

SofTec Microsystems

Application Note AN003: Using the Trimming Feature with inDART-HC08

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This Application Note describes the how to take advantage of the internal oscillator available on some devices of the Motorola HC08 family when using SofTec Microsystems inDART-HC08 in-circuit debugger/programmer.

This Application Note assumes that the user is familiar with inDART-HC08 and with the main features of the HC08 family. Full documentation on these topics is available in device-specific datasheets and in the inDART-HC08 user's manual.

0. Overview

In the HC08 family there are two main categories of devices featuring an internal oscillator.

The first category includes devices with a calibratable (trimmable) internal oscillator (internal oscillator which, in turn, can be used to generate the device's internal bus clock).

The second category includes devices with a non trimmable internal oscillator (and consequently, this internal oscillator is not suggested for generating the device's internal bus clock).

The internal oscillator of the devices belonging to the first category (e.g. MC68HC908QT/QY/QL/QB/QF, MC68HC908KX, MC68HC908GT) is designed to be used without additional external components (no crystals, resonators, or passive components are required), thus reducing production costs and eliminating the need for dedicated clock circuitry microcontroller pins.



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The downside of utilizing the internal clock is that the frequency is not as accurate as that of a crystal or resonator and this limitation has to be taken into account in the system design. Parametric spreads during manufacture result in an overall un-trimmed accuracy of $\pm 25\%$ from the specified nominal frequency. In many applications this may be good enough and no trimming will be required. Sometimes, however, greater accuracy will be required and through the trimming procedure it is possible to improve the accuracy to within $\pm 0.3\%$.

This is done by calculating and writing an appropriate value in a dedicated RAM location. This operation must be done after every reset, since the appropriate trimming value may change from device to device, depending on conditions such as desired frequency (some devices can generate more than one internal frequency), power supply voltage, temperature, etc.

Some devices (e.g. MC68HC908QT/QY) are factory pre-programmed with a default trimming value in a dedicated FLASH location (specified in the datasheet). However, due to the different real-world conditions of the user's system, it is always suggested to recalibrate the internal oscillator to reflect the actual working conditions.

Since the trimming value is programmed into a FLASH location, every time the device is mass-erased the trimming value is lost.

This Application Note describes how inDART-HC08 can take advantage of the internal oscillator present in the above mentioned devices (not only when programming the device, but also during application development, allowing the user to use the internal oscillator as the device's clock source). Additionally, inDART-HC08, by using the target device's internal oscillator, allows the external oscillator pins to be freed for user purposes.

1. Internal Oscillator Peripherals

Devices which feature a trimmable internal oscillator have one of the following peripherals:

1. OSC (Internal Oscillator) peripheral (e.g. MC68HC908QT/QY);
2. ICG (Internal Clock Generator) peripheral (e.g. MC68HC908KX/GT).

The Internal Oscillator Module (OSC) is present on those devices which do not require specific working frequencies—where the important thing is just to provide the microcontroller with an internal bus clock without additional components. This peripheral is therefore able to generate a single, fixed clock frequency or, depending on the device, a clock frequency selectable among few different values.

The following table summarizes the frequencies available from the OSC module of some devices.

Device	OSC Frequency
MC68HC908QT/QY	3.2MHz
MC68HC908QB	1MHz (default), 2MHz, 3.2MHz
MC68HC908QL	3.2MHz (default), 6.4MHz
MC68HLC908QT/QY	1MHz

The FLASH location suggested by Motorola where to save the trimming value is 0xFFC0.

The Internal Clock Generator Module (ICG) features a more powerful clock generator. Besides the internal oscillator, it provides the versatility of a PLL in that the clock frequency is programmable over a wide range (307.2KHz to 39MHz in multiples of 307.2KHz) and can be changed as required during normal code execution. As with all HC08s, the bus frequency is a quarter of this clock frequency. Motorola does not suggest any FLASH location where to save the trimming value.

