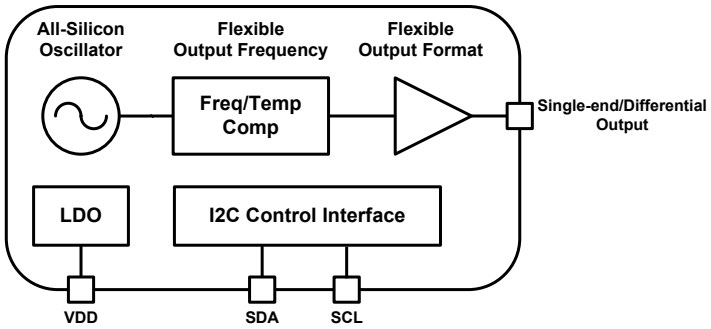
AS5003 Low Jitter I²C Programmable Differential Silicon Oscillator

Description

The AS5003 Arcadium™ all-silicon oscillator utilizes proprietary frequency synthesis and sensor technologies to provide a quartz-free, MEMS-free, low jitter clock at any output frequency. The device is fully programmable to any frequency from 10 kHz to 350 MHz with 0.026 ppb resolution and maintains low jitter across its operating range. The AS5003 uses on-chip temperature and strain sensors, and an advanced LC tank architecture to achieve excellent reliabilities even in high impact shock scenarios.

AS5003's on-chip power supply filtering provides industry-leading power supply noise rejection, simplifying the task of generating low jitter clocks in noisy systems that use switched-mode power supplies. Offered in a variety of industry-standard packages, the AS5003 has a dramatically simplified supply chain that enables Aeonsemi to ship samples shortly after receipt of order. The AS5003 is userconfigurable with an I2C interface for a wide variety of user specifications, including frequency, output format, and DCO mode. Default configuration is factory programmed at time of shipment. It also guarantees 100% electrical testing of every device before shipment.



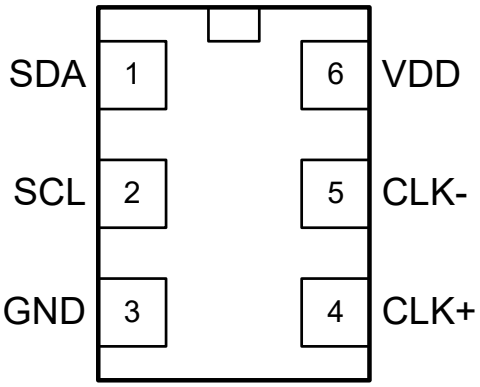
Key Features

- Quartz-free and MEMS-free without mechanical moving parts
- LVCMOS output: 10 kHz to 212.5 MHz
- Differential output: 10 kHz to 350 MHz
- Low jitter: 350 fs Typ
  (12 kHz – 20 MHz, @156.25 MHz)
- Compliant to PCIe Gen 1/2/3/4/5/6 jitter spec
- Temperature stability:
  - ±20 ppm (-20 to 85 ℃)
  - ±35 ppm (-40 to 85 ℃)
  - ±35 ppm (-40 to 105 ℃)
- Programmable output frequencies and formats by I²C
- Integrated LDO for on-chip power supply noise filtering
- Support 1.8V, 2.5V, 3.3V V_{DD} supply operation
- Industrial standard 3225 and 5032 package footprints

Application

- 1G/10G/40G/100G/200G Ethernet
- Servers, switches, storage, NICs, search acceleration
- Test and measurement
- Clock and data recovery
- FPGA/ASIC clocking

Pin definition



Top view

Pin#	Description
1	SDA = I²C serial data
2	SCL = I²C serial clock
3	GND = Ground
4	CLK+ = Clock output
5	CLK- = Complementary clock output
6	VDD = Power supply

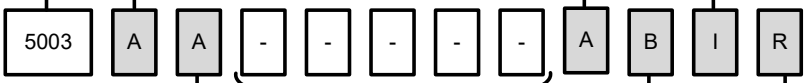
1. Ordering Guide

XO Series	Description
5003	I^2C Programmable

	Device Type
A	General
B	Factory defined setting

	Package
A	5032
B	3225

	Temperature Grade
I	-40 to 85 °C
E	-40 to 105 °C



	Startup Output Status
A	Low Power State
B	Output Disabled
C	Output Enabled

Configuration Code[1]	Description
xxxxx	Five digit numeric code

AS5003 supports user-defined startup output frequency, format and output status. A user-defined 7-bit I^2C address is supported.

Each unique startup configuration and I2C address combination is assigned a 5-digit code

Device Revision

Code	Packing type	Qty
T	7-inch reel	250
R	13-inch reel	2500
<blank>	Bulk	Sample

Note:

1. The five-digit numeric code is an identification of the configurations. Check the datasheet appendix for the details.

2. Electrical Specifications

Table 2.1. Electrical Specifications

Parameter	Symbol	Min	Typ	Max	Unit	Note
Operating Temperature Range						
Temperature Range	T_A	-40	—	85	℃	Industrial grade
		-40	—	105	℃	Extended industrial grade
Supply Voltage and Power Consumption						
Supply Voltage	V_{DD}	1.71	—	3.47	V	
Supply Current (F_{CLK} = 156.25 MHz)	I_{DD}	—	40	50	mA	Tristate Hi-Z (OE = 0)
		—	1	2	mA	Ready State (ACT = 0)
		—	70	80	mA	LVPECL (Standard)
		—	60	70	mA	LVPECL (Self-Biased)
		—	45	55	mA	LVDS
		—	60	70	mA	HCSL
		—	60	70	mA	CML
		—	40	55	mA	Single LVCMOS (C_L = 15 pF)
		—	60	70	mA	Dual LVCMOS (C_L = 15 pF)
Frequency Range						
Frequency Range	F_{CLK}	0.01	—	212.5	MHz	LVCMOS output
		0.01	—	350	MHz	Differential output
Frequency Tolerance						
Initial frequency accuracy	F_{INIT}	-10	—	10	ppm	Inclusive of initial frequency tolerance at 25℃ and variations over supply voltage, load and humidity after soldering-reflow shift settles.
Temperature stability	F_{STAB}	-20	—	20	ppm	-20 - 85℃
		-35	—	35	ppm	-40 - 85℃
		-35	—	35	ppm	-40 - 105℃
Aging	F_{AGING}	-5	—	5	ppm	10 Year at 25 ℃
IO Characteristics						
SDA, SCL	V_{IH}	0.7×V_{DD}	—	—	V	Input high voltage
	V_{IL}	—	—	0.3×V_{DD}	V	Input low voltage
	V_{OH}	0.83×V_{DD}	—	—	V	Output high voltage
	V_{OL}	—	—	0.17×V_{DD}	V	Output low voltage

Continued on next page

Parameter	Symbol	Min	Typ	Max	Unit	Note
Output Characteristics						
Powerup time	T_{OSC}	—	—	4	ms	Time from power reaches 0.9 × V_{DD} to output frequency (F_{CLK}) within spec
Duty cycle	DC	45	—	55	%	All formats
Rise/Fall time (20% to 80% VPP)	$T_{R/F}$	—	0.5	1.5	ns	LVCMOS (C_L = 15 pF)
		—	—	350	ps	LVPECL / LVDS / CML
		—	—	550	ps	HCSL
LVPECL (Standard)	V_{OC}	V_{DD}-1.55	V_{DD}-1.4	V_{DD}-1.25	V	Mid-level
	V_O	1.35	1.6	1.85	V_{PP}	Swing (Diff)
LVPECL (Self-Biased)	V_O	1.35	1.6	1.85	V_{PP}	Swing (Diff)
LVDS	V_{OC}	1.125	1.20	1.275	V	Mid-level (2.5V, 3.3V V_{DD})
		0.78	0.85	0.92	V	Mid-level (1.8V V_{DD})
	V_O	0.64	0.8	0.96	V_{PP}	Swing (Diff)
HCSL (R_{TERM} = 50 Ω)	V_{OC}	0.35	0.4	0.45	V	Mid-level
	V_O	1.28	1.6	1.92	V_{PP}	Swing (Diff)
HCSL (R_{TERM} = 42.5 Ω)	V_{OC}	0.35	0.4	0.45	V	Mid-level
	V_O	1.29	1.62	1.94	V_{PP}	Swing (Diff)
CML	V_{OC}	V_{DD}-0.35	V_{DD}-0.4	V_{DD}-0.45	V	Mid-level
	V_O	1.28	1.6	1.92	V_{PP}	Swing (Diff)
LVCMOS	V_{OH}	0.83×V_{DD}	—	—	V	C_L = 15 pF
	V_{OL}	—	—	0.17×V_{DD}	V	
Phase Noise and Jitter						
RMS jitter BW: 12k - 20MHz	R_J	—	350	750	fs	F_{CLK} >= 100 MHz
		—	450	750	fs	F_{CLK} >= 25 MHz
Phase noise 156.25MHz LVDS output V_{DD} = 1.8 - 3.3V	PN_{1k}	—	-80	—	dBc/Hz	Phase noise at 1kHz offset
	PN_{10k}	—	-110	—	dBc/Hz	Phase noise at 10kHz offset
	PN_{100k}	—	-133	—	dBc/Hz	Phase noise at 100kHz offset
	PN_{1M}	—	-152	—	dBc/Hz	Phase noise at 1MHz offset
	PN_{10M}	—	-161	—	dBc/Hz	Phase noise at 10MHz offset
PSRR						
Spurs from power noise 50mV ripple V_{DD} = 1.8V	PSRR	—	-76	—	dBc	100 kHz sine wave
		—	-75	—	dBc	200 kHz sine wave
		—	-75	—	dBc	500 kHz sine wave
		—	-75	—	dBc	1 MHz sine wave
Spurs from power noise 50mV ripple V_{DD} = 2.5 or 3.3V	PSRR	—	-83	—	dBc	100 kHz sine wave
		—	-83	—	dBc	200 kHz sine wave
		—	-83	—	dBc	500 kHz sine wave
		—	-82	—	dBc	1 MHz sine wave
Thermal Resistance						
Thermal resistance 5032 6-pin DFN Still air	θ_{JA}	—	105	—	°C/W	Junction to ambient
	θ_{JB}	—	81	—	°C/W	Junction to board
	T_J	—	125	—	°C/W	Maximum junction temperature
Thermal resistance 3225 6-pin DFN Still air	θ_{JA}	—	108	—	°C/W	Junction to ambient
	θ_{JB}	—	84	—	°C/W	Junction to board
	T_J	—	125	—	°C/W	Maximum junction temperature

