ULTRA-LOW POWER HIGH PRECISION OSCILLATOR
SERIES „ULPPO”

32.768 kHz

FEATURES
+ 100% pin-to-pin drop-in replacement to quartz-based XO
+ Low Power High Precision Oscillator for Low Cost
+ Excellent long time reliability—outperforms quartz-based XO
+ 32.768 kHz ±5, ±10, ±20 ppm frequency stability options
+ World’s smallest TCXO in a 1.5 x 0.8 mm housing
+ Ultra-low power: <1 µA
+ VΩ supply range: 1.5V to 3.63V
+ Improved stability reduces system power
+ Internal filtering eliminates external VΩ-bypass cap and saves space
+ Programmable output swing for lowest power
+ Pb-free, RoHS and REACH compliant / MSL1Ω2b°

APPLICATIONS
+ Smart Phones
+ Tablets
+ Health and Wellness Monitors
+ Fitness Watches
+ Sport Video Cams
+ Wireless Keypads
+ Ultra-Small Notebook PC
+ Pulse-per-Second (pps) Timekeeping
+ RTC Reference Clock
+ Battery Management Timekeeping
+ Wearables
+ IoT
+ GPS
+ Smart Metering
+ Home Automation

GENERAL DATA

<table>
<thead>
<tr>
<th>PARAMETER AND CONDITIONS</th>
<th>SYMBOL</th>
<th>MIN.</th>
<th>TYP.</th>
<th>MAX.</th>
<th>UNIT</th>
<th>CONDITION</th>
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<tbody>
<tr>
<td>FREQUENCY</td>
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<tr>
<td>Output Frequency</td>
<td>F_out</td>
<td>32.768</td>
<td>kHz</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>FREQUENCY STABILITY</td>
<td></td>
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</tbody>
</table>
| Frequency Stability Over Temperature (with Initial Offset) | F_stab | -5.0 | +5.0 | PPM | Stability part number code = 5A
| Frequency Stability Over Temperature (without Initial Offset) | F_stab | -10 | +10 | PPM | Stability part number code = 10B
| Frequency Stability vs Voltage | F_VDD | -0.75 | +0.75 | PPM | Stability part number code = 20X
| First Year Frequency Aging | F_aging | -1.0 | +1.0 | PPM | Stability part number code = 22X
| Operating Temperature Range | T_use | 0 | +70 | °C | Commercial |
| Storage Temperature Range | T_stor | -55 | +125 | °C | Industrial |

NOTES:
1. No board level underfill. Measured as peak-to-peak/2. Inclusive of 3x-reflow and ±20% load variation. Tested with Agilent 53132A frequency counter. Due to the low operating frequency, the gate time must be >100 ms to ensure an accurate frequency measurement.
2. Initial offset is defined as the frequency deviation from the ideal 32.768 kHz at room temperature, post reflow.
3. Core operating current does not include output driver operating current or load current. To derive total operating current (no load), add core operating current + output driver operating current, which is a function of the output voltage swing. See the description titled, Calculating Load Current.
GENERAL DATA (continued)

<table>
<thead>
<tr>
<th>PARAMETER AND CONDITIONS</th>
<th>SYMBOL</th>
<th>MIN.</th>
<th>TYP.</th>
<th>MAX.</th>
<th>UNIT</th>
<th>CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>JITTER PERFORMANCE (Ta = OVER TEMP)</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Long Term Jitter</td>
<td></td>
<td>2.5</td>
<td>µspp</td>
<td>81920 cycles (2.5 sec), 100 samples</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period Jitter</td>
<td></td>
<td>35</td>
<td>nsng</td>
<td>Cycles = 10,000, Ta = 25°C, VDD = 1.5V – 3.63V</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| LVCMOS OUTPUT (STANDARD VERSION) | | | | | | |
| Output Rise/Fall Time        | tf, tf | 100  | 200  | ns   | 10–90% (Voh), 15 pF Load |
| Output Clock Duty Cycle      | DC     | 48   | 52   | %    |
| Output Voltage High          | VOH    | 90%  | V    | VDD: 1.5V – 3.63V, IOH = -1µA, 15 pF Load |
| Output Voltage Low           | VOL    | 10%  | V    | VDD: 1.5V – 3.63V, IOL = 1µA, 15 pF Load |

