Training Linux Debugging for Intel® x86/x64

TRACE32 Online Help

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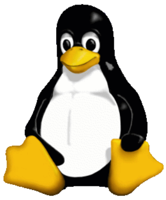
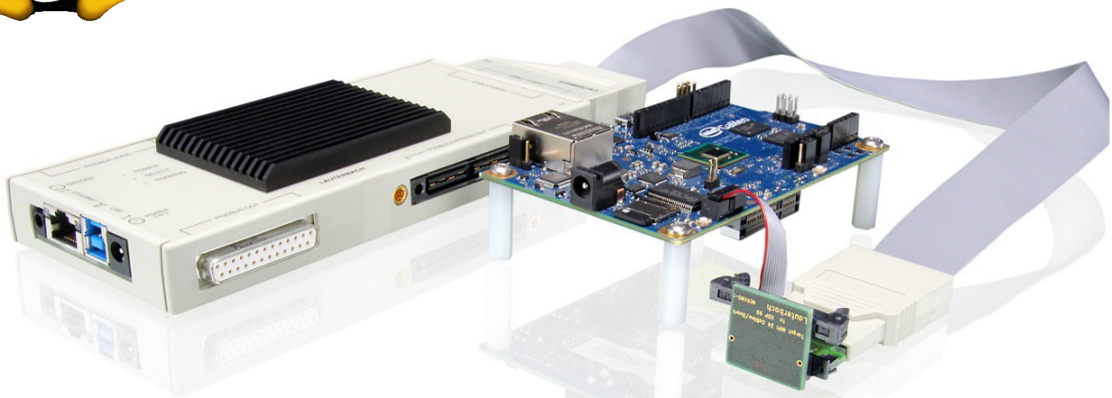
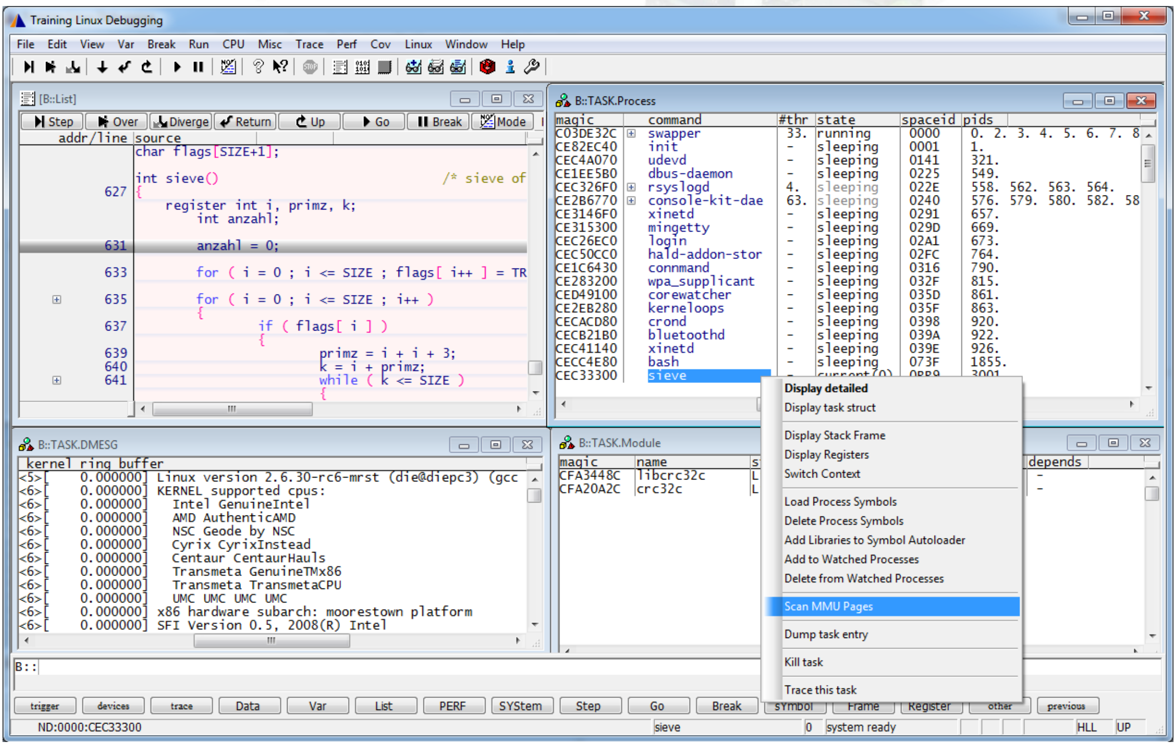






Prolog

This training will have the main subjects:

- **Basic terms on embedded Linux**
- **Building the kernel, a kernel module and a simple demo application**
- **Setting up a script for Linux-aware debugging**
- **Debugging Linux components by TRACE32 Linux menu**
- **Troubleshooting**

Further TRACE32 documents related to Linux Debugging:

This is a quick-tutorial. It will **not** introduce you to all features of the Linux awareness. For a complete description, refer to the **"RTOS Debugger for Linux - Stop Mode"** (rtos_linux_stop.pdf).

The latest version of the training manual is available for download under:

www.lauterbach.com/training.html

Basic Terms on Embedded Linux

This part describes essential basics and terms related to Linux and Linux-Debugging.

1. **Linux Components**
2. **The Linux Awareness**
3. **Virtual Memory Management in Linux**
4. **Run-Mode vs. Stop-Mode Debugging**

1.) Linux Components

From the point of view of a debugger, a Linux system consists of the following components:

- The Linux Kernel
- Kernel Modules
- Processes and Threads
- Libraries (Shared Objects)

Moreover, we can talk about two different spaces of executed code: kernel space with privileged rights which includes the kernel and kernel modules and user space with limited rights which includes processes, threads and libraries.

Please note that this training does not handle the debugging of bootloaders.

The Kernel

The Linux kernel is the most important part in a Linux system. It runs in privileged kernel space and takes care of hardware initialization, device drivers, process scheduling, interrupts, memory management... The Linux kernel is generally contained in a statically linked executable in one of the object files supported by Linux (e.g. ELF) called “vmlinux”. You can also find the kernel in compressed binary format (zImage/uImage). You will see later in this training how to configure the Linux kernel for Linux-aware debugging.

Kernel Threads:

It is often useful for the kernel to perform operations in the background. The kernel accomplishes this via kernel threads. Kernel threads exist solely in kernel space. The significant difference between kernel threads and processes is that kernel threads operate in kernel space and do not have their own address space.

Kernel Modules

Kernel modules (*.ko) are software packages that are loaded and linked dynamically to the kernel at run time. They can be loaded and unloaded from the kernel within a user shell by the commands “insmod” and “rmmod”. Typically kernel modules contain code for device drivers, file systems, etc. Kernel modules run at kernel level with kernel privileges (supervisor).

Processes and Threads

A process is an application in the midst of execution. It also includes, additionally to executed code, a set of resources such as open files, pending signals, a memory address space with one or more memory mappings...

Linux-Processes are encapsulated by memory protection. Each process has its own virtual memory which can only be accessed by this process and the kernel. Processes run in user space with limited privileges.

A process could have one or more threads of execution. Each thread includes a unique program counter, process stack and set of process registers. **To the Linux kernel, there is no concept of a thread.** Linux implements all threads as standard processes. For Linux, a thread is a processes that shares certain resources with other processes.

In this training, you will also find the term “task” which denotes kernel threads, processes and threads.

Libraries (Shared Objects)

Libraries (shared objects, *.so) are commonly used software packages loaded and used by processes and linked to them at run-time. Libraries run in the context and memory space of the process that loaded them having the same limited privilege as the owning process. Same as processes, also libraries are always loaded and executed as a file through a file system.

2.) The Linux Awareness

Debugging an operating system like Linux requires special support from the debugger. We say that the debugger needs to be **“aware”** of the operating system. Since TRACE32 supports a wide range of target operating systems, this special support is not statically linked in the debugger software but can be dynamically loaded as an extension depending on which operating system is used. Additional commands, options and displays will be then available and simplify the debugging of the operating system.The set of files providing these operating system debugging capabilities is called here **“awareness”**.

To be able to read the task list or to allow process or module debugging, the Linux awareness accesses the kernel’s internal structures using the kernel symbols. **Thus the kernel symbols must always be available otherwise Linux aware debugging will not be possible**. The file vmlinux has to be compiled with debugging information enabled as will be shown later.

The Linux awareness files can be found in the TRACE32 installation directory under
`~~/demo/<arch>/kernel/linux/<linux_version>`

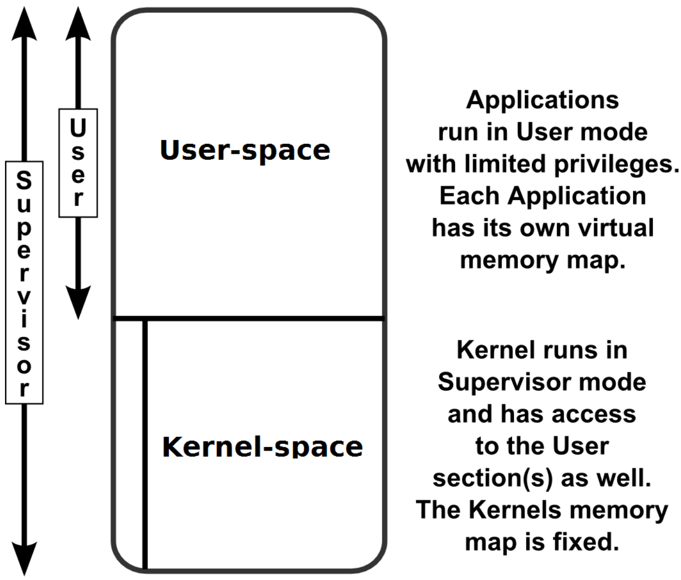
You can check the version of the loaded Linux awareness in the **VERSION.SOFTWARE** window. This information will only be shown if the Linux awareness is already loaded. You will see later in this training how to load the Linux awareness.

3.) Virtual Memory Management in Linux

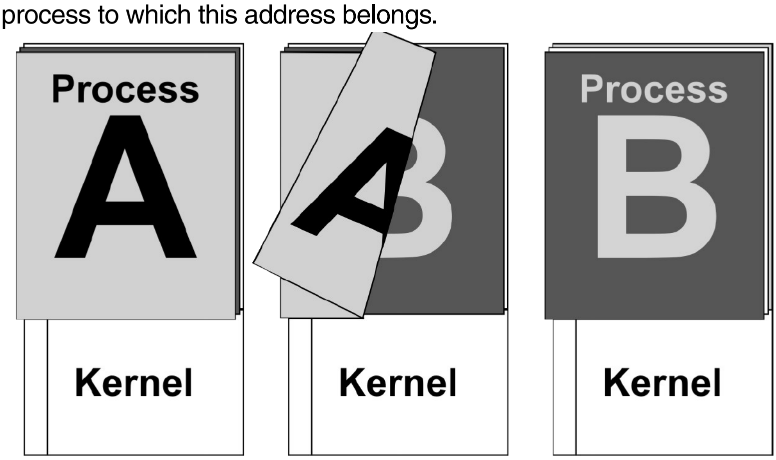
Before actually going into the details on how to debug a Linux system with TRACE32, we need to look at the helping features of TRACE32 that make Linux debugging possible.

Virtual Address Map of Linux

We start by discussing the virtual address map used by a running Linux system. Basically the memory is split into two sections: one section is reserved for the kernel and the second one for the user applications. The kernel runs in Supervisor/Privileged mode and has full access to the whole system. Next to Supervisor/ Privileged mode there is User/Non-Privileged mode which is used for user space processes. While the CPU is in User/Non-Privileged mode, only parts of the memory are visible. Thus the kernel, which runs in Supervisor mode, has full visibility of the whole virtual address map, while the user processes have only a partial visibility. It's the task of the kernel to maintain the virtual address map and also the virtual to physical address translations for each application/ process.



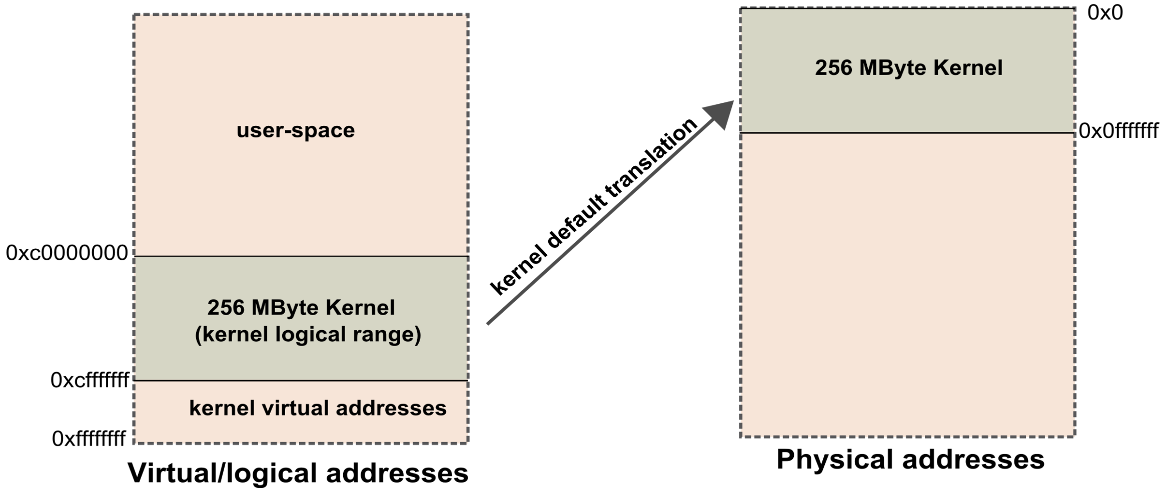
The kernel space is exclusively used by the kernel, this means that a logical/virtual address in this section can have, at a given time, one single virtual-to-physical address mapping. On the other hand, the user space is shared by all running processes. Thus a virtual address in the user space can have different mappings depending on the process to which this address belongs.



The kernel space includes the kernel logical address range which is mapped to a continuous block in the physical memory. The kernel logical addresses and their associated physical addresses differ only by a constant offset. We denote this kernel logical to physical address translation as "***kernel default translation***". The rest of the kernel space includes the kernel virtual addresses which do not have necessarily the linear one-to-one mapping to physical addresses. This includes for instance memory allocated with vmalloc.

For a 32 bit Linux, the logical start address of the kernel is fixed by the kernel `CONFIG_PAGE_OFFSET` macro which is per default `0xC0000000` and the end address is the value of the `high_memory` variable minus one.

Example: kernel logical range from `0xC0000000` to `0xCFFFFFFF` mapped to the physical memory block starting at `0x00000000`.



For a 64 bit Linux the kernel logical range lays from `0xFFFF880000000000` to `0xFFFFC7FFFFFFFFFF` where you have a direct mapping of all physical memory. Moreover, 512MB of physical memory starting at `0x0` are also mapped to the logical range `0xFFFFFFFF80000000--0xFFFFFFFF9FFFFFFF` (kernel text mapping). The memory mapping for the 64 bit kernel is described in details in the kernel documentation under `Documentation/x86/x86_64_mm.txt`.

Kernel modules also run in the kernel space and are located for x86/x64 above the kernel logical range.

Debugger Memory Access

With disabled debugger address translation, the debugger accesses the memory virtually (through the core). This way, it is only possible to access memory pages which are currently mapped in the TLBs.

Alternatively, you can set up the debugger to access the memory physically. This way, the debugger will have access to all the existing physical memory. However, Linux operates completely in virtual memory space: all functions, variables, pointers etc. work with virtual addresses. Also, the symbols are bound to virtual addresses. Hence, if the user tries to read the value of a variable, the debugger has to find the virtual to physical address translation for this variable and access it using its physical address.

The debugger holds a local translation list. Translations can be added to this list manually using the **TRANSlation.Create** command. This local translation list can be viewed using the **TRANSlation.List** command. If no translation is found in this local list and if the translation **"table walk"** is enabled then the debugger will read the target MMU page table(s) to find the virtual to physical address translation. We call this process **"*debugger table walk*"**.

Please note that the debugger local translation list has the highest priority in the debugger translation process.

In contrast to the CPU address translation, if the virtual to physical address mapping is not found in the page table when performing a debugger table walk, no page fault is generated. It is then not possible for the debugger to access this address. A debugger memory access doesn't modify the MMU page tables.

	The debugger translation and the debugger table walk are per default enabled in TRACE32 for x86/x64

Without further settings, the debugger can only access the current page table pointed by the CR3 CPU register. However, each process as well as the kernel, has its own page table. Hence, by walking only through the current page table, it is not possible to find the virtual to physical address mapping of a process which is not the current executing one and as follows it is not possible to access the memory of such a process.

But since the Linux kernel manages the switching of the MMU for all processes, kernel structures hold the pointers for the translation pages tables for every process. The debugger just needs to get this information from the kernel data structures to be able to access the memory for any running task in the system. It is the task of the Linux awareness to get the page table descriptors for all running tasks on the system. You can display these descriptors by execution the TRACE32 commands **TRANSlation.ScanID** and **TRANSlation.ListID**.

	To be able to access the kernel logical range at any time, the debugger needs to know the kernel logical to physical address translation.

Space IDs

Under Linux, different processes may use identical virtual address. To distinguish between those addresses, the debugger uses an additional identifier, the so-called **space ID** (memory space identifier). It specifies which virtual memory space an address refers to. The space ID is zero for all tasks using the kernel address space (kernel threads). For processes using their own address space, the space ID equals the lower 16bits of the process ID. Threads of a particular process use the memory space of the invoking parent process. Consequently threads have the same space ID as the parent process (main thread).

If you enter commands with a virtual address without the TRACE32 space ID, the debugger will access the virtual address space of the current running task.

The following command enables the use of space IDs in TRACE32:

```
SYStem.Option MMUSPACES ON
```

SYStem.Option MMUSPACES ON doesn't switch on the processor MMU. It just **extends the addresses with space IDs.**

After this command, a virtual address looks like "`001E:10001244`", which means virtual address 0x10001244 with space ID 0x1E (pid = 30.).

