

## GENERAL DESCRIPTION



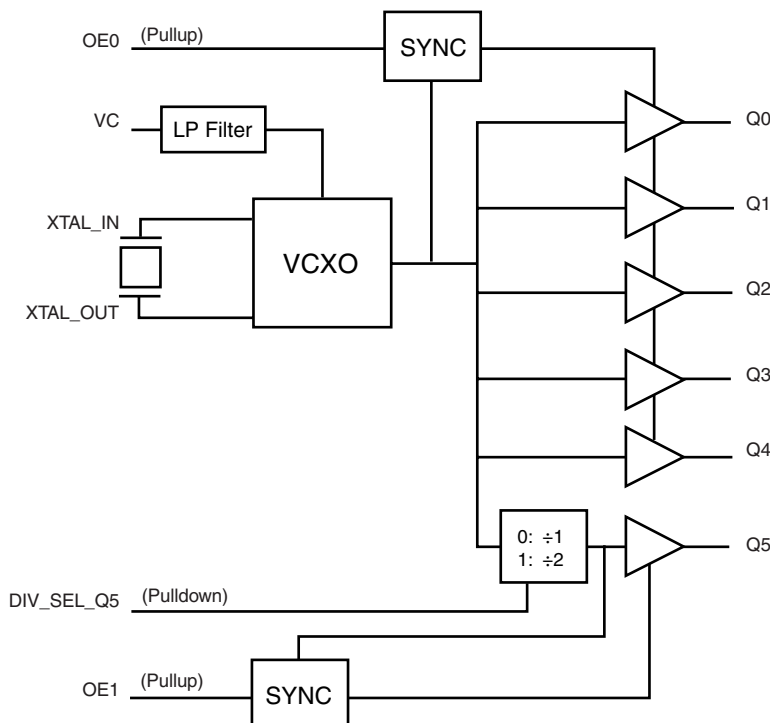
The ICS81006I is a high performance, low jitter/low phase noise VCXO and is a member of the HiPerClockS™ family of high performance clock solutions from IDT. The ICS81006I works in conjunction with a pullable crystal to generate an output clock over the range of 12MHz - 40MHz and has 6 LVCMOS outputs, effectively integrating a fanout buffer function.

The frequency of the VCXO is adjusted by the VC control voltage input. The output range is  $\pm 100\text{ppm}$  around the nominal crystal frequency. The VC control voltage range is  $0 - V_{DD}$ . The device is packaged in a small 4mm x 4mm VFQFN package and is ideal for use on space constrained boards typically encountered in ADSL/VDSL applications.

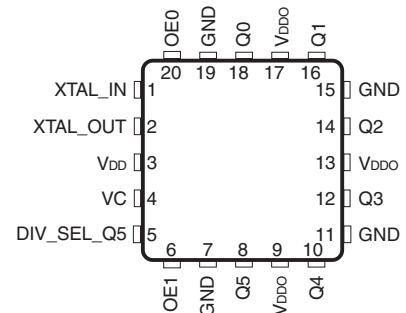
## FEATURES

- Six LVCMOS/LVTTL outputs, 20Ω nominal output impedance
- Output Q5 can be selected for  $\div 1$  or  $\div 2$  frequency relative to the crystal frequency
- Output frequency range: 12MHz to 40MHz
- Crystal pull range:  $\pm 90\text{ppm}$  (typical)
- Synchronous output enable places outputs in High-Z state
- On-chip filter on VIN to suppress noise modulation of VCXO
- $V_{DD}/V_{DDO}$  combinations
  - 3.3V/3.3V
  - 3.3V/2.5V
  - 3.3V/1.8V
  - 2.5V/2.5V
  - 2.5V/1.8V
- 4mm x 4mm 20 Lead VFQFN package is ideal for space constrained designs
- $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$  ambient operating temperature
- Available in both standard (RoHS 5) and lead-free (RoHS 6) packages

