

## General Description

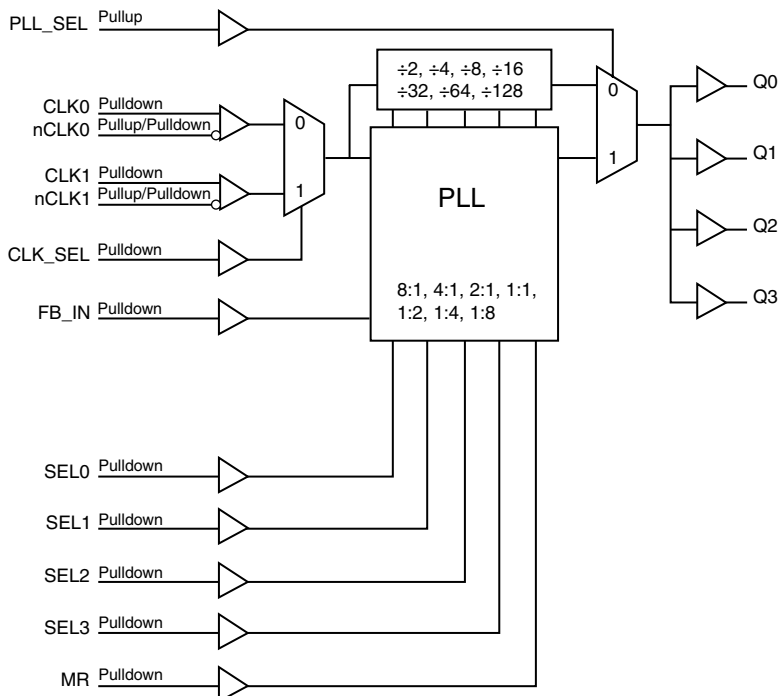


The ICS87004 is a highly versatile 1:4 Differential-to-LVCMOS/LVTTL Clock Generator and a member of the HiPerClockS® family of High Performance Clock Solutions from IDT. The ICS87004 has two selectable clock inputs. The CLK0, nCLK0 and CLK1, nCLK1 pairs can accept most standard differential input levels. Internal bias on the nCLK0 and nCLK1 inputs allows the CLK0 and CLK1 inputs to accept LVCMOS/LVTTL. The ICS87004 has a fully integrated PLL and can be configured as zero delay buffer, multiplier or divider and has an input and output frequency range of 15.625MHz to 250MHz. The reference divider, feedback divider and output divider are each programmable, thereby allowing for the following output-to-input frequency ratios: 8:1, 4:1, 2:1, 1:1, 1:2, 1:4, 1:8. The external feedback allows the device to achieve “zero delay” between the input clock and the output clocks. The PLL\_SEL pin can be used to bypass the PLL for system test and debug purposes. In bypass mode, the reference clock is routed around the PLL and into the internal output dividers.

## Features

- Four LVCMOS/LVTTL outputs, 7Ω typical output impedance
- Selectable CLK0/nCLK0 or CLK1/nCLK1 clock inputs
- CLKx/nCLKx pairs can accept the following differential input levels: LVPECL, LVDS, LVHSTL, HCSL, SSTL
- Internal bias on nCLK0 and nCLK1 to support LVCMOS/LVTTL levels on CLK0 and CLK1 inputs
- Output frequency range: 15.625MHz to 250MHz
- Input frequency range: 15.625MHz to 250MHz
- VCO range: 250MHz to 500MHz
- External feedback for “zero delay” clock regeneration with configurable frequencies
- Programmable dividers allow for the following output-to-input frequency ratios: 8:1, 4:1, 2:1, 1:1, 1:2, 1:4, 1:8
- Fully integrated PLL
- Cycle-to-cycle jitter: 45ps (maximum)
- Output skew: 50ps (maximum)
- Static phase offset: 50ps ± 125ps (3.3V ± 5%), CLK0/nCLK0
- Full 3.3V or 2.5V output operating supply
- 5V tolerant inputs
- 0°C to 70°C ambient operating temperature
- Available in both standard (RoHS 5) and lead-free (RoHS 6) packages

## Block Diagram



## Pin Assignment

GND	1	24	Q1
Q0	2	23	VDDO
VDDO	3	22	Q2
SEL0	4	21	GND
SEL1	5	20	Q3
SEL2	6	19	VDDO
SEL3	7	18	MR
CLK_SEL	8	17	FB_IN
VDD	9	16	PLL_SEL
CLK0	10	15	CLK1
nCLK0	11	14	nCLK1
GND	12	13	VDDA

