Using JTAG Hardware Debuggers with the QNX Neutrino RTOS

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1. Introduction

This document describes how to use JTAG hardware debuggers with the QNX Neutrino real-time operating system for embedded software development. With QNX Neutrinos microkernel architecture, you rarely have to use a hardware debugger. On those occasions when you need to use one, you'll use it in a different manner from on other operating systems. This article describes how JTAG hardware debuggers fit into the QNX development cycle, what capabilities they provide, and what's required in order to use them with the QNX Neutrino RTOS. Finally, an example is provided that demonstrates debugging a QNX target using a commercially available JTAG hardware debugger.

2. Software vs. Hardware Debuggers (pdebug vs. JTAG)

This section examines fundamental differences between QNX Neutrino and conventional RTOSs, and how these differences affect debugging embedded software.

The QNX Neutrino RTOS architecture differs significantly from more traditional monolithic operating systems, and as a result, it enhances the software development and debugging processes.

Traditional embedded software development often requires hardware debuggers connected through a JTAG interface. This is necessary for development of drivers, and possibly user applications, because they're linked into the same memory space as the kernel. If a driver or application crashes, the kernel and system may crash as a result. This makes using software debuggers difficult, because they depend on a running system.

Debugging target systems with the QNX Neutrino RTOS is different because its architecture is significantly different from other embeddable RTOSs. All QNX applications (including drivers) run in their own memory-protected virtual address space. This has the advantage that the software is more reliable and fault tolerant. However, conventional hardware debuggers rely on decoding physical memory addresses, making them incompatible with debugging user applications based in a virtual memory environment. Furthermore, QNX Neutrino lets you develop multi-threaded applications, which hardware debuggers generally don't support.

QNX provides a software debugging agent called **pdebug** that makes it easier for you to debug system drivers and user applications. The **pdebug** agent runs on the target system and communicates with the host debugger over a serial or Ethernet connection. It can debug virtual-memory-based and multi-threaded applications. Even more, because all applications run in their own memory-protected address space, using a software debugger is much more reliable than on traditional embedded RTOSs. In the event that a driver or user application crashes, the system is protected and can be recovered by simply restarting the process. In addition, you can stop and restart drivers and applications as required on a running system, making the debugger easy to use and highly reliable.

Using **pdebug** for debugging applications and drivers is extremely reliable because crashing applications don't crash the kernel. However, the major constraint of using **pdebug** is that the kernel must already be running on the target.

A Board Support Package (BSP) is the software responsible for initializing the system in preparation for the kernel. Each target board requires its own BSP, which includes the Initial Program Loader (IPL) and

Startup program. The role of the IPL is to find where the QNX Neutrino image is located and then set up an environment so that the Startup program (present in the image) can run. The role of the Startup program is to configure the processor and hardware, detect system resources, and start the OS.

The IPL and Startup must run properly, so that the kernel and **pdebug** can run, and drivers and user applications can be developed. In the case of BSP development, a software debug agent such as **pdebug** isn't available. However, the IPL and Startup program run with the CPU in physical mode, allowing them to be debugged with conventional hardware debuggers. This is the primary function of the JTAG debugger throughout the QNX software development phase. You use the hardware debugger to debug the QNX BSP (IPL and Startup), and **pdebug** to debug drivers and applications once the kernel is running. You can also use a hardware debugger to examine registers and view memory while the kernel and applications are running, if you know the physical addresses.

Some hardware debuggers have built-in QNX Neutrino RTOS Awareness, which lets you use a JTAG to debug applications. These debuggers can interpret kernel information as well as perform the necessary translation between virtual and physical memory addresses to view application data. Currently, Lauterbach provides QNX Neutrino RTOS integration support for their Trace32 hardware debugger, and Applied Microsystems Corporation (AMC) is working on integrating PowerTAP and WireTAP products with QNX Neutrino.

3. Producing Debug Symbol Information for IPL and Startup

You can use hardware debuggers to debug QNX IPL and Startup programs without any extra information. However, in this case, you're limited to assembly-level debugging, and assembler symbols such as subroutine names aren't visible. To perform full source-level debugging, you need to provide the hardware debugger with the symbol information and C source code.

This section describes the steps necessary to generate the symbol and debug information required by a hardware debugger for source-level debugging. The steps described are based on the PPC (PowerPC) Board Support Package available for QNX Neutrino 6.2 for both IPL and Startup of the Motorola Sandpoint hardware reference platform. The steps below are described for a QNX 6.2 self-hosted environment, but the commands are similar under other development platforms. These examples assume that you're logged in on the development host with root privileges.

To generate symbol information for the IPL, you must recompile both the IPL library and the Sandpoint IPL with debug information.

The general procedure is as follows:

1. Modify the IPL source.
2. Build the IPL library and Sandpoint IPL.
3. Burn the IPL into the flash memory of the Sandpoint board using a flash burner or JTAG.
4. Modify the *sandpoint.lnk* file to output ELF format.
5. Recompile the IPL library and Sandpoint IPL source with debug options.
6. Load the Sandpoint IPL ELF file containing debug information into the hardware debugger.

Note: Be sure to synchronize the source code, the IPL burned into flash, and the IPL debug symbols.

To build the IPL library with debug information:

```
# cd /usr/src/bsp-6.2.0/libs/src/hardware/ipl/lib/ppc/a.be
# make clean
# make CCOPTS=-g
# cp libipl.a /usr/src/bsp-6.2.0/ppc/sandpoint/scratch/ppcbe/lib
# make install
```

The above steps recompile the PowerPC IPL library (*libipl.a*) with DWARF debug information and copy this library to the Sandpoint scratch directory. The Sandpoint BSP is configured to look for this library first in its scratch directory. The `make` **install** is optional, and copies *libipl.a* to */ppcbe/usr/lib*.

Note: If you're using the AMC hardware debugger, use the STABS format instead of DWARF, by specifying **-gstabs+** instead of the **-g** option.

The Sandpoint BSP has been set up to work with SREC format files. However, to generate debug and symbol information to be loaded into the hardware debugger, you must generate ELF-format files.

Modify the `sandpoint.lnk` file to output ELF format:

```
# cd /usr/src/bsp-6.2.0/ppc/sandpoint/src/hardware/ipl/boards/sandpoint
```

Edit the file *sandpoint.lnk*, changing the first lines from:

```
TARGET(elf32-powerpc)
OUTPUT_FORMAT(srec)
ENTRY(entry_vec)
```

to:

```
TARGET(elf32-powerpc)
OUTPUT_FORMAT(elf32-powerpc)
ENTRY(entry_vec)
```

You can now rebuild the Sandpoint IPL to produce symbol and debug information in ELF format.

To build the Sandpoint IPL with debug information:

```
# cd /usr/src/bsp-
6.2.0/ppc/sandpoint/src/hardware/ipl/boards/sandpoint/ppc/be
# make clean
# make CCOPTS=-g
```

The *ipl-sandpoint* file is now in ELF format with debug symbols from both the IPL library and Sandpoint IPL.

Note: To rebuild the BSP, you need to change the *sandpoint.lnk* file back to outputting SREC format. It's also important to keep the IPL that's burned into the Sandpoint flash memory in synch with the generated debug information; if you modify the IPL source, you need to rebuild the BSP, burn the new IPL into flash, and rebuild the IPL symbol and debug information.

You can use the **objdump** utility to view the ELF information.

To view the symbol information contained in the ipl-sandpoint file:

```
# objdump -t ipl-sandpoint | less
```

You can now import the *ipl-sandpoint* file into a hardware debugger to provide the symbol information required for debugging. In addition, the hardware debugger needs the source code listings found in the following directories:

- */usr/src/bsp-6.2.0/ppc/sandpoint/src/hardware/ipl/boards/sandpoint*
- */usr/src/bsp-6.2.0/libs/src/hardware/ipl/lib*
- */usr/src/bsp-6.2.0/libs/src/hardware/ipl/lib/ppc*

To generate symbol information for Startup, you must recompile both the Startup library and Sandpoint Startup with debug information.

The general procedure is as follows:

Modify the Startup source:

1. Build the Startup library and Sandpoint Startup with debug information.
2. Rebuild the image and symbol file.
3. Load the symbol file into the hardware debugger program.
4. Transfer the image to the Sandpoint target (burn into flash, transfer over a serial connection).

