

## GENERAL DESCRIPTION

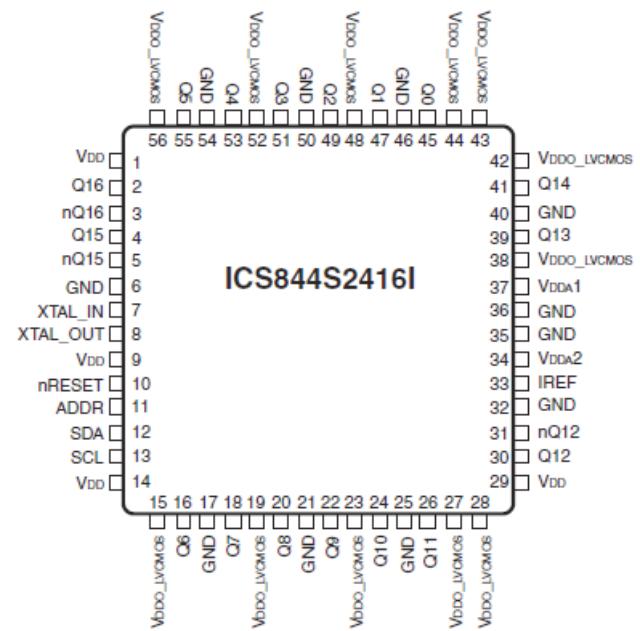
The 844S2416 is a 17 output, dual-PLL frequency synthesizer optimized to generate a variety of clocks for Ethernet, USB and other interfaces. Using a 25MHz 18pF parallel resonant crystal, the device will generate 24MHz, 25MHz, 100MHz and 200MHz clocks with mixed HCSL and LVCMS/LVTTL levels.

The 844S2416 is packaged in a 56-pin VFQFN package that is optimum for applications with space limitations.

## FEATURES

- Two LVCMS/LVTTL single-ended outputs at 24MHz
- Twelve LVCMS/LVTTL single-ended outputs at 25MHz
- Two differential HCSL output pairs at 100MHz
- One differential HCSL output pair at 100MHz or 200MHz
- Crystal oscillator interface: 25MHz
- PLL1 – VCO: 2.4GHz
- PLL2 – VCO range: 1.8GHz - 2.2GHz
  - ±10% frequency margining in 1.25% steps
  - Selectable spread spectrum – downspread at -0.5%
- I<sup>2</sup>C control interface with address configuration pin and with default loading on release of active low reset
- 3.3V supply voltage
- -40°C to 85°C ambient operating temperature
- Available in lead-free (RoHS 6) package

