# FemtoClocks Crystal-TO-LVDS Frequency Synthesizer

# 844002I-01

DATA SHEET

### **General Description**

The 844002I-01 is a 2 output LVDS Synthesizer optimized to generate Ethernet reference clock frequencies. Using a 25MHz, 18pF parallel resonant crystal, the following frequencies can be generated based on the 2 frequency

select pins (F\_SEL[1:0]): 156.25MHz, 125MHz and 62.5MHz. The 844002I-01 uses IDT's 3<sup>rd</sup> generation low phase noise VCO technology and can achieve <1ps typical rms phase jitter, easily meeting Ethernet jitter requirements. The 844002I-01 is packaged in a small 20-pin TSSOP package.

#### **Features**

- Two differential LVDS outputs
- Selectable crystal oscillator interface or single-ended LVCMOS/LVTTL input
- Supports the following output frequencies: 156.25MHz, 125MHz, 62.5MHz
- VCO range: 560MHz 680MHz
- RMS phase jitter @ 156.25MHz, using a 25MHz crystal (1.875MHz – 20MHz): 0.41ps (typical)
- Full 2.5V supply mode
- -40°C to 85°C ambient operating temperature
- Available in lead-free (RoHS 6) package

### **Block Diagram**

#### F\_SEL[1:0] Pulldown 20 VDDO ncΓ 19 🗖 Q1 Vddo 🗆 2 PLL\_SEL Pulldown Q0 🛛 3 18 🗖 Q1 Q0 17 🗖 GND F\_SEL[1:0] QO 16 <u>nc</u> MR 5 REF\_CLK\_Pulldown 00 ÷4 PLL\_SEL 15 XTAL\_SEL 6 01 ÷5 nc 7 14 REF\_CLK 25MHz 10 ÷10 VCO VDDA 8 13 XTAL\_IN XTAL IN r Phase 11 not used Q1 F\_SEL0 9 12 XTAL\_OUT OSC 0 625MHz 0 Detector (w/25MHz VDD 10 11 F\_SEL1 Q1 XTAL OUT Reference) 844002I-01 XTAL\_SEL \_Pulldown 20-Lead TSSOP 6.5mm x 4.4mm x 0.925mm M = 25 (fixed) package body G Package **Top View** MR\_Pulldown

### **Pin Assignment**



### Table 1. Pin Descriptions

Number	Name	Ţ	уре	Description
1, 7	nc	Unused		No connect.
2, 20	V <sub>DDO</sub>	Power		Output supply pins.
3, 4	Q0, <u>Q0</u>	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 Qx to go low and the inverted outputs $\overline{Qx}$ to go high. When logic LOW, the internal dividers and the outputs are enabled. LVCMOS/LVTTL interface levels.
6	PLL_SEL	Input	Pulldown	Selects between the PLL and REF_CLK as input to the dividers. When LOW, selects PLL (PLL Enable). When HIGH, deselects the reference clock (PLL Bypass). LVCMOS/LVTTL interface levels.
8	V <sub>DDA</sub>	Power		Analog supply pin.
9, 11	FSEL0, F_SEL1	Input	Pulldown	Frequency select pins. LVCMOS/LVTTL interface levels.
10	V <sub>DD</sub>	Power		Core supply pins.
12, 13	XTAL_OUT, XTAL_IN	Input		Parallel resonant crystal interface. XTAL_OUT is the output, XTAL_IN is the input.
14	REF_CLK	Input	Pulldown	Non-inverting differential clock input.
15	XTAL_SEL	Input	Pulldown	Selects between crystal or REF_CLK inputs as the PLL Reference source. Selects XTAL inputs when LOW. Selects REF_CLK when HIGH. LVCMOS/LVTTL interface levels.
16	nc	Unused		No connect.
17	GND	Power		Power supply ground.
18, 19	<u>Q1</u> , Q1	Output		Differential output pair. LVDS interface levels.

NOTE: Pulldown refers 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>PULLDOWN</sub>	Input Pulldown Resistor			51		kΩ

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 <sub>DD</sub>	4.6V	
Inputs, V <sub>I</sub>	-0.5V to V <sub>DD</sub> + 0.5V	
Outputs, I <sub>O</sub> Continuous Current Surge Current	10mA 15mA	
Package Thermal Impedance, $\theta_{\text{JA}}$	73.2°C/W (0 lfpm)	
Storage Temperature, T <sub>STG</sub>	-65°C to 150°C	

### **DC Electrical Characteristics**

Table 3A. Power Supply DC Characteristics,  $V_{DD} = V_{DDA} = V_{DDO} = 2.5V \pm 5\%$ ,  $T_A = -40^{\circ}C$  to  $85^{\circ}C$ 

