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PRELIMINARY

## PCI EXPRESS™ CLOCK GENERATOR

ICS841S04I

### GENERAL DESCRIPTION

 The ICS841S04I is a PLL-based clock generator specifically designed for PCI\_Express™ Clock Generation applications. This device generates a 100MHz HCSL clock. The device offers a HCSL (Host Clock Signal Level) clock output from a clock input reference of 25MHz. The input reference may be derived from an external source or by the addition of a 25MHz crystal to the on-chip crystal oscillator. An external reference may be applied to the XTAL\_IN pin with the XTAL\_OUT pin left floating.

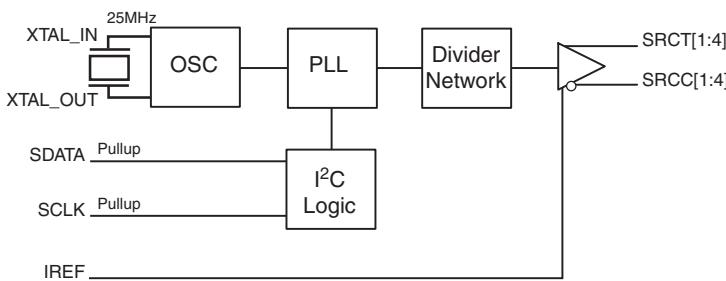
The device offers spread spectrum clock output for reduced EMI applications. An I<sup>2</sup>C bus interface is used to enable or disable spread spectrum operation as well as select either a down spread value of -0.35% or -0.5%.

The ICS841S04I is available in both standard and lead-free 24-Lead TSSOP packages.

### FEATURES

- Four 0.7V current mode differential HCSL output pairs
- Crystal oscillator interface, 25MHz
- Output frequency: 100MHz
- RMS period jitter: 3ps (maximum)
- Output skew: 70ps (maximum)
- Cycle-to-cycle jitter: 35ps (maximum)
- I<sup>2</sup>C support with readback capabilities up to 400kHz
- Spread Spectrum for electromagnetic interference (EMI) reduction
- 3.3V operating 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

SRCT3	1	24	SRCC4
SRCC3	2	23	SRCT4
VSS_SRC	3	22	VDD_SRC
VDD_SRC	4	21	SDATA
SRCT2	5	20	SCLK
SRCC2	6	19	XTAL_OUT
SRCT1	7	18	XTAL_IN
SRCC1	8	17	VDD_REF
VSS_SRC	9	16	VSS_REF
VDD_SRC	10	15	nc
VSS_SRC	11	14	VDDA
IREF	12	13	VSSA

**ICS841S04I**

**24-Lead TSSOP**

4.40mm x 7.8mm x 0.92mm

package body

**G Package**

Top View

The Preliminary Information presented herein represents a product in pre-production. The noted characteristics are based on initial product characterization and/or qualification. Integrated Device Technology, Incorporated (IDT) reserves the right to change any circuitry or specifications without notice.

**TABLE 1. PIN DESCRIPTIONS**

Number	Name	Type	Description			
1, 2 5, 6 7, 8	SRCT3, SRCC3 SRCT2, SRCC2 SRCT1, SRCC1	Output	Differential output pair. HCSL interface levels.			
3, 9, 11	$V_{SS\_SRC}$	Power	Ground for core and SRC outputs.			
4, 10, 22	$V_{DD\_SRC}$	Power	Power supply for core and SRC outputs.			
12	IREF	Input	A fixed precision resistor ( $475\Omega$ ) from this pin to ground provides a reference current used for differential current-mode SRCCx, SRCTx clock outputs.			
13	$V_{SSA}$	Power	Analog ground pin.			
14	$V_{DDA}$	Power	Power supply for PLL.			
15	nc	Unused	No connect.			
16	$V_{SS\_REF}$	Power	Ground for crystal interface			
17	$V_{DD\_REF}$	Power	Power supply for crystal interface.			
18, 19	XTAL_IN, XTAL_OUT	Input	Crystal oscillator interface. XTAL_IN is the input. XTAL_OUT is the output.			
20	SCLK	Input	Pullup	SMBus compatible SCLK. This pin has an internal pullup resistor, but is in high impedance in powerdown mode. LVCMOS/LVTTL interface levels.		
21	SDATA	Input/ Output	Pullup	SMBus compatible SDATA. This pin has an internal pullup resistor, but is in high impedance in powerdown mode. LVCMOS/LVTTL interface levels.		
23, 24	SRCT4, SRCC4	Output		Differential output pair. HCSL interface levels.		

