PRELIMINARY

Integrated Circuit Systems, Inc.

ICS8735-31

1:5 Differential-to-3.3V LVPECL Zero Delay Clock Generator

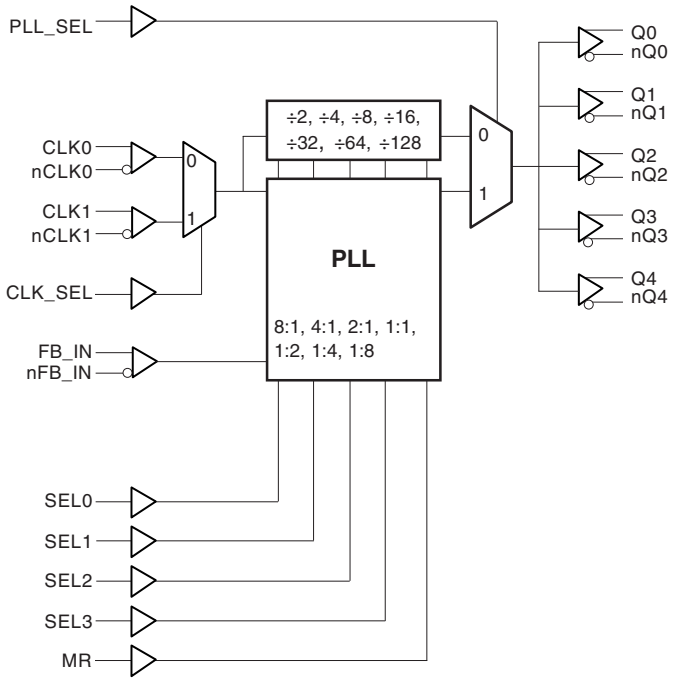
General Description

The ICS8735-31 is a highly versatile 1:5 Differential-to-3.3V LVPECL clock generator and a member of the HiPerClockS™ family of High Performance Clock Solutions from ICS. The ICS8735-31 has a fully integrated PLL and can be configured as zero delay buffer, multiplier or divider, and has an output frequency range of 15.625MHz to 350MHz. The reference divider, feedback divider and output divider are each programmable, thereby allowing for the following output-to-input frequency ratios: 8:1, 4:1, 2:1, 1:1, 1:2, 1:4, 1:8. The external feedback allows the device to achieve "zero delay" between the input clock and the output clocks. The PLL_SEL pin can be used to bypass the PLL for system test and debug purposes. In bypass mode, the reference clock is routed around the PLL and into the internal output dividers.

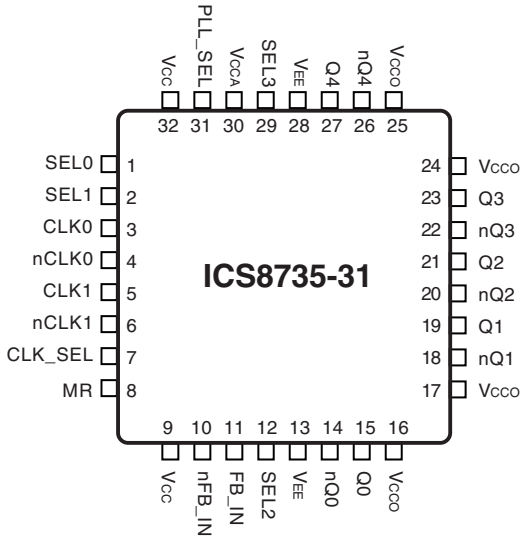
Features

- 5 differential 3.3V LVPECL outputs
- Selectable differential clock inputs
- CLKx, nCLKx pair can accept the following differential input levels: LVDS, LVPECL, LVHSTL, SSTL, HCSL
- Output frequency range: 15.625MHz - 350MHz
- Input frequency range: 15.625MHz - 350MHz
- VCO range: 250MHz - 700MHz
- Programmable dividers allow for the following output-to-input frequency ratios: 8:1, 4:1, 2:1, 1:1, 1:2, 1:4, 1:8
- External feedback for "zero delay" clock regeneration with configurable frequencies
- Cycle-to-cycle jitter: 30ps (typical)
- Output skew: 25ps (typical)
- Static phase offset: TBD ± 100ps
- 3.3V supply voltage
- 0°C to 70°C ambient operating temperature
- Industrial temperature information available upon request

Block Diagram



Pin Assignment



32-Lead QFP (LQFP)
7mm x 7mm x 1.4mm package body
Y Package
Top View

The Preliminary Information presented herein represents a product in prototyping or pre-production. The noted characteristics are based on initial product characterization. Integrated Circuit Systems, Incorporated (ICS) reserves the right to change any circuitry or specifications without notice.

TABLE 1. PIN DESCRIPTIONS

Number	Name	Type		Description
1	SEL0	Input	Pulldown	Determines output divider values in Table 3. LVCMOS interface levels.
2	SEL1	Input	Pulldown	Determines output divider values in Table 3. LVCMOS interface levels.
3	CLK0	Input	Pulldown	Non-inverting differential clock input.
4	nCLK0	Input	Pullup	Inverting differential clock input.
5	CLK1	Input	Pulldown	Non-inverting differential clock input.
6	nCLK1	Input	Pullup	Inverting differential clock input.
7	CLK_SEL	Input	Pulldown	Clock select input. When HIGH, selects CLK1, nCLK1. When LOW, selects CLK0, nCLK0. LVCMOS interface levels.
8	MR	Input	Pulldown	Master reset. Resets the output divider.
9, 32	V_{CC}	Power		Positive supply pins. Connect to 3.3V.
10	nFB_IN	Input	Pullup	Feedback input to phase detector for regenerating clocks with "zero delay".
11	FB_IN	Input	Pulldown	Feedback input to phase detector for regenerating clocks with "zero delay".
12	SEL2	Input	Pulldown	Determines output divider values in Table 3. LVCMOS interface levels.
13, 28	V_{EE}	Power		Negative supply pins. Connect to ground.
14, 15	nQ0, Q0	Output		Differential output pair. LVPECL interface levels.
16, 17, 24, 25	V_{CCO}	Power		Output supply pins. Connect to 3.3V.
18, 19	nQ1, Q1	Output		Differential output pair. LVPECL interface levels.
20, 21	nQ2, Q2	Output		Differential output pair. LVPECL interface levels.
22, 23	nQ3, Q3	Output		Differential output pair. LVPECL interface levels.
26, 27	nQ4, Q4	Output		Differential output pair. LVPECL interface levels.
29	SEL3	Input	Pulldown	Determines output divider values in Table 3. LVCMOS interface levels.
30	V_{CCA}	Power		Analog supply pin. Connect to 3.3V.
31	PLL_SEL	Input	Pullup	Selects between the PLL and reference clock as the input to the dividers. When LOW, selects reference clock.When HIGH, selects PLL. LVCMOS interface levels.

