



# FEMTOCLOCKS™ CRYSTAL-TO-HCSL CLOCK GENERATOR

ICS841654I

## GENERAL DESCRIPTION

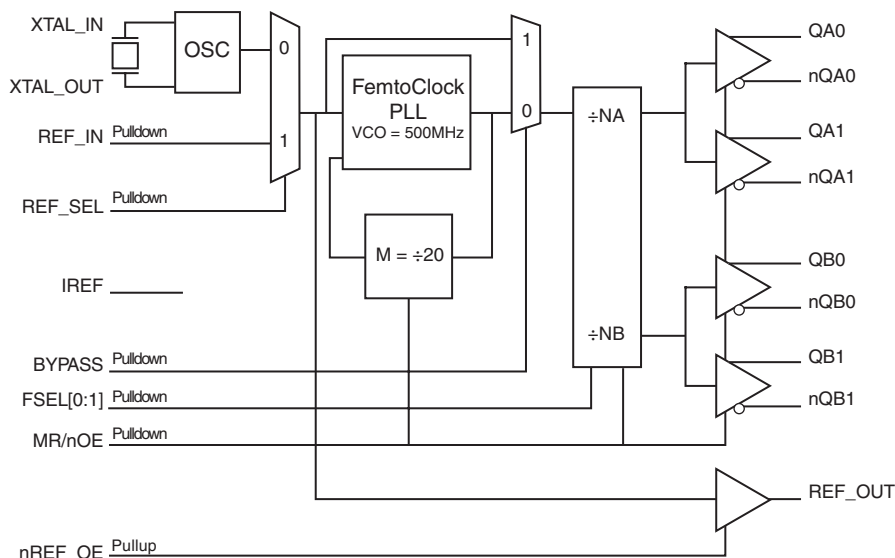


The ICS841654I is an optimized PCIe and sRIO clock generator and member of the HiPerClocks™ family of high-performance clock solutions from IDT. The device uses a 25MHz parallel crystal to generate 100MHz and 125MHz clock signals, replacing solutions requiring multiple oscillator and fanout buffer solutions. The device has excellent phase jitter (< 1ps rms) suitable to clock components requiring precise and low-jitter PCIe or sRIO or both clock signals. Designed for telecom, networking and industrial applications, the ICS841654I can also drive the high-speed sRIO and PCIe SerDes clock inputs of communication processors, DSPs, switches and bridges.

## FEATURES

- Four differential HCSL clock outputs: configurable for PCIe (100MHz) and sRIO (100MHz or 125MHz) clock signals  
One REF\_OUT LVCMOS/LVTTL clock output
- Selectable crystal oscillator interface, 25MHz, 18pF parallel resonant crystal or LVCMOS/LVTTL single-ended reference clock input
- Supports the following output frequencies:  
100MHz or 125MHz
- VCO: 500MHz
- PLL bypass and output enable
- RMS phase jitter at 100MHz, using a 25MHz crystal (1.875MHz - 20MHz): 0.44ps (typical)
- Full 3.3V power supply mode
- -40°C to 85°C ambient operating temperature
- Available in both standard (RoHS 5) and lead-free (RoHS 6) packages

## BLOCK DIAGRAM



## PIN ASSIGNMENT

VDD	1	28	IREF
REF_OUT	2	27	FSELO
GND	3	26	FSEL1
QA0	4	25	QB0
nQA0	5	24	nQB0
VDDOA	6	23	VDDOB
GND	7	22	GND
QA1	8	21	QB1
nQA1	9	20	nQB1
nREF_OE	10	19	MR/nOE
BYPASS	11	18	VDD
REF_IN	12	17	XTAL_IN
REF_SEL	13	16	XTAL_OUT
VDDA	14	15	GND

**ICS841654I**

**28-Lead TSSOP**

6.1mm x 9.7mm x 0.925mm  
package body  
**G Package**  
Top View

TABLE 1. PIN DESCRIPTIONS

Number	Name	Type		Description
1, 18	V <sub>DD</sub>	Power		Core supply pins.
2	REF_OUT	Output		Single-ended reference frequency clock output. LVCMOS/LVTTL interface levels.
3, 7, 15, 22	GND	Power		Power supply ground.
4, 5, 8, 9	QA0, nQA0, QA1, nQA1	Output		Differential Bank A output pairs. HCSL interface levels.
6	V <sub>DDOA</sub>	Power		Output supply pin for Bank A outputs.
10	nREF_OE	Input	Pullup	Active low REF_OUT enable/disable. See Table 3E. LVCMOS/LVTTL interface levels.
11	BYPASS	Input	Pulldown	Selects PLL operation/PLL bypass operation. See Table 3C. LVCMOS/LVTTL interface levels.
12	REF_IN	Input	Pulldown	Single-ended PLL reference clock input. LVCMOS/LVTTL interface levels.
13	REF_SEL	Input	Pulldown	Reference select. Selects the input reference source. See Table 3B. LVCMOS/LVTTL interface levels.
14	V <sub>DDA</sub>	Power		Analog supply pin.
16, 17	XTAL_OUT, XTAL_IN	Input		Parallel resonant crystal interface. XTAL_OUT is the output, XTAL_IN is the input. (PLL reference.)
19	MR/nOE	Input	Pulldown	Active HIGH master reset. Active LOW output enable. When logic HIGH, the internal dividers are reset and the differential outputs are in high impedance (HiZ). When logic LOW, the internal dividers and the differential outputs are enabled. See Table 3D. LVCMOS/LVTTL interface levels.
20, 21, 24, 25	nQB1, QB1, nQB0, QB0	Output		Differential Bank B output pairs. HCSL interface levels.
23	V <sub>DDOB</sub>	Power		Output supply pin for Bank B outputs.
26, 27	FSEL1, FSEL0	Input	Pulldown	Output frequency select pins. LVCMOS/LVTTL interface levels.
28	IREF	Output		HCSL current reference external resistor output. A fixed precision resistor (RREF = 475Ω) from this pin to ground provides a reference current used for differential current-mode QA[0:1]/nQA[0:1] and QB[0:1]/nQB[0:1] clock outputs.

