

Features

- 1 Hz to 2.5 MHz ±5 ppm all-inclusive frequency stability
- Factory programmable output frequency
- World's smallest TC-MO Footprint: 1.2 mm²
 - 1.5 x 0.8 mm CSP
 - No external bypass cap required
- Improved stability reduces system power with fewer network timekeeping updates
- Ultra-low power: +6.0 µA (100 kHz)
- Supply voltage: +1.62 V to +3.63 V
- Operating temperature ranges: -20°C to +70°C, -40°C to +85°C
- Pb-free, RoHS and REACH compliant

Applications

- Health and wellness monitors
- Smart pens
- ULP input devices
- Proprietary wireless
- Sensor interface



Table 1. Electrical Characteristics

Conditions: Min/Max limits are over temperature, Vdd = +1.8V ±10%, unless otherwise stated. Typicals are at +25°C and Vdd = +1.8V.

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Frequency and Stability						
Output Frequency	F _{out}	1		2.5M	Hz	
Total Frequency Stability [1]	F _{stab}	-5		+5	ppm	All inclusive, Stability code: E
		-20		+20	ppm	All inclusive, Stability code: G
Allan Deviation	AD		1e-8	4e-8		1 second averaging time
First Year Frequency Aging	F _{aging}		±1		ppm	T _A = +25°C, Vdd = +1.8V
Jitter Performance						
Integrated Phase Jitter	IPJ		2	3.5	ns _{RMS}	F _{OUT} > 1 kHz. Integration bandwidth = 100 Hz to F _{OUT} /2. Inclusive of +50 mV peak-to-peak sinusoidal noise on Vdd. Noise frequency 100 Hz to 20 MHz.
Period Jitter	PJ		2.2	4.5	ns _{RMS}	Cycles = 10,000, f = 100kHz. Per JEDEC standard 65B, tested at 100kHz. See performance plot for other frequencies.
Peak-to-Peak Period Jitter	PJ _{p-p}		20	35	ns _{p-p}	
Supply Voltage and Current Consumption						
Operating Supply Voltage	Vdd	+1.62		+3.63	V	
Supply Current	I _{dd}		+3.65	+5	µA	F _{OUT} = 1 Hz, Vdd = +1.8V, no load
			+4.5	+5.5		F _{OUT} = 33 kHz, Vdd = +1.8V, no load
			+6.0	+10		F _{OUT} = 100 kHz, Vdd = +1.8V, no load
			+13	+20		F _{OUT} = 1 MHz, Vdd = +1.8V, no load
			+33	+40		F _{OUT} = 2 MHz, Vdd = +1.8V, no load
Start-up Time at Power-up	t _{start}		150	300	ms	F _{out} > 200 Hz. Measured when supply reaches 90% of final Vdd to the first output pulse and within specified min/max frequency limit.
			300+ 2.0 cycles	300+ 2.5 cycles		10 Hz < F _{out} ≤ 200 Hz. Measured when supply reaches 90% of final Vdd to the first output pulse and within specified min/max frequency limit.
				500+ 2.5 cycles		1 Hz ≤ F _{out} ≤ 10 Hz. Measured when supply reaches 90% of final Vdd to the first output pulse and within specified min/max frequency limit.
Operating Temperature Range						
Operating Temperature Range	Op_Temp	-20		+70	°C	"D" ordering code
		-40		+85	°C	"I" ordering code
LVC MOS Output						
Output Rise/Fall Time	tr, tf		9	20	ns	20-80%, 15 pF Load, Vdd = 1.8 +/- 10%
Output Clock Duty Cycle	DC	45		55	%	
Output Voltage High	VOH	90%			Vdd	I _{OH} = -50 µA, 15pF load
Output Voltage Low	VOL			10%	Vdd	I _{OL} = +50 µA 15pF load

Note:

1. Includes initial tolerance, over temp stability, 2x reflow, Vdd range, board-level underfill, and 20% load variation. Tested with Agilent 53132A frequency counter. Measured with ≥100 ms gate time for accurate frequency measurement.

