



LOW SKEW, 1-TO-12 LVCMOS/LVTTL CLOCK MULTIPLIER/ ZERO DELAY BUFFER

ICS87972I-147

General Description



The ICS87972I-147 is a low skew, LVCMOS/LVTTL Clock Generator and a member of the HiPerClockS™ family of High Performance Clock Solutions from ICS. The ICS87972I-147 has three selectable inputs and provides 14 LVCMOS/LVTTL outputs.

The ICS87972I-147 is a highly flexible device. Using the crystal oscillator input, it can be used to generate clocks for a system. All of these clocks can be the same frequency or the device can be configured to generate up to three different frequencies among the three output banks. Using one of the single ended inputs, the ICS87972I-147 can be used as a zero delay buffer/multiplier/divider in clock distribution applications.

The three output banks and feedback output each have their own output dividers which allows the device to generate a multitude of different bank frequency ratios and output-to-input frequency ratios. In addition, 2 outputs in Bank C (QC2, QC3) can be selected to be inverting or non-inverting. The output frequency range is 10MHz to 150MHz. Input frequency range is 6MHz to 150MHz.

The ICS87972I-147 also has a QSYNC output which can be used for system synchronization purposes. It monitors Bank A and Bank C outputs and goes low one period of the faster clock prior to coincident rising edges of Bank A and Bank C clocks. QSYNC then goes high again when the coincident rising edges of Bank A and Bank C occur. This feature is used primarily in applications where Bank A and Bank C are running at different frequencies, and is particularly useful when they are running at non-integer multiples of one another.

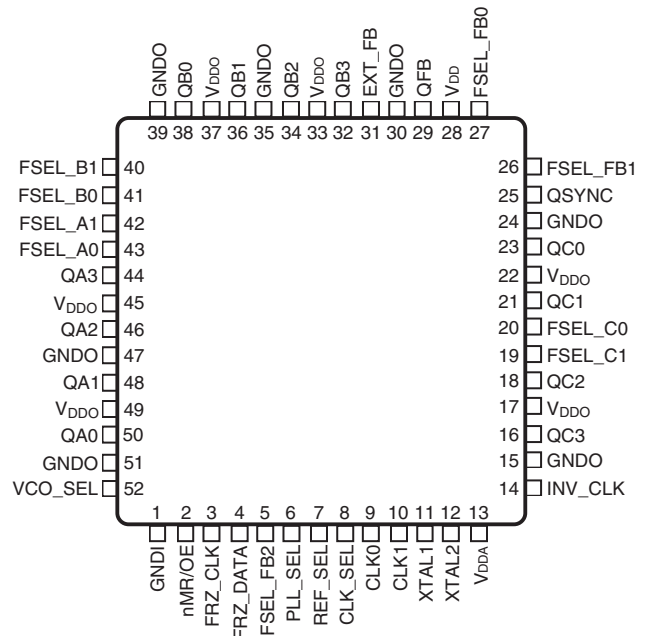
Example Applications:

- System Clock generator:** Use a 16.66 MHz Crystal to generate eight 33.33MHz copies for PCI and four 100MHz copies for the CPU or PCI-X.
- Line Card Multiplier:** Multiply 19.44MHz from a back plane to 77.76MHz for the line Card ASICs and Serdes.
- Zero Delay buffer for Synchronous memory:** Fan out up to twelve 100MHz copies from a memory controller reference clock to the memory chips on a memory module with zero delay.

Features

- Fully integrated PLL
- Fourteen LVCMOS/LVTTL outputs; (12)clocks, (1)feedback, (1)sync
- Selectable crystal oscillator interface or LVCMOS/LVTTL reference clock inputs
- CLK0, CLK1 can accept the following input levels: LVCMOS or LVTTL
- Output frequency range: 10MHz to 150MHz
- VCO range: 240MHz to 500MHz
- Output skew: 200ps (maximum)
- Cycle-to-cycle jitter, (all banks ±4): 55ps (maximum)
- Full 3.3V supply voltage
- 40°C to 85°C ambient operating temperature
- Compatible with PowerPC™ and Pentium™ Microprocessors
- Available in both standard (RoHS 5) and lead-free (RoHS 6) packages.

