NVIDIA DOCA DPA GDB Server Tool

Table of contents

This document describes the DPA GDB Server tool.

> **Info**
>
> The DPA GDB Server Tool is currently supported at beta level.

Introduction

The DPA GDB Server tool (`dpa-gdbserver`) enables debugging FlexIO DEV programs.

DEV programs for debugging are selected using a token (8-byte value) provided by the FlexIO process owner.

> **Info**
>
> Any GDB, familiar with RISC-V architecture, can be used for the debug.
> Refer to this page for information how to work with GDB.

Glossary

Term	Description
PUD	Process under debug. DEV-side processes intended for debug.
EU	Execution unit (similar to hardware CPU core)
DPA	Data path accelerator
RPC	Remote process communication. Mechanism used in FlexIO to run DEV-side code instantly. Runtime is limited to 6 seconds.
HOST	x86 or aarch64 Linux OS which manages dev-side code (i.e., DEV)
DEV	RISC-V code, loaded by HOST into the DPA's device. Triggered to run by different types of interrupts. DEV side is directly connected to ConnectX adapter card.

Term	Description
GDB	GNU Project debugger. Allows users to monitor another program while it executes.
GDBSERVER	Tool for remote debug programs
RTOS	Real-time operation system running on RISC-V core. Manages handling of interrupts and calls to DEV user processes routines.
RSP	Remote serial protocol. Used for interaction between GDB and GDBSERVER.

Known Limitations

- DPA GDB technology does not catch fatal errors. Therefore, if a fatal error occurs, core dump (created by `flexio_coredump_create()`) should be used.
- DPA GDB technology does not support Outbox access. GDB users cannot write to Doorbell or to Window configuration areas.
- DPA GDB technology does not support Window access. Read/write to Window memory does not work properly.

DPA-specific Notes

Token

The process under debug (PUD) can expose a debugging token. Every external process, using this token, get full access to the process with given token. To not show it constantly (e.g., for security reasons), users can modify their host application temporary. See `flexio_process_udbg_token_get()`.

Connection on Application Launch

If the code which needs debugging begins to run immediately after launch, the user should modify the host application to stop upon start to give the user time to run `dpa-gdbserver`. One possible way of doing this is to place function `getchar()` immediately after process creation.

Dummy Thread Concept

Something to consider with DPA debugging is that a PUD does not have a running thread all time (e.g., the process's thread may exist but be waiting for incoming packets). In a regular Linux application, this scenario is not possible and GDB does not support such cases.

Therefore, when no thread is running, `dpa-gdbserver` reports a dummy thread:

```
(gdb) info thread
  Id   Target Id                                     Frame
* 1    Thread 1.805378433 (Dummy Flexio thread) 0x0800000000000000 in ??
()
(gdb)
```

In this case user can inspect memory, create breakpoints, and give the `continue` command.

Commands like `step`, `next`, and `stepi` can not be executed for the Dummy thread.

Watchdog Issues

The RTOS has a watchdog timer that limits DEV code interrupt processes to 120 seconds. This timer is stopped when the user connects to DEV with GDB. Therefore users will have no time limitation for debugging.

Tool TCP Port and Execution Unit (EU)

By default, `dpa-gdbserver` uses TCP port 1981 and runs on EU 29. If this conflicts with another application (or if other instances of `dpa-gdbserver` are running), users should change the defaults as follows:

```
$> dpa-gdbserver mlx5_0 -T <token> -s <port> -E <eu_id>
```

Debugging

Preparation for Debug

Modify your FlexIO application if needed. Make sure the HOST code prints `udbg_token` and waits for GDB connection if needed:

```
+       uint64_t udbg_token;

        flexio_process_create(..., &flexio_process);

+       udbg_token =
flexio_process_udbg_token_get(flexio_process);
+       if (udbg_token)
+               printf("Process created. Use token >>> %#lx <<< for debug\n",
udbg_token);

+       printf("Stop point for waiting of GDB connection. Press Enter to continue...");   /* Usually
you don't need this stop point */
+       fflush(stdout);
+       getchar();
```