MO1576

1.2mm² μ Power, Low-Jitter, 1Hz – 2.5MHz Super TC-MO



Table 2. Pin Configuration

CSP Pin	Symbol	I/O	Functionality
1	NC	Internal Test	No Connect. Leave floating. Pin 1 is for internal testing and is designed to be left floating.
2	CLK Out	OUT	Oscillator clock output.
3	Vdd	Power Supply	Operates from nominal supply voltages between +1.8V and +3.3V. Under normal operating conditions, Vdd does not require external bypass/decoupling capacitor(s). MO1576 includes on-chip Vdd filtering.
4	GND	Power Supply Ground	Connect to ground.

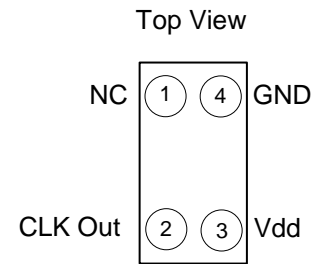


Figure 1. Pin Assignment

Table 3. Absolute Maximum Ratings

Attempted operation outside the absolute maximum ratings may cause permanent damage to the part. Actual performance of the IC is only guaranteed within the operational specifications, not at absolute maximum ratings.

Parameters	Test Conditions	Value	Unit
Continuous Power Supply Voltage Range (Vdd)		-0.5 to +4.0	V
Continuous Maximum Operating Temperature Range		+105	°C
Short Duration Maximum Operating Temperature Range	≤ 30 minutes	+125	°C
Human Body Model (HBM) ESD Protection	JESD22-A114	+2000	V
Charge-Device Model (CDM) ESD Protection	JESD22-C101	+750	V
Machine Model (MM) ESD Protection	JESD22-A115	+300	V
Latch-up Tolerance	JESD78 Compliant		
Mechanical Shock Resistance	Mil 883, Method 2002	20,000	g
Mechanical Vibration Resistance	Mil 883, Method 2007	70	g
1508 CSP Junction Temperature		+150	°C
Storage Temperature		-65 to +150	°C

System Block Diagram

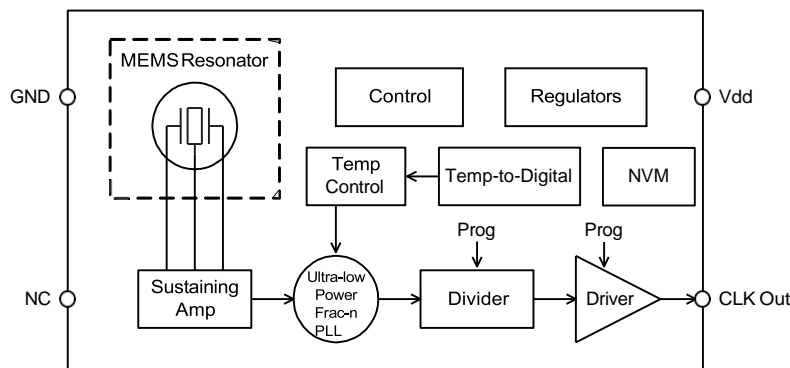


Figure 2. MO1576 Block Diagram

Description

MO1576 is an ultra-small and ultra-low power Factory programmable TC-MO with an output frequency range between 1 Hz to 2.5 MHz. KDS's silicon MEMS technology enables the first 1 Hz – 2.5 MHz TC-MO in the world's smallest footprint and chip-scale packaging (CSP). Typical supply current is only +6.0 μ A (100 kHz).

KDS's MEMS oscillators consist of MEMS resonators and a programmable analog circuit. MO1576 MEMS resonators is built with unique MEMS First™ process. A key manufacturing step is EpiSeal™ during which the MEMS resonator is annealed with temperatures over +1000°C. EpiSeal creates an extremely strong, clean, vacuum chamber that encapsulates the MEMS resonator and ensures the best performance and reliability. During EpiSeal, a poly silicon cap is grown on top of the resonator cavity, which eliminates the need for additional cap wafers or other exotic packaging. As a result, KDS's MEMS resonator die can be used like any other semiconductor die. One unique result of KDS's MEMS First and EpiSeal manufacturing processes is the capability to integrate KDS's MEMS die with a SOC, ASIC, microprocessor or analog die within a package to eliminate external timing components and provide a highly integrated, smaller, cheaper solution to the customer.

