




# FEMTOCLOCK™ CRYSTAL-TO-LVHSTL FREQUENCY SYNTHESIZER

# ICS8422002I-07

## General Description

 The ICS8422002I-07 is a 2 output LVHSTL Synthesizer optimized to generate Fibre Channel reference clock frequencies and is a member of the HiPerClocks™ family of high performance clock solutions from IDT. Using a 26.5625MHz 18pF parallel resonant crystal, the following frequencies can be generated based on the 2 frequency select pins (F\_SEL[1:0]): 212.5MHz, 187.5MHz, 159.375MHz, 106.25MHz and 53.125MHz. The ICS8422002I-07 uses IDT's 3<sup>rd</sup> generation low phase noise VCO technology and can achieve 1ps or lower typical rms phase jitter, easily meeting Fibre Channel jitter requirements. The ICS8422002I-07 is packaged in a 20-pin TSSOP, EPad package.

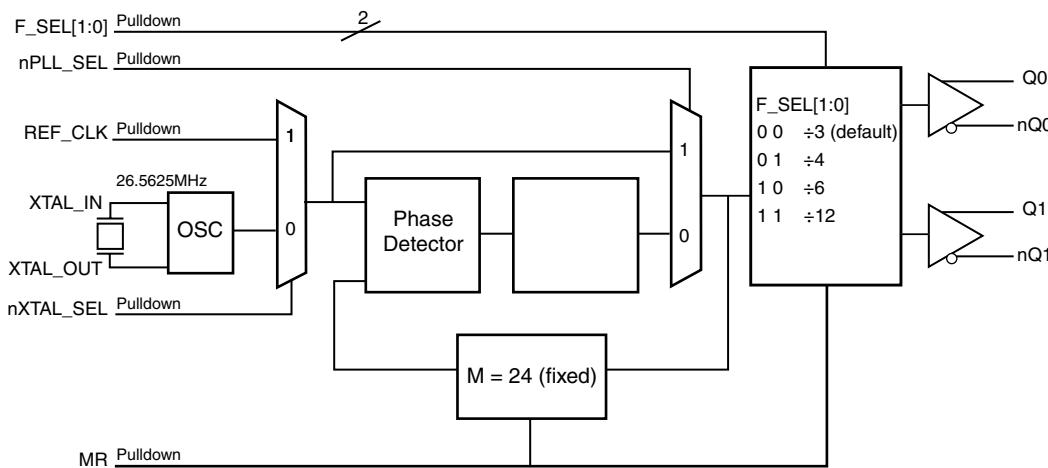
## Features

- Two LVHSTL outputs ( $V_{OH\_max} = 1.2V$ )
- Selectable crystal oscillator interface or LVCMOS/LVTTL single-ended input
- Supports the following output frequencies: 212.5MHz, 187.5MHz, 159.375MHz, 106.25MHz, 53.125MHz
- VCO range: 560MHz - 680MHz
- RMS phase jitter @ 212.5MHz, using a 25MHz crystal (637kHz - 10MHz): 0.59ps (typical) design target
- Power supply modes:  
Core/Output  
3.3V/1.8V  
2.5V/1.8V
- -40°C to 85°C ambient operating temperature
- Available in both standard (RoHS 5) and lead-free (RoHS 6) packages

### Frequency Select Function Table

| Input Frequency (MHz) | Inputs      |             |              | N Div. Value | M/N Div. Value | Output Frequency (MHz) |
|-----------------------|-------------|-------------|--------------|--------------|----------------|------------------------|
|                       | F_SEL1      | F_SEL0      | M Div. Value |              |                |                        |
| 26.5625               | 0 (default) | 0 (default) | 24           | 3            | 8              | 212.5                  |
| 26.5625               | 0           | 1           | 24           | 4            | 6              | 159.375                |
| 26.5625               | 1           | 0           | 24           | 6            | 4              | 106.25                 |
| 26.5625               | 1           | 1           | 24           | 12           | 2              | 53.125                 |
| 23.4375               | 0 (default) | 0 (default) | 24           | 3            | 8              | 187.5                  |

## Block Diagram



## Pin Assignment

|          |    |    |           |
|----------|----|----|-----------|
| nc       | 1  | 20 | VDD0      |
| VDD0     | 2  | 19 | Q1        |
| Q0       | 3  | 18 | nQ1       |
| nQ0      | 4  | 17 | GND       |
| MR       | 5  | 16 | VDD       |
| nPLL_SEL | 6  | 15 | nXTAL_SEL |
| nc       | 7  | 14 | REF_CLK   |
| VDDA     | 8  | 13 | XTAL_IN   |
| F_SEL0   | 9  | 12 | XTAL_OUT  |
| VDD      | 10 | 11 | F_SEL1    |

**ICS422002I-07**  
**20-Lead TSSOP, EPad**  
**4.4mm x 6.5mm x 0.90mm**  
**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   | Q0, nQ0              | Output |          | Differential output pair. LVHSTL 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 nQx to go high. When logic LOW, the internal dividers and the outputs are enabled. LVCMOS/LVTTL interface levels. |
| 6      | nPLL_SEL             | Input  | Pulldown | PLL select control. When LOW, the selected reference clock is frequency-multiplied by the PLL. When HIGH, the PLL is bypassed and the selected reference clock is routed directly to the output dividers. LVCMOS/LVTTL interface levels.                    |
| 8      | V <sub>DDA</sub>     | Power  |          | Analog supply pin.                                                                                                                                                                                                                                          |
| 9, 11  | F_SEL0,<br>F_SEL1    | Input  | Pulldown | Frequency select pins. LVCMOS/LVTTL interface levels.                                                                                                                                                                                                       |
| 10, 16 | V <sub>DD</sub>      | Power  |          | Core supply pins.                                                                                                                                                                                                                                           |
| 12, 13 | XTAL_OUT,<br>XTAL_IN | Input  |          | Parallel resonant crystal interface. XTAL_OUT is the output, XTAL_IN is the input.                                                                                                                                                                          |
| 14     | REF_CLK              | Input  | Pulldown | Single-ended reference clock input. LVCMOS/LVTTL interface levels.                                                                                                                                                                                          |
| 15     | nXTAL_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.                                                                                              |
| 17     | GND                  | Power  |          | Power supply ground.                                                                                                                                                                                                                                        |
| 18, 19 | nQ1, Q1              | Output |          | Differential output pair. LVHSTL 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 | 50mA<br>100mA            |
| Package Thermal Impedance, $\theta_{JA}$              | 33.1°C/W (0 mps)         |
| Storage Temperature, $T_{STG}$                        | -65°C to 150°C           |

