FEMTOCLOCKS™ CRYSTAL-TO-3.3V, 2.5V LVPECL FREQUENCY SYNTHESIZER

ICS843002I

GENERAL DESCRIPTION

The ICS843002I is a 2 output LVPECL synthesizer optimized to generate Fibre Channel reference clock frequencies and is a member of the HiPerClocks™ family of high performance clock solutions from ICS. 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 ICS843002I uses ICS' FemtoClock™ low phase noise VCO technology and can achieve 1ps or lower typical rms phase jitter, easily meeting Fibre Channel jitter requirements. The ICS843002I is packaged in a small 20-pin TSSOP package.

FEATURES

- Two 3.3V or 2.5V LVPECL outputs

- Selectable crystal oscillator interface or LVCMOS/LVTTL single-ended input

- Supports the following output frequencies: 212.5MHz, 187.5MHz, 159.375MHz, 106.25MHz and 53.125MHz

- VCO range: 560MHz - 680MHz

- RMS phase jitter @212.5MHz (2.55MHz - 20MHz): 0.50ps (typical)

- Full 3.3V or 2.5V supply modes

- -40°C to 85°C ambient operating temperature

- Available in both standard and lead-free RoHS compliant packages

FREQUENCY SELECT FUNCTION TABLE

Inputs						Output Frequency (MHz)
Input Frequency	F_SEL1	F_SEL0	M Divider Value	N Divider Value	M/N Divider Value	
26.5625	0	0	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	0	24	3	8	187.5

PIN ASSIGNMENT

nc	1	20	Vcco
Vcco	2	19	Q1
Q0	3	18	nQ1
nQ0	4	17	VEE
MR	5	16	Vcc
nPLL_SEL	6	15	nXTAL_SEL
nc	7	14	REF_CLK
Vcca	8	13	XTAL_IN
F_SEL0	9	12	XTAL_OUT
Vcc	10	11	F_SEL1

ICS843002I
20-Lead TSSOP
6.5mm x 4.4mm x 0.92mm
package body
G Package
Top View

BLOCK DIAGRAM

Tᴀʙʟᴇ 1. Pɪɴ Dᴇꜱᴄʀɪᴘᴛɪᴏɴꜱ
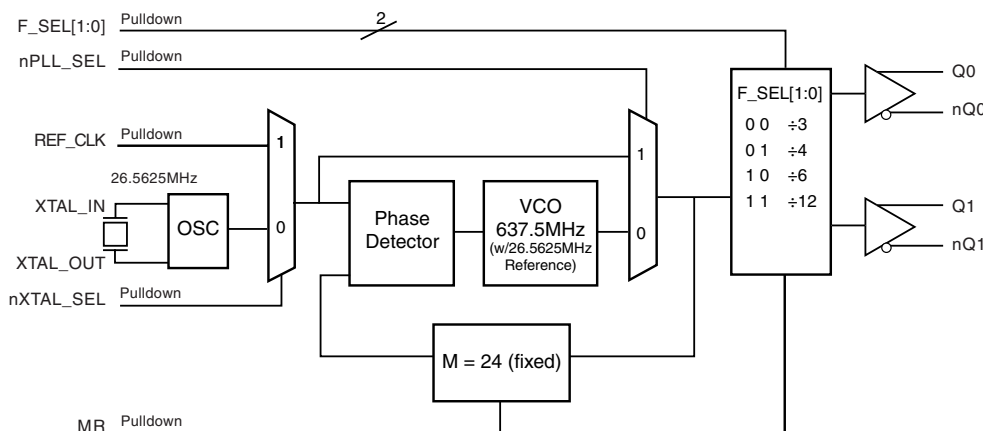
Number	Name	Type		Description
1, 7	nc	Unused		No connect.
2, 20	V_{CCO}	Power		Output supply pins.
3, 4	Q0, nQ0	Ouput		Differential output pair. LVPECL interface levels.
5	MR	Input	Pulldown	Active HIGH Master Reset. When logic HIGH, the internal dividers are reset causing the true outputs Qx to go low 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	Determines whether synthesizer is in PLL or bypass mode. LVCMOS/LVTTL interface levels.
8	V_{CCA}	Power		Analog supply pin.
9, 11	F_SEL0, F_SEL1	Input	Pulldown	Frequency select pins. LVCMOS/LVTTL interface levels.
10, 16	V_{CC}	Power		Core supply pin.
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	LVCMOS/LVTTL reference clock input.
15	nXTAL_SEL	Input	Pulldown	Selects between crystal or REF_CLK inputs as the the PLL Reference source. Selects XTAL inputs when LOW. Selects REF_CLK when HIGH. LVCMOS/LVTTL interface levels.
17	V_{EE}	Power		Negative supply pins.
18, 19	nQ1, Q1	Output		Differential output pair. LVPECL interface levels.

NOTE: *Pulldown* refer to internal input resistors. See Table 2, Pin Characteristics, for typical values.