Table 2.2. PCIe Clock Output Performance (100MHz HCSL)

Parameter	Specification	Max	Unit	Test Condition
PCIe Gen 1.1	N/A	0.311	ps	Includes PLL BW 1.5 - 22 MHz Peaking = 3dB, T_D=10 ns
PCIe Gen 2.1	3.1	0.022	ps	Includes PLL BW 5MHz & 8 - 16 MHz Peaking = 0.01 - 1 dB & 3 dB, T_D=12ns Low Band, F $<$ 1.5 MHz
	3.0	0.259	ps	Includes PLL BW 5MHz & 8 - 16 MHz Peaking = 0.01 - 1 dB & 3 dB, T_D=12ns High Band, 1.5 MHz $<$ F $<$ Nyquist
PCIe Gen 3.0 common clock	1	0.085	ps	Includes PLL BW 2 - 4 MHz & 5 MHz Peaking = 0.01 - 2dB & 1dB, T_D=12 ns CDR = 10 MHz
PCIe Gen 4.0 common clock	0.5	0.085	ps	Includes PLL BW 2 - 4 MHz & 5 MHz Peaking = 0.01 - 2dB & 1dB, T_D=12 ns CDR = 10 MHz
PCIe Gen 5.0 common clock	0.15	0.033	ps	Includes PLL BW 500 kHz - 1.8 MHz Peaking = 0.01 – 2dB, T_D=12 ns CDR = 20 MHz
PCIe Gen 6.0 common clock	0.1	0.021	ps	Includes PLL BW 500 kHz – 1 MHz Peaking = 0.01 – 2dB, T_D=12 ns CDR = 10 MHz

Class	Data Rate	Architecture	Specs	Max HF RMS	Max LF RMS	Max Pk-Pk	Compliance Summary
GEN1	2.5 Gb/s	Common Clock	1.1 2.1 3.1	310.77 fs	41.59 fs	N/A	N/A
GEN2	5 Gb/s	Common Clock	1.1 2.1 3.1	259.42 fs	21.89 fs	N/A	All PASS
GEN3	8 Gb/s	Common Clock	3.1 4.0	84.54 fs	4.68 fs	N/A	All PASS
GEN4	16 Gb/s	Common Clock	4.0	84.54 fs	4.68 fs	N/A	All PASS
GEN5	32 Gb/s	Common Clock	5.0	32.92 fs	2.09 fs	N/A	All PASS
GEN6	64 Gb/s	Common Clock	6.0	21.00 fs	0.88 fs	N/A	All PASS

Figure 2.1. PCI-Express clock Compliance Summary

Table 2.3. Environmental Compliance and Package Information

Parameter	Value
Moisture sensitivity level (MSL)	1

Notes:

For additional product information not listed in the data sheet (e.g. RoHS Certifications, MSDS data, qualification data, REACH Declarations, ECCN codes, etc.), contact aeonsemi.com/contact_us

Table 2.4. Absolute Maximum Ratings[1]

Parameter	Symbol	Rating	Unit
Maximum operating temperature	T_{AMAX}	125	℃
Storage temperature	T_S	-55 - 125	℃
Supply voltage	V_{DD_MAX}	-0.5 - 3.8	V
Input voltage	V_{IN_MAX}	-0.5 - V_{DD}+0.3	V
ESD HBM (JESD22-A114)	HBM	4.0	kV
ESD CDM (JESD22-C101)	CDM	1.0	kV
Solder Temperature[2]	T_{PEAK}	260	℃
Solder time at T_{PEAK}[2]	T_P	20 - 40	sec

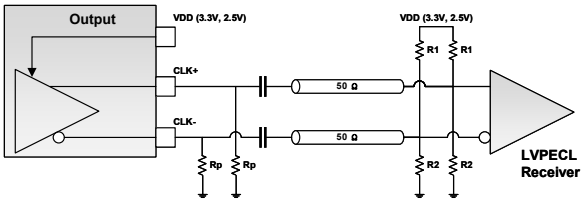
Notes:

1. Stresses beyond those listed in this table may cause permanent damage to the device. Functional operation specification compliance is not implied at these conditions. Exposure to maximum rating conditions for extended periods may affect device reliability.
2. The device is compliant with JEDEC J-STD-020.

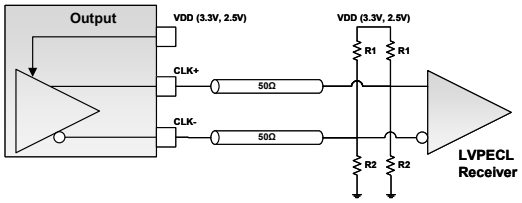
3. Recommended Output Terminations

3.1. Differential Output

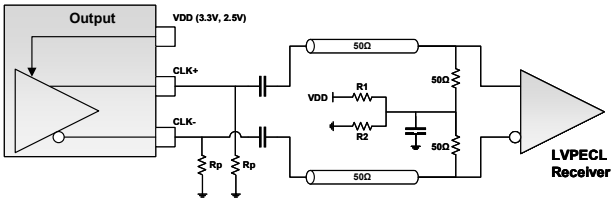
The output drivers support AC-coupled or DC-coupled terminations as shown in figures below.



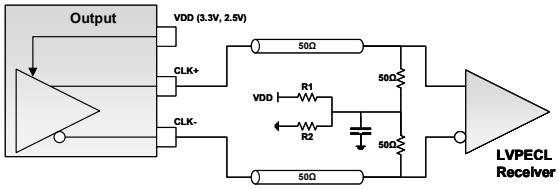
AC-Coupled LVPECL - Thevenin Termination



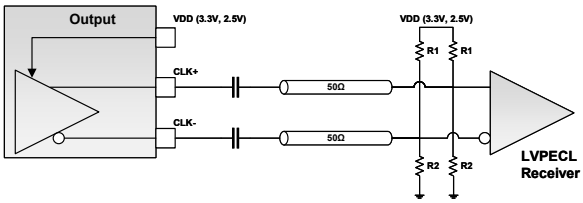
DC-Coupled LVPECL - Thevenin Termination



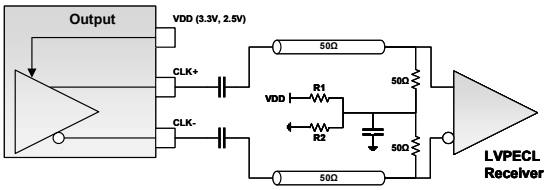
AC-Coupled LVPECL - 50 Ω with VTT Bias



DC-Coupled LVPECL - 50 Ω with VTT Bias



AC-Coupled Self-Biased LVEPCL - Thevenin Termination



AC-Coupled Self-Biased LVEPCL - 50 Ω with VTT Bias

Figure 3.1. LVPECL Output Terminations

Table 3.1. LVPECL Termination Resistor Values

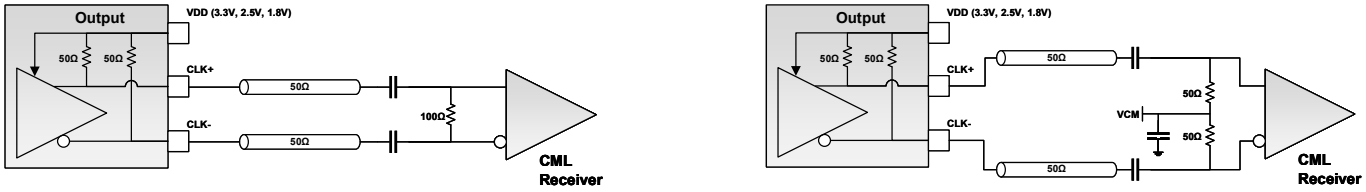
AC Coupled LVPECL Termination Resistor Values			
V_{DD}(V)	R_P	R_1	R_2
3.3 V	158 Ω	127 Ω	82.5 Ω
2.5 V	92 Ω	250 Ω	62.5 Ω