## DC Electrical Characteristics

**Table 3A. Power Supply DC Characteristics,  $V_{DD} = 3.3V \pm 5\%$ ,  $V_{DDO} = 1.8V \pm 0.2V$ ,  $T_A = -40^\circ C$  to  $85^\circ C$**

| 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 |                 | $V_{DD} - 0.10$ | 3.3     | $V_{DD}$ | V     |
| $V_{DDO}$ | Output Supply Voltage |                 | 1.6             | 1.8     | 2.0      | V     |
| $I_{DD}$  | Core Supply Current   |                 |                 |         | 112      | mA    |
| $I_{DDA}$ | Analog Supply Current |                 |                 |         | 10       | mA    |
| $I_{DDO}$ | Output Supply Current | No Load         |                 |         | 1        | mA    |

**Table 3B. Power Supply DC Characteristics,  $V_{DD} = 2.5V \pm 5\%$ ,  $V_{DDO} = 1.8V \pm 0.2V$ ,  $T_A = -40^\circ C$  to  $85^\circ C$**

| 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 |                 | $V_{DD} - 0.10$ | 2.5     | $V_{DD}$ | V     |
| $V_{DDO}$ | Output Supply Voltage |                 | 1.6             | 1.8     | 2.0      | V     |
| $I_{DD}$  | Core Supply Current   |                 |                 |         | 106      | mA    |
| $I_{DDA}$ | Analog Supply Current |                 |                 |         | 10       | mA    |
| $I_{DDO}$ | Output Supply Current | No Load         |                 |         | 1        | mA    |

**Table 3C. LVCMOS/LVTTL DC Characteristics,  $T_A = -40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$** 

| Symbol   | Parameter          | Test Conditions                                                                                                       | Minimum | Typical | Maximum        | Units         |
|----------|--------------------|-----------------------------------------------------------------------------------------------------------------------|---------|---------|----------------|---------------|
| $V_{IH}$ | Input High Voltage | $V_{DD} = 3.3\text{V}$                                                                                                | 2       |         | $V_{DD} + 0.3$ | V             |
|          |                    | $V_{DD} = 2.5\text{V}$                                                                                                | 1.7     |         | $V_{DD} + 0.3$ | V             |
| $V_{IL}$ | Input Low Voltage  | $V_{DD} = 3.3\text{V}$                                                                                                | -0.3    |         | 0.8            | V             |
|          |                    | $V_{DD} = 2.5\text{V}$                                                                                                | -0.3    |         | 0.7            | V             |
| $I_{IH}$ | Input High Current | REF_CLK, MR, F_SEL[0:1], nPLL_SEL, nXTAL_SEL<br>$V_{DD} = V_{IN} = 3.465\text{V}$<br>or $2.625\text{V}$               |         |         | 150            | $\mu\text{A}$ |
| $I_{IL}$ | Input Low Current  | REF_CLK, MR, F_SEL[0:1], nPLL_SEL, nXTAL_SEL<br>$V_{DD} = 3.465\text{V}$ or $2.625\text{V}$ ,<br>$V_{IN} = 0\text{V}$ | -5      |         |                | $\mu\text{A}$ |

**Table 3D. LVHSTL DC Characteristics,  $V_{DD} = 3.3\text{V} \pm 5\%$ ,  $V_{DDO} = 1.8\text{V} \pm 0.2\text{V}$ ,  $T_A = -40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$** 

| Symbol      | Parameter                         | Test Conditions | Minimum | Typical | Maximum | Units |
|-------------|-----------------------------------|-----------------|---------|---------|---------|-------|
| $V_{OH}$    | Output High Voltage; NOTE 1       |                 | 0.9     |         | 1.2     | V     |
| $V_{OL}$    | Output Low Voltage; NOTE 1        |                 | 0       |         | 0.4     | V     |
| $V_{OX}$    | Output Crossover Voltage; NOTE 2  |                 | 0.45    |         | 0.80    | V     |
| $V_{SWING}$ | Peak-to-Peak Output Voltage Swing |                 | 0.6     |         | 1.2     | V     |

NOTE 1: Outputs termination with  $50\Omega$  to ground.

NOTE 2: Defined with respect to output voltage swing at a given condition.

**Table 3E. LVHSTL DC Characteristics,  $V_{DD} = 2.5\text{V} \pm 5\%$ ,  $V_{DDO} = 1.8\text{V} \pm 0.2\text{V}$ ,  $T_A = -40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$** 

| Symbol      | Parameter                         | Test Conditions | Minimum | Typical | Maximum | Units |
|-------------|-----------------------------------|-----------------|---------|---------|---------|-------|
| $V_{OH}$    | Output High Voltage; NOTE 1       |                 | 0.9     |         | 1.2     | V     |
| $V_{OL}$    | Output Low Voltage; NOTE 1        |                 | 0       |         | 0.4     | V     |
| $V_{OX}$    | Output Crossover Voltage; NOTE 2  |                 | 0.50    |         | 0.90    | V     |
| $V_{SWING}$ | Peak-to-Peak Output Voltage Swing |                 | 0.6     |         | 1.2     | V     |

NOTE 1: Outputs termination with  $50\Omega$  to ground.

NOTE 2: Defined with respect to output voltage swing at a given condition.

**Table 4. Crystal Characteristics**

| Parameter                          | Test Conditions | Minimum     | Typical | Maximum | Units    |
|------------------------------------|-----------------|-------------|---------|---------|----------|
| Mode of Oscillation                |                 | Fundamental |         |         |          |
| Frequency                          |                 | 23.33       | 26.5625 | 28.33   | MHz      |
| Equivalent Series Resistance (ESR) |                 |             |         | 50      | $\Omega$ |
| Shunt Capacitance                  |                 |             |         | 7       | pF       |