Tᴀʙʟᴇ 2. Pɪɴ Cʜᴀʀᴀᴄᴛᴇʀɪꜱᴛɪᴄꜱ

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
C_{IN}	Input Capacitance			4		pF
$R_{PULLDOWN}$	Input Pulldown Resistor			51		kΩ

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, V_{CC}	4.6V
Inputs, V_I	-0.5V to V_{CC} + 0.5V
Outputs, I_O	
Continuous Current	50mA
Surge Current	100mA
Package Thermal Impedance, θ_{JA}	73.2°C/W (0 lfpm)
Storage Temperature, T_{STG}	-65°C to 150°C

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.

TABLE 3A. POWER SUPPLY DC CHARACTERISTICS, $V_{CC} = V_{CCA} = V_{CCO}$ = 3.3V±10%, T_A = -40°C TO 85°C

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
V_{CC}	Core Supply Voltage		2.97	3.3	3.63	V
V_{CCA}	Analog Supply Voltage		2.97	3.3	3.63	V
V_{CCO}	Output Supply Voltage		2.97	3.3	3.63	V
I_{EE}	Power Supply Current				130	mA
I_{CCA}	Analog Supply Current				13	mA

TABLE 3B. POWER SUPPLY DC CHARACTERISTICS, $V_{CC} = V_{CCA} = V_{CCO}$ = 2.5V±5%, T_A = -40°C TO 85°C

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
V_{CC}	Core Supply Voltage		2.375	2.5	2.625	V
V_{CCA}	Analog Supply Voltage		2.375	2.5	2.625	V
V_{CCO}	Output Supply Voltage		2.375	2.5	2.625	V
I_{EE}	Power Supply Current				115	mA
I_{CCA}	Analog Supply Current				12	mA

TABLE 3C. LVCMOS / LVTTL DC CHARACTERISTICS, $V_{CC} = V_{CCA} = V_{CCO}$ = 3.3V±10% OR 2.5V±5%, T_A = -40°C TO 85°C

Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
V_{IH}	Input High Voltage		V_{CC} = 3.3V	2		V_{CC} + 0.3	V
			V_{CC} = 2.5V	1.7		V_{CC} + 0.3	V
V_{IL}	Input Low Voltage		V_{CC} = 3.3V	-0.3		0.8	V
			V_{CC} = 2.5V	-0.3		0.7	V
I_{IH}	Input High Current	REF_CLK, MR, F_SEL0, F_SEL1, nPLL_SEL, nXTAL_SEL	V_{CC} = V_{IN} = 3.63V or 2.625V			150	μA
I_{IL}	Input Low Current	REF_CLK, MR, F_SEL0, F_SEL1, nPLL_SEL, nXTAL_SEL	V_{CC} = 3.63V or 2.625V, V_{IN} = 0V	-150			μA

TABLE 3D. LVPECL DC CHARACTERISTICS, $V_{CC} = V_{CCA} = V_{CCO} = 3.3V \pm 10\%$ OR $2.5V \pm 5\%$, $T_A = -40°C$ TO $85°C$

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

NOTE 1: Outputs terminated with 50Ω to V_{CCO} - 2V.

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	Ω
Shunt Capacitance				7	pF
Drive Level				1	mW

NOTE: Characterized using an 18pF parallel resonant crystal.

TABLE 5A. AC CHARACTERISTICS, $V_{CC} = V_{CCA} = V_{CCO} = 3.3V \pm 10\%$, $T_A = -40°C$ TO $85°C$

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
f_{OUT}	Output Frequency	F_SEL[1:0] = 00	186.67		226.67	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		56.67	MHz
$t$sk(o)	Output Skew; NOTE 1, 2				30	ps
$t$jit(Ø)	RMS Phase Jitter (Random); NOTE 3	212.5MHz, (2.55MHz - 20MHz)		0.50		ps
		159.375MHz, (1.875MHz - 20MHz)		0.54		ps
		106.25MHz, (637kHz - 5MHz)		0.68		ps
		53.125MHz, (637kHz - 5MHz)		0.70		ps
t_R / t_F	Output Rise/Fall Time	20% to 80%	350		650	ps
odc	Output Duty Cycle	F_SEL[1:0] ≠ 00	49		51	%
		F_SEL[1:0] = 00	43		57	%

NOTE 1: Defined as skew between outputs at the same supply voltages and with equal load conditions.
Measured at the output differential cross points.
NOTE 2: This parameter is defined in accordance with JEDEC Standard 65.
NOTE 3: Measured using crystal input.

