1-to-5 Differential-to-3.3V LVPECL PLL Clock Driver W/Dynamic Clock Switch

87993I

DATASHEET

General Description

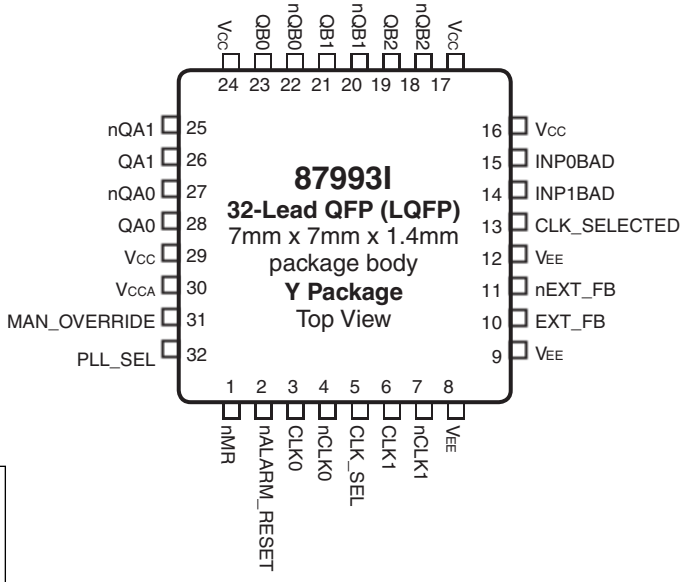
The 87993I is a PLL clock driver designed specifically for redundant clock tree designs. The device receives two differential LVPECL clock signals from which it generates 5 new differential LVPECL clock outputs. Two of the output pairs regenerate the input signal frequency and phase while the other three pairs generate 2x, phase aligned clock outputs. External PLL feedback is used to also provide zero delay buffer performance.

The 87993I Dynamic Clock Switch (DCS) circuit continuously monitors both input CLK signals. Upon detection of a failure (CLK stuck HIGH or LOW for at least 1 period), the INP_BAD for that CLK will be latched (H). If that CLK is the primary clock, the DCS will switch to the good secondary clock and phase/frequency alignment will occur with minimal output phase disturbance. The typical phase bump caused by a failed clock is eliminated.

Features

- Five differential 3.3V LVPECL outputs
- Selectable differential clock inputs
- CLKx, nCLKx pair can accept the following differential input levels: LVPECL, LVDS, LVHSTL, HCSL, SSTL
- Output frequency range: 50MHz to 250MHz
- VCO range: 200MHz to 500MHz
- External feedback for "zero delay" clock regeneration with configurable frequencies
- Cycle-to-cycle jitter (RMS): 20ps (maximum)
- Output skew: 70ps (maximum), within one bank
- 3.3V supply voltage
- -40°C to 85°C ambient operating temperature
- Lead-Free package available
- Pin compatible with MPC993