### ICS87004

#### 24-Lead TSSOP

7.8mm x 4.4mm x 0.925mm package body

#### G Package

#### Top View

**Table 1. Pin Descriptions**

Number	Name	Type		Description
1, 12, 21	GND	Power		Power supply ground.
2, 20, 22, 24	Q0, Q3, Q2, Q1	Output		Single-ended clock outputs. 7Ω typical output impedance. LVCMOS/LVTTL interface levels.
3, 19, 23	V <sub>DDO</sub>	Power		Output supply pins.
4, 5, 6, 7	SEL0, SEL1, SEL2, SEL3	Input	Pulldown	Determines output divider values in Table 3. LVCMOS / LVTTL interface levels.
8	CLK_SEL	Input	Pulldown	Clock select input. When HIGH, selects differential CLK1, nCLK1. When LOW, selects differential CLK0, nCLK0. LVCMOS/LVTTL interface levels.
9	V <sub>DD</sub>	Power		Core supply pin.
10	CLK0	Input	Pulldown	Non-inverting differential clock input.
11	nCLK0	Input	Pullup/ Pulldown	Inverting differential clock input. V <sub>DD</sub> /2 default when left floating.
13	V <sub>DDA</sub>	Power		Analog supply pin.
14	nCLK1	Input	Pullup/ Pulldown	Inverting differential clock input. V <sub>DD</sub> /2 default when left floating.
15	CLK1	Input	Pulldown	Non-inverting differential clock input.
16	PLL_SEL	Input	Pullup	PLL select. Selects between the PLL and reference clock as the input to the dividers. When LOW, selects the reference clock (PLL Bypass). When HIGH, selects PLL (PLL Enabled). LVCMOS/LVTTL interface levels.
17	FB_IN	Input	Pulldown	Feedback input to phase detector for regenerating clocks with “Zero Delay.” Connect to one of the outputs. LVCMOS/LVTTL interface levels.
18	MR	Input	Pulldown	Active HIGH Master Reset. When logic HIGH, the internal dividers are reset causing the outputs to go low. When logic LOW, the internal dividers and the outputs are enabled. LVCMOS / LVTTL 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
R <sub>PULLUP</sub>	Input Pullup Resistor			51		kΩ
R <sub>PULLDOWN</sub>	Input Pulldown Resistor			51		kΩ
C <sub>PD</sub>	Power Dissipation Capacitance (per output)	V <sub>DD</sub> , V <sub>DDO</sub> = 3.465V			23	pF
		V <sub>DD</sub> , V <sub>DDO</sub> = 2.625V			17	pF
R <sub>OUT</sub>	Output Impedance		5	7	12	Ω

## Function Tables

Table 3A. PLL Enable Function Table

Inputs					Outputs PLL_SEL = 1 PLL Enable Mode
SEL3	SEL2	SEL1	SEL0	Reference Frequency Range (MHz)	Q[0:3]
0	0	0	0	125 - 250	÷1
0	0	0	1	62.5 - 125	÷1
0	0	1	0	31.25 - 62.5	÷1
0	0	1	1	15.625 - 31.25	÷1
0	1	0	0	125 - 250	÷2
0	1	0	1	62.5 - 125	÷2
0	1	1	0	31.25 - 62.5	÷2
0	1	1	1	125 - 250	÷4
1	0	0	0	62.5 - 125	÷4
1	0	0	1	125 - 250	÷8
1	0	1	0	62.5 - 125	x2
1	0	1	1	31.25 - 62.5	x2
1	1	0	0	15.625 - 31.25	x2
1	1	0	1	31.25 - 62.5	x4
1	1	1	0	15.625 - 31.25	x4
1	1	1	1	15.625 - 31.25	x8

**Table 3B. PLL Bypass Function Table**

Inputs				Outputs PLL_SEL = 0 PLL Bypass Mode
SEL3	SEL2	SEL1	SEL0	Q[0:3]
0	0	0	0	÷8
0	0	0	1	÷8
0	0	1	0	÷8
0	0	1	1	÷16
0	1	0	0	÷16
0	1	0	1	÷16
0	1	1	0	÷32
0	1	1	1	÷32
1	0	0	0	÷64
1	0	0	1	÷128
1	0	1	0	÷4
1	0	1	1	÷4
1	1	0	0	÷8
1	1	0	1	÷2
1	1	1	0	÷4
1	1	1	1	÷2

## Absolute Maximum Ratings

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.

Item	Rating
Supply Voltage, $V_{DD}$	4.6V
Inputs, $V_I$	-0.5V to $V_{DD} + 0.5V$
Outputs, $V_O$	-0.5V to $V_{DDO} + 0.5V$
Package Thermal Impedance, $\theta_{JA}$	70°C/W (0 lfpm)
Storage Temperature, $T_{STG}$	-65°C to 150°C

## DC Electrical Characteristics

**Table 4A. Power Supply DC Characteristics,  $V_{DD} = V_{DDO} = 3.3V \pm 5\%$ ,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$**

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		3.135	3.3	3.465	V
$V_{DDO}$	Output Supply Voltage		3.135	3.3	3.465	V
$I_{DD}$	Power Supply Current				100	mA
$I_{DDA}$	Analog Supply Current				16	mA
$I_{DDO}$	Output Supply Current				6	mA

**Table 4B. Power Supply DC Characteristics,  $V_{DD} = V_{DDO} = 2.5V \pm 5\%$ ,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$**

