-</sub> = 3.3V (see Figure 3, Note 15)	+25	-	25	35	Ω
		Full	-	-	40	Ω
ON-Resistance, r <sub>ON</sub>	V <sub>DD</sub> = 3.3V, V <sub>BUS</sub> = 4.4V, CTRL = 0V or V <sub>DD</sub> , I <sub>COMx</sub> = 40mA, V <sub>D+</sub> or V <sub>D-</sub> = 0V to 400mV (see Figure 3, Note 15)	25	-	5.4	6	Ω
		Full	-	-	7.5	Ω
r <sub>ON</sub> Matching Between Channels, Δr <sub>ON</sub>	V <sub>DD</sub> = 3.3V, V <sub>BUS</sub> = 4.4V, CTRL = 0V or V <sub>DD</sub> , I <sub>COMx</sub> = 40mA, V <sub>D+</sub> or V <sub>D-</sub> = Voltage at max r <sub>ON</sub> (Notes 15, 16)	25	-	0.02	0.25	Ω
		Full	-	-	0.25	Ω
r <sub>ON</sub> Flatness, R <sub>FLAT</sub> (ON)	V <sub>DD</sub> = 3.3V, V <sub>BUS</sub> = 4.4V, CTRL = 0V or V <sub>DD</sub> , I <sub>COMx</sub> = 40mA, V <sub>D+</sub> or V <sub>D-</sub> = 0V to 400mV (Notes 14, 15)	25	-	0.45	0.55	Ω
		Full	-	-	0.6	Ω
OFF Leakage Current, I <sub>D+</sub> (OFF) or I <sub>D-</sub> (OFF)	V <sub>DD</sub> = 3.6V, V <sub>BUS</sub> = 0V, CTRL = 3.6V, V <sub>COM-</sub> or V <sub>COM+</sub> = 0.5V, 0V, V <sub>D+</sub> or V <sub>D-</sub> = 0V, 0.5V, V <sub>L</sub> and V <sub>R</sub> = float	25	-10	4	10	nA
		Full	-50	-	50	nA
ON Leakage Current, I <sub>DX</sub>	V <sub>DD</sub> = 3.6V, V <sub>BUS</sub> = 5.25V, CTRL = 0V or V <sub>DD</sub> , V <sub>D+</sub> or V <sub>D-</sub> = 2.7V, V <sub>COM-</sub> or V <sub>COM+</sub> = Float, V <sub>L</sub> and V <sub>R</sub> = float; measuring current through 200k resistor at COM side	25	-20	11	20	μA
		Full	-30	-	30	μA
DYNAMIC CHARACTERISTICS						
USB Turn-ON Time, t <sub>ON</sub>	V <sub>DD</sub> = 2.7V, R <sub>L</sub> = 50Ω, C <sub>L</sub> = 10pF (see Figure 1)	25	-	43	-	ns
USB Turn-OFF Time, t <sub>OFF</sub>	V <sub>DD</sub> = 2.7V, R <sub>L</sub> = 50Ω, C <sub>L</sub> = 10pF (see Figure 1)	25	-	14.5	-	ns
Audio Turn-ON Time, t <sub>ON</sub>	V <sub>DD</sub> = 2.7V, R <sub>L</sub> = 50Ω, C <sub>L</sub> = 10pF (see Figure 1)	25	-	7.5	-	μs
Audio Turn-OFF Time, t <sub>OFF</sub>	V <sub>DD</sub> = 2.7V, R <sub>L</sub> = 50Ω, C <sub>L</sub> = 10pF (see Figure 1)	25	-	130	-	ns
Skew, t <sub>SKEW</sub>	V <sub>DD</sub> = 3.0V, V <sub>BUS</sub> = 5.0V, CTRL = 0V or 3V, R <sub>L</sub> = 45Ω, C <sub>L</sub> = 10pF, t <sub>R</sub> = t <sub>F</sub> = 750ps at 480Mbps, (Duty Cycle = 50%) (see Figure 6)	25	-	50	-	ps
Total Jitter, t <sub>J</sub>	V <sub>DD</sub> = 3.0V, V <sub>BUS</sub> = 5.0V, CTRL = 0V or 3V, R <sub>L</sub> = 50Ω, C <sub>L</sub> = 10pF, t <sub>R</sub> = t <sub>F</sub> = 750ps at 480Mbps	25	-	210	-	ps
Propagation Delay, t <sub>PD</sub>	V <sub>DD</sub> = 3.0V, V <sub>BUS</sub> = 5.0V, CTRL = 0V or 3V, R <sub>L</sub> = 45Ω, C <sub>L</sub> = 10pF (see Figure 6)	25	-	250	-	ps

**Electrical Specifications - 2.7V to 3.6V Supply** Test Conditions:  $V_{DD} = +3.0V$ ,  $GND = 0V$ ,  $V_{BUS} = 3.8V$ ,  $V_{BUSL} = 3.2V$ ,  $V_{CTRLH} = 1.4V$ ,  $V_{CTRL} = 0.5V$ , (Note 11), Unless Otherwise Specified.  
**Boldface limits apply over the operating temperature range, -40°C to +85°C. (Continued)**

PARAMETER	TEST CONDITIONS	TEMP (°C)	MIN (Notes 12, 13)	TYP	MAX (Notes 12, 13)	UNITS
Audio Crosstalk R to COM-, L to COM+	$V_{DD} = 3.0V$ , $V_{BUS} = \text{float}$ , $CTRL = 3.0V$ , $R_L = 32\Omega$ , $f = 20\text{Hz}$ to $20\text{kHz}$ , $V_R$ or $V_L = 0.707V_{RMS}$ (2V <sub>p-p</sub> ) (see Figure 5)	25	-	-100	-	dB
Crosstalk (Audio to USB, USB to Audio)	$V_{DD} = 3.0V$ , $R_L = 50\Omega$ , $f = 100\text{kHz}$ (see Figure 5)	25	-	-100	-	dB
OFF-Isolation	$V_{DD} = 3.0V$ , $R_L = 50\Omega$ , $f = 100\text{kHz}$	25	-	95	-	dB
OFF-Isolation	$V_{DD} = 3.0V$ , $R_L = 15\Omega$ , $f = 20\text{Hz}$ to $20\text{kHz}$	25	-	111	-	dB
OFF-Isolation	$V_{DD} = 3.0V$ , $R_L = 32\Omega$ , $f = 20\text{Hz}$ to $20\text{kHz}$	25	-	105	-	dB
OFF-Isolation	$V_{DD} = 3.0V$ , $R_L = 1\text{k}\Omega$ , $f = 20\text{Hz}$ to $20\text{kHz}$	25	-	75	-	dB
OFF-Isolation	$V_{DD} = 3.0V$ , $R_L = 10\text{k}\Omega$ , $f = 20\text{Hz}$ to $20\text{kHz}$	25	-	57	-	dB
OFF-Isolation	$V_{DD} = 3.0V$ , $R_L = 100\text{k}\Omega$ , $f = 20\text{Hz}$ to $20\text{kHz}$	25	-	45	-	dB
Total Harmonic Distortion	$f = 20\text{Hz}$ to $20\text{kHz}$ , $V_{DD} = 3.0V$ , $V_{BUS}$ $= \text{Float}$ , $CTRL = 3.0V$ , $V_L$ or $V_R = 180\text{mV}_{RMS}$ (509mV <sub>p-p</sub> ) $R_L = 32\Omega$	25	-	0.014	-	%
Total Harmonic Distortion	$f = 20\text{Hz}$ to $20\text{kHz}$ , $V_{DD} = 3.0V$ , $V_{BUS}$ $= \text{Float}$ , $CTRL = 3.0V$ , $V_L$ or $V_R = 0.707V_{RMS}$ (2V <sub>p-p</sub> ), $R_L = 32\Omega$	25	-	0.056	-	%
Total Harmonic Distortion	$f = 20\text{Hz}$ to $20\text{kHz}$ , $V_{DD} = 3.0V$ , $V_{BUS}$ $= 0V$ , $CTRL = 3.0V$ , $V_L$ or $V_R = 180\text{mV}_{RMS}$ (509mV <sub>p-p</sub> ), $R_L = 15\Omega$	25	-	0.043	-	%
Total Harmonic Distortion	$f = 20\text{Hz}$ to $20\text{kHz}$ , $V_{DD} = 3.0V$ , $V_{BUS} = 0V$ , $CTRL = 3.0V$ , $V_L$ or $V_R = 0.707V_{RMS}$ (2V <sub>p-p</sub> ), $R_L = 15\Omega$	25	-	0.19	-	%
Click and Pop	$V_{DD} = 3.3V$ , $CTRL = 0V$ , $V_{BUS} = \text{float}$ , $R_L = 1\text{k}\Omega$ , $V_L$ or $V_R = 0$ to $1.25V$ DC step or $1.25V$ to $0V$ DC step (see Figure 7)	25	-	60	-	$\mu\text{Vp}$
Click and Pop	$V_{DD} = 3.3V$ , $CTRL = 0.5\text{Hz}$ square wave, $V_{BUS} = \text{float}$ , $R_L = 1\text{k}\Omega$ , $V_L$ or $V_R = \text{AC-coupled to ground}$ (see Figure 8)	25	-	500	-	$\mu\text{Vp}$
USB Switch -3dB Bandwidth	Signal = 0dBm, 0.2VDC offset, $R_L = 50\Omega$ , $C_L = 5\text{pF}$	25	-	700	-	MHz
D+/D- OFF Capacitance, $C_{D+OFF}$ , $C_{D-OFF}$	$f = 1\text{MHz}$ , $V_{DD} = 3.0V$ , $V_{BUS} = \text{float}$ , $CTRL = 3.0V$ , $V_{D-}$ or $V_{D+} = V_{COMx} = 0V$ (see Figure 4)	25	-	4	-	pF
COM ON Capacitance, $C_{COM-(ON)}$ , $C_{COM+(ON)}$	$f = 1\text{MHz}$ , $V_{DD} = 3.0V$ , $V_{BUS} = 5.0V$ , $CTRL = 0V$ , $V_{D-}$ or $V_{D+} = V_{COMx} = 0V$ (see Figure 4)	25	-	9	-	pF
COM ON Capacitance, $C_{COM-(ON)}$ , $C_{COM+(ON)}$	$f = 240\text{MHz}$ , $V_{DD} = 3.0V$ , $V_{BUS} = 5.0V$ , $CTRL = 0V$ , $V_{D-}$ or $V_{D+} = V_{COMx} = 0V$ (see Figure 4)	25	-	4.2	-	pF

