

To our customers,

Old Company Name in Catalogs and Other Documents

On April 1st, 2010, NEC Electronics Corporation merged with Renesas Technology Corporation, and Renesas Electronics Corporation took over all the business of both companies. Therefore, although the old company name remains in this document, it is a valid Renesas Electronics document. We appreciate your understanding.

Renesas Electronics website: <http://www.renesas.com>

April 1st, 2010
Renesas Electronics Corporation

Issued by: Renesas Electronics Corporation (<http://www.renesas.com>)

Send any inquiries to <http://www.renesas.com/inquiry>.

Notice

1. All information included in this document is current as of the date this document is issued. Such information, however, is subject to change without any prior notice. Before purchasing or using any Renesas Electronics products listed herein, please confirm the latest product information with a Renesas Electronics sales office. Also, please pay regular and careful attention to additional and different information to be disclosed by Renesas Electronics such as that disclosed through our website.
2. Renesas Electronics does not assume any liability for infringement of patents, copyrights, or other intellectual property rights of third parties by or arising from the use of Renesas Electronics products or technical information described in this document. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
3. You should not alter, modify, copy, or otherwise misappropriate any Renesas Electronics product, whether in whole or in part.
4. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation of these circuits, software, and information in the design of your equipment. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from the use of these circuits, software, or information.
5. When exporting the products or technology described in this document, you should comply with the applicable export control laws and regulations and follow the procedures required by such laws and regulations. You should not use Renesas Electronics products or the technology described in this document for any purpose relating to military applications or use by the military, including but not limited to the development of weapons of mass destruction. Renesas Electronics products and technology may not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations.
6. Renesas Electronics has used reasonable care in preparing the information included in this document, but Renesas Electronics does not warrant that such information is error free. Renesas Electronics assumes no liability whatsoever for any damages incurred by you resulting from errors in or omissions from the information included herein.
7. Renesas Electronics products are classified according to the following three quality grades: “Standard”, “High Quality”, and “Specific”. The recommended applications for each Renesas Electronics product depends on the product’s quality grade, as indicated below. You must check the quality grade of each Renesas Electronics product before using it in a particular application. You may not use any Renesas Electronics product for any application categorized as “Specific” without the prior written consent of Renesas Electronics. Further, you may not use any Renesas Electronics product for any application for which it is not intended without the prior written consent of Renesas Electronics. Renesas Electronics shall not be in any way liable for any damages or losses incurred by you or third parties arising from the use of any Renesas Electronics product for an application categorized as “Specific” or for which the product is not intended where you have failed to obtain the prior written consent of Renesas Electronics. The quality grade of each Renesas Electronics product is “Standard” unless otherwise expressly specified in a Renesas Electronics data sheets or data books, etc.
 - “Standard”: Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; and industrial robots.
 - “High Quality”: Transportation equipment (automobiles, trains, ships, etc.); traffic control systems; anti-disaster systems; anti-crime systems; safety equipment; and medical equipment not specifically designed for life support.
 - “Specific”: Aircraft; aerospace equipment; submersible repeaters; nuclear reactor control systems; medical equipment or systems for life support (e.g. artificial life support devices or systems), surgical implantations, or healthcare intervention (e.g. excision, etc.), and any other applications or purposes that pose a direct threat to human life.
8. You should use the Renesas Electronics products described in this document within the range specified by Renesas Electronics, especially with respect to the maximum rating, operating supply voltage range, movement power voltage range, heat radiation characteristics, installation and other product characteristics. Renesas Electronics shall have no liability for malfunctions or damages arising out of the use of Renesas Electronics products beyond such specified ranges.
9. Although Renesas Electronics endeavors to improve the quality and reliability of its products, semiconductor products have specific characteristics such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Further, Renesas Electronics products are not subject to radiation resistance design. Please be sure to implement safety measures to guard them against the possibility of physical injury, and injury or damage caused by fire in the event of the failure of a Renesas Electronics product, such as safety design for hardware and software including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult, please evaluate the safety of the final products or system manufactured by you.
10. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. Please use Renesas Electronics products in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. Renesas Electronics assumes no liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
11. This document may not be reproduced or duplicated, in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products, or if you have any other inquiries.

(Note 1) “Renesas Electronics” as used in this document means Renesas Electronics Corporation and also includes its majority-owned subsidiaries.

(Note 2) “Renesas Electronics product(s)” means any product developed or manufactured by or for Renesas Electronics.