## AC Electrical Characteristics

**Table 5A. AC Characteristics,  $V_{DD} = 3.3V \pm 5\%$ ,  $V_{DDO} = 1.8V \pm 0.2V$ ,  $T_A = -40^\circ C$  to  $85^\circ C$**

| Parameter            | Symbol                               | Test Conditions               | Minimum | Typical | Maximum | Units |
|----------------------|--------------------------------------|-------------------------------|---------|---------|---------|-------|
| $f_{OUT}$            | Output Frequency                     | F_SEL[1:0] = 00               | 186.67  |         | 226.66  | MHz   |
|                      |                                      | F_SEL[1:0] = 01               | 140     |         | 170     | MHz   |
|                      |                                      | F_SEL[1:0] = 10               | 93.33   |         | 113.33  | MHz   |
|                      |                                      | F_SEL[1:0] = 11               | 46.67   |         | 56.66   | MHz   |
| $t_{sk(o)}$          | Output Skew; NOTE 1, 2               |                               |         | 35      | ps      |       |
| $f_{jit}(\emptyset)$ | RMS Phase Jitter (Random);<br>NOTE 3 | 212.5MHz, (637kHz – 10MHz)    |         | 0.59    |         | ps    |
|                      |                                      | 187.5MHz, (637kHz – 10MHz)    |         | 0.53    |         | ps    |
|                      |                                      | 159.375MHz, (637kHz – 10MHz)  |         | 0.56    |         | ps    |
|                      |                                      | 106.25MHz, (1.875MHz – 20MHz) |         | 0.56    |         | ps    |
|                      |                                      | 53.125MHz, (637kHz – 10MHz)   |         | 0.66    |         | ps    |
| $t_R / t_F$          | Output Rise/Fall Time                | 20% to 80%                    | 275     |         | 875     | ps    |
| odc                  | Output Duty Cycle                    | $N \neq 3$                    | 48      |         | 52      | %     |
|                      |                                      | $N = 3$                       | 40      |         | 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 lfpm. The 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  $V_{DDO}/2$ .

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,  $V_{DD} = 2.5V \pm 5\%$ ,  $V_{DDO} = 1.8V \pm 0.2V$ ,  $T_A = -40^\circ C$  to  $85^\circ C$**

| Parameter            | Symbol                               | Test Conditions               | Minimum | Typical | Maximum | Units |
|----------------------|--------------------------------------|-------------------------------|---------|---------|---------|-------|
| $f_{OUT}$            | Output Frequency                     | F_SEL[1:0] = 00               | 186.67  |         | 226.66  | MHz   |
|                      |                                      | F_SEL[1:0] = 01               | 140     |         | 170     | MHz   |
|                      |                                      | F_SEL[1:0] = 10               | 93.33   |         | 113.33  | MHz   |
|                      |                                      | F_SEL[1:0] = 11               | 46.67   |         | 56.66   | MHz   |
| $t_{sk(o)}$          | Output Skew; NOTE 1, 2               |                               |         | 35      | ps      |       |
| $f_{jit}(\emptyset)$ | RMS Phase Jitter (Random);<br>NOTE 3 | 212.5MHz, (637kHz – 10MHz)    |         | 0.60    |         | ps    |
|                      |                                      | 187.5MHz, (637kHz – 10MHz)    |         | 0.72    |         | ps    |
|                      |                                      | 159.375MHz, (637kHz – 10MHz)  |         | 0.64    |         | ps    |
|                      |                                      | 106.25MHz, (1.875MHz – 20MHz) |         | 0.55    |         | ps    |
|                      |                                      | 53.125MHz, (637kHz – 10MHz)   |         | 0.68    |         | ps    |
| $t_R / t_F$          | Output Rise/Fall Time                | 20% to 80%                    | 250     |         | 650     | ps    |
| odc                  | Output Duty Cycle                    | $N \neq 3$                    | 48      |         | 52      | %     |
|                      |                                      | $N = 3$                       | 40      |         | 60      | %     |

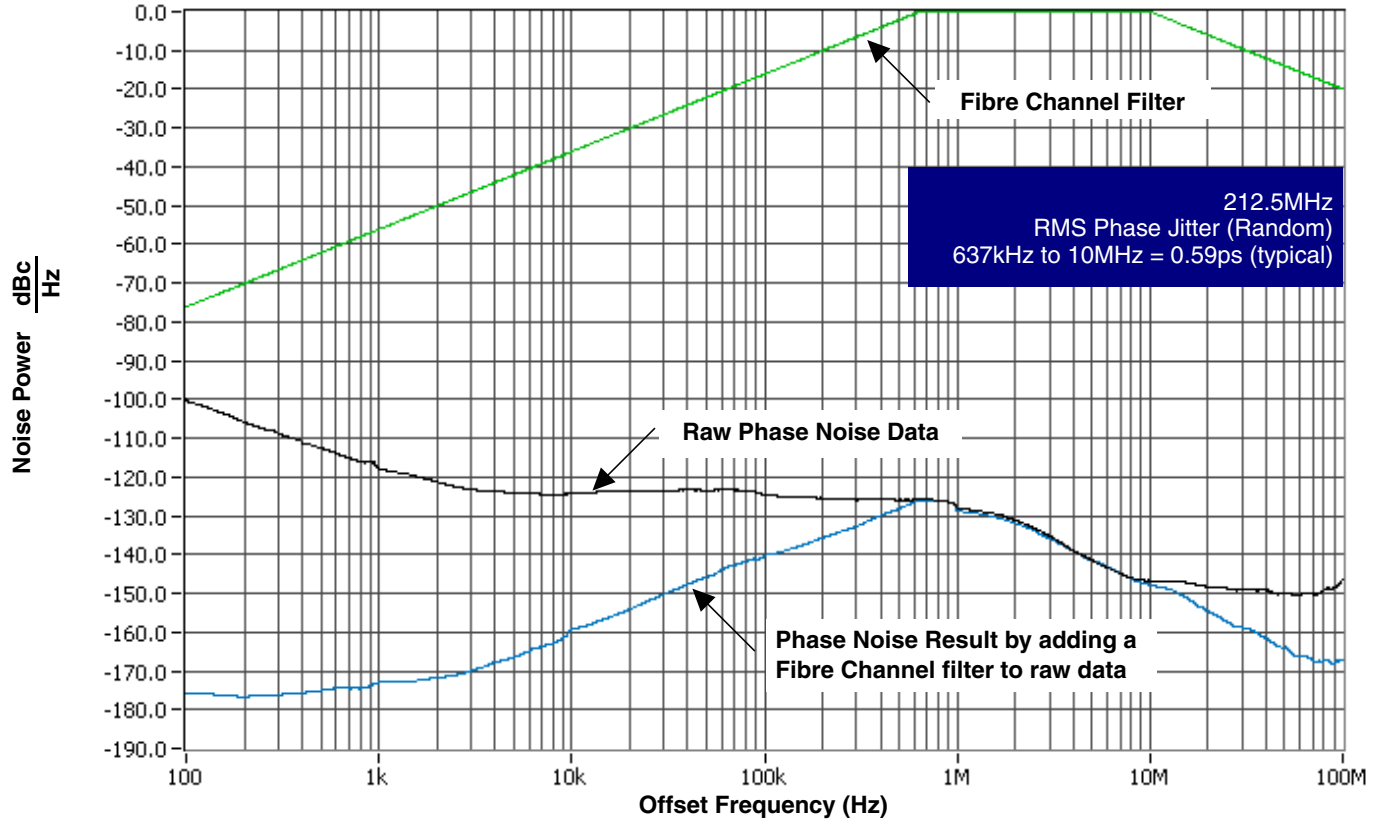
NOTE: Electrical parameters are guaranteed over the specified ambient operating temperature range, which is established when the device is mounted in a test socket with maintained transverse airflow greater than 500 lfpm. The device will meet specifications after thermal equilibrium has been reached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