Pin Assignment



Block Diagram

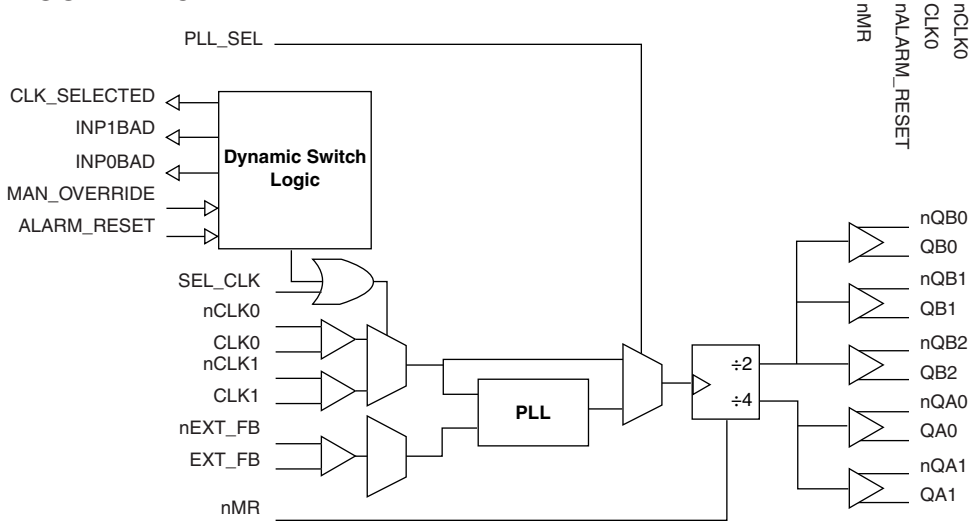


Table 1. Pin Descriptions

Number	Name	Type		Description
1	nMR	Input	Pullup	Active LOW Master Reset. When logic LOW, the internal dividers are reset causing the true outputs Qx to go low and the inverted outputs nQx to go high. When logic HIGH, the internal dividers and the outputs are enabled. LVCMOS / LVTTL interface levels.
2	nALARM_RESET	Input	Pullup	When LOW, resets the input bad flags and aligns CLK_SELECTED with SEL_CLK. LVCMOS / LVTTL interface levels.
3	CLK0	Input	Pulldown	Non-inverting differential clock input.
4	nCLK0	Input	Pullup	Inverting differential clock input.
5	SEL_CLK	Input	Pulldown	Clock select input. When LOW, selects CLK0, nCLK0 inputs. When HIGH, selects CLK1, nCLK1 inputs. LVCMOS / LVTTL interface levels.
6	CLK1	Input	Pulldown	Non-inverting differential clock input.
7	nCLK1	Input	Pullup	Inverting differential clock input.
8, 9, 12	V_{EE}	Power		Negative supply pins.
10	EXT_FB	Input	Pulldown	Differential external feedback.
11	nEXT_FB	Input	Pullup	Differential external feedback.
13	CLK_SELECTED	Output		LOW, when CLK0, nCLK0 is selected, HIGH, when CLK1, nCLK1 is selected. LVCMOS / LVTTL interface levels.
14	INP1BAD	Output		Indicates detection of a bad input reference clock 1 with respect to the feedback signal. The output is active HIGH and will remain HIGH until the alarm reset is asserted.
15	INP0BAD	Output		Indicates detection of a bad input reference clock 0 with respect to the feedback signal. The output is active HIGH and will remain HIGH until the alarm reset is asserted.
16, 17, 24, 29	V_{CC}	Power		Core supply pins.
18, 19	nQB2, QB2	Output		Differential output pair. LVPECL interface levels.
20, 21	nQB1, QB1	Output		Differential output pair. LVPECL interface levels.
22, 23	nQB0, QB0	Output		Differential output pair. LVPECL interface levels.
25, 26	nQA1, QA1	Output		Differential output pair. LVPECL interface levels.
27, 28	nQA0, QA0	Output		Differential output pair. LVPECL interface levels.
30	V_{CCA}	Power		Analog supply pin.
31	MAN_OVERRIDE	Input	Pulldown	Manual override. When HIGH, disables internal clock switch circuitry. LVCMOS / LVTTL interface levels.
32	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.

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

Absolute Maximum Ratings

Supply Voltage, V_{CC}	4.6V
Inputs, V_I	-0.5V to V_{CC} + 0.5 V
Outputs, I_O	
Continuous Current	50mA
Surge Current	100mA
Package Thermal Impedance, θ_{JA}	47.9°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 3A. Power Supply DC Characteristics, $V_{CC} = V_{CCA} = 3.3V \pm 5\%$, 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
I_{EE}	Power Supply Current			80	180	mA
I_{CCA}	Analog Supply Current			15	20	mA

Table 3B. LVCMOS/LVTTL DC Characteristics, $V_{CC} = V_{CCA} = 3.3V \pm 5\%$, T_A = -40°C to 85°C

Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
V_{IH}	Input High Voltage	LVCMOS Inputs		2		3.3	V
V_{IL}	Input Low Voltage	LVCMOS Inputs		-0.3		0.8	V
I_{IH}	Input High Current	SEL_CLK, MAN_OVERRIDE	$V_{IN} = V_{CC} = 3.465V$			5	µA
		nALARM_RESET, PLL_SEL, nMR	$V_{IN} = V_{CC} = 3.465V$			120	µA
I_{IL}	Input Low Current	SEL_CLK, MAN_OVERRIDE	$V_{IN} = 0V, V_{CC} = 3.465V$	-5			µA
		nALARM_RESET, PLL_SEL, nMR	$V_{IN} = 0V, V_{CC} = 3.465V$	-120			µA
V_{OH}	Output High Voltage; NOTE 1			2.4			
V_{OL}	Output Low Voltage; NOTE 1					0.5	

NOTE 1: Outputs terminated with 50Ω to $V_{CC}/2$. See Parameter Measurement Information Section, "3.3V Output Load AC Test Circuit diagram".

Table 3C. Differential DC Characteristics, $V_{CC} = V_{CCA} = 3.3V \pm 5\%$, T_A = -40°C to 85°C

Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
I_{IH}	Input High Current	CLK0, CLK1, EXT_FB	$V_{IN} = V_{CC} = 3.465V$			5	µA
		nCLK0, nCLK1, nEXT_FB	$V_{IN} = V_{CC} = 3.465V$			120	µA
I_{IL}	Input Low Current	CLK0, CLK1, EXT_FB	$V_{IN} = 0V, V_{CC} = 3.465V$	-5			µA
		nCLK0, nCLK1, nEXT_FB	$V_{IN} = 0V, V_{CC} = 3.465V$	-120			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 appliations, the maximum input voltage for CLK, nCLK is V_{CC} + 0.3V.