To build the Startup library with debug information:

```
# cd /usr/src/bsp-6.2.0/libs/src/hardware/startup/lib/ppc/a.be
# make clean
# make CCOPTS=-g
# cp libstartup.a /usr/src/bsp-6.2.0/ppc/sandpoint/scratch/ppcbe/lib
# make install
```

The above steps recompile the PowerPC Startup library (*libstartup.a*) with DWARF debug information and copy this library to the Sandpoint scratch directory. The Sandpoint BSP is configured to look for this library first in its scratch directory. The **make install** is optional, and copies *libstartup.a* to */ppcbe/usr/lib*.

Note: Once again, if you're using the AMC hardware debugger, use the STABS format instead of DWARF, by specifying **-gstabs+** instead of the **-g** option.

To build the Sandpoint Startup with debugging information:

```
# cd /usr/src/bsp-
6.2.0/ppc/sandpoint/src/hardware/startup/boards/sandpoint/ppc/be
# make clean
# make CCOPTS=-g
# make install
```

The above steps generate the file *startup-sandpoint* with symbol and debug information. Again, you can use the **gstabs+** debug option instead of **-g**. The **make install** is necessary, and copies *startup-sandpoint* into the Sandpoint scratch directory, */usr/src/bsp6.2.0/ppc/sandpoint/scratch/ppcbe/boot/sys*.

Note: You can't load the *startup-sandpoint* ELF file into the hardware debugger to obtain the debug symbols, because the **mkifs** utility adds an offset to the addresses defined in the symbols according to the offset specified in the build file.

Modify the build file to include the `+keeplinked` attribute for Startup:

```
# cd /usr/src/bsp-6.2.0/ppc/sandpoint/images
```

Modify the startup line of your build file to look like:

```
[image=0x10000]
[virtual=ppcbe,binary +compress] .bootstrap = {
[+keeplinked] startup-sandpoint -vvv -D8250
PATH=/proc/boot procnto-600 -vv
}
```

The **+keeplinked** option makes **mkifs** generate a symbol file that represents the debug information positioned within the image filesystem by the specified offset.

Rebuild the image to generate symbol file:

```
# cd /usr/src/bsp-6.2.0/ppc/sandpoint/images
# make clean
# make all (if you're using one of the provided .build files)
```

or:

```
# mkifs v r ../scratch myfile.build image
```

These commands create the symbol file, *startup-sandpoint.sym*. You can use the **objdump** utility to view the ELF information.

To view the symbol information contained in the `startup-sandpoint.sym` file:

```
# objdump -t startup-sandpoint.sym | less
```

You can now import the *startup-sandpoint.sym* file into a hardware debugger to provide the symbol information required for debugging startup. In addition, the hardware debugger needs the source code listings found in the following directories:

- */usr/src/bsp-6.2.0/libs/src/hardware/startup/lib*
- */usr/src/bsp-6.2.0/libs/src/hardware/startup/lib/public/ppc*

- */usr/src/bsp-6.2.0/libs/src/hardware/startup/lib/public/sys*
- */usr/src/bsp-6.2.0/libs/src/hardware/startup/lib/ppc*
- */usr/src/bsp-6.2.0/ppc/sandpoint/src/hardware/startup/boards/sandpoint*

If you have access to the kernel source files, you can use a hardware debugger to debug the QNX Neutrino kernel. Follow a similar procedure as described above, modifying the build file to use the **keeplinked** attribute on **procnto**:

Modify the build file to include the `+keeplinked` attribute for `procnto`:

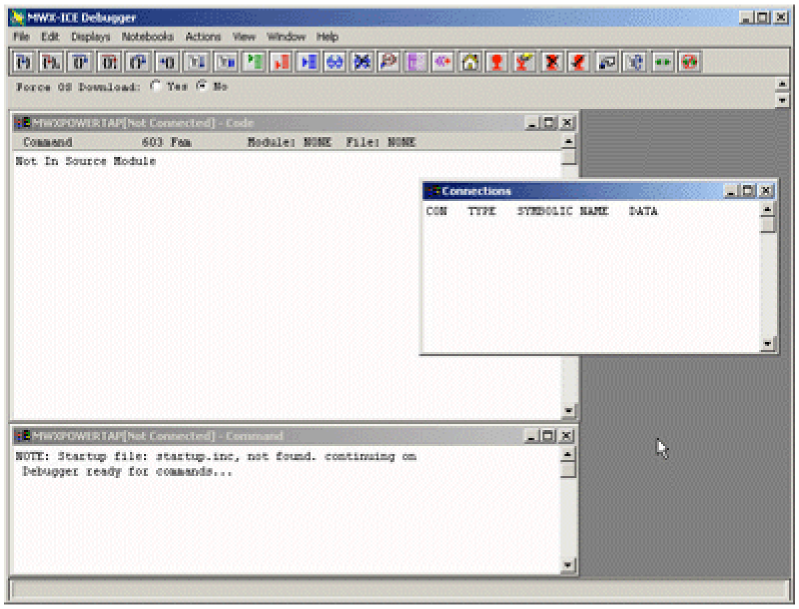
```
[image=0x10000]
[virtual=ppcbe,binary +compress] .bootstrap = {
[+keeplinked] startup-sandpoint -vvv -D8250
[+keeplinked] PATH=/proc/boot procnto-600 -vv
}
```

4. Example using AMC PowerTAP JTAG and MWX-ICE

This section describes how to use a JTAG hardware debugger to debug QNX IPL and Startup programs for the Motorola Sandpoint reference platform. The example is based on the AMC MWX-ICE debugger connected to a PowerTAP JTAG.

We assume that you've installed the AMC PowerTAP and MWX-ICE debugger on the host and configured them properly for the Sandpoint board, and that the target is connected and powered. This example also assumes that the IPL already has been burned into flash memory.

Launch the MWX-ICE debugger, shown below:


MWX-ICE Debugger
File Edit Displays Notebooks Actions View Window Help
MWXPOWERTAP[Not Connected] - Code
Connections
MWXPOWERTAP[Not Connected] - Command

Force OS Download: Yes [✓ No]

```
Command            603 Fam          Module: NONE  File: NONE
Not In Source Module
```

```
CON    TYPE    SYMBOLIC NAME    DATA
```

```
NOTE: Startup file: startup.inc, not found. continuing on
 Debugger ready for commands...
```

Figure 1 - MWX-ICE Debugger main window.

Across the top of the main window is a row of buttons that you'll use in the steps described below.

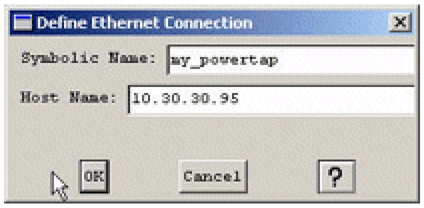
With the Connections window in focus, choose **Actions→Define Ethernet Connection** from the main menu. Enter a name for the connection, and the IP address that the PowerTAP is configured to on the network. After selecting OK, choose **Actions→Connect to connect to the PowerTAP** and target. The output is displayed in the Command window.

You need to configure the MWX-ICE debugger for the particular target being used; consult AMC for details. For this example, we've entered the following configuration commands in the Command window:

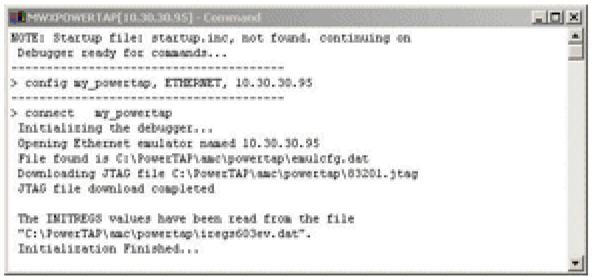
```
size read 4
mem_rd_del 0x500
pcimap mapb
bptype onchip
```

You can also use the Emulator Config window (**Displays→Emulator Config**) to set these values.

Note: This isn't an exhaustive list of configurations required for this target. Also, AMC recommends the memory read delay be between `0x500` and `0xF00`.



Symbolic Name: my_powertap
Host Name: 10.30.30.95



```
NOTE: Startup file: startup.inc, not found. continuing on
 Debugger ready for commands...
-----------------------------------------
> config my_powertap, ETHERNET, 10.30.30.95
-----------------------------------------
> connect   my_powertap
 Initializing the debugger...
 Opening Ethernet emulator named 10.30.30.95
 File found is C:\PowerTAP\amc\powertap\emulcfg.dat
 Downloading JTAG file C:\PowerTAP\amc\powertap\83201.jtag
 JTAG file download completed

 The INITREGS values have been read from the file
 "C:\PowerTAP\amc\powertap\iregs603ev.dat".
 Initialization Finished...
```

Figure 2 The Define Ethernet Connection and Command windows.