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

TABLE 2. PIN CHARACTERISTICS

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

TABLE 3A. CONTROL INPUT FUNCTION TABLE

Inputs					Outputs PLL_SEL = 1 PLL Enable Mode
SEL3	SEL2	SEL1	SEL0	Reference Frequency Range (MHz)	Q0 - Q4, nQ0 - nQ4
0	0	0	0	125 - 350	÷ 1
0	0	0	1	62.5 - 175	÷ 1
0	0	1	0	31.25 - 87.5	÷ 1
0	0	1	1	15.625 - 43.75	÷ 1
0	1	0	0	125 - 350	÷ 2
0	1	0	1	62.5 - 175	÷ 2
0	1	1	0	31.25 - 87.5	÷ 2
0	1	1	1	125 - 350	÷ 4
1	0	0	0	62.5 - 175	÷ 4
1	0	0	1	125 - 350	÷ 8
1	0	1	0	62.5 - 175	x 2
1	0	1	1	31.25 - 87.5	x 2
1	1	0	0	15.625 - 43.75	x 2
1	1	0	1	31.25 - 87.5	x 4
1	1	1	0	15.625 - 43.75	x 4
1	1	1	1	15.625 - 43.75	x 8

TABLE 3B. PLL BYPASS FUNCTION TABLE

Inputs				Outputs PLL_SEL = 0 PLL Bypass Mode
SEL3	SEL2	SEL1	SEL0	Q0 - Q4, nQ0 - nQ4
0	0	0	0	÷ 8
0	0	0	1	÷ 8
0	0	1	0	÷ 8
0	0	1	1	÷ 16
0	1	0	0	÷ 16
0	1	0	1	÷ 16
0	1	1	0	÷ 32
0	1	1	1	÷ 32
1	0	0	0	÷ 64
1	0	0	1	÷ 128
1	0	1	0	÷ 4
1	0	1	1	÷ 4
1	1	0	0	÷ 8
1	1	0	1	÷ 2
1	1	1	0	÷ 4
1	1	1	1	÷ 2

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, V_{CCx}	4.6V
Inputs, V_I	-0.5V to V_{CC}+0.5 V
Outputs, V_O	-0.5V to V_{CCO}+0.5V
Package Thermal Impedance, θ_{JA}	47.9°C/W (0 lfpm)
Storage Temperature, T_{STG}	-65°C to 150°C

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 4A. POWER SUPPLY DC CHARACTERISTICS, $V_{CC} = V_{CCA} = V_{CCO} = 3.3V±5\%$, T_A = 0°C TO 70°C

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
V_{CC}	Positive Supply Voltage		3.135	3.3	3.465	V
V_{CCA}	Analog Supply Voltage		3.135	3.3	3.465	V
V_{CCO}	Output Supply Voltage		3.135	3.3	3.465	V
I_{EE}	Power Supply Current			100		mA
I_{CCA}	Analog Supply Current			10		mA

TABLE 4B. LVCMOS/LVTTL DC CHARACTERISTICS, $V_{CC} = V_{CCA} = V_{CCO} = 3.3V±5\%$, T_A = 0°C TO 70°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_SEL, MR, SEL0, SEL1, SEL2, SEL3	V_{IN} = *V_{CCx} = 3.465V			150	µA
		PLL_SEL	V_{IN} = *V_{CCx} = 3.465V			5	µA
I_{IL}	Input Low Current	CLK_SEL, MR, SEL0, SEL1, SEL2, SEL3	V_{IN} = 0V, *V_{CCx} = 3.465V	-5			µA
		PLL_SEL	V_{IN} = 0V, *V_{CCx} = 3.465V	-150			µA

*NOTE 1: V_{CCx} denotes V_{CC}, V_{CCA}, and V_{CCO}.

TABLE 4C. DIFFERENTIAL DC CHARACTERISTICS, $V_{CC} = V_{CCA} = V_{CCO} = 3.3V±5\%$, T_A = 0°C TO 70°C

Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
I_{IH}	Input High Current	CLK0, CLK1, FB_IN	$V_{IN} = V_{CC}$ = 3.465V			150	µA
		nCLK0, nCLK1, nFB_IN	$V_{IN} = V_{CC}$ = 3.465V			5	µA
I_{IL}	Input Low Current	CLK0, CLK1, FB_IN	V_{IN} = 0V, V_{CC} = 3.465V	-5			µA
		nCLK0, nCLK1, nFB_IN	V_{IN} = 0V, V_{CC} = 3.465V	-150			µA
V_{PP}	Peak-to-Peak Input Voltage			0.15		1.3	V
V_{CMR}	Common Mode Input Voltage; NOTE 1, 2			V_{EE} + 0.5		V_{CC} - 0.85	V

NOTE 1: For single ended applications, the maximum input voltage for CLK, nCLK is V_{CC} + 0.3V.
NOTE 2: Common mode voltage is defined as V_{IH}.