TABLE 3D. LVPECL DC CHARACTERISTICS, $V_{CC} = V_{CCA} = 3.3V \pm 5\%$, T_A = -40°C TO 85°C

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

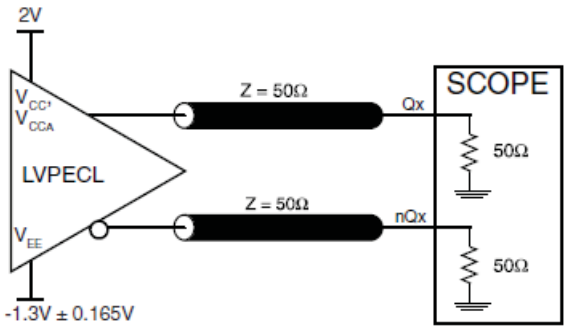
NOTE 1: Outputs terminated with 50W to V_{CC} - 2V.

TABLE 4. AC CHARACTERISTICS, $V_{CC} = V_{CCA} = 3.3V \pm 5\%$, T_A = -40°C TO 85°C

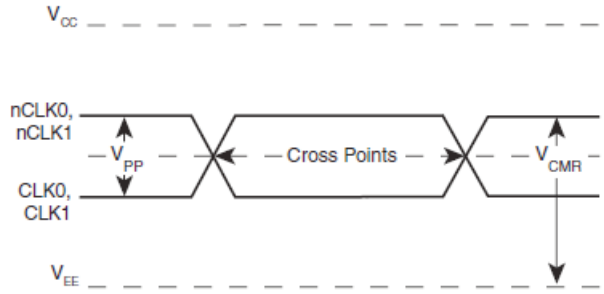
Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
f_{VCO}	PLL VCO Lock Range			200		500	MHz
t_{PWI}				25		75	%
t_{PD}	Propagation Delay	CLKx to Q	PLL_SEL = LOW	2.8	3.45	4.1	ns
		CLKx to EXT_FB; NOTE 2	PLL_SEL = HIGH fVCO ≤ 360MHz	-150	0	170	ps
			PLL_SEL = HIGH fVCO ≤ 500MHz	-150	0	200	ps
t_R / t_F	Output Rise Time		20% to 80% @ 50MHz	200		800	ps
tsk(o)	Output Skew; NOTE 3	Within Bank				70	ps
		All Outputs				100	ps
$D_{PER/CYCLE}$	Rate of change of Periods	75MHz Output; NOTE 1, 4	Tested at typical conditions		20	50	ps/cycle
		150MHz Output; NOTE 1, 4			10	25	ps/cycle
		75MHz Output; NOTE 1, 5			200	400	ps/cycle
		150MHz Output; NOTE 1, 5			100	200	ps/cycle
odc	Output Duty Cycle		f ≤ 360MHz	45		55	%
tjit(cc)	Cycle-to-Cycle Jitter (RMS); NOTE 1					20	ps
t_L	PLL Lock Time; NOTE 1					10	ms

All parameters measured at f_{MAX} unless noted otherwise.
NOTE 1: These parameters are guaranteed by characterization. Not tested in production.
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: Specification holds for a clock switch between two signals no greater than 400ps out of phase. Delta period change per cycle is averaged over the clock switch excursion.
NOTE 5: Specification holds for a clock switch between two signals no greater than ±p out of phase. Delta period change per cycle is averaged over the clock switch excursion.

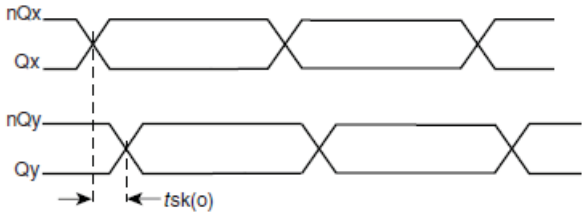
PARAMETER MEASUREMENT INFORMATION



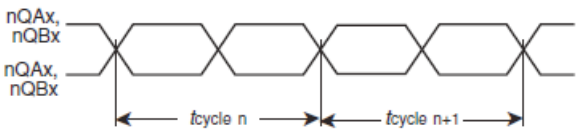
3.3V OUTPUT LOAD AC TEST CIRCUIT



DIFFERENTIAL INPUT LEVEL



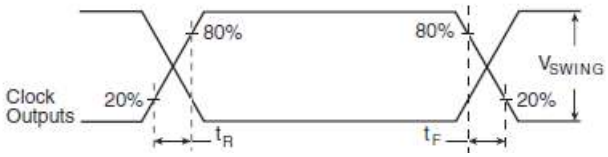
OUTPUT SKEW



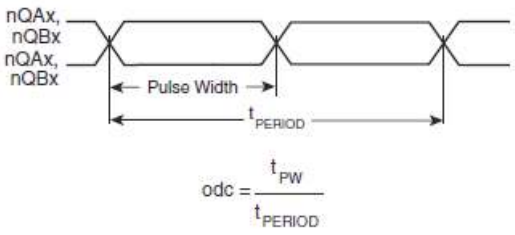
$t_{jit(cc)} = t_{cycle\ n} - t_{cycle\ n+1}$