## BLOCK DIAGRAM



## PIN ASSIGNMENT



**ICS81006I**  
**20-Lead VFQFN**  
 4mm x 4mm x 0.95 package body  
**K Package**  
 Top View

TABLE 1. PIN DESCRIPTIONS

Number	Name	Type		Description
1, 2	XTAL_IN, XTAL_OUT	Input		Crystal oscillator interface. XTAL_IN is the input. XTAL_OUT is the output.
3	V <sub>DD</sub>	Power		Core supply pin.
4	VC	Input		Control voltage input.
5	DIV_SEL_Q5	Input	Pulldown	Output divider select pin for Q5 output. When LOW, ÷1. When HIGH, ÷2, LVCMOS/LVTTL interface levels.
6	OE1	Input	Pullup	Output enable pin. When HIGH, Q5 output is enabled. When LOW, forces Q5 to HiZ state. LVCMOS/LVTTL interface levels.
7, 11, 15, 19	GND	Power		Power supply ground.
8, 10, 12, 14, 16, 18	Q5, Q4, Q3, Q2, Q1, Q0	Output		Single-ended clock outputs. LVCMOS/LVTTL interface levels. 15Ω typical output impedance.
9, 13, 17	V <sub>DDO</sub>	Power		Output supply pins.
20	OE0	Input	Pullup	Output enable pin. When HIGH, Q0:Q4 outputs are enabled. When LOW, forces Q0:Q4 to HiZ state. LVCMOS/LVTTL interface levels.

NOTE: Pullup and Pulldown 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 <sub>IN</sub>	Input Capacitance	OE0, OE1			4		pF
C <sub>PD</sub>	Power Dissipation Capacitance		V <sub>DD</sub> = V <sub>DDO</sub> = 3.465V			3	pF
			V <sub>DD</sub> = 3.465V or 2.625V, V <sub>DDO</sub> = 2.625V			4	pF
			V <sub>DD</sub> = 3.465V or 2.625V, V <sub>DDO</sub> = 2V			6	pF
R <sub>PULLUP</sub>	Input Pullup Resistor				51		kΩ
R <sub>PULLDOWN</sub>	Input Pulldown Resistor				51		kΩ
R <sub>OUT</sub>	Output Impedance		V <sub>DDO</sub> = 3.3V			20	Ω
			V <sub>DDO</sub> = 2.5V			25	Ω
			V <sub>DDO</sub> = 1.8V			38	Ω

## 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 $V_{DD} + 0.5V$
Package Thermal Impedance, $\theta_{JA}$	60.4°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 3A. POWER SUPPLY DC CHARACTERISTICS,  $V_{DD} = 3.3V \pm 5\%$ ,  $V_{DDO} = 3.3V \pm 5\% = 2.5V \pm 5\% = 1.8V \pm 0.2V$ ,  $T_A = -40^\circ\text{C}$  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
$V_{DDO}$	Output Supply Voltage		3.135	3.3	3.465	V
			2.375	2.5	2.625	V
			1.6	1.8	2.0	V
$I_{DD}$	Power Supply Current			50	mA	
$I_{DDO}$	Output Supply Current			20	mA	

TABLE 3B. POWER SUPPLY DC CHARACTERISTICS,  $V_{DD} = 2.5V \pm 5\%$ ,  $V_{DDO} = 2.5V \pm 5\% = 1.8V \pm 0.2V$ ,  $T_A = -40^\circ\text{C}$  TO  $85^\circ\text{C}$

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{DD}$	Core Supply Voltage		2.375	2.5	2.625	V
$V_{DDO}$	Output Supply Voltage		2.375	2.5	2.625	V
			1.6	1.8	2.0	V
					50	mA
$I_{DD}$	Power Supply Current			50	mA	
$I_{DDO}$	Output Supply Current			20	mA	

TABLE 3C. LVCMOS/LVTTL DC CHARACTERISTICS,  $T_A = -40^\circ\text{C}$  TO  $85^\circ\text{C}$

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{IH}$	Input High Voltage	$V_{DD} = 3.3V \pm 5\%$	2		$V_{DD} + 0.3$	V
		$V_{DD} = 2.5V \pm 5\%$	1.7		$V_{DD} + 0.3$	V
$V_{IL}$	Input Low Voltage	OE0, OE1, DIV_SEL_Q5 $V_{DD} = 3.3V \pm 5\%$	-0.3		0.8	V
		$V_{DD} = 2.5V \pm 5\%$	-0.3		0.7	V
VC	VCXO Control Voltage		0		$V_{DD}$	V
$I_{IH}$	Input High Current	DIV_SEL_Q5 $V_{DD} = 3.3V$ or $2.5V \pm 5\%$			150	$\mu\text{A}$
		OE0, OE1 $V_{DD} = 3.3V$ or $2.5V \pm 5\%$			5	$\mu\text{A}$
$I_{IL}$	Input Low Current	DIV_SEL_Q5 $V_{DD} = 3.3V$ or $2.5V \pm 5\%$	-5			$\mu\text{A}$
		OE0, OE1 $V_{DD} = 3.3V$ or $2.5V \pm 5\%$	-150			$\mu\text{A}$
$I_I$	Input Current of VC pin	$V_{DD} = 3.465V$ or $2.625V$	-100		100	$\mu\text{A}$
$V_{OH}$	Output High Voltage;NOTE 1	$V_{DDO} = 3.3V \pm 5\%$	2.6			V
		$V_{DDO} = 2.5V \pm 5\%$	1.8			V
		$V_{DDO} = 1.8V \pm 0.2V$	1.5			V
$V_{OL}$	Output Low Voltage;NOTE 1	$V_{DDO} = 3.3V$ or $2.5V \pm 5\%$			0.5	V
		$V_{DDO} = 1.8V \pm 0.2V$			0.4	V

NOTE 1: Outputs terminated with  $50\Omega$  to  $V_{DDO}/2$ . See Parameter Measurement section, "Load Test Circuit" diagrams.