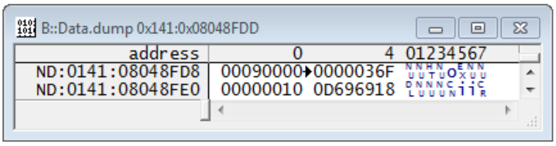
You can now access the complete memory:

```
Data.dump 0x10002480            ; Will show the memory at virtual address
                                ; 0x10002480 of the current running task

List 0x2F:0x10003000            ; Will show a code window at the address
                                ; 0x10003000 of the process having the space
                                ; id 0x2F

Data.dump A:0x10002000          ; Will show the memory at physical address
                                ; 0x10002000
```

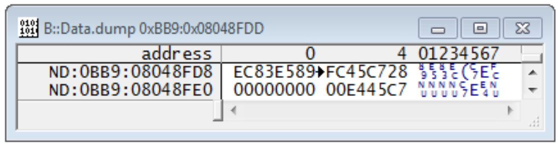
Symbols are always bound to a specific space ID. When loading the symbols, you need to specify, to which space ID they should belong. If you load the symbols without specifying the space ID, they will be bound to space ID zero (i.e. the kernel's space ID). See chapter **"Debugging the Linux Components by TRACE32 Linux Menu"**, page 36 for details.

Because the symbols already contain the information of the space ID, you don't have to specify it manually.

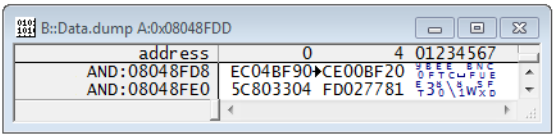
```
Data.dump myVariable          ; Will show the memory at the virtual
                              ; address of "myVariable" with the space ID
                              ; of the process holding this variable
```



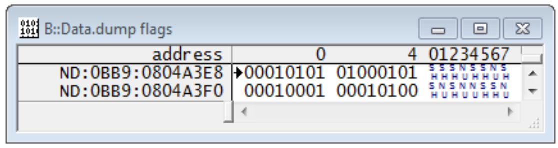
virtual address of current process 0x141



virtual address of specified process 0xBB9

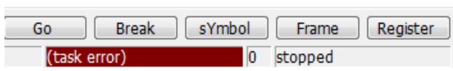


access to physical address A:0x8048FDD



Symbol "flags" with process 0xBB9

If the Linux awareness is enabled, the debugger tries to get the space ID of the current process by accessing the kernel's internal data structures. If this fails e.g. because of wrong symbol information, an access error, or because the kernel's data structures have not been yet initialized (in case you stop the target early in the kernel boot process), the debugger set the current space ID to 0xFFFF and shows the message "task error" in the status line.



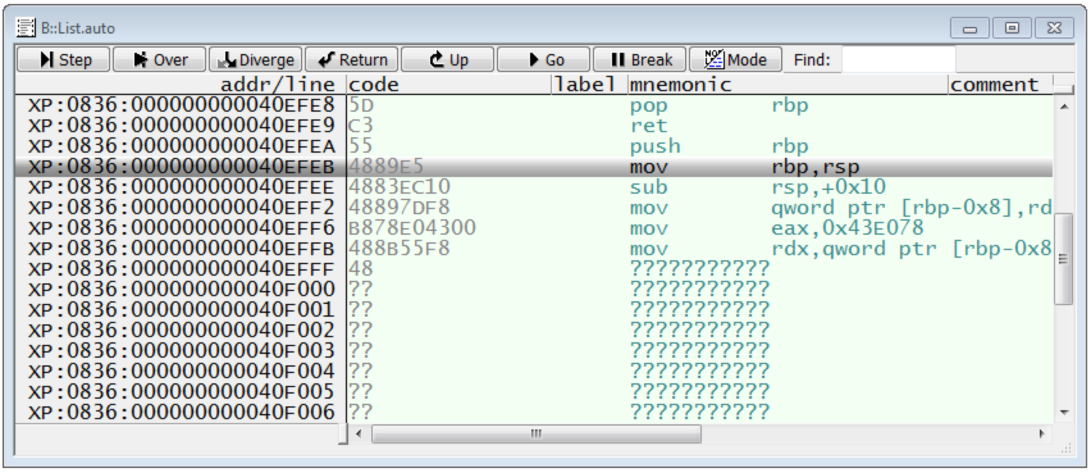
You can ignore the "task error" message as long as the kernel has not yet booted.

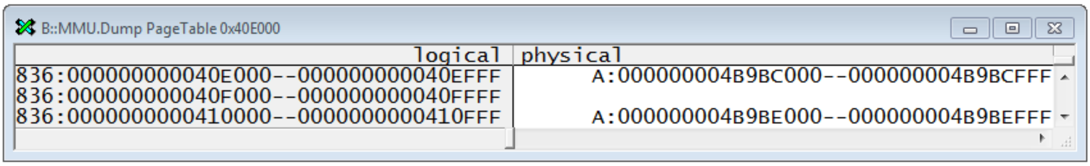
On Demand Paging

Linux is designed for heavy MMU usage with demand paging. Demand paging means that code and data pages of processes (and libraries) are loaded when they are first accessed. If the process tries to access a memory page that is not yet loaded, it creates a page fault. The page fault handler then loads the appropriate page. Only the actually used pages are really loaded.

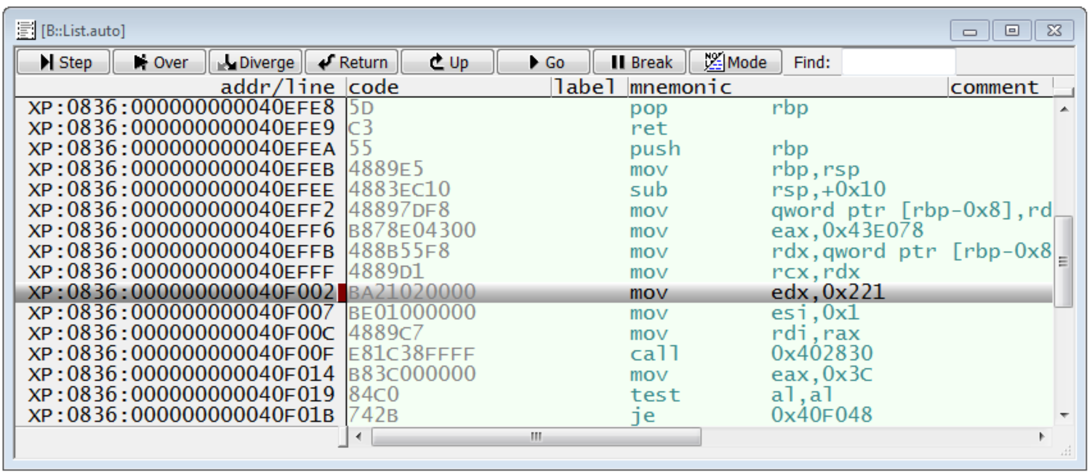
However, this demand paging disturbs the debugger a lot. As a workaround, two patches are available to avoid demand paging while debugging. One is placed in the ELF loader, the other one is placed in the process handler. Please see **"RTOS Debugger for Linux - Stop Mode"** (rtos_linux_stop.pdf) for details.

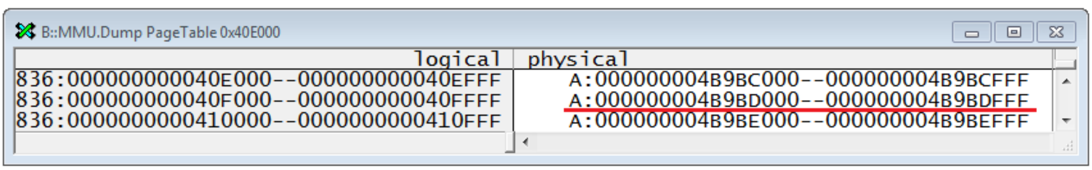
The following screen shots show an example of “on demand paging”. The instruction pointer is near the 4KB page boundary at the address `0x40EFFB`. The next memory page beginning at `0x40F000` cannot be accessed by the debugger since it wasn’t yet accessed by the core and thus doesn’t have a mapping in the MMU page table of the current process.





We set an on-chip breakpoint somewhere in the next memory page and resume the execution. A page fault then occurs and the memory page is loaded and gets a mapping in the current page table.



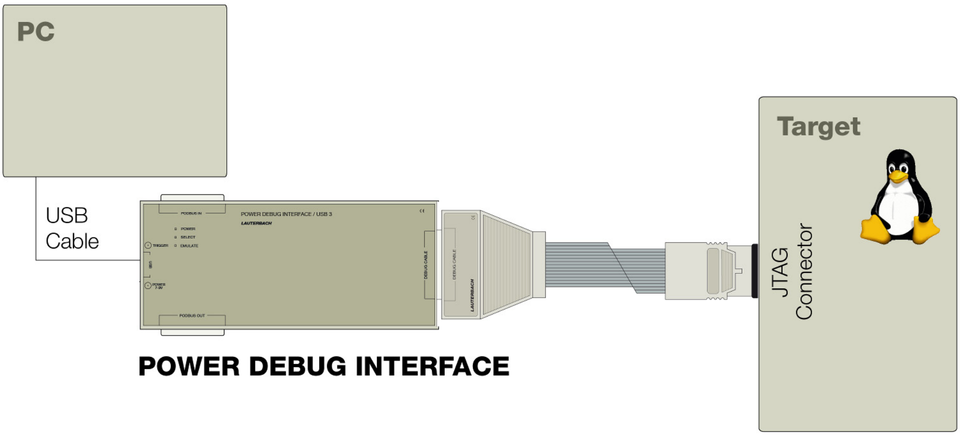


4.) Run-Mode vs. Stop-Mode Debugging

There are two main alternatives for debugging a Linux target: hardware based (stop mode) and software based (run mode). This chapter gives a small introduction regarding the differences between stop and run mode debugging which are both supported by TRACE32.

Hardware Based Debuggers

A hardware-based debugger uses special hardware to access target, processor and memory (e.g. by using the JTAG interface). No software components are required on the target for debugging. This allows debugging of bootstraps (right from the reset vector), interrupts, and any other software. Even if the target application runs into a complete system crash, you are still able to access the memory contents (post mortem debugging).



A breakpoint is handled by hardware, too. If it is reached, the whole target system (i.e. the processor) is stopped. Neither the kernel, nor other processes will continue. When resuming the target, it continues at the exact state, as it was halted at the breakpoint. This is very handy to debug interrupts or communications. However, keep in mind that also “keep alive” routines may be stopped (e.g. watchdog handlers).

The debugger is able to access the memory physically over the complete address range, without any restrictions. All software parts residing in physically memory are visible, even if they are not currently mapped by the TLBs. If the debugger knows the address translation of all processes, you gain access to any process data at any time.

The “on demand paging” mechanism used by Linux implies that pages of the application may be physically not present in the system, as long as they are not accessed. The debugger cannot access such pages (including software breakpoints), as long as they are not loaded.

Advantages:

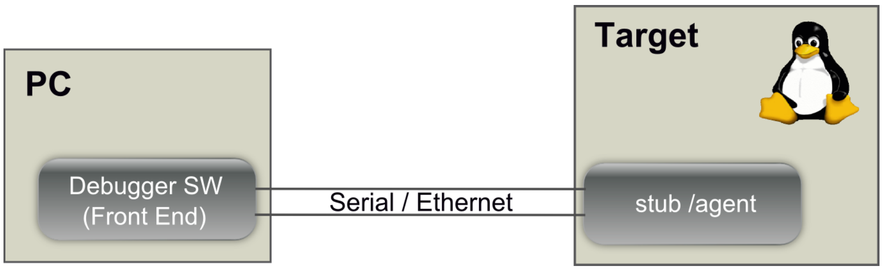
- **bootstrap, interrupt or post mortem debugging is possible**
- **no software restrictions (like memory protection, ...) apply to the debugger**
- **the full MMU table and code of all processes alive can be made visible**
- **only JTAG is required, no special communication interface as RS232 or Ethernet is needed**

Disadvantages:

- **halts the complete CPU, not only the desired process**
- **synchronization and communications to peripherals usually get lost**
- **debug HW and a debug interface on the target are needed**

Software Based Debuggers

Software based debuggers, e.g. GDB, usually use a standard interface to the target, e.g. serial line or Ethernet. There is a small program code on the target (called “stub” or “agent”) that waits for debugging requests on the desired interface line and executes the appropriate actions. Of course, this part of the software must run, in order for the debugger to work correctly. This implies that the target must be up and running, and the driver for the interface line must be working. Hence, no bootstrap, interrupt or post mortem debugging is possible.



When using such a debugger to debug a process, a breakpoint halts only the desired process. The kernel and all other processes in the target continue to run. This may be helpful, if e.g. protocol stacks need to continue while debugging, but hinders the debugging of inter-process communication.

Because the debugging execution engine is part of the target program, all software restrictions apply to the debugger, too. In the case of a gdbserver for example, which is a user application, the debugger can only access the resources of the currently debugged processes. In this case, it is not possible to access the kernel or other processes.

Advantages:

- **halts only the desired process**
- **synchronization and communications to peripherals usually continue**
- **no debugger hardware and no JTAG interface are needed**

Disadvantages:

- **no bootstrap, interrupt or post mortem debugging is possible**
- **all software restrictions apply to the debugger too (memory protection, ...)**
- **only the current MMU and code of this scheduled process is visible**
- **actions from GDB change the state of the target (e.g page faults are triggered)**
- **one RS232 or Ethernet interface of the target is blocked**

!	**Software based debugging is less robust and has many limitations in comparison to hardware based debugging. Thus, it is recommended to use JTAG based debugging if possible.**

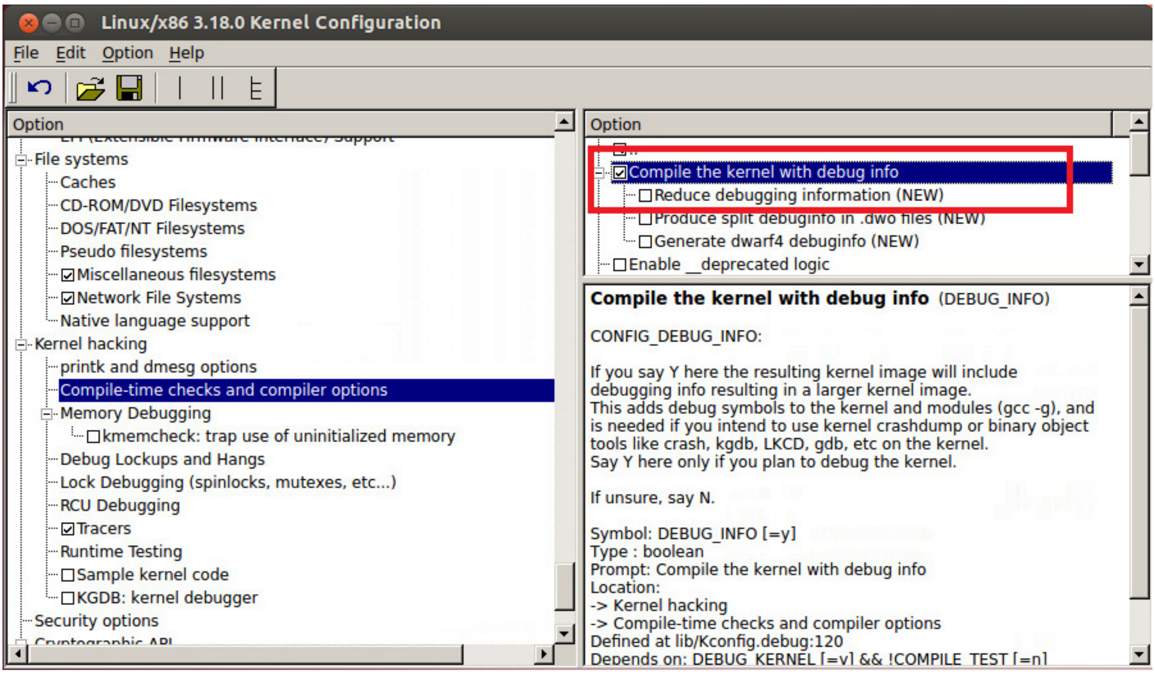
Run mode debugging is not covered by this training, for more information please refer to **"RTOS Debugger for Linux - Run Mode"** (rtos_linux_run.pdf) and **"TRACE32 as GDB Front-End"** (frontend_gdb.pdf).

5.) Building the Kernel, a Kernel Module and a Simple Demo Application

Before going forward with writing Linux TRACE32 scripts and debugging the different Linux components, we will show the important steps when building the kernel, kernel modules and user applications.

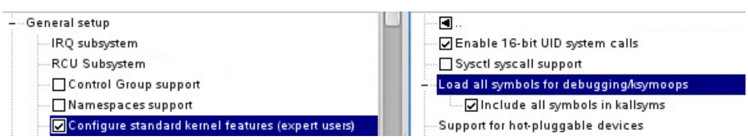
Building the Kernel

To be able to do Linux aware debugging, the vmlinux file must be compiled with debug info enabled. Thus, you need to ensure that `CONFIG_DEBUG_INFO` is enabled in the kernel configuration. You can find this option under "**Kernel hacking -> Compile the kernel with debug info**" (in newer kernel versions under "**Kernel hacking -> Compile-time checks and compiler options -> Compile the kernel with debug info**"). Please also make sure that `CONFIG_DEBUG_INFO_REDUCED` is **not** set (Reduce debugging information)



Building a Kernel Module

The kernel contains all section information if it has been configured with `CONFIG_KALLSYMS=y`. When configuring the kernel, set the option **"General Setup"-> "Configure standard kernel features" -> "Load all symbols"** to yes. Without `KALLSYMS`, no section information is available and debugging kernel modules is not possible.



Building a User Application

When compiling an application, you need to use the “-g” compiler option to enable debug information:

```
$ gcc -g -o hello hello.c
```

Setting up a Script for Linux-Aware Debugging

This chapter will tell about the **typical steps** how to prepare a Linux target and the TRACE32 debugger **for convenient Linux-Debugging**.