Pin Assignment



ICS87972I-147

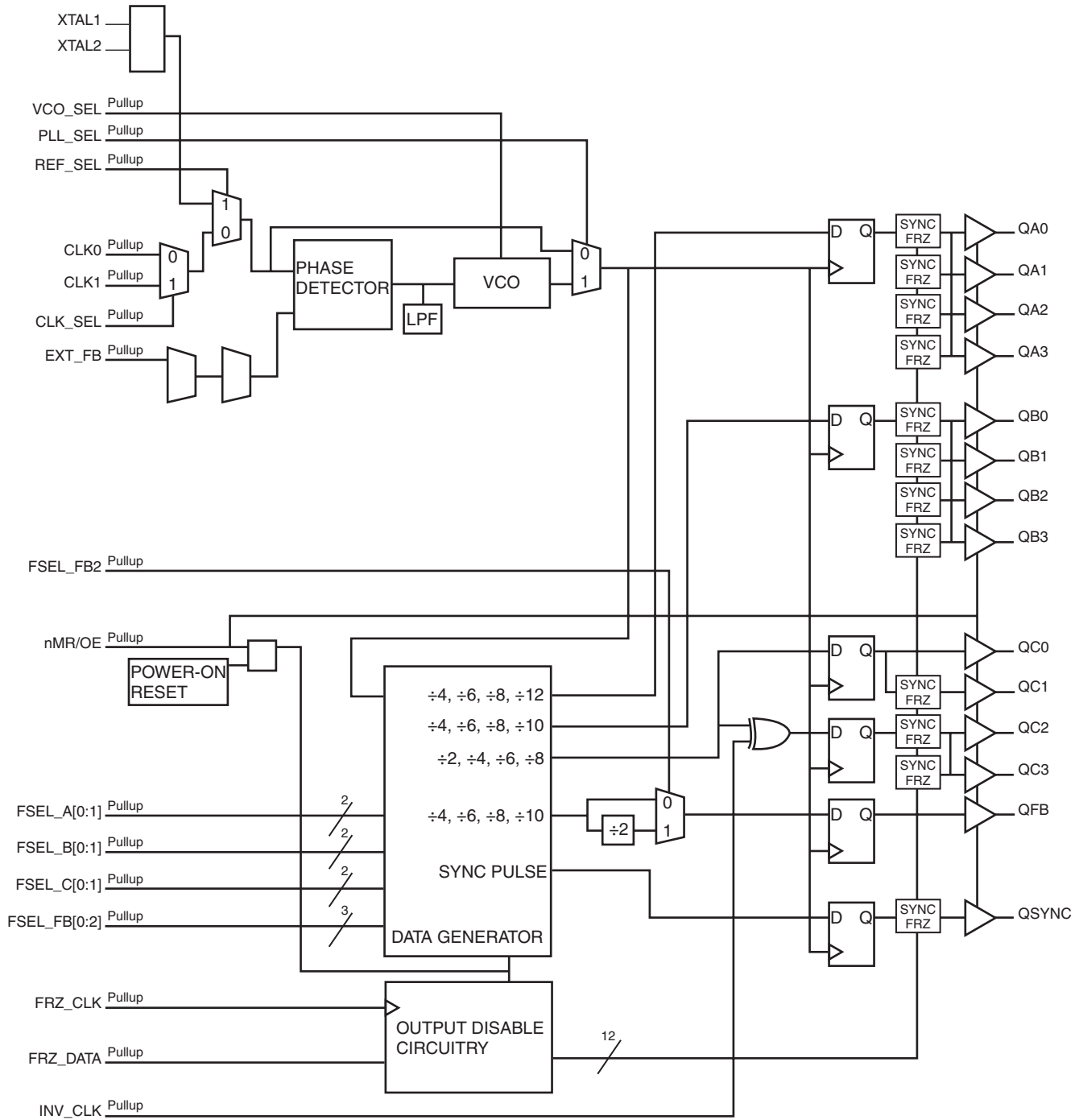
52-Lead LQFP

10mm x 10mm x 1.4mm package body

Y Package

Top View

Block Diagram



Simplified Block Diagram

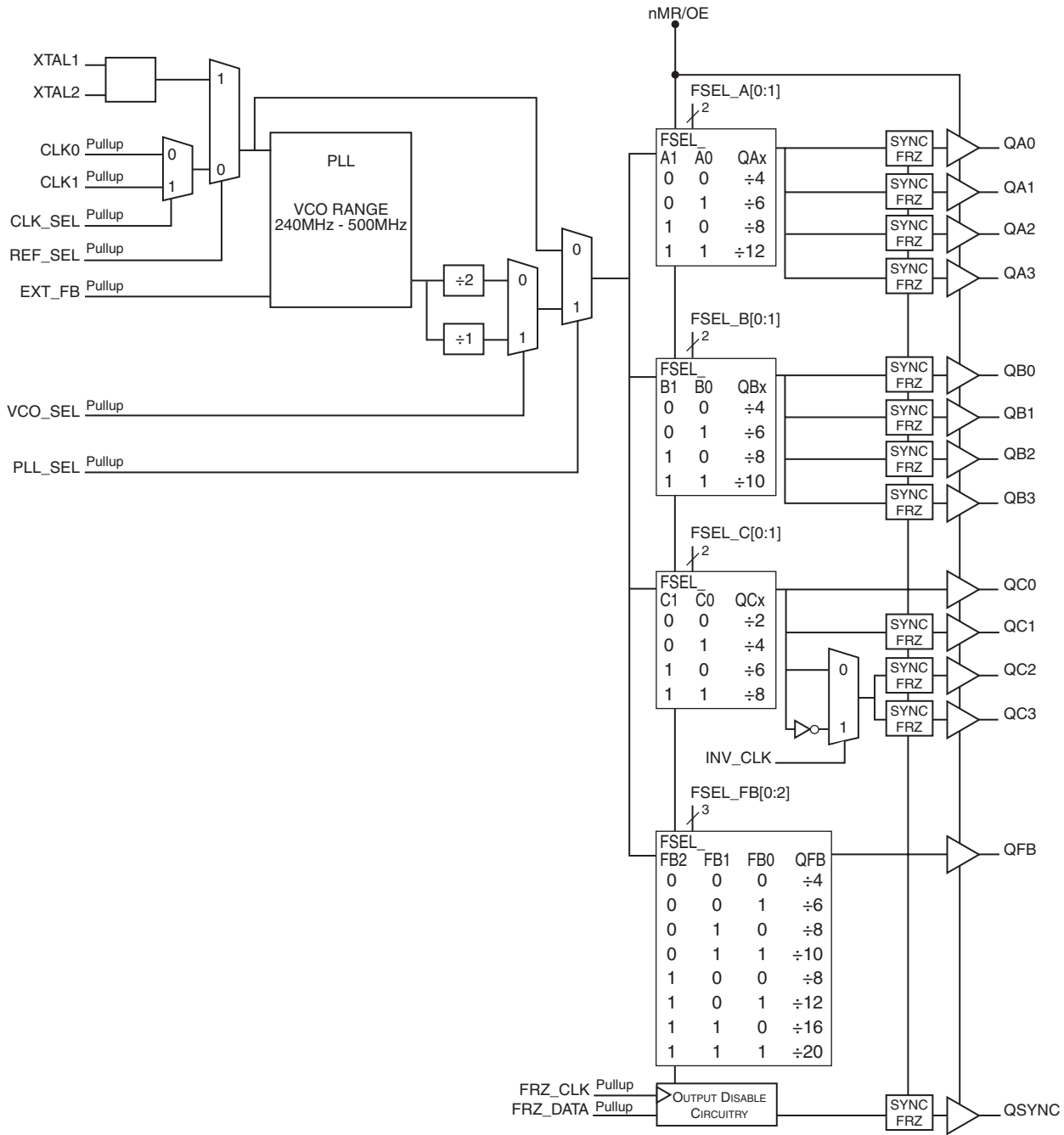


Table 1. Pin Descriptions

| Number | Name | Type | | Description |
|----------------------------|------------------------------|--------|--------|---|
| 1 | GNDI | Power | | Power supply ground. |
| 2 | nMR/OE | Input | Pullup | Master reset and output enable. When HIGH, enables the outputs. When LOW, resets the outputs to Hi-Z and resets output divide circuitry. Enables and disables all outputs. LVCMOS / LVTTL interface levels. |
| 3 | FRZ_CLK | Input | Pullup | Clock input for freeze circuitry. LVCMOS / LVTTL interface levels. |
| 4 | FRZ_DATA | Input | Pullup | Configuration data input for freeze circuitry. LVCMOS / LVTTL interface levels. |
| 5, 26, 27 | FSEL_FB2, FSEL_FB1, FSEL_FB0 | Input | Pullup | Select pins control Feedback Divide value. LVCMOS / LVTTL interface levels. See Table 3B. |
| 6 | PLL_SEL | Input | Pullup | Selects between the PLL and reference clocks as the input to the output dividers. When HIGH, selects PLL. When LOW, bypasses the PLL and reference clocks. LVCMOS / LVTTL interface levels. |
| 7 | REF_SEL | Input | Pullup | Selects between crystal and reference clock. When LOW, selects CLK0 or CLK1. When HIGH, selects crystal inputs. LVCMOS / LVTTL interface levels. |
| 8 | CLK_SEL | Input | Pullup | Clock select input. When LOW, selects CLK0. When HIGH, selects CLK1. LVCMOS / LVTTL interface levels. |
| 9, 10 | CLK0, CLK1 | Input | Pullup | Single-ended reference clock inputs. LVCMOS/LVTTL interface levels. |
| 11, 12 | XTAL_1, XTAL_2 | Input | | Crystal oscillator interface. XTAL_1 is the input. XTAL_2 is the output. |
| 13 | V _{DDA} | Power | | Analog supply pin. |
| 14 | INV_CLK | Input | Pullup | Inverted clock select for QC2 and QC3 outputs. LVCMOS / LVTTL interface levels. |
| 15, 24, 30, 35, 39, 47, 51 | GND0 | Power | | Power supply ground. |
| 16, 18, 21, 23 | QC3, QC2, QC1, QC0 | Output | | Single-ended Bank C clock outputs. LVCMOS/ LVTTL interface levels. |
| 17, 22, 33, 37, 45, 49 | V _{DDO} | Power | | Output power supply pins. |
| 19, 20 | FSEL_C1, FSEL_C0 | Input | Pullup | Select pins for Bank C outputs. LVCMOS / LVTTL interface levels. See Table 3A. |
