



# FEMTOCLOCKS™ CRYSTAL-TO-3.3V LVPECL FREQUENCY SYNTHESIZER

# ICS843001-21

## Description



The ICS843001-21 is a highly versatile, low phase noise LVPECL Synthesizer which can generate low jitter reference clocks for a variety of communications applications and is a member of the HiPerClocks™ family of high performance clock solutions from IDT. The dual crystal interface allows the synthesizer to support up to two communications standards in a given application (i.e. 1Gb Ethernet with a 25MHz crystal and 1Gb Fibre Channel using a 26.5625MHz crystal). The rms phase jitter performance is typically less than 1ps, thus making the device acceptable for use in demanding applications such as OC48 SONET and 10Gb Ethernet. The ICS843001-21 is packaged in a small 24-pin TSSOP package.

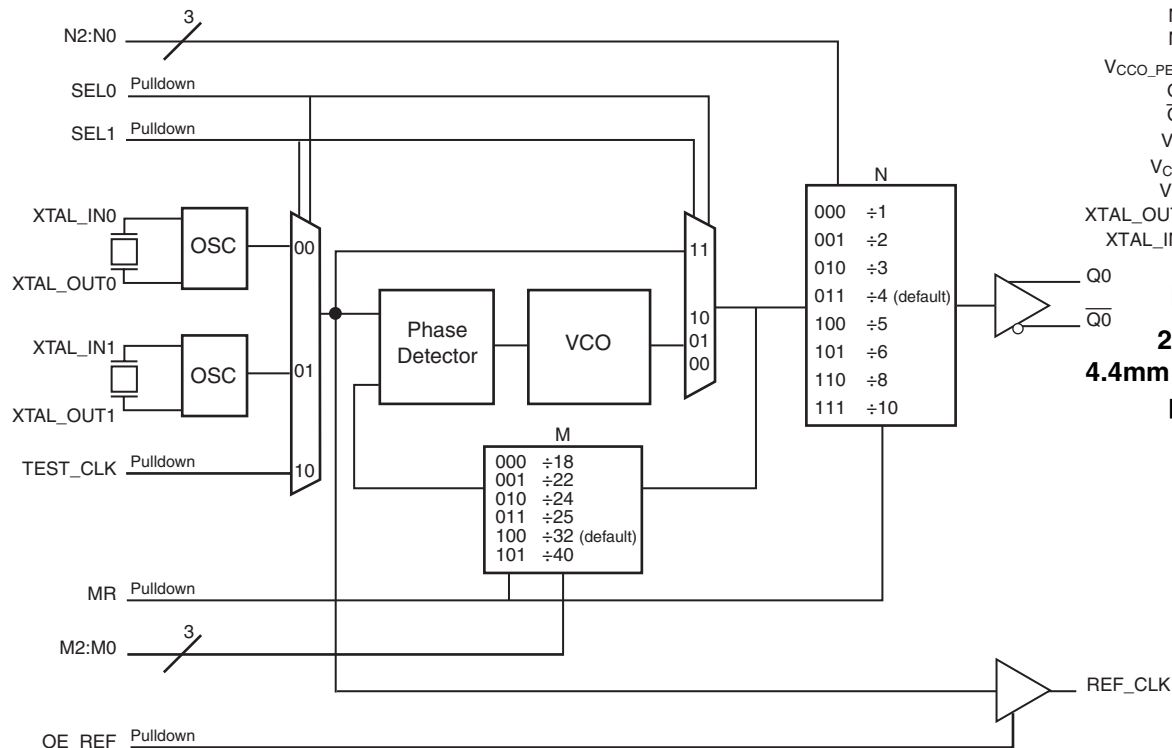
## Features

- One 3.3V differential LVPECL output pair and one LVCMOS/LVTTL single-ended reference clock output
- Selectable crystal oscillator interface or LVCMOS/LVTTL single-ended input
- VCO range: 560MHz – 700MHz
- Supports the following applications: SONET, Ethernet, Fibre Channel, Serial ATA, and HDTV
- Selectable ÷1 or ÷2 operation
- RMS phase jitter @ 622.08MHz (12kHz - 20MHz): 0.80ps (typical)

Offset	Noise Power
100Hz .....	-60.3 dBc/Hz
1kHz .....	-88.5 dBc/Hz
10kHz .....	-111.9 dBc/Hz
100kHz .....	-113.0 dBc/Hz

- Full 3.3V supply mode
- 0°C to 70°C ambient operating temperature
- Available in both standard (RoHS 5) and lead-free (RoHS 6) packages

## Block Diagram



## Pin Assignment

VCCO_CMOS	1	24	REF_CLK
N0	2	23	VEE
N1	3	22	OE_REF
N2	4	21	M2
VCCO_PECL	5	20	M1
Q0	6	19	M0
Q̄0	7	18	MR
VEE	8	17	SEL1
VCCA	9	16	SEL0
VCC	10	15	TEST_CLK
XTAL_OUT1	11	14	XTAL_IN0
XTAL_IN1	12	13	XTAL_OUT0

