

# LOW SKEW, 1-TO-9 DIFFERENTIAL-TO-LVCMOS ZERO DELAY BUFFER

## ICS87951I-147

### GENERAL DESCRIPTION

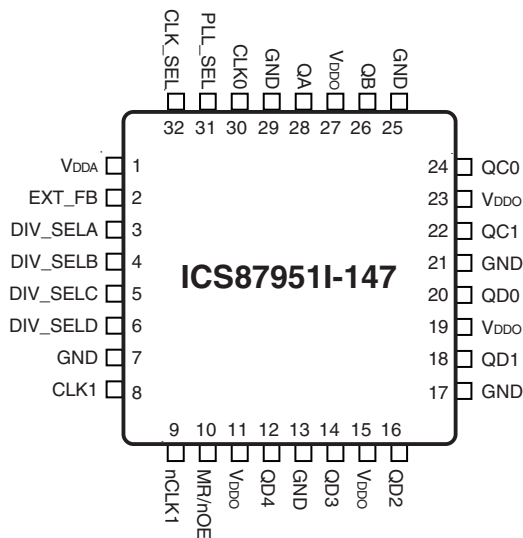


The ICS87951I-147 is a low voltage, low skew 1-to-9 Differential-to-LVCMOS/LVTTL Zero Delay Buffer and a member of the HiPerClockS™ family of High Performance Clock Solutions from ICS. The ICS87951I-147 has two selectable clock inputs. The single ended clock input accepts LVCMOS or LVTTL input levels. The CLK1, nCLK1 pair can accept most standard differential input levels. With output frequencies up to 180MHz, the ICS87951I-147 is targeted for high performance clock applications. Along with a fully integrated PLL, the ICS87951I-147 contains frequency configurable outputs and an external feedback input for regenerating clocks with “zero delay”.

### FEATURES

- Fully integrated PLL
- Nine single ended 3.3V or 2.5V LVCMOS/LVTTL outputs
- Selectable single ended CLK0 or differential CLK1, nCLK1 inputs
- The single ended CLK0 input can accept the following input levels: LVCMOS or LVTTL input levels
- CLK1, nCLK1 supports the following input types: LVDS, LVPECL, LVHSTL, SSTL, HCSSL
- Output frequency range: 31.25MHz to 200MHz
- VCO range: 250MHz to 500MHz
- External feedback for “zero delay” clock regeneration
- Cycle-to-cycle jitter, RMS: 7ps (maximum)
- Output skew: 270ps (maximum)
- Full 3.3V operating supply at -40°C to 85°C ambient operating temperature
- Full 2.5V operating supply at 0°C to 85°C ambient operating temperature
- Available in both standard and lead-free RoHS compliant packages