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

**TABLE 2. PIN CHARACTERISTICS**

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$C_{IN}$	Input Capacitance			4		pF
$R_{PULLUP}$	Input Pullup Resistor			51		k $\Omega$
$C_{OUT}$	Output Pin Capacitance		3		5	pF
$L_{IN}$	Pin Inductance				7	nH

## SERIAL DATA INTERFACE

To enhance the flexibility and function of the clock synthesizer, a two-signal serial interface is provided. Through the Serial Data Interface, various device functions, such as individual clock output buffers, can be individually enabled or disabled. The registers associated with the Serial Data Interface initialize to their default setting upon power-up, and therefore, use of this interface is optional. Clock device register changes are normally made upon system initialization, if any are required. The interface cannot be used during system operation for power management functions.

## DATA PROTOCOL

The clock driver serial protocol accepts byte write, byte read, block write, and block read operations from the controller. For block write/read operation, the bytes must be accessed in sequential order from lowest to highest byte (most significant bit first) with the ability to stop after any complete byte has been transferred. For byte write and byte read operations, the system controller can access individually indexed bytes. The offset of the indexed byte is encoded in the command code, as described in *Table 3A*.

The block write and block read protocol is outlined in *Table 3B*, while *Table 3C* outlines the corresponding byte write and byte read protocol. The slave receiver address is 11010010 (D2h).

**TABLE 3A. COMMAND CODE DEFINITION**

BIT	Description
7	0 = Block read or block write operation, 1 = Byte read or byte write operation.
6:5	Chip select address, set to "00" to access device.
4:0	Byte offset for byte read or byte write operation. For block read or block write operations, these bits must be "00000".

**TABLE 3B. BLOCK READ AND BLOCK WRITE PROTOCOL**

BIT	Description = Block Write	BIT	Description = Block Read
1	Start	1	Start
2:8	Slave address - 7 bits	2:8	Slave address - 7 bits
9	Write	9	Write
10	Acknowledge from slave	10	Acknowledge from slave
11:18	Command Code - 8 bits	11:18	Command Code - 8 bits
19	Acknowledge from slave	19	Acknowledge from slave
20:27	Byte Count - 8 bits	20	Repeat start
28	Acknowledge from slave	21:27	Slave address - 7 bits
29:36	Data byte 1 - 8 bits	28	Read = 1
37	Acknowledge from slave	29	Acknowledge from slave
38:45	Data byte 2 - 8 bits	30:37	Byte Count from slave - 8 bits
46	Acknowledge from slave	38	Acknowledge
	Data Byte/Slave Acknowledges	39:46	Data Byte 1 from slave - 8 bits
	Data Byte N - 8 bits	47	Acknowledge
	Acknowledge from slave	48:55	Data Byte 2 from slave - 8 bits
	Stop	56	Acknowledge
			Data Bytes from Slave / Acknowledges
			Data Byte N from slave - 8 bits
			Not Acknowledge

**TABLE 3C. BYTE READ AND BYTE WRITE PROTOCOL**

<b>BIT</b>	<b>Description = Byte Write</b>	<b>BIT</b>	<b>Description = Byte Read</b>
1	Start	1	Start
2:8	Slave address - 7 bits	2:8	Slave address - 7 bits
9	Write	9	Write
10	Acknowledge from slave	10	Acknowledge from slave
11:18	Command Code - 8 bits	11:18	Command Code - 8 bits
19	Acknowledge from slave	19	Acknowledge from slave
20:27	Data byte - 8 bits	20	Repeat start
28	Acknowledge from slave	21:27	Slave address - 7 bits
29	Stop	28	Read
		29	Acknowledge from slave
		30:37	Data from slave - 8 bits
		38	Not Acknowledge
		39	Stop