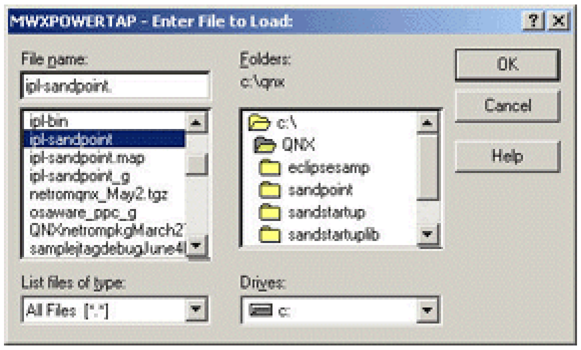
At this point, the MWX-ICE debugger should be configured and ready to begin debugging the Sandpoint reference platform via the PowerTAP.

This section describes how to debug the QNX IPL using the symbol information generated using the Sandpoint BSP.

First, you must import the IPL symbols into the debugger.

1. From the main menu, choose **File→Load** to display the Load window.
2. Under List Files of type, select All Files [*.*].
3. Select the *ipl-sandpoint* ELF file generated in the previous section, and click **OK**.
4. After loading the symbol information, the debugger likely displays the Append new Directory popup to request the location of the source files.
5. Select the directory where the IPL library source is located.

6. Repeat this for each of the IPL-related source directories listed at the end of the ***Generating IPL Debug*** Symbols section, by selecting **File→Append Source Path**.



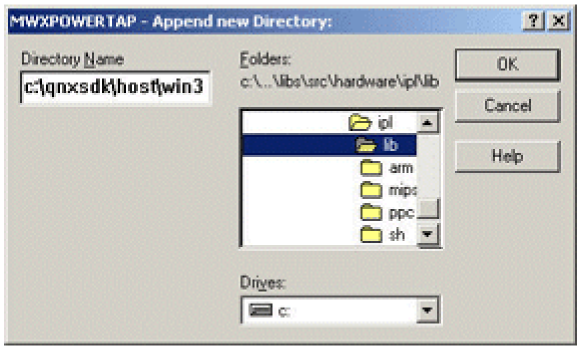
MWXPOWERTAP - Enter File to Load:

File name: ipl-sandpoint

Folders: c:\qnx

List files of type: All Files [*.*]

Drives: c:



MWXPOWERTAP - Append new Directory:

Directory Name: c:\qnxsdk\host\win3

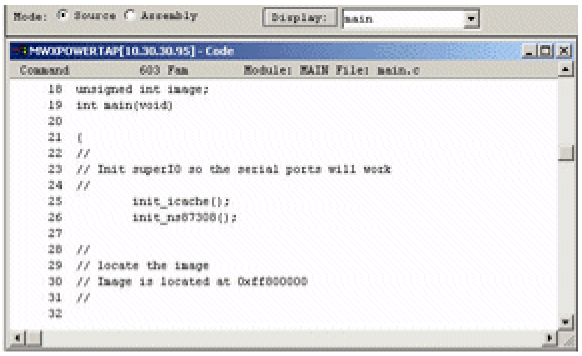
Folders: c:\...\libs\src\hardware\ipl\lib

Drives: c:

Figure 3 The Load Symbols and Append Directory windows.

The debugger is now ready to debug the IPL. To reset the target, click the **Reset** button.

To view the **main**() function from the Sandpoint IPL source code, bring the Code window in focus, set the **Mode** to **Source**, type `main` in the text box, and click the **Display** button.



Mode: [✓ Source] Assembly   Display: main

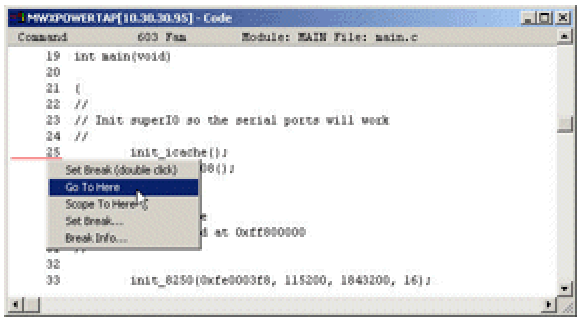
MWXPOWERTAP[10.30.30.95] - Code

Command   603 Fam   Module: MAIN File: main.c

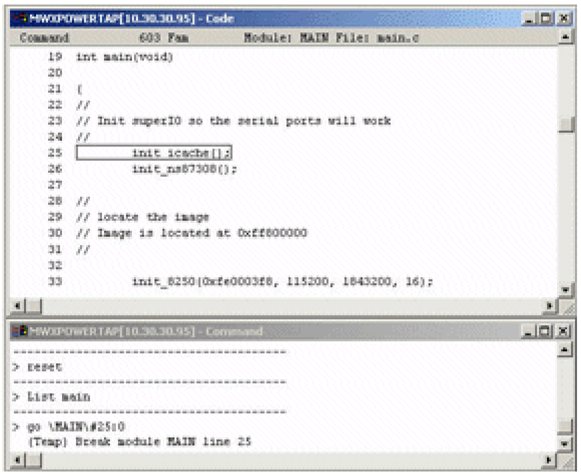
```
unsigned int image;
int main(void)

{
//
// Init superIO so the serial ports will work
//
        init_icache();
        init_ns87308();

//
// locate the image
// Image is located at 0xff800000
//

```

Figure 4 Viewing the source for the *main*() function.

The Code window displays the C source code for the **main**() function. In the Code window, right-click on the line number in **main**() that you wish to break at, and select **Go To Here** from the popup menu. The debugger runs the IPL program, and breaks on this line.



```
Command              603 Fam          Module: MAIN File: main.c
   19  int main(void)
   20
   21  {
   22  //
   23  // Init superIO so the serial ports will work
   24  //
   25          init_icache();
                      08();

                      e
                      d at 0xff800000

   32
   33          init_8250(0xfe0003f8, 115200, 1843200, 16);
```

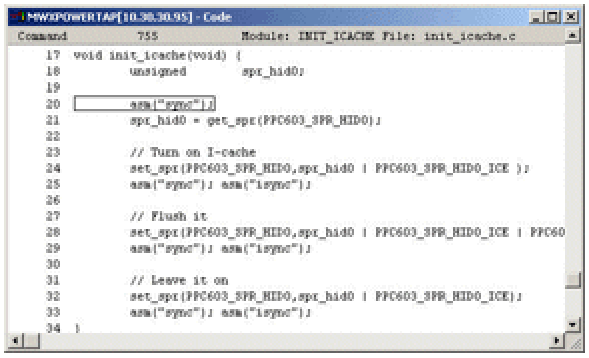

MWXPOWERTAP[10.30.30.95] - Code
MWXPOWERTAP[10.30.30.95] - Command

```
Command              603 Fam          Module: MAIN File: main.c
   19  int main(void)
   20
   21  {
   22  //
   23  // Init superIO so the serial ports will work
   24  //
   25          init_icache();
   26          init_ns87308();
   27
   28  //
   29  // locate the image
   30  // Image is located at 0xff800000
   31  //
   32
   33          init_8250(0xfe0003f8, 115200, 1843200, 16);
```

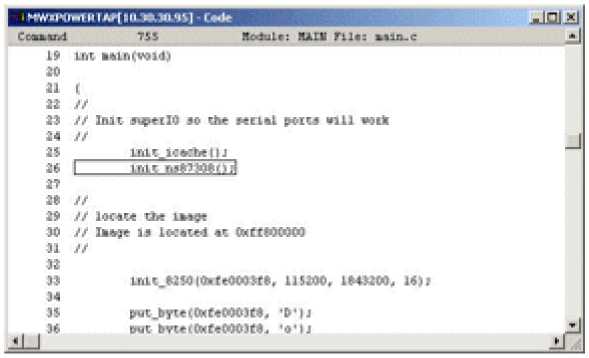
```
----------------------------------------
> reset
----------------------------------------
> List main
----------------------------------------
> go \MAIN\#25:0
  (Temp) Break module MAIN line 25
```

Figure 5 Running the IPL and breaking on the first line in *main*().