### PIN ASSIGNMENT



**32-Lead LQFP**

7mm x 7mm x 1.4mm package body

**Y package**  
Top View

## BLOCK DIAGRAM

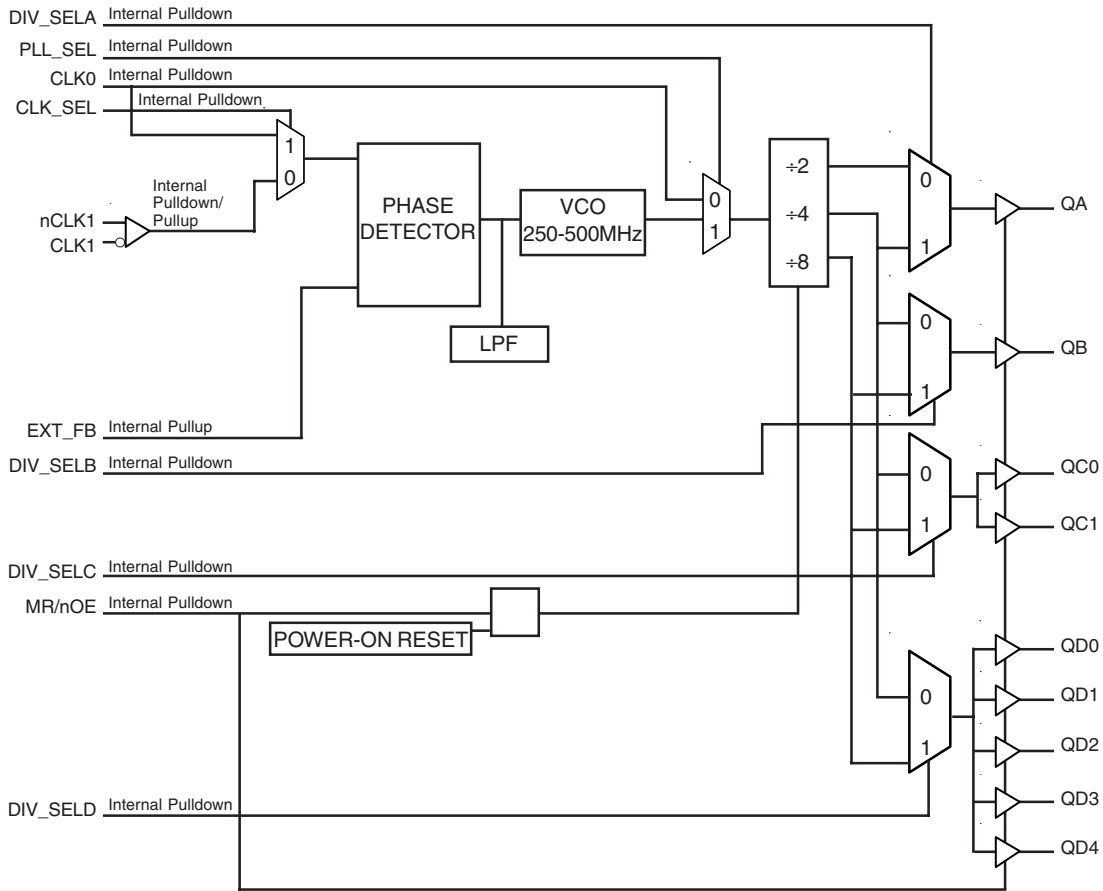


TABLE 1. PIN DESCRIPTIONS

Number	Name	Type		Description
1	V <sub>DDA</sub>	Power		Analog supply pin.
2	EXT_FB	Input	Pullup	Feedback input to phase detector for regenerating clocks with "zero delay". LVCMOS / LVTTTL interface levels.
3	DIV_SELA	Input	Pulldown	Selects divide value for Bank A output as described in Table 3D. LVCMOS / LVTTTL interface levels.
4	DIV_SELB	Input	Pulldown	Selects divide value for Bank B output as described in Table 3D. LVCMOS / LVTTTL interface levels.
5	DIV_SELC	Input	Pulldown	Selects divide value for Bank C outputs as described in Table 3D. LVCMOS / LVTTTL interface levels.
6	DIV_SELD	Input	Pulldown	Selects divide value for Bank D outputs as described in Table 3D. LVCMOS / LVTTTL interface levels.
7, 13, 17, 21, 25, 29	GND	Power		Power supply ground.
8	CLK1	Input	Pullup	Non-inverting differential clock input.
9	nCLK1	Input	Pulldown	Inverting differential clock input.
10	MR/nOE	Input	Pulldown	Active High Master Reset. Active LOW output enable. When logic HIGH, the internal dividers are reset and the outputs are tri-stated (HiZ). When logic LOW, the internal dividers and outputs are enabled. LVCMOS / LVTTTL interface levels.
11, 15, 19, 23, 27	V <sub>DDO</sub>	Power		Output supply pins.
12, 14, 16, 18, 20	QD4, QD3, QD2, QD1, QD0	Output		Bank D clock outputs. 7Ω typical output impedance. LVCMOS / LVTTTL interface levels.
22, 24	QC1, QC0	Output		Bank C clock outputs. 7Ω typical output impedance. LVCMOS / LVTTTL interface levels.
26	QB	Output		Bank B clock output. 7Ω typical output impedance. LVCMOS / LVTTTL interface levels.
28	QA	Output		Bank A clock output. 7Ω typical output impedance. LVCMOS / LVTTTL interface levels.
30	CLK0	Input	Pulldown	LVCMOS / LVTTTL phase detector reference clock input.
31	PLL_SEL	Input	Pulldown	Selects between the PLL and the reference clock as the input to the dividers. When HIGH, selects PLL. When LOW, selects the reference clock. LVCMOS / LVTTTL interface levels.
32	CLK_SEL	Input	Pulldown	Clock select input. When HIGH, selects CLK0. When LOW, selects CLK1, nCLK1. LVCMOS / LVTTTL interface levels.

NOTE: *Pullup* and *Pulldown* refer to internal input resistors. See Table 2, Pin Characteristics, for typical values.

TABLE 2. PIN CHARACTERISTICS

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
C <sub>IN</sub>	Input Capacitance			4		pF
C <sub>PD</sub>	Power Dissipation Capacitance (per output)	V <sub>DDA</sub> , V <sub>DDO</sub> = 3.465V		25		pF
		V <sub>DDA</sub> , V <sub>DDO</sub> = 2.625V		15		pF
R <sub>PULLUP</sub>	Input Pullup Resistor			51		kΩ
R <sub>PULLDOWN</sub>	Input Pulldown Resistor			51		kΩ

TABLE 3A. OUTPUT CONTROL PIN FUNCTION TABLE

Input	Outputs			
MR/nOE	QA	QB	QC0, QC1	QD0:QD4
1	HiZ	HiZ	HiZ	HiZ
0	Enabled	Enabled	Enabled	Enabled

