

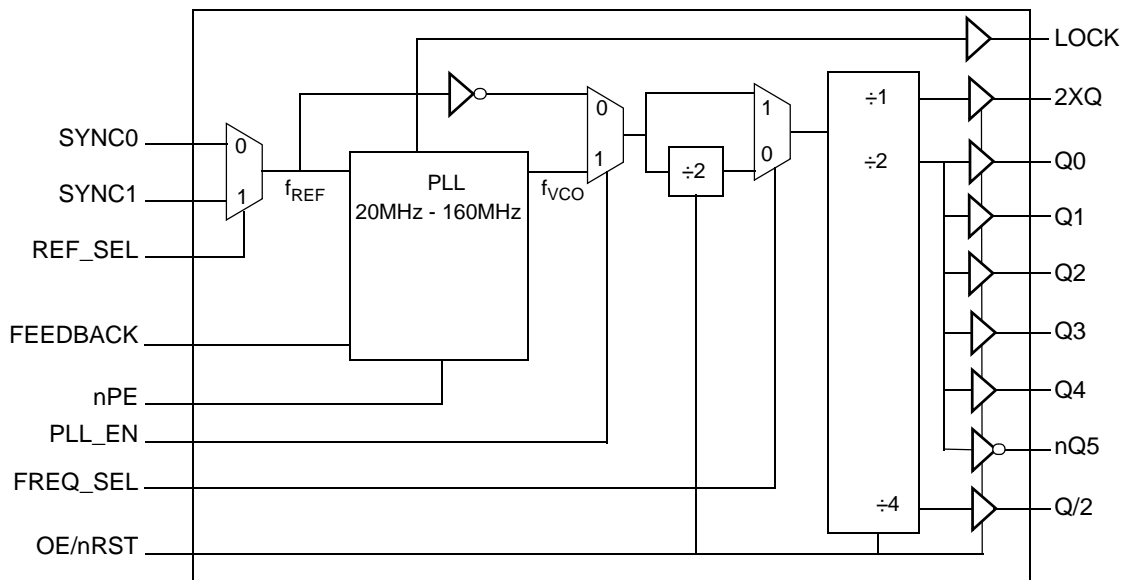
## General Description

The ICS870919I is an LVC MOS clock generator that uses an internal phase lock loop (PLL) for frequency multiplication and to lock the low-skew outputs to the selected reference clock. The device offers eight outputs. The PLL loop filter is completely internal and does not require external components. Several output configurations of the PLL feedback and a divide-by-2 (controlled by FREQ\_SEL) allow applications to optimize frequency generation over a wide range of input reference frequencies. The PLL can also be disabled by the PLL\_EN control signal to allow for low frequency or DC testing. The LOCK output asserts to indicate when phase-lock has been achieved. The ICS870919I device is a member of the family of high performance clock solutions from IDT.

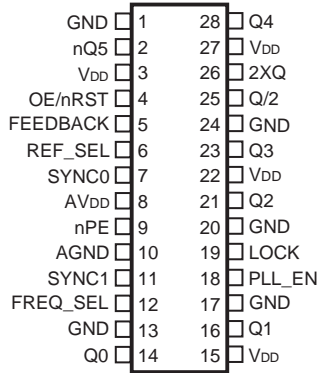
## Features

- Two selectable single-ended input reference clocks
- Eight single-ended clock outputs
- Internal PLL does not require external loop filter components
- 5V tolerant inputs
- Maximum output frequency: 160MHz, (2XQ output)
- Maximum output frequency: 80MHz, (Q0:Q4 and nQ5 outputs)
- LVC MOS interface levels for all inputs and outputs
- PLL disable feature for low-frequency testing
- PLL lock output
- Selectable synchronization of output to input edge
- Output drive capability:  $\pm 24\text{mA}$
- Output skew: 300ps (maximum), Q0:Q4
- Output skew: 500ps (maximum), all outputs
- Full 3.3V supply voltage
- Available in lead-free (RoHS 6) packages
- $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$  ambient operating temperature