**ICS843001-21**  
**24-Lead TSSOP**  
**4.4mm x 7.8mm x 0.925mm**  
**package body**  
**G Package**  
**Top View**

**Table 1. Pin Descriptions**

Number	Name	Type		Description
1	V <sub>CCO_CMOS</sub>	Power		Output supply pin for REF_CLK output.
2, 3	N0, N1	Input	Pullup	Output divider select pins. Default ÷4. LVCMOS/LVTTL interface levels. See Table 3C.
4	N2	Input	Pulldown	
5	V <sub>CCO_PECL</sub>	Power		Output supply pin for LVPECL output.
6, 7	Q0, Q $\bar{0}$	Output		Differential output pair. LVPECL interface levels.
8, 23	V <sub>EE</sub>	Power		Negative supply pins.
9	V <sub>CCA</sub>	Power		Analog supply pin.
10	V <sub>CC</sub>	Power		Core supply pin.
11, 12	XTAL_OUT1, XTAL_IN1	Input		Parallel resonant crystal interface. XTAL_OUT1 is the output, XTAL_IN1 is the input.
13, 14	XTAL_OUT0, XTAL_IN0	Input		Parallel resonant crystal interface. XTAL_OUT0 is the output, XTAL_IN0 is the input.
15	TEST_CLK	Input	Pulldown	LVCMOS/LVTTL clock input.
16, 17	SEL0, SEL1	Input	Pulldown	Input MUX select pins. LVCMOS/LVTTL interface levels. See Table 3D.
18	MR	Input	Pulldown	Active HIGH Master Reset. When logic HIGH, the internal dividers are reset causing the true output Q0 to go low and the inverted output Q $\bar{0}$ to go high. When logic LOW, the internal dividers and the outputs are enabled. LVCMOS/LVTTL interface levels.
19, 20	M0, M1	Input	Pulldown	Feedback divider select pins. Default ÷32. See Table 3B LVCMOS/LVTTL interface levels.
21	M2	Input	Pullup	
22	OE_REF	Input	Pulldown	Reference clock output enable. Default Low. LVCMOS/LVTTL interface levels.
24	REF_CLK	Output		Reference clock output. 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		k $\Omega$
R <sub>PULLDOWN</sub>	Input Pulldown Resistor			51		k $\Omega$
R <sub>OUT</sub>	Output Impedance			7		$\Omega$

## Function Tables

Table 3A. Common Configuration Table

Input Reference Clock (MHz)	M Divider Value	N Divider Value	VCO (MHz)	Output Frequency (MHz)	Application
27	22	8	594	74.25	HDTV
24.75	24	8	594	74.25	HDTV
14.8351649	40	8	593.4066	74.1758245	HDTV
19.44	32	4	622.08	155.52	SONET
19.44	32	8	622.08	77.76	SONET
19.44	32	1	622.08	622.08	SONET
19.44	32	2	622.08	311.04	SONET
19.53125	32	4	625	156.25	10 GigE
25	25	5	625	125	1 GigE
25	25	10	625	62.5	1 GigE
25	24	6	600	100	PCI Express
25	24	4	600	150	SATA
25	24	8	600	75	SATA
26.5625	24	6	637.5	106.25	Fibre Channel 1
26.5625	24	3	637.5	212.5	4 Gig Fibre Channel
26.5625	24	4	637.5	159.375	10 Gig Fibre Channel
31.25	18	5	562.5	187.5	12 GigE

Table 3B. Programmable M Output Divider Function Table

Inputs			M Divider Value	Input Frequency (MHz)	
M2	M1	M0		Minimum	Maximum
0	0	0	18	31.1	38.9
0	0	1	22	25.5	31.8
0	1	0	24	23.3	29.2
0	1	1	25	22.4	28.0
1	0	0	32	17.5	21.9
1	0	1	40	14.0	17.5

**Table 3C. Programmable N Output Divider  
Function Table**

Inputs			M Divider Value
N2	N1	N0	
0	0	0	1
0	0	1	2
0	1	0	3
0	1	1	4
1	0	0	5
1	0	1	6
1	1	0	8
1	1	1	10

**Table 3D. Bypass Mode Function Table**

Inputs		Reference	PLL Mode
SEL1	SEL0		
0	0	XTAL0	1
0	1	XTAL1	2
1	0	TEST_CLK	8
1	1	TEST_CLK1	10

## 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, $V_{CC}$	4.6V
Inputs, $V_I$	-0.5V to $V_{CC} + 0.5V$
Outputs, $I_O$ (LVPECL) Continuous Current Surge Current	50mA 100mA
Outputs, $V_O$ (LVCMOS)	-0.5V to $V_{CCO\_CMOS} + 0.5V$
Package Thermal Impedance, $\theta_{JA}$	70°C/W (0 mps)
Storage Temperature, $T_{STG}$	-65°C to 150°C

## DC Electrical Characteristics

**Table 4A. Power Supply DC Characteristics,  $V_{CC} = V_{CCA} = V_{CCO\_CMOS} = V_{CCO\_PECL} = 3.3V \pm 5\%$ ,  $T_A = 0^\circ C$  to  $70^\circ C$**

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{CC}$	Core Supply Voltage		3.135	3.3	3.465	V
$V_{CCA}$	Analog Supply Voltage		3.135	3.3	3.465	V
$V_{CCO\_PECL}$ , $V_{CCO\_CMOS}$	Output Supply Voltage		3.135	3.3	3.465	V
$I_{EE}$	Power Supply Current				170	mA
$I_{CCA}$	Analog Supply Current				11	mA
$I_{CCO\_PECL}$ , $I_{CCO\_CMOS}$	Output Supply Current				8	mA