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

TABLE 2. PIN CHARACTERISTICS

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
C <sub>IN</sub>	Input Capacitance			4		pF
R <sub>PULLUP</sub>	Input Pullup Resistor			51		kΩ
R <sub>PULLDOWN</sub>	Input Pulldown Resistor			51		kΩ

TABLE 3A. FSELx FUNCTION TABLE ( $f_{ref} = 25\text{MHz}$ )

Inputs			Outputs Frequency Settings	
FSEL1	FSEL0	M	QA0:1/nQA0:1	QB0:1/nQB0:1
0	0	20	VCO/5 (100MHz)	VCO/5 (100MHz) (default)
0	1	20	VCO/5 (100MHz)	VCO/4 (125MHz)
1	0	20	VCO/5 (100MHz)	QB0:1 = L, nQB0:1 = H
1	1	20	VCO/4 (125MHz)	VCO/4 (125MHz)

TABLE 3B. REF\_SEL FUNCTION TABLE

Input	
REF_SEL	Input Reference
0	XTAL (default)
1	REF_IN

TABLE 3C. BYPASS FUNCTION TABLE

Input	
BYPASS	PLL Configuration <sup>NOTE 1</sup>
0	PLL on (default)
1	PLL bypassed (QA, QB = fref/N)

NOTE 1: Asynchronous function.

TABLE 3D. MR/nOE FUNCTION TABLE

Input	
MR/nOE	Function <sup>NOTE 1</sup>
0	Outputs enabled (default)
1	Device reset, outputs disabled (High Impedance)

NOTE 1: Asynchronous function.

TABLE 3E. nREF\_OE FUNCTION TABLE

Input	
nREF_OE	Function <sup>NOTE 1</sup>
0	REF_OUT enabled
1	REF_OUT disabled (High Impedance) (default)

NOTE 1: Asynchronous function.

#### ABSOLUTE MAXIMUM RATINGS

Supply Voltage, $V_{DD}$	4.6V
Inputs, $V_I$	-0.5V to $V_{DD} + 0.5V$
Outputs, $V_O$	-0.5V to $V_{DDOX} + 0.5V$
Package Thermal Impedance, $\theta_{JA}$	64.4°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 CHARACTERISTICS,  $V_{DD} = V_{DDOA} = V_{DDOB} = 3.3V \pm 5\%$ ,  $T_A = -40^\circ\text{C}$  TO  $85^\circ\text{C}$**

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{DD}$	Core Supply Voltage		3.135	3.3	3.465	V
$V_{DDA}$	Analog Supply Voltage		$V_{DD} - 0.20$	3.3	3.465	V
$V_{DDOA}$ , $V_{DDOB}$	Output Supply Voltage		3.135	3.3	3.465	V
$I_{DD}$	Power Supply Current	Unterminated			85	mA
$I_{DDA}$	Analog Supply Current	Unterminated			20	mA
$I_{DDOA}$ and $I_{DDOB}$	Output Supply Current	Unterminated, $R_{REF} = 475\Omega \pm 1\%$			5	mA

**TABLE 4B. LVCMOS / LVTTTL DC CHARACTERISTICS,  $V_{DD} = 3.3V \pm 5\%$ ,  $T_A = -40^\circ\text{C}$  TO  $85^\circ\text{C}$**

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{IH}$	Input High Voltage		2		$V_{DD} + 0.3$	V
$V_{IL}$	Input Low Voltage		-0.3		0.8	V
$I_{IH}$	Input High Current	REF_IN, REF_SEL, BYPASS, MR/nOE, FSEL0, FSEL1	$V_{DD} = V_{IN} = 3.465\text{ V}$		150	$\mu\text{A}$
		nREF_OE	$V_{DD} = V_{IN} = 3.465\text{ V}$		5	$\mu\text{A}$
$I_{IL}$	Input Low Current	REF_IN, REF_SEL, BYPASS, MR/nOE, FSEL0, FSEL1	$V_{DD} = 3.465\text{ V}, V_{IN} = 0\text{ V}$	-5		$\mu\text{A}$
		nREF_OE	$V_{DD} = 3.465\text{ V}, V_{IN} = 0\text{ V}$	-150		$\mu\text{A}$
$V_{OH}$	Output High Voltage; NOTE 1	REF_OUT	$V_{DD} = 3.465\text{ V}$	2.6		V
$V_{OL}$	Output Low Voltage; NOTE 1	REF_OUT	$V_{DD} = 3.465\text{ V}$		0.5	V
$Z_{OUT}$	Output Impedance	REF_OUT	$V_{DD} = 3.465\text{ V}$	20		$\Omega$

NOTE 1: Outputs terminated with  $50\Omega$  to  $V_{DD}/2$ . See Parameter Measurement Information Section, *Output Load Test Circuit diagram*.

TABLE 5. CRYSTAL CHARACTERISTICS

Parameter	Test Conditions	Minimum	Typical	Maximum	Units
Mode of Oscillation		Fundamental			
Frequency			25		MHz
Equivalent Series Resistance (ESR)				50	$\Omega$
Shunt Capacitance				7	pF

NOTE: Characterized using an 18pF parallel resonant crystal.

TABLE 6A. LVCMOS AC CHARACTERISTICS,  $V_{DD} = 3.3V \pm 5\%$ ,  $T_A = -40^\circ C$  TO  $85^\circ C$

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$f_{MAX}$	Output Frequency	REF_OUT		25		MHz
$t_R / t_F$	Output Rise/Fall Time	20% to 80%	0.60		1.80	ns
odc	Output Duty Cycle		49		51	%

TABLE 6B. HCSL AC CHARACTERISTICS,  $V_{DD} = V_{DDOA} = V_{DDOB} = 3.3V \pm 5\%$ ,  $T_A = -40^\circ C$  TO  $85^\circ C$

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$f_{MAX}$	Output Frequency	VCO/5		100		MHz
		VCO/4		125		MHz
$f_{jit}(\emptyset)$	RMS Phase Jitter (Random); NOTE 1	100MHz, (1.875MHz - 20MHz)		0.44		ps
		125MHz, (1.875MHz - 20MHz)		0.44		ps
$f_{jit}(cc)$	Cycle-to-Cycle Jitter; NOTE 3				35	ps
$t_{sk}(o)$	Output Skew; NOTE 2, 3	QAx/nQAx, QBx/nQBx			100	ps
$t_L$	PLL Lock Time				100	ms
$V_{HIGH}$	Voltage High	125MHz	650	700	950	mV
$V_{LOW}$	Voltage Low		-150		150	mV
$V_{OVS}$	Max. Voltage, Overshoot				0.3	V
$V_{UDS}$	Min. Voltage, Undershoot		-0.3			V
$V_{rb}$	Ringback Voltage				0.2	V
$V_{CROSS}$	Absolute Crossing Voltage		200		550	mV
$\Delta V_{CROSS}$	Total Variation of $V_{CROSS}$ over all edges				160	mV
$t_R / t_F$	Output Rise/Fall Time	QAx/nQAx, QBx/nQBx	measured between 0.175V to 0.525V	100	700	ps
$\Delta t_R / \Delta t_F$	Rise/Fall Time Variation				125	ps
odc	Output Duty Cycle	QAx/nQAx, QBx/nQBx	48		52	%

NOTE: All specifications are taken at 100MHz and 125MHz.