| 25 | QYSNC | Output | | Synchronization output for Bank A and Bank C. Refer to Figure 1, Timing Diagrams. LVCMOS / LVTTL interface levels. |
| 28 | V _{DD} | Power | | Power supply pin. |
| 29 | QFB | Output | | Single-ended feedback clock output. LVCMOS / LVTTL interface levels. |
| 31 | EXT_FB | Input | Pullup | External feedback. LVCMOS / LVTTL interface levels. |
| 32, 34, 36, 38 | QB3, QB2, QB1, QB0 | Output | | Single-ended Bank B clock outputs. LVCMOS/ LVTTL interface levels. |
| 40, 41 | FSEL_B1, FSEL_B0 | Input | Pullup | Select pins for Bank B outputs. LVCMOS / LVTTL interface levels. See Table 3A. |
| 42, 43 | FSEL_A1, FSEL_A0 | Input | Pullup | Select pins for Bank A outputs. LVCMOS / LVTTL interface levels. See Table 3A. |
| 44, 46, 48, 50 | QA3, QA2, QA1, QA0 | Output | | Single-ended Bank A clock outputs. LVCMOS/ LVTTL interface levels. |
| 52 | VCO_SEL | Input | Pullup | Selects VCO. When HIGH, selects VCO ÷ 1. When LOW, selects VCO ÷ 2. LVCMOS / LVTTL interface levels. |

NOTE: Pullup 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_{IN} | Input Capacitance | | | 4 | | pF |
| R_{PULLUP} | Input Pullup Resistor | | | 51 | | k Ω |
| C_{PD} | Power Dissipation Capacitance (per output) | $V_{DD}, V_{DDA}, V_{DDO} = 3.465V$ | | | 18 | pF |
| R_{OUT} | Output Impedance | | 5 | 7 | 12 | Ω |

Function Tables**Table 3A. Output Bank Configuration Select Function Table**

| Inputs | | Outputs | Inputs | | Outputs | Inputs | | Outputs |
|---------|---------|-----------|---------|---------|-----------|---------|---------|----------|
| FSEL_A1 | FSEL_A0 | QA | FSEL_B1 | FSEL_B0 | QB | FSEL_C1 | FSEL_C0 | QC |
| 0 | 0 | $\div 4$ | 0 | 0 | $\div 4$ | 0 | 0 | $\div 2$ |
| 0 | 1 | $\div 6$ | 0 | 1 | $\div 6$ | 0 | 1 | $\div 4$ |
| 1 | 0 | $\div 8$ | 1 | 0 | $\div 8$ | 1 | 0 | $\div 6$ |
| 1 | 1 | $\div 12$ | 1 | 1 | $\div 10$ | 1 | 1 | $\div 8$ |

Table 3B. Feedback Configuration Select Function Table

| Inputs | | | Outputs |
|----------|----------|----------|-----------|
| FSEL_FB2 | FSEL_FB1 | FSEL_FB0 | QFB |
| 0 | 0 | 0 | $\div 4$ |
| 0 | 0 | 1 | $\div 6$ |
| 0 | 1 | 0 | $\div 8$ |
| 0 | 1 | 1 | $\div 10$ |
| 1 | 0 | 0 | $\div 8$ |
| 1 | 0 | 1 | $\div 12$ |
| 1 | 1 | 0 | $\div 16$ |
| 1 | 1 | 1 | $\div 20$ |