## CONTROL REGISTERS

**TABLE 4A. BYTE 0:CONTROL REGISTER 0**

<b>BIT</b>	<b>@Pup</b>	<b>Name</b>	<b>Description</b>
7	0	Reserved	Reserved
6	1	SRC[T/C]4	SRC[T/C]4 Output Enable 0 = Disable (Hi-Z) 1 = Enable
5	1	SRC[T/C]3	SRC[T/C]3 Output Enable 0 = Disable (Hi-Z) 1 = Enable
4	1	SRC[T/C]2	SRC[T/C]2 Output Enable 0 = Disable (Hi-Z) 1 = Enable
3	1	SRC[T/C]1	SRC[T/C]1 Output Enable 0 = Disable (Hi-Z) 1 = Enable
2	1	Reserved	Reserved
1	0	Reserved	Reserved
0	0	Reserved	Reserved

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**TABLE 4B. BYTE 1:CONTROL REGISTER 1**

BIT	@Pup	Name	Description
7	0	Reserved	Reserved
6	0	Reserved	Reserved
5	0	Reserved	Reserved
4	0	Reserved	Reserved
3	0	Reserved	Reserved
2	0	Reserved	Reserved
1	0	Reserved	Reserved
0	0	Reserved	Reserved

**TABLE 4C. BYTE 2:CONTROL REGISTER 2**

BIT	@Pup	Name	Description
7	1	SRCT/C	Spread Spectrum Selection 0 = -0.35%, 1 = -0.50%
6	1	Reserved	Reserved
5	1	Reserved	Reserved
4	0	Reserved	Reserved
3	1	Reserved	Reserved
2	0	SRC	SRC Spread Spectrum Enable 0 = Spread Off, 1 = Spread On
1	1	Reserved	Reserved
0	1	Reserved	Reserved

**TABLE 4D. BYTE 3:CONTROL REGISTER 3**

BIT	@Pup	Name	Description
7	1	Reserved	Reserved
6	0	Reserved	Reserved
5	1	Reserved	Reserved
4	0	Reserved	Reserved
3	1	Reserved	Reserved
2	1	Reserved	Reserved
1	1	Reserved	Reserved
0	1	Reserved	Reserved

**TABLE 4E. BYTE 4:CONTROL REGISTER 4**

BIT	@Pup	Name	Description
7	0	Reserved	Reserved
6	0	Reserved	Reserved
5	0	Reserved	Reserved
4	0	Reserved	Reserved
3	0	Reserved	Reserved
2	0	Reserved	Reserved
1	0	Reserved	Reserved
0	1	Reserved	Reserved

**TABLE 4F. BYTE 5:CONTROL REGISTER 5**

BIT	@Pup	Name	Description
7	0	Reserved	Reserved
6	0	Reserved	Reserved
5	0	Reserved	Reserved
4	0	Reserved	Reserved
3	0	Reserved	Reserved
2	0	Reserved	Reserved
1	0	Reserved	Reserved
0	0	Reserved	Reserved

**TABLE 4G. BYTE 6:CONTROL REGISTER 6**

BIT	@Pup	Name	Description
7	0	TEST_SEL	REF/N or Hi-Z Select 0 = Hi-Z, 1 = REF/N
6	0	TEST_MODE	TEST Clock Mode Entry Control 0 = Normal Operation, 1 = REF/N or Hi-Z Mode
5	0	Reserved	Reserved
4	1	Reserved	Reserved
3	0	Reserved	Reserved
2	0	Reserved	Reserved
1	1	Reserved	Reserved
0	1	Reserved	Reserved