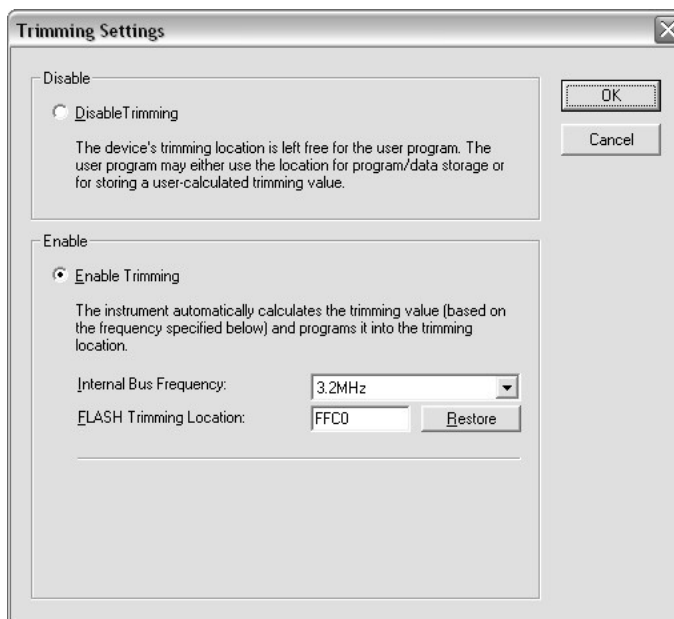
2. inDART-HC08 and Devices with Internal Oscillator

inDART-HC08 allows the user to enable the internal oscillator calibration (trimming) through the *Trimming Settings* dialog box.

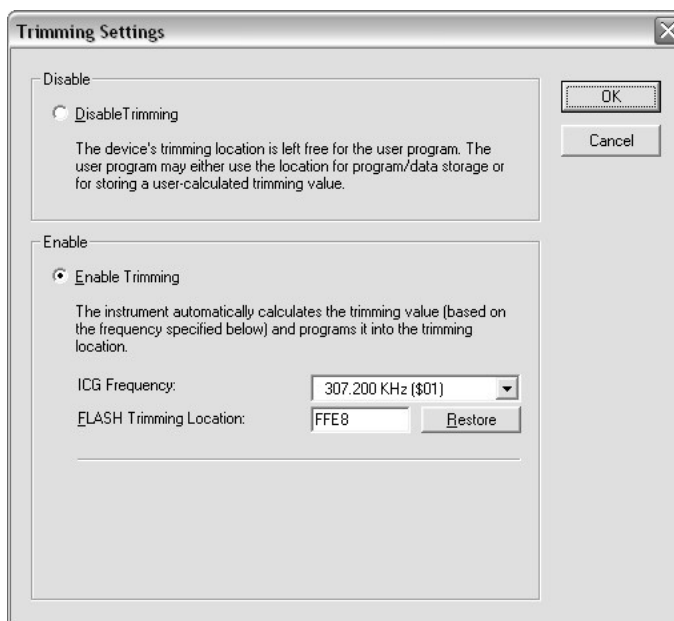
The *Trimming Settings* dialog box is specific for the selected device. If the selected device incorporates the OSC module, then the *Trimming Settings* dialog box allows the user to select the OSC frequency to be calibrated (**Internal Bus Frequency**, if more than one internal bus clock frequency is available on that device).

If, instead, the selected device incorporates the ICG module, then the *Trimming Settings* dialog box allows the user to select the ICG frequency to be calibrated (**ICG Frequency**), with the corresponding multiplier.

In both cases, it is possible to specify whether to save the calculated trimmed value in the default location (the location suggested either by Motorola or SofTec Microsystems, restorable at any moment via the **Restore** button) or into a different location (**Flash Trimming Location**).



Trimming Settings Dialog Box for OSC Module Devices



Trimming Settings Dialog Box for ICG Module Devices

The selection of the frequency allows for a finer oscillator calibration. Care must be taken in choosing the frequency properly: the frequency must be compatible with the device's working voltage (especially when working with voltages less than 5V).

