

## General Description

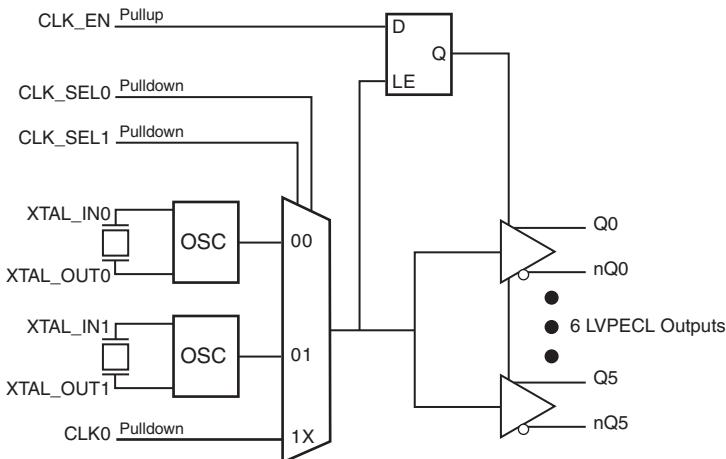
The 8536-02 is a low skew, high performance 1-to-6, Dual Crystal or LVCMS Input-to-3.3V, 2.5V LVPECL Fanout Buffer. The 8536-02 has selectable crystal or single ended clock input. The single ended clock input accepts LVCMS or LVTTL input levels and translates them to LVPECL levels. The output enable 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 8536-02 ideal for those applications demanding well defined performance and repeatability.

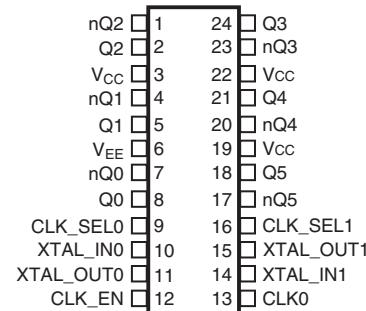
## Features

- Six 3.3V, 2.5V differential LVPECL output pairs
- Selectable crystal oscillator interface or LVCMS/LVTTL single-ended input
- Maximum output frequency: 266MHz
- Crystal frequency range: 14MHz – 40MHz
- Output skew: 55ps (maximum)
- Part-to-part skew: 500ps (maximum)
- Propagation delay: 1.85ns (maximum), 3.3V
- Additive phase jitter, RMS: 0.149ps (typical)
- Full 3.3V or 2.5V supply modes
- 0°C to 70°C ambient operating temperature
- Industrial temperature information available upon request
- Available in lead-free (RoHS 6) package

## Block Diagram



## Pin Assignment



8536-02  
24-Lead TSSOP  
4.4mm x 7.8mm x 0.925mm package body  
G Package  
Top View

**Table 1. Pin Descriptions**

Number	Name	Type	Description			
1, 2	nQ2, Q2	Output	Differential output pair. LVPECL interface levels.			
3, 19, 22	V <sub>CC</sub>	Power	Power supply pins.			
4, 5	nQ1, Q1	Output	Differential output pair. LVPECL interface levels.			
6	V <sub>EE</sub>	Power	Negative supply pin.			
7, 8	nQ0, Q0	Output	Differential output pair. LVPECL interface levels.			
9, 16	CLK_SEL0, CLK_SEL1	Input	Pulldown	Clock select pins. LVCMOS/LVTTL interface levels. See Table 3B.		
10, 11	XTAL_IN0, XTAL_OUT0	Input		Parallel resonant crystal interface. XTAL_OUT0 is the output, XTAL_IN0 is the input.		
12	CLK_EN	Input	Pullup	Synchronizing clock enable. When HIGH, clock outputs follow clock input. When LOW, the outputs are disabled. LVCMOS / LVTTL interface levels. See Table 3A.		
13	CLK0	Input	Pulldown	Single-ended clock input. LVCMOS/LVTTL interface levels.		
14, 15	XTAL_IN1, XTAL_OUT1	Input		Parallel resonant crystal interface. XTAL_OUT1 is the output, XTAL_IN1 is the input.		
17, 18	nQ5, Q5	Output		Differential output pair. LVPECL interface levels.		
20, 21	nQ4, Q4	Output		Differential output pair. LVPECL interface levels.		
23, 24	nQ3, Q3	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 <sub>IN</sub>	Input Capacitance			4		pF
R <sub>PULLUP</sub>	Input Pullup Resistor			51		kΩ
R <sub>PULLDOWN</sub>	Input Pulldown Resistor			51		kΩ

## Function Tables

Table 3. Control Input Function Table

Inputs				Outputs	
CLK_EN	CLK_SEL1	CLK_SEL0	Selected Source	Q[0:5]	nQ[0:5]
0	0	0	XTAL0	Disabled	Disabled
0	0	1	XTAL1	Disabled	Disabled
0	1	X	CLK0	Disabled	Disabled
1	0	0	XTAL0	Enabled	Enabled
1	0	1	XTAL1	Enabled	Enabled
1	1	X	CLK0	Enabled	Enabled

After CLK\_EN switches, the clock outputs are disabled or enabled following a rising and falling input clock edge as show in Figure 1. In the active mode, the state of the outputs are a function of the selected clock input.

