ICS8EN31AK
LOW SKEW, 1-TO-9 DIFFERENTIAL-TO-3.3V LVPECL FANOUT BUFFER

GENERAL DESCRIPTION

ICS HiPerClockS™

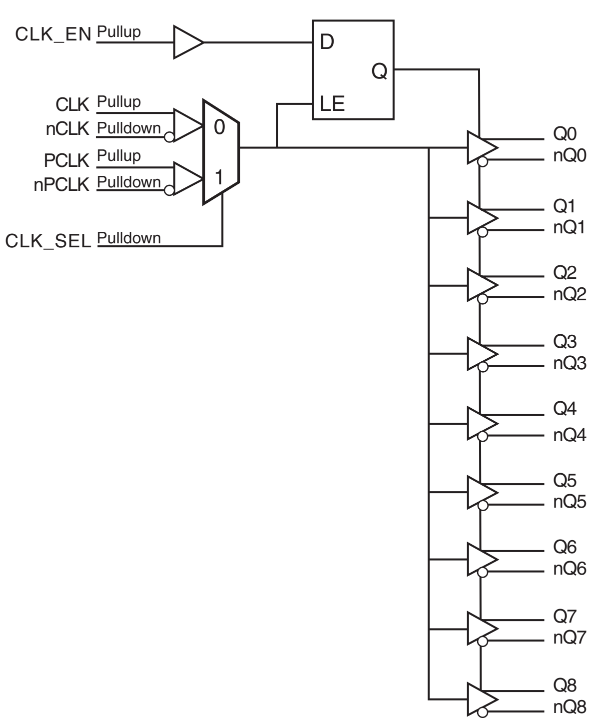
The ICS8EN31AK is a low skew, high performance 1-to-9 Differential-to-3.3V LVPECL Fanout Buffer and a member of the HiPerClockS™ family of High Performance Clock Solutions from ICS. The ICS8EN31AK has two selectable clock inputs. The CLK, nCLK pair can accept most standard differential input levels. The PCLK, nPCLK pair can accept LVPECL, CML, or SSTL input levels. The clock enable is internally synchronized to eliminate runt pulses on the outputs during asynchronous assertion/deassertion of the clock enable pin.

Guaranteed output skew and part-to-part skew characteristics make the ICS8EN31AK ideal for high performance workstation and server applications.

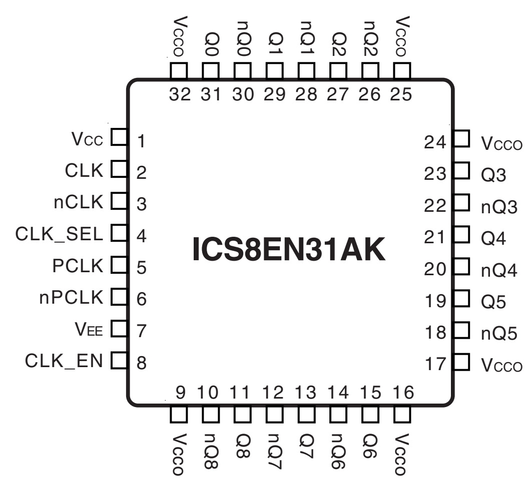
FEATURES

- Nine differential 3.3V LVPECL outputs
- Selectable differential CLK, nCLK or LVPECL clock inputs
- CLK, nCLK pair can accept the following differential input levels: LVPECL, LVDS, LVHSTL, SSTL, HCSL
- PCLK, nPCLK supports the following input types: LVPECL, CML, SSTL
- Maximum output frequency: 500MHz
- Translates any single ended input signal (LVCMOS, LVTTL, GTL) to 3.3V LVPECL levels with resistor bias on nCLK input
- Output skew: 40ps (maximum)
- Part-to-part skew: 350ps (maximum)
- Propagation delay: 1.9ns (maximum)
- 3.3V operating supply
- 0°C to 70°C ambient operating temperature
- Available in both standard and lead-free RoHS compliant packages
- Industrial temperature information available upon request

