NXP Semiconductors
User's Guide

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WCT1012VLF/WCT1013VLH Consumer MP-A11 (WCT-15W1CFFPD) V1.0 Wireless Charging Application User's Guide

1. Key features

The WCT1012VLF/WCT1013VLH Consumer MP-A11_Rev1.0 (MP-A11_Rev1_SCH-32212_B, MP-A11_Rev1_LAY-32212_B) wireless charging TX demo (WCT-15W1CFFPD) is used to wirelessly transfer power to a charged device. The charged device can be any electronic device equipped with a dedicated Qi wireless charging receiver.

The main parameters of the Wireless Charging Transmitter (WCT) are:

- Support for QC 3.0 and USB PD 2.0/3.0 input. The input voltage ranges from 5 to 19 V DC.
- The input voltage can drop down to 5 V DC during the start-stop function.
- The nominal power delivered to the receiver is 15 W, up to 22 W (at the output of the receiver) and compatible with a 5 W receiver.
- Designed to meet the Qi 1.2.4 specification.
- Operation frequency: 120 kHz ~ 130 kHz (the default is 127.772 kHz) for Qi devices.

Contents

2. Hardware setup

2.1. Package contents

1. WCT Consumer MP-A11 (WCT-15W1CFFPD) demo board.

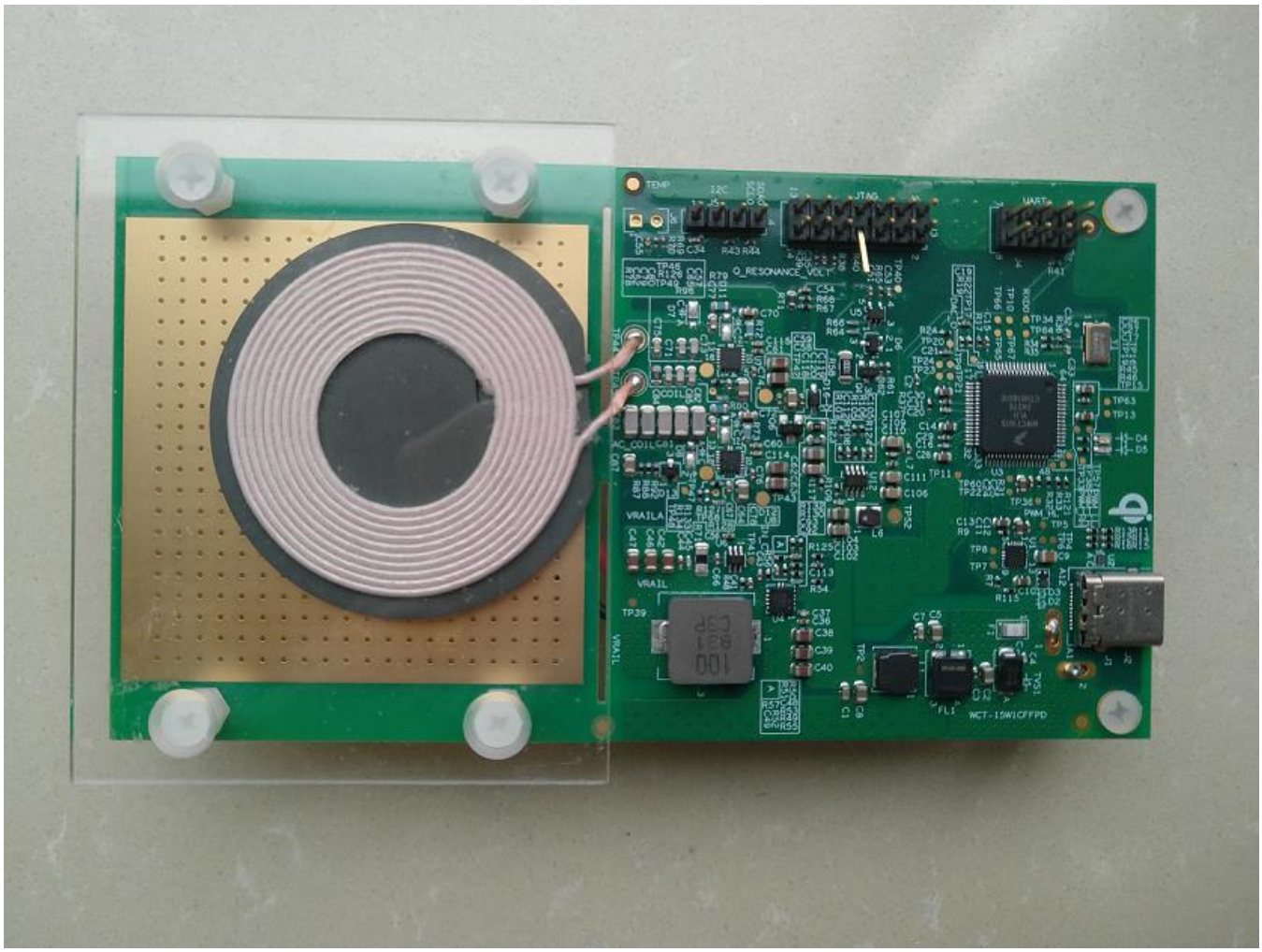


Figure 1. MP-A11 (WCT-15W1CFFPD) demo board

2.2. Board description

The WCT board is powered through the on-board power connector.

The connectors on the upper-middle part of the board provides the JTAG connection for programming and debugging and 1xUART for the FreeMASTER tool connection for the debug option and console connection. The I^2C connector is placed on the upper left-hand side of the board.

Figure 2 shows the device.

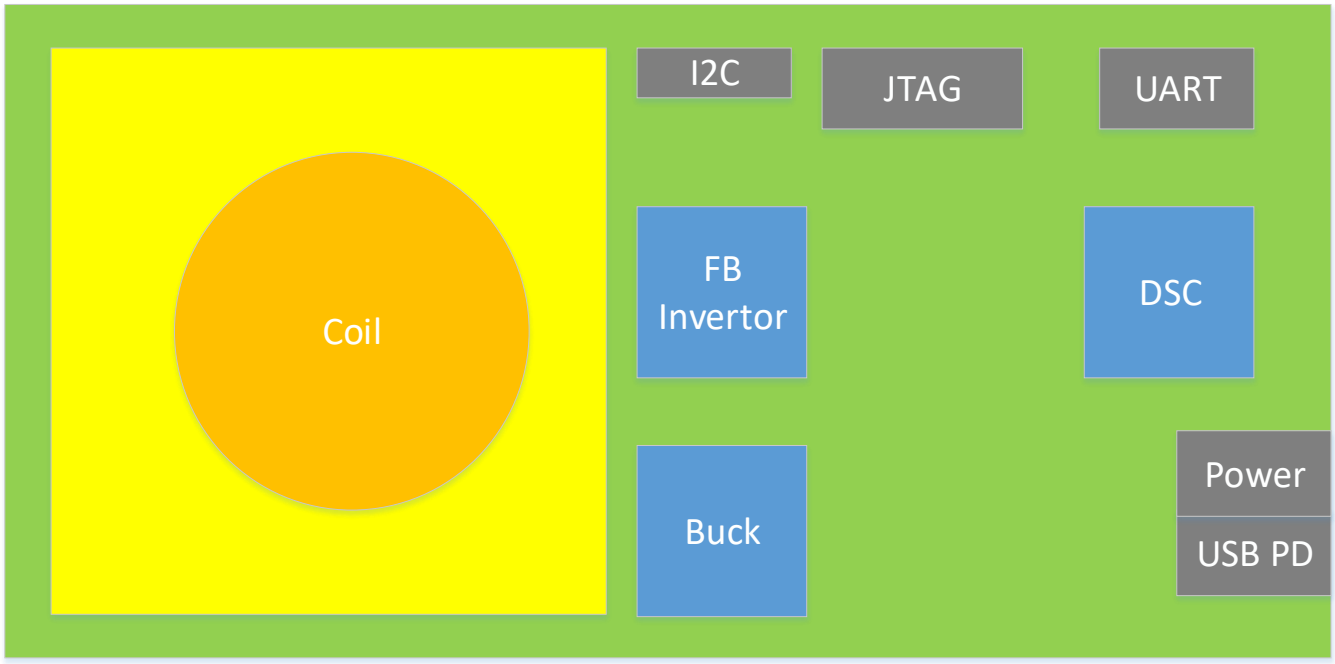


Figure 2. Device overview

2.3. Powering the board on

To power the board on, perform these steps:

1. Plug the USB PD or QC adaptor.
2. Connect the board with the USB PD or QC adaptor by an USB type-C cable.

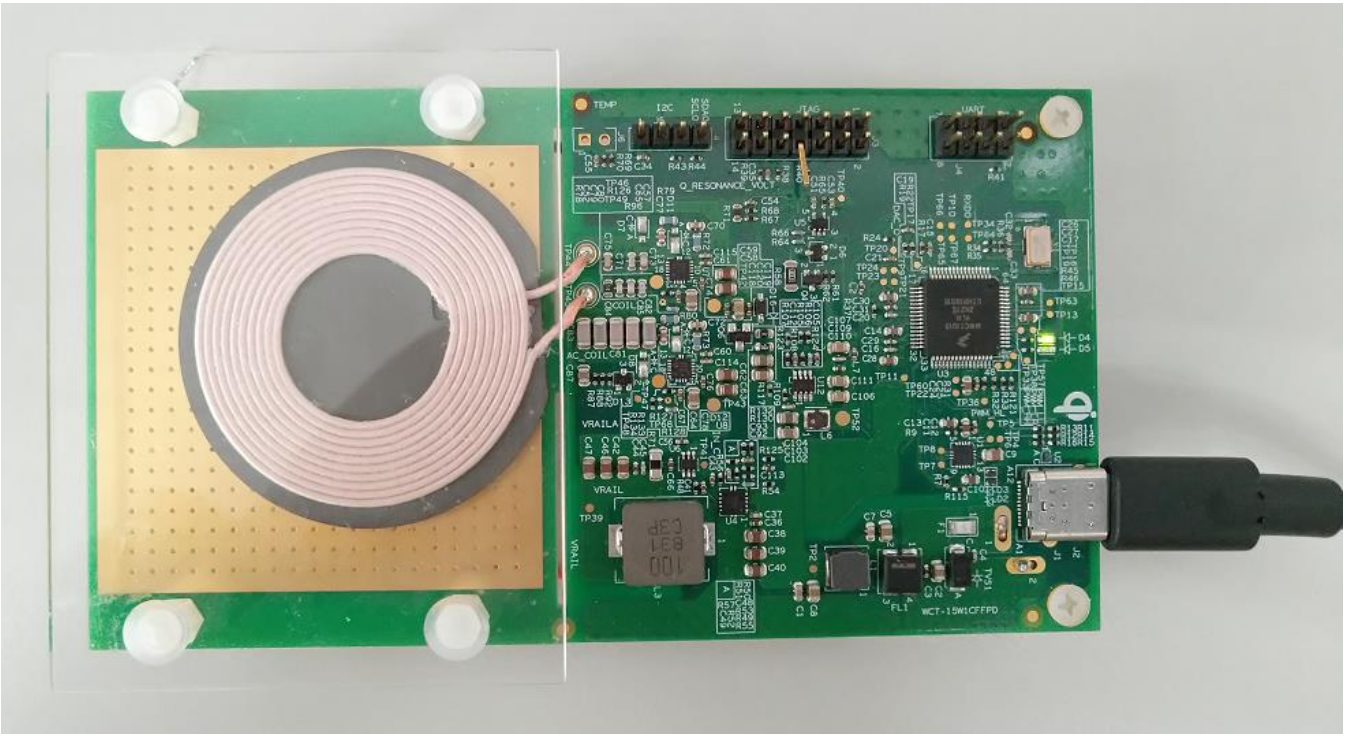
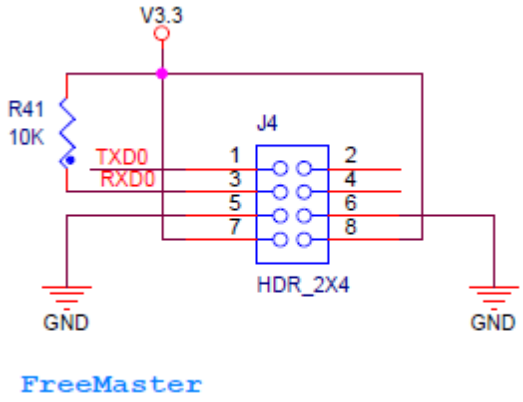


Figure 3. Power supply components

2.4. Hardware setup for FreeMASTER and console communication

To set up the hardware for the FreeMASTER and console communication, perform these steps:

1. Find the UART-to-USB adapter on the board and install the UART-to-USB device driver on the computer. The virtual serial port on the computer should work well.
2. Plug the USB-UART converting board to the SCI connector according to the SCH signal pin position.



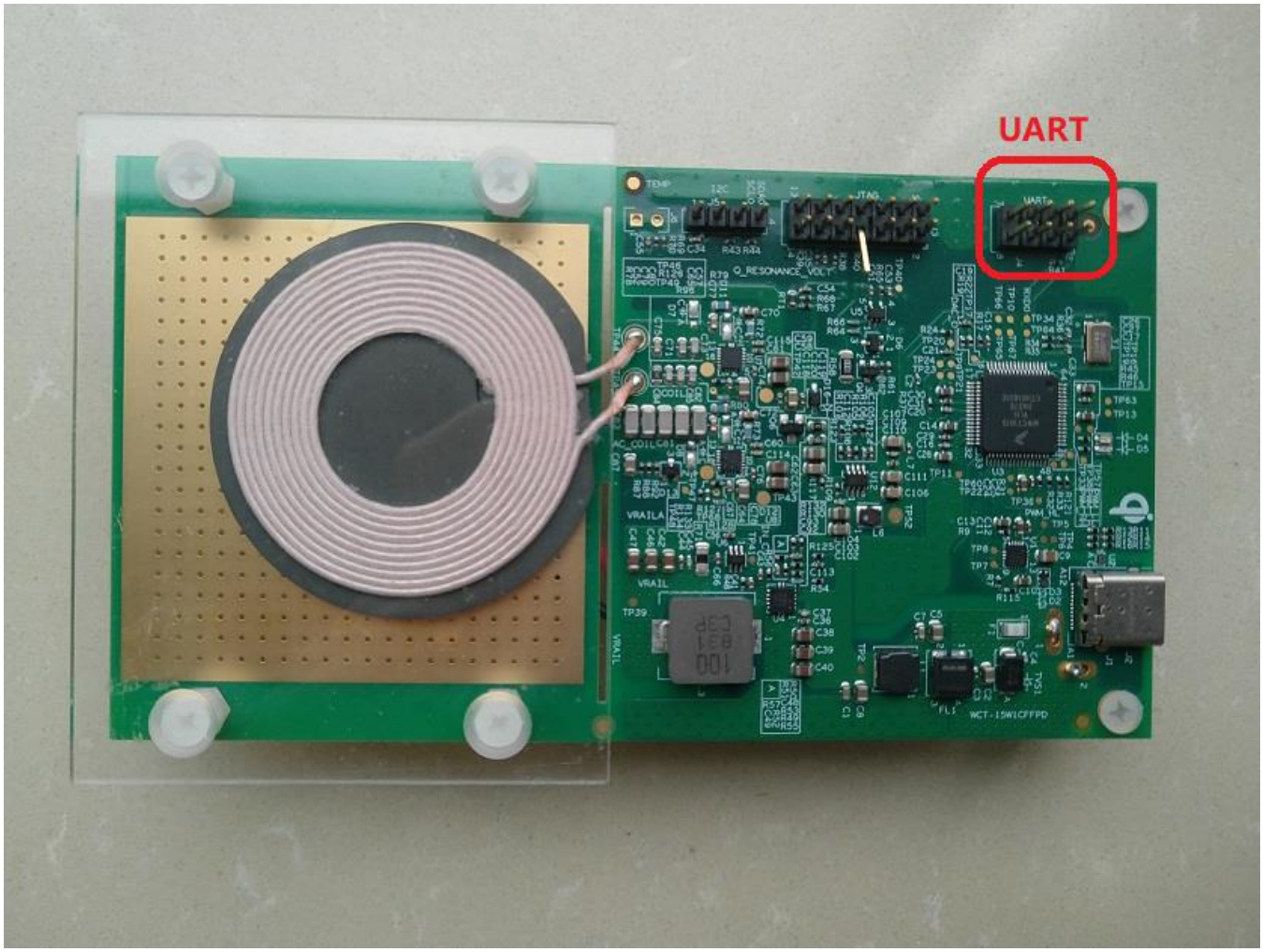


Figure 4. UART and JTAG connectors

3. Application operation

Connect the demo to the USB PD or QC adaptor using a cable. The WCT starts to periodically send the power ping to check whether a compatible Wireless Charging Receiver (WCR) is placed on the charging surface.

When a Qi-compliant receiver is placed on the top of the TX coil area, the WCT starts the charging process. If there is no correct Qi answer from the WCR side, the TX does not start the Qi charging process.

If the WCR answers properly, the power transfer starts. The actual level of the transferred power is controlled by the WCT in accordance with the WCR requirements. The receiver sends messages to the WCT through the ASK on the coil resonance power signal and the transmitter sends the information to the receiver using FSK, as per the Qi specification. The power transfer is terminated when the receiver is removed from the WCT magnetic field.

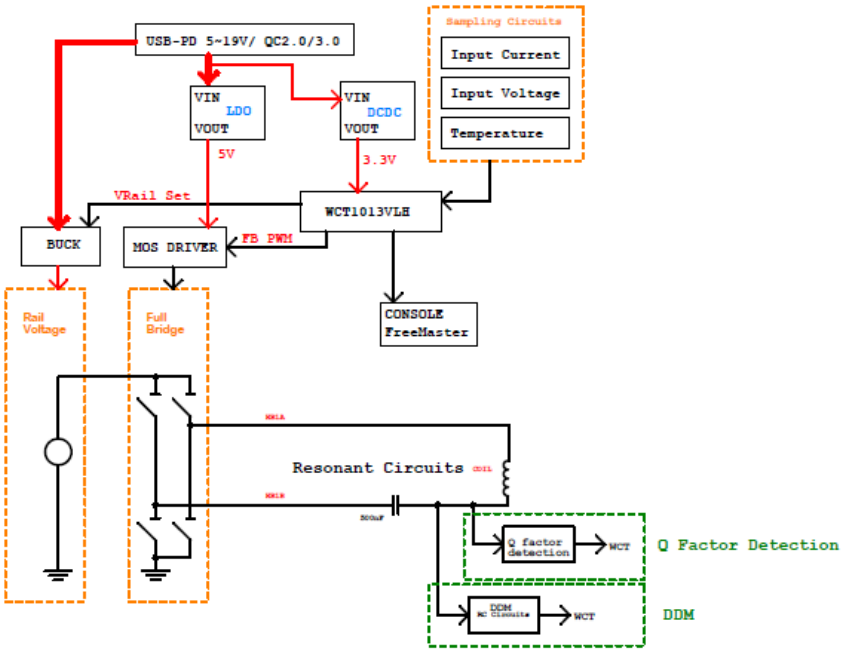
The system supports all Qi WCR devices: Qi_Ver-1.0 compliance, Qi_Ver-1.1 compliance, and the Qi EPP receiver. The system supports all the FOD features for different receivers. For the BPP receiver, the power loss FOD is supported. For the EPP receiver, both the Q-value FOD method and the power loss FOD method are supported.

4. Hardware description

Figure 5 shows the block diagram of the consumer wireless charger MP-A11 (WCT-15W1CFFPD).

Visit www.nxp.com to get the latest hardware design files.

The whole design consists of several blocks, which are described in the following sections.



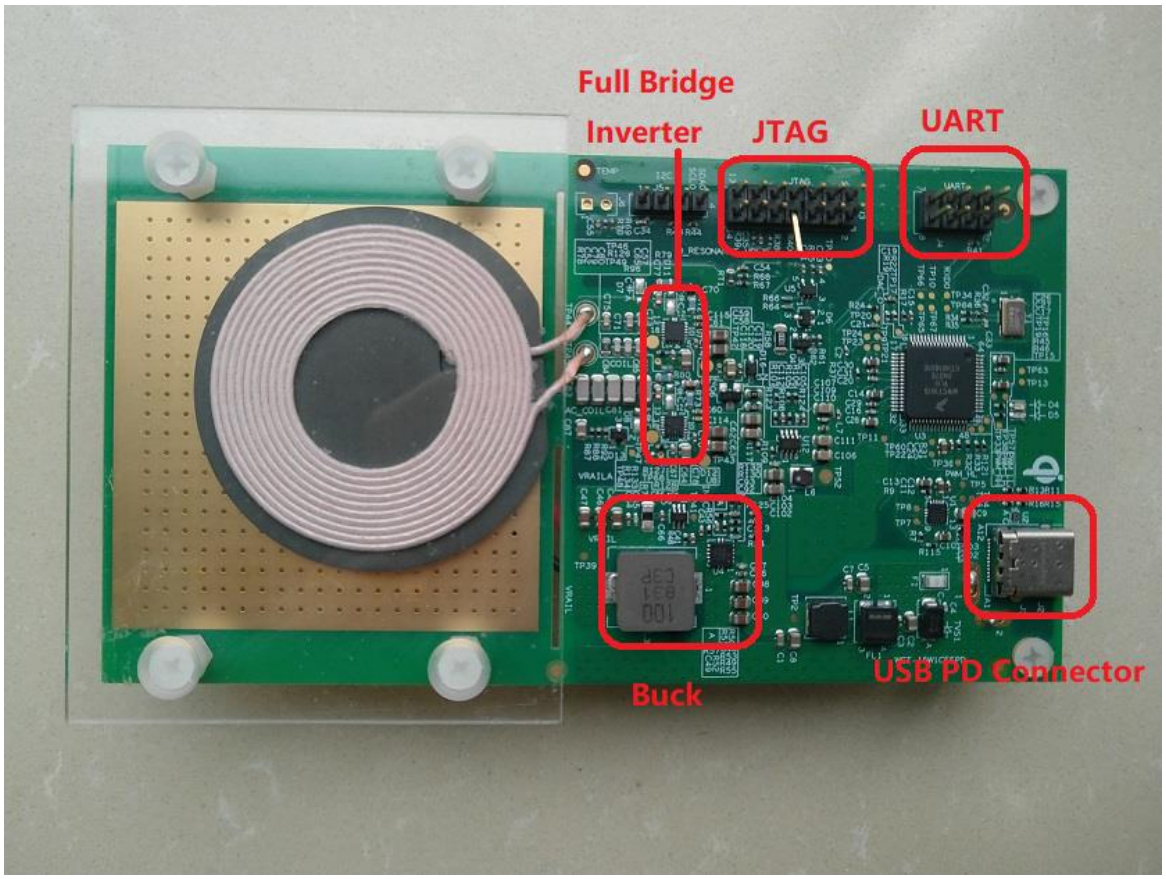


Figure 5. Block diagram of the consumer wireless charger MP-A11 (WCT-15W1CFFPD)

4.1. Input EMI filter

The input filter consists of the common-mode filter FL1 and filter capacitors C2, C3, C5, C7, and L1.