| PROGRAMMABLE, REDUCED SWING OUTPUT (ADAPTABLE TO CUSTOMERS REQUIREMENT) | | | | | | |
| Output Rise/Fall Time        | tf, tf | 200  | ns   | 30–70% (VOL/Voh), 10 pF Load |
| Output Clock Duty Cycle      | DC     | 48   | 52   | %    |
| AC-coupled/Programmable Output Swing | V_sw | 0.20 to 0.80 | V | ULPPO does not internally AC-coupled. This output description is intended for a receiver that is AC-coupled. VDD: 1.5V – 3.63V, 10 pF Load, IOH / IOL = ±0.2 µA. |
| DC-Biased Programmable Output Voltage High Range | VOH | 0.6 to 1.225 | V | VDD: 1.5V – 3.63V, IOH = -0.2 µA, 10 pF Load. |
| DC-Biased Programmable Output Voltage Low Range | VOL | 0.35 to 0.80 | V | VDD: 1.5V – 3.63V, IOL = 0.2 µA, 10 pF Load. |
| Programmable Output Voltage Swing Tolerance | -0.055 | 0.055 | V | TA = -40°C to +85°C, VDD = 1.5V to 3.63V. |

EXCELLENT RELIABILITY DATA

| MTBF | 500 million hours |
| Shock Resistance | 10,000 g |
| Vibration Resistance | 70 g |

PIN DESCRIPTION

<table>
<thead>
<tr>
<th>Pin</th>
<th>Symbol</th>
<th>V/I</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 4</td>
<td>GND</td>
<td>Power Supply Ground</td>
<td>Connect to ground. All GND pins must be connected to power supply ground. The GND pins can be connected together, as long as both GND pins are connected ground.</td>
</tr>
<tr>
<td>2</td>
<td>CLK Out</td>
<td>OUT</td>
<td>Oscillator clock output. When interfacing to an MCU’s XTAL, the CLK Out is typically connected to the receiving IC’s X IN pin. The ULPPO oscillator output includes an internal driver. As a result, the output swing and operation is not dependent on capacitive loading. This makes the output much more flexible, layout independent, and robust under changing environmental and manufacturing conditions.</td>
</tr>
<tr>
<td>3</td>
<td>VDD</td>
<td>Power Supply</td>
<td>Connect to power supply 1.5V ≤ Vdd ≤ 3.63V. Under normal operating conditions, Vdd does not require external bypass decoupling capacitors. For more information about the internal power-supply filtering, see Power-Supply Noise Immunity section in the detailed description. Contact factory for applications that require a wider operating supply voltage range.</td>
</tr>
</tbody>
</table>

FIGURE 1. 1.5X0.8 MM PACKAGE (TOP VIEW)
DESCRIPTION

The ULPPO is an ultra-small and ultra-low power 32.768 kHz high-precision oscillator optimized for battery-powered applications. The silicon oscillator technology enables a 32.768 kHz high-precision oscillator in the smallest footprint of 1.5x0.8mm housing. Typical core supply current is only 1 µA. And unlike standard oscillators, the ULPPO features programmable output swing, a factory programmed output that reduces the voltage swing to minimize power.

HIGH-PRECISION FREQUENCY STABILITY

The ULPPO is factory calibrated 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 ppm/°C temperature coefficient, the ULPPO temperature coefficient is calibrated and corrected over temperature with an active temperature correction circuit. The result is a 32.768 kHz ULPPO with extremely tight frequency stability over the -40°C to +85°C temperature range. Contact Petermann-Technik’s engineers for applications that require a wider supply voltage range>3.63V, or lower operating frequency below 32.768 kHz.