Table 3C. Control Input Select Function Table

| Control Pin | Logic 0 | Logic 1 |
|-------------|--------------------------|-------------------|
| VCO_SEL | VCO/2 | VCO |
| REF_SEL | CLK0 or CLK1 | XTAL |
| CLK_SEL | CLK0 | CLK1 |
| PLL_SEL | BYPASS PLL | Enable PLL |
| nMR/OE | Master Reset/Output Hi-Z | Enable Outputs |
| INV_CLK | Non-Inverted QC2, QC3 | Inverted QC2, QC3 |

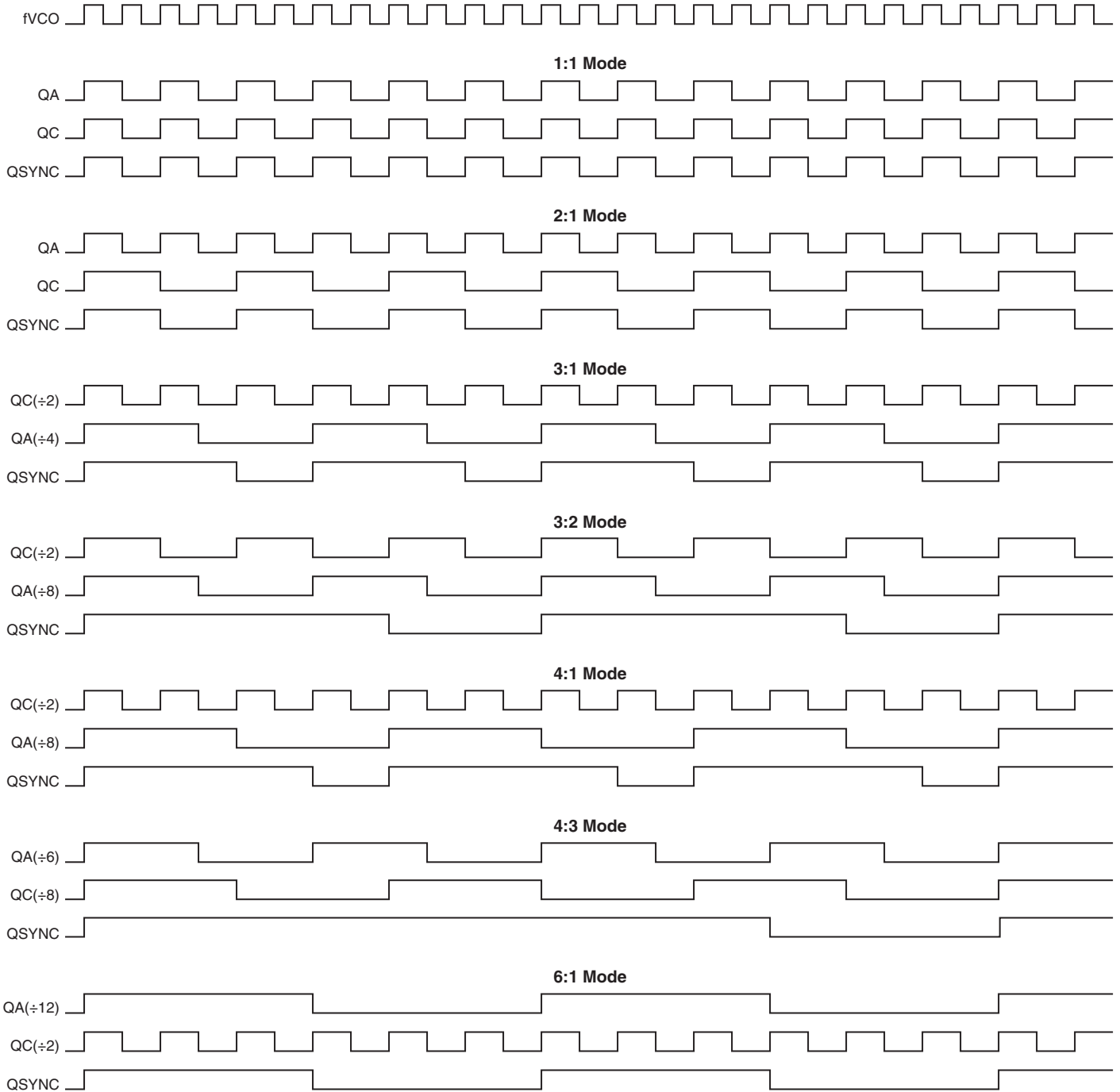


Figure 1. Timing Diagrams

Absolute Maximum Ratings

NOTE: Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These ratings are stress specifications only. Functional operation of product at these conditions or any conditions beyond those listed in the *DC Characteristics* or *AC Characteristics* is not implied. Exposure to absolute maximum rating conditions for extended periods may affect product reliability.

| Item | Rating |
|--|---------------------------|
| Supply Voltage, V_{DD} | 4.6V |
| Inputs, V_I | -0.5V to $V_{DD} + 0.5V$ |
| Outputs, V_O | -0.5V to $V_{DDO} + 0.5V$ |
| Package Thermal Impedance, θ_{JA} | 42.3°C/W (0 lfpm) |
| Storage Temperature, T_{STG} | -65°C to 150°C |

DC Electrical Characteristics

Table 4A. Power Supply DC Characteristics, $V_{DD} = V_{DDA} = V_{DDO} = 3.3V \pm 5\%$, $T_A = -40^\circ C$ 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 | | 3.135 | 3.3 | 3.465 | V |
| V_{DDO} | Output Supply Voltage | | 3.135 | 3.3 | 3.465 | V |
| I_{DD} | Power Supply Current | | | | 250 | mA |
| I_{DDA} | Analog Supply Current | | | | 20 | mA |

Table 4B. LVCMOS/LVTTL DC Characteristics, $V_{DD} = V_{DDA} = V_{DDO} = 3.3V \pm 5\%$, $T_A = -40^\circ C$ to $85^\circ C$

| Symbol | Parameter | Test Conditions | Minimum | Typical | Maximum | Units |
|----------|-----------------------------|---|---------|---------|----------------|---------|
| V_{IH} | Input High Voltage | | 2 | | $V_{DD} + 0.3$ | V |
| V_{IL} | Input Low Voltage | VCO_SEL, PLL_SEL, REF_SEL, CLK_SEL, EXT_FB, FSEL_FB[0:2], FSEL_A[0:1], FSEL_B[0:1], FSEL_C[0:1], FRZ_DATA | -0.3 | | 0.8 | V |
| | | CLK0, CLK1, INV_CLK, FRZ_CLK | -0.3 | | 1.3 | V |
| I_{IN} | Input Current | | | | ± 120 | μA |
| V_{OH} | Output High Voltage; NOTE 1 | $I_{OH} = -20mA$ | 2.4 | | | V |
| V_{OL} | Output Low Voltage; NOTE 1 | $I_{OL} = 20mA$ | | | 0.5 | V |

NOTE 1: Outputs terminated with 50Ω to $V_{DDO}/2$. See Parameter Measurement Information section. *Load Test Circuit diagram*.