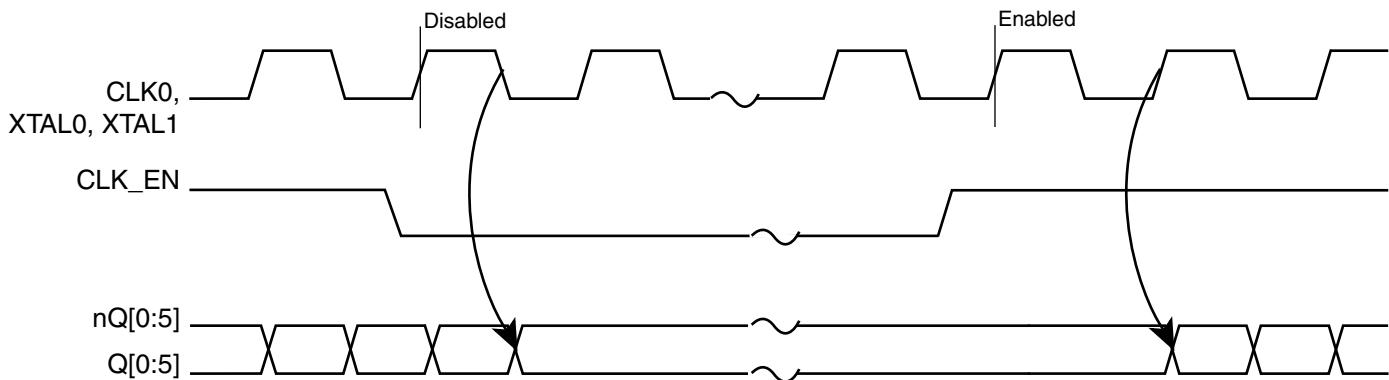


Figure 1. CLK\_EN Timing Diagram

## 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, $V_I$ XTAL_IN Other Input	0V to $V_{CC}$ -0.5V to $V_{CC} + 0.5V$
Outputs, $I_O$ (LVPECL) Continuous Current Surge Current	50mA 100mA
Package Thermal Impedance, $\theta_{JA}$	87.8°C/W (0 mps)
Storage Temperature, $T_{STG}$	-65°C to 150°C

## DC Electrical Characteristics

**Table 4A. Power Supply DC Characteristics**,  $V_{CC} = 3.3V \pm 5\%$ ,  $V_{EE} = 0V$ ,  $T_A = 0^\circ C$  to  $70^\circ C$

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				89	mA

**Table 4B. Power Supply DC Characteristics**,  $V_{CC} = 2.5V \pm 5\%$ ,  $V_{EE} = 0V$ ,  $T_A = 0^\circ C$  to  $70^\circ C$

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{CC}$	Core Supply Voltage		2.375	2.5	2.625	V
$I_{EE}$	Power Supply Current				84	mA

**Table 4C. LVC MOS/LV TTL DC Characteristics**,  $T_A = 0^\circ C$  to  $70^\circ C$

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	$V_{CC} = V_{IN} = 3.465V$ or $2.625V$			150	$\mu A$
		$V_{CC} = V_{IN} = 3.465V$ or $2.625V$			5	$\mu A$
$I_{IL}$	Input Low Current	$V_{CC} = 3.465V$ or $2.625V$ , $V_{IN} = 0V$	-5			$\mu A$
		$V_{CC} = 3.465V$ or $2.625V$ , $V_{IN} = 0V$	-150			$\mu A$

**Table 4D. LVPECL DC Characteristics,  $V_{CC} = 3.3V \pm 5\%$ ,  $V_{EE} = 0V$ ,  $T_A = 0^\circ C$  to  $70^\circ C$** 

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  $50\Omega$  to  $V_{CC} - 2V$ .

**Table 4E. LVPECL DC Characteristics,  $V_{CC} = 2.5V \pm 5\%$ ,  $V_{EE} = 0V$ ,  $T_A = 0^\circ C$  to  $70^\circ C$** 

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		$V_{CC} - 2.0$		$V_{CC} - 1.5$	V
$V_{SWING}$	Peak-to-Peak Output Voltage Swing		0.4		1.0	V

NOTE 1: Outputs terminated with  $50\Omega$  to  $V_{CC} - 2V$ .

**Table 5. Crystal Characteristics**

Parameter	Test Conditions	Minimum	Typical	Maximum	Units
Mode of Oscillation		Fundamental			
Frequency		14		40	MHz
Equivalent Series Resistance (ESR)				50	$\Omega$
Shunt Capacitance				7	pF

NOTE: Characterized using an 18pF parallel resonant crystal.

## AC Electrical Characteristics

**Table 6A. AC Characteristics,  $V_{CC} = 3.3V \pm 5\%$ ,  $V_{EE} = 0V$ ,  $T_A = 0^\circ C$  to  $70^\circ C$**

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$f_{OUT}$	Output Frequency				266	MHz
$t_{PD}$	Propagation Delay; NOTE 1		1.35		1.85	ns
$\text{f}_{\text{jit}}$	Buffer Additive Phase Jitter, RMS; NOTE 2	155.52MHz, Integration Range: 12kHz – 20MHz		0.149		ps
$t_{sk(o)}$	Output skew; NOTE 3, 4				55	ps
$t_{sk(pp)}$	Part-to-Part skew; NOTE 4, 5				500	ps
$t_R / t_F$	Output Rise/Fall Time	20% to 80%	200		700	ps
odc	Output Duty Cycle		47		53	%
MUX_ISOLATION	MUX Isolation; NOTE 6	$f = 150\text{MHz}$		48		dB
		$f = 250\text{MHz}$		45		dB

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: All parameters measured at  $f_{OUT}$  unless noted otherwise.

NOTE 1: Measured from  $V_{CC}/2$  of the input crossing point to the differential output crossing point.

NOTE 2: Driving CLK0 input.

NOTE 3: Defined as skew between outputs at the same supply voltage and with equal load conditions. Measured at the output differential cross points.

NOTE 4: This parameter is defined in accordance with JEDEC Standard 65.

