



Audio Playback Control Development

- **Model-based audio playback development at Delphi**
- **Stateflow logics for behavior, error handling, and communication**
- **Efficient production code generation with TargetLink**

Audio playbacks are mechanisms that read data from a storage medium, such as CD digital audio, CD-R or MP3 disc, and produce commands and signals that an audio system turns into music. Playbacks are constantly changed to meet market demands, requiring the control software to be updated quickly and efficiently. A development team at Delphi demonstrated working units running production-ready code within 12 months by using model-based design and automatic production code generation with TargetLink from dSPACE.

A modern radio is constructed of building blocks, such as the AM/FM tuner, the human-machine interface (HMI), communications, the playback mechanism, and so forth. The various building blocks are run as tasks, controlled by the operating system (OS). The OS calls these tasks, based on assigned priorities and interdependencies triggered either internally or in response to button-presses or media insertions on the radio faceplate. Audio playback mechanisms ("playbacks") are typically the most complex building block in a radio. Aggressive price-cutting by playback vendors and a steady flow of new functions

and requirements all drive rapid change. To handle changes of such complex products, radio suppliers must accelerate software development, testing, and implementation for playbacks. Modular design within a universal architecture is a design goal, using customizable building blocks from a reuse library.

Special Challenges

The interface between the main board and the playback is typically a low-end microprocessor sending and receiving digital communications messages in two directions using a protocol such as Inter Integrated Circuit (I²C). Despite communication standards, playbacks vary in their implementation of I²C or other protocols – a problem usually related to the low level drivers. A further difficulty is the fact that not all digital audio CDs follow the Red Book industry standard, since numerous widely available CD burning programs do not comply. If every CD followed the standards and never received a scratch, if every playback worked perfectly, and if no driver allowed their children to insert hotel keycards into their car radios, playback control would be a straightforward task.

Behavior Modeling

Playbacks execute typical commands known to all users of modern audio devices, such as: load, eject, play, stop/pause, scan, fast forward/reverse, seek up/down (track and/or folder), and options such as shuffle. The functionalities which are evoked in response to these commands are called behaviors. The logic for behaviors, error behavior and communications is captured in Stateflow® Interfaces, and control signals are captured in Simulink®.



▲ Example of a modern navigation radio consisting of several building blocks.

Efficient Code Generation Process

Upon completion of unit testing, we used the production code generator TargetLink to automatically generate ANSI compliant C code. A data dictionary, developed in-house at Delphi, was employed to capture engineering variable characteristics and to map software variables to hardware I/O. TargetLink provides automated documentation in HTML format, which facilitates reading and review of the generated code.

"Using TargetLink, code was generated and tested in just a fraction of the time that is typically required for hand-code implementation of the same algorithm."

Lev Vitkin, Delphi Electronics & Safety

A comparison of bytes for hand-code (14903 bytes) versus automatically generated code (12437 bytes) shows an improvement of about 17%.

Lessons Learned

Near the project endpoint, a new playback unit was being considered. As a test case, we adapted the interfaces to the new unit in only four hours. This demonstrates the considerable time savings possible with a modular architecture, reusable building blocks and customizable, adaptive interfaces.

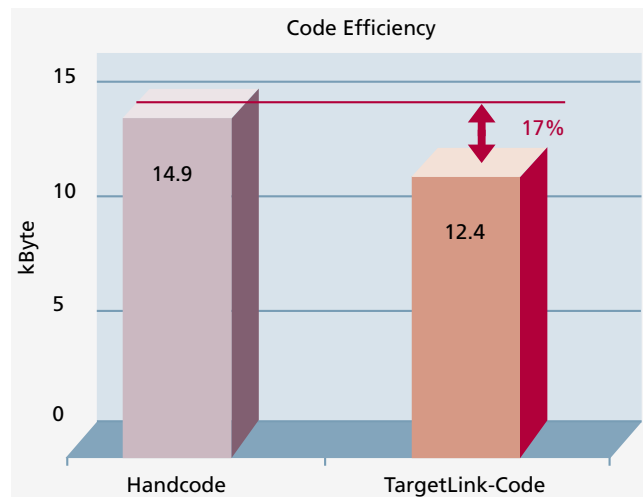
Benefits

We found that the visual nature of the architecture made it accessible to high-level managers and less-technical supervisors, as well as facilitated technical discussions amongst our team. We found legacy code easy to integrate with either Stateflow or TargetLink. Code was generated and tested in just a fraction of the time that is typically required for hand-code implementation of the same algorithm.

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▲ Radio user interface for virtual control.



▲ Comparison between handcoded software and code generated with TargetLink for identical function models.

Glossary

Red Book –

The standard for audio CDs is defined in the Red Book. It is named after one of a set of color-bound books that contain the technical specifications for all CD and CD-ROM formats. It was ratified as IEC 908.

Inter Integrated Circuit (I²C) –

A multi-master serial computer bus that is used to attach low-speed peripherals to devices like a motherboard or embedded system.

Reference:
Model-based Development
for Event-driven
Applications using
MATLAB: Audio Playback
Case Study, SAE World
Congress 2007, paper
2007-01-0783