

Debugging and debug flags

We will cover

- How to enable debug flags (examples of DRAM and Exec) [Not doing this]
- `--debug-help`
- Adding a new debug flag
- Functions other than DPRINTF
- Panic/fatal/assert
- gdb? Mahyar's opinion: does not sound interesting or exclusive to gem5 and hard to teach.

DebugFlags: Debugging and Logging in gem5

IMPORTANT: This slide deck builds on top of what has already been developed in [Introduction to SimObjects](#).

DebugFlags

DebugFlags help with debug printing. Debug printing is useful for debugging models in gem5 and logging.

Each DebugFlag enables printing certain statements within the gem5 code base. Run the following commands to see all the available DebugFlags in gem5.

```
cd gem5
./build/NULL/gem5.opt --debug-help
```

This command will show you a list of all the DebugFlags. You can choose to use a specific DebugFlag, like Activity, or you can choose a class of DebugFlags, like Registers, which will enable the following DebugFlags: IntRegs, FloatRegs, VecRegs, VecPredRegs, MatRegs, CCRs, MiscRegs.

In the following slide, you will see the expected output.

```
gem5 git:(v24.0.0.0-0-g43769abaf0) ./build/NULL/gem5.opt --debug-help
```



DebugFlags: HelloExampleFlag

To define a new DebugFlag in gem5, you just have to define it in **any** SConscript in the gem5 directory. However, it is convention that DebugFlags are defined in the same SConscript that registers SimObjects that are relevant to the DebugFlag.

To define a new DebugFlag that we will use to print debug/log statement in HelloSimObject, open src/bootcamp/hello-sim-object/SConscript in your editor of choice and add the following line.

```
DebugFlag("HelloExampleFlag")
```

Adding this line will create a new **auto-generated** header file (with the same name as the DebugFlag) that defines the DebugFlag in C++.

DebugFlags: Using HelloExampleFlag in Code

One of the functions in gem5 that allows for debug printing is `DPRINTF`, which will let you print a formatted string if a certain `DebugFlag` is enabled (more on how to enable `DebugFlags` later). `DPRINTF` is defined in `src/base/trace.hh`. Make sure to include it every time you want to use `DPRINTF`.

Now let's get to actually adding `HelloExampleFlag` in C++. As I mentioned, the header files for `DebugFlags` are auto-generated. For now, trust that the header file for `HelloExampleFlag` will be in `build/NULL/debug/HelloExampleFlag.hh` when we recompile gem5.

Let's include the header files in `hello_sim_object.cc` by adding the following lines. Remember to follow the conventional order of includes!

```
#include "base/trace.hh"
#include "debug/HelloExampleFlag.hh"
```

Now let's add a simple `DPRINTF` statement inside the constructor of `HelloSimObject` to print Hello from Do it by adding the following line after the for-loop. **NOTE:** `__func__` will return the name of the function we're in as a string.

```
DPRINTF(HelloExampleFlag, "%s: Hello from HelloSimObject's constructor!\n", __func__);
```

DebugFlags: How Files Look Like

Below is how `src/bootcamp/hello-sim-object/SConscript` should look like after the changes.

```
Import("*")

SimObject("HelloSimObject.py", sim_objects=["HelloSimObject"])

Source("hello_sim_object.cc")

DebugFlag("HelloExampleFlag")
```

Below is how `src/bootcamp/hello-sim-object/hello_sim_object.cc` looks like with changes

Continued

```
#include "bootcamp/hello-sim-object/hello_sim_object.hh"

#include <iostream>

#include "base/trace.hh"
#include "debug/HelloExampleFlag.hh"

namespace gem5
{
    HelloSimObject::HelloSimObject(const HelloSimObjectParams& params):
        SimObject(params)
    {
        for (int i = 0; i < params.num_hellos; i++) {
            std::cout << "i: " << i << ", Hello from HelloSimObject's constructor!" << std::endl;
        }
        DPRINTF(HelloExampleFlag, "%s: Hello from HelloSimObject's constructor!\n", __func__);
    }

} // namespace gem5
```


Let's Recompile

Now, let's recompile gem5 with the command below. After compilation is done, you should be able to find the header file in `build/NULL/debug/HelloExampleFlag.hh`.

```
scons build/NULL/gem5.opt -j$(nproc)
```

Continued on the next slide.

And here is a snippet of the contents of `build/NULL/debug/HelloExampleFlag.hh`.

```
/**
 * DO NOT EDIT THIS FILE!
 * File automatically generated by
 *   build_tools/debugflaghh.py:139
 */

#ifdef __DEBUG_HelloExampleFlag_HH__
#define __DEBUG_HelloExampleFlag_HH__

#include "base/compiler.hh" // For namespace deprecation
#include "base/debug.hh"
namespace gem5
{
    namespace debug
    {
        namespace unions
        {
            inline union HelloExampleFlag
            {
                ~HelloExampleFlag() {}
                SimpleFlag HelloExampleFlag = {
                    "HelloExampleFlag", "", false
                };
            } HelloExampleFlag;
        } // namespace unions
    }

    inline constexpr const auto& HelloExampleFlag =
        ::gem5::debug::unions::HelloExampleFlag.HelloExampleFlag;
} // namespace debug
} // namespace gem5

#endif // __DEBUG_HelloExampleFlag_HH__
```

DebugFlags: After Adding HelloExampleFlag

Now, our `HelloExampleFlag` should be listed whenever we print debug help from `gem5`. Let's run the following command in the base `gem5` directory to verify that our `DebugFlag` is added.

```
./build/NULL/gem5.opt --debug-help
```