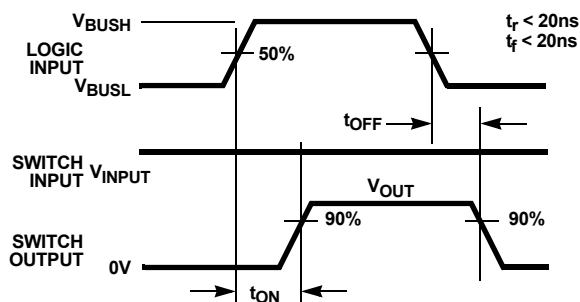
**Electrical Specifications - 2.7V to 3.6V Supply** Test Conditions:  $V_{DD} = +3.0V$ ,  $GND = 0V$ ,  $V_{BUSH} = 3.8V$ ,  $V_{BUSL} = 3.2V$ ,  $V_{CTRLH} = 1.4V$ ,  $V_{CTRL} = 0.5V$ , (Note 11), Unless Otherwise Specified.  
**Boldface limits apply over the operating temperature range, -40°C to +85°C. (Continued)**

PARAMETER	TEST CONDITIONS	TEMP (°C)	MIN (Notes 12, 13)	TYP	MAX (Notes 12, 13)	UNITS
<b>POWER SUPPLY CHARACTERISTICS</b>						
Power Supply Range, $V_{DD}$		Full	<b>2.7</b>	-	<b>3.6</b>	V
Positive Supply Current, $I_{DD}$ (Audio Mode)	$V_{DD} = 3.6V$ , $V_{BUS} = 0V$ , $CTRL = 3.6V$	25	-	7	10	$\mu A$
		Full	-	-	<b>12</b>	$\mu A$
Positive Supply Current, $I_{DD}$ (USB Mode)	$V_{DD} = 3.6V$ , $V_{BUS} = 5.25V$ , $CTRL = 3.6V$	25	-	2.4	4	$\mu A$
		Full	-	-	<b>5</b>	$\mu A$
Positive Supply Current, $I_{DD}$ (Mute Mode)	$V_{DD} = 3.6V$ , $V_{BUS} = 0V$ , $CTRL = 0V$	25	-	2.4	4	$\mu A$
		Full	-	-	<b>5</b>	$\mu A$
$V_{BUS}$ Current, $I_{VBUS}$	$V_{DD} = 0V$ , $V_{BUS} = 5.25V$ , $CTRL = \text{Float}$	25	-	-	1	$\mu A$
<b>DIGITAL INPUT CHARACTERISTICS</b>						
$V_{BUS}$ Voltage Low, $V_{VBUSL}$	$V_{DD} = 2.7V$ to $3.6V$	Full	-	-	<b><math>V_{DD} + 0.2V</math></b>	V
$V_{BUS}$ Voltage High, $V_{VBUSH}$	$V_{DD} = 2.7V$ to $3.6V$	Full	<b><math>V_{DD} + 0.8V</math></b>	-	-	V
$CTRL$ Voltage Low, $V_{CTRL}$	$V_{DD} = 2.7V$ to $3.6V$	Full	-	-	<b>0.5</b>	V
$CTRL$ Voltage High, $V_{CTRLH}$	$V_{DD} = 2.7V$ to $3.6V$	Full	<b>1.4</b>	-	-	V
Input Current, $I_{VBUSL}$ , $I_{CTRL}$	$V_{DD} = 3.6V$ , $V_{BUS} = 0V$ or float, $CTRL = 0V$ or Float	Full	<b>-50</b>	2	<b>50</b>	nA
Input Current, $I_{VBUSH}$	$V_{DD} = 3.6V$ , $V_{BUS} = 5.25V$ , $CTRL = 0V$ or float	Full	<b>-2</b>	1	<b>2</b>	$\mu A$
Input Current, $I_{CTRLH}$	$V_{DD} = 3.6V$ , $V_{BUS} = 0V$ or float, $CTRL = 3.6V$	Full	<b>-2</b>	1	<b>2</b>	$\mu A$
$V_{BUS}$ Pull-Down Resistor, $R_{VBUS}$	$V_{DD} = 3.6V$ , $V_{BUS} = 5.25V$ , $CTRL = 0V$ or float, measure current through the internal pull-down resistor and calculate resistance value.	Full	-	4	-	M $\Omega$
$CTRL$ Pull-Down Resistor, $R_{CTRL}$	$V_{DD} = 3.6V$ , $V_{BUS} = 0V$ or float, $CTRL = 3.6V$ , measure current through the internal pull-down resistor and calculate resistance value.	Full	-	4	-	M $\Omega$

## NOTES:

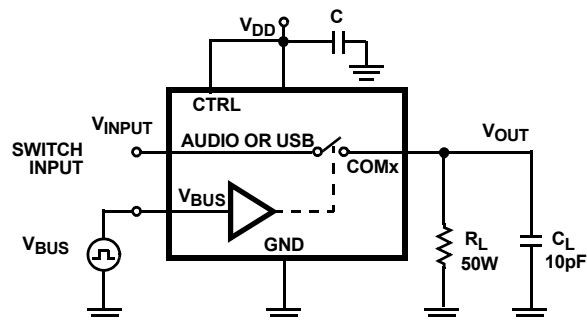
11.  $V_{LOGIC}$  = Input voltage to perform proper function.
12. The algebraic convention, whereby the most negative value is a minimum and the most positive a maximum.
13. Parameters with MIN and/or MAX limits are 100% tested at +25°C, unless otherwise specified. Temperature limits established by characterization and are not production tested.
14. Flatness is defined as the difference between maximum and minimum value of ON-resistance over the specified analog signal range.
15. Limits established by characterization and are not production tested.
16.  $r_{ON}$  matching between channels is calculated by subtracting the channel with the highest max  $r_{ON}$  value from the channel with lowest max  $r_{ON}$  value, between L and R or between D+ and D-.

## Test Circuits and Waveforms



Logic input waveform is inverted for switches that have the opposite logic sense.

FIGURE 1A. MEASUREMENT POINTS

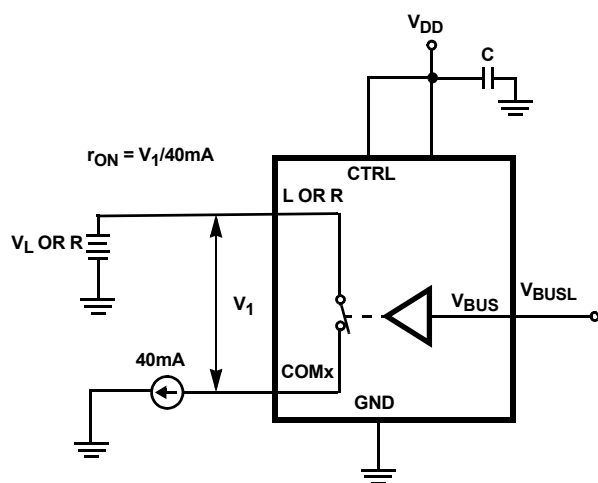


Repeat test for all switches.  $C_L$  includes fixture and stray capacitance.