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{DD}$	Core Supply Voltage		2.375	2.5	2.625	V
$V_{DDA}$	Analog Supply Voltage		2.375	2.5	2.625	V
$V_{DDO}$	Output Supply Voltage		2.375	2.5	2.625	V
$I_{DD}$	Power Supply Current				96	mA
$I_{DDA}$	Analog Supply Current				15	mA
$I_{DDO}$	Output Supply Current				6	mA

**Table 4C. LVCMOS/LVTTL DC Characteristics,  $V_{DD} = V_{DDO} = 3.3V \pm 5\%$  or  $2.5V \pm 5\%$ ,  $T_A = 0^{\circ}C$  to  $70^{\circ}C$** 

Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
$V_{IH}$	Input High Voltage		$V_{DD} = 3.3V$	2		$V_{DD} + 0.3$	V
			$V_{DD} = 2.5V$	1.7		$V_{DD} + 0.3$	V
$V_{IL}$	Input Low Voltage		$V_{DD} = 3.3V$	-0.3		0.8	V
			$V_{DD} = 2.5V$	-0.3		0.7	V
$I_{IH}$	Input High Current	SEL[0:3], MR, FB_IN, CLK_SEL	$V_{DD} = V_{IN} = 3.465V$ or $2.625V$			150	$\mu A$
		PLL_SEL	$V_{DD} = V_{IN} = 3.465V$ or $2.625V$			5	$\mu A$
$I_{IL}$	Input Low Current	SEL[0:3], MR, FB_IN, CLK_SEL	$V_{DD} = 3.465V$ or $2.625V$ , $V_{IN} = 0V$	-5			$\mu A$
		PLL_SEL	$V_{DD} = 3.465V$ or $2.625V$ , $V_{IN} = 0V$	-150			$\mu A$
$V_{OH}$	Output High Voltage; NOTE 1		$V_{DDO} = 3.465V$	2.6			V
			$V_{DDO} = 2.625V$	1.8			V
$V_{OL}$	Output Low Voltage; NOTE 1		$V_{DD} = 3.465V$ or $2.625V$			0.5	V

NOTE 1: Outputs terminated with  $50\Omega$  to  $V_{DDO}/2$ . In the Parameter Measurement Information Section, see *Output Load Test Circuit Diagrams*.

**Table 4D. Differential DC Characteristics,  $V_{DD} = V_{DDO} = 3.3V \pm 5\%$  or  $2.5V \pm 5\%$ ,  $T_A = 0^{\circ}C$  to  $70^{\circ}C$** 

Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
$I_{IH}$	Input High Current	CLK0/nCLK0, CLK1/nCLK1	$V_{DD} = V_{IN} = 3.465V$ or $2.625V$			150	$\mu A$
$I_{IL}$	Input Low Current	CLK0, CLK1	$V_{DD} = 3.465V$ or $2.625V$ , $V_{IN} = 0V$	-5			$\mu A$
		nCLK0, nCLK1	$V_{DD} = 3.465V$ or $2.625V$ , $V_{IN} = 0V$	-150			$\mu A$
$V_{PP}$	Peak-to-Peak Voltage; NOTE 1			0.15		1.3	V
$V_{CMR}$	Common Mode Input Voltage; NOTE 1, 2			GND + 0.5		$V_{DD} - 0.85$	V

NOTE 1:  $V_{IL}$  should not be less than -0.3V.

NOTE 2: Common mode input voltage is defined as  $V_{IH}$ .

## AC Electrical Characteristics

**Table 5A. AC Characteristics,  $V_{DD} = V_{DDO} = 3.3V \pm 5\%$ ,  $T_A = 0^\circ C$  to  $70^\circ C$**

Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
$f_{MAX}$	Output Frequency			15.625		250	MHz
$t_{PD}$	Propagation Delay; NOTE 1	CLK0, nCLK0 CLK1, nCLK1	PLL_SEL = 0V, $f \leq 250MHz$ , $Qx \div 2$	5		6.2	ns
$t(\phi)$	Static Phase Offset; NOTE 2, 4	CLK0, nCLK0	PLL_SEL = 3.3V, $f_{REF} \leq 167MHz$ , $Qx \div 1$	-75	50	175	ps
		CLK1, nCLK1		-190	-65	175	ps
$t_{sk(o)}$	Output Skew; NOTE 3, 4	CLK0, nCLK0 CLK1, nCLK1	PLL_SEL = 0V		40	50	ps
$\eta_{jit(cc)}$	Cycle-to-Cycle Jitter; NOTE 4		$f_{OUT} > 40MHz$		30	45	ps
$t_L$	PLL Lock Time					1	ms
$t_R / t_F$	Output Rise/Fall Time		20% to 80%	400		800	ps
odc	Output Duty Cycle			40	50	60	%

NOTE: Electrical parameters are guaranteed over the specified ambient operating temperature range, which is established when the device is mounted in a test socket with maintained transverse airflow greater than 500 lfm. The device will meet specifications after thermal equilibrium has been reached under these conditions.