4.2. USB power supply

A USB type-C cable can be plugged to the USB type-C connector J2. The PTN5110 USB PD PCTC PHY is selected to support the type-C Configuration Channel (CC) interface and the USB PD physical layer functions.

The MPA-11 design also supports the Qualcomm Quick Charge 2.0/3.0 technology. The WCT controller manages the Qualcomm QC 2.0/3.0 protocol through the GPIOs and resistors connected to the D+/D- data line.

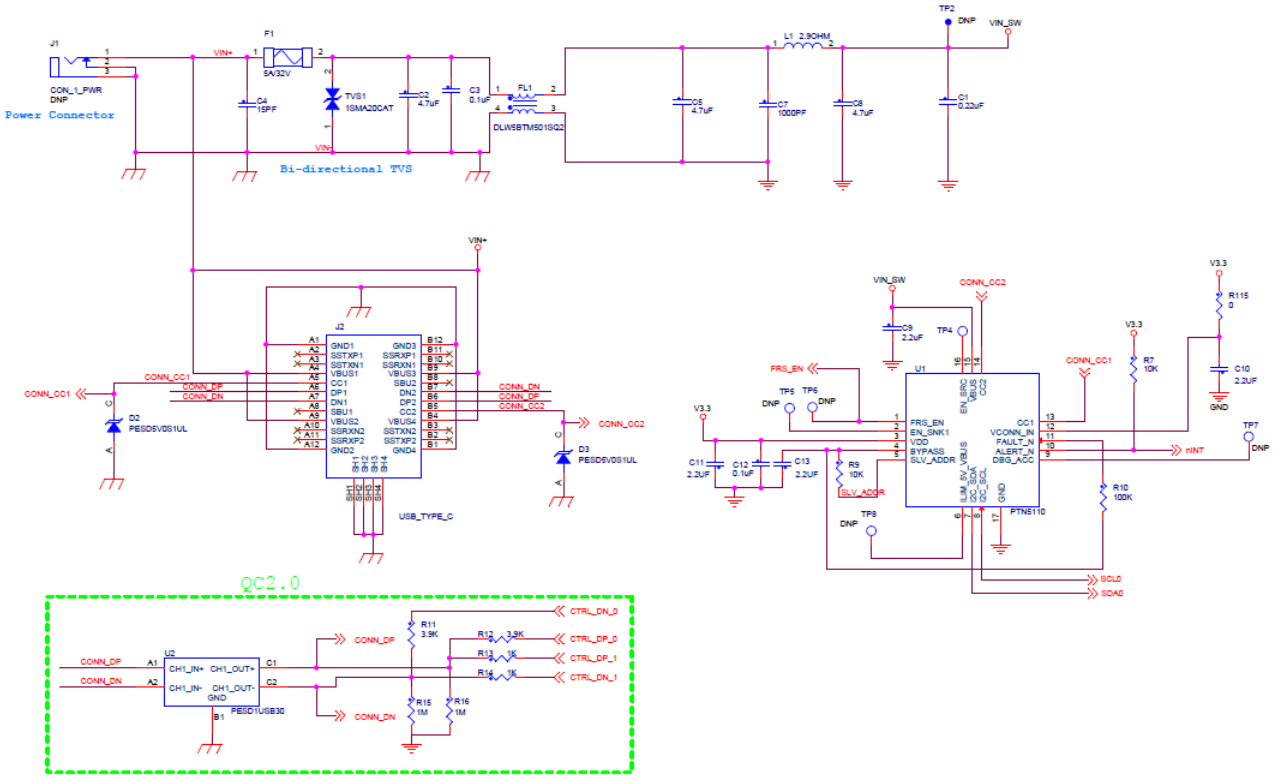


Figure 6. USB PD power supply and QC circuits

4.3. System voltage DCDC

The USB PD or QC adaptor input is connected to buck converter U12 (MP2314). Its output is 3.3 V. This 3.3 V output is mainly for the WCT1012VLF/WCT1013VLH and other 3.3 V-powered components. Generally, the DCDC load current is low. It is preferable to select a DCDC with a high efficiency in the light-load condition.

The MP-A11 design can also support other customized-propriety power protocols.

4.4. Rail voltage generated by analog buck chip

The Qi specification for the MP-A11 topology requires the DC voltage control to control the power transferred to the receiver. The buck converter is selected to get the regulated DC voltage ranging from 3 V DC to 18 V DC for the full-bridge inverter power supply. The buck is controlled by the individual analog buck converter and the WCT chip only controls the output voltage feedback.

For the analog buck module, MP2229 (or a similar IC like SY8286) is selected to generate the rail voltage. The WCT chip generates one analog signal from the PWM and controls the rail voltage using this signal. This analog signal adjusts the analog buck converter feedback, and the system can get the rail voltage as the system expects.

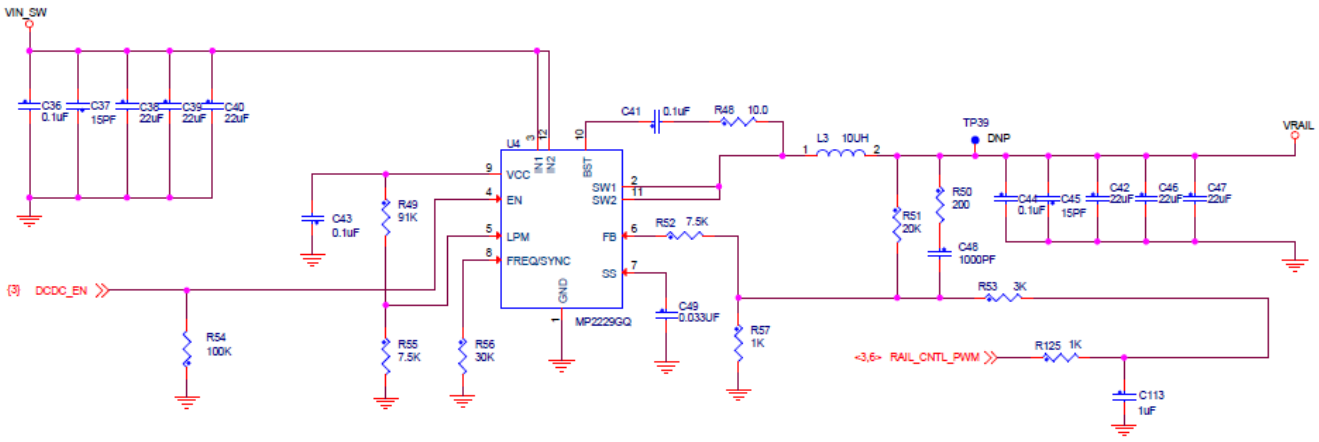


Figure 7. Analog buck-boost main circuits

4.5. Full-bridge and resonant circuits

The full-bridge power stage consists of integrated power stage unit (U7 and U8). The MOSFETs and their driver are integrated inside the power stage unit. The full-bridge power stage converts the variable DC voltage VRAIL to the square-wave 50 % duty-cycle voltage with a default frequency of 127.772 kHz. The range of the frequency used (from 120 kHz to 130 kHz) is defined in the Qi specification for the MP-A11 topology.

The resonant circuits consist of C81, C82, C83, C84, C85, and coils, all of which are fixed values defined in the Qi specification for the MP-A11 topology. The snubber RC pairs connected in parallel to the integrated power stages are used to lower the high frequency of the EMI products. The Vrail discharge circuit (Q4 and R58) is switched ON while the system is terminated.

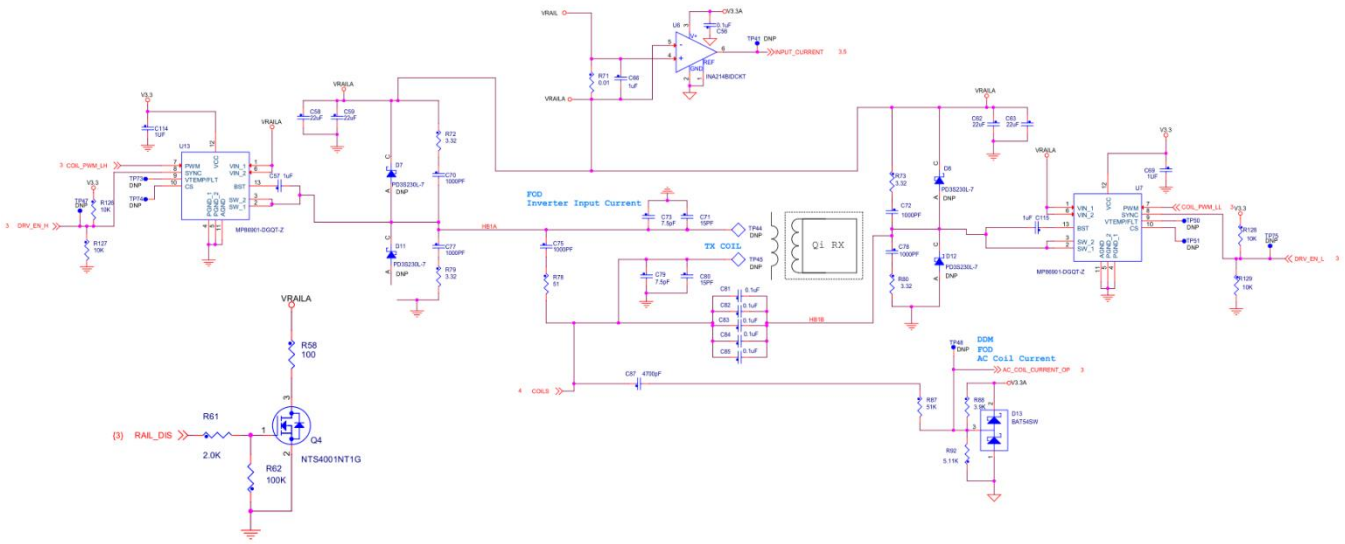


Figure 8. Full bridge circuits

4.6. Communication

There is bi-way communication between the EPP power transceiver and receiver. Communication from RX to TX: The RX measures the received power and sends the information about the required power level back to the transmitter. This message is Amplitude Modulated (AM) on the coil current and sensed by the TX.

The RC circuits C87, R87, R88, and R92 (known as DDM) sample the signal from the coil, compress the signal amplitude, and feed it to the ADC B-channel of the WCT1012VLF/WCT1013VLH. The information about the current amplitude and modulated data are processed by the embedded software routine.

Communication from TX to RX: The TX shall negotiate with the RX in the negotiation phase (if requested by the RX). The TX uses the FSK modulation to communicate with the RX, and the communication frequency is about 512 times the operating frequency.

4.7. FOD based on power loss

The power loss P_{LOSS}, which is defined as the difference between the Transmitted Power P_{PT} and the Received Power P_{PR}, i.e. $P_{LOSS} = P_{PT} - P_{PR}$, provides the power absorption in foreign objects, as shown in Figure 9.

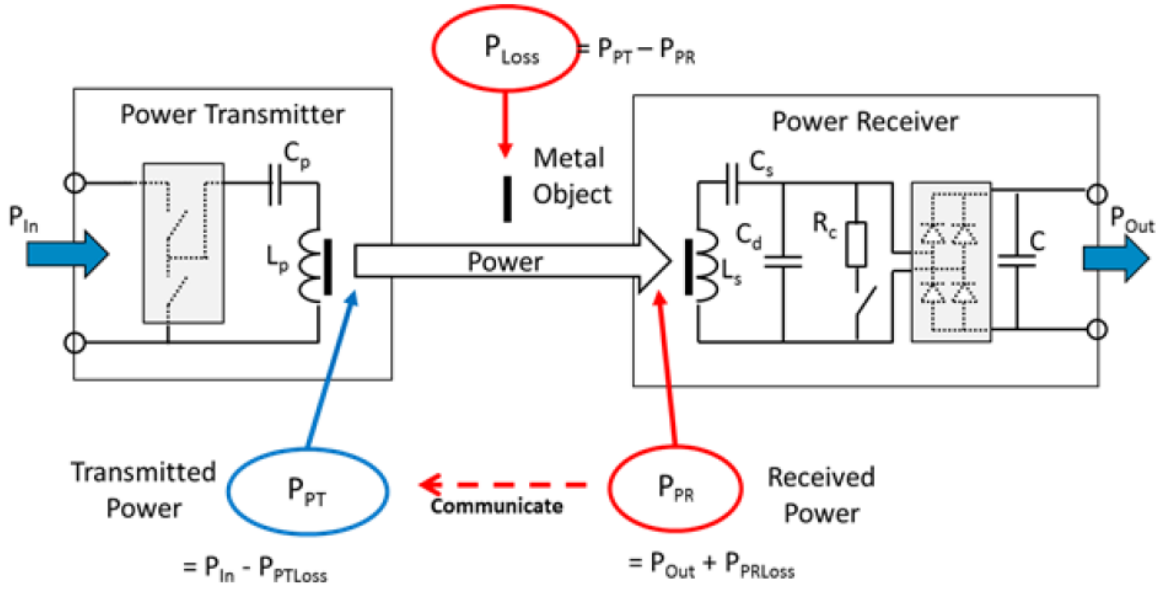


Figure 9. Power loss illustrated

When the FO is implemented in the power transfer, the power loss increases accordingly, and the FO can be detected based on the power loss method.

The power loss FOD method is divided into two types: FOD for the baseline power profile (TX and RX can transfer no more than 5 W of power) and extensions power profile (TX and RX can transfer power above 5 W).

4.7.1. Power-loss FOD baseline

The equation for the power-loss FOD baseline is $P_{LOSS} = P_{PT} - P_{PR}$.

The Transmitted Power P_{PT} represents the amount of power that leaves the TX due to the magnetic field of the TX, and $P_{PT} = P_{in} - P_{PTloss}$, where P_{in} represents the input power of the TX and P_{PTloss} is the power dissipated inside the TX. P_{in} can be measured by sampling the input voltage and input current, and P_{PTloss} can be estimated using the coil current.

The Received Power P_{PR} represents the amount of power that is dissipated within the RX due to the magnetic field of the TX, and $P_{PR} = P_{Out} + P_{PRloss}$. The power P_{Out} is provided at the RX output and P_{PRloss} is the power lost inside the RX.

When the NXP MP-A11 transmitter charges the baseline profile RX, the power-loss baseline is applied. The TX continuously monitors P_{LOSS}, and if it exceeds the threshold several times, the TX terminates the power transfer.

4.7.2. Power loss FOD extensions

Typically, the RX estimates the power loss inside itself to determine its received power. Similarly, the TX estimates the power loss inside itself to determine its transmitted power. A systematic bias in these estimates results in a difference between the transmitted power and the received power, even if there is no Foreign Object (FO) present on the interface surface. To increase the effectiveness of the power-loss method, the TX can remove the bias in the calculated power loss by calibration. For this purpose, the TX and the power RX execute the calibration phase before the power transfer phase starts. The TX must verify that there is no FO present on its interface surface before the calibration phase and FOD based on the Q factor can work.

Because the bias in the estimates may depend on the power level, the TX and RX determine their Transmitted Power and Received Power at two load conditions—a "light" load and a "connected" load. The "light" load is close to the minimum expected output power, and the "connected" load is close to the maximum expected output power. Based on the two load conditions, the power transmitter can calibrate its transmitted power using linear interpolation. Alternatively, the power transmitter can calibrate the reported received power.

Take the calibrated transmitted power as an example:

$$P_{PT}^{cal} = a * P_{PT} + b$$

$$\mathrm{a} = \frac{P_{PR}^{(connected)} - P_{PR}^{(light)}}{P_{PT}^{(connected)} - P_{PT}^{(light)}}$$

$$\mathrm{b} = \frac{P_{PT}^{(connected)} * P_{PR}^{(light)} - P_{PR}^{(connected)} * P_{PT}^{(light)}}{P_{PT}^{(connected)} - P_{PT}^{(light)}}$$

Therefore, the TX uses the calibrated transmitted power to determine the power loss as follows:

$$P_{LOSS} = P_{PT}^{cal} - P_{PR}$$

When the MP-A11 transmitter charges an RX baseline, only the power-loss FOD baseline works. If an RX extension is placed on the MP-A11 transmitter, the Q factor is measured first to detect if there is an FO present. If yes, the TX stops charging; otherwise, the TX can proceed to the calibration phase and the power transfer phase, and the power-loss FOD extension works to detect if an FO is inserted during the power transfer phase.

For more details about the FOD, see the *WCT1012VLF /WCT1013VLH Consumer MP-A11 Run-Time Debug User's Guide* (document WCT101XRTDUG).

4.8. FOD based on Q factor change

A change in the environment of the TX coil typically causes its inductance to decrease or its equivalent series resistance to increase. Both effects lead to a decrease of the TX coil's Q factor. The RX sends a packet including the reference Q factor for the TX to compare and determine if the FO exists, as shown in Figure 10.

The reference Q factor is defined as the Q factor of the test power transmitter #MP1's primary coil at the operating frequency of 100 kHz with RX positioned on the interface surface and no FO nearby. Due to the differences between its design and that of the test power transmitter #MP1, the TX needs to convert the Q factor it measured to that of the test power transmitter #MP1. NXP provides the conversion method and must get the on-board parameters first. The TX performs the automatic calibration and gets the parameters at the first powerup after a new image is flashed. These parameters are then written to the flash memory. Therefore, it is necessary to ensure that there is no object on the TX surface during the first powerup after flashing a new image.

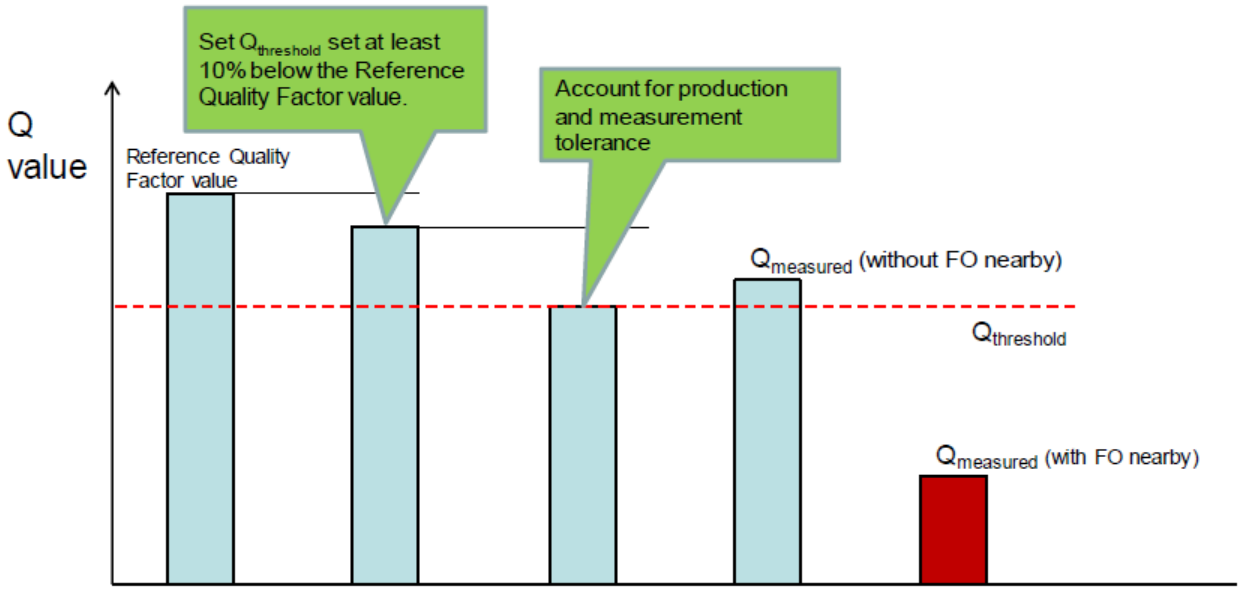


Figure 10. Q factor threshold example

4.8.1. Free-resonance Q factor

The free-resonance Q factor detection detects the decay rate of the resonance signal, as shown in Figure 11. With the system's high Q, just a few pulses near the resonant frequency are sufficient to serve as impulses and start the system ringing. Collect the ADC data of the tank voltage (or coil current), and get the decay rate of the signal.

$$Q=\pi/(-\ln(Rate))$$

Rate is the value of the decay rate of the resonance signal.

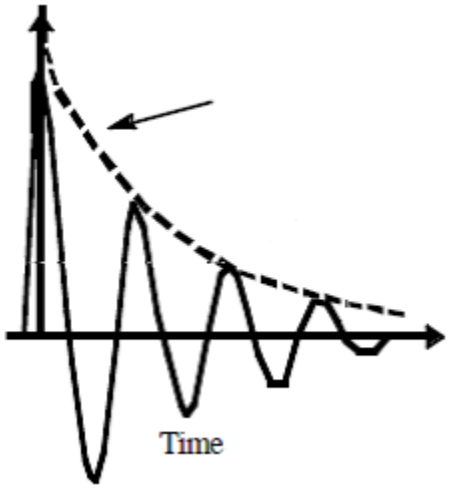


Figure 11. Resonance signal

The circuit for the free-resonance Q measurement is as shown in the following figure, which samples the signal on resonance capacitors.

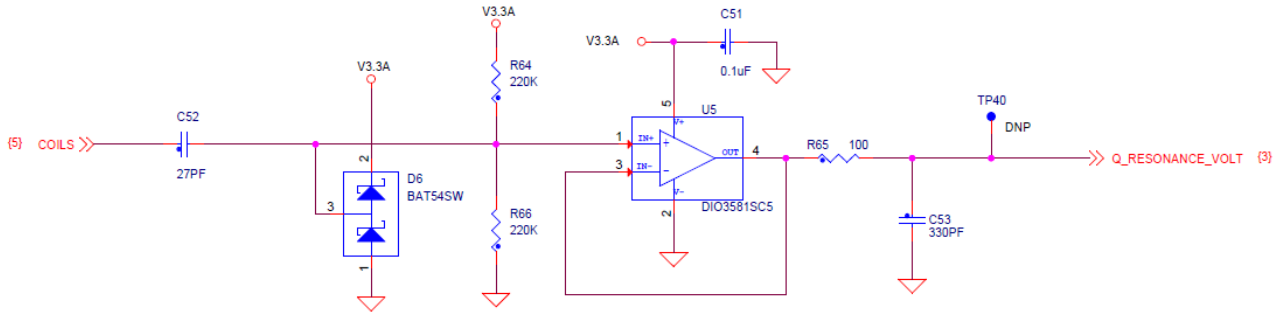


Figure 12. Free-resonance Q measurement circuit

4.8.2. Pre-FOD based on the Q factor

The pre-FOD serves to detect foreign objects without an RX. The TX uses analog ping to detect objects. If an object is detected, a digital ping is initiated to decide if it is an RX. If the object is a metal FO, it is heated by a digital ping. The TX provides a pre-FOD method based on the Q factor to detect the foreign object and prevent it from being heated before the transfer is initiated.