NOTE 5: Defined as skew between outputs on different devices operating at the same supply voltage, same temperature, same frequency and with equal load conditions. Using the same type of inputs on each device, the outputs are measured at the differential cross points.

NOTE 6: Measured on either XTAL0 or XTAL1 when single-ended CLK0 switching at 150MHz or 250MHz.

**Table 6B. AC Characteristics,  $V_{CC} = 2.5V \pm 5\%$ ,  $V_{EE} = 0V$ ,  $T_A = 0^\circ C$  to  $70^\circ C$**

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$f_{OUT}$	Output Frequency				266	MHz
$t_{PD}$	Propagation Delay; NOTE 1		1.4		1.9	ns
$\text{f}_{\text{jit}}$	Buffer Additive Phase Jitter, RMS; NOTE 2	155.52MHz, Integration Range: 12kHz – 20MHz		0.149		ps
$t_{sk(o)}$	Output skew; NOTE 3, 4				55	ps
$t_{sk(pp)}$	Part-to-Part skew; NOTE 4, 5				500	ps
$t_R / t_F$	Output Rise/Fall Time	20% to 80%	200		700	ps
odc	Output Duty Cycle		47		53	%
MUX_ISOLATION	MUX Isolation; NOTE 6	$f = 150\text{MHz}$		40		dB
		$f = 250\text{MHz}$		40		dB

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: All parameters measured at  $f_{OUT}$  unless noted otherwise.

NOTE 1: Measured from  $V_{CC}/2$  of the input crossing point to the differential output crossing point.

NOTE 2: Driving CLK0 input.

NOTE 3: Defined as skew between outputs at the same supply voltage and with equal load conditions. Measured at the output differential cross points.

NOTE 4: This parameter is defined in accordance with JEDEC Standard 65.

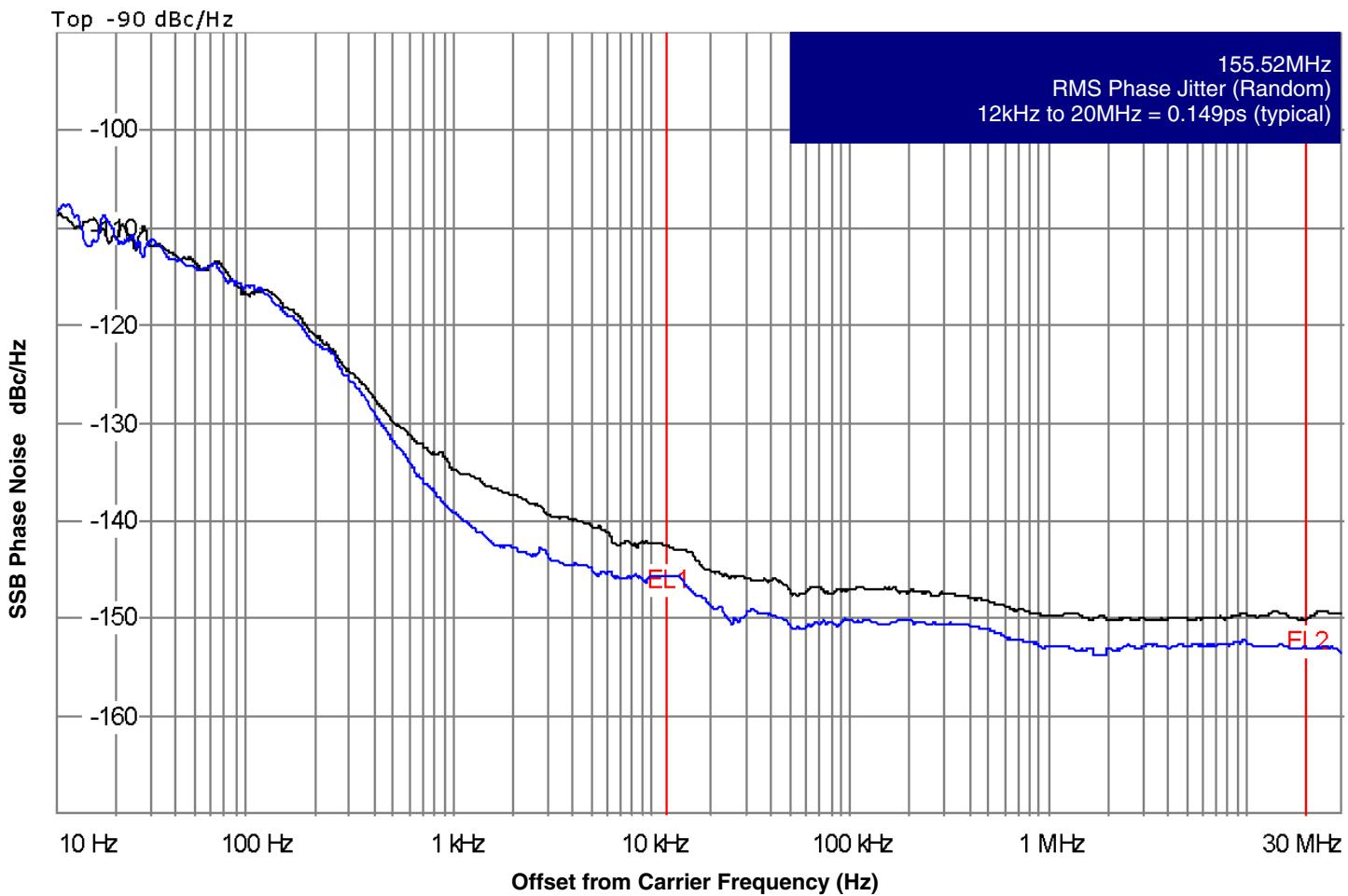
NOTE 5: Defined as skew between outputs on different devices operating at the same supply voltage, same temperature, same frequency and with equal load conditions. Using the same type of inputs on each device, the outputs are measured at the differential cross points.

