Low Skew, 1-To-4, Crystal Oscillator/LVCMOS-To-3.3V LVPECL Fanout Buffer

ICS8535I-31

General Description

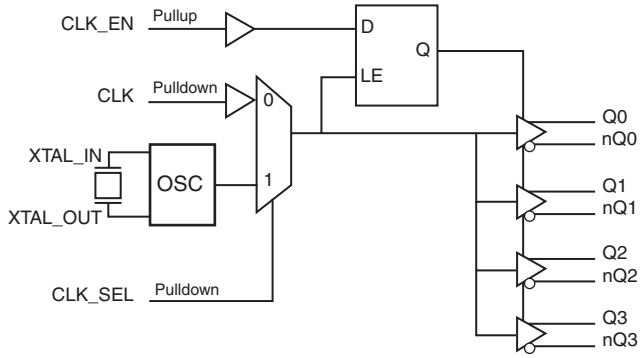
The ICS8535I-31 is a low skew, high performance 1-to-4 3.3V Crystal Oscillator/LVCMOS-to-3.3V LVPECL fanout buffer. The ICS8535I-31 has selectable single ended clock or crystal inputs. The single ended clock input accepts LVCMOS or LVTTL input levels and translate them to 3.3V LVPECL levels. The output enable is internally synchronized to eliminate runt pulses on the outputs during asynchronous assertion/deassertion of the clock enable pin.

Guaranteed output and part-to-part skew characteristics make the ICS8535I-31 ideal for those applications demanding well defined performance and repeatability.

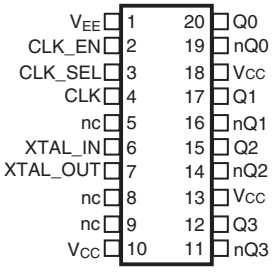
Features

- Four differential 3.3V LVPECL outputs
- Selectable LVCMOS/LVTTL CLK or crystal inputs
- CLK can accept the following input levels: LVCMOS, LVTTL
- Maximum output frequency: 266MHz
- Output skew: 30ps (typical)
- Part-to-part skew: 200ps (maximum)
- Propagation delay: 1.75ns (maximum)
- Additive phase jitter, RMS: 0.057ps (typical)
- Full 3.3V supply mode
- -40°C to 85°C ambient operating temperature
- Replaces the ICS8535I-11
- Available in both standard (RoHS 5) and lead-free (RoHS 6) packages

Block Diagram



Pin Assignment



ICS8535I-31

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

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Table 1. Pin Descriptions

Number	Name	Type		Description
1	V_{EE}	Power		Negative supply pin.
2	CLK_EN	Input	Pullup	Synchronizing clock enable. When HIGH, clock outputs follows clock input. When LOW, Q outputs are forced low, nQ outputs are forced high. LVCMOS / LVTTL interface levels.
3	CLK_SEL	Input	Pulldown	Clock select input. When HIGH, selects XTAL inputs When LOW, selects CLK input. LVCMOS / LVTTL interface levels.
4	CLK	Input	Pulldown	Single-ended clock input. LVCMOS/LVTTL interface levels.
5, 8, 9	nc	Unused		No connect.
6, 7	XTAL_IN, XTAL_OUT	Input		Crystal oscillator interface. XTAL_IN is the input. XTAL_OUT is the output.
10, 13, 18	V_{CC}	Power		Positive supply pins.
11, 12	nQ3, Q3	Output		Differential output pair. LVPECL interface levels.
14, 15	nQ2, Q2	Output		Differential output pair. LVPECL interface levels.
16, 17	nQ1, Q1	Output		Differential output pair. LVPECL interface levels.
19, 20	nQ0, Q0	Output		Differential output pair. LVPECL interface levels.