$$V_{OUT} = V_{(INPUT)} \frac{R_L}{R_L + r_{ON}}$$

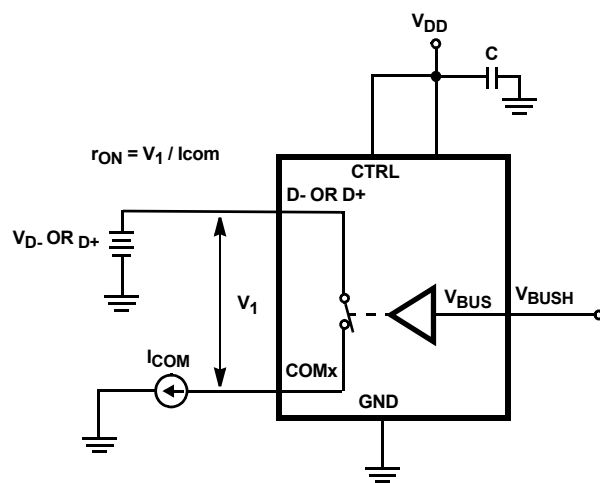
FIGURE 1B. TEST CIRCUIT

FIGURE 1. SWITCHING TIMES



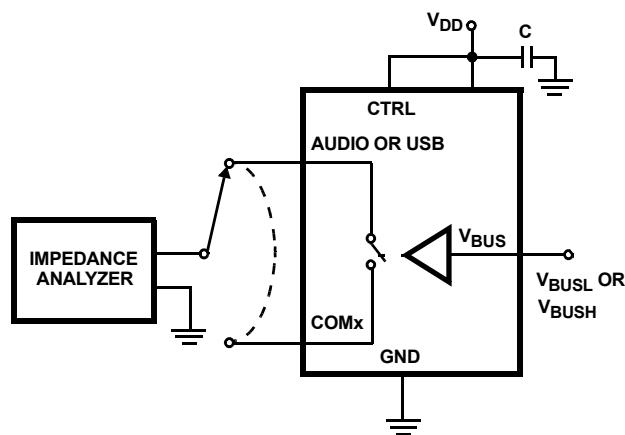
REPEAT TEST FOR ALL SWITCHES

FIGURE 2. AUDIO  $r_{ON}$  TEST CIRCUIT



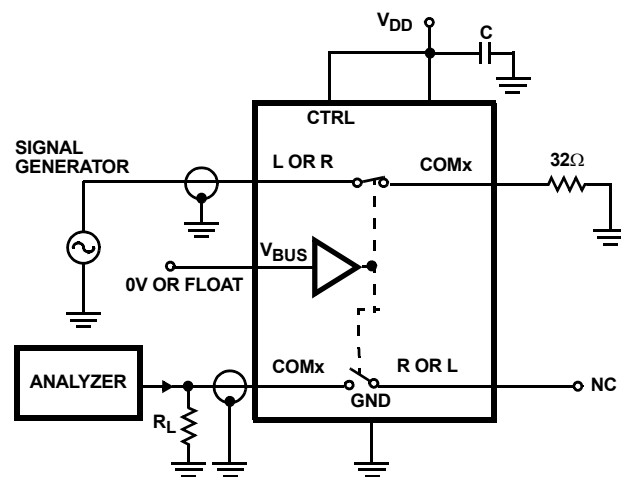
REPEAT TEST FOR ALL SWITCHES

FIGURE 3. USB  $r_{ON}$  TEST CIRCUIT



REPEAT TEST FOR ALL SWITCHES

FIGURE 4. CAPACITANCE TEST CIRCUIT



REPEAT TEST FOR ALL SWITCHES

FIGURE 5. AUDIO CROSSTALK TEST CIRCUIT



## Test Circuits and Waveforms (Continued)

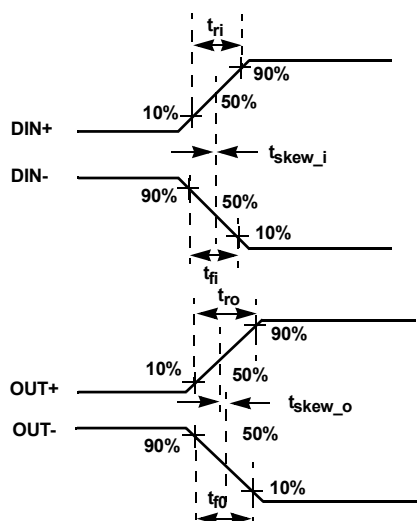
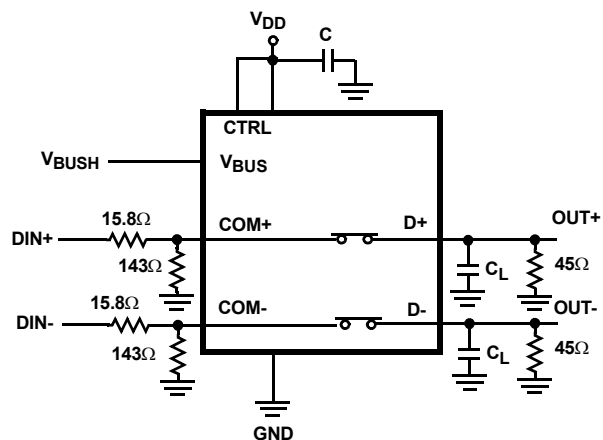


FIGURE 6A. MEASUREMENT POINTS



$|t_{ro} - t_{ri}|$  Delay Due to Switch for Rising Input and Rising Output Signals.

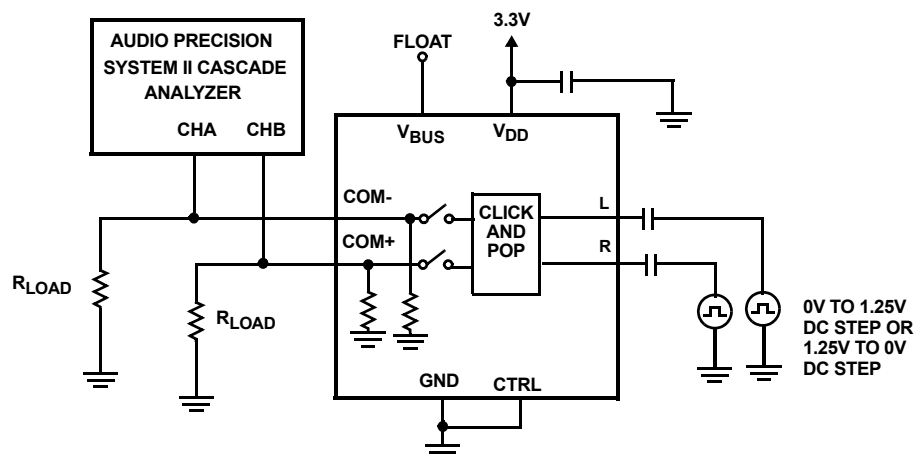
$|t_{fo} - t_{fi}|$  Delay Due to Switch for Falling Input and Falling Output Signals.

$|t_{skew\_o}|$  Change in Skew through the Switch for Output Signals.

$|t_{skew\_i}|$  Change in Skew through the Switch for Input Signals.

FIGURE 6B. TEST CIRCUIT

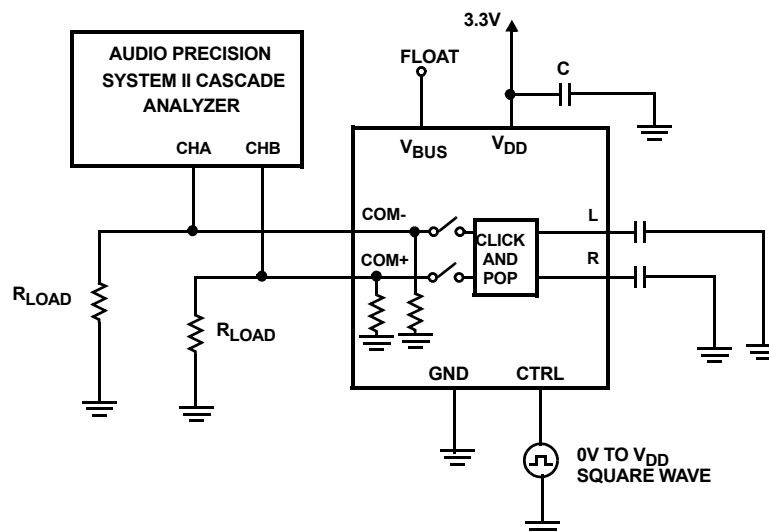
FIGURE 6. SKEW TEST



SET AUDIO ANALYZER FOR PEAK DETECTION, 32 SAMPLES/SEC, A WEIGHTED FILTER, MANUAL RANGE 1X/Y, UNITS TO DBV

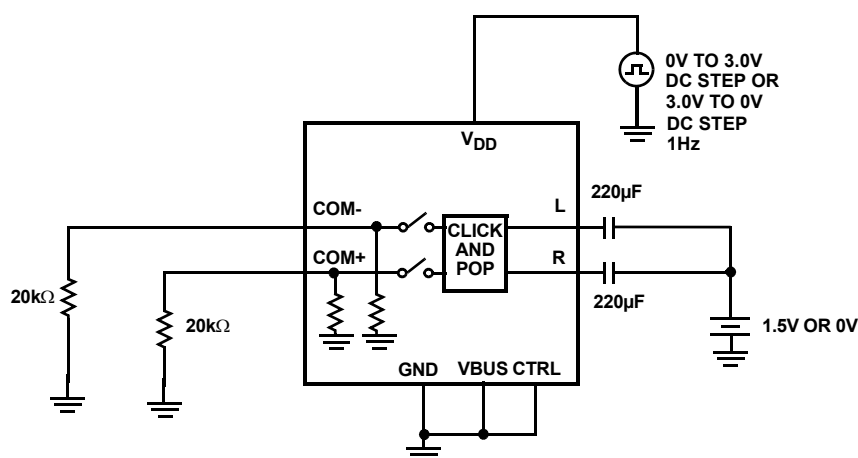
FIGURE 7. CLICK AND POP TEST CIRCUIT

## Test Circuits and Waveforms (Continued)



SET AUDIO ANALYZER FOR PEAK DETECTION, 32 SAMPLES/SEC, A WEIGHTED FILTER, MANUAL RANGE 1X/Y, UNITS TO DBV

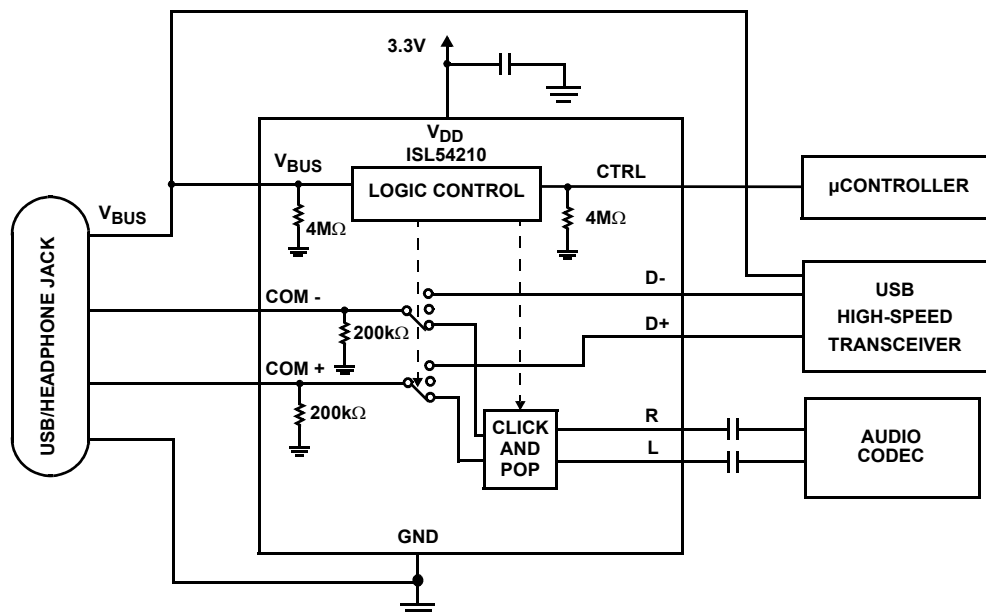
FIGURE 8. CLICK AND POP TEST CIRCUIT



POWER SUPPLY TURN-ON/TURN-OFF CLICK AND POP TRANSIENT TEST

FIGURE 9. CLICK AND POP TEST CIRCUIT #2

## Typical Application Block Diagram



## Detailed Description

The ISL54210 device is a dual single pole/double throw (SPDT) analog switch that operates from a single DC power supply in the range of 2.7V to 3.6V. It was designed to function as a dual 2-to-1 multiplexer to select between USB differential data signals and audio L and R stereo signals. It comes in tiny  $\mu$ TQFN and TDFN packages for use in MP3 players, PDAs, cellphones, and other personal media players.

The part consists of two 2.5 $\Omega$  audio switches and two 5.5 $\Omega$  USB switches. The audio switches can accept signals that swing below ground. They were designed to pass audio left and right stereo signals, that are ground referenced, with minimal distortion. The USB switches were designed to pass high-speed USB differential data signals with minimal edge and phase distortion.

