CAN as trace source

Code and data trace allow a limited view of real-time behavior of embedded systems. Complex systems with more than one core as well as powerful peripherals only become controllable with new trace technologies.

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Reference
[1] The Nexus 5001 Forum Standard for a Global Embedded Processor Debug Interface Version 2.0;
http://www.nexus5001.org

On-chip trace has been established as the state-of-the-art technology for debugging and comprehensive system analysis. It is commonly used for testing and performance measurements. Apart from a few exceptions, most microcontroller architectures are available with on-chip trace and all major debug tool vendors promote their support. In general the term 'on-chip trace' means the recording of instruction executions – known as instruction trace – and the recording of data transfers between cores and memories and on the system networks – known as data trace. To meet the customers' requirements for global system observability, major silicon vendors have extended their trace solutions and added signal trace for peripherals like CAN controllers, which are important for debugging, testing, and comprehensive system analysis.

Peripheral trace of Infineon's Aurix

With the Aurix family, Infineon has introduced powerful automotive microcontrollers onto the market during the last year. The combination of three TriCore 1.6 CPUs, a lockstep mechanism and an access permission system makes Aurix suitable for powertrain applications demanding high performance and sophisticated security features. A range of peripherals matches present car drives including hybrid and electrical vehicles.

Debugging and system analysis of such microcontrollers requires sophisticated on-chip debug support and trace. Henceforth for run-time analysis not only program and data trace from cores and busses are needed, but also a bunch of single-bit and multi-bit signals from peripherals have to be taken into account. The challenge was to extend the trace solution to meet these requirements. However with up to a few hundred single-bit signals which want to be part of the trace output, the trace hardware put on the die and not least the trace port come to their limits very quickly. The only way out is to limit the amount of signals coming out of the peripherals according to the actual debug use-case.

For that purpose Infineon has extended the On-Chip Debug System (OCDS) of the Aurix MCUs with a trigger switch (Fig. 1). It allows transfering selected bunches of signals from peripherals to different sinks of the debug system. One of those sinks is the Multi-Core Debug Solution (MCDS) – the trace system of the present Infineon microcontrollers. The vast number of accrued data is preselected by means of multiplexer cascades. Typically sets of 16 or 32 bit signals form so called trigger sets. While the containing signals are fixed for each trigger set, selected trigger ▷

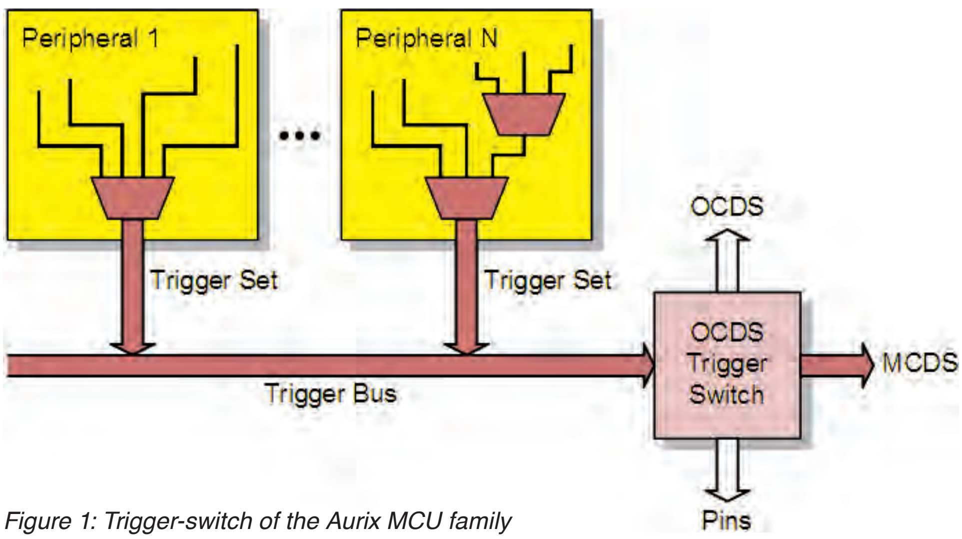

Figure 1: Trigger-switch of the Aurix MCU family

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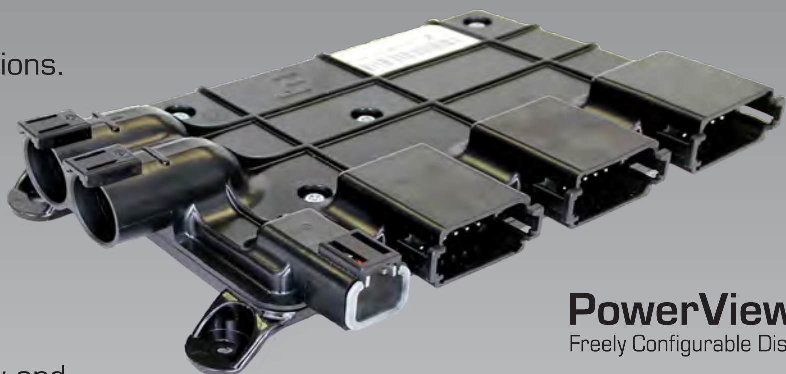

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sets are then transferred by OCDS trigger busses to the internal trace interface. The trace interface itself does not know anything about the origin and content of the trigger sets. It just sees data packets. Therefore, when the captured trace data is decoded, the tool needs to know the actual configuration of the multiplexers and which trigger sets are selected to be part of the trace data.