You can use the **Stepin Src** button, to step into the **init_icache**() function, and the **Stepout** button, to step back out of it.



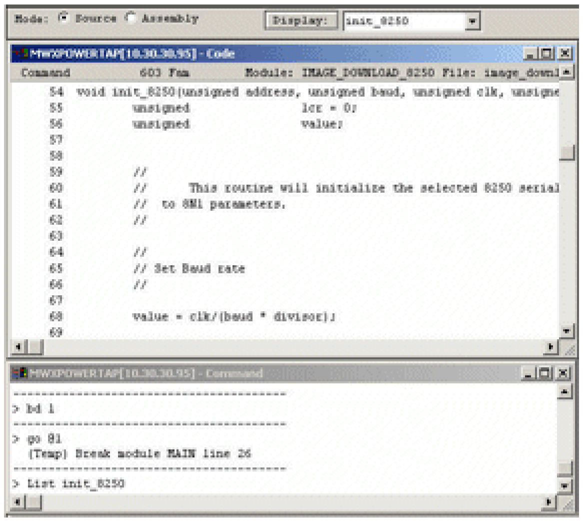
```
Command              755          Module: INIT_ICACHE File: init_icache.c
   17  void init_icache(void) {
   18          unsigned        spr_hid0;
   19
   20          asm("sync");
   21          spr_hid0 = get_spr(PPC603_SPR_HID0);
   22
   23          // Turn on I-cache
   24          set_spr(PPC603_SPR_HID0,spr_hid0 | PPC603_SPR_HID0_ICE );
   25          asm("sync"); asm("isync");
   26
   27          // Flush it
   28          set_spr(PPC603_SPR_HID0,spr_hid0 | PPC603_SPR_HID0_ICE | PPC60
   29          asm("sync"); asm("isync");
   30
   31          // Leave it on
   32          set_spr(PPC603_SPR_HID0,spr_hid0 | PPC603_SPR_HID0_ICE);
   33          asm("sync"); asm("isync");
   34  }
```



```
int main(void)

{
//
// Init superIO so the serial ports will work
//
        init_icache();
        init_ns87308();

//
// locate the image
// Image is located at 0xff800000
//

        init_8250(0xfe0003f8, 115200, 1843200, 16);

        put_byte(0xfe0003f8, 'D');
        put_byte(0xfe0003f8, 'o');
```

Figure 6 Stepping in and out of the *init_icache*() function.

You can also debug the source code in the IPL library. For example, in the Code window, type `init_8250` in the text box and push the Display button to view this function.

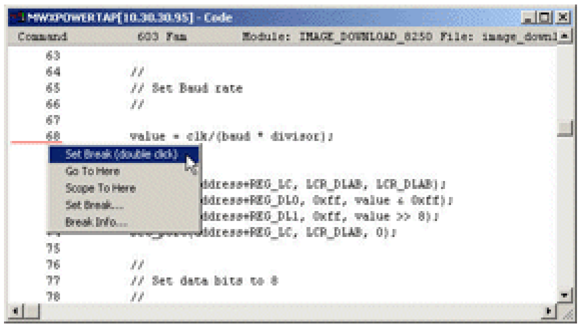

Mode:
Source
Assembly
Display:
init_8250
MWXPOWERTAP[10.30.30.95] - Code
Command
603 Fam
Module: IMAGE_DOWNLOAD_8250 File: image_downl
MWXPOWERTAP[10.30.30.95] - Command

```
void init_8250(unsigned address, unsigned baud, unsigned clk, unsigne
        unsigned                lcr = 0;
        unsigned                value;


        //
        //      This routine will initialize the selected 8250 serial
        //  to 8N1 parameters.
        //

        //
        // Set Baud rate
        //

        value = clk/(baud * divisor);
```

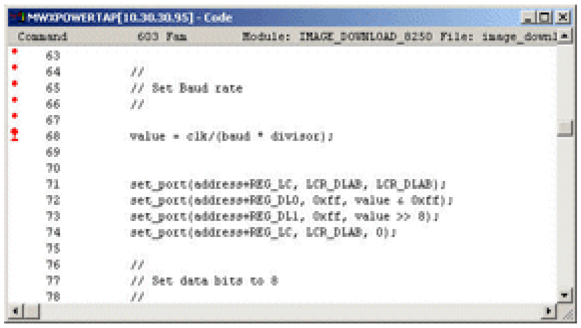
```
----------------------------------------
> bd 1
----------------------------------------
> go 81
  (Temp) Break module MAIN line 26
----------------------------------------
> List init_8250
```

Figure 7 Viewing IPL library source code.

To set a breakpoint in the **`init_8250`**() function, right-click over a line number and select **Set Break** from the popup menu. The breakpoint is now indicated. You can also open the breakpoint display window (**Displays→Breakpoints**) to see the breakpoint.

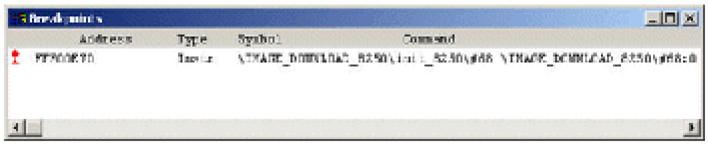


```

        //
        // Set Baud rate
        //

        value = clk/(baud * divisor);

        ddress+REG_LC, LCR_DLAB, LCR_DLAB);
        ddress+REG_DL0, 0xff, value & 0xff);
        ddress+REG_DL1, 0xff, value >> 8);
        ddress+REG_LC, LCR_DLAB, 0);

        //
        // Set data bits to 8
        //
```



```
MWXPOWERTAP[10.30.30.95] - Code
Command            603 Fam        Module: IMAGE_DOWNLOAD_8250 File: image_downl

        //
        // Set Baud rate
        //

        value = clk/(baud * divisor);


        set_port(address+REG_LC, LCR_DLAB, LCR_DLAB);
        set_port(address+REG_DL0, 0xff, value & 0xff);
        set_port(address+REG_DL1, 0xff, value >> 8);
        set_port(address+REG_LC, LCR_DLAB, 0);

        //
        // Set data bits to 8
        //
```

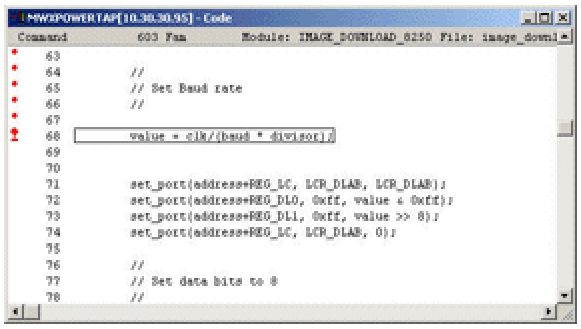
Figure 8 Setting and viewing a breakpoint in the *init_8250*() function.



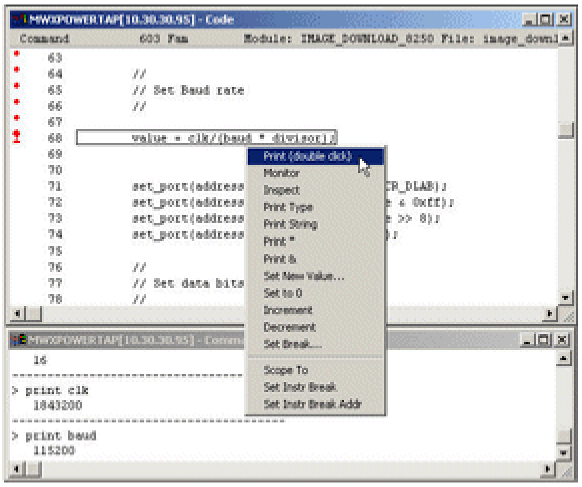
```
Breakpoints
      Address      Type    Symbol                                  Command
  FF800E70         Instr   \IMAGE_DOWNLOAD_8250\init_8250\#68  \IMAGE_DOWNLOAD_8250\#68:0
```

Figure 9 The Breakpoints window.