The ISL54210 was specifically designed for MP3 players, personal media players and cellphone applications that need to combine the audio headphone jack and the USB data connector into a single shared connector, thereby saving space and component cost. A "Typical Application Block Diagram" of this functionality is shown on page 11.

The ISL54210 incorporates circuitry for the detection of the USB  $V_{BUS}$  voltage, which is used to switch between the audio CODEC drivers and USB transceiver of the MP3 player or cellphone. The ISL54210 contains a logic control pin (CTRL) that when driven low while  $V_{BUS}$  is low, opens all switches and activates the audio click and pop circuitry.

A detailed description of the two types of switches are provided in the following sections. In a typical application, the USB transmission and audio playback are intended to be mutually exclusive operations.

## Audio Switches

The two audio switches (L, R) are 2.5 $\Omega$  switches that can pass signals that swing below ground. Crosstalk between the audio switches is <-100dB over the audio band. These switches have excellent off-isolation >105dB over the audio band with a 32 $\Omega$  load.

Over a signal range of  $\pm 1V$  (0.707 $V_{RMS}$ ) with  $V_{DD} > 2.7V$ , these switches have an extremely low  $r_{ON}$  resistance variation. They can pass ground referenced audio signals with very low distortion (<0.06% THD+N) when delivering 15.6mW into a 32 $\Omega$  headphone speaker load. See Figures 16, 17, 18, and 19 THD+N in "Typical Performance Curves" beginning on page 14.

The audio drivers should be connected at the L and R side of the switch (pins 5 and 6 for  $\mu$ TQFN, pins 6 and 7 for TDFN) and the speaker loads should be connected at the COM side of the switch (pins 2 and 3 for  $\mu$ TQFN, pins 3 and 4 for TDFN).

The audio switches have click and pop circuitry on the L and R side that is activated when the  $V_{BUS}$  voltage is  $\leq V_{DD} + 0.2V$  or floating and the CTRL voltage  $\leq$  to 0.5V or floating. The ISL54210 should be put in this mode before powering down or powering up of the audio CODEC drivers. In this mode, both the audio and USB in-line switches will be OFF and the audio click and pop circuitry will be ON. The high off-isolation of the audio switches along with the click and pop circuitry will isolate the transients generated during power-up and power-down of the audio CODECs from getting through to the headphones, thus eliminating click and pop noise in the headphones.

The audio switches are active (turned ON) whenever the  $V_{BUS}$  voltage is  $\leq V_{DD} + 0.2V$  or floating and the CTRL voltage  $\geq$  to 1.4V.

## USB Switches

The two USB switches (D+, D-) are 5.5Ω bidirectional switches that were specifically designed to pass high-speed USB differential signals typically in the range of 0V to 400mV. The switches have low capacitance and high bandwidth to pass USB high-speed signals (480Mbps) with minimum edge and phase distortion to meet USB 2.0 signal quality specifications. See Figure 20 for high-speed eye pattern taken with switch in the signal path.

These switches can also swing rail-to-rail and pass USB full-speed signals (12Mbps) with minimal distortion. See Figure 21 for full-speed eye pattern taken with switch in the signal path.

The maximum signal range for the USB switches is from -1.5V to  $V_{DD}$ . The signal voltage at D- and D+ should not be allowed to exceed the  $V_{DD}$  voltage rail or go below ground by more than -1.5V.

The USB switches are active (turned ON) whenever the  $V_{BUS}$  voltage is  $\geq V_{DD} + 0.8V$ .  $V_{BUS}$  is internally pulled low, so when  $V_{BUS}$  is floating the USB switches are OFF.

## ISL54210 Operation

The following discusses using the ISL54210 in the "Typical Application Block Diagram" on page 11.

### $V_{DD}$ SUPPLY

The DC power supply connected at  $V_{DD}$  (Pin 10 for  $\mu$ TQFN, Pin 1 for TDFN) provides the required bias voltage for proper switch operation. Its voltage should be kept in the range of 2.7V to 3.6V when used in a USB/Audio application to ensure you get proper switching when the  $V_{BUS}$  voltage is at its lower limit of 4.4V.

In a typical USB/Audio application for portable battery powered devices, the  $V_{DD}$  voltage will come from a battery or an LDO and be in the range of 2.7V to 4.3V. For best possible USB full-speed operation (12Mbps), it is recommended that the  $V_{DD}$  voltage be  $\geq 2.7V$  in order to get a USB data signal level above 2.7V.

Before power-up and power-down of the ISL54210 part, the  $V_{BUS}$  and CTRL control pins should be driven to ground or tri-stated. This will put the switch in the mute state which turns all switches OFF and activates the click and pop circuitry. Which will minimize transients at the speaker loads during power-up and power-down.

### LOGIC CONTROL

The state of the ISL54210 device is determined by the voltage at the  $V_{BUS}$  pin (Pin 1 for  $\mu$ TQFN, Pin 2 for TDFN) and the CTRL pin (Pin 9 for  $\mu$ TQFN, Pin 10 for TDFN). The part has three states or modes of operation: Audio Mode, USB Mode and Mute Mode. Refer to the "Truth Table" on page 2.

The  $V_{BUS}$  pin and CTRL pin are internally pulled low through 4MΩ resistors to ground and can be left floating

or tri-stated. The CTRL control pin is only active when  $V_{BUS}$  is logic "0".

### Logic Control Voltage Levels:

$V_{BUS}$  = Logic "0" (Low) when  $V_{BUS} \leq V_{DD} + 0.2V$  or Floating.

$V_{BUS}$  = Logic "1" (High) when  $V_{BUS} \geq V_{DD} + 0.8V$

CTRL = Logic "0" (Low) when  $\leq 0.5V$  or Floating.

CTRL = Logic "1" (High) when  $\geq 1.4V$

### Audio Mode

If the  $V_{BUS}$  pin = Logic "0" and CTRL pin = Logic "1", the part will be in the Audio mode. In Audio mode, the L (left) and R (right) 2.5Ω audio switches are ON, the D- and D+ 5.5Ω switches are OFF (high impedance) and the audio click and pop circuitry is OFF (high impedance).

In a typical application,  $V_{DD}$  will be in the range of 2.7V to 3.6V and will be connected to the battery or LDO of the MP3 player or cellphone. When a headphone is plugged into the common connector, nothing gets connected at the  $V_{BUS}$  pin (its internally pulled low) and as long as the CTRL = Logic "1" the ISL54210 part remains in the audio mode and the audio drivers of the player can drive the headphones and play music.

### USB Mode

If the  $V_{BUS}$  pin = Logic "1" and CTRL pin = Logic "0" or Logic "1" the part will go into USB mode. In USB mode, the D- and D+ 5.5Ω switches are ON and the L and R 2.5Ω audio switches are OFF (high impedance).

When a USB cable from a computer or USB hub is connected at the common connector, the voltage at the  $V_{BUS}$  pin will be driven with the USB  $V_{BUS}$  voltage which will be in the range of 4.4V to 5.25V. The ISL54210 part will go into the USB mode. In USB mode, the computer or USB hub transceiver and the MP3 player or cellphone USB transceiver are connected and digital data will be able to be transmitted back and forth.

When the USB cable is disconnected the ISL54210 automatically turns the D+ and D- switches OFF.

### Mute Mode

If the  $V_{BUS}$  pin = Logic "0" and CTRL pin = Logic "0", the part will be in the Mute mode. In the Mute mode, the audio switches and the USB switches are OFF (high impedance) and the audio click and pop circuitry is ON.

Before powering down or powering up of the audio CODECs drivers, the ISL54210 should be put in the Mute mode. In Mute mode transients present at the L and R signal pins due to the changing DC voltage of the audio drivers will not pass to the headphones preventing clicks and pops in the headphones. See "AC-Coupled click and pop operation" on page 13.

Before power-up and power-down of the ISL54210 part, the  $V_{BUS}$  and CTRL control pins should be driven to ground or tri-stated. This will put the switch in the mute state, which turns all switches OFF and activates the click and pop circuitry. This will minimize transients at the

speaker loads during power-up and power-down. See Figure 30 in the "Typical Performance Curves" on page 18.

### AC-COUPLED CLICK AND POP OPERATION

Single supply audio drivers have their signal biased at a DC offset voltage (usually at 1/2 the DC supply voltage of the driver). As this DC bias voltage comes up or goes down during power-up or power-down of the driver, a transient can be coupled into the speaker load through the DC blocking capacitor (see the "Typical Application Block Diagram" on page 11).

When a driver is OFF and then turned ON, the rapidly changing DC bias voltage at the output of the driver will cause an equal voltage at the input side of the switch due to the fact that the voltage across the blocking capacitor cannot change instantly. If the switch is in the Audio mode or there is no low impedance path to discharge the blocking capacitor voltage at the input of the switch, before turning on the audio switch, a transient discharge will occur in the speaker, generating a click/pop noise.

Proper elimination of a click/pop transient at the speaker loads while powering up or down of the audio drivers requires that the ISL54210 have its click/pop circuitry activated by putting the part in the Mute mode. This allows the transients generated by the audio drivers to be discharged through the click and pop shunt circuitry.

Once the driver DC bias has reached  $V_{DD}/2$  and the transient on the switch side of the DC blocking capacitor has been discharged to ground through the click/pop shunt circuitry, the audio switches can be turned ON and connected through to the speaker loads without generating any undesirable click/pop noise in the speakers.

With a typical DC blocking capacitor of 220 $\mu$ F and the click/pop shunt circuitry designed to have a resistance of 20 $\Omega$  to 70 $\Omega$ , allowing a 100ms wait time to discharge the transient before placing the switch in the Audio mode will prevent the transient from getting through to the speaker load. See Figures 28 and 29 in the "Typical Performance Curves" page 17.