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
V <sub>DD</sub>	Core Supply Voltage		2.375	2.5	2.625	V
V <sub>DDA</sub>	Analog Supply Voltage		2.375	2.5	2.625	V
V <sub>DDO</sub>	Output Supply Voltage		2.375	2.5	2.625	V
I <sub>DD</sub>	Power Supply Current				98	mA
I <sub>DDA</sub>	Analog Supply Current				12	mA
I <sub>DDO</sub>	Output Supply Current				98	mA

#### Table 3B. LVCMOS/LVTTL DC Characteristics, $V_{DD} = V_{DDA} = V_{DDO} = 2.5V \pm 5\%$ , $T_A = -40^{\circ}C$ to $85^{\circ}C$

Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
V <sub>IH</sub>	Input High Voltage		2.5V	1.7		V <sub>DD</sub> + 0.3	V
V <sub>IL</sub>	Input Low Voltage		2.5V	-0.3		0.7	V
I <sub>IH</sub>	Input High Current	REF_CLK, MR, FSEL0, FSEL1, PLL_SEL, XTAL_SEL	V <sub>DD</sub> = V <sub>IN</sub> = 2.625V			150	μA
IIL	Input Low Current	REF_CLK, MR, FSEL0, FSEL1, PLL_SEL, XTAL_SEL	V <sub>DD</sub> = 2.625V, V <sub>IN</sub> = 0V	-5			μA

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
V <sub>OD</sub>	Differential Output Voltage		240		550	mV
$\Delta V_{OD}$	V <sub>OD</sub> Magnitude Change			40		mV
V <sub>OS</sub>	Offset Voltage		0.7	1.1	1.5	V
$\Delta V_{OS}$	V <sub>OS</sub> Magnitude Change			50		mV

#### Table 3C. LVDS DC Characteristics, $V_{DD} = V_{DDA} = V_{DDO} = 2.5V \pm 5\%$ , $T_A = -40^{\circ}C$ to $85^{\circ}C$

#### Table 4. Crystal Characteristics

Parameter	Test Conditions	Minimum	Typical	Maximum	Units
Mode of Oscillation			Fundamenta	I	
Frequency		22.4	25	27.2	MHz
Equivalent Series Resistance (ESR)				50	Ω
Shunt Capacitance				7	pF
Drive Level				1	mW

### **AC Electrical Characteristics**

Table 5. AC Characteristics,  $V_{DD} = V_{DDA} = V_{DDO} = 2.5V \pm 5\%$ ,  $T_A = -40^{\circ}C$  to  $85^{\circ}C$ 

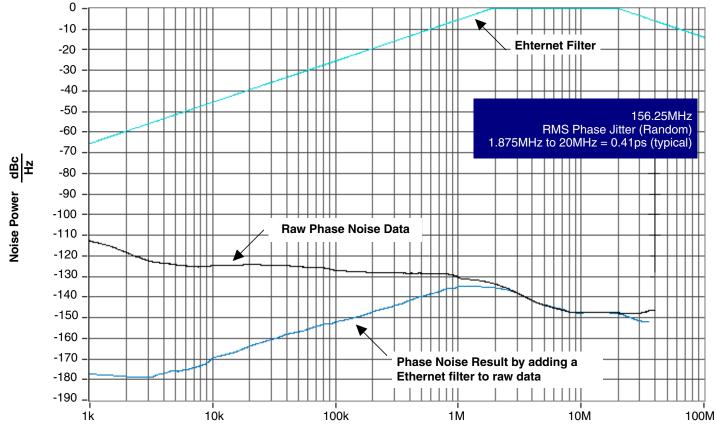
Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
		FSEL[1:0] = 00	140		170	MHz
f <sub>OUT</sub>	Output Frequency	FSEL[1:0] = 01	112		136	MHz
		FSEL[1:0] = 10	56		68	MHz
<i>t</i> sk(o)	Output Skew; NOTE 1, 2			5	20	ps
		156.25MHz, (1.875MHz – 20MHz)		0.41		ps
<i>t</i> jit(Ø)	RMS Phase Jitter, (Random);	125MHz, (1.875MHz – 20MHz)		0.44		ps
		62.5MHz, (1.875MHz – 20MHz)		0.47		ps
t <sub>R</sub> / t <sub>F</sub>	Output Rise/Fall Time	20% to 80%	250		550	ps
odc	Output Duty Cycle		48		52	%
tL	PLL Lock Time				100	ms

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

NOTE 1: Defined as skew between outputs at the same supply voltages and with equal load conditions. Measured at V<sub>DDO</sub>/2.

NOTE 2: This parameter is defined in accordance with JEDEC Standard 65.