TABLE 4D. LVPECL DC CHARACTERISTICS, $V_{CC} = V_{CCA} = V_{CCO} = 3.3V \pm 5\%$, $T_A = 0°C$ TO $70°C$

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
V_{OH}	Output High Voltage; NOTE 1		V_{CCO} - 1.4		V_{CCO} - 1.0	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		0.9	V

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

TABLE 5. INPUT FREQUENCY CHARACTERISTICS, $V_{CC} = V_{CCA} = V_{CCO} = 3.3V \pm 5\%$, $T_A = 0°C$ TO $70°C$

Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
f_{IN}	Input Frequency	CLK0, nCLK0, CLK1, nCLK1	PLL_SEL = 1	15.625		350	MHz
			PLL_SEL = 0			700	MHz

TABLE 6. AC CHARACTERISTICS, $V_{CC} = V_{CCA} = V_{CCO} = 3.3V \pm 5\%$, $T_A = 0°C$ TO $70°C$

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
f_{MAX}	Output Frequency				350	MHz
t_{PD}	Propagation Delay; NOTE 1	PLL_SEL = 0V, f ≤ 350MHz		4.5		ns
t(Ø)	Static Phase Offset; NOTE 2, 5	PLL_SEL = 3.3V	-100	TBD	+100	ps
*t*sk(o)	Output Skew; NOTE 3, 5			25		ps
*t*jit(cc)	Cycle-to-Cycle Jitter; NOTE 5			30		ps
*t*jit(θ)	Phase Jitter; NOTE 4, 5			±50		ps
t_L	PLL Lock Time				1	ms
t_R	Output Rise Time	20% to 80% @ 50MHz	300		700	ps
t_F	Output Fall Time	20% to 80% @ 50MHz	300		700	ps
odc	Output Duty Cycle		47		53	%

All parameters measured at f_{MAX} unless noted otherwise.
NOTE 1: Measured from the differential input crossing point to the differential output crossing point.
NOTE 2: Defined as the time difference between the input reference clock and the averaged feedback input signal, when the PLL is locked and the input reference frequency is stable.
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: Phase jitter is dependent on the input source used.
NOTE 5: This parameter is defined in accordance with JEDEC Standard 65.