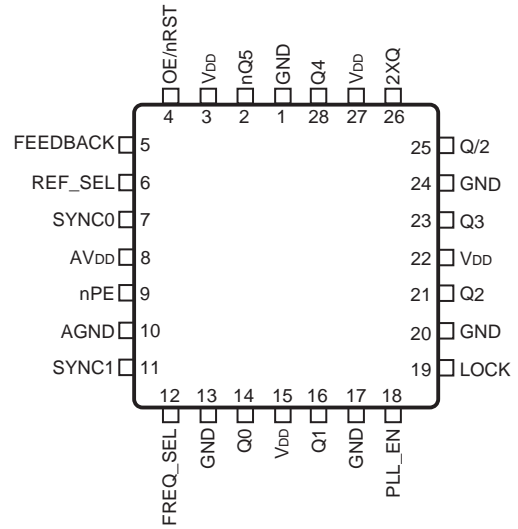
## Block Diagram



## Pin Assignments



**ICS870919I**  
**28-Lead QSOP, 150Mil**  
**3.9mm x 9.9mm x 1.5mm package body**  
**R Package**  
**Top View**



**ICS870919I**  
**28-Lead PLCC**  
**11.5mm x 11.5mm x 4.4mm package body**  
**V Package**  
**Top View**

**Table 1. Pin Descriptions**

Number	Name	Type		Description
1, 13, 17, 20, 24	GND	Power		Power supply ground.
2	nQ5	Output		Single-ended clock output (phase is inverted with respect to other outputs). LVCMOS/LVTTL interface levels
3, 15, 22, 27	V <sub>DD</sub>	Power		Positive power supply pins.
4	OE/nRST	Input		Output enable and asynchronous reset. Resets all outputs. Logic LOW, the outputs are in a high impedance state. Logic HIGH enables all outputs. Internally a Power On reset circuit will ensure that the nQ5 output is inverted relative to Q[4:0]. If OE/nRST is pulsed low, it must be held low for a minimum of 10 ns for a complete reset operation. This reset may be applied asynchronously to the input reference.
5	FEEDBACK	Input		PLL feedback input which is connected to one of the clock outputs to close the PLL feedback loop. LVCMOS/LVTTL interface levels.
6	REF_SEL	Input		Input reference clock select. Logic LOW selects the SYNC0. Logic HIGH selects the SYNC1 input as the PLL reference input. LVCMOS/LVTTL interface levels.
7, 11	SYNC0, SYNC1	Input		Single-ended reference clock inputs. LVCMOS/LVTTL interface levels.
8	AVDD	Power		Positive power supply for the PLL.
9	nPE	Input	Pulldown	Output phase synchronization. In PLL mode (PLL_EN = HIGH) and when logic LOW, the rising edges of the outputs (2XQ, Q0:Q4, Q/2) are synchronized to the rising edge of the selected reference clock (SYNCn). In PLL mode (PLL_EN = HIGH) and when logic HIGH, the falling edges of the outputs (2XQ, Q0:Q4, Q/2) are synchronized to the falling edge of the selected reference clock (SYNCn). LVCMOS/LVTTL interface levels.
10	AGND	Power		Power supply ground for the PLL. Internally connected to GND.
12	FREQ_SEL	Input		Frequency select. Logic LOW level inserts a divide-by-2 into the PLL output and feedback path. Logic HIGH inserts a divide-by-1 into the PLL output and feedback path. LVCMOS/LVTTL interface levels.
14, 16, 21, 23, 28	Q0, Q1, Q2, Q3, Q4	Output		Single-ended clock outputs. LVCMOS/LVTTL interface levels.
18	PLL_EN	Input		PLL enable. Enable and disables the PLL. Logic HIGH enables the PLL. Logic LOW disables the PLL and the input reference signal is routed to the output dividers (PLL bypass). LVCMOS/LVTTL interface levels.
19	LOCK	Output		PLL lock indication output. Logic HIGH indicates PLL lock. Logic LOW indicates PLL is not locked. LVCMOS/LVTTL interface levels.
25	Q/2	Output		Single-ended clock output. LVCMOS/LVTTL interface levels.
26	2XQ	Output		Single-ended clock output. LVCMOS/LVTTL interface levels.

NOTE: *Pulldown* refers to internal input resistor. 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
C <sub>PD</sub>	Power Dissipation Capacitance (total)	V <sub>DD</sub> = AV <sub>DD</sub> = 3.6V		240		pF
R <sub>PULLDOWN</sub>	Input Pulldown Resistor	nPE		56		kΩ
R <sub>OUT</sub>	Output Impedance			15		Ω

**Device Configuration**

The ICS870919I requires a connection of one of the clock outputs to the FEEDBACK input to close the PLL feedback path. The selection of the output (output divider) for PLL feedback will impact the device

configuration and input to output frequency ratio and frequency ranges. See [Table 3G](#) for details.

**Function Tables**

**Table 3A. OE/nRST Mode Configuration Table**

Input	Operation
0	Device is reset and the outputs Q0:Q4, nQ5, 2XQ, Q/2 are in high-impedance state. This control is asynchronous. Synchronous output operation requires a reset to the device at start-up by applying logic LOW level.
1	Outputs are enabled.

**Table 3B. REF\_SEL Mode Configuration Table**

Input	Operation
0	SYNC0 is the selected PLL reference clock.
1	SYNC1 is the selected PLL reference clock.

**Table 3C. nPE Mode Configuration Table**

Input	Operation
0	The rising edge of the 2XQ, Q0:Q4 and Q/2 outputs and the falling edge of the nQ5 output are synchronized.
1	The falling edge of the 2XQ, Q0:Q4 and Q/2 outputs and the rising edge of the nQ5 output are synchronized.

**Table 3D. FREQ\_SEL Mode Configuration Table**

Input	
FREQ_SEL	Operation
0	The VCO output is frequency-divided by 2. This setting allows for a lower input frequency range. See also table 3G for available frequency ranges.
1	The VCO output is frequency-divided by 1. This setting allows for a higher input frequency range. See also table 3G for available frequency ranges.

**Table 3E. PLL\_EN Mode Configuration Table**

Input	
PLL_EN	Operation
0	The PLL is bypassed. The selected input reference clock is routed to the output dividers for low-frequency board test purpose. The PLL-related AC specifications do not apply in PLL bypass mode.
1	The PLL is enabled and locks to the selected input reference signal.

**Table 3F. LOCK Mode Configuration Table**

Output	
LOCK	Operation
0	PLL is not locked to the selected input reference clock.
1	PLL is locked to the selected input reference clock.