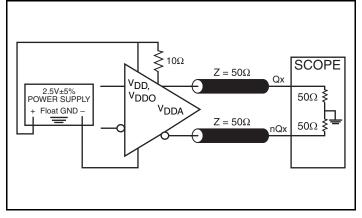
NOTE 3: Please refer to the Phase Noise Plot.

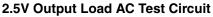


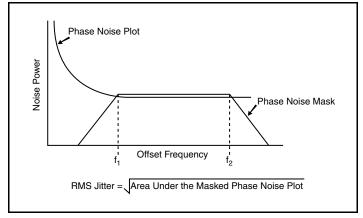
### **Typical Phase Noise at 156.25MHz**

Offset Frequency (Hz)

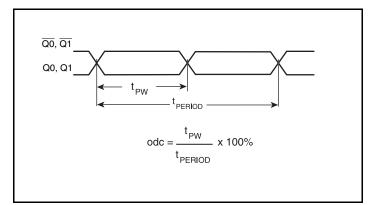
### **Parameter Measurement Information**



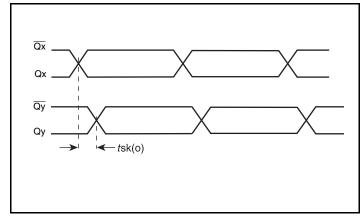




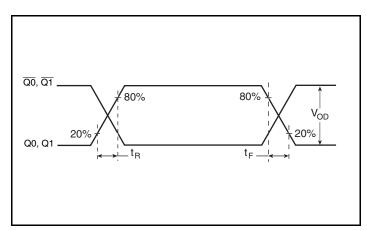
**RMS Phase Jitter** 



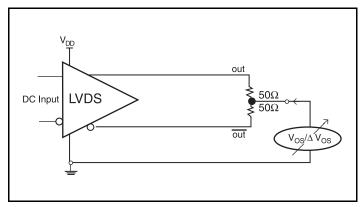
Output Duty Cycle/Pulse Width/Period





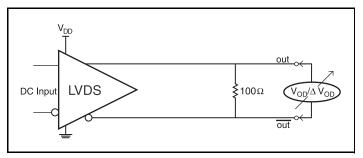


**Output Rise/Fall Time** 



Offset Voltage Setup

### Parameter Measurement Information, continued



**Differential Offset Voltage Setup** 

### **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 844002I-01 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  $0.01\mu$ 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  $10\mu$ F bypass capacitor be connected to the  $V_{DDA}$  pin.

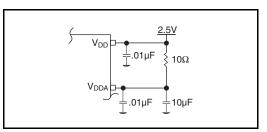


Figure 1. Power Supply Filtering

#### **Recommendations for Unused Input and Output Pins**

#### Inputs:

#### **LVCMOS Control Pins**

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

#### **REF\_CLK Input**

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

#### **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  $1k\Omega$  resistor can be tied from XTAL\_IN to ground.

#### **Outputs:**

#### LVDS Outputs

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

#### **Crystal Input Interface**

The 844002I-01 has been characterized with 18pF parallel resonant crystals. The capacitor values shown in *Figure 2* below

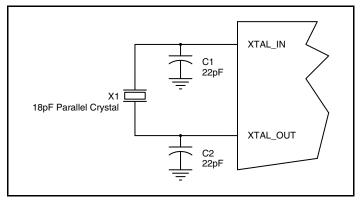


Figure 2. Crystal Input Interface

#### **LVCMOS to XTAL Interface**

The XTAL\_IN input can accept a single-ended LVCMOS 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 LVCMOS 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 (Ro) plus the series resistance (Rs) 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, R1 and R2 in parallel should equal the transmission line impedance. For most 50 $\Omega$  applications, R1 and R2 can be 100 $\Omega$ . This can also be accomplished by removing R1 and making R2 50 $\Omega$ .

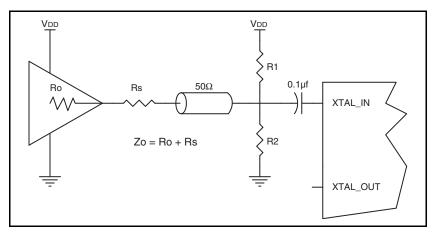


Figure 3. General Diagram for LVCMOS Driver to XTAL Input Interface

were determined using a 25MHz, 18pF parallel resonant crystal and were chosen to minimize the ppm error.

### 2.5V LVDS Driver Termination

Figure 4 shows a typical termination for LVDS driver in characteristic impedance of  $100\Omega$  differential ( $50\Omega$  single) transmission line

environment. For buffer with multiple LVDS driver, it is recommended to terminate the unused outputs.