TC-MO Frequency Stability

MO1576 is factory calibrated (trimmed) over multiple temperature points to guarantee extremely tight stability over temperature. Unlike quartz crystals that have a classic tuning fork parabola temperature curve with a +25°C turnover point with a 0.04 to 0.06 ppm/°C² temperature coefficient, the MO1576 temperature coefficient is calibrated and corrected over temperature with an active temperature correction circuit. The result is a 32 kHz TC-MO with extremely tight frequency variation over the -40°C to +85°C temperature range.

When measuring the output frequency of MO1576 with a frequency counter, it is important to make sure the counter's gate time is >100 ms. Shorter gate times may lead to inaccurate measurements. Similarly, the gate time will need to increase for frequencies in the 1Hz to 500Hz frequency range.

Dynamic Temperature Frequency Response

Dynamic Temperature Frequency Response is the rate of frequency change during temperature ramps. This is an important performance metric when the oscillator is mounted near a high power component (e.g. SoC or power management) that may rapidly change the temperature of surrounding components.

For moderate temperature ramp rates (<+2°C/sec), the dynamic response is primarily determined by the steady-state frequency vs. temperature of the device. The best dynamic response is obtained from parts which have been trimmed to be flat in frequency over temperature.

For high temperature ramp rates (>+5°C/sec), the latency in the temperature compensation loop contributes a larger frequency error, which is dependent on the temperature compensation update rate. This part achieves excellent performance at 3Hz update rate. This device family supports faster update rates for further reducing dynamic frequency error at the expense of slightly increased current consumption.

Typical Operating Curves

($T_A = +25^\circ\text{C}$, $V_{DD} = +1.8\text{V}$, supply current plots are no load, unless otherwise stated)