The following pages will show the setup by now step by step:

1. **Capture of commands for a script**
2. **Linux Setup-Steps and -Commands**
3. **Example Linux Setup-Script file**

1.) Capture of Commands for a Script

It can be an advantage to record the commands and wanted settings used inside the TRACE32 graphical user interface (GUI) right from the start. So you should open first a LOG-file:

LOG.OPEN *<file>*	Create and open a file for the commands to be logged. The default extension for LOG-files is (`.log`)
LOG.CLOSE	Close the LOG-file

This log file contains all of the TRACE32 actions, including the menu selection and mouse-clicks. Whereas the **ClipSTOre** and **STOre** <file> commands save only specific actions like system settings (e.g STOre SYStem).

STOre *<file>* **SYStem**	Create a batch to restore the SYStem settings
ClipSTOre SYStem	Provide the commands to restore the SYStem settings in the cliptext

The **HISTory** command only samples the commands from the command line. But it offers a quick access to the commands used already. Use the cursor key “UP” or mouse to select commands form the **HISTory** list.

HISTory.type	Display the command history

2.) Linux Setup-Steps and -Commands

To be able to do Linux aware debugging, some configuration needs to be done in TRACE32. The minimal setup includes the following steps:

- Connect to the target platform
- Load the Linux kernel symbols
- Set up the debugger address translation
- Load the Linux awareness and the Linux menu

These are the only needed configuration steps if you want to attach to a running Linux kernel. In case you want to debug the kernel boot, then you additionally need to make sure to stop the execution before the kernel start.

Moreover, it is possible to download the kernel image to the RAM using the debugger. We will discuss in this chapter which setup is needed in this case.

You can find Linux demo scripts in the TRACE32 installation directory under `~~/demo/x86/kernel/linux/board` and `~~/demo/x64/kernel/linux/board`.

Debugger Reset for Linux Debugging

Especially if you restart debugging during a debug session you are not sure about the state the debugger was in. So use command **RESet** for a complete restart or the specific resets for each debugger function..

```
RESet                              ; reset debugger completely
```

> **The RESet command doesn't reset the target but only the debugger environment.**

Moreover, it is also good to clear all debugger windows before connecting to the target using the **WinCLEAR** command.

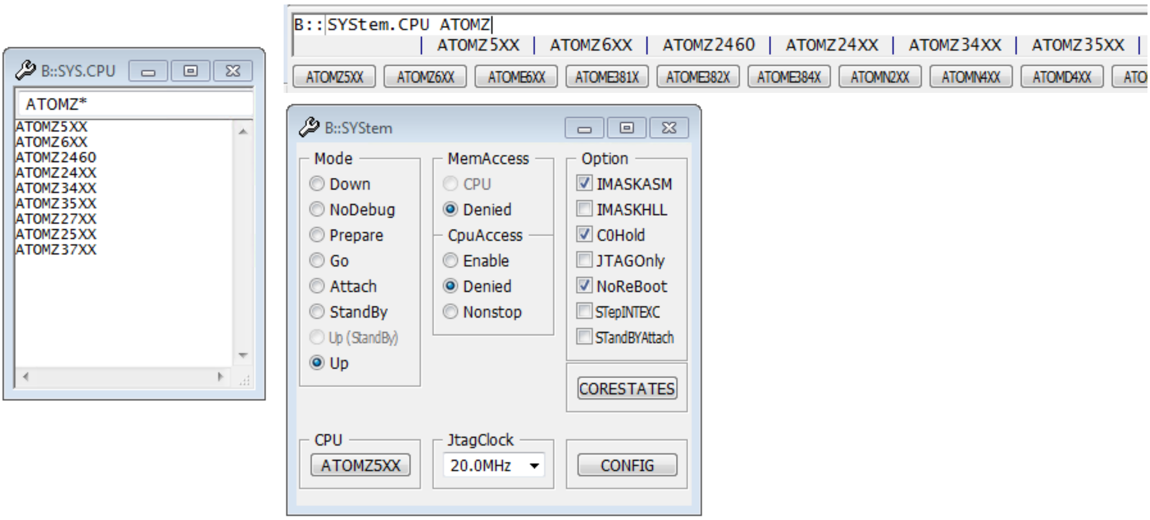
```
WinCLEAR                           ; clear all debugger windows
```

Debugger Setup

First you need to set up the debugger to be able to connect to the target platform. This includes e.g. selecting the appropriated CPU, setting the JTAG clock and selecting target-specific debugger options. Moreover, some additional options related to Linux debugging have to be enabled like address extension. Finally, you need to connect to the target using **SYStem.Up** or **SYStem.Mode Attach**.

CPU Selection

You need to select a CPU to debug your target. We select for example the ATOMZ5XX for the Crown Beach target:



You can use the search field in the **SYStem.CPU** window to find your CPU name. Alternatively, you can use the command line to write the CPU name partially to be completed by pressing the tabulator key on the keyboard. This way also the amount of displayed CPUs is reduced temporarily.

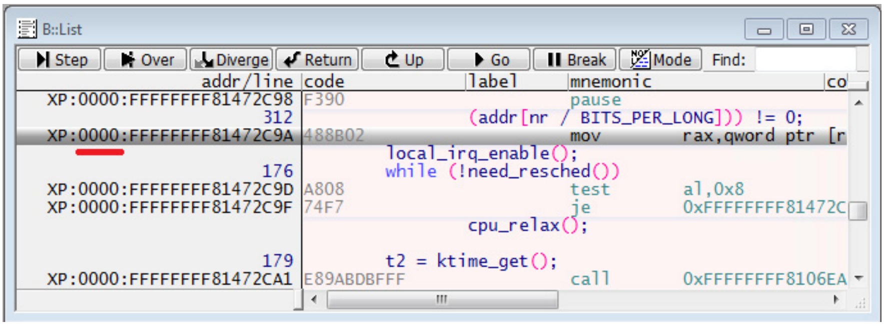
```
SYStem.CPU ATOMZ5XX            ; ATOMZ5XX target to be debugged
```

JTAG Clock

Using the command **SYStem.JtagClock** you can select an appropriated JTAG clock for you target. This could be necessary if the default clock set by the debugger is too high. You can see the selected JTAG clock in the **SYStem** window.

```
SYStem.JtagClock 20MHz
```

Switch on the debugger's virtual address extension to use space IDs (needed to differ e.g. several "main" functions of different processes). The addresses in the **List** and **Data.dump** windows will be extended with a space ID (e.g **0000**:FFFFFFF81472C9A).




```
SYStem.Option MMUSPACES ON      ; enable space IDs to virtual addresses
```

Remark: Older documentation and TRACE32 software uses "SYStem.Option MMU ON" instead of "SYStem.Option MMUSPACES ON". Please use only the new naming.

The "SYStem.Option MMUSPACES" should be enabled at the beginning of the script before loading any debug symbols.

Connect to the Target

The command **SYStem.Up** reset the target (if supported by the JTAG interface) and enters debug mode.

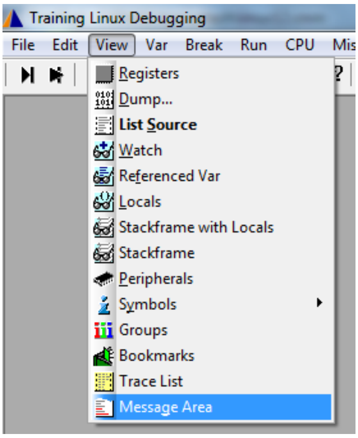
```
SYStem.Up                       ; activates the JTAG communication
```

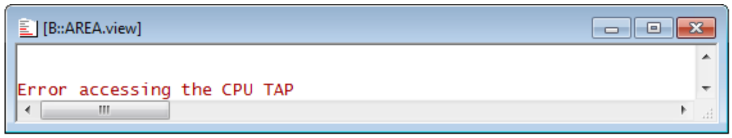
The command **SYStem.Mode Attach** attaches to the target without resetting the cores.

```
SYStem.Mode Attach              ; attach to the cores
```

At this stage the Linux awareness has not yet been loaded, so if a problem occurs then it is related to the debugger settings or to a problem on the target. Please check in this case the AREA window for errors and warnings.

AREA.view [<*area*>]





Please refer to **"Intel® x86/x64 Debugger"** (debugger_x86.pdf) for architecture specific setup and options.

Set Single Step Behavior

While single stepping, external interrupts may occur. On some architectures, this leads with the next single step into the interrupt handler. This effect normally disturbs during debugging. The following sequence masks external interrupts while executing assembler single steps. Keep interrupts enabled during HLL single steps to allow paging while stepping through source code.

```
SETUP.IMASKASM ON        ; suppress interrupts during assembler stepping
SETUP.IMASKHLL OFF       ; allow interrupts while HLL single stepping
```

If an assembler single step causes a page fault, the single step will jump into the page fault handler, regardless of the above setting. The debugger will restore the interrupt mask to the value before the single step. So it might be wrong at this state and cause an unpredictable behavior of the target.

Open a Terminal Window

You can open a serial terminal window in TRACE32 using the **TERM** command:

```
TERM.RESet                          ; reset old and set new definitions
TERM.METHOD COM com1 115200. 8 NONE 1STOP NONE
                                    ; for com10 use \\.\com10
TERM.SIZE 80 1000                   ; define capacity of the TERM window
TERM.SCROLL ON                      ; scrolling follows to the TERM cursor
TERM.Mode VT100                     ; or ASCII (default), STRING, HEX ...
WINPOS 50% 0%  50% 100% term_win    ; define next window position and size
TERM.view                           ; open the TERM window
SCREEN.ALways                       ; TERM window always updated
```

You can also use the `term.cmm` script available in the TRACE32 installation under `~~/demo/etc/terminal/serial` which takes two arguments: the COM port and the baud rate e.g.

```
DO ~~/demo/etc/terminal/serial/term.cmm COM1 115200.
```

Load the Kernel Symbols

You can load the kernel symbols using the **Data.LOAD.Elf** command. Without any further options, this command loads the symbols and download the code to the target. In order to only load the kernel symbols into the debugger without downloading the code, you need to use the /NOCODE option.

```
Data.LOAD.Elf vmlinux /NOCODE
```

For some older GNU compilers, you also need to use the /GNU option:

```
Data.LOAD.Elf vmlinux /NOCODE /GNU
```

Displaying the Source Code

If you are not running TRACE32 on the host where you compiled your kernel, the debugger, which uses per default the compile path to find the source files, will not find these files. Thus, the debugger needs to be set up to be able to find the source code. Two options are available in the **Data.LOAD** command for this purpose: **/STRIPPART** and **/SourcePATH.** With the option **/STRIPPART** you can remove parts of the path stored in the object file. With the option **/SourcePATH** you can specify a basis directory for the source files. The debugger will take the rest of the compile path (without the stripped part) and will append it to the specified source path. The source path can also be set using the command **sYmbol.SourcePATH**.

For example, if you have compiled your kernel on a Linux machine in the directory `/home/atom230/linux-3.13.1` and you are running TRACE32 on a Windows machine where you have the kernel source files tree under `C:\Linux\training\sources\linux-3.13.1`, you can for example load the kernel symbols with

```
Data.LOAD.Elf vmlinux /NoCODE /STRIPPART "atom230"
                               /SOURCEPATH C:\Linux\training\sources
```

or

```
Data.LOAD.Elf vmlinux /NoCODE /STRIPPART 3.
                              /SOURCEPATH  C:\Linux\training\sources
```

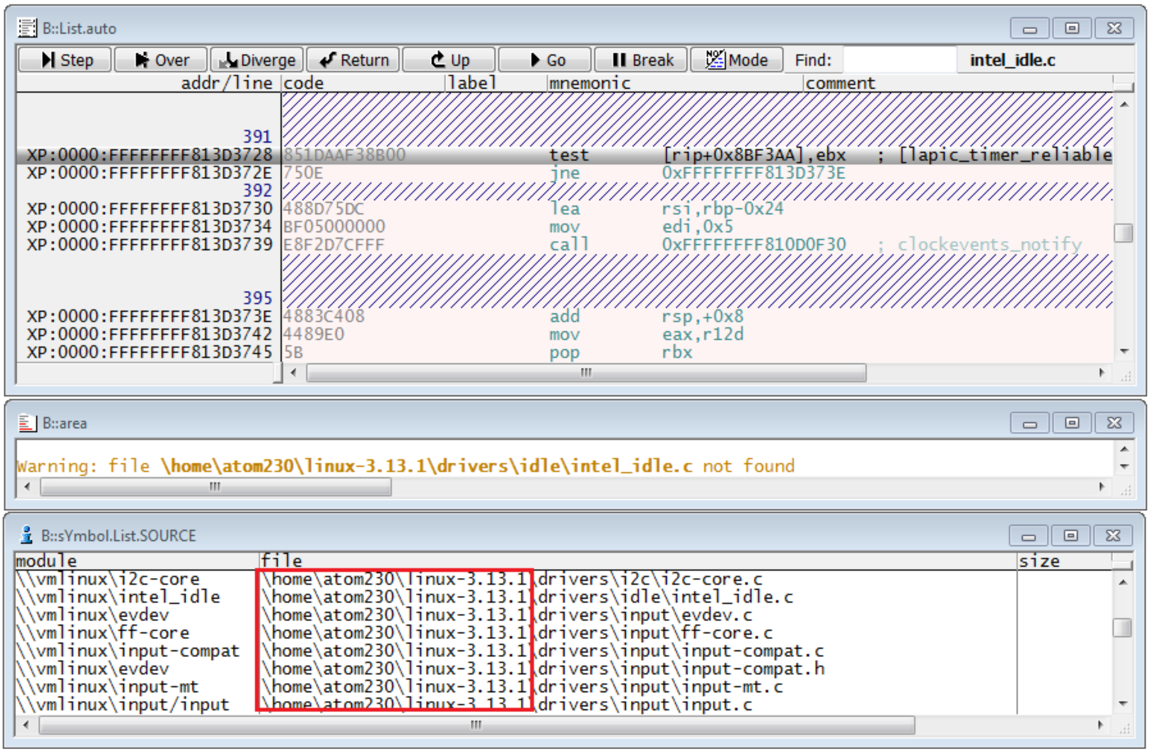
or

```
Data.LOAD.Elf vmlinux /NoCODE /STRIPPART 3.
sYmbol.SourcePATH C:\Linux\training\sources
```

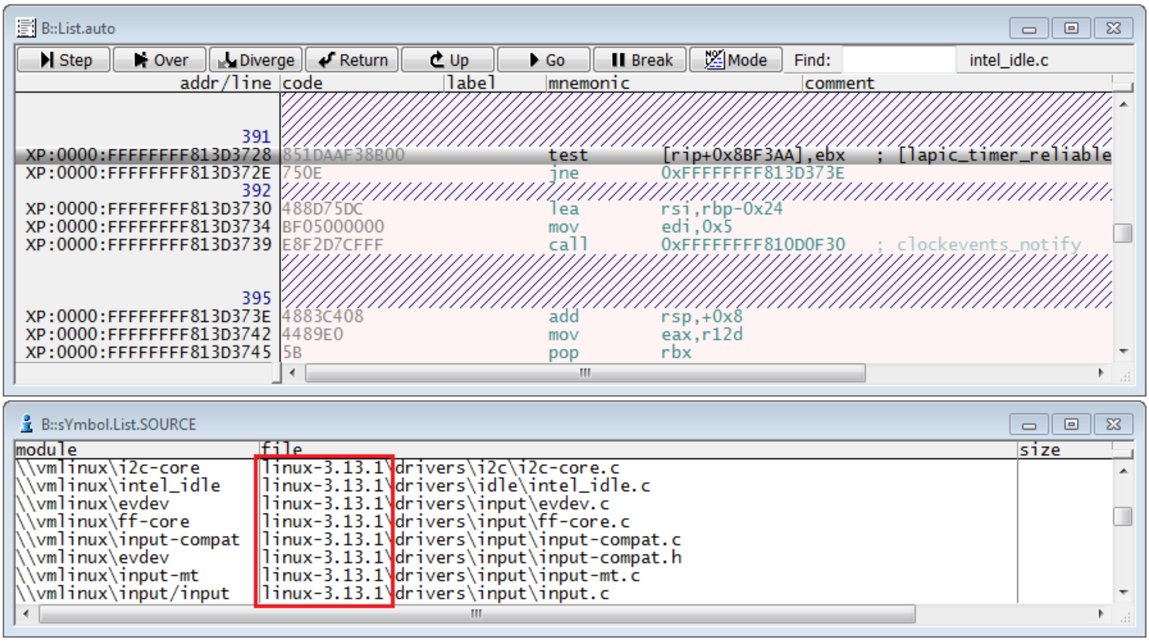
In this case we get the same result if we use the /STRIPPART option with the parameter `"atom230"` or 3. (`"/"+"home/"+"atom230/"`).