The calculation of the trimmed value and its writing to the specified address are carried out transparently when programming the device (or during download when debugging).

If the user doesn't want to reserve a FLASH location for the calibration, but use it as "normal" memory instead, it is possible to disable the trimming feature (**Disable Trimming**) and therefore free the trimming FLASH location for application purposes.

As already pointed out, although some devices are factory pre-programmed with a default trimming value, it is always suggested to recalibrate the internal oscillator to reflect the actual working conditions.

Again, since the trimming value is programmed into a FLASH location, every time the device is mass-erased the trimming value is lost.

In order to program or erase a device it is necessary to execute a monitor mode entry. Various monitor mode entry methods exist, each with its advantages and disadvantages. inDART-HC08 always uses the **Normal Monitor Mode**. This method has been chosen for its ability to access the device under any condition: it makes it possible, for example, to erase a programmed device or to program a blank device.

On the other hand, the Normal Monitor Mode requires the device to have an external clock and that all of the MON08 lines are properly tied to the device. Consequently, even if the user application runs with the internal oscillator, it is still necessary to implement an external clock source in the target board. This external clock source is required only during erasing/programming.

inDART-HC08 can take advantage of the internal oscillator not only when programming the device, but also during application development, allowing the user to use the internal oscillator as the device's clock source. By using the internal oscillator, inDART-HC08 can (after the download phase) free all of the MON08 lines (exception made for the serial communication line, **COM**). By providing the target board with appropriate jumpers, it is therefore possible to make extra I/O pins available for the user application, pins that would have been otherwise reserved. These I/O pins, anyway, must be reconnected to the MON08 connector at every program download. The Communication Settings dialog box shows the I/O lines that must be tied (for a given device) to the MON08 connector.

By taking advantage of the internal oscillator, inDART-HC08 can be profitably used on those devices with a low pin count, such as MC68HC908QT family devices. On a MC68HC908QT4, for example, two out of eight pins are required for the power supply, one for the external oscillator, and five for the MON08 connector. By using the internal oscillator, however, inDART-HC08 frees (after the download phase) four MON08 pins plus the external oscillator pin.

3. Programming with DataBlaze

The DataBlaze programming utility automatically calculates the internal oscillator calibration value and saves the calculated value to the specified FLASH location.

To enable the trimming algorithm (after selecting the device to be programmed), select **Operations > Communication Settings** from DataBlaze's main menu, and then click the "**Trimming Settings**" button. The *Trimming Settings* dialog box will open, allowing the user to enable the trimming algorithm and to set the trimming frequency and store location.

DataBlaze automatically detects the device's internal oscillator peripheral (OSC or ICG) and opens the appropriate *Trimming Settings* dialog box, thus allowing the user to select among consistent parameters.

As already mentioned, the trimming value is calculated (and stored into the device's FLASH memory) only during device programming, by enabling the "**Program TRIMLOC**" check box either in the Program or Auto operations. Later, the trimmed value can be read back by enabling the "**Read TRIMLOC**" check box in the Read operation.

Since inDART-HC08 uses the Normal Monitor Mode, an external clock source is necessary to enter this monitor mode (the clock signal provided by inDART-HC08 can be used for this purpose).

4. Debugging with the Internal Oscillator

As already described, inDART-HC08 offers two main advantages over other HC08 in-circuit emulators. Firstly, it allows for debugging using the device's internal oscillator; and secondly (when the internal oscillator is used), after entering Normal Monitor Mode, it frees all of the MON08 lines (exception made for the COM line), making them available for the user application.

To better understand how all this is done, a deep knowledge of the HC08 monitor is required (reading device-specific datasheets is suggested). The following points outline some key ideas.

