Different trace methods and efficient ways to utilize them

Robert Chyla
Thomas Andersson

Agenda

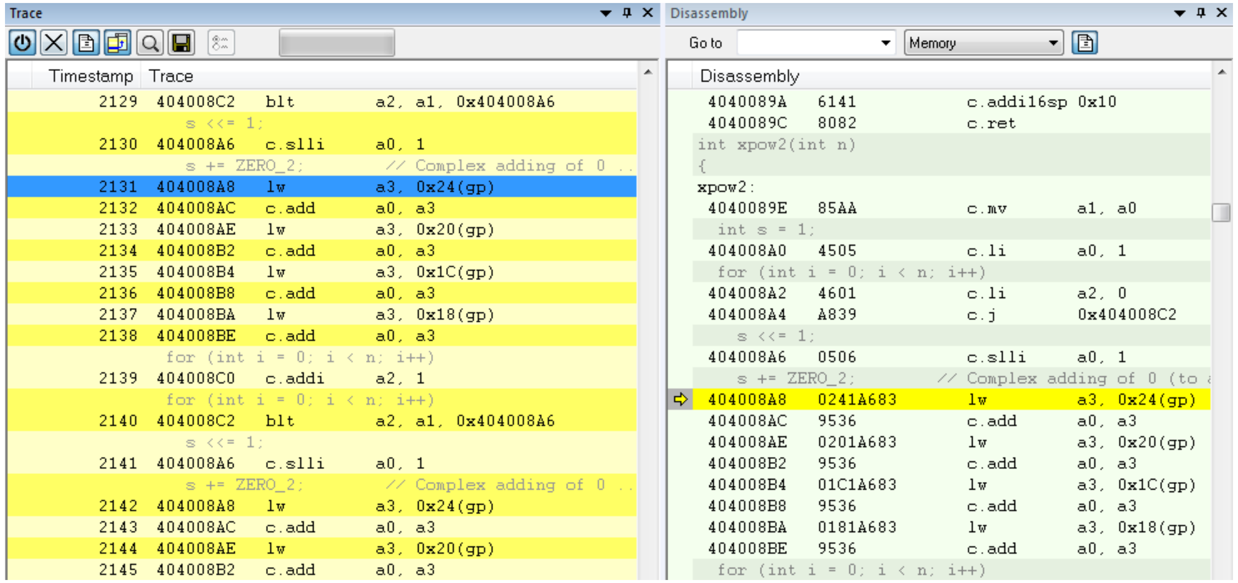
- What is Trace
- Why do I want trace?
- Different types of trace
- Analyze your trace
- HW and SW tools

RISC-V Trace specifics

- Specifications of standard RISC-V trace are “in the making”
  - Processor Trace TG define trace encoder packets and core ➔encoder interface
  - More work is needed to make all aspects of trace standard (trace control & trace export)
- Goal is to get on par with what is already existing on more mature architectures
- Done right it enables easy adoption of existing trace viewers, hardware trace probes and trace analysis tools
- Some implementations are already around
  - RISC-V architecture deserves good trace in every device from IoT to servers
  - Even simple, standard trace is better than no trace …

What is trace

- In contrast to traditional debugging trace is more like non intrusively observing your application
- Trace can include full PC flow (no need for printf nor UART …)
- It is non-intrusive to your application
- Go back in time
- Quickly isolate exceptions/hard faults
  - Find bugs that are rare and dependent on order-of-execution
- But trace is not only about finding bugs
- Performance and coverage monitoring
  - Live trace streams can be integrated in your debugger



Seeing every instruction

- With integrated support for trace in your development tools every day code development/debugging can really be enhanced
  - See how you arrived at your current execution point
  - Go back in time
- Power measurements can be correlated with program flow
- Do all of these things in a multicore environment
- But tracing can be like finding a needle in a haystack when looking for a bug
  - Just a few seconds of execution time can produce hundreds of millions of instructions
  - Instrumentation may enhance visibility
  - Advanced navigation and search capabilities is essential
  - If your compiler/debugger tools have it, use Trace triggers to constrain trace data to only what you need