1000 Cycles

CYCLE-TO-CYCLE JITTER



OUTPUT RISE/FALL TIME



$$odc = \frac{t_{PW}}{t_{PERIOD}}$$

OUTPUT DUTY CYCLE/PULSE WIDTH/PERIOD

APPLICATION INFORMATION

POWER SUPPLY FILTERING TECHNIQUES

As in any high speed analog circuitry, the power supply pins are vulnerable to random noise. The 87993I provides separate power supplies to isolate any high switching noise from the outputs to the internal PLL. V_{CC} and V_{CCA} 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.

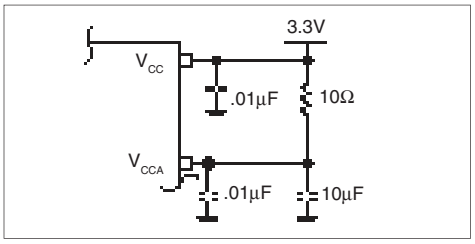


FIGURE 1. POWER SUPPLY FILTERING

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.

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 2A and 2B* 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.

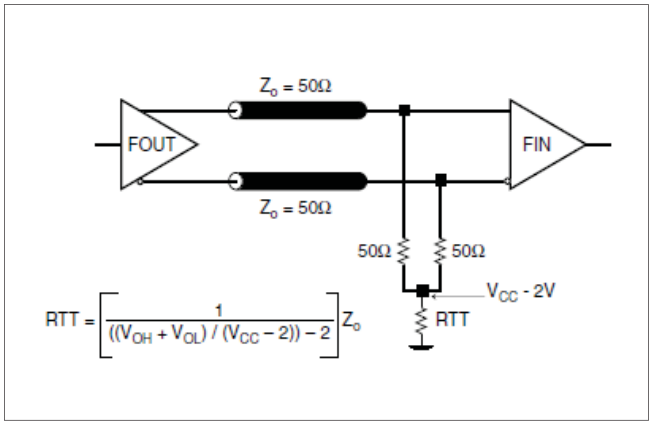


FIGURE 2A. LVPECL OUTPUT TERMINATION

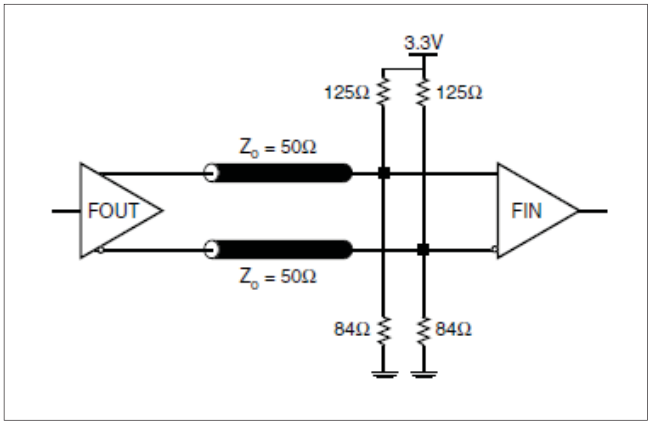


FIGURE 2B. LVPECL OUTPUT TERMINATION

Wiring the Differential Input to Accept Single Ended Levels

Figure 3 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.

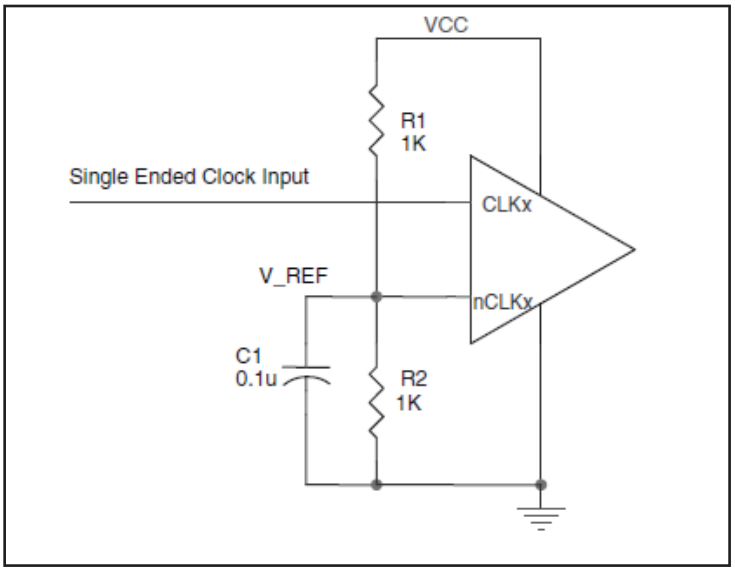


Figure 3. Single Ended Signal Driving Differential Input

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 4A to 4D 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 4A,* the input termination applies for IDT's LVHSTL drivers. If you are using an LVHSTL driver from another vendor, use their termination recommendation.