NOTE: *Pullup and Pulldown* refer 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		kΩ
$R_{PULLDOWN}$	Input Pulldown Resistor			51		kΩ

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Function Tables

Table 3A. Control Input Function Table

Inputs			Outputs	
CLK_EN	**CLK_SEL**	**Selected Source**	**Q0:Q3**	**nQ0:nQ3**
0	0	CLK0	Disabled; Low	Disabled; High
0	1	CLK1	Disabled; Low	Disabled; High
1	0	CLK0	Enabled	Enabled
1	1	CLK1	Enabled	Enabled

After CLK_EN switches, the clock outputs are disabled or enabled following a rising and falling input clock or crystal oscillator edge as shown in *Figure 1.* In the active mode, the state of the outputs are a function of the CLK input as described in *Table 3B.*

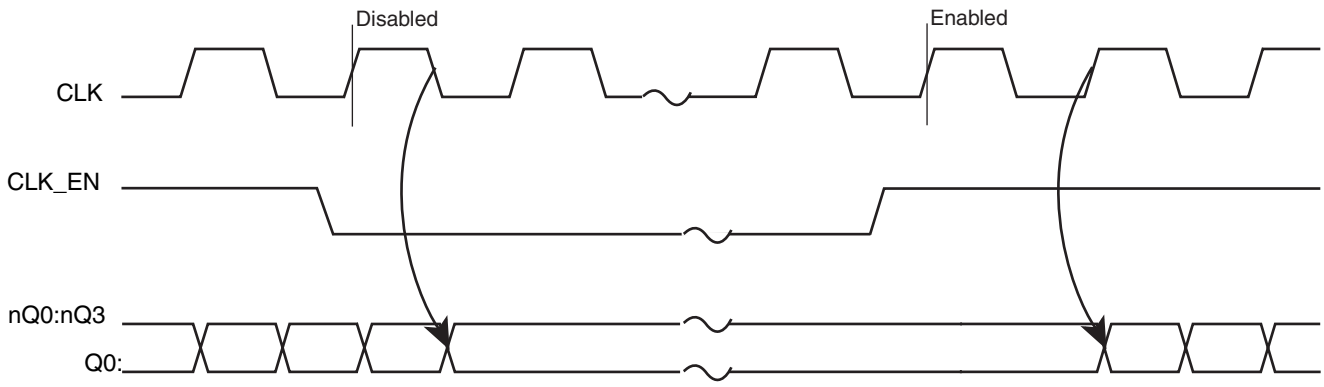

Figure 1. CLK_EN Timing Diagram

Table 3B. Clock Input Function Table

Inputs	Outputs	
CLK	**Q0:Q3**	**nQ0:nQ3**
0	LOW	HIGH
1	HIGH	LOW

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

DC Electrical Characteristics

Table 4A. Power Supply DC Characteristics, V_{CC} = 3.3V ± 5%, T_A = -40°C to 85°C

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
V_{CC}	Core Supply Voltage		3.135	3.3	3.465	V
I_{EE}	Power Supply Current				65	mA

Table 4B. LVCMOS/LVTTL DC Characteristics, V_{CC} = 3.3V ± 5%, T_A = -40°C to 85°C

Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
V_{IH}	Input High Voltage			2		V_{CC} + 0.3	V
V_{IL}	Input Low Voltage			-0.3		0.8	V
I_{IH}	Input High Current	CLK, CLK_SEL	V_{CC} = V_{IN} = 3.465V			150	µA
		CLK_EN	V_{CC} = V_{IN} = 3.465V			5	µA
I_{IL}	Input Low Current	CLK, CLK_SEL	V_{CC} = 3.465V, V_{IN} = 0V	-5			µA
		CLK_EN	V_{CC} = 3.465V, V_{IN} = 0V	-150			µA

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Table 4C. LVPECL DC Characteristics, V_{CC} = 3.3V ± 5%, T_A = -40°C to 85°C

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

NOTE 1: Outputs terminated with 50Ω to V_{CC} – 2V

Table 5. 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
Drive Level				1	mW

AC Electrical Characteristics

Table 6. AC Characteristics, V_{CC} = 3.3V ± 5%, T_A = -40°C to 85°C

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
f_{MAX}	Output Frequency				266	MHz
t_{PD}	Propagation Delay; NOTE 1		1.4		1.75	ns
*t*jit	Buffer Additive Phase Jitter, RMS; refer to Additive Phase Jitter Section	155.52MHz, Integration Range: 12kHz – 20MHz		0.057		ps
*t*sk(o)	Output Skew; NOTE 2, 3			30		ps
*t*sk(pp)	Part-to-Part Skew; NOTE 3, 4				200	ps
t_R / t_F	Output Rise/Fall Time	20% to 80%	300		600	ps
odc	Output Duty Cycle		46		54	%