4.9. Analog sensing

Some ports of the ADC A-channel of the WCT1012VLF/WCT1013VLH are used to sense analog signals, such as the temperature, full-bridge input current, input voltage, and rail voltage.

5. Application monitoring and control using FreeMASTER

FreeMASTER is a user-friendly real-time debug monitor and data visualization tool for application development and information management. Supporting non-intrusive variable monitoring on a running system, FreeMASTER allows the data from multiple variables to be viewed in an evolving oscilloscope-like display or in a plain-text format. The application can also be monitored and operated from the web-page-like control panel.

5.1. Software setup

To set up the software, perform these steps:

1. Install FreeMASTER version 2.0.2 (or later) from the NXP website: www.nxp.com/freemaster.
2. Plug the USB-UART converting board to the SCI connector J4, and connect the FreeMASTER Micro-USB port to your computer.
3. Open the Device Manager, and check the number of the COM port.

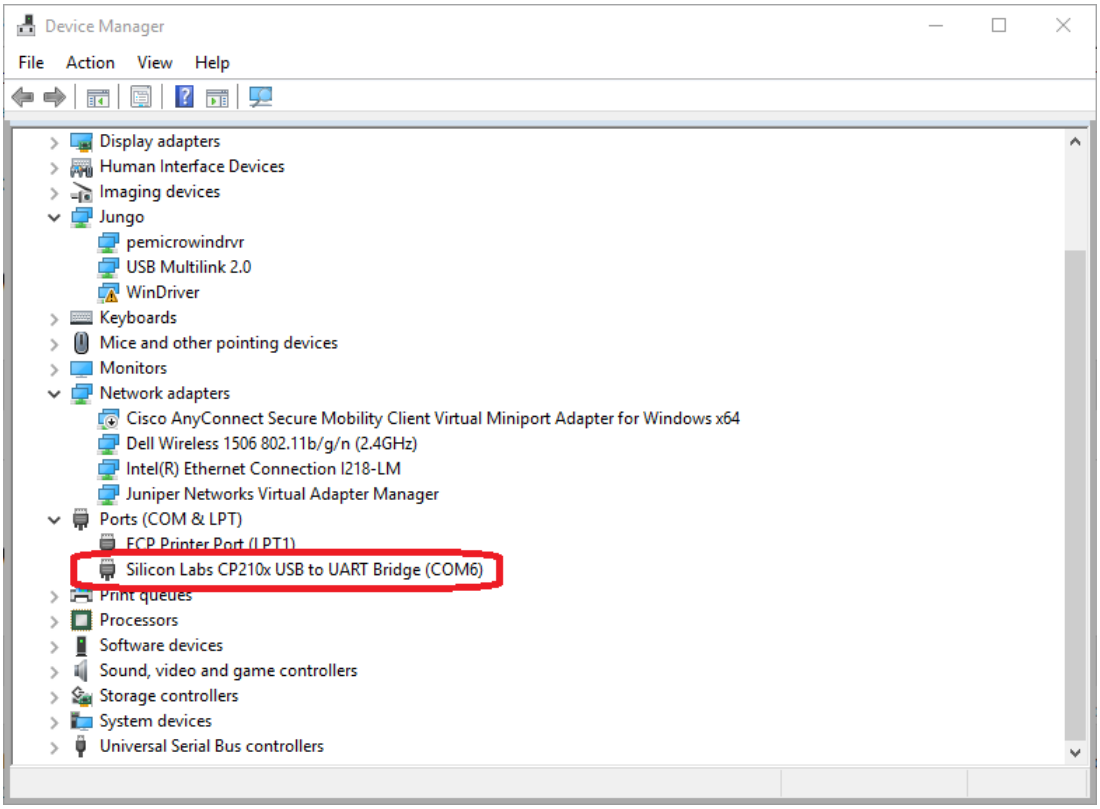


Figure 13. Device Manager

4. Unpack the embedded source code to your local disk.
5. Start the FreeMASTER application by opening:
   - MWCT1013

   <unpacked_files_location>/15W_MP/example/wct1013PD/ wct1013pd.pmp

6. Choose “Project” –> “Options”.

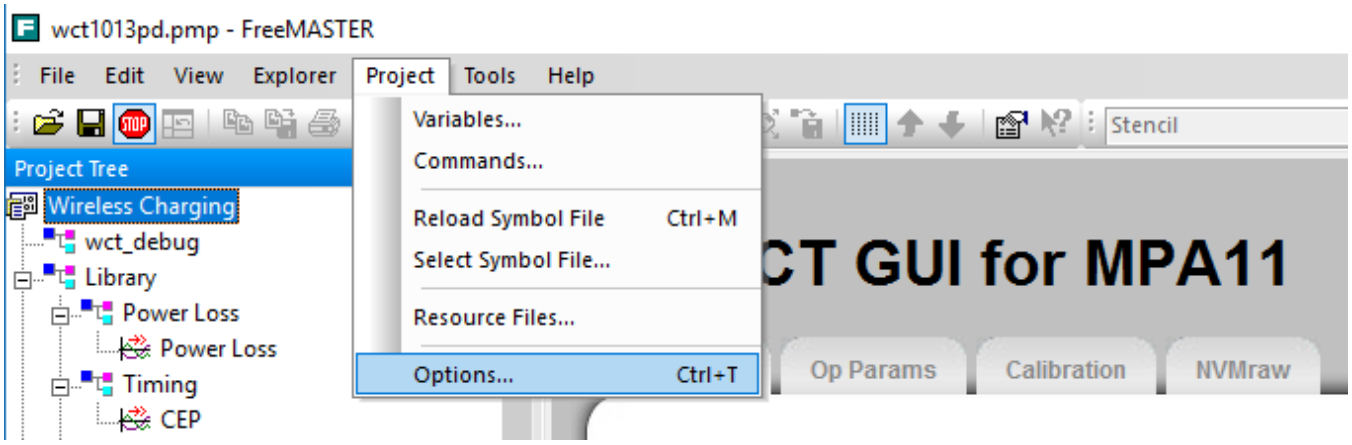


Figure 14. Choosing “Options”

7. Ensure that the correct virtual port (according to Step 3) and speed are selected.

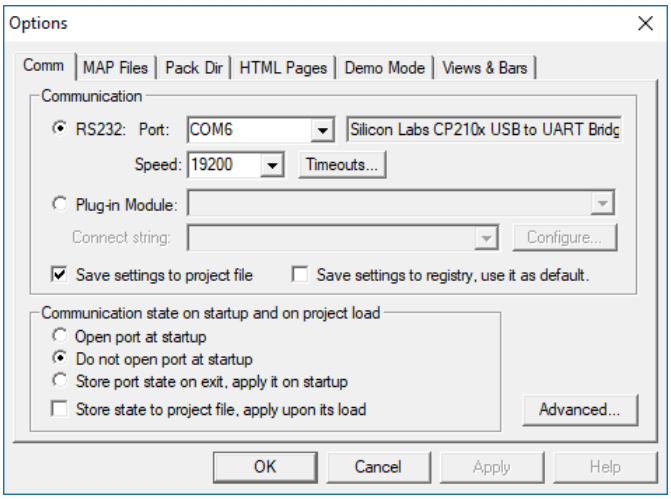


Figure 15. Setting port and speed

8. Ensure that the MAP file is correct. The default directories are:

   - MWCT1013

   <unpacked_files_location>/15W_MP/build/demo/wct1013PDdemo/demo_ldm_debug/wct1013PDdemo_debug.elf

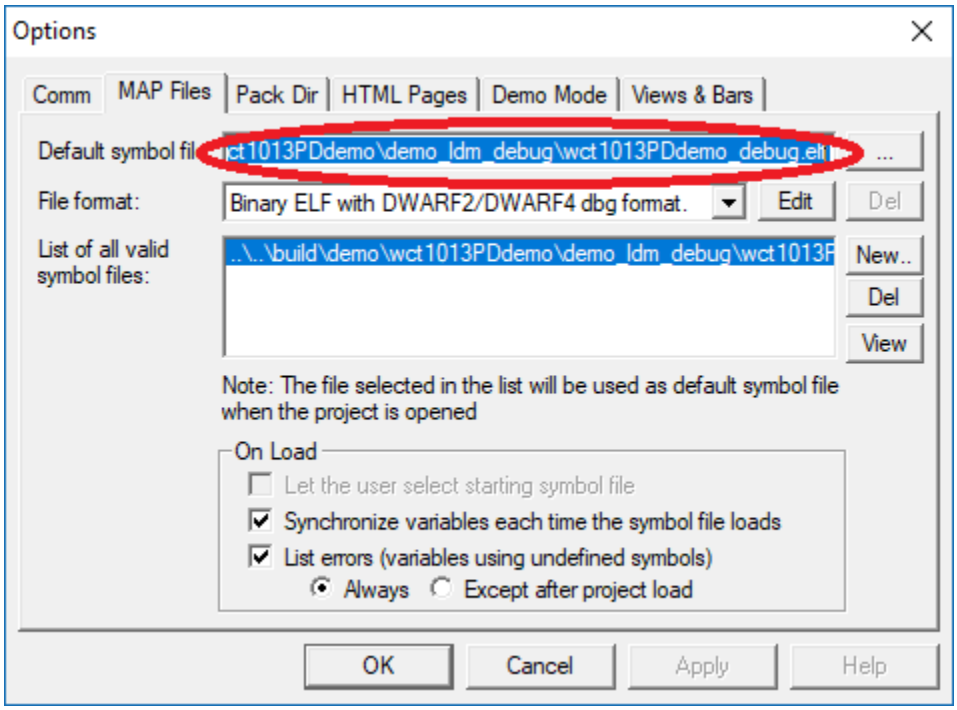


Figure 16. Setting the MAP file

9. Connect FreeMASTER.

   Power the MP-A11 on and start the communication by clicking the “STOP” button in the FreeMASTER GUI.

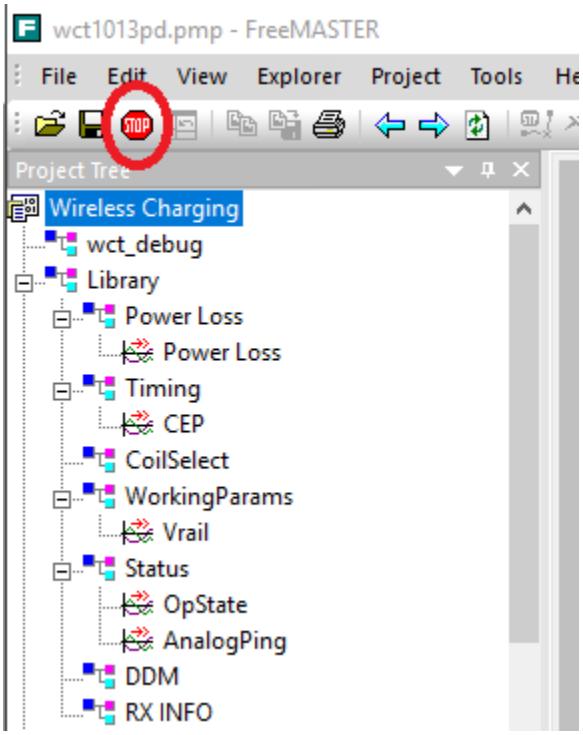


Figure 17. “STOP” button

5.2. Real-time application variables monitoring

FreeMASTER enables the monitoring and updating of all the application global variables. In this application, several key variables are displayed in the scope windows. These variables are divided into different blocks, as shown in the following figure.

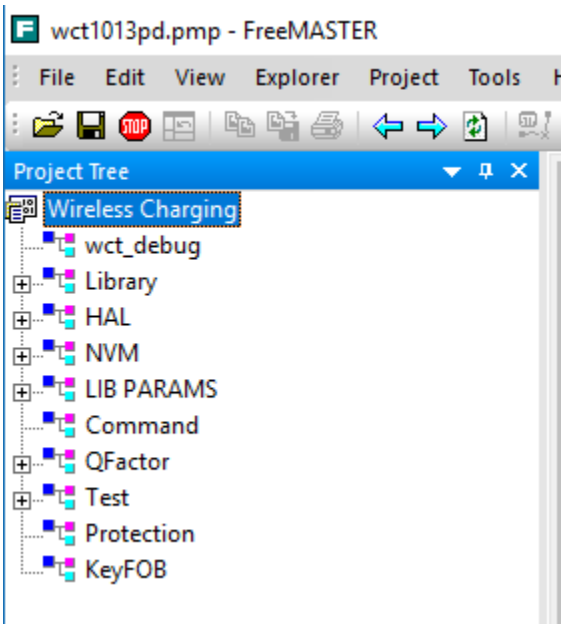


Figure 18. Real-time application variables

- `wct_debug`
  This block shows the variables used for the GUI command.
- `Library`
  This block contains the power loss variables, timing variables, coil selection variables, working parameters, system status, DDM variables, and RX information.
- `HAL`
  This block contains the ADC raw data and DDM buffer values.
- `NVM`
  This block lists all NVM parameters. The Q factor sub-block shows the Q factor calibration constants. The RRQD sub-block shows the quick-removal calibration constants. The FOD sub-block shows the FOD characterization calibration constants. The normalization sub-block shows the FOD normalization constants. The analog sub-block shows the rail voltage calibration constants.
- `LIB PARAMS`
  This block lists all the parameters used for the WCT library.
- `Command`
  The command variable is used to stop the WCT, start the WCT, and perform automatic calibration.

- `QFactor`
  This block contains the variables for the Q factor detection.
- `Test`
  This block contains some variables for debugging.
- `Protection`
  This block contains protection variables, such as the input voltage protection, input current protection, and temperature protection.

NOTE

Besides the above variables, all the global variables can be added to FreeMASTER. The procedure to generate and add variables to the watch window is described in the FreeMASTER user manual.

5.3. Application parameters modification

The application parameters (NVM parameters) can be easily viewed and changed in the control panel. The control panel contains the web page elements (buttons, check boxes, and text fields) that enable a user-friendly way to visualize and change the application control parameters.

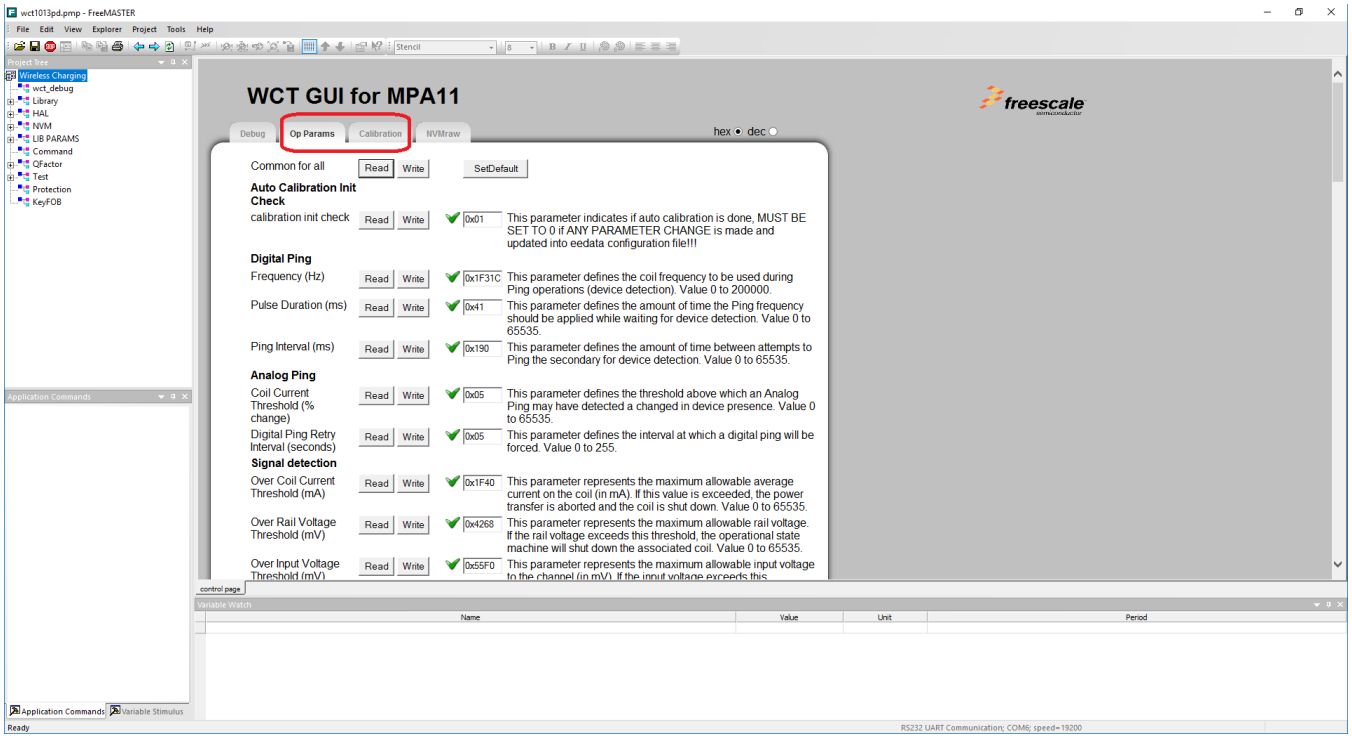


Figure 19. Application variables

The application variables are divided into these tabs:

- “Op Params”—enables access to variables related to the operation control.

- “Calibration”—a group of parameters for calibration of the input current, input voltage, and foreign objects detector.

The meaning of each parameter is described next to the text field.

NOTE

The parameters of the “Calibration” tab can be changed at run-time, but the parameters of the “Op Params” tab cannot take effect immediately. To modify the parameters in the “Op Params” page: enter the debug mode, modify the parameters, and exit the debug mode. The parameters can then take effect.

6. Application monitoring using console

The application sends some information and error states through the SCI to the console. The information is sent when the board is turned on, when the device is charging, or in case of an error state.

On the MP-A11 design, only one SCI port (SCI0) is available on the J4 connector. SCI0 is used for FreeMASTER by default. Select an alternative method to enable the debug console.

1. Disable FreeMASTER and configure the SCI0 as the debug console.
    a) #define DEBUG_CONSOLE_SUPPORTED (TRUE)

       #define FREEMASTER_SUPPORTED (FASLE)

       The macros are defined in *example->wct101xa–>configure-> appcfg.h*.

    b) #define QSCI_CONSOLE_INDEX 0

       #define QSCI_FREEMASTER_INDEX 1

       The macros are defined in *example->wct101xa->driver->qsci.h*.

    c) gWCT_Params.tDebugConfig.bGeneralDbg = 1;

       This variable is in *wct_LibParams.c*.
2. Change the FreeMASTER communication interface to JTAG and configure the SCI0 as the debug console.
    a) #define DEBUG_CONSOLE_SUPPORTED (TRUE)

       #define FREEMASTER_SUPPORTED (TRUE)

       The macros are defined in *example->wct101xa–>configure-> appcfg.h*.

    b) #define QSCI_CONSOLE_INDEX 0

       #define QSCI_FREEMASTER_INDEX 1

       The macros are defined in *example->wct101xa->driver->qsci.h*.

    c) #define FMSTR_USE_SCI 0 /* To select SCI communication interface */

       #define FMSTR_USE_JTAG 1 /* 56F8xxx: use JTAG interface */

The macros are defined in *example->wct101xa–>configure-> freemaster_cfg.h*.

d) gWCT_Params.tDebugConfig.bGeneralDbg = 1;

This variable is in *wct_LibParams.c*.

6.1. Software setup

1. Plug the USB-UART converting board to SCI connector J4 and connect the console Micro-USB port to the computer.
2. Open the Device Manager and check the number of the COM port.

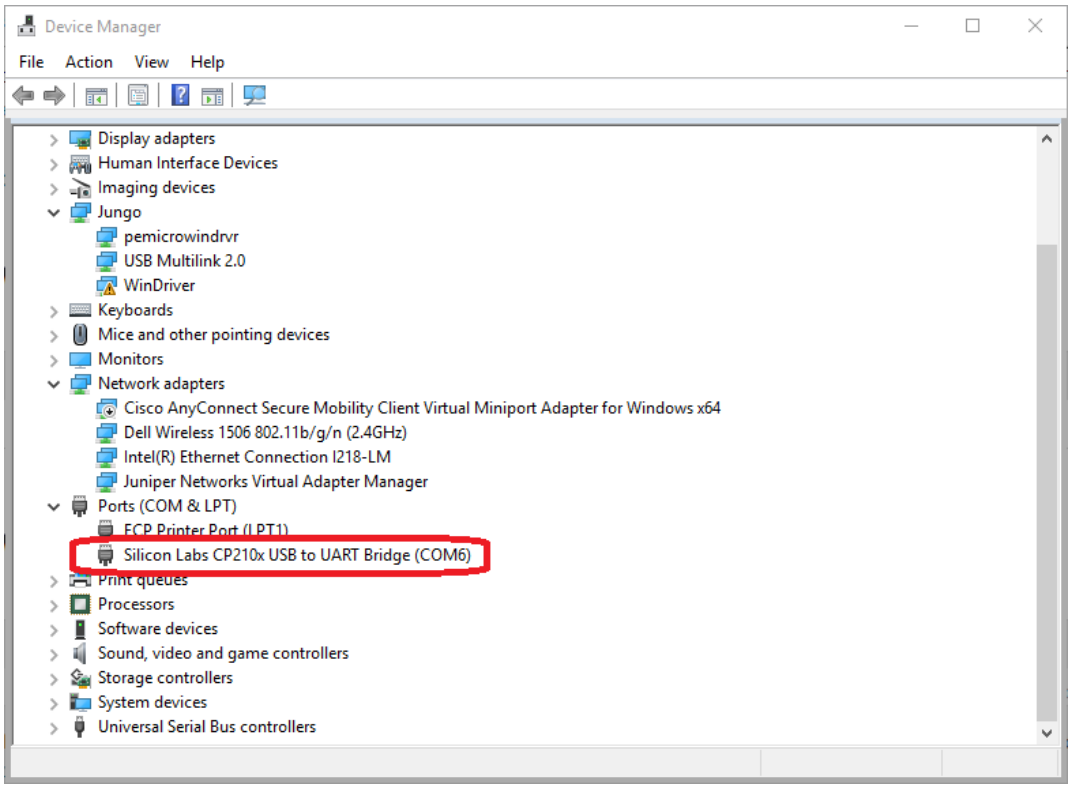


Figure 20. Device Manager

3. Run the communication program supporting console, such as HyperTerminal or RealTerm.
4. The following table shows the communication setup.