Below shows the expected output.

```
GDBExtra: Dump extra information on reads and writes
GDBMisc: Breakpoints, traps, watchpoints, etc.
GDBRead: Reads to the remote address space
GDBRecv: Messages received from the remote application
GDBSend: Messages sent to the remote application
GDBWrite: Writes to the remote address space
GUPSGen:
GarnetSyntheticTraffic:
HMCController:
HWPrefetch:
HWPrefetchQueue:
HelloExample: For Learning gem5 Part 2. Simple example debug flag
HelloExampleFlag:
```



Enabling DebugFlags: Using Configuration Script

To enable a DebugFlag you can import flags from m5.debug and access the flag by indexing flags. You can enable and disable flags by calling enable and disable methods. Below is an example of what your second-hello-example.py would look like if you wanted to enable HelloExampleFlag.

CAUTION: Do **not** make this change in your configuration script for now.

```
import m5
from m5.debug import flags
from m5.objects.Root import Root
from m5.objects.HelloSimObject import HelloSimObject

root = Root(full_system=False)
root.hello = HelloSimObject(num_hellos=5)

m5.instantiate()

flags["HelloExampleFlag"].enable()

exit_event = m5.simulate()

print(f"Exited simulation because: {exit_event.getCause()}")
```

Enabling DebugFlags: Using Command Line

Alternatively you can pass `--debug-flags=[comma-separated list of DebugFlags]` to your `gem5` binary when running your configuration script. As an example, below is a shell command that you can use to enable `HelloExampleFlag` (like always, run it in the base `gem5` directory).

```
./build/NULL/gem5.opt --debug-flags=HelloExampleFlag configs/bootcamp/hello-sim-object/second-hello-example.py
```

Simulate: Without HelloExampleFlag

Now let's simulate `second-hello-example.py` with and without `DebugFlags` and compare the output.

Run the following command to simulate `second-hello-example.py` without `DebugFlags`.

```
./build/NULL/gem5.opt configs/bootcamp/hello-sim-object/second-hello-example.py
```

Below is a recording of my terminal when doing this.

A terminal window with a dark background. The prompt is 'gem5 git:(v24.0.0.0-0-g43769abaf0)'. The command being executed is './build/NULL/gem5.opt configs/bootcamp/hello-sim-object/second-hello-example.py'.

```
gem5 git:(v24.0.0.0-0-g43769abaf0) ./build/NULL/gem5.opt configs/bootcamp/hello-sim-object/second-hello-example.py
```



Simulate: With HelloExampleFlag

Run the following command to simulate `second-hello-example.py` with `HelloExampleFlag`.

```
./build/NULL/gem5.opt --debug-flags=HelloExampleFlag configs/bootcamp/hello-sim-object/second-hello-example.py
```

Below is a recording of my terminal when doing this.



A terminal window with a dark background. The prompt is `gem5 git:(v24.0.0.0-g43769abaf0)`. The command entered is `./build/NULL/gem5.opt --debug-flags=HelloExampleFlag configs/bootcamp/hello-sim-object/second-hello-example.py`. A large white play button icon is centered in the terminal window.

```
gem5 git:(v24.0.0.0-g43769abaf0) ./build/NULL/gem5.opt --debug-flags=HelloExampleFlag configs/bootcamp/hello-sim-object/second-hello-example.py
```

Assertions in gem5

I strongly recommend using `assert` and `static_assert` when developing for gem5. They will help you find untrue assumptions you've made, and they will help you find any development mistakes early. `assert` and `static_assert` are standard C++ functions that you can (and are strongly encouraged to) use while developing in gem5.

`fatal`, `fatal_if`, `panic`, and `panic_if` are gem5's specific assert-like functions that allow you to print error messages. gem5 convention is to use `fatal` and `fatal_if` to assert assumptions on user inputs (similar to `ValueError`). As an example, if a user tries to configure your `SimObject` with negative capacity you can use `fatal` or `fatal_if` in your `SimObject` to let the user (most probably yourself) know their mistake. Below shows an example of doing this with `fatal` and `fatal_if`.

```
if (capacity < 0) { fatal("capacity can not be negative.\n"); }  
\ \ OR  
fatal_if(capacity < 0, "capacity can not be negative.\n");
```

You should use `panic`, and `panic_if` to catch developer mistakes. We will see some examples in [Ports](#).

Other Debugging Facilities in gem5

- Most `DebugFlags` require that there is a `name()` function in the current scope (called from a `SimObject` member function).
- Only use the `DebugFlags` if you are using `gem5.opt` or `gem5.debug`.

```
DPRINTF(Flag, __VA_ARGS__)
```

- Takes a flag, and a format string + format parameters.
- Prints the formatted string only when the `Flag` is enabled.

```
DPRINTFR(Flag, __VA_ARGS__)
```

- Outputs debug statements without printing a name
- Useful for using debug statements in object that are not `SimObjects` that do not have a `name()` function.

Other Debugging Facilities in gem5

```
DPRINTF5(Flag, SimObject, __VA_ARGS__)
```

- Useful for debugging from private subclass of a `SimObject` that has a pointer to its owner.

```
DPRINTFN(__VA_ARGS__)
```

```
DPRINTFNR(__VA_ARGS__)
```

- These don't take a flag as a parameter, will always print whenever debugging is enabled.

```
DDUMP(Flag, data, count)
```

- Prints binary data of length `count` bytes.
- Formatted in user-readable hex.

Learn more at: https://www.gem5.org/documentation/learning_gem5/part2/debugging/