**TABLE 4H. BYTE 7:CONTROL REGISTER 7**

BIT	@Pup	Name	Description
7	0		Revision Code Bit 3
6	0		Revision Code Bit 2
5	0		Revision Code Bit 1
4	0		Revision Code Bit 0
3	0		Vendor ID Bit 3
2	0		Vendor ID Bit 2
1	0		Vendor ID Bit 1
0	1		Vendor ID Bit 0

**ABSOLUTE MAXIMUM RATINGS**

Supply Voltage, $V_{DD}$	4.6V
Inputs, $V_I$	-0.5V to $V_{DD\_REF} + 0.5$ V
Outputs, $V_O$	-0.5V to $V_{DD\_SRC} + 0.5$ V
Package Thermal Impedance, $\theta_{JA}$	70°C/W (0 mps)
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 5A. POWER SUPPLY DC CHARACTERISTICS,  $V_{DD\_REF} = V_{DDA} = V_{DD\_SRC} = 3.3V \pm 5\%$ ,  $T_A = -40^\circ C$  TO  $85^\circ C$**

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{DD\_REF}$	Power Supply Voltage		3.135	3.3	3.465	V
$V_{DDA}$	Analog Supply Voltage		$V_{DD\_REF} - 0.25$	3.3	$V_{DD\_REF}$	V
$V_{DD\_SRC}$	Core/SRC Supply Voltage		3.135	3.3	3.465	V
$I_{DD\_REF}$	Crystal Supply Current				8	mA
$I_{DD\_SRC}$	Core/SRC Supply Current				160	mA
$I_{DDA}$	Analog Supply Current				25	mA

**TABLE 5B. DC CHARACTERISTICS,  $V_{DD\_REF} = V_{DDA} = V_{DD\_SRC} = 3.3V \pm 5\%$ ,  $T_A = -40^\circ C$  TO  $85^\circ C$**

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{IHSMBUS}$	Input High Voltage	SDATA, SCLK		2.2		V
$V_{ILSMBUS}$	Input Low Voltage	SDATA, SCLK			1.0	V
$I_{IH}$	Input High Current	SDATA, SCLK	$V_{DD} = V_{IN} = 3.465V$		5	$\mu A$
$I_{IL}$	Input Low Current	SDATA, SCLK	$V_{DD} = 3.465V, V_{IN} = 0V$	-150		$\mu A$
$I_{OH}$	Output Current			14		mA
$I_{OZ}$	High Impedance Leakage Current		-10		10	$\mu A$

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**TABLE 6. AC CHARACTERISTICS,  $V_{DD\_REF} = V_{DDA} = V_{DD\_SRC} = 3.3V \pm 5\%$ ,  $TA = -40^{\circ}C$  to  $85^{\circ}C$**

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$f_{ref}$	Frequency			25		MHz
$sclk$	SCLK Frequency			400		kHz
	Frequency Tolerance; NOTE 1	XTAL		50		ppm
		External Reference		0		ppm
$odc$	SRCT/SRCC Duty Cycle; NOTE 2, 7		47		53	%
$tsk(o)$	SRCT/C to SRCT/C Clock Skew; NOTE 2, 7			70		ps
$t_{PERIOD}$	Average Period; NOTE 3		9.9970		10.0533	ns
$t_{jit(cc)}$	SRCT/C Cycle-to-Cycle Jitter; NOTE 2, 7			35		ps
$t_{jit(per)}$	Period Jitter, RMS; NOTE 2, 7			3		ps
$t_R / t_F$	SRCT/SRCC Rise/Fall Time; NOTE 4		175		700	ps
$t_{RFM}$	Rise/Fall Time Matching; NOTE 5			20		%
$t_{DC}$	XTAL_IN Duty Cycle; NOTE 6		47.5		52.5	%
$\Delta t_R / t_F$	Rise/Fall Time Variation			125		ps
$V_{HIGH}$	Voltage High		520		800	mV
$V_{LOW}$	Voltage Low		-150			mV
$V_{CROSS}$	Absolute Crossing Voltage		250		550	mV
$\Delta V_{CROSS}$	Total Variation of $V_{CROSS}$ over all edges			140		mV
$V_{OX}$	Output Crossover Voltage	@ 0.7V Swing	250		550	mV
$V_{OVS}$	Maximum Overshoot Voltage				$V_{HIGH} + 0.3$	V
$V_{UDS}$	Minimum Undershoot Voltage		-0.3			V
$V_{RB}$	Ring Back Voltage				0.2	V

NOTE 1: With recommended crystal.