You can click the **Go** button, to let the program run until it reaches the breakpoint. Once the debugger has stopped on the breakpoint, you can print data values by right-clicking on top of a variable and selecting **Print**.



```
MWXPOWERTAP[10.30.30.95] - Code
Command            603 Fam        Module: IMAGE_DOWNLOAD_8250 File: image_downl

        //
        // Set Baud rate
        //

        value = clk/(baud * divisor);


        set_port(address+REG_LC, LCR_DLAB, LCR_DLAB);
        set_port(address+REG_DL0, 0xff, value & 0xff);
        set_port(address+REG_DL1, 0xff, value >> 8);
        set_port(address+REG_LC, LCR_DLAB, 0);

        //
        // Set data bits to 8
        //
```

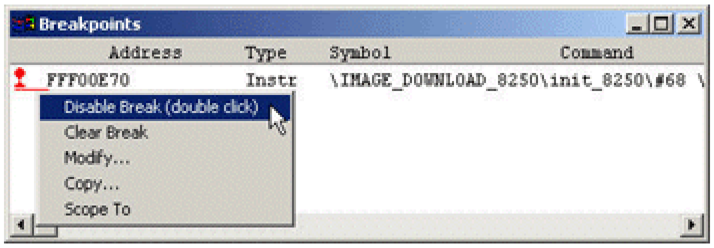


```
MWXPOWERTAP[10.30.30.95] - Code
Command            603 Fam        Module: IMAGE_DOWNLOAD_8250 File: image_downl

        //
        // Set Baud rate
        //

        value = clk/(baud * divisor);


        set_port(address                    CR_DLAB);
        set_port(address                  e & 0xff);
        set_port(address                  e >> 8);
        set_port(address                  );

        //
        // Set data bits
        //
```

```
MWXPOWERTAP[10.30.30.95] - Comma
  16
--------------------------------------
> print clk
  1843200
--------------------------------------
> print baud
  115200
```

Figure 10 Hitting the breakpoint, and printing variable data.

Processors have a limited number of hardware breakpoints. After stopping at the hardware breakpoint, you should disable it because some stepping commands (such as stepping over or stepping out of source) require the use of breakpoints. To disable, place the cursor over the breakpoint in either the Code or Breakpoint window, right-click, and select **Disable Break** from the pop-up menu.

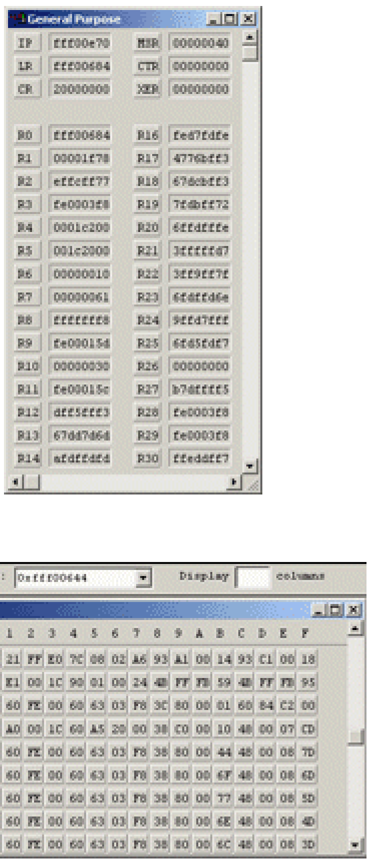


Address	Type	Symbol	Command
FFF00E70	Instr	\IMAGE_DOWNLOAD_8250\init_8250\#68	\

Figure 11 Disabling breakpoints.

The MWX-ICE debugger provides many useful debugging tool displays, including Registers, Memory, Stack, and Trace. For example, to view the IP and other common CPU registers, select **Displays→Registers→General Purpose**. Through this interface, the debugger lets you modify the contents of the registers - you can even modify the CPUs instruction pointer.

To view target memory, select **Displays→Memory**. The Memory window lets you enter an address to view system memory. This interface also lets you modify the contents of memory.



IP	fff00e70	MSR	00000040
LR	fff00684	CTR	00000000
CR	20000000	XER	00000000
R0	fff00684	R16	fed7fdfe
R1	00001f78	R17	4776bff3
R2	effeff77	R18	67dcbff3
R3	fe0003f8	R19	7fdbff72
R4	0001c200	R20	6ffdfffe
R5	001c2000	R21	3ffffd7
R6	00000010	R22	3ff9ff7f
R7	00000061	R23	6fdffd6e
R8	fffffff8	R24	9ffd7fff
R9	fe00015d	R25	6fd5fdf7
R10	00000030	R26	00000000
R11	fe00015c	R27	b7dffff5
R12	dff5fff3	R28	fe0003f8
R13	67dd7d6d	R29	fe0003f8
R14	afdffdfd	R30	ffeddff7

Start Address: 0xfff00644 Display columns

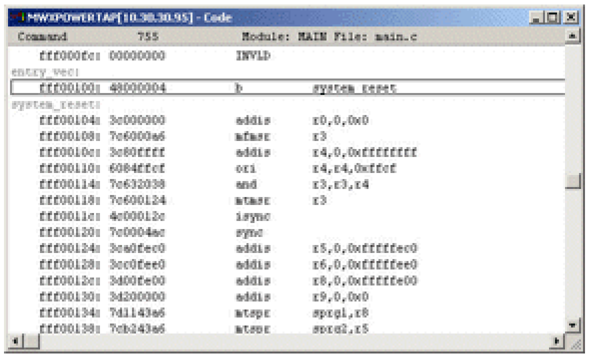
Address	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
FFF00644	94	21	FF	E0	7C	08	02	A6	93	A1	00	14	93	C1	00	18
FFF00654	93	E1	00	1C	90	01	00	24	48	FF	FB	59	48	FF	FB	95
FFF00664	3C	60	FE	00	60	63	03	F8	3C	80	00	01	60	84	C2	00
FFF00674	3C	A0	00	1C	60	A5	20	00	38	C0	00	10	48	00	07	CD
FFF00684	3C	60	FE	00	60	63	03	F8	38	80	00	44	48	00	08	7D
FFF00694	3C	60	FE	00	60	63	03	F8	38	80	00	6F	48	00	08	6D
FFF006A4	3C	60	FE	00	60	63	03	F8	38	80	00	77	48	00	08	5D
FFF006B4	3C	60	FE	00	60	63	03	F8	38	80	00	6E	48	00	08	4D
FFF006C4	3C	60	FE	00	60	63	03	F8	38	80	00	6C	48	00	08	3D

Figure 12 The General Purpose Register and Memory Display windows.

This example shows assembly-level debugging of the IPL from the reset vector.

In the Code window, set the mode to Assembly. Click the **Reset** button, to reset the target and cause the debugger to jump to the first assembly line instruction executed on reset labeled as **`entry_vec`** at address `0xFFF00100`.

Note: You might need to select **View→Scope to PC** to see the assembly instructions. The assembly source may not be viewable if you didn't set the memory read delay command, **`mem_rd_del`** `0x500`, as described earlier.



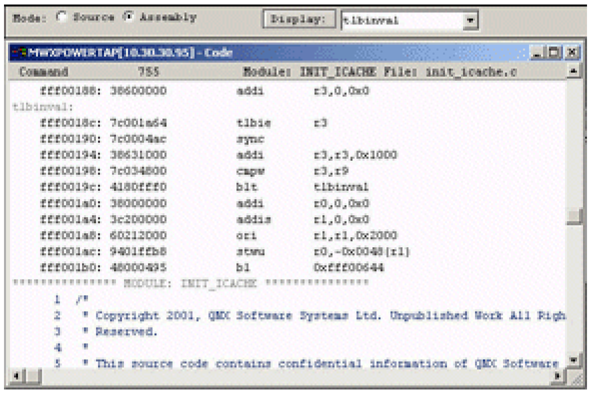
```
MWXPOWERTAP[10.30.30.95] - Code
Command             755             Module: MAIN File: main.c
    fff000fc: 00000000          INVLD
entry_vec:
    fff00100: 48000004          b           system_reset
system_reset:
    fff00104: 3c000000          addis       r0,0,0x0
    fff00108: 7c6000a6          mfmsr       r3
    fff0010c: 3c80ffff          addis       r4,0,0xffffffff
    fff00110: 6084ffcf          ori         r4,r4,0xffcf
    fff00114: 7c632038          and         r3,r3,r4
    fff00118: 7c600124          mtmsr       r3
    fff0011c: 4c00012c          isync
    fff00120: 7c0004ac          sync
    fff00124: 3ca0fec0          addis       r5,0,0xfffffec0
    fff00128: 3cc0fee0          addis       r6,0,0xfffffee0
    fff0012c: 3d00fe00          addis       r8,0,0xfffffe00
    fff00130: 3d200000          addis       r9,0,0x0
    fff00134: 7d1143a6          mtspr       sprg1,r8
    fff00138: 7cb243a6          mtspr       sprg2,r5
```

Figure 13 Debugging Assembly instructions, starting from target reset.