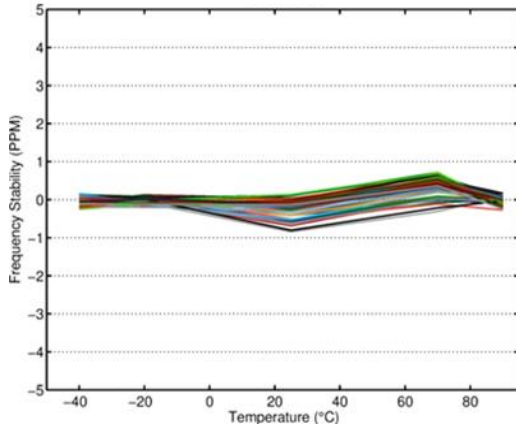


Figure 3. Frequency Stability over Temperature

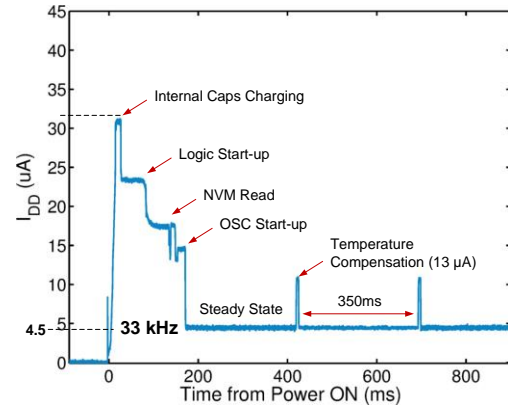


Figure 4. Start-up and Steady-State Current Profile

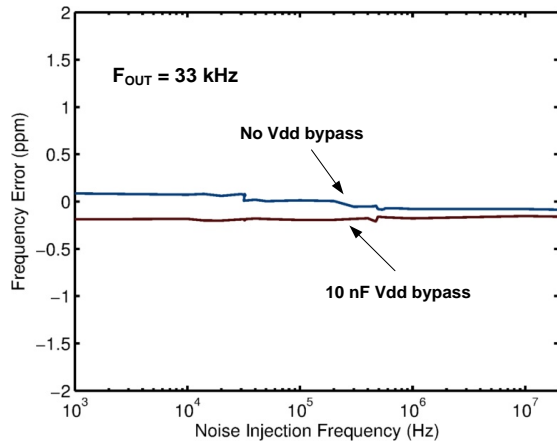


Figure 5. Power Supply Noise Rejection

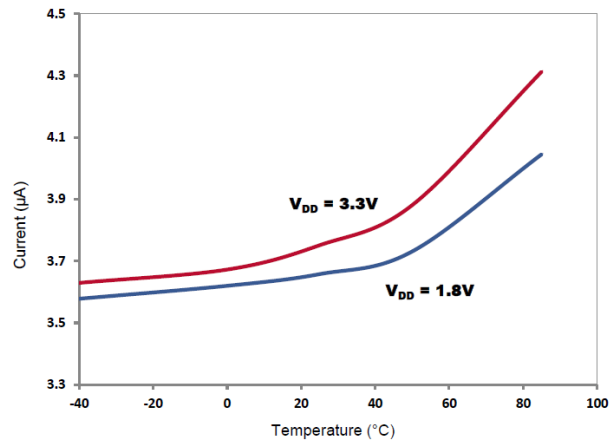


Figure 6. Supply Current vs Temperature (Fout = 1 Hz)

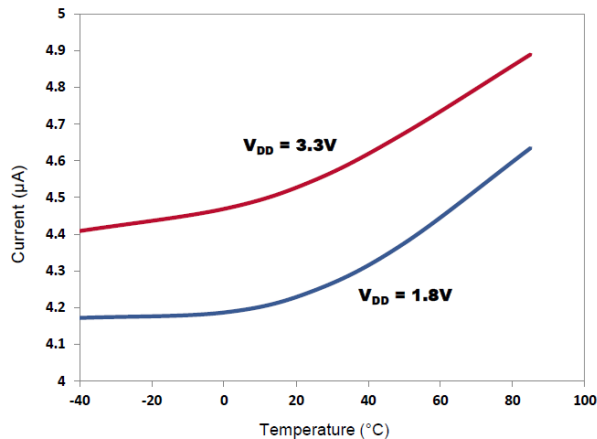


Figure 7. Supply Current vs Temperature (Fout = 100 Hz)

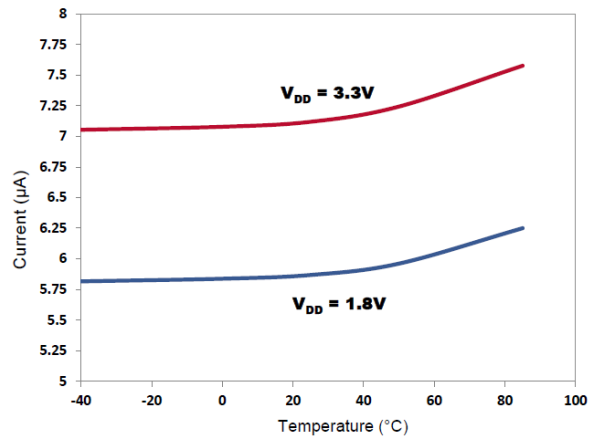


Figure 8. Supply Current vs Temperature (Fout = 100 kHz)

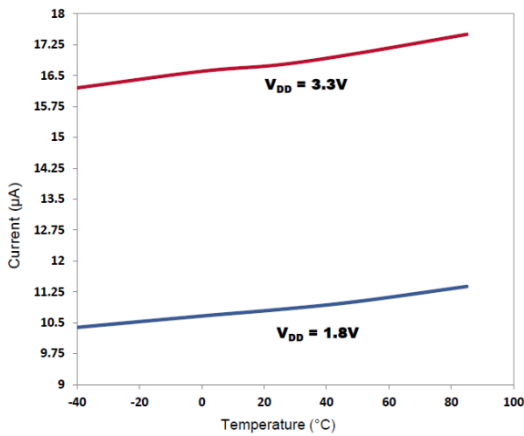


Figure 9. Supply Current vs Temperature (Fout = 500 kHz)