**Table 3G. Frequency Configuration Table**

Outputs Used for PLL Feedback	FREQ_SEL	Input Frequency Range (MHz)	Output Frequency Range (MHz) and Output-to-Input Frequency Multiplication Factor		
		SYNC[0:1]	Q[0:4], nQ5 <sup>NOTE1</sup>	2XQ	Q/2
Q0, Q1, Q2, Q3, Q4 or nQ5	0	5 - 40	5 - 40 (1x)	10 - 80 (2x)	2.5 - 20 (0.5x)
	1	10 - 80	10 - 80 (1x)	20 - 160 (2x)	5 - 40 (0.5x)
2XQ	0	10 - 80	5 - 40 (0.5x)	10 - 80 (1x)	2.5 - 20 (0.25x)
	1	20 - 100 <sup>NOTE2</sup>	10 - 50 (0.5x)	20 - 100 (1x)	5 - 25 (0.25x)
Q/2	0	2.5 - 20	5 - 40 (2x)	10 - 80 (4x)	2.5 - 20 (1x)
	1	5 - 40	10 - 80 (2x)	20 - 160 (4x)	5 - 40 (1x)

NOTE 1: The nQ5 output is inverted (180° phase shift) with respect to Q0:Q4.

NOTE 2: The input reference frequency is limited to 100MHz maximum.

## Absolute Maximum Ratings

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.

Item	Rating
Supply Voltage, $V_{DD(ABS MAX)}$	4.6V
Inputs, $V_I$	-0.5V to $V_{DD(ABS MAX)} + 0.5V$
Outputs, $V_O$	-0.5V to $V_{DD(ABS MAX)} + 0.5V$
Package Thermal Impedance, $\theta_{JA}$ 28 Lead QSOP 28 Lead PLCC	66.0°C/W (0 lfp/m) 46.4°C/W (0 lfp/m)
Storage Temperature, $T_{STG}$	-65°C to 150°C

## DC Electrical Characteristics

**Table 4A. Power Supply DC Characteristics,  $V_{DD} = AV_{DD} = 3.3V \pm 0.3V$ ,  $T_A = -40^\circ C$  to  $85^\circ C$**

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{DD}$ , $AV_{DD}$	Positive Supply Voltage		3.0	3.3	3.6	V
$I_{DDQ}$	Quiescent Power Supply Current	$V_{DD} = AV_{DD} = \max.$ , OE/nRST = 0, SYNCx = 0, all outputs open			5	mA

**Table 4B. LVCMOS/LVTTL DC Characteristics,  $V_{DD} = AV_{DD} = 3.3V \pm 0.3V$ ,  $T_A = -40^\circ C$  to  $85^\circ C$**

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	FREQ_SEL, FEEDBACK, SYNCn, OE/nRST, REF_SEL, PLL_EN	$V_{DD} = V_{IN} = 3.3V$		5	$\mu A$
		nPE	$V_{DD} = V_{IN} = 3.3V$		150	$\mu A$
$I_{IL}$	Input Low Current	FREQ_SEL, FEEDBACK, nPE, SYNCn, OE/nRST, REF_SEL, PLL_EN	$V_{DD} = 3.3V$ , $V_{IN} = 0V$	-5		$\mu A$
$V_{OH}$	Output High Voltage	Q0:Q4, nQ5, 2XQ, Q/2, LOCK	$I_{OH} = -24mA$	2.6		V
$V_{OL}$	Output Low Voltage	Q0:Q4, nQ5, 2XQ, Q/2, LOCK	$I_{OL} = 24mA$		0.5	V
$I_{OZ}$	Output Leakage Current	Q0:Q4, nQ5, 2XQ, Q/2	OE/nRST = 0, $V_{OUT} = 0V$ or $V_{DD}$ , $V_{DD} = 3.6V$		$\pm 5$	$\mu A$

**Table 5. AC Electrical Characteristics,  $V_{DD} = AV_{DD} = 3.3V \pm 0.3V$ ,  $T_A = -40^{\circ}C$  to  $85^{\circ}C$** 

Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
$f_{REF}$	SYNC[0:1] Input Reference Frequency		Feedback of Q[0:4] or nQ5, $FREQ\_SEL = 0$	5		40	MHz
			Feedback of Q[0:4] or nQ5, $FREQ\_SEL = 1$	10		80	MHz
			Feedback of 2XQ, $FREQ\_SEL = 0$	10		80	MHz
			Feedback of 2XQ or $FREQ\_SEL = 1$	20		100	MHz
			Feedback of Q/2, $FREQ\_SEL = 0$	2.5		20	MHz
			Feedback of Q/2 or $FREQ\_SEL = 1$	5		40	MHz
$f_{OUT}$	Output Frequency		2XQ			160	MHz
			Q[0:4], nQ5			80	MHz
			Q/2			40	MHz
$idc$	Input Duty Cycle		SYNC0, SYNC1	25		75	%
$t_R / t_F$	Input Rise/ Fall Time		SYNC0, SYNC1			3	ns
$tsk(o)$	Output Skew; NOTE 1, 2		Rising edges of Q[0:4] (incl. Q/2 if nPE = 0)			300	ps
	Output Skew; NOTE 1, 2		Falling edges of Q[0:4] (incl. Q/2 if nPE = 1)			300	ps
	Output Skew; NOTE 1, 2, 3		Rising edge of Q[0:4] 2XQ, Q/2 and Falling edge of nQ5			500	ps
$t_{PW}$	Pulse Width		2XQ	>40MHz	$t_{PERIOD}/2 - 0.4$	$t_{PERIOD}/2 + 0.4$	ns
			Q[0:4], nQ5	80MHz	$t_{PERIOD}/2 - 0.4$	$t_{PERIOD}/2 + 0.4$	ns
			Q/2	40MHz	$t_{PERIOD}/2 - 0.4$	$t_{PERIOD}/2 + 0.4$	ns
$t_{jit(cc)}$	Cycle-to-Cycle Jitter		Q[0:4], nQ5	20MHz, $FREQ\_SEL = 0$		165	ps
			Q[0:4], nQ5	20MHz, $FREQ\_SEL = 1$		415	ps
$t(\phi)$	Static Phase Offset, (SYNC[0:1] to FEEDBACK delay); NOTE 2, 4		Q[0:4], nQ5	80MHz and nPE = 0	-500	1200	ps
			Q[0:4], nQ5	80MHz and nPE = 1	-500	500	ps
$t_{PZL}$	Output Enable Time; NOTE 5	OE/nRST	Low-to-High			14	ns
$t_{PHZ} / t_{PLZ}$	Output Disable Time; NOTE 5	OE/nRST	High-to-Low			14	ns
$t_R / t_F$	Output Rise/ Fall Time	Q[0:4], nQ5, 2XQ, Q/2	0.8V – 2.0V	0.2		2	ns
$t_{LOCK}$	PLL Lock Time					10	ms

NOTE: Electrical parameters are guaranteed over the specified ambient operating temperature range, which is established when the device is mounted in a test socket with maintained transverse airflow greater than 500 lfm. The device will meet specifications after thermal equilibrium has been reached under these conditions.

NOTE 1: Defined as skew between outputs at the same supply voltage and with equal load conditions. Measured at  $V_{DD}/2$ .

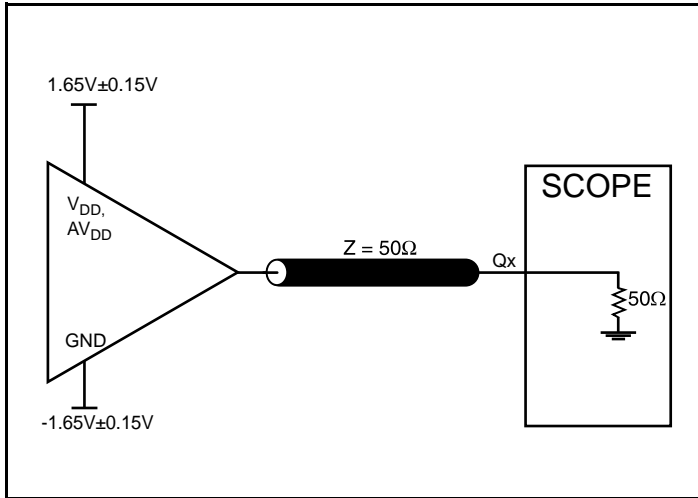
NOTE 2: This parameter is defined in accordance with JEDEC Standard 65.

NOTE 3: Measured between coincident rising output edges of Q0:Q4, 2XQ, Q/2 and the falling edge of nQ5.

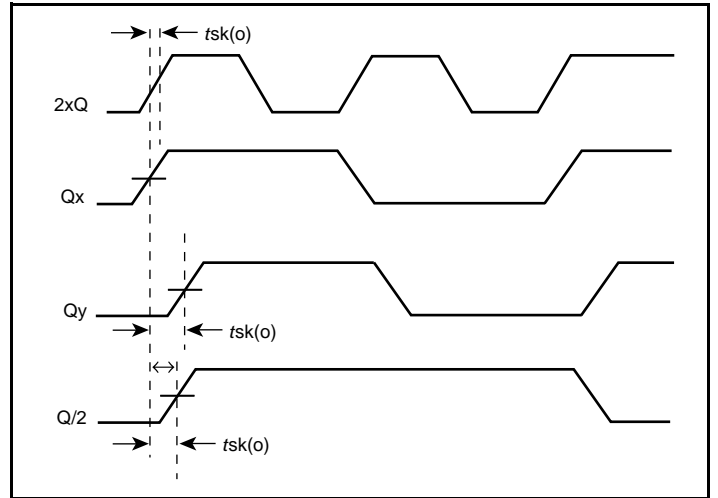
NOTE 4: Defined as the time difference between the input reference clock and the average feedback input signal when the PLL is locked and the input reference frequency is stable.

NOTE 5: These parameters are guaranteed by characterization. Not tested in production.