To look for the source file `drivers/idle/intel_idle.c` the debugger will here use the path
`C:\Linux\training\sources\ + ` ~~`/home/atom230`~~`/linux-3.13.1/drivers/idle/`
thus
`C:\Linux\training\sources\linux-3.13.1\drivers\idle\`

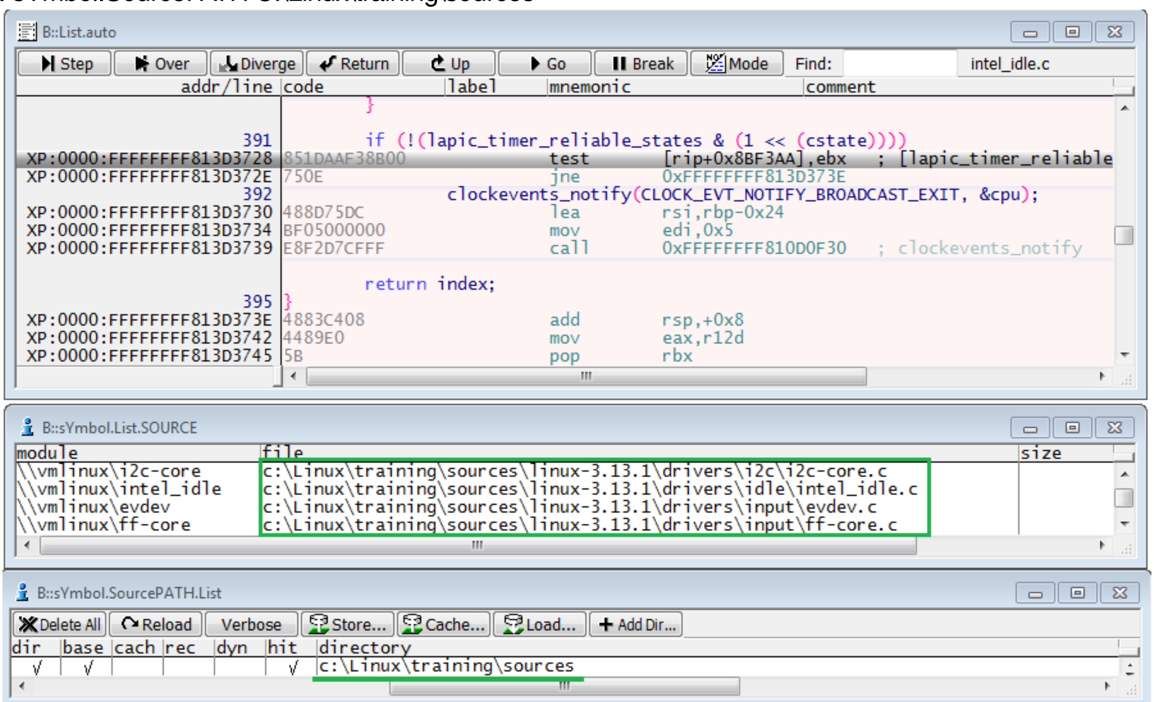
1. Data.LOAD.Elf vmlinux /NoCODE /NoREG



2. Data.LOAD.Elf vmlinux /NoCODE /NoREG /STRIPPART 3.



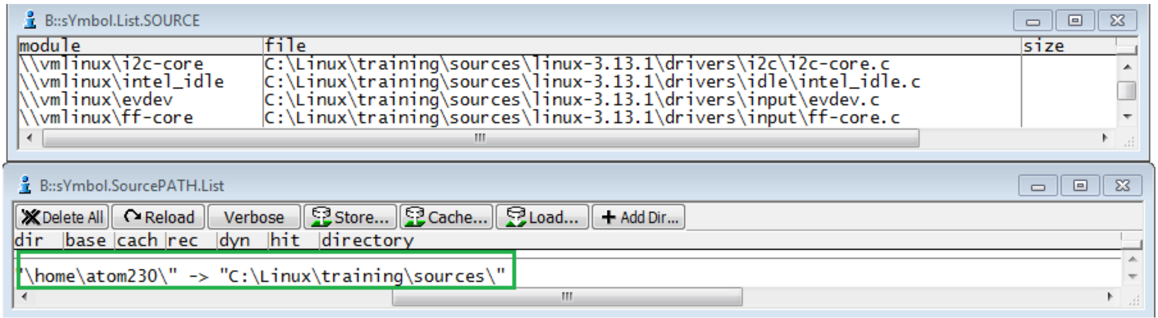
3. sYmbol.SourcePATH C:\Linux\training\sources



If you don't specify the source path, the debugger will append the rest of the stripped path to the path of the loaded vmlinux file.

You can also instead of using **/STRIPPART** and **/SourcePATH** to specify the path to the source file, use the command **sYmbol.SourcePATH.Translate** to translate a “compile” source path to a “host” source path. The command would be in our case:

```
sYmbol.SourcePATH.Translate "\home\atom230\" "C:\Linux\training\sources\"
```



Download the Kernel

It is normally the task of the bootloader to load the kernel e.g. from the hard drive to the RAM. However, you can also use the debugger to download the kernel to the target memory over JTAG. In this case you just need to omit the /NOCODE option in the **Data.LOAD.Elf** command. We use here the memory class “A:” (absolute addressing) to download the code on the physical memory:

```
Data.LOAD.Elf vmlinux A:0
```

This command will load the kernel symbols and download the kernel at the physical address `0x0`.

To be able to start the kernel, you can either set up the registers and the kernel boot parameters with the debugger or download the kernel when the instruction pointer is at the kernel entry point (at this time, everything has already been set up by the bootloader).

Downloading the kernel code at the kernel entry

You can set an on-chip breakpoint at the kernel entry point which is usually at the address `0x01000000` and let the system run. When you stop at the breakpoint, you can then download the kernel to the target memory. In this case, no further settings are needed since everything has been prepared by the bootloader:

```
Go 0x01000000 /Onchip
WAIT !STATE.RUN()

Data.LOAD.Elf vmlinux A:0
```

Then you can simply continue the execution:

```
Go                              ; let the kernel boot
```

Downloading the Kernel after the Bootloader Target Initialization

You can stop the bootloader just after the target initialization and download the kernel. This way, you need to set the values of several registers and to set up the kernel boot parameters manually. Moreover, you need to enable the protected mode and the 64bit mode for the 64bit kernel.

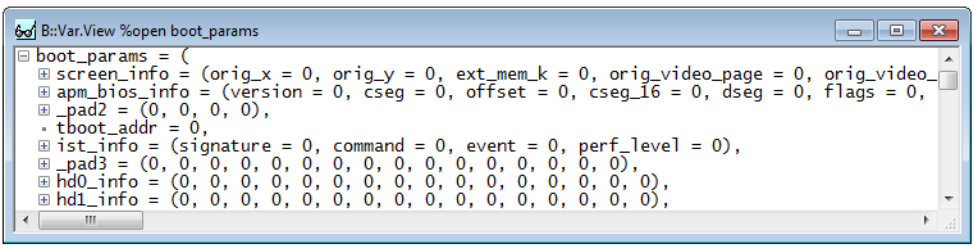
Setting the CPU Registers

The instruction pointer should be set to value defined by `CONFIG_PHYSICAL_START` and the stack pointer to a valid address e.g. `0x00010000`.

```
Register.RESet                  ; reset all registers
Register.Set ESP 0x00010000     ; initialize stack pointer
Register.Set EIP 0x01000000     ; set IP to start of vmlinux
```

Setting the Kernel Boot Parameters

The kernel boot parameters are located in a structure of type (`struct boot_params`) pointed by the register `ESI`. You can access this structure after the kernel has booted using the `boot_params` symbol



In the following example, we first set the `boot_params` area to zero and then set the parameters `alt_mem_k`, `hrd.type_pf_loader`, `hdr.ramdisk_image` and `hdr.ramdisk_size` (since we use a ramdisk as a file system) as well as the boot command line `ptr hdr.cmd_line_ptr`. The offsets of the structure elements are hard coded.

```
&bpb=0x20000                    ; base address of boot parameters
Register.Set ESI &bpb           ; set ESI to point to struct boot_params
Data.Set (&bpb+0x0000)++0x0fff 0x0   ; empty boot params area
Data.Set &bpb+0x01e0 %Long 0x3fc00   ; alt_mem_k=(256-1)*1024kB=256-1MB
Data.Set &bpb+0x0210 %Byte 0x80      ; hdr.tpye_of_loader = U-Boot
Data.Set &bpb+0x0218 %Long 0x02000000  ;  hdr.ramdisk_image
Data.Set &bpb+0x021c %Long 0x00800000  ;  hdr.ramdisk_size
Data.Set &bpb+0x0228 %Long &bpb+0x1000 ; cmd_line_ptr
Data.Set &bpb+0x1000 "console=ttyS1,115200 console=ttyUSB0 "
Data.Set , "initrd=0x02000000,0x800000 root=/dev/ram "
Data.Set , "mem=240M slram=appdisk,0x0F000000,+0x1000000 "
Data.Set , 0
```

Set up the Protected Mode

The Linux kernel runs in protected mode. If you stop the bootloader before the protected mode has been enabled then you need to prepare the registers and descriptor tables manually for the protected mode. You can use for this the `setup_protected_mode.cmm` script available in the TRACE32 demo directory.

Set up the 64 Bit Mode

In case you are using a 64 bit kernel, you also need to set the CPU in 64 bit mode. A script is also available for this purpose in the TRACE32 demo directory under
`~~/demo/x64/kernel/linux/board/setup_64bit_mode.cmm`

Download the File System

In case you are using a ramdisk image as file system, you can download this image to the target memory using the **Data.LOAD.Binary** command:

```
Data.LOAD.Binary ramdisk.image.gz A:0x02000000 /NoClear
```

You need to use the /NoClear option here, otherwise the already loaded kernel symbols will be cleared. We also use here the “A:” memory class to force downloading the data to the physical memory. We use the `0x02000000` address since this is what has been specified in the kernel boot parameters (“`initrd=0x02000000`”).

Set up the Debugger Address Translation

The debugger needs to have some information about the format of the MMU tables used by the kernel and the kernel address translation. This is configured using the command **MMU.FORMAT** .

The first argument of this command is the format of the MMU tables. Please check **"RTOS Debugger for Linux - Stop Mode"** (rtos_linux_stop.pdf) for actual format specifier. The second argument is a kernel symbol pointing to the start of the kernel page table and is usually called `swapper_pg_dir` for a 32bit kernel and `init_level4_pgt` for a 64bit kernel. The third parameter is the logical to physical kernel address mapping.

```
; Example setup for x86
MMU.FORMAT STD swapper_pg_dir 0xc0000000--0xcfffffff 0x0
```

```
; Example setup for x64
MMU.FORMAT LINUX64 init_level4_pgt
                              0xffffffff80000000--0xffffffff9fffffff 0x0
```

	If you get the error message "invalid combination" after the MMU.FORMAT command, check if you have enabled the MMUSPACES.

For x64, you additionally need to create static translations for the direct mapping (`0xffff880000000000 -- 0xffffc7ffffffffff` = 64 TB) and the kernel text mapping (`0xffffffff80000000 -- 0xffffffffa0000000` = 512MB). Please refer to `Documentation/x86/x86_64/mm.txt` for more info.

```
TRANSlation.Create 0xffff880000000000--0xffffc7ffffffffff 0x0
TRANSlation.Create 0xffffffff80000000--0xffffffff9fffffff 0x0
```

Moreover, you need to set the common address range with the command **TRANSlation.COMMON**. This is actually the common address range for all processes and is everything above the process address range:

```
TRANSlation.COMMON 0xc0000000--0xffffffff
```

Finally you need to enable the MMU table walk with **TRANSlation.TableWalk ON** and enable the debugger address translation with the command **TRANSlation.ON**.

```
TRANSlation.TableWalk ON
TRANSlation.ON
```

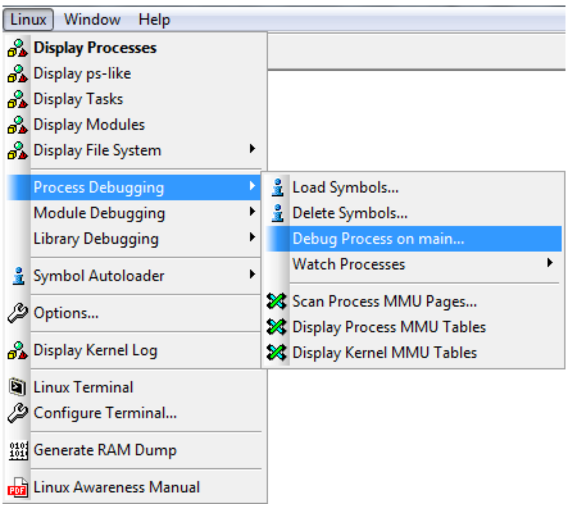
If the table walk is enabled, when accessing a virtual address which has no mapping in the debugger local address translation list (**TRANSlation.List**), the debugger tries to access the MMU page tables to get the corresponding physical address and then access the memory physically.

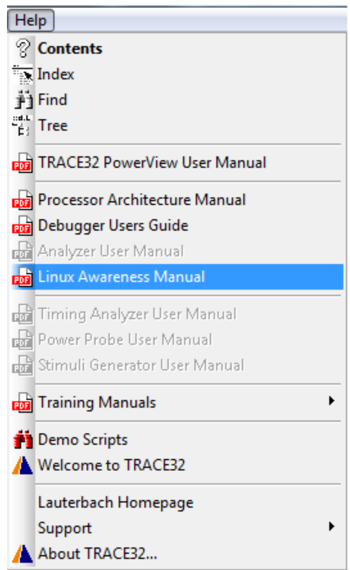
Set up the Linux Awareness

We need to load now the Linux awareness and Linux menu in TRACE32. For kernel versions 2.x, the Linux awareness is based on the file linux.t32 located under “`~~/demo/<arch>/kernel/linux/linux-2.x/`” where `<arch>` is “x86” for a 32 bit kernel and “x64” for a 64 bit kernel. The Linux awareness for kernel versions 3.x is based on the file linux3.t32 located under “`~~/demo/<arch>/kernel/linux/linux-3.x/`“.

```
; load the awareness for Linux-3.x on x64
TASK.CONFIG ~~/demo/x64/kernel/linux/linux-3.x/linux3.t32
; load Linux menu:
MENU.ReProgram ~~/demo/x64/kernel/linux/linux-3.x/linux.men
```

The Linux menu file includes many useful menu items developed for the TRACE32-GUI to ease Linux Debugging.





The Linux awareness and Linux menu uses scripts also available under `~~/demo/<arch>/kernel/linux/<linux_version>`. You should always load the awareness from the TRACE32 installation directory to avoid compatibility problems between the Linux awareness and the mentioned scripts. If you load the Linux awareness outside the TRACE32 installation, you will get the warning **“please use awareness files from TRACE32 installation directory”**

Mark the Kernel Address Space

For better visibility, you can mark the kernel address space to be displayed with a red bar.!

```
GROUP.Create "kernel" 0xC0000000--0xFFFFFFFF /RED ; 32 bit kernel
```

```
GROUP.Create "kernel" 0xffffffff80000000--0xffffffffffffffff /RED
                                                    ; 64 bit kernel
```

Everything is set up now. If the kernel is not already running and if you are not interested in debugging the kernel boot, you can let Linux run as long as it needs to boot completely (e.g. 10 seconds).

```
Go
WAIT 10.s
Break
```

3.) Example Linux Setup-Scripts

You can find demo startup scripts for different target boards in the TRACE32 installation directory under `~~/demo/x86/kernel/linux/board` and `~~/demo/x64/kernel/linux/board`. You can also search for the newest scripts in the Lauterbach home page under the following link:

http://www.lauterbach.com/frames.html?scripts.html

The first example script set up Linux aware debugging for a 32 bit kernel running on the Intel Galileo board. In this example the kernel is already running on the target.

```
REset
WinCLEAR

SYStem.CPU QUARK
SYStem.Option MMUSPACES ON ; enable space IDs to virtual addresses
SYStem.Attach
SETUP.IMASKASM ON          ; lock interrupts while single stepping

; Open a serial terminal window
DO ~~/demo/etc/terminal/serial/term.cmm COM1 115200.

; Open a Code Window -- we like to see something
WINPOS 0. 0. 75. 20.
List
SCREEN

; Load the Linux kernel symbols
Data.LOAD.Elf vmlinux /NOCODE

MMU.FORMAT PAE swapper_pg_dir 0xC0000000--0xCFFFFFFF 0x0
TRANSLATION.COMMON 0xC0000000--0xFFFFFFFF
TRANSLATION.TableWalk ON
TRANSlation.ON

; Initialize Linux Awareness
PRINT "initializing multi task support..."
; loads Linux awareness:
TASK.CONFIG ~~/demo/x86/kernel/linux/linux-3.x/linux3.t32
; loads Linux menu:
MENU.ReProgram ~~/demo/x86/kernel/linux/linux-3.x/linux.men

; Group kernel area to be displayed with red bar
GROUP.Create "kernel" 0xC0000000--0xFFFFFFFF /RED


ENDDO
```

The second example script set up Linux aware debugging for a 64 bit kernel running on the Crown Beach Board. We connect to the target using the **SYStem.Up** command which reset the cores. We let then bootloader initialize the target hardware. The bootloader is stopped before the Linux kernel is loaded. We continue then the setup using the debugger.The kernel as well as the ramdisk image are downloaded to the target memory over JTAG. The script also set the initial values for the CPU registers and the kernel boot parameters.

```
RESet

; setup of ICD
PRINT "initializing..."
SYStem.CPU ATOMZ5XX
SYStem.JtagClock 20MHz
SYStem.Option MMUSPACES ON     ; enable space IDs to virtual addresses
SYStem.Up

; Open a serial terminal window
DO ~~/demo/etc/terminal/serial/term.cmm COM1 115200.

SETUP.IMASKASM ON          ; lock interrupts while single stepping

 ; Let the boot monitor set up the board
    Go
    PRINT "target setup..."
    WAIT 10.s
    Break

; Load the Linux kernel code and symbols
Data.LOAD.Elf vmlinux A:0 /GNU

; Loading RAM disk
Data.LOAD.Binary ramdisk.image.gz A:0x02000000 /NoClear /NoSymbol

; Initialize CPU protected mode. 0x10000 is the GDT base address
DO setup_protected_mode.cmm 0x10000

; Set PC on physical start address of the kernel
Register.Set EIP 0x01000000
; Initialize stack pointer
Register.Set ESP 0x00010000

; Setup boot_params in a separate script (please refer to 4.b)
DO setup_boot_params.cmm

; Open a Code Window -- we like to see something
WINPOS 0. 0. 75. 20.
List
SCREEN
```

continued on next page.

continued:

```
PRINT "initializing debugger MMU..."
MMU.FORMAT LINUX64 init_level4_pgt 0xffffffff80000000--0xffffffff9fffffff 0x0
TRANSLATION.Create 0xffff880000000000--0xffffc7ffffffffff 0x0
TRANSLATION.Create 0xffffffff80000000--0xffffffff9fffffff 0x0
TRANSLATION.COMMON 0xffff880000000000--0xffffffffffffffff
TRANSLATION.TableWalk ON
TRANSlation.ON

; Initialize Linux Awareness
PRINT "initializing multi task support..."
; loads Linux awareness:
TASK.CONFIG ~~/demo/x64/kernel/linux/linux-3.x/linux3.t32
; loads Linux menu:
MENU.ReProgram ~~/demo/x64/kernel/linux/linux-3.x/linux.men

; Group kernel area to be displayed with red bar
GROUP.Create "kernel" 0xffffffff80000000--0xffffffffffffffff /RED

; set CPU in 64bit mode (see IA-32 manual, Vol 3 Ch 9.8.5), specify GDTB
; and page directory
DO ../setup_64bit_mode.cmm

Go x86_64_start_kernel
WAIT !STATE.RUN()

SYStem.Option C0Hold ON ; prohibit power down

PRINT "booting Linux..."
Go

ENDDO
```

Debugging the Linux Components by TRACE32 Linux Menu

This chapter will show how to debug the different Linux components explained in the previous chapters. First you will see the easy handling by the special included Linux menu.