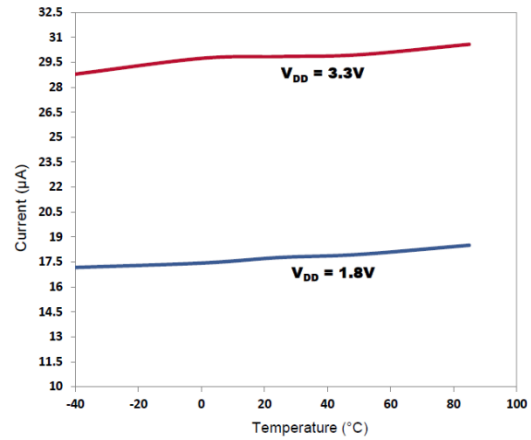


Figure 10. Supply Current vs Temperature (Fout = 1 MHz)

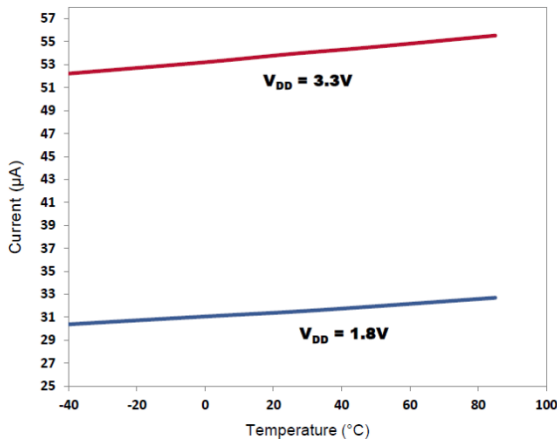


Figure 11. Supply Current vs Temperature (Fout = 1.85 MHz)