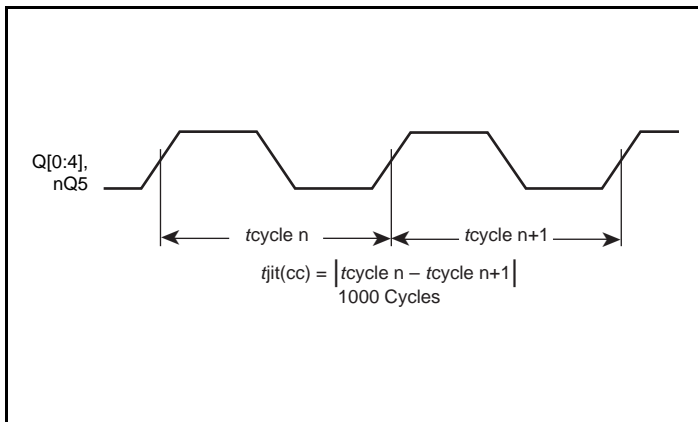
## Parameter Measurement Information



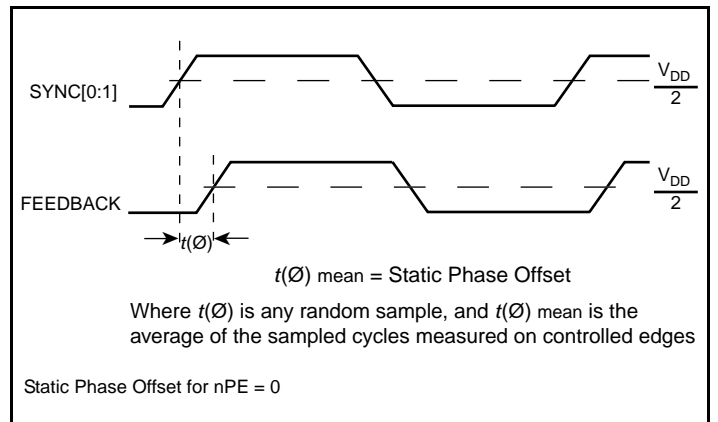
3.3V Output Load AC Test Circuit



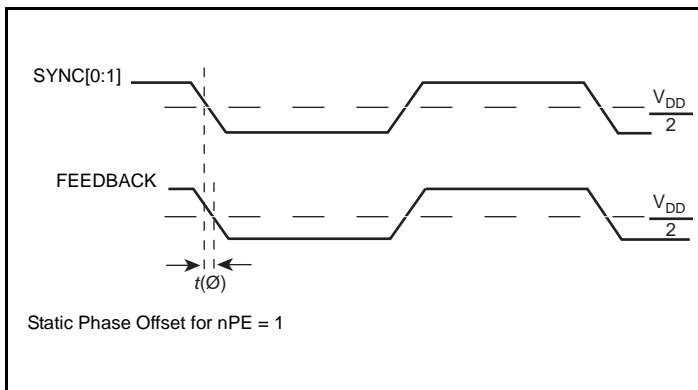
Output Skew



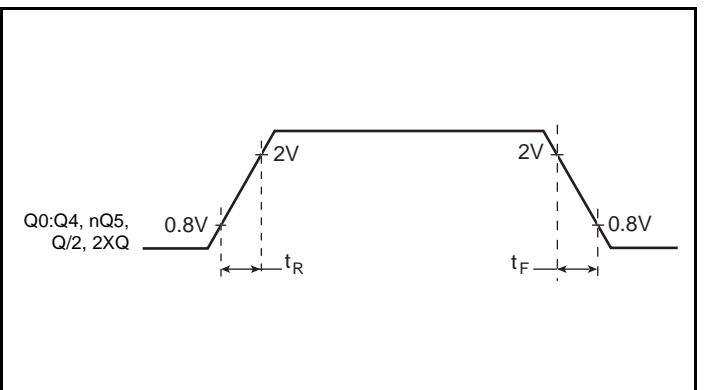
Cycle-to-Cycle Jitter



Static Phase Offset



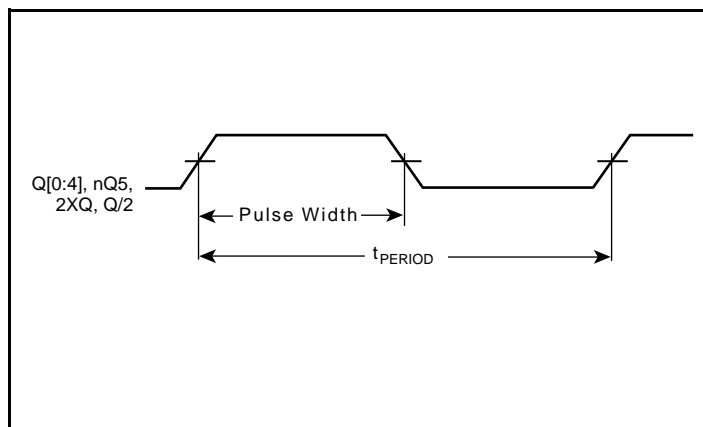
Static Phase Offset



Output Rise/Fall Time



## Parameter Measurement Information



Pulse Width

## Application Information

### Recommendations for Unused Output Pins

#### Outputs:

##### LVC MOS Outputs

All unused LVC MOS output can be left floating. There should be no trace attached.

## Schematic Layout

Figure 1 shows an example of 870919I application schematic. In this example, the device is operated at  $V_{DD} = AV_{DD} = 3.3V$ . As with 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 870919I provides separate power supplies to isolate any high switching noise from coupling into the internal PLL.