**Table 4B. LVCMOS/LVTTL DC Characteristics,  $V_{CC} = V_{CCA} = V_{CCO\_CMOS} = 3.3V \pm 5\%$ ,  $T_A = 0^\circ C$  to  $70^\circ C$** 

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{IH}$	Input High Voltage		2		$V_{CC} + 0.3$	V
$V_{IL}$	Input Low Voltage	SEL0, SEL1, OE_REF, N0:N2, MR, M0:M2	-0.3		0.8	V
		TEST_CLK	-0.3		1.3	V
$I_{IH}$	Input High Current	TEST_CLK, M0, M1, N2, MR, OE_REF, SEL0, SEL1	$V_{CC} = V_{IN} = 3.465V$		150	$\mu A$
		M2, N0, N1	$V_{CC} = V_{IN} = 3.465V$		5	$\mu A$
$I_{IL}$	Input Low Current	TEST_CLK, M0, M1, N2, MR, OE_REF, SEL0, SEL1	$V_{CC} = 3.465V,$ $V_{IN} = 0V$	-5		$\mu A$
		M2, N0, N1	$V_{CC} = 3.465V,$ $V_{IN} = 0V$	-150		$\mu A$
$V_{OH}$	Output High Voltage: NOTE 1	REF_CLK	2.6			V
$V_{OL}$	Output Low Voltage: NOTE 1	REF_CLK			0.5	V

NOTE 1: Output terminated with  $50\Omega$  to  $V_{CCO\_CMOS}/2$ . See Parameter Measurement Information Section, "3.3V LVCMOS Output Load Test Circuit Diagram".

**Table 4C. LVPECL DC Characteristics,  $V_{CC} = V_{CCA} = V_{CCO\_PECL} = 3.3V \pm 5\%$ ,  $T_A = 0^\circ C$  to  $70^\circ C$** 

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{OH}$	Output High Current; NOTE 1		$V_{CCO} - 1.4$		$V_{CCO} - 0.9$	$\mu A$
$V_{OL}$	Output Low Current; NOTE 1		$V_{CCO} - 2.0$		$V_{CCO} - 1.7$	$\mu A$
$V_{SWING}$	Peak-toPeak Output Voltage Swing		0.6		1.0	V

NOTE 1: Outputs termination with  $50\Omega$  to  $V_{CCO\_PECL} - 2V$ .

**Table 5. Crystal Characteristics**

Parameter	Test Conditions	Minimum	Typical	Maximum	Units
Mode of Oscillation		Fundamental			
Frequency		12		40	MHz
Equivalent Series Resistance (ESR)				50	$\Omega$
Shunt Capacitance				7	pF

NOTE: Characterized using an 18pF parallel resonant crystal.

## AC Electrical Characteristics

**Table 6. AC Characteristics,  $V_{CC} = V_{CCA} = V_{CCO\_CMOS} = V_{CCO\_PECL} = 3.3V \pm 5\%$ ,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$**

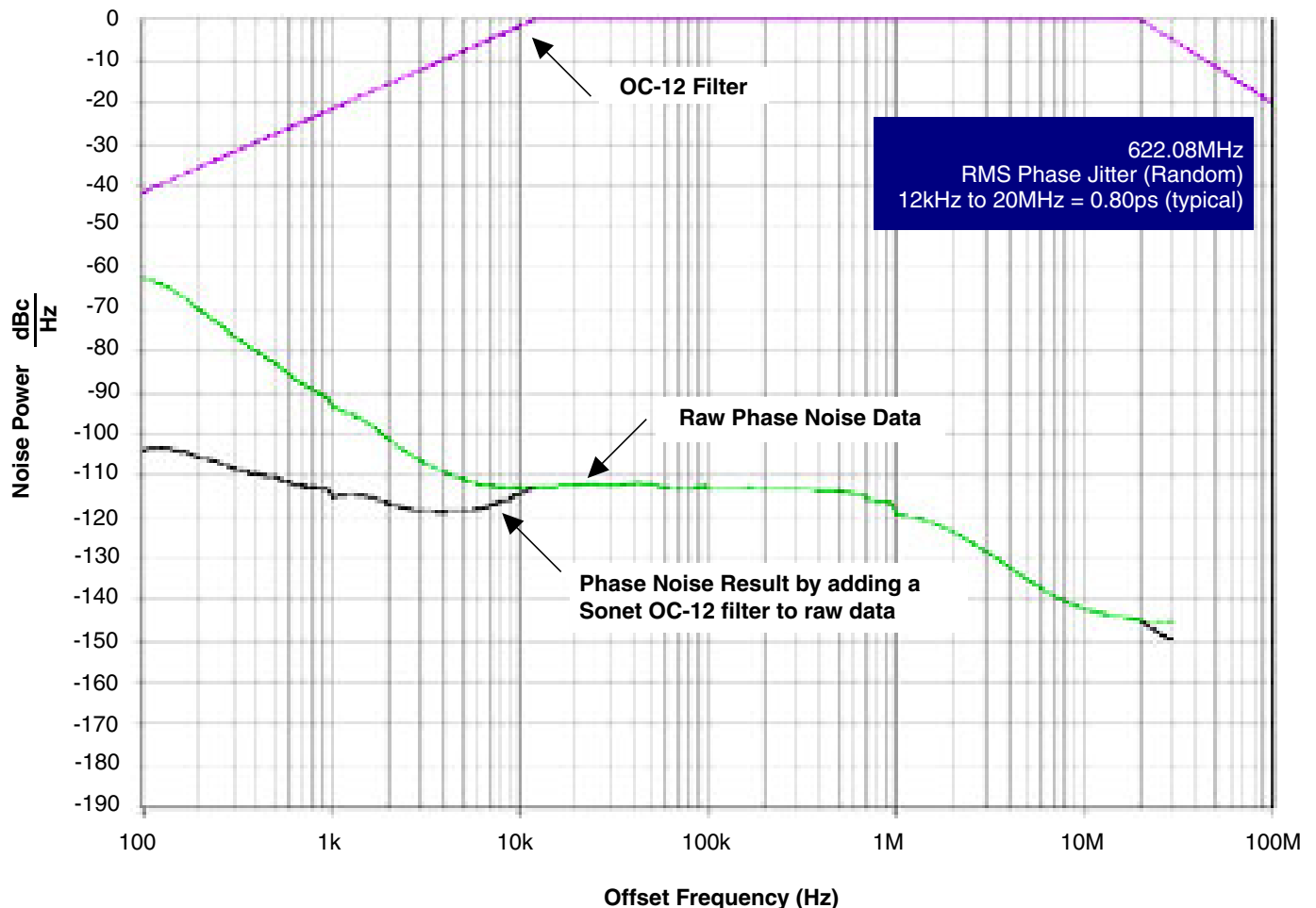
Parameter	Symbol	Test Conditions	Minimum	Typical	Maximum	Units
$f_{OUT}$	Output Frequency		56		700	MHz
$t_{PD}$	Propagation Delay; NOTE 1	TEST_CLK to REF_CLK	2.3		2.8	ns
$f_{jit}(\emptyset)$	RMS Phase Jitter, (Random); NOTE 2, 3	622.08MHz, (12kHz – 20MHz)		0.80		ps
$t_{VCO}$	PLL VCO Lock Range		560		700	MHz
$t_R / t_F$	Output Rise/Fall Time	Q0, $\overline{Q0}$	20% to 80%	200	500	ps
		REF_CLK	20% to 80%	300	800	ps
odc	Output Duty Cycle	Q0, $\overline{Q0}$		45	55	%
		REF_CLK		44	56	%