PARAMETER MEASUREMENT INFORMATION

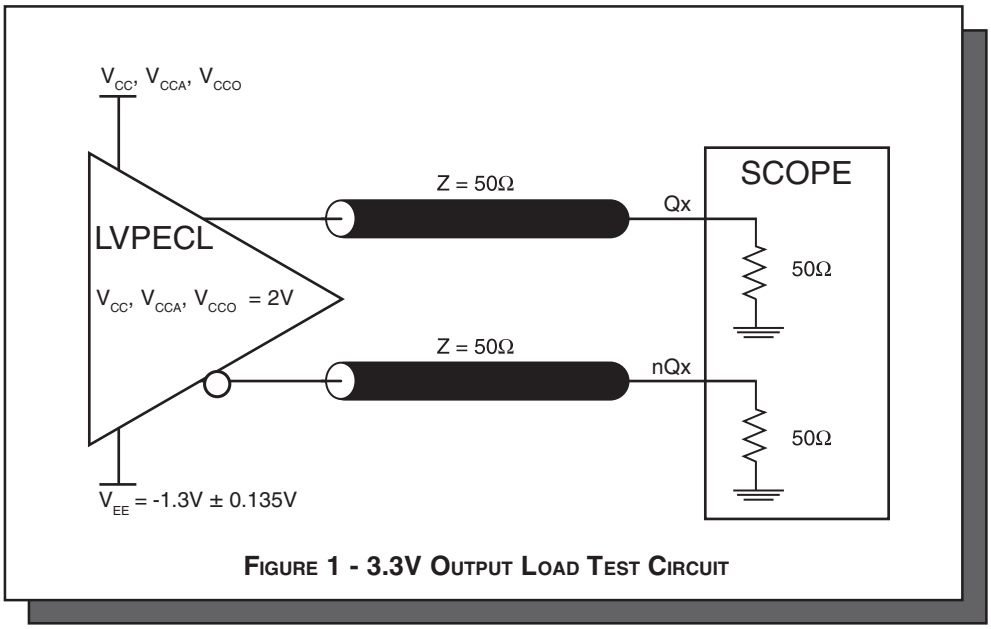


FIGURE 1 - 3.3V OUTPUT LOAD TEST CIRCUIT

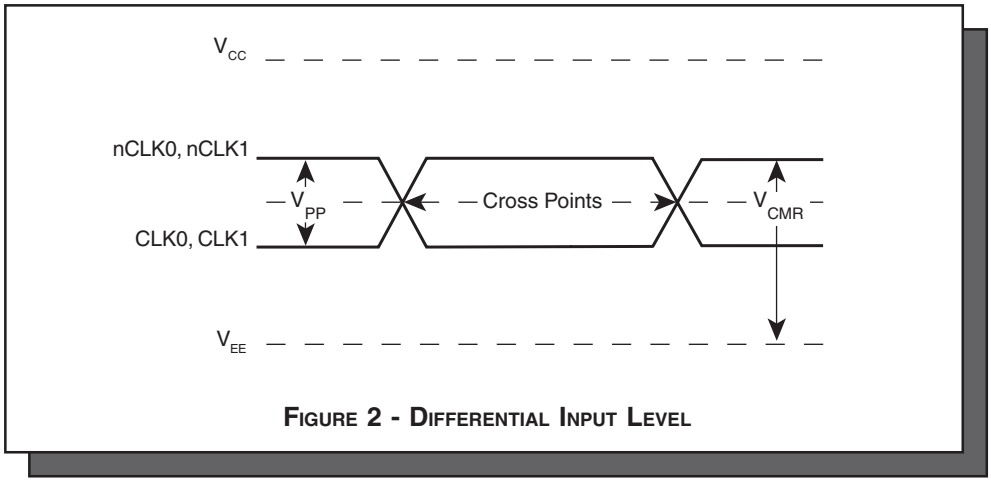


FIGURE 2 - DIFFERENTIAL INPUT LEVEL

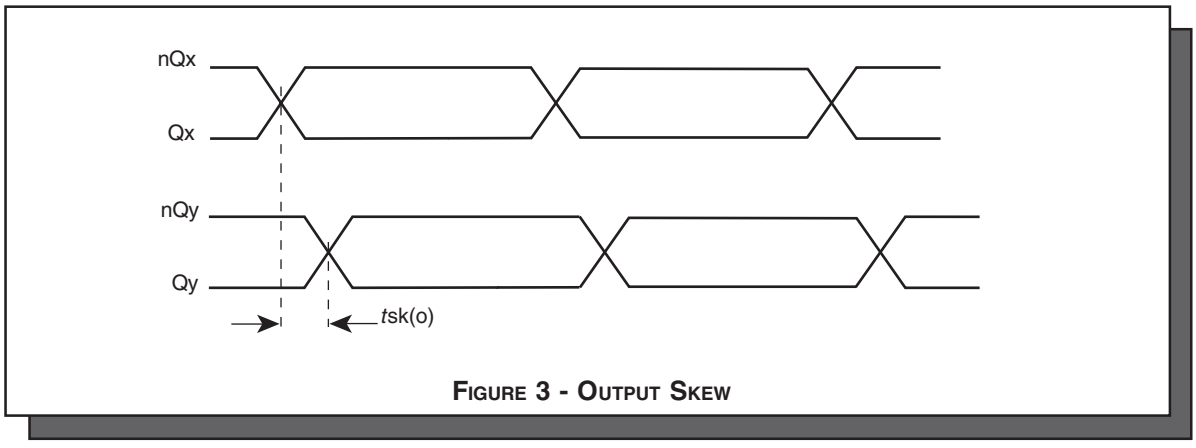
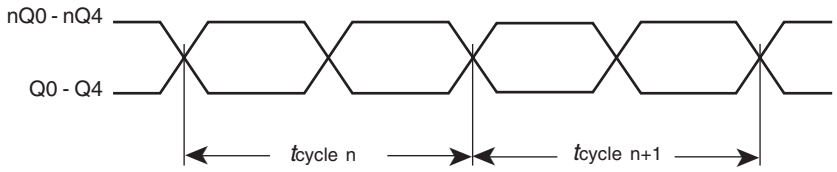
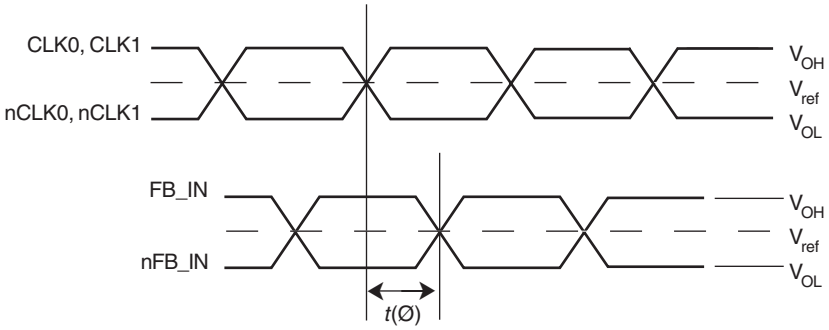


FIGURE 3 - OUTPUT SKEW



$$tjit(cc) = tcycle\ n - tcycle\ n+1$$
1000 Cycles

FIGURE 4 - Cycle-to-Cycle Jitter



$tjit(Ø) = |t(Ø) - t(Ø)\ mean| =$ Phase Jitter $t(Ø)\ mean =$ Static Phase Offset

(where $t(Ø)$ is any random sample, and $t(Ø)\ mean$ is the average of the sampled cycles measured on controlled edges)

FIGURE 5 - PHASE JITTER AND STATIC PHASE OFFSET

FIGURE 6 - INPUT AND OUTPUT RISE AND FALL TIME

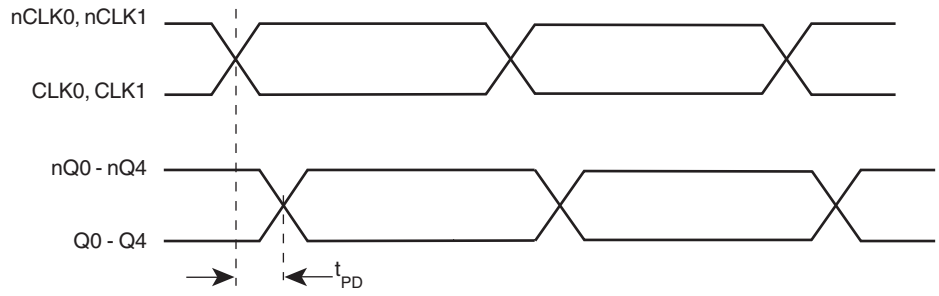


FIGURE 7 - PROPAGATION DELAY

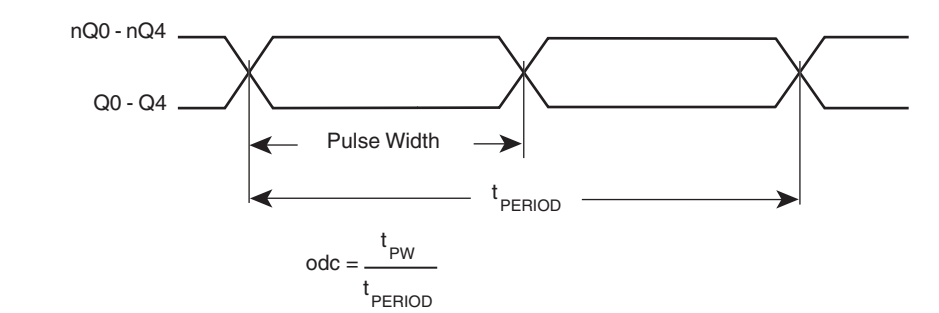


FIGURE 8 - odc & t_{PERIOD}

APPLICATION INFORMATION

WIRING THE DIFFERENTIAL INPUT TO ACCEPT SINGLE ENDED LEVELS

Figure 9 shows how the differential input can be wired to accept single ended levels. The reference voltage V_REF = V_{CC}/2 is generated by the bias resistors R1, R2 and C1. This bias circuit should be located as close as possible to the input pin. The ratio of R1 and R2 might need to be adjusted to position the V_REF in the center of the input voltage swing. For example, if the input clock swing is only 2.5V and V_{CC} = 3.3V, V_REF should be 1.25V and R2/R1 = 0.609.