## PIN ASSIGNMENT



**56-Lead VFQFN**  
8mm x 8mm x 0.925mm package body  
**K Package**  
Top View

## BLOCK DIAGRAM

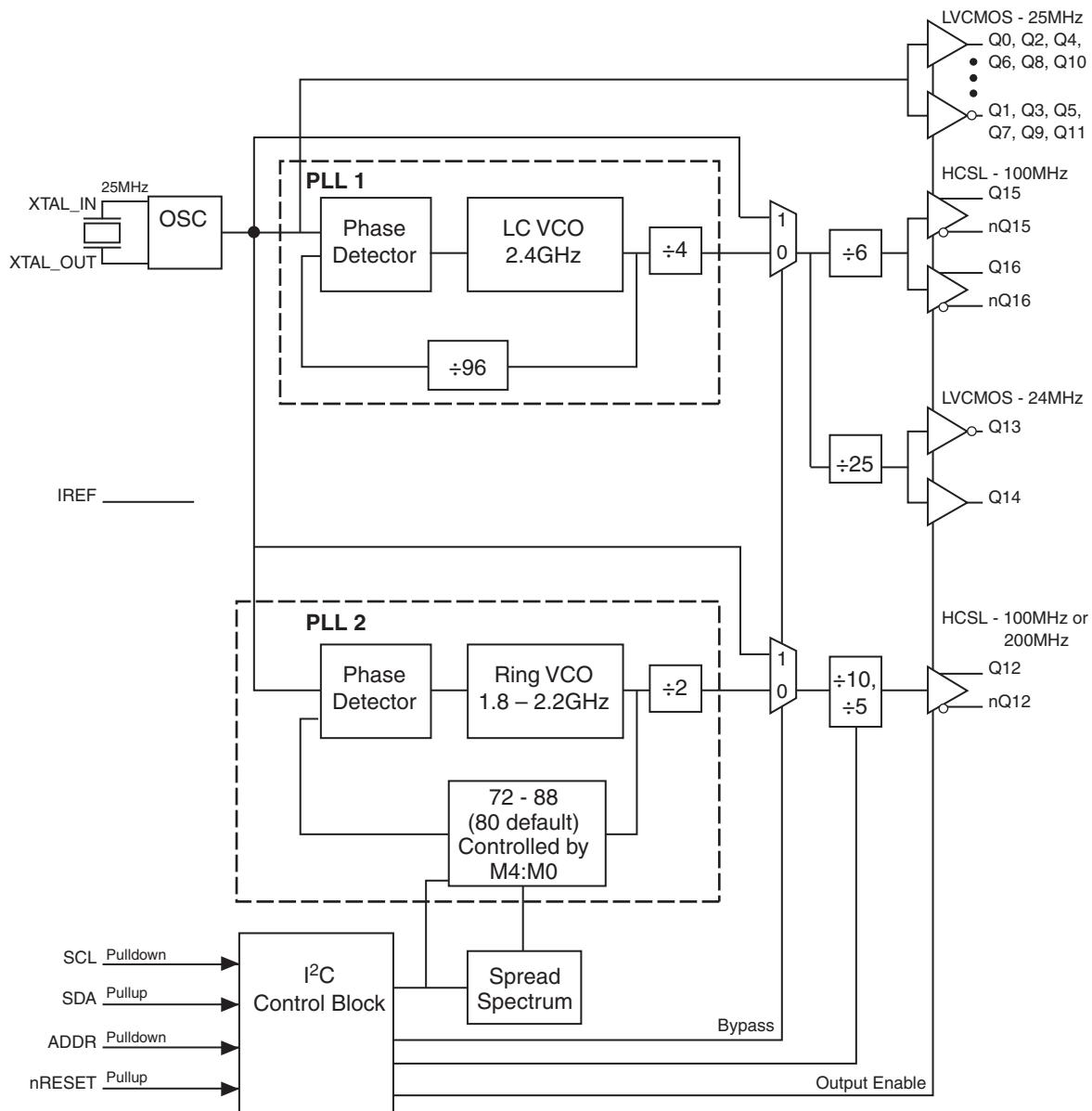


TABLE 1. PIN DESCRIPTIONS

Number	Name	Type	Description				
1, 9, 14, 29	$V_{DD}$	Power	Core supply pins.				
2, 3	Q16, nQ16	Output	Differential clock outputs. HCSL interface levels.				
4, 5	Q15, nQ15	Output	Differential clock outputs. HCSL interface levels.				
6, 17, 21, 25, 32, 35, 36, 40, 46, 50, 54	GND	Power	Power supply ground.				
7, 8	XTAL_IN, XTAL_OUT	Input	Crystal oscillator interface. XTAL_IN is the input. XTAL_OUT is the output.				
10	nRESET	Input	Pullup	nRESET signal resets all the output dividers, default setting of PLL1 and I <sup>2</sup> C registers. nRESET signal also puts Q0:Q11 outputs in the Hi-Z state for power sequencing. LVCMS/LVTTL interface levels.			
11	ADDR	Input	Pulldown	Serial address select pin. LVCMS/LVTTL interface levels.			
12	SDA	I/O	Pullup	I <sup>2</sup> C serial data input. LVCMS/LVTTL interface levels.			
13	SCL	Input	Pulldown	I <sup>2</sup> C serial clock input. LVCMS/LVTTL interface levels.			
15, 19, 23, 27, 28, 38, 42, 43, 44, 48, 52, 56	$V_{DDO\_LVCMS}$	Power	Output supply pins for LVCMS/LVTTL outputs.				
16, 20, 24, 41, 45, 49, 53	Q6, Q8, Q10, Q14, Q0, Q2, Q4	Output	Single-ended non-inverted clock outputs. LVCMS/LVTTL interface levels.				
18, 22, 26, 39, 47, 51, 55	Q7, Q9, Q11, Q13, Q1, Q3, Q5		Single-ended inverted clock outputs. LVCMS/LVTTL interface levels.				
30, 31	Q12, nQ12	Output	Differential clock outputs. HCSL interface levels.				
33	IREF		HCSL current reference resistor output. An external fixed precision resistor (475Ω) from this output to ground provides a reference current used for differential current mode outputs Q12/nQ12, Q15/nQ15 and Q16/nQ16.				
34	$V_{DDA2}$	Power	Analog supply pin for PLL2.				
37	$V_{DDA1}$	Power	Analog supply pin for PLL1.				

NOTE: *Pullup* and *Pulldown* refer to internal input resistors. See Table 5, Pin Characteristics, for typical values.

TABLE 2. PIN CHARACTERISTICS

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$C_{IN}$	Input Capacitance			2		pF
$R_{PULLUP}$	Input Pullup Resistor			51		kΩ
$R_{PULLDOWN}$	Input Pulldown Resistor			51		kΩ
$R_{OUT}$	Output Impedance	Q0:Q11, Q13:Q14		21		Ω

The 844S2416 uses an industry standard I<sup>2</sup>C interface to control the programming of the output enables of every output, the feedback divider value for PLL2, spread spectrum enabling for PLL2, and

output divider clock source selection. The I<sup>2</sup>C control registers and default settings are shown below:

**Output Enable Control Bits:** Q0:Q11, Q13:Q14, Q15:Q16/nQ15:nQ16 outputs are enabled, Q12/nQ12 is disabled

**PLL2 M Divider Value:** 80

**SSC:** Off

**BYPASS:** Output divider clock source is the PLL

**Q12 Frequency (f):** 200MHz

## I<sup>2</sup>C REGISTER SUMMARY

### Data Byte 0

Control Bit	Q16_EN	Q15_EN	Q14_EN	Q13_EN	Q12_EN	Q11_EN	Q10_EN	Q9_EN
Power-up Default Value	1	1	1	1	0	1	1	1

### Data Byte 1

Control Bit	Q8_EN	Q7_EN	Q6_EN	Q5_EN	Q4_EN	Q3_EN	Q2_EN	Q1_EN
Power-up Default Value	1	1	1	1	1	1	1	1

### Data Byte 2

Control Bit	Q0_EN	M4	M3	M2	M1	M0	SSC	BYPASS
Power-up Default Value	1	0	1	0	0	0	0	0

### Data Byte 3

Control Bit	f (Q12)	Revision	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved
Power-up Default Value	0	1	X	X	X	X	X	X

## FUNCTION TABLES

TABLE 3A. OUTPUT STATES FUNCTION TABLE

Outputs	Output Levels	Disable State
Q0:Q11	LVCMOS	Hi-Z
Q12/nQ12	HCSL	Hi-Z
Q13:Q14	LVCMOS	Hi-Z
Q15/nQ15	HCSL	Hi-Z
Q16/nQ16	HCSL	Hi-Z

**TABLE 3B. PLL2 FEEDBACK DIVIDER FUNCTION TABLE (Q12/nQ12, ÷10 MODE)**

VCO Frequency (MHz)	Q12/nQ12 Frequency (MHz)	Feedback Divide	M4	M3	M2	M1	M0
1800	90	72	0	0	0	0	0
1825	91.25	73	0	0	0	0	1
1850	92.5	74	0	0	0	1	0
1875	93.75	75	0	0	0	1	1
1900	95	76	0	0	1	0	0
1925	96.25	77	0	0	1	0	1
1950	97.5	78	0	0	1	1	0
1975	98.75	79	0	0	1	1	1
2000	100	80 (default)	0	1	0	0	0
2025	101.25	81	0	1	0	0	1
2050	102.5	82	0	1	0	1	0
2075	103.75	83	0	1	0	1	1
2100	105	84	0	1	1	0	0
2125	106.25	85	0	1	1	0	1
2150	107.5	86	0	1	1	1	0
2175	108.75	87	0	1	1	1	1
2200	110	88	1	0	0	0	0
Not Used	Not Used	Not Used	1	0	0	0	1
			• • •				
			1	1	1	1	1

**TABLE 3C. PLL2, SSC MODE FUNCTION TABLE**

Register Bit	
SSC	SS Mode
0	
1	

**TABLE 3D. BYPASS CLOCK SELECTION TABLE**

Register Bit	
Bypass	Clock Source
0 (default)	
1	

**TABLE 3E. Q12 FREQUENCY SELECTION TABLE**

Register Bit	
Q12 Frequency	Output Frequency
0 (default)	200MHz
1	100MHz

**TABLE 3F. REVISION DESCRIPTION TABLE**

Register Bit	
Revision	Part Revision
0	Revision B
1	Revision C

## I<sup>2</sup>C ADDRESSING

The 844S2416 can be set to decode one of two addresses to minimize the chance of address conflict on the I<sup>2</sup>C bus. The address that **ADDR = 0**

ADDR = 0 Default							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	0	0	1	1	0	0	R/W