NOTE 1: Measured from the differential input crossing point to the output at  $V_{DDO}/2$ .

NOTE 2: Defined as the time difference between the input reference clock and the average feedback input signal when the PLL is locked and the input reference frequency is stable.

NOTE 3: Defined as skew between outputs at the same supply voltage and with equal load conditions. Measured at  $V_{DDO}/2$ .

NOTE 4: This parameter is defined in accordance with JEDEC Standard 65.

**Table 5B. AC Characteristics,  $V_{DD} = V_{DDO} = 2.5V \pm 5\%$ ,  $T_A = 0^\circ C$  to  $70^\circ C$**

Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
$f_{MAX}$	Output Frequency			15.625		250	MHz
$t_{PD}$	Propagation Delay; NOTE 1	CLK0, nCLK0 CLK1, nCLK1	PLL_SEL = 0V, $f \leq 250MHz$ , $Qx \div 2$	5.3		6.9	ns
$t(\phi)$	Static Phase Offset; NOTE 2, 4	CLK0, nCLK0	PLL_SEL = 2.5V, $f_{REF} \leq 167MHz$ , $Qx \div 1$	-175	-25	125	ps
		CLK1, nCLK1		-290	-115	125	ps
$t_{sk(o)}$	Output Skew; NOTE 3, 4	CLK0, nCLK0 CLK1, nCLK1	PLL_SEL = 0V		40	45	ps
$\eta_{jit(cc)}$	Cycle-to-Cycle Jitter; NOTE 4		$f_{OUT} > 40MHz$		35	45	ps
$t_L$	PLL Lock Time					1	ms
$t_R / t_F$	Output Rise/Fall Time		20% to 80%	400		700	ps
odc	Output Duty Cycle			44	50	56	%

NOTE: Electrical parameters are guaranteed over the specified ambient operating temperature range, which is established when the device is mounted in a test socket with maintained transverse airflow greater than 500 lfm. The device will meet specifications after thermal equilibrium has been reached under these conditions.

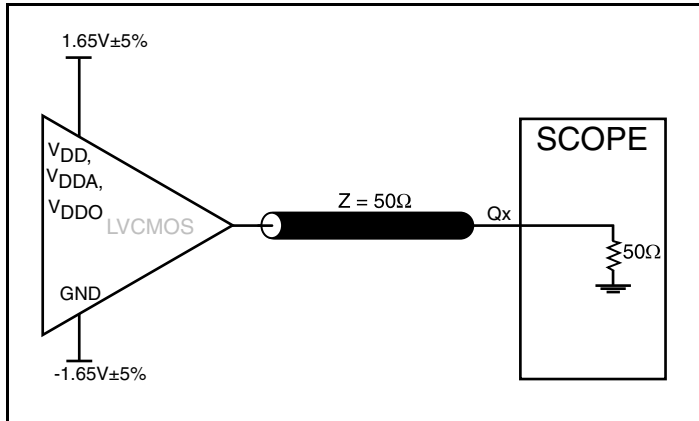
NOTE 1: Measured from the differential input crossing point to the output at  $V_{DDO}/2$ .

NOTE 2: Defined as the time difference between the input reference clock and the average feedback input signal, when the PLL is locked and the input reference frequency is stable.

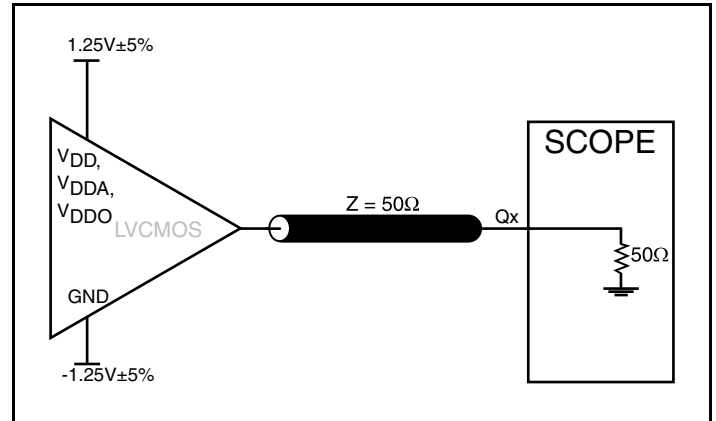
NOTE 3: Defined as skew between outputs at the same supply voltage and with equal load conditions. Measured at  $V_{DDO}/2$ .

NOTE 4: This parameter is defined in accordance with JEDEC Standard 65.