1. **Debugging Linux Components**
2. **Linux specific Windows and Features**

1.) Debugging Linux Components

Each of the components used to build a Linux system needs a different handling for debugging. This chapter describes in detail, how to set up the debugger for the individual components. If you want to debug different components at once, you have to aggregate the commands for the components.

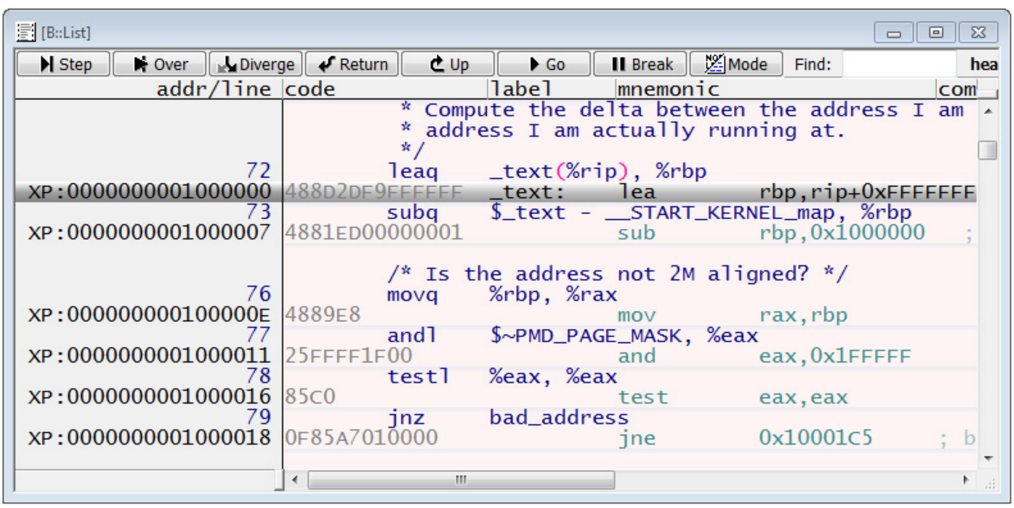
When using several symbol files at once (e.g. kernel, processes and libraries), it is convenient to use the **GROUP** command to mark each component with a dedicated color. Find some example settings below.

The **"RTOS Debugger for Linux - Stop Mode"** (rtos_linux_stop.pdf) manual gives additional detailed instructions.

1.1) The Kernel

Kernel Startup

With kernel startup we refer here to the kernel boot code executed before the enabling of the target MMU. The bootloader jumps into the kernel startup routine (`phys_startup_32` / `phys_startup_64`) generally located at the address `0x01000000`. It starts at physical address space, does some initialization and set up the MMU. **Finally the kernel startup switches into logical address space**.



To be able to see the debug symbols for the kernel startup, the kernel should be loaded with an offset. The offset is needed here since the kernel runs on physical addresses. The kernel symbols are however linked to logical addresses.

Data.LOAD.Elf vmlinux *<phys._start_addr>-<logical_start_addr>* **/NoCODE**

Please note that a single minus sign “-” is used here which means that we subtract the logical start address from the physical start address.

For a 64 bit Linux, this should be:

```
Data.LOAD.Elf vmlinux 0x0-0xFFFFFFFF80000000 /NoCODE /NOREG
```

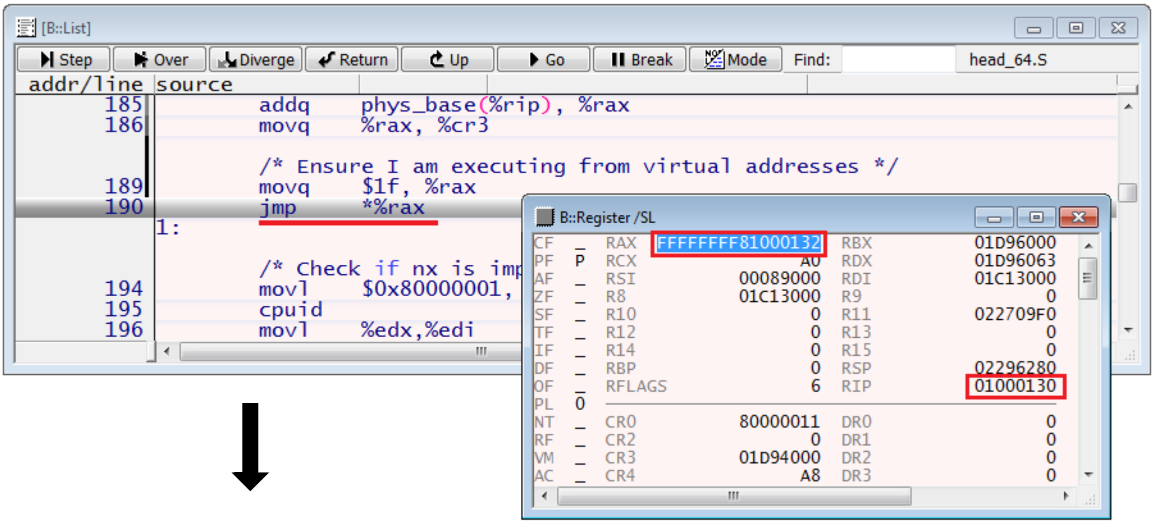
Specifying an offset is only needed to debug the kernel startup in HLL. As soon as the kernel jumps to logical addresses after enabling the target MMU, the kernel symbols should be loaded without any offset.

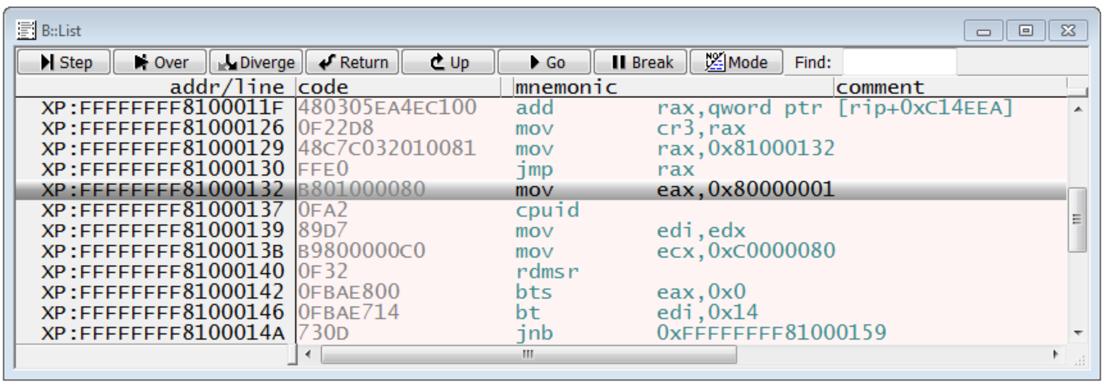
Loading the kernel symbols with an offset is only needed if you want to debug the kernel startup code which runs with disabled MMU.

As long as the target MMU is not enabled, logical addresses cannot be accessed by the debugger. Thus, if you want to set a breakpoint on a logical address (for instance `start_kernel`), you should use on-chip breakpoints:

```
Break.Set start_kernel /Onchip
```

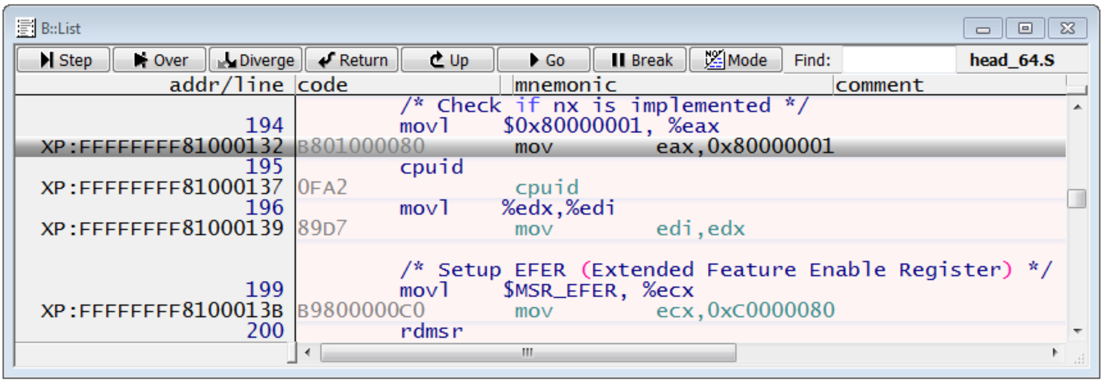
After enabling the target MMU, the kernel startup code will jump to logical addresses:





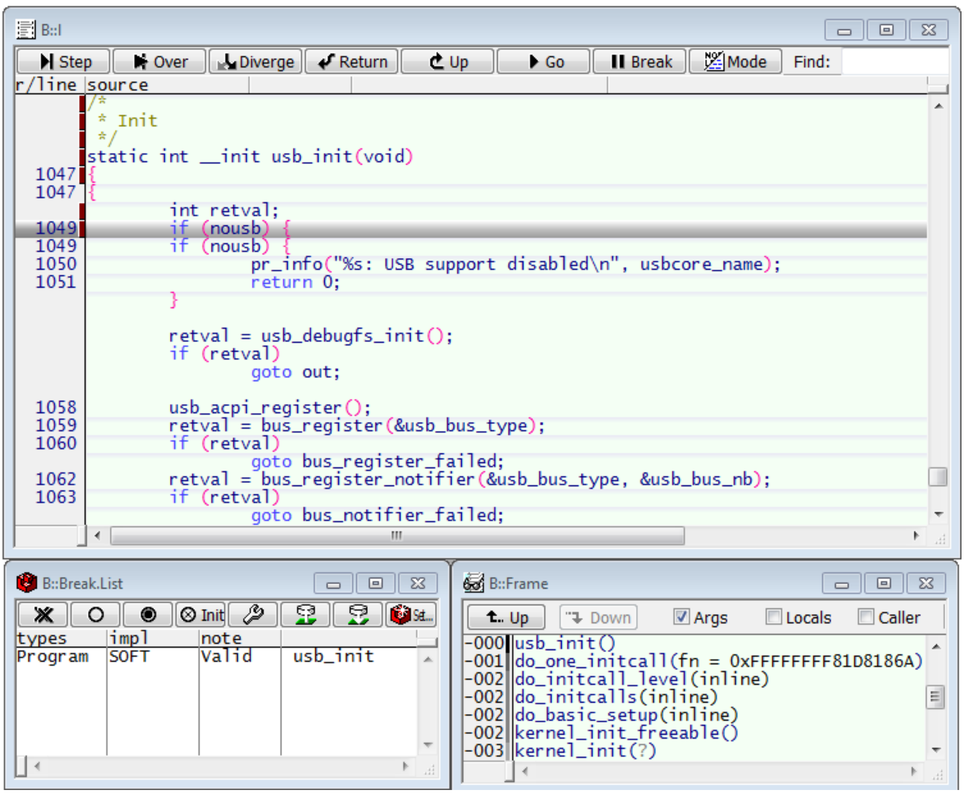
From now on, the Linux kernel runs completely in logical address space. The symbols are all bound to these logical addresses, so simply load the Linux symbols without any offset:

```
Data.LOAD.Elf vmlinux /NoCODE /NOREG
```

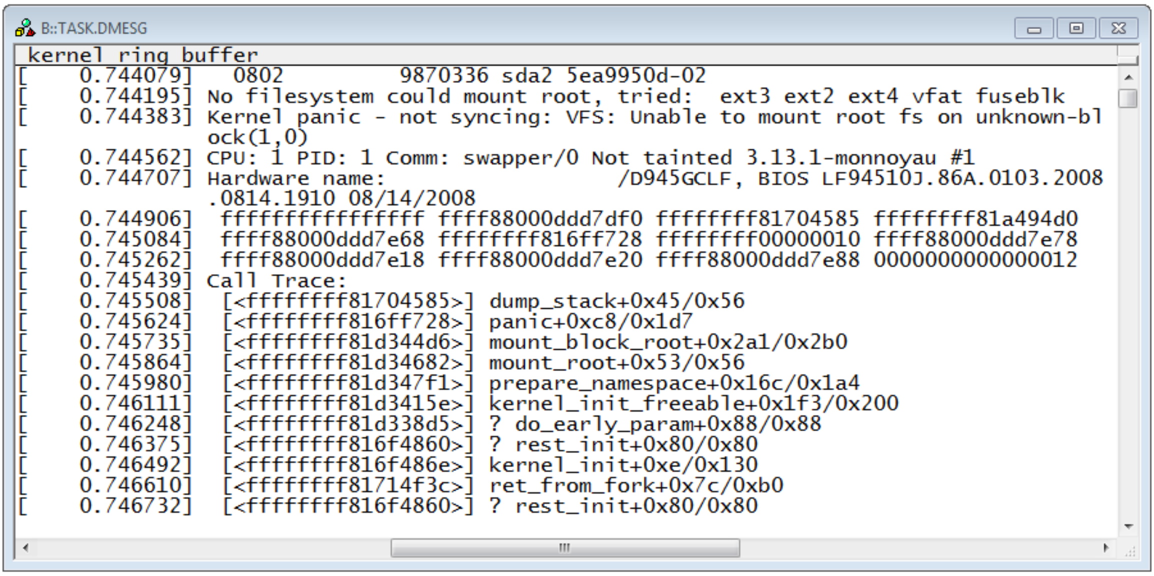


Now you need to set up the debugger address translation and load the Linux awareness as described in the previous chapter.

You can use now software breakpoints in the kernel range since all the kernel code is accessible.



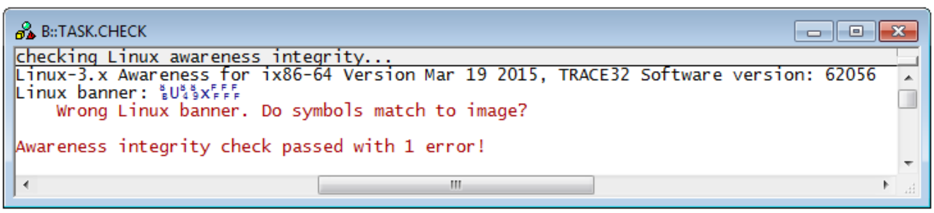
If the kernel doesn't boot correctly, you can use the **TASK.DMESG** command to display the kernel boot log. This is especially helpful, if you don't have a serial console or if the kernel crashes in an early boot phase.



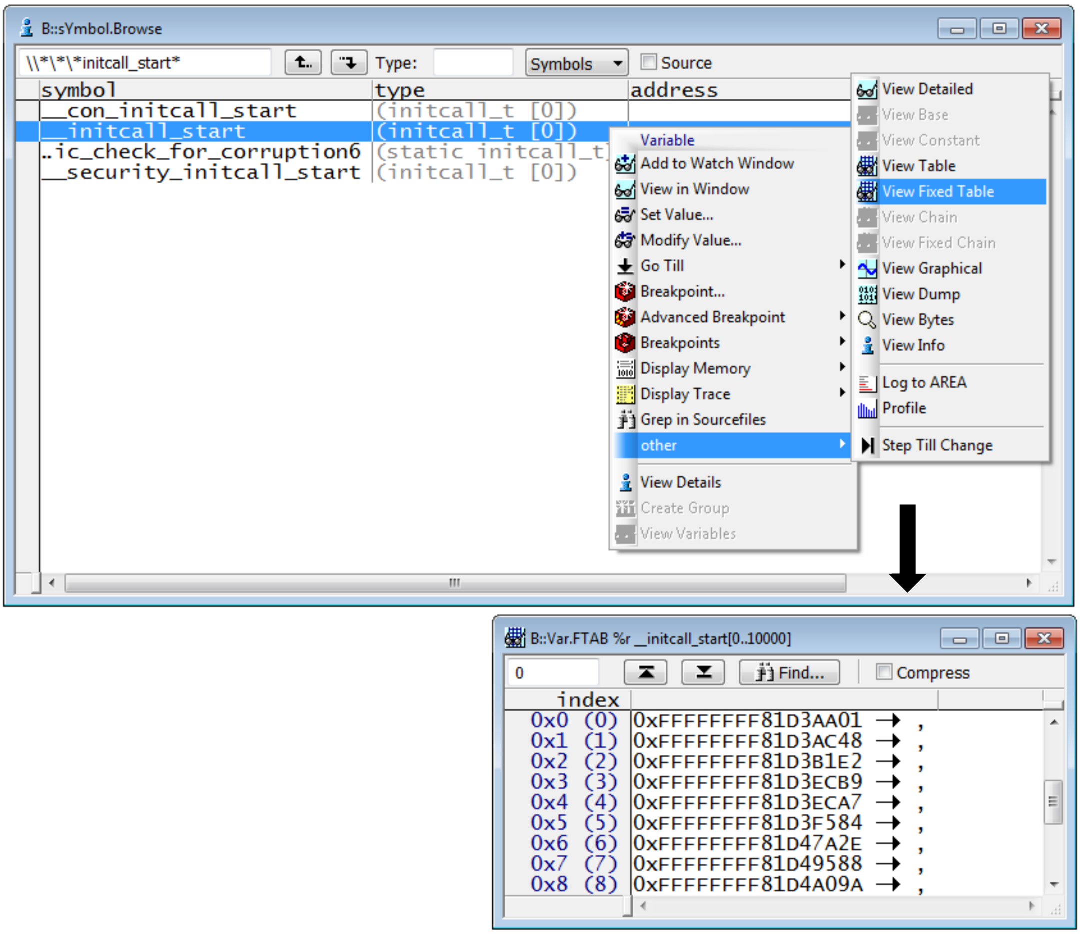
Verifying Image and Symbols

It is very important that the kernel running on the target is from the **very same build** as the symbol file loaded into the debugger. A typical error is that the loaded vmlinux file doesn't match the executed kernel on the target. This can lead to different errors.