NOTE 6: Measured on either XTAL0 or XTAL1 when single-ended CLK0 switching at 150MHz or 250MHz.

## 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

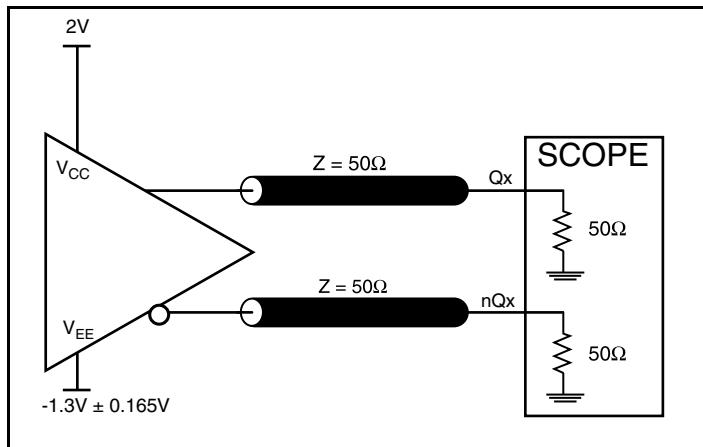
in the fundamental. When the required offset is specified, the phase noise is called a **dBc** value, which simply means dBm at a specified offset from the fundamental. By investigating jitter in the frequency domain, we get a better understanding of its effects on the desired application over the entire time record of the signal. It is mathematically possible to calculate an expected bit error rate given a phase noise plot.



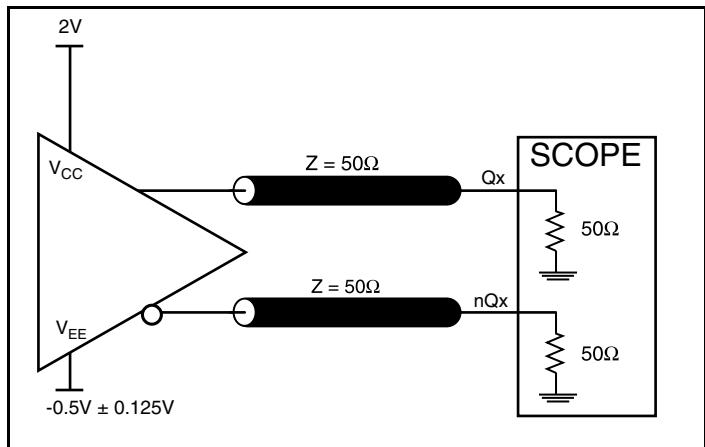
As with most timing specifications, phase noise measurements has issues relating to the limitations of the equipment. Often the noise floor of the equipment is higher than the noise floor of the device. This is illustrated above. The device meets the noise floor of what is shown, but can actually be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

The source generator "SMA 100 Generator 9kHz – 6GHz as external input to an Agilent 8133A 3GHz Pulse Generator".