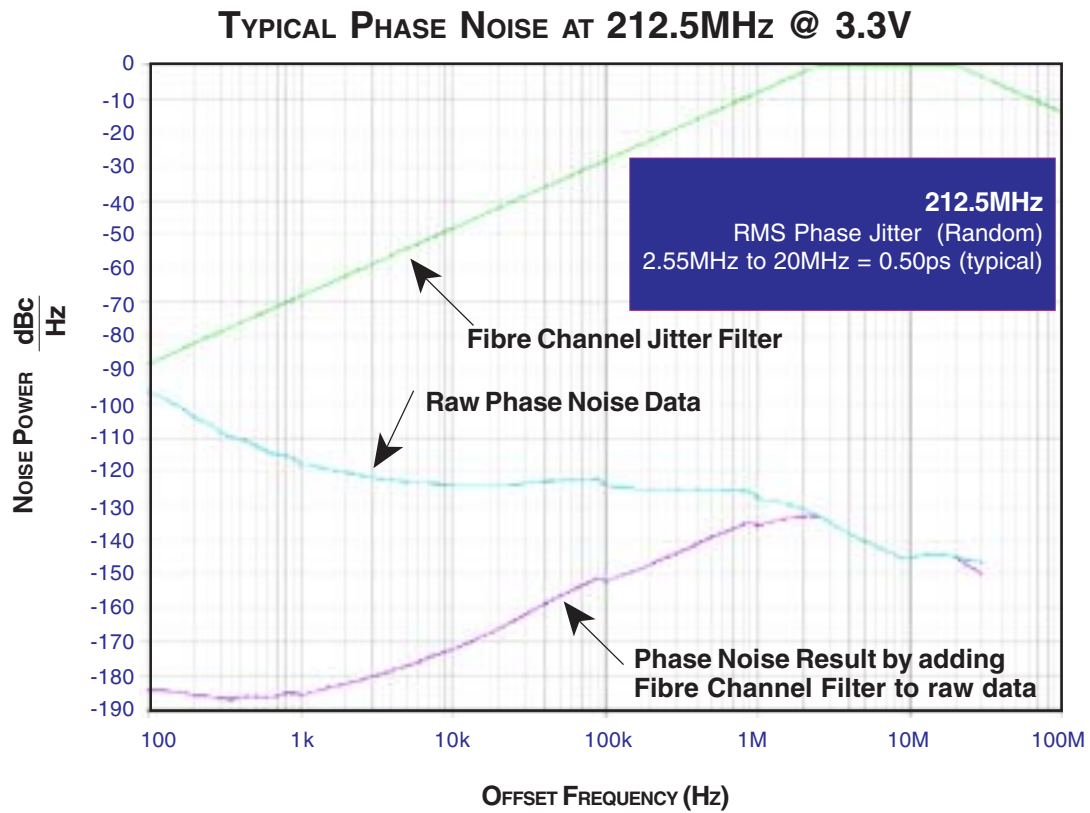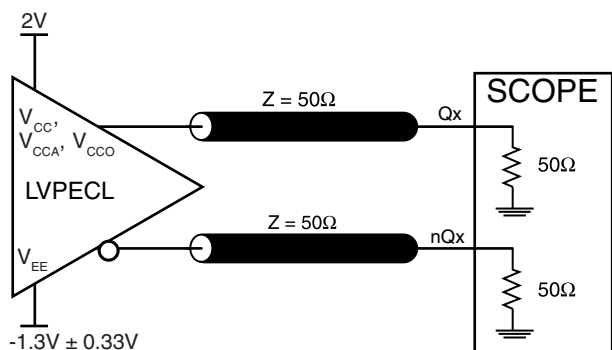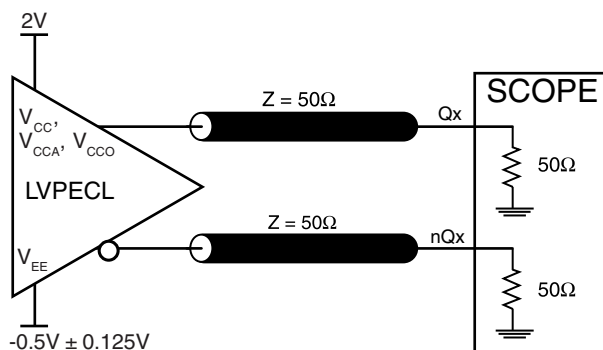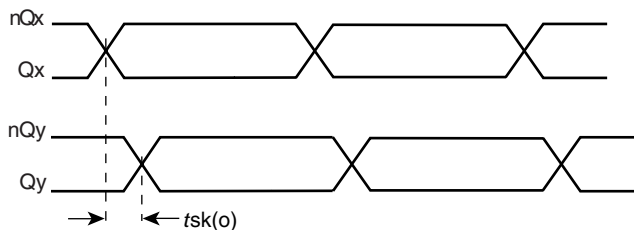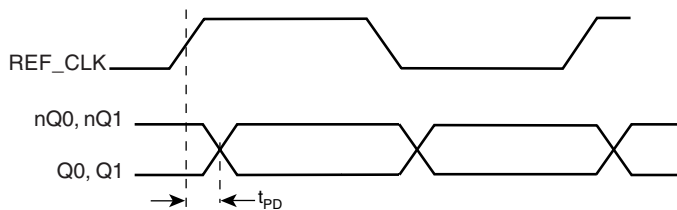TABLE 5B. AC CHARACTERISTICS, $V_{CC} = V_{CCA} = V_{CCO}$ = 2.5V±5%, TA = -40°C TO 85°C