H8/300L

Hardware Interface Technique to Oscillator (HWosc)

Introduction

This application note is to assist the product design engineers in selecting the correct crystal oscillator and external capacitors required for H8/300L Super Low Power (SLP) series microcomputer.

The product design engineer should also consult with the crystal manufacturer about the needs of their product design.

For product success, it is important that the designer understand how an oscillator operates in order to select the correct crystal.

Target Device

H8/300L Super Low Power series – H8/38024F microcomputer

Contents

1. About Crystal.....	3
2. Equivalent Circuit	3
3. Types of Connection	4
3.1 Connection to Crystal Oscillator.....	4
3.2 Connection to Ceramic Oscillator	4
4. Selection of Components	5
5. Determining Best Values for Crystal, C1, C2, Rf and Rd	5
6. Specification of a Crystal.....	6
6.1 How to calculate a “ppm to Hz” tolerance.....	6
6.2 How to calculate a “Hz to ppm” tolerance.....	7
7. Notes on Oscillator Stabilization Time	7
8. Notes on Crystal Oscillator Element	8
9. Arrangement of Crystals & Board Design	8
9.1 Arrangement of Crystals	8
9.2 Board Design	9
10. Notes on Unused Clock Pins	9
11. Notes on External Clock Input	9
12. Final Notes.....	9
Reference.....	10

1. About Crystal

The oscillator circuit is often overlooked and selection of components is based largely on the manufacturer's table. If the circuit starts up and works, then further thoughts would not be given to it, right?

However, many conditions can negatively affect the performance of our design. Conditions such as higher temperatures and lower supply voltages can lower the loop gain in the oscillator circuit, causing poor, or slow or no startup; colder temperatures and higher supply voltages can increase the loop gain of the oscillator circuit, causing the crystal to be overdriven, and potentially damaged; or the circuit can be forced to another harmonic and throw off the timing or cease functioning altogether. It is also possible to waste power through the improper selection of components.

We shall now look at how a quartz crystal operates internally.

Quartz or piezoelectric (quartz) crystal oscillators appear most often in high-quality digital equipment. Designer appreciates their highly accurate frequency output. In addition, the resonance has a very high Q ranging from 10,000 to several hundred thousand. It is possible in some cases, to achieve 2 millions. However, with this merits, it also contributes to its limitation: difficulty to tune a crystal oscillator. The practical frequency for fundamental mode AT-cut crystals is 600KHz to 30MHz. The fundamental frequency of the crystal ranges as high as 40MHz. This application note shall focus on fundamental frequency mode.

2. Equivalent Circuit

The schematic symbol for a quartz crystal and the equivalent circuit are shown in Figure 1.1.

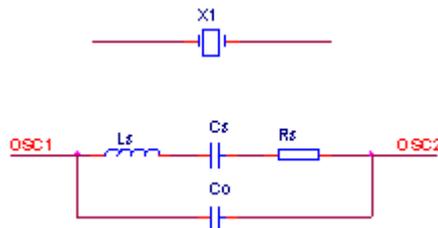


Figure 1.1 **Equivalent Circuit**

The equivalent circuit is an electrical representation of the quartz crystal's mechanical and electrical behavior. The crystal is after all a vibrating piece of quartz. The components C_s , L_s and R_s are called the motional arm and represent the mechanical behavior of the crystal element. C_o represents the electrical behavior of the crystal element and holder.

C_s represents the motional arm capacitance measured in Farads. It represents the elasticity of the quartz, the area of the electrodes on the face, thickness and shape of the quartz wafer.

L_s represents motional arm inductance measured in Henrys. It represents the vibrating mechanical mass of the quartz in motion.

R_s represents the resistance measured in ohms. It represents the real resistive losses within the crystal.

C_o represents the shunt capacitance measured in Farads. It is the sum of the capacitance due to the electrodes on the crystal plate plus stray capacitance due to the crystal holder and enclosure.

Let's look at the following example crystal's electrical specification that you would find in a crystal data sheet. See Table 1.

Parameter	Value
Frequency (MHz)	4.193
Rs (ohm)	100 (max.)
Co (pF)	16 (max.)

Table 1 Electrical Specification of Crystal

When purchasing a crystal, the designer specifies a particular frequency along with load capacitance as well as mode of operation. Notice that the motional parameters, Cs, Ls, Rs are not typically given in data sheet. You must get them from the crystal manufacturer or measured yourself.

3. Types of Connection

3.1 Connection to Crystal Oscillator

Figure 3.1 shows a typical method of connecting a crystal oscillator.