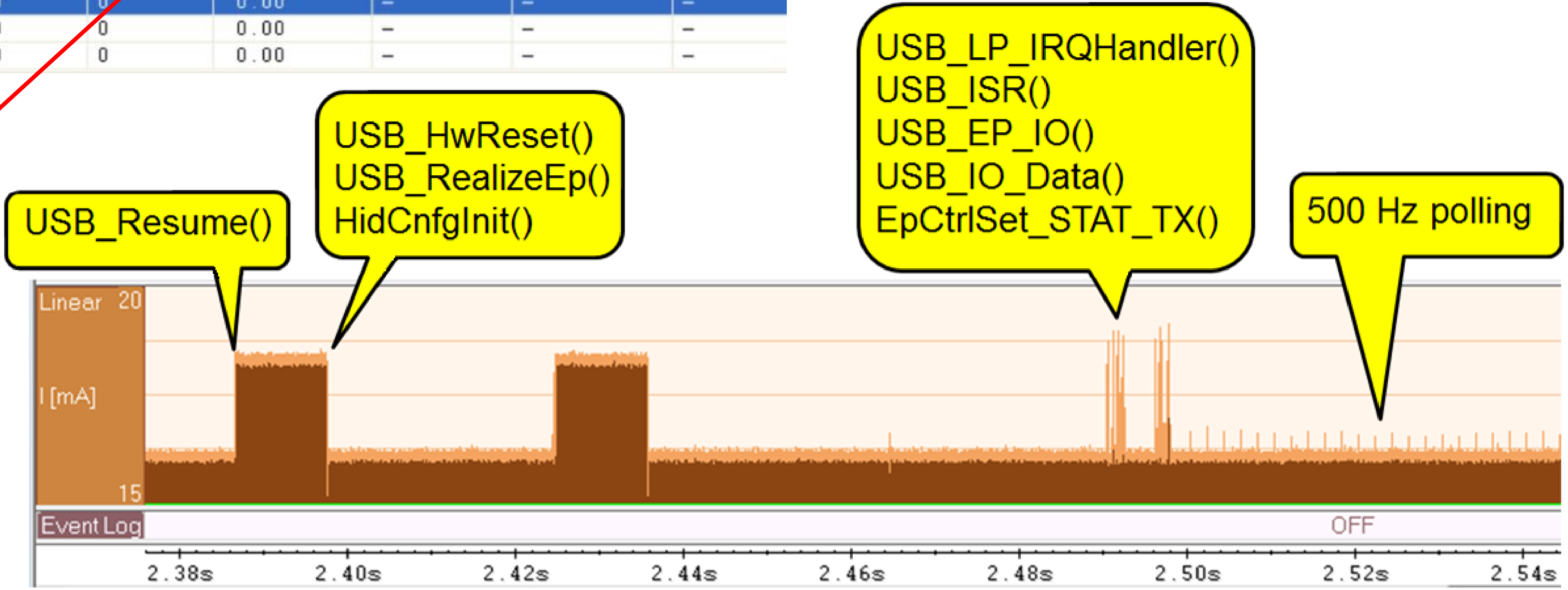
Example of power debugging and profiling

Function Profiler

277000,000us - 537000,000us

Function	PC Sam...	PC Sample...	Power S...	Energy (%)	Avg Curre...	Min Current [...	Max Curr...
putchar	0	0.00	0	0.00	–	–	–
out	0	0.00	0	0.00	–	–	–
memcmp	164	14.35	2	13.01	196.0	193	199
main()	151	13.21	2	13.64	205.5	199	212
exit	0	0.00	0	0.00	–	–	–
abort	0	0.00	0	0.00	–	–	–
_main	0	0.00	0	0.00	–	–	–
_exit	0	0.00	0	0.00	–	–	–
__write	0	0.00	0	0.00	–	–	–

Includes power measurements



- Power samples is one form of trace too
- Especially if it is synced with your PC

Why do I want Trace?

