

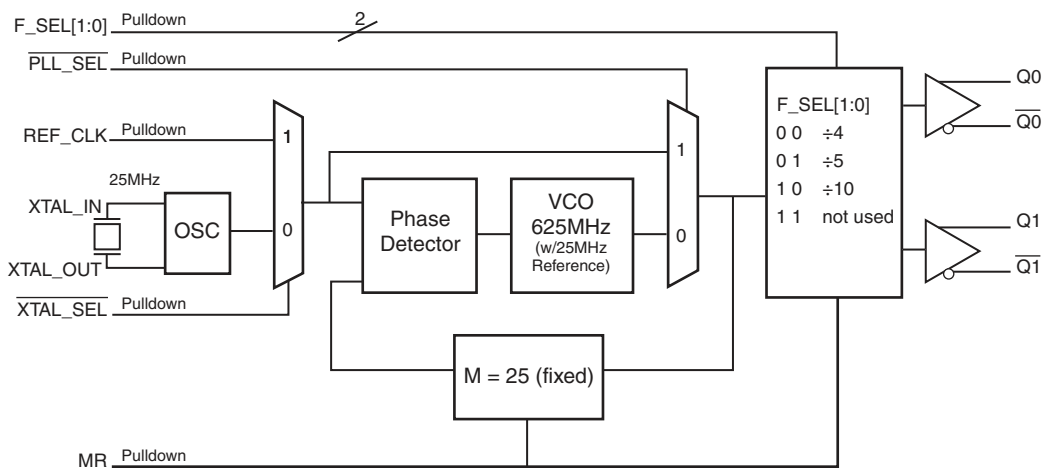
## Description

The 844002-01 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 844002-01 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 844002-01 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 3.3V and 2.5V supply modes
- 0°C to 70°C ambient operating temperature
- Available in lead-free (RoHS 6) package

## Block Diagram



## Pin Assignment

|         |    |    |          |
|---------|----|----|----------|
| nc      | 1  | 20 | VDDO     |
| VDDO    | 2  | 19 | Q1       |
| Q0      | 3  | 18 | Q1-bar   |
| Q0-bar  | 4  | 17 | GND      |
| MR      | 5  | 16 | nc       |
| PLL_SEL | 6  | 15 | XTAL_SEL |
| nc      | 7  | 14 | REF_CLK  |
| VDDA    | 8  | 13 | XTAL_IN  |
| F_SEL0  | 9  | 12 | XTAL_OUT |
| VDD     | 10 | 11 | F_SEL1   |

**844002-01**  
**20-Lead TSSOP**  
**6.5mm x 4.4mm x 0.925mm**  
**package body**  
**G Package**  
**Top View**

**Table 1. Pin Descriptions**

| Number | Name                            | Type   |          | Description  |
|--------|---------------------------------|--------|----------|--|
| 1, 7   | nc                              | Unused |          | No connect.  |
| 2, 20  | V <sub>DDO</sub>                | Power  |          | Output supply pins.  |
| 3, 4   | Q <sub>0</sub> , Q <sub>0</sub> | 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 Q <sub>x</sub> to go low and the inverted outputs Q <sub>x</sub> 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 | Q <sub>1</sub> , Q <sub>1</sub> | 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    |

## 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, $I_O$<br>Continuous Current<br>Surge Current | 10mA<br>15mA             |
| Package Thermal Impedance, $\theta_{JA}$              | 73.2°C/W (0 lfpm)        |
| Storage Temperature, $T_{STG}$                        | -65°C to 150°C           |

## DC Electrical Characteristics

**Table 3A. 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 |                 | $V_{DD} - 0.13$ | 3.3     | $V_{DD}$ | V     |
| $V_{DDO}$ | Output Supply Voltage |                 | 3.135           | 3.3     | 3.465    | V     |
| $I_{DD}$  | Power Supply Current  |                 |                 |         | 105      | mA    |
| $I_{DDA}$ | Analog Supply Current |                 |                 |         | 13       | mA    |
| $I_{DDO}$ | Output Supply Current |                 |                 |         | 110      | mA    |