1. During program download, the device's monitor entry is executed in Normal Monitor Mode, since this is the only method that allows to erase/program the device under any condition (blank or programmed). To use the Normal Monitor Mode, however, some lines must be set appropriately at power up:
 - The IRQ line must be driven to V_{TST} ;
 - The RST line must be driven to V_{DD} or V_{TST} ;
 - The OSC1 line must be driven by an external clock signal;
 - The bidirectional PTA0 line is used for the asynchronous communication with inDART-HC08;
 - Two or more lines (depending on the device) must be driven to a particular logic level.
2. Program download is done each time the user enters a debug session. Program download consists of device mass erasing followed by device programming with user code.
3. While the IRQ line is held at V_{TST} , the Configuration Registers (CONFIG1 and CONFIG2, writable only once after reset) settings are by-passed (therefore the internal oscillator cannot be used), the RST pin acts as a RESET pin and the OSC1 pin must be connected to an external clock source. After the IRQ line voltage goes below V_{TST} , the Configuration Registers settings become active, and consequently the functions associated to the corresponding pins (IRQ, RST and OSC1) change.
4. inDART-HC08 uses the IRQ line to stop the user's program execution. In order for this to work, registers must be properly configured, and the IRQ interrupt vector must be properly handled.

When inDART-HC08 drives the IRQ line to GND, the Configuration Registers settings become active immediately.

On devices with the OSC module, inDART-HC08 configures the Configuration Register 1 (CONFIG1, so that the COP is disabled), the Oscillator Trim Register (OSCTRIM, with the calculated trimmed value), and the Oscillator Status and Control Register (OSCSC, present on devices with more than one internal oscillator frequency).

On devices with the ICG module, inDART-HC08 configures the Configuration Register 1 (CONFIG1, so that the COP is disabled), the ICG Control Register (ICGCR) and ICG Multiplier Register (ICGMR), and the ICG Trim Register (ICGTR, with the calculated trimmed value).

After reset, the Configuration Register 2 (CONFIG2) enables by default the internal oscillator. The user should not change the clock source, otherwise communication between inDART-HC08 and the target device will stop.

After reset, the pins listed at point 1 are shared by the user application, the MON08 connector and the external oscillator. This situation may lead to short circuits on the target board. This is why the user should place jumpers in the target board so that the MON08 lines and the external oscillator can be connected/disconnected to/from the target device as required, together with the appropriate circuitry (pull-ups, pull-downs, etc.).

inDART-HC08 comes to help to the user by displaying appropriate messages before to enter the Normal Monitor Mode (when, that is, it is necessary to connect the MON08 lines and the external clock to the device) and before to switch to using the internal oscillator (and therefore the MON08 lines and the external clock line can be used by the user application).

Two drawbacks:

1. Since inDART-HC08 uses the IRQ pin to halt the user program execution, if the IRQ pin is freed for the user application, inDART-HC08 can no longer stop the user program execution. inDART-HC08 detects this inability to stop the user program (by means of a feedback mechanism) and it generates a POR instead.
2. The same thing holds for the RST line: if this line is freed for the user application, every reset operation issued by inDART-HC08 generates a POR instead.

Two additional remarks must be pointed out:

1. On some devices (e.g. MC68HC908KX), the RST line acts as a reset only if the IRQ pin is driven to V_{TST} . Consequently, when using the internal oscillator, the user must not drive the IRQ pin to V_{TST} ; doing so will result in resetting the device.
2. As described on section 1, the ICG module allows to change the internal clock frequency at any time. If the internal clock frequency changes, the internal bus frequency changes, too, and therefore the communication speed between inDART-HC08 and the target device

changes. inDART-HC08, however, cannot recognize this change of bus frequency, and this results in communication errors.

Here below are described the operations that inDART-HC08 performs during program download, during the first run command (run, step, etc.) and during the reset or halt command.

DOWNLOAD SEQUENCE

- Message box: “The instrument will now enter the Normal Monitor Mode.” User must connect the appropriate device pins to the MON08 connector and to the external oscillator before to click the “OK” button.
- Microcontroller power-up and monitor mode entry in Normal Monitor Mode.
- Device mass erase.
- Trimming location programming.
- Device programming.