Implementing trace IP in your device gives you the possibility to non intrusively track your product as it is running

Types of trace

- Serial
  - Enough for PC sampled trace (good for statistical code profiling)
  - Light instrumentation, RTOS monitoring, variable tracing etc.
  - With a good probe it is still possible to reach speeds up to several M bytes/s
- High speed parallel interfaces (4 to16-bit dual-edge)
  - Capture everything (clock speed can be very high)
  - Traces via “breadcrumbs” left when control flow diversion occurs
  - Guarantees you every single instruction executed (may need optional stall)
  - Trace breadcrumbs are stored on debugger probe
- RAM Buffer
  - Either small dedicated RAM or shared with system memory
  - Even 4KB of trace RAM can provide enough to be really useful
- High speed serial
  - Speeds of 10 Gbits/s or higher
  - Mainly suitable for bigger, complex systems
- Trace over functional interfaces (USB3.0 provides a lot of bandwidth!)
  - Use cases are limited – not an option for small IoT devices

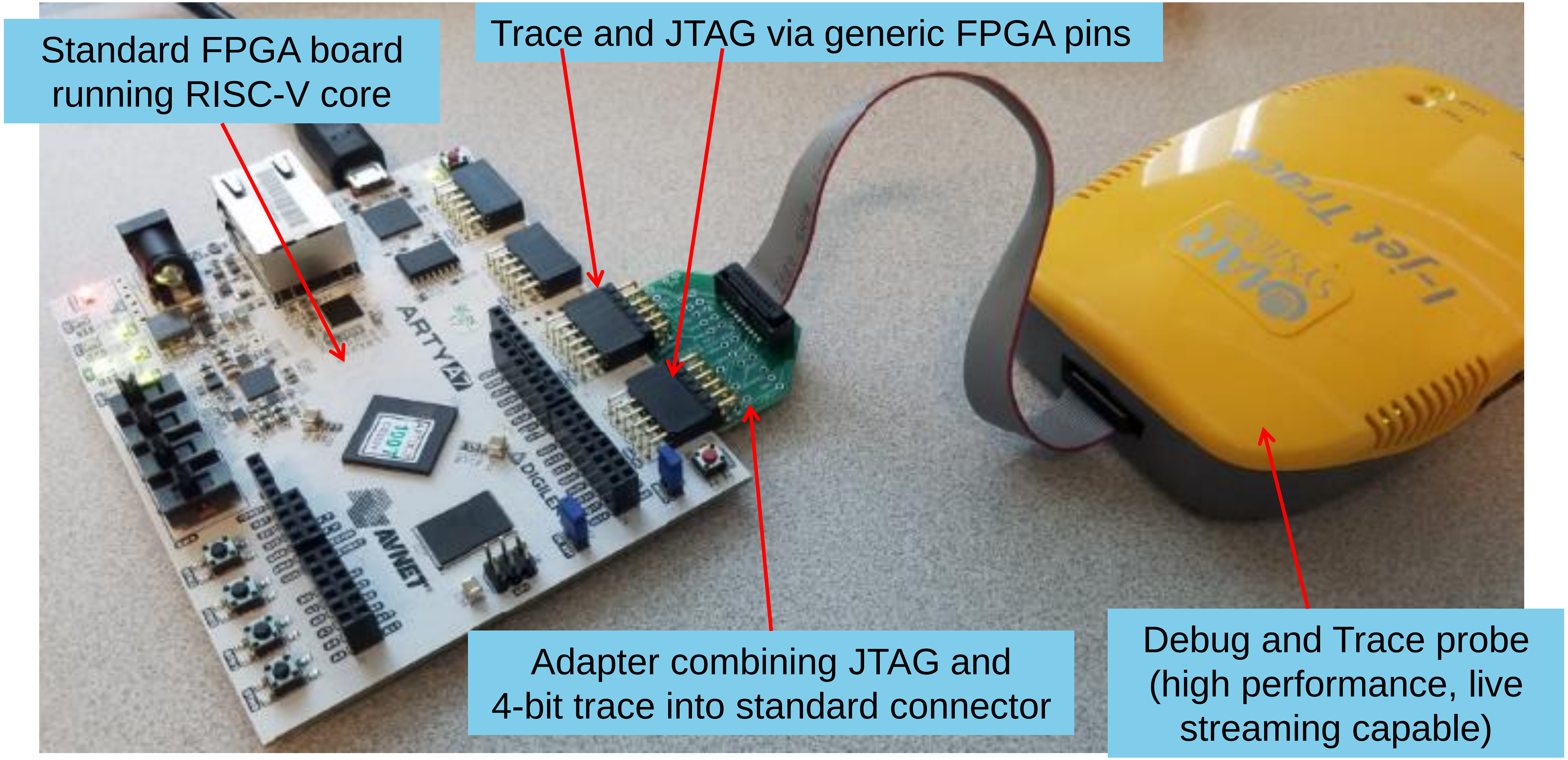
Debugging exceptions / faults

- Exceptions/unhandled faults can be caused by:
  - Pointer problems
  - Illegal instructions
  - Data aborts
- Typically, your stack (and call-frame information) gets trashed
- You have full application history with trace
  - By using trace, you can inspect the program flow up to a specific state, for instance an application crash, and use the trace data to locate the origin of the problem
- Trace data can be useful for locating programming errors that have irregular symptoms and occur sporadically
  - Some “million-dollar” bugs can be found here

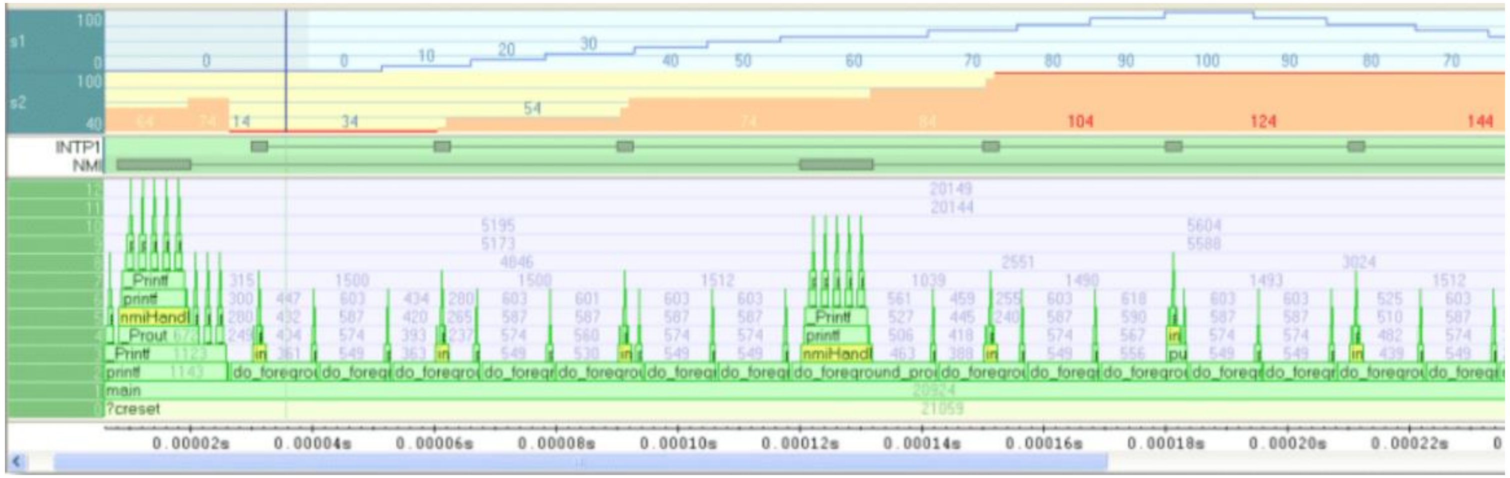
HW and SW tools Integration

The best approach is to integrate trace analysis capacity already in your everyday development environment

