ICS8735I-21

700MHz, Differential-to-3.3V LVPECL Zero Delay Clock Generator

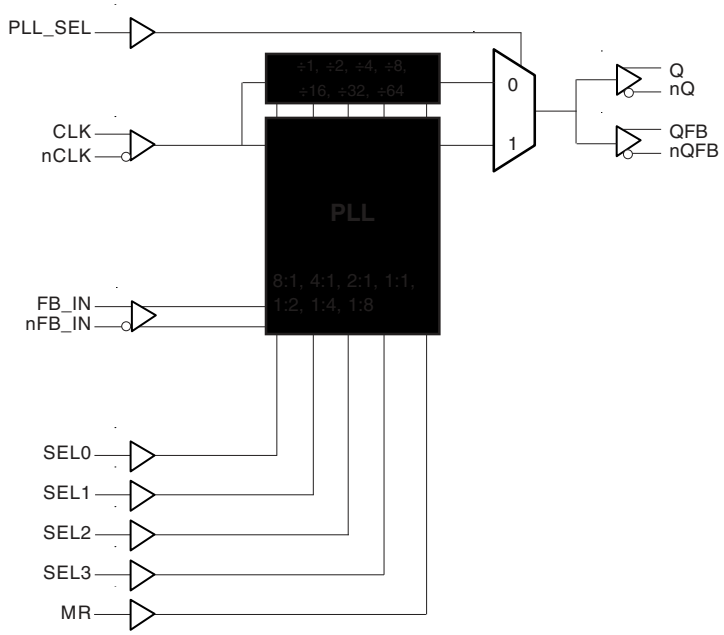
General Description

The ICS8735I-21 is a highly versatile 1:1 Differential-to-3.3V LVPECL clock generator. The CLK, nCLK pair can accept most standard differential input levels. The ICS8735I-21 has a fully integrated PLL and can be configured as zero delay buffer, multiplier or divider, and has an output frequency range of 31.25MHz to 700MHz. 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.

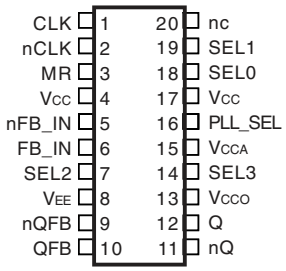
Features

- One differential 3.3V LVPECL output pair, one differential feedback output pair
- Differential CLK, nCLK input pair
- CLK, nCLK pair can accept the following differential input levels: LVDS, LVPECL, LVHSTL, SSTL, HCSL
- Output frequency range: 31.25MHz to 700MHz
- Input frequency range: 31.25MHz to 700MHz
- VCO range: 250MHz to 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: 40ps (maximum)
- Static phase offset: 50ps ± 150ps
- 3.3V supply voltage
- -40°C to 85°C ambient operating temperature
- Available in both standard and lead-free RoHS compliant packages

Block Diagram



Pin Assignment



ICS8735I-21

20-Lead, 300-MIL SOIC
7.5mm x 12.8mm x 2.3mm body package
M Package
Top View

Table 1. Pin Descriptions

Number	Name	Type		Description
1	CLK	Input	Pulldown	Non-inverting differential clock input.
2	nCLK	Input	Pullup	Inverting differential clock input.
3	MR	Input	Pulldown	Active HIGH Master Reset. When logic HIGH, the internal dividers are reset causing the true outputs Q and QFB to go low and the inverted outputs nQ and nQFB to go high. When LOW, the internal dividers and the outputs are enabled. LVCMOS / LVTTL interface levels.
4, 17	V_{CC}	Power		Core supply pins.
5	nFB_IN	Input	Pullup	Feedback input to phase detector for regenerating clocks with "zero delay". Connect to pin 9.
6	FB_IN	Input	Pulldown	Feedback input to phase detector for regenerating clocks with "zero delay". Connect to pin 10.
7	SEL2	Input	Pulldown	Determines output divider values in Table 3. LVCMOS / LVTTL interface levels.
8	V_{EE}	Power		Negative supply pin.
9, 10	nQFB, QFB	Output		Differential feedback outputs. LVPECL interface levels.
11, 12	nQ, Q	Output		Differential clock outputs. LVPECL interface levels.
13	V_{CCO}	Power		Output supply pin.
14	SEL3	Input	Pulldown	Determines output divider values in Table 3. LVCMOS / LVTTL interface levels.
15	V_{CCA}	Power		Analog supply pin.
16	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 / LVTTL interface levels.
18	SEL0	Input	Pulldown	Determines output divider values in Table 3. LVCMOS / LVTTL interface levels.
19	SEL1	Input	Pulldown	Determines output divider values in Table 3. LVCMOS / LVTTL interface levels.
20	nc	Unused		No connect.