**Table 3B. 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 |                 | $V_{DD} - 0.12$ | 2.5     | $V_{DD}$ | V     |
| $V_{DDO}$ | Output Supply Voltage |                 | 2.375           | 2.5     | 2.625    | V     |
| $I_{DD}$  | Power Supply Current  |                 |                 |         | 98       | mA    |
| $I_{DDA}$ | Analog Supply Current |                 |                 |         | 12       | mA    |
| $I_{DDO}$ | Output Supply Current |                 |                 |         | 98       | mA    |

**Table 3C. 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 | 3.465V   | 2  |         | $V_{DD} + 0.3$ | V       |
|          |                    | 2.625V   | 1.7  |         | $V_{DD} + 0.3$ | V       |
| $V_{IL}$ | Input Low Voltage  | 3.465V   | -0.3   |         | 0.8            | V       |
|          |                    | 2.625V   | -0.3   |         | 0.7            | V       |
| $I_{IH}$ | Input High Current | REF_CLK, MR,<br>FSEL0, FSEL1,<br>PLL_SEL, XTAL_SEL | $V_{DD} = V_{IN} = 3.465V$ or<br>$2.625V$        |         | 150            | $\mu A$ |
| $I_{IL}$ | Input Low Current  | REF_CLK, MR,<br>FSEL0, FSEL1,<br>PLL_SEL, XTAL_SEL | $V_{DD} = 3.465V$ or $2.625V$ ,<br>$V_{IN} = 0V$ |         |                | $\mu A$ |

**Table 3D. LVDS DC 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 |
|-----------------|-----------------------------|-----------------|---------|---------|---------|-------|
| $V_{OD}$        | Differential Output Voltage |                 | 300     |         | 600     | mV    |
| $\Delta V_{OD}$ | $V_{OD}$ Magnitude Change   |                 |         | 40      |         | mV    |
| $V_{OS}$        | Offset Voltage              |                 | 1.3     | 1.5     | 1.7     | V     |
| $\Delta V_{OS}$ | $V_{OS}$ Magnitude Change   |                 |         | 50      |         | mV    |

**Table 3E. LVDS DC 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 |
|-----------------|-----------------------------|-----------------|---------|---------|---------|-------|
| $V_{OD}$        | Differential Output Voltage |                 | 240     |         | 550     | mV    |
| $\Delta V_{OD}$ | $V_{OD}$ Magnitude Change   |                 |         | 40      |         | mV    |
| $V_{OS}$        | Offset Voltage              |                 | 0.7     | 1.1     | 1.5     | V     |
| $\Delta V_{OS}$ | $V_{OS}$ Magnitude Change   |                 |         | 50      |         | mV    |

**Table 4. Crystal Characteristics**

| Parameter                          | Test Conditions | Minimum     | Typical | Maximum | Units    |
|------------------------------------|-----------------|-------------|---------|---------|----------|
| Mode of Oscillation                |                 | Fundamental |         |         |          |
| Frequency                          |                 | 22.4        | 25      | 27.2    | MHz      |
| Equivalent Series Resistance (ESR) |                 |             |         | 50      | $\Omega$ |
| Shunt Capacitance                  |                 |             |         | 7       | pF       |
| Drive Level                        |                 |             |         | 1       | mW       |