NOTE 2: Measured at crossing point  $V_{OX}$ .

NOTE 3: Measured at crossing point  $V_{OX}$  at 100MHz.

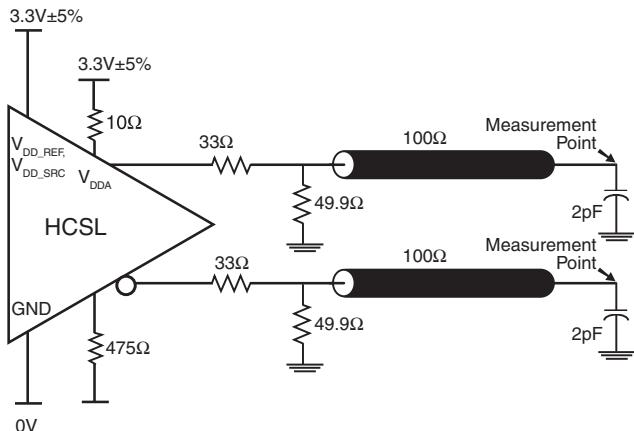
NOTE 4: Measured from  $V_{OL} = 0.175V$  to  $V_{OH} = 0.525V$ .

NOTE 5: Determined as a fraction of  $2*(t_R - t_F) / (t_R + t_F)$ .

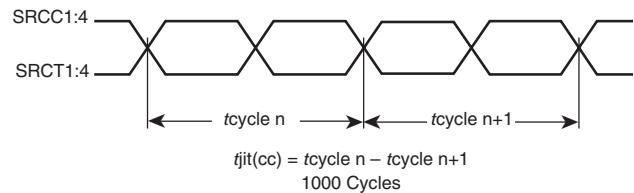
NOTE 6: The device will operate reliably with input duty cycles up to 30/70% but the REF clock duty cycle will not be within specification.

NOTE 7: Measured using a  $50\Omega$  to GND termination.

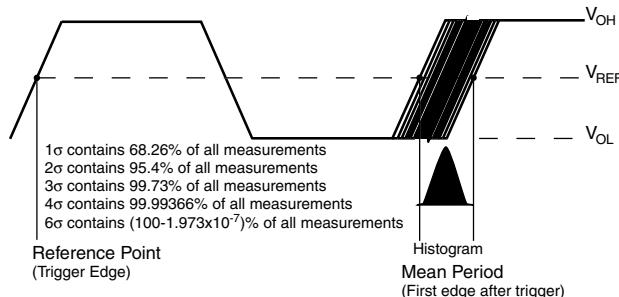
## PARAMETER MEASUREMENT INFORMATION



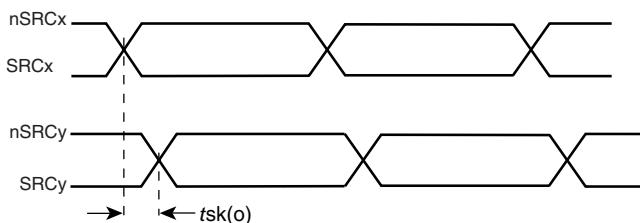
**3.3V HCSL OUTPUT LOAD AC TEST CIRCUIT**