All parameters measured at $f \leq$ 266MHz unless noted otherwise.
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: Measured from V_{CC}/2 of the input to the differential output crossing point.
NOTE 2: Defined as skew between outputs at the same supply voltage and with equal load conditions.
Measured at the differential output crossing point.
NOTE 3: This parameter is defined in accordance with JEDEC Standard 65.
NOTE 4: Defined as skew between outputs on different devices operating at the same supply voltage and with equal load conditions. Using the same type of inputs on each device, the outputs are measured at the differential cross points.

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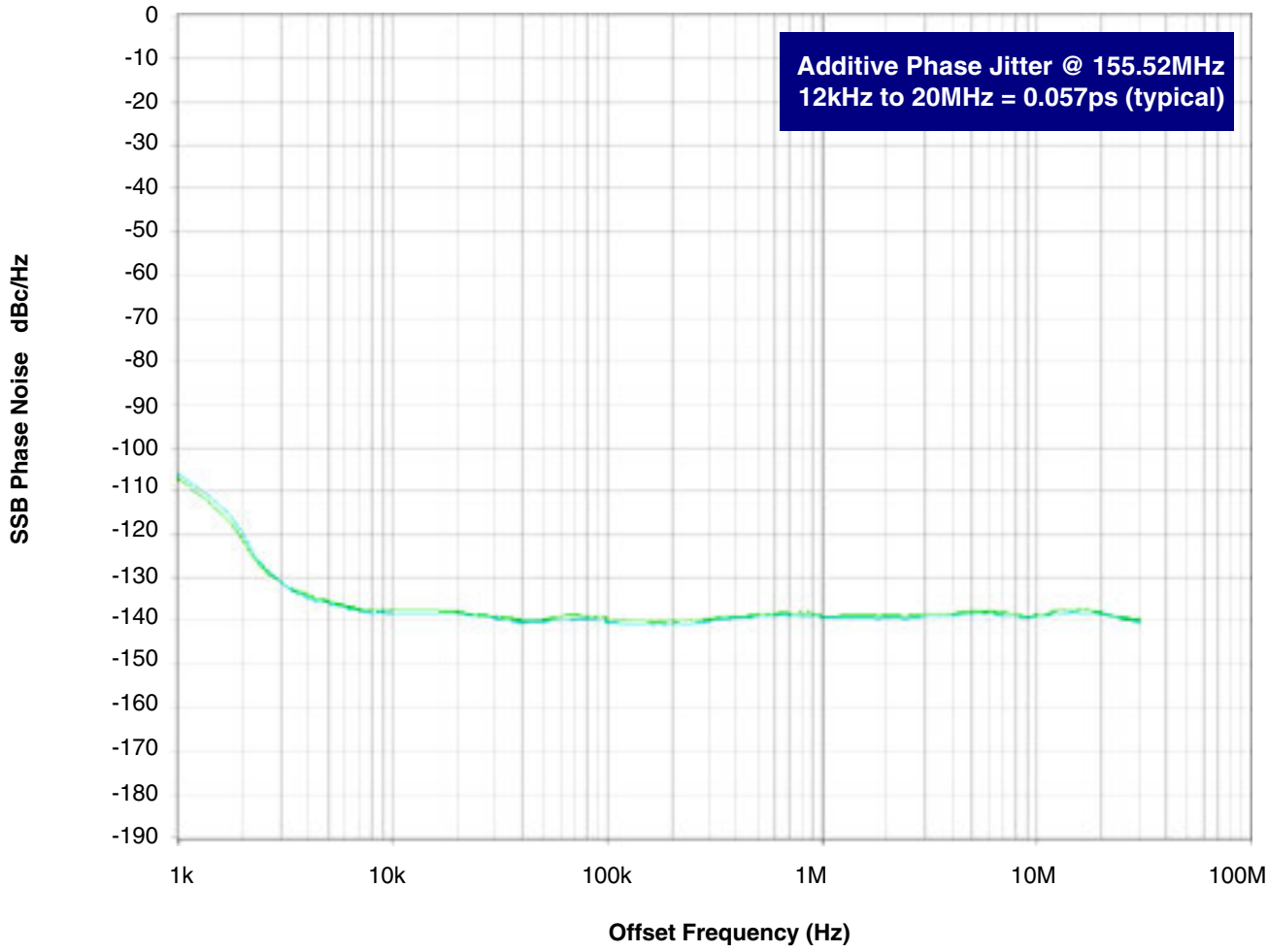
Additive Phase Jitter