Table 5. Input Frequency Characteristics, $V_{DD} = V_{DDA} = V_{DDO} = 3.3V \pm 5\%$, $T_A = -40^{\circ}C$ to $85^{\circ}C$

| Symbol | Parameter | Test Conditions | Minimum | Typical | Maximum | Units |
|----------|-----------------|--------------------|---------|---------|---------|-------|
| F_{IN} | Input Frequency | CLK0, CLK1; NOTE 1 | | | 150 | MHz |
| | | XTAL1, XTAL | | 12 | 40 | MHz |
| | | FRZ_CLK | | | 20 | MHz |

NOTE 1: Input frequency depends on the feedback divide ratio to ensure "clock * feedback divide" is in the VCO range of 240MHz to 500MHz.

Table 6. Crystal Characteristics

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

AC Electrical Characteristics

Table 7. AC Characteristics, $V_{DD} = V_{DDA} = V_{DDO} = 3.3V \pm 5\%$, $T_A = -40^{\circ}C$ to $85^{\circ}C$

| Parameter | Symbol | Test Conditions | Minimum | Typical | Maximum | Units | |
|---------------------|-------------------------------|-----------------|--|---------|---------|-------|----|
| f_{MAX} | Output Frequency | $\div 2$ | | | 150 | MHz | |
| | | $\div 4$ | | | 125 | MHz | |
| | | $\div 6$ | | | 83.33 | MHz | |
| | | $\div 8$ | | | 62.5 | MHz | |
| $t(\emptyset)$ | Static Phase Offset; NOTE 1 | CLK0 | QFB $\div 8$, In Frequency = 50MHz | -10 | 145 | 300 | ps |
| | | CLK1 | | -65 | 90 | 245 | ps |
| $t_{sk(o)}$ | Output Skew; NOTE 2, 3 | | | | 200 | ps | |
| $t_{jit(cc)}$ | Cycle-to-Cycle Jitter; NOTE 3 | | All Banks $\div 4$ | | 55 | ps | |
| f_{VCO} | PLL VCO Lock Range | | 240 | | 500 | MHz | |
| t_{LOCK} | PLL Lock Time; NOTE 4 | | | | 10 | ms | |
| t_R / t_F | Output Rise/Fall Time | | 0.8V to 2V | | 0.15 | 0.7 | ns |
| odc | Output Duty Cycle | | 45 | | 55 | % | |
| t_{PZL}, t_{PZH} | Output Enable Time; NOTE 4 | | | | 10 | ns | |
| t_{PLZL}, t_{PHZ} | Output Disable Time; NOTE 4 | | | | 8 | ns | |

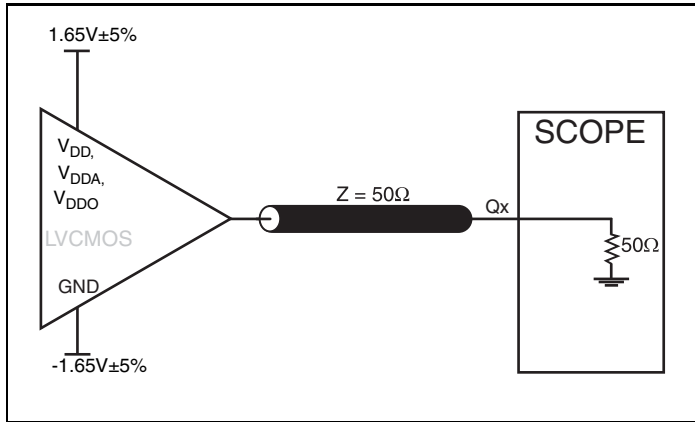
NOTE 1: Defined as the time difference between the input reference clock and the average feedback input signal when the PLL is locked and the input reference frequency is stable.

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

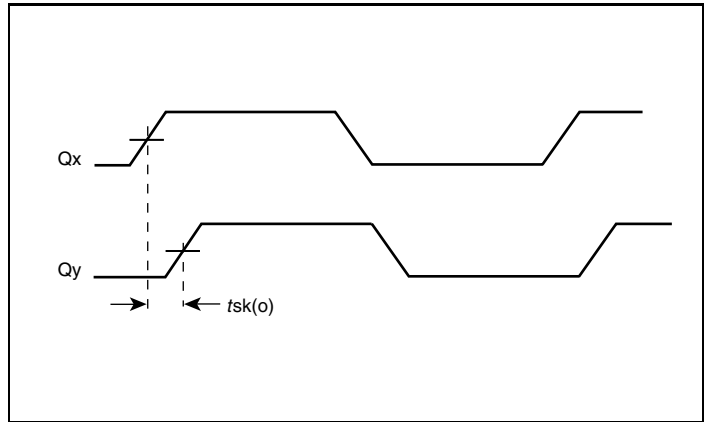
NOTE 3: This parameter is defined in accordance with JEDEC Standard 65.

NOTE 4: These parameters are guaranteed by characterization. Not tested in production.