**TABLE 4A. AC CHARACTERISTICS,  $V_{DD} = V_{DDO} = 3.3V \pm 5\%$ ,  $T_A = -40^\circ\text{C}$  TO  $85^\circ\text{C}$** 

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$f_{OUT}$	Output Frequency		12	19.44	40	MHz
$f_{jit}(\emptyset)$	RMS Phase Jitter (Random); NOTE 1	Integration Range: 1kHz- 1MHz		0.35		ps
tsk(o)	Output Skew; NOTE 2, 3	Q0:Q4			30	ps
		Q0:Q5	DIV_SEL_Q5 = ÷1		100	ps
$t_R / t_F$	Output Rise/Fall Time	20% to 80%	200		750	ps
odc	Output Duty Cycle		44		56	%

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.

**TABLE 4B. AC CHARACTERISTICS,  $V_{DD} = 3.3V \pm 5\%$ ,  $V_{DDO} = 2.5V \pm 5\%$ ,  $T_A = -40^\circ\text{C}$  TO  $85^\circ\text{C}$** 

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$f_{OUT}$	Output Frequency		12	19.44	40	MHz
$f_{jit}(\emptyset)$	RMS Phase Jitter (Random); NOTE 1	Integration Range: 1kHz- 1MHz		0.38		ps
tsk(o)	Output Skew; NOTE 2, 3	Q0:Q4			20	ps
		Q0:Q5	DIV_SEL_Q5 = ÷1		90	ps
$t_R / t_F$	Output Rise/Fall Time	20% to 80%	300		800	ps
odc	Output Duty Cycle		45		55	%

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.

**TABLE 4C. AC CHARACTERISTICS,  $V_{DD} = 3.3V \pm 5\%$ ,  $V_{DDO} = 1.8V \pm 0.2V$ ,  $T_A = -40^\circ\text{C}$  TO  $85^\circ\text{C}$** 

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$f_{OUT}$	Output Frequency		12	19.44	40	MHz
$f_{jit}(\emptyset)$	RMS Phase Jitter (Random); NOTE 1	Integration Range: 1kHz-1MHz		0.27		ps
tsk(o)	Output Skew; NOTE 2, 3	Q0:Q4			50	ps
		Q0:Q5	DIV_SEL_Q5 = ÷1		180	ps
$t_R / t_F$	Output Rise/Fall Time	20% to 80%	450		1400	ps
odc	Output Duty Cycle		45		55	%

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.

TABLE 4D. AC CHARACTERISTICS,  $V_{DD} = V_{DDO} = 2.5V \pm 5\%$ ,  $T_A = -40^\circ\text{C}$  TO  $85^\circ\text{C}$ 

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$f_{OUT}$	Output Frequency		12	19.44	40	MHz
$f_{jit}(\emptyset)$	RMS Phase Jitter (Random); NOTE 1	Integration Range: 1kHz-1MHz		0.28		ps
$tsk(o)$	Output Skew; NOTE 2, 3	Q0:Q4			25	ps
		Q0:Q5	DIV_SEL_Q5 = ÷1		105	ps
$t_R / t_F$	Output Rise/Fall Time	20% to 80%	300		800	ps
odc	Output Duty Cycle		45		55	%

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.

TABLE 4E. AC CHARACTERISTICS,  $V_{DD} = 2.5V \pm 5\%$ ,  $V_{DDO} = 1.8V \pm 0.2V$ ,  $T_A = -40^\circ\text{C}$  TO  $85^\circ\text{C}$ 