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
f_{OUT}	Output Frequency	F_SEL[1:0] = 00	186.67		226.67	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		56.67	MHz
$t$sk(o)	Output Skew; NOTE 1, 2				30	ps
$t$jit(Ø)	RMS Phase Jitter (Random); NOTE 3	212.5MHz, (2.55MHz - 20MHz)		0.50		ps
		159.375MHz, (1.875MHz - 20MHz)		0.55		ps
		106.25MHz, (637kHz - 5MHz)		0.75		ps
		53.125MHz, (637kHz - 5MHz)		0.76		ps
t_R / t_F	Output Rise/Fall Time	20% to 80%	350		650	ps
odc	Output Duty Cycle	F_SEL[1:0] ≠ 00	49		51	%
		F_SEL[1:0] = 00	43		57	%

NOTE 1: Defined as skew between outputs at the same supply voltages and with equal load conditions.
Measured at the output differential cross points.
NOTE 2: This parameter is defined in accordance with JEDEC Standard 65.
NOTE 3: Measured using crystal input.

TYPICAL PHASE NOISE AT 212.5MHz @ 3.3V

212.5MHz
RMS Phase Jitter (Random)
2.55MHz to 20MHz = 0.50ps (typical)

Fibre Channel Jitter Filter

Raw Phase Noise Data

Phase Noise Result by adding
Fibre Channel Filter to raw data

OFFSET FREQUENCY (Hz)

PARAMETER MEASUREMENT INFORMATION

2V

V_{CC}, V_{CCA}, V_{CCO}

LVPECL

V_{EE}

-1.3V ± 0.33V

Z = 50Ω

Z = 50Ω

Qx

nQx

SCOPE

50Ω

50Ω

3.3V CORE/3.3V OUTPUT LOAD AC TEST CIRCUIT

2V

V_{CC}, V_{CCA}, V_{CCO}

LVPECL

V_{EE}

-0.5V ± 0.125V

Z = 50Ω

Z = 50Ω

Qx

nQx

SCOPE

50Ω

50Ω

2.5V CORE/2.5V OUTPUT LOAD AC TEST CIRCUIT

nQx

Qx

nQy

Qy

$t$sk(o)

OUTPUT SKEW

REF_CLK

nQ0, nQ1

Q0, Q1

t_{PD}

PROPAGATION DELAY

Phase Noise Plot

Noise Power

Phase Noise Mask

f_1 Offset Frequency f_2

RMS Jitter = $\sqrt{\text{Area Under the Masked Phase Noise Plot}}$

RMS PHASE JITTER

nQ0, nQ1

Q0, Q1

t_{PW}

t_{PERIOD}

$$odc = \frac{t_{PW}}{t_{PERIOD}} \times 100\%$$
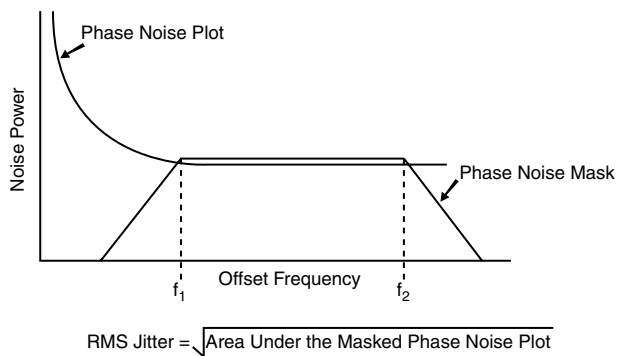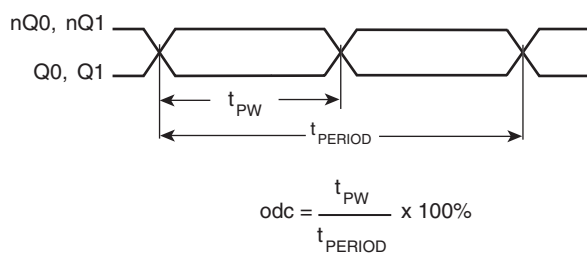
OUTPUT DUTY CYCLE/PULSE WIDTH/PERIOD

Clock Outputs

80%   80%

20%   20%

V_{SWING}

t_R t_F
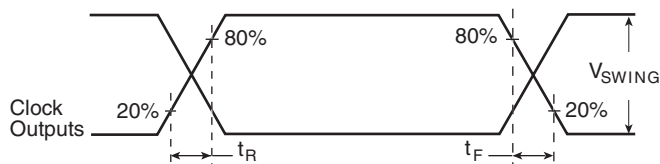
OUTPUT RISE/FALL TIME

APPLICATION INFORMATION

POWER SUPPLY FILTERING TECHNIQUES

As in any high speed analog circuitry, the power supply pins are vulnerable to random noise. The ICS843002I provides separate power supplies to isolate any high switching noise from the outputs to the internal PLL. V_{CC}, V_{CCA}, and V_{CCO} 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 10Ω resistor along with a 10µF and a .01µF bypass capacitor should be connected to each V_{CCA}. The 10Ω resistor can also be replaced by a ferrite bead.
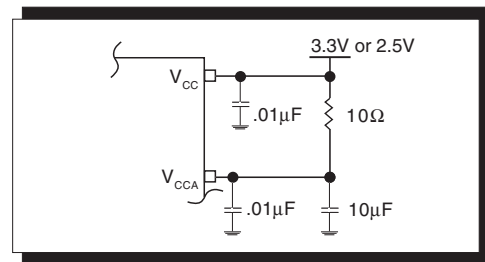
FIGURE 1. POWER SUPPLY FILTERING