DC Coupled LVPECL Termination Resistor Values		
V_{DD}(V)	R_1	R_2
3.3 V	127 Ω	82.5 Ω
2.5 V	250 Ω	62.5 Ω

AC-Coupled LVDS

DC-Coupled LVDS

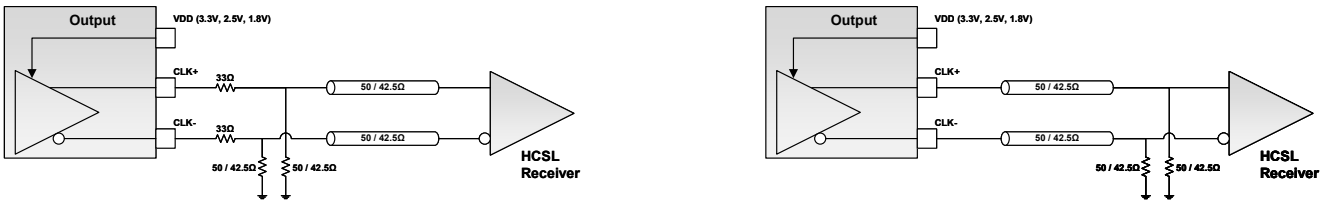
Figure 3.2. LVDS Output Terminations



AC-Coupled CML without VCM

AC-Coupled CML with VCM

Figure 3.3. CML Output Terminations



Source Terminated HCSL

Destination Terminated HCSL

Figure 3.4. HCSL Output Terminations

3.2. CMOS Output

Dual CMOS output format options support either complementary or in-phase signals for two identical frequency outputs. This feature enables replacement of multiple XOs with a single AS5003 device.

Figure 3.5. Integrated 1:2 CMOS Buffer Supports In-Phase or Complementary Outputs

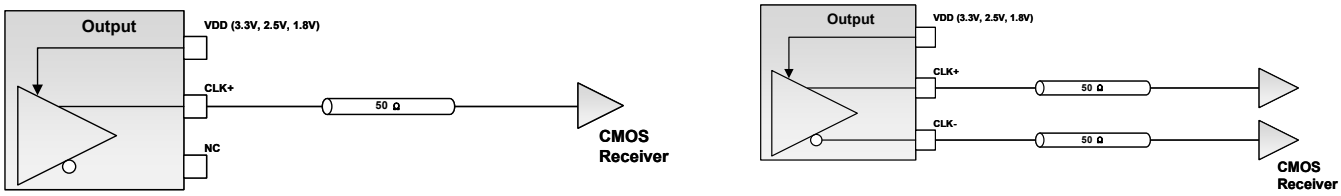


Figure 3.6. LVCMOS Output Terminations

4. Configuring via I²C Interface

4.1. I²C Serial Interface

The I²C interface on the AS5203 is fully compatible with the "UM10204 I2C-bus specification and user manual, Rev. 6 - 4 April 2014" standard, as described in Table 4.1.

Table 4.1. I²C Compatibility

I²C Protocol	Speed	Compliance	Notes
Standard	100 kHz	Compliant	N/A
Fast	400 kHz	Compatible	SDA failing edge can be faster than 20 ns depending on loading.
Fast+	1 MHz	Compatible	SDA falling edge can be faster than 20 ns depending on loading. SDA max pull down current is 6 mA.

4.2. I²C Register Write and Read Protocol

AS5203 implements an 8-bit I²C address space with 256 addressable byte register locations. Certain device register and bits are reserved, and they must not be changed from their default reset state. In an I²C bus system, the AS5203 acts as a slave device connected to the I²C serial interface bus. It is accessed via a 7-bit factory programmed (per user specification) slave address. Allowed values of this device address are in the range from 8 to 119. Both write and read register transactions with register address auto increment are enabled as shown in Figure 4.1.

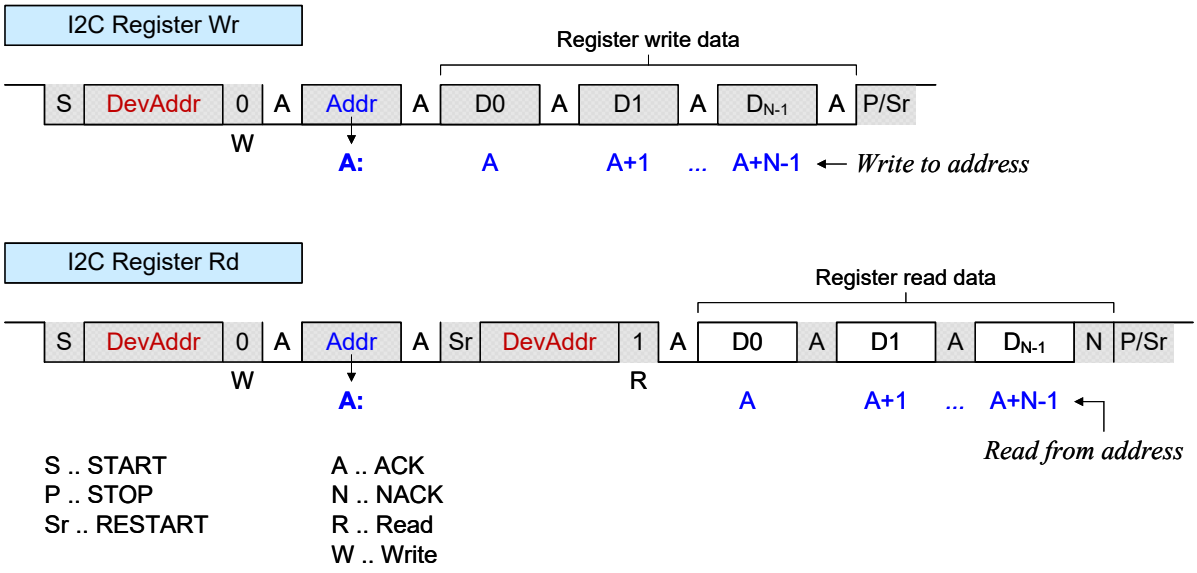


Figure 4.1. I²C Write and Read Transactions

Write register transaction is an I²C write transaction with an 8-bit register address data byte stream. It is followed by one or more register data bytes. Read register sequence starts after a write transaction to set the read register address. It is followed by the I²C read transaction to read one or more data bytes.

The register address autoincrement is enabled upon power up. It is incremented till a maximum address 0xFF of the I²C register space is reached.

Data and address bytes appear on the SDA bus with the most significant bit (MSB) first per I²C standard. During I²C transactions, SCL clock bus is never stalled by the device.

4.3. Device Operation

After an initial power up sequence, the device operates in either Ready state or an Active state depending on customization in factory. The Ready state is a power down standby state when majority of internal circuitries are powered down. The Active state is the device active mode with all internal circuitries powered up. Writing to register bUSYS_CTRL can move the device between Ready state and Active state.

The following three power up options are available for factory configuration:

1. Ready state: The device is in the power down standby mode. Writing transaction to register bUSYS_CTRL is required to enable the device and enable the Active state.
2. Active state with bODIV_CTRL=0: The device generates frequency internally, but output is disabled. Writing transaction to register bODIV_CTRL is required to enable output driver to propagate output frequency.
3. Active state with bODIV_CTRL=1: The device is fully functional, and output is enabled.

In the state 1 and 2 above, user can write to I^2C to change drive mode or central frequency from the factory set values prior to enabling the device output or before moving to Active state.

4.4. Changing Frequency and Output Driver Mode

After startup, the device is at the factory set frequency, output driver strength, and device state. The device is ready to be controlled by I^2C register writes. All register writes can take immediate effect, except fUSER_FREQ registers which require a follow on Apply command. User frequency register, “fUSER_FREQ”, is a 4-byte big endian register representing frequency as a binary32 IEEE 754-2008 standard number, in [Hz] units.

Changing frequency and driver mode requires two steps:

1. Writing fUSER_FREQ registers with the new desired central frequency and/or driver mode. Only the changing register needs to be written. Writing order in bytes is not essential. Writing these registers only records the new values, but does not invoke any internal processing.
2. Writing bUSYS_CTRL register with one of four Apply* commands. Once the Apply* command is accepted, the device uses the fUSER_FREQ register values and invokes internal central frequency and/or driver mode.

Changing frequency can be completed by either disabling the output driver or keeping the output drive enabled. This is determined by applying different Apply* commands. The bUSYS_CTRL values and descriptions are shown in Table 4.2.

Table 4.2. System Control Register bUSYS_CTRL

Value	Mnemonic	Description	stat_busy
0	UsysNop	No operation	—
1	UsysReady	Ready standby power down state	—
2	UsysActive	Active state	—
3	reserved	No operation	—
4	UsysRstSys	Invoke system reset restart	—
5	UsysRstPor	Invoke power-on reset restart	—
6	reserved	Do not use	—
7	reserved	Do not use	—
8	UsysApply	Apply: Disable output if active, update only changed frequency/driver mode	Check/Set
9	UsysApplyForce	Apply force: Disable output if active, force frequency/driver mode update	Check/Set
10	UsysApplyAct	Apply active: Keep output running if active, update only changed frequency/driver mode	Check/Set
11	UsysApplyActForce	Apply active force: Keep output running if active, force frequency/driver mode update	Check/Set
12	UsysRefresh	Refresh: Refresh fUSER_FREQ and bDRV_MODE register values to reflect the actual current device frequency and driver mode settings	Check/Set
Others	UsysNop	Do not use	—

Writing to “bUSYS_CTRL” register generates an acceptance request. When this command is accepted, the “bUSYS_CTRL” register is cleared. If a read from “bUSYS_CTRL” returns a non-zero value, it means that the writing command is still waiting to be accepted. A command acceptance happens in less than 5 us from the finishing of writing to the “bUSYS_CTRL” register. An accepted command can be either processed or ignored.

