ISL12022M Oscillator Accuracy

Introduction

The ISL12022M devices are high-accuracy, temperature compensated Real Time Clock (RTC) modules that incorporate the RTC die and the quartz crystal. The RTC contains an internal temperature sensor and state machine to adjust the oscillator frequency and allow factory calibration to less than ±5ppm error over the -40°C to +85°C ambient operating temperature range. There are numerous items that affect the final accuracy of the module once assembled on a PC board, including handling and shock, reflow temperature profile, maximum temperature, number of reflows (or wave solder) and if ultrasound is used (note that the ISL12022M family refers to the ISL12022M, ISL12022MA and ISL12022MR5421 products).

This application note will discuss the expected accuracy of the device when mounted on a board, at room temperature and as temperature varies. Also discussed will be the measurement techniques and analyzing the results.

Expected Oscillator Accuracy and Time Drift

The oscillator accuracy is summarized in Table 1. The main point of this table is that after the module device is reflow soldered to a PC board, the accuracy spec in the ISL12022M datasheet will have additional errors such that the resulting accuracy will exceed the maximum datasheet specification. Also, due to the variability of the reflow process and customer application PC boards, there cannot be a maximum stated error after reflow, only the expected value based on the estimated change. The best assurance of getting the best accuracy is to minimize the peak time and temperature of the assembly reflow process.

Datasheet Specifications

The datasheet provides separate accuracy specifications for room temperature at a fixed V_{DD} = 3.3V, over V_{DD} supply voltage variation, and over the rated temperature range. “DC Operating Characteristics RTC” on page 2 shows a portion of the datasheet extracted to show just the overall conditions and the individual accuracy specs.

Let’s look more closely at each line item spec.

- “Oscillator Stability vs Temperature” refers to the maximum variation from a perfect 0ppm error with the device at an ambient temperature from -40°C to +85°C. Oscillator stability in this case refers to the average frequency measured over a period of time, since the digital correction mechanism inserts periodic correction, at intervals of greater than 1 second in most cases. A measurement at 1 or 2 second intervals may not provide an accurate or stable reading due to the digital correction. The 5ppm is the maximum guaranteed for a packaged device as it is shipped to the customer.
- “Oscillator Stability vs Voltage” is the maximum deviation, at room temperature, from a perfect 0ppm error as the V_{DD} voltage is varied from 2.7V to 5.5V.
- “Oscillator Initial Accuracy” is measured at T_A = +25°C only; the maximum variation from 0ppm error is at V_{DD} = 3.3V, V_{BAT} = 0.0V.
- “Temperature Sensor Accuracy” is the maximum error at T_A = +25°C of the digital temperature reading (TEMP registers) from exact chip temperature. It is listed here since the oscillator calibration takes effect at <20°C and >30°C, as measured by the chip as opposed to actual temperature.

Related Literature

- ISL12022M datasheet
- ISL12022MA datasheet
- ISL12022MR5421 datasheet

TABLE 1. ISL12022M OSCILLATOR ACCURACY SUMMARY

TEMP. RANGE >	+25°C (ppm)	+25°C (SEC/DAY)	-40°C to +85°C (ppm)	-40°C to +85°C (SEC/DAY)
Before Reflow	±3 (max)	0.26 (max)	±5 (max)	0.43 (max)
After Reflow	±6 (typically)	0.52 (typically)	±8 (typically)	0.69 (typically)

DC Operating Characteristics RTC

Test Conditions: V_{DD} = +2.7 to +5.5V, T_A = -40°C to +85°C, unless otherwise stated. **Boldface limits apply across the operating temperature range, -40°C to +85°C.**

SYMBOL	PARAMETER	CONDITIONS	MIN (Note 1)	TYP (Note 2)	MAX (Note 1)	UNITS
OSCILLATOR ACCURACY						
$\Delta Fout_I$	Oscillator Initial Accuracy	V_{DD} = 3.3V (Notes 3, 5)	-2		+8	ppm
$\Delta Fout_R$	Oscillator Accuracy after Reflow Cycle	V_{DD} = 3.3V (Notes 3, 5)		±5		ppm
$\Delta Fout_T$	Oscillator Stability vs Temperature	V_{DD} = 3.3V (Notes 3, 6)		±2		ppm
$\Delta Fout_V$	Oscillator Stability vs Voltage	2.7V ≤ V_{DD} ≤ 5.5V (Note 7)	-3		+3	ppm
Temp	Temperature Sensor Accuracy	V_{DD} = V_{BAT} = 3.3V (Note 4)		±2		°C

NOTES:

1. Parameters with MIN and/or MAX limits are 100% tested at +25°C, unless otherwise specified. Temperature limits established by characterization and are not production tested.
2. Specified at +25°C.
3. The ISL12022M Oscillator Initial Accuracy can change after solder reflow attachment. The amount of change will depend on the reflow temperature and length of exposure. A general rule is to use only one reflow cycle and keep the temperature and time as short as possible. Changes on the order of ±1ppm to ±3ppm can be expected with typical reflow profiles.
4. Limits should be considered typical and are not production tested.
5. Defined as the deviation from a target oscillator frequency of 32,768.0Hz at room temperature.
6. Defined as the deviation from the room temperature measured 1Hz frequency, V_{DD} = 3.3V, at T_A = -40°C to +85°C.
7. Defined as the deviation at room temperature from the measured 1Hz frequency (or equivalent) at V_{DD} = 3.3, over the range of V_{DD} = 2.7V to V_{DD} = 5.5V.

In addition to the error specs listed, Note 3 is pertaining to the error that results from high temperature assembly reflow.