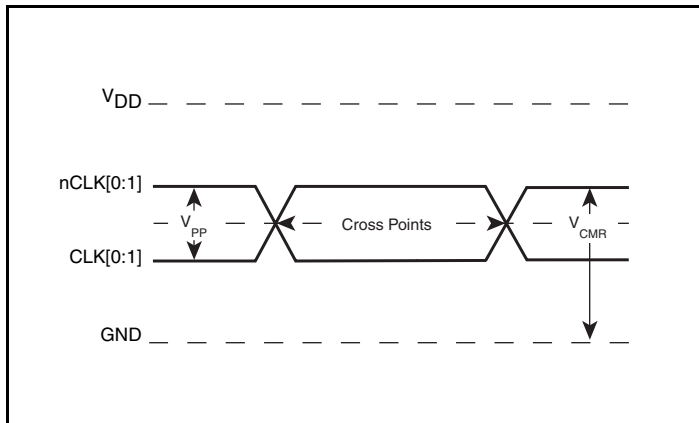
## Parameter Measurement Information



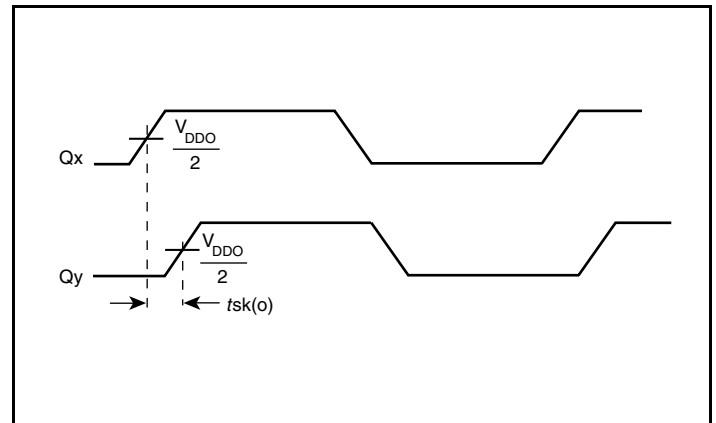
3.3V Output Load AC Test Circuit



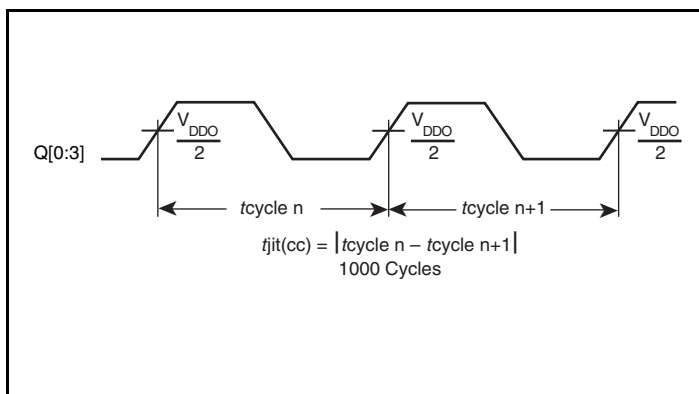
2.5V Output Load AC Test Circuit



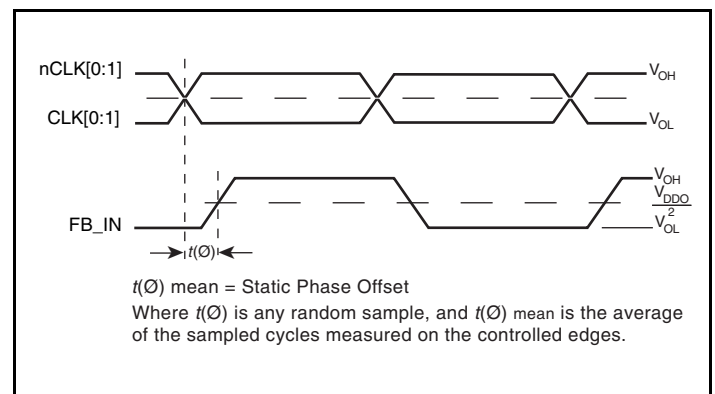
Differential Input Level



Output Skew



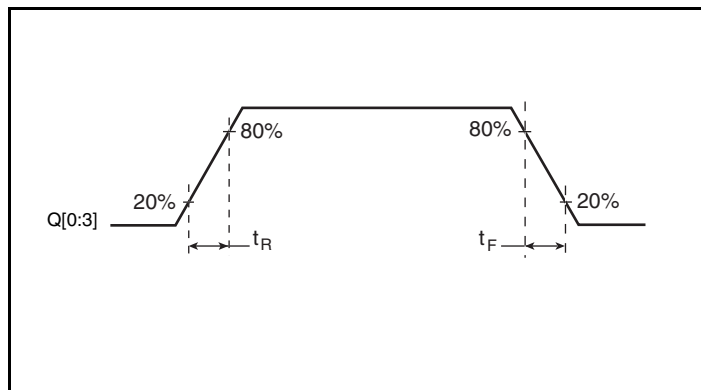
Cycle-to-Cycle Jitter



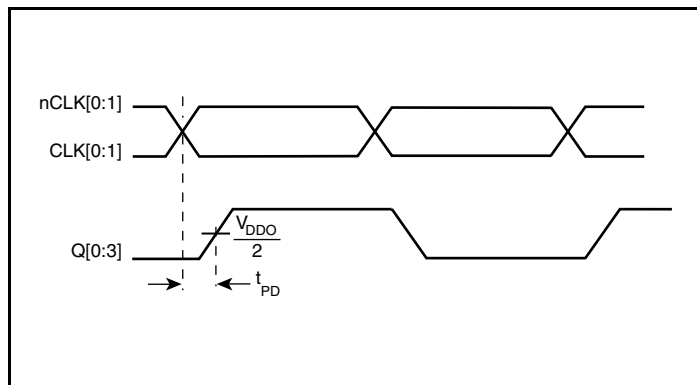
Static Phase Offset



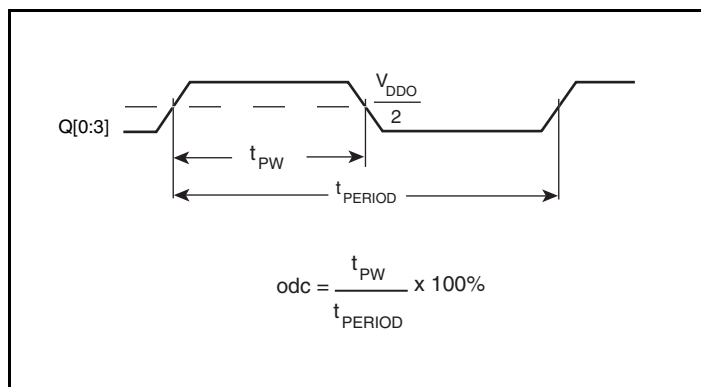
## Parameter Measurement Information, continued



**Output Rise/Fall Time**



**Propagation Delay**



**Output Duty Cycle/Pulse Width/Period**

## Application Information

### Power Supply Filtering Technique

As in any high speed analog circuitry, the power supply pins are vulnerable to random noise. To achieve optimum jitter performance, power supply isolation is required. The ICS87004 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  $0.01\mu\text{F}$  bypass capacitors should be used for each pin. *Figure 1* illustrates