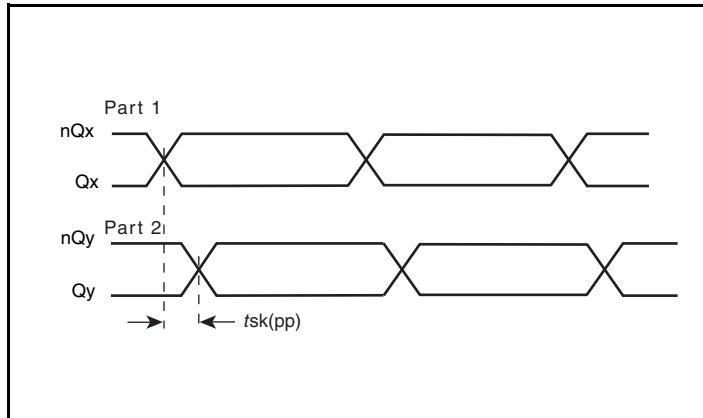
## Parameter Measurement Information



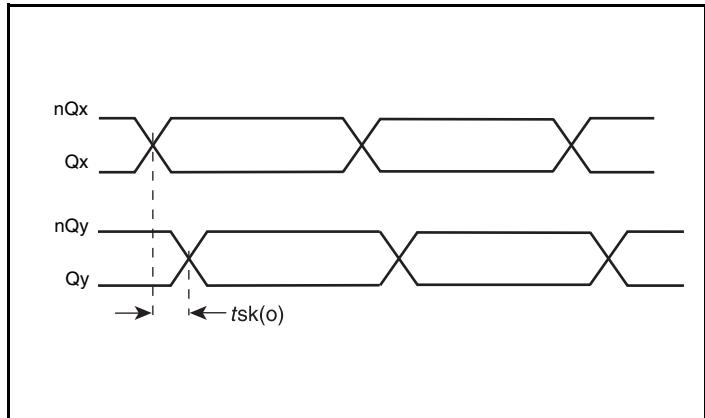
3.3V LVPECL Output Load AC Test Circuit



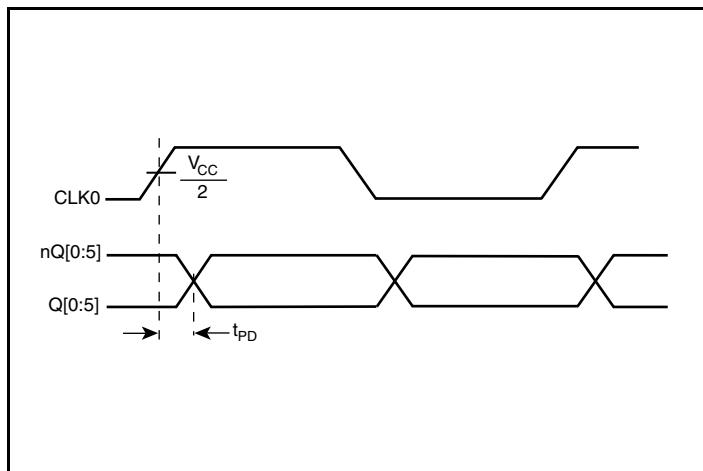
2.5V LVPECL Output Load AC Test Circuit



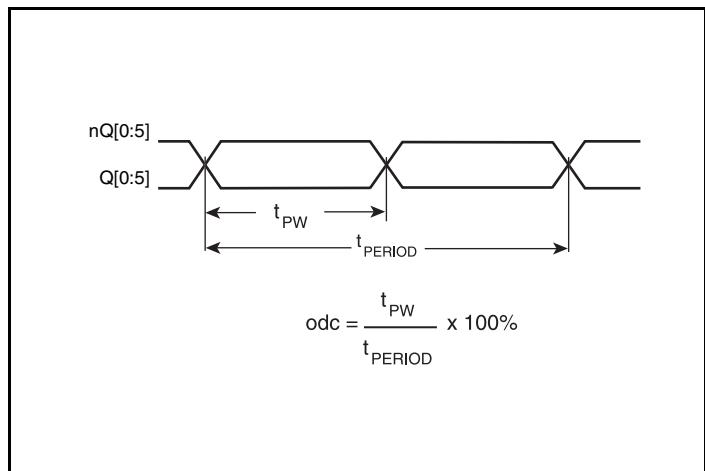
Part-to-Part Skew



Output Skew

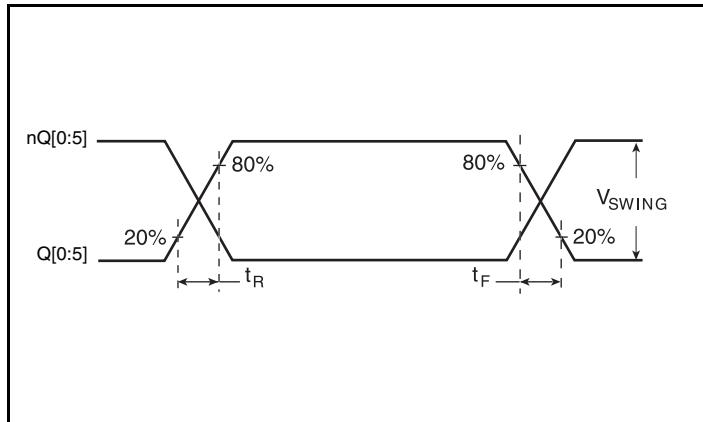


Propagation Delay

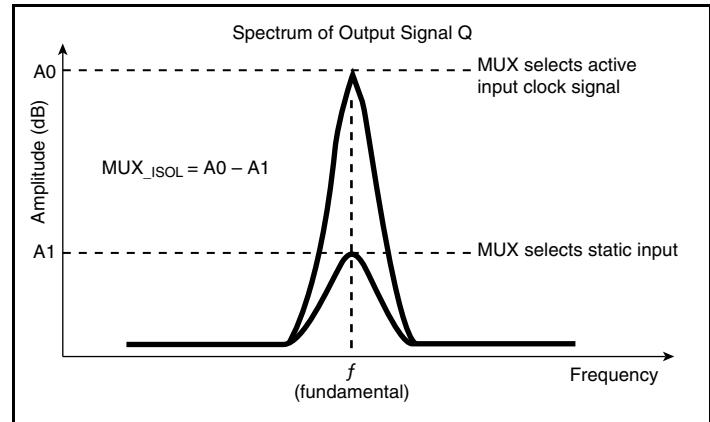


Output Duty Cycle/Pulse Width/Period

## Parameter Measurement Information, continued



Output Rise/Fall Time



MUX\_ISOLATION

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

##### CLK0 Input

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 CLK0 input to ground.

##### LVCMS Control Pins

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

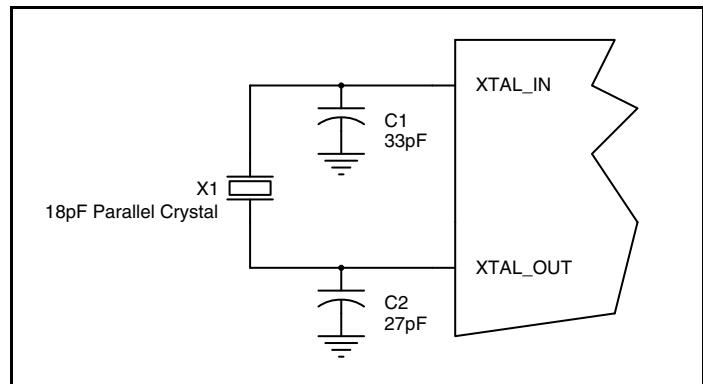
#### Outputs:

##### LVPECL Outputs

The unused LVPECL output pair 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 8536-02 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.