FIRST RUN COMMAND SEQUENCE

- Registers are set to use the device’s internal oscillator.
- IRQ line driven to GND.
- Message box: “The target microcontroller will now use the internal oscillator.” User must disconnect the external oscillator and, if used by the application, the MON08 lines (the COM line must be kept connected to the MON08 connector) before to click the “OK” button.
- Run command execution.

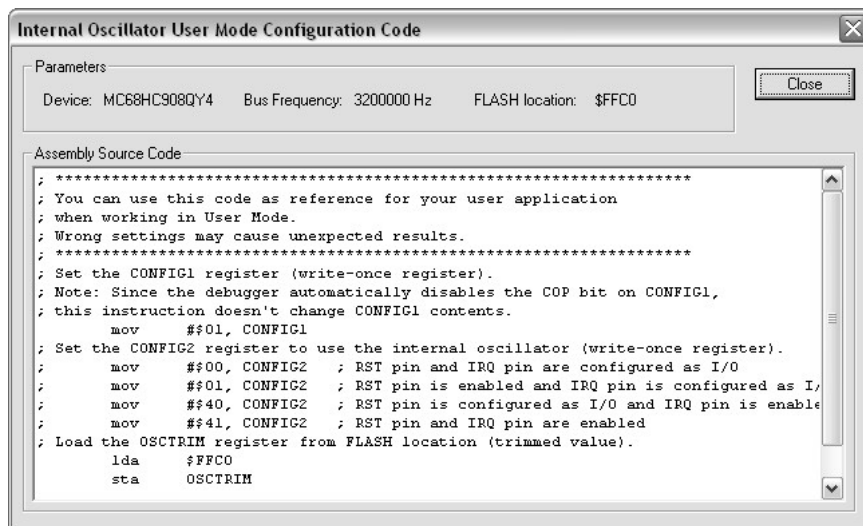
RESET COMAND SEQUENCE

- Message box: “The instrument will now enter the Normal Monitor Mode.” User must connect the appropriate device pins to the MON08 connector and to the external oscillator before to click the “OK” button.
- Microcontroller power-up and monitor mode entry in Normal Monitor Mode.

During debug, trimming settings are handled via a *Trimming Settings* dialog box similar to that explained in section 2. This dialog box can be accessed by selecting **inDART-HC08 > MCU Configuration > “Communication Settings” button > “Trimming Settings” button** from the CodeWarrior’ main menu.

The *Trimming Settings* dialog box available in CodeWarrior is identical to the one describes in section 2, but has an additional **“Use the Internal Oscillator”** check box. If checked, the debug will be carried on using the device’s internal oscillator and, when prompted, the user must connect/disconnect the MON08 lines and the external clock signal as explained above.

Additionally, by clicking the “**Internal Oscillator Configuration Code**” button, a dialog box will open showing the Assembly code you should copy and paste into your application when working in User Mode. This code is useful to correctly initialize the appropriate registers to work with the internal oscillator and the IRQ and RST pins (if used by the application). This Assembly code is required only when working in User Mode, that is, without inDART-HC08. inDART-HC08 automatically configures the microcontroller, as described above.

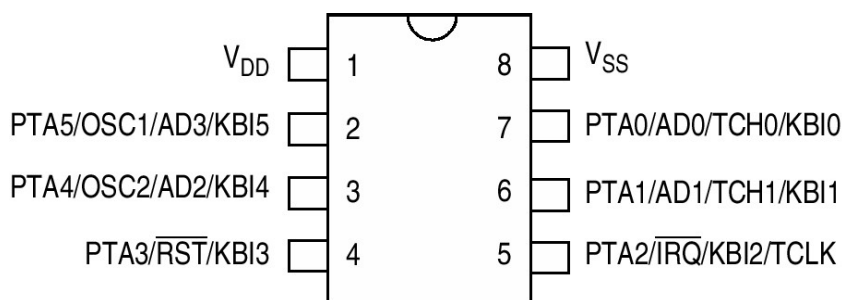


Internal Oscillator Configuration Code Dialog Box for the MC68HC908QY4

Trimming takes place only during code download. Any change to the trimming settings (via the *Trimming Settings* dialog box) takes place when re-entering a debug session.