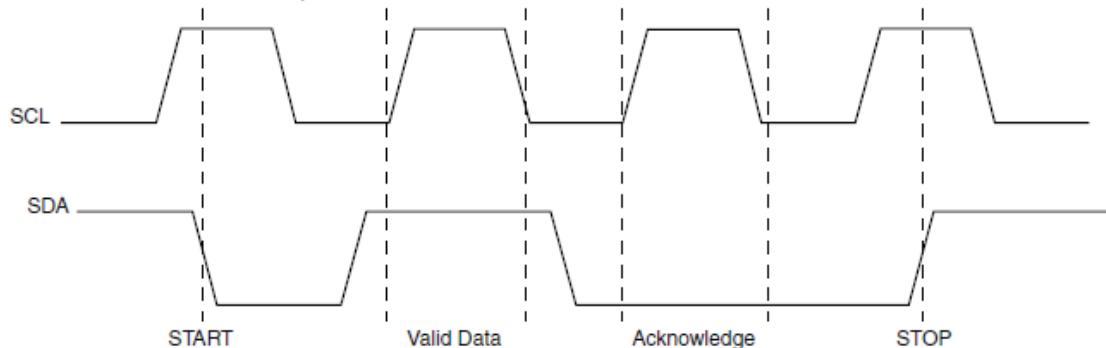
is decoded is controlled by the setting of the ADDR pin as shown below.

## ADDR = 1

ADDR = 1							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	0	0	1	1	1	0	R/W

## I<sup>2</sup>C INTERFACE - PROTOCOL

The 844S2416 is a slave-only device and uses the standard I<sup>2</sup>C protocol as shown in the below diagrams. The maximum SCL



**START (ST)** – defined as high-to-low transition on SDA while holding SCL HIGH.

**DATA** - Between START and STOP cycles, SDA is synchronous with SCL.

Data may change only when SCL is LOW and must be stable when SCL is HIGH.

**ACKNOWLEDGE (AK)** – SDA is driven LOW before the SCL rising edge and held LOW until the SCL falling edge.

**STOP (SP)** – defined as low-to-high transition on SDA while holding SCL HIGH.

## I<sup>2</sup>C INTERFACE - A WRITE EXAMPLE

A serial transfer to the 844S2416 always consists of an address cycle followed by 4 data bytes. Once the 4 data bytes are loaded and the master generates a stop condition, the values in the serial

frequency is greater than 10MHz which is more than sufficient for standard I<sup>2</sup>C clock speeds.

control register are latched into the M divider and control bits, and the device will move to the new frequency and any changes to the state of the control bits will take effect.

ST	Slave Address: 7 Bits								R/W	AK
1 Bit	Refer to I <sup>2</sup> C Addressing section for address choices based on ADDR pin setting								1 Bit	1 Bit
Data Byte 0: 8 Bits										AK
Q16_EN	Q15_EN	Q14_EN	Q13_EN	Q12_EN	Q11_EN	Q10_EN	Q9_EN			
Data Byte 1: 8 Bits										AK
Q8_EN	Q7_EN	Q6_EN	Q5_EN	Q4_EN	Q3_EN	Q2_EN	Q1_EN			
Data Byte 2: 8 Bits										AK
Q0_EN	M4	M3	M2	M1	M0	SSC	BYPASS			
Data Byte 3: 8 Bits										AK
f (Q12)	Revision	Reserved	1 Bit	SP						

↑  
Data Byte values latched into control registers here.

## ABSOLUTE MAXIMUM RATINGS

Supply Voltage, $V_{DD}$	4.6V
Inputs, $V_I$	-0.5V to $V_{DD} + 0.5$ V
Outputs, $V_O$ (LVCMOS & HCSL)	-0.5V to $V_{DD\_LVCMOS} + 0.5$ V
Package Thermal Impedance, $\theta_{JA}$	31.4°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 4A. POWER SUPPLY DC CHARACTERISTICS,  $V_{DD} = V_{DD\_LVCMOS} = 3.3V \pm 5\%$ ,  $TA = -40^\circ\text{C}$  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
$V_{DDA1}, V_{DDA2}$	Analog Supply Voltage		$V_{DD} - 0.31$	3.3	$V_{DD}$	V
$V_{DD\_LVCMOS}$	Output Supply Voltage		3.135	3.3	3.465	V
$I_{DD}$	Power Supply Current	No Load			170	mA
$I_{DDA1}$	PLL1 Analog Supply Current				9	mA
$I_{DDA2}$	PLL2 Analog Supply Current				22	mA
$I_{DD\_LVCMOS}$	Output Supply Current	No Load $Q[0:11]$ at 25MHz, $Q13, Q14$ at 24MHz			16	mA

TABLE 4B. LVCMOS / LVTTL DC CHARACTERISTICS,  $V_{DD} = V_{DD\_LVCMOS} = 3.3V \pm 5\%$ ,  $TA = -40^\circ\text{C}$  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	ADDR, SCL	$V_{DD} = V_{IN} = 3.465V$		150	$\mu\text{A}$
		SDA, nRESET	$V_{DD} = V_{IN} = 3.465V$		10	$\mu\text{A}$
$I_{IL}$	Input Low Current	ADDR, SCL	$V_{DD} = 3.465V, V_{IN} = 0V$	-10		$\mu\text{A}$
		SDA, nRESET	$V_{DD} = 3.465V, V_{IN} = 0V$	-150		$\mu\text{A}$
$V_{OH}$	Output High Voltage	$I_{OH} = -12\text{mA}$	2.6			V
$V_{OL}$	Output Low Voltage	$I_{OL} = 12\text{mA}$			0.5	V

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
Drive Level				100	$\mu\text{W}$

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

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$f_{OUT}$	Output Frequency	Q0:Q11		25		MHz
		Q12/nQ12		100		MHz
		Q13, Q14		24		MHz
		Q15:Q16/nQ15:nQ16		100		MHz
$t_{JIT(PER)}$	Period Jitter, Peak-to-Peak	Q12/nQ12	BER = 10E-12, 100MHz		70	ps
		Q13, Q14	BER = 10E-12, 24MHz		95	ps
		Q15:Q16/nQ15:nQ16	BER = 10E-12, 100MHz		70	ps
$t_{JIT(CC)}$	Cycle-to-Cycle Jitter; NOTE 1, 2	Q0:Q11	25MHz		30	ps
		Q12/nQ12	100MHz		80	ps
		Q13, Q14	24MHz		90	ps
		Q15:Q16/nQ15:nQ16	100MHz		70	ps
$t_{RESET}$	Minimum Reset Time for nRESET		1.6			ns
$t_{OEPD}$	Maximum Propagation Delay from OE Register to Clock				$10 + t_{PER}$	ns
$t_L$	PLL Lock Time				50	ms
$F_{XTAL}$	Crystal Input Range; NOTE 1			25		MHz
$F_M$	SSC Modulation Frequency; NOTE 3		29		33.33	kHz
$F_{MF}$	SSC Modulation Factor; NOTE 3			-0.4	-0.5	%
$SSC_{RED}$	Spectral Reduction; NOTE 3		4	6		dB
$t_{STABLE}$	Power-up to Stable Clock Output, NOTE 4, 5		500			ps
$V_{MAX}$	Absolute Maximum Output Voltage; NOTE 6, 7	HCSL Levels			1150	mV
$V_{MIN}$	Absolute Minimum Output Voltage; NOTE 6, 8	HCSL Levels	-300			mV
$V_{RB}$	Ringback Voltage; NOTE 4, 5	HCSL Levels	-100		100	mV
$V_{CROSS}$	Absolute Crossing Voltage; NOTE 6, 9, 10	HCSL Levels	250		550	mV
$\Delta V_{CROSS}$	Total Variation of $V_{CROSS}$ ; NOTE 6, 9, 11	HCSL Levels			140	mV
$t_R / t_F$	Output Rise/Fall Time	Q[0:11], Q13, Q14	20% - 80%	150	350	ps
	Rise/Fall Edge Rate; NOTE 4, 12			0.6	5	V/ns
odc	Output Duty Cycle; NOTE 4	Q[0:11]		42	58	%
		Q13, Q14		49	51	%
		Q12/nQ12, Q15/nQ15, Q16/nQ16		49	51	%