POWER SUPPLY NOISE IMMUNITY

In addition to eliminating external output load capacitors common with standard XTALs, the ULPPO includes special power supply filtering and thus, eliminates the need for an external VIL bypass-decoupling capacitor to keep the footprint as small as possible. Internal power supply filtering is designed to reject more than ±150 mV noise and frequency components from low frequency to more than 10 MHz.

START-UP AND STEADY-STATE SUPPLY CURRENT

The ULPPO starts-up to a valid output frequency within 300 ms [180 ms typ]. To ensure the device starts-up within the specified limit, make sure the power-supply ramps-up in approximately 10 - 20 ms (to within 90% of VDD). During initial power-up, the ULPPO power-cycles internal blocks as shown in the power-supply start-up and steady state plot in the typical operating curves section. Power-up and initialization is typically 200 ms, and during that time, the peak supply current reaches 28 µA as the internal capacitors are charged, then sequentially drops to its 990 nA steady-state current. During steady-state operation, the internal temperature compensation circuit turns on every 350 ms for a duration of approximately 10 ms.

OUTPUT VOLTAGE

The ULPPO has two output voltage options. One option is a standard DC-coupled rail-to-rail LVCMOS output swing. The second option is the programmable output swing reduced swing output and current. Output swing is customer specific and factory programmed between 200 mV and 800 mV. For DC-coupled applications, output VOH and VOL are individually factory programmed to the customers’ requirement. VOH programming range is between 600 mV and 1.225V in 100 mV increments. Similarly, VOL programming range is between 350 mV and 800 mV. For example; a PMIC or MCU is internally 1.8V logic compatible, and requires a 1.2V VIH and a 0.6V VI.L. Simply select ULPPO programmable output swing factory programming code to be “D14” and the correct output thresholds will match the downstream IC or MCU input requirements. Interface logic will vary by manufacturer and we recommend that you review the input voltage requirements for the input interface. For DC-biased programmable output swing configuration, the minimum VOL is limited to 350mV and the maximum allowable swing VOH - VOL is 750mV. For example, 1.1V VOH and 400mV VOL is acceptable, but 1.2V VOH and 400 mV VOL is not acceptable.

+ When the output is interfacing to an XTAL input that is internally AC-coupled, the ULPPO output can be factory programmed to match the input swing requirements. For example, if a IC or MCU input is internally AC-coupled and requires an 800mV swing, then simply choose the ULPPO programming code “AA8” in the part number. It is important to note that the ULPPO does not include internal AC-coupling capacitors. Please see the Part Number Ordering section at the end of the datasheet for more information about the part number ordering scheme.

ULPPO PROGRAMMABLE OUTPUT SWING

Figure 2 shows a typical ULPPO output waveform (into a 10 pF load) when factory programmed for a 0.70V swing and DC bias [VSW/VOL] for 1.8V logic:

EXAMPLE:

+ Programmable output swing part number coding: D14. Example part number: ULPPO18-1508-SA-W-32.768kHz-T-D14
+ \( V_{OH} = 1.1V, \ V_{OL} = 0.4V \) \( (V_{SW} = 0.70V) \)
Table 1 shows the supported programmable output swing $V_{OH}$, $V_{OL}$ factory programming options.

**TABLE 1. ACCEPTABLE $V_{OH}/V_{OL}$ PROGRAMMABLE OUTPUT SWING LEVELS**

<table>
<thead>
<tr>
<th>$V_{VDD}$</th>
<th>D28</th>
<th>D18</th>
<th>D08</th>
<th>D97</th>
<th>D17</th>
<th>D07</th>
<th>D96</th>
<th>D6</th>
<th>D15</th>
<th>D05</th>
<th>D95</th>
<th>D85</th>
<th>D75</th>
<th>D26</th>
<th>D16</th>
<th>D06</th>
<th>D94</th>
<th>D6</th>
<th>D25</th>
<th>D03</th>
<th>D93</th>
<th>D83</th>
<th>D73</th>
<th>D63</th>
</tr>
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<tbody>
<tr>
<td>0.800</td>
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<td>0.700</td>
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<td>0.500</td>
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<td>0.400</td>
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<td>0.350</td>
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</table>

Table 2 shows the supported AC coupled Swing levels. The “AC-coupled” terminology refers to the programming description for applications where the downstream chipset includes an internal AC-coupling capacitor, and therefore, only the output swing is important and $V_{OH}/V_{OL}$ are not relevant. For these applications, refer to Table 2 for the acceptable voltage swing options.