Extract the DPA application from the FlexIO application. For example:

```
$> dpacc-extract cc-host/app/host/flexio_app_name -o
```

```
flexio_app_name.rv5
```

Start Debugging

1. Run your FlexIO application. It should expose the debug token:

```
$> flexio_app_name mlx5_0
Process created. Use token >>> 0xd6278388ce4e682c <<< for
debug
```

2. Run `dpa-gdbserver` with the debug token received:

```
$> dpa-gdbserver mlx5_0 -T 0xd6278388ce4e682c
Registered on device mlx5_0
Listening for GDB connection on port 1981
```

3. Run any GDB with RISC-V support. For example, `gdb-multiarch`:

```
$> gdb-multiarch -q flexio_app_name.rv5
Reading symbols from flexio_app_name.rv5...
(gdb)
```

4. Connect to the gdbserver using proper TCP port and hostname, if needed:

```
(gdb) target remote :1981
Remote debugging using :1981
0x0800000000000000 in ?? ()
```

DPA-specific Debugging Techniques

Easy Example of Transitioning from Dummy to Real Thread

Transitioning between the dummy thread and a real thread is not standard practice for debugging under GDB. In an ideal situation, the user would know exactly the entry points for all their routines and can set breakpoints for all of them. Then the user may run the `continue` command:

```
(gdb) target remote :1981
Remote debugging using :1981
0x0800000000000000 in ?? ()
(gdb) info threads
  Id   Target Id                                  Frame
* 1    Thread 1.805378433 (Dummy Flexio thread) 0x0800000000000000 in ??
()
(gdb) b foo
Breakpoint 1 at 0x400000b2: file ../tests/path/hello.c, line 58.
(gdb) b bar
Breakpoint 2 at 0x40000518: file ../tests/path/hallo.c, line 113.
(gdb) continue
Continuing.
```

Initiate interrupts for your DEV program (depends your task), and GDB should catch a breakpoint and now the real thread of the PUD appear instead of the dummy:

```
(gdb) continue
Continuing.
(gdb) [New Thread 1.2]
[New Thread 1.130]
[New Thread 1.258]
[New Thread 1.386]
[Switching to Thread 1.2]
```

```
Thread 2 hit Breakpoint 1, foo(thread_arg=9008)
    at ../tests/path/hello.c:58
58                struct host_data *hdata = NULL;
(gdb) info threads
  Id   Target Id                                    Frame
* 2    Thread 1.2 (Process 0 thread 0x1 GVMI 0)     foo (arg=9008)
at ../tests/path/hello.c:58
  3    Thread 1.130 (Process 0 thread 0x81 GVMI 0)  foo (arg=9264) at
../tests/path/hello.c:58
  4    Thread 1.258 (Process 0 thread 0x101 GVMI 0) foo (arg=9648) at
../tests/path/hello.c:58
  5    Thread 1.386 (Process 0 thread 0x181 GVMI 0) foo (arg=9904) at
../tests/path/hello.c:58
(gdb)
```

From this point, you may examine memory and trace your code as usual.

Complicated Example of Transitioning from Dummy to Real Thread

In a more complicated situation, the interrupt happens after GDB connection. In this case, the real thread should start running but cannot because the PUD is in HALT state. The user can type the command `info threads`, see new thread instead of the old dummy, and then switch to the new thread manually:

```
(gdb) target remote :1981
Remote debugging using :1981
0x0800000000000000 in ?? ()
(gdb) info threads
  Id   Target Id                                Frame
* 1    Thread 1.805378433 (Dummy Flexio thread) 0x0800000000000000 in ??
()
(gdb) info threads
[New Thread 1.32769]
```

```
  Id   Target Id                                              Frame
  2    Thread 1.32769 (Process 0 thread 0x8000 GVMI 0) bar (arg=0xc0,
len=0)
    at /path/lib/src/stub.c:167

The current thread <Thread ID 1> has terminated.  See `help
thread'.
(gdb) thread 2
[Switching to thread 2 (Thread 1.32769)]
#0  bar (arg=0xc0, len=0)
    at /path/lib/src/stub.c:167
167      {
(gdb) bt
#0  bar (arg=0xc0, len=0)
    at /path/lib/src/stub.c:167
#1  0x000000004000017a in foo (thread_arg=3221)
    at ../path/dev/hello.c:182
#2  0x0000000000000000 in ?? ()
Backtrace stopped: frame did not save the PC
(gdb)
```