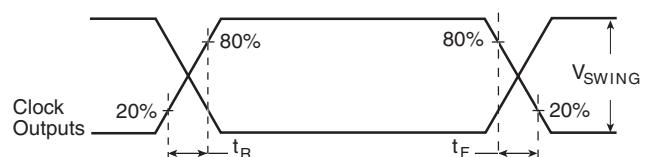
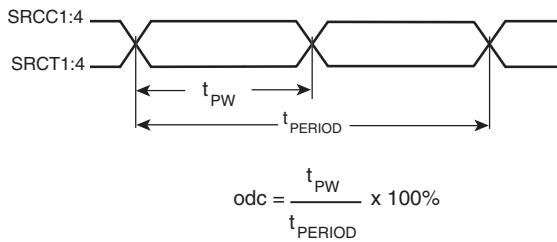
**CYCLE-TO-CYCLE JITTER**



**PERIOD JITTER**



**OUTPUT SKEW**



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

**HCSL 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 ICS841S04I provides separate power supplies to isolate any high switching noise from the outputs to the internal PLL.  $V_{DD\_REF}$ ,  $V_{DD\_SRC}$ , and  $V_{DDA}$  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  $10\Omega$  resistor along with a  $10\mu F$  and a  $.01\mu F$  bypass capacitor should be connected to each  $V_{DDA}$ . The  $10\Omega$  resistor can also be replaced by a ferrite bead.

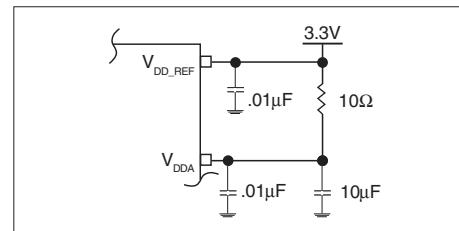


FIGURE 1. POWER SUPPLY FILTERING

### USING THE ON-BOARD CRYSTAL OSCILLATOR

The ICS841S04I features a fully integrated Pierce oscillator to minimize system implementation costs. The ICS841S04I may be operated with a 25MHz crystal and without additional components. Recommended operation for the crystal should be of a parallel resonant type and a load specification of  $C_L = 18pF$ . See Table 7 for complete crystal specifications.

If more precise frequency control is desired, the addition of capacitors from each of the XTAL\_IN and XTAL\_OUT pins to ground may be used to trim the frequency as shown in Figure 2.

The crystal and optional trim capacitors should be located as close to the ICS841S04I XTAL\_IN and XTAL\_OUT pins as possible to avoid any board level parasitic.

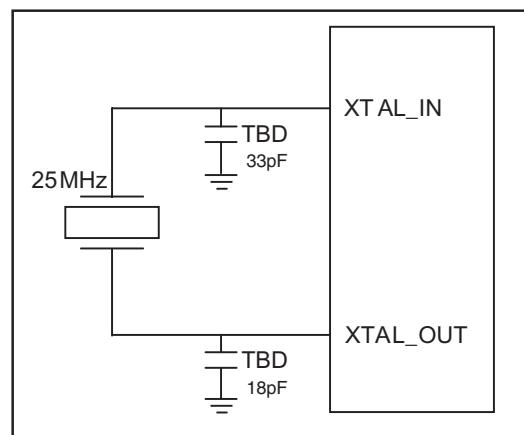


FIGURE 2. CRYSTAL OSCILLATOR WITH TRIM CAPACITOR

TABLE 7. RECOMMENDED CRYSTAL SPECIFICATIONS

Parameter	Value
Crystal Cut	Fundamental AT Cut
Resonance	Parallel Resonance
Shunt Capacitance ( $C_L$ )	5-7pF
Load Capacitance ( $C_o$ )	18pF
Equivalent Series Resistance (ESR)	20-50Ω

## RECOMMENDATIONS FOR UNUSED INPUT AND OUTPUT PINS

### INPUTS:

#### 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.

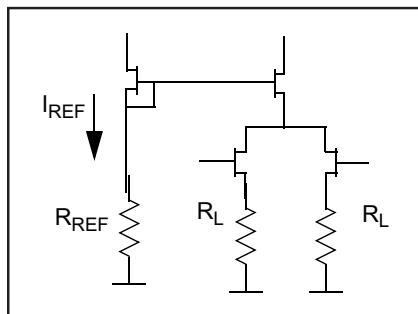
### OUTPUTS:

#### DIFFERENTIAL OUTPUTS

All unused differential 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.