**TABLE 2. ACCEPTABLE AC-COUPLED SWING LEVELS**

<table>
<thead>
<tr>
<th>SWING</th>
<th>0.800</th>
<th>0.700</th>
<th>0.600</th>
<th>0.500</th>
<th>0.400</th>
<th>0.300</th>
<th>0.250</th>
<th>0.200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Code</td>
<td>AA8</td>
<td>AA7</td>
<td>AA6</td>
<td>AA5</td>
<td>AA4</td>
<td>AA3</td>
<td>AA2</td>
<td>AA1</td>
</tr>
</tbody>
</table>

**EXAMPLE:**

+ Programmable output swing part number coding: AA2. Example part number: ULPPO-1508-5A-W-32.768KHZ-T-AA2
+ Output voltage swing: 0.250V

The values listed in Tables 1 and 2 are nominal values at 25°C and will exhibit a tolerance of ±55 mV across Vdd and -40°C to 85°C operating temperature range.

**EXAMPLE:**

+ LVCMOS rail-to-rail output part number coding is always S
+ Example part number: ULPPO33-1508-5A-W-32.768KHZ-T-S

**CALCULATING LOAD CURRENT**

**NO LOAD SUPPLY CURRENT**

When calculating no-load power for the ULPPO, the core and output driver components need to be added. Since the output voltage swing can be programmed for reduced swing between 250 mV and 800 mV, the output driver current is variable. Therefore, no-load operating supply current is broken into two sections; core and output driver. The equation is as follows:

Total Supply Current (no load) = $I_{dd\ Core} + (65nA/V)(V_{outpp})$

**EXAMPLE 1: FULL-SWING LVCMOS**

+ $V_{dd} = 1.8V$
+ $I_{dd\ Core} = 990nA$ (typ)
+ $V_{outpp} = 1.8V$ (LVCMOS)
+ $I_{dd\ Output\ Driver} = (C_{driver})(V_{out})(F_{out}) = (3.5pF)(1.8V)(32768Hz) = 206nA$

Supply Current = $990nA + 206nA = 1.2µA$

**EXAMPLE 2: REDUCED SWING**

+ $V_{dd} = 1.8V$
+ $I_{dd\ Core} = 990nA$ (typ)
+ $V_{outpp}(Programmable) = V_{OH} - V_{OL} = 1.1V - 0.6V = 500mV$
+ $I_{dd\ Output\ Driver} = (C_{driver})(V_{out})(F_{out}) = (3.5pF)(0.50V)(32768Hz) = 57nA$
+ Supply Current = $990nA + 57nA = 1.05µA$
CALCULATING LOAD CURRENT

TOTAL SUPPLY CURRENT WITH LOAD
To calculate the total supply current, including the load, follow the equation listed below. Note the 30% reduction in power with Programmable output swing.

Total Current = Icc Core + Icc Output Driver + Load Current (C*V*F)

EXAMPLE 1: FULL-SWING LVCMOS
+ VDD = 1.8V
+ Icc Core = 990nA
+ Load Capacitance = 10pF
+ Idd Output Driver: (Cderv)(Vout)(Fout) = (3.5pF)(1.8V)(32768Hz) = 206nA
+ Load Current: (10pF)(1.8V)(32768Hz) = 590nA
+ Total Current = 990nA + 206nA + 590nA = 1.79µA

EXAMPLE 2: PROGRAMMED REDUCED SWING
+ VDD = 1.8V
+ Icc Core = 990nA
+ Load Capacitance = 10pF
+ Voutpp (Programmable): Vol - Vol = 1.1V - 0.6V = 500mV
+ Idd Output Driver: (Cderv)(Vout)(Fout) = (3.5pF)(0.5V)(32768Hz) = 57nA
+ Load Current: (10pF)(0.5V)(32768Hz) = 164nA
+ Total Current = 990nA + 57nA + 164nA = 1.2µA
TYPICAL OPERATING CURVES