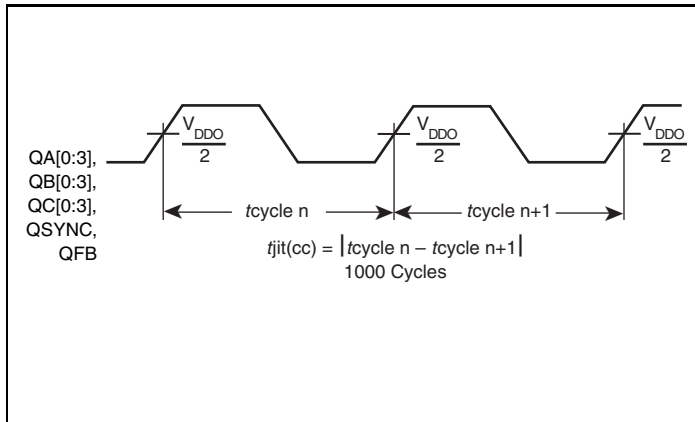
Parameter Measurement Information



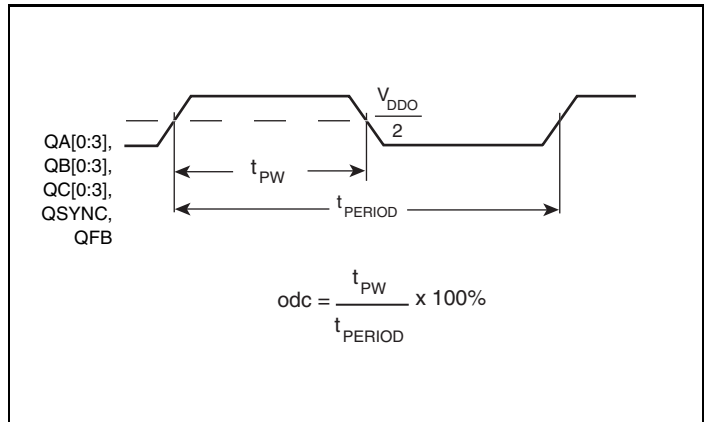
3.3V Core/3.3V LVCMOS Output Load AC Test Circuit



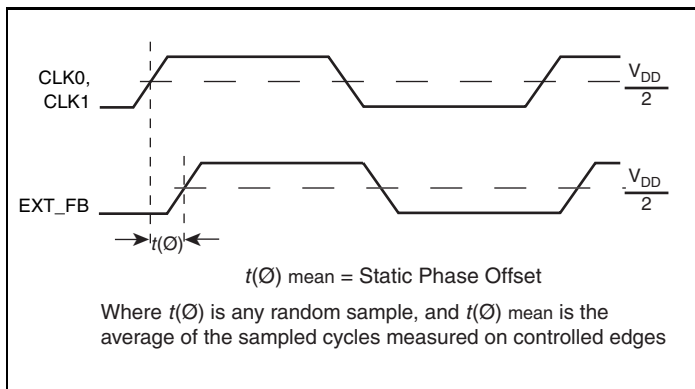
Output Skew



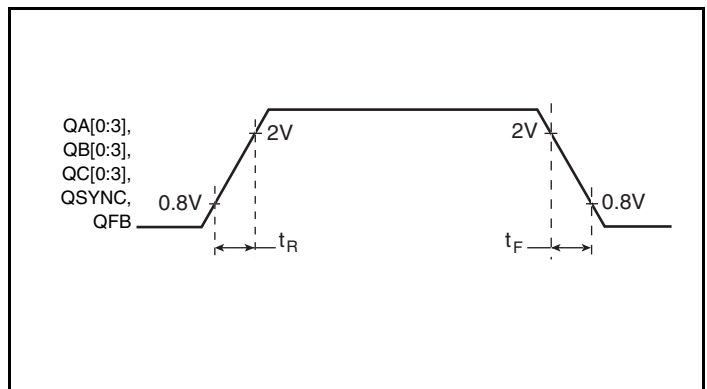
Cycle-to-Cycle Jitter



Output Duty Cycle/Pulse Width Period



Static Phase Offset



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. To achieve optimum jitter performance, power supply isolation is required. The ICS87972I-147 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 2* illustrates this for a generic V_{DD} pin and also shows that V_{DDA} requires that an additional 10Ω resistor along with a $10\mu\text{F}$ bypass capacitor be connected to the V_{DDA} pin.

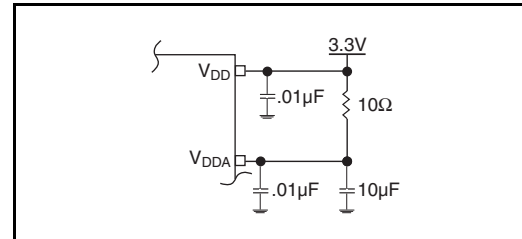


Figure 2. Power Supply Filtering

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

CLK Inputs

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

LVCMOS Control Pins

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

Outputs:

LVCMOS Outputs

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

Crystal Input Interface

The ICS87972I-147 has been characterized with 18 pF parallel resonant crystals. External capacitors are not required for this crystal interface. While layout the PC board, it is recommended to have spare footprints capacitor C1 and C2. If required, the spare

C1 and C2 footprints can be used for fine tuned further for more accurate frequency. The possible C1 and C2 value are ranged from 2pF – 25pF. The suggest footprint size is 0402 or 0603.

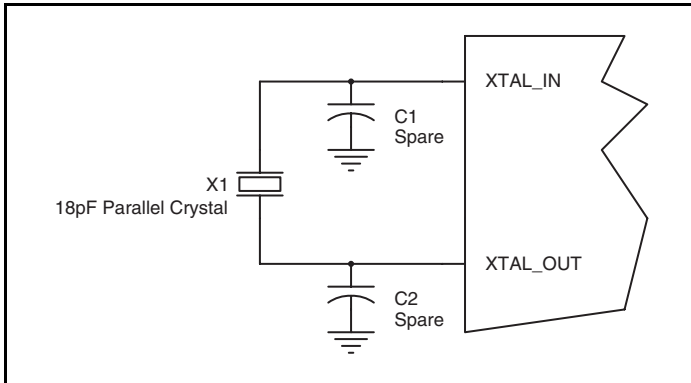


Figure 3. Crystal Input Interface

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 4*. 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 (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.