TABLE 3B. OPERATING MODE FUNCTION TABLE

Input	Operating Mode
PLL_SEL	
0	Bypass
1	PLL

TABLE 3C. PLL INPUT FUNCTION TABLE

Inputs	
CLK_SEL	PLL Input
0	CLK1, nCLK1
1	CLK0

TABLE 3D. PROGRAMMABLE OUTPUT FREQUENCY FUNCTION TABLE

Inputs				Outputs			
DIV_SELA	DIV_SELB	DIV_SELC	DIV SELD	QA	QB	QCx	QDx
0	0	0	0	VCO/2	VCO/4	VCO/4	VCO/4
0	0	0	1	VCO/2	VCO/4	VCO/4	VCO/8
0	0	1	0	VCO/2	VCO/4	VCO/8	VCO/4
0	0	1	1	VCO/2	VCO/4	VCO/8	VCO/8
0	1	0	0	VCO/2	VCO/8	VCO/4	VCO/4
0	1	0	1	VCO/2	VCO/8	VCO/4	VCO/8
0	1	1	0	VCO/2	VCO/8	VCO/8	VCO/4
0	1	1	1	VCO/2	VCO/8	VCO/8	VCO/8
1	0	0	0	VCO/4	VCO/4	VCO/4	VCO/4
1	0	0	1	VCO/4	VCO/4	VCO/4	VCO/8
1	0	1	0	VCO/4	VCO/4	VCO/8	VCO/4
1	0	1	1	VCO/4	VCO/4	VCO/8	VCO/8
1	1	0	0	VCO/4	VCO/8	VCO/4	VCO/4
1	1	0	1	VCO/4	VCO/8	VCO/4	VCO/8
1	1	1	0	VCO/4	VCO/8	VCO/8	VCO/4
1	1	1	1	VCO/4	VCO/8	VCO/8	VCO/8

## ABSOLUTE MAXIMUM RATINGS

Supply Voltage, $V_{DD}$	4.6V
Inputs, $V_I$	-0.5V to $V_{DDA} + 0.5V$
Outputs, $V_O$	-0.5V to $V_{DDO} + 0.5V$
Package Thermal Impedance, $\theta_{JA}$	42.1°C/W (0 lfpm)
Storage Temperature, $T_{STG}$	-65°C to 150°C

NOTE: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These ratings are stress specifications only. Functional operation of product at these conditions or any conditions beyond those listed in the *DC Characteristics* or *AC Characteristics* is not implied. Exposure to absolute maximum rating conditions for extended periods may affect product reliability.

TABLE 4A. POWER SUPPLY DC CHARACTERISTICS,  $V_{DDA} = V_{DDO} = 3.3V \pm 5\%$ ,  $T_A = -40^\circ\text{C}$  TO  $85^\circ\text{C}$ 

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{DDA}$	Analog Supply Voltage		3.135	3.3	3.465	V
$V_{DDO}$	Output Supply Voltage		3.135	3.3	3.465	V
$I_{DDO}$	Power Supply Current	All $V_{DD}$ pins			115	mA
$I_{DDA}$	Analog Supply Current				20	mA

TABLE 4B. POWER SUPPLY DC CHARACTERISTICS,  $V_{DDA} = V_{DDO} = 2.5V \pm 5\%$ ,  $T_A = 0^\circ\text{C}$  TO  $85^\circ\text{C}$ 

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{DDA}$	Analog Supply Voltage		2.375	2.5	2.625	V
$V_{DDO}$	Output Supply Voltage		2.375	2.5	2.625	V
$I_{DDO}$	Power Supply Current	All $V_{DD}$ pins			75	mA
$I_{DDA}$	Analog Supply Current				12	mA

TABLE 4C. DC CHARACTERISTICS,  $V_{DDA} = V_{DDO} = 3.3V \pm 5\%$ ,  $T_A = -40^\circ\text{C}$  TO  $85^\circ\text{C}$ 

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{IH}$	Input High Voltage	DIV_SELA:DIV_SEL D, EXT_FB, MR/nOE, PLL_SEL, CLK_SEL	2		$V_{DD} + 0.3$	V
$V_{IL}$	Input Low Voltage	DIV_SELA:DIV_SEL D, EXT_FB, MR/nOE, PLL_SEL, CLK_SEL	-0.3		0.8	V
		CLK0	-0.3		1.3	V
$I_{IN}$	Input Current				$\pm 120$	$\mu\text{A}$
$V_{PP}$	Peak-to-Peak Input Voltage	CLK1, nCLK1	0.15		1.3	V
$V_{CMR}$	Common Mode Input Voltage; NOTE 1, 2	CLK1, nCLK1	GND + 0.5		$V_{DD} - 0.85$	V
$V_{OH}$	Output High Voltage	$I_{OH} = -40\text{mA}$	2.4			V
$V_{OL}$	Output Low Voltage	$I_{OL} = 40\text{mA}$			0.55	V
		$I_{OL} = 12\text{mA}$			0.3	V

NOTE 1: Common mode voltage is defined as  $V_{IH}$ .

NOTE 2: For single ended applications, the maximum input voltage for CLK1 and nCLK1 is  $V_{DDA} + 0.3V$ .