Commands other than “Apply*” and “Refresh” are always processed after the acceptance. It is possible to interrupt any “Apply*” or “Refresh” command under processing. A processing time depends on the command and its current state of the device, in most cases it is from 1 to 5 us, but can be up to 160 us when the command is generated in the middle of the frequency change.

“Apply*” and “Refresh” commands are only processed when “bUSYS_STATS.stat_busy” = 0. When “bUSYS_STATS.stat_busy” = 1, although new “Apply*” and “Refresh” commands are accepted, they are ignored. The “bUSYS_STATS.stat_busy” = 1 status bit is the beginning of internal processing. The “bUSYS_STATS.stat_busy” = 0 occurs after this internal processing finishes. Changing frequency and output driver must be completed before invoking a new command.

Issuing a “Refresh” command reset the values of registers to match the actual state of the device. During a normal operation, the device keeps the values of fUSER_FREQ synchronized with the internal state of the device. Reading these registers represent the actual frequency and output driver mode. However, the values could be different if writing occurs before applying the “Apply*” or “Refresh” command. If the “Apply*” command is not applied, then the registers value are the previous written values. Thus, issuing the “Refresh” command is necessary.

“fUSER_FREQ” and “bUSYS_STAT” registers are located back to back in I^2C address space. As a result, the most used operation is done in I^2C transaction as shown below. This example shows changing the frequency to a 70 MHz, which corresponds a 32-bit floating point number, 0x4c8583b0 in [Hz]. It is followed by a **“Apply”** command to invoke the internal frequency update, and assumed that the I^2C register address auto increment is enabled, which is a default.

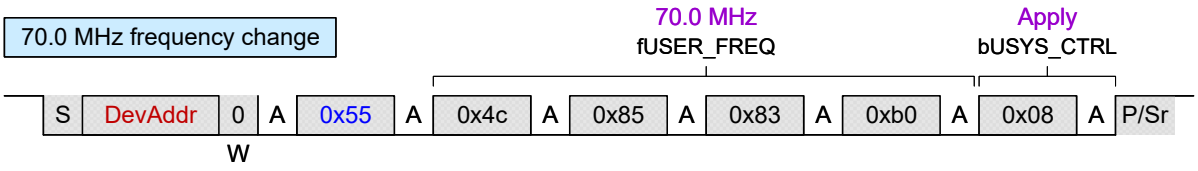


Figure 4.2. Frequency Change I2C Transaction

4.5. System Status

“bUSYS_STAT” is a read only system status register. It is readable any time and it reflects the current device status. All possible values of the register are listed in Table 4.3.

Table 4.3. System Status bUSYS_STAT Register Values

bUSYS_STAT								Description
stat_busy			stat_trans	stat_rst	stat_tune	stat_active	stat_ready	
[7]	[6]	[5]	[4]	[3]	[2]	[1]	[0]	
0	0	0	0	0	0	0	0	Start up
v	0	0	0	0	0	0	1	Ready state
v	0	0	0	0	0	1	0	Active state
v	0	0	0	0	1	1	0	Active state, tuning to new frequency
v	0	0	1	0	0	0	1	Ready to Active transition
v	0	0	1	0	0	1	0	Active to Ready transition
0	0	0	1	1	0	0	0	Reset processing, shutting down
0	0	0	0	1	0	0	0	Reset accepted

stat_busy bit [7] value v denotes value 0 or 1. The bit is 1 at the beginning of Apply* and Refresh commands internal processing and is 0 when the processing is done.

4.6. Output Driver Control

The output driver is powered up only in an Active state. CLKP and CLKM output signals are enabled or disabled by OE control register bits, “bUDRV_CTRL.udrv_oe_stop” and “bODIV_CTRL.odiv_oe_ena”. The simplified control flow of output driver is shown in Figure 4.3.

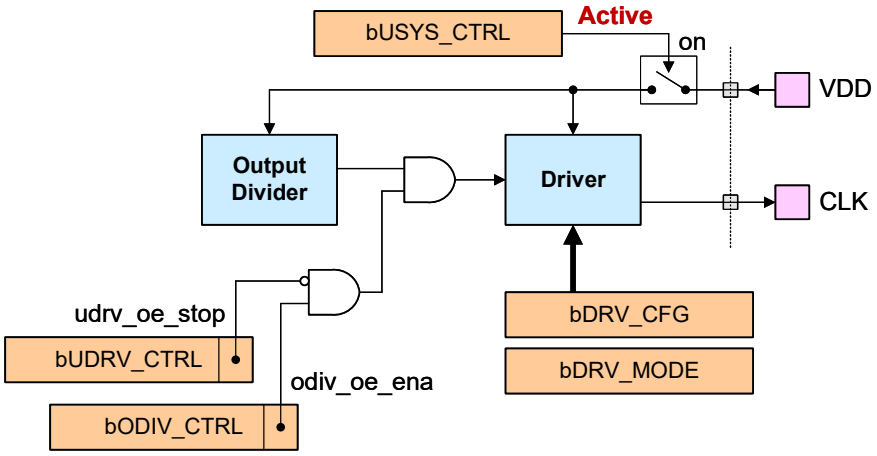


Figure 4.3. Driver Control Flow

Putting system to Ready state or disabling the driver with “bDRV_MODE” = 0 to issue one of the “Apply*” commands power down the output driver.

4.7. Center Frequency Control

Changing “fUSER_FREQ” register value controls the center frequency. The step does not apply to the DCXO feature. Frequency change request shown in Figure 4.4. and Figure 4.5.

Figure 4.4. shows a timing of frequency change by using “Apply” command when a “fUSER_FREQ” register value is different from the current frequency; or using “ApplyForce” command with the output disabled during the frequency change.

Figure 4.5. marks the time when a “Apply*” command is written to a “bUSYS_CTRL” register which corresponds with the write of the last data bit to this “bUSYS_CTRL” register.

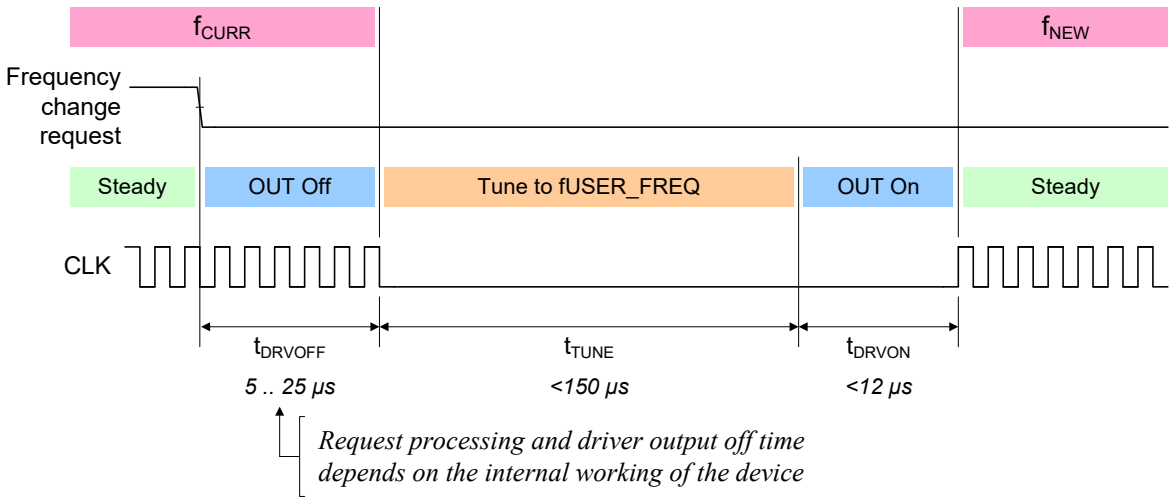


Figure 4.4. Frequency Change by “Apply” Command

Figure 4.5. shows either using an “ApplyAct” command when a “fUSER_FREQ” register has different value from the current frequency; or using an “ApplyActForce” command when the output keeps active during the frequency change. No signal glitches at the output occurs during the frequency change. However, there could be some periods in the output

frequency corresponding when the current frequency and new frequency interval are not aligned. This behavior is device dependent and it also depends on the actual values and relationships in between the current and new frequencies.