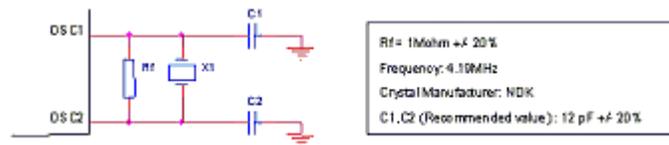


Figure 3.1 Connection to Crystal Oscillator

3.2 Connection to Ceramic Oscillator

Figure 3.2 shows a typical method of connecting a ceramic oscillator.

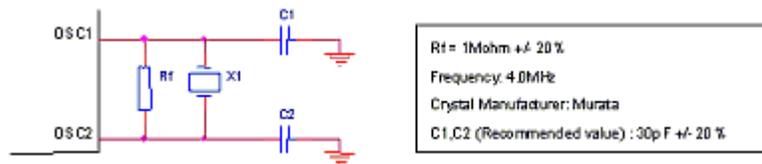


Figure 3.2 Connection to Ceramic Oscillator

4. Selection of Components

There are several factors that go into the selection and arrangement of these external components. Some of these are: Amplifier Gain, Desired Frequency, Resonant Frequency(s) of the crystal, Temperature of Operation, Supply Voltage and its range, Start Up Time, Stability, Crystal Life, Power Consumption, Simplification of the Circuit, Use of the Standard Components (as few as possible).

5. Determining Best Values for Crystal, C1, C2, Rf and Rd

Crystals are usually selected by their parallel resonant frequency only. The H8/300L SLP series microcomputer utilizes a parallel oscillator circuit that requires a parallel resonant crystal. A specific range of load capacitance would need to be used in order to oscillate the crystal closest to the desired frequency. However, it may be necessary to juggle these values in order to achieve other benefits.

C1 & C2 are the load capacitance and they provide the phase lag of 180°. They should also be initially selected based on the load capacitance as suggested by the crystal manufacturer and also the values suggested in the specific device hardware manual. However, this can only be used as a starting point for your fine-tuning.

Ideally, the lowest capacitance is chosen (within the range of the recommended crystal load preferably) that will oscillate at the highest temperature and lowest VCC that the circuit will be expected to perform. High temperature and low VCC both have a limiting effect on the loop gain, such that if the circuit functions all these extremes the designer can be more assured of proper operation at other temperatures and supply voltages.

Besides loading the crystal for proper frequency response, these capacitors can also have the affect of lowering loop gain if their value is increased. C2 can be selected to affect the overall loop gain of the circuit.

However, C values that are too high can store and dump too much current through the crystal so C1 & C2 should not become too large.

Rf is the feedback resistance, and it provides negative feedback around the inverter in order to put it in the linear region, so the oscillation will start when power is applied. If the value of Rf is too large, and if the insulation resistance of the input inverter is accidentally decreased, oscillation will stop due to the loss of loop gain. Also, with large Rf, noise from other circuits can be introduced into the oscillation circuit. Obviously, if Rf is too small, loop gain will be low. An Rf of 1MΩ is generally used with crystal or ceramic oscillator.

Rd is a series resistor for damping purpose, it is selected to prevent overdriving the crystal. It is often not needed if C1 & C2 are selected properly.

6.2 How to calculate a “Hz to ppm” tolerance

The equation for calculating from Hz to ppm :

$$\text{Tolerance in Hz/Frequency in MHz} = \text{Result in ppm}$$

Example: How many ppm is +/- 200Hz for a 20.0MHz crystal?

$$\text{Max} = +200\text{ppm} / 20\text{MHz} = +10\text{ppm}, \text{ or } 20000000\text{Hz} + 200\text{Hz} = 20000200\text{Hz}$$

$$\text{Min} = -200\text{ppm} / 20\text{MHz} = -10\text{ppm}, \text{ or } 20000000 \text{ Hz} - 200\text{Hz} = 19999800\text{Hz}$$

7. Notes on Oscillator Stabilization Time

The following description is based on the H8/38024/F microcomputer.

Oscillator stabilization time is defined as the time from the point at which the system clock oscillator oscillation waveform starts to change when an interrupt is generated, until the amplitude of the oscillation waveform increases and the oscillation frequency stabilizes.

Wait time is defined as the time required for the CPU and peripheral functions to begin operating after the oscillation waveform frequency and system clock have stabilized. To give an example on how to set this wait time, we refer to the H8/38024/F microcomputer; simply set the standby timer select bits 2 to 0 [STS2 to STS0] [bits 6 or 4 in the system control register (SYSCR1)].