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 PLL_SEL = 1 PLL Enable Mode
SEL3	SEL2	SEL1	SEL0	Reference Frequency Range (MHz)*	Q, nQ; QFB, nQFB
0	0	0	0	250 - 700	÷ 1
0	0	0	1	125 - 350	÷ 1
0	0	1	0	62.5 - 175	÷ 1
0	0	1	1	31.25 - 87.5	÷ 1
0	1	0	0	250 - 700	÷ 2
0	1	0	1	125 - 350	÷ 2
0	1	1	0	62.5 - 175	÷ 2
0	1	1	1	250 - 700	÷ 4
1	0	0	0	125 - 350	÷ 4
1	0	0	1	250 - 700	÷ 8
1	0	1	0	125 - 350	x 2
1	0	1	1	62.5 - 175	x 2
1	1	0	0	31.25 - 87.5	x 2
1	1	0	1	62.5 - 175	x 4
1	1	1	0	31.25 - 87.5	x 4
1	1	1	1	31.25 - 87.5	x 8

*NOTE: VCO frequency range for all configurations above is 250MHz to 700MHz.

Table 3B. PLL Bypass Function Table

Inputs				Outputs PLL_SEL = 0 PLL Bypass Mode
SEL3	SEL2	SEL1	SEL0	Q, nQ; QFB, nQFB
0	0	0	0	÷ 4
0	0	0	1	÷ 4
0	0	1	0	÷ 4
0	0	1	1	÷ 8
0	1	0	0	÷ 8
0	1	0	1	÷ 8
0	1	1	0	÷ 16
0	1	1	1	÷ 16
1	0	0	0	÷ 32
1	0	0	1	÷ 64
1	0	1	0	÷ 2
1	0	1	1	÷ 2
1	1	0	0	÷ 4
1	1	0	1	÷ 1
1	1	1	0	÷ 2
1	1	1	1	÷ 1

Absolute Maximum Ratings

Supply Voltage, V_{CC}	4.6V
Inputs, V_{CC}	-0.5V to V_{CC} + 0.5 V
Outputs, V_{CCO}	-0.5V to V_{CCO} + 0.5V
Package Thermal Impedance, θ_{JA}	46.2°C/W (0 lfpm)
Storage Temperature, T_{STG}	-65°C to 150°C

NOTE: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These ratings are stress specifications only. Functional operation of product at these conditions or any conditions beyond those listed in the *DC Characteristics* or *AC Characteristics* is not implied. Exposure to absolute maximum rating conditions for extended periods may affect product reliability.

Table 4A. Power Supply DC Characteristics, $V_{CC} = V_{CCA} = V_{CCO} = 3.3V±5\%$, 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
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				150	mA
I_{CCA}	Analog Supply Current				15	mA

Table 4B. LVCMOS/LVTTL DC Characteristics, $V_{CC} = V_{CCA} = V_{CCO} = 3.3V±5\%$, 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	SEL0, SEL1, SEL2, SEL3, MR	$V_{CC} = V_{IN} = 3.465V$			150	µA
		PLL_SEL	$V_{CC} = V_{IN} = 3.465V$			5	µA
I_{IL}	Input Low Current	SEL0, SEL1, SEL2, SEL3, MR	$V_{CC} = 3.465V$, $V_{IN} = 0V$	-5			µA
		PLL_SEL	$V_{CC} = 3.465V$, $V_{IN} = 0V$	-150			µA

Table 4C. Differential DC Characteristics, $V_{CC} = V_{CCA} = V_{CCO} = 3.3V±5\%$, T_A = -40°C to 85°C

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

Table 4D. LVPECL DC Characteristics, $V_{CC} = V_{CCA} = V_{CCO} = 3.3V \pm 5\%$, T_A = -40°C to 85°C