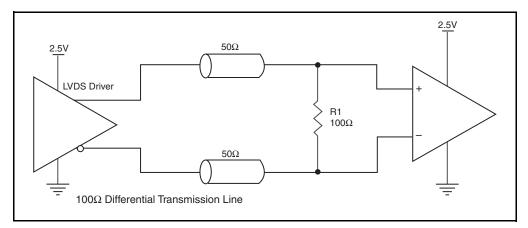


Figure 4. Typical LVDS Driver Termination

### **Power Considerations**

This section provides information on power dissipation and junction temperature for the 844002I-01. Equations and example calculations are also provided.

#### 1. Power Dissipation.

The total power dissipation for the ICS44002I-01 is the sum of the core power plus the analog power plus the power dissipated in the load(s). The following is the power dissipation for  $V_{DD} = 2.5V + 5\% = 2.625V$ , which gives worst case results.

- Power (core)<sub>MAX</sub> = V<sub>DD\_MAX</sub> \* (I<sub>DD\_MAX</sub> + I<sub>DDA\_MAX</sub>) = 2.625V \* (98mA + 12mA) = 288.75mW
- Power (outputs)<sub>MAX</sub> = V<sub>DDO MAX</sub> \* I<sub>DDO MAX</sub> = 2.625V \* 98mA = 257.25mW

Total Power\_MAX = 288.75mW + 257.25mW = 546mW

#### 2. Junction Temperature.

Junction temperature, Tj, 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 Tj is as follows: Tj =  $\theta_{JA}$  \* Pd\_total + T<sub>A</sub>

Tj = Junction Temperature

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

Pd\_total = Total Device Power Dissipation (example calculation is in section 1 above)

T<sub>A</sub> = 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, Tj for an ambient temperature of 85°C with all outputs switching is:

85°C + 0.546W \* 66.6°C/W = 121.4°C. This is below the limit of 125°C.

This calculation is only an example. Tj 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

	$\theta_{\text{JA}}$ 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

### **Reliability Information**

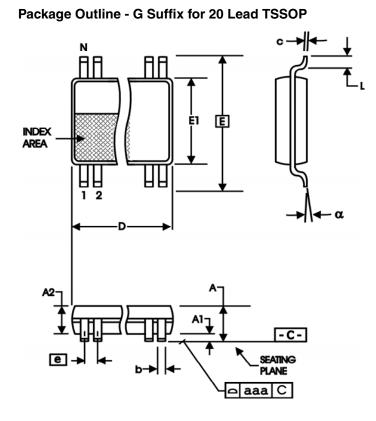
Table 7.  $\theta_{\text{JA}}$  vs. Air Flow Table for a 20 Lead TSSOP

	$\theta_{\text{JA}}$ 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

#### **Transistor Count**

The transistor count for 844002I-01 is: 2914

### Package Outline and Package Dimensions



All Dimensions in Millimeters					
Symbol	Minimum	Maximum			
b	0.19	0.30			
С	0.09	0.20			
D	6.40	6.60			
E	6.40	Basic			
E1	4.30	4.50			
е	0.65	Basic			
L	0.45	0.75			
α	0°	<b>8</b> °			
aaa		0.10			

Reference Document: JEDEC Publication 95, MO-153

#### Table 8. Package Dimensions

All Dimensions in Millimeters					
Symbol	Minimum	Maximum			
N	20				
Α		1.20			
A1	0.05	0.15			
A2	0.80	1.05			



### **Ordering Information**

#### Table 9. Ordering Information

Part/Order Number	Marking	Package	Shipping Packaging	Temperature
844002AGI-01LF	ICS4002AI01L	"Lead-Free" 20 Lead TSSOP	Tube	-40°C to 85°C
844002AGI-01LFT	ICS4002AI01L	"Lead-Free" 20 Lead TSSOP	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.

## **Revision History Sheet**

Rev	Table	Page	Description of Change	Date
		1	Pin Assignment - correct pin 16 from V <sub>DD</sub> to nc.	
	T1	2	Pin Description Table - deleted pin 16 from V <sub>DD</sub> row. Added Pin 16 row, "nc".	
С	T3B	3	LVCMOS DC Characteristics Table - corrected $I_{IL}$ from -150µA min. to -5µA min.	9/28/07
		7	Parameter Measurement Information - corrected Output Rise/Fall Time diagram.	
		10	Power Considerations - updated calculations.	
	Т5	4	AC Characteristics Table - added PLL Lock Time.	
D	6	Parameter Measurement Information - deleted 3.3V Output Load AC Test Circuit and added RMS Phase Jitter diagram.	10/20/08	
D	Т9	12	Ordering Information - removed leaded devices. Updated data sheet format.	6/9/15



#### **Corporate Headquarters** 6024 Silver Creek Valley Road San Jose, CA 95138 USA

Sales 1-800-345-7015 or 408-284-8200 Fax: 408-284-2775 www.IDT.com

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