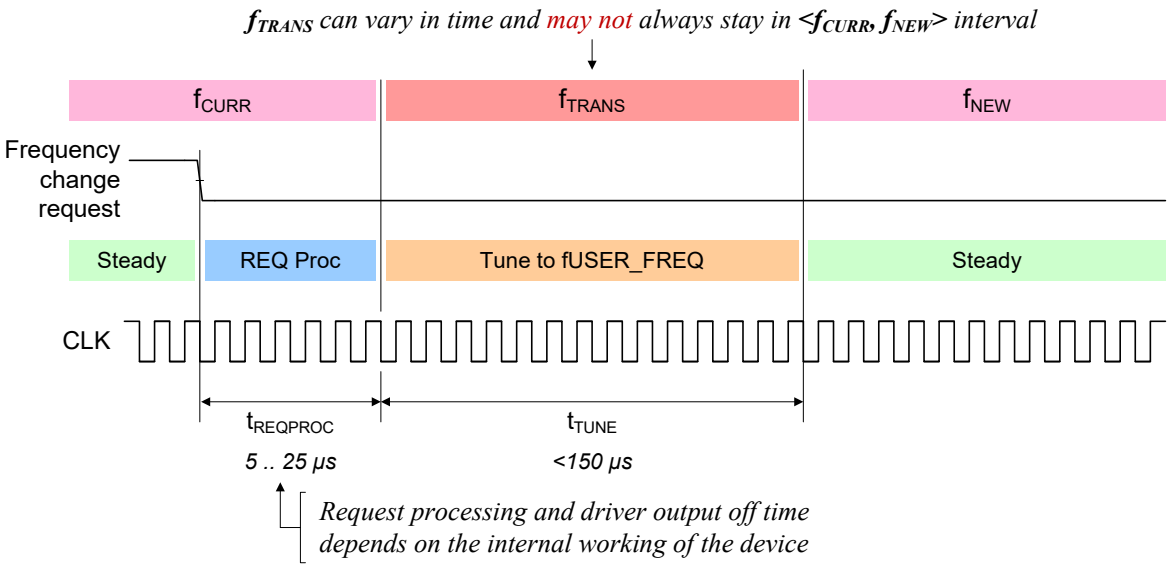


Figure 4.5. Frequency Change by "ApplyAct" Command

4.8. DCXO Control

The device incorporates a Digital Controlled Oscillator (DCXO) feature to allow seamless and fast setting of the frequency deviation from the center frequency. It implements a 32-bit signed "jDCXO_DATA" register in 11.21s signed bit format, which represents frequency offset from the current center frequency in "fUSER_FREQ" register in [0.9536743164 ppm] units. The [ppm] is a frequency step equal to 10^{-6} * fUSER_FREQ in [Hz]. The scaling factor is 0.9536743164 = $10^6/2^{20}$. It is possible to move the output frequency from the center frequency within the range ±975 ppm.

The DCXO feature must be configured before writing to "bDCXO_CTRL" and "bDCXO_SHIFT" registers with an additional optional configuration, which is provided by "bVC_LPF_BW_DIR" and "bVC_LPF_ABS_SAT" registers. When a new frequency offset register "jDCXO_DATA" is written, the output signal changes to a new frequency seamlessly and glitchlessly. The settlement time of a new output frequency from the end of last data bit of the byte written to a "bDCXO_DATAL" register is less than 8 us.

The DCXO data path configuration is schematically shown in Figure 4.6. Numerical values are shown in "**NN.MMs**" notation where "NN" is the number of MSB bits representing integer part of the number, while MM represents number of LSB bits representing fractional part of the number. The letter 's' means signed, and the letter 'u' is unsigned value. Signed values are represented in binary 2's complement. The values are labeled in [ppm] in Figure 4.6. for simplicity. The numerical binary values must be multiplied by the factor of 0.9536743164 to represent the real [ppm] frequency offset value from the current center frequency.

Writing to a 32-bit "jDCXO_DATA" register normally requires an I2C transaction of 6 bytes. Every update of the DCXO value would take 6 byte writing on an I2C bus, which takes around 56 us if using an I^2C Fast+ with 1 MHz speed, or around 140 us if using an I^2C Fast 400 kHz speed. In some applications, faster update speed may be required while the full 32-bit frequency offset resolution is not needed. To accommodate faster DCXO offset updates using I^2C, the DCXO has the following configurable features:

1. Data size: bDCXO_CTRL.dcxo_size = {0,1,2,3,4}
   Select to write only 1, 2, 3, or all 4 bytes signed numbers, 0 means 4.
2. Left shift: bDCXO_SHIFT = [0, 24] range
   Configurable shift of the entered input value to the left with up to 24 bits to scale small numbers to proper position within 32 bit number.
3. Data input:
   Direct register mode: bDCXO_CTRL.dcxo_stream_mode = 0
   Write an input value to the jDCXO_DATA bytes directly
   Streaming mode: bDCXO_CTRL.dcxo_stream_mode = 1
   Use only LSB byte of "jDCXO_DATA" as a streaming window. It requires to disable I2C register address autoincrement

by writing “bI2C_INC_DIS” = 1 to allow DCXO offset updates in a very long I2C transaction, which is feeding only data bytes to the same register address

4. Data application:
   Absolute mode: bDCXO_CTRL.dcxo_rel_mode = 0
   Apply the input offset value directly as a frequency offset.
   Relative mode: bDCXO_CTRL.dcxo_rel_mode = 1
   Apply the input offset value as a relative change from the current DCXO frequency offset in the internal 32-bit register, different from the” jDCXO_DATA” input register. This allows applying only incremental steps to move the internal frequency offset.

A DCXO register description in Figure 4.6. and Table 4.11. provide more detailed descriptions.

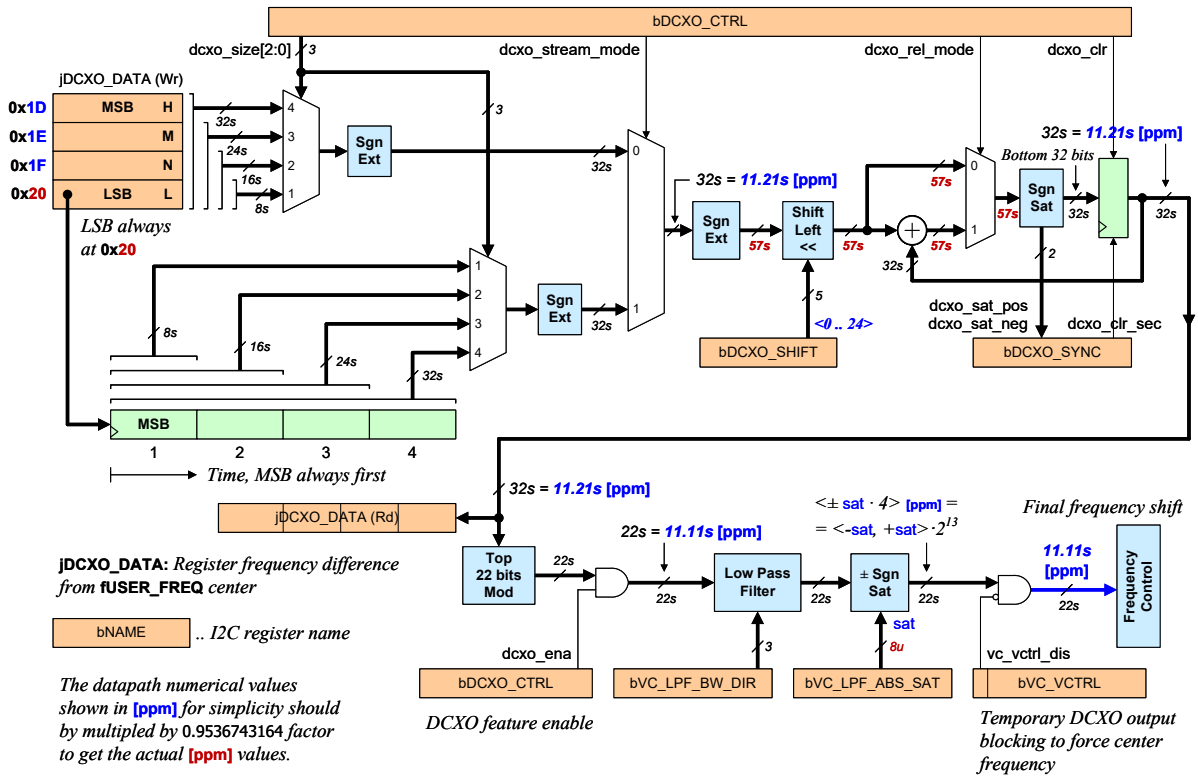


Figure 4.6. DCXO control and data processing

4.9. I²C Register Reference

The I²C interface is a byte-oriented interface. Registers are wider than 8 bits requiring to be split into multiple bytes located on subsequent register addresses. There are two types of multi byte registers:

1. Array of arrays, prefix ab, for example abUSER_ID[4] are organized in little endian fashion, byte abUSER_ID[0] is located at the lowest address, and the last byte of the array abUSER_ID[3] is located at the highest address.
2. An assigned 32-bit long integer, prefix j, and a 32-bit IEEE 754-2008 floating point number, prefix f are organized in big endian fashion, such that the most significant byte (MSB) is located at the lowest address.

Any unassigned byte registers have prefix b. Registers in the I²C address space 0x00...0xFF without specifications in the register description table are reserved for factory use. All register bit fields labeled [reserved] are read only and are reserved for factory use. Read value should be ignored. Any register bits not specifically mentioned in “Bits” columns are unused. Writing to these registers is ignored and a read always returns a 0. Numerical values are either hexadecimal with 0x prefix or decimal without any prefix.