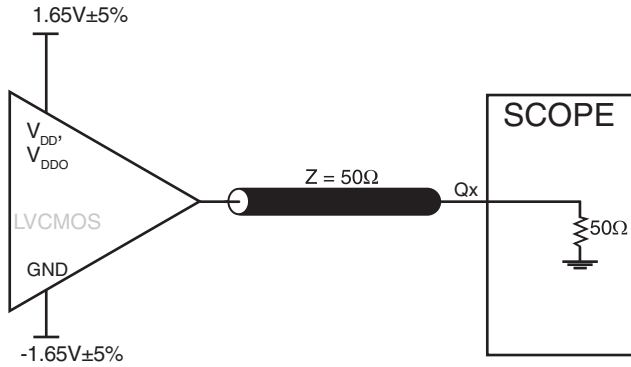
Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$f_{OUT}$	Output Frequency		12	19.44	40	MHz
$f_{jit}(\emptyset)$	RMS Phase Jitter (Random); NOTE 1	Integration Range: 1kHz-1MHz		0.26		ps
$tsk(o)$	Output Skew; NOTE 2, 3	Q0:Q4			40	ps
		Q0:Q5	DIV_SEL_Q5 = ÷1		185	ps
$t_R / t_F$	Output Rise/Fall Time	20% to 80%	450		1400	ps
odc	Output Duty Cycle		40		60	%

NOTE 1: Please refer to the Phase Noise Plot.

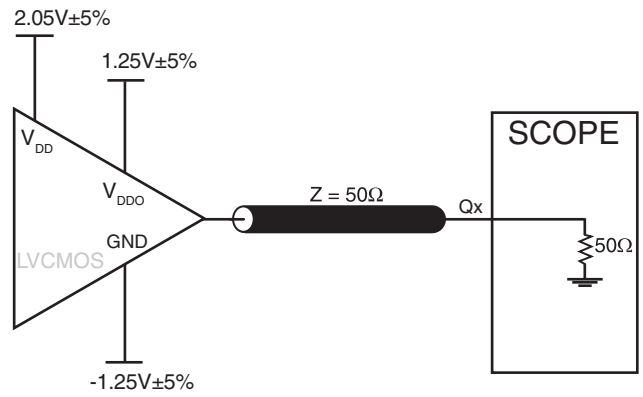
NOTE 2: Defined as skew between outputs at the same supply voltage and with equal load conditions.  
Measured at the output differential cross points.

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

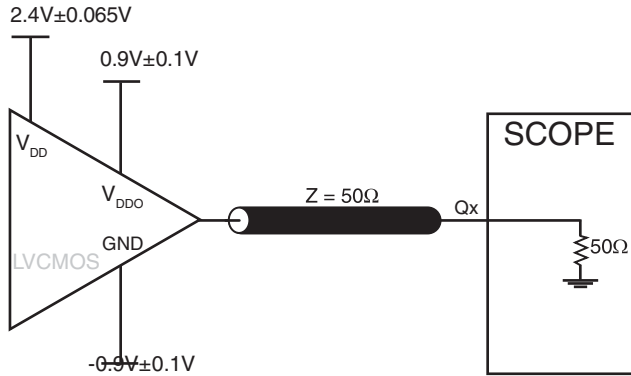
## PARAMETER MEASUREMENT INFORMATION



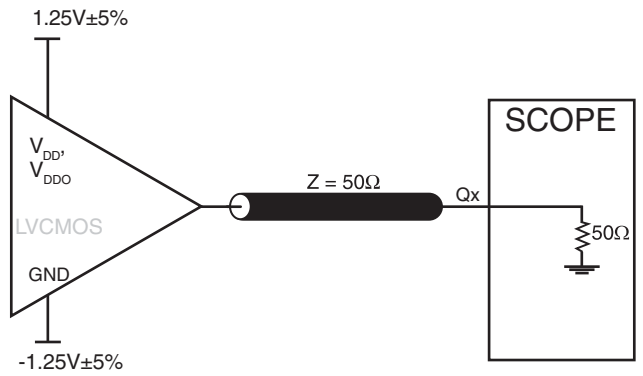
3.3V CORE/3.3V OUTPUT LOAD AC TEST CIRCUIT



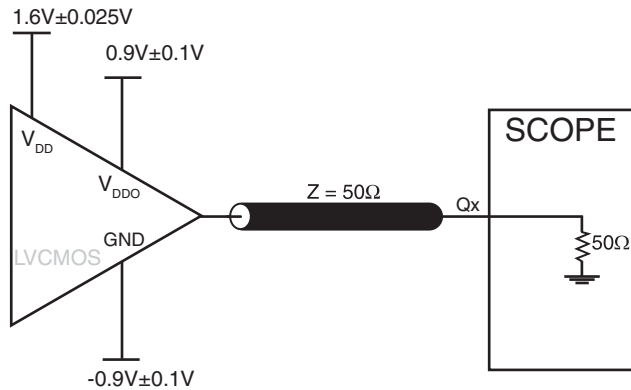
3.3V CORE/2.5V OUTPUT LOAD AC TEST CIRCUIT