The spectral purity in a band at a specific offset from the fundamental compared to the power of the fundamental is called the ***dBc Phase Noise.*** This value is normally expressed using a Phase noise plot and is most often the specified plot in many applications. Phase noise is defined as the ratio of the noise power present in a 1Hz band at a specified offset from the fundamental frequency to the power value of the fundamental. This ratio is expressed in decibels (dBm) or a ratio of the power in the 1Hz band to the power in the fundamental. When the required offset is specified, the phase noise is called a ***dBc*** value, which simply means dBm at a specified offset from the fundamental. By investigating jitter in the frequency domain, we get a better understanding of its effects on the desired application over the entire time record of the signal. It is mathematically possible to calculate an expected bit error rate given a phase noise plot.



As with most timing specifications, phase noise measurements has issues relating to the limitations of the equipment. Often the noise floor of the equipment is higher than the noise floor of the device. This is illustrated above. The device meets the noise floor of what is shown, but can actually be lower. The phase noise is dependent on the input source and measurement equipment.

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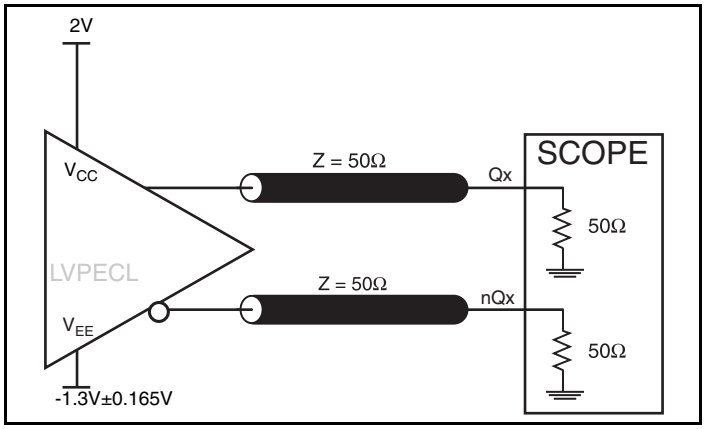
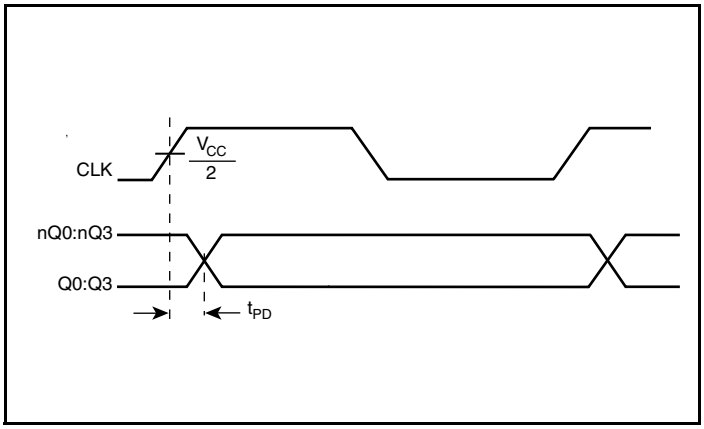
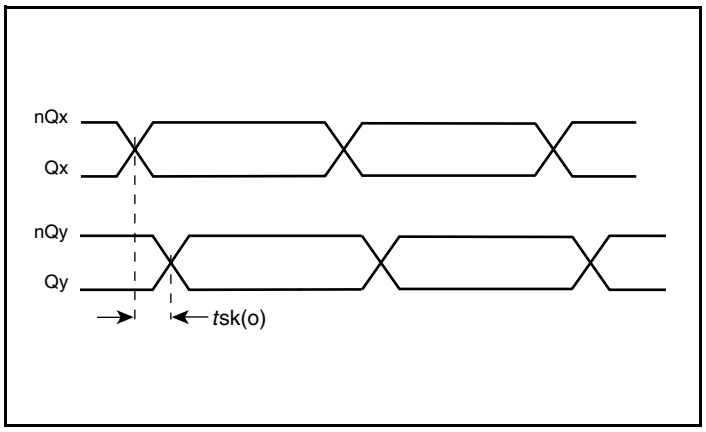
Parameter Measurement Information