FIGURE 4. FREQUENCY STABILITY OVER TEMPERATURE (PRE-REFLOW)

FIGURE 5. FREQUENCY STABILITY OVER TEMPERATURE (POST-REFLOW)

FIGURE 6. CORE CURRENT OVER TEMPERATURE

FIGURE 7. OUTPUT STAGE CURRENT OVER TEMPERATURE

FIGURE 8. SUPPLY CURRENT OVER TEMPERATURE, LVCMOS (CORE + LVCMOS OUTPUT DRIVER, NO LOAD)

FIGURE 9. START-UP AND STEADY-STATE CURRENT PROFILE
TYPICAL OPERATING CURVES

FIGURE 10. POWER SUPPLY NOISE REJECTION (+/- 150MV NOISE)

Noise Injection Frequency (Hz)

FIGURE 11. TEMPERATURE RAMP RESPONSE

FIGURE 12. PROGRAMMABLE OUTPUT SWING WAVEFORM
(V_{OH} = 1.2V, V_{OL} = 0.4V, 10 PF LOAD; ULPPO)

FIGURE 13. LVCMOS OUTPUT WAVEFORM
(V_{SWING} = 1.8V, ULPP0,10 PF LOAD)
DIMENSIONS AND PATTERNS

PACKAGE SIZE – DIMENSIONS (UNIT:MM)
1.55 X 0.85 MM

RECOMMENDED LAND PATTERN (UNIT:MM) [4]

0.25 (4x) NSMD pads

0.35 (4x) Soldermask opening

[soldermask openings shown with heavy dashed line]

Recommended 4-mil (0.1mm) stencil thickness

REFLOW SOLDER PROFILE

Profile Feature | Pb-Free Assembly
--- | ---
Average ramp-up rate (TL to TP) | 3°C/second max.
Preheat:
| Temperature Min (T<sub>s</sub>min) | 150°C
| Temperature Max (T<sub>s</sub>max) | 200°C
| Time (t<sub>s</sub>min to t<sub>s</sub>max) | 60-180 seconds
Time maintained above:
| Temperature (TL) | 217°C
| Time (tL) | 60-150 seconds
Peak/Classification Temperature (Tp) | 240°C
| Time within 5°C of actual Peak Temperature (tP) | 20-45 seconds
Ramp-down Rate | 4°C/second max.
| Time 25°C to Peak Temperature | 8 minutes max.
ORDERING INFORMATION

OSCILLATOR FAMILY
ULPPO

SUPPLY VOLTAGE
"X2" any 1.5-3.63

TEMPERATURE RANGE
"C" for 0+70°C
"W" for -40+85°C

FREQUENCY
32.768kHz

FREQUENCY STABILITY
SEE PAGE 1

PACKING METHOD
"T": TAPE & REEL
3000 pcs. per Reel
Smaller quantities possible

PACKAGE SIZE
"1508" for 1.5 X 0.8 mm

OUTPUT DRIVE STRENGTH
"S" Standard
(datasheet limits)

EXAMPLE: ULPPOX2-1508-5A-W-32.768kHz-T-S

PLEASE INDICATE YOUR REQUIRED PARAMETERS

EXPRESS SAMPLES ARE DELIVERABLE ON THE SAME DAY
IF ORDERED UNTIL 02:00 PM!
PREMIUM QUALITY BY PETERMANN-TECHNIK

OUR COMPANY IS CERTIFIED ACCORDING TO ISO 9001:2008 IN OCTOBER 2013 BY THE DMSZ CERTIFIKATION GMBH.

THIS IS FOR YOU TO ENSURE THAT THE PRINCIPLES OF QUALITY MANAGEMENT ARE FULLY IMPLEMENTED IN OUR QUALITY MANAGEMENT SYSTEM AND QUALITY CONTROL METHODS ALSO DOMINATE OUR QUALITY STANDARDS.