

## GENERAL DESCRIPTION

The ICS874003I-02 is a high performance Differential-to-LVDS Jitter Attenuator designed for use in PCI Express systems. In some PCI Express systems, such as those found in desktop PCs, the PCI Express clocks are generated from a low bandwidth, high phase noise PLL frequency synthesizer. In these systems, a jitter attenuator may be required to attenuate high frequency random and deterministic jitter components from the PLL synthesizer and from the system board. The ICS874003I-02 has a bandwidth of 400kHz. The 400kHz provides an intermediate bandwidth that can easily track triangular spread profiles, while providing good jitter attenuation.

The ICS874003I-02 uses IDT's 3<sup>rd</sup> Generation FemtoClock™ PLL technology to achieve the lowest possible phase noise. The device is packaged in a 20 Lead TSSOP package, making it ideal for use in space constrained applications such as PCI Express add-in cards.

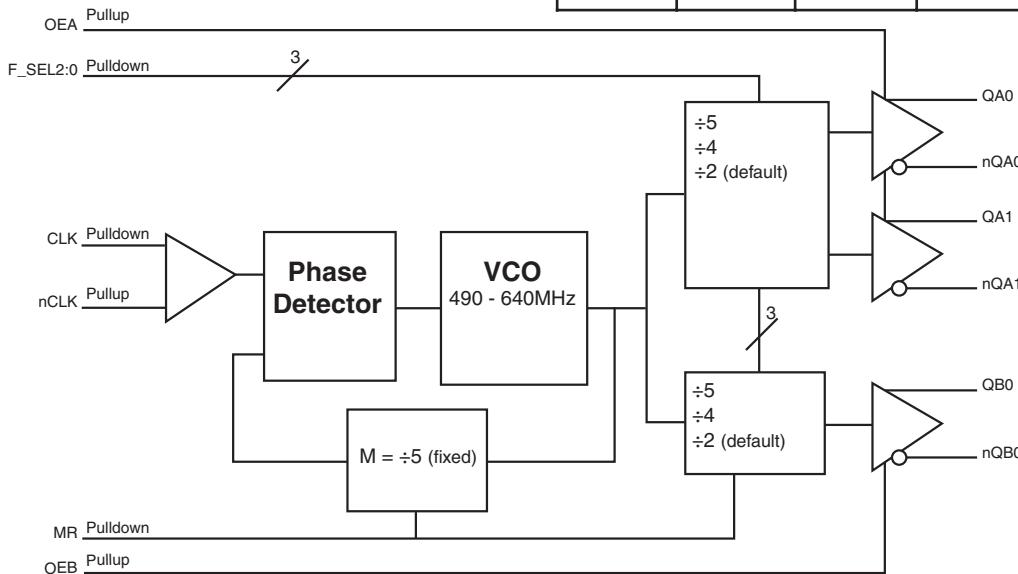
## FEATURES

- Three Differential LVDS output pairs
- One Differential clock input
- CLK and nCLK supports the following input types: LVPECL, LVDS, LVHSTL, SSTL, HCSL
- Output frequency range: 98MHz - 320MHz
- Input frequency range: 98MHz - 128MHz
- VCO range: 490MHz - 640MHz
- Cycle-to-cycle jitter: 35ps (maximum)
- Supports PCI-Express Spread-Spectrum Clocking
- The 400kHz bandwidth mode allows the system designer to make jitter attenuation/tracking skew design trade-offs
- 3.3V operating supply
- 40°C to 85°C ambient operating temperature
- Lead-free (RoHS 6) packaging

F\_SEL[2:0] FUNCTION TABLE

Inputs			Outputs	
F_SEL2	F_SEL1	F_SEL0	QA0, nQA0:QA1, nQA1	QB0, nQB0
0	0	0	÷2	÷2
1	0	0	÷5	÷2
0	1	0	÷4	÷2
1	1	0	÷2	÷4
0	0	1	÷2	÷5
1	0	1	÷5	÷4
0	1	1	÷4	÷5
1	1	1	÷4	÷4