Table 1. Port configurations

Port number	Serial port from Device Manager
Baud	19200
Data Bits	8
Stop Bits	1
Parity	None
Hardware Flow Control	None
Display As	ASCII

5. Open the port or start the communication, depending on the terminal used.

7. Programming new software and calibration

The provided software package includes a WCT1013 project and a binary file (*.elf* or *.S*). You can flash the alternative to the board. After flashing a new software, carry out the board calibration.

7.1. Installing the latest CodeWarrior IDE

NOTE

The following steps demonstrate the installation of the CodeWarrior for Microcontrollers v10.7 IDE as an example. You can also select a later version.

1. Download installation files.

   For a proper installation of CodeWarrior 10.7, install both the CodeWarrior for Microcontrollers 10.7 IDE and the CodeWarrior for MCUs v10.7 service pack.

   Access the following webpage and log in:

   www.nxp.com/products/developer-resources/software-development-tools/codewarrior-development-tools/codewarrior-development-suites/codewarrior-development-suite-special:CW-SUITE-SPECIAL?tab=Design_Tools_Tab

   Click the “Download” button for the CodeWarrior Special Edition (offline or online).

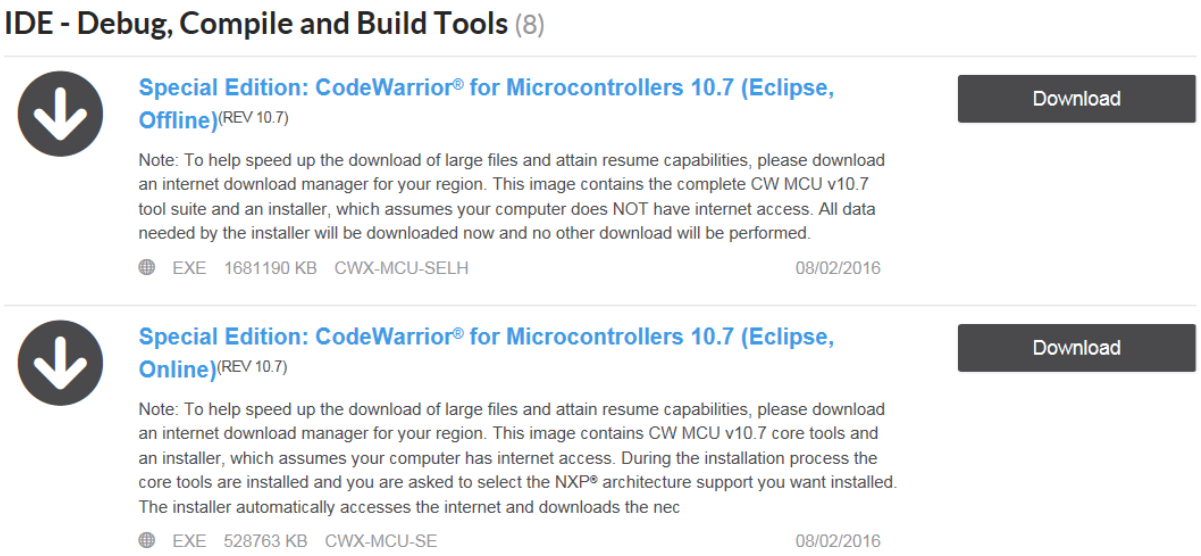


Figure 21. Clicking “Download” for CodeWarrior Special Edition

   Download the CodeWarrior for Microcontrollers 10.7 service pack at this link:

   www.nxp.com/products/power-management/wireless-charging-ics/15-watt-wireless-charging-transmitter-ics-for-automotive-applications:MWCT1x1xA?tab=Design_Tools_Tab

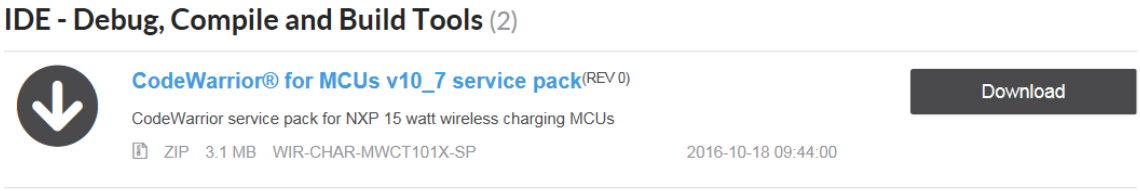


Figure 22. Downloading CodeWarrior for MCU v10.7 service pack

2. Double-click the *CW_MCU_v10.7_b160721_SE.exe* file after downloading.

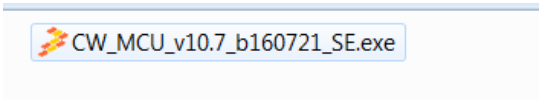


Figure 23. Setup file

3. Make sure that the “DSC” option is selected.

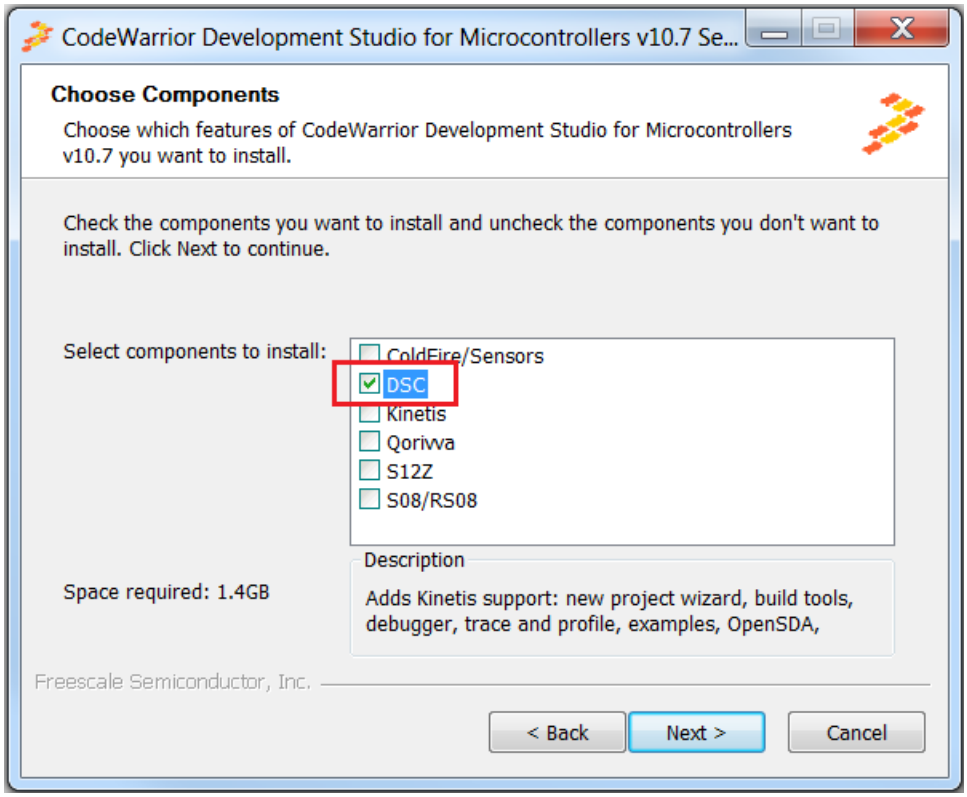


Figure 24. DSC installed

4. Launch CodeWarrior, create a folder workspace, and select it as the default workspace.

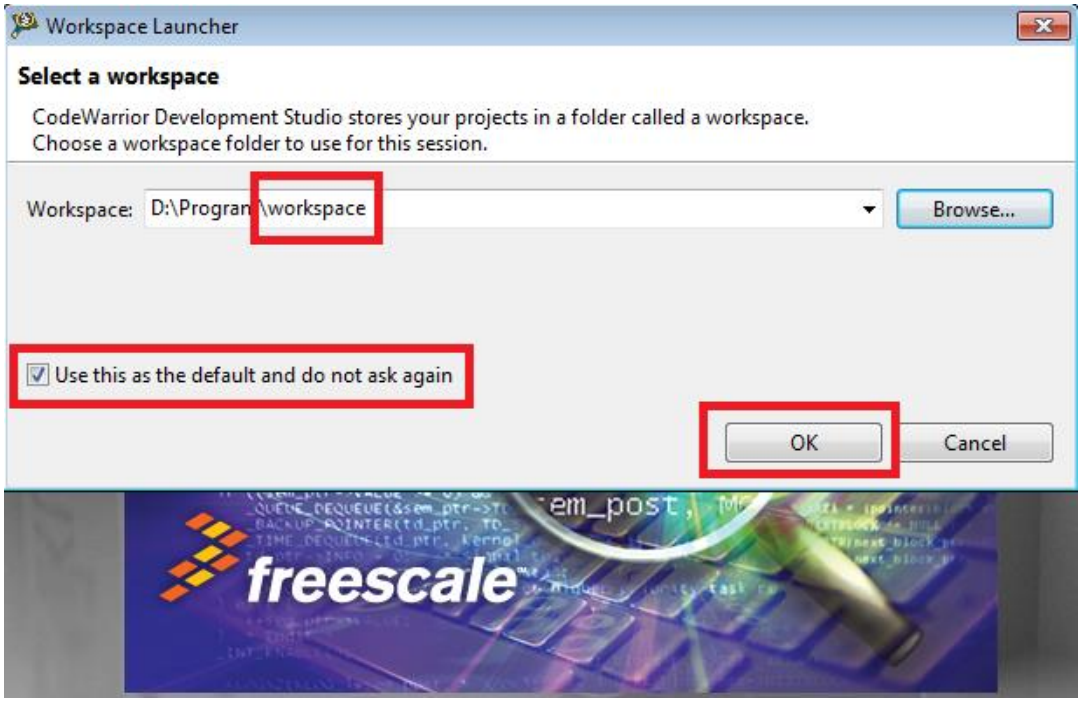


Figure 25. Workspace Launcher dialog box

5. Select “Help” –> “Install New Software”.

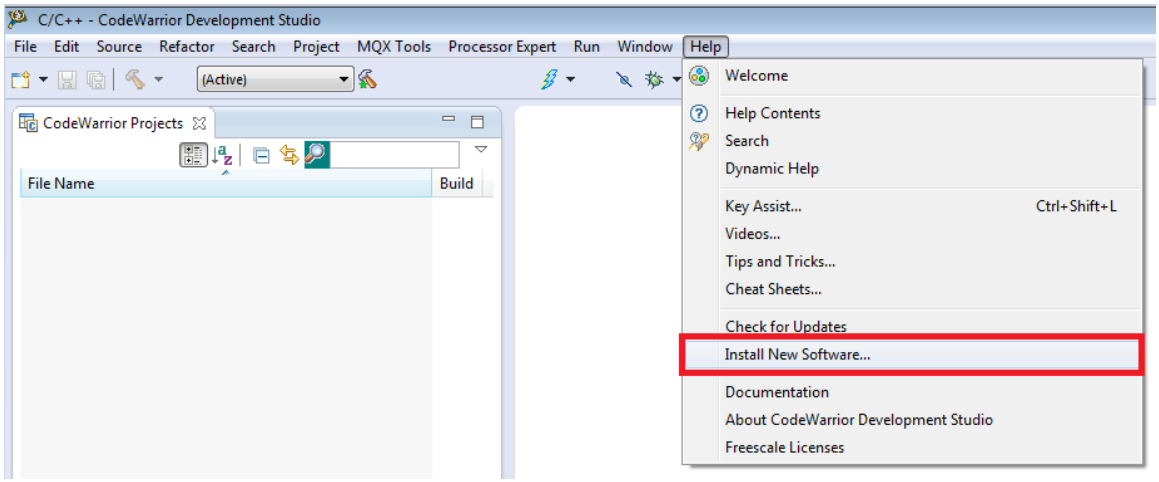


Figure 26. Install New Software

6. Click the “Add”, “Archive”, and then select the *mcu10_7.Wireless_Charging_MWCT101x.win.sp.v1.0.1.zip* file.

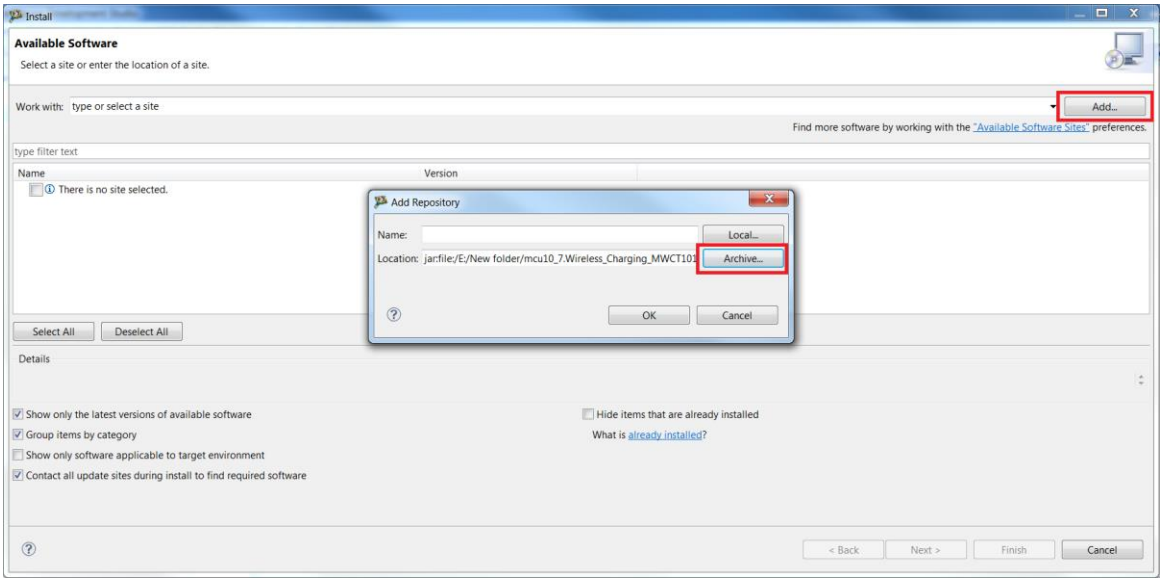


Figure 27. Selecting the update pack

7. Select the “MCU v10.7 DSC Service Packs” option, and then click “Next”.

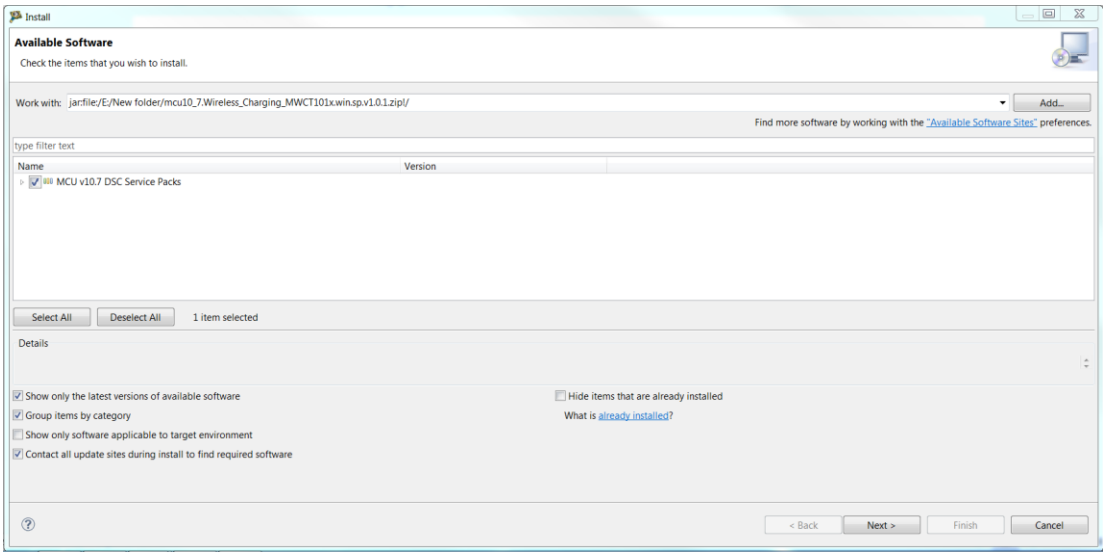


Figure 28. Selecting service packs

8. Review the license terms. If you agree with the license terms, select “I accept the terms of the license agreement” and then click “Finish”.

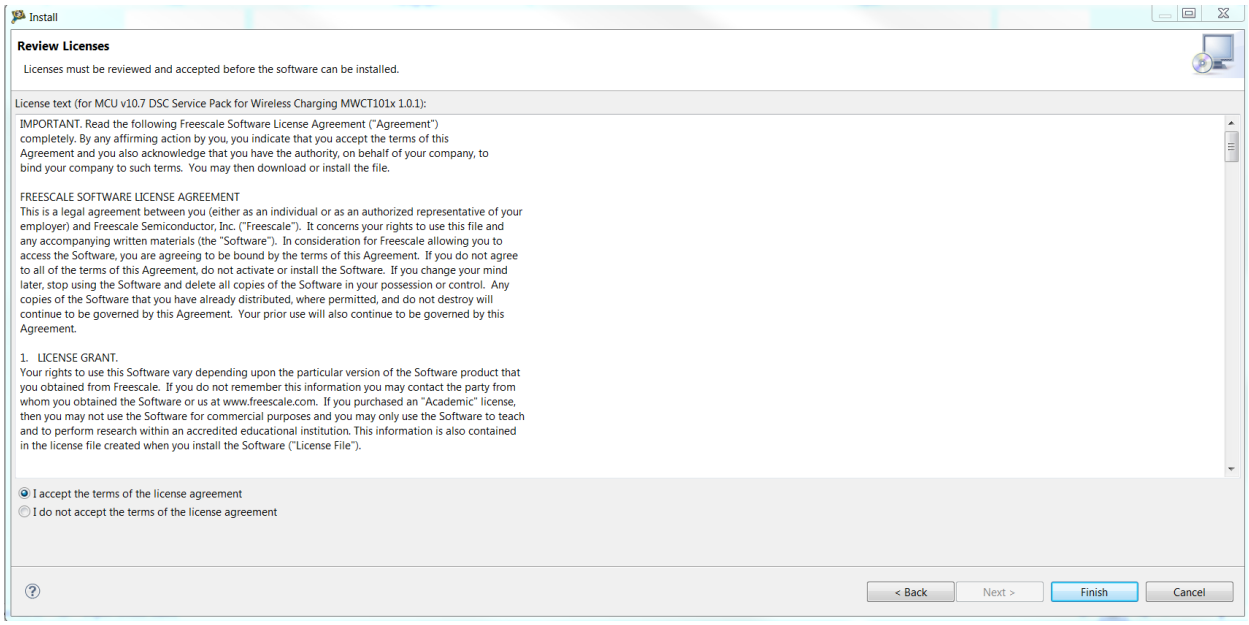


Figure 29. Installation finished

7.2. Board and programmer connection

Connect the 14-pin debug cable to J3 on the board (notice the pin-1 position of the cable).

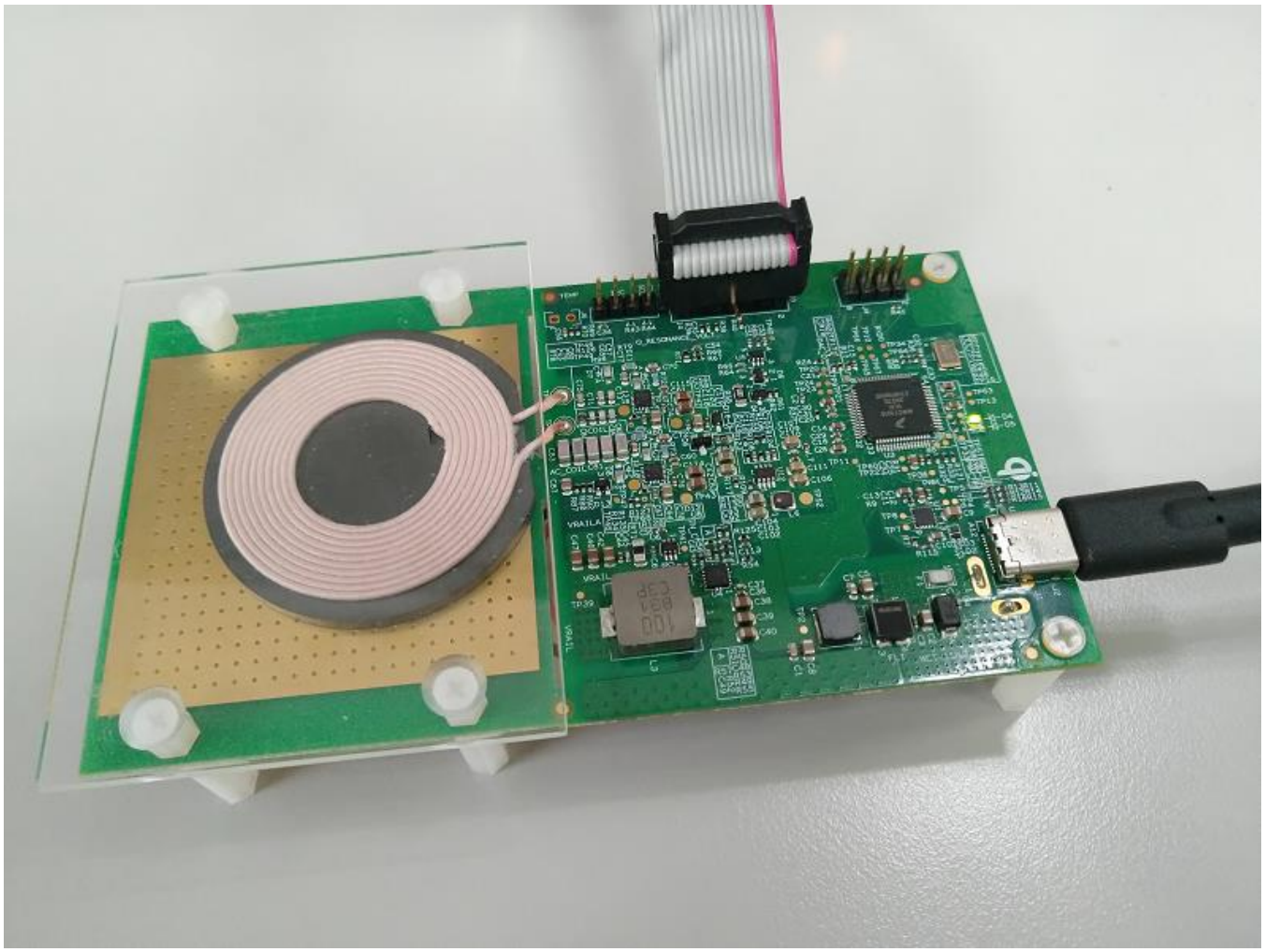


Figure 30. Connecting the debug cable to the board

7.3. Programming project files

1. Import a project.
2. Select the “File” tab and then click the “Import” button to import an existing project, as shown in the following figures.