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

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

Table 5. Input Frequency Characteristics, $V_{CC} = V_{CCA} = V_{CCO} = 3.3V \pm 5\%$, T_A = -40°C to 85°C

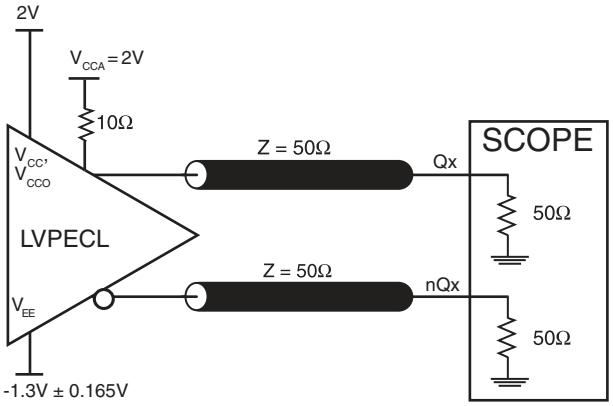
Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
f_{IN}	Input Frequency	CLK, nCLK	PLL_SEL = 1	31.25		700	MHz
			PLL_SEL = 0			700	MHz

Table 6. AC Characteristics, $V_{CC} = V_{CCA} = V_{CCO} = 3.3V \pm 5\%$, T_A = -40°C to 85°C

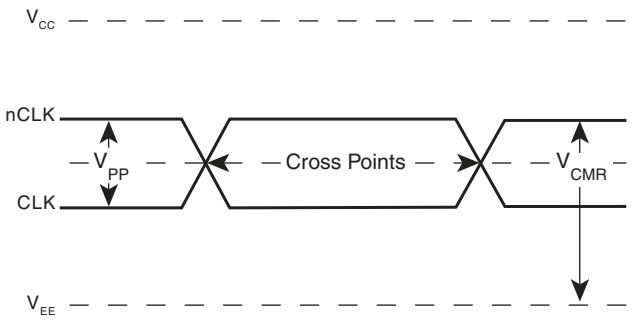
Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
f_{MAX}	Output Frequency				700	MHz
t_{PD}	Propagation Delay; NOTE 1	PLL_SEL = 0V, f ≤ 700MHz	2.8		4.9	ns
tsk(o)	Output Skew; NOTE 4, 5	PLL_SEL = 0V			35	ps
t(Ø)	Static Phase Offset; NOTE 2, 5	PLL_SEL = 3.3V	-100	50	200	ps
*t*jit(cc)	Cycle-to-Cycle Jitter; NOTE 5, 6				40	ps
*t*jit(θ)	Phase Jitter; NOTE 3, 5, 6				±65	ps
t_L	PLL Lock Time				1	ms
t_R / t_F	Output Rise/Fall Time	20% to 80%	200		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 average feedback input signal, when the PLL is locked and the input reference frequency is stable.
NOTE 3: Phase jitter is dependent on the input source used.
NOTE 4: Defined as skew between outputs at the same supply voltage and with equal load conditions. Measured at the output differential crosspoints.
NOTE 5: This parameter is defined in accordance with JEDEC Standard 65.
NOTE 6: Characterized at VCO frequency of 622MHz.