## Typical Performance Curves $T_A = +25^\circ\text{C}$ , Unless Otherwise Specified

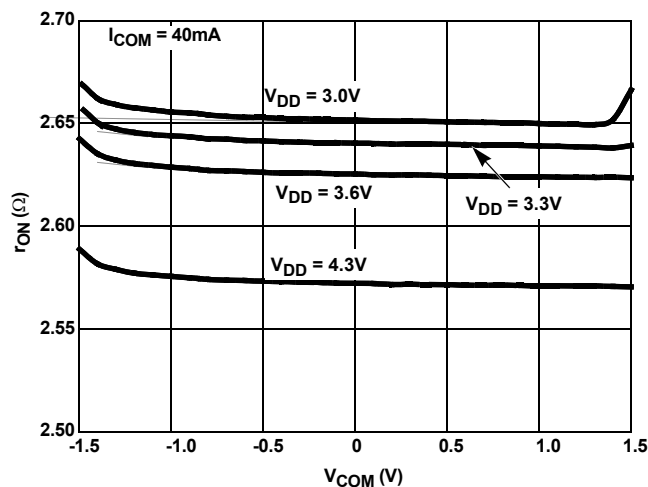


FIGURE 10. AUDIO ON-RESISTANCE vs SUPPLY VOLTAGE vs SWITCH VOLTAGE

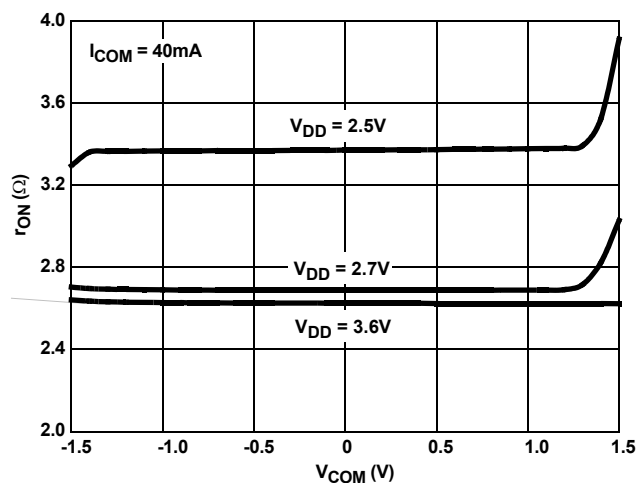


FIGURE 11. AUDIO ON-RESISTANCE vs SUPPLY VOLTAGE vs SWITCH VOLTAGE

## Typical Performance Curves $T_A = +25^\circ\text{C}$ , Unless Otherwise Specified (Continued)

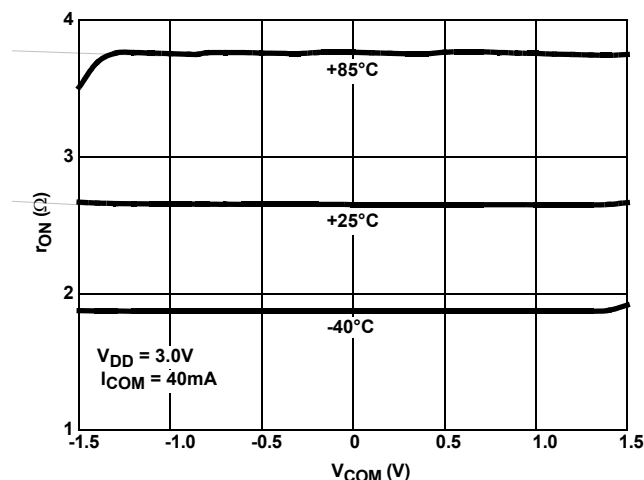


FIGURE 12. AUDIO ON-RESISTANCE vs SWITCH VOLTAGE vs TEMPERATURE

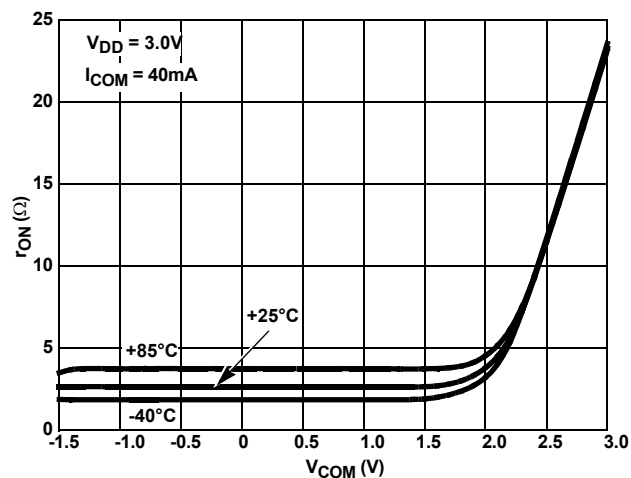


FIGURE 13. AUDIO ON-RESISTANCE vs SWITCH VOLTAGE vs TEMPERATURE

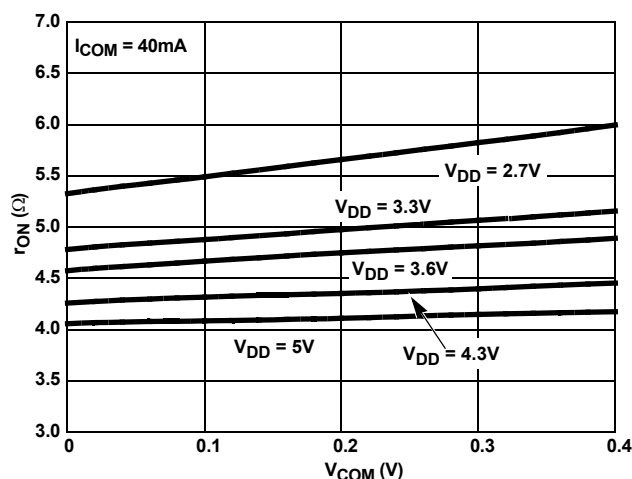


FIGURE 14. USB ON-RESISTANCE vs SUPPLY VOLTAGE vs SWITCH VOLTAGE

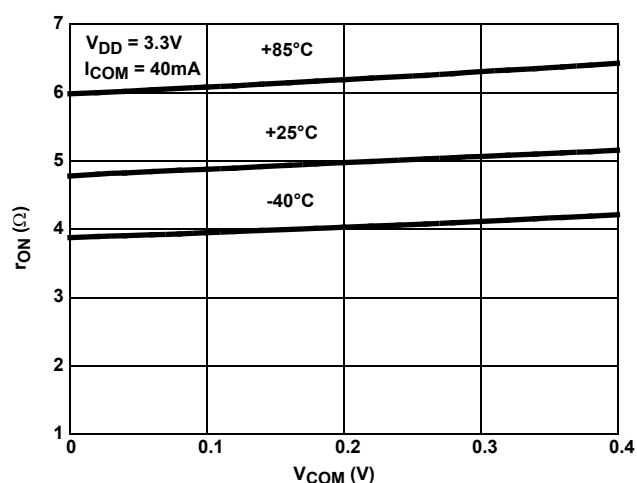


FIGURE 15. USB ON-RESISTANCE vs SWITCH VOLTAGE vs TEMPERATURE

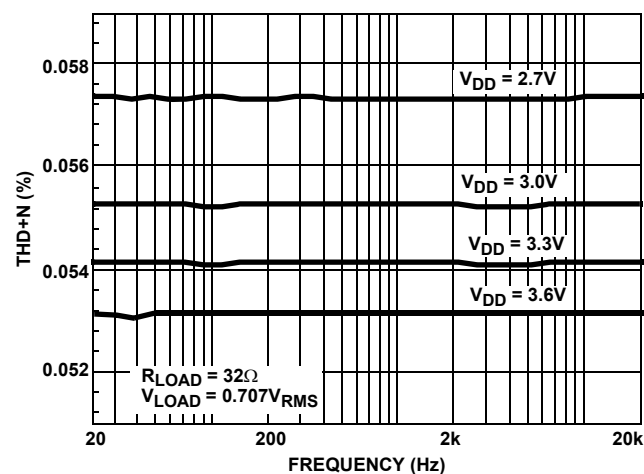


FIGURE 16. THD+N vs SUPPLY VOLTAGE vs FREQUENCY

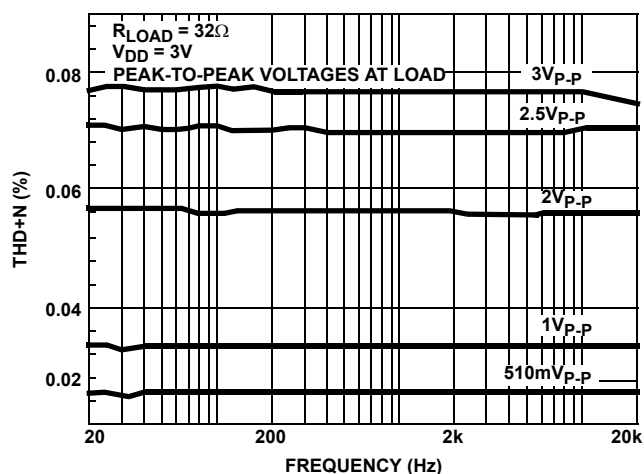