NOTE 1: This parameter is defined in accordance with JEDEC Standard 65.

NOTE 2: Only valid within the VCO operating range.

NOTE 3: Spread Spectrum clocking enabled.

NOTE 4: Measurement taken from differential waveform.

NOTE 5:  $T_{STABLE}$  is the time the differential clock must maintain a minimum  $\pm 150$ mV differential voltage after rising/falling edges before it is allowed to droop back into the  $V_{RB} \pm 100$ mV differential range. See Parameter Measurement Information Section.NOTE 6: Measurement taken from single-ended  $V_{RB}$  waveform.

NOTES continued on next page.

NOTE 7: Defined as the maximum instantaneous voltage including overshoot. See Parameter Measurement Information Section.

NOTE 8: Defined as the minimum instantaneous voltage including undershoot. See Parameter Measurement Information Section.

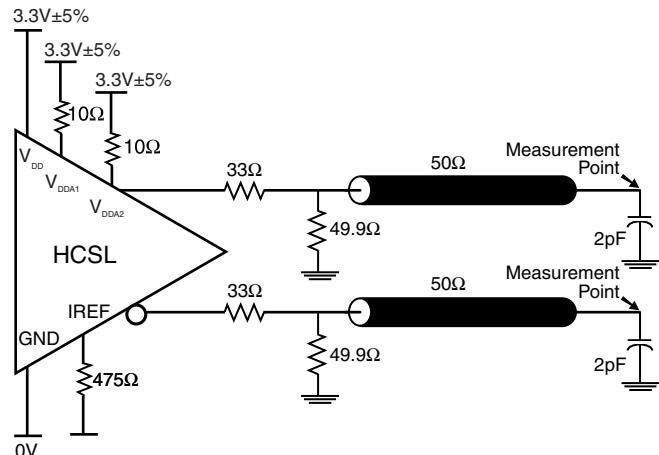
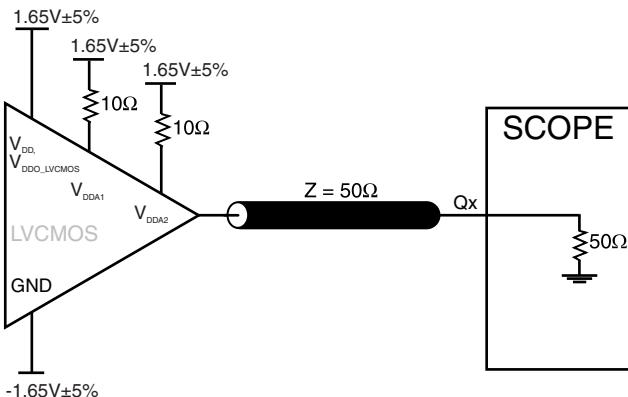
NOTE 9: Measured at crossing point where the instantaneous voltage value of the rising edge of Qx equals the falling edge of nQx. See Parameter Measurement Information Section.

NOTE 10: Refers to the total variation from the lowest crossing point to the highest, regardless of which edge is crossing. Refers to all crossing points for this measurement. See Parameter Measurement Information Section.

NOTE 11: Defined as the total variation of all crossing voltage of Rising Qx and Falling nQx. This is the maximum allowed variance in the  $V_{CROSS}$  for any particular system. See Parameter Measurement Information Section.

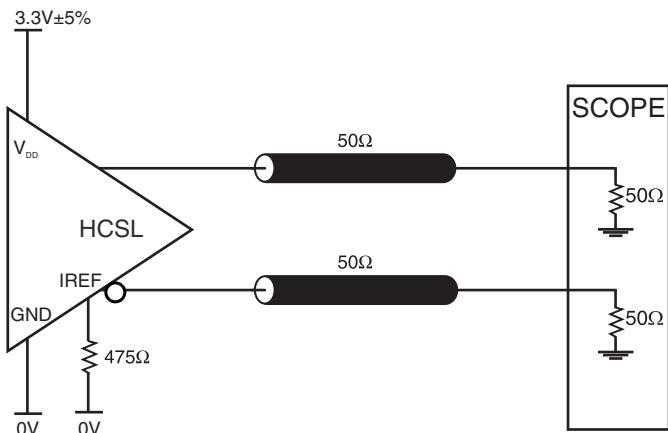
NOTE 12: Measured from -150mV to +150mV on the differential waveform (derived from Qx minus nQx). The signal must be monotonic through the measurement region for rise and fall time. The 300mV measurement window is centered on the differential zero crossing. See Parameter Measurement Information Section.

## PARAMETER MEASUREMENT INFORMATION



**3.3V CORE/3.3V LVC MOS Output Load AC TEST CIRCUIT**

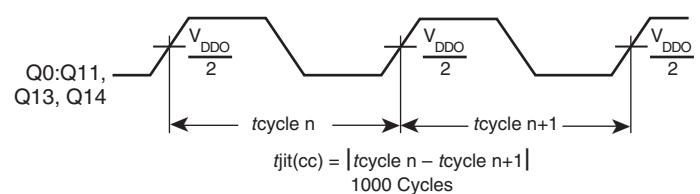
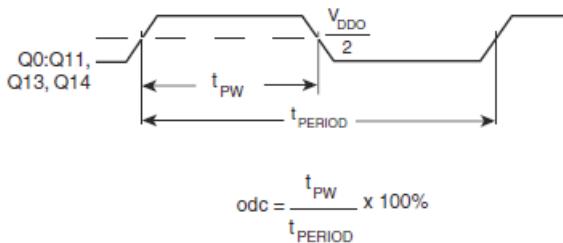
**3.3V CORE/3.3V HCSL Output Load AC TEST CIRCUIT**



This load condition is used for  $I_{DD}$ ,  $I_{DDA1}$ ,  $I_{DDA2}$  and  $t_{jitter}$  measurements.