[1] – When standby mode, watch mode, or sub-active mode is cleared by an interrupt or reset, and a transition is made to active (high-speed/medium-speed) mode, the oscillation waveform begins to change at the point when the interrupt is accepted. Therefore, when an oscillator element is connected in standby mode, watch mode, or sub-active mode, since the system clock oscillator is halted, the time from the point at which this oscillation waveform starts to change till the amplitude of the oscillator waveform increases and the oscillation frequency stabilizes, this refer to the oscillation stabilization time required. Please refer to Figure 6.1.

[2] – The oscillation stabilization time in the case of these state transitions is the same as the oscillation time at power-on where the power supply voltage reaches the prescribed level until the oscillation stabilizes. This is specified in the AC characteristics by Oscillation Stabilization time *trc*.

[4] – A wait time of at least 8-states is necessary in order for the CPU and peripheral functions to operate normally.

Thus the time required from interrupt generation until operation of CPU and peripheral functions is the sum of the oscillation stabilization time and wait time. This total time is called oscillation stabilization wait time and expressed by following equation:

$$\text{Oscillation Stabilization Wait Time} = [\text{trc} + (8 \text{ to } 16,384 \text{ states})]$$

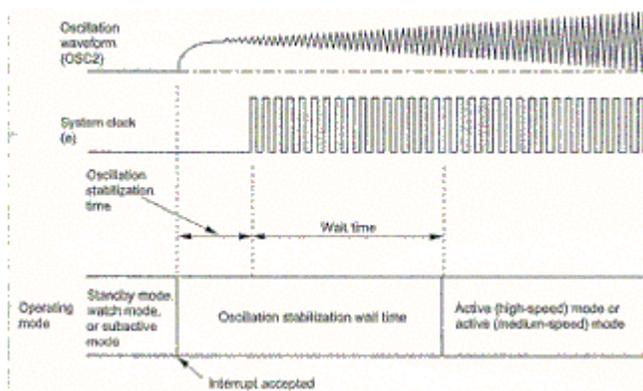


Figure 6.1 Oscillation Stabilization Time

8. Notes on Crystal Oscillator Element

This section highlights the various concerns for crystal oscillator element but excludes ceramic oscillator element.

When a microcomputer operates, the internal power supply potential fluctuates slightly in synchronization with the system clock.

Depending on the individual crystal oscillator element characteristics, the oscillator waveform amplitude may not be sufficiently large immediately after the oscillation stabilization wait time, making the oscillation waveform susceptible to influence by fluctuation in the power supply potential.

In this state, the oscillation waveform may be disrupted, leading to an unstable system clock and erroneous operation of the microcomputer.

If erroneous operation occurs, change the setting of standby timer select bits 2 to 0 (STS2 to STS0) (bits 6 to 4 in system control system register) to give a longer wait time.

If the same kind of erroneous operation occurs after a reset as after a state transition, hold the RESET(_RES) pin low for a longer period.

9. Arrangement of Crystals & Board Design

9.1 Arrangement of Crystals

Oscillator characteristics are closely related to board design and should be carefully evaluated by the user. Figure8.1 provide an example of the arrangement of the components. Oscillator circuit constants will differ depending on the oscillator element, stray capacitance in the interconnecting circuits, and other factors.

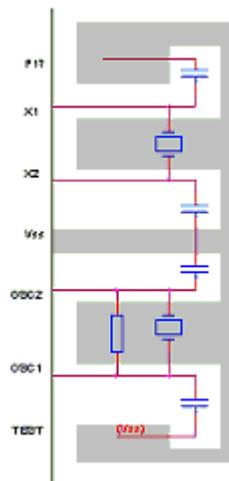


Figure 8.1 Arrangement of Components

9.2 Board Design

When generating clock pulses by connecting a crystal or ceramic oscillator, one needs to take note of the following points:

- Avoid running signal lines close to the oscillator circuit, since the oscillator may be adversely affected by induction current. [See Figure 8.2]
- The board should be designed so that the oscillator and load capacitors are located as close as possible to pins OSC1 and OSC2.

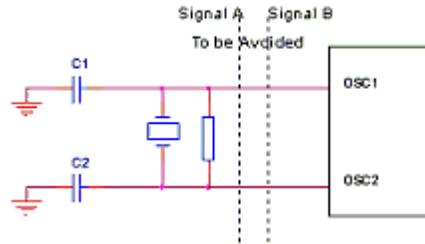


Figure 8.2 Signal Lines

10. Notes on Unused Clock Pins

For unused clock pins such as the sub-clock pins, X1 & X2, connect X1 pin to Ground and leave X2 pin open.