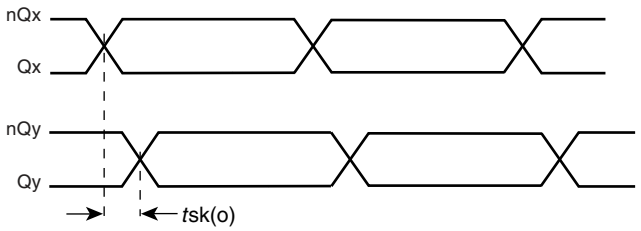
Parameter Measurement Information



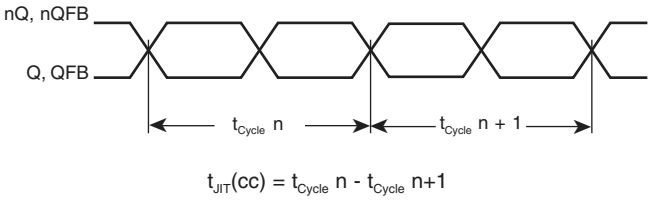
3.3V Output Load AC Test Circuit



Differential Input Level

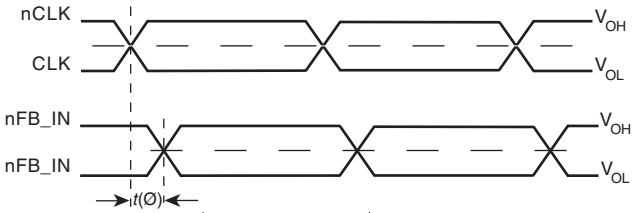


Output Skew



$t_{JIT}(cc) = t_{Cycle}\ n - t_{Cycle}\ n+1$

Cycle-to-Cycle Jitter

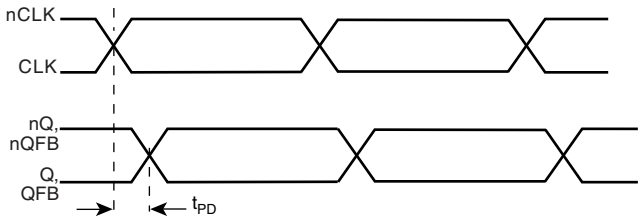


$tjit(Ø) = \left| t(Ø) - t(Ø)_{mean} \right|$ = Phase Jitter

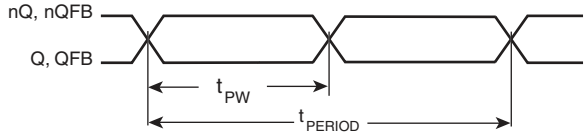
$t(Ø)_{mean}$ = Static Phase Offset

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

Phase Jitter and Static Phase Offset

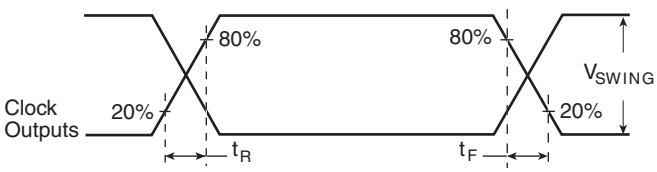


Propagation Delay



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

Output Duty Cycle/Pulse Width/Period



Output Rise/Fall Time

Application Information

Power Supply Filtering Techniques

As in any high speed analog circuitry, the power supply pins are vulnerable to random noise. The ICS8735I-21 provides separate power supplies to isolate any high switching noise from the outputs to the internal PLL. V_{CC}, V_{CCA}, and V_{CCO} should be individually connected to the power supply plane through vias, and bypass capacitors should be used for each pin. To achieve optimum jitter performance, power supply isolation is required. *Figure 1* illustrates how a 10Ω resistor along with a 10µF and a .01µF bypass capacitor should be connected to each V_{CCA} pin. The 10Ω resistor can also be replaced by a ferrite bead.

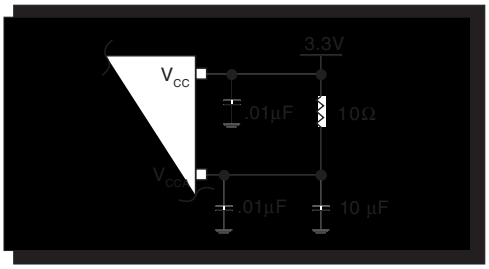


Figure 1. Power Supply Filtering

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.

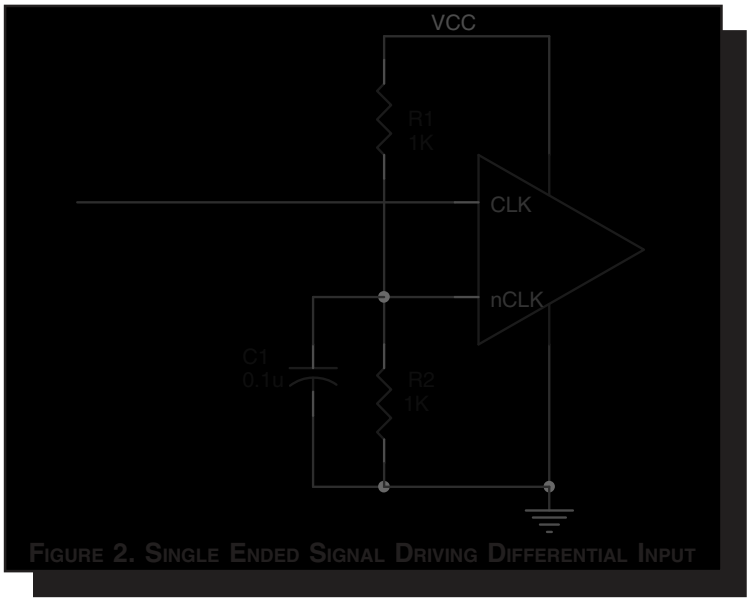


Figure 2. Single Ended Signal Driving Differential Input

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 3D show interface examples for the 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 LVHSTL drivers. If you are using an LVHSTL driver from another vendor, use their termination recommendation.