TABLE 4D. DC CHARACTERISTICS,  $V_{DDA} = V_{DDO} = 2.5V \pm 5\%$ ,  $T_A = 0^\circ C$  TO  $85^\circ C$ 

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{IH}$	Input High Voltage	DIV_SELA:DIV_SELD, EXT_FB, MR/nOE, PLL_SEL, CLK_SEL	2		$V_{DD} + 0.3$	V
$V_{IL}$	Input Low Voltage	DIV_SELA:DIV_SELD, EXT_FB, MR/nOE, PLL_SEL, CLK_SEL	-0.3		0.8	V
		CLK0	-0.3		0.8	V
$I_{IN}$	Input Current				$\pm 150$	$\mu A$
$V_{PP}$	Peak-to-Peak Input Voltage	CLK1, nCLK1	0.15		1.3	V
$V_{CMR}$	Common Mode Input Voltage; NOTE 1, 2	CLK1, nCLK1	GND + 0.5		$V_{DD} - 0.85$	V
$V_{OH}$	Output High Voltage	$I_{OH} = -15mA$	1.8			V
$V_{OL}$	Output Low Voltage	$I_{OL} = 15mA$			0.6	V

NOTE 1: Common mode voltage is defined as  $V_{IH}$ .NOTE 2: For single ended applications, the maximum input voltage for CLK1 and nCLK1 is  $V_{DDA} + 0.3V$ .TABLE 5. PLL INPUT REFERENCE CHARACTERISTICS,  $V_{DDA} = V_{DDO} = 3.3V \pm 5\%$ ,  $T_A = -40^\circ C$  TO  $85^\circ C$ 

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$f_{REF}$	Input Reference Frequency				250	MHz

TABLE 6A. AC CHARACTERISTICS,  $V_{DDA} = V_{DDO} = 3.3V \pm 5\%$ ,  $T_A = -40^\circ C$  TO  $85^\circ C$ 

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units	
$f_{MAX}$	Output Frequency	QA $\pm 2$			250	MHz	
		Qx $\pm 4$			125	MHz	
		QB, QC, QD $\pm 8$			62.5	MHz	
$f_{VCO}$	PLL VCO Lock Range		250		500	MHz	
$t(\theta)$	Static Phase Offset; NOTE 1,3	CLK0	$f_{REF} = 50MHz$ Feedback = VCO/8	-135		170	ps
		CLK1, nCLK1		-420		-100	ps
$t_{sk(o)}$	Output Skew; NOTE 2, 3				270	ps	
$t_{jit(cc)}$	Cycle-to-Cycle Jitter, RMS; NOTE 3	All Outputs @ Same Frequency			7.5	ps	
$t_{LOCK}$	PLL Lock Time; NOTE 3				10	mS	
$t_R / t_F$	Output Rise/Fall Time	20% to 80%	300		800	ps	
odc	Output Duty Cycle		46		54	%	
$t_{PZL}$	Output Enable Time				6	ns	
$t_{PLZ}, t_{PHZ}$	Output Disable Time				7	ns	

All parameters measured at  $f_{MAX}$  unless noted otherwise.

NOTE 1: Defined as the time difference between the input reference clock and the averaged feedback input signal, when the PLL is locked and the input reference frequency is stable.

NOTE 2: Defined as skew between outputs at the same supply voltage and with equal load conditions. Measured at  $V_{DDO}/2$ .

NOTE 3: This parameter is defined in accordance with JEDEC Standard 65.

TABLE 6B. AC CHARACTERISTICS,  $V_{DDA} = V_{DDO} = 2.5V \pm 5\%$ ,  $T_A = 0^\circ C$  TO  $85^\circ C$ 

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$f_{MAX}$	Output Frequency	QA $\div 2$			200	MHz
		Qx $\div 4$			120	MHz
		QB, QC, QD $\div 8$			60	MHz
$f_{VCO}$	PLL VCO Lock Range		250		500	MHz
$t(\emptyset)$	Static Phase Offset; NOTE 1,3	CLK0	-180		220	ps
		CLK1, nCLK1	-500		-165	ps
$t_{sk(o)}$	Output Skew; NOTE 2, 3				310	ps
$f_{jit(cc)}$	Cycle-to-Cycle Jitter, RMS; NOTE 3	FVCO $\leq 400$ MHz, All Outputs @ same frequency			9	ps
$t_{LOCK}$	PLL Lock Time; NOTE 3				10	mS
$t_R / t_F$	Output Rise/Fall Time	20% to 80%	300		700	ps
odc	Output Duty Cycle		46		54	%
$t_{PZL}$	Output Enable Time				6	ns
$t_{PLZ}, t_{PHZ}$	Output Disable Time				7	ns

All parameters measured at  $f_{MAX}$  unless noted otherwise.

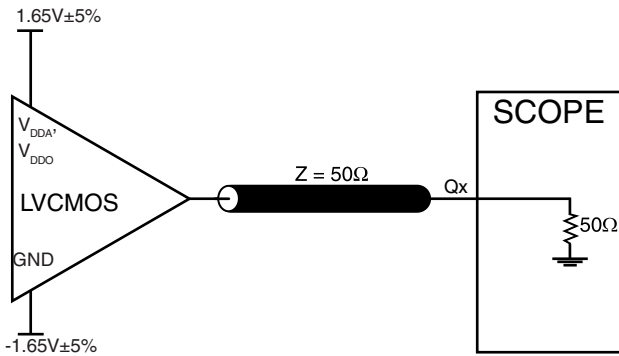
NOTE 1: Defined as the time difference between the input reference clock and the averaged feedback input signal, when the PLL is locked and the input reference frequency is stable.