FIGURE 17. THD+N vs SIGNAL LEVELS vs FREQUENCY

## Typical Performance Curves $T_A = +25^\circ\text{C}$ , Unless Otherwise Specified (Continued)

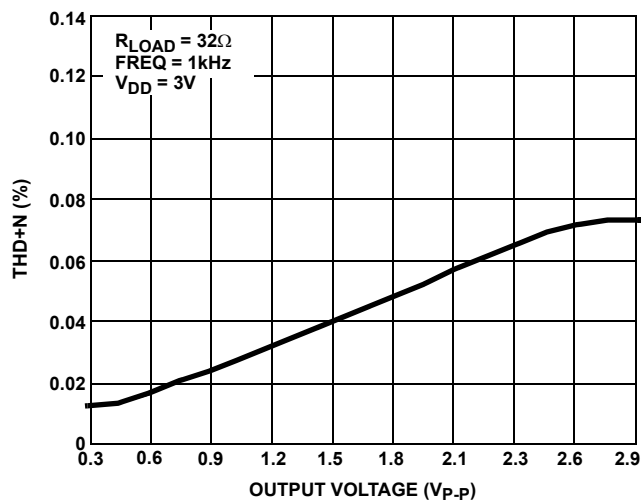


FIGURE 18. THD+N vs OUTPUT VOLTAGE

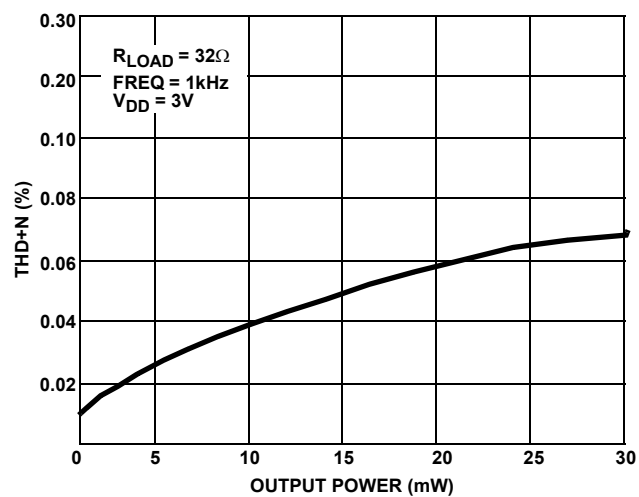


FIGURE 19. THD+N vs OUTPUT POWER

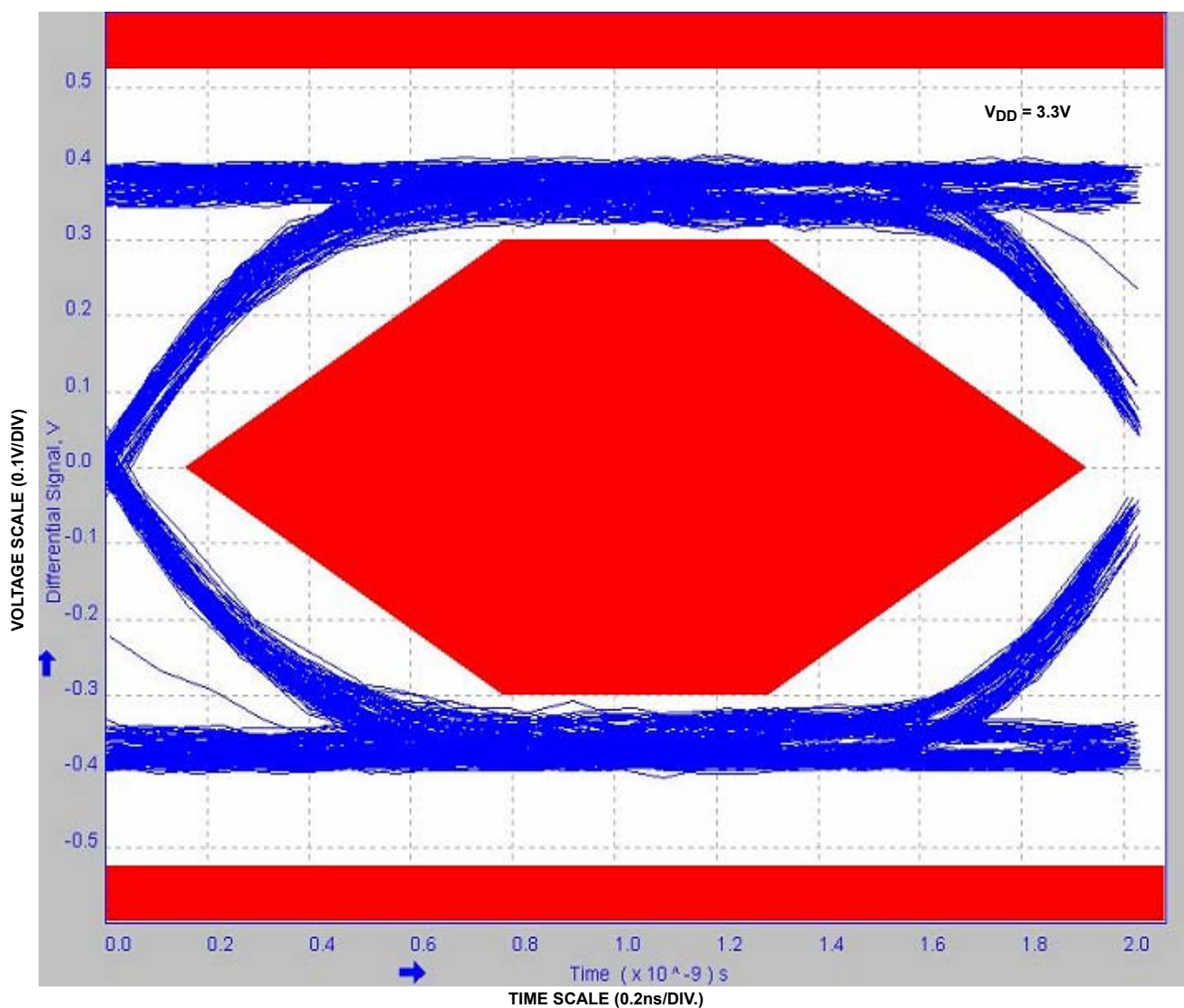


FIGURE 20. EYE PATTERN: 480Mbps WITH USB SWITCHES IN THE SIGNAL PATH



# Typical Performance Curves $T_A = +25^\circ\text{C}$ , Unless Otherwise Specified (Continued)

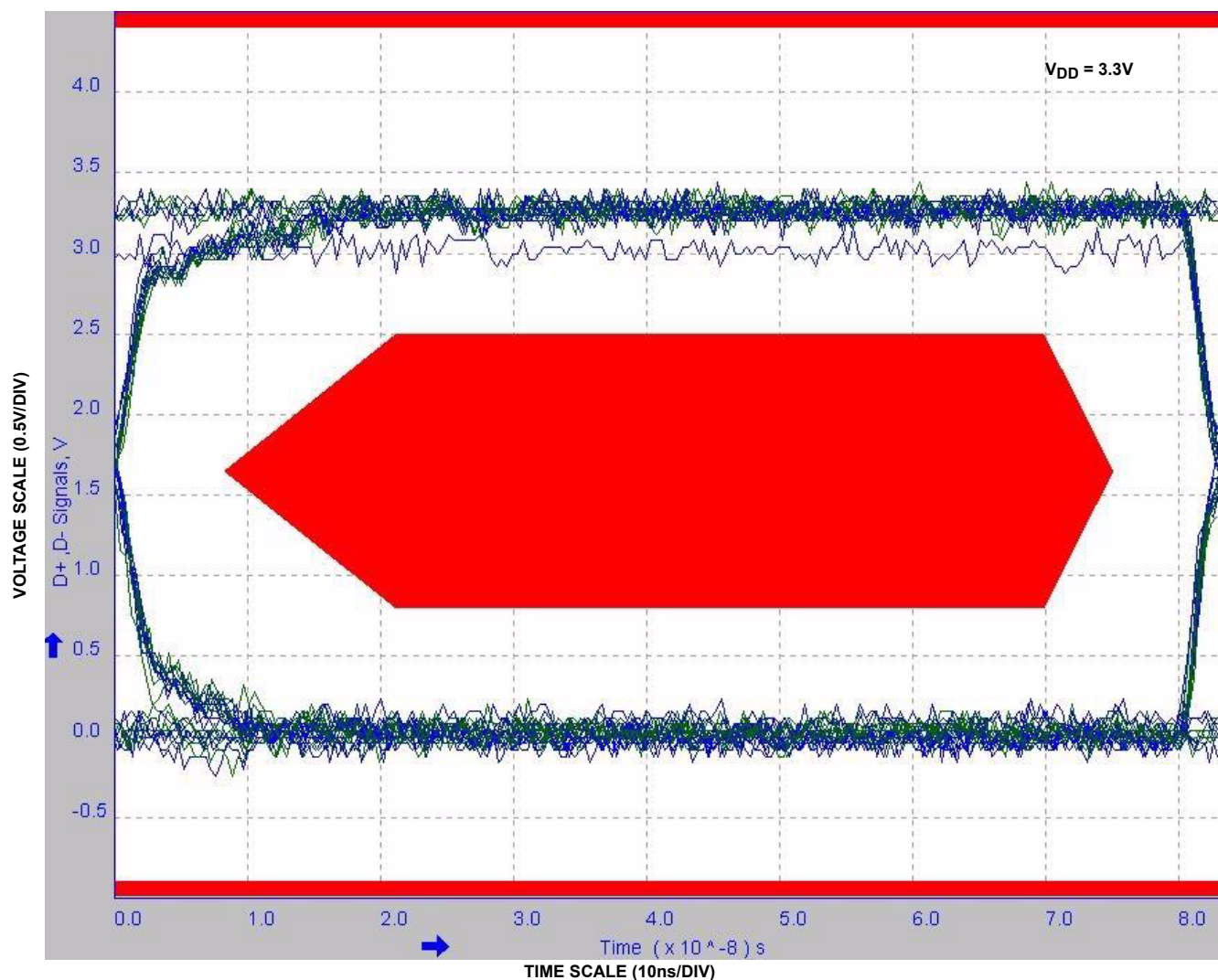


FIGURE 21. EYE PATTERN: 12Mbps USB SIGNAL WITH USB SWITCHES IN THE SIGNAL PATH

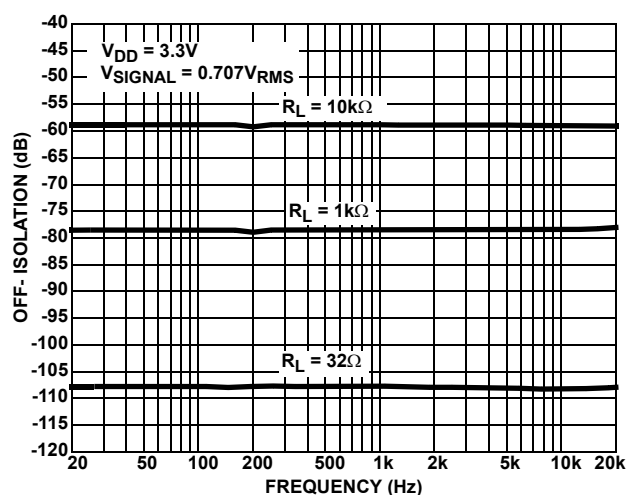


FIGURE 22. OFF-ISOLATION AUDIO SWITCHES vs LOADING

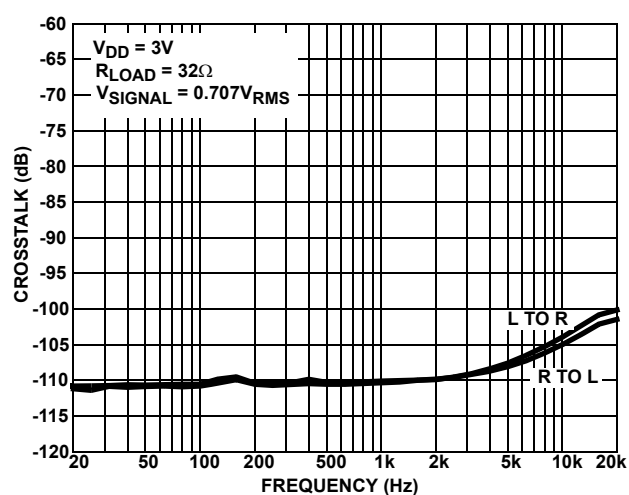


FIGURE 23. AUDIO CHANNEL-TO-CHANNEL CROSSTALK



# Typical Performance Curves $T_A = +25^\circ\text{C}$ , Unless Otherwise Specified (Continued)

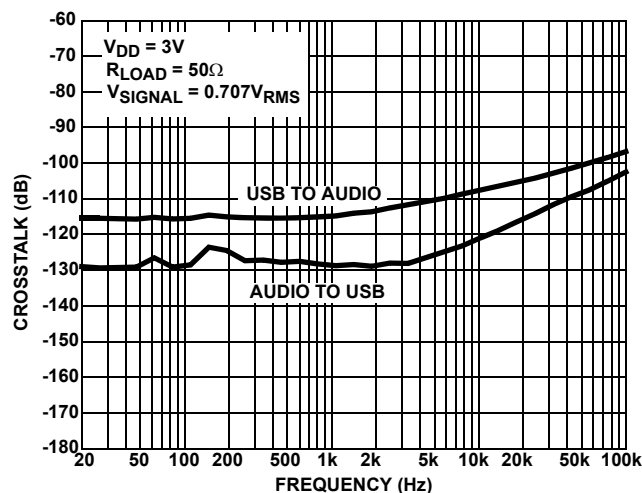