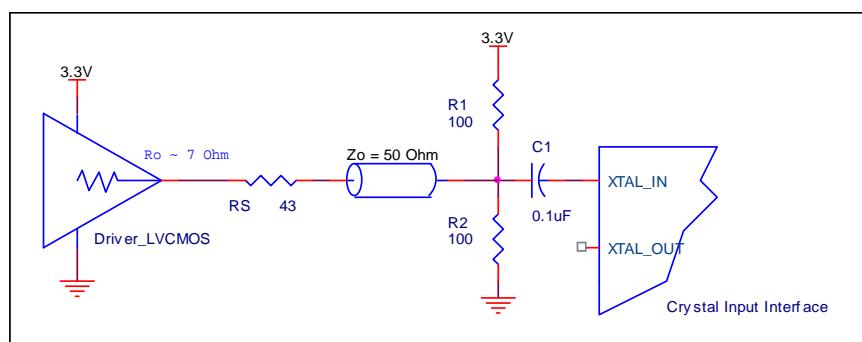


**Figure 2. Crystal Input Interface**

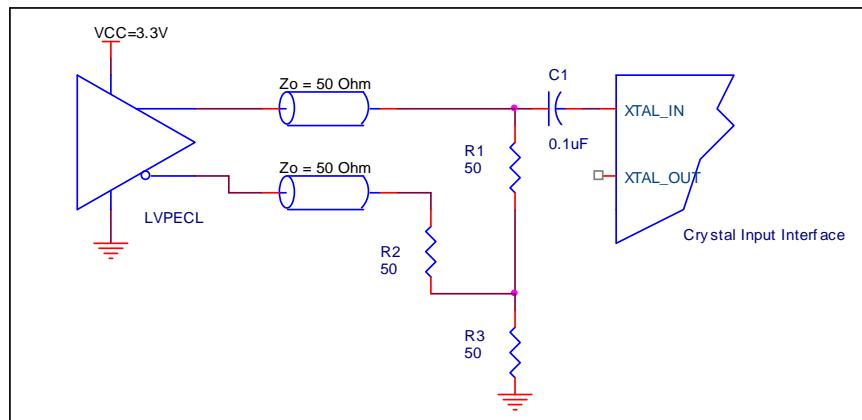
## Overdriving the XTAL Interface

The XTAL\_IN input can accept a single-ended LVCMOS signal through an AC coupling capacitor. A general interface diagram is shown in *Figure 3A*. The XTAL\_OUT pin can be left floating. The maximum amplitude of the input signal should not exceed 2V and the input edge rate can be as slow as 10ns. This configuration requires that the output impedance of the driver ( $R_o$ ) plus the series resistance ( $R_s$ ) equals the transmission line impedance. In addition,

matched termination at the crystal input will attenuate the signal in half. This can be done in one of two ways. First,  $R_1$  and  $R_2$  in parallel should equal the transmission line impedance. For most  $50\Omega$  applications,  $R_1$  and  $R_2$  can be  $100\Omega$ . This can also be accomplished by removing  $R_1$  and making  $R_2 50\Omega$ . By overdriving the crystal oscillator, the device will be functional, but note, the device performance is guaranteed by using a quartz crystal.



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



**Figure 3B. General Diagram for LVPECL 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  $50\Omega$

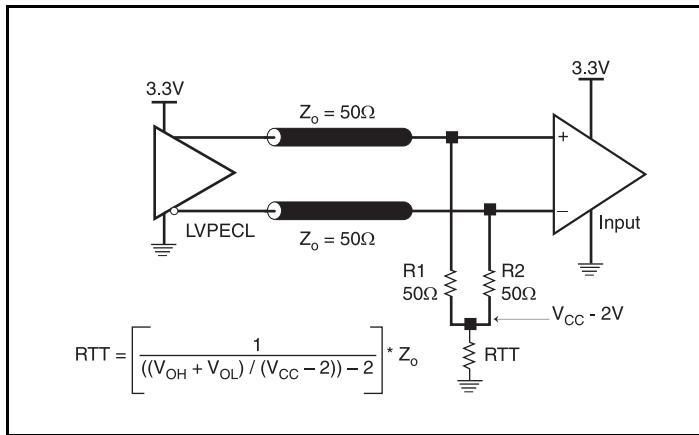


Figure 4A. 3.3V LVPECL Output Termination

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.

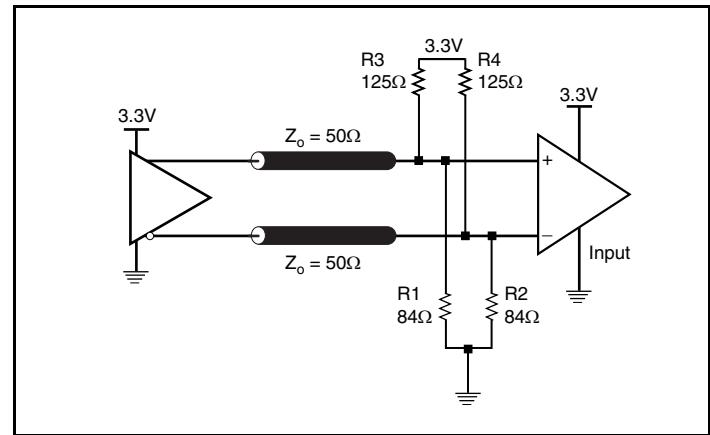


Figure 4B. 3.3V LVPECL Output Termination

## Termination for 2.5V LVPECL Outputs

Figure 5A and Figure 5B show examples of termination for 2.5V LVPECL driver. These terminations are equivalent to terminating 50Ω to  $V_{CC} - 2V$ . For  $V_{CC} = 2.5V$ , the  $V_{CC} - 2V$  is very close to