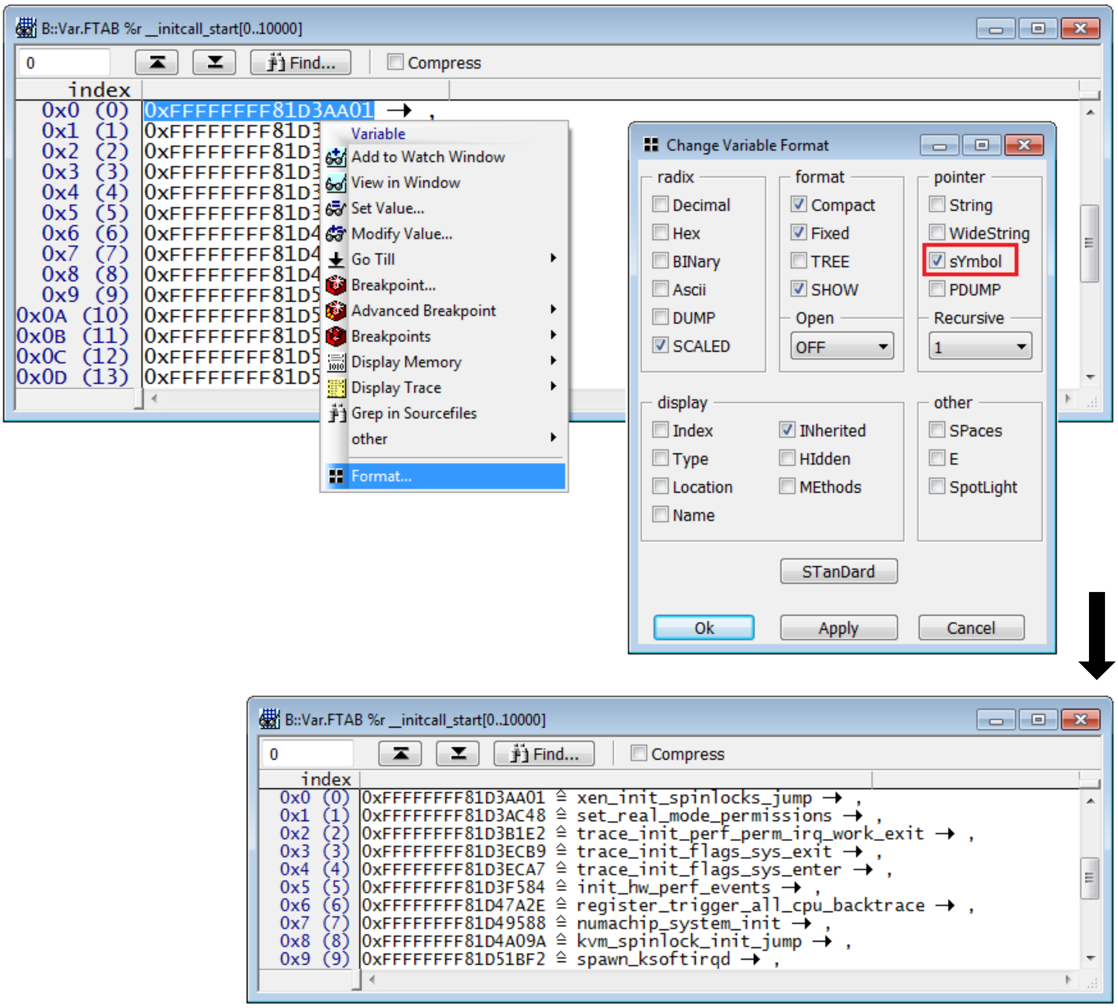
You can check if the kernel code matches the loaded symbols using the **TASK.CHECK** command. First let the kernel boot, stop the target and then execute **TASK.CHECK**. When the symbols does not match the kernel code, you will get an error message in this window:



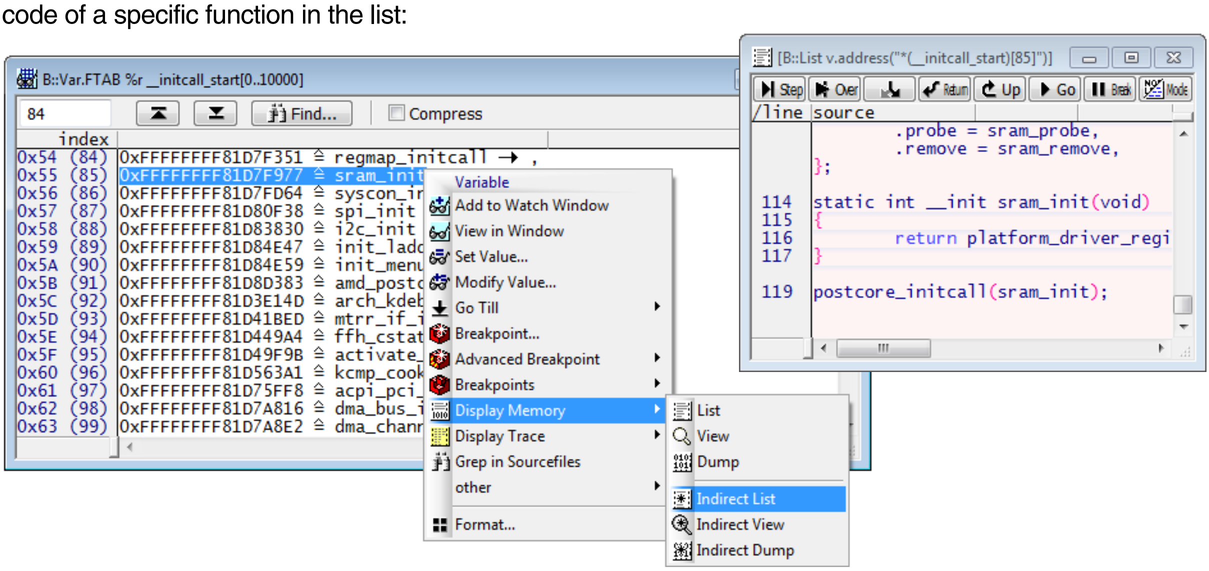
Most of the built-in device drivers are registered in the initcall table. You can search for the "`__initcall_start`" label (in newer Linux kernel versions "`__initcall0_start`", "`__initcall1_start`",...) in the **sYmbol.Browse** window and view it as a fixed table:



You will get a table with the start addresses of the device drivers init functions you can display the names of the functions by checking the “sYmbol” item in the “pointer” category:



By selecting **Display Memory** and then **Indirect List** from the popup menu, you can display the source code of a specific function in the list:

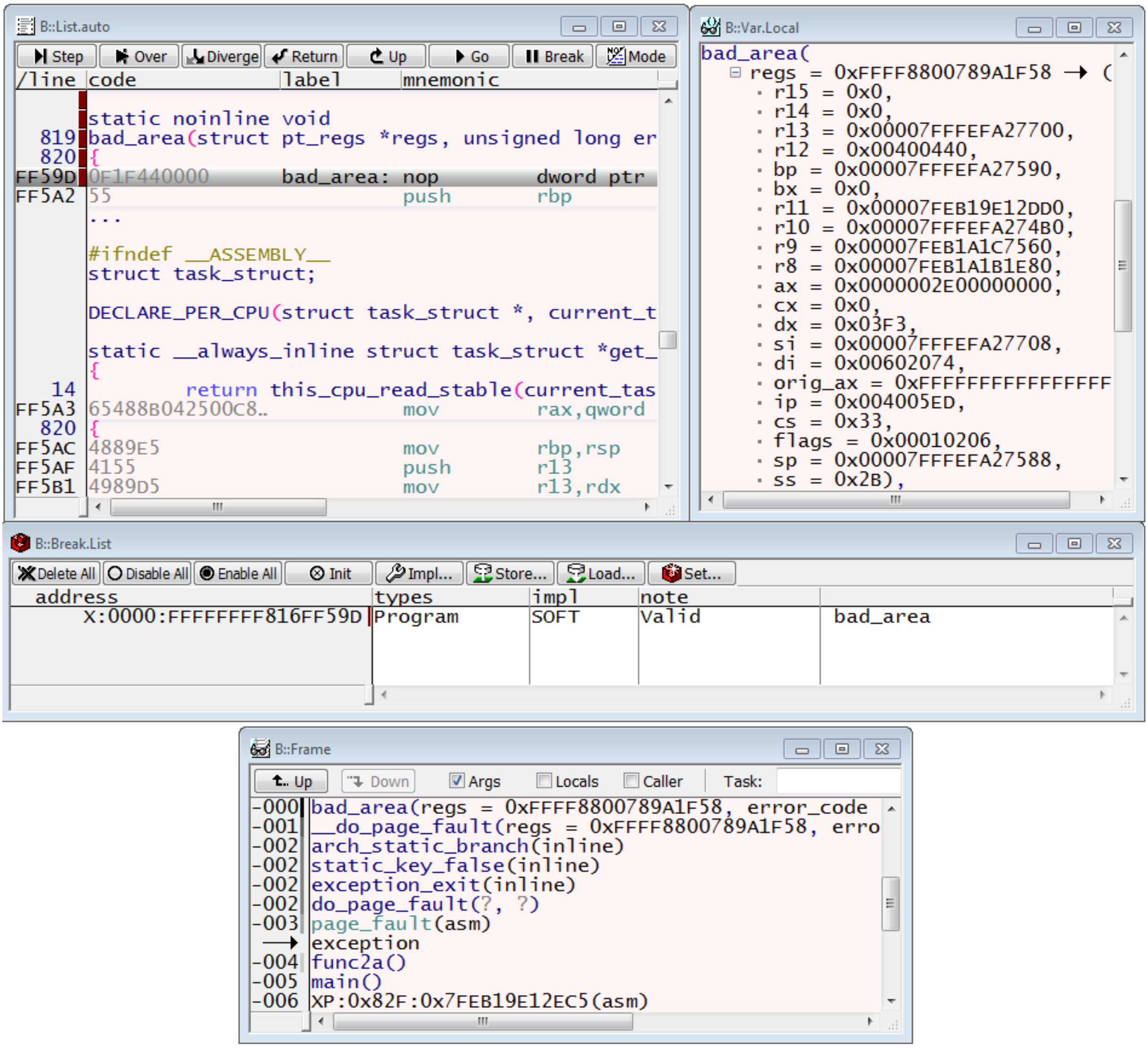


Please note that the kernel overwrites this table after booting.

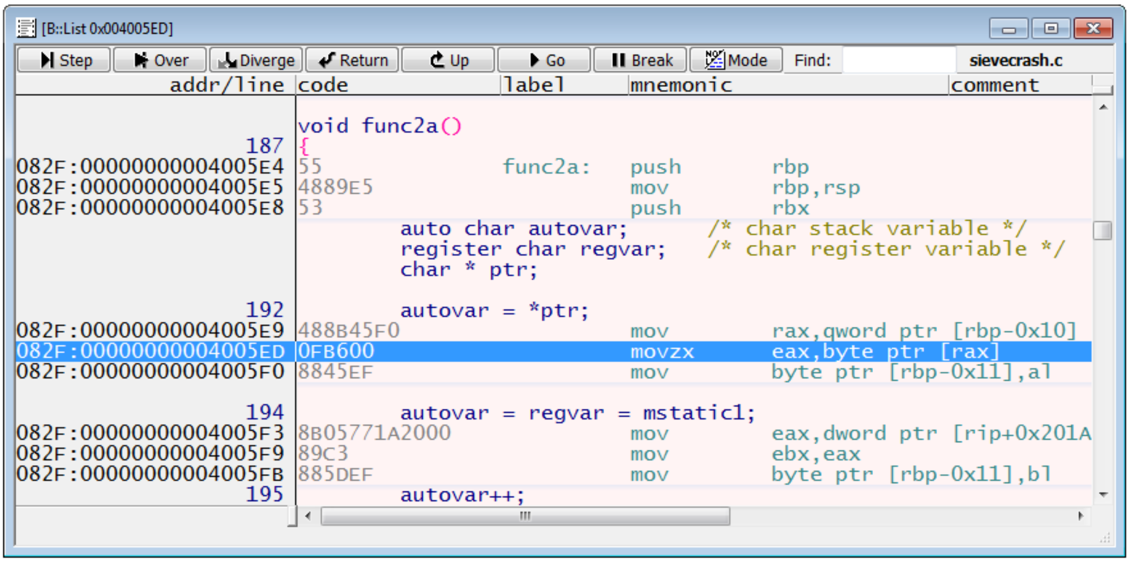
Example: trapping segmentation violation

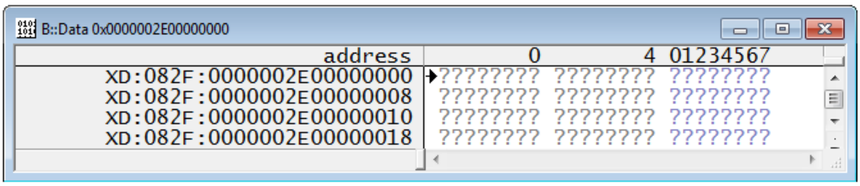
Segmentation violation happens if the code tries to access a memory location that cannot be mapped in an appropriate way. E.g. if a process tries to write to a read-only area or if the kernel tries to read from an non existent address. A segmentation violation is detected inside the kernel routine “`__do_page_fault`”.

In the case of a segmentation violation, the kernel jumps to the function “`bad_area`”. To trap the segmentation violation, we set a software breakpoint at this label. When the breakpoint is hit, we take a look to the “`regs`” structure which contains the complete register set at the location where the fault occurred. The **Frame** window will show then the call stack.



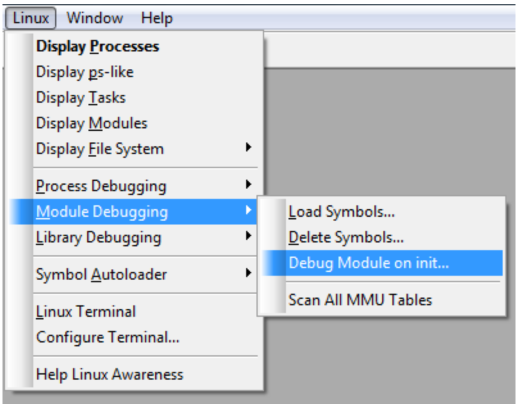
The “ip” parameter of the “regs” structure contains the value of the instruction pointer where the segmentation violation occurred. If we display the assembly code at this address, we see that the code accesses the memory pointed by the register rax. We can see from the “regs” structure that this register has the value 0x2E00000000 which is an invalid memory address. The pointer “ptr” has been actually here accessed without being initialized and has a random value.

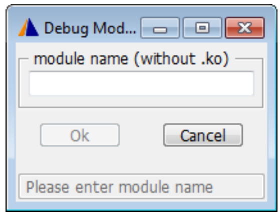




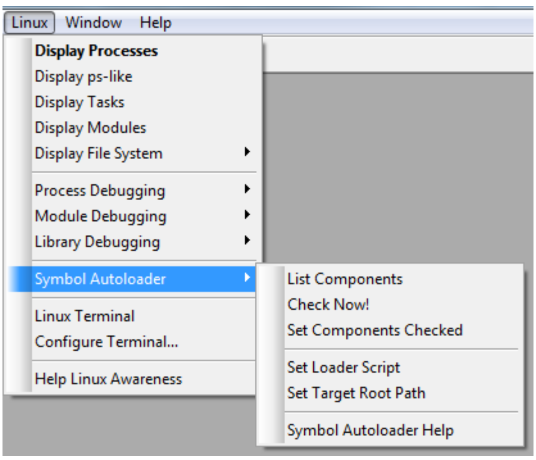
1.2) Kernel Modules

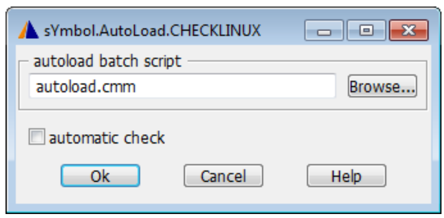
Kernel modules are loaded and linked into the kernel at run-time. To ease the debugging of kernel modules, the enhanced Linux menu offers the item **“Debug Module on init...“** which waits until a module is loaded, loads the debug symbols and continue the execution until the init function of the loaded kernel module is called.

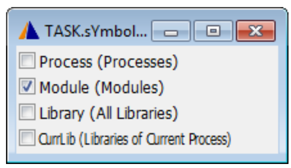




This **“Module Debugging” menu depends on the “autoloader“** function of the TRACE32 Linux awareness based on the script “~~/demo/*<arch>*/kernel/linux/*<linux_version>*/autoload.cmm”..