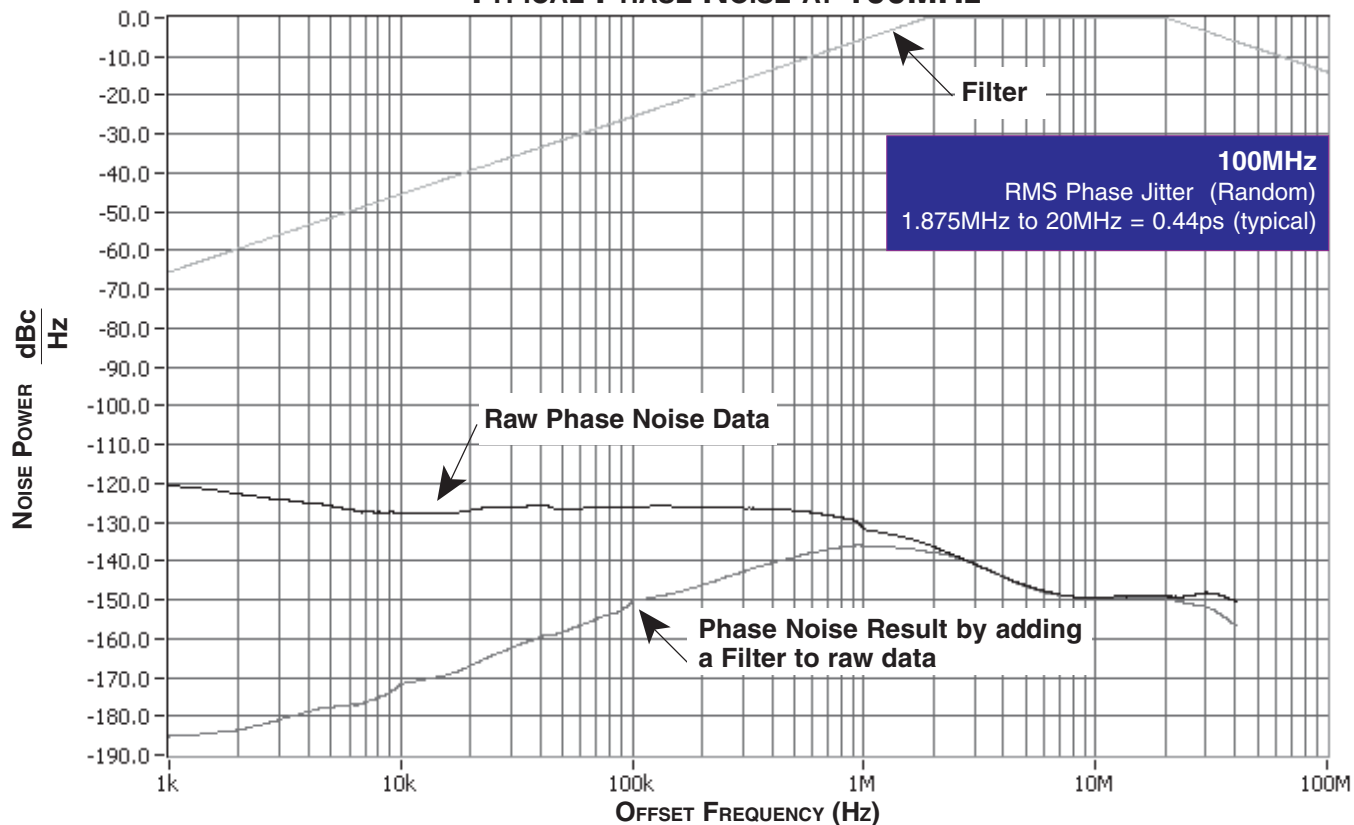
NOTE 1: Please refer to the Phase Noise Plot.

NOTE 2: Defined as skew between outputs at the same supply voltage and with equal load conditions.

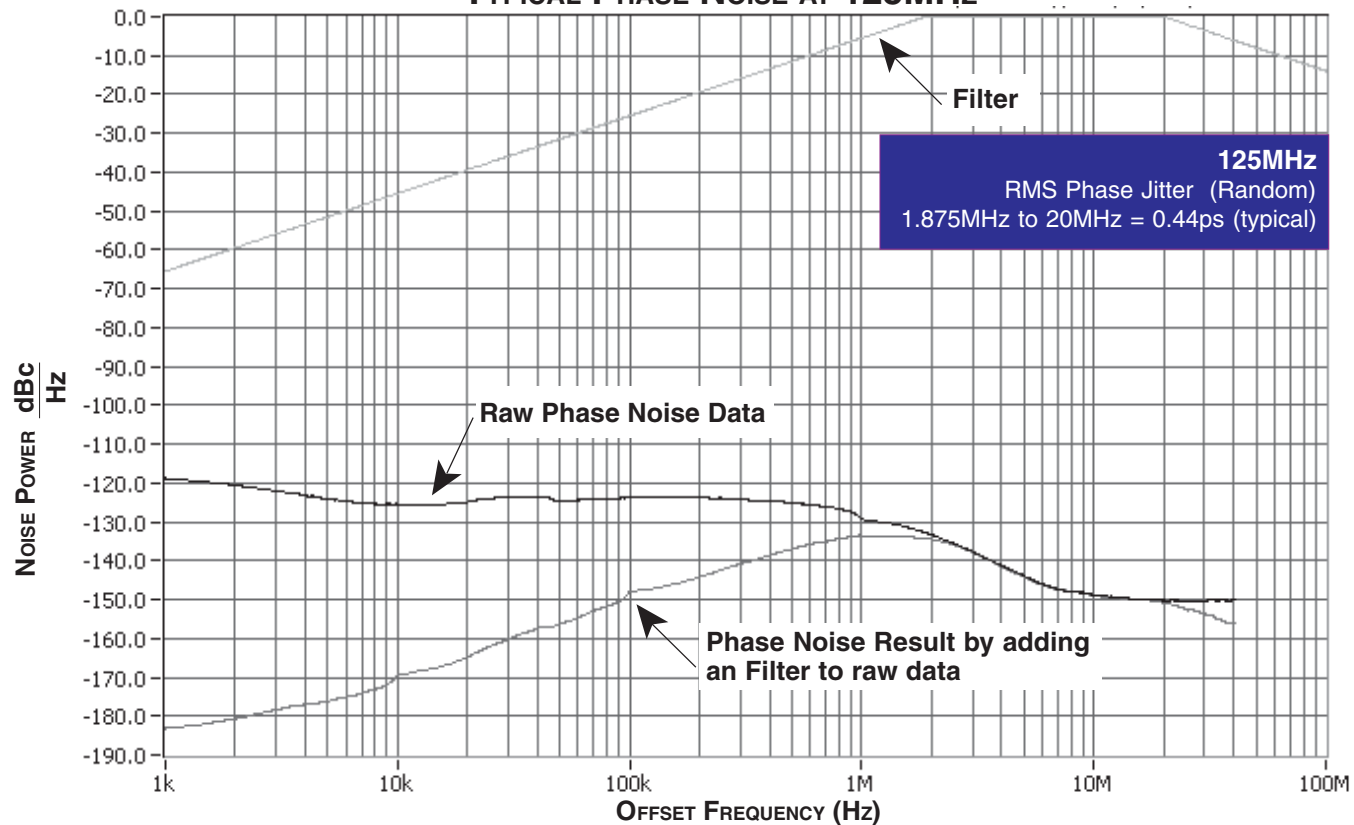
Measured at the output differential cross points.