Descriptions of register table columns:

Table 4.4. Register Table Columns

Register	Description
Addr	I²C register address.
Register	Register name.
Bytes	Number of bytes in the register. Wider than single byte registers span several subsequent bytes in an address space.
Endian	Endian for registers wider than one byte. Not applicable for single byte registers.
B	Big endian. The most significant byte (MSB) of the register appears at the lowest address.
L	Little endian. The least significant byte (LSB) of the register appears at the lowest address.
Field	Field name within the register.
[reserved]	Reserved for factory use and readable only
Bits	Field bit locations within a register. When the field spans more than one bit, the [M:L] notate. Denoting locations of a most significant bit M and a least significant bit L within the register are used.
Type	Field access type.
R/W	Read/write field by I²C.
R	Read only field by I²C.
W1	Writing a 1 triggers an associated event, while writing a 0 has no effect. A read always returns 0.
Rst	Field reset value. The value ‘Factory’ indicates that the value depends on the individual device factory configuration.

4.10. Register Map

Table 4.5. I²C Address Autoincrement Control

Register	Addr	Field	Bits	Type	Rst	Description
bI2C_INC_DIS	0x06	i2c_inc_dis	[0]	R/W	0	Disable automatic I²C register address increment. If this bit is set the automatic I²C register address increment after each write or a read data is disabled. This is useful in situations when the user wants to repeatedly read a same address location. For example, monitoring some status bit or using the DCXO feature in a single I²C transaction.

Table 4.6. User Identification

Register	Addr	Field	Bits	Type	Rst	Description
abCFG_ID[6]	0x2d	cfg_id	[47:0]	R/W	Fact	Configuration identification

Table 4.7. Output Driver Configuration

Register	Addr	Field	Bits	Type	Rst	Description
bDRV_CFG	0x3b	drv_stop_hiz	[0]	R/W	0	Setting to 1, the driver is tri-stated when stopped.
		drv_cmos_high_str	[1]	R/W	0	Enable CMOS driver to be 35 Ω output impedance rather than default 50 Ω. 0 .. 50 Ω 1 .. 35 Ω
		drv_cmos_slew	[3:2]	R/W	0	CMOS driver output slew rate control. (C_L = 15 pF) 0 .. none 1 .. 9 ns 2 .. 6.4 ns 3 .. 4 ns
		drv_cmos_clkp_inv	[4]	R/W	0	Invert clock polarity for CMOS CLK+ driver. It also determines polarity of the output when CMOS driver output is disabled.
		drv_cmos_clkm_inv	[5]	R/W	0	Invert clock polarity for CMOS CLK- driver. It also determines polarity of the output when CMOS driver output is disabled.

Table 4.8. Output Driver Enable

Register	Addr	Field	Bits	Type	Rst	Description
bODIV_CTRL	0x3c	odiv_oe_ena	[0]	R/W	Fact	Output divider and driver enable: 0 .. Output is disabled 1 .. Output is enabled

Table 4.9. User System Control

Register	Addr	Field	Bits	Type	Rst	Description
bDRV_MODE	0x54	drv_mode	[7:0]	R/W	Fact	Desired driver configuration. See Table 4.10. for encoding. I^2C write to bDRV_MODE has no immediate effect. The user is required to write a command to bUSYS_CTRL register to invoke the driver mode change process.
fUSER_FREQ	0x55	user_freq	[31:0]	R/W	Fact	Floating point binary32 IEEE 754-2008 number in big endian representation with the most significant byte at the lowest address. It represents user desired output center frequency in [Hz]. I^2C write to fUSER_FREQ has no immediate effect. The user is required to write a command to bUSYS_CTRL register to invoke the frequency change process.
bUSYS_CTRL	0x59	usys_ctrl	[7:0]	R/W	0	User system control. Command byte to be written whenever the frequency change, driver mode change, or special system action is required. See Table 4.2. for command values.
bUSYS_STAT	0x5a	stat_ready	[0]	R	0	Ready state reached
		stat_active	[1]	R	0	Active state reached
		stat_tune	[2]	R	0	In Active tuning to a new frequency. If 1, then stat_active = 1.
		stat_rst	[3]	R	0	Reset request accepted
		stat_tran	[4]	R	0	In system state transition. Based on the initial state the device is transitioning from, bUSYS_STAT.stat_ready, bUSYS_STAT.stat_active, or bUSYS_STAT.stat_rst is set to 1.
		stat_busy	[7]	R	0	Busy processing tuning to a new frequency and/or driver mode change. This bit is checked, set, and cleared only by Apply* and Refresh commands.

Table 4.10. Driver Mode bDRV_MODE Value Encoding

Value	Description
0	Driver disabled
1	CMOS single CLK+
2	CMOS single CLK-
3	CMOS dual
4	LVDS 2.5 & 3.3 V
5	LVDS 1.8 V
6	Reserved
7	Reserved
8	HCSL 50 Ω external
9	Reserved
10	HCSL 42.5 Ω external
11	Reserved
12	Standard LVPECL
13	LVPECL AC-coupled low power
14	Reserved
15	CML 50 Ω internal
16	Reserved
17	Reserved
18 .. 31	Reserved, behaves as 0, driver will be disabled
Others	Unused, driver setting will stay unchanged

Table 4.11. DCXO Configuration Registers

Register	Addr	Field	Bits	Type	Rst	Description
bDCXO_SYNC	0x1a	dcxo_stream_sync	[0]	W1	0	Writing a 1 to this bit clears the streaming mode synchronization logic. The next write to the bDCXO_DATAL register byte is treated as the MSB byte of the burst. This bit allows to forcibly synchronize the streaming operation when in doubt. Note that any write to bDCXO_CTRL register also clears the streaming mode synchronization logic.
		dcxo_clr_sec	[1]	W1	0	Secondary duplicated clear pulse bit for user convenience, same function as bDCXO_CTRL.dcxo_clr bit. See the bDCXO_CTRL description. The clear affects only the DCXO data processing and not the DCXO I2C control registers. All the current DCXO settings as set in bDCXO_CTRL and bDCXO_SHIFT registers stay intact.
		dcxo_sat_neg	[6]	R	0	If 1, then DCXO frequency deviation internal value has saturated to minimum negative value. Register bit updated every time when the 32-bit DCXO internal value is updated. The bit is not sticky. Cleared by bDCXO_SYNC.dcxo_clr_sec = 1 or bDCXO_CTRL.dcxo_clr = 1.
		dcxo_sat_pos	[7]	R	0	If 1, then DCXO frequency deviation internal value has saturated to maximum positive value. Register bit updated every time the 32-bit DCXO internal value is updated. The bit is not sticky. Cleared by bDCXO_SYNC.dcxo_clr_sec = 1 or bDCXO_CTRL.dcxo_clr =1.
bDCXO_SHIFT	0x1b	dcxo_shift	[4:0]	R/W	0	Number of bits to shift the input jDCXO_DATA value to the left before internal processing. The left bit shift is always applied at the input DCXO value in all modes and configurations. The shift value is in the range of [0, 24] bits. If the shift number is greater than 24, then it is internally forced to 24.
bDCXO_CTRL	0x1c	dcxo_size	[2:0]	R/W	0	Number of streamed bytes per input value or number of bottom jDCXO_DATA bytes to be used as input value in direct register access mode. The valid values are 0, 1, 2, 3, and 4 bytes. Default value 0 is an alias of value 4. The value greater than 4 is internally forced to 4. All values are internally sign-extended to 57 bits before the value is used. The bDCXO_SHIFT left shift is applied on the internally sign-extended 57-bit number. For streamed mode the number denotes the size of ordered byte burst in the I^2C transaction: 4 .. {H,M,N,L} .. 32 bits, the last L byte is always LSB 3 .. {M,N,L} .. 24 bits 2 .. {N,L} .. 16 bits 1 .. {L} .. 8 bits For direct register mode, this number denotes the number of LSB bytes from the jDCXO_DATA. It is used to form a number to be internally sign-extended to 57 bits. The number of bytes and their order is the same as in the streaming table above. The H denotes the MSB byte at byte address jDCXO_DATA while the L denotes the LSB byte at the byte address jDCXO_DATA + 3. When used as 4 bytes, the jDCXO_DATA is a 32-bit signed integer stored in a big endian fashion. MSB is at lower address. The bDCXO_DATAL byte at byte address jDCXO_DATA + 3 is always the LSB byte for all widths and could be viewed as the value alignment anchor.