BLOCK DIAGRAM



PIN ASSIGNMENT



32-Lead VFQFN
5mm x 5mm x 0.95 package body
K Package
Top View

TABLE 1. PIN DESCRIPTIONS

Number	Name	Type		Description
1	V_{CC}	Power		Power supply pin.
2	CLK	Input	Pulldown	Non-inverting differential clock input.
3	nCLK	Input	Pullup	Inverting differential clock input.
4	CLK_SEL	Input	Pulldown	Clock Select input. When HIGH, selects PCLK, nPCLK inputs. When LOW, selects CLK, nCLK. LVTTL / LVCMOS interface levels.
5	PCLK	Input	Pulldown	Non-inverting differential LVPECL clock input.
6	nPCLK	Input	Pullup	Inverting differential LVPECL clock input.
7	V_{EE}	Power		Negative supply pin.
8	CLK_EN	Input	Pullup	Synchronizing clock enable. When HIGH, clock outputs follow clock input. When LOW, Q outputs are forced low, nQ outputs are forced high. LVTTL / LVCMOS interface levels.
9, 16, 17, 24, 25, 32	V_{CCO}	Power		Output supply pins.
10, 11	nQ8, Q8	Output		Differential output pair. LVPECL interface level.
12, 13	nQ7, Q7	Output		Differential output pair. LVPECL interface level.
14, 15	nQ6, Q6	Output		Differential output pair. LVPECL interface level.
18, 19	nQ5, Q5	Output		Differential output pair. LVPECL interface level.
20, 21	nQ4, Q4	Output		Differential output pair. LVPECL interface level.
22, 23	nQ3 Q3	Output		Differential output pair. LVPECL interface level.
26, 27	nQ2, Q2	Output		Differential output pair. LVPECL interface level.
28, 29	nQ1, Q1	Output		Differential output pair. LVPECL interface level.
30, 31	nQ0, Q0	Output		Differential output pair. LVPECL interface level.

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

TABLE 3A. CONTROL INPUT FUNCTION TABLE

Inputs			Outputs	
CLK_EN	**CLK_SEL**	**Selected Source**	**Q0:Q8**	**nQ0:nQ8**
0	0	CLK, nCLK	Disabled; LOW	Disabled; HIGH
0	1	PCLK, nPCLK	Disabled; LOW	Disabled; HIGH
1	0	CLK, nCLK	Enabled	Enabled
1	1	PCLK, nPCLK	Enabled	Enabled

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

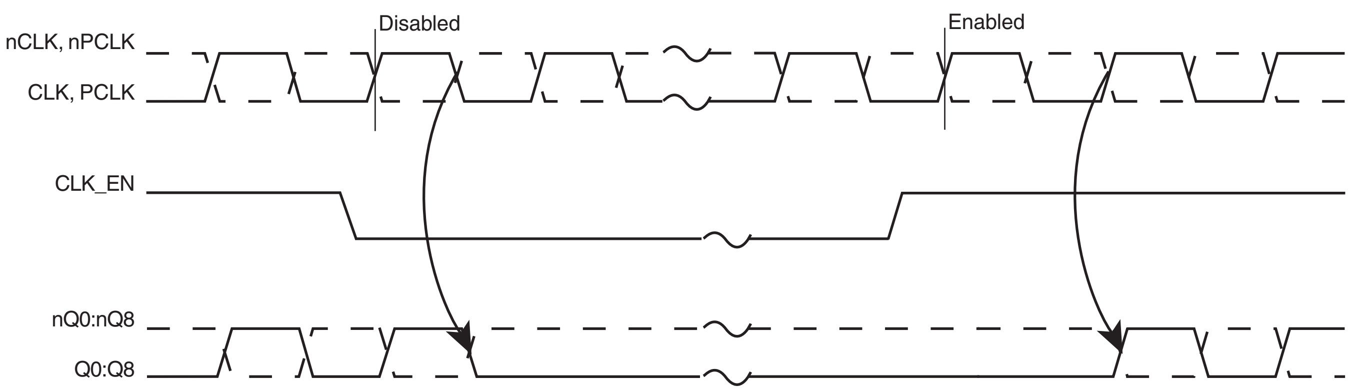


FIGURE 1. CLK_EN TIMING DIAGRAM

TABLE 3B. CLOCK INPUT FUNCTION TABLE

Inputs		Outputs		Input to Output Mode	Polarity
CLK or PCLK	**nCLK or nPCLK**	**Q0:Q8**	**nQ0:nQ8**		
0	1	LOW	HIGH	Differential to Differential	Non Inverting
1	0	HIGH	LOW	Differential to Differential	Non Inverting
0	Biased; NOTE 1	LOW	HIGH	Single Ended to Differential	Non Inverting
1	Biased; NOTE 1	HIGH	LOW	Single Ended to Differential	Non Inverting
Biased; NOTE 1	0	HIGH	LOW	Single Ended to Differential	Inverting
Biased; NOTE 1	1	LOW	HIGH	Single Ended to Differential	Inverting

NOTE 1: Please refer to the Application Information section, "Wiring the Differential Input to Accept Single Ended Levels".