## BLOCK DIAGRAM



## PIN ASSIGNMENT

QA1	1	20	nQA1
V <sub>DDO</sub>	2	19	V <sub>DDO</sub>
QA0	3	18	QB0
nQA0	4	17	nQB0
MR	5	16	F_SEL2
F_SEL0	6	15	OEB
nc	7	14	GND
V <sub>DDA</sub>	8	13	nCLK
F_SEL1	9	12	CLK
V <sub>DD</sub>	10	11	OEA

**ICS874003I-02**  
20-Lead TSSOP

6.5mm x 4.4mm x 0.92mm

package body

**G Package**

Top View

TABLE 1. PIN DESCRIPTIONS

Number	Name	Type	Description	
1, 20	QA1, nQA1	Output	Differential output pair. LVDS interface levels.	
2, 19	$V_{DDO}$	Power	Output supply pins.	
3, 4	QA0, nQA0	Output	Differential output pair. LVDS interface levels.	
5	MR	Input	Pulldown	Active HIGH Master Reset. When logic HIGH, the internal dividers are reset causing the true outputs ( $nQx$ ) to go low and the inverted outputs ( $Qx$ ) to go high. When logic LOW, the internal dividers and the outputs are enabled. LVCMOS/LVTTL interface levels.
6, 9, 16	$F_{SEL0}$ , $F_{SEL1}$ , $F_{SEL2}$	Input	Pulldown	Frequency select pin for QAx/nQAx and QBx0/nQB0 outputs. LVCMOS/LVTTL interface levels.
7	nc	Unused		No connect.
8	$V_{DDA}$	Power		Analog supply pin.
10	$V_{DD}$	Power		Core supply pin.
11	OEA	Input	Pullup	Output enable pin for QA pins. When HIGH, the QAx/nQAx outputs are active. When LOW, the QAx/nQAx outputs are in a high impedance state. LVCMOS/LVTTL interface levels.
12	CLK	Input	Pulldown	Non-inverting differential clock input.
13	nCLK	Input	Pullup	Inverting differential clock input.
14	GND	Power		Power supply ground.
15	OEB	Input	Pullup	Output enable pin for QB pins. When HIGH, the QBx/nQBx outputs are active. When LOW, the QBx/nQBx outputs are in a high impedance state. LVCMOS/LVTTL interface levels.
17, 18	nQB0, QB0	Output		Differential output pair. LVDS 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
$C_{IN}$	Input Capacitance			4		pF
$R_{PULLUP}$	Input Pullup Resistor			51		k $\Omega$
$R_{PULLDOWN}$	Input Pulldown Resistor			51		k $\Omega$

TABLE 3. OUTPUT ENABLE FUNCTION TABLE

Inputs		Outputs	
OEA	OEB	QA0/nQA0, QA1/nQA1	QB0/nQB0
0	0	HiZ	HiZ
1	1	Enabled	Enabled

## ABSOLUTE MAXIMUM RATINGS

Supply Voltage, $V_{DD}$	4.6V
Inputs, $V_I$	-0.5V to $V_{DD} + 0.5$ V
Outputs, $V_O$	-0.5V to $V_{DD} + 0.5$ V
Package Thermal Impedance, $\theta_{JA}$	73.2°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,  $V_{DD} = V_{DDA} = V_{DDO} = 3.3V \pm 5\%$ ,  $T_A = -40^\circ\text{C}$  TO  $85^\circ\text{C}$ 

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{DD}$	Core Supply Voltage		3.135	3.3	3.465	V
$V_{DDA}$	Analog Supply Voltage		$V_{DD} - 0.12$	3.3	$V_{DD}$	V
$V_{DDO}$	Output Supply Voltage		3.135	3.3	3.465	V
$I_{DD}$	Power Supply Current				75	mA
$I_{DDA}$	Analog Supply Current				12	mA
$I_{DDO}$	Output Supply Current				75	mA