NOTE 3: This parameter is defined in accordance with JEDEC Standard 65.

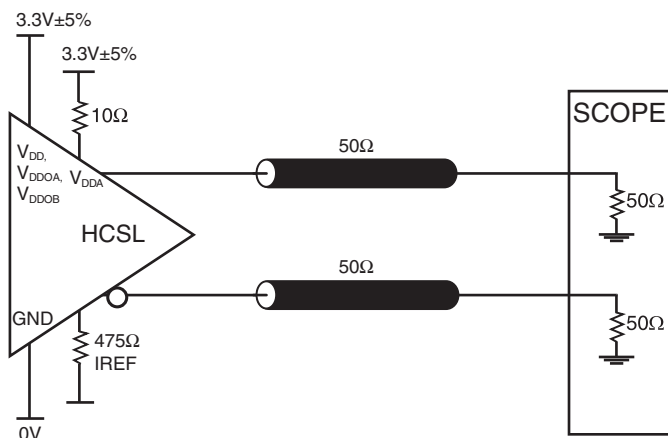
### TYPICAL PHASE NOISE AT 100MHz



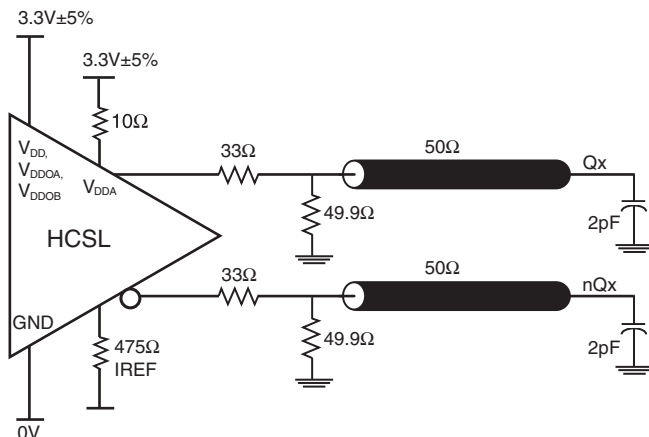
### TYPICAL PHASE NOISE AT 125MHz



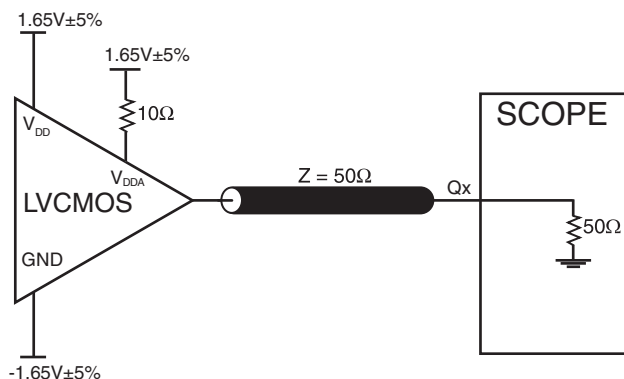
## PARAMETER MEASUREMENT INFORMATION



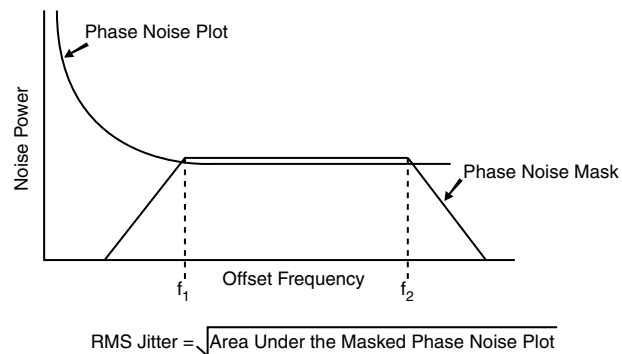
HCSL OUTPUT LOAD AC TEST CIRCUIT



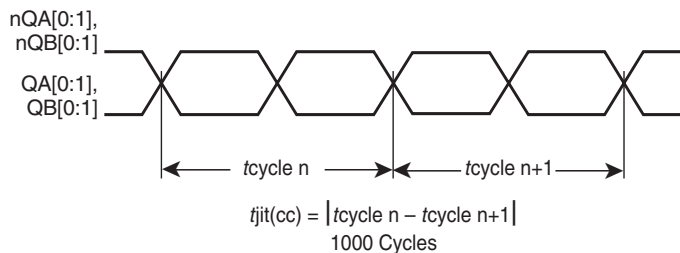
HCSL OUTPUT LOAD AC TEST CIRCUIT



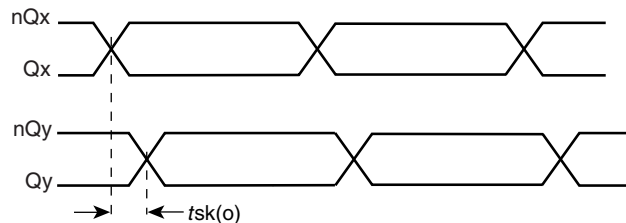
3.3V LVCMOS OUTPUT LOAD AC TEST CIRCUIT



RMS PHASE JITTER

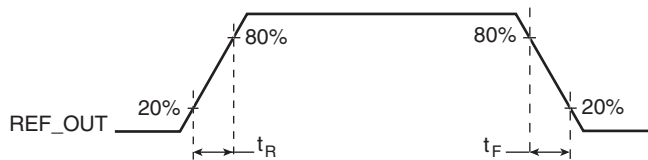


CYCLE-TO-CYCLE JITTER

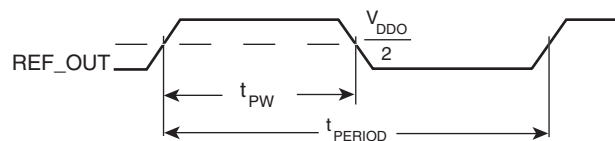


HCSL OUTPUT SKEW

## PARAMETER MEASUREMENT INFORMATION, CONTINUED

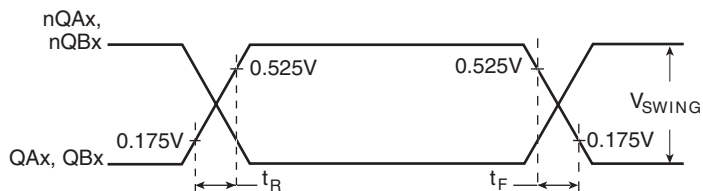


**LVC MOS OUTPUT RISE/FALL TIME**

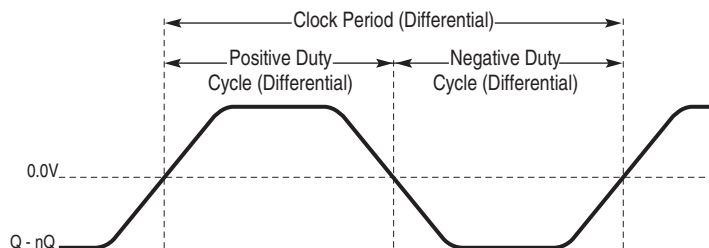


$$\text{odc} = \frac{t_{PW}}{t_{PERIOD}} \times 100\%$$

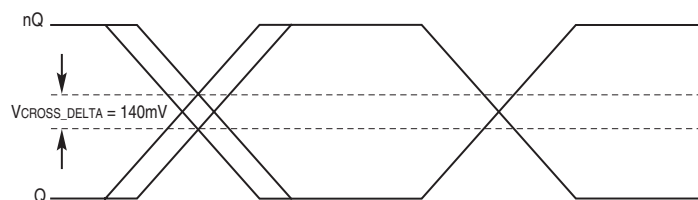
**LVC MOS OUTPUT DUTY CYCLE/PULSE WIDTH/PERIOD**



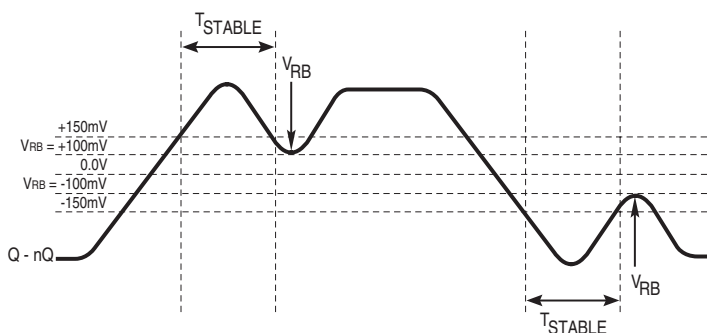
**DIFFERENTIAL MEASUREMENT POINTS FOR RISE/FALL TIME**



**DIFFERENTIAL MEASUREMENT POINTS FOR DUTY CYCLE/PERIOD**



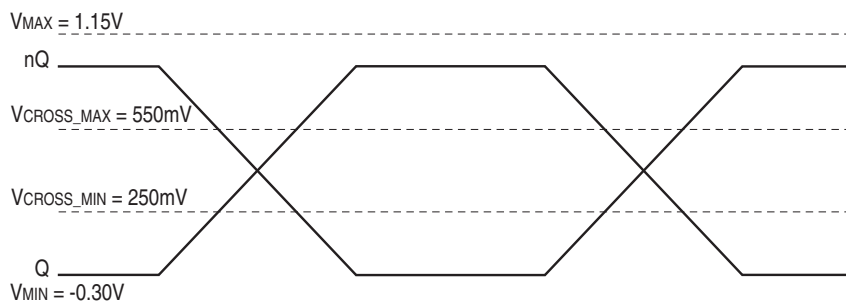
**SE MEASUREMENT POINTS FOR DELTA CROSS POINT**



**DIFFERENTIAL MEASUREMENT POINTS FOR RINGBACK**



## PARAMETER MEASUREMENT INFORMATION, CONTINUED



### SE MEASUREMENT POINTS FOR ABSOLUTE CROSS POINT/SWING

## APPLICATION INFORMATION

### POWER SUPPLY FILTERING TECHNIQUES

As in any high speed analog circuitry, the power supply pins are vulnerable to random noise. To achieve optimum jitter performance, power supply isolation is required. The ICS841654I provides separate power supplies to isolate any high switching noise from the outputs to the internal PLL.  $V_{DD}$ ,  $V_{DDA}$ ,  $V_{DDOA}$  and  $V_{DDOB}$  should be individually connected to the power supply plane through vias, and  $0.01\mu\text{F}$  bypass capacitors should be used for each pin. Figure 1 illustrates this for a generic  $V_{DD}$  pin and also shows that  $V_{DDA}$  requires that an additional  $10\Omega$  resistor along with a  $10\mu\text{F}$  bypass capacitor be connected to the  $V_{DDA}$  pin.

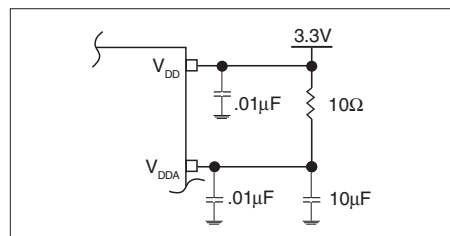


FIGURE 1. POWER SUPPLY FILTERING

### RECOMMENDATIONS FOR UNUSED INPUT AND OUTPUT PINS

#### INPUTS:

##### CRYSTAL INPUTS

For applications not requiring the use of the crystal oscillator input, both XTAL\_IN and XTAL\_OUT can be left floating. Though not required, but for additional protection, a  $1\text{k}\Omega$  resistor can be tied from XTAL\_IN to ground.

##### REF\_IN INPUT

For applications not requiring the use of the reference clock, it can be left floating. Though not required, but for additional protection, a  $1\text{k}\Omega$  resistor can be tied from the REF\_IN to ground.

##### LVC MOS 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  $1\text{k}\Omega$  resistor can be used.

#### OUTPUTS:

##### HCSL OUTPUTS

All unused HCSL 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.

##### LVC MOS OUTPUT

The unused LVC MOS output can be left floating. We recommend that there is no trace attached.

## CRYSTAL INPUT INTERFACE

The ICS841654I has been characterized with 18pF parallel resonant crystals. The capacitor values shown in *Figure 2* below

were determined using a 25MHz, 18pF parallel resonant crystal and were chosen to minimize the ppm error.