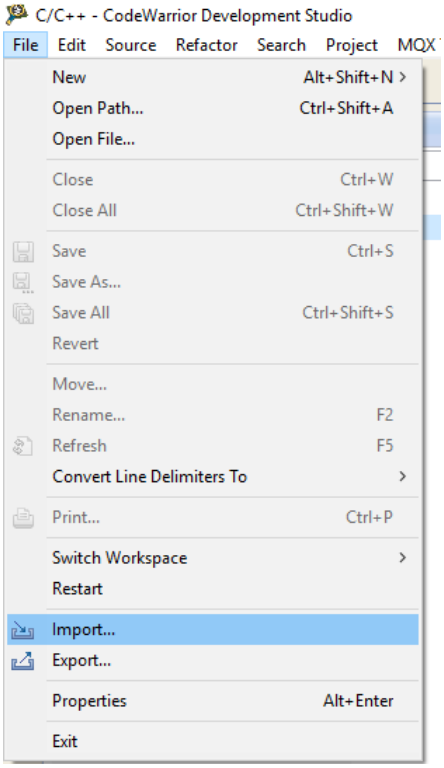


Figure 31. Importing a project (1)

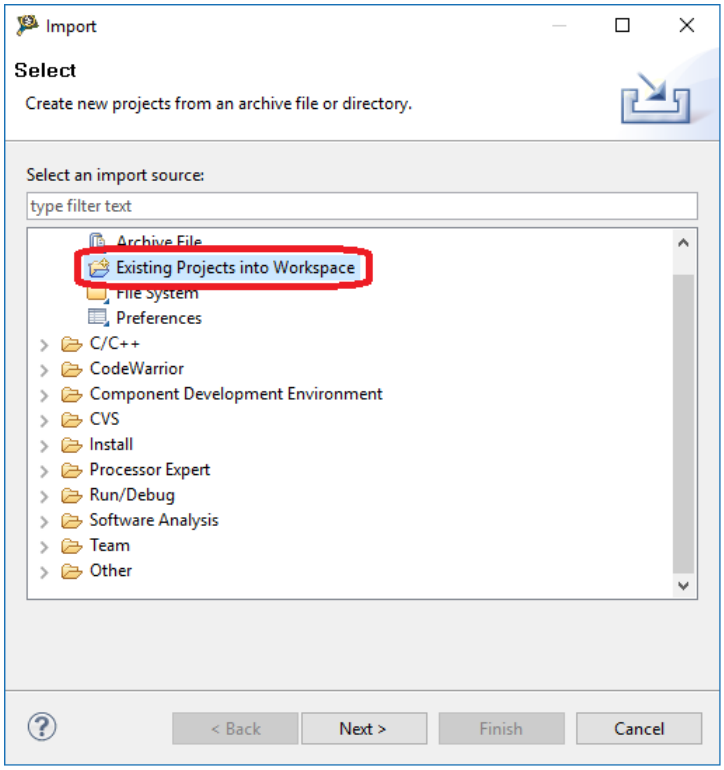


Figure 32. Importing a project (2)

3. Select the project directory, as shown in the following figure.

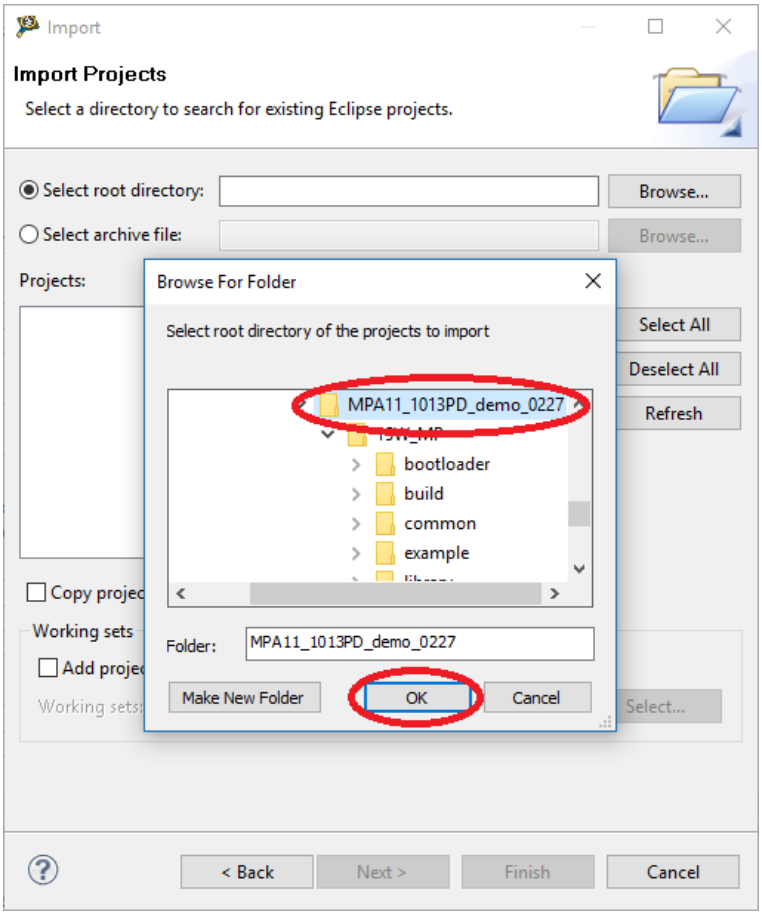


Figure 33. Importing a project (3)

4. Select the WCT1013 project.

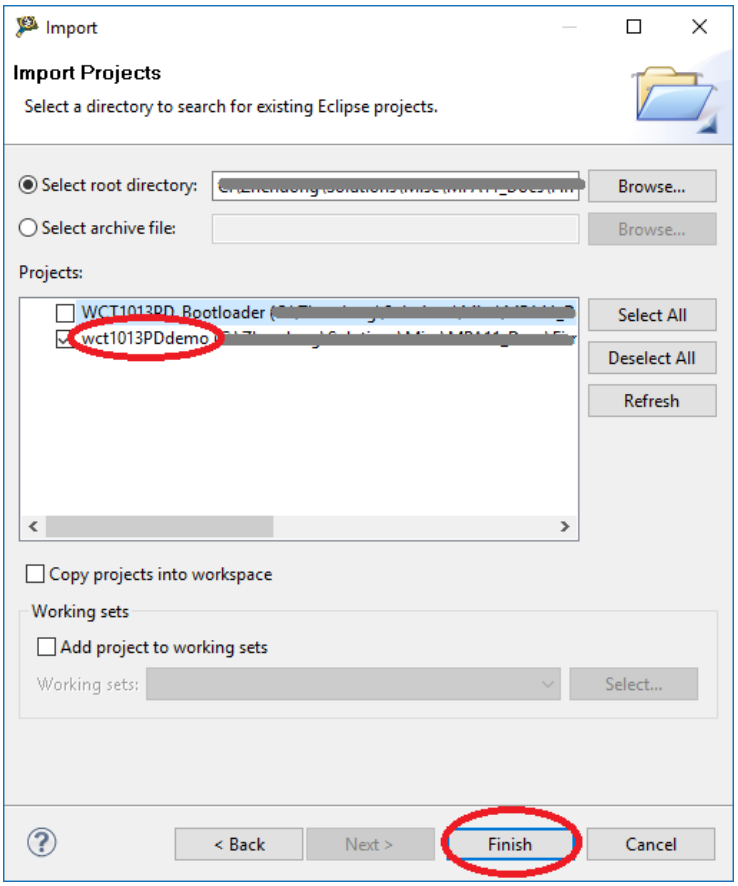


Figure 34. Importing a project (4)

5. Build a project.

   Select the build configurations by clicking the project name in the project window, as shown in the following figure. The “demo_ldm_debug” build contains debug information. The “demo_ldm_release” is the same as the “demo_ldm_debug”, except for debug information.

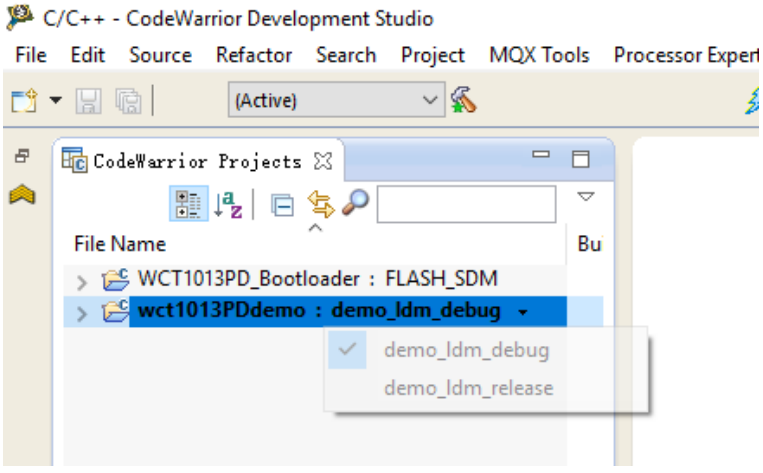


Figure 35. Building a project (1)

6. Right-click “wct1013demo” and select the “Clean Project” and “Build Project” options.

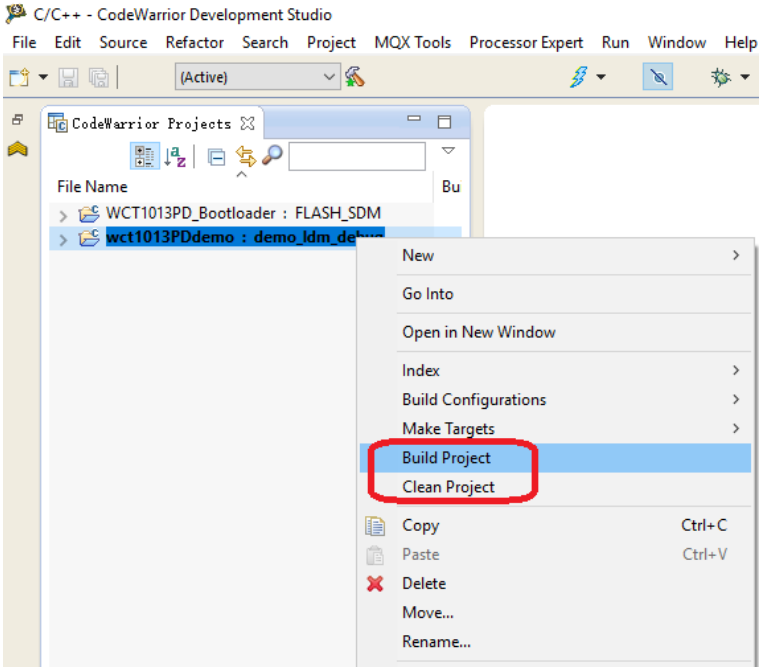


Figure 36. Clean Project and Build Project options

7. Download the project.

   Download the project from the “Debug” drop-down list or from “Run” -> “Debug”. In “Download Configurations”, select a download configuration according to your build configurations and debugger type: USB TAP, PnE Multilink, or OSJTAG.

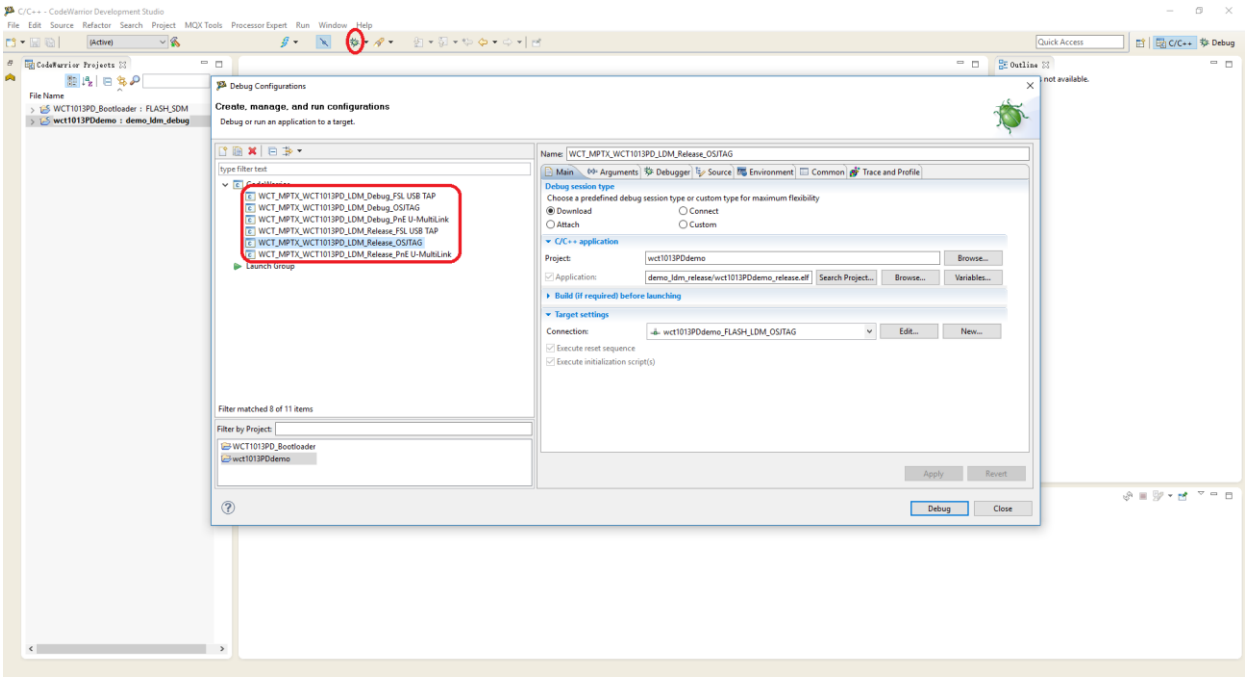


Figure 37. Downloading the project

After the project is downloaded, the MCU stops at the startup code. Click the “Run” button or press the “F8” key to run the MCU. Make sure that there is no object on the TX surface before running the MCU. Due to the automatic calibration of the rail voltage, the Q-factor and quick removal is done the first time the TX runs after flashing a new image.