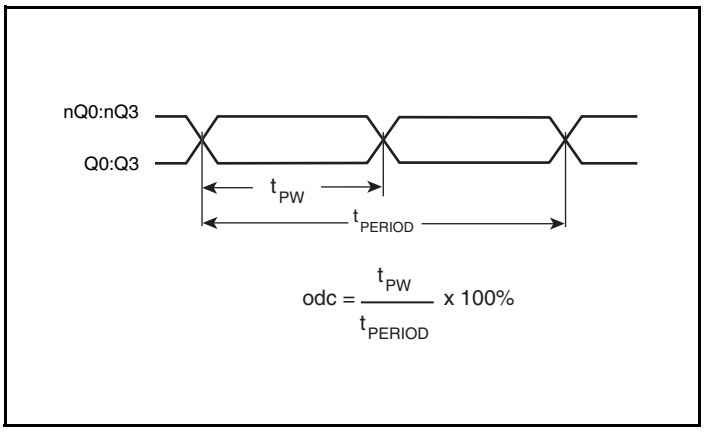
3.3V Core/3.3V Output Load AC Test Circuit



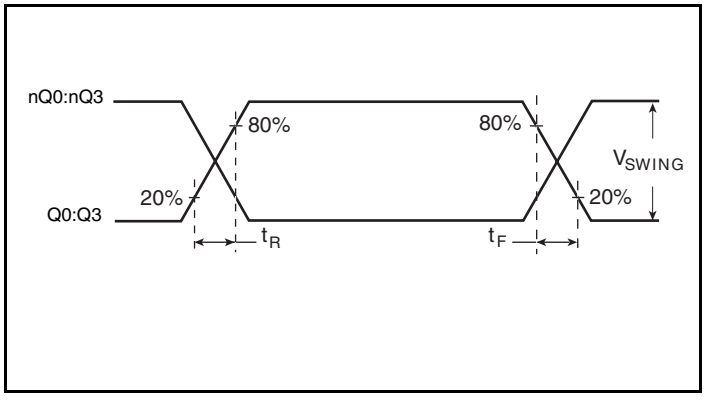
Propagation Delay



Output Skew



Output Duty Cycle/Pulse Width/Period



Output Rise/Fall Time

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Application Information

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 1kΩ resistor can be tied from XTAL_IN to ground.

CLK Input

For applications not requiring the use of a clock input, it can be left floating. Though not required, but for additional protection, a 1kΩ resistor can be tied from the 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 Outputs

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 ICS8535I-31 has been characterized with 18pF parallel resonant crystals. The capacitor values shown in *Figure 2* below were determined using an 18pF parallel resonant crystal and were chosen to minimize the ppm error.

These same capacitor values will tune any 18pF parallel resonant crystal over the frequency range and other parameters specified in this data sheet. The optimum C1 and C2 values can be slightly adjusted for different board layouts

.