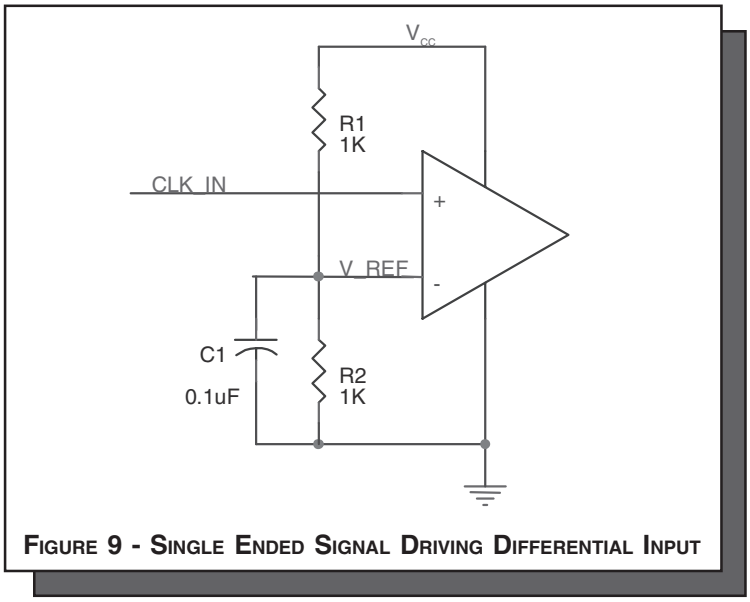


FIGURE 9 - SINGLE ENDED SIGNAL DRIVING DIFFERENTIAL INPUT

POWER SUPPLY FILTERING TECHNIQUES

As in any high speed analog circuitry, the power supply pins are vulnerable to random noise. The ICS8735-31 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 10* illustrates how a 10Ω resistor along with a 10µF and a .01µF bypass capacitor should be connected to each V_{CCA} pin.

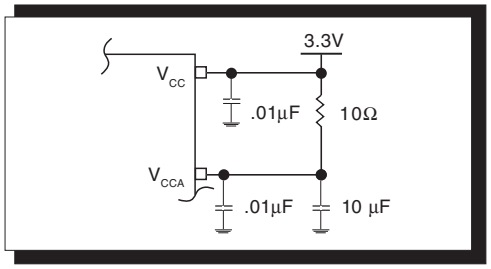


FIGURE 10 - POWER SUPPLY FILTERING

TERMINATION FOR 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.

Qx and nQx 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. There are a few simple termination schemes. *Figures 11A and 11B* 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.

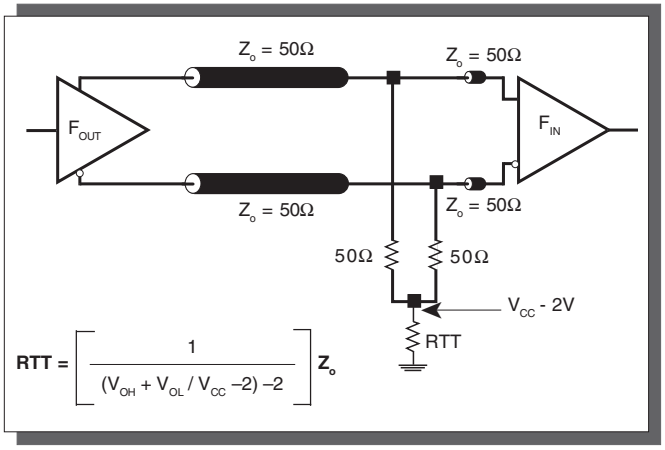


FIGURE 11A - LVPECL OUTPUT TERMINATION

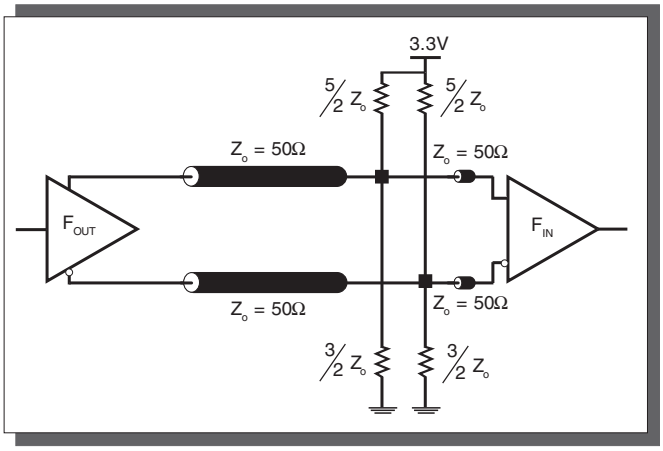


FIGURE 11B - LVPECL OUTPUT TERMINATION

LAYOUT GUIDELINE

The schematic of the ICS8735-31 layout example is shown in *Figure 12.* The ICS8735-31 recommended PCB board layout for this example is shown in *Figure 13.* This layout example is used as a general guideline. The layout in the actual system will depend on the selected component types, the density of the components, the density of the traces, and the stacking of the P.C. board.