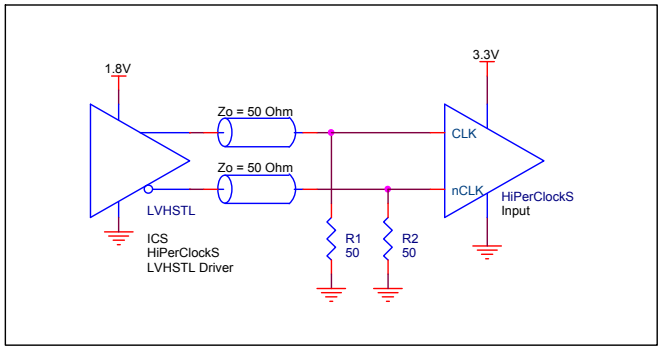


Figure 3A. CLK/nCLK Input Driven by LVHSTL Driver

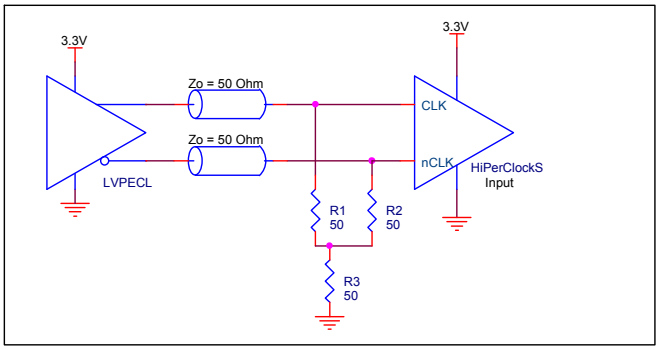


Figure 3B. CLK/nCLK Input Driven by 3.3V LVPECL Driver

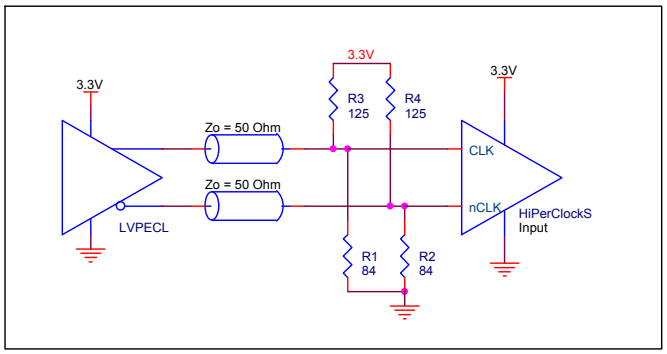


Figure 3C. CLK/nCLK Input Driven by 3.3V LVPECL Driver

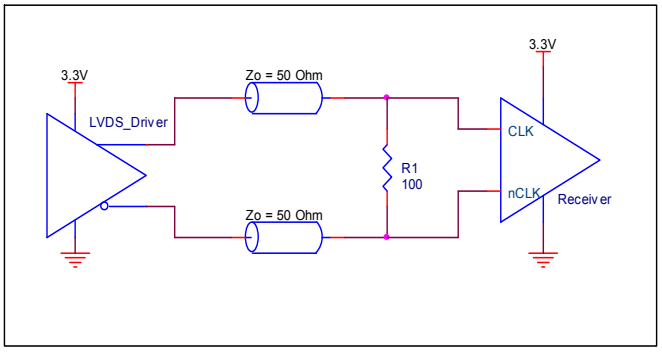


Figure 3D. CLK/nCLK Input Driven by 3.3V LVDS Driver

Recommendations for Unused Input Pins

Inputs:

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.

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 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.