In order to achieve the best possible filtering, it is recommended that the placement of the filter components be on the device side of the PCB as close to the power pins as possible. If space is limited, the  $0.1\mu F$  capacitor in each power pin filter should be placed on the device side. The other components can be on the opposite side of the PCB.

Power supply filter recommendations are a general guideline to be used for reducing external noise from coupling into the devices. The filter performance is designed for a wide range of noise frequencies. This low-pass filter starts to attenuate noise at approximately 10kHz. If a specific frequency noise component is known, such as switching power supplies frequencies, it is recommended that component values be adjusted and if required, additional filtering be added. Additionally, good general design practices for power plane voltage stability suggests adding bulk capacitance in the local area of all devices.

The schematic example focuses on functional connections and is not configuration specific. Refer to the pin description and functional tables in the datasheet to ensure that the logic control inputs are properly set.

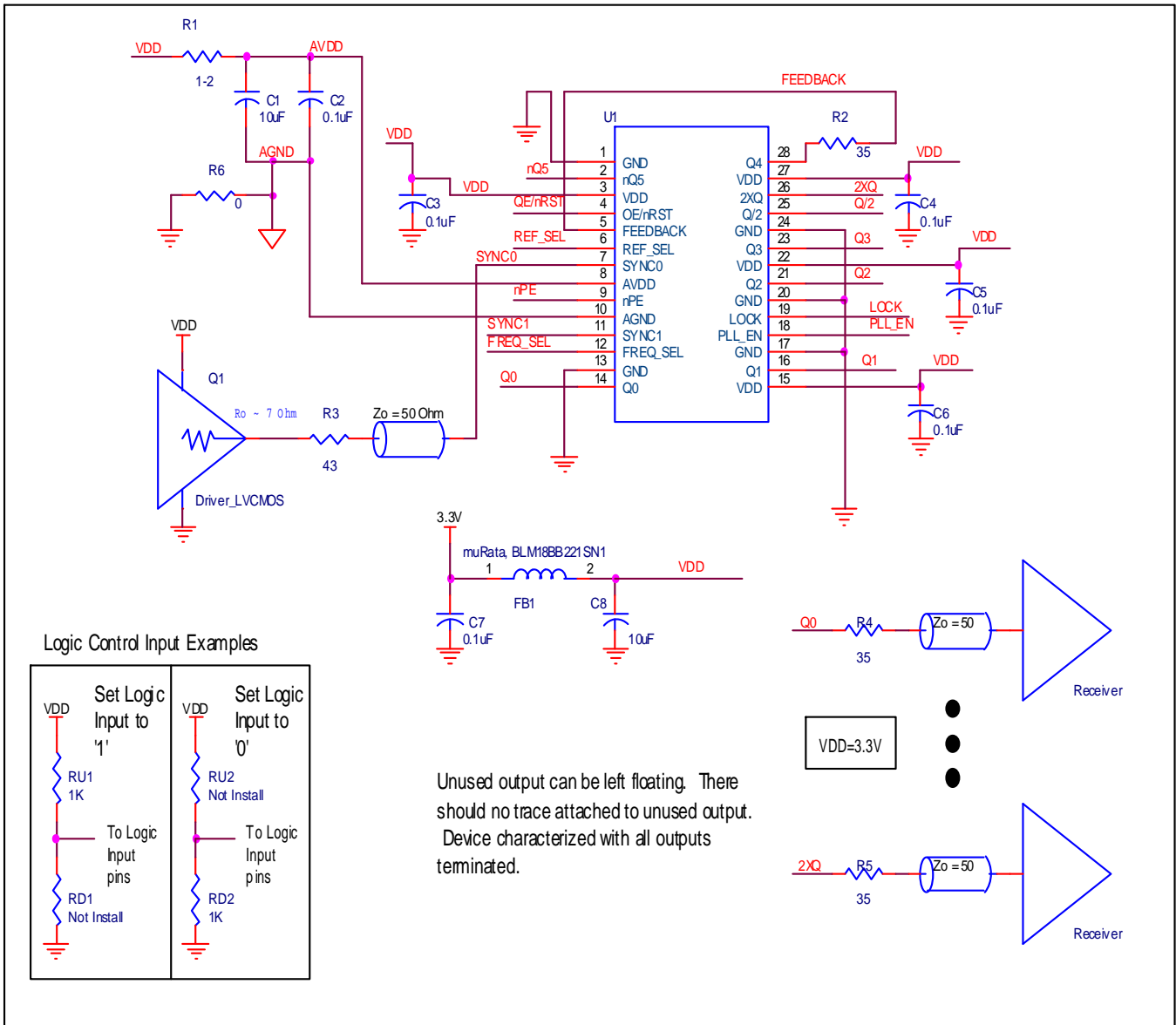


Figure 1. 870919I Application Schematic

## Power Considerations

This section provides information on power dissipation and junction temperature for the ICS870919I. Equations and example calculations are also provided.

### 1. Power Dissipation.

The total power dissipation for the ICS870919I is the sum of the core power plus the power dissipated in the load(s). The following is the power dissipation for  $V_{DD} = 3.3V + 0.3V = 3.6V$ , which gives worst case results.