NOTE 1: Measured from the  $V_{CC}/2$  of the input to  $V_{CCO\_CMOS}/2$  of the output.

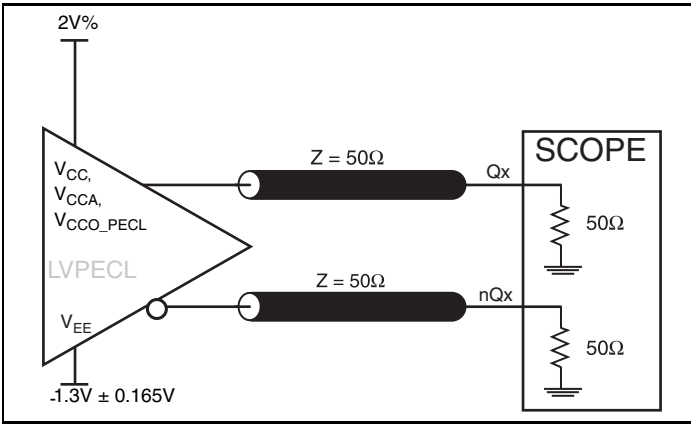
NOTE 2: Phase jitter measured using a 19.44MHz quartz crystal.

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

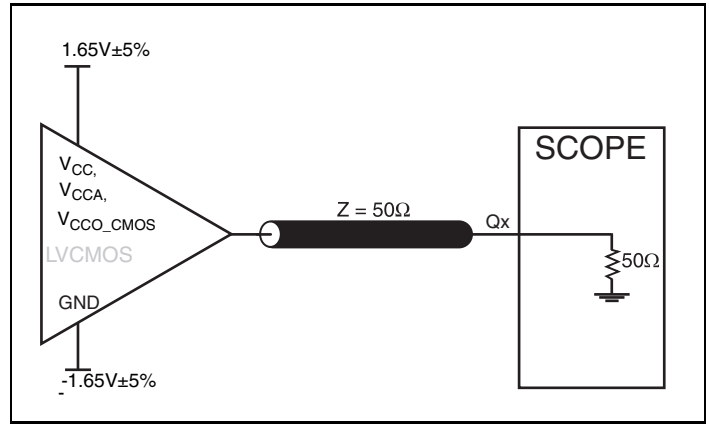
### Typical Phase Noise at 622.08MHz



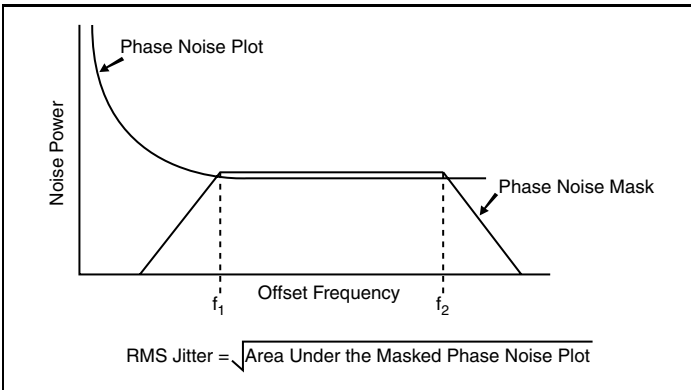
### Parameter Measurement Information



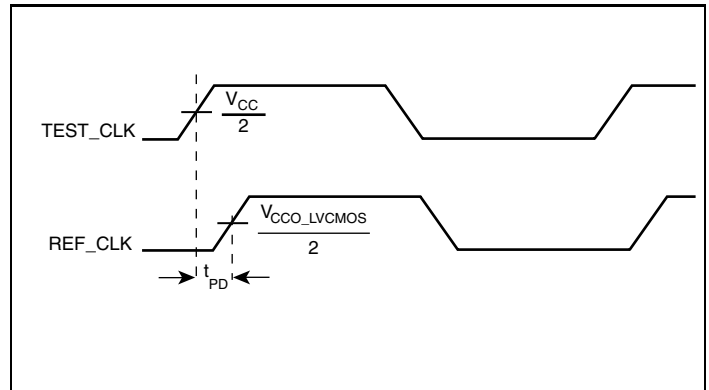
3.3V LVPECL Output Load AC Test Circuit



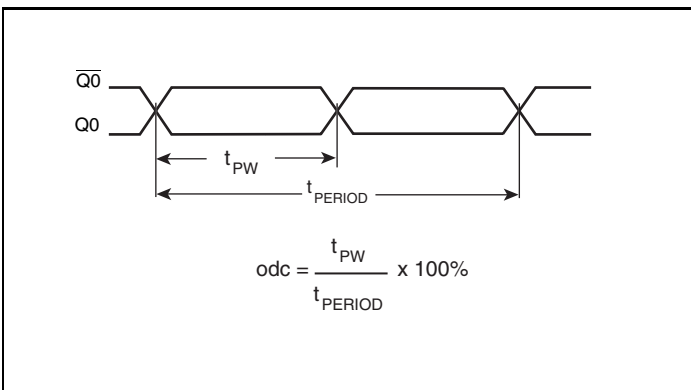
3.3V LVCMOS Output Load AC Test Circuit



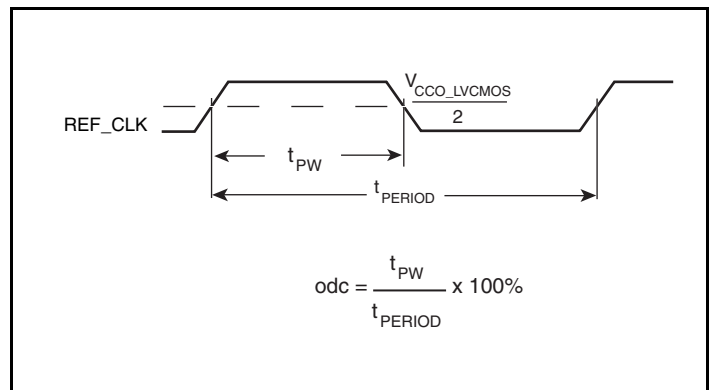
RMS Phase Jitter



Propagation Delay



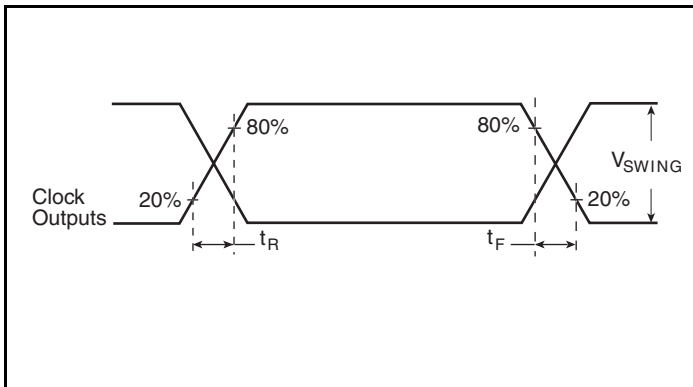