RECOMMENDATIONS FOR UNUSED INPUT AND OUTPUT PINS

INPUTS:

CRYSTAL INPUT:
For applications not requiring the use of the crystal oscillator input, both XTAL_IN and XTAL_OUT can be left floating. Though not required, but for additional protection, a 1kΩ resistor can be tied from XTAL_IN to ground.

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 1kΩ resistor can be tied from the REF_CLK to ground.

LVCMOS CONTROL PINS:
All control pins have internal pull-ups or pull-downs; additional resistance is not required but can be added for additional protection. A 1kΩ resistor can be used.
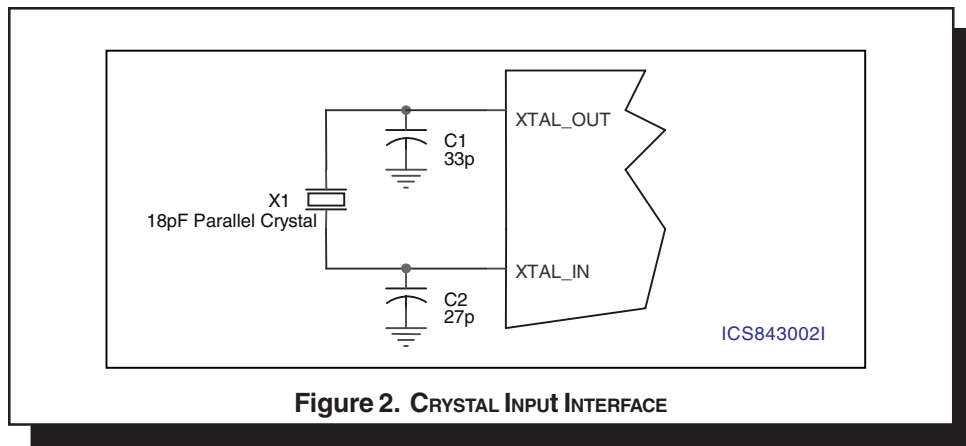
OUTPUTS:

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

CRYSTAL INPUT INTERFACE

The ICS843002I has been characterized with 18pF parallel resonant crystals. The capacitor values shown in *Figure 2* below were determined using a 26.5625MHz, 18pF parallel resonant crystal and were chosen to minimize the ppm error.


Figure 2. CRYSTAL INPUT INTERFACE

TERMINATION FOR 3.3V LVPECL OUTPUT

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

FOUT and nFOUT are low impedance follower outputs that generate ECL/LVPECL compatible outputs. Therefore, terminating resistors (DC current path to ground) or current sources must be used for functionality. These outputs are designed to drive 50Ω transmission lines. Matched impedance techniques should be used to maximize operating frequency and minimize signal distortion. *Figures 3A and 3B* show two different layouts which are recommended only as guidelines. Other suitable clock layouts may exist and it would be recommended that the board designers simulate to guarantee compatibility across all printed circuit and clock component process variations.

FIGURE 3A. LVPECL OUTPUT TERMINATION

FIGURE 3B. LVPECL OUTPUT TERMINATION
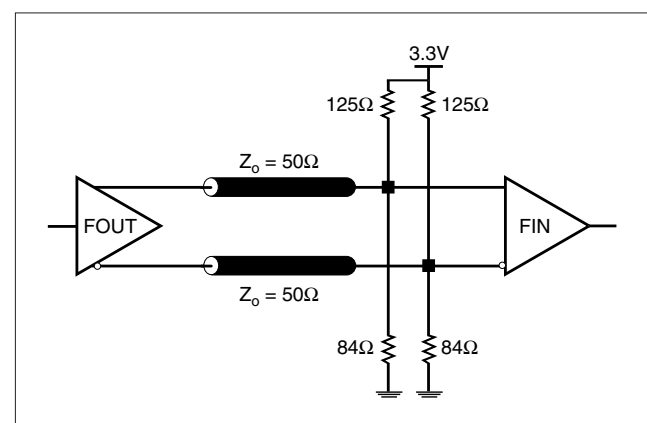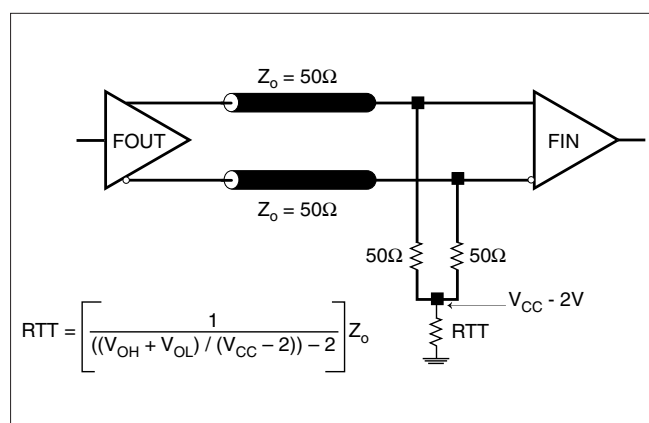
TERMINATION FOR 2.5V LVPECL OUTPUT