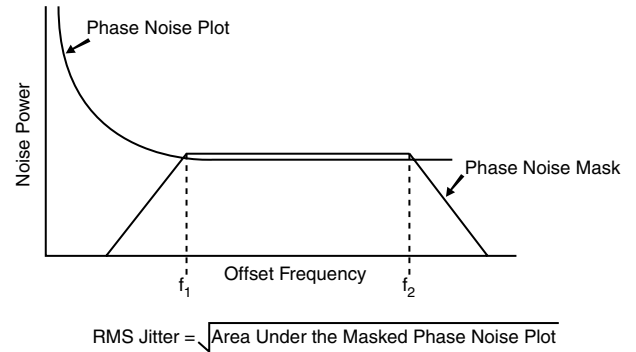
3.3V CORE/1.8V OUTPUT LOAD AC TEST CIRCUIT



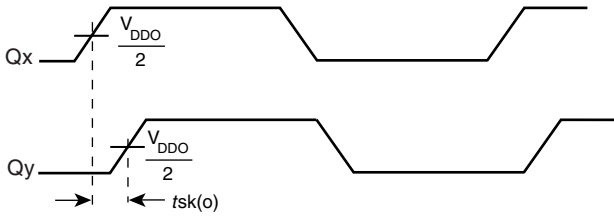
2.5V CORE/2.5V OUTPUT LOAD AC TEST CIRCUIT



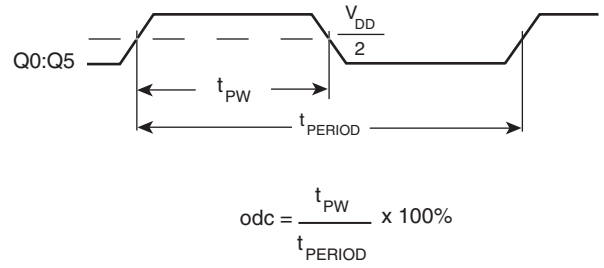
2.5V CORE/1.8V OUTPUT LOAD AC TEST CIRCUIT



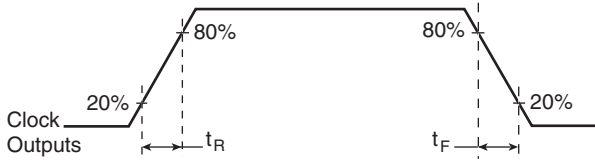
RMS PHASE JITTER



OUTPUT SKEW



OUTPUT DUTY CYCLE/PULSE WIDTH/PERIOD



OUTPUT RISE/FALL TIME

## APPLICATION INFORMATION

### VCXO CRYSTAL SELECTION

Choosing a crystal with the correct characteristics is one of the most critical steps in using a Voltage Controlled Crystal Oscillator (VCXO). The crystal parameters affect the tuning range and

accuracy of a VCXO. Below are the key variables and an example of using the crystal parameters to calculate the tuning range of the VCXO.

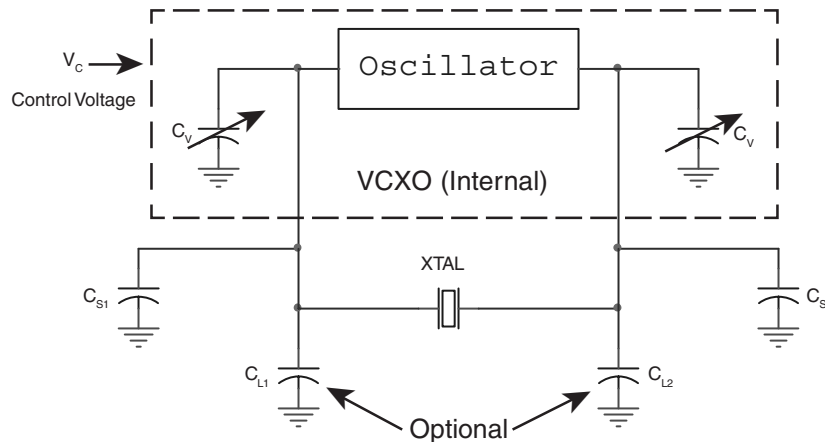


FIGURE 1: VCXO OSCILLATOR CIRCUIT

$V_c$  Control voltage used to tune frequency

$C_v$  Varactor capacitance, varies due to the change in control voltage

$C_{L1}, C_{L2}$  Load tuning capacitance used for fine tuning or centering nominal frequency

$C_{s1}, C_{s2}$  Stray Capacitance caused by pads, vias, and other board parasitics