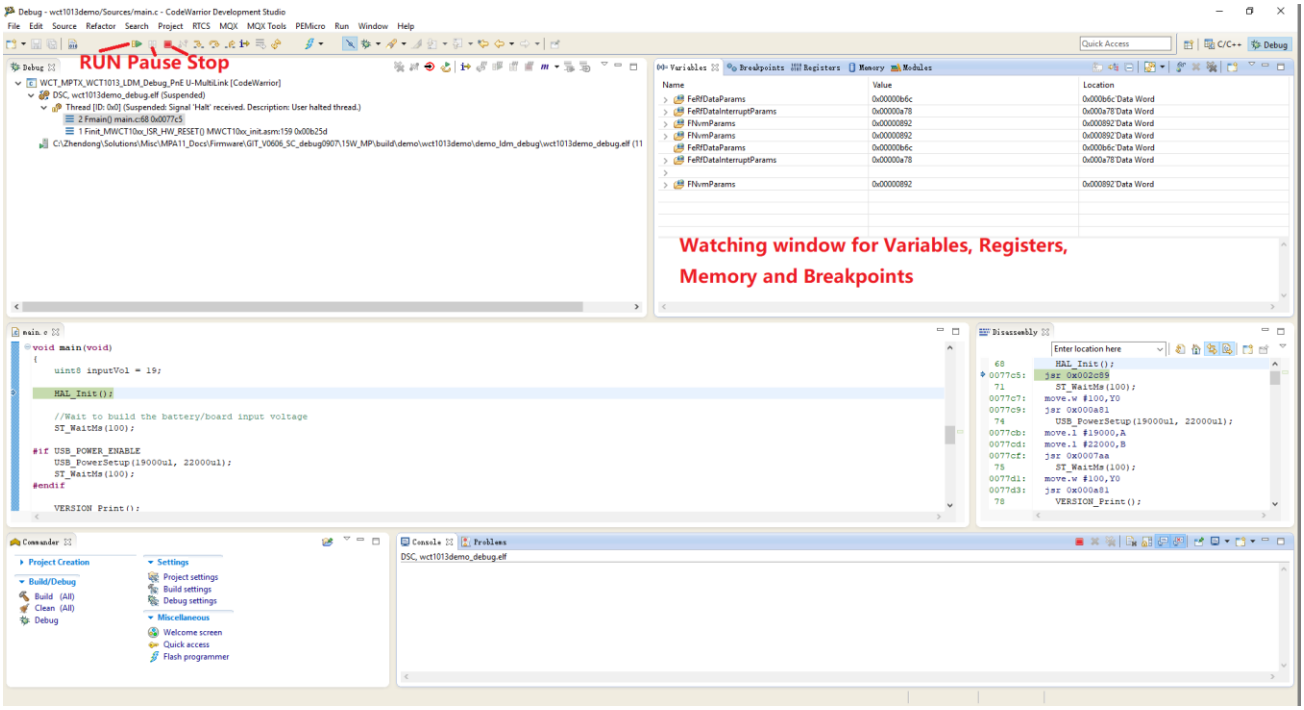


Figure 38. Project downloaded

7.4. Programming the binary file (.elf or .S)

1. Select “Flash Programmer” –> “Flash File to Target”.

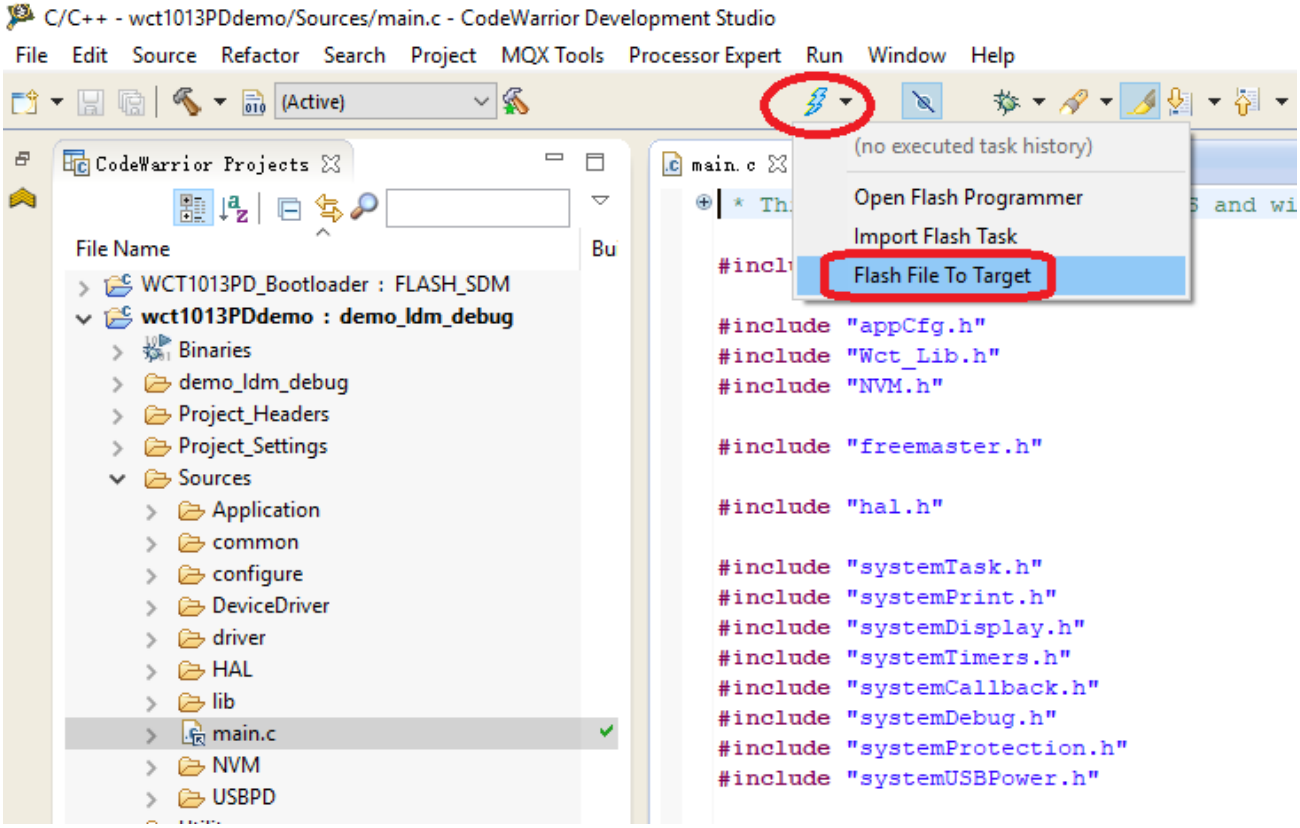


Figure 39. Choosing Flash File to Target

2. Click the “New” button to create a new connection.

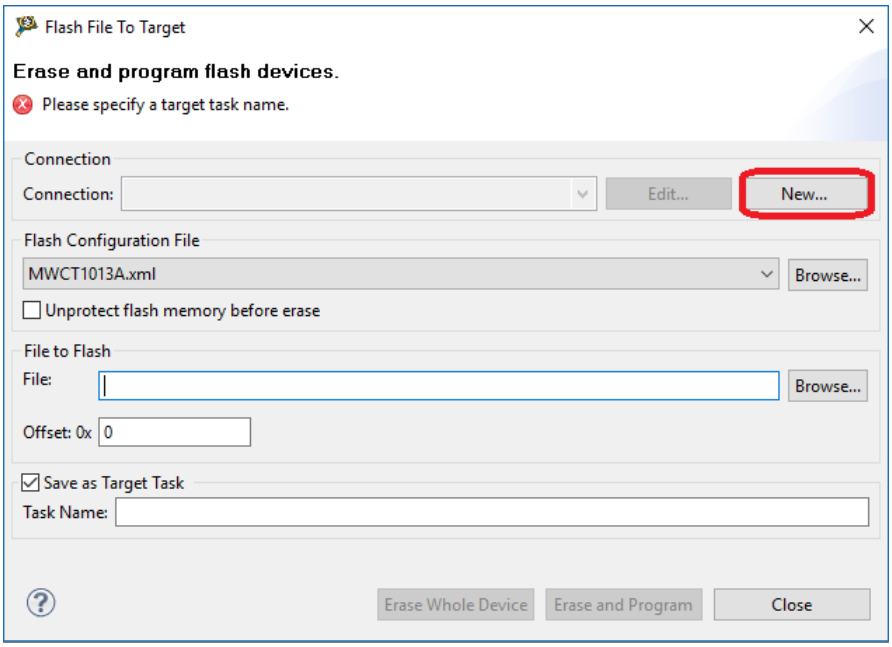


Figure 40. Creating a new connection

3. In the “New Connection” text box, select “Hardware or Simulator Connection” and click “Next”.

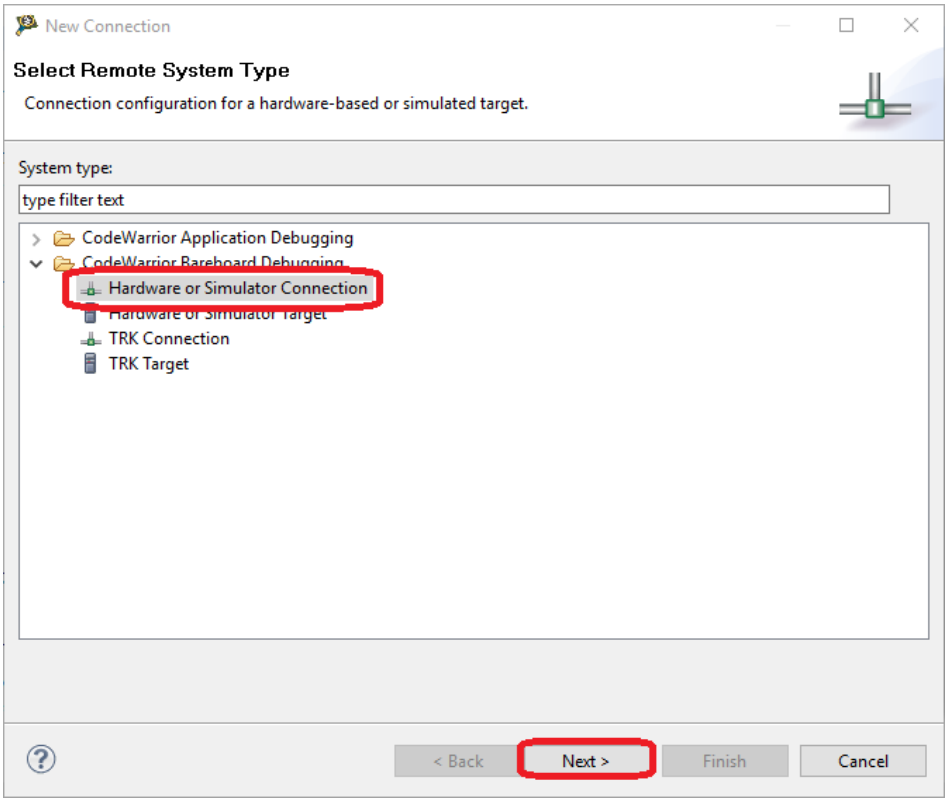


Figure 41. Entering a connection name

4. In the “Name” text box, enter a connection name (any name is OK), and click “New” to create a target.

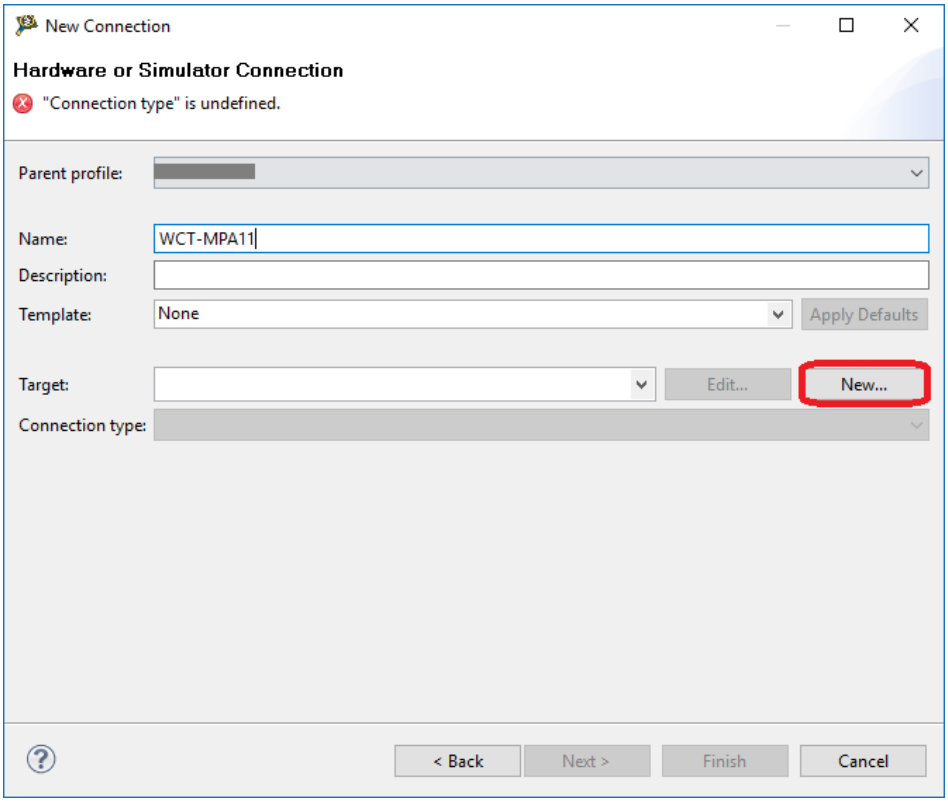


Figure 42. Entering a connection name

5. In the “Name” text box, enter a target name (any name is OK, but it cannot be the same as the connection name) and choose “dsc.MWCT101x” -> “MWCT1013A” from the “Target Type” drop-down menu.

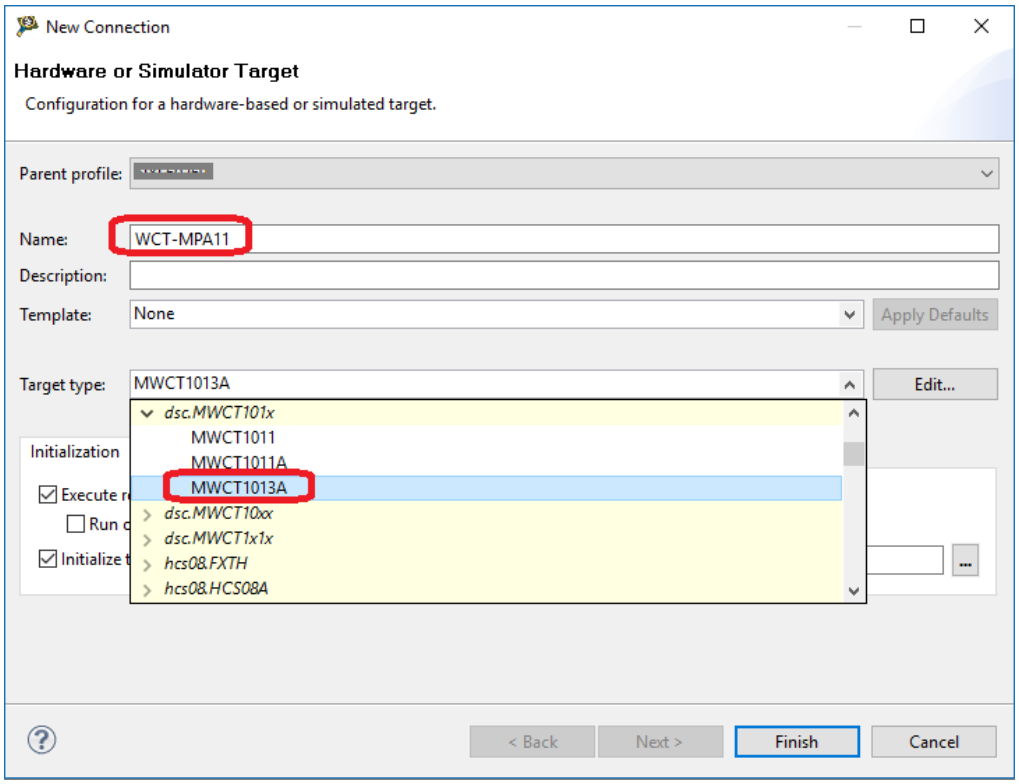


Figure 43. Choosing MWCT1013A

6. Select “Execute reset” and “Initialize target”, set the initialization target file path to the CodeWarrior IDE installation folder, and then select *MWCT1013A.tcl*.

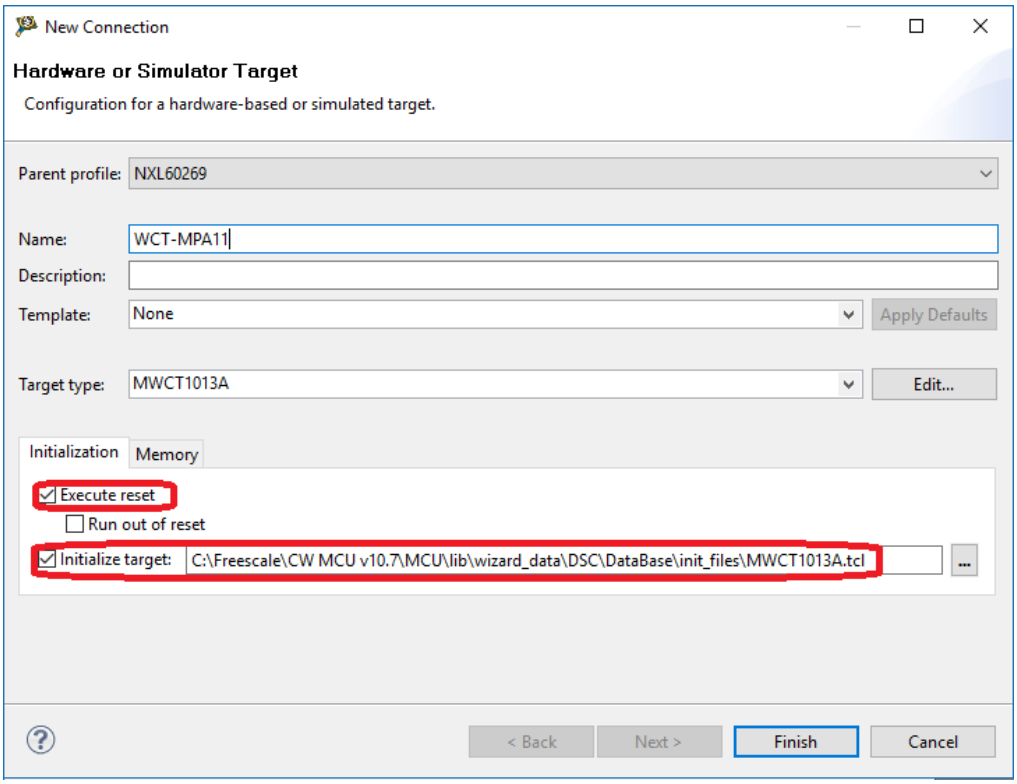


Figure 44. Executing reset and initializing target

7. Click the “Memory” tab.
8. Select “Memory configuration”, set the memory configuration file path to the CodeWarrior IDE installation folder, and then select “MWCT1013A.mem”.
9. Click “Finish”.

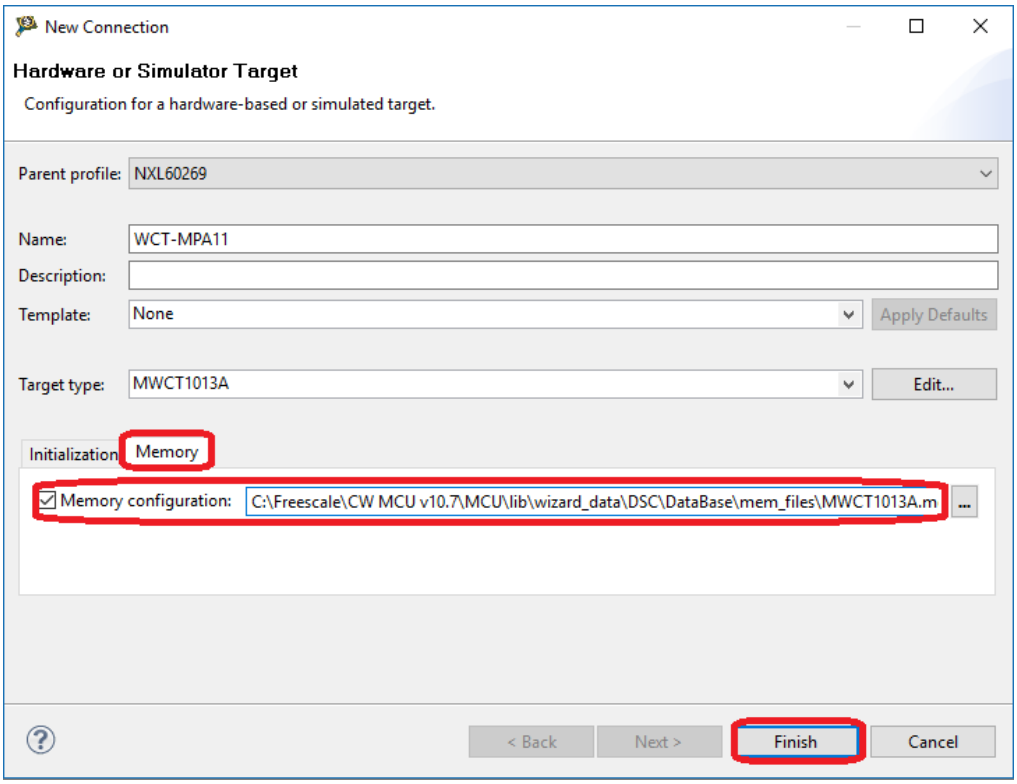


Figure 45. Memory configuration

10. Select “USB TAP” for the “Connection type”, and then click “Finish”.

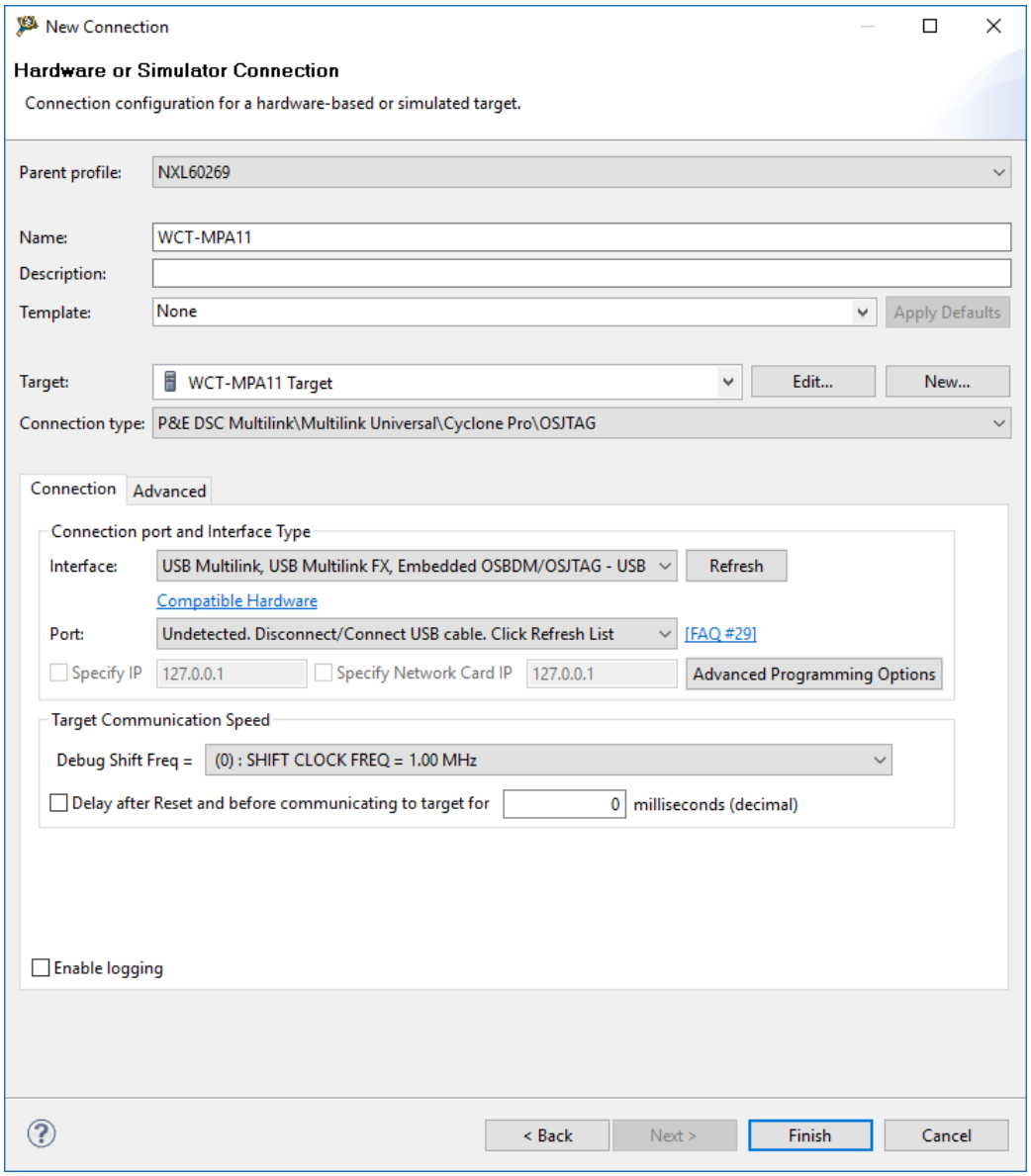


Figure 46. Setting the connection type

11. Set the binary file path to “File to Flash”. Select “Save the Target Task” for future programming. Power the MP-A11 on and click “Erase and Program”.

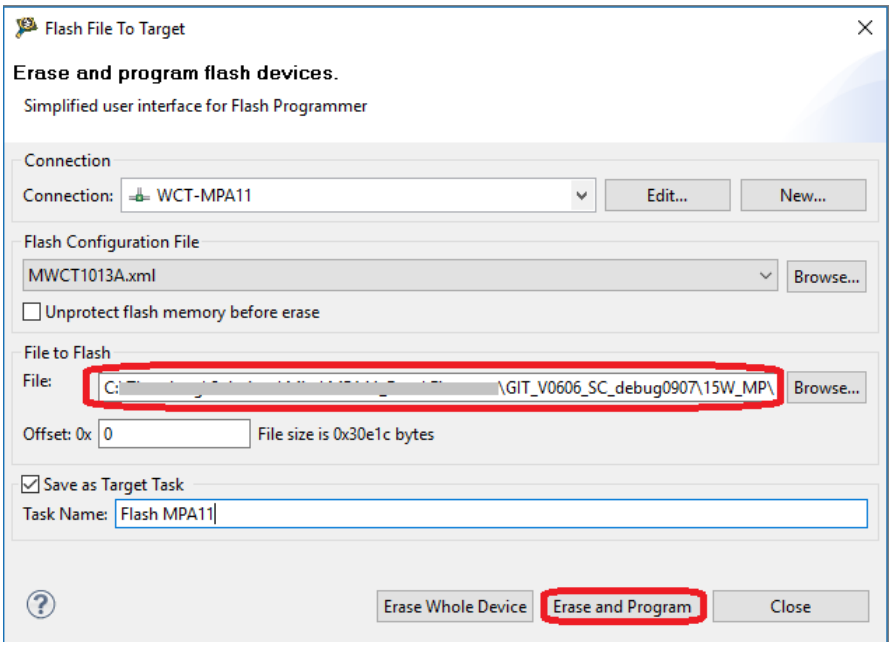


Figure 47. Erase and Program

12. Specify the task path and click “OK” to save the task.

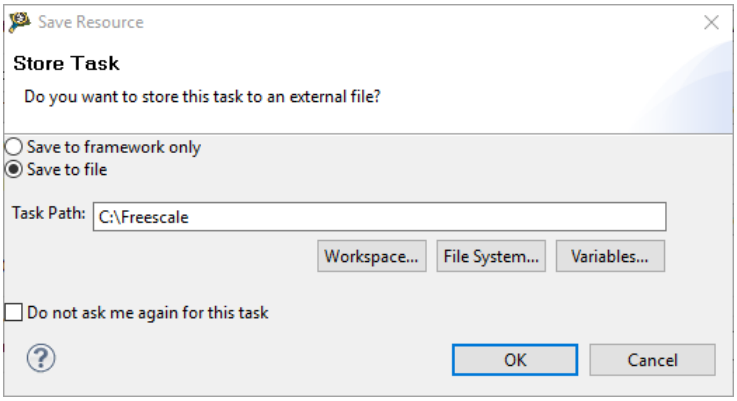


Figure 48. Selecting the task path

13. When program is finished, the “Console” window displays the following log.

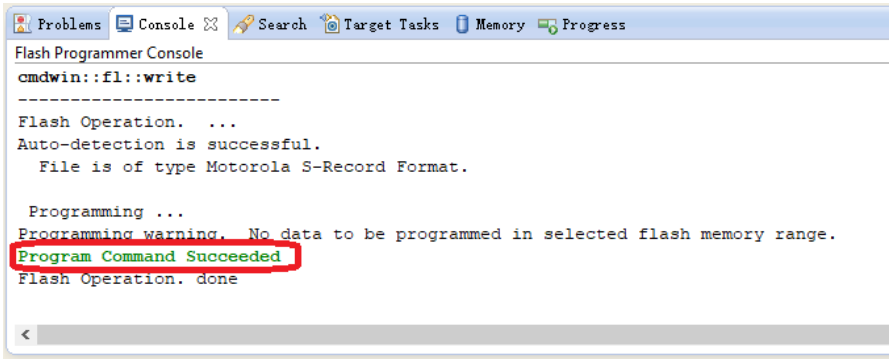


Figure 49. Programming finished log

7.5. Programming by bootloader

The bootloader is independent of the application codes and can reside in the flash forever after the application code is downloaded. When a system is reset, the bootloader starts. After a boot delay (in seconds), the bootloader jumps to the programmed application code without receiving the application S-record file. When receiving the application S-record file, the bootloader programs the application code to the on-chip flash. After completion, the bootloader jumps to the application startup code.

1. The bootloader code is not flashed to the board by default. Download the bootloader code. Import the bootloader project and follow the steps described in Section 7.3 to download the project.

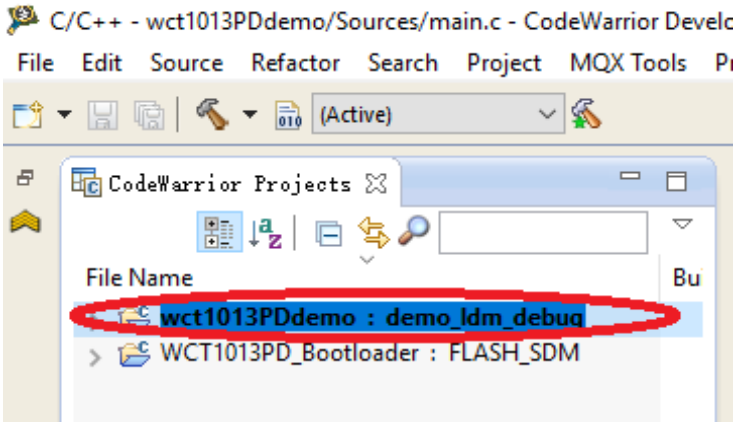


Figure 50. Bootloader project

2. Generate an application S-record file.

   Enable the bootloader function. Set the following macro to TRUE in *appcfg.h*.