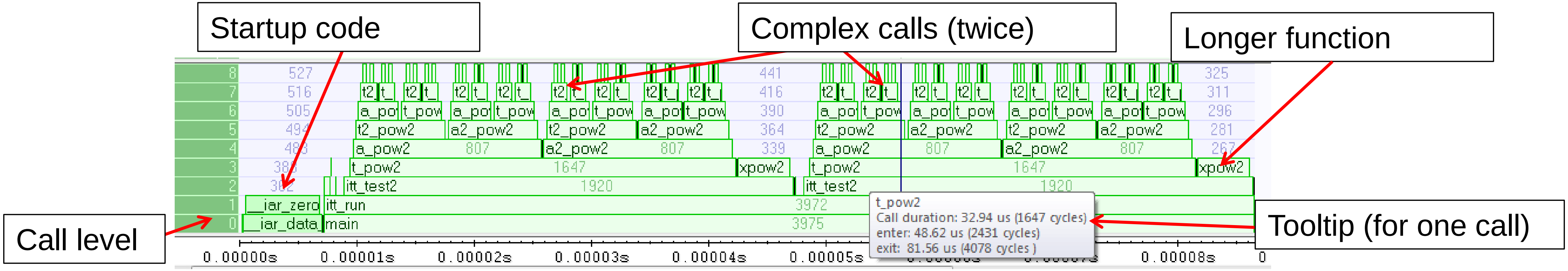
Parallel Trace (4-bit) from RISC-V FPGA Implementation