11. Notes on External Clock Input

For external clock connection to system (main) clock, connect an external clock to pin OSC1 and leave OSC2 open. For external clock connection to sub-clock, connect an external clock to pin X1 and leave X2 open. Ensure that the duty cycle is between 45% ~ 55% for proper operation.

12. Final Notes

The most difficult time for the oscillator to start up is waking up from a halted state. This is because the load capacitance has partially charged to some quiescent value and phase differential at wake up is minimal. Thus more time is required for stable oscillation. Also remembers that low voltage, high temperature imposes limitations on loop gain, which in turn affects start up.

An oscillator circuit depends on some stray noise to start up. Usually the power up process will provide this, but if the processor is halted, the oscillator will have to start up on wake up without power up ramp (although some noise is created internally by the wake up logic).

Some suggestions to help start up are using of a cheap R_s resistor which made of carbon film or carbon composition resistor, as it generate some amount of white noise which when placed in the crystal oscillator path can assist start up; Increase C2 over C1 to increase phase shift and help start up, especially at low frequencies.

However, it is also possible for a circuit with too much gain not being able to start up. This usually occurs when using a low frequency crystal, like 32KHz, since at high frequencies; the high gain is dissipated more easily by the load capacitance.

Lastly, if you would like to have the circuit oscillate at resonant frequency to be as accurate as possible, you may better served by adding a R_s to the circuit as needed and keep the capacitor values closer to the load capacitance suggested by the crystal manufacturer.

Reference

1. H8/38024 Series, H8/38024F-ZTAT™ Hardware Manual
2. www.embedded.com

Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	Sep.03	-	First edition issued

Keep safety first in your circuit designs!

1. Renesas Technology Corporation puts the maximum effort into making semiconductor products better and more reliable, but there is always the possibility that trouble may occur with them. Trouble with semiconductors may lead to personal injury, fire or property damage. Remember to give due consideration to safety when making your circuit designs, with appropriate measures such as (i) placement of substitutive, auxiliary circuits, (ii) use of nonflammable material or (iii) prevention against any malfunction or mishap.

Notes regarding these materials

1. These materials are intended as a reference to assist our customers in the selection of the Renesas Technology Corporation product best suited to the customer's application; they do not convey any license under any intellectual property rights, or any other rights, belonging to Renesas Technology Corporation or a third party.
2. Renesas Technology Corporation assumes no responsibility for any damage, or infringement of any third-party's rights, originating in the use of any product data, diagrams, charts, programs, algorithms, or circuit application examples contained in these materials.
3. All information contained in these materials, including product data, diagrams, charts, programs and algorithms represents information on products at the time of publication of these materials, and are subject to change by Renesas Technology Corporation without notice due to product improvements or other reasons. It is therefore recommended that customers contact Renesas Technology Corporation or an authorized Renesas Technology Corporation product distributor for the latest product information before purchasing a product listed herein.
The information described here may contain technical inaccuracies or typographical errors. Renesas Technology Corporation assumes no responsibility for any damage, liability, or other loss rising from these inaccuracies or errors.
Please also pay attention to information published by Renesas Technology Corporation by various means, including the Renesas Technology Corporation Semiconductor home page (<http://www.renesas.com>).
4. When using any or all of the information contained in these materials, including product data, diagrams, charts, programs, and algorithms, please be sure to evaluate all information as a total system before making a final decision on the applicability of the information and products. Renesas Technology Corporation assumes no responsibility for any damage, liability or other loss resulting from the information contained herein.
5. Renesas Technology Corporation semiconductors are not designed or manufactured for use in a device or system that is used under circumstances in which human life is potentially at stake. Please contact Renesas Technology Corporation or an authorized Renesas Technology Corporation product distributor when considering the use of a product contained herein for any specific purposes, such as apparatus or systems for transportation, vehicular, medical, aerospace, nuclear, or undersea repeater use.
6. The prior written approval of Renesas Technology Corporation is necessary to reprint or reproduce in whole or in part these materials.
7. If these products or technologies are subject to the Japanese export control restrictions, they must be exported under a license from the Japanese government and cannot be imported into a country other than the approved destination.
Any diversion or reexport contrary to the export control laws and regulations of Japan and/or the country of destination is prohibited.
8. Please contact Renesas Technology Corporation for further details on these materials or the products contained therein.