The following two sections contain two examples of debug sessions using the internal oscillator: one with a device which features the OSC module (MC68HC908QT4) and one with a device which features the ICG module (MC68HC908KX8).

5. Debugging Session with MC68HC908QT4



MC68HC908QT4 Pinout

The MC68HC908QT4 microcontroller is a device with only eight pins. As already shown, when working in Normal Monitor Mode (with an external oscillator) all of the device’s pins are reserved:

- V_{DD} e V_{SS} are the power supply pins;
- PTA5/OSC1 is connected to the external clock source;
- PTA4/OSC2 must be tied to GND (to enter the Normal Monitor Mode);
- PTA3/RST is set as a reset line (until IRQ is tied to V_{TST});
- PTA2/IRQ must be tied to V_{TST} ;
- PTA1 must be tied to V_{DD} (to enter the Normal Monitor Mode);
- PTA0 is the bi-directional MON08 communication line.

Here below is described what happens during debug when the **“Use the Internal Oscillator”** option is checked in the *Trimming Settings* dialog box.

During program download the device’s pins must be connected as outlined above. After program download (and if the MON08 TGT lines are correctly connected), the PTA1 and PTA4 lines are automatically “freed” by inDART-HC08. The first time a run command is issued (run, single step, etc.) a message box appears: “The target microcontroller will now use the internal oscillator.” From this moment on, the PTA2/IRQ, PTA3/RST and PTA5/OSC1 lines can be freed (via jumpers) as well.

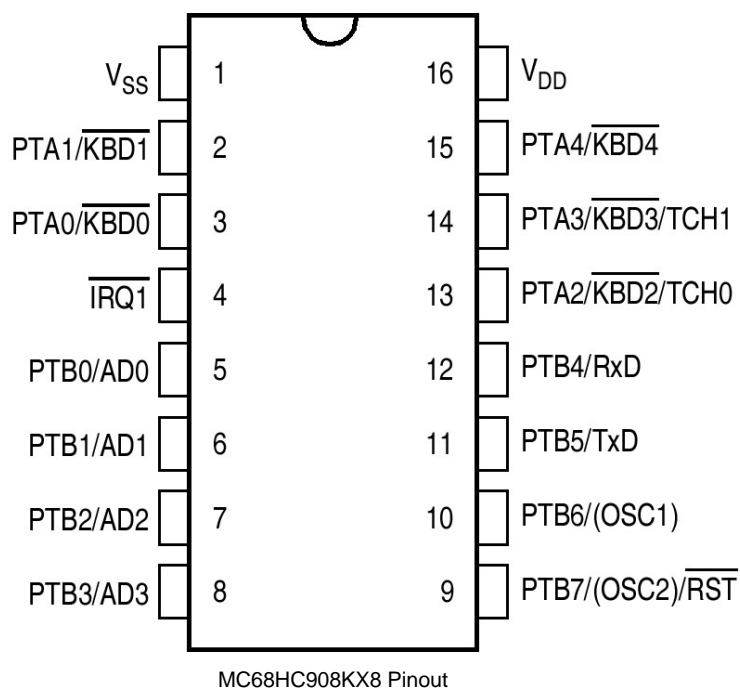
The user application must now correctly set the Configuration Register 2 (CONFIG2). This register (writable only once after reset) determines the status of the PTA2/IRQ, PTA3/RST and PTA5/OSC1 pins. In particular, the OSCOPT[0..1] bits must be set to 0, in order to enable the internal oscillator.

As mentioned earlier, if the IRQ/RST pins are freed by the user application, stop/reset commands (respectively) will result in a device POR. If the IRQ line is freed by the user application, and the user wants to stop the program execution, it is suggested to insert a breakpoint at the desired location.