LVPECL Output Duty Cycle/Pulse Width/Period



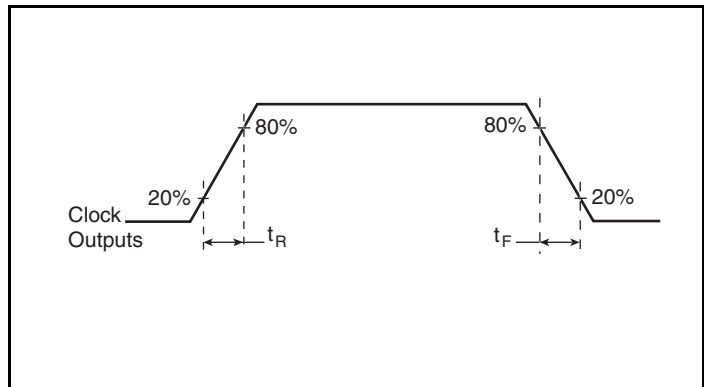
LVCMOS Output Duty Cycle/Pulse Width/Period



## Parameter Measurement Information, continued



LVPECL Output Rise/Fall Time



LVCMOS Output Rise/Fall Time

## Application Information

### Power Supply Filtering Technique

As in any high speed analog circuitry, the power supply pins are vulnerable to random noise. The ICS843001-21 provides separate power supplies to isolate any high switching noise from the outputs to the internal PLL.  $V_{CC}$ ,  $V_{CCA}$  and  $V_{CCO\_X}$  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  $10\mu\text{F}$  and a  $.01\mu\text{F}$  bypass capacitor should be connected to each  $V_{CCA}$  pin.