**HCSL Output Load AC Test Circuit**

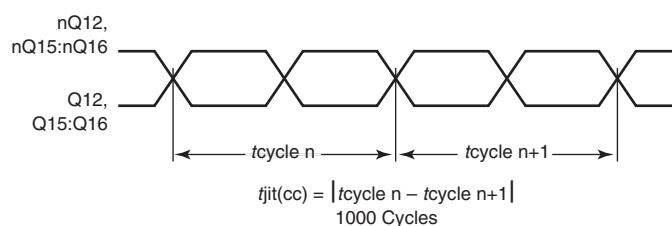
**PERIOD JITTER**



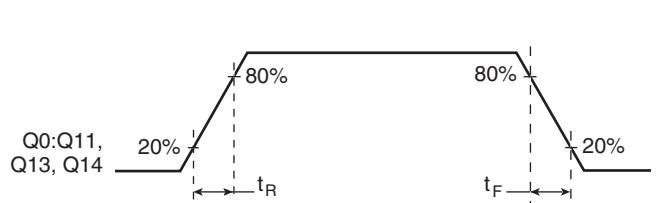
**LVC MOS Output Duty Cycle/Pulse Width/Period**

**LVC MOS CYCLE-TO-CYCLE JITTER**

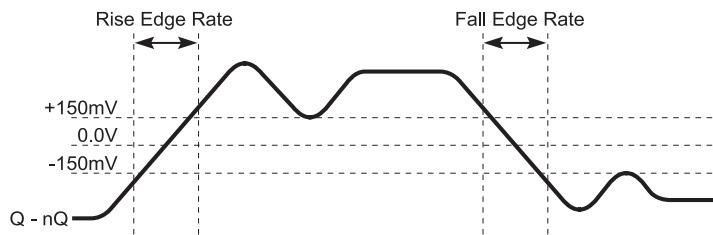
## PARAMETER MEASUREMENT INFORMATION, CONTINUED



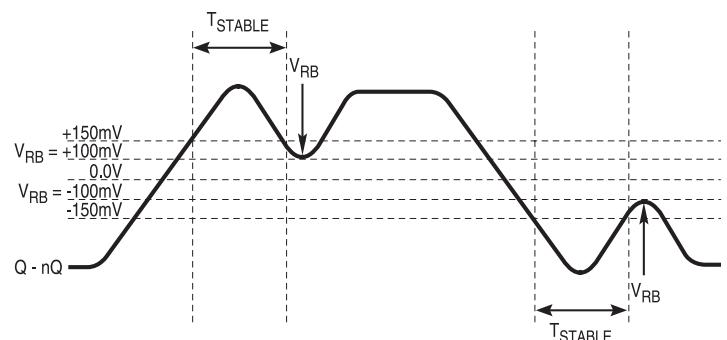
**HCSL CYCLE-TO-CYCLE JITTER**



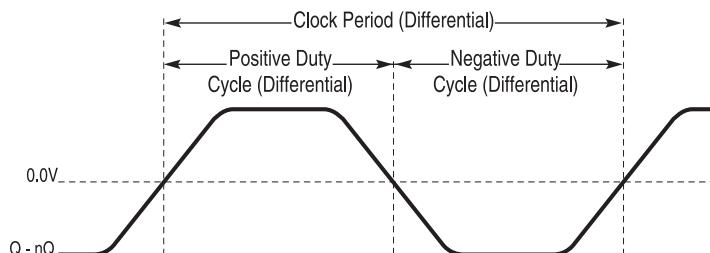
**LVC MOS OUTPUT RISE/FALL TIME**



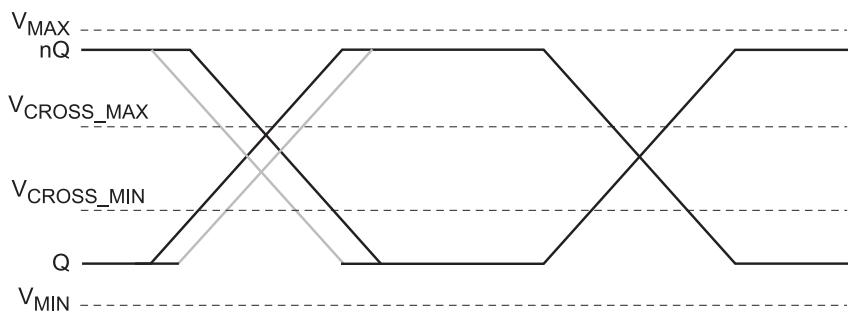
**DIFFERENTIAL HCSL MEASUREMENT POINTS FOR RISE/FALL EDGE RATE**



**DIFFERENTIAL MEASUREMENT POINTS FOR RINGBACK**



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



**SINGLE-ENDED 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 844S2416 provides separate power supplies to isolate any high switching noise from the outputs to the internal PLL.  $V_{DD}$ ,  $V_{DDAX}$  and  $V_{DDO,LVCMOS}$  should be individually connected to the power supply plane through vias, and  $0.01\mu F$  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  $10\mu F$  bypass capacitor be connected to the  $V_{DDA}$  pin.

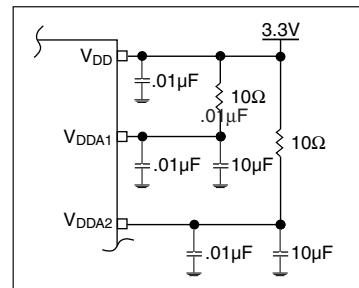


FIGURE 1. POWER SUPPLY FILTERING

### 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  $1k\Omega$  resistor can be used.

#### OUTPUTS:

##### LVC MOS OUTPUTS

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

##### 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.

## CRYSTAL INPUT INTERFACE

The 844S2416 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. The value can be varied for different board layouts.

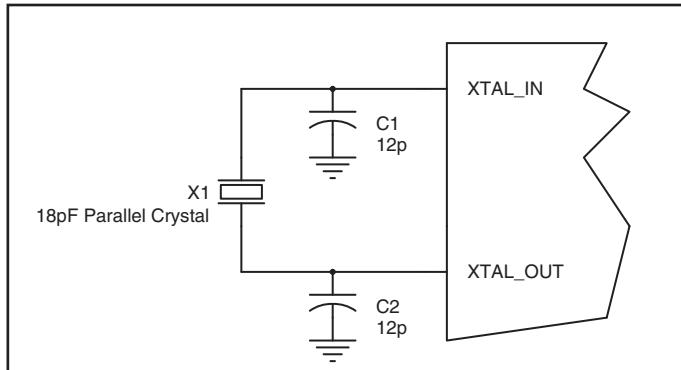


FIGURE 2. CRYSTAL INPUT INTERFACE

## LVC MOS TO XTAL INTERFACE

The XTAL\_IN input can accept a single-ended LVC MOS signal through an AC coupling 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 ( $Ro$ ) plus the series resistance ( $Rs$ ) 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,  $R1$  and  $R2$  in parallel should equal the transmission line impedance. For most  $50\Omega$  applications,  $R1$  and  $R2$  can be  $100\Omega$ . This can also be accomplished by removing  $R1$  and making  $R2$   $50\Omega$ .