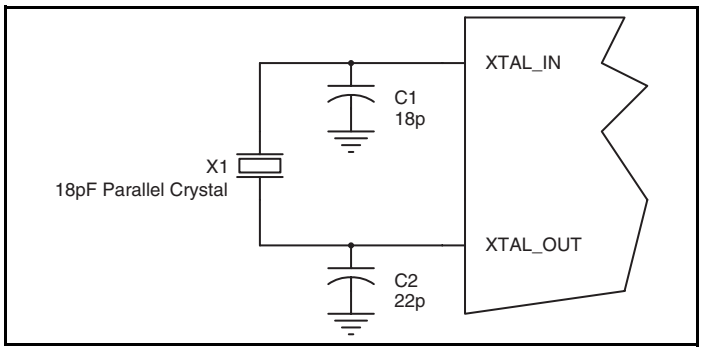

Figure 2. Crystal Input Interface

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LVCMOS to XTAL Interface

The XTAL_IN input can accept a single-ended LVCMOS signal through an AC coupling capacitor. A general interface diagram is shown in *Figure 3.* The XTAL_OUT pin can be left floating. The input edge rate can be as slow as 10ns. For LVCMOS signals, it is recommended that the amplitude be reduced from full swing to half swing in order to prevent signal interference with the power rail and to reduce noise. This configuration requires that the output impedance of the driver (Ro) plus the series resistance (Rs) equals the transmission line impedance. In addition, matched termination at the crystal input will attenuate the signal in half. This can be done in one of two ways. First, R1 and R2 in parallel should equal the transmission line impedance. For most 50Ω applications, R1 and R2 can be 100Ω. This can also be accomplished by removing R1 and making R2 50Ω. By overdriving the crystal oscillator, the device will be functional, but note, the device performance is guaranteed by using a quartz crystal.

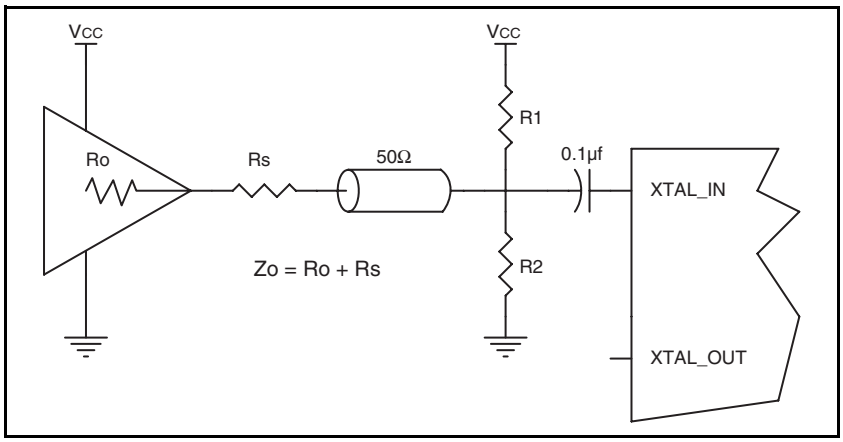

Figure 3. General Diagram for LVCMOS Driver to XTAL Input Interface

Termination for 3.3V LVPECL Outputs

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

The differential outputs 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 4A and 4B* 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.

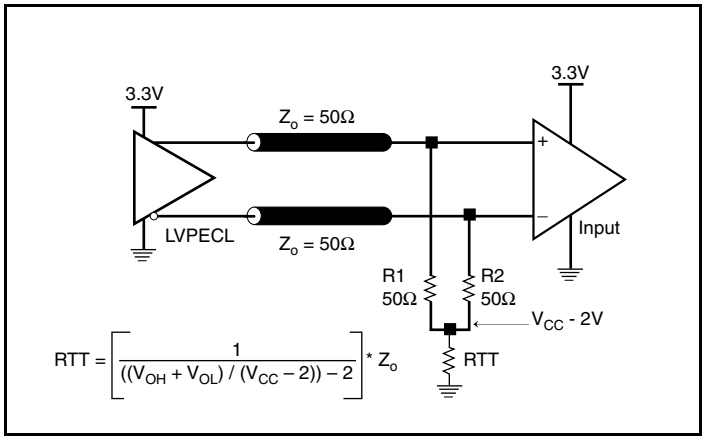

Figure 4A. 3.3V LVPECL Output Termination

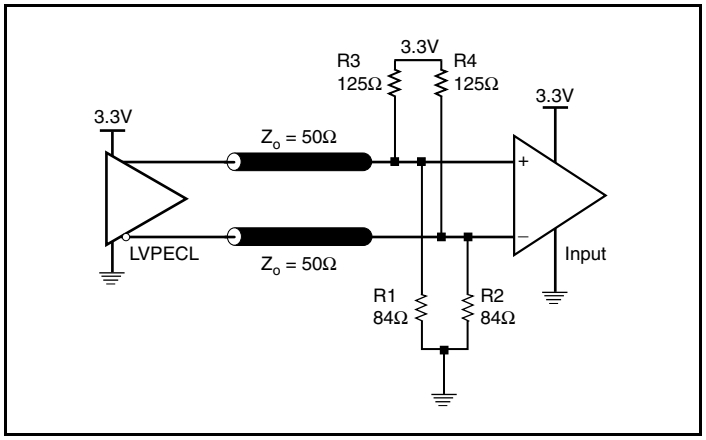

Figure 4B. 3.3V LVPECL Output Termination

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Power Considerations

This section provides information on power dissipation and junction temperature for the ICS8535I-31.
Equations and example calculations are also provided.