FIGURE 24. CHANNEL-TO-CHANNEL CROSSTALK

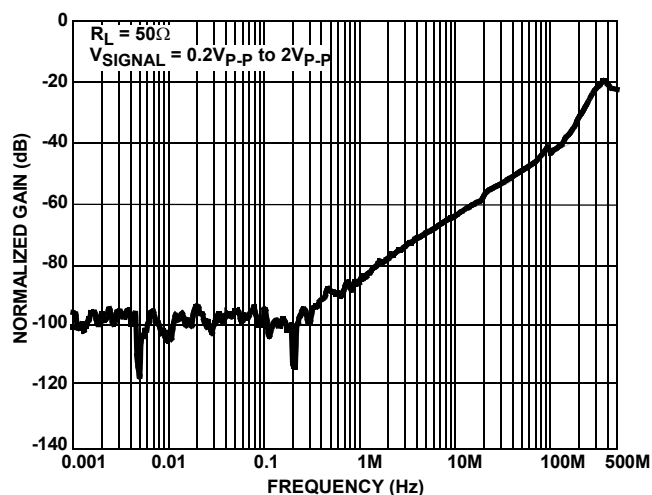


FIGURE 25. OFF-ISOLATION USB SWITCHES

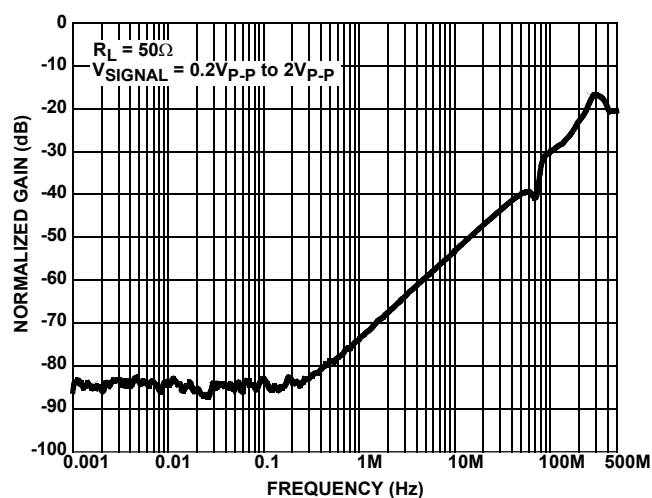


FIGURE 26. OFF-ISOLATION AUDIO SWITCHES

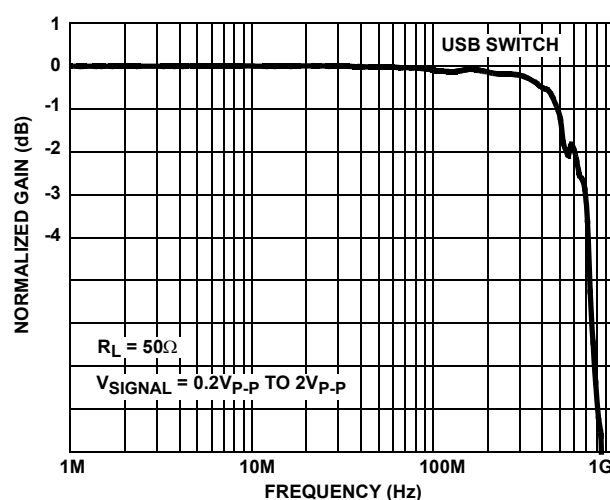


FIGURE 27. FREQUENCY RESPONSE

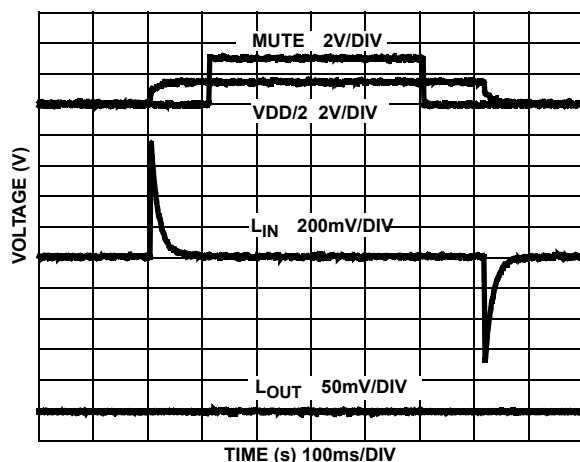


FIGURE 28. 32Ω AC-COUPLED CLICK AND POP REDUCTION

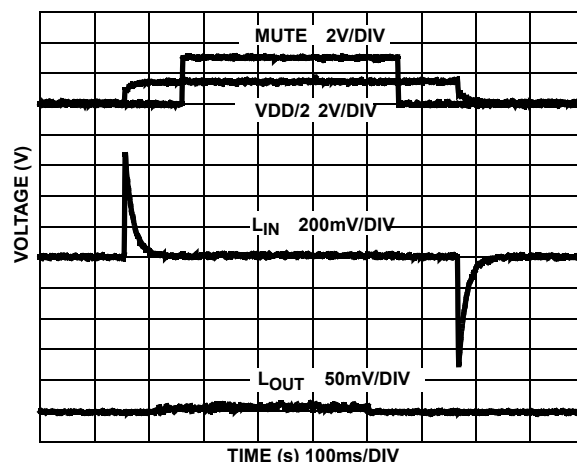


FIGURE 29. 1kΩ AC-COUPLED CLICK AND POP REDUCTION

## Typical Performance Curves $T_A = +25^\circ\text{C}$ , Unless Otherwise Specified (Continued)

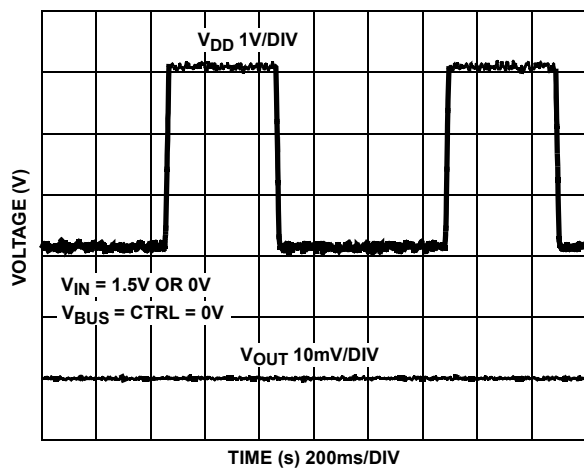


FIGURE 30. POWER-UP/POWER-DOWN CLICK AND POP TRANSIENT

### Die Characteristics

SUBSTRATE AND TDFN THERMAL PAD  
POTENTIAL (POWERED UP):

GND

TRANSISTOR COUNT:

98

PROCESS:

Submicron CMOS

## Revision History

The revision history provided is for informational purposes only and is believed to be accurate, but not warranted. Please go to web to make sure you have the latest Rev.