## AC Electrical Characteristics

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

| Parameter            | Symbol                                | Test Conditions               | Minimum | Typical | Maximum | Units |
|----------------------|---------------------------------------|-------------------------------|---------|---------|---------|-------|
| $f_{OUT}$            | Output Frequency                      | FSEL[1:0] = 00                | 140     |         | 170     | MHz   |
|                      |                                       | FSEL[1:0] = 01                | 112     |         | 136     | MHz   |
|                      |                                       | FSEL[1:0] = 10                | 56      |         | 68      | MHz   |
| $t_{sk(o)}$          | Output Skew; NOTE 1, 2                |                               |         | 5       | 20      | ps    |
| $f_{jit}(\emptyset)$ | RMS Phase Jitter, (Random);<br>NOTE 3 | 156.25MHz, (1.875MHz – 20MHz) |         | 0.41    |         | ps    |
|                      |                                       | 125MHz, (1.875MHz – 20MHz)    |         | 0.44    |         | ps    |
|                      |                                       | 62.5MHz, (1.875MHz – 20MHz)   |         | 0.47    |         | ps    |
| $t_R / t_F$          | Output Rise/Fall Time                 | 20% to 80% @ 50MHz            | 250     |         | 550     | ps    |
| odc                  | Output Duty Cycle                     |                               | 48      |         | 52      | %     |

NOTE 1: Defined as skew between outputs at the same supply voltages and with equal load conditions. Measured at  $V_{DDO}/2$ .