Peripherals like Flexray, DMA controllers, and CAN of course influence run-time behavior. The integration of their debug signals into the trace system – which is called signal trace in the following – allows reconstructing an almost complete system state via the debug tool and the observation of interactions between CPUs and peripherals.

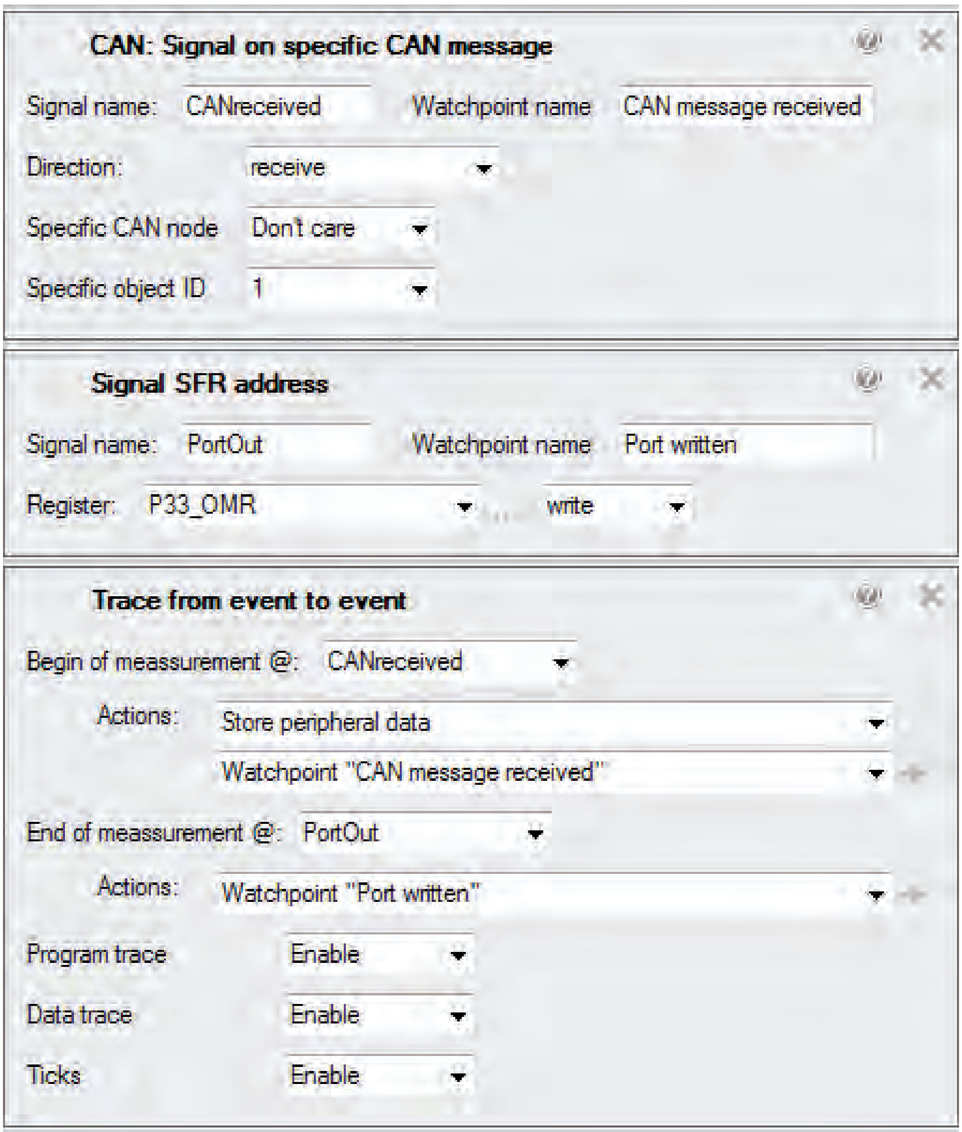

Figure 2: Graphical configuration of a mixed program and signal trace

Managing data floods

We have seen that with the new trace sources – the peripherals – a lot of additional trace data becomes available. However this data flood is hardly controllable. The on-chip debug hardware alone doesn't have the performance to capture all the data and put them off-chip to the debug tool. On chip data are already filtered to keep the required bandwidth for the trace to be reasonable. Of course this is also a matter of analysis efforts. The bigger the information flood the more difficult it is for the tool and in the end for the developer to identify possible functional errors or performance bugs.