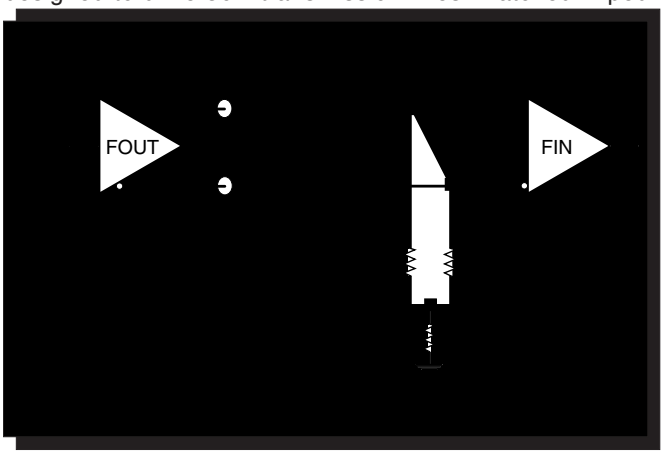


Figure 4A. LVPECL Output Termination

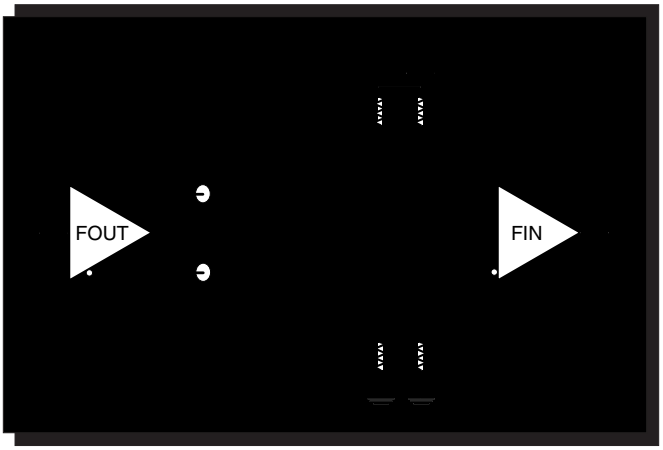


Figure 4B. LVPECL Output Termination

Schematic Example

Figure 5 shows a schematic example of the ICS8735I-21. In this example, the input is driven by an HCSL driver. The zero delay buffer is configured to operate at 155.52MHz input and 77.75MHz output. The logic control pins are configured as follows: SEL [3:0] = 0101; PLL_SEL = 1
The decoupling capacitors should be physically located near the power pin.