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

NOTE 3: Please refer to the Phase Noise Plot.

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

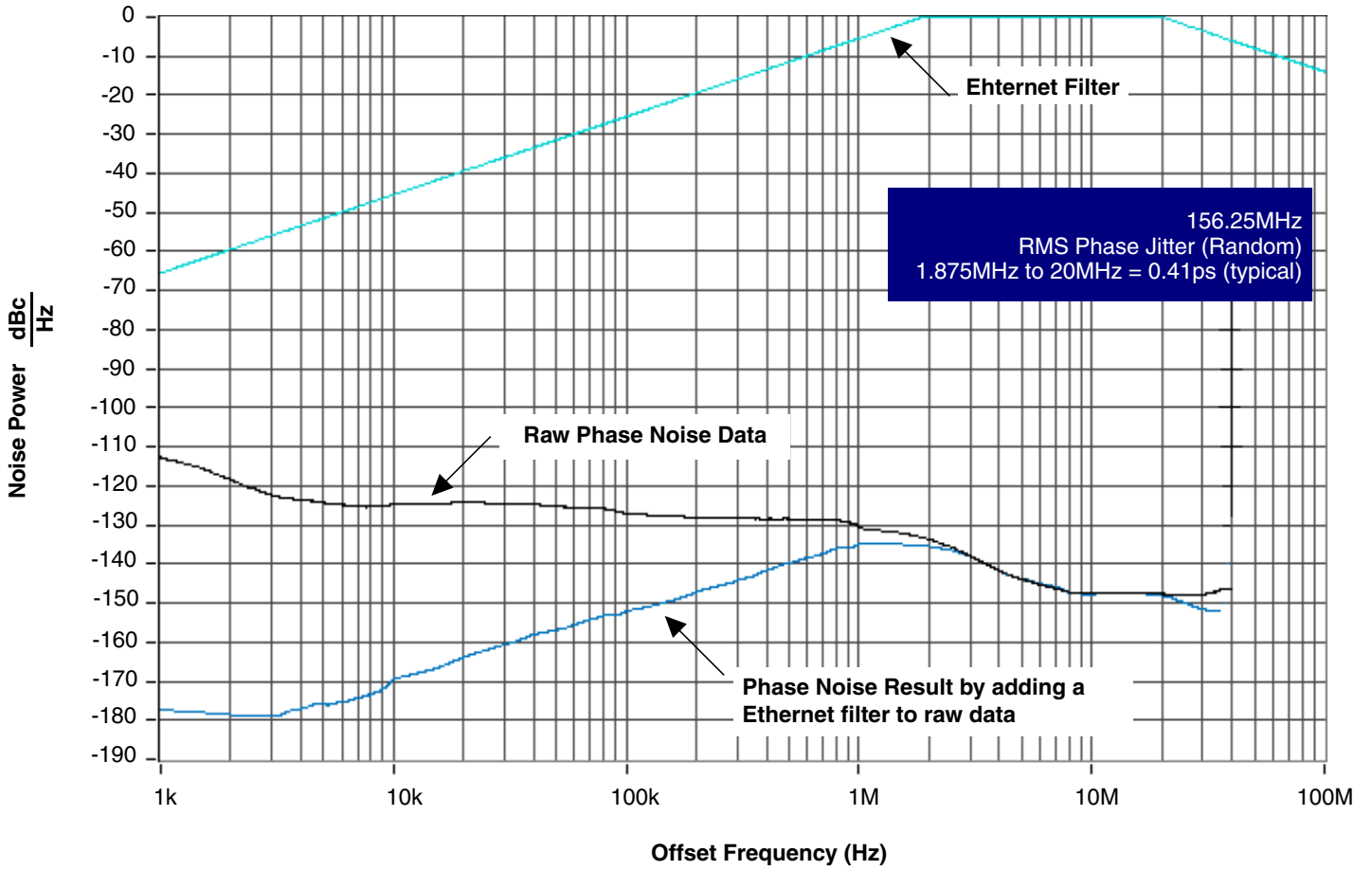
| Parameter            | Symbol                                | Test Conditions               | Minimum | Typical | Maximum | Units |
|----------------------|---------------------------------------|-------------------------------|---------|---------|---------|-------|
| $f_{OUT}$            | Output Frequency                      | FSEL[1:0] = 00                | 140     |         | 170     | MHz   |
|                      |                                       | FSEL[1:0] = 01                | 112     |         | 136     | MHz   |
|                      |                                       | FSEL[1:0] = 10                | 56      |         | 68      | MHz   |
| $t_{sk(o)}$          | Output Skew; NOTE 1, 2                |                               |         | 5       | 20      | ps    |
| $f_{jit}(\emptyset)$ | RMS Phase Jitter, (Random);<br>NOTE 3 | 156.25MHz, (1.875MHz – 20MHz) |         | 0.41    |         | ps    |
|                      |                                       | 125MHz, (1.875MHz – 20MHz)    |         | 0.44    |         | ps    |
|                      |                                       | 62.5MHz, (1.875MHz – 20MHz)   |         | 0.47    |         | ps    |
| $t_R / t_F$          | Output Rise/Fall Time                 | 20% to 80% @ 50MHz            | 250     |         | 550     | ps    |
| odc                  | Output Duty Cycle                     |                               | 48      |         | 52      | %     |