TABLE 5. EXAMPLE CRYSTAL PARAMETERS

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$f_N$	Nominal Frequency			19.44		MHz
$f_T$	Frequency Tolerance				±20	ppm
$f_S$	Frequency Stability				±20	ppm
	Operating Temperature Range		0		70	°C
$C_L$	Load Capacitance			12		pF
$C_O$	Shunt Capacitance			4		pF
$C_0, C_1$	Pullability Ratio			220	240	
ESR	Equivalent Series Resistance				20	
	Drive Level				1	mW
	Aging @ 25°C		±3 per year			ppm
	Mode of Operation		Fundamental			



TABLE 6. VARACTOR PARAMETERS

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$C_{V\_LOW}$	Low Varactor Capacitance	$V_C = 0V$		15.4		pF
$C_{V\_HIGH}$	High Varactor Capacitance	$V_C = 3.3V$		29.6		pF

## FORMULAS

$$C_{Low} = \frac{(C_{L1} + C_{S1} + C_{V\_Low}) \cdot (C_{L2} + C_{S2} + C_{V\_Low})}{(C_{L1} + C_{S1} + C_{V\_Low}) + (C_{L2} + C_{S2} + C_{V\_Low})}$$

$$C_{High} = \frac{(C_{L1} + C_{S1} + C_{V\_High}) \cdot (C_{L2} + C_{S2} + C_{V\_High})}{(C_{L1} + C_{S1} + C_{V\_High}) + (C_{L2} + C_{S2} + C_{V\_High})}$$

- $C_{Low}$  is the effective capacitance due to the low varactor capacitance, load capacitance and stray capacitance.  $C_{Low}$  determines the high frequency component on the TPR.
- $C_{High}$  is the effective capacitance due to the high varactor capacitance, load capacitance and stray capacitance.  $C_{High}$  determines the low frequency component on the TPR.

$$Total\ Pull\ Range\ (TPR) = \left( \frac{1}{2 \cdot C_0 / C_1 \cdot \left(1 + C_{Low} / C_0\right)} - \frac{1}{2 \cdot C_0 / C_1 \cdot \left(1 + C_{High} / C_0\right)} \right) \cdot 10^6$$

Absolute Pull Range (APR) = Total Pull Range – (Frequency Tolerance + Frequency Stability + Aging)

## EXAMPLE CALCULATIONS

Using the tables and figures above, we can now calculate the TPR and APR of the VCXO using the example crystal parameters. For the numerical example below there were some assumptions made. First, the stray capacitance ( $C_{S1}$ ,  $C_{S2}$ ), which is all the excess capacitance due to board parasitic, is 4pF. Second, the expected lifetime of the project is 5 years; hence the inaccuracy due to

aging is  $\pm 15$ ppm. Third, though many boards will not require load tuning capacitors ( $C_{L1}$ ,  $C_{L2}$ ), it is recommended for long-term consistent performance of the system that two tuning capacitor pads be placed into every design. Typical values for the load tuning capacitors will range from 0 to 4pF.

$$C_{Low} = \frac{(0 + 4\text{ pf} + 15.4\text{ pf}) \cdot (0 + 4\text{ pf} + 15.4\text{ pf})}{(0 + 4\text{ pf} + 15.4\text{ pf}) + (0 + 4\text{ pf} + 15.4\text{ pf})} = 9.7\text{ pf}$$

$$C_{High} = \frac{(0 + 4\text{ pf} + 29.6\text{ pf}) \cdot (0 + 4\text{ pf} + 29.6\text{ pf})}{(0 + 4\text{ pf} + 29.6\text{ pf}) + (0 + 4\text{ pf} + 29.6\text{ pf})} = 16.8\text{ pf}$$

$$TPR = \left( \frac{1}{2 \cdot 220 \cdot \left(1 + \frac{9.7\text{ pF}}{4\text{ pF}}\right)} - \frac{1}{2 \cdot 220 \cdot \left(1 + \frac{16.8\text{ pF}}{4\text{ pF}}\right)} \right) \cdot 10^6 = 226.5\text{ ppm}$$

TPR =  $\pm 113.25$ ppm

APR =  $113.25$ ppm – (20ppm + 20ppm + 15ppm) =  $\pm 58.25$ ppm

The example above will ensure a total pull range of  $\pm 113.25$  ppm with an APR of  $\pm 58.25$ ppm. Many times, board designers may select their own crystal based on their application. If the application requires a tighter APR, a crystal

with better pullability (C0/C1 ratio) can be used. Also, with the equations above, one can vary the frequency tolerance, temperature stability, and aging or shunt capacitance to achieve the required pullability.