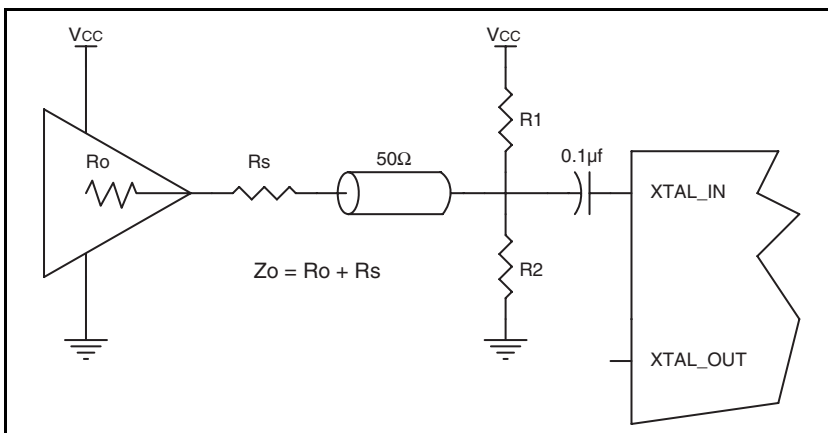


Figure 4. General Diagram for LVCMOS Driver to XTAL Input Interface

Using the Output Freeze Circuitry

OVERVIEW

To enable low power states within a system, each output of ICS87972I-147 (Except QC0 and QFB) can be individually frozen (stopped in the logic "0" state) using a simple serial interface to a 12 bit shift register. A serial interface was chosen to eliminate the need for each output to have its own Output Enable pin, which would dramatically increase pin count and package cost. Common sources in a system that can be used to drive the ICS87972I-147 serial interface are FPGA's and ASICs.

PROTOCOL

The Serial interface consists of two pins, FRZ_Data (Freeze Data) and FRZ_CLK (Freeze Clock). Each of the outputs which can be frozen has its own freeze enable bit in the 12 bit shift register. The sequence is started by supplying a logic "0" start bit followed by 12NRZ freeze enable bits. The period of each FRZ_DATA bit equals the period of the FRZ_CLK signal. The FRZ_DATA serial transmission should be timed so the ICS87972I-147 can sample

each FRZ_DATA bit with the rising edge of the FRZ_CLK signal. To place an output in the freeze state, a logic "0" must be written to the respective freeze enable bit in the shift register. To unfreeze an output, a logic "1" must be written to the respective freeze enable bit. Outputs will not become enabled/disabled until all 12 data bits are shifted into the shift register. When all 12 data bits are shifted in the register, the next rising edge of FRZ_CLK will enable or disable the outputs. If the bit that is following the 12th bit in the register is a logic "0", it is used for the start bit of the next cycle; otherwise, the device will wait and won't start the next cycle until it sees a logic "0" bit. Freezing and unfreezing of the output clock is synchronous (see the timing diagram below). When going into a frozen state, the output clock will go LOW at the time it would normally go LOW, and the freeze logic will keep the output low until unfrozen. Likewise, when coming out of the frozen state, the output will go HIGH only when it would normally go HIGH. This logic, therefore, prevents runt pulses when going into and out of the frozen state.

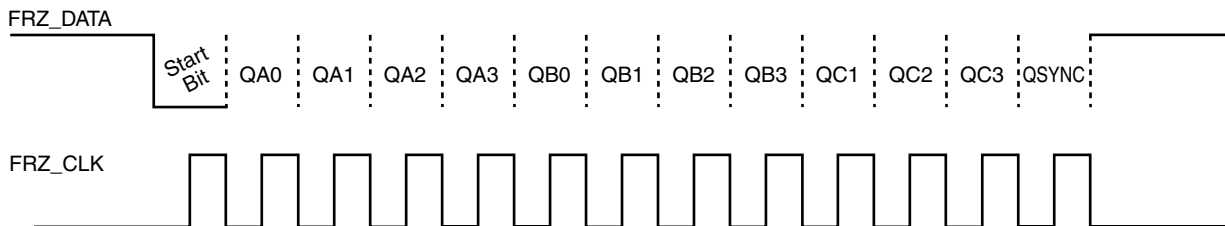


Figure 5A. Freeze Data Input Protocol

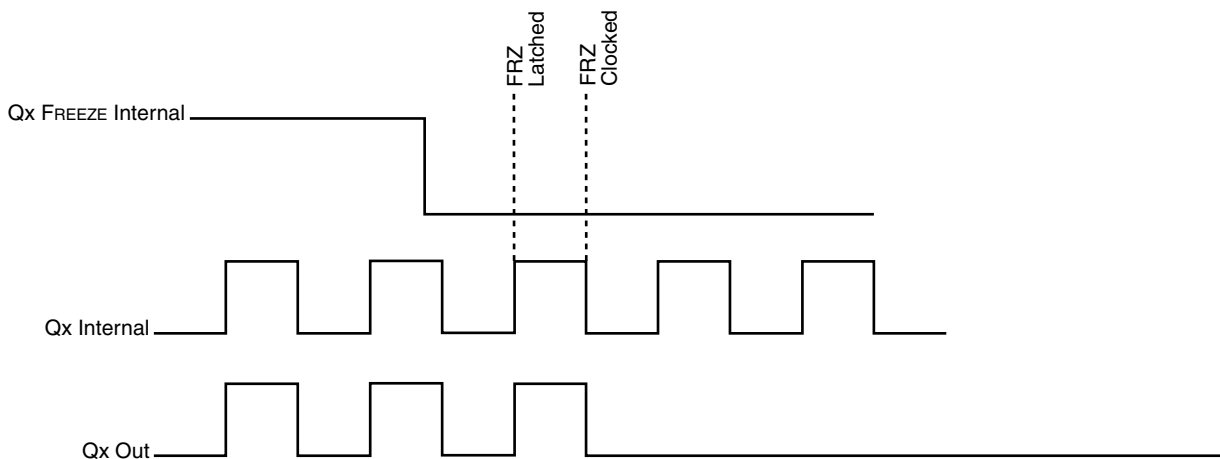


Figure 5B. Output Disable Timing Diagram

Reliability Information

Table 8. θ_{JA} vs. Air Flow Table for a 52 Lead LQFP

| θ_{JA} by Velocity | | | |
|--|----------|----------|----------|
| Linear Feet per Minute | 0 | 200 | 500 |
| Single-Layer PCB, JEDEC Standard Test Boards | 58.0°C/W | 47.1°C/W | 42.0°C/W |
| Multi-Layer PCB, JEDEC Standard Test Boards | 42.3°C/W | 36.4°C/W | 34.0°C/W |

NOTE: Most modern PCB designs use multi-layered boards. The data in the second row pertains to most designs.