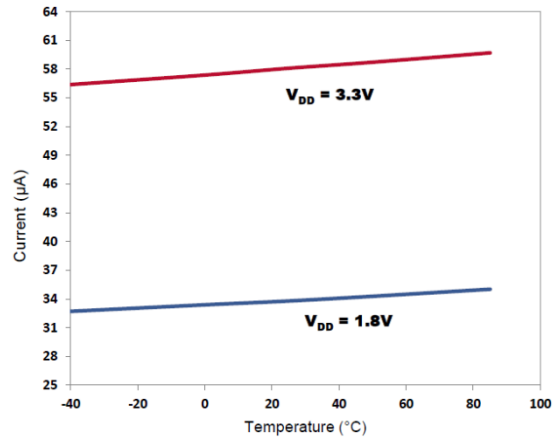
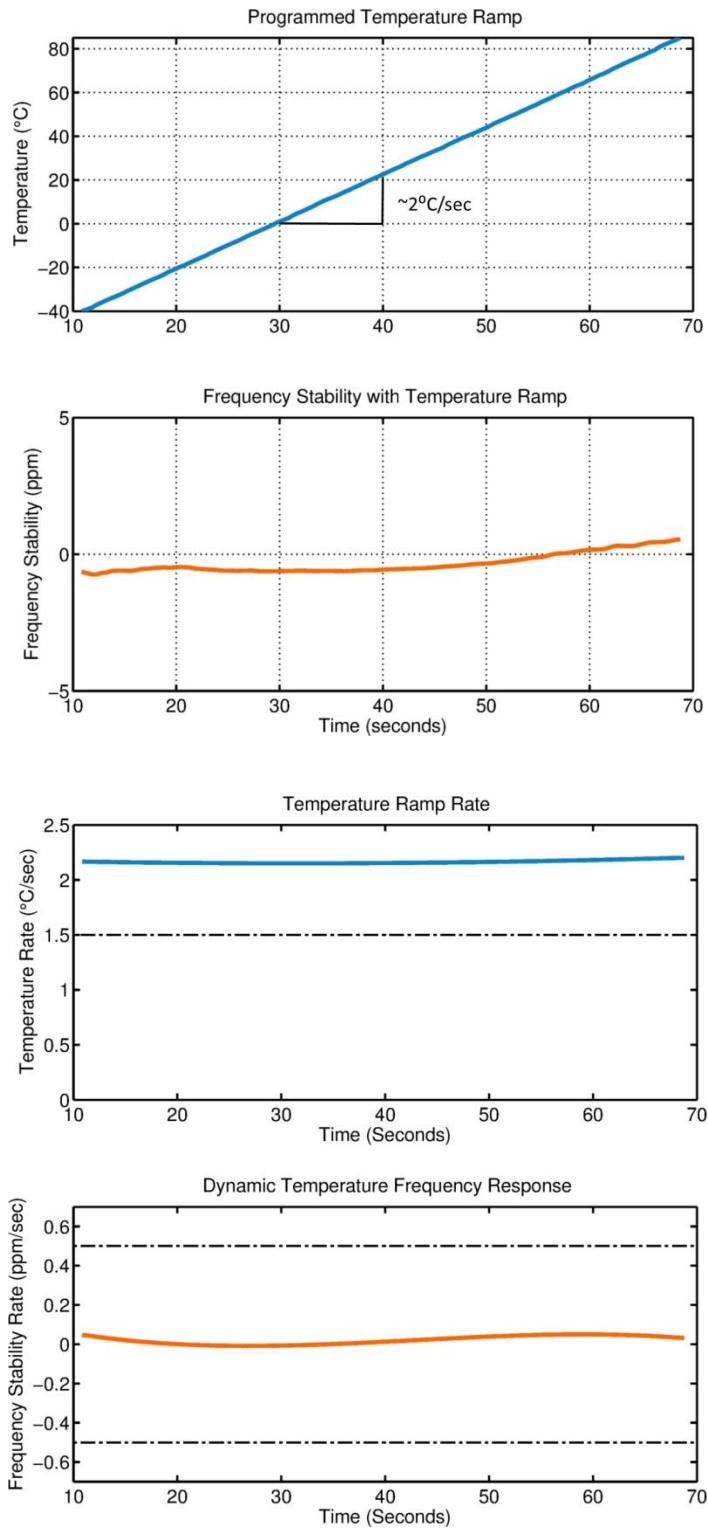


Figure 12. Supply Current vs Temperature (Fout = 2 MHz)