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

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{IH}$	Input High Voltage		2		$V_{DD} + 0.3$	V
$V_{IL}$	Input Low Voltage		-0.3		0.8	V
$I_{IH}$	Input High Current	OEA, OEB	$V_{DD} = V_{IN} = 3.465$ V		5	$\mu\text{A}$
		F_SEL0, F_SEL1 F_SEL2, MR	$V_{DD} = V_{IN} = 3.465$ V		150	$\mu\text{A}$
$I_{IL}$	Input Low Current	OEA, OEB	$V_{DD} = 3.465$ V, $V_{IN} = 0$ V	-150		$\mu\text{A}$
		F_SEL0, F_SEL1 F_SEL2, MR	$V_{DD} = 3.465$ V, $V_{IN} = 0$ V	-5		$\mu\text{A}$

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

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$I_{IH}$	Input High Current	CLK	$V_{DD} = V_{IN} = 3.465$ V		150	$\mu\text{A}$
		nCLK	$V_{DD} = V_{IN} = 3.465$ V	5		
$I_{IL}$	Input Low Current	CLK	$V_{DD} = V_{IN} = 3.465$ V		150	$\mu\text{A}$
		nCLK	$V_{DD} = V_{IN} = 3.465$ V	-150		
$V_{PP}$	Peak-to-Peak Input Voltage		0.15		1.3	V
$V_{CMR}$	Common Mode Input Voltage; NOTE 1, 2		GND + 0.5		$V_{DD} - 0.85$	V

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

NOTE 2: For single ended applications, the maximum input voltage for CLK, nCLK and FB\_IN, nFB\_IN is  $V_{DD} + 0.3$  V.

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

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{OD}$	Differential Output Voltage		275	375	485	mV
$\Delta V_{OD}$	$V_{OD}$ Magnitude Change				50	mV
$V_{OS}$	Offset Voltage		1.2	1.35	1.5	V
$\Delta V_{OS}$	$V_{OS}$ Magnitude Change				50	mV

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

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$f_{MAX}$	Output Frequency		98		320	MHz
$t_{JIT(cc)}$	Cycle-to-Cycle Jitter, NOTE 1				35	ps
$t_{SK(o)}$	Output Skew; NOTE 2, 3				145	ps
$t_{SK(b)}$	Bank Skew; NOTE 1, 4	Bank A			55	ps
$t_R / t_F$	Output Rise/Fall Time	20% to 80%	275		725	ps
$odc$	Output Duty Cycle		47		53	%

NOTE 1: This parameter is defined in accordance with JEDEC Standard 65.

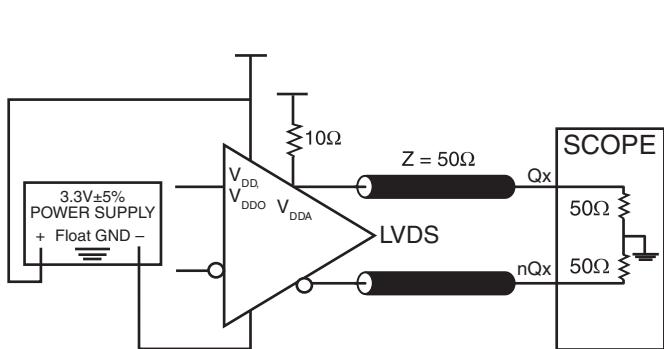
NOTE 2: Defined as skew between outputs at the same supply voltage and with equal load conditions.

Measured at  $V_{DDO}/2$ .

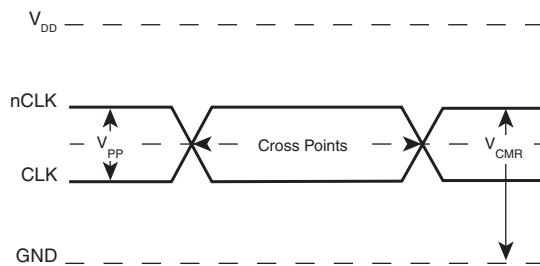
NOTE 3: These parameters are guaranteed by characterization. Not tested in production.