   ```
   #define BOOTLOADER_USED    (TRUE)
   ```

   See the figure below to configure the application project settings. Select the “Sort by Address” option. Set “Max S-Record Length” to a value that does not exceed 255. Select “DOS (\\r\\n)” for the “S-Record EOL Character”.

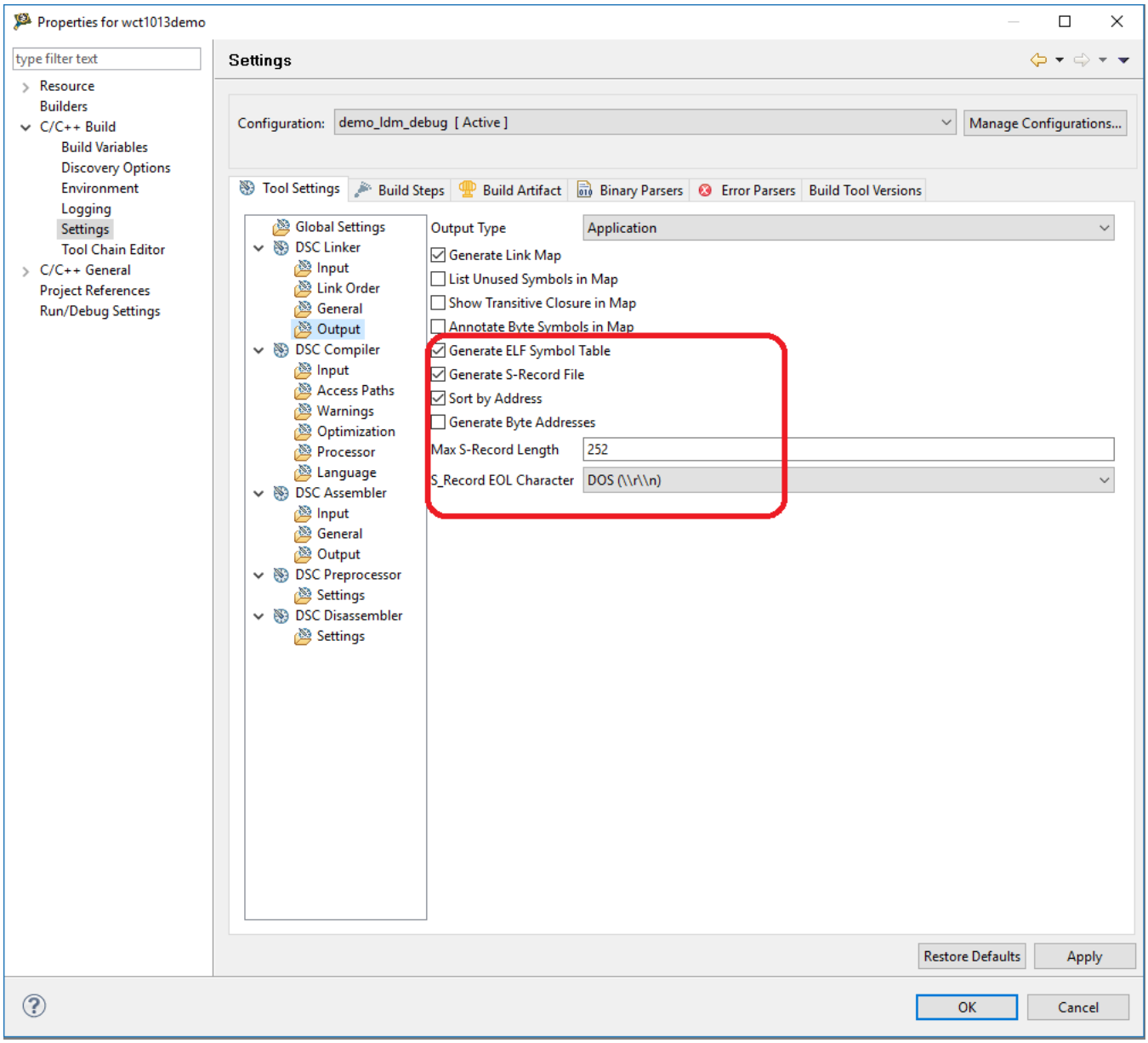


Figure 51. Configure project settings

Recompile the project after completing the configuration above. The generated S-record file is in the *<unpacked_files>\15W_MP\build\demo\wct1013PDdemo\demo_ldm_debug* folder for the WCT1013 chip. The S-record file is the combined p and x S-record file without ".p" or ".x" in the extension name (.s).

3. Download the application code using the bootloader.

   Most serial terminal programs can be used to send the S-Record file from the host to the WCT1013 board using the bootloader. For example, Tera Term can be used in the Windows OS platform.

SCI0 is used for communication. Plug the USB-UART converter to the SCI connector J2 and the computer. Open Tera Term, and select “Serial” and “Port”. Check the COM port in the Device Manager.

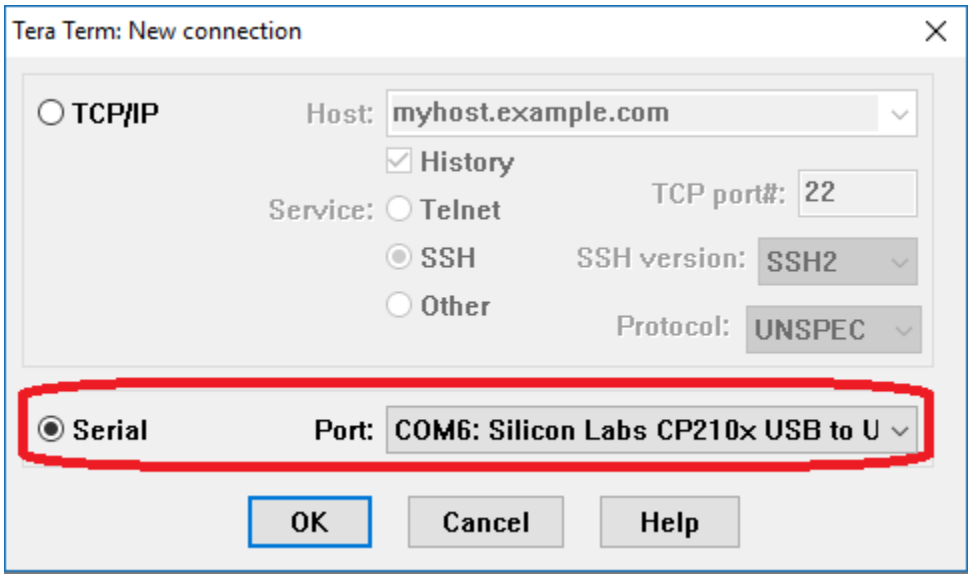


Figure 52. Tera Term connection

4. Choose “Setup” -> “Serial port” to configure the COM properties, as shown in the following figure.

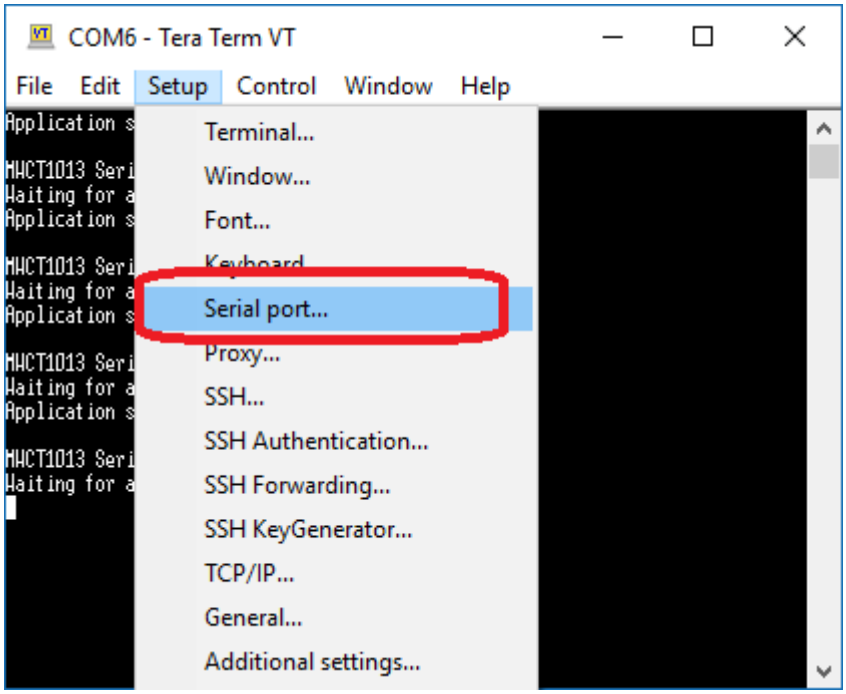


Figure 53. Serial port

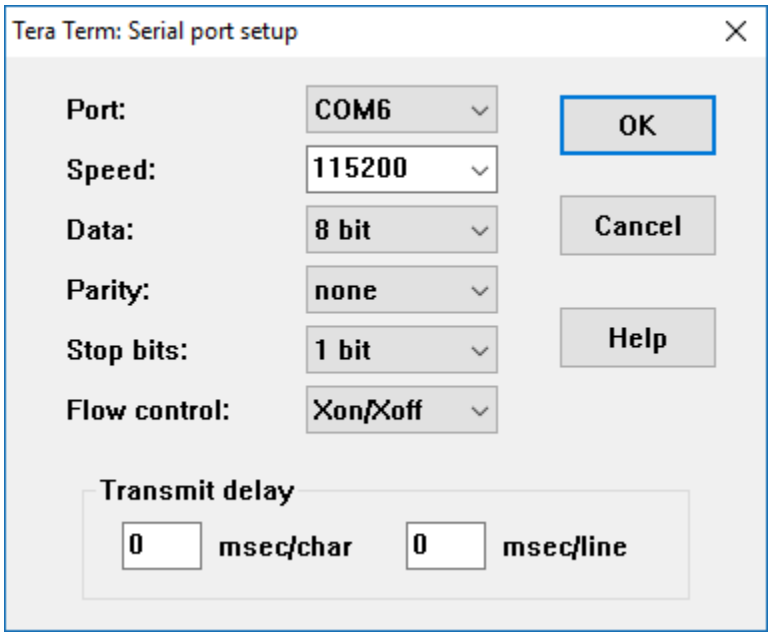


Figure 54. Serial port setup

5. Choose “File” -> “Send file”.

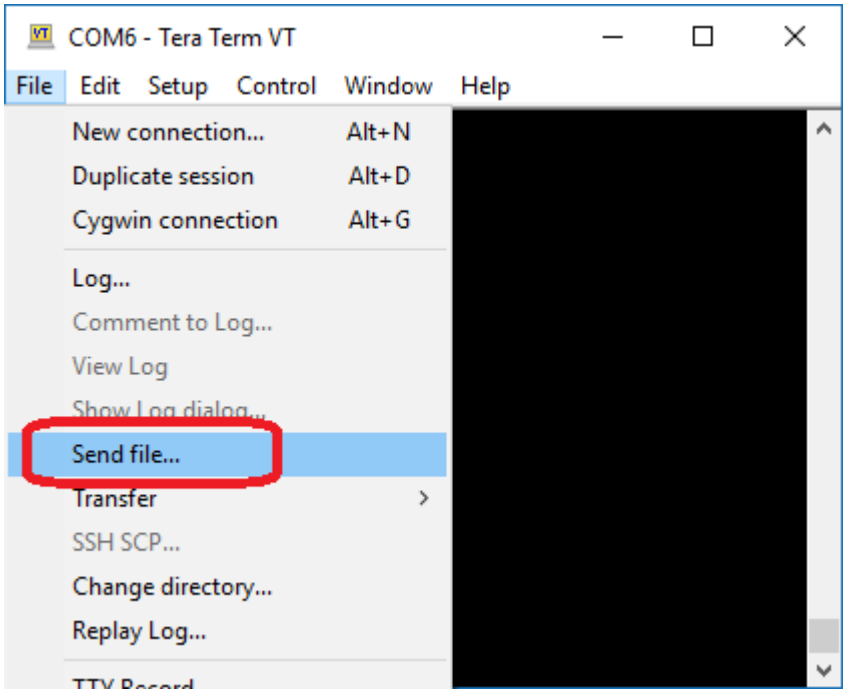


Figure 55. Send file

6. Select the application S-Record file and click “Open”.

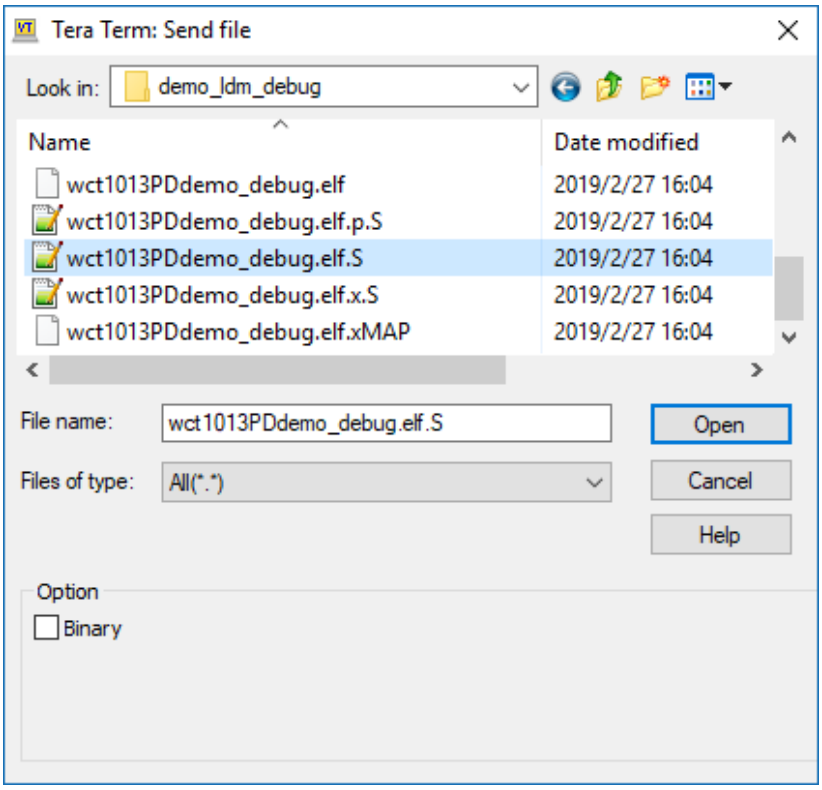


Figure 56. Send application S-Record file

The download progress is displayed in the Tera Term window. After the download completes, the application code starts.

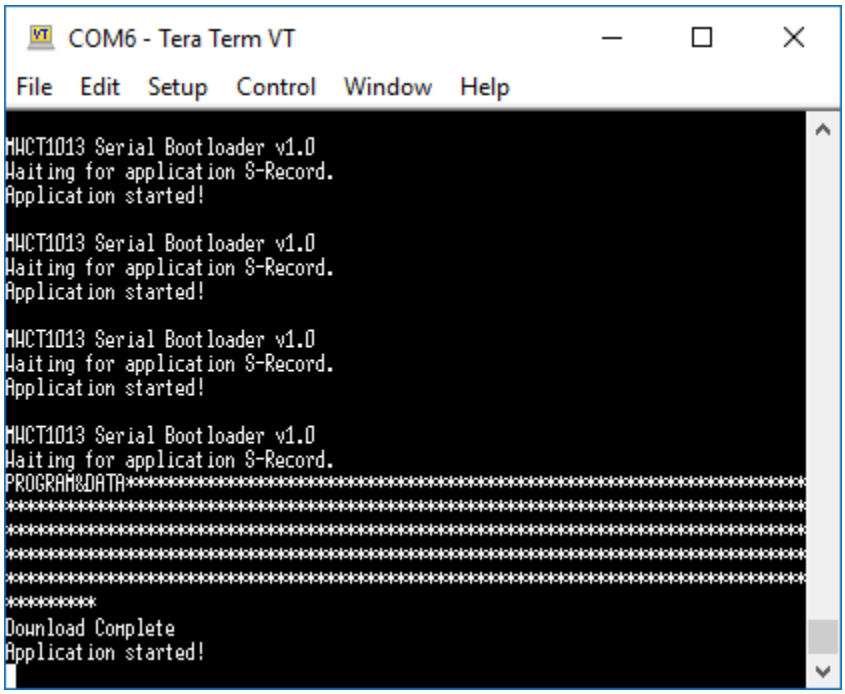


Figure 57. S-Record file download complete

7.6. Board calibration

NXP provides the FreeMASTER GUI tool for calibration and parameters tuning. For board calibration, see the *WCT1012VLF/WCT1013VLH Consumer MP-A11 V1.0 Run-Time Debugging User's Guide* (document WCT101XV10RTDUG).

8. Software description

8.1. Software overview

8.1.1. Directory structure

The following figure shows an example of the directory structure of the whole WCT1013_MP-A11 distribution.

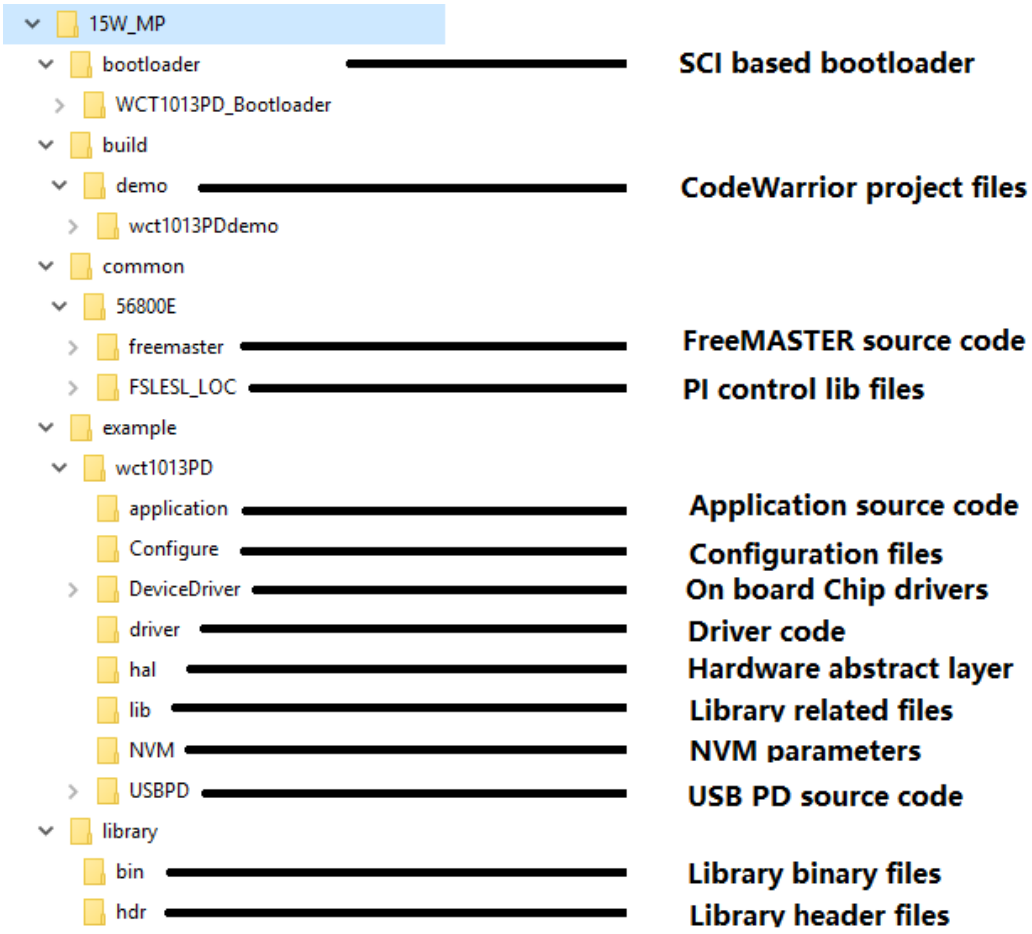


Figure 58. Directory structure of the whole WCT1013_MP-A11 distribution

8.2. CodeWarrior projects

There are four CodeWarrior projects in the package. The following figure shows all four projects in the CodeWarrior GUI when all of them are imported.

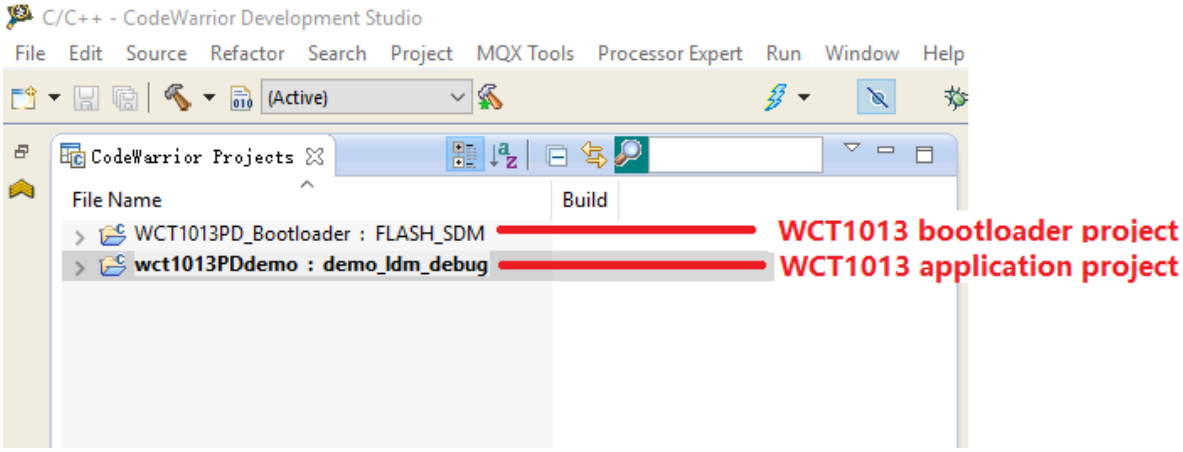


Figure 59. CodeWarrior projects

Combined with different program models and different user cases, multiple build configurations are predefined in the respective projects.

There are two program models provided for the WCT parts.

- Small program model: The compiler generates a more efficient switch table when the code is in the range of 0x0-0xFFFF. This model is more efficient, but the code size is limited to 64-KB words.
- Larger program model: Extends the DSP56800E addressing range by providing 24-bit address capability to the instructions. This enables the user accesses beyond the 64-KB word boundary of 16-bit addressing.

For the WCT1013 of the MP-A11 design, only the larger program model is provided.

For WCT1013, there are two build configurations:

- “demo_ldm_debug”: larger program model, including the code for debugging.
- “demo_ldm_release”: larger program model, excluding the debugging code to save memory size.