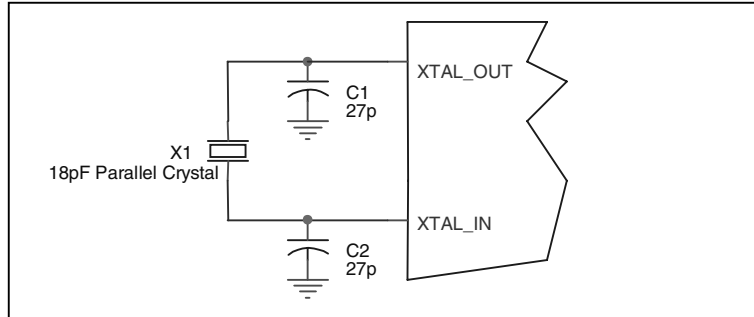


FIGURE 2. CRYSTAL INPUT INTERFACE

## LVC MOS TO XTAL INTERFACE

The XTAL\_IN input can accept a single-ended LVC MOS signal through an AC couple capacitor. A general interface diagram is shown in *Figure 3*. The XTAL\_OUT pin can be left floating. The input edge rate can be as slow as 10ns. For LVC MOS inputs, it is recommended that the amplitude be reduced from full swing to half swing in order to prevent signal interference with the power rail and to reduce noise. This configuration requires that the output impedance of the driver ( $R_o$ ) plus the

series resistance ( $R_s$ ) equals the transmission line impedance. In addition, matched termination at the crystal input will attenuate the signal in half. This can be done in one of two ways. First,  $R_1$  and  $R_2$  in parallel should equal the transmission line impedance. For most 50Ω applications,  $R_1$  and  $R_2$  can be 100Ω. This can also be accomplished by removing  $R_1$  and making  $R_2$  50Ω.

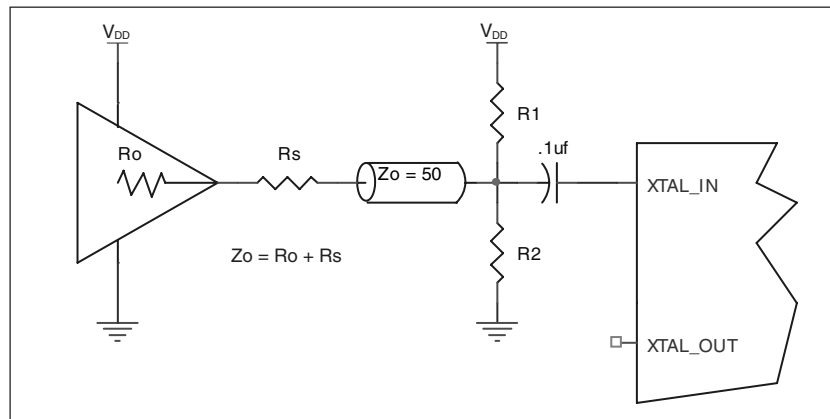
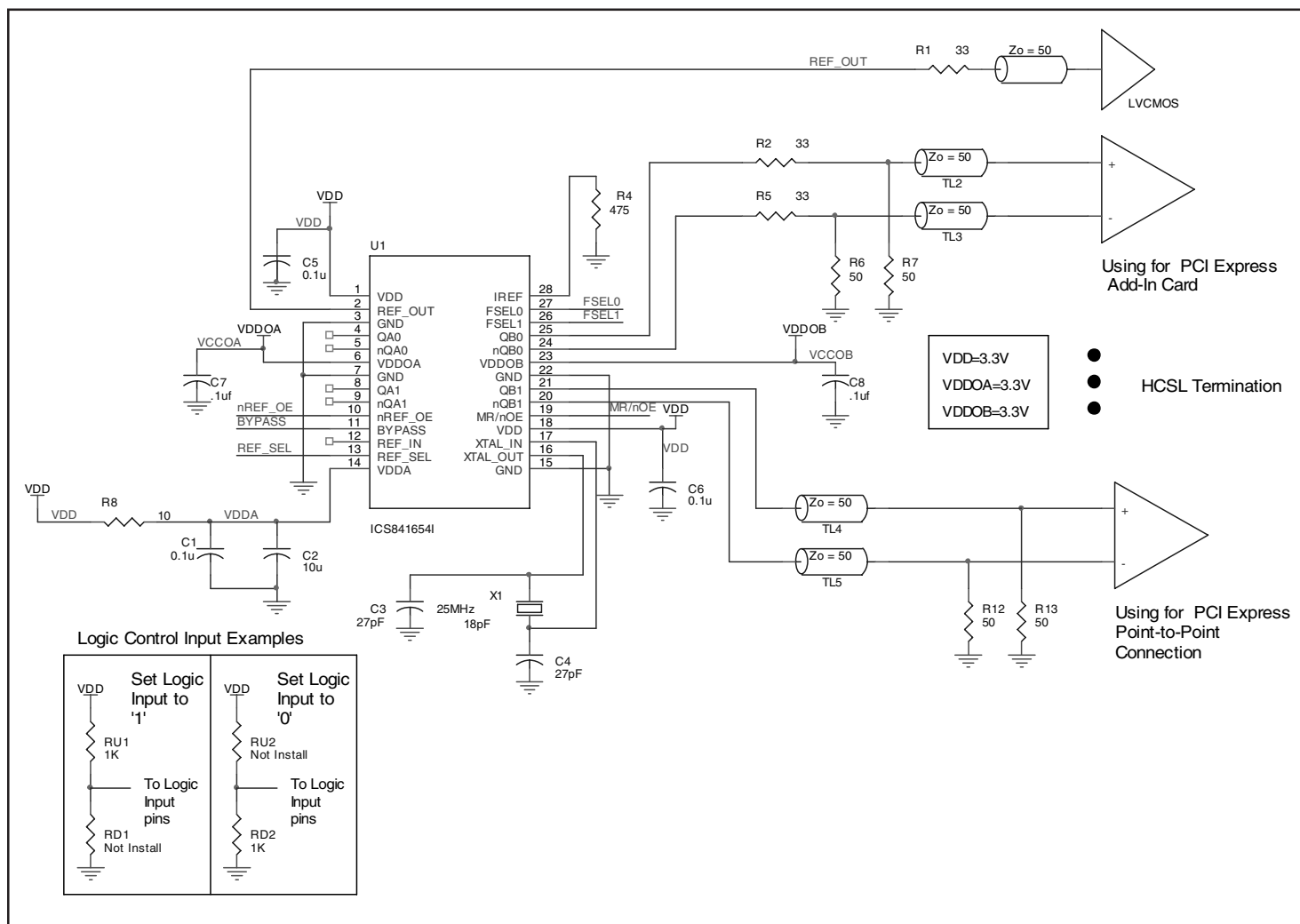


FIGURE 3. GENERAL DIAGRAM FOR LVC MOS DRIVER TO XTAL INPUT INTERFACE

## SCHEMATIC LAYOUT

Figure 4 shows an example of ICS841654I application schematic. In this example, the device is operated at  $V_{CC} = 3.3V$ . The 18pF parallel resonant 25MHz crystal is used. The  $C1 = 27pF$  and  $C2 = 27pF$  are recommended for frequency accuracy. For different board layout, the  $C1$  and

C2 may be slightly adjusted for optimizing frequency accuracy. One example of HCSL and one example of LVCMOS terminations are shown in this schematic. The decoupling capacitors should be located as close as possible to the power pin.