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

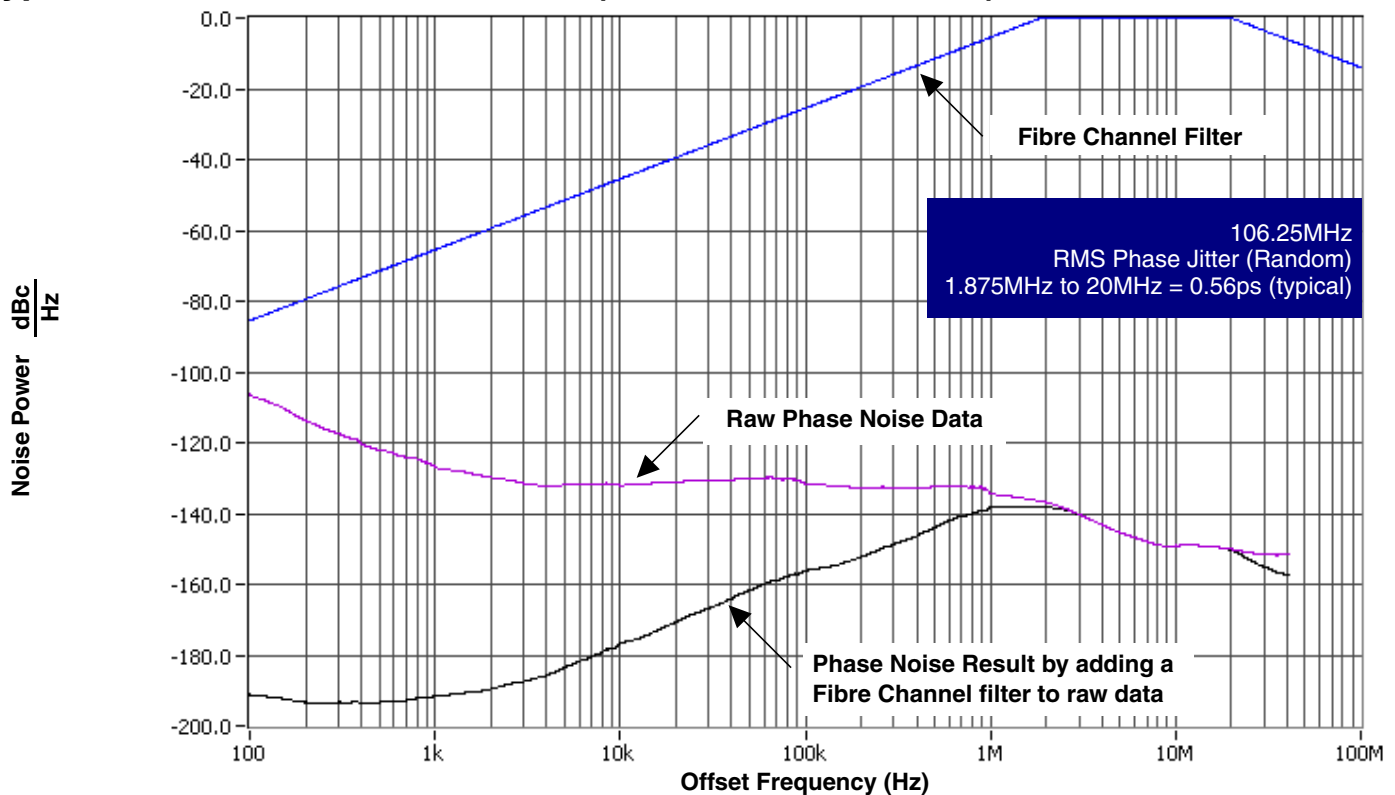
NOTE 2: This parameter is defined in accordance with JEDEC Standard 65.

NOTE 3: Please refer to the Phase Noise Plot.

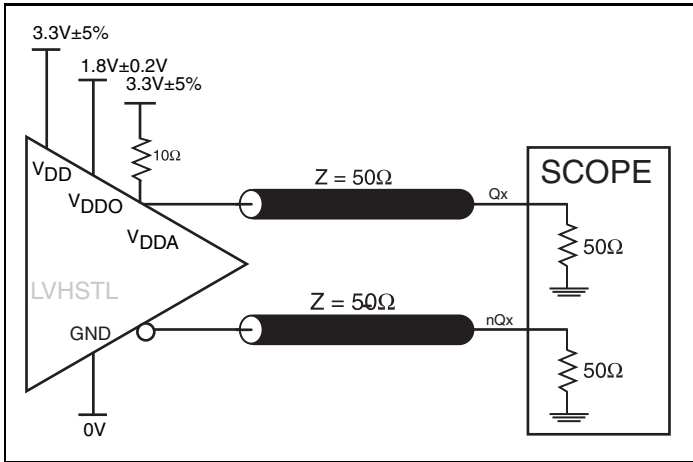
### Typical Phase Noise at 212.5MHz ( $V_{DD} = 3.3V$ , $V_{DDO} = 1.8V$ )