Dynamic Frequency Response for Moderate Temperature Ramps

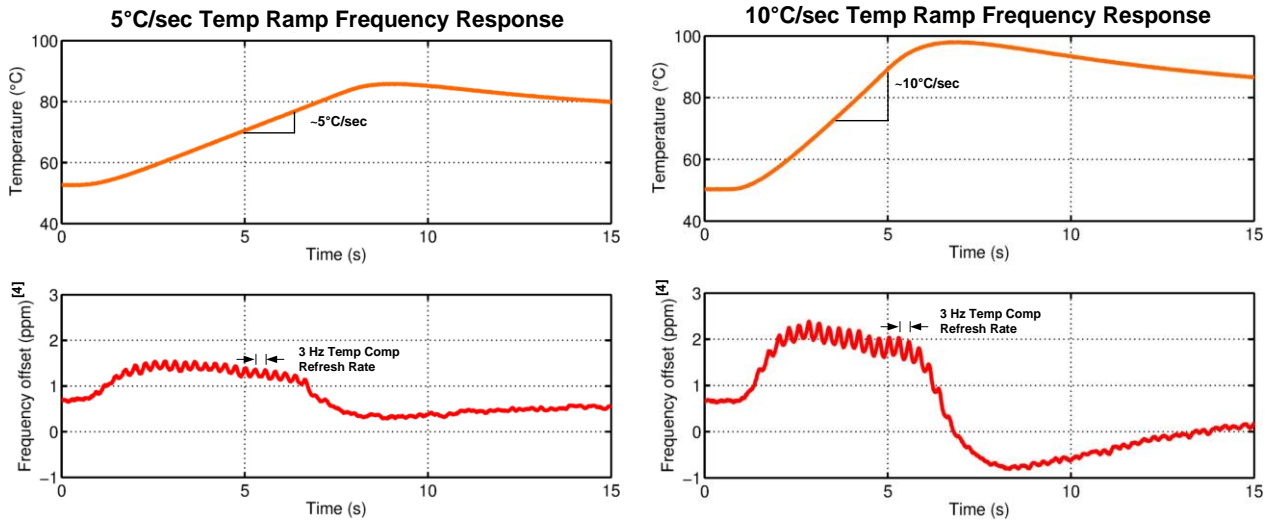


Frequency accuracy under a moderate temperature ramp up to $2^{\circ}\text{C}/\text{sec}$ is limited by the TC-MO's trimmed accuracy of the frequency stability over-temperature.

Note:

- 2. Measured relative to 32.768 kHz.

Dynamic Frequency Response for Fast Temperature Ramps



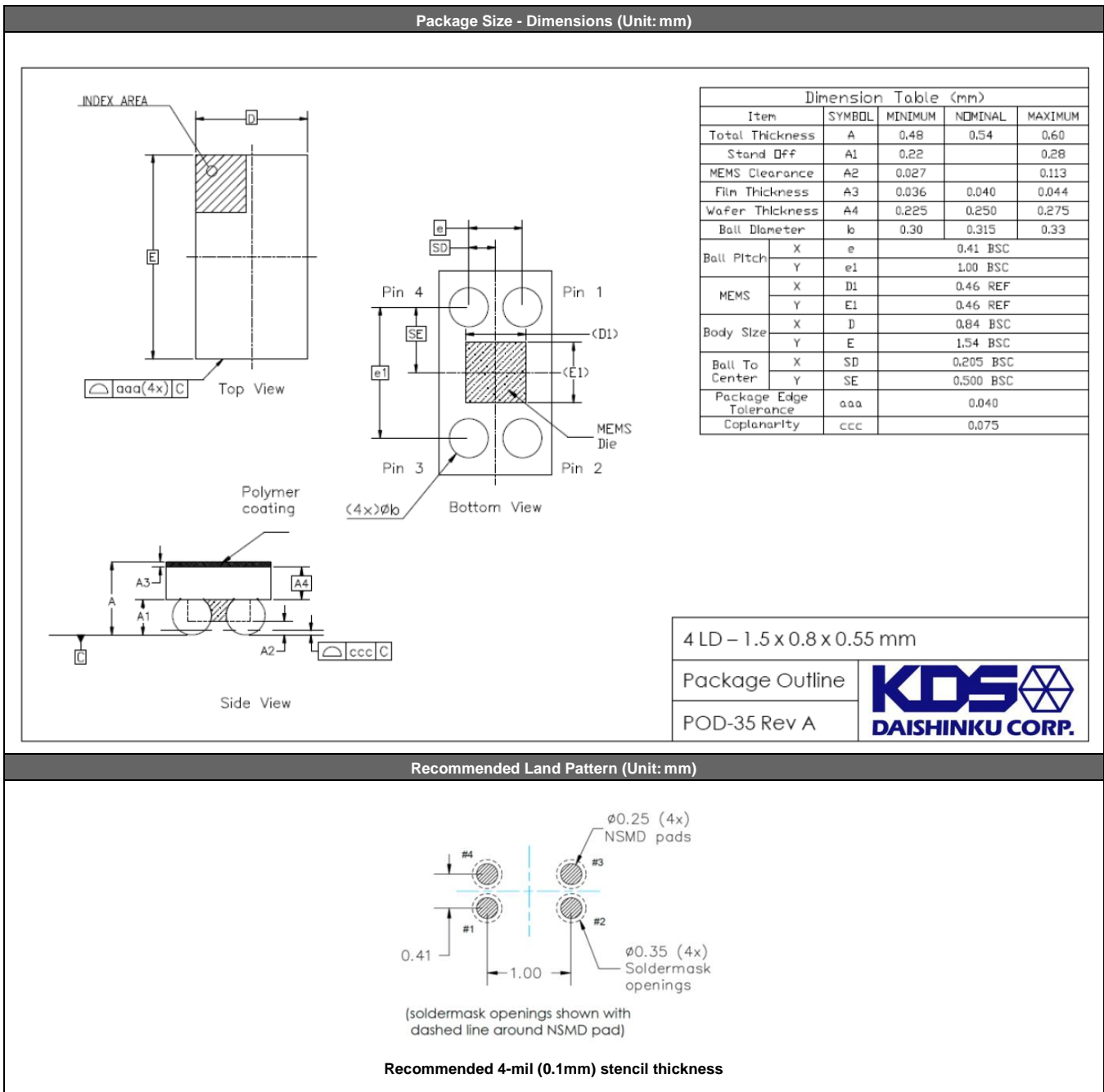
For temperature ramps $>+5^{\circ}\text{C}/\text{sec}$, the frequency accuracy is limited by the update rate of the temperature compensation path (see the $+5^{\circ}\text{C}/\text{sec}$ and $+10^{\circ}\text{C}/\text{sec}$ plots).