this for a generic  $V_{DD}$  pin and also shows that  $V_{DDA}$  requires that an additional  $10\Omega$  resistor along with a  $10\mu\text{F}$  bypass capacitor be connected to the  $V_{DDA}$  pin. The  $10\Omega$  resistor can also be replaced by a ferrite bead.

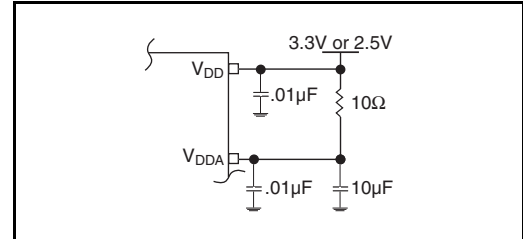


Figure 1. Power Supply Filtering

### 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  $2.5\text{V}$  and  $V_{DD} = 3.3\text{V}$ ,  $V_{REF}$  should be  $1.25\text{V}$  and  $R2/R1 = 0.609$ .

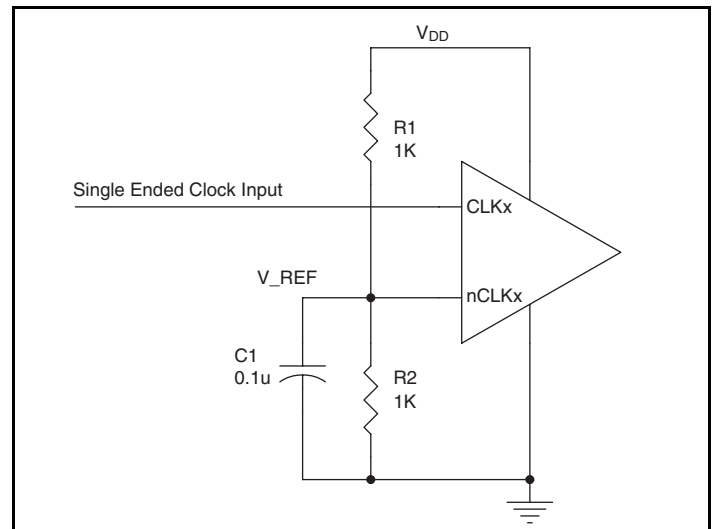


Figure 2. Single-Ended Signal Driving Differential Input

### Recommendations for Unused Input and Output Pins

#### Inputs:

##### CLK/nCLK Inputs

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  $1\text{k}\Omega$  resistor can be tied from CLK to ground.

##### LVC MOS Control Pins

All control pins have internal pullups or pulldowns; additional resistance is not required but can be added for additional protection. A  $1\text{k}\Omega$  resistor can be used.