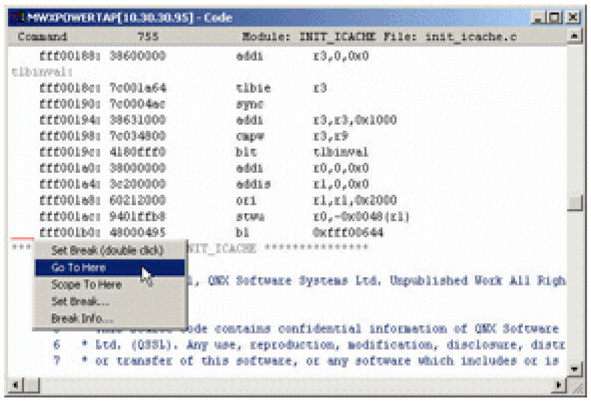
You can step through the assembly instructions by selecting the **Stepin Asm** button.

For example, you can step through the initial assembly code into the IPLs **main**() function. In the Code windows text box, type `tlbinval` and click Display. The **tlbinval**() assembler routine contains the branch instruction to the IPL **main**() function. To run the debugger up to the last instruction, right-click at the very left of the last line of **tlbinval**() and select **Go To Here** from the popup menu.

Note: Ensure that you've disabled the breakpoint set in the previous section.



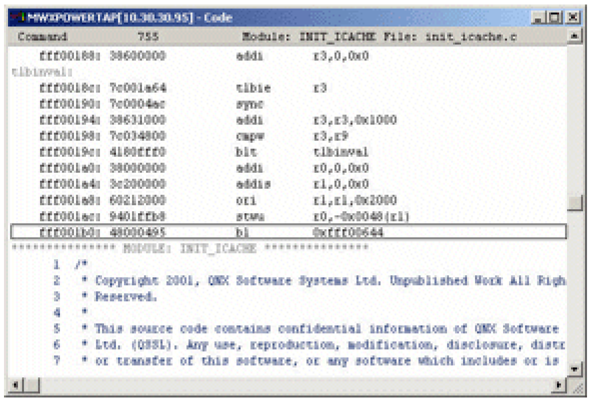
```
Mode: ( ) Source (•) Assembly        Display: tlbinval
MWXPOWERTAP[10.30.30.95] - Code
Command             755             Module: INIT_ICACHE File: init_icache.c
    fff00188: 38600000          addi        r3,0,0x0
tlbinval:
    fff0018c: 7c001a64          tlbie       r3
    fff00190: 7c0004ac          sync
    fff00194: 38631000          addi        r3,r3,0x1000
    fff00198: 7c034800          cmpw        r3,r9
    fff0019c: 4180fff0          blt         tlbinval
    fff001a0: 38000000          addi        r0,0,0x0
    fff001a4: 3c200000          addis       r1,0,0x0
    fff001a8: 60212000          ori         r1,r1,0x2000
    fff001ac: 9401ffb8          stwu        r0,-0x0048(r1)
    fff001b0: 48000495          bl          0xfff00644
*************** MODULE: INIT_ICACHE ***************
      1  /*
      2   * Copyright 2001, QNX Software Systems Ltd. Unpublished Work All Righ
      3   * Reserved.
      4   *
      5   * This source code contains confidential information of QNX Software
```



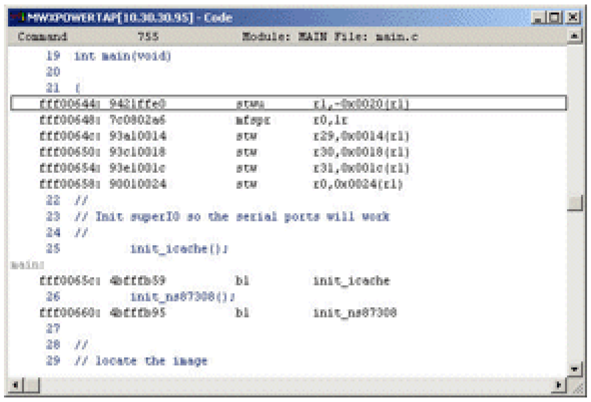
```
MWXPOWERTAP[10.30.30.95] - Code
Command          755            Module: INIT_ICACHE File: init_icache.c
    fff00188: 38600000          addi       r3,0,0x0
tlbinval:
    fff0018c: 7c001a64          tlbie      r3
    fff00190: 7c0004ac          sync
    fff00194: 38631000          addi       r3,r3,0x1000
    fff00198: 7c034800          cmpw       r3,r9
    fff0019c: 4180fff0          blt        tlbinval
    fff001a0: 38000000          addi       r0,0,0x0
    fff001a4: 3c200000          addis      r1,0,0x0
    fff001a8: 60212000          ori        r1,r1,0x2000
    fff001ac: 9401ffb8          stwu       r0,-0x0048(r1)
    fff001b0: 48000495          bl         0xfff00644
***                      NIT_ICACHE ***************
                         l, QNX Software Systems Ltd. Unpublished Work All Righ

                         ode contains confidential information of QNX Software
       6   * Ltd. (QSSL). Any use, reproduction, modification, disclosure, distr
       7   * or transfer of this software, or any software which includes or is
```

Figure 14 Displaying the tlbinval() subroutine and running to the branch instruction.

If you click the **Stepin Asm** button, the debugger jumps to the **main**() function assembly code. If you've set the debuggers **LINES=ON** option, the C source code is intermixed with assembly code in the Assembly window.



```
MWXPOWERTAP[10.30.30.95] - Code
Command          755            Module: INIT_ICACHE File: init_icache.c
    fff00188: 38600000          addi       r3,0,0x0
tlbinval:
    fff0018c: 7c001a64          tlbie      r3
    fff00190: 7c0004ac          sync
    fff00194: 38631000          addi       r3,r3,0x1000
    fff00198: 7c034800          cmpw       r3,r9
    fff0019c: 4180fff0          blt        tlbinval
    fff001a0: 38000000          addi       r0,0,0x0
    fff001a4: 3c200000          addis      r1,0,0x0
    fff001a8: 60212000          ori        r1,r1,0x2000
    fff001ac: 9401ffb8          stwu       r0,-0x0048(r1)
    fff001b0: 48000495          bl         0xfff00644
*************** MODULE: INIT_ICACHE ***************
       1  /*
       2   * Copyright 2001, QNX Software Systems Ltd. Unpublished Work All Righ
       3   * Reserved.
       4   *
       5   * This source code contains confidential information of QNX Software
       6   * Ltd. (QSSL). Any use, reproduction, modification, disclosure, distr
       7   * or transfer of this software, or any software which includes or is
```



```
MWXPOWERTAP[10.30.30.95] - Code
Command          755            Module: MAIN File: main.c
      19  int main(void)
      20
      21  {
    fff00644: 9421ffe0          stwu       r1,-0x0020(r1)
    fff00648: 7c0802a6          mfspr      r0,lr
    fff0064c: 93a10014          stw        r29,0x0014(r1)
    fff00650: 93c10018          stw        r30,0x0018(r1)
    fff00654: 93e1001c          stw        r31,0x001c(r1)
    fff00658: 90010024          stw        r0,0x0024(r1)
      22  //
      23  // Init superIO so the serial ports will work
      24  //
      25          init_icache();
main:
    fff0065c: 4bfffb59          bl         init_icache
      26          init_ns87308();
    fff00660: 4bfffb95          bl         init_ns87308
      27
      28  //
      29  // locate the image
```

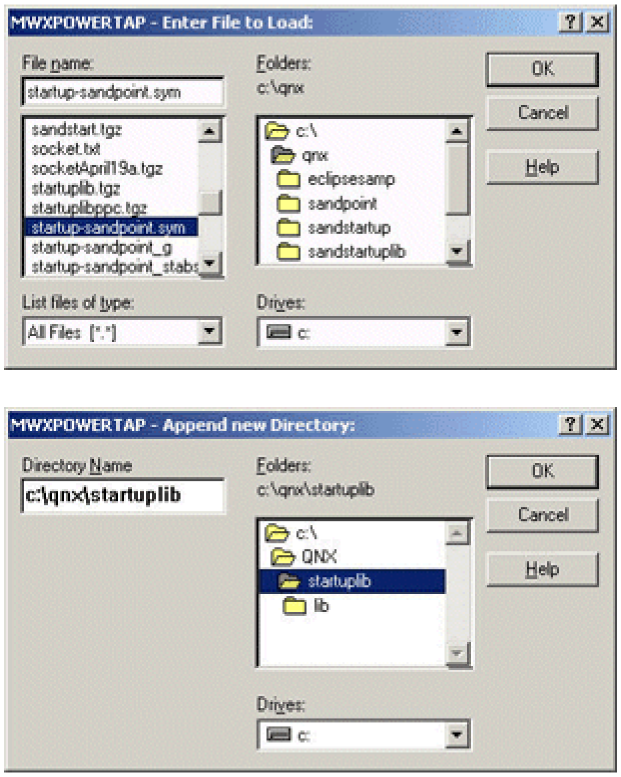
Figure 15 Stepping into the main() function.