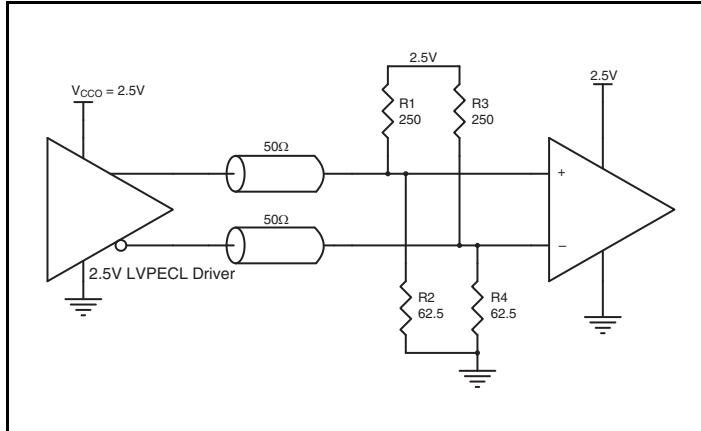


Figure 5A. 2.5V LVPECL Driver Termination Example

ground level. The R3 in Figure 5B can be eliminated and the termination is shown in Figure 5C.

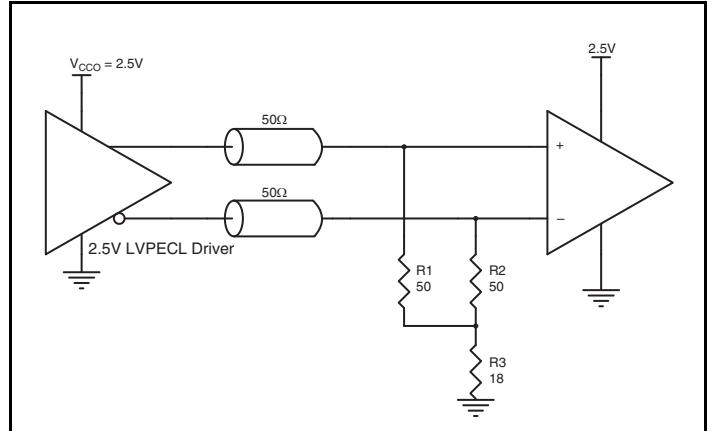


Figure 5B. 2.5V LVPECL Driver Termination Example

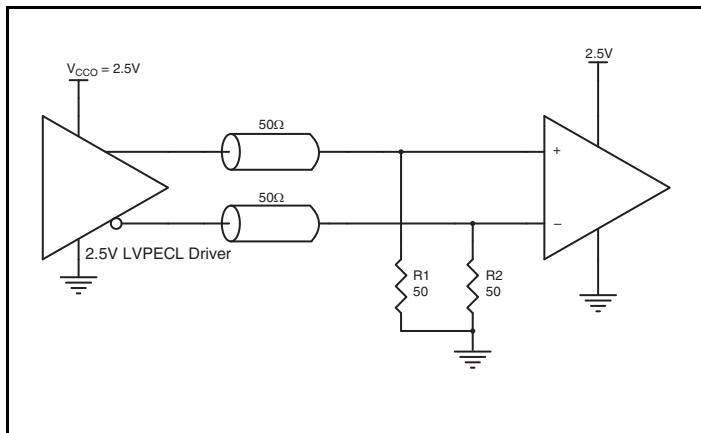


Figure 5C. 2.5V LVPECL Driver Termination Example

## Power Considerations

This section provides information on power dissipation and junction temperature for the 8536-02. Equations and example calculations are also provided.

### 1. Power Dissipation.

The total power dissipation for the 8536-02 is the sum of the core power plus the power dissipated in the load(s). The following is the power dissipation for  $V_{CC} = 3.3V + 5\% = 3.465V$ , 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> =  $V_{CC\_MAX} * I_{EE\_MAX} = 3.465V * 89mA = 308.385mW$
- Power (outputs)<sub>MAX</sub> = **30mW/Loaded Output pair**  
If all outputs are loaded, the total power is  $6 * 30mW = 180mW$

**Total Power<sub>MAX</sub>** (3.3V, with all outputs switching) =  $308.385mW + 180mW = 488.385mW$

### 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 is 125°C. Limiting the internal transistor junction temperature,  $T_j$ , to 125°C ensures that the bond wire and bond pad temperature remains below 125°C.

The equation for  $T_j$  is as follows:  $T_j = \theta_{JA} * P_{d\_total} + T_A$

$T_j$  = Junction Temperature

$\theta_{JA}$  = Junction-to-Ambient Thermal Resistance

$P_{d\_total}$  = 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 87.8°C/W per Table 7 below.

Therefore,  $T_j$  for an ambient temperature of 70°C with all outputs switching is:

$70^{\circ}C + 0.488W * 87.8^{\circ}C/W = 112.8^{\circ}C$ . This is below the limit of 125°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).

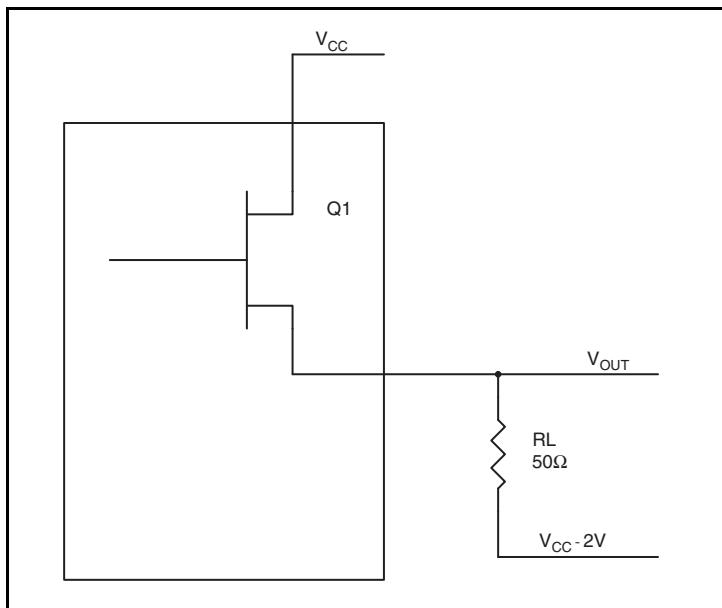
**Table 7. Thermal Resistance  $\theta_{JA}$  for 24 Lead TSSOP, Forced Convection**

$\theta_{JA}$ vs. Air Flow			
Meters per Second	0	1	2.5
Multi-Layer PCB, JEDEC Standard Test Boards	87.8°C/W	83.5°C/W	81.3°C/W

### 3. Calculations and Equations.

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

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  $50\Omega$  load, and a termination voltage of  $V_{CC} - 2V$ .