#### Outputs:

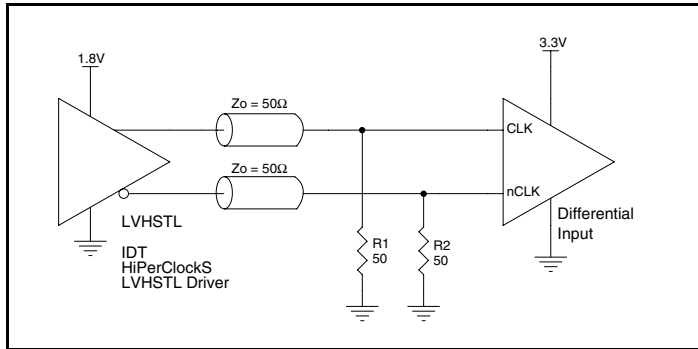
##### LVC MOS Outputs

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

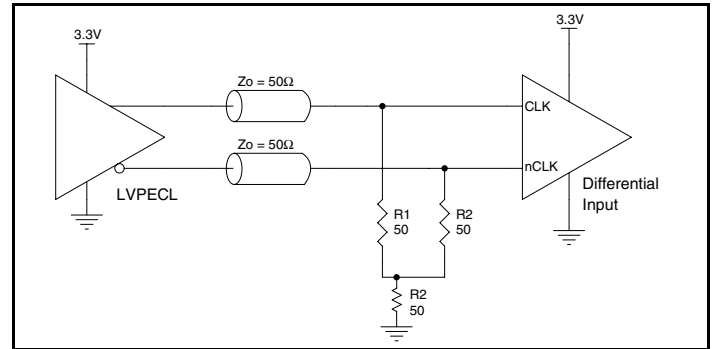
## Differential Clock Input Interface

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 3F* 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

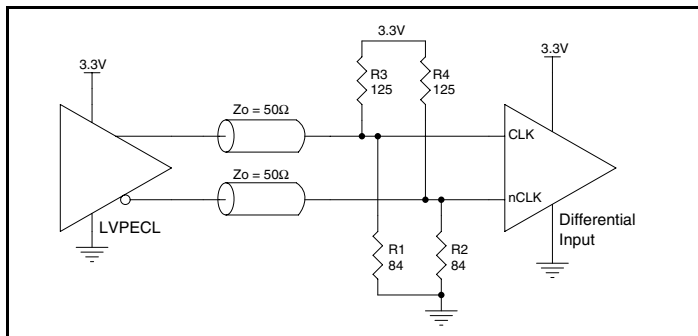
component to confirm the driver termination requirements. For example, in Figure 3A, the input termination applies for IDT HiPerClockS open emitter LVHSTL drivers. If you are using an LVHSTL driver from another vendor, use their termination recommendation.



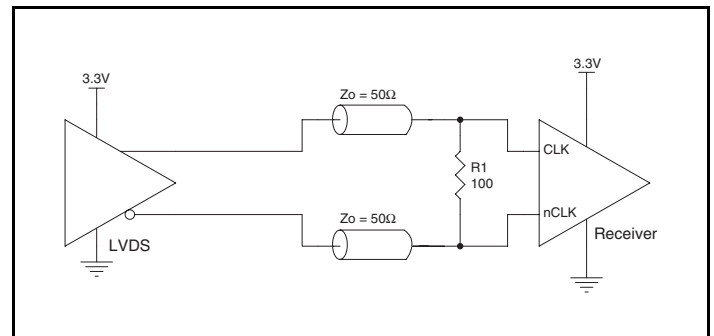
**Figure 3A. HiPerClockS CLK/nCLK Input Driven by an IDT Open Emitter HiPerClockS LVHSTL Driver**



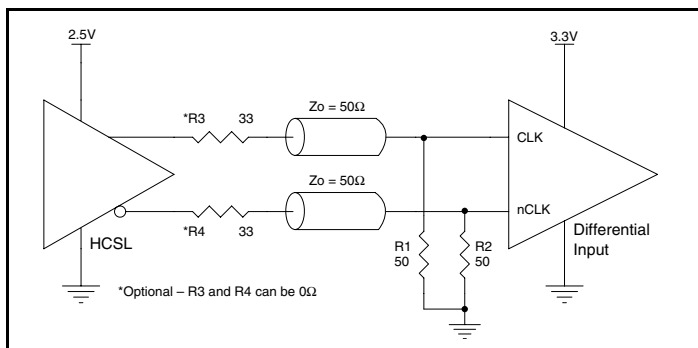
**Figure 3B. HiPerClockS CLK/nCLK Input Driven by a 3.3V LVPECL Driver**



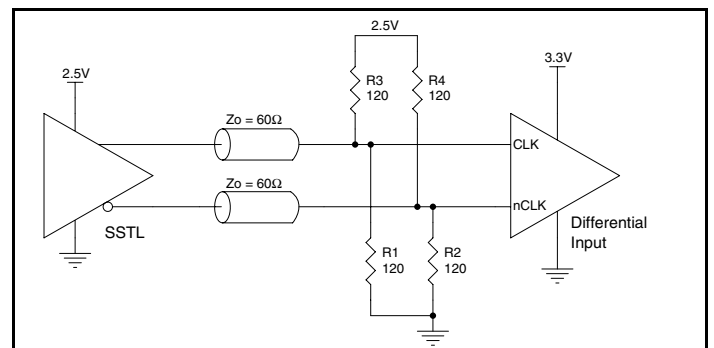
**Figure 3C. HiPerClockS CLK/nCLK Input Driven by a 3.3V LVPECL Driver**