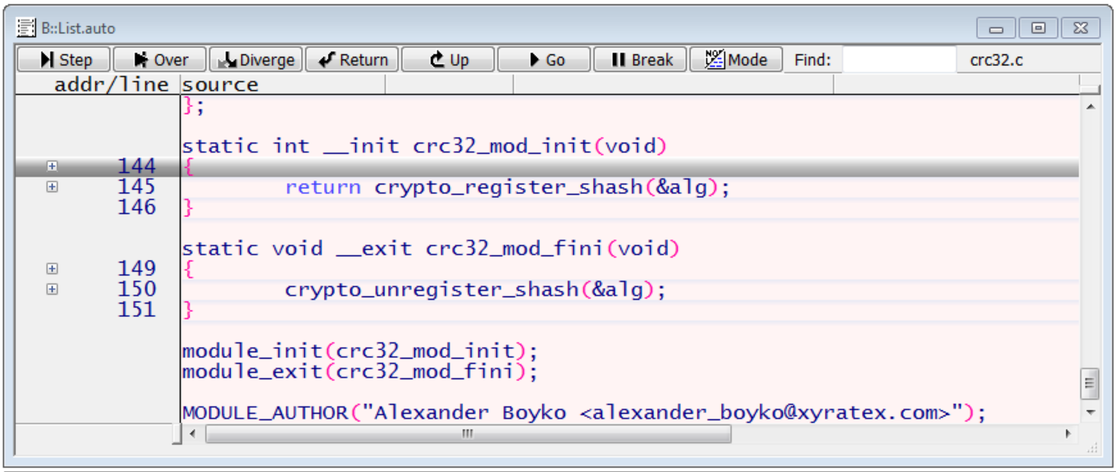


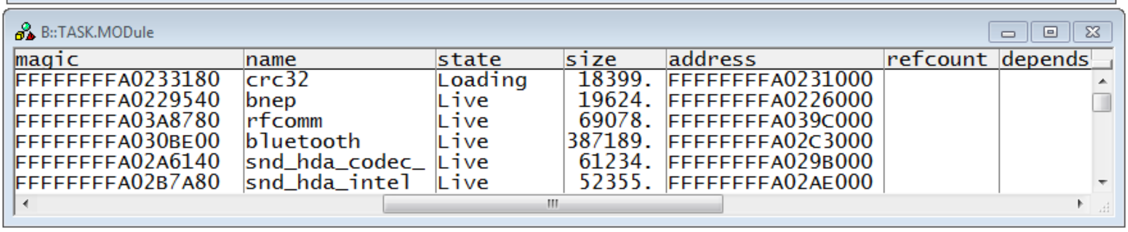


Remember that **the kernel modules are part of the kernel address range and should be covered by** **TRANSlation.COMMON**.

Please note that the section addresses (and with them the possibility to debug kernel modules) for Linux kernel version 2.4 are only available under certain circumstances! See **“RTOS Debugger for Linux - Stop Mode”** (rtos_linux_stop.pdf), how to set up these prerequisites, and how to debug the initialization routine of a kernel module.

We load here for example the crc32.ko kernel module by calling the command “`insmod crc32.ko`”. The debugger will then stop the execution at the init function of this kernel module (`crc32_mod_init`).





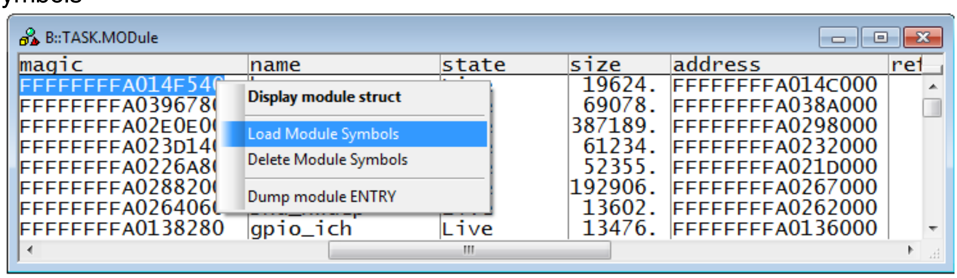
The demo directory contains a script file called “mod_debug.cmm” which has the same functionality as the menu item **“Debug Module on init...“** e.g:

```
DO ~~/demo/x64/kernel/linux/linux-3.x/mod_debug.cmm crc32
```

It is also possible to load the debug symbols for an already running kernel module using the command **TASK.sYmbol.LOADMOD**

```
TASK.sYmbol.LOADMOD "crc32"          ; load module symbols
```

You can also load the kernel module symbols by selection the TRACE32 Linux menu **“Module Debugging“** then **“Load Module Symbols...”** or by doing a right mouse click in the **TASK.MODule** window then “Load Module Symbols”



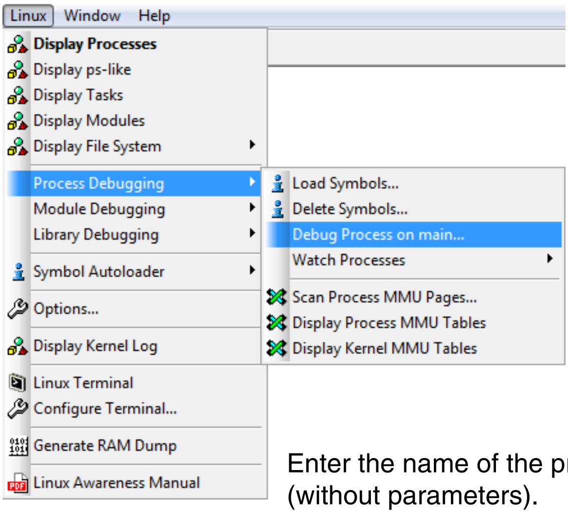
If you remove a kernel module (with “`rmmod`”), you **should** remove the symbols of the module from the debugger.

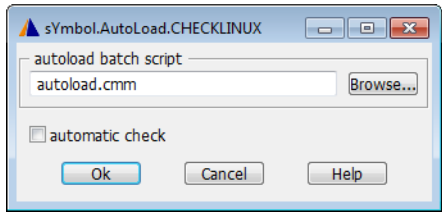
```
TASK.sYmbol.DELeteMod "crc32"          ; erase obsolete module symbols
```

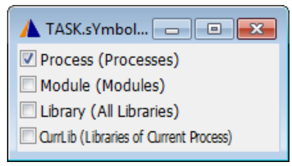
1.3) Processes

Debugging a process from the start

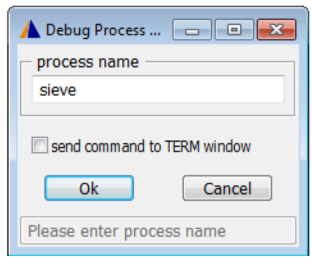
You can configure the debugger to debug a process from its main function. **The Linux menu** provides a comfortable way to debug processes from its start. The process will be stopped right after the instruction at main is executed. (Due to the page fault handling the needed page could not be available until the CPU wants to execute the instruction at main.)







Enter the name of the process (without parameters).
By checking the “send command to TERM window”, the process will be started from the TERM window.

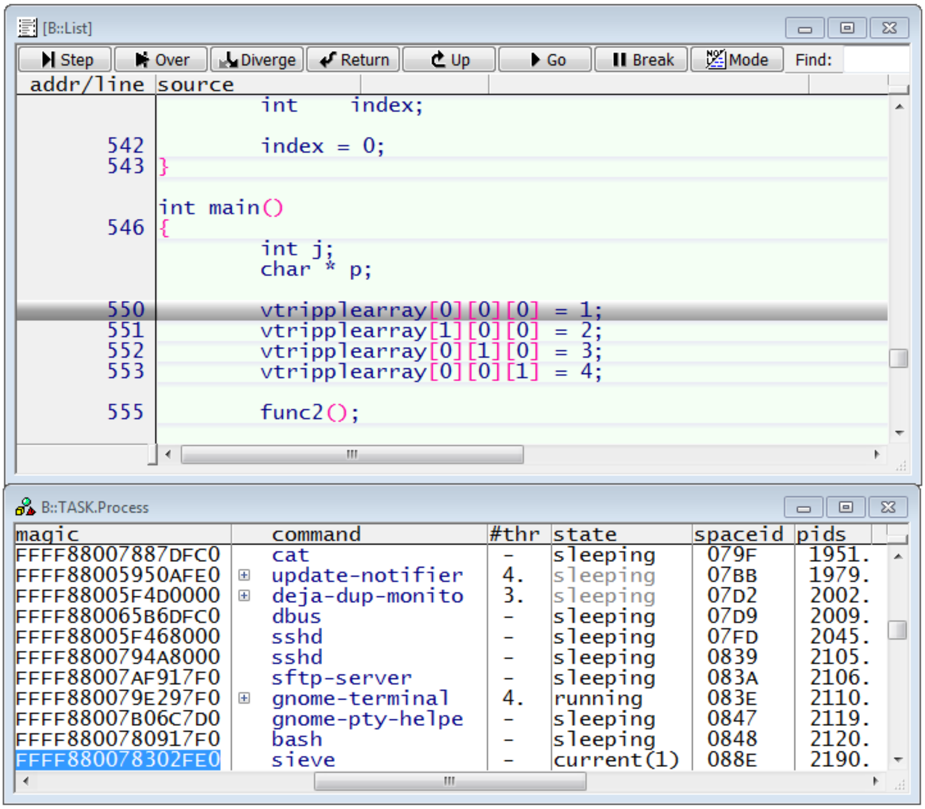


You can also use the script **app_debug.cmm** available under ~~/demo/*<arch>*/kernel/linux/*<linux_version>*/ to debug processes on main e.g.

```
DO ~~/demo/x86/kernel/linux/linux-3.x/app_debug.cmm sieve
```

Now after this preparation you can wait till the application reaches the main function of the given process. Internally a conditional software breakpoint is set on a specific kernel function. When this breakpoint is hit, TRACE32 checks if the specified process is the current one. If so the debugger extracts the space ID and loads the symbols. At this stage, the code of the process has not yet been loaded so we can’t set software breakpoints on the process’ code. We use instead here an on-chip breakpoint to the first instruction HLL line after main().

As soon as the process is started, the code will be loaded and executed and the breakpoint will be hit.

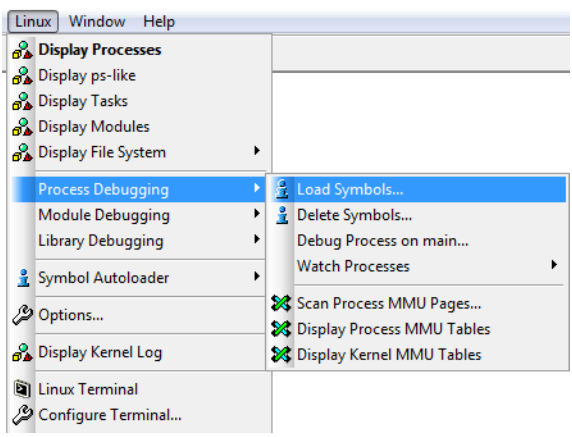


Debugging a process started already

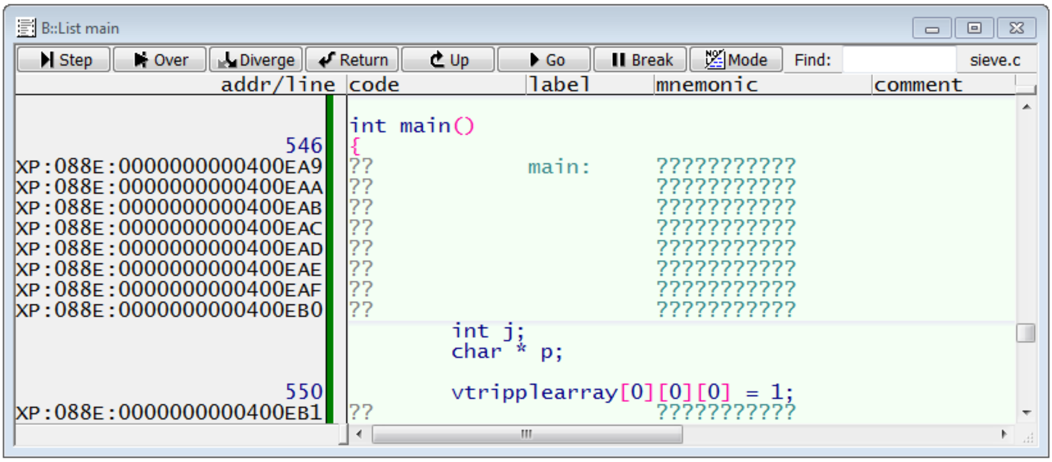
You can also load the debug symbols of an already running process using the TRACE32 command **TASK.sYmbol.LOAD**

```
TASK.sYmbol.LOAD "sieve"              ; load process symbols
```

The process symbols can also be loaded from the TRACE32 Linux menu **"Process Debugging"** -> **"Load Symbols..."** or per mouse click in the **TASK.DTask** or **TASK.Process** window.



After the process “sieve” exits its symbols are no more valid:

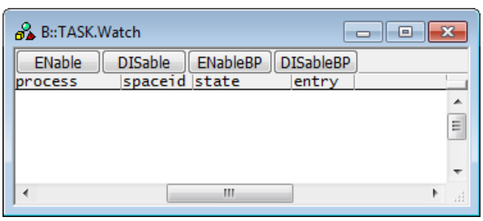


You should delete the symbols with the following command:

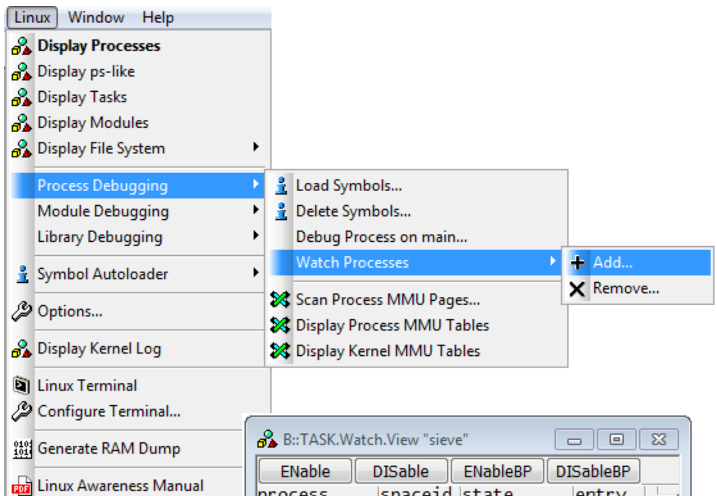
```
sYmbol.Delete \\sieve                    ; get rid of invalid symbols
```

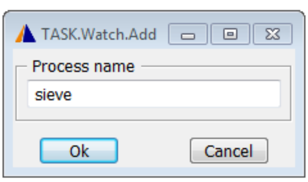
Process watch system

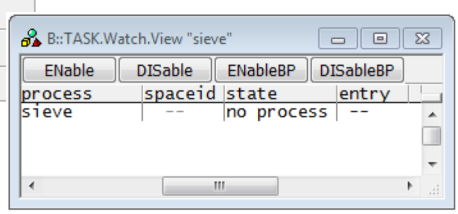
There is a **“process watch system”** available that watches for the creation and termination of specified processes. This watch system then loads and deletes symbols automatically and keeps the MMU in sync. See **TASK.Watch** in **“RTOS Debugger for Linux - Stop Mode”** (rtos_linux_stop.pdf) for details.



Use the watch system and the menu to add and remove processes to be observed and synchronized to.



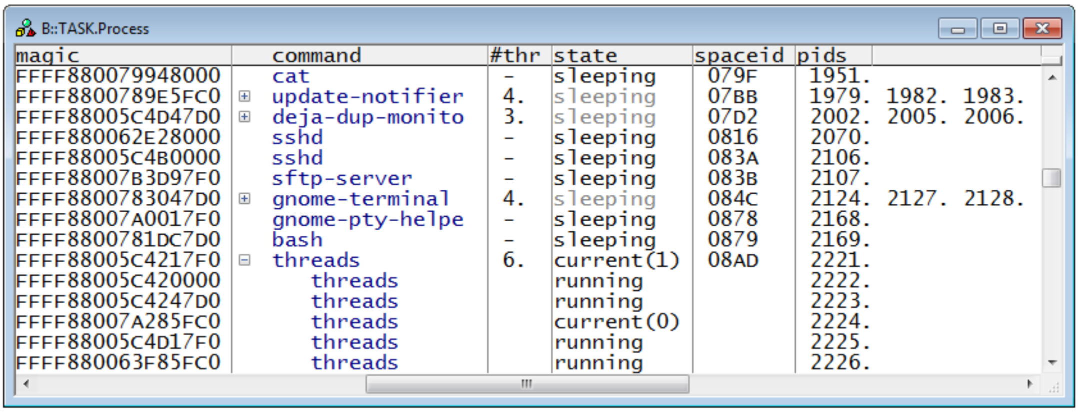




Further exiting features of the TRACE32 Linux awareness are shown in chapter “Linux specific Windows and Features”.

1.4) Threads

Threads are Linux tasks that share the same virtual memory space. The Linux awareness assignes the space ID of the creating process to all threads of this process. Because symbols are bound to a specific space ID, they are automatically valid for all threads of the same process. There is no special handling for threads. See chapter “Processes” how to load and handle these symbols.