A comparatively easy method to configure the multiplexers and filter mechanisms of the Aurix on-chip trigger switch and MCDS is to use the Universal Emulation Configurator (UEC). UEC is part of the Universal Debug Engine (UDE) from PLS and has been in use for powerful on-chip trace units with comprehensive trigger and filter mechanisms for years. The flexible concept behind UECs allows a combination of 'common' program and data trace with the new signal trace. That way a trace task can be created completely with one single tool without the need to separate between on-chip trigger switches and MCDS.

Of course, the combination of program or data trace and signal trace from peripherals provides benefits if a certain event or interaction between different parts of the controller is of interest. As an example, with trace the time an interrupt service requires from an incoming CAN message to respond with a signal on an external port pin can easily be measured. The on-chip trace recognizes a particular message on the CAN network – it is even possible to filter for the origin and message type – and starts the trace recording. The write access to the port pin is visible to the trace unit as well and can be used as an event to stop the trace. Figure 2 shows the trace task configured with the graphical editor of the Universal Emulation Configurator (UEC). Apart from the time measurement the configuration contains the setup for a complete program and data trace as well. For trace analysis all captured trace data from different trace sources are merged and displayed in a combined view (Fig. 3).

Will signal trace become mainstream?

That is an interesting question. For industrial and automotive applications, signal trace is for sure an important extension to the controller's debug functionality. However you only get these things with some investments in hardware and tools. To keep the hardware costs within limits Infineon pursues their concept of two different controller types: an emulation device with all the additional hardware for high level debugging and trace and a production device to be built in the products only with basic debug support.

Apart from Infineon with its MCDS, another important player in the area of ▷

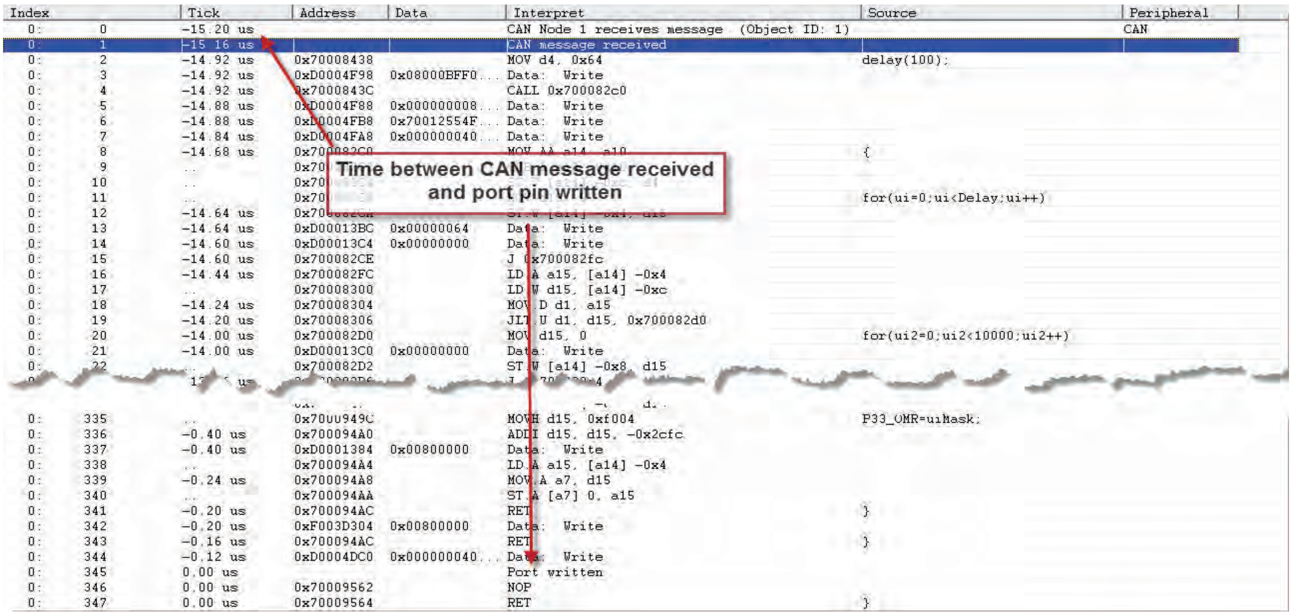

Figure 3: Measurement of latency of an interrupt service triggered from CAN message with program and data trace information as well as signal trace of CAN controller

trace support for industrial and automotive controllers is the Nexus forum [1]. They recognized the need for signal trace too and extended the revision of the Nexus standard 2012 with a new trace type called 'in-circuit trace'. However the CAN network as well as other peripherals are still not attached to the trace system of current Nexus implementations.

For sure the coverage of peripherals by the trace system is an important step forward to fully testable embedded applications. With that, trace becomes more and more an instrument for system analysis of complex and complete systems-on-a-chip and not only for the cores. Now the mission for tool vendors like PLS is to provide software tools like the Universal Emulation Configurator, which allow to fully utilize trace features and to unrestrictedly define tailor-made measurement tasks. ◀