NOTE 4: Defined as skew within a bank of outputs at the same voltages and with equal load conditions.

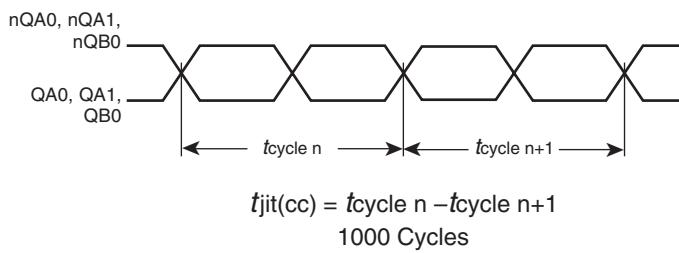
## PARAMETER MEASUREMENT INFORMATION



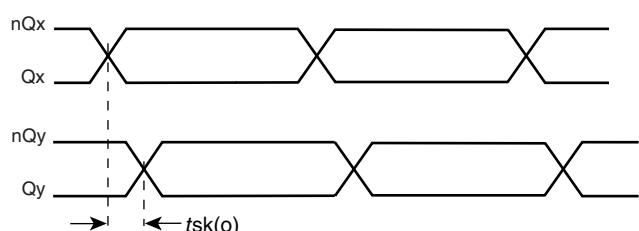
3.3V LVDS OUTPUT LOAD AC TEST CIRCUIT



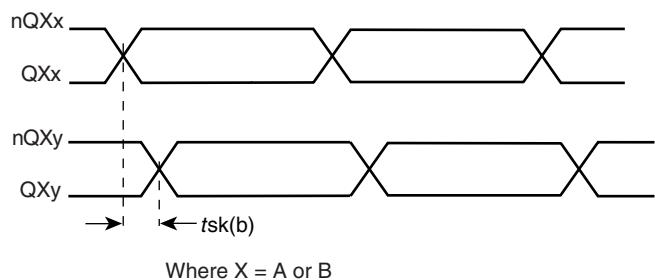
DIFFERENTIAL INPUT LEVEL



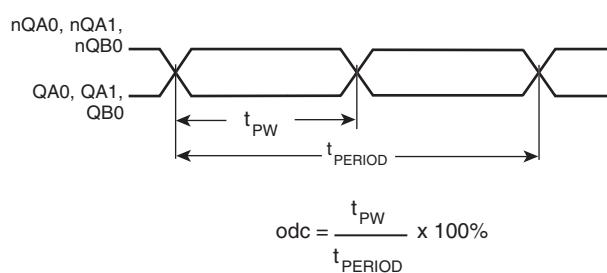
CYCLE-TO-CYCLE JITTER



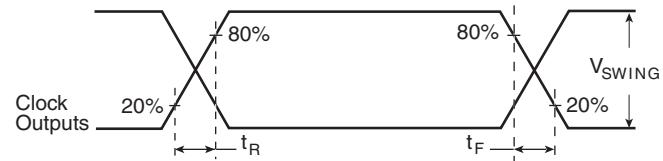
OUTPUT SKEW



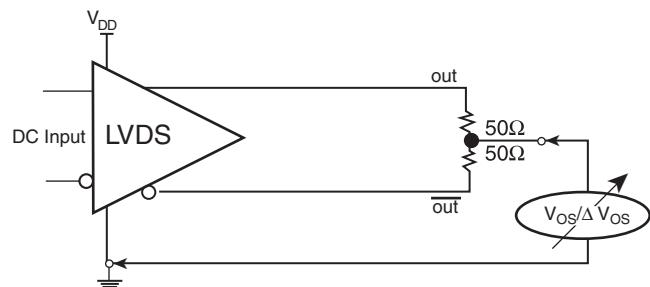
BANK SKEW



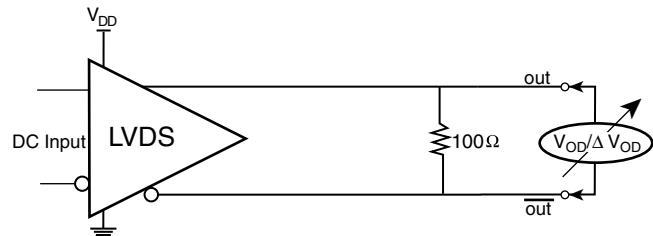
OUTPUT DUTY CYCLE/PULSE WIDTH/PERIOD



OUTPUT RISE/FALL TIME



OFFSET VOLTAGE SETUP



DIFFERENTIAL OUTPUT VOLTAGE SETUP

## APPLICATION INFORMATION

### POWER SUPPLY FILTERING TECHNIQUES

As in any high speed analog circuitry, the power supply pins are vulnerable to random noise. The ICS874003I-02 provides separate power supplies to isolate any high switching noise from the outputs to the internal PLL.  $V_{DD}$ ,  $V_{DDA}$ , 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 1* illustrates how a  $10\Omega$  resistor along with a  $10\mu F$  and a  $0.01\mu F$  bypass capacitor should be connected to each  $V_{CCA}$  pin.

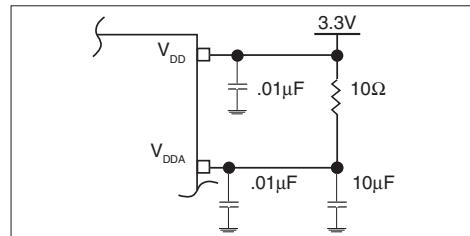


FIGURE 1. POWER SUPPLY FILTERING

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

*Figure 2* 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  $R2/R1 = 0.609$ .

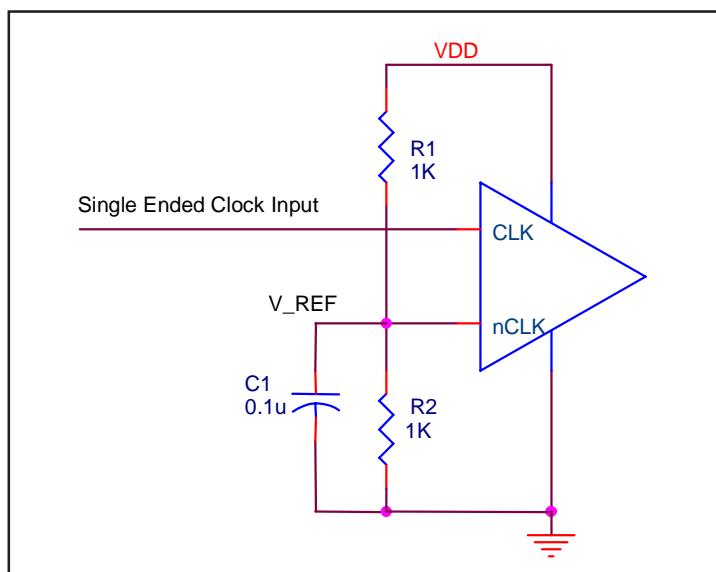


FIGURE 2. SINGLE ENDED SIGNAL DRIVING DIFFERENTIAL INPUT

## 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

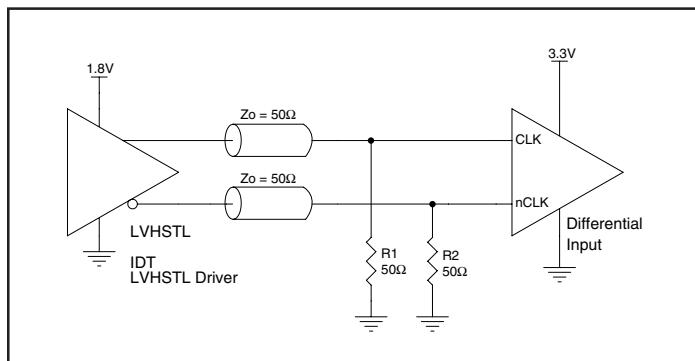


FIGURE 3A. CLK/nCLK INPUT DRIVEN BY  
ICS LVHSTL DRIVER

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 LVHSTL drivers. If you are using an LVHSTL driver from another vendor, use their termination recommendation.