1. Power Dissipation.

The total power dissipation for the ICS8535I-31 is the sum of the core power plus the power plus the power dissipated in the load(s).
The following is the power dissipation for V_{CC} = 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 $(core)_{MAX} = V_{CC_MAX} * I_{EE_MAX}$ = 3.465V * 65mA = **225.2mW**
- Power $(outputs)_{MAX}$ = **30mW/Loaded Output Pair**

  If all outputs are loaded, the total power is 4 * 30mW = 120mW

Total Power$_{_MAX}$ (3.465V, with all outputs switching) = 225.2mW + 120mW = **345.2mW**

2. Junction Temperature.

Junction temperature, Tj, is the temperature at the junction of the bond wire and bond pad directly affects the reliability of the device. The maximum recommended junction temperature is 125°C. Limiting the internal transistor junction temperature, Tj, to 125°C ensures that the bond wire and bond pad temperature remains below 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 meter 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 + 0.345W * 66.6°C/W = 108°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 (multi-layer).

Table 7. Thermal Resistance θ_{JA} for 20 Lead TSSOP, Forced Convection

θ_{JA} by Velocity			
Linear Feet per minute	**0**	**200**	**500**
Multi-Layer PCB, JEDEC Standard Test Boards	73.2°C/W	66.6°C/W	63.5°C/W

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3. Calculations and Equations.

The purpose of this section is to calculate the power dissipation for the LVPECL output pairs.

LVPECL output driver circuit and termination are shown in *Figure 5.*

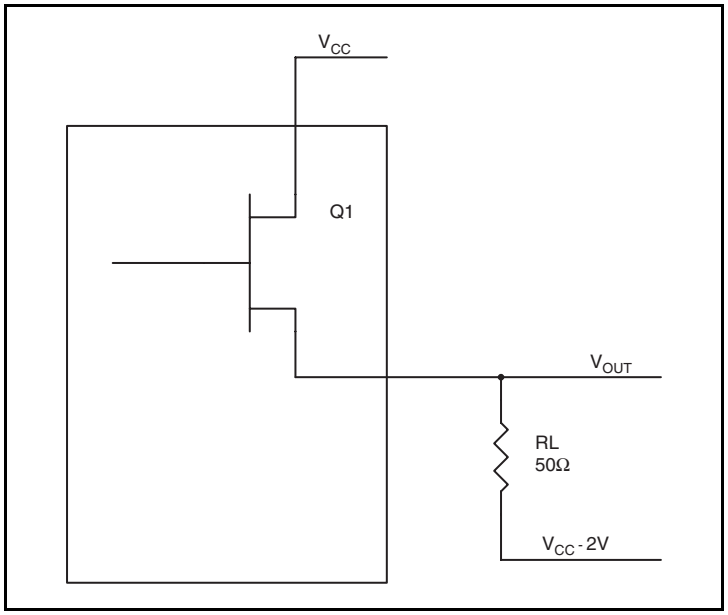

Figure 5. LVPECL Driver Circuit and Termination

To calculate worst case power dissipation into the load, use the following equations which assume a 50Ω load, and a termination voltage of V_{CC} – 2V.

- For logic high, $V_{OUT} = V_{OH_MAX} = \mathbf{V_{CC_MAX} – 0.9V}$
  $(V_{CC_MAX} – V_{OH_MAX}) = \mathbf{0.9V}$
- For logic low, $V_{OUT} = V_{OL_MAX} = \mathbf{V_{CC_MAX} – 1.7V}$
  $(V_{CC_MAX} – V_{OL_MAX}) = \mathbf{1.7V}$

Pd_H is power dissipation when the output drives high.

Pd_L is the power dissipation when the output drives low.