NOTE 2: Defined as skew between outputs at the same supply voltage and with equal load conditions.

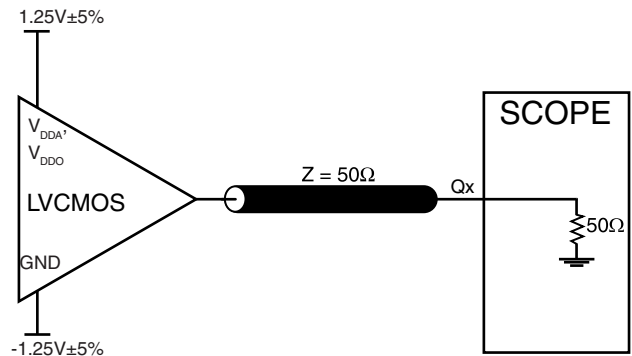
Measured at  $V_{DDO}/2$ .

NOTE 3: This parameter is defined in accordance with JEDEC Standard 65.

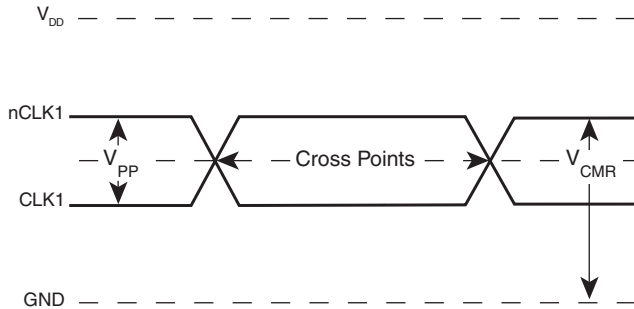
## PARAMETER MEASUREMENT INFORMATION



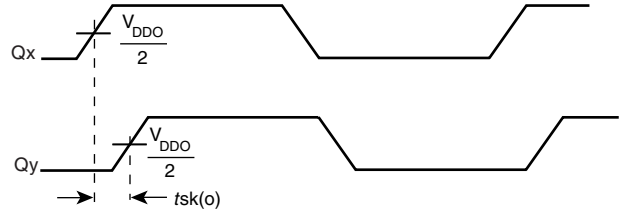
**3.3V OUTPUT LOAD AC TEST CIRCUIT**



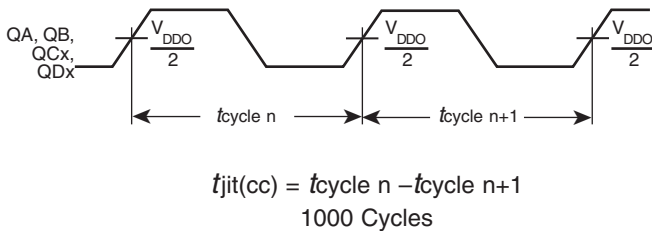
**2.5V OUTPUT LOAD AC TEST CIRCUIT**



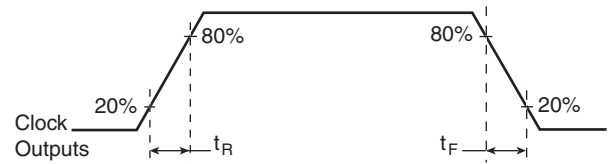
**DIFFERENTIAL INPUT LEVEL**



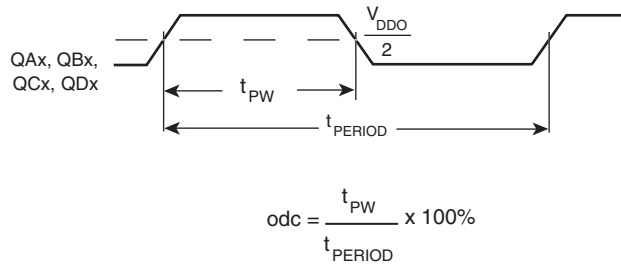
**OUTPUT SKEW**



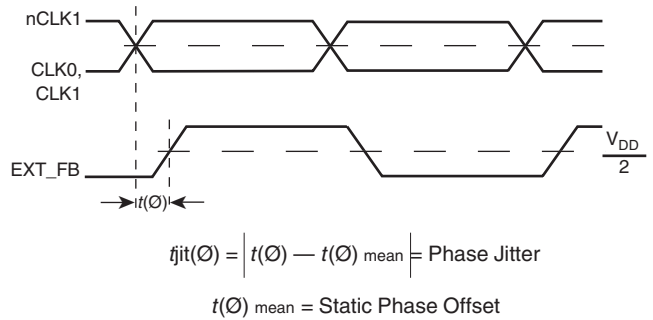
**CYCLE-TO-CYCLE JITTER**



**OUTPUT RISE/FALL TIME**



**OUTPUT DUTY CYCLE/PULSE WIDTH/PERIOD**



**PHASE JITTER AND STATIC PHASE OFFSET**



## APPLICATION INFORMATION

### WIRING THE DIFFERENTIAL INPUT TO ACCEPT SINGLE ENDED LEVELS

Figure 1 shows how the differential input can be wired to accept single ended levels. The reference voltage  $V_{REF} = V_{DD}/2$  is generated by the bias resistors R1, R2 and C1. This bias circuit should be located as close as possible to the input pin. The ratio