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}	34.8°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 4A. POWER SUPPLY DC CHARACTERISTICS, $V_{CC} = V_{CCO}$ = 3.3V±5%, TA = 0°C TO 70°C

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
V_{CC}	Power 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				80	mA

TABLE 4B. LVCMOS / LVTTL DC CHARACTERISTICS, $V_{CC} = V_{CCO}$ = 3.3V±5%, TA = 0°C TO 70°C

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

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

Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
I_{IH}	Input High Current	CLK	$V_{CC} = V_{IN}$ = 3.465V			150	µA
		nCLK	$V_{CC} = V_{IN}$ = 3.465V			5	µA
I_{IL}	Input Low Current	CLK	V_{IN} = 0V, V_{CC} = 3.465V	-5			µA
		nCLK	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 and nCLK is V_{CC} + 0.3V.
NOTE 2: Common mode input voltage is defined as V_{IH}.

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

Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
I_{IH}	Input High Current	PCLK	$V_{CC} = V_{IN} = 3.465V$			150	µA
		nPCLK	$V_{CC} = V_{IN} = 3.465V$			5	µA
I_{IL}	Input Low Current	PCLK	$V_{IN} = 0V$, $V_{CC} = 3.465V$	-5			µA
		nPCLK	$V_{IN} = 0V$, $V_{CC} = 3.465V$	-150			µA
V_{PP}	Peak-to-Peak Input Voltage			0.3		1	V
V_{CMR}	Common Mode Input Voltage; NOTE 1, 2			V_{EE} + 1.5		V_{CC}	V
V_{OH}	Output High Voltage; NOTE 3			V_{CCO} - 1.4		V_{CCO} - 0.9	V
V_{OL}	Output Low Voltage; NOTE 3			V_{CCO} - 2.0		V_{CCO} - 1.7	V
V_{SWING}	Peak-to-Peak Output Voltage Swing			0.6		1.0	V

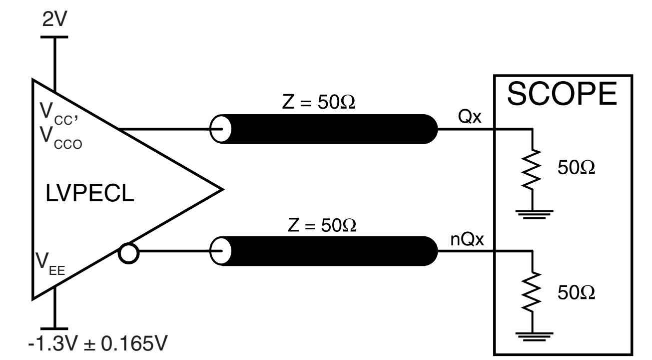
NOTE 1: Common mode input voltage is defined as V_{IH}.
NOTE 2: For single ended applications, the maximum input voltage for PCLK and nPCLK is V_{CC} + 0.3V.
NOTE 3: Outputs terminated with 50Ω to V_{CCO} - 2V.

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

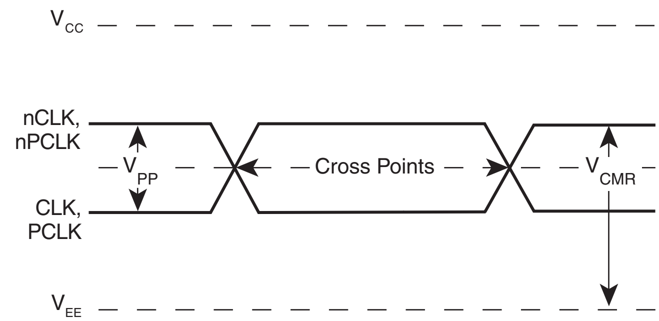
Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
f_{MAX}	Output Frequency				500	MHz
t_{PD}	Propagation Delay; NOTE 1		0.9		1.9	ns
*t*sk(o)	Output Skew; NOTE 2, 4				40	ps
*t*sk(pp)	Part-to-Part Skew; NOTE 3, 4				350	ps
t_R / t_F	Output Rise/Fall Time	20% to 80%	250		600	ps
odc	Output Duty Cycle		45	50	55	%

NOTE 1: Measured from the differential input crossing point 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 output differential cross points.
NOTE 3: Defined as skew between outputs on different devices operating at the same supply voltages and with equal load conditions. Using the same type of inputs on each device, the outputs are measured at the differential cross points.
NOTE 4: This parameter is defined in accordance with JEDEC Standard 65.