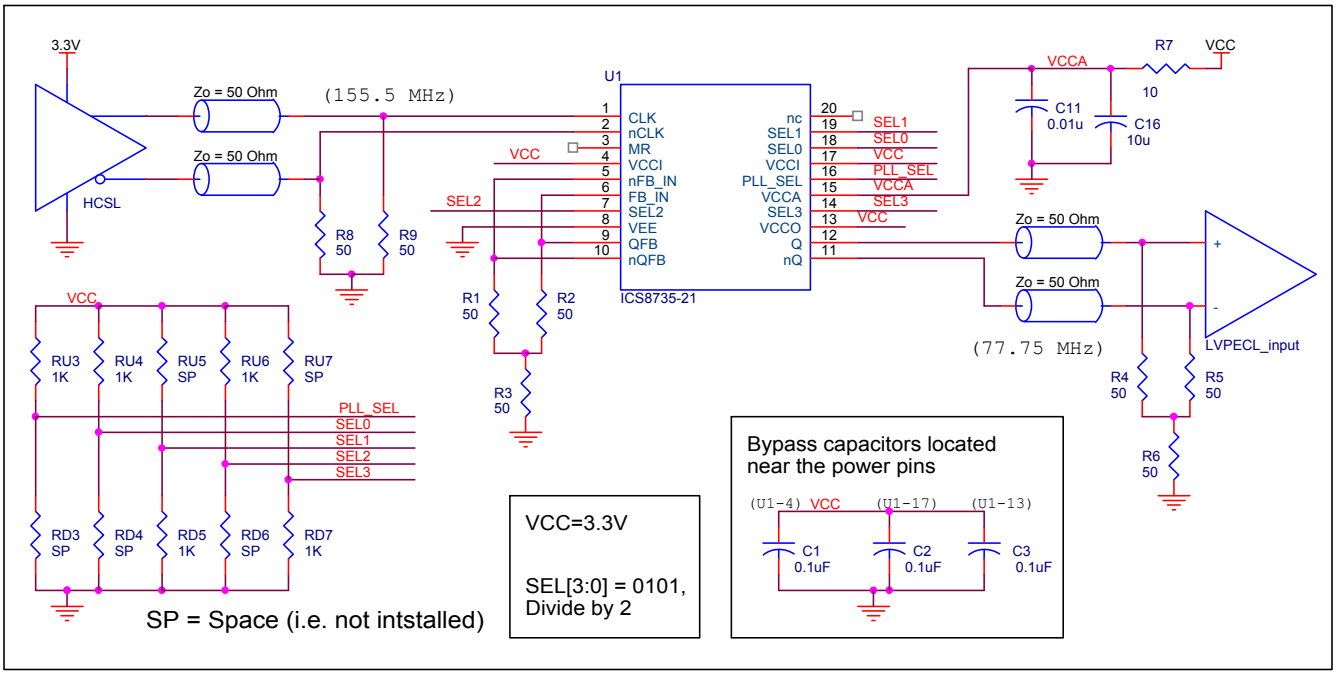


Figure 5. ICS8735I-21 LVPECL Buffer Schematic Example

Power Considerations

This section provides information on power dissipation and junction temperature for the ICS8735I-21.
Equations and example calculations are also provided.

1. Power Dissipation.
The total power dissipation for the ICS8735I-21 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 * 150mA = **519.75mW**
- Power (outputs)$_{MAX}$ = **30mW/Loaded Output pair**
  If all outputs are loaded, the total power is 2 * 30mW = **60mW**

Total Power$_{_MAX}$ (3.465V, with all outputs switching) = 519.75mW + 60mW = **579.75mW**

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 the 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 39.7°C/W per Table 7 below.

Therefore, Tj for an ambient temperature of 85°C with all outputs switching is:
85°C + 0.580W * 39.7°C/W = 108°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 20-pin SOIC, Forced Convection

θ_{JA} by Velocity (Linear Feet per Minute)			
	0	**200**	**500**
Single-Layer PCB, JEDEC Standard Test Boards	83.2°C/W	65.7°C/W	57.5°C/W
Multi-Layer PCB, JEDEC Standard Test Boards	46.2°C/W	39.7°C/W	36.8°C/W

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

3. Calculations and Equations.

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

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

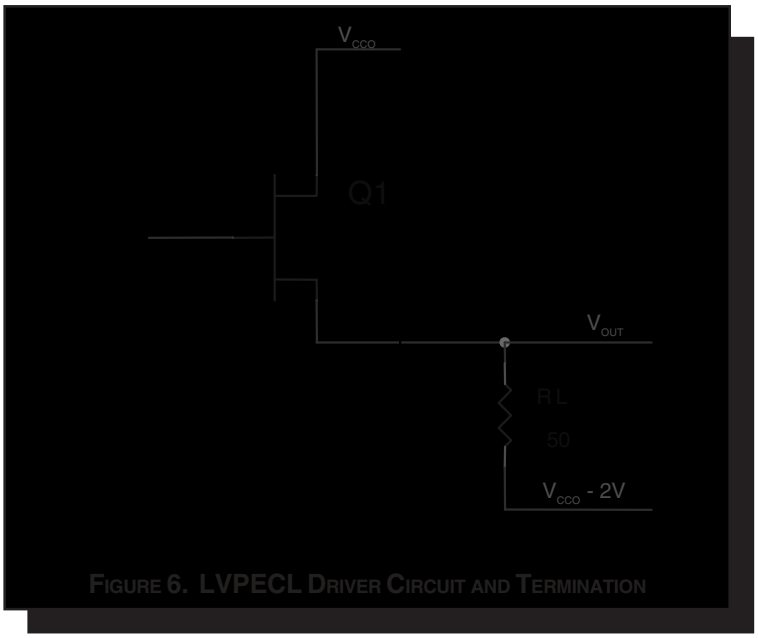


Figure 6. LVPECL Driver Circuit and Termination

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

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

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

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

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

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

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

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

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

Reliability Information

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

θ_{JA} by Velocity (Linear Feet per Minute)			
	0	**200**	**500**
Single-Layer PCB, JEDEC Standard Test Boards	83.2°C/W	65.7°C/W	57.5°C/W
Multi-Layer PCB, JEDEC Standard Test Boards	46.2°C/W	39.7°C/W	36.8°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 ICS8735I-21 is: 2969