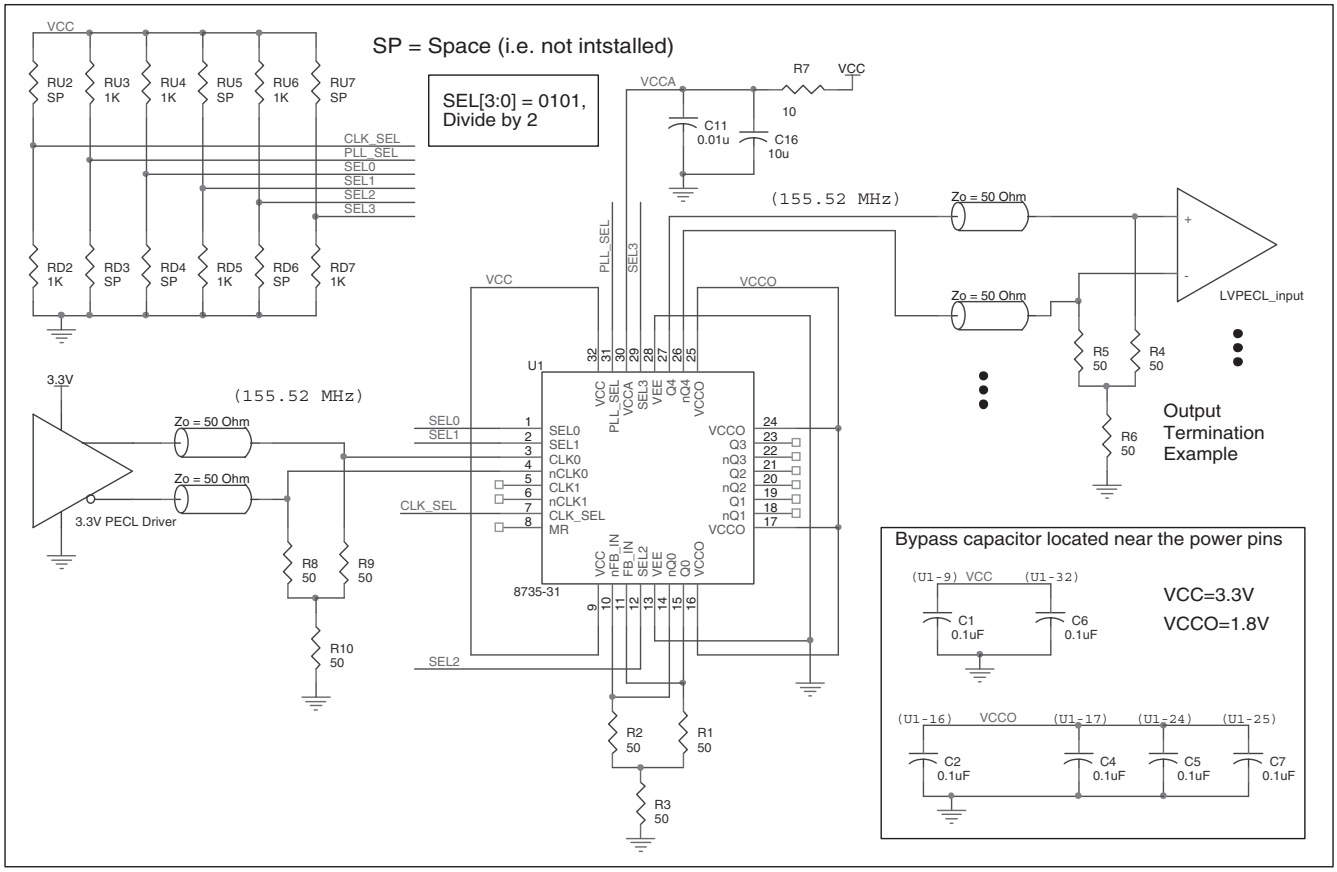


FIGURE 12 - ICS8735-31 LVPECL ZERO DELAY BUFFER SCHEMATIC EXAMPLE

The following component footprints are used in this layout example:

All the resistors and capacitors are size 0603.

POWER AND GROUNDING

Place the decoupling capacitors C1, C6, C2, C4, C5, and C7, as close as possible to the power pins. If space allows, placement of the decoupling capacitor on the component side is preferred. This can reduce unwanted inductance between the decoupling capacitor and the power pin caused by the via.

Maximize the power and ground pad sizes and number of vias capacitors. This can reduce the inductance between the power and ground planes and the component power and ground pins.

The RC filter consisting of R7, C11, and C16 should be placed as close to the V_{CCA} pin as possible.

CLOCK TRACES AND TERMINATION

Poor signal integrity can degrade the system performance or cause system failure. In synchronous high-speed digital systems, the clock signal is less tolerant to poor signal integrity than other signals. Any ringing on the rising or falling edge or excessive ring back can cause system failure. The shape of the trace and the trace delay might be restricted by the available space on the board and the component location. While routing the traces, the clock signal traces should be routed first and should be locked prior to routing other signal traces.

- The differential 50Ω output traces should have same length.
- Avoid sharp angles on the clock trace. Sharp angle turns cause the characteristic impedance to change on the transmission lines.
- Keep the clock traces on the same layer. Whenever possible, avoid placing vias on the clock traces. Placement of vias on the traces can affect the trace characteristic impedance and hence degrade signal integrity.
- To prevent cross talk, avoid routing other signal traces in parallel with the clock traces. If running parallel traces is unavoidable, allow a spearation of at least three trace widths between the differential clock trace and the other signal trace.
- Make sure no other signal traces are routed between the clock trace pair.
- The matching termination resistors should be located as close to the receiver input pins as possible.