of R1 and R2 might need to be adjusted to position the  $V_{REF}$  in the center of the input voltage swing. For example, if the input clock swing is only 2.5V and  $V_{DD} = 3.3V$ ,  $V_{REF}$  should be 1.25V and  $R2/R1 = 0.609$ .

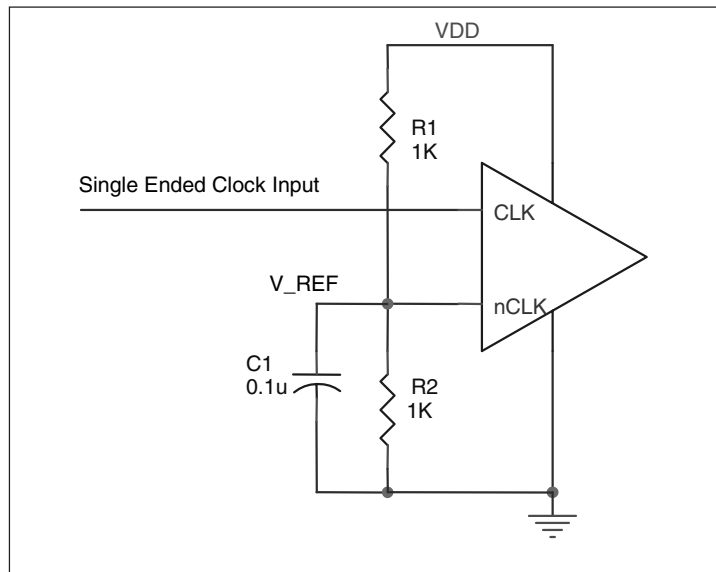


FIGURE 1. SINGLE ENDED SIGNAL DRIVING DIFFERENTIAL INPUT

### POWER SUPPLY FILTERING TECHNIQUES

As in any high speed analog circuitry, the power supply pins are vulnerable to random noise. The ICS879511-147 provides separate power supplies to isolate any high switching noise from the outputs to the internal PLL.  $V_{DDA}$  and  $V_{DDO}$  should be individually connected to the power supply plane through vias, and bypass capacitors should be used for each pin. To achieve optimum jitter performance, power supply isolation is required. Figure 2 illustrates how a  $10\Omega$  resistor along with a  $10\mu F$  and a  $.01\mu F$  bypass capacitor should be connected to each  $V_{DDA}$  pin.

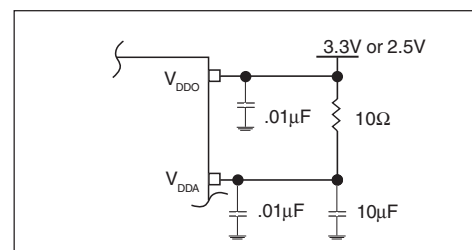


FIGURE 2. POWER SUPPLY FILTERING

## RECOMMENDATIONS FOR UNUSED INPUT AND OUTPUT PINS

### INPUTS:

#### CLK INPUT:

For applications not requiring the use of a clock input, it can be left floating. Though not required, but for additional protection, a 1k $\Omega$  resistor can be tied from the CLK input to ground.

#### CLK/nCLK INPUT:

For applications not requiring the use of the differential input, both CLK and nCLK can be left floating. Though not required, but for additional protection, a 1k $\Omega$  resistor can be tied from CLK to ground.

#### LVCNOS CONTROL PINS:

All control pins have internal pull-ups or pull-downs; additional resistance is not required but can be added for additional protection. A 1k $\Omega$  resistor can be used.

### OUTPUTS:

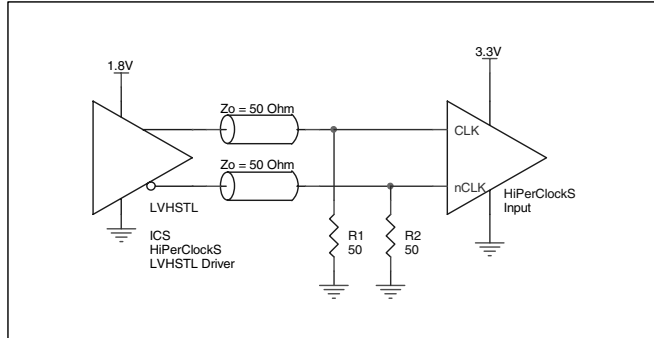
#### LVCNOS OUTPUT:

All unused LVCNOS output can be left floating. There should be no trace attached.