## OUTPUT DRIVER CURRENT

The ICS841S04I outputs are HCSL current drive with the current being set with a resistor from  $I_{REF}$  to ground. For a  $50\Omega$  pc board trace, the drive current would typically be set with a  $R_{REF}$  of  $475\Omega$  which products an  $I_{REF}$  of  $2.32\text{mA}$ . The  $I_{REF}$  is multiplied by a current mirror to an output drive of  $6*2.32\text{mA}$  or  $13.92\text{mA}$ . See *Figure 3* for current mirror and output drive details.

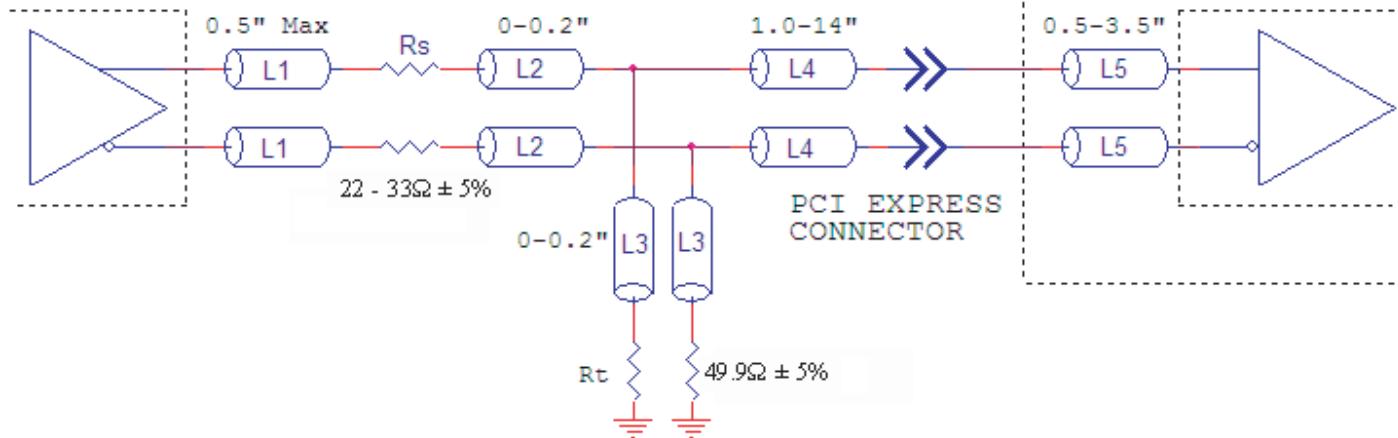


**FIGURE 3. HCSL CURRENT MIRROR AND OUTPUT DRIVE**

## RECOMMENDED TERMINATION

Figure 4A is the recommended termination for applications which require the receiver and driver to be on a separate PCB. All traces should be  $50\Omega$  impedance.

0.7V Differential HCSL  
 Clock Driver

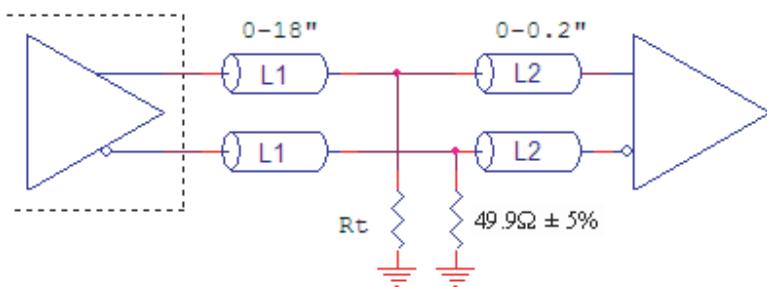


**FIGURE 4A. RECOMMENDED TERMINATION**

Figure 4B 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  $50\Omega$  impedance.