If you set the mode to Source in the Code window, the debugger displays the C source code for the **main**() function and lets you step through the source as previously described.

This section describes how to begin debugging the QNX Startup program using the symbol information generated using the Sandpoint BSP. We assume that you've already connected the debugger to the PowerTAP, as described in previous sections.

To start, you must import the Startup symbols into the debugger. From the main menu, select **File→Load** to display the Load window. Under List Files of type, select All Files [*.*]. Select the *sandpoint-startup.sym* file described previously and choose OK.

After loading the symbol information, the debugger likely displays the Append new Directory popup to request the location of the source files. Select the directory where the Startup library source is located. You need repeat this for each of the Startup-related source directories listed at the end of the ***Generating Startup Debug Symbols*** section by choosing **File→Append Source Path...**


MWXPOWERTAP - Enter File to Load:
OK
Cancel
Help
MWXPOWERTAP - Append new Directory:
OK
Cancel
Help

MWXPOWERTAP - Enter File to Load:

File name: startup-sandpoint.sym

sandstart.tgz
socket.txt
socketApril19a.tgz
startuplib.tgz
startuplibppc.tgz
startup-sandpoint.sym
startup-sandpoint_g
startup-sandpoint_stabs

Folders: c:\qnx

c:\
qnx
eclipsesamp
sandpoint
sandstartup
sandstartuplib

List files of type: All Files [*.*]

Drives: c:

MWXPOWERTAP - Append new Directory:

Directory Name: c:\qnx\startuplib

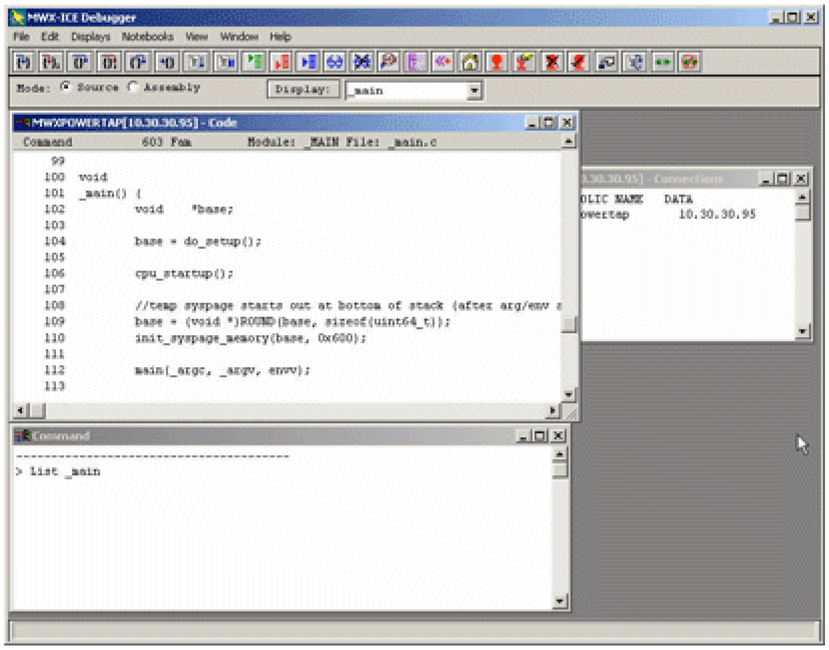
Folders: c:\qnx\startuplib

c:\
QNX
startuplib
lib

Drives: c:

Figure 16 The Load Symbols and Append Directory windows.

To display the **_main**() function in the Startup library, select the Code window (**Displays→Code**). Set the **Mode** to **Source**, type `_main` in the text box, then click the **Display** button. This loads the source into the Code window:


MWX-ICE Debugger
File Edit Displays Notebooks View Window Help
Mode: (•) Source ( ) Assembly
Display: _main
MWXPOWERTAP[10.30.30.95] - Code
Command 603 Fam Module: _MAIN File: _main.c
10.30.30.95] - Connections
Command

```
 99
100  void
101  _main() {
102          void    *base;
103
104          base = do_setup();
105
106          cpu_startup();
107
108          //temp syspage starts out at bottom of stack (after arg/env s
109          base = (void *)ROUND(base, sizeof(uint64_t));
110          init_syspage_memory(base, 0x600);
111
112          main(_argc, _argv, envv);
113
```

```
OLIC NAME   DATA
owertap       10.30.30.95
```

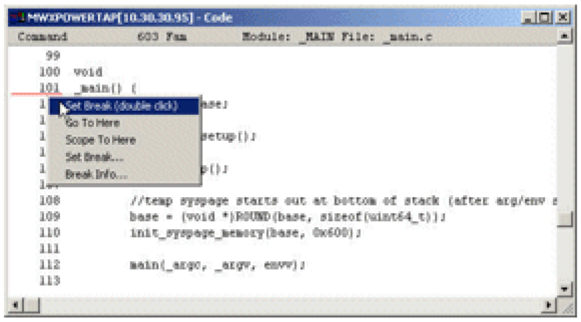
```
----------------------------------------
> list _main
```

Figure 17 Displaying the _main() function.

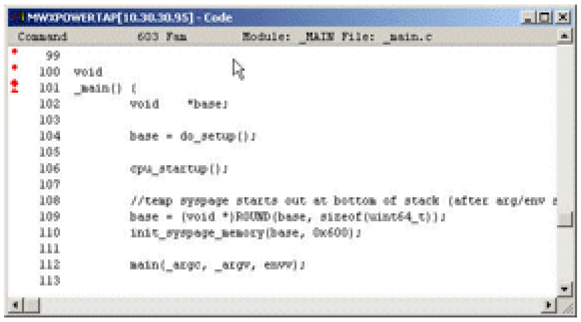
You can now set a breakpoint in the **_main**() function.

Note: Ensure that you've set the command **bptype onchip**, and that you've disabled any previous breakpoints.

To set a hardware breakpoint on **_main**(), bring the Code window to the front, right-click over the line number associated with the start of **_main**(), and choose **Set Break**.


MWXPOWERTAP[10.30.30.95] - Code
Command 603 Fam Module: _MAIN File: _main.c
Set Break (double click)
Go To Here
Scope To Here
Set Break...
Break Info...

```
 99
100  void
101  _main() {
108          //temp syspage starts out at bottom of stack (after arg/env s
109          base = (void *)ROUND(base, sizeof(uint64_t));
110          init_syspage_memory(base, 0x600);
111
112          main(_argc, _argv, envv);
113
```