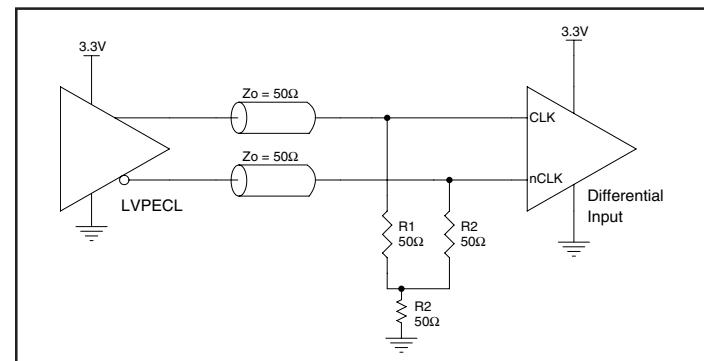


FIGURE 3B. CLK/nCLK INPUT DRIVEN BY  
3.3V LVPECL DRIVER

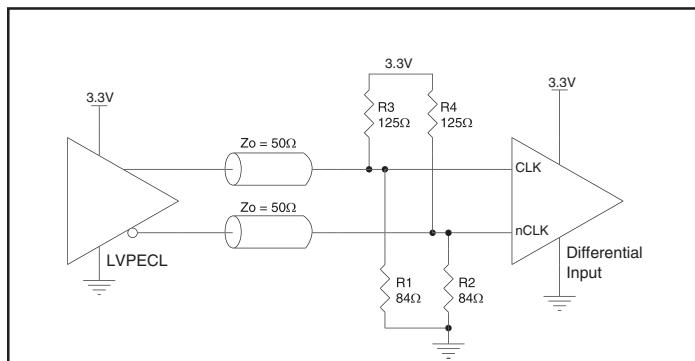


FIGURE 3C. CLK/nCLK INPUT DRIVEN BY  
3.3V LVPECL DRIVER

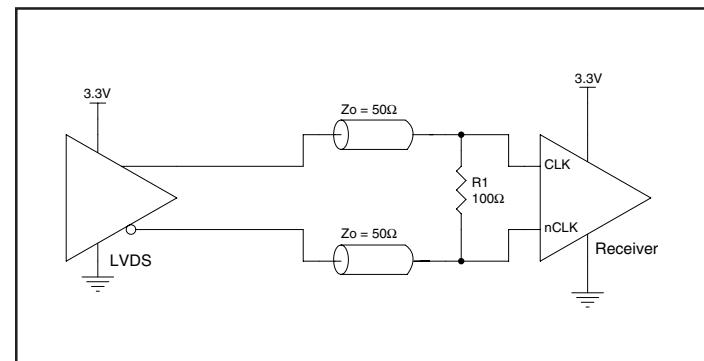


FIGURE 3D. CLK/nCLK INPUT DRIVEN BY  
3.3V LVDS DRIVER

## RECOMMENDATIONS FOR UNUSED INPUT AND OUTPUT PINS

### INPUTS:

#### LVC MOS 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 1kΩ resistor can be used.

### OUTPUTS:

#### LVDS

All unused LVDS output pairs can be either left floating or terminated with 100Ω across. If they are left floating, we recommend that there is no trace attached.

## LVDS DRIVER TERMINATION

A general LVDS interface is shown in *Figure 4*. In a  $100\Omega$  differential transmission line environment, LVDS drivers require a matched load termination of  $100\Omega$  across near the

receiver input. For a multiple LVDS outputs buffer, if only partial outputs are used, it is recommended to terminate the unused outputs.