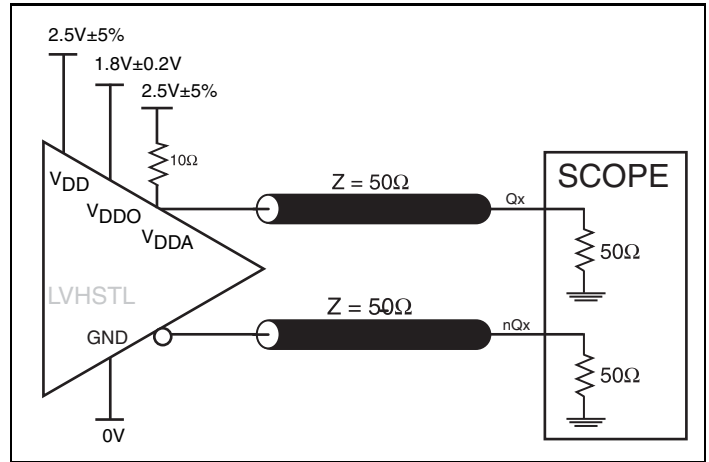
### Typical Phase Noise at 106.25MHz ( $V_{DD} = 3.3V$ , $V_{DDO} = 1.8V$ )



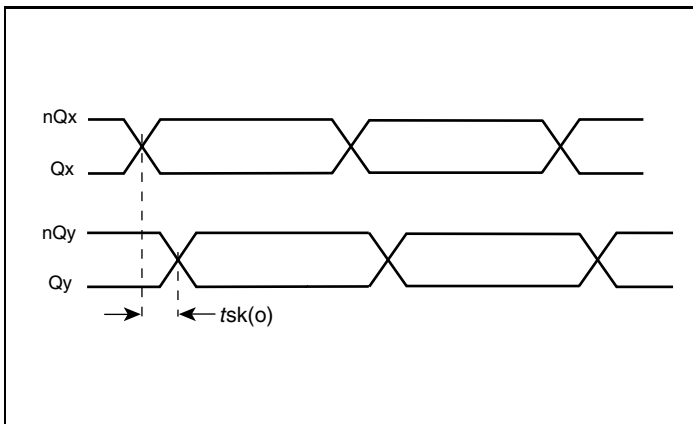
### Parameter Measurement Information



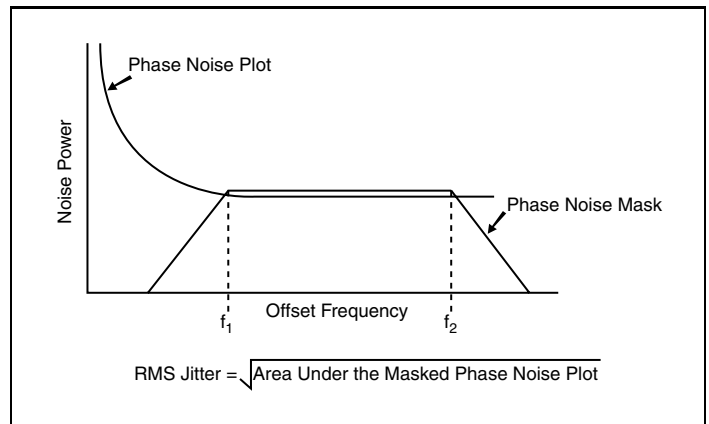
3.3V/1.8V Output Load AC Test Circuit



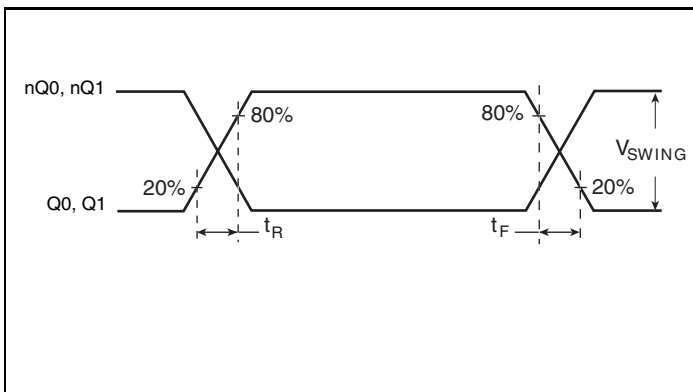
2.5V/1.8V Output Load AC Test Circuit



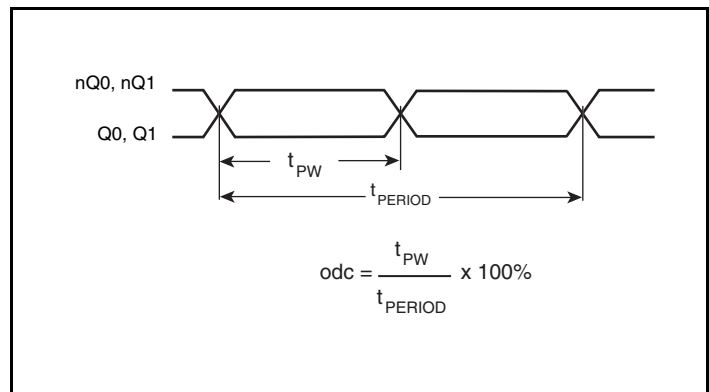
Output Skew



RMS Phase Jitter



Output Rise/Fall Time



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 ICS8422002I-07 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.

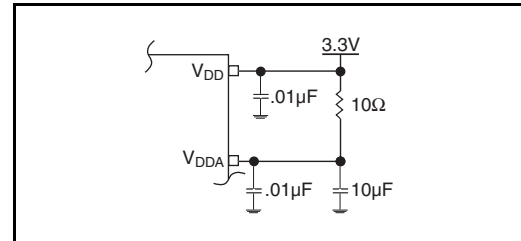


Figure 1. Power Supply Filtering

## Recommendations for Unused Input and Output Pins

### Inputs:

#### LVC MOS Control Pins

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

#### 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.

#### 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.

### Outputs:

#### LVHSTL Outputs

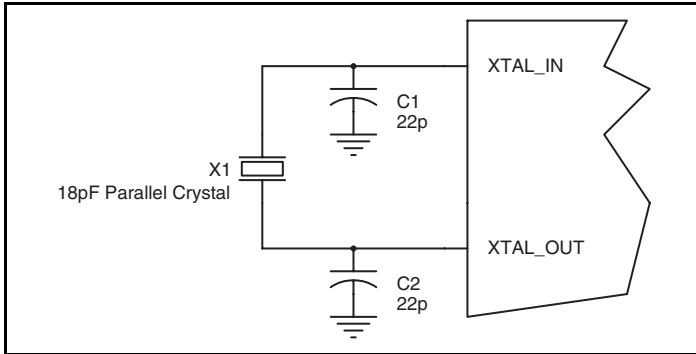
All unused LVHSTL outputs can be left floating. We recommend that there is no trace attached. Both sides of the differential output pair should either be left floating or terminated.