## RECOMMENDATIONS FOR UNUSED INPUT AND OUTPUT PINS

### INPUTS:

#### 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. The VC pin can not be floated.

### OUTPUTS:

#### LVCMOS OUTPUT:

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

## SCHEMATIC EXAMPLE

Figure 2 shows an example of ICS81006I application schematic. The decoupling capacitors should be located as close as possible to the power pin. For the LVCMOS 20 $\Omega$  output drivers,

series termination example is shown in the schematic. Additional termination approaches are shown in the LVCMOS Termination Application Note.

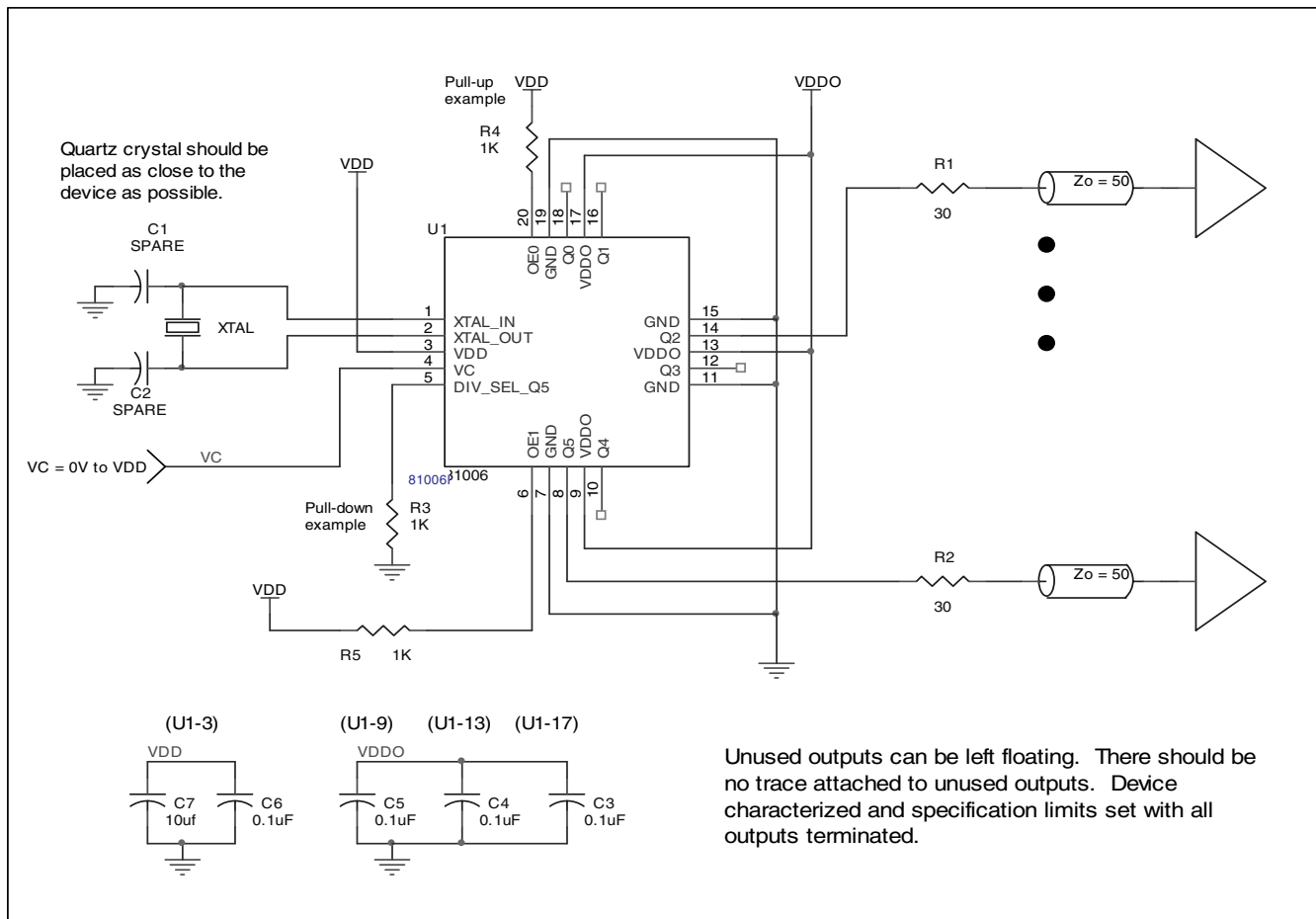


FIGURE 2. ICS81006I SCHEMATIC EXAMPLE

## RELIABILITY INFORMATION

TABLE 7.  $\theta_{JA}$  VS. AIR FLOW TABLE FOR 20 LEAD VFQFN

$\theta_{JA}$ by Velocity (Meters per Second)			
	0	1	3
Multi-Layer PCB, JEDEC Standard Test Boards	60.4°C/W	52.8°C/W	46.0°C/W