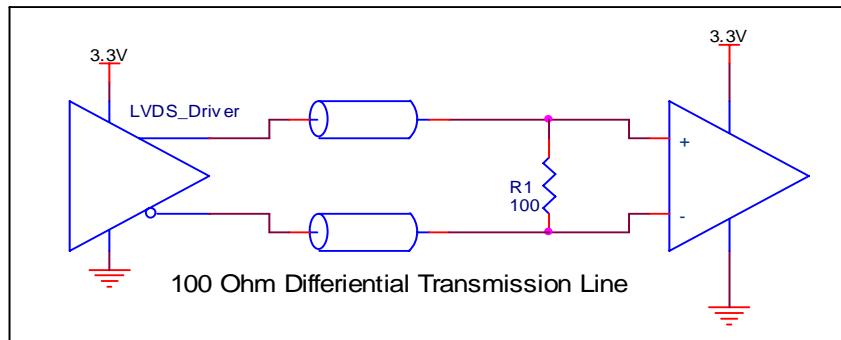


FIGURE 4. TYPICAL LVDS DRIVER TERMINATION

## POWER CONSIDERATIONS

This section provides information on power dissipation and junction temperature for the ICS874003I-02. Equations and example calculations are also provided.

### 1. Power Dissipation.

The total power dissipation for the ICS874003I-02 is the sum of the core power plus the power dissipated due to the load.

The following is the power dissipation for  $V_{DD} = 3.3V + 5\% = 3.465V$ , which gives worst case results.

- Power (core)<sub>MAX</sub> =  $V_{DD\_MAX} * (I_{DD\_MAX} + I_{DDA\_MAX}) = 3.465V * (75mA + 12mA) = 301.45mW$
- Power (outputs)<sub>MAX</sub> =  $V_{DDO\_MAX} * I_{DDO\_MAX} = 3.465V * 75mA = 259.87mW$

$$\text{Total Power}_{MAX} = 301.45mW + 259.87mW = 561.32mW$$

### 2. Junction Temperature.

Junction temperature,  $T_j$ , is the temperature at the junction of the bond wire and bond pad and directly affects the reliability of the device. The maximum recommended junction temperature is 125°C.

The equation for  $T_j$  is as follows:  $T_j = \theta_{JA} * P_{d\_total} + T_A$

$T_j$  = Junction Temperature

$\theta_{JA}$  = Junction-to-Ambient Thermal Resistance

$P_{d\_total}$  = Total Device Power Dissipation (example calculation is in section 1 above)

$T_A$  = Ambient Temperature

In order to calculate junction temperature, the appropriate junction-to-ambient thermal resistance  $\theta_{JA}$  must be used. Assuming a moderate air flow of 200 linear feet per minute and a multi-layer board, the appropriate value is 66.6°C/W per Table 6 below.

Therefore,  $T_j$  for an ambient temperature of 85°C with all outputs switching is:

$$85^\circ\text{C} + 0.561W * 66.6^\circ\text{C}/\text{W} = 122.4^\circ\text{C}.$$

This is below the limit of 125°C.

This calculation is only an example.  $T_j$  will obviously vary depending on the number of loaded outputs, supply voltage, air flow, and the type of board (single layer or multi-layer).

**TABLE 6. THERMAL RESISTANCE  $\theta_{JA}$  FOR 20-LEAD TSSOP, FORCED CONVECTION**

### $\theta_{JA}$ by Velocity (Linear Feet per Minute)

	0	200	500
Single-Layer PCB, JEDEC Standard Test Boards	114.5°C/W	98.0°C/W	88.0°C/W
Multi-Layer PCB, JEDEC Standard Test Boards	73.2°C/W	66.6°C/W	63.5°C/W