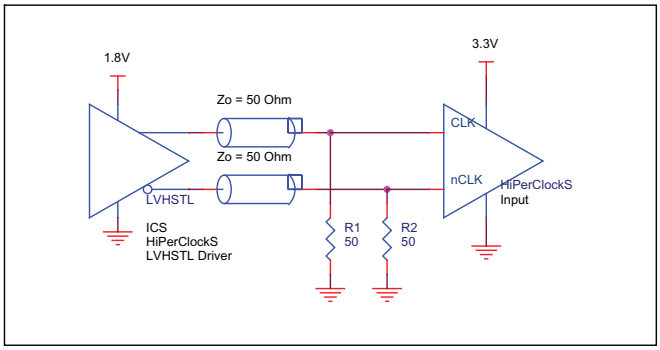


Figure 4A. CLK/nCLK Input Driven by IDT's LVHSTL Driver

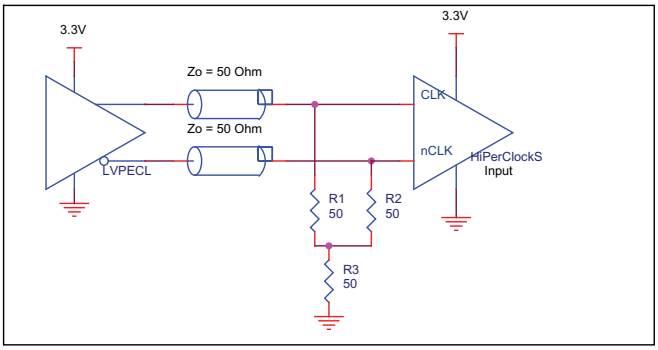


Figure 4B. CLK/nCLK Input Driven by 3.3V LVPECL Driver

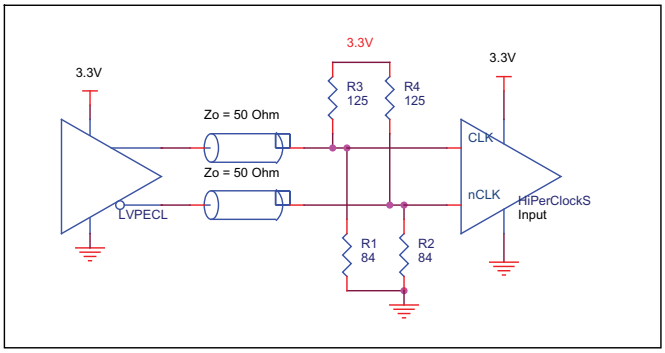


Figure 4C. CLK/nCLK Input Driven by 3.3V LVPECL Driver

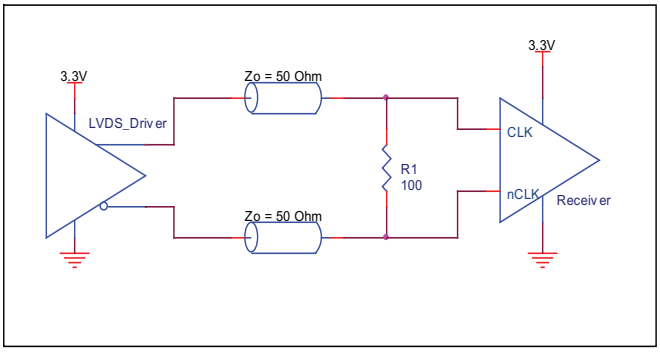


Figure 4D. CLK/nCLK Input Driven by 3.3V LVDS Driver

Schematic Example

Figure 5A shows a schematic example of the 87993I. In this example, the CLK0/nCLK0 input is selected as primary. The input is driven by an LVPECL driver. Feedback can be either from Bank A or Bank B depending on the application. The decoupling capacitors should be physically located near the power pin. For 87993I, the unused outputs can be left floating.