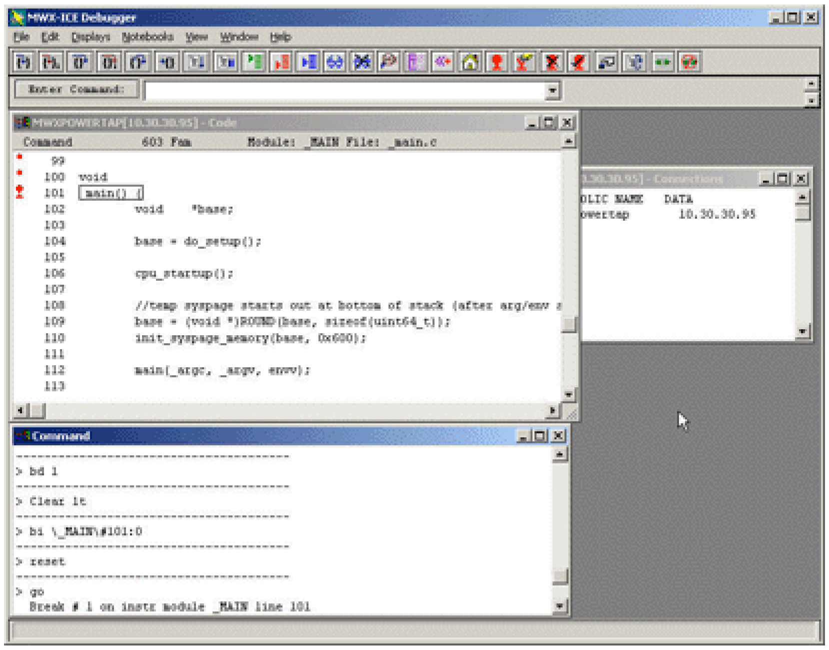
```
Command            603 Fam         Module: _MAIN File: _main.c
   99
  100  void
  101  _main() {
  102          void    *base;
  103
  104          base = do_setup();
  105
  106          cpu_startup();
  107
  108          //temp syspage starts out at bottom of stack (after arg/env s
  109          base = (void *)ROUND(base, sizeof(uint64_t));
  110          init_syspage_memory(base, 0x600);
  111
  112          main(_argc, _argv, envv);
  113
```

Figure 18 Setting and viewing a breakpoint in the *_main()* function.

To begin debugging the Startup, click the **Reset**,

and **Run**,

buttons. If you've burned the Startup into the Sandpoints flash memory along with the IPL, the debugger stops at the breakpoint. If you have to download the image over a serial connection (via the **sendnto** utility or the Sandpoint ROM monitor), the debugger breaks on this instruction once the image has been loaded into RAM and executed. It's also possible for you to trace through the IPL program to the point where it transfers control over to the Startup.



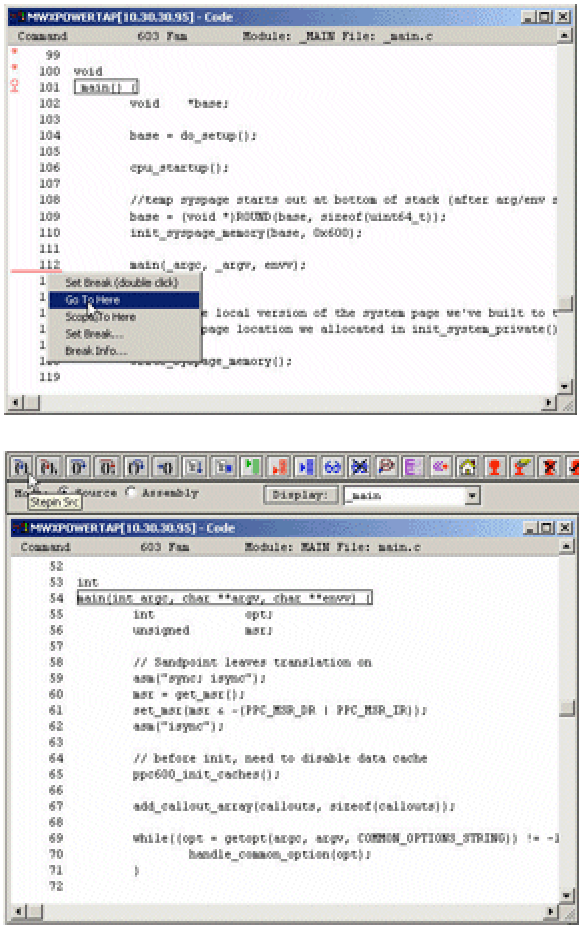
```
Command            603 Fam         Module: _MAIN File: _main.c
   99
  100  void
  101  _main() {
  102          void    *base;
  103
  104          base = do_setup();
  105
  106          cpu_startup();
  107
  108          //temp syspage starts out at bottom of stack (after arg/env s
  109          base = (void *)ROUND(base, sizeof(uint64_t));
  110          init_syspage_memory(base, 0x600);
  111
  112          main(_argc, _argv, envv);
  113
```

```
OLIC NAME   DATA
owertap       10.30.30.95
```

```
----------------------------------------
> bd 1
----------------------------------------
> Clear lt
----------------------------------------
> bi \_MAIN\#101:0
----------------------------------------
> reset
----------------------------------------
> go
  Break # 1 on instr module _MAIN line 101
```

Figure 19 Debugger stopped on the *_main()* function.

You can use the debugger to debug the Startup source code in the same ways described in the **Debugging the Sandpoint IPL** section. For instance, you can let the debugger run to the Sandpoint Startup **main**() function, and then step into the source.



```
void
main() {
        void    *base;

        base = do_setup();

        cpu_startup();

        //temp syspage starts out at bottom of stack (after arg/env s
        base = (void *)ROUND(base, sizeof(uint64_t));
        init_syspage_memory(base, 0x600);

        main(_argc, _argv, envv);


                          e local version of the system page we've built to t
                          page location we allocated in init_system_private()

                          syspage_memory();
```

```
int
main(int argc, char **argv, char **envv) {
        int             opt;
        unsigned        msr;

        // Sandpoint leaves translation on
        asm("sync; isync");
        msr = get_msr();
        set_msr(msr & ~(PPC_MSR_DR | PPC_MSR_IR));
        asm("isync");

        // before init, need to disable data cache
        ppc600_init_caches();

        add_callout_array(callouts, sizeof(callouts));

        while((opt = getopt(argc, argv, COMMON_OPTIONS_STRING)) != -1
                handle_common_option(opt);
        }

```

Figure 20 Stepping into the Sandpoint Startup *main()* function.

Once Startup completes initializing the environment, it transfers control over to the QNX Neutrino microkernel, **procnto**. Then, the kernel switches on the CPUs MMU, transferring the system over to virtual memory mode. From this point on, you can use a standard hardware debugger such as the AMC MWX-ICE to step through the kernels instructions, examine registers, etc., but you can't look at kernel or application data, because this memory is accessed in virtual memory mode. At this point however, the target board is up and running, and you can develop and debug user applications (including drivers) by using the standard QNX software debugging agent, **pdebug**, in conjunction with the standard QNX development tools.

The IPL program is responsible for basic setup of the CPU, including the memory controller, and copies the QNX Neutrino image into RAM. It's also possible for you to circumvent the IPL by using a hardware debugger. Hardware debuggers let you transfer an image in ELF or SREC format directly to target memory. In order to transfer a QNX Neutrino image (which includes the Startup program) to a target and run the RTOS, you must first configure the CPU and environment similar to the steps performed by the IPL. This is often done using a script that programs CPU registers and the memory controller before the image is downloaded and executed.

The **pdebug** software debugger requires a free serial port or Ethernet connection on the target board. There are a number of alternatives to debug user applications on deeply embedded targets without free communication ports:

- **ROM Emulator** - Some ROM emulators provide the capability of communication through the emulated ROM. For example, a virtual serial driver is available for QNX targets based on the AMC NetROM, letting you debug applications by using **pdebug** through this virtual serial port.
- **Serial Through JTAG** - A driver is available for the AMC PowerTAP and WireTAP, creating a virtual serial port connection between the host and target hardware over a JTAG connection to be used for debugging.
- **QNX Neutrino RTOS Aware JTAG** - Some hardware debuggers are available with knowledge of the QNX Neutrino RTOS, allowing for debugging of user applications. Contact AMC and Lauterbach for more details.

5. Summary

The software development and debugging process differs between QNX Neutrino and conventional embedded RTOSs. The QNX virtual memory based microkernel architecture protects the system from unstable applications and drivers. The modular QNX Neutrino architecture allows for reliable software debugging. You can start and stop QNX applications and drivers as desired on a running system, and you can debug them using the software debug agent **pdebug**. Hardware debuggers can also be valuable tools in the development of embedded systems, but are generally used differently than with other embedded RTOSs. Hardware debuggers are most useful in debugging software that's running in physical memory mode, such as QNX IPL, Startup, and kernel callouts.

6. References

1. **System Architecture**, QNX Software Systems.
2. **Building Embedded Systems**, QNX Software Systems.
3. **The New Business Imperative: Achieving Shorter Development Cycles while Improving Product Quality**, Paul N. Leroux, QNX Software Systems.
4. **Embedded Systems Design An Introduction to Processes, Tools, & Techniques**, Arnold S. Berger, CMP Books.
5. **An Embedded Software Primer**, David E. Simon, Addison Wesley.