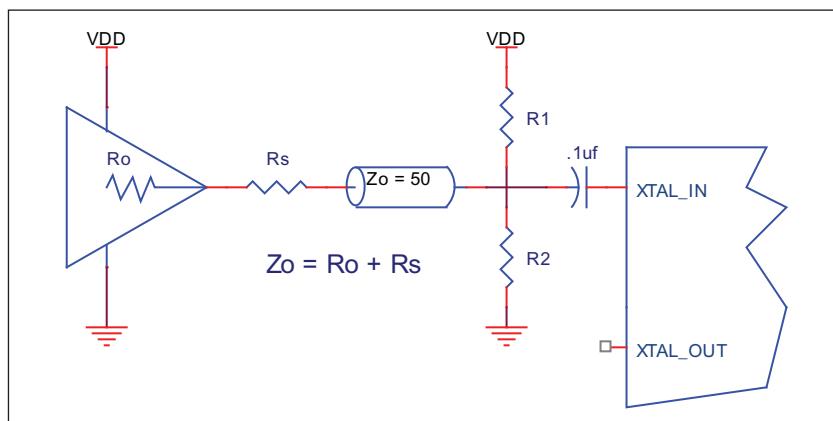


FIGURE 3. GENERAL DIAGRAM FOR LVC MOS DRIVER TO XTAL INPUT INTERFACE

## VFQFN EPAD THERMAL RELEASE PATH

In order to maximize both the removal of heat from the package and the electrical performance, a land pattern must be incorporated on the Printed Circuit Board (PCB) within the footprint of the package corresponding to the exposed metal pad or exposed heat slug on the package, as shown in *Figure 4*. The solderable area on the PCB, as defined by the solder mask, should be at least the same size/shape as the exposed pad/slug area on the package to maximize the thermal/electrical performance. Sufficient clearance should be designed on the PCB between the outer edges of the land pattern and the inner edges of pad pattern for the leads to avoid any shorts.

While the land pattern on the PCB provides a means of heat transfer and electrical grounding from the package to the board through a solder joint, thermal vias are necessary to effectively conduct from the surface of the PCB to the ground plane(s). The land pattern must be connected to ground through these vias. The vias act as "heat pipes". The number of vias (i.e. "heat pipes") are application

specific and dependent upon the package power dissipation as well as electrical conductivity requirements. Thus, thermal and electrical analysis and/or testing are recommended to determine the minimum number needed. Maximum thermal and electrical performance is achieved when an array of vias is incorporated in the land pattern. It is recommended to use as many vias connected to ground as possible. It is also recommended that the via diameter should be 12 to 13mils (0.30 to 0.33mm) with 1oz copper via barrel plating. This is desirable to avoid any solder wicking inside the via during the soldering process which may result in voids in solder between the exposed pad/slug and the thermal land. Precautions should be taken to eliminate any solder voids between the exposed heat slug and the land pattern. Note: These recommendations are to be used as a guideline only. For further information, refer to the Application Note on the *Surface Mount Assembly* of Amkor's Thermally/Electrically Enhance Leadfame Base Package, Amkor Technology.

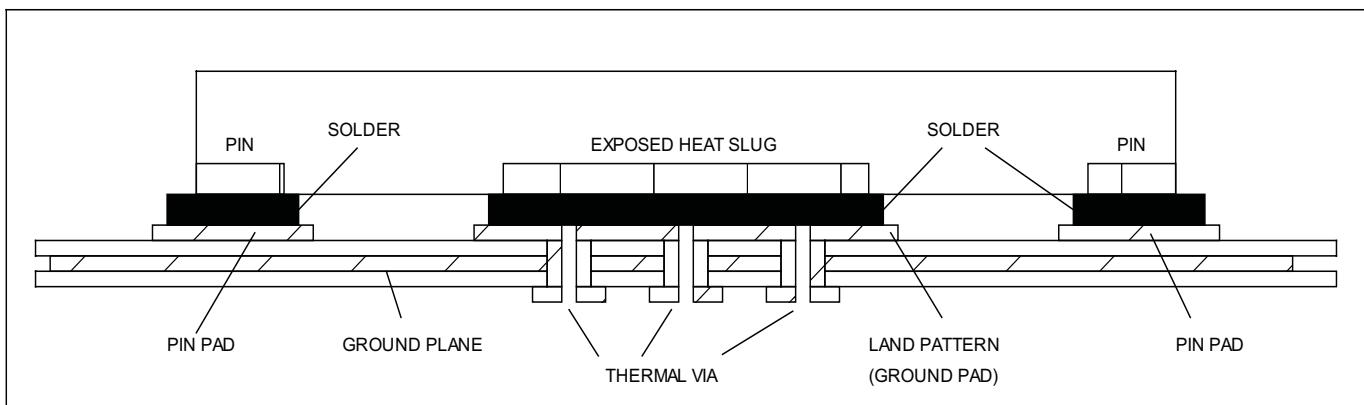


FIGURE 4. P.C. ASSEMBLY FOR EXPOSED PAD THERMAL RELEASE PATH –SIDE VIEW (DRAWING NOT TO SCALE)