NOTE 1: Defined as skew between outputs at the same supply voltages and with equal load conditions. Measured at  $V_{DDO}/2$ .

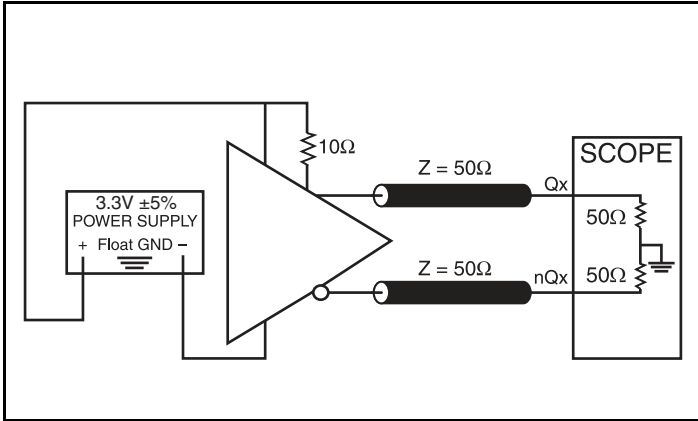
NOTE 2: This parameter is defined in accordance with JEDEC Standard 65.

NOTE 3: Please refer to the Phase Noise Plot.

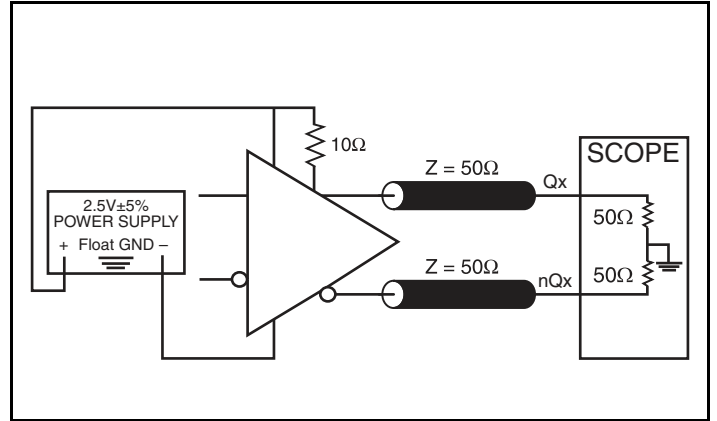
## Typical Phase Noise at 156.25MHz



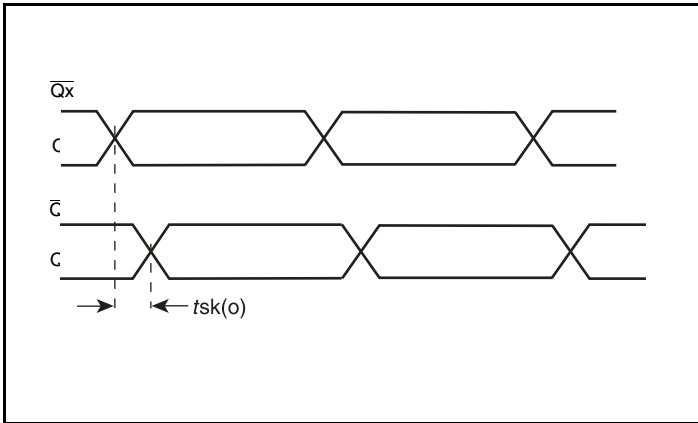
## Parameter Measurement Information



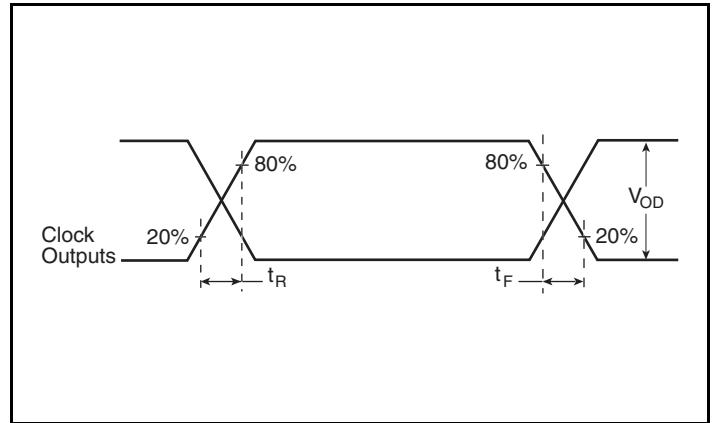
3.3V Output Load AC Test Circuit



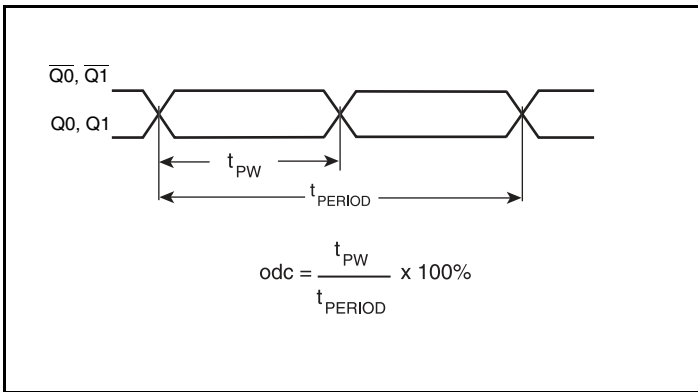
2.5V Output Load AC Test Circuit



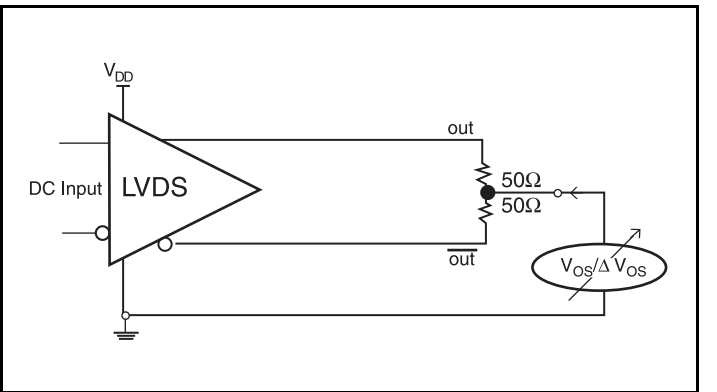
Output Skew



Output Rise/Fall Time