Some remarks:

1. If the IRQ line is freed by the user application (IRQEN bit of CONFIG2 register set to 0), it works only as an input.
2. The Configuration Register 1 (CONFIG1) is automatically set by inDART-HC08 so that the COP is disabled. Since the CONFIG1 register can be written only once after reset, any other attempt to modify it by the user application will not succeed.
3. The Oscillator Status Register (OSCTAT) is automatically set by inDART-HC08 to the specified frequency.
4. The Oscillator Trim Register (OSCTRIM) is automatically set by inDART-HC08 to the calculated trimmed value.

6. Debugging Session with MC68HC908KX8



The MC68HC908KX8 microcontroller has a built-in ICG peripheral which can generate an internal clock signal from 307 KHz to 39 MHz.

To enter the Normal Monitor Mode the following pins must be used:

- IRQ1 must be tied to V_{TST} ;
- PTB7/OSC2/RST is set as a reset line (until IRQ is tied to V_{TST}) and must be held to V_{DD} ;
- PTB6/OSC1 is connected to the external clock source;
- PTB1 must be tied to GND (to enter the Normal Monitor Mode);
- PTB0 must be tied to V_{DD} (to enter the Normal Monitor Mode);
- PTA1 must be tied to GND (to enter the Normal Monitor Mode);
- PTA0 is the bi-directional MON08 communication line.

Here below is described what happens during debug when the **“Use the Internal Oscillator”** option is checked in the *Trimming Settings* dialog box.

During program download the device’s pins must be connected as outlined above. After program download (and if the MON08 TGT lines are correctly connected), the PTA1, PTB0 and PTB1 lines are automatically “freed” by inDART-HC08. The first time a run command is issued (run, single step, etc.) a message box appears: “The target microcontroller will now use the internal oscillator.” From this moment on, the PTB7/OSC2/RST, PTB6/OSC1 and IRQ1 lines can be freed (via jumpers) as well.

The user application must now correctly set the Configuration Register 2 (CONFIG2). This register (writable only once after reset) determines the status of the PTB7/OSC2/RST and PTB6/OSC1 pins. In particular, the EXTCLKEN bit must be set to 0, in order to enable the internal oscillator.

As mentioned earlier, if the IRQ/RST pins are freed by the user application, stop/reset commands (respectively) will result in a device POR. If the IRQ line is freed by the user application, and the user wants to stop the program execution, it is suggested to insert a breakpoint at the desired location.

Some remarks:

1. The IRQ line, if freed by the user application, works only as an external interrupt.
2. The RST line does not act as a reset if the IRQ voltage drops below V_{TST} .
3. The Configuration Register 1 (CONFIG1) is automatically set by inDART-HC08 so that the COP is disabled. Since the CONFIG1 register can be written only once after reset, any other attempt to modify it by the user application will not succeed.
4. ICG registers are automatically set by inDART-HC08 in order to obtain the desired frequency. In some cases the obtained frequency may differ from the desired frequency; this because inDART-HC08 always favors frequencies that result in valid MON08 communication baud rates. During debug it is not suggested to modify ICG registers, since this may result in communication problems between inDART-HC08 and the target device.
5. The ICG Trim Register (ICGTR) is automatically set by inDART-HC08 to the calculated trimmed value.

7. Troubleshooting

The calibration value calculated and programmed into the microcontroller may be wrong.

This warning is displayed when the trimming algorithm returns an invalid value (a value out of the valid calibration range). This may happen if the device's internal oscillator is defective.

When using the internal oscillator, the device seem to reset.

This problem may occur when the IRQ line is accidentally driven to V_{TST} by the user application while the RST line is driven to GND. Under this condition the RST line acts as a reset line, and being held at GND, resets the microcontroller.

MON08 communication loss.

The user should verify the correct setting of the CONFIG2, OSCTRIM and OSCSTAT registers (for devices which feature the OSC module) or the correct setting of the CONFIG2, ICGTR, ICGCR and ICGMR registers (for devices which feature the ICG module). Additionally, the user application should not change the internal bus frequency.

8. References

AN2498/D - Initial trimming of the MC68HC908 ICG.
Microcontroller-specific datasheets.
inDART-HC08 user's manual.