### FIGURE 4. ICS841654I SCHEMATIC LAYOUT

## POWER CONSIDERATIONS

This section provides information on power dissipation and junction temperature for the ICS841654I. Equations and example calculations are also provided.

### 1. Power Dissipation.

The total power dissipation for the ICS841654I is the sum of the core power plus the power dissipated in the load(s). The following is the power dissipation for  $V_{DD} = 3.3V + 5\% = 3.465V$ , which gives worst case results.

**NOTE:** Please refer to Section 3 for details on calculating power dissipated in the load.

- Power (core)<sub>MAX</sub> =  $V_{DD\_MAX} * I_{DD\_MAX} = 3.465V * 85mA = 294.5mW$
- Power (outputs)<sub>MAX</sub> = **50.06mW/Loaded Output pair**  
If all outputs are loaded, the total power is  $4 * 50.06mW = 200.24mW$

**Total Power**<sub>MAX</sub> (3.465V, with all outputs switching) =  $294.5mW + 200.24mW = 494.74mW$

### 2. Junction Temperature.

Junction temperature,  $T_j$ , is the temperature at the junction of the bond wire and bond pad and directly affects the reliability of the device. The maximum recommended junction temperature for HiPerClockS™ devices is 125°C.

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

$T_j$  = Junction Temperature

$\theta_{JA}$  = 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  $\theta_{JA}$  must be used. Assuming no air flow and a multi-layer board, the appropriate value is 64.5°C/W per Table 7 below.

Therefore,  $T_j$  for an ambient temperature of 85°C with all outputs switching is:  
 $85°C + 0.495W * 64.5°C/W = 116.9°C$ . This is below the limit of 125°C.

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

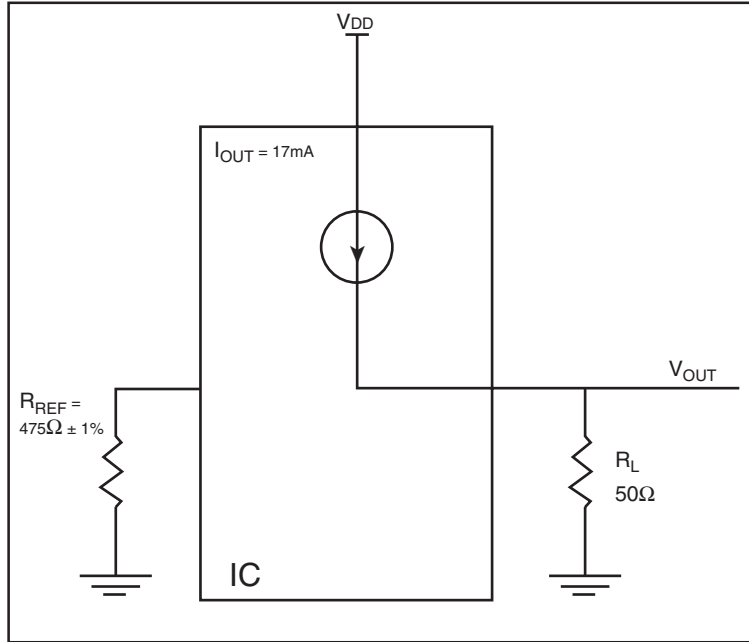
**TABLE 7. THERMAL RESISTANCE  $\theta_{JA}$  FOR 28-LEAD TSSOP, FORCED CONVECTION**

$\theta_{JA}$ by Velocity (Meters per Second)			
	0	1	2.5
Multi-Layer PCB, JEDEC Standard Test Boards	64.5°C/W	60.4°C/W	58.5°C/W

### 3. Calculations and Equations.

The purpose of this section is to calculate power dissipation on the IC per HCSL output pair.

HCSL output driver circuit and termination are shown in *Figure 4*.



**FIGURE 4. HCSL DRIVER CIRCUIT AND TERMINATION**

HCSL is a current steering output which sources a maximum of 17mA of current per output. To calculate worst case on-chip power dissipation, use the following equations which assume a 50Ω load to ground.

The highest power dissipation occurs when  $V_{DD}$  is HIGH.

$$\begin{aligned} \text{Power} &= (V_{DD\_HIGH} - V_{OUT}) * I_{OUT}, \text{ since } V_{OUT} = I_{OUT} * R_L \\ &= (V_{DD\_HIGH} - I_{OUT} * R_L) * I_{OUT} \\ &= (3.465V - 17mA * 50\Omega) * 17mA \end{aligned}$$

Total Power Dissipation per output pair = **50.06mW**

## RECOMMENDED TERMINATION

Figure 5A is the recommended termination for applications which require the receiver and driver to be on a separate PCB. All traces should be 50Ω impedance.