$Pd_H = [(V_{OH_MAX} – (V_{CC_MAX} – 2V))/R_L] * (V_{CC_MAX} – V_{OH_MAX}) = [(2V - (V_{CC_MAX} – V_{OH_MAX}))/R_L] * (V_{CC_MAX} – V_{OH_MAX}) =$
$[(2V - 0.9V)/50\Omega] * 0.9V =$ **19.8mW**

$Pd_L = [(V_{OL_MAX} – (V_{CC_MAX} – 2V))/R_L] * (V_{CC_MAX} – V_{OL_MAX}) = [(2V – (V_{CC_MAX} – V_{OL_MAX}))/R_L] * (V_{CC_MAX} – V_{OL_MAX}) =$
$[(2V – 1.7V)/50\Omega] * 1.7V =$ **10.2mW**

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

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Reliability Information

Table 8. θ_{JA} vs. Air Flow Table for a 20 Lead TSSOP

θ_{JA} by Velocity			
Linear Feet per minute	**0**	**200**	**500**
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 ICS8535I-31 is: 428

Package Outline and Package Dimensions

Package Outline - G Suffix for 20 Lead TSSOP

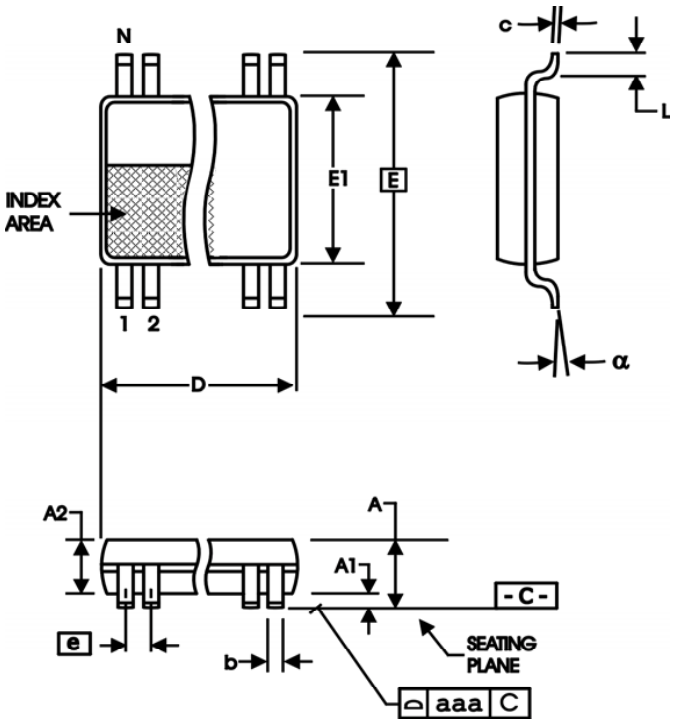

Table 9. Package Dimensions 20 Lead TSSOP

All Dimensions in Millimeters		
Symbol	**Minimum**	**Maximum**
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

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Ordering Information

Table 10. Ordering Information

Part/Order Number	Marking	Package	Shipping Packaging	Temperature
8535AGI-31	ICS8535AGI31	20 Lead TSSOP	Tube	-40°C to 85°C
8535AGI-31T	ICS8535AGI31	20 Lead TSSOP	2500 Tape & Reel	-40°C to 85°C
8535AGI-31LF	ICS8535AI31L	“Lead-Free” 20 Lead TSSOP	Tube	-40°C to 85°C
8535AGI-31LFT	ICS8535AI31L	“Lead-Free” 20 Lead 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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Revision History Sheet

Rev	Table	Page	Description of Change	Date
A	 T10	8 9 13	Added *Recommendations for Unused Input and Output Pins.* Added *LVCMOS-to-Crystal Interface* section. Ordering Information Table - added lead-free marking.	8/16/07
A		8	Crystal Input Interface - Updated Drawing	7/29/09
A	T6	5 8 9	AC Characteristics Table - added Thermal note. Figure 2, Crystal Input Interface - added C1/C2 values. LVCMOS to XTAL Interface - added new sentence to end of paragraph. Updated Header/Footer throughout the datasheet.	7/30/09
A	T6	5	AC Characteristics Table heading - corrected temperature from “0 to 70°C” to “-40 to 85°C”	1/27/10

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