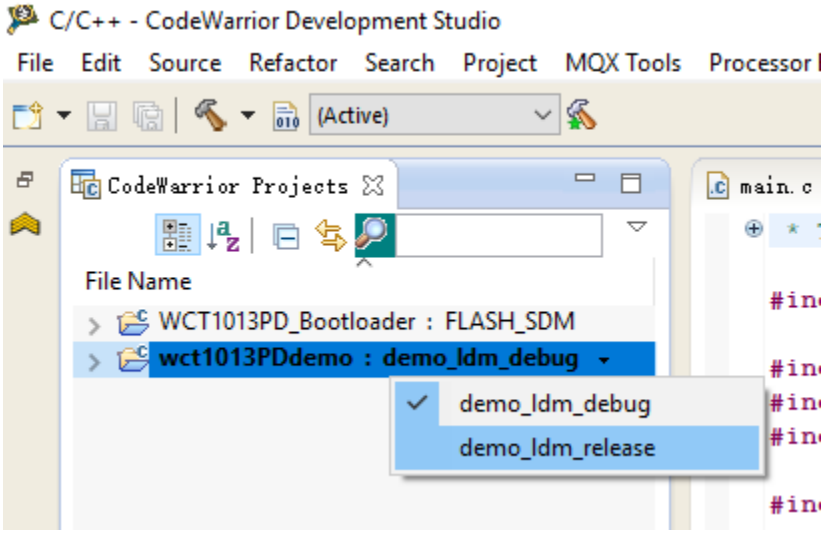


Figure 60. WCT1013 build configuration

8.3. Functional description

NXP provides full-featured wireless charging functions on the reference board. If a certain function is not needed, disable it by the definitions in the header file.

8.3.1. FreeMASTER

- FreeMASTER is supported. The following configuration is used to enable or disable it.

Table 2. FreeMASTER configurations

Configurations	Default value	Location	Description
FREEMASTER_SUPPORTED	TRUE	**appcfg.h**	Enables or disables the function. Set TRUE to enable it. Set FALSE to disable it.

- FreeMASTER communication interface configuration is in *freemaster_cfg.h*. The SCI interface is enabled and the JTAG interface is disabled by default. Only one interface can be set at a time.

```
#define FMSTR_USE_SCI          1    /* To select SCI communication interface */
#define FMSTR_USE_JTAG         0    /* 56F8xxx: use JTAG interface */
```

- The FreeMASTER SCI port is SCI0 by default.

1) `#define FMSTR_SCI_BASE          0xE080 /* base address of SCI_0  */`

   The macro is in *freemaster_cfg.h*.

2) `#define QSCI_FREEMASTER_INDEX  0 //QSCI0`

   The macro is in *qsci.h*.

8.3.2. Low-power mode

The low-power mode is supported. In the analog ping interval, the MCU enters the LPSTOP mode and the DCDC module is closed. The following configuration is used to enable or disable it.

Table 3. Low power mode configurations

Configurations	Default value	Location	Description
LOW_POWER_MODE_ENABLE	FALSE	**appcfg.h**	Enables or disables the function. Set TRUE to enable it. Set FALSE to disable it.

8.3.3. Debug console

The debug console is supported. The following configuration is used to enable or disable it.

Table 4. Debug console configurations

Configurations	Default value	Location	Description
DEBUG_CONSOLE_SUPPORTED	FALSE	**appcfg.h**	Enables or disables the function. Set TRUE to enable it. Set FALSE to disable it.

For the WCT1011A/WCT1013A digital buck-boost platform, only one SCI port is available. This port is used for FreeMASTER by default. If the debug console is used, disable the FreeMASTER or change the FreeMASTER communication interface to JTAG. The configurations are described in Chapter 6.

8.3.4. Bootloader

Bootloader is supported. The following configuration is used to enable or disable it.

Table 5. Bootloader configurations

Configurations	Default value	Location	Description
BOOTLOADER_USED	FALSE	**appcfg.h**	Enables or disables the function. Set TRUE to enable it. Set FALSE to disable it.

If the bootloader is used, download the bootloader project to the board. Then change BOOTLOADER_USED to TRUE, rebuild the application project, and download the application *.s* file using the bootloader.

8.3.5. DCDC control type

NXP provides two DCDC control types: digital buck-boost and analog buck-boost. Because the MPA11 design doesn't use the buck-boost circuit, the default one shall be FALSE.

Table 6. DCDC control type configurations

Configurations	Default value	Location	Description
DIGITAL_BUCKBOOST	FALSE	**appcfg.h**	Switch the DCDC control type. Set TRUE to enable the digital buck-boost. Set FALSE to enable the analog buck-boost.

8.3.6. Library functions

Some key functions are implemented in the WPC library and can be enabled or disabled in the application. The following configurations are used to enable or disable them.

Table 7. Library functions configurations

Function	Function description	Variables	Default value	Description
FOD	Foreign object detection based on power loss during power transfer state	gWCT_Params.uCtrlBit.bFODEnable	1	FOD feature enable or disable. 1: enable, 0: disable.
RX removal quick detection	RX removal quick detection based on current and voltage (~350 ms) instead of communication timeout (1.5 s)	gWCT_Params.uCtrlBit.bRRQDEnable	1	RX removal quick detection enable or disable. 1: enable, 0: disable.
Safe digital ping	Digital ping with lower coupling to avoid large current damage of a large metal	gWCT_Params.uCtrlBit.bSafeDPEnable	1	Safe digital ping enable or disable. 1: enable, 0: disable.
Maximum voltage limit	Refer to MVL in the WPC Qi specification	gWCT_Params.uCtrlBit.bMVLEnable	1	Maximum voltage limit enable or disable. 1: enable, 0: disable.
Fast charging	Enable fast charging for some types of phones, contact NXP for details	gWCT_Params.uCtrlBit.bFastChargingEnable	1	Fast charging enable or disable. 1: enable, 0: disable.
Analog ping	Use several power pulses to detect object before digital ping	gWCT_Params.uCtrlBit.bAnalogPingDisable	0	Analog ping enable or disable. 0: enable, 1: disable.
Q factor recharge retry	Foreign object removal detection based on Q factor method during recharge retry state	gWCT_Params.uCtrlBit.bQfactorRetry	1	Using Q factor method for recharge retry state. 1: enable, 0: disable.
Maximum power limit	TX maximum output power limit	gWCT_Params.uCtrlBit.bMPLEnable	1	Maximum power limit enable or disable. 1: enable, 0: disable.
Active power protection	Refer to overvoltage protection in the WPC Qi specification	gWCT_Params.uCtrlBit.bActivePowerProtectionEnable	1	Active power protection enable or disable. 1: enable, 0: disable
Low-power mode for recharge retry state	Low-power mode enable or disable when TX is under the recharge retry state	gWCT_Params.uCtrlBit.bRechargeRetryLowPowerEnable	0	Low power mode enable or disable under recharge retry state. 1: enable, 0: disable

Power down for maximum rail voltage	Power down or keep the maximum rail voltage when rail voltage exceeds the maximum	gWCT_Params.uCtrlBit.bPowerDownForMaxVrail	1	Power down or not when rail voltage exceed maximum value. 1: power down, 0: keep maximum
“Not Res Sens” bit for TX capability packet	Set “Not Res Sens” bit for TX capability packet	gWCT_Params.uCtrlBit.bNotResSens	1	Set the value of Not Res Sens bit for TX capability packet, 0: set this bit to 0, 1: set this bit to 1
Pre-FOD	FOD protection when TX is in standby state	gWCT_Params.uCtrlBit.bPreFODEnable	1	Pre-FOD enable or disable during standby state, 1:enable, 0:disable
Duty cycle control	Duty cycle control when TX rail voltage is down to minimum value	gWCT_Params.uCtrlBit.bEnableDutyCycleControlForMinRailVol	0	Duty cycle control enable or disable, 1:enable, 0:disable
BPP transmitter	TX behaves as BPP transmitter	gWCT_Params.uCtrlBit.bBPPOnly	0	Only BPP mode enable or disable. 1: BPP mode, 0: EPP mode

8.4. Protection mechanisms

The following table lists the protection that can be implemented.

Table 8. Protection mechanisms

Protection	Default limits	Variables	Description
Rail voltage	17000 mV	gPROT_Params.wMaxRailVol	Application implemented. If the rail voltage exceeds the limit, charging is turned off. The limit value can be changed by FreesMASTER GUI.
Battery voltage	Min: 8000 mV Max: 22000 mV Hysteresis: 1000 mV	gPROT_Params.wMinBatteryVol gPROT_Params.wMaxBatteryVol gPROT_Params.wBatteryHystVol	Application implemented. If the battery voltage exceeds the maximum, the WCT library stops. When the battery voltage is lower than the difference between the maximum and hysteresis, the WCT library starts. When the battery voltage is lower than the minimum, the WCT library stops. When the battery voltage is higher than the sum of the minimum and hysteresis, the WCT library starts. The minimum and maximum limits can be changed by the FreeMASTER GUI. The hysteresis value can be changed in PROT_Init().
Input current	5000 mA	gPROT_Params.wMaxInputCurrent	Application implemented. If the input current exceeds the limit, charging is turned off. The limit value can be changed by the FreeMASTER GUI.

Coil current	8000 mA	gPROT_Params.wMaxCoilCurrent	Application implemented. If the coil current exceeds the limit, charging is turned off. The limit value can be changed by the FreeMASTER GUI.
Temperature	Max: 60 ℃ Hysteresis: 10 ℃	gPROT_Params.swTemperatureThreshold gPROT_Params.wTemperatureHyst	Application implemented. If the temperature exceeds the maximum, the WCT library stops. When the temperature is lower than the difference between the maximum and hysteresis, the WCT library starts. The maximum limit can be changed by the FreeMASTER GUI. The hysteresis value can be changed in PROT_Init().
Safe digital ping	200 mA	gPROT_Params.wSafeDigitalPingInputCurrentThreshold	Library implemented. If the input current sampled at the beginning of the digital ping exceeds the limit, digital ping stops. The limit value can be changed in PROT_Init().
FOD	BPP RX: 400 mW EPP RX: 800 mW EPP5W RX: 450 mW	gWCT_Params.wBPPLPPowerLossThresholdInOperationMode gWCT_Params.wEPPMPPowerLossThresholdInOperationMode gWCT_Params.wEPPLPPowerLossThresholdInOperationMode	Library implemented. If the power loss exceeds the limit, charging is turned off for 5 minutes. The limit value can be changed by the FreeMASTER GUI.

9. System bring up

9.1. Ping sequences

When the low-power mode is disabled and no receiver is placed on the charging surface, the ping sequence is as follows:

The digital ping appears about every 5 seconds and the analog ping appears about every 400 ms. There are 12 to 13 analog pings between two digital pings.

The following figures show the PWM waveforms of the ping sequence and ping patterns.

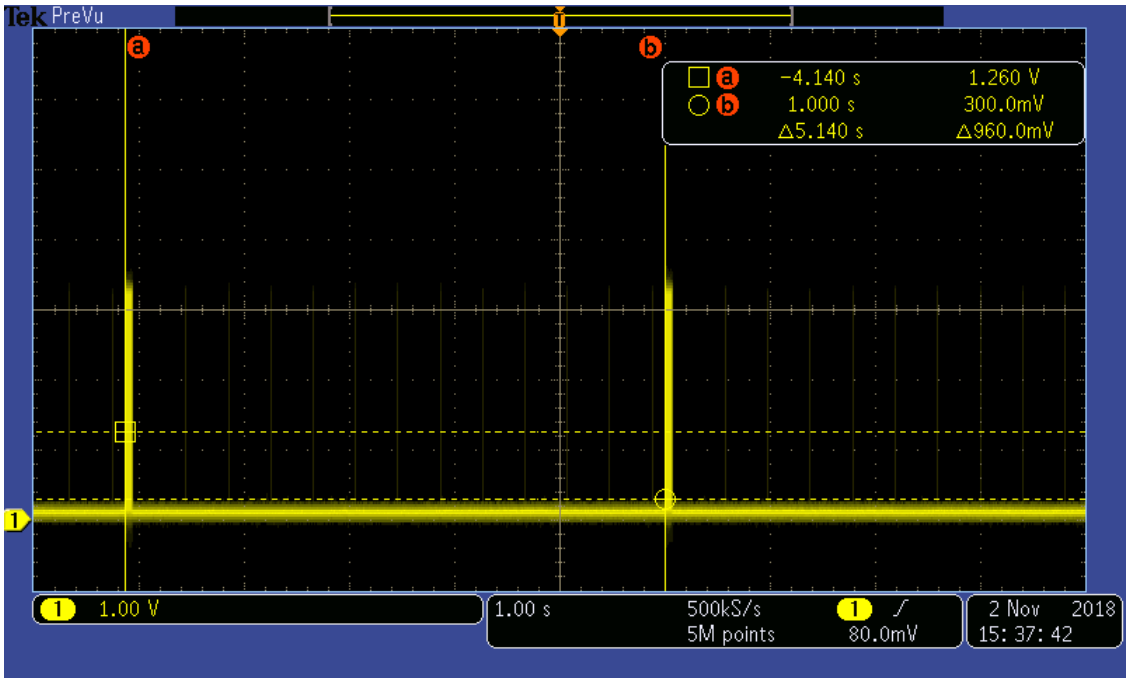


Figure 61. Digital ping interval

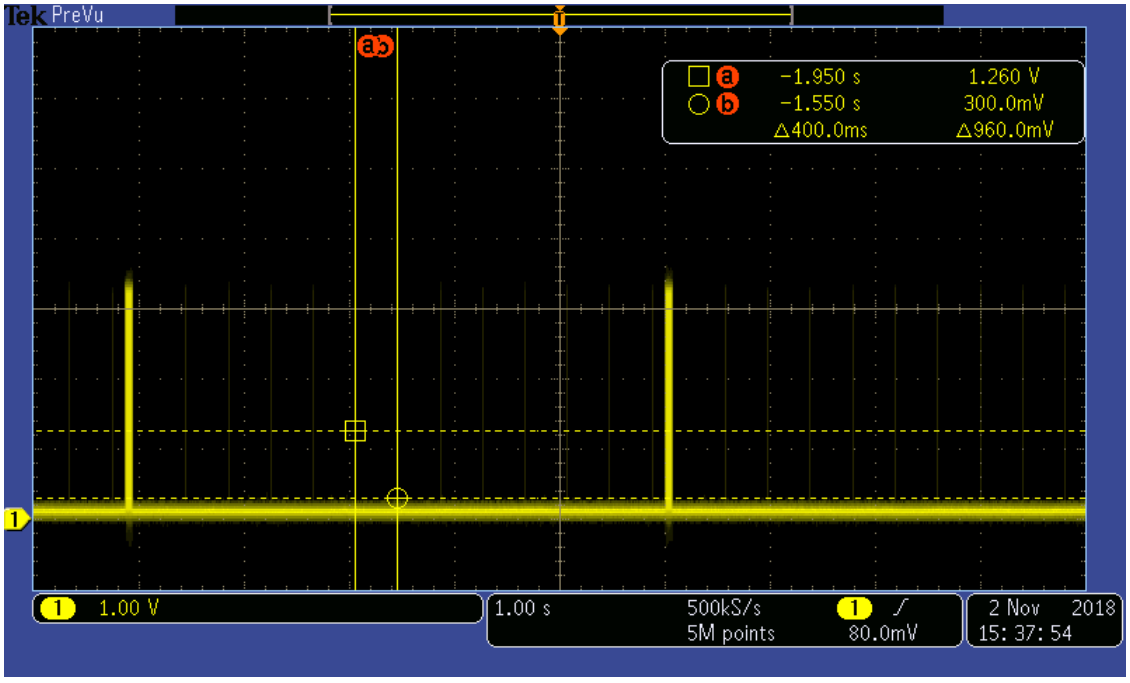


Figure 62. Analog ping interval

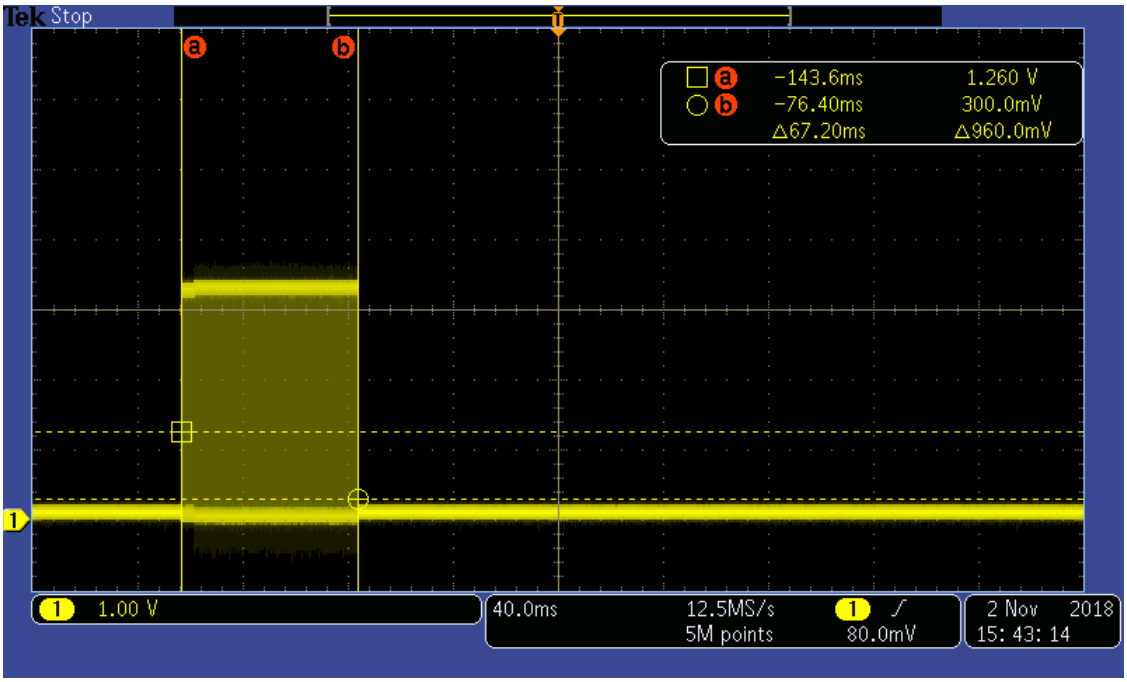


Figure 63. Digital ping pattern

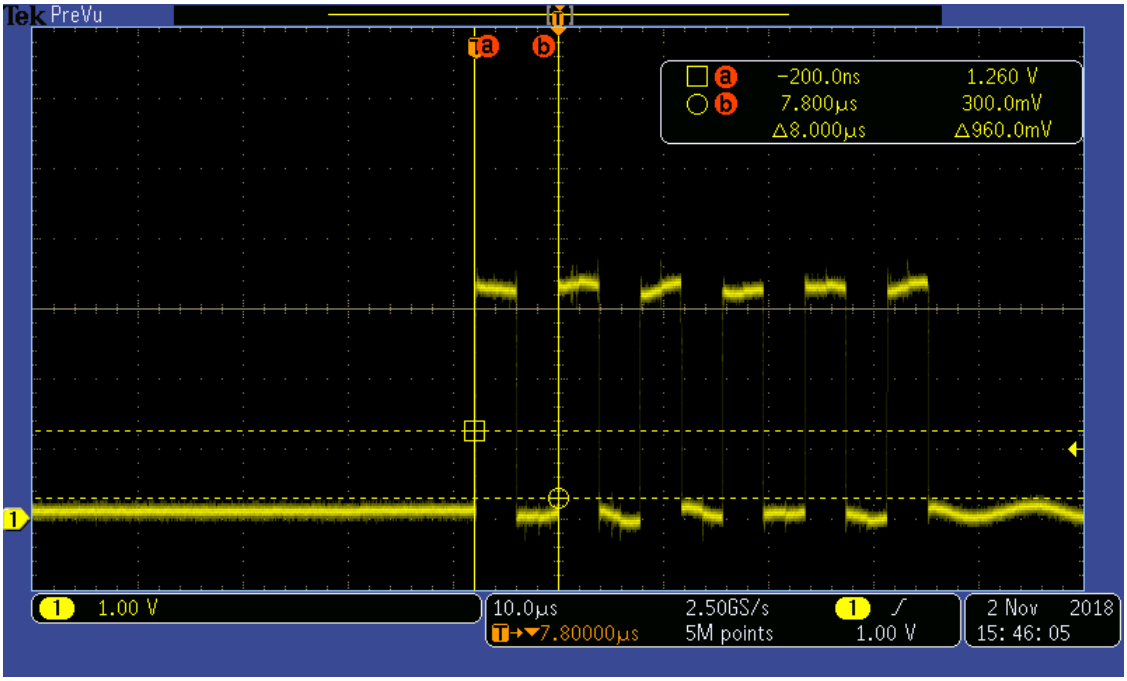


Figure 64. Analog ping pattern

9.2. LED indication

The default LED display modes for different TX working states are shown in the following table.

Table 9. LED display modes

LED number	LED operational status					
	Standby	Charging	Charging complete	D fault	TX fault	RX fault
LED 1 (Red)	Off	Blink	Off	On	On	On
LED 2 (Green)	Blink	On	On	Off	Off	Off

The display pattern can be changed in WCT_UpdateDevUsrIndication().

9.3. Debug messages

The system can print messages from a specified SCI port to inform you what happened in the system. The messages help you to understand the system working procedure and debug the issues.

Message: `ID, T/O`

Prints information when the identification packet times out.

Message: `EXT ID, T/O`

Prints information when the extended identification packet times out.

Message: `CFG, HOLDOFF Invalid`

Prints information when the hold off time is out of range.

Message: `CFG, Incorrect Count, Count1 (Count2)`

Prints information when the amount of optional configuration packets received does not match the number in the configuration packet.

- *Count 1*: the number in the configuration packet.
- *Count 2*: The amount of TX optional configuration packets received.

Message: `CFG, Over CP`

Prints information when the RX power is beyond capability.

Message: `CFG, Rcvd 0xXX`

Prints the packet type that should not be received in the configuration phase.

Message: `CFG, T/O`

Prints information when the configuration packet times out.

Message: `XFER, INCOMP`

Prints information when the RX version is not compatible.

Message: `XFER, RCVPWR T/O`

Prints information when the receive power packet times out.

Message: `XFER, PLoss T/O`

Prints information when the FOD happens.

Message: `PROP, <Packet type>`

Prints the proprietary packet header.

Message: `XFER, Rcvd 0xXX Reset`

Prints the packet type that is not received in the power-transfer phase. Charging is reset.

Message: `XFER, Rcvd 0xXX`

Prints the packet type that is not defined in the WPC specification.

10. Revision history

Table 10 summarizes the changes done to this document since the initial release.

Table 10. Revision history

Revision number	Date	Substantive changes
0	04/2019	Initial release.
1	05/2019	Updated Section 1, “Key features” and Section 4.5, “Full-bridge and resonant circuits”. Updated Table 8.

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