Note

The same command `info threads` in lines 4 and 7 gives different results. This happens because the interrupt occurs between the instances and the real code begins to run.

The user must switch to the new thread manually (see line 14). After this, they can trace/debug the flow as usual (i.e., using the commands `step`, `next`, `stepi`).

Finishing Real Thread without Finishing PUD

Every interrupt handler at some point finishes its way and returns the CPU resources to RTOS. The most common way to do this is to call function `flexio_dev_thread_reschedule()`. The command `next` on this function will have the same effect as the command `continue`:

```
205                 __dpa_thread_fence(__DPA_MEMORY, __DPA_W,
__DPA_W);
(gdb) next
206                 flexio_dev_cq_arm(dtctx,
app_ctx.rq_cq_ctx.cq_idx, app_ctx.rq_cq_ctx.cq_number);
(gdb) next
208                 if ((dev_errno =
flexio_dev_get_and_rst_errno(dtctx))) {
(gdb) next
213                 print_sim_str("Nothing to do. Wait for next duar\n", 0);
(gdb) next
214                 flexio_dev_thread_reschedule();
(gdb) next
```

Info

GDB waits until the user types `^C` or a breakpoint is reached after the next interrupt occurred.

Error Reporting

Info

The DPA GDB server tool has been validated with `gdb-multiarch` (version 9.2) and with GDB version 12.1 from RISC-V tool chain.

Note

The GDB server should support all commands described in GDB RSP (remote serial protocol) for GDB stubs. But only the most common GDB commands are supported.

Should a dpa-gdbserver bug occur, please provide the following data:

- Used GDB (name and version)
- Commands sequence to reproduce the issue
- DPA GDB server tool console output
- DPA GDB server tool log directory content (see next part for details)
- Optional – output data printed when `dpa-gdbserver` is run in verbose mode

Tool Log Directory

For every run, a temporary directory is created with the template `/tmp/flexio_gdbs.XXXXXX`.

To locate the latest one, run the following command:

```
$> ls -ldtr /tmp/flexio_gdbs.* | tail
```

Verbosity Level of gdbserver

By default, `dpa-gdbserver` does not print any log information to screen. Adding - `v` option to command line increases verbosity level, printing additional info to `dpa-gdbserver` terminal display. Verbosity level is incremented according to number of 'v' in command line switch (i.e. `-vv`, `-vvv` etc.).

One `-v` shows the RSP exchange. This is a textual protocol, so users can read and understand requests from GDB and answers from the GDB server:

```
<<<<<  "qTStatus"
>>>>>  ""
<<<<<  "?"
>>>>>  "S05"
<<<<<  "qfThreadInfo"
>>>>>  "mp01.30011981"
<<<<<  "qsThreadInfo"
>>>>>  "l"
<<<<<  "qAttached:1"
>>>>>  "1"
<<<<<  "Hc-1"
>>>>>  "OK"
<<<<<  "qC"
>>>>>  "QCp01.30011981"
```

Info

In the examples, `<<<<<` and `>>>>>` are used to indicate data received from GDB and transmitted to GDB, respectively.