Call Stack and interrupt timeline

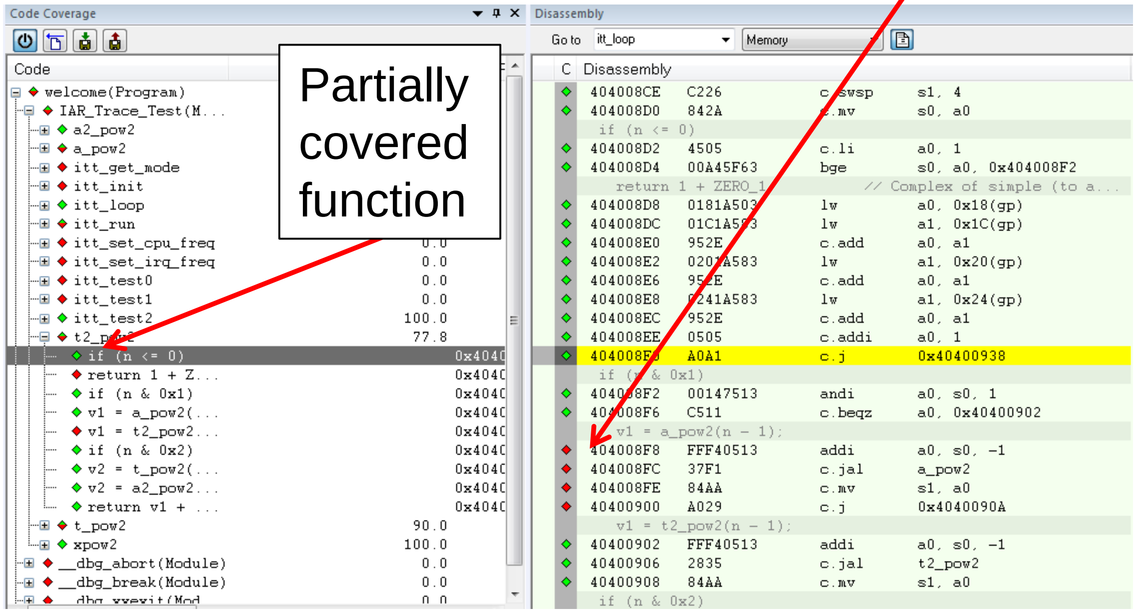


Example of a Timeline combining the call stack and interrupts and variable logs

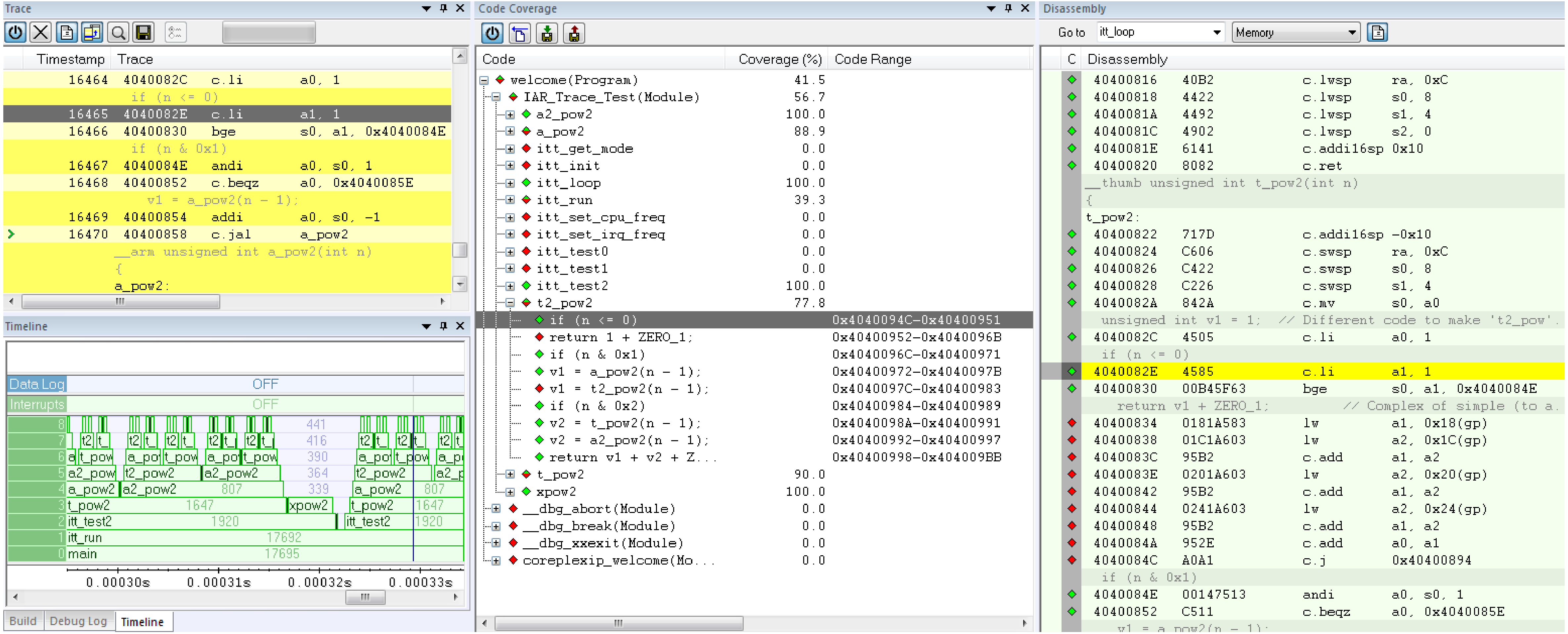


Code quality

- Performance monitoring
  - Trace can help you see where your application is spending its execution time
    - Excessive interrupts?
    - Not responding fast enough?
  - Trace can provide cycle-accurate counts
- Code coverage
  - Proves code has been exercised at least once
  - Isolate dead code / show test deficiencies
  - Functional safety certifications strongly recommend code coverage
- Trace and a static code analysis tools is a good complement
  - Ensures code compliance with branch specific standards and best programming practices
- Silicon vendors provide a lot of BSP code – you better know how it really runs!



Everything together (synchronized)



Thank you for your attention!

iar.com