- Power (core)<sub>MAX</sub> =  $V_{DD\_MAX} * I_{DD\_MAX} = 3.6V * 5mA = 18mW$
- Output Impedance  $R_{OUT}$  Power Dissipation due to Loading  $50\Omega$  to  $V_{DD}/2$   
Output Current  $I_{OUT} = V_{DD\_MAX} / [2 * (50\Omega + R_{OUT})] = 3.6V / [2 * (50\Omega + 15\Omega)] = 27.7mA$
- Power Dissipation on the  $R_{OUT}$  per LVCMOS output  
Power ( $R_{OUT}$ ) =  $R_{OUT} * (I_{OUT})^2 = 15\Omega * (27.7mA)^2 = 11.5mW$  per output
- Total Power ( $R_{OUT}$ ) =  $R_{OUT}$  (per output) \* number of outputs =  $11.5mW * 8$  outputs = **92mW**

### Dynamic Power Dissipation for Q = 80MHz

$$\text{Power (80MHz)} = C_{PD} * \text{Frequency} * (V_{DD})^2 = 240pF * 80MHz * (3.6V)^2 = 249mW$$

### Total Power

$$\begin{aligned} &= \text{Power (core)}_{MAX} + \text{Total Power (R}_{OUT}) + \text{Power (80MHz)} \\ &= 18mW + 92mW + 249mW \\ &= \mathbf{359mW} \end{aligned}$$

### 2. Junction Temperature.

Junction temperature,  $T_j$ , is the temperature at the junction of the bond wire and bond pad directly affects the reliability of the device. The maximum recommended junction temperature is  $125^\circ\text{C}$ . Limiting the internal transistor junction temperature,  $T_j$ , to  $125^\circ\text{C}$  ensures that the bond wire and bond pad temperature remains below  $125^\circ\text{C}$ .

$$\text{The equation for } T_j \text{ is as follows: } T_j = \theta_{JA} * Pd_{total} + T_A$$

$T_j$  = 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  $66^\circ\text{C/W}$  per Table 6 below.

Therefore,  $T_j$  for an ambient temperature of  $85^\circ\text{C}$  with all outputs switching is:

$$85^\circ\text{C} + 0.359W * 66^\circ\text{C/W} = 108.7^\circ\text{C}. \text{ This is below the limit of } 125^\circ\text{C}.$$

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 (multi-layer).

**Table 6. Thermal Resistance  $\theta_{JA}$  for a 28 Lead QSOP, Forced Convection**

$\theta_{JA}$ by Velocity			
Linear Feet per Minute	<b>0</b>	<b>200</b>	<b>500</b>
Multi-Layer PCB, JEDEC Standard Test Boards	66.0°C/W	58.3°C/W	55.2°C/W

## Reliability Information

**Table 7A.  $\theta_{JA}$  vs. Air Flow Table for a 28 Lead QSOP, 150MIL**

$\theta_{JA}$ vs. Air Flow			
Linear Feet per Minute	<b>0</b>	<b>200</b>	<b>500</b>
Multi-Layer PCB, JEDEC Standard Test Boards	66.0°C/W	58.3°C/W	55.2°C/W

**Table 7B.  $\theta_{JA}$  vs. Air Flow Table for a 28 Lead PLCC**

$\theta_{JA}$ vs. Air Flow			
Linear Feet per Minute	<b>0</b>	<b>200</b>	<b>500</b>
Multi-Layer PCB, JEDEC Standard Test Boards	46.4°C/W	38.6°C/W	36.2°C/W

## Transistor Count

The transistor count for ICS870919L: 1654

## Package Outline and Package Dimensions

Package Outline - R Suffix for 28 Lead QSOP, 150MIL

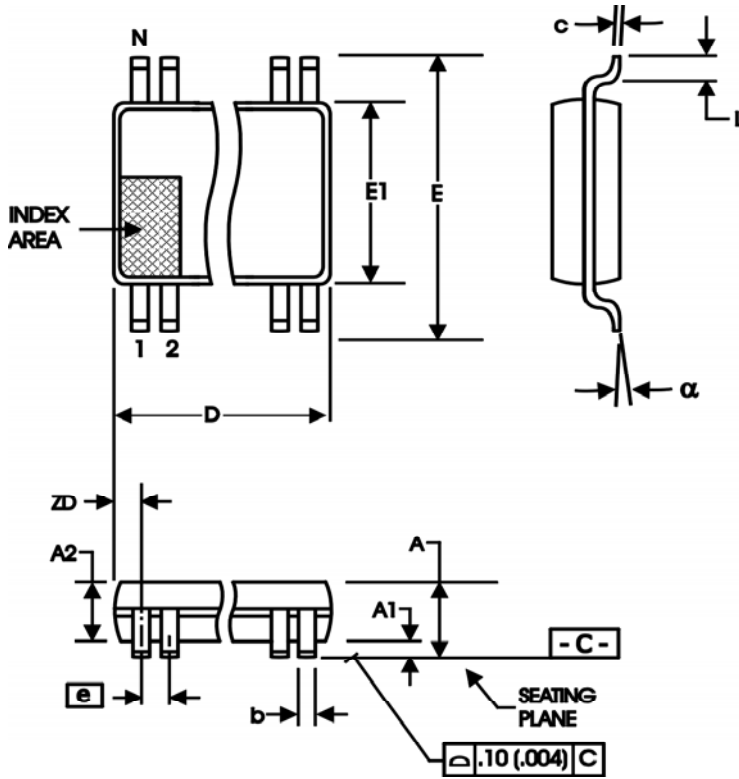


Table 8A. Package Dimensions for 28 Lead QSOP

All Dimensions in Millimeters		
Symbol	Minimum	Maximum
N	28	
A	1.35	1.75
A1	0.10	0.25
A2		1.50
b	0.20	0.30
c	0.18	0.25
D	9.80	10.00
E	5.80	6.20
E1	3.80	4.00
e	0.635 Basic	
L	0.40	1.27
$\alpha$	0°	8°
ZD	0.84 Ref	