When running with a higher verbosity level (e.g., run `dpa-gdbserver` with option `-vv` or higher), the exchange with the RTOS module is shown:

```
<<<<< "qfThreadInfo"
/   2/dgdbs_handler - cmd 0x5
/   2/dgdbs_handler - retval 0x4
>>>>> "mp01.30011981"
<<<<< "qsThreadInfo"
/   2/dgdbs_handler - cmd 0x5
/   2/dgdbs_handler - retval 0x5
>>>>> "l"
<<<<< "m8000000000000000,4"
/   2/dgdbs_handler - cmd 0xc
/   2/dgdbs_handler - retval 0x9
>>>>> "E0a"
<<<<< "m7ffffffffffffffc,4"
/   2/dgdbs_handler - cmd 0xc
/   2/dgdbs_handler - retval 0x9
>>>>> "E0a"
<<<<< "qSymbol::"
>>>>> "OK"
```

Info

Lines beginning with `/ #/` provide the number of internal RTOS threads printed from the DEV side.

Useful Info Regarding Work with GDB

This section provides useful information about commands and methods which can help users when performing DPA debug. This is not related to the `dpa-gdbserver` itself. But this is about remote debugging and FlexIO sources.

Command "directory"

GDB can run on a different host from the one where compilation was done. For example, users may have compiled and run their application on `host1` and run their instance of GDB on `host2`. In this case, users will see the error message `../xxx/yyy/zzz/your_file.c: No such file or directory`. To solve this problem, copy sources to the host running GDB (`host2` in the example). Make sure to save the original code hierarchy. Use GDB command `directory` to inform where the sources are to GDB:

```
host2~$> gdb-multiarch -q /tmp/my_riscv.elf
Reading symbols from /tmp/my_riscv.elf...
(gdb) b foo
Breakpoint 1 at 0x4000016c: file ../xxx/yyy/zzz/my_file.c, line 182.
(gdb) target remote host1:1981
Remote debugging using host1:1981
0x0800000000000000 in ?? ()
(gdb) c
Continuing.
[New Thread 1.32769]
[Switching to Thread 1.32769]

Thread 2 hit Breakpoint 1, foo (thread_arg=5728) at
../xxx/yyy/zzz/my_file.c:182
182     ../xxx/yyy/zzz/my_file.c: No such file or directory.
(gdb) directory /tmp/apps/
Source directories searched: /tmp/apps:$cdir:$cwd
(gdb) list
179             struct flexio_dev_thread_ctx *dtctx;
180             uint64_t dev_errno;
181
182             print_sim_str("=====> NET event handler started\n", 0);
183
184             flexio_dev_print("Hello GDB user\n");
185
```

Note

Pay attention to the exact path reported by GDB. The argument for the command `directory` should point to the start point for this path. For example, if GDB looks for `../xxx/yyy/zzz` and you placed the sources in local directory `/tmp/copy_of_worktree`, then the command should be
`(gdb) directory /tmp/copy_of_worktree/xxx/` and not
`(gdb) directory /tmp/copy_of_worktree/`.

Sometimes, the `*.elf` file provides a global path from the root. In this case, use the command `set substitute-path <from> <to>`. For example, if the file `/foo/bar/baz.c` was moved to `/mnt/cross/baz.c`, then the command `(gdb) set substitute-path /foo/bar /mnt/cross` instructs *GDB* to replace `/foo/bar` with `/mnt/cross`, which allows GDB to find the file `baz.c` even though it was moved.

See this page of GDB documentation for more examples of specifying source directories.