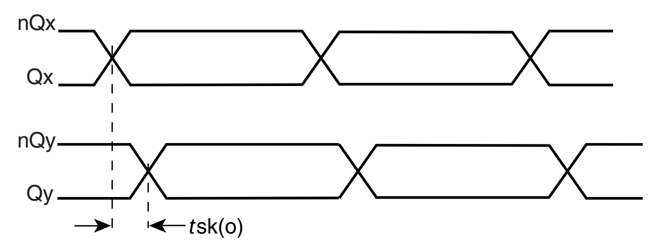
PARAMETER MEASUREMENT INFORMATION



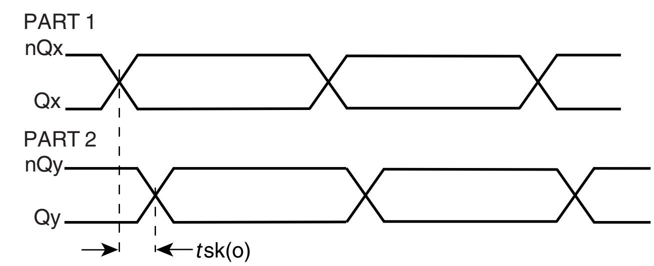
3.3V OUTPUT LOAD AC TEST CIRCUIT



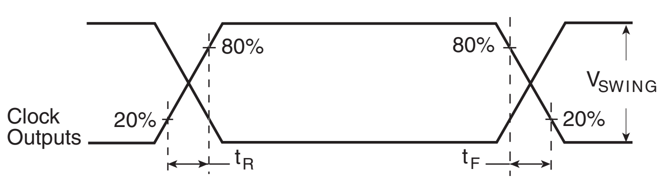
DIFFERENTIAL INPUT LEVEL



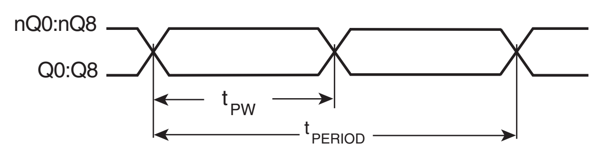
OUTPUT SKEW



PART-TO-PART SKEW

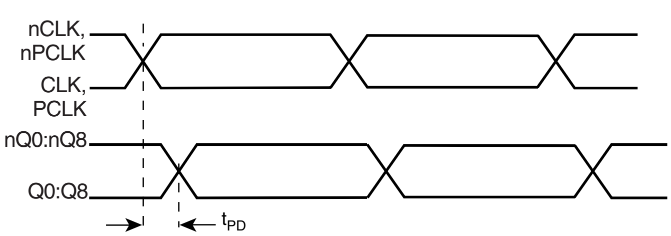


OUTPUT RISE/FALL TIME



$$odc = \frac{t_{PW}}{t_{PERIOD}} \times 100\%$$

OUTPUT DUTY CYCLE/PULSE WIDTH/PERIOD



PROPAGATION DELAY

APPLICATION INFORMATION

WIRING THE DIFFERENTIAL INPUT TO ACCEPT SINGLE ENDED LEVELS

Figure 2 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.

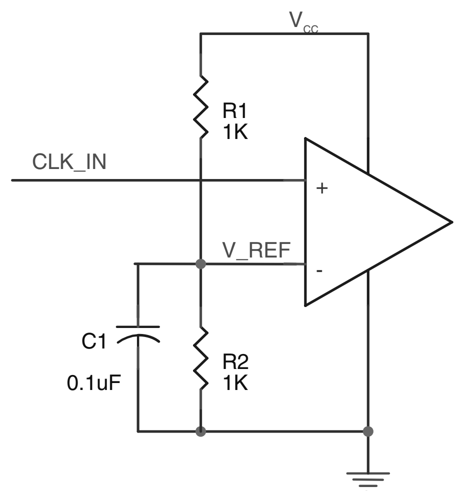


FIGURE 2. SINGLE ENDED SIGNAL DRIVING DIFFERENTIAL INPUT

RECOMMENDATIONS FOR UNUSED INPUT AND OUTPUT PINS

INPUTS:

CLK/nCLK INPUT:
For applications not requiring the use of the differential input, both CLK and nCLK can be left floating. Though not required, but for additional protection, a 1kΩ resistor can be tied from CLK to ground.

PCLK/nPCLK INPUT:
For applications not requiring the use of a differential input, both the PCLK and nPCLK pins can be left floating. Though not required, but for additional protection, a 1kΩ resistor can be tied from PCLK 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.

