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Device Drivers, Part 10: Kernel-Space Debuggers in Linux

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This article, which is part of the [series on Linux device drivers](http://www.opensourceforu.com/tag/linux-device-drivers-series/) (<http://www.opensourceforu.com/tag/linux-device-drivers-series/>), talks about kernel-space debugging in Linux.

Shweta, back from hospital, was relaxing in the library, reading various books. Ever since she learned of the `ioct1` way of debugging, she was impatient to find out more about debugging in kernel-space. She was curious about how and where to run the kernel-space debugger, if there was any. This was in contrast with application/user-space debugging, where we have the OS running underneath, and a shell or a GUI over it to run the debugger (like `gdb` , and the data display debugger, `ddd`). Then she came across this interesting kernel-space debugging mechanism using `kgdb` , provided as part of the kernel itself, since kernel 2.6.26.

The debugger challenge in kernel-space



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As we need some interface to be up to run a debugger to debug anything, a kernel debugger could be visualised in two possible ways:

- Put the debugger into the kernel itself, accessible via the usual console. For example, in the case of `kdb`, which was not official until kernel 2.6.35, one had to download source code (two sets of patches — one architecture-dependent, one architecture-independent) from this FTP address (<ftp://oss.sgi.com/projects/kdb/download/>) and then patch these into the kernel source. However, since kernel 2.6.35, the majority of it is in the officially released kernel source. In either case, `kdb` support needs to be enabled in kernel source, with the kernel compiled, installed and booted with. The boot screen itself would give the `kdb` debugging interface.
- Put a minimal debugging server into the kernel; a client would connect to it from a remote host or local user-space over some interface (say serial or Ethernet). This is `kgdb`, the kernel's `gdb` server, to be used with `gdb` as its client. Since kernel 2.6.26, its serial interface is part of the official kernel release. However, if you're interested in a network interface, you still need to patch with one of the releases from the `kgdb` project page (<http://sourceforge.net/projects/kgdb/>). In either case, you need to enable `kgdb` support in the kernel, recompile, install and boot the new kernel.

Please note that in both the above cases, the complete kernel source for the kernel to be debugged is needed, unlike for building modules, where just headers are sufficient. Here is how to play around with `kgdb` over the serial interface.

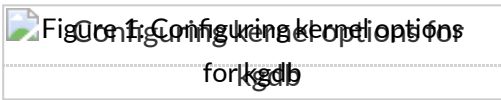
Setting up the Linux kernel with kgdb

Here are the prerequisites: Either the kernel source package for the running kernel should be installed on your system, or a corresponding kernel source release should have been downloaded from kernel.org (<http://kernel.org/>).

First of all, the kernel to be debugged needs to have `kgdb` enabled and built into it. To achieve that, the kernel source has to be configured with `CONFIG_KGDB=y`. Additionally, for `kgdb` over serial, `CONFIG_KGDB_SERIAL_CONSOLE=y` needs to be configured. And `CONFIG_DEBUG_INFO` is preferred for symbolic data to be built into the kernel, to make debugging with `gdb` more meaningful.

`CONFIG_FRAME_POINTER=y` enables frame pointers in the kernel, allowing `gdb` to construct more accurate stack back-traces. All these options are available under “Kernel hacking” in the menu obtained in the kernel source directory (preferably as root, or using `sudo`), by issuing the following command:

```
$ make mrproper      # To clean up properly
$ make oldconfig      # Configure the kernel same as the current running
$ make menuconfig     # Start the ncurses based menu for further config
```



See the highlighted selections in Figure 1, for how and where these options would be:

- “KGDB: kernel debugging with remote gdb” -> `CONFIG_KGDB`
- “KGDB: use kgdb over the serial console” -> `CONFIG_KGDB_SERIAL_CONSOLE`
- “Compile the kernel with debug info” -> `CONFIG_DEBUG_INFO`

From a personal preference perspective, I would choose an open source solution, any day (<http://opensourceforu.com/2016/01/%c2%93from-a-personal-preference-perspective-i-would-choose-an-open-source-solution-any-day/>)

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- “Compile the kernel with frame pointers” ->
CONFIG_FRAME_POINTER

Once configuration is saved, build the kernel (run `make`), and then a `make install` to install it, along with adding an entry for the installed kernel in the GRUB configuration file. Depending on the distribution, the GRUB configuration file may be `/boot/grub/menu.lst`, `/etc/grub.cfg`, or something similar. Once installed, the `kgdb`-related kernel boot parameters need to be added to this new entry, as shown in the highlighted text in Figure 2.

Figure 2: GRUB configuration for kgdb

`kgdboc` is for `gdb` connecting over the console, and the basic format is `kgdboc= <serial_device>, <baud-rate>` where:

- `<serial_device>` is the serial device file (port) on the system running the kernel to be debugged
- `<baud-rate>` is the baud rate of this serial port

`kgdbwait` tells the kernel to delay booting till a `gdb` client connects to it, and `kgdb` can only connect after `kgdboc`.
(<http://opensourceforu.com>)

Make a copy of the `vmlinux` kernel image for use on the `gdb` client system. Reboot, and at the GRUB menu, choose the entry with `kgdboc=` and the `kgdbwait` option.

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should work for any 2.6.3x release of the kernel source. Also, the snapshot for `kgdb` was captured over the serial device file `/dev/ttyS0`, i.e., the first serial port.

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Setting up gdb on another system

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To get `gdb` to connect to the waiting kernel, launch `gdb` from the shell and run these commands:

```
(gdb) file vmlinux
(gdb) set remote interrupt-sequence Ctrl-C
(gdb) set remotebaud 115200
(gdb) target remote /dev/ttyS0
(gdb) continue
```

In the above commands, `vmlinux` is the kernel image copied from the system to be debugged.

Debugging using gdb with kgdb

After this, it is all like debugging an application from `gdb`. One may stop execution using `Ctrl+C`, add break points using `b [reak]`, stop execution using `s [tep]` or `n [ext]` ... — the usual `gdb` way. There are enough GDB tutorials available online, if you need them. In fact, if you are not comfortable with text-based GDB, use any of the standard GUI tools over `gdb`, like `ddd`, `Eclipse`, etc.

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Summing up

By now, Shweta was excited about wanting to try out `kgdb` . Since she needed two systems to try it out, she went to the Linux device drivers' lab. There, she set up the systems and ran `gdb` as described above.

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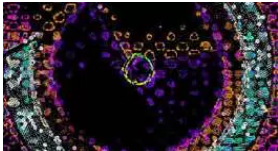
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The author is a freelance trainer in Linux internals, Linux device drivers, embedded Linux and related topics. Prior to this, he had worked at Intel and Nvidia. He has been exploring Linux since 1994. A gold medallist from the Indian Institute of Science, Linux and knowledge-sharing are two of his many passions.

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