## 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  $50\Omega$  impedance.

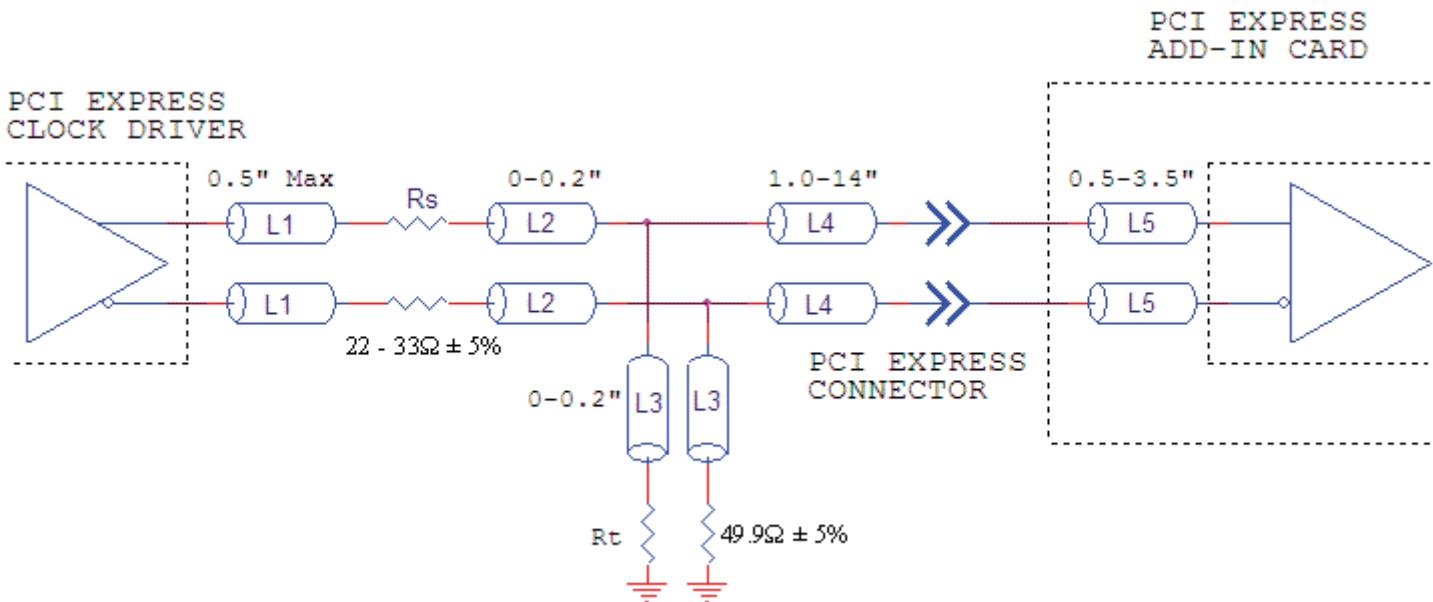


FIGURE 5A. RECOMMENDED TERMINATION

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  $50\Omega$  impedance.

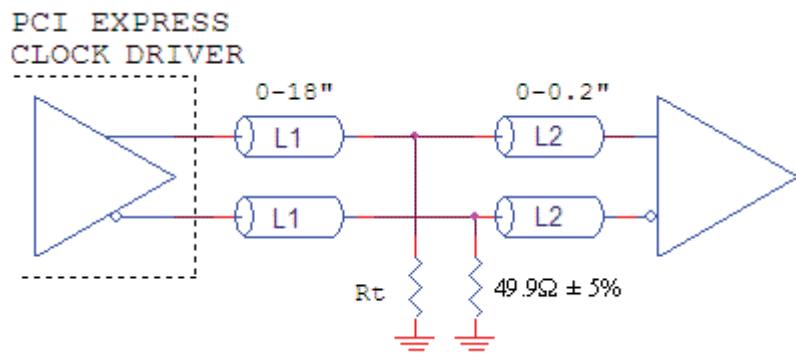


FIGURE 5B. RECOMMENDED TERMINATION

## POWER CONSIDERATIONS

This section provides information on power dissipation and junction temperature for the 844S2416. Equations and example calculations are also provided.

### 1. Power Dissipation.

The total power dissipation for the 844S2416 is the sum of the core power plus the analog 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.

### Core and HCSL Output Power Dissipation

- Power (core)<sub>MAX</sub> =  $V_{DD\_MAX} * (I_{DD} + I_{DDA1} + I_{DDA2}) = 3.465V * (170 + 9mA + 22mA) = 696.5mW$
- Power (HCSL)<sub>MAX</sub> = **44.5mW/Loaded Output Pair**  
If all outputs are loaded, the total power is  $3 * 44.5mW = 133.5mW$

### LVC MOS Output Power Dissipation

- Output Impedance  $R_{OUT}$  Power Dissipation due to Loading  $50\Omega$  to  $V_{DD}/2$   
 $Output\ Current\ I_{OUT} = V_{DD\_MAX} / [2 * (50\Omega + R_{OUT})] = 3.465V / [2 * (50\Omega + 21\Omega)] = 24.4mA$
- Power Dissipation on the  $R_{OUT}$  per LVC MOS output  
 $Power(R_{OUT}) = R_{OUT} * (I_{OUT})^2 = 21\Omega * (24.4mA)^2 = 12.5mW\ per\ output$
- Total Power Dissipation on the  $R_{OUT}$   
**Total Power ( $R_{OUT}$ ) =  $12.5mW * 14 = 175mW$**
- Dynamic Power Dissipation at 24MHz and 25MHz  
 $Power\ Dynamic = V_{DD\_LVC\ MOS\_MAX} * I_{DD\_LVC\ MOS} = 3.465V * 16mA = 55.44mW$

### Total Power Dissipation

- **Total Power**  
= Power (core) + Power (HCSL) + Total Power ( $R_{OUT}$ ) + Total Power ( $R_{OUT}$ ) + Total Power (Dynamic)  
=  $696.5mW + 133.5mW + 175mW + 55.44mW$   
**= 1060.4mW**

## 2. Junction Temperature.

Junction 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°C. Limiting the internal transistor junction temperature,  $T_j$ , to 125°C ensures that the bond wire and bond pad temperature remains below 125°C.

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

$T_j$  = Junction Temperature

$\theta_{JA}$  = Junction-to-Ambient Thermal Resistance

$P_{d\_total}$  = 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 air flow of 1 meter per second and a multi-layer board, the appropriate value is 27.5°C/W per Table 7.

Therefore,  $T_j$  for an ambient temperature of 85°C with all outputs switching is:

$$85^\circ\text{C} + 1.06\text{W} * 27.5^\circ\text{C/W} = 114.2^\circ\text{C}. \text{ This is below the limit of } 125^\circ\text{C.}$$

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.

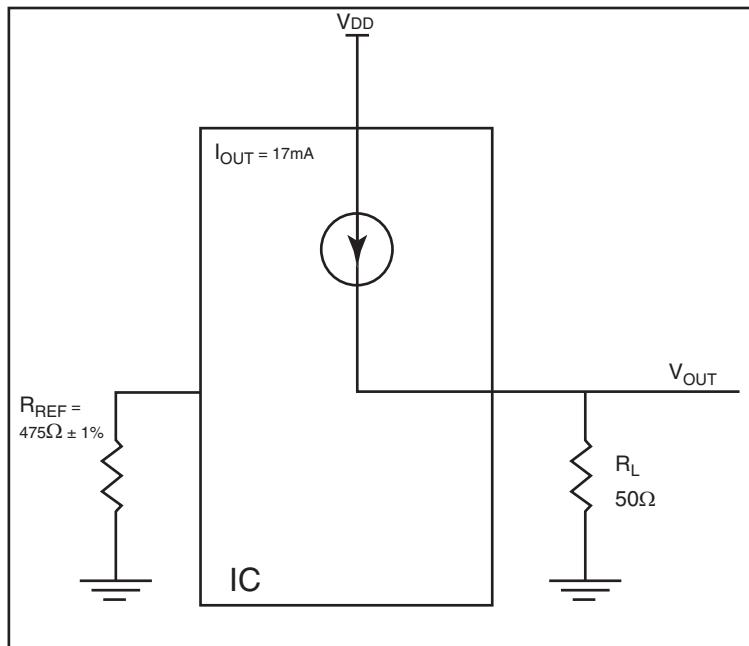
**TABLE 7. THERMAL RESISTANCE  $\theta_{JA}$  FOR 56-LEAD VFQFN, FORCED CONVECTION**

<b><math>\theta_{JA}</math> vs. Air Flow (Meters per Second)</b>			
Multi-Layer PCB, JEDEC Standard Test Boards	<b>0</b> 31.4°C/W	<b>1</b> 27.5°C/W	<b>2.5</b> 24.6°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 6*.