DIFFERENTIAL CLOCK INPUT INTERFACE

The CLK /nCLK accepts LVDS, LVPECL, LVHSTL, SSTL, HCSL and other differential signals. Both V_{SWING} and V_{OH} must meet the V_{PP} and V_{CMR} input requirements. Figures 3A to 3E show interface examples for the HiPerClockS CLK/nCLK input driven by the most common driver types. The input interfaces suggested here are examples only. Please consult with the vendor of the driver component to confirm the driver termination requirements. For example in *Figure 3A,* the input termination applies for ICS HiPerClockS LVHSTL drivers. If you are using an LVHSTL driver from another vendor, use their termination recommendation.

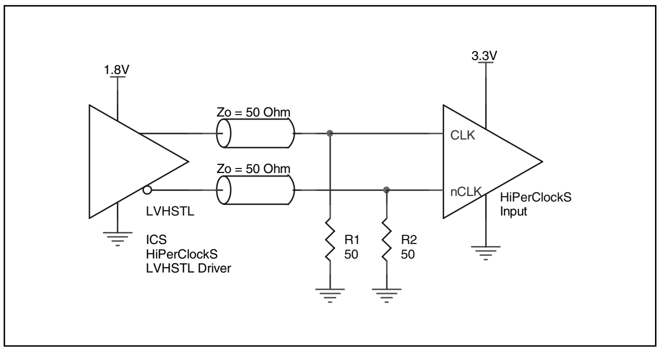


FIGURE 3A. HIPERCLOCKS CLK/nCLK INPUT DRIVEN BY ICS HIPERCLOCKS LVHSTL DRIVER

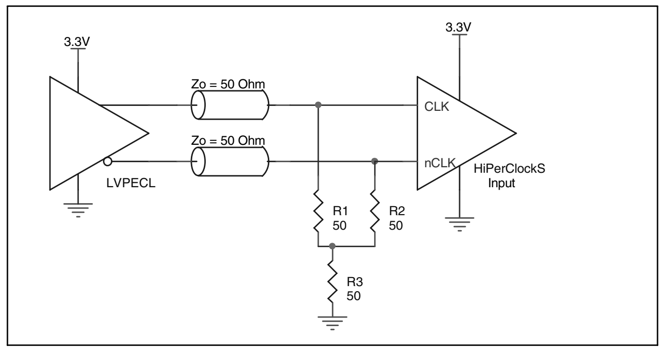


FIGURE 3B. HIPERCLOCKS CLK/nCLK INPUT DRIVEN BY 3.3V LVPECL DRIVER

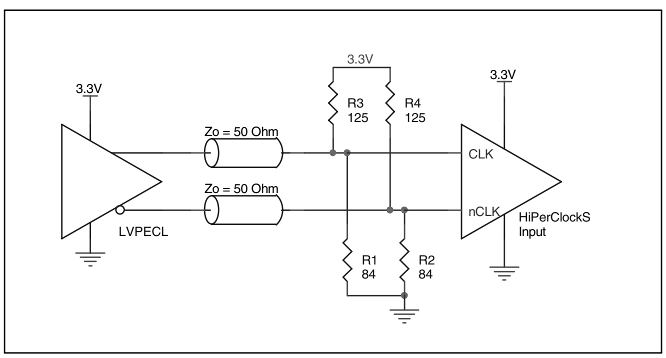


FIGURE 3C. HIPERCLOCKS CLK/nCLK INPUT DRIVEN BY 3.3V LVPECL DRIVER

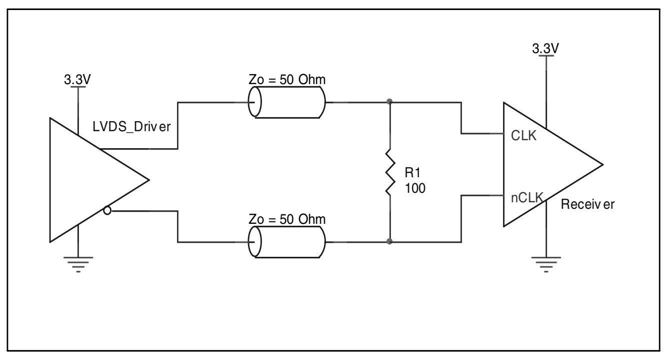


FIGURE 3D. HIPERCLOCKS CLK/nCLK INPUT DRIVEN BY 3.3V LVDS DRIVER

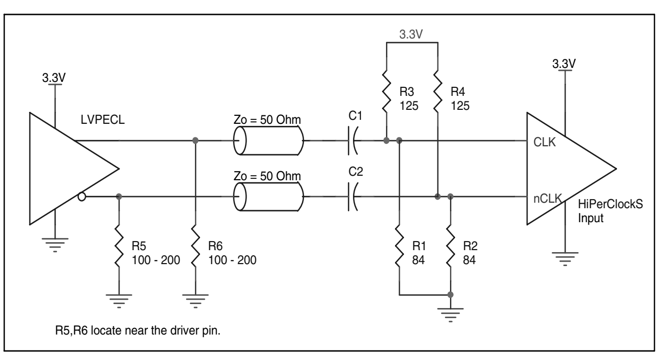


FIGURE 3E. HIPERCLOCKS CLK/nCLK INPUT DRIVEN BY 3.3V LVPECL DRIVER WITH AC COUPLE

LVPECL CLOCK INPUT INTERFACE