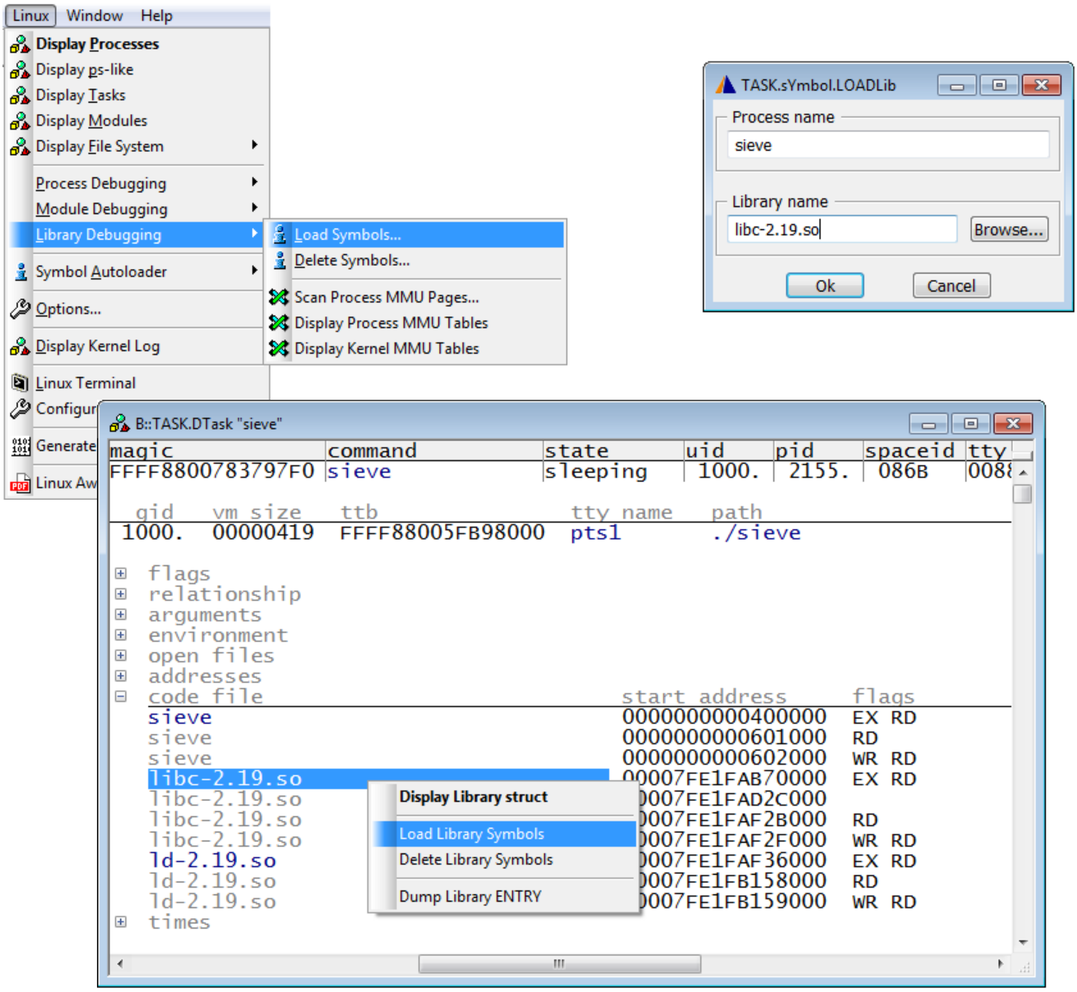

B::TASK.Process

magic	command	#thr	state	spaceid	pids
FFFF880079948000	cat	-	sleeping	079F	1951.
FFFF8800789E5FC0	update-notifier	4.	sleeping	07BB	1979. 1982. 1983.
FFFF88005C4D47D0	deja-dup-monito	3.	sleeping	07D2	2002. 2005. 2006.
FFFF880062E28000	sshd	-	sleeping	0816	2070.
FFFF88005C4B0000	sshd	-	sleeping	083A	2106.
FFFF88007B3D97F0	sftp-server	-	sleeping	083B	2107.
FFFF8800783047D0	gnome-terminal	4.	sleeping	084C	2124. 2127. 2128.
FFFF88007A0017F0	gnome-pty-helpe	-	sleeping	0878	2168.
FFFF8800781DC7D0	bash	-	sleeping	0879	2169.
FFFF88005C4217F0	threads	6.	current(1)	08AD	2221.
FFFF88005C420000	threads		running		2222.
FFFF88005C4247D0	threads		running		2223.
FFFF88007A285FC0	threads		current(0)		2224.
FFFF88005C4D17F0	threads		running		2225.
FFFF880063F85FC0	threads		running		2226.

1.5) Libraries

Libraries are loaded and linked dynamically to processes. Thus, they run in the virtual address space of the process and have dynamic addresses. To debug libraries, you can use the menu **"Library Debugging"**:

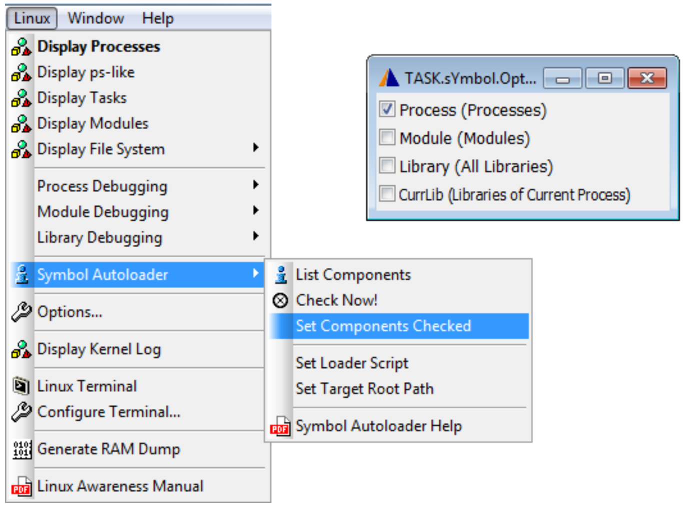
You can also display first the task list using the command **TASK.DTask** and then continue with double or right-clicks:



In case you want to load or delete the symbols of the library from the debugger command line or a PRACTICE script, you can use the following commands:

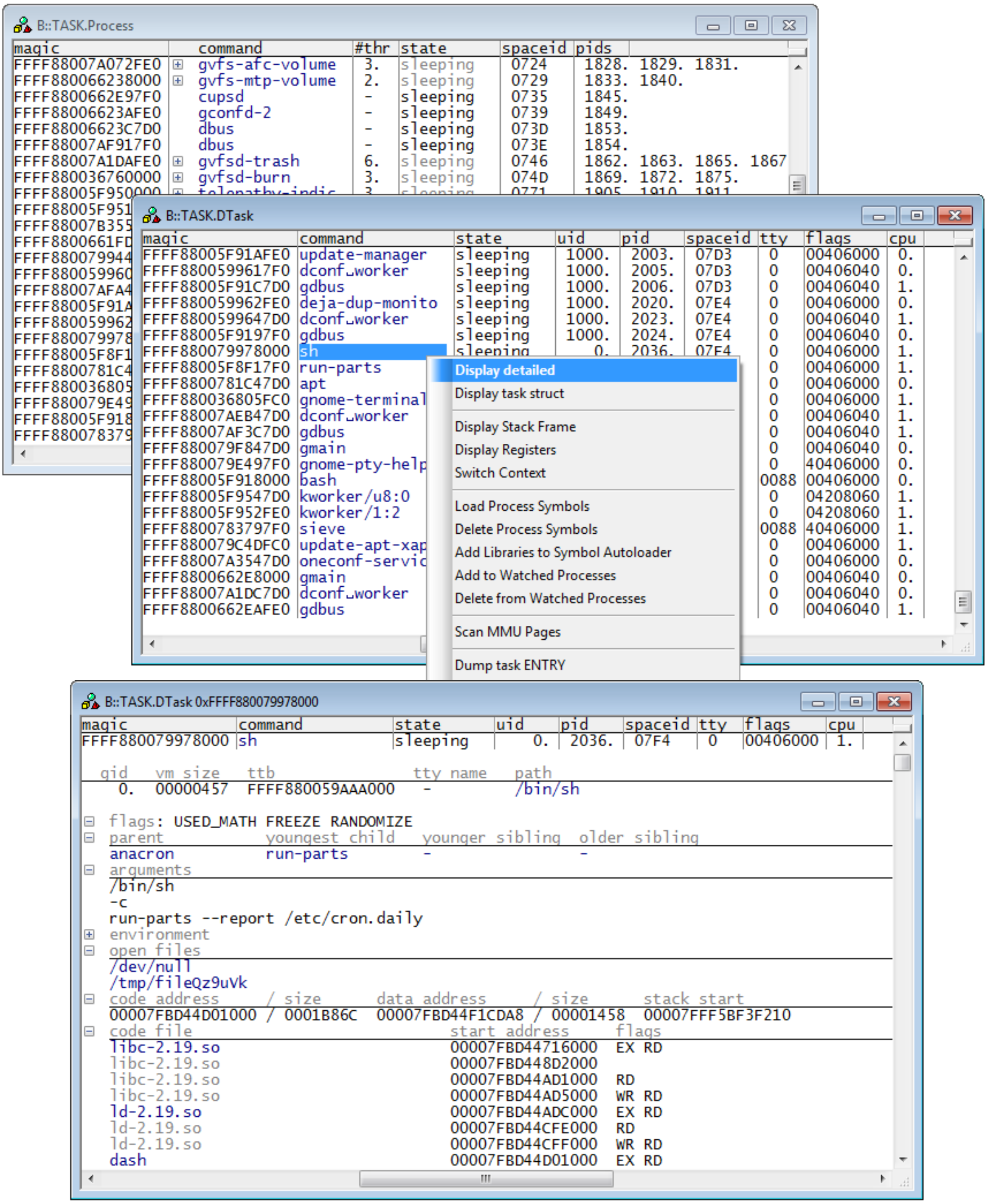
```
TASK.sYmbol.LOADLib "sieve" "libc-2.19.so"      ; load library symbols

TASK.sYmbol.DELeteLib "\\libc-2.19"             ; erase library symbols
```

Please remember to configure the “autoloader” for libraries!



Display of System Resources

You can display different Linux resources (list of running tasks, kernel modules...) using special TRACE32 commands. Several windows are available to display e.g. the process list. **TASK.PS** displays the process table similar to the output of the “ps” shell command. **TASK.DTask** give you more detailed information. **TASK.Process** displays the processes with their threads. You can open all there window from the Linux menu or from the command line.

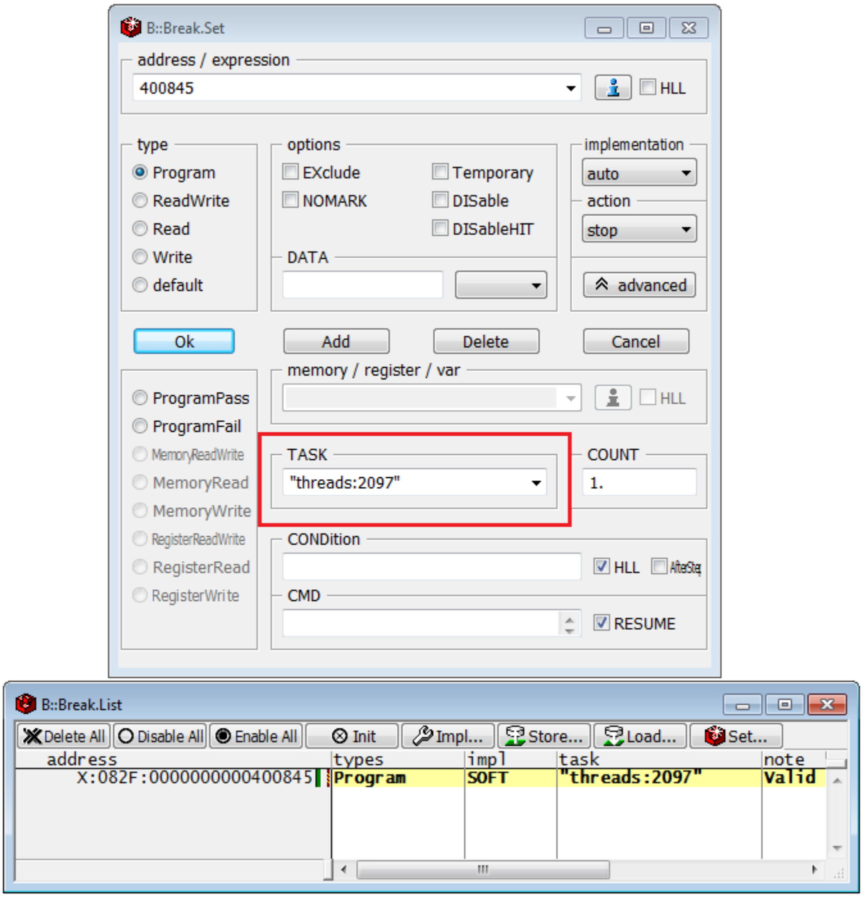


Task Related Breakpoints

You can set conditional breakpoints on shared code halting only if hit by a specified task

```
Break.Set myfunction /TASK "mytask"
```

When the breakpoint is hit, the debugger will check if the current task is the specified one. If it is not the case, the execution will be resumed.



Task Related Single Stepping

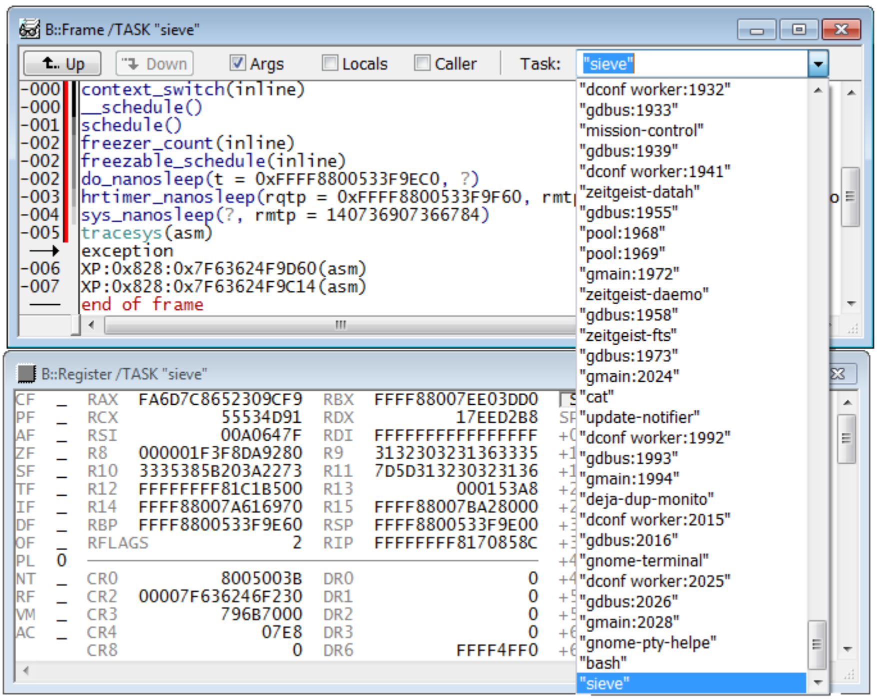
If you debug shared code with HLL single step, which is based on breakpoints, a different task could hit the step-breakpoint. You can avoid this by using the following command:

```
SETUP.StepWithinTask ON
```

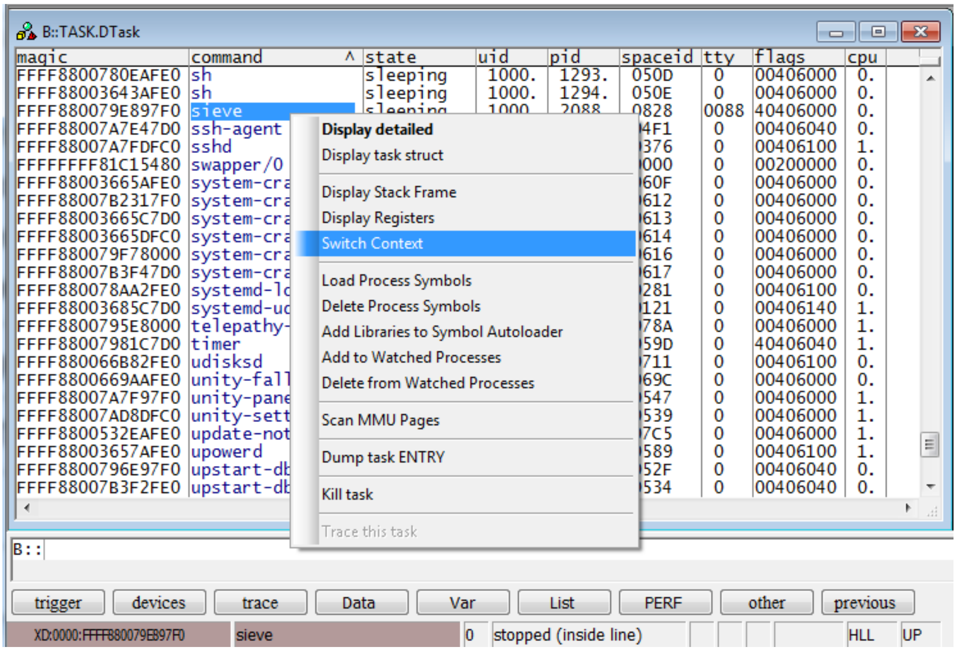
Conditional breakpoints on the current task will be then used for step into / step over and you will not “leave” the task that you want to debug.

You can display the memory or the registers of a task which is not currently executing. Moreover, you can display the stack frame of any running task on the system.

```
List /TASK "mytask"
Register /TASK "mytask"
Frame /TASK "mytask"
```



You can additionally "virtually" switch the context also from the **TASK.DTask** window by popup menu-item **"Switch Context"**:



Troubleshooting

Most of the errors in Linux aware debugging are due to a wrong symbol information or to an incorrect setup of the debugger address translation.

The loaded vmlinux file must match the kernel binary executed on the target. To verify if this is the case, you can perform the following steps:

- Load the vmlinux file to the debugger virtual memory (VM:) using the following command.

```
Data.LOAD.Elf vmlinux AVM:0
```

- Display the Linux banner string from the debugger VM or print it to the area window:

```
Data AVM:linux_banner
PRINT Data.STRING(AVM:linux_banner)
```

- Compare the Linux banner string with the output of the Linux command “cat /proc/version”. Both strings must be identical including the timestamps.

Moreover, you need to make sure that the kernel was configured with `CONFIG_DEBUG_INFO` enabled and with `CONFIG_DEBUG_INFO_REDUCED` **not** set.

The next point to check in case you are having trouble is if the debugger address translation is correctly set. Problems due to an incorrect setup of the debugger address translation especially show up when debugging kernel modules or debugging in the user-space. You need to check the following:

- Is the MMU Format set with the **MMU.FORMAT** command correct?
- Is the kernel logical address translation correct? To check this translation, you can use the command **MMU.List.PageTable** address with the kernel logical start address as parameter when the kernel has already booted e.g.

```
MMU.List PageTable 0xC0000000
```

If you are still having trouble, please select the TRAC32 menu “**Help**” -> “**Support**” -> “**Systeminfo...**”, store your system information to a file and send this file together with your setup scripts as well as the content of the TASK.TEST window to rtoslinux-support@lauterbach.com

Epilog

Thank you for reading and working through this training manual. You should now be able to debug Linux targets. This tutorial was written with as much care as possible for accuracy and comprehensibility.

However, Linux is a very complex system with different and changing internal structures. Please forgive any unclear or even incorrect content. If you find any mistakes, or if you have any comments/ideas to improve this document, feel free to mail your proposals to the Linux support team at Lauterbach. Your feedback as user of our tools is the most valuable input for us.

The LAUTERBACH Team (rtoslinux-support@lauterbach.com).