**Figure 3D. HiPerClockS CLK/nCLK Input Driven by a 3.3V LVDS Driver**



**Figure 3E. HiPerClockS CLK/nCLK Input Driven by a 3.3V HCSL Driver**



**Figure 3F. HiPerClockS CLK/nCLK Input Driven by a 2.5V SSTL Driver**

## Reliability Information

**Table 6.  $\theta_{JA}$  vs. Air Flow Table for a 24 Lead TSSOP**

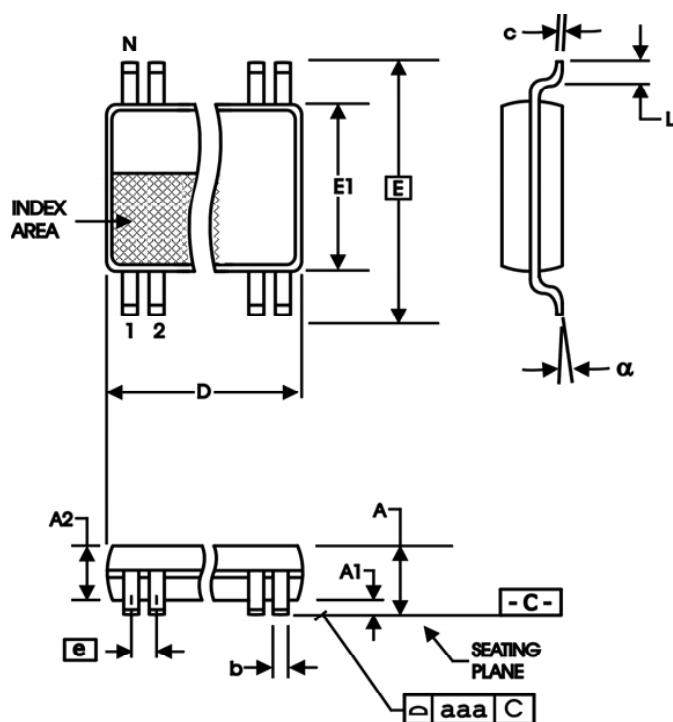
$\theta_{JA}$ vs. Air Flow			
Linear Feet per Minute	0	200	500
Multi-Layer PCB, JEDEC Standard Test Boards	70°C/W	63°C/W	60°C/W

## Transistor Count

The transistor count for ICS87004 is: 2578

## Package Outline and Package Dimensions

**Package Outline - G Suffix for 24 Lead TSSOP**



**Table 7. Package Dimensions**

All Dimensions in Millimeters		
Symbol	Minimum	Maximum
N	24	
A		1.20
A1	0.05	0.15
A2	0.80	1.05
b	0.19	0.30
c	0.09	0.20
D	7.70	7.90
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

## Ordering Information

Table 8. Ordering Information

Part/Order Number	Marking	Package	Shipping Packaging	Temperature
87004AG	ICS87004AG	24 Lead TSSOP	Tube	0°C to 70°C
87004AGT	ICS87004AG	24 Lead TSSOP	2500 Tape & Reel	0°C to 70°C
87004AGLF	ICS87004AGLF	"Lead-Free" 24 Lead TSSOP	Tube	0°C to 70°C
87004AGLFT	ICS87004AGLF	"Lead-Free" 24 Lead TSSOP	2500 Tape & Reel	0°C to 70°C

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

## Revision History Sheet

Rev	Table	Page	Description of Change	Date
A	T8	13	Ordering Information Table - added Lead-Free marking.	6/16/04
A	T8	13	Ordering Information Table - corrected Lead-Free part number. Added Lead-Free note.	5/17/05
B	T5A T5B	6 6 10	3.3V AC Characteristics Table - adjusted $t_{PD}$ parameter from 6ns max. to 6.2ns max. 2.5V AC Characteristics Table - adjusted $t_{PD}$ parameter from 6.7ns max. to 6.9ns max. Added Recommendations for Unused Input and Output Pins section.	10/7/05
C	T4D	6	Differential DC Characteristics Table - updated NOTES 1, 2.	10/6/09
	T5A, T5B	7	AC Characteristics Tables - Static Phase Offset, split CLKx into 2 rows. Specs changed for CLK1/nCLK1. Added Thermal note.	
		11	Updated Differential Clock Input Interface section.	
	T8	13	Ordering Information Table - deleted "ICS" prefix from Part/Order Number column. Converted datasheet format.	
C		1	Features section - corrected output skew from 465ps to 50ps (maximum)	12/1/09



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### Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,  
Koto-ku, Tokyo 135-0061, Japan  
[www.renesas.com](http://www.renesas.com)

### Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:  
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