## Crystal Input Interface

The ICS8422002I-07 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.

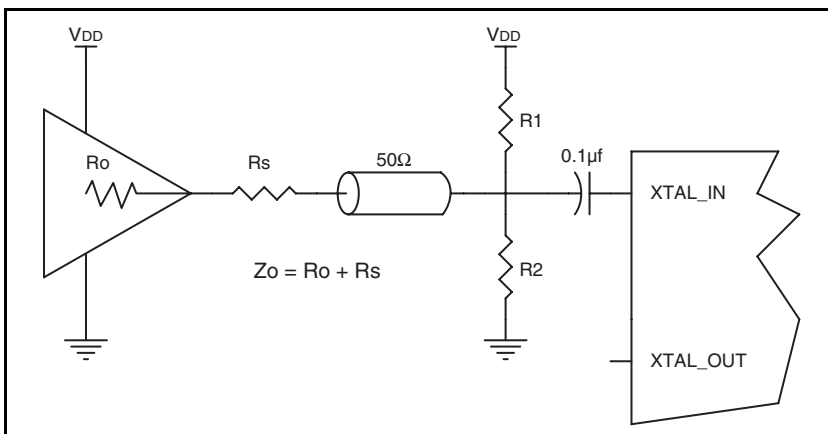


**Figure 2. Crystal Input Interface**

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



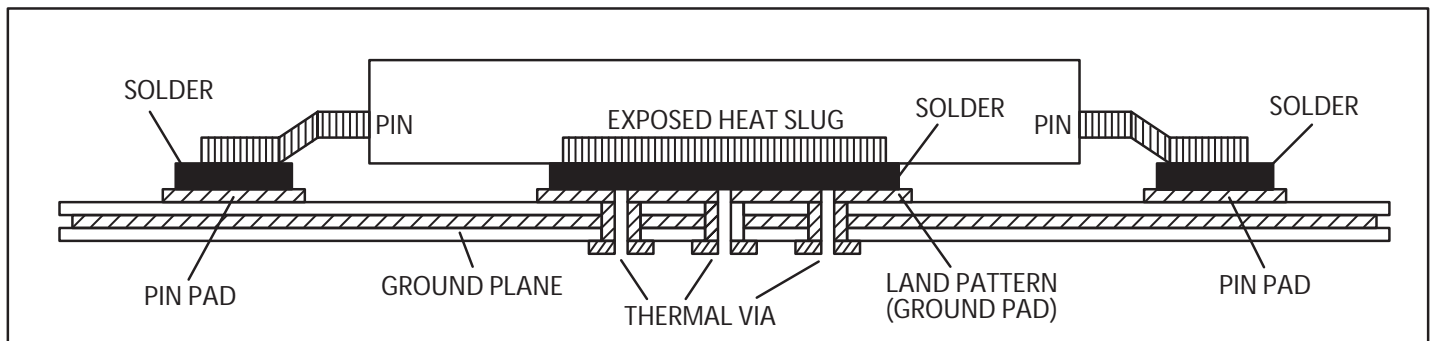
**Figure 3. General Diagram for LVC MOS Driver to XTAL Input Interface**

## EPAD Thermal Release Path

In order to maximize both the removal of heat from the package and the electrical performance, a land pattern must be incorporated on the Printed Circuit Board (PCB) within the footprint of the package corresponding to the exposed metal pad or exposed heat slug on the package, as shown in *Figure 4*. The solderable area on the PCB, as defined by the solder mask, should be at least the same size/shape as the exposed pad/slug area on the package to maximize the thermal/electrical performance. Sufficient clearance should be designed on the PCB between the outer edges of the land pattern and the inner edges of pad pattern for the leads to avoid any shorts.

While the land pattern on the PCB provides a means of heat transfer and electrical grounding from the package to the board through a solder joint, thermal vias are necessary to effectively conduct from the surface of the PCB to the ground plane(s). The land pattern must be connected to ground through these vias. The vias act as “heat pipes”. The number of vias (i.e. “heat pipes”) are

application specific and dependent upon the package power dissipation as well as electrical conductivity requirements. Thus, thermal and electrical analysis and/or testing are recommended to determine the minimum number needed. Maximum thermal and electrical performance is achieved when an array of vias is incorporated in the land pattern. It is recommended to use as many vias connected to ground as possible. It is also recommended that the via diameter should be 12 to 13mils (0.30 to 0.33mm) with 1oz copper via barrel plating. This is desirable to avoid any solder wicking inside the via during the soldering process which may result in voids in solder between the exposed pad/slug and the thermal land. Precautions should be taken to eliminate any solder voids between the exposed heat slug and the land pattern. Note: These recommendations are to be used as a guideline only. For further information, refer to the Application Note on the *Surface Mount Assembly* of Amkor’s Thermally/Electrically Enhance Leadframe Base Package, Amkor Technology.



**Figure 4. Assembly for Exposed Pad Thermal Release Path - Side View (drawing not to scale)**

### Schematic Example

Figure 5 shows an example of the ICS8422002I-07 application schematic. In this example, the device is operated at  $V_{DD} = 3.3V$  and  $V_{DDO} = 1.8V$ . Both input options are shown. The device can either be driven using a quartz crystal or a 3.3V LVCMOS signal. The  $C1 = 22pF$  and  $C2 = 22pF$  are recommended for frequency

accuracy. For different board layouts, the  $C1$  and  $C2$  may be slightly adjusted for optimizing frequency accuracy. The LVHSTL output driver termination examples are shown in this schematic. The decoupling capacitors should be located as close as possible to the power pin.