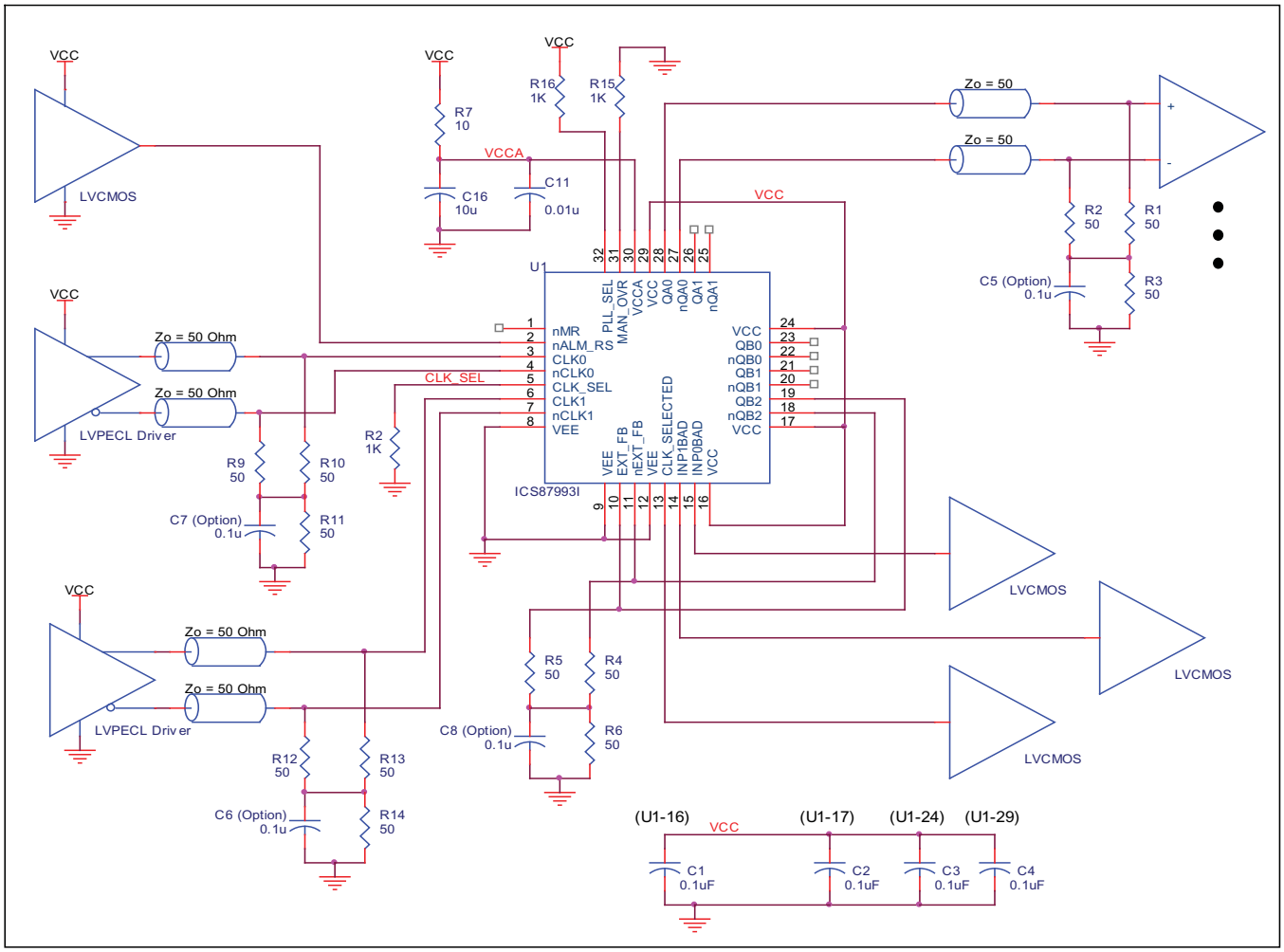


Figure 5A. 87993I LVPECL Schematic Example

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 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_{DDA} 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 separation 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 series termination resistors should be located as close to the driver pins as possible.