The PCLK /nPCLK accepts LVPECL, CML, SSTL and other differential signals. Both V_{SWING} and V_{OH} must meet the V_{PP} and V_{CMR} input requirements. *Figures 4A to 4F* show interface examples for the HiPerClockS PCLK/nPCLK input driven by the most common driver types. The input interfaces suggested here are examples only. If the driver is from another vendor, use their termination recommendation. Please consult with the vendor of the driver component to confirm the driver termination requirements.

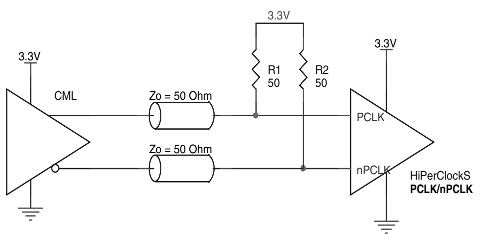


FIGURE 4A. HIPERCLOCKS PCLK/nPCLK INPUT DRIVEN BY AN OPEN COLLECTOR CML DRIVER

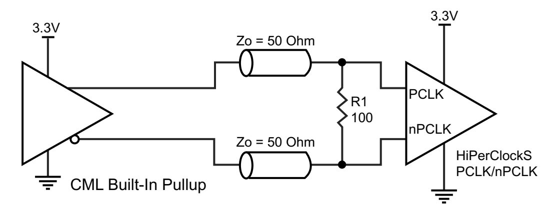


FIGURE 4B. HIPERCLOCKS PCLK/nPCLK INPUT DRIVEN BY A BUILT-IN PULLUP CML DRIVER

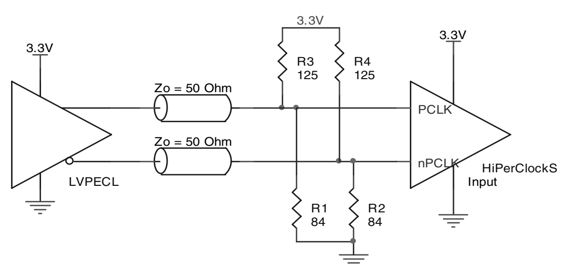


FIGURE 4C. HIPERCLOCKS PCLK/nPCLK INPUT DRIVEN BY A 3.3V LVPECL DRIVER

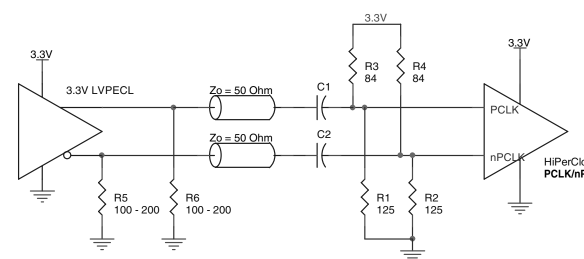


FIGURE 4D. HIPERCLOCKS PCLK/nPCLK INPUT DRIVEN BY A 3.3V LVPECL DRIVER WITH AC COUPLE

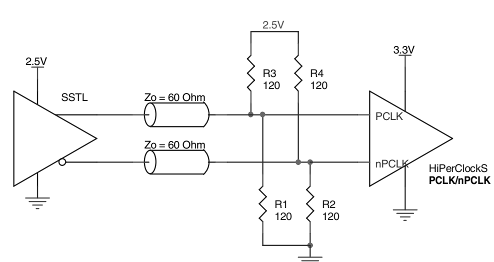


FIGURE 4E. HIPERCLOCKS PCLK/nPCLK INPUT DRIVEN BY AN SSTL DRIVER

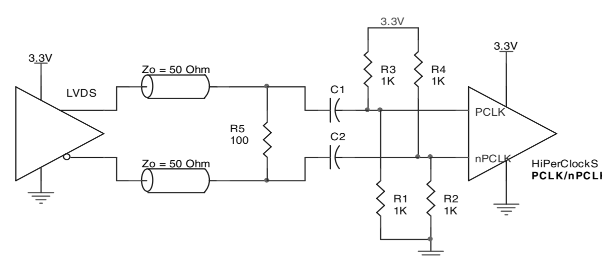


FIGURE 4F. HIPERCLOCKS PCLK/nPCLK INPUT DRIVEN BY A 3.3V LVDS DRIVER

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.