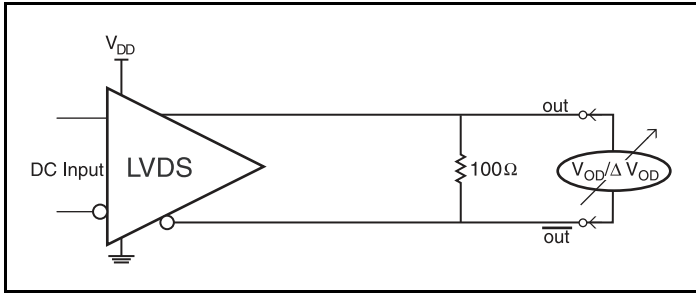


Output Duty Cycle/Pulse Width/Period



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. The 844002-01 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 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  $0.01\mu\text{F}$  bypass capacitor should be connected to each  $V_{DDA}$  pin.

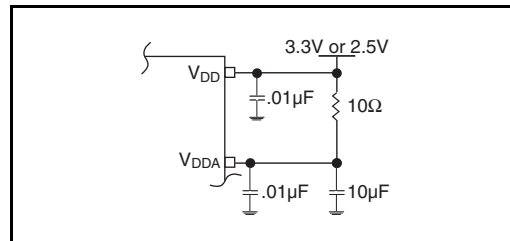


Figure 1. Power Supply Filtering

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

### Outputs:

#### LVDS Outputs

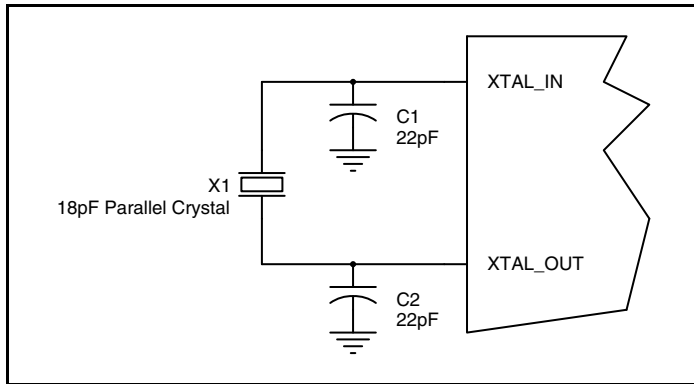
All unused LVDS output pairs can be either left floating or terminated with  $100\Omega$  across. If they are left floating, we recommend that there is no trace attached.