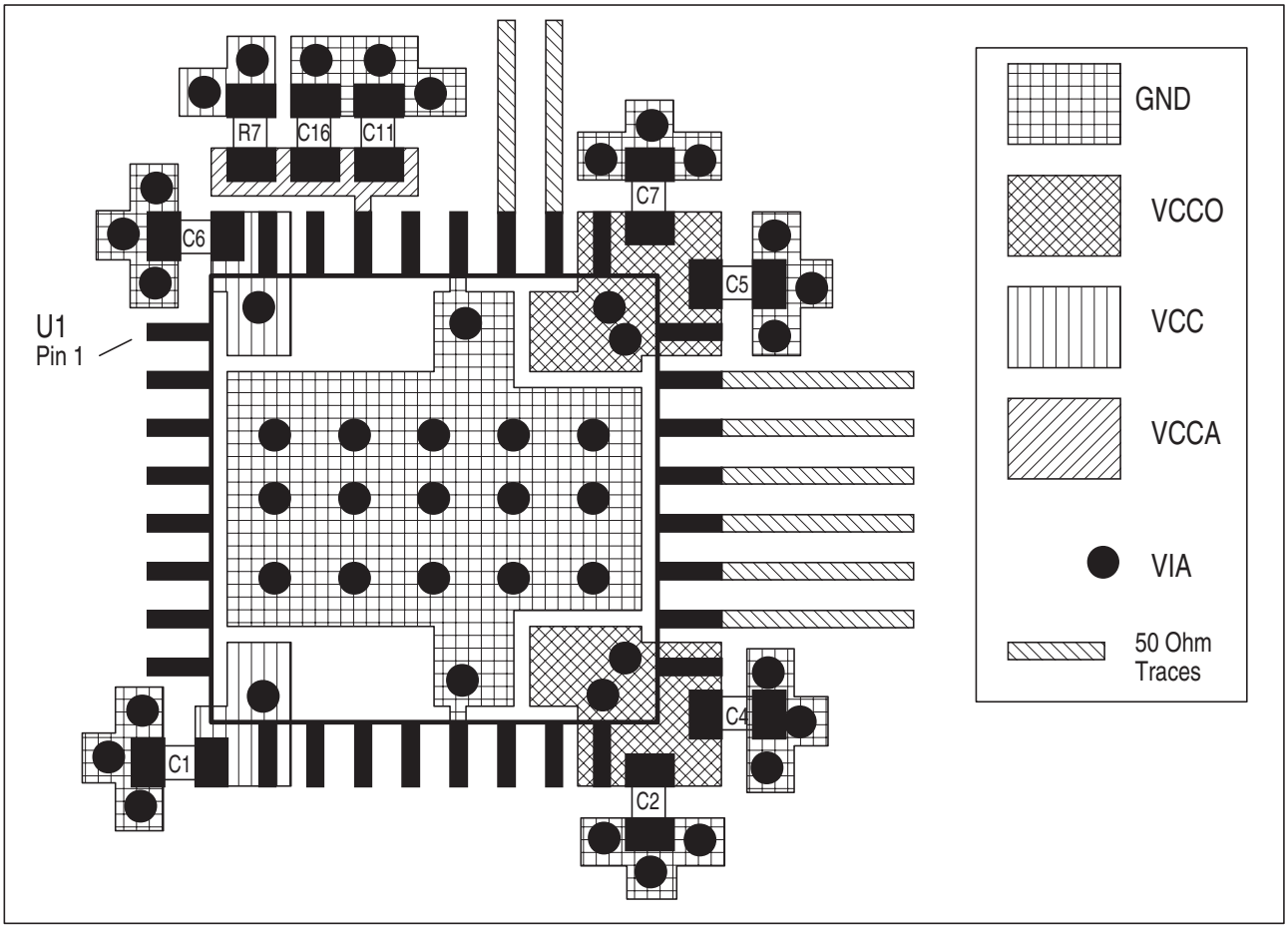


FIGURE 13 - PCB BOARD LAYOUT FOR ICS8735-31

POWER CONSIDERATIONS

This section provides information on power dissipation and junction temperature for the ICS8735-31.
Equations and example calculations are also provided.

1. Power Dissipation.
The total power dissipation for the ICS8735-31 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 $(core)_{MAX} = V_{CC\_MAX} * I_{EE\_MAX}$ = 3.465V * 100mA = **347mW**
- Power $(outputs)_{MAX}$ = **30.2mW/Loaded Output pair**
  If all outputs are loaded, the total power is 5 * 30.2mW = **151mW**

Total Power$_{_MAX}$ (3.465V, with all outputs switching) = 347mW + 151mW = **498mW**

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 42.1°C/W per Table 7 below.

Therefore, Tj for an ambient temperature of 70°C with all outputs switching is:
70°C + 0.498W * 42.1°C/W = 91°C. This is well 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 32-pin LQFP, Forced Convection

θ_{JA} by Velocity (Linear Feet per Minute)	0	200	500
Single-Layer PCB, JEDEC Standard Test Boards	67.8°C/W	55.9°C/W	50.1°C/W
Multi-Layer PCB, JEDEC Standard Test Boards	47.9°C/W	42.1°C/W	39.4°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 14.*

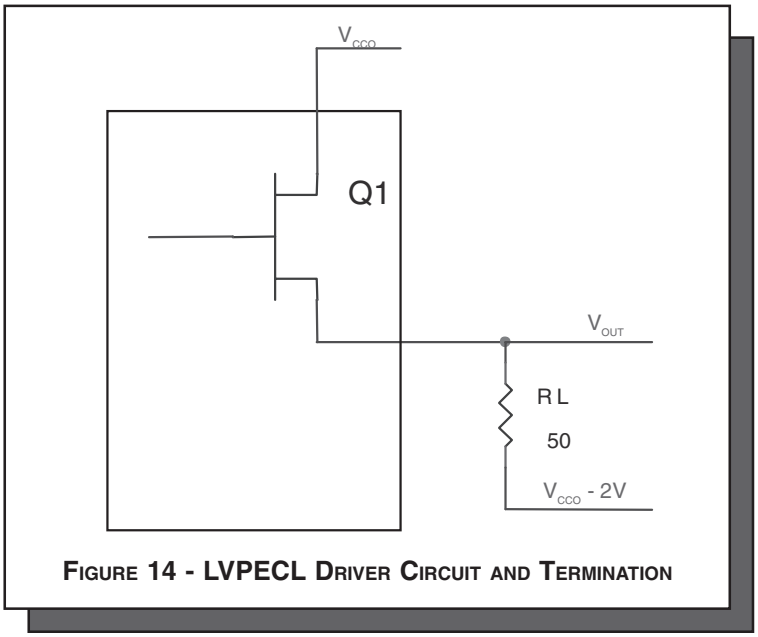


FIGURE 14 - LVPECL DRIVER CIRCUIT AND TERMINATION

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, $V_{OUT} = V_{OH\_MAX} = \mathbf{V_{CCO\_MAX} - 1.0V}$

  $(V_{CCO\_MAX} - V_{OH\_MAX}) = \mathbf{1.0V}$

- 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.