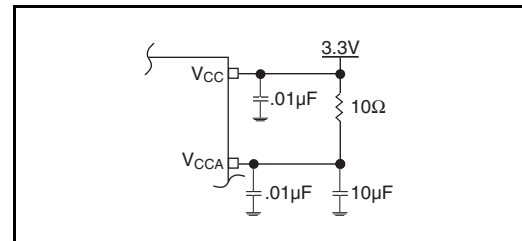
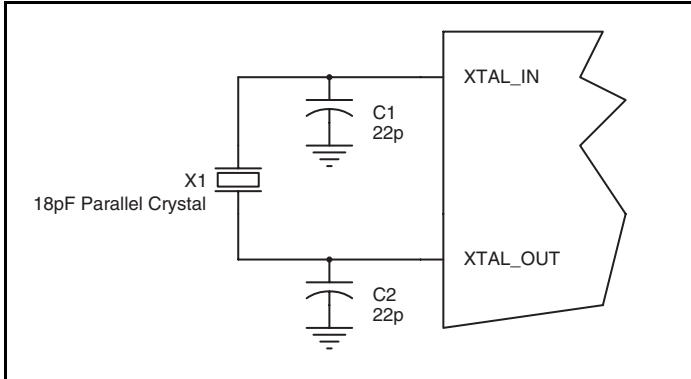


Figure 1. Power Supply Filtering

## Crystal Input Interface

The ICS843001-21 has been characterized with 18pF parallel resonant crystals. The capacitor values shown in *Figure 2* below

were determined using a 19.44MHz, 18pF parallel resonant crystal and were chosen to minimize the ppm error.

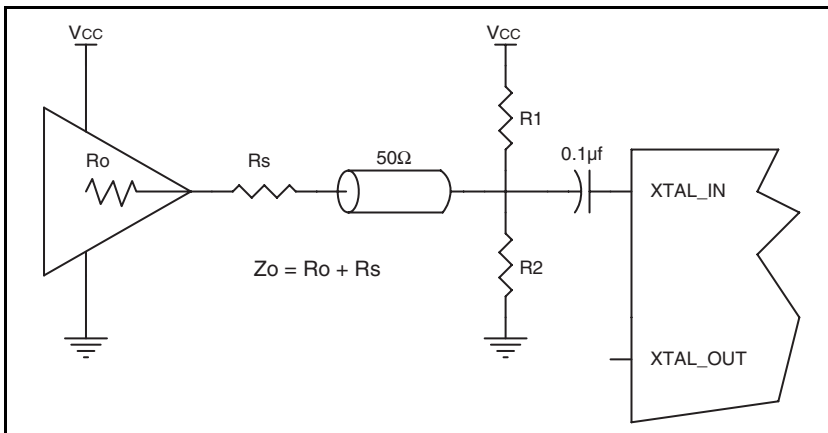


**Figure 2. Crystal Input Interface**

## LVC MOS to XTAL Interface

The XTAL\_IN input can accept a single-ended LVC MOS signal through an AC coupling capacitor. A general interface diagram is shown in *Figure 3*. The XTAL\_OUT pin can be left floating. The input edge rate can be as slow as 10ns. For LVC MOS inputs, it is recommended that the amplitude be reduced from full swing to half swing in order to prevent signal interference with the power rail and to reduce noise. This configuration requires that the output

impedance of the driver ( $R_o$ ) plus the series resistance ( $R_s$ ) equals the transmission line impedance. In addition, matched termination at the crystal input will attenuate the signal in half. This can be done in one of two ways. First,  $R_1$  and  $R_2$  in parallel should equal the transmission line impedance. For most 50Ω applications,  $R_1$  and  $R_2$  can be 100Ω. This can also be accomplished by removing  $R_1$  and making  $R_2$  50Ω.



**Figure 3. General Diagram for LVC MOS Driver to XTAL Input Interface**

## Recommendations for Unused Input and Output Pins

### Inputs:

#### Crystal Inputs:

For applications not requiring the use of the crystal oscillator input, both XTAL\_IN and XTAL\_OUT can be left floating. Though not required, but for additional protection, a 1kΩ resistor can be tied from XTAL\_IN to ground.

#### TEST\_CLK Input:

For applications not requiring the use of the test clock, it can be left floating. Though not required, but for additional protection, a 1kΩ resistor can be tied from the TEST\_CLK to ground.

#### 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:

#### LVPECL Output:

All unused LVPECL outputs can be left floating. We recommend that there is no trace attached. Both sides of the differential output pair should either be left floating or terminated.

#### LVC MOS Output:

All unused LVC MOS output can be left floating. We recommend that there is no trace attached.

## Termination for 3.3V LVPECL Outputs

The clock layout topology shown below is a typical termination for LVPECL outputs. The two different layouts mentioned are recommended only as guidelines.

FOUT and  $\overline{\text{FOUT}}$  are low impedance follower outputs that generate ECL/LVPECL compatible outputs. Therefore, terminating resistors (DC current path to ground) or current sources must be used for functionality. These outputs are designed to drive 50Ω

transmission lines. Matched impedance techniques should be used to maximize operating frequency and minimize signal distortion. *Figures 4A and 4B* show two different layouts which are recommended only as guidelines. Other suitable clock layouts may exist and it would be recommended that the board designers simulate to guarantee compatibility across all printed circuit and clock component process variations.