Transistor Count

The transistor count for ICS87972I-147: 8364

Pin Compatible with MPC972

Package Outline and Package Dimensions

Package Outline - Y Suffix for 52 Lead LQFP

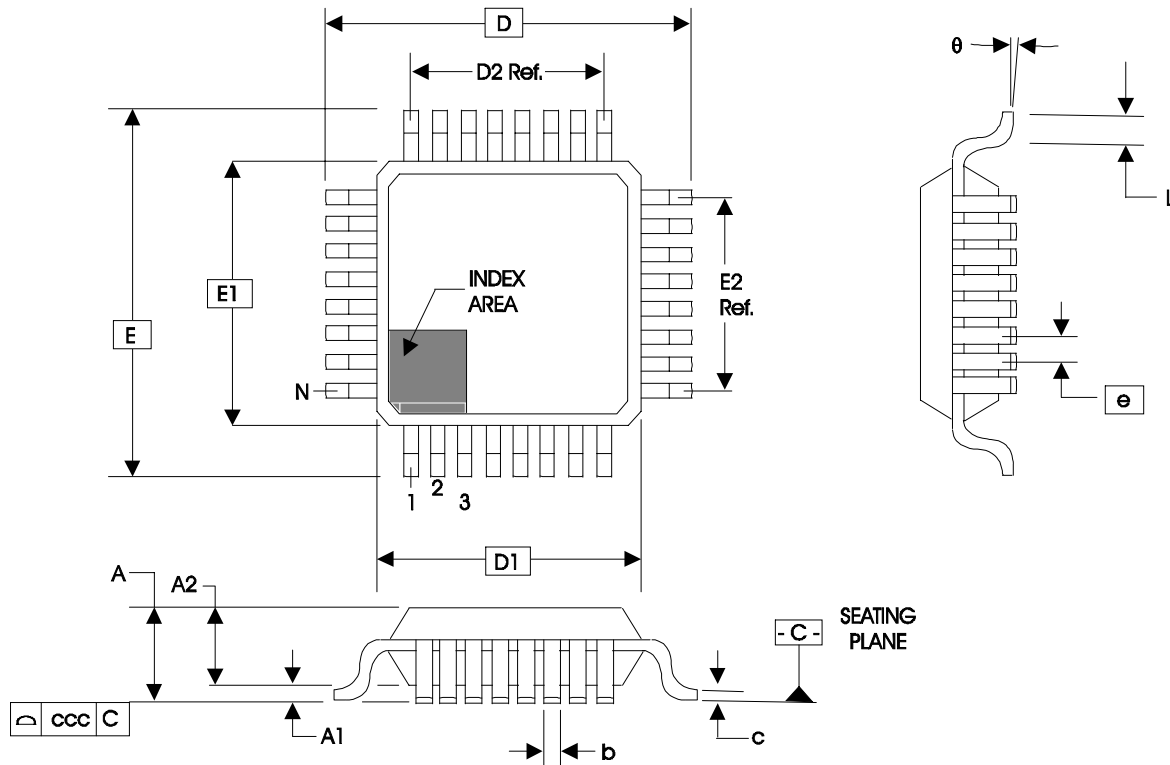


Table 9. Package Dimensions for 52 Lead LQFP

| JEDEC Variation: BCC | | | |
|-------------------------------|-------------|---------|---------|
| All Dimensions in Millimeters | | | |
| Symbol | Minimum | Nominal | Maximum |
| N | 52 | | |
| A | | | 1.60 |
| A1 | 0.05 | 0.10 | 0.15 |
| A2 | 1.35 | 1.40 | 1.45 |
| b | 0.22 | | 0.38 |
| c | 0.09 | | 0.20 |
| D & E | 12.00 Basic | | |
| D1 & E1 | 10.00 Basic | | |
| D2 & E2 | 7.80 Ref. | | |
| e | 0.65 Basic | | |
| L | 0.45 | 0.60 | 0.75 |
| θ | 0° | | 7° |
| ccc | | | 0.10 |

Reference Document: JEDEC Publication 95, MS-026

Ordering Information

Table 10. Ordering Information

| Part/Order Number | Marking | Package | Shipping Packaging | Temperature |
|-------------------|-----------------|--------------------------|--------------------|---------------|
| 87972DYI-147 | ICS87972DYI-147 | 52 Lead LQFP | Tray | -40°C to 85°C |
| 87972DYI-147T | ICS87972DYI-147 | 52 Lead LQFP | 1000 Tape & Reel | -40°C to 85°C |
| 87972DYI-147LF | ICS87972DI147L | "Lead-Free" 52 Lead LQFP | Tray | -40°C to 85°C |
| 87972DYI-147LFT | ICS87972DI147L | "Lead-Free" 52 Lead LQFP | 1000 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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Revision History Sheet

| Rev | Table | Page | Description of Change | Date |
|-----|-----------|------|--|--------|
| A | T9 T10 | 1 | Features Section - added leaf-free bullet. | 6/5/08 |
| | | 10 | Added <i>Recommendations for Unused Input/Output Pins</i> section. | |
| | | 11 | Added <i>LVCMOS to XTAL Interface</i> section. | |
| | | 14 | Package Dimensions Table - added L and θ dimensions. | |
| | | 15 | Ordering Information Table - added 52 Lead LQFP ordering information; corrected non-LF marking from ICS87972DYI147 to ICS87972DYI-147. | |
| | | | | |
| | | | | |

ICS87972I-147

LOW SKEW, 1-TO-12, LVCMOS/LVTTL CLOCK MULTIPLIER/ZERO DELAY BUFFER

Contact Information:

www.IDT.com

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+408-284-8200 (outside USA)
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