This note indicates that an additional tolerance of typically up to 3ppm is added to the error specification after reflow. Combining this change with the initial accuracy specs gives the ±6ppm initial accuracy expected value at +25°C, as shown in Table 1 on page 1.

Environmental Effects

Thermal Effects

SOLDER REFLOW HEAT, PCB ASSEMBLY

Typical surface mount production assembly flows include at least one infrared reflow pass for soldering components to pads on the PC board. Heating profiles for reflow cycles have peak temperatures of up to 260°C for 10 to 30 seconds, which is high enough to slightly change the characteristic of the quartz crystal in the RTC module. After cooling, the typical final effect on the module is a slightly lower oscillator frequency (sometimes but not often higher frequency). Therefore, the RTC module after reflow assembly, will have a different accuracy range than that specified on the datasheet as shipped from the factory. See Table 1 on page 1.

The customer should take this accuracy change into account when considering the final system accuracy for the assembled RTC module on their PC board. Also, every effort needs to be made to minimize the peak reflow temperature and peak time as well and the number of reflow cycles. Thus, reducing the frequency change after reflow. RTC module devices can have accuracy error exceeding 8ppm and still be within the expected range after a production reflow at +260°C peak temperature.

Mechanical Effects

PCB CUTTING WITH ROUTERS

Usually at the end of the pick and place process, a PCB panel needs to have the single PCBs separated from each other with a cutting tool or router. These machines sometimes generate vibrations on the PCB that have a fundamental or harmonic frequencies close to 32.768kHz. This might cause breakage of the crystal blanks inside the module due to resonance. Note: The customer should monitor their cutting tool speed and the speed should be adjusted to avoid resonant vibration. If this is not done, there can be very large accuracy error in the RTC oscillator or sometimes even failure of the oscillator if the crystal is damaged sufficiently.

ULTRASOUND CLEANING

Ultrasound cleaning of PCBs is a common practice after assembly. This cleaning removes any material from the soldering process by submersing in a bath and using high frequency ultrasound to loosen the foreign material.

The RTC crystal can be damaged by this process if a lower frequency is used and the intensity is high enough to cause resonance in the crystal. Generally, frequencies higher than 500kHz should avoid damage and also any harmonic of the 32.768kHz frequency should be avoided. Note: The customer should monitor the ultrasound frequency and the frequency should be adjusted to avoid crystal harmonics. Failure to observe proper ultrasound frequency control can result in either large RTC oscillator frequency error or possible oscillator failure due to a damaged crystal.

MECHANICAL SHOCK AND VIBRATION

Possible sources of crystal frequency offset include mechanical shock. The datasheet lists a maximum shock resistance of 5000g for 0.3ms, 1/2 sine test, which can give a ±5ppm frequency change. Likewise, the maximum vibration spec is 20g at 10 to 2000Hz. Note that ultrasound cleaning and PCB panel cutting vibrations fall under the broader mechanical shock and vibration spec as well. The customer should avoid any mechanical handling that produces an impact or high vibration on the module. Failure to observe proper precautions handling the device, before or after, assembly can result in higher than expected oscillator frequency error.

Summary

The ISL12022M provides a high accuracy 3-in-1 RTC solution for real time clock timing requirements. The oscillator accuracy is guaranteed for the device shipped from the factory. The PCB assembly process adds environmental factors, such as heat and vibration that will cause the accuracy error to increase after assembly. This change will be evident when testing the final assembled PC board RTC oscillator frequency. The major contributors to additional accuracy error are solder reflow, board cutting or routing, ultrasound cleaning and mechanical handling shocks or vibrations.

For final product oscillator accuracy, the customer must consider the assembly effects and the resulting board mounted module device may not be within the expected accuracy limits shown on the datasheet. The customer can adjust their system to address this change in accuracy or look into other ways of adjusting final oscillator accuracy.

NOTE: If the customer has the capability to test, access the serial interface, make adjustments and test again, there are methods to readjust the device for better accuracy after assembly. Please contact Intersil applications about this possibility.

The customer needs to read and understand the environmental effects on the crystal oscillator accuracy and make every effort to minimize these effects, which will result in the highest possible accuracy of the board mounted RTC. In some cases, the customer may be forced to use an assembly process that is known to cause additional accuracy error as listed in this document. They should immediately contact Intersil to verify the hazard and possible impact and to identify alternative procedures that may be possible.

Appendix

Figure 1 is sample data for the ISL12022M parts that were subjected to 1 reflow cycle. The parts were socket tested and frequency accuracy data recorded, then sent through a production reflow oven and allowed to cool and settle. The parts were then socket tested again and the data recorded, with the change or delta frequency out calculated.

Parts soldered to a board may exhibit less change after reflow as the heat is distributed across the PC board. As the devices are cooled they maintain shape when attached to the PC board.

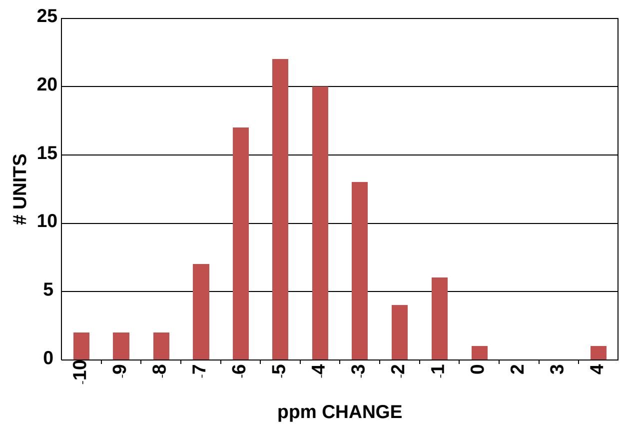

FIGURE 1. SAMPLE REFLOW DATA