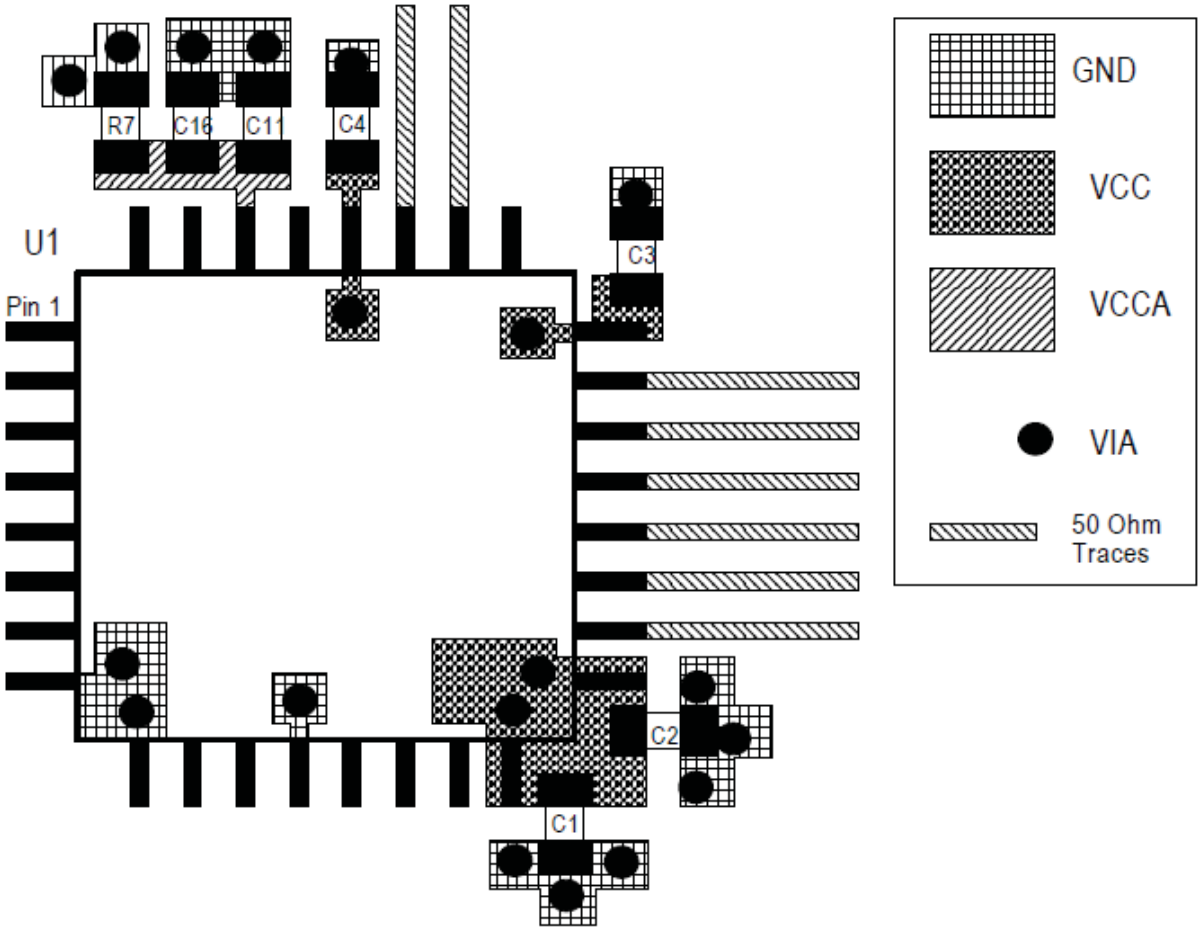


Figure 5B. PCB Board Layout For 87993I

Power Considerations

This section provides information on power dissipation and junction temperature for the 87993I.
Equations and example calculations are also provided.

1. Power Dissipation.
The total power dissipation for the 87993I 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 * 180 = **624mW**
- 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) = 624mW + 151mW = **775mW**

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 5 below.

Therefore, Tj for an ambient temperature of 85°C with all outputs switching is:
85°C + 0.775W * 42.1°C/W = 117.6°C. This is below the limit of 125°C.

This calculation is only an example. Tj will obviously vary depending on the number of loaded outputs, supply voltage, air flow, and the type of board (single layer or multi-layer).

Table 5. 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 6.*

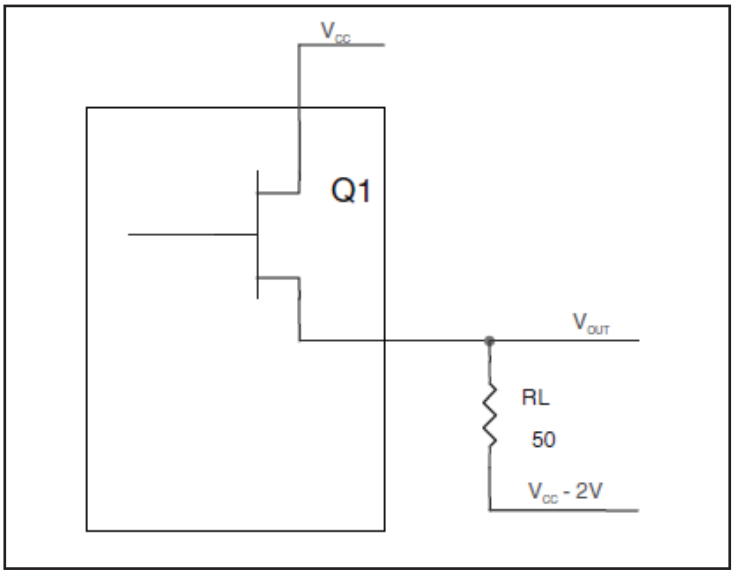


FIGURE 6. LVPECL DRIVER CIRCUIT AND TERMINATION

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

- For logic high, $V_{OUT} = V_{OH\_MAX} = \mathbf{V_{CC\_MAX} – 1.0V}$

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

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

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

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

$Pd\_H = [(V_{OH\_MAX} – (V_{CC\_MAX} - 2V))/R_L] * (V_{CC\_MAX} - V_{OH\_MAX}) = [(2V - (V_{CC\_MAX} - V_{OH\_MAX}))/R_L] * (V_{CC\_MAX} - V_{OH\_MAX}) =$
$[(2V - 1V)/50\Omega] * 1V = \mathbf{20.0mW}$