0.7V Differential HCSL  
 Clock Driver



**FIGURE 4B. RECOMMENDED TERMINATION**

## RELIABILITY INFORMATION

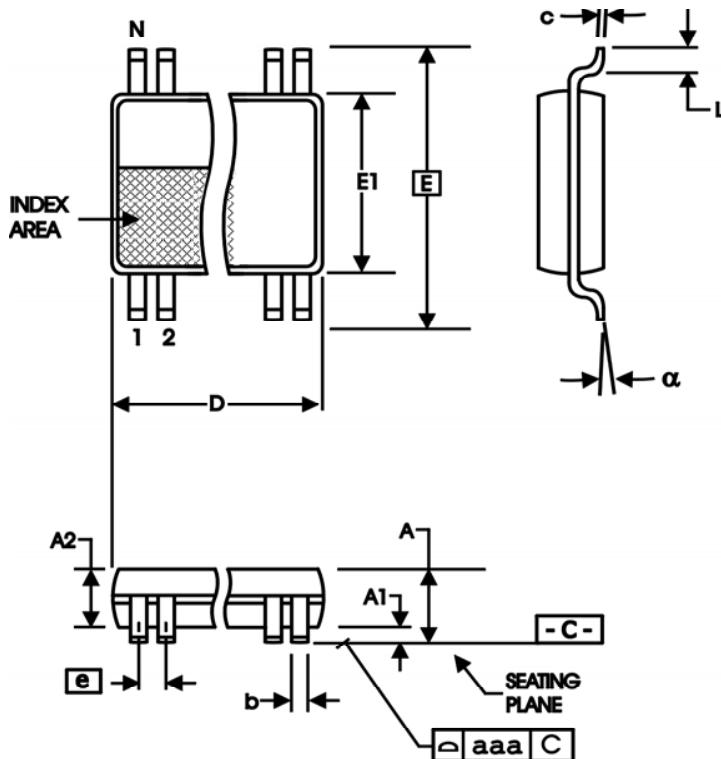
**TABLE 8.  $\theta_{JA}$  vs. AIR FLOW TABLE FOR 24 LEAD TSSOP**

<b><math>\theta_{JA}</math> by Velocity (Meters per Second)</b>			
	<b>0</b>	<b>1</b>	<b>2.5</b>
Multi-Layer PCB, JEDEC Standard Test Boards	70°C/W	65°C/W	62°C/W

**TRANSISTOR COUNT**

The transistor count for ICS841S04I is: 1874

**PACKAGE OUTLINE - G SUFFIX FOR 24 LEAD TSSOP**



**TABLE 9. PACKAGE DIMENSIONS**

SYMBOL	Millimeters	
	Minimum	Maximum
N	24	
A	--	1.20
A1	0.05	0.15
A2	0.80	1.05
b	0.19	0.30
c	0.09	0.20
D	7.70	7.90
E	6.40 BASIC	
E1	4.30	4.50
e	0.65 BASIC	
L	0.45	0.75
$\alpha$	$0^\circ$	$8^\circ$
aaa	--	0.10

Reference Document: JEDEC Publication 95, MO-153

**TABLE 10. ORDERING INFORMATION**

Part/Order Number	Marking	Package	Shipping Packaging	Temperature
ICS841S04BGI	ICS841S04BGI	24 Lead TSSOP	tube	-40°C to 85°C
ICS841S04BGIT	ICS841S04BGI	24 Lead TSSOP	2500 tape & reel	-40°C to 85°C
ICS841S04BGILF	ICS841S04BGIL	24 Lead "Lead-Free" TSSOP	tube	-40°C to 85°C
ICS841S04BGILFT	ICS841S04BGIL	24 Lead "Lead-Free" TSSOP	2500 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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**ICS841S04I**  
**PCI EXPRESS™ CLOCK GENERATOR**

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