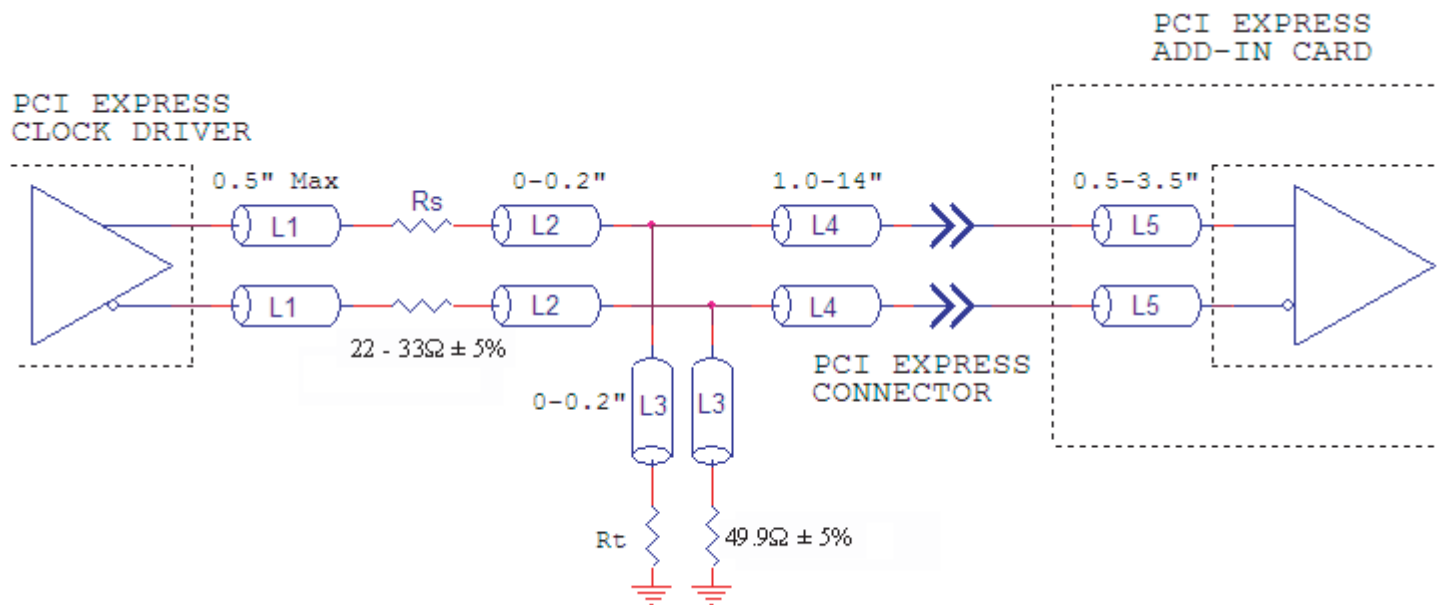


FIGURE 5A. RECOMMENDED TERMINATION

Figure 5B is the recommended termination for applications which require a point to point connection and contain the driver and receiver on the same PCB. All traces should all be 50Ω impedance.

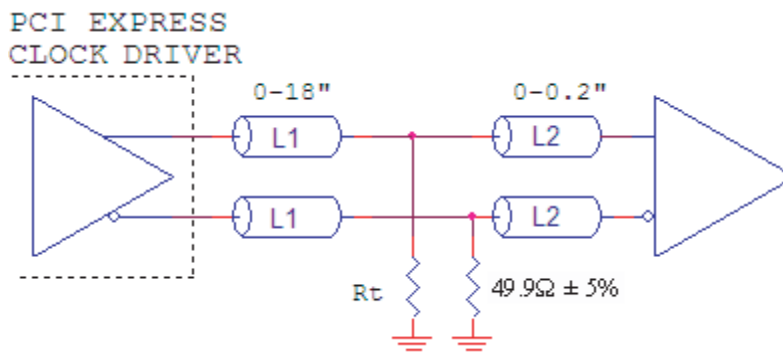


FIGURE 5B. RECOMMENDED TERMINATION

## RELIABILITY INFORMATION

TABLE 8.  $\theta_{JA}$  VS. AIR FLOW TABLE FOR 28 LEAD TSSOP

$\theta_{JA}$ by Velocity (Meters per Second)			
	0	1	2.5
Multi-Layer PCB, JEDEC Standard Test Boards	64.5°C/W	60.4°C/W	58.5°C/W

### TRANSISTOR COUNT

The transistor count for ICS841654I is: 2954

## PACKAGE OUTLINE AND PACKAGE DIMENSIONS

PACKAGE OUTLINE - G SUFFIX FOR 28 LEAD TSSOP

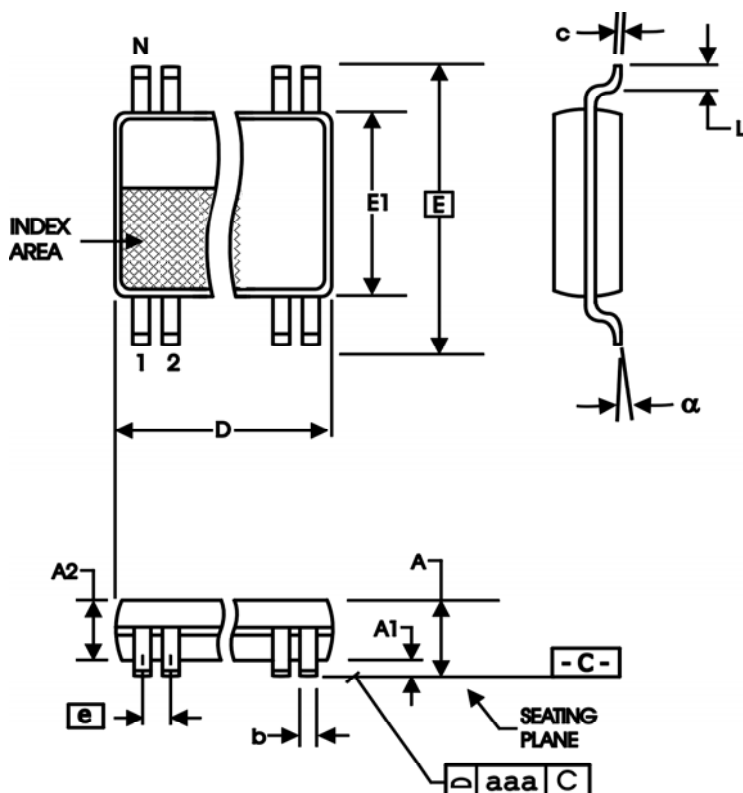


TABLE 9. PACKAGE DIMENSIONS

SYMBOL	Millimeters	
	Minimum	Maximum
N	28	
A	--	1.20
A1	0.05	0.15
A2	0.80	1.05
b	0.19	0.30
c	0.09	0.20
D	9.60	9.80
E	8.10 BASIC	
E1	6.00	6.20
e	0.65 BASIC	
L	0.45	0.75
$\alpha$	0°	8°
aaa	--	0.10

Reference Document: JEDEC Publication 95, MO-153

**TABLE 10. ORDERING INFORMATION**

Part/Order Number	Marking	Package	Shipping Packaging	Temperature
ICS841654AGI	ICS841654AGI	28 Lead TSSOP	tube	-40°C to 85°C
ICS841654AGIT	ICS841654AGI	28 Lead TSSOP	1000 tape & reel	-40°C to 85°C
ICS841654AGILF	ICS841654AGILF	28 Lead "Lead-Free" TSSOP	tube	-40°C to 85°C
ICS841654AGILFT	ICS841654AGILF	28 Lead "Lead-Free" TSSOP	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.

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