**FIGURE 6. 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 = **44.5mW**

## RELIABILITY INFORMATION

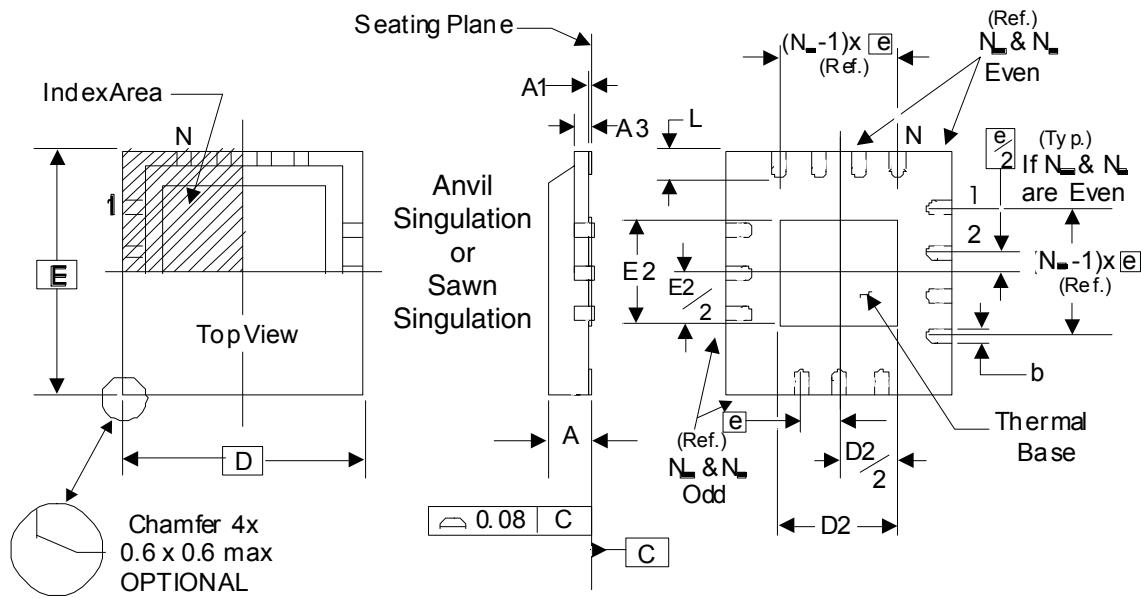
TABLE 8.  $\theta_{JA}$  VS. AIR FLOW TABLE FOR 56 LEAD VFQFN

$\theta_{JA}$ by Velocity (Meters per second)			
Multi-Layer PCB, JEDEC Standard Test Boards	0 31.4°C/W	1 27.5°C/W	2.5 24.6°C/W

### TRANSISTOR COUNT

The transistor count for 844S2416 is: 13,890

## PACKAGE OUTLINE - K SUFFIX FOR 56 LEAD VFQFN



NOTE: The following package mechanical drawing is a generic drawing that applies to any pin count VFQFN package. This drawing is not intended to convey the actual pin count or pin layout of this

device. The pin count and pinout are shown on the front page. The package dimensions are in Table 8 below.

TABLE 9. PACKAGE DIMENSIONS

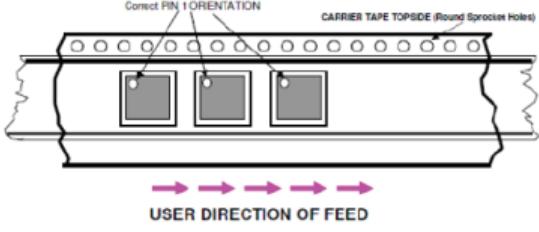
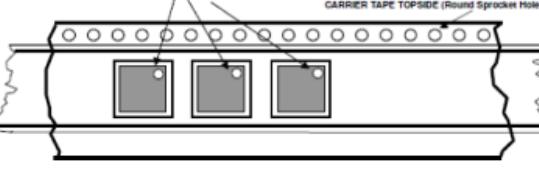
JEDEC VARIATION ALL DIMENSIONS IN MILLIMETERS		
SYMBOL	MINIMUM	MAXIMUM
N	56	
A	0.80	1.0
A1	0	0.05
A3	0.25 Reference	
b	0.18	0.30
e	0.50 BASIC	
N <sub>d</sub>	14	
N <sub>e</sub>	14	
D	8.0	
D2	4.35	4.65
E	8.0	
E2	5.05	5.35
L	0.3	0.55

Reference Document: JEDEC Publication 95, MO-220

**TABLE 10. ORDERING INFORMATION**

Part/Order Number	Marking	Package	Shipping Packaging	Temperature
844S2416CKILF	ICS44S2416CIL	56 lead "Lead Free" VFQFN	tray	-40°C to 85°C
844S2416CKILFT	ICS44S2416CIL	56 lead "Lead Free" VFQFN	tape & reel, Pin 1 orientation (EIA-481-C)	-40°C to 85°C
844S2416CKILF/W	ICS44S2416CIL	56 lead "Lead Free" VFQFN	tape & reel, Pin 1 orientation, (EIA-481-D)	-40°C to 85°C

**TABLE 11. PIN 1 ORIENTATION IN TAPE AND REEL PACKAGING**

Part Number Suffix	Pin 1 Orientation	Illustration
T	Quadrant 1 (EIA-481-C)	
W	Quadrant 2 (EIA-481-D)	

## REVISION HISTORY SHEET

Rev	Table	Page	Description of Change	Date
A		1 17	General Description - deleted HiperClocks logo. First sentence, deleted HiperClocks reference. Power Considerations - updated <i>Junction Temperature</i> sentence.	12/2/13
A	T10 T11	21 21	Ordering Information - Added W part number. Added Pin 1 orientation table.	7/6/15
A	T10	21	Ordering Information - Deleted LF note below table. Updated data sheet header and footer.	4/29/16



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### Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,  
Koto-ku, Tokyo 135-0061, Japan  
[www.renesas.com](http://www.renesas.com)

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