## Crystal Input Interface

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

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

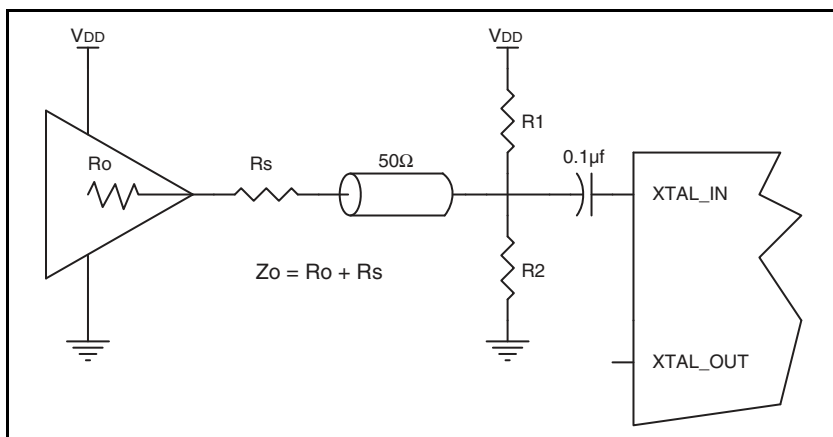


**Figure 2. Crystal Input Interface**

## 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  $50\Omega$  applications,  $R_1$  and  $R_2$  can be  $100\Omega$ . This can also be accomplished by removing  $R_1$  and making  $R_2$   $50\Omega$ .

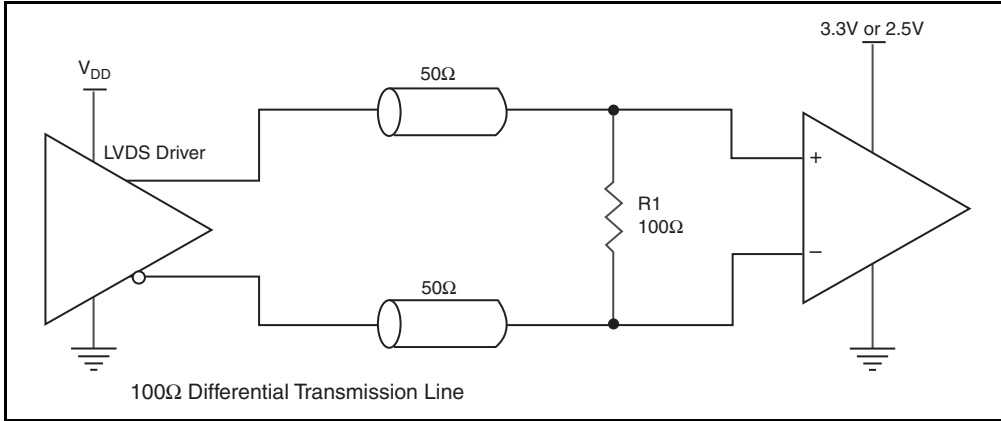


**Figure 3. General Diagram for LVC MOS Driver to XTAL Input Interface**

### 3.3V, 2.5V LVDS Driver Termination

A general LVDS interface is shown in *Figure 4*. In a 100Ω differential transmission line environment, LVDS drivers require a matched load termination of 100Ω 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 844002-01. Equations and example calculations are also provided.

### 1. Power Dissipation.

The total power dissipation for the ICS44002-01 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  $V_{DD} = 3.3V + 5\% = 3.465V$ , 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> =  $V_{DD\_MAX} * (I_{DD\_MAX} + I_{DDA\_MAX}) = 3.465V * (105mA + 13mA) = \mathbf{408.87mW}$
- Power (outputs)<sub>MAX</sub> =  $V_{DDO\_MAX} * I_{DDO\_MAX} = 3.465V * 110mA = \mathbf{381.15mW}$

**Total Power<sub>MAX</sub> = 381.15mW + 408.87mW = 790.02mW**

### 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 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 70°C with all outputs switching is:

$$70^\circ\text{C} + 0.790\text{W} * 66.6^\circ\text{C/W} = 123^\circ\text{C}. \text{ This is below the limit of } 125^\circ\text{C}.$$