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

## RELIABILITY INFORMATION

TABLE 6.  $\theta_{JA}$  VS. AIR FLOW TABLE FOR 20 LEAD TSSOP

### $\theta_{JA}$ by Velocity (Linear Feet per Minute)

	0	200	500
Single-Layer PCB, JEDEC Standard Test Boards	114.5°C/W	98.0°C/W	88.0°C/W
Multi-Layer PCB, JEDEC Standard Test Boards	73.2°C/W	66.6°C/W	63.5°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 ICS874003I-02 is: 1408

## PACKAGE OUTLINE - G SUFFIX FOR 20 LEAD TSSOP

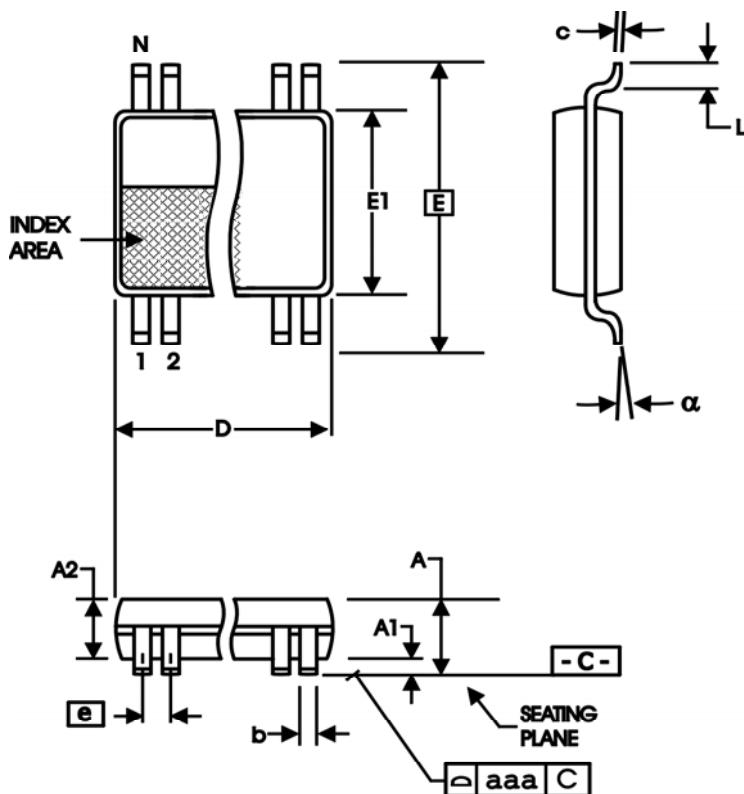


TABLE 7. PACKAGE DIMENSIONS

SYMBOL	Millimeters	
	MIN	MAX
N	20	
A	--	1.20
A1	0.05	0.15
A2	0.80	1.05
b	0.19	0.30
c	0.09	0.20
D	6.40	6.60
E	6.40 BASIC	
E1	4.30	4.50
e	0.65 BASIC	
L	0.45	0.75
$\alpha$	0°	8°
aaa	--	0.10

Reference Document: JEDEC Publication 95, MO-153

**TABLE 8. ORDERING INFORMATION**

<b>Part/Order Number</b>	<b>Marking</b>	<b>Package</b>	<b>Shipping Packaging</b>	<b>Temperature</b>
874003AGI-02LF	ICS4003AI02L	20 lead "Lead Free" TSSOP	Tube	-40°C to +85°C
874003AGI-02LFT	ICS4003AI02L	20 lead "Lead Free" TSSOP	Tape and Reel	-40°C to +85°C

TABLE 9. REVISION HISTORY

REV	TABLE	PAGE	CHANGE	DATE
A	Function T	1	Corrected typo 'QA0, nQA0:QA1, nQA1'.	5/1/2013
		1	Removed HiPerClockS logo.	
		8	Removed HiPerClockS references from drawings	
		10	Removed HiPerClockS reference from Power Considerations	

ICS874003-02

PCI EXPRESS™ JITTER ATTENUATOR

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