$Pd\_H = [(V_{OH\_MAX} – (V_{CC\_MAX} - 2V))/R_L] * (V_{CC\_MAX} - V_{OH\_MAX}) = [(2V - (V_{CCO} - V_{OH\_MAX}))/R_L] * (V_{CCO} - V_{OH\_MAX}) = (2V - 1V) * 1V = 20.0mW$

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

Total Power Dissipation per output pair = Pd_H + Pd_L = **30.2mW**

RELIABILITY INFORMATION

TABLE 8. θ_{JA} VS. AIR FLOW TABLE

θ_{JA} by Velocity (Linear Feet per Minute)			
	0	**200**	**500**
Single-Layer PCB, JEDEC Standard Test Boards	67.8°C/W	55.9°C/W	50.1°C/W
Multi-Layer PCB, JEDEC Standard Test Boards	47.9°C/W	42.1°C/W	39.4°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 ICS8735-31 is: 2969

PACKAGE OUTLINE - Y SUFFIX

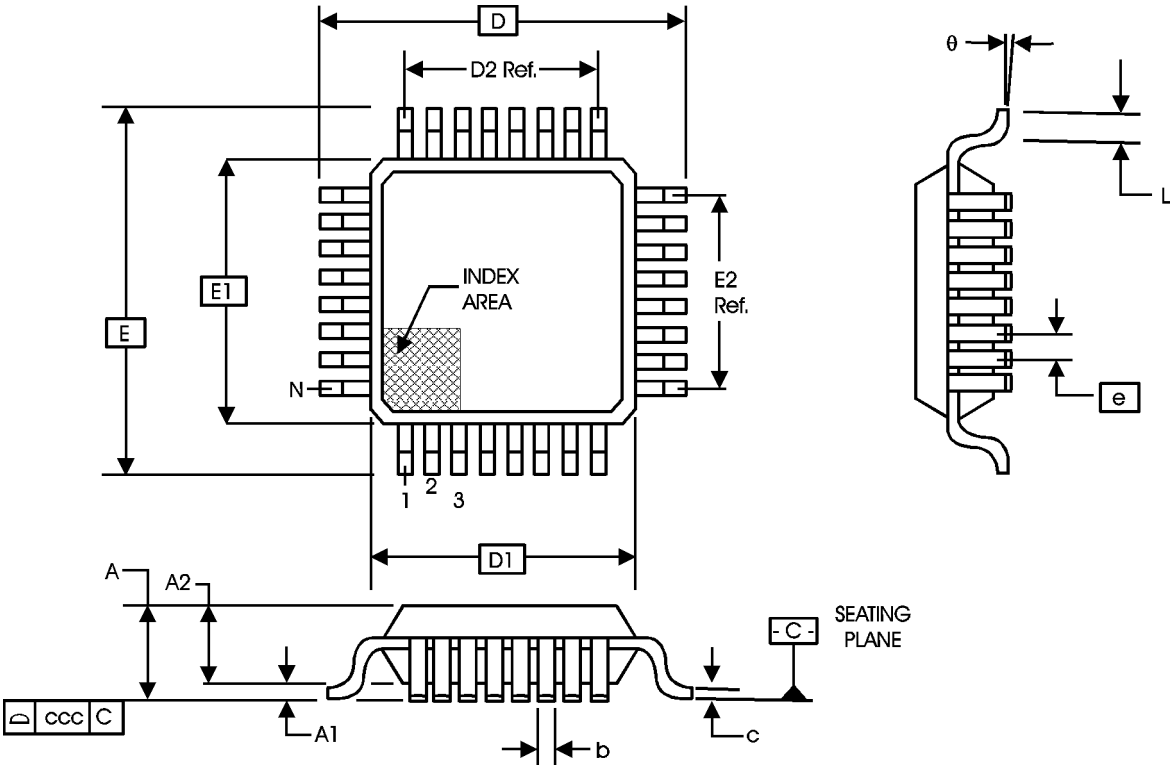


TABLE 9. PACKAGE DIMENSIONS

JEDEC VARIATION ALL DIMENSIONS IN MILLIMETERS			
SYMBOL	BBA		
	MINIMUM	NOMINAL	MAXIMUM
N		32	
A	--	--	1.60
A1	0.05	--	0.15
A2	1.35	1.40	1.45
b	0.30	0.37	0.45
c	0.09	--	0.20
D		9.00 BASIC	
D1		7.00 BASIC	
D2		5.60 Ref.	
E		9.00 BASIC	
E1		7.00 BASIC	
E2		5.60 Ref.	
e		0.80 BASIC	
L	0.45	0.60	0.75
θ	0°	--	7°
ccc	--	--	0.10

Reference Document: JEDEC Publication 95, MS-026

TABLE 10. ORDERING INFORMATION

Part/Order Number	Marking	Package	Count	Temperature
ICS8735AY-31	ICS8735AY-31	32 Lead LQFP	250 per tray	0°C to 70°C
ICS8735AY-31T	ICS8735AY-31	32 Lead LQFP on Tape and Reel	1000	0°C to 70°C