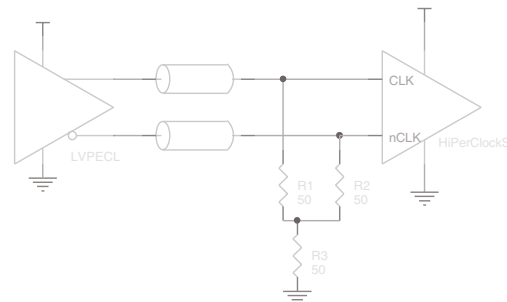
## DIFFERENTIAL CLOCK INPUT INTERFACE

The CLK /nCLK accepts LVDS, LVPECL, LVHSTL, SSTL, HCSL and other differential signals. Both  $V_{SWING}$  and  $V_{OH}$  must meet the  $V_{PP}$  and  $V_{CMR}$  input requirements. Figures 3A to 3D show interface examples for the HiPerClockS CLK/nCLK input driven by the most common driver types. The input interfaces suggested here are

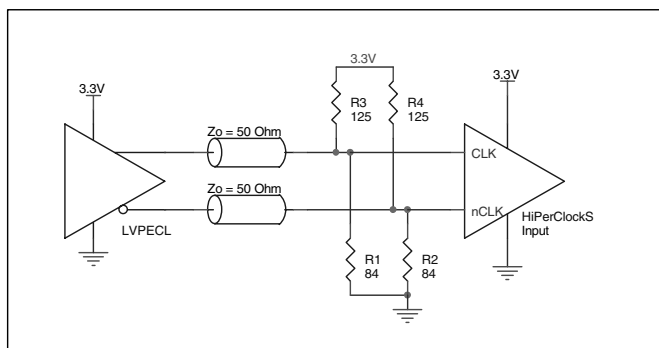
examples only. Please consult with the vendor of the driver component to confirm the driver termination requirements. For example in *Figure 3A*, the input termination applies for ICS HiPerClockS LVHSTL drivers. If you are using an LVHSTL driver from another vendor, use their termination recommendation.



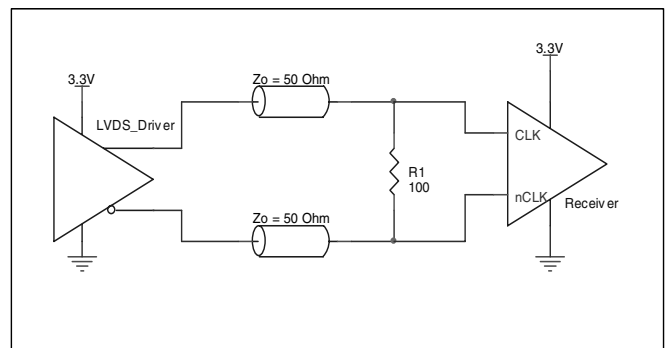
**FIGURE 3A. HiPerClockS CLK/nCLK INPUT DRIVEN BY ICS HiPerClockS LVHSTL DRIVER**



**FIGURE 3B. HiPerClockS CLK/nCLK INPUT DRIVEN BY 3.3V LVPECL DRIVER**



**FIGURE 3C. HiPerClockS CLK/nCLK INPUT DRIVEN BY 3.3V LVPECL DRIVER**



**FIGURE 3D. HiPerClockS CLK/nCLK INPUT DRIVEN BY 3.3V LVDS DRIVER**

## RELIABILITY INFORMATION

TABLE 7.  $\theta_{JA}$  vs. AIR FLOW TABLE FOR 32 LEAD LQFP

$\theta_{JA}$ by Velocity (Linear Feet per Minute)			
	0	200	500
Single-Layer PCB, JEDEC Standard Test Boards	67.8°C/W	55.9°C/W	50.1°C/W
Multi-Layer PCB, JEDEC Standard Test Boards	47.9°C/W	42.1°C/W	39.4°C/W