### TRANSISTOR COUNT

The transistor count for ICS81006I is: 983

PACKAGE OUTLINE - K SUFFIX FOR 20 LEAD VFQFN

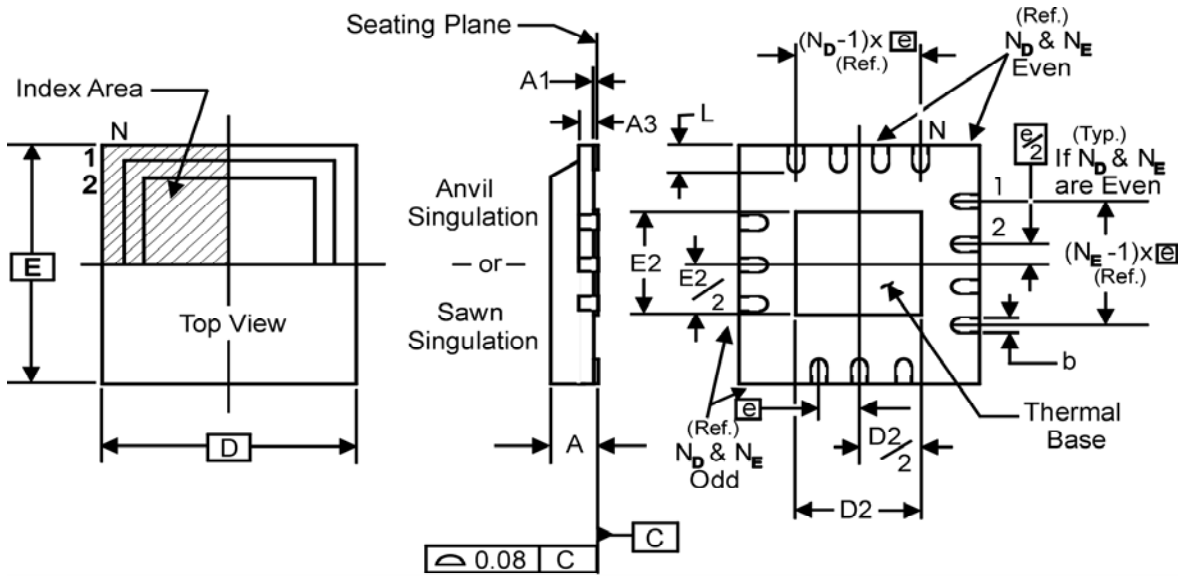


TABLE 8. PACKAGE DIMENSIONS FOR 20 LEAD VFQFN

JEDEC VARIATION ALL DIMENSIONS IN MILLIMETERS		
SYMBOL	MINIMUM	MAXIMUM
N	20	
A	0.80	1.0
A1	0	0.05
A3	0.25 Reference	
b	0.18	0.30
e	0.50 BASIC	
$N_D$	5	
$N_E$	5	
D	4.0	
D2	0.75	2.80
E	4.0	
E2	0.75	2.80
L	0.35	0.75

Reference Document: JEDEC Publication 95, MO-220

TABLE 9. ORDERING INFORMATION

Part/Order Number	Marking	Package	Shipping Packaging	Temperature
ICS81006AKI	1006AI	20 lead VFQFN	tube	-40°C to 85°C
ICS81006AKIT	1006AI	20 lead VFQFN	2500 tape & reel	-40°C to 85°C
ICS81006AKILF	TBD	20 lead "Lead-Free" VFQFN	tube	-40°C to 85°C
ICS81006AKILFT	TBD	20 lead "Lead-Free" VFQFN	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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netcom@idt.com  
480-763-2056

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**Corporate Headquarters**

Integrated Device Technology, Inc.  
6024 Silver Creek Valley Road  
San Jose, CA 95138  
United States  
800 345 7015  
+408 284 8200 (outside U.S.)

**Asia Pacific and Japan**

Integrated Device Technology  
Singapore (1997) Pte. Ltd.  
Reg. No. 199707558G  
435 Orchard Road  
#20-03 Wisma Atria  
Singapore 238877  
+65 6 887 5505

**Europe**

IDT Europe, Limited  
321 Kingston Road  
Leatherhead, Surrey  
KT22 7TU  
England  
+44 (0) 1372 363 339  
Fax: +44 (0) 1372 378851