Figure 4A and *Figure 4B* show examples of termination for 2.5V LVPECL driver. These terminations are equivalent to terminating 50Ω to V_{cc} - 2V. For V_{cco} = 2.5V, the V_{cco} - 2V is very close to ground level. The R3 in Figure 4B can be eliminated and the termination is shown in *Figure 4C.*
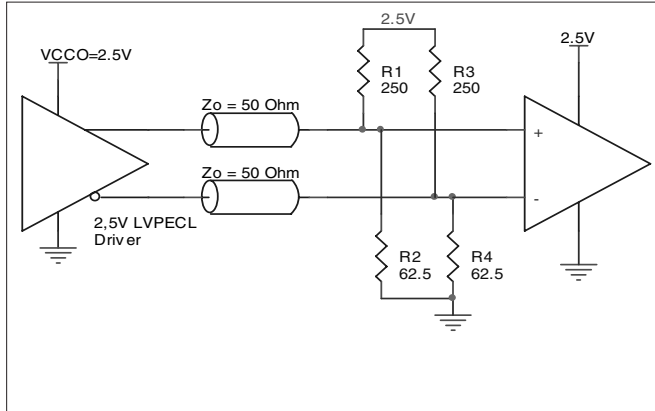

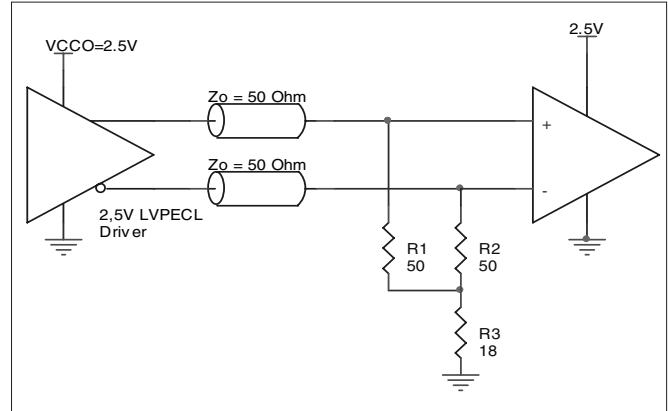**FIGURE 4A. 2.5V LVPECL DRIVER TERMINATION EXAMPLE**
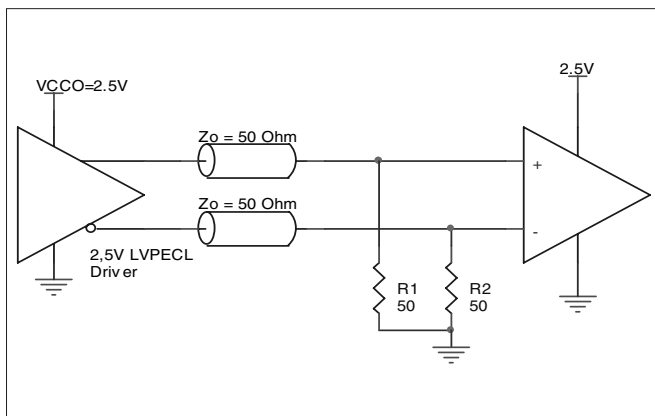