DATE	REVISION	CHANGE
3/18/10	FN6661.2	<p>Converted to New Intersil Template</p> <p>Replaced note, page 3: "<math>\theta_{JA}</math> is measured with the component mounted on a high effective thermal conductivity test board in free air. See Tech Brief TB379 for details." with "direct attached note"</p> <p>Added "Boldface limits apply over the operating temperature range, -40°C to +85°C." to Electrical Specifications table.</p> <p>On page 1 in "Related Literature" section added App Note AN1407.</p> <p>On page 1 in "Features" section added "Low On Capacitance at 240MHz 4.2pF"</p> <p>On page 2 added thermal pad (PD) to TDFN pinout and added PD column to "Pin Descriptions" table.</p> <p>Page 4 in "Abs Max Rating" section added HBM rating for COM pins of 6kV and Latchup level.</p> <p>Thermal information <math>T_{jc}</math> for uTQFN changed from "61.9" to "105" and note for <math>T_{ja}</math> was added to reference no direct attach, added <math>T_{jc}</math> to show the case temp location at top center.</p> <p>Page 4 in Electrical Spec Table - Removed Note Reference from Typical Column and Added to specific specs in Audio Switches and USB Switches as follows: On Resistance, <math>r_{ON}</math> Matching Between Channels and <math>r_{ON}</math> Flatness.</p> <p>Page 6 in electrical specifications table added "On Capacitance at 240MHz parameter.</p> <p>Page 15 Figure 20 Change from USB far end mask to USB near end mask.</p> <p>Page 18 in "Die Characteristics" section added TDFN thermal pad potential.</p>
1/6/09	FN6661.1	Corrected Order Information.
7/2/08	FN6661.0	Initial Release to web

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\*For a complete listing of Applications, Related Documentation and Related Parts, please see the respective device information page on intersil.com: [ISL54210](http://www.intersil.com/ISL54210)

To report errors or suggestions for this datasheet, please go to [www.intersil.com/askourstaff](http://www.intersil.com/askourstaff)

FITs are available from our website at <http://rel.intersil.com/reports/search.php>

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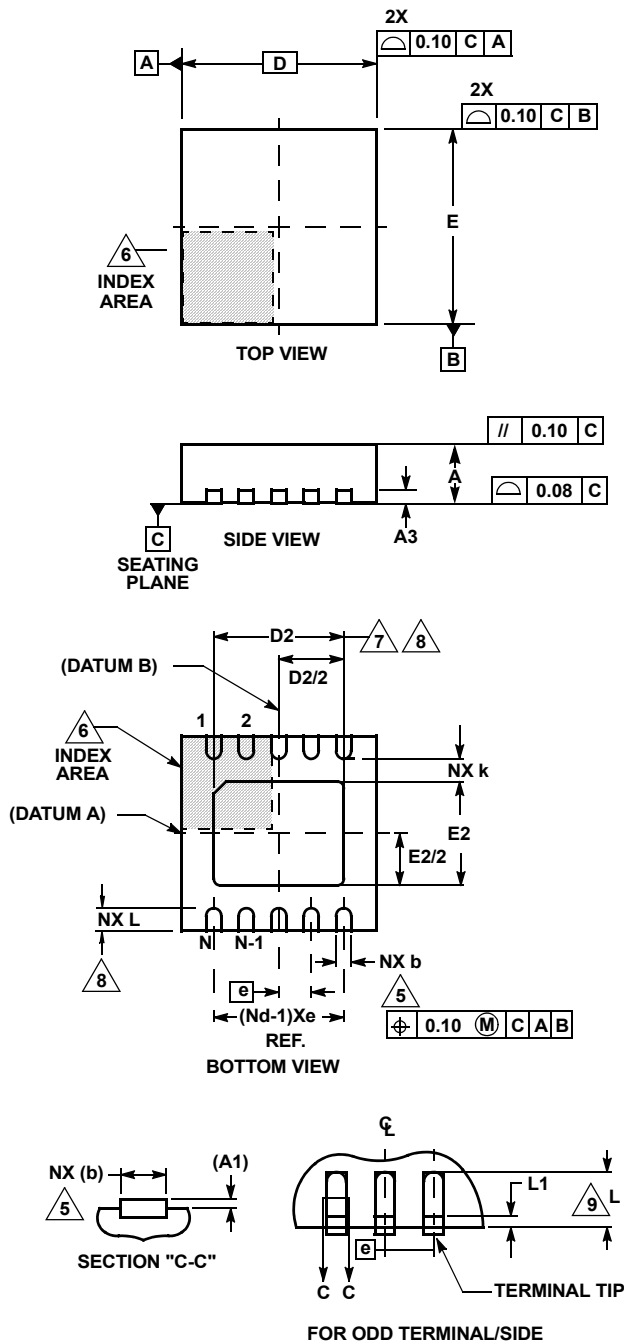
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# Thin Dual Flat No-Lead Plastic Package (TDFN)



## L10.3x3A

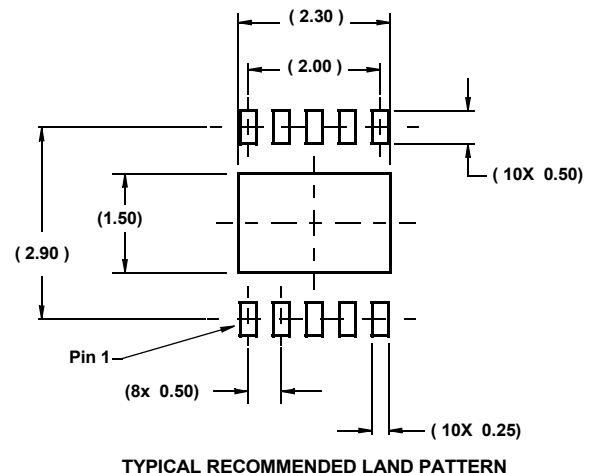
### 10 LEAD THIN DUAL FLAT NO-LEAD PLASTIC PACKAGE

SYMBOL	MILLIMETERS			NOTES
	MIN	NOMINAL	MAX	
A	0.70	0.75	0.80	-
A1	-	-	0.05	-
A3	0.20 REF			-
b	0.20	0.25	0.30	5, 8
D	2.95	3.0	3.05	-
D2	2.25	2.30	2.35	7, 8
E	2.95	3.0	3.05	-
E2	1.45	1.50	1.55	7, 8
e	0.50 BSC			-
k	0.25	-	-	-
L	0.25	0.30	0.35	8
N	10			2
Nd	5			3

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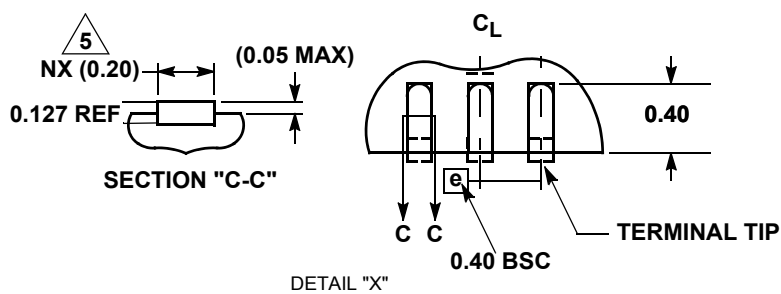
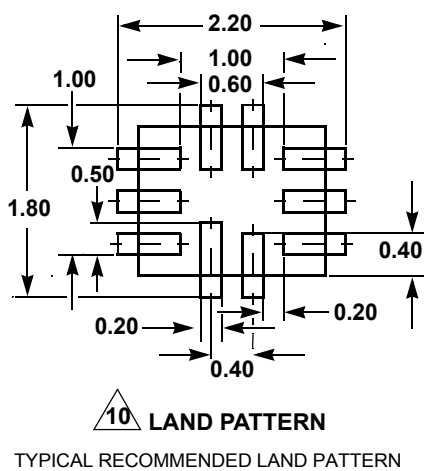
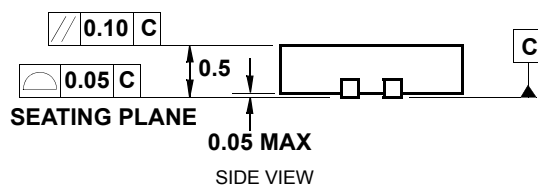
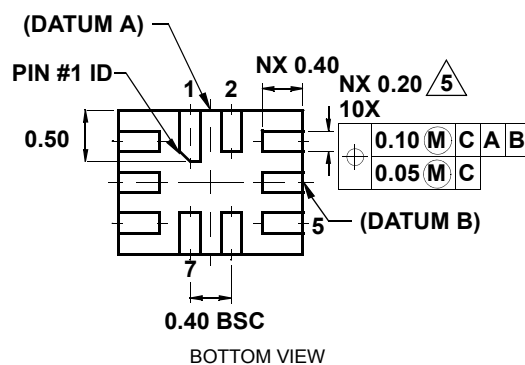
#### NOTES:

1. Dimensioning and tolerancing conform to ASME Y14.5-1994.
2. N is the number of terminals.
3. Nd refers to the number of terminals on D.
4. All dimensions are in millimeters. Angles are in degrees.
5. Dimension b applies to the metallized terminal and is measured between 0.15mm and 0.30mm from the terminal tip.
6. The configuration of the pin #1 identifier is optional, but must be located within the zone indicated. The pin #1 identifier may be either a mold or mark feature.
7. Dimensions D2 and E2 are for the exposed pads which provide improved electrical and thermal performance.
8. Nominal dimensions are provided to assist with PCB Land Pattern Design efforts, see Intersil Technical Brief TB389.
9. Compliant to JEDEC MO-229-WEED-3 except for D2 dimensions.



**10 LEAD ULTRA THIN QUAD FLAT NO-LEAD PLASTIC PACKAGE**

Diagram of the TOP VIEW of a mechanical part. The part is a rectangle with a width of 1.80 and a height of 1.40. A shaded rectangular area is located in the bottom-left corner, with a width of 0.10 and a height of 0.10. This shaded area is labeled with a triangle containing the number 6 and the text INDEX AREA. The shaded area is also labeled with 2X, a semi-circle symbol, 0.10, and C. The dimensions 1 and 2 are indicated along the bottom edge of the shaded area. The dimensions A and B are indicated along the right edge of the part.



1. Dimensioning and tolerancing conform to ASME Y14.5-1994.
2. N is the number of terminals. Total 10 leads.
3. Nd and Ne refer to the number of terminals on D (4) and E (6) side, respectively.
4. All dimensions are in millimeters. Tolerances  $\pm 0.05\text{mm}$  unless otherwise noted. Angles are in degrees.
5. Dimension b applies to the metallized terminal and is measured between 0.15mm and 0.30mm from the terminal tip.
6. The configuration of the pin #1 identifier is optional, but must be located within the zone indicated. The pin #1 identifier may be either a mold or mark feature.
7. Maximum package warpage is 0.05mm.
8. Maximum allowable burrs is 0.076mm in all directions.
9. JEDEC Reference MO-255.
10. For additional information, to assist with the PCB Land Pattern Design effort, see Intersil Technical Brief TB389.

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- Поставка электронных компонентов под контролем ВП;
- Система менеджмента качества сертифицирована по Международному стандарту ISO 9001;
- При необходимости вся продукция военного и аэрокосмического назначения проходит испытания и сертификацию в лаборатории (по согласованию с заказчиком);
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«FORSTAR» (основан в 1998 г.)

ВЧ соединители, коаксиальные кабели,  
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(Применяются в телекоммуникациях гражданского и специального назначения, в средствах связи, РЛС, а так же военной, авиационной и аэрокосмической отраслях промышленности).



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