**NOTE:** Most modern PCB designs use multi-layered boards. The data in the second row pertains to most designs.

### TRANSISTOR COUNT

The transistor count for ICS87951I-147 is: 2674

Pin compatible with the MPC951

PACKAGE OUTLINE - Y SUFFIX FOR 32 LEAD LQFP

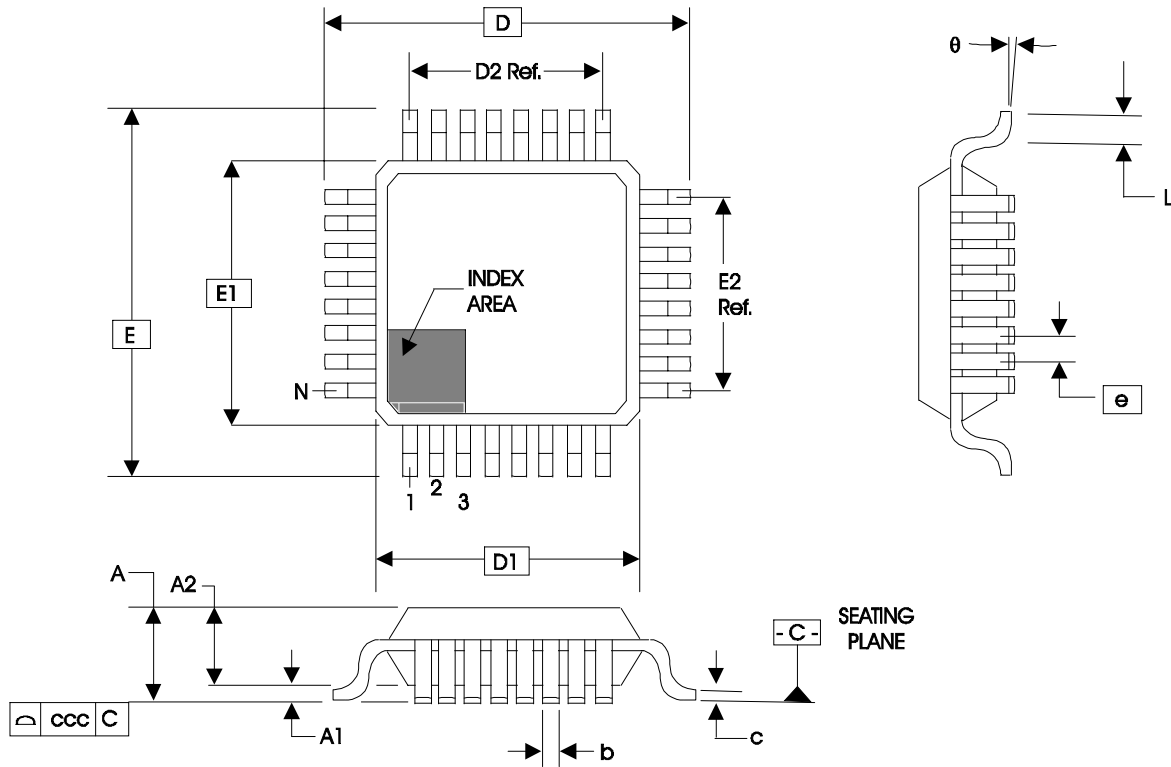


TABLE 8. PACKAGE DIMENSIONS

JEDEC VARIATION ALL DIMENSIONS IN MILLIMETERS			
SYMBOL	BBA		
	MINIMUM	NOMINAL	MAXIMUM
N	32		
A	--	--	1.60
A1	0.05	--	0.15
A2	1.35	1.40	1.45
b	0.30	0.37	0.45
c	0.09	--	0.20
D	9.00 BASIC		
D1	7.00 BASIC		
D2	5.60 Ref.		
E	9.00 BASIC		
E1	7.00 BASIC		
E2	5.60 Ref.		
e	0.80 BASIC		
L	0.45	0.60	0.75
theta	0°	--	7°
ccc	--	--	0.10

Reference Document: JEDEC Publication 95, MS-026

TABLE 9. ORDERING INFORMATION

Part/Order Number	Marking	Package	Shipping Packaging	Temperature
ICS87951AYI-147	ICS87951AYI-147	32 Lead LQFP	tray	-40°C to 85°C
ICS87951AYI-147T	ICS87951AYI-147	32 Lead LQFP	1000 tape & reel	-40°C to 85°C
ICS87951AYI-147LF	ICS951AI147L	32 Lead "Lead-Free" LQFP	tray	-40°C to 85°C
ICS87951AYI-147LFT	ICS951AI147L	32 Lead "Lead-Free" LQFP	1000 tape & reel	-40°C to 85°C

NOTE: Parts that are ordered with an "LF" suffix to the part number are the Pb-Free configuration and are RoHS compliant.

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## REVISION HISTORY SHEET

Rev	Table	Page	Description of Change	Date
A	T9	1 13	Features Section - added Lead-Free bullet. Ordering Information Table - added Lead-Free part number and note.	6/14/05
A	T9	10 13	Added <i>Recommendations for Unused Input and Output Pins</i> . Ordering Information Table - corrected standard marking and added lead-free marking.	6/21/06

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408-284-8200  
Fax: 408-284-2775

**For Tech Support**

netcom@idt.com  
480-763-2056

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**Corporate Headquarters**

Integrated Device Technology, Inc.  
6024 Silver Creek Valley Road  
San Jose, CA 95138  
United States  
800 345 7015  
+408 284 8200 (outside U.S.)

**Asia Pacific and Japan**

Integrated Device Technology  
Singapore (1997) Pte. Ltd.  
Reg. No. 199707558G  
435 Orchard Road  
#20-03 Wisma Atria  
Singapore 238877  
+65 6 887 5505

**Europe**

IDT Europe, Limited  
321 Kingston Road  
Leatherhead, Surrey  
KT22 7TU  
England  
+44 (0) 1372 363 339  
Fax: +44 (0) 1372 378851



www.IDT.com