Continued on next page

Register	Addr	Field	Bits	Type	Rst	Description
bDCXO_CTRL	0x1c	dcxo_stream_mode	[4]	R/W	0	DCXO frequency offset value input mode. 0 .. regular direct register mode. For situations when I^2C address autoincrement is active (default mode), the jDCXO_DATA four byte array can be written any time. Whenever the bDCXO_DATAL location at the jDCXO_DATA + 3 byte address is written, the number of bytes is selected by bDCXO_CTRL.dxco_size number is taken from the bottom of the jDCXO_DATA value, aligned towards bDCXO_DATAL location as LSB byte. Those selected bytes are sign-extended to 57 bits and left shifted by the bDCXO_SHIFT value. The resulting number is then either used to add to the existing internal DCXO value in 57 bit addition, thus the sum is then sign saturated to bottom 32 bits to be used as a new DCXO value, or the value is sign saturated to 32 bits to be used directly as the new DCXO value. 1 .. streaming mode. For situations when I^2C register address autoincrement is disabled, user must write a register bI2C_INC_DIS = 1 to actively disable the I^2C register address autoincrement. The setting is global and applies to all I^2C register accesses, not only to the DCXO data registers. The user must choose to stream 4 {H,M,N,L}, 3 {M,N,L}, 2 {N,L}, or 1 {L} byte by setting the bDCXO_SIZE register before starting streaming operation. The stream byte order is from left to right and the LSB is always come last in the value burst. All data is written to bDCXO_DATAL register only. Writing to other jDCXO_DATA register bytes are ignored. The streamed byte value is then treated the same way as in the regular direct register mode described above. The streaming mode is useful for very fast DCXO value updates, possibly in a single and very long I^2C transaction.
		dcxo_rel_mode	[5]	R/W	0	DCXO frequency offset value usage mode. 0 .. absolute mode. The user signed DCXO input value obtained using the current access mode is sign-extended to 57 bits and then left shifted by bDCXO_SHIFT bits. The shifted signed value is sign-saturated to bottom 32 bits and used as the internal DCXO frequency offset value. 1 .. relative mode. The user signed DCXO input value obtained using the current access mode is sign-extended to 57 bits and then left shifted by bDCXO_SHIFT bits. The shifted signed value is added to the current internal 32-bit DCXO value resulting in 57-bit internal signed addition number. The signed 57-bit sum is sign saturated to bottom 32 bits and then used as the internal DCXO frequency offset value. If the bottom 32-bit saturation happened, the read only saturation flags bDCXO_SYNC.dcxo_sat_pos and bDCXO_SYNC.dcxo_sat_neg reflect the saturation operation of the last update of the internal DCXO frequency offset value.

Continued on next page

Register	Addr	Field	Bits	Type	Rst	Description
bDCXO_CTRL	0x1c	dcxo_ena	[6]	R/W	0	Enable the DCXO operation. If this bit is 1, then the DCXO operation is enabled. If this bit is 0, then the DXCO operation is disabled. All control bits in bDCXO_CTRL register are ignored with an exception of bDCXO_CTRL.dcxo_clr, which can be written as 1 to clear DCXO processing module.
		dcxo_clr	[7]	W1	0	Writing 1 to this bit clears all the DCXO internal frequency offset value registers, all DCXO value holding registers, and streaming mode synchronization logic. All mentioned registers are cleared even if bDCXO_CTRL.dcxo_ena = 0. The clear does not affect bDCXO_SHIFT register. Note that the streaming mode synchronization logic is cleared every time the bDCXO_CTRL register is written, even if the bDCXO_CTRL.dcxo_ena = 0 or bDCXO_CTRL.dcxo_clr = 0. It is highly recommended that this bit is written as 1 when the DCXO is being enabled by setting bDCXO_CTRL.dcxo_ena = 1 to clear the internal processing registers.
jDCXO_DATA	0x1d	dcxo_data	[31:0]	R/W	0	DCXO data register through which the actual signed 32 bit DCXO control data is applied. Increasing value increases the output frequency. The 32-bit input value represents 11.21s signed 2's complement number in [0.9536743164 ppm] units as deviation from current central frequency. The 4 register bytes can be viewed separately as bDCXO_DATAH, bDCXO_DATAM, bDCXO_DATAN, and bDCXO_DATAL data bytes and writing to them depends on the write mode selected. bDCXO_DATAH .. jDCXO_DATA address + 0 bDCXO_DATAM .. jDCXO_DATA address + 1 bDCXO_DATAN .. jDCXO_DATA address + 2 bDCXO_DATAL .. jDCXO_DATA address + 3 .. always LSB The bDCXO_DATAL LSB byte refers to the jDCXO_DATA[7:0] bits, which is the byte at the highest address (jDCXO_DATA address + 3) since the register value is represented in big endian. MSB is at lower address. There are holding registers for 3 MSB upper value bytes and the written value will get applied internally only if the bDCXO_DATAL byte is written. In a regular direct register access mode, bDCXO_CTRL.dcxo_stream_mode = 0, any byte in the 4- byte jDCXO_DATA register can be written at any time. The most convenient way is to write it as a burst of bytes with incrementing byte address after each byte write. The written value is applied internally only after the last bDCXO_DATAL byte is written. The user DCXO input value is formed as a signed selection of bottom N bytes (N = DCXO_CTRL.dcxo_size), where bDCXO_DATAL is always the LSB byte of the signed number.

Continued on next page

Register	Addr	Field	Bits	Type	Rst	Description
						In a streaming access mode, bDCXO_CTRL.dcxo_stream_mode = 1, the bDCXO_DATAL byte is used to stream the data. Writing to the rest of the bytes in the jDCXO_DATA register is ignored in streaming mode. The user could decide to stream 4 {H,M,N,L}, 3 {M,N,L}, 2 {N,L}, or 1 {L} byte, all in big endian fashion. After the last byte of the value burst is written, the signed numerical value represented by 4, 3, 2, or 1 byte based on the streaming number configuration form the input user DCXO value. Reading from jDCXO_DATA register always returns current signed internal 32-bit DCXO value, which is applied to the input of the DCXO frequency control low pass filter in [0.9536743164 ppm] units as deviation from current central frequency. The read value does not depend on any write mode configuration and is always the current internal DCXO frequency offset value. This also applies in the streaming mode. The streaming mode applies only for value writes. To read the current 32-bit internal value even in streaming mode the user needs to read all 4 bytes of this register to get the 32- bit current internal value. See Figure 4.6.

Table 4.12. DCXO Low Pass Filter Configuration

Register	Addr	Field	Bits	Type	Rst	Description
bLPF_BW_DIR	0x41	vc_lpf_bw_dir	[2:0]	R/W	7	Frequency offset low pass filter bandwidth control. The LPF bandwidth formula: BW = 1166 * 2vc_lpf_bw_dir [Hz] which corresponds to the following values: 0.. 1.2 kHz 1.. 2.3 kHz 2.. 4.7 kHz 3.. 9.3 kHz 4.. 18.7 kHz 5.. 37.3 kHz 6.. 74.6 kHz 7.. pass through .. default value
bLPF_ABS_SAT	0x42	vc_lpf_abs_sat	[7:0]	R/W	255	An unsigned absolute saturation value of a frequency offset to user limits the maximum frequency offset swing. The unsigned 8-bit value is shifted left by 13 bits form 10.11 us unsigned absolute saturation value of the 11.11 s output. The 22-bit signed output will be saturated to fall in the value range [-vc_lpf_abs_sat, + vc_lpf_abs_sat] * 213. See Figure 4.6. The value 0 squelches the frequency offset and forces central frequency while value 255 allows full frequency offset range to be utilized.
bVCTRL	0x43	vc_vctrl_dis	[0]	R/W	0	Disable the DCXO frequency control output and force the value to 0. This feature is to provide temporary disable for DCXO datapath to see how the device is doing while keeping the DCXO setting unchanged and the datapath active. See Figure 4.6.

5. Package Outline Drawing

Figure 5.1. shows the package outline drawing for the AS5003 devices. Details of dimension for different size options are listed in Table 5.1.

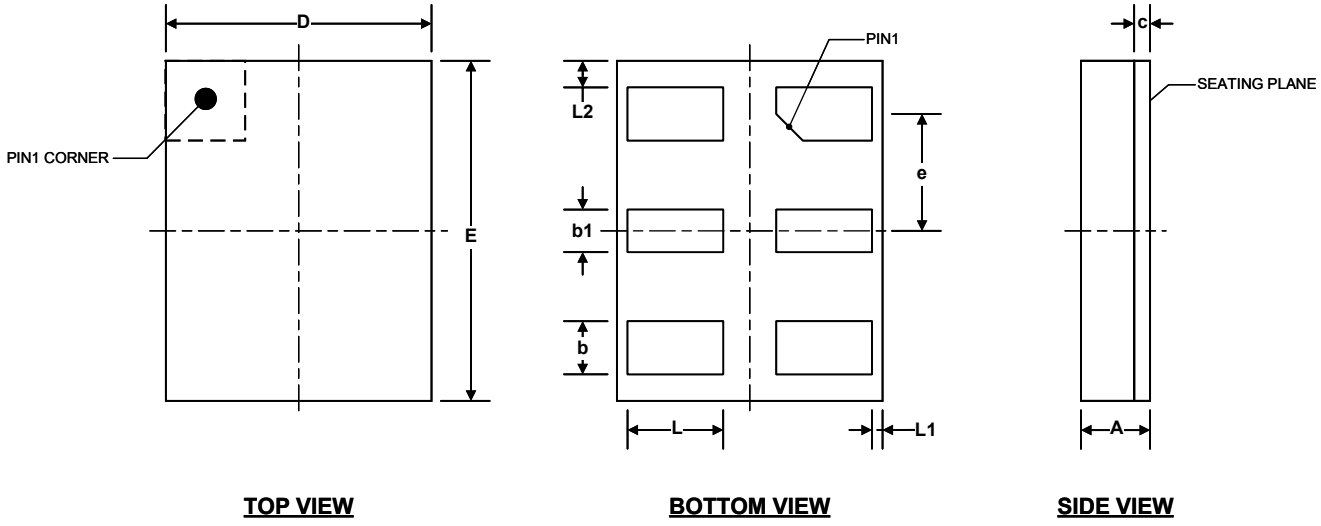


Figure 5.1. Package Outline Drawing

Table 5.1. Dimensions of Package Outline Drawing (mm)

Symbol	5032 Package	3225 Package
A	0.85 ± 0.05	0.85 ± 0.05
b	0.64 ± 0.05	0.65 ± 0.05
b1	0.64 ± 0.05	0.50 ± 0.05
D	3.20 ± 0.10	2.50 ± 0.10
e	1.27 BSC	1.175 BSC
E	4.00 ± 0.10	3.20 ± 0.10
L	0.75 ± 0.05	0.70 ± 0.05
L1	0.10 ± 0.05	0.10 ± 0.05

6. Recommended PCB Land Pattern

Figure 6.1. shows the drawing of recommended PCB land pattern for the AS5003 devices. Details of dimension for different size options are listed in Table 6.1.