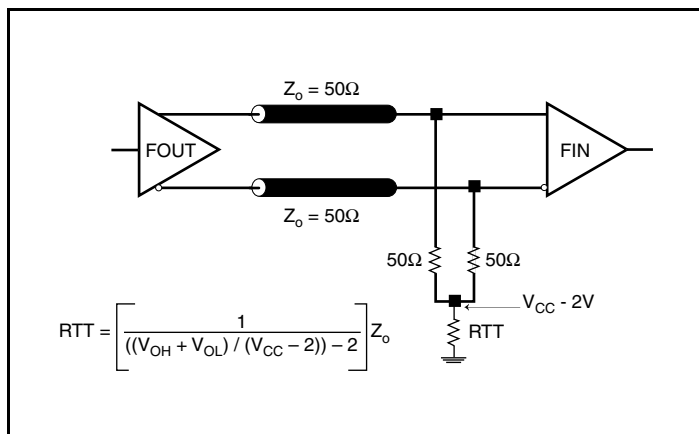


Figure 4A. 3.3V LVPECL Output Termination

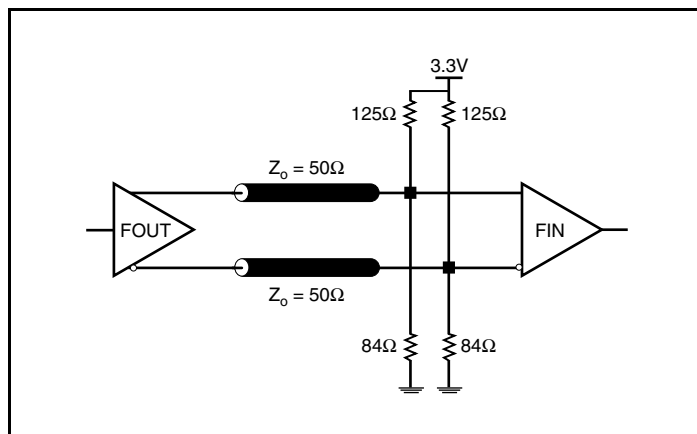


Figure 4B. 3.3V LVPECL Output Termination

## Power Considerations

This section provides information on power dissipation and junction temperature for the ICS843001.21. Equations and example calculations are also provided.

### 1. Power Dissipation.

The total power dissipation for the ICS843001-21 is the sum of the core power plus the power dissipated in the load(s). The following is the power dissipation for  $V_{CC} = 3.3V + 5\% = 3.465V$ , which gives worst case results.

NOTE: Please refer to Section 3 for details on calculating power dissipated in the load.

- Power (core)<sub>MAX</sub> =  $V_{CC\_MAX} * I_{EE\_MAX} = 3.465V * 170mA = 589.05mW$
- Power (outputs)<sub>MAX</sub> = **30mW/Loaded Output pair**

**Total Power**<sub>MAX</sub> (3.3V, with all outputs switching) =  $589.05mW + 30mW = 619.05mW$

### 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 for HiPerClockS devices is 125°C.

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

$T_j$  = Junction Temperature

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

$Pd\_total$  = 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 1 meter per second and a multi-layer board, the appropriate value is 65°C/W per Table 7 below.

Therefore,  $T_j$  for an ambient temperature of 70°C with all outputs switching is:

$$70^\circ\text{C} + 0.619\text{W} * 65^\circ\text{C/W} = 110.2^\circ\text{C}. \text{ This is below the limit of } 125^\circ\text{C}.$$

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).

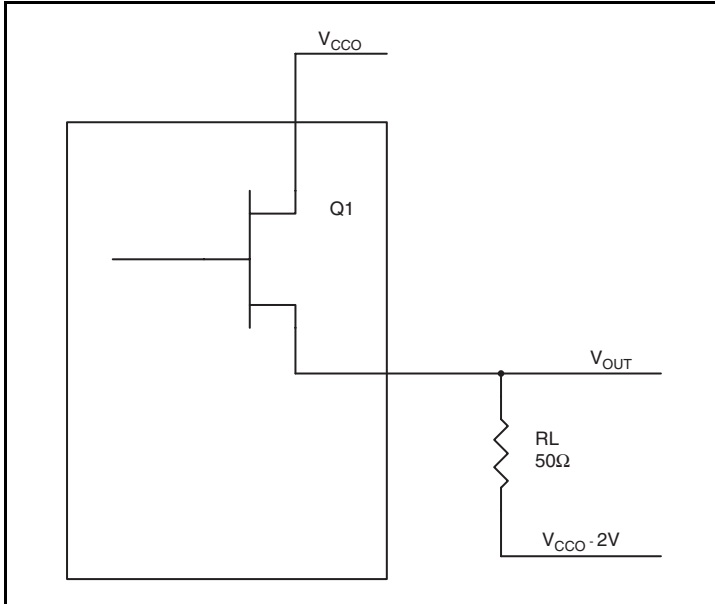
**Table 7. Thermal Resistance  $\theta_{JA}$  for 24 Lead TSSOP, Forced Convection**

Meters per Second	$\theta_{JA}$ vs. Air Flow		
	0	1	2.5
Multi-Layer PCB, JEDEC Standard Test Boards	70°C/W	65	62

### 3. Calculations and Equations.

The purpose of this section is to derive the power dissipated into the load.

LVPECL output driver circuit and termination are shown in *Figure 5*.



