# Debugging offloaded kernels on AMD GPUs

Linux Plumbers Conference 2021 Andrew Stubbs

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Demonstration

**GCC** Implementation





#### About me: Andrew Stubbs

Sourcerer at CodeSourcery / Mentor Graphics, now part of Siemens.

GCC developer working on (most recently):

- AMD GCN backend.
- OpenMP & OpenACC for GCN & NVPTX.
- GCN DWARF support.



## ROCGDB

The Radeon Open Compute project is porting and adapting GDB to allow debugging programs that combine both CPU code and GPU code (kernels) in one seamless session.

- Developed by AMD.
- Supports AMD GCN5 GPUs upwards.
- Included with ROCm driver installs.
- ROCm is available for Ubuntu, CentOS/RHEL, & SLES.

https://rocmdocs.amd.com/ https://rocmdocs.amd.com/en/latest/ROCm\_Tools/ROCgdb.html



#### GCC "OG11"

The compiler demonstrated here is built from the "OG11" development branch: devel/omp/gcc-11

Work continues merging OpenACC and debugging features to GCC mainline.

Build/install instructions: <u>https://gcc.gnu.org/wiki/Offloading</u>

Binaries are available from some Linux distributions:

- Ubuntu: gcc-11-offload-amdgcn
- SUSE: cross-amdgcn-gcc11



# Demonstration

https://youtu.be/IGWFph4SlpU

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#### **Challenge 1: Register sizes (complete)**

GCN has 64-bit addresses, but only 32-bit registers, so the stack pointer & frame pointer each consist of a pair of adjacent registers.

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- The *only* GCC architecture to do so.
- GCC's target-independent DWARF support needed a full retro-fit.
- DWARF itself does not work naturally.

#### Challenge 2: Early debug information (complete)

GCC emits DWARF in two phases: the "early" debug comes before LTO stream-out, the rest when code generation is complete. These are then combined by the linker.

- "Before LTO stream-out" implies that this is *x86-64 debug code*.
- The binary file containing the early debug must be translated to GCN before it can be linked in.
- "mkoffload" does binary editing in the ELF file.
  - Extract sections from the LTO object.
  - Apply the correct ELF headers.
  - Convert all the relocation codes.
  - Weaken references to host symbols not present in the offload code.



#### Challenge 3: Incomplete DWARF (in progress)

Offload kernels are formed as nested functions within the host function, but that function *does not exist within the GCN binary*.

- GDB simply ignores DWARF for functions that "do not exist", including functions nested within.
- The DWARF encoding for the "notional" parent functions must be adjusted.
  - The OG11 development branch has an interim fix.
  - Abid Qadeer is working on a real solution for mainline.

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#### Challenge 4: Address spaces (to do)

OpenACC "gang-private" variables are located in the local on-chip low-latency memory (LDS).

- GDB cannot extract the variable unless the address space information is set correctly.
- ROCGDB did not support this yet, so GCC support was not added.
- (Last time I tried it; there have been updates since.)



#### Challenge 5: Scalars in vectors (to do)

GCN has many instructions that are only available for use with vectors and vector registers, therefore GCC often places scalar variables in vector registers.

- GDB does not know that the vector is being used in a scalar mode.
  - GDB expressions using the variable give unexpected results!
- GCC needs to encode the variable location differently.
  - AMD have proposed DWARF extensions permit this.
- This is also a problem for vector variables that use fewer than 64 lanes.

In general, vectorized code can be expected to be hard to debug (which is why the demo didn't do that).



# **Questions?**

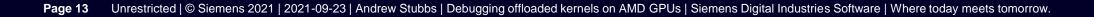


# Contact

Published by Siemens 2021

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