Core Dump Usage

If the code runs into a fatal error even though the host side of your project is implemented correctly, a core dump is saved which allows analyzing the core. It should point exactly to where the fatal error occurred. The command `backtrace` can be used to examine the memory and its registers. Change the frame to see local variables of every function on the backtrace list:

```
$> gdb-multiarch -q -c crash_demo.558184.core /tmp/my_riscv.elf
Reading symbols from /tmp/my_riscv.elf...

[New LWP 1]
```

```
#0  0x000000004000126e in read_test (line=153, ptr=0x30) at
/xxx/yyy/zzz/my_file.c:109
109             val = *(volatile uint64_t *)ptr;
(gdb) bt
#0  0x000000004000126e in read_test (line=153, ptr=0x30) at
/xxx/yyy/zzz/my_file.c:109
#1  0x000000004000031a in tlb_miss_test (op_code=1) at
/xxx/yyy/zzz/my_file.c:153
#2  0x0000000040000144 in test_thread_err_events_entry_point
(h2d_daddr=3221258560) at /xxx/yyy/zzz/my_file.c:588
#3  0x00000000400013fc in
_dpacc_flexio_dev_arg_unpack_test_err_events_dev_test_thread_err_ev
(argbuf=0xc0008228, func=0x400000b0
<test_thread_err_events_entry_point>)
    at /tmp/dpacc_xExkvE/test_err_events_dev.dpa.device.c:67
#4  0x0000000040001680 in flexio_hw_rpc (host_arg=3221258752) at
/local_home/www/flexio-sdk/libflexio-
dev/src/flexio_dev_entry_point.c:75
#5  0x0000000000000000 in ?? ()
Backtrace stopped: frame did not save the PC
(gdb) frame 4
#4  0x0000000040001680 in flexio_hw_rpc (host_arg=3221258752) at
/local_home/igorle/flexio-sdk/libflexio-
dev/src/flexio_dev_entry_point.c:75
75                      retval = unpack_cb(&data_from_host-
>func_params.arg_buf,
(gdb) p /x *data_from_host
$2 = {poll_lkey = 0x1ff2b1, window_id = 0x3, poll_haddr =
0x55dc0f40b900, entry_point = 0x400013d8, func_params = {func_wo_pack =
0x0, dev_func_entry = 0x400000b0, arg_buf = 0xc0008140}}
(gdb)
```

Debug of Optimized Code

Usually highly optimized code is compiled and run.

Two types of mistakes in code can be considered:

- Logical errors
- Optimization-related errors

Logical errors (e.g., using `&` instead of `&&`) are reproduced on the non-optimized version of the code. Optimization related errors (e.g., forgetting volatile classification, non-usage of memory barriers) only impact optimization. Non-optimized code is much easier for tracing with GDB, because every C instruction is translated directly to assembly code.

It is good practice to check if an issue can be reproduced on non-optimized code. That helps observing the application flow:

```
$> build.sh -O 0
```

For tracing this code, using GDB commands `next` and `step` should be sufficient.

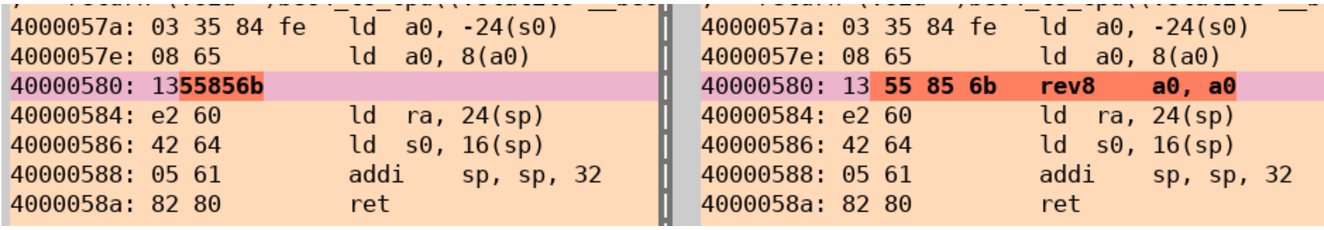
But if an issue can only be reproduced on on optimized code, you should start debugging it. This would require reading disassembly code and using the GDB command `stepi` because it becomes a challenge to understand exactly which C-code line executed.

Disassembly of Advanced RISC-V Commands

DPA core runs on a RISC-V CPU with an extended instruction set. The GDB may not be familiar with some of those instructions. Therefore, `asm` view mode shows numbers instead of disassembly. In this case it is recommended to disassemble your RISC-V binary code manually. Use the `dpa-objdump` utility with the additional option `--mcpu=nv-dpa-bf3`.

```
$> dpa-objdump -sSdxl --mcpu=nv-dpa-bf3 my_riscv.elf >
my_riscv.asm
```

The following screenshot shows the difference:



Notice