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 6. Thermal Resistance  $\theta_{JA}$  for 20 Lead TSSOP, Forced Convection**

| Linear Feet per Minute                       | $\theta_{JA}$ by Velocity |          |          |
|--|---------------------------|----------|----------|
|  | 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.  $\theta_{JA}$  vs. Air Flow Table for a 20 Lead TSSOP

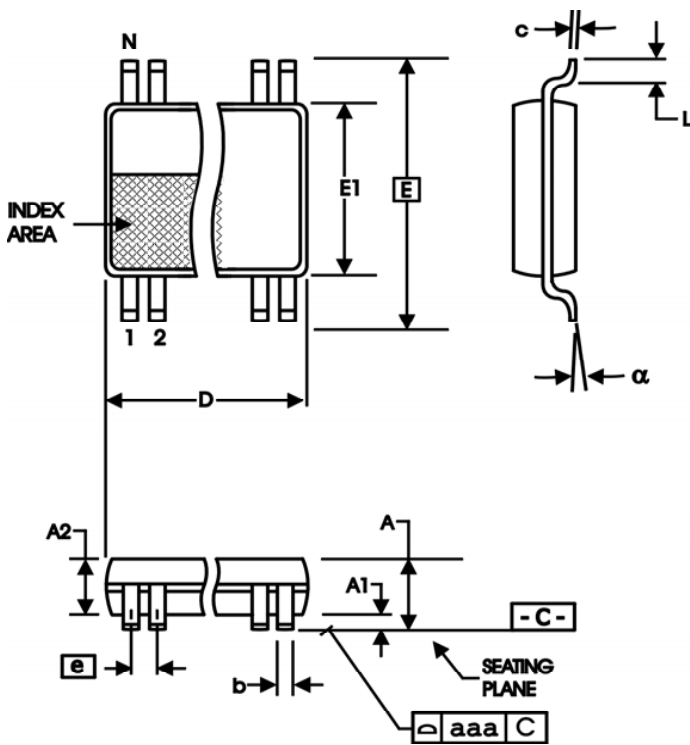
| $\theta_{JA}$ by Velocity                    |           |          |          |
|--|-----------|----------|----------|
| Linear Feet per Minute                       | 0         | 200      | 500      |
| Single-Layer PCB, JEDEC Standard Test Boards | 114.5°C/W | 98.0°C/W | 88.0°C/W |
| Multi-Layer PCB, JEDEC Standard Test Boards  | 73.2°C/W  | 66.6°C/W | 63.5°C/W |

## Transistor Count

The transistor count for 844002-01 is: 2914

## Package Outline and Package Dimension

Package Outline - G Suffix for 20 Lead TSSOP



| All Dimensions in Millimeters |            |         |
|-------------------------------|------------|---------|
| Symbol                        | Minimum    | Maximum |
| $b$                           | 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. Package Dimensions

| All Dimensions in Millimeters |         |         |
|-------------------------------|---------|---------|
| Symbol                        | Minimum | Maximum |
| $N$                           | 20      |         |
| $A$                           |         | 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 |
|-------------------|--------------|---------------------------|--------------------|-------------|
| 844002AG-01LF     | ICS44002A01L | "Lead-Free" 20 Lead TSSOP | Tube               | 0°C to 70°C |
| 844002AG-01LFT    | ICS44002A01L | "Lead-Free" 20 Lead TSSOP | 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   | T1    | 1    | Pin Assignment - correct pin 16 from VDD to nc.                              | 9/28/07 |
|     |       | 2    | Pin Description Table - deleted pin 16 from VDD row. Added Pin 16 row, "nc". |         |
|     |       | 7    | Parameter Measurement Information - corrected Output Rise/Fall Time diagram. |         |
| A   | T9    | 13   | Ordering Information - removed leaded devices.<br>Updated data sheet format. | 6/9/15  |



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