Package Outline - M Suffix for 20 Lead SOIC

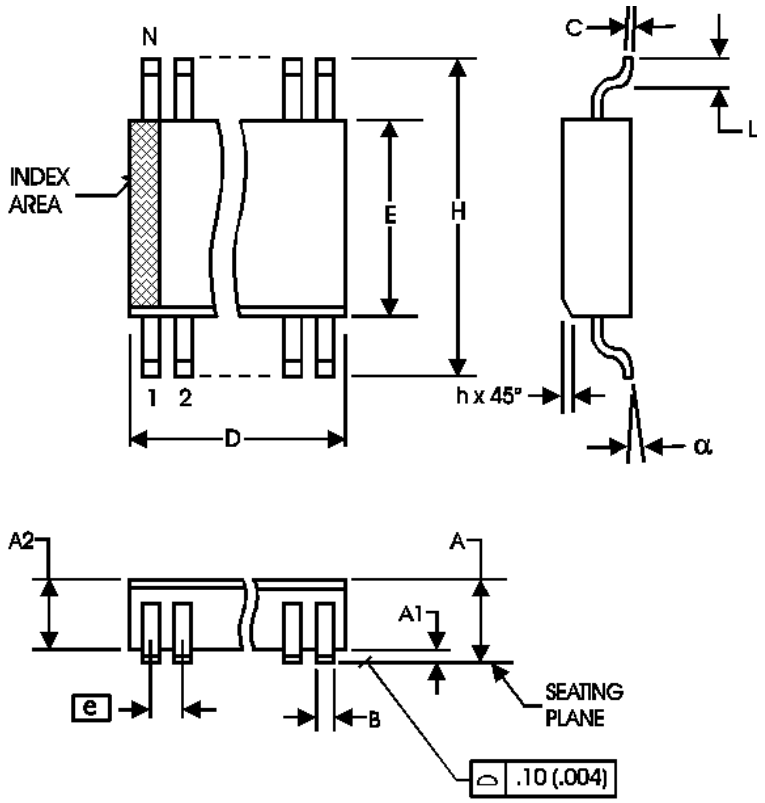


Table 9. Package Dimensions

SYMBOL	Millimeters	
	Minimum	Maximum
N	20	
A	--	2.65
A1	0.10	--
A2	2.05	2.55
B	0.33	0.51
C	0.18	0.32
D	12.60	13.00
E	7.40	7.60
e	1.27 BASIC	
H	10.00	10.65
h	0.25	0.75
L	0.40	1.27
α	0°	8°

Reference Document: JEDEC Publication 95, MS-013, MO-119

Table 10. Ordering Information

Part/Order Number	Marking	Package	Shipping Packaging	Temperature
8735AMI-21	ICS8735AMI-21	20 Lead SOIC	Tube	-40°C to 85°C
8735AMI-21T	ICS8735AMI-21	20 Lead SOIC	1000 Tape & Reel	-40°C to 85°C
8735AMI-21LF	ICS8735AMI-21LF	20 Lead "Lead-Free" SOIC	Tube	-40°C to 85°C
8735AMI-21LFT	ICS8735AMI-21LF	20 Lead "Lead-Free" SOIC	1000 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

REVISION HISTORY SHEET				
Rev	**Table**	**Page**	**Description of Change**	**Date**
B	T2 T10	1 2 6 8 14	Features Section - added Lead-Free bullet. Pin Characteristics Table - changed C_{IN} from 4pF max. to 4pF typical. Updated Output Load AC Test Circuit diagram. Updated Differential Clock Input Interface section. Added *Recommendations for Unused Input Pins.* Ordering Information Table - added Lead-Free part number, marking and note.	2/17/06
C	T4D	5 10 - 11	LVPECL DC Characteristics Table -corrected V_{OH} max. from V_{CCO} - 1.0V to V_{CCO} - 0.9V Power Considerations - corrected power dissipation to reflect V_{OH} max in Table 4D.	4/13/07
C	T10	14 16	Updated datasheet's header/footer with IDT from ICS. Removed ICS prefix from Part/Order Number column. Added Contact Page.	8/11/10

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