FIGURE 4B. 2.5V LVPECL DRIVER TERMINATION EXAMPLE

FIGURE 4C. 2.5V LVPECL TERMINATION EXAMPLE

Layout Guideline

Figure 5A shows a schematic example of the ICS843002I. An example of LVEPCL termination is shown in this schematic. Additional LVPECL termination approaches are shown in the LVPECL Termination Application Note. In this example, an 18pF parallel resonant 26.5625MHz crystal is used. The C1=27pF and C2=33pF are recommended for frequency accuracy. For different board layout, the C1 and C2 may be slightly adjusted for optimizing frequency accuracy.
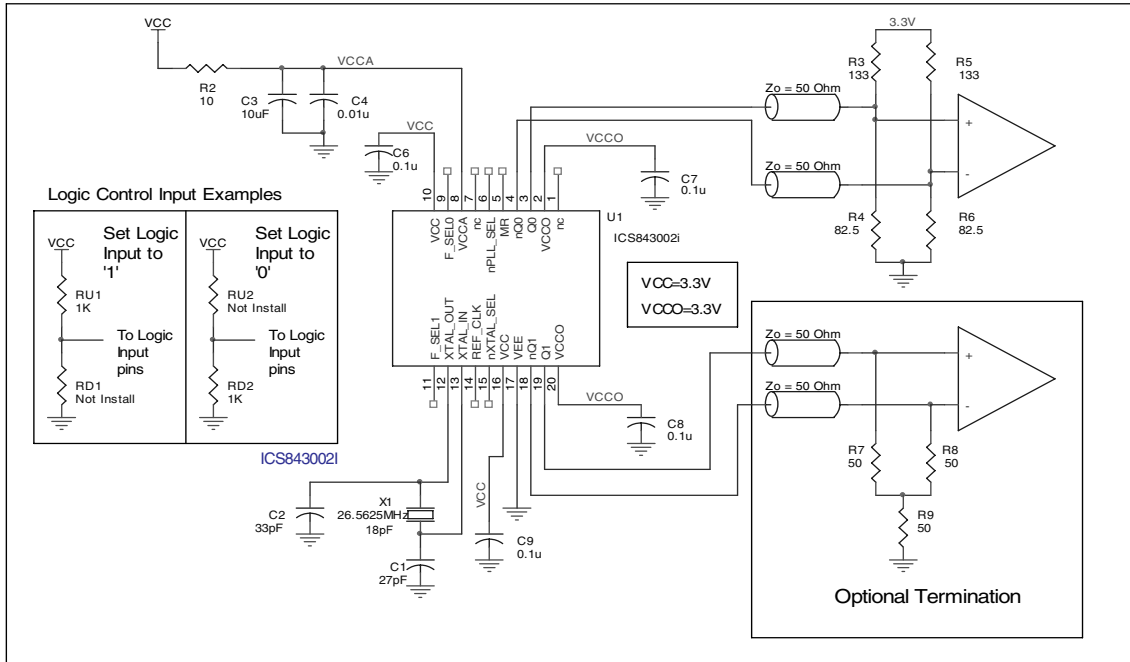

FIGURE 5A. ICS843002I SCHEMATIC EXAMPLE

PC Board Layout Example

Figure 5B shows an example of ICS843002I P.C. board layout. The crystal X1 footprint shown in this example allows installation of either surface mount HC49S or through-hole HC49 package. The footprints of other components in this example are listed in the *Table 6.* There should be at least one decoupling capacitor per power pin. The decoupling capacitors should be located as close as possible to the power pins. The layout assumes that the board has clean analog power ground plane.
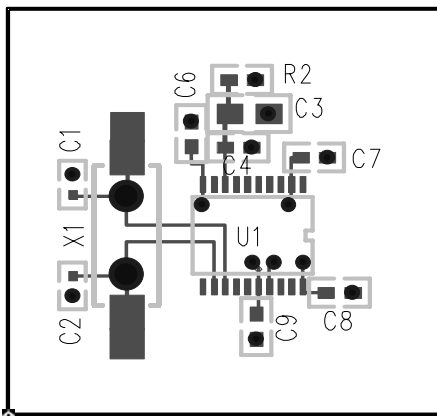

FIGURE 5B. ICS843002I PC BOARD LAYOUT EXAMPLE

TABLE 6. FOOTPRINT TABLE

Reference	Size
C1, C2	0402
C3	0805
C4, C5, C6, C7, C8	0603
R2	0603

NOTE: Table 6, lists component sizes shown in this layout example.

POWER CONSIDERATIONS

This section provides information on power dissipation and junction temperature for the ICS843002I.
Equations and example calculations are also provided.

1. Power Dissipation.
The total power dissipation for the ICS843002I is the sum of the core power plus the power dissipated in the load(s).
The following is the power dissipation for V_{CC} = 3.3V + 10% = 3.63V, which gives worst case results.
NOTE: Please refer to Section 3 for details on calculating power dissipated in the load.

- Power (core)$_{MAX}$ = V_{CC_MAX} * I_{EE_MAX} = 3.63V * 130mA = **471.9mW**

- Power (outputs)$_{MAX}$ = **30mW/Loaded Output pair**
  If all outputs are loaded, the total power is 2 * 30mW = **60mW**

  Total Power$_{\_MAX}$ (3.63V, with all outputs switching) = 471.9mW + 60mW = **531.9mW**

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: $Tj = \theta_{JA} * Pd\_total + T_A$

Tj = Junction Temperature

θ_{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 θ_{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 7 below.

Therefore, Tj for an ambient temperature of 85°C with all outputs switching is:
85°C + 0.532W * 66.6°C/W = 120.4°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 7. THERMAL RESISTANCE θ_{JA} FOR 20-PIN TSSOP, FORCED CONVECTION**