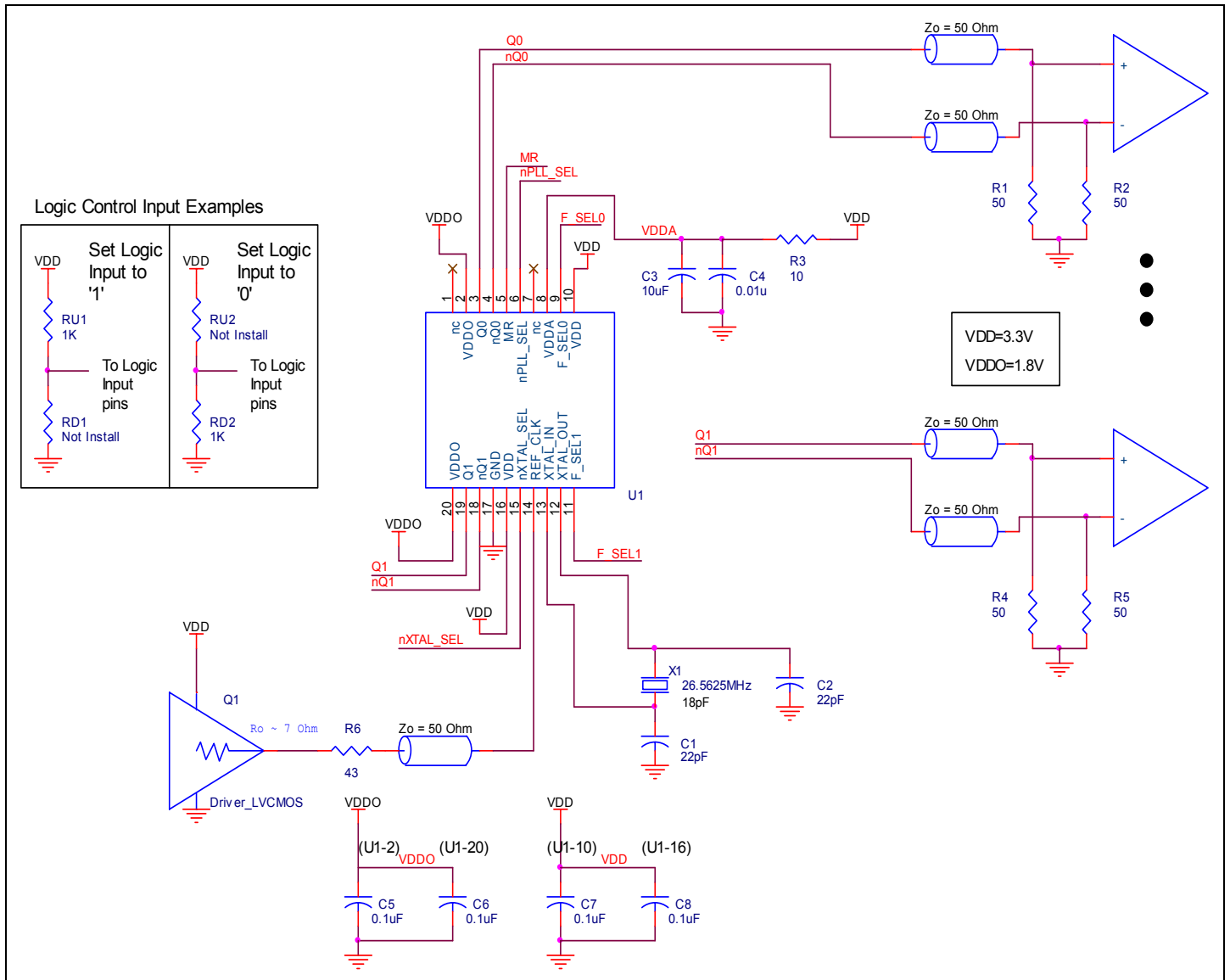


Figure 5. ICS8422002I-07 LVHSTL Schematic Example

## Power Considerations

This section provides information on power dissipation and junction temperature for the ICS8422002I-07. Equations and example calculations are also provided.

### 1. Power Dissipation.

The total power dissipation for the ICS8422002I-07 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> =  $V_{DD\_MAX} * (I_{DD\_MAX} + I_{DDA\_MAX}) = 3.465V * (112mA + 10mA) = \mathbf{422.73mW}$
- Power (outputs)<sub>MAX</sub> = **32mW/Loaded Output pair**  
If all outputs are loaded, the total power is  $2 * 32mW = \mathbf{64mW}$

**Total Power**<sub>MAX</sub> (3.465V, with all outputs switching) =  $422.73mW + 64mW = \mathbf{486.73mW}$

### 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 no air flow and a multi-layer board, the appropriate value is 33.1°C/W per Table 6 below.

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

$$85^\circ\text{C} + 0.487\text{W} * 33.1^\circ\text{C/W} = 101.1^\circ\text{C}. \text{ This is well below the limit of } 125^\circ\text{C}.$$

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 (multi-layer).

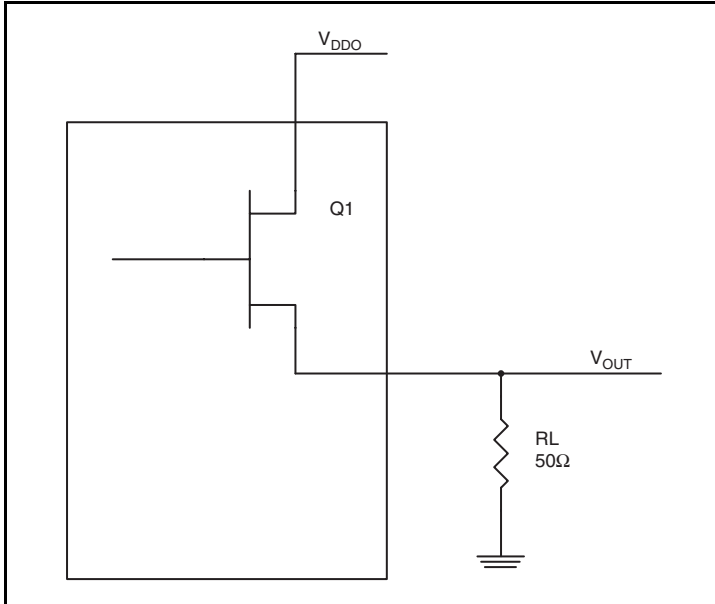
**Table 6. Thermal Resistance  $\theta_{JA}$  for 20 Lead TSSOP, EPad Forced Convection**

| Meters per Second                           | $\theta_{JA}$ by Velocity |          |          |
|---------------------------------------------|---------------------------|----------|----------|
|                                             | 0                         | 1        | 2.5      |
| Multi-Layer PCB, JEDEC Standard Test Boards | 33.1°C/W                  | 26.6°C/W | 25.1°C/W |

### 3. Calculations and Equations.

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

LVHSTL output driver circuit and termination are shown in *Figure 6*.



**Figure 6. LVHSTL Driver Circuit and Termination**

To calculate worst case power dissipation into the load, use the following equations which assume a 50Ω load.