Contact Factory for applications that require improved dynamic performance.

Note:

3. Referenced to 32.768 kHz.

Dimensions and Patterns



Manufacturing Guidelines

- 1) No Ultrasonic or Megasonic cleaning: Do not subject MO1576 to an ultrasonic or megasonic cleaning environment. Permanent damage or long term reliability issues may occur.
- 2) Applying board-level underfill and overmold is acceptable and will not impact the reliability of the device.
- 3) Reflow profile, per JESD22-A113D.
- 4) The MO1576 CSP includes a protective, opaque polymer top-coat. If the MO1576 will see intense light, especially in the 1.0-1.2 μ m IR spectrum, we recommend a protective "glob-top" epoxy or other cover to keep the light from negatively impacting the frequency stability.
- 5) For additional manufacturing guidelines and marking/tape-reel instructions, contact KDS.

Ordering Information

M O 1 5 7 6 I L 4 - D C C E - Y Y - 0 1 0 0 0 0 E

Part Family
"MO1576"

Temperature Range
"D" Ext. Commercial -20°C to +70°C
"I" Industrial -40°C to +85°C

Package Size
"L4" 1.5 x 0.8 mm CSP

AC-or DC-coupled
"D" DC-coupled Signal Path or
Rail-to-Rail LVCMOS

DC-coupled Output V_{OH}
"C" Rail-to-Rail LVCMOS

DC-coupled Output V_{OL}
"C" Rail-to-Rail LVCMOS

Packing
"E" 8mm Tape & Reel, 1ku reel
"Q" 8mm Tape & Reel, 5ku reel

Output Frequency
Continuous frequency options from
1Hz to 2.5 MHz
Enter your desired frequency as
shown below:
2.500 MHz -> "2500000"
1.000 MHz -> "1000000"
100.000 kHz -> "0100000"
10.000 kHz -> "0010000"
1.000 kHz -> "0001000"
100 Hz -> "0000100"
10 Hz -> "0000010"
1 Hz -> "0000001"

Supply Voltage
"YY" +1.8 V to +3.3V
"18" +1.8 V
"20" +2.0 V
"25" +2.5 V
"30" +3.0 V
"33" +3.3 V

Frequency Stability
"E" ± 5.0 ppm
"G" ± 20.0 ppm

Table 4. Revision History

Revision	Release Date	Change Summary
0.25	01/13/2016	Initial Release of Advanced datasheet
0.5	03/10/2016	Preliminary datasheet initial release
0.9	02/15/2017	Updated Package Outline Drawing (POD) Updated part number ordering information Updated max programmable frequency Updated logo and company address, other page layout changes
1.0	05/09/2017	Final Release Updated supply current vs frequency Updated start-up time
1.1	06/12/2017	Updated max operating frequency to 2.0 MHz
1.2	08/03/2017	Added additional typical operating curves Updated typical No Load Supply Curren
1.3	03/15/2018	Updated max operating frequency from 2.0 MHz to 2.5 MHz