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

3. Calculations and Equations.

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

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

FIGURE 6. LVPECL DRIVER CIRCUIT AND TERMINATION
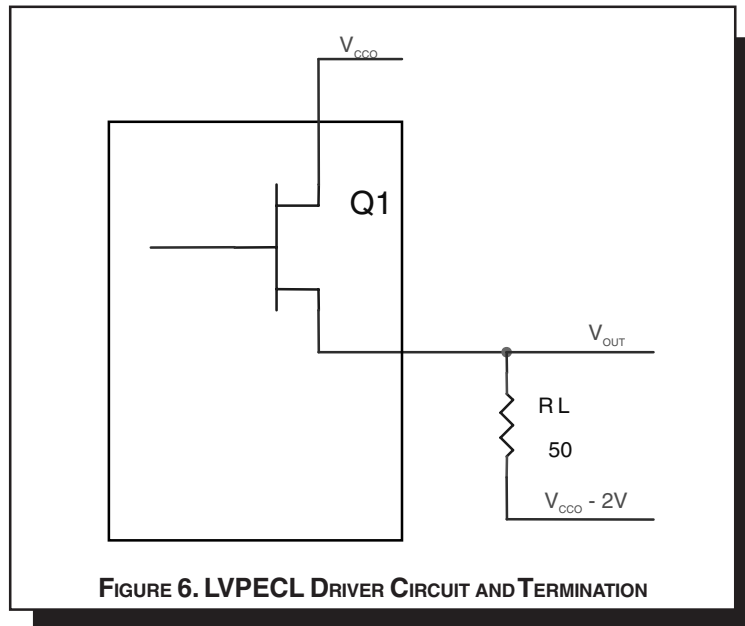
To calculate worst case power dissipation into the load, use the following equations which assume a 50Ω load, and a termination voltage of V_{CCO} - 2V.

- For logic high, $V_{OUT} = V_{OH\_MAX} = \mathbf{V_{CCO\_MAX} - 0.9V}$

    $(V_{CCO\_MAX} - V_{OH\_MAX}) = \mathbf{0.9V}$

- For logic low, $V_{OUT} = V_{OL\_MAX} = \mathbf{V_{CCO\_MAX} - 1.7V}$

    $(V_{CCO\_MAX} - V_{OL\_MAX}) = \mathbf{1.7V}$

Pd_H is power dissipation when the output drives high.
Pd_L is the power dissipation when the output drives low.

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

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

Total Power Dissipation per output pair = Pd_H + Pd_L = **30mW**

RELIABILITY INFORMATION

TABLE 8. θ_{JA} VS. AIR FLOW TABLE FOR 20 LEAD TSSOP

θ_{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

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 ICS843002I is: 2578

PACKAGE OUTLINE - G SUFFIX FOR 20 LEAD TSSOP
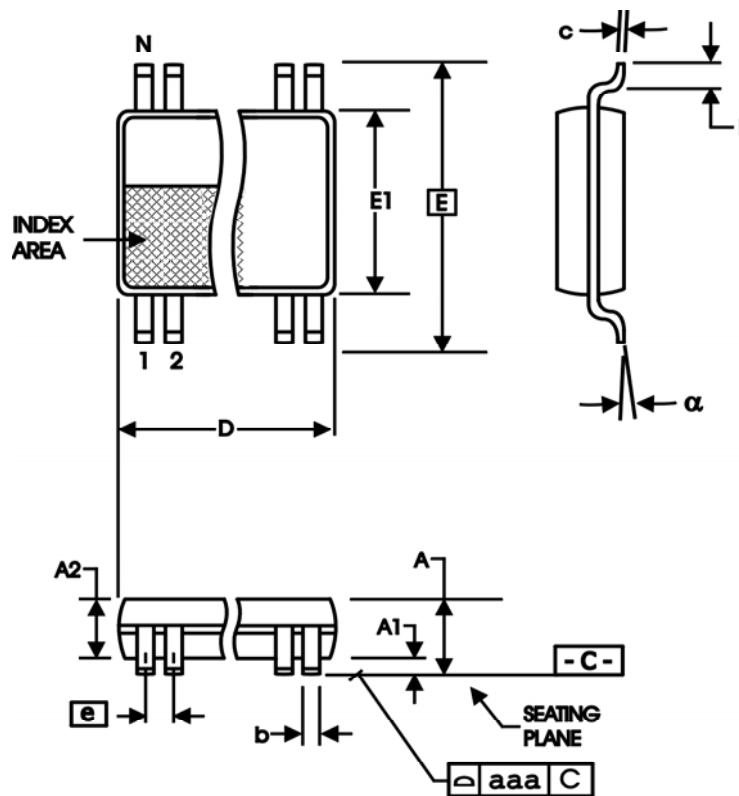
TABLE 9. PACKAGE DIMENSIONS

SYMBOL	Millimeters	
	MIN	**MAX**
N	20	
A	--	1.20
A1	0.05	0.15
A2	0.80	1.05
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
α	0°	8°
aaa	--	0.10

Reference Document: JEDEC Publication 95, MO-153

TABLE 10. ORDERING INFORMATION

Part/Order Number	Marking	Package	Shipping Packaging	Temperature
ICS843002AGI	ICS843002AGI	20 Lead TSSOP	tube	-40°C to 85°C
ICS843002AGIT	ICS843002AGI	20 Lead TSSOP	2500 tape & reel	-40°C to 85°C
ICS843002AGILF	ICS843002AGILF	20 Lead "Lead-Free" TSSOP	tube	-40°C to 85°C
ICS843002AGILFT	ICS843002AGILF	20 Lead "Lead-Free" TSSOP	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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