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 5A and 5B* 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.

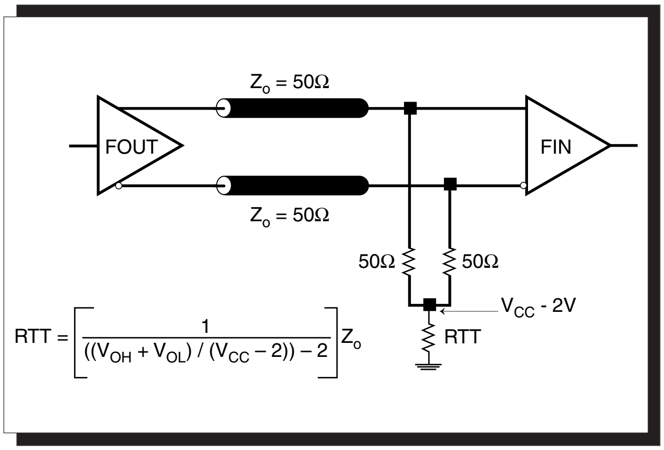


FIGURE 5A. LVPECL OUTPUT TERMINATION

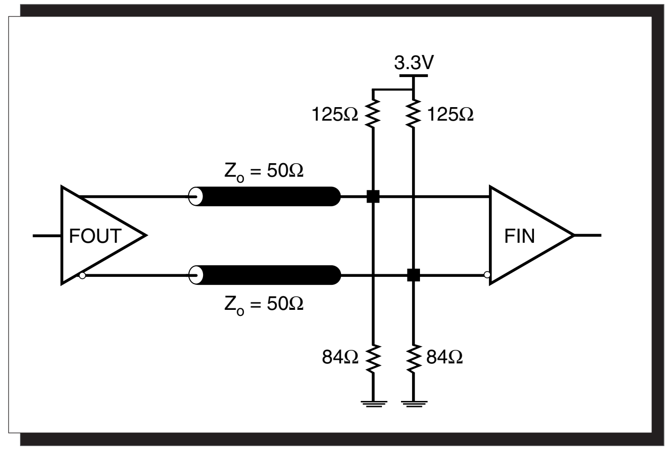


FIGURE 5B. LVPECL OUTPUT TERMINATION

POWER CONSIDERATIONS

This section provides information on power dissipation and junction temperature for the ICS8EN31AK.
Equations and example calculations are also provided.

1. Power Dissipation.
The total power dissipation for the ICS8EN31AK 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 * 80mA = **277.2mW**
- Power (outputs)$_{MAX}$ = **30mW/Loaded Output pair**
  If all outputs are loaded, the total power is 9 * 30mW = **270mW**

Total Power $_{\_MAX}$ (3.465V, with all outputs switching) = 277.2mW + 270mW = **547.2mW**

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 0 air flow and a multi-layer board, the appropriate value is 34.8°C/W per Table 6 below.

Therefore, Tj for an ambient temperature of 70°C with all outputs switching is:
70°C + 0.547W * 34.8°C/W = 89°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 6. THERMAL RESISTANCE θ_{JA} FOR 32-PIN LQFP FORCED CONVECTION

θ_{JA} 0 Air Flow (Linear Feet per Minute)	
	0
Multi-Layer PCB, JEDEC Standard Test Boards	34.8°C/W

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.*

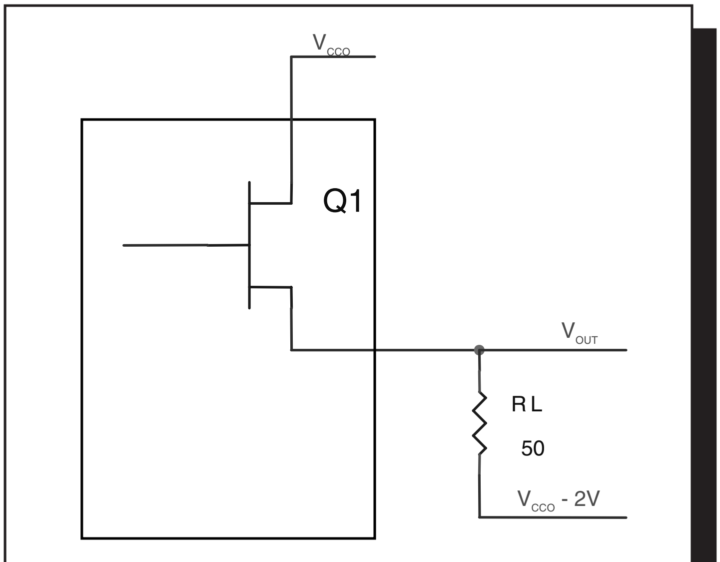


FIGURE 6. LVPECL DRIVER CIRCUIT AND TERMINATION

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 7. θ_{JA} VS. AIR FLOW TABLE FOR 32 LEAD VFQFN