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

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

RELIABILITY INFORMATION

TABLE 6. θ_{JA} VS. AIR FLOW TABLE FOR 32 LEAD LQFP

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 87993I is: 2745

Package Outline - Y Suffix for 32 Lead LQFP

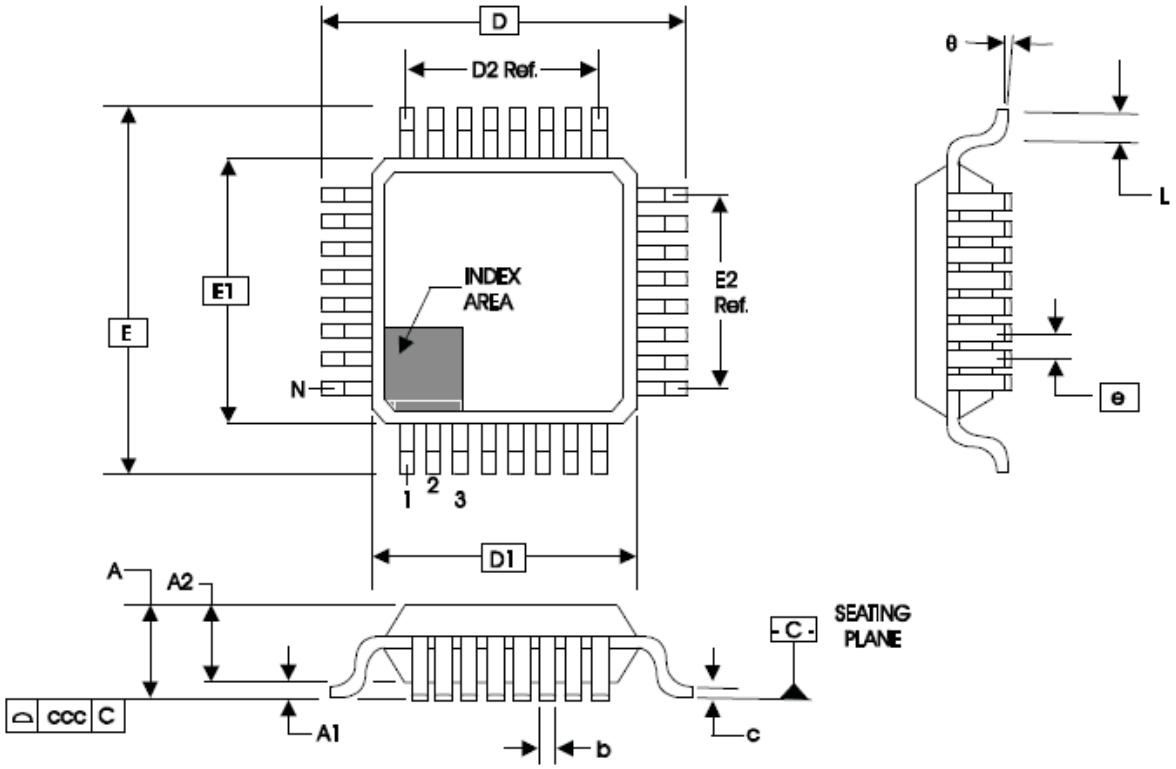


Table 7. Package Dimensions

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 8. ORDERING INFORMATION

Part/Order Number	Marking	Package	Shipping Packaging	Temperature
87993AYILF	ICS87993AILF	32 Lead “Lead-Free” LQFP	tray	-40°C to 85°C
87993AYILFT	ICS87993AILF	32 Lead “Lead-Free” LQFP	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
A	T4	4 7	AC Table - deleted Note 6. Added “Wiring the Differential Input to Accept Single Ended Levels”.	1/16/03
B	 T1 T2 T4	1 2 2 3 4	Features Section - changed VCO max. from 360MHz to 500MHz. Pin Descriptions Table - revised nMR description. Pin Characteristics Table - changed C_{IN} from max. 4pF to typical 4pF. Absolute Maximum Ratings - changed V_O to I_O and included Continuous Current and Surge Current AC Characteristics Table - changed fVCO from 360MHz to 500MHz. t_{PD} - added test conditions to CLKx to EXT_FB. Added another line with 500MHz test conditions. odc - added test conditions.	5/21/03
		8 9 & 10	Added Differential Clock Input Interface in the Application Information section. Added Schematic Example.	
B	T8	15	Ordering Information Table - added Lead-Free part number.	10/21/04
C	T8	 15 17	Updated datasheet’s header/footer with IDT from ICS. Removed “ICS” prefix from Part/Order Number column. Added Contact Page.	7/26/10
C	T8	15	Ordering Information - removed leaded devices, PDN CQ-13-02 Updated data sheet format	2/18/15

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