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

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

$$Pd_H = (V_{OH\_MAX} / R_L) * (V_{DDO\_MAX} - V_{OH\_MAX})$$

$$Pd_L = (V_{OL\_MAX} / R_L) * (V_{DDO\_MAX} - V_{OL\_MAX})$$

$$Pd_H = (1.2V / 50\Omega) * (2V - 1.2V) = \mathbf{19.2mW}$$

$$Pd_L = (0.4V / 50\Omega) * (2V - 0.4V) = \mathbf{12.8mW}$$

$$\text{Total Power Dissipation per output pair} = Pd_H + Pd_L = \mathbf{32mW}$$

## Reliability Information

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

| $\theta_{JA}$ by Velocity                   |          |          |          |
|---------------------------------------------|----------|----------|----------|
| Meters per Second                           | 0        | 1        | 2.5      |
| Multi-Layer PCB, JEDEC Standard Test Boards | 33.1°C/W | 26.6°C/W | 25.1°C/W |

## Transistor Count

The transistor count for ICS8422002I-07 is: 2951

# Package Outline and Package Dimensions

## Package Outline - G Suffix for 20 Lead TSSOP, EPad

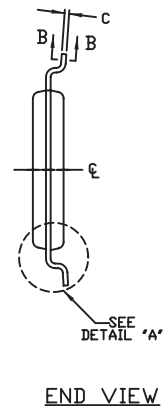
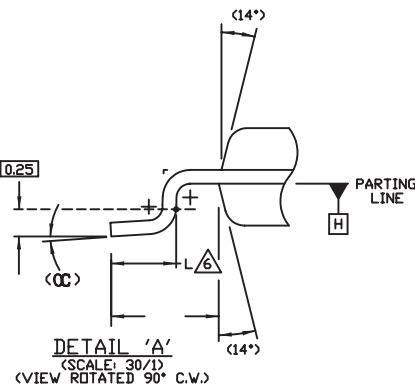
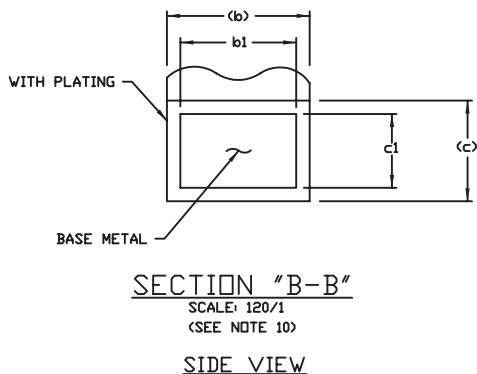
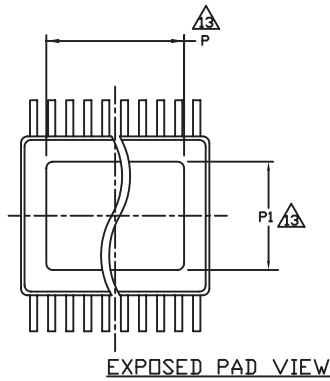
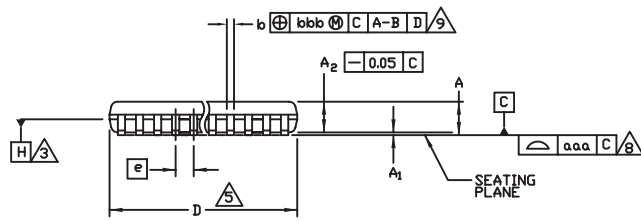
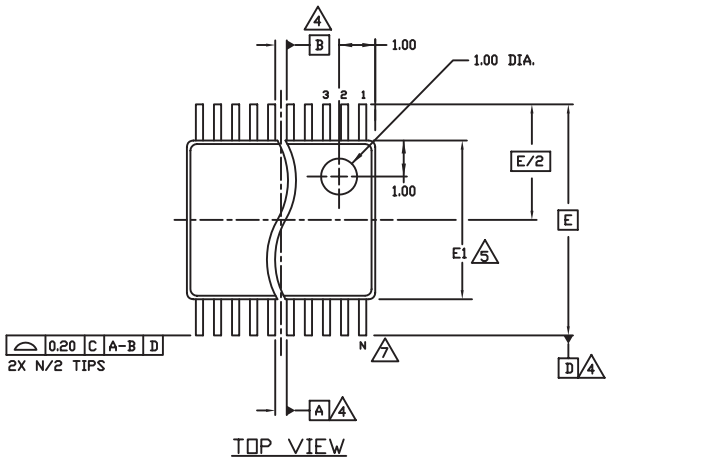
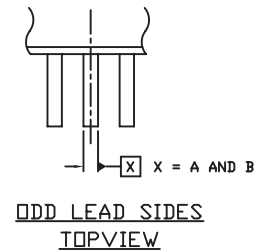
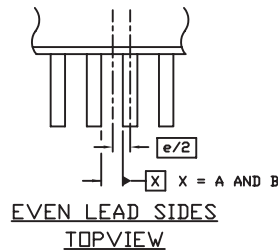


Table 8. Package Dimensions for 20 Lead TSSOP, EPad

| All Dimensions in Millimeters |            |         |
|-------------------------------|------------|---------|
| Symbol                        | Minimum    | Maximum |
| N                             | 20         |         |
| A                             |            | 1.10    |
| A1                            | 0.05       | 0.15    |
| A2                            | 0.85       | 0.95    |
| b                             | 0.19       | 0.30    |
| b1                            | 0.19       | 0.25    |
| c                             | 0.09       | 0.20    |
| c1                            | 0.09       | 0.16    |
| D                             | 6.40       | 6.60    |
| E                             | 6.40 Basic |         |
| E1                            | 4.30       | 4.50    |
| e                             | 0.65 Basic |         |
| L                             | 0.50       | 0.70    |
| P                             | 4.2        |         |
| P1                            | 3.0        |         |
| $\alpha$                      | 0°         | 8°      |
| aaa                           | 0.076      |         |
| bbb                           | 0.10       |         |

Reference Document: JEDEC Publication 95, MO-153



## Ordering Information

Table 9. Ordering Information

| Part/Order Number | Marking      | Package                          | Shipping Packaging | Temperature   |
|-------------------|--------------|----------------------------------|--------------------|---------------|
| 8422002AGI-07LF   | ICS2002AI07L | "Lead-Free" 20 Lead TSSOP, E-Pad | Tube               | -40°C to 85°C |
| 8422002AGI-07LFT  | ICS2002AI07L | "Lead-Free" 20 Lead TSSO, E-Pad  | 2500 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.

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