θ_{JA} 0 Air Flow (Linear Feet per Minute)	
	0
Multi-Layer PCB, JEDEC Standard Test Boards	34.8°C/W

TRANSISTOR COUNT

The transistor count for ICS8EN31AK is: 632

PACKAGE OUTLINE AND DIMENSIONS - K SUFFIX FOR 32 LEAD VFQFN

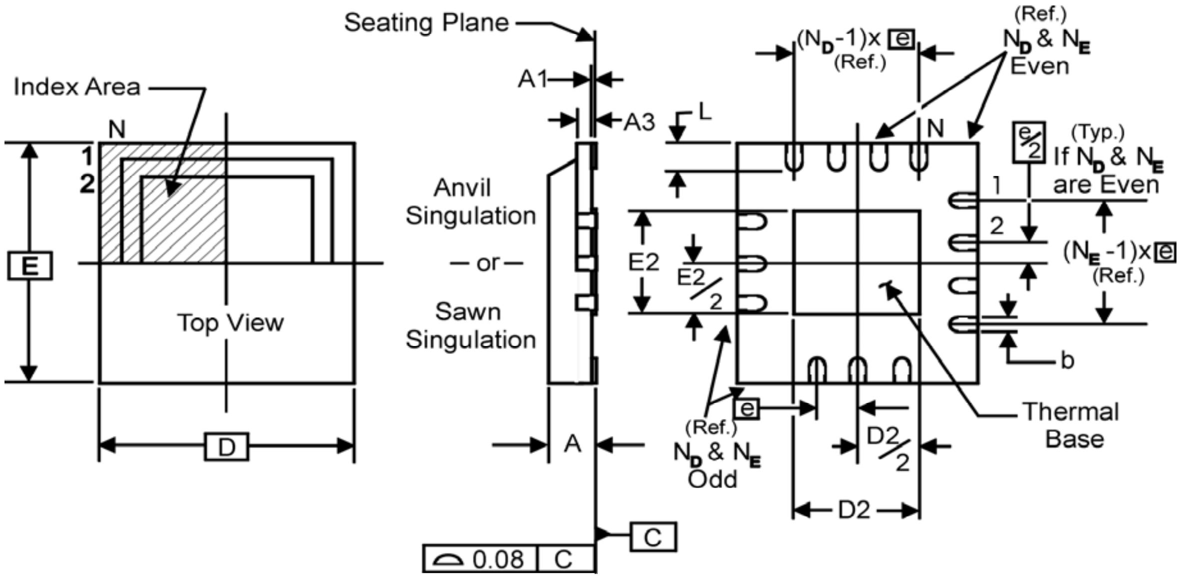


TABLE 8. PACKAGE DIMENSIONS

JEDEC VARIATION ALL DIMENSIONS IN MILLIMETERS			
SYMBOL	VHHD-2		
	MINIMUM	NOMINAL	MAXIMUM
N		32	
A	0.80	--	1.00
A1	0	--	0.05
A3		0.25 Ref.	
b	0.18	0.25	0.30
N_D			8
N_E			8
D		5.00 BASIC	
D2	1.25	2.25	3.25
E		5.00 BASIC	
E2	1.25	2.25	3.25
e		0.50 BASIC	
L	0.30	0.40	0.50

Reference Document: JEDEC Publication 95, MO-220

TABLE 9. ORDERING INFORMATION

Part/Order Number	Marking	Package	Shipping Packaging	Temperature
ICS8EN31AK	ICS8EN31AK	32 Lead VFQFN	tray	0°C to 70°C
ICS8EN31AKT	ICS8EN31AK	32 Lead VFQFN	2500 tape & reel	0°C to 70°C
ICS8EN31AKLF	ICS8EN31AKL	32 Lead "Lead-Free" VFQFN	tray	0°C to 70°C
ICS8EN31AKLFT	ICS8EN31AKL	32 Lead "Lead-Free" VFQFN	2500 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.