Reference Document: JEDEC Publication 95, MO-137

Package Outline - V Suffix for 28 Lead PLCC

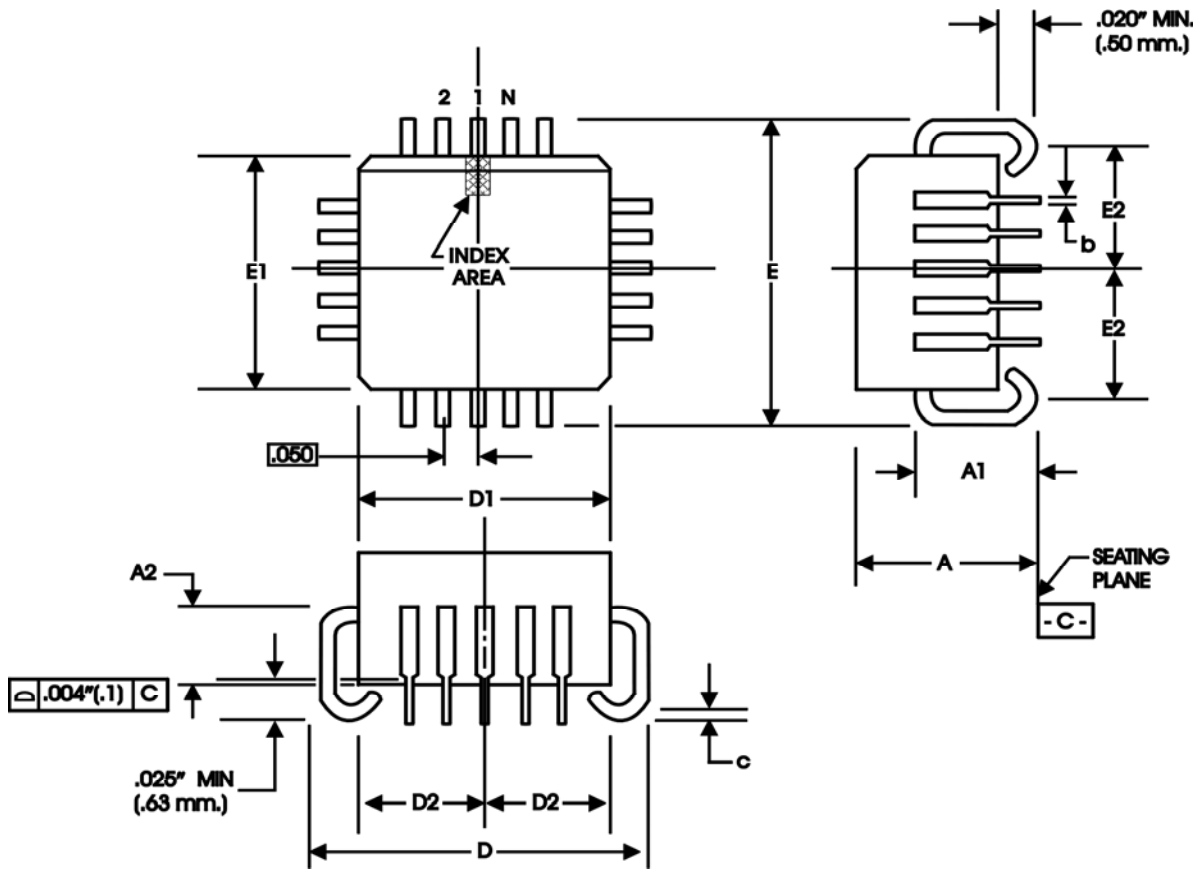


Table 8B. Package Dimensions for 28 Lead PLCC

JEDEC All Dimensions in Millimeters		
Symbol	Minimum	Maximum
N	28	
A	4.19	4.57
A1	2.29	3.05
A2	1.57	2.11
b	0.33	0.53
c	0.19	0.32
D & E	12.32	12.57
D1 & E1	11.43	11.58
D2 & E2	4.85	5.56

Reference Document: JEDEC Publication 95, MS-018

## Ordering Information

**Table 9. Ordering Information**

Part/Order Number	Marking	Package	Shipping Packaging	Temperature
870919BRILF	870919BRILF	"Lead-Free" 28 Lead QSOP	Tube	-40°C to 85°C
870919BRILFT	870919BRILF	"Lead-Free" 28 Lead QSOP	2500 Tape & Reel	-40°C to 85°C
870919BVILF	ICS870919BVILF	"Lead-Free" 28 Lead PLCC	Tube	-40°C to 85°C
870919BVILFT	ICS870919BVILF	"Lead-Free" 28 Lead PLCC	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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