**Figure 5. LVPECL Driver Circuit and Termination**

To calculate worst case power dissipation into the load, use the following equations which assume a 50Ω load, and a termination voltage of  $V_{CCO} - 2V$ .

- For logic high,  $V_{OUT} = V_{OH\_MAX} = V_{CCO\_MAX} - 0.9V$   
( $V_{CCO\_MAX} - V_{OH\_MAX}$ ) = **0.9V**
- For logic low,  $V_{OUT} = V_{OL\_MAX} = V_{CCO\_MAX} - 1.7V$   
( $V_{CCO\_MAX} - V_{OL\_MAX}$ ) = **1.7V**

$Pd\_H$  is power dissipation when the output drives high.

$Pd\_L$  is the power dissipation when the output drives low.

$$Pd\_H = [(V_{OH\_MAX} - (V_{CCO\_MAX} - 2V))/R_L] * (V_{CCO\_MAX} - V_{OH\_MAX}) = [(2V - (V_{CCO\_MAX} - V_{OH\_MAX}))/R_L] * (V_{CCO\_MAX} - V_{OH\_MAX}) = [(2V - 0.9V)/50\Omega] * 0.9V = \mathbf{19.8mW}$$

$$Pd\_L = [(V_{OL\_MAX} - (V_{CCO\_MAX} - 2V))/R_L] * (V_{CCO\_MAX} - V_{OL\_MAX}) = [(2V - (V_{CCO\_MAX} - V_{OL\_MAX}))/R_L] * (V_{CCO\_MAX} - V_{OL\_MAX}) = [(2V - 1.7V)/50\Omega] * 1.7V = \mathbf{10.2mW}$$

Total Power Dissipation per output pair =  $Pd\_H + Pd\_L = \mathbf{30mW}$

## Reliability Information

Table 8.  $\theta_{JA}$  vs. Air Flow Table for a 24 Lead TSSOP

$\theta_{JA}$ vs. Air Flow			
Meters per Second	0	1	2.5
Multi-Layer PCB, JEDEC Standard Test Boards	70°C/W	65	62

## Transistor Count

The transistor count for ICS843001-21 is: 4057

## Package Outline and Package Dimension

Package Outline - G Suffix for 24 Lead TSSOP

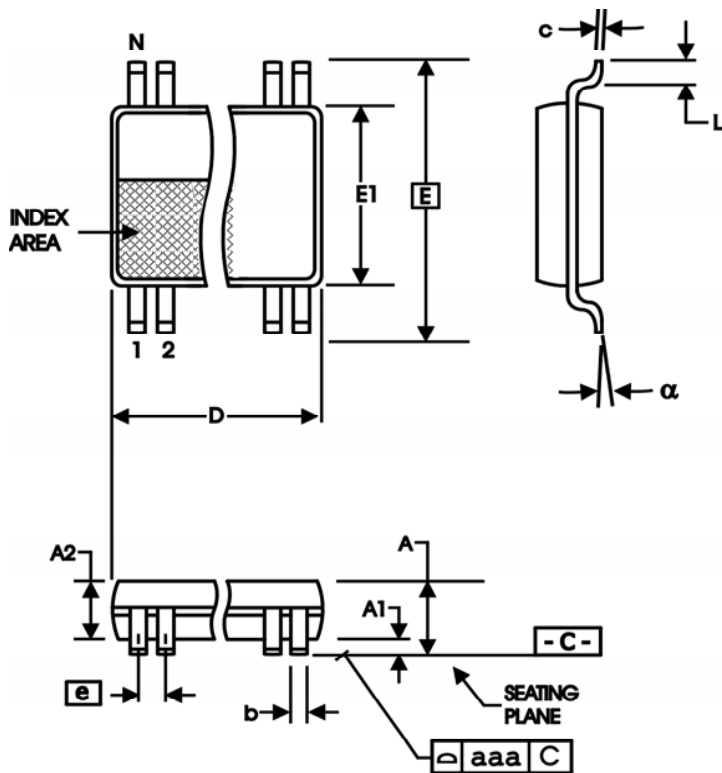


Table 9. Package Dimensions

All Dimensions in Millimeters		
Symbol	Minimum	Maximum
N	24	
A		1.20
A1	0.5	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 10. Ordering Information

Part/Order Number	Marking	Package	Shipping Packaging	Temperature
843001AG-21	ICS843001A21	24 Lead TSSOP	Tube	0°C to 70°C
843001AG-21T	ICS843001A21	24 Lead TSSOP	2500 Tape & Reel	0°C to 70°C
843001AG-21LF	ICS843001A21L	"Lead-Free" 24 Lead TSSOP	Tube	0°C to 70°C
843001AG-21LFT	ICS843001A21L	"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.

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## Revision History Sheet

Rev	Table	Page	Description of Change	Date
A	T10	1 14	Features Section - added Lead-Free bullet. Ordering Information table - added Lead-Free marking.	2/8/05
A	T3C T10	3 9 10	Programmable N Output Divider Function Table - corrected heading from M Divide Value to N Divide value. Added <i>Recommendations for Unused Input and Output Pins</i> . Ordering Information Table - added lead-free note.	10/26/05
A		1 9 10	General Description - corrected crystal frequency from 25.5625MHz crystal to 26.5625MHz crystal. Added <i>LVC MOS Output RiseFall Time Diagram</i> . Added <i>LVC MOS to XTAL Interface</i> section. Updated format throughout the datasheet.	3/15/07



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