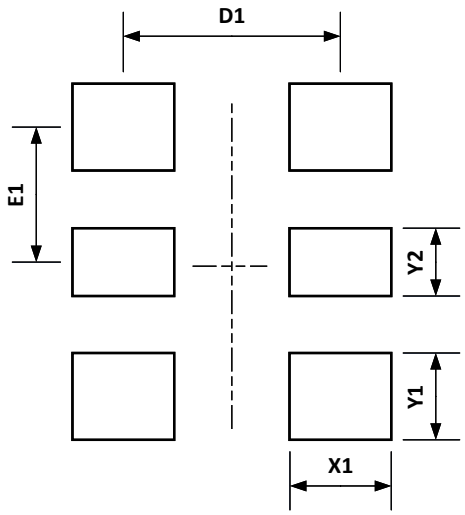


Figure 6.1. Recommended PCB Land Pattern

Table 6.1. Dimensions of Recommended PCB Land Pattern (mm)

Symbol	5032 Package	3225 Package
D1	2.35	1.70
E1	1.27	1.175
X1	1.05	1.00
Y1	0.84	0.85
Y2	0.84	0.7

Notes:

The following notes and stencil design are shared as recommendations only. A customer or user may find it necessary to use different parameters and fine-tune their SMT process as required for their application and tooling.

General

1. All dimensions shown are in millimeters (mm) unless otherwise noted.
2. Dimensioning and Tolerancing is per the ANSI Y14.5M-1994 specification.
3. This Land Pattern Design is based on the IPC-7351 guidelines.
4. All dimensions shown are at Maximum Material Condition (MMC). Least Material Condition (LMC) is calculated based on a Fabrication Allowance of 0.05 mm.

Solder Mask Design

1. All metal pads are to be non-solder mask defined (NSMD). Clearance between the solder mask and the metal pad is to be 60 µm minimum, all the way around the pad.

Stencil Design

1. A stainless steel, laser-cut and electro-polished stencil with trapezoidal walls should be used to assure good solder paste release.
2. The stencil thickness should be 0.125 mm (5 mils).
3. The ratio of stencil aperture to land pad size should be 0.8 1 for the pads.

Card Assembly

1. A No-Clean, Type-3 solder paste is recommended.
2. The recommended card reflow profile is per the JEDEC/IPC J-STD-020 specification for Small Body Components.

7. Top Mark

Figure 7.1. shows the top mark specifications for the AS5003 devices. Description of each line is listed in Table 7.1.

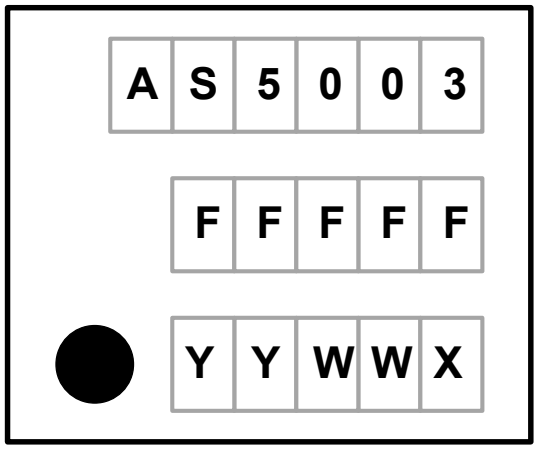


Figure 7.1. Top Mark

Table 7.1. Top Mark Description

Line	Position	Description
1	1-6	Device Name
2	1-5	Unique 5-digit Device Configuration Number
3	1	Pin 1 orientation mark (dot)
	2-3	Year (last two digits of the year), to be assigned by assembly site (ex: 2025 = 25)
	4-5	Calendar Work Week number (1-53), to be assigned by assembly site
	6	Manufacturer code

8. Packing Specification

Figure 8.1. shows the packing specifications for the AS5003 devices. Details of the tape specifications are listed in Table 8.1.

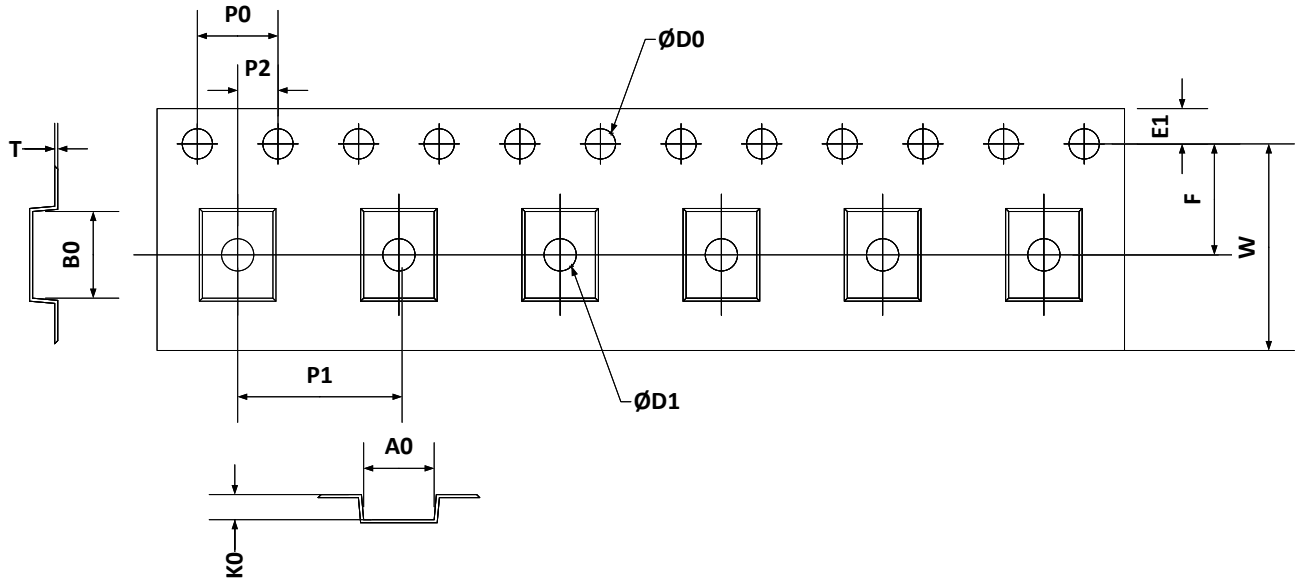


Figure 8.1. Tape Specification

Table 8.1. Dimensions of Tape (mm)

Symbol	5032 Package	3225 Package
A0	3.50 ± 0.10	2.80 ± 0.10
B0	4.30 ± 0.10	3.50 ± 0.10
K0	1.25 ± 0.10	1.05 ± 0.10
E1	1.75 ± 0.10	1.75 ± 0.10
F	5.50 ± 0.05	5.50 ± 0.05
W	12.00 ± 0.30	12.00 ± 0.30
T	0.30 ± 0.05	0.30 ± 0.05
P0	4.00 ± 0.10	4.00 ± 0.10
P1	8.00 ± 0.10	8.00 ± 0.10
P2	2.00 ± 0.05	2.00 ± 0.05
ØD0	1.50 ± 0.10	1.50 ± 0.10
ØD1	1.60 ± 0.10	1.60 ± 0.10

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10. Revision History

Revision	Date	Description
1.14	Jul 2026	Correct the LVPECL resistor value and the recommended PCB land pattern value
1.13	Aug 2025	Corrected the tape specification
1.12	Aug 2024	Add packing specification
1.11	Mar 2024	Updated the frequency offset
1.10	Jul 2022	Updated the top mark specification
1.01	Dec 2021	Adjusted the PCB land pattern dimensions
1.00	Sep 2021	With certain specification update
0.95	Jun 2021	Corrected the Ordering Guide Insert -40 - 105 ℃ temperature range option Insert section ”IMPORTANT NOTICE AND DISCLAIMER”
0.20	Mar 2021	Changed the frequency range and ordering guide
0.10	Feb 2021	Initial release