- For logic high,  $V_{OUT} = V_{OH\_MAX} = V_{CC\_MAX} - 0.9V$   
 $(V_{CC\_MAX} - V_{OH\_MAX}) = 0.9V$
- For logic low,  $V_{OUT} = V_{OL\_MAX} = V_{CC\_MAX} - 1.7V$   
 $(V_{CC\_MAX} - V_{OL\_MAX}) = 1.7V$

$Pd_H$  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 =  $Pd_H + Pd_L = 30mW$

## Reliability Information

Table 8.  $\theta_{JA}$  vs. Air Flow Table for a 24 Lead TSSOP

$\theta_{JA}$ vs. Air Flow			
Meters per Second	0	1	2.5
Multi-Layer PCB, JEDEC Standard Test Boards	87.8°C/W	83.5°C/W	81.3°C/W

## Transistor Count

The transistor count for 8536-02 is: 467

## Package Outline and Package Dimensions

Package Outline - G Suffix for 24 Lead TSSOP

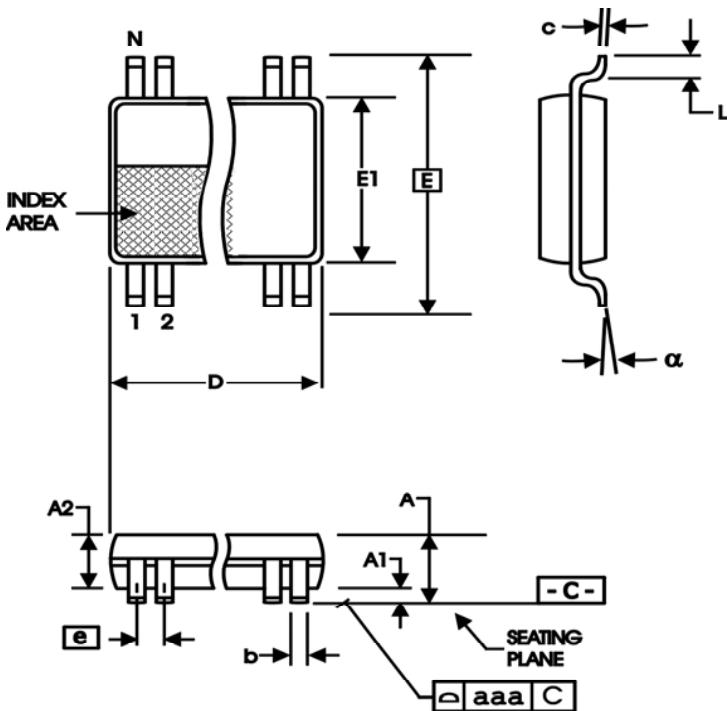


Table 9. Package Dimensions

All Dimensions in Millimeters		
Symbol	Minimum	Maximum
N	24	
A		1.20
A1	0.5	0.15
A2	0.80	1.05
b	0.19	0.30
c	0.09	0.20
D	7.70	7.90
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

## Ordering Information

**Table 10. Ordering Information**

Part/Order Number	Marking	Package	Shipping Packaging	Temperature
8536AG-02LF	ICS8536AG-02L	“Lead-Free” 24 Lead TSSOP	Tube	0°C to 70°C
8536AG-02LFT	ICS8536AG-02L	“Lead-Free” 24 Lead TSSOP	Tape & Reel	0°C to 70°C

NOTE: Parts that are ordered with an "LF" suffix to the part number are the Pb-Free configuration and are RoHS compliant.

## Revision History Sheet

Rev	Table	Page	Description of Change	Date
A	T10	16	Ordering Information - removed leaded devices. Updated data sheet format.	7/10/15



## IMPORTANT NOTICE AND DISCLAIMER

RENESAS ELECTRONICS CORPORATION AND ITS SUBSIDIARIES ("RENESAS") PROVIDES TECHNICAL SPECIFICATIONS AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR NON-INFRINGEMENT OF THIRD-PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for developers who are designing with Renesas products. You are solely responsible for (1) selecting the appropriate products for your application, (2) designing, validating, and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. Renesas grants you permission to use these resources only to develop an application that uses Renesas products. Other reproduction or use of these resources is strictly prohibited. No license is granted to any other Renesas intellectual property or to any third-party intellectual property. Renesas disclaims responsibility for, and you will fully indemnify Renesas and its representatives against, any claims, damages, costs, losses, or liabilities arising from your use of these resources. Renesas' products are provided only subject to Renesas' Terms and Conditions of Sale or other applicable terms agreed to in writing. No use of any Renesas resources expands or otherwise alters any applicable warranties or warranty disclaimers for these products.

(Disclaimer Rev.1.01)

### Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,  
Koto-ku, Tokyo 135-0061, Japan  
[www.renesas.com](http://www.renesas.com)

### Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.

### Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit [www.renesas.com/contact-us/](http://www.renesas.com/contact-us/).