Generating Optimized Code for Embedded Microcontroller Algorithms

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Key Takeaways

1. Reduce costs by minimizing hardware resources
2. Create innovative products by maximizing algorithm content
3. Expand code generation use to more applications (e.g., 8-16 bit)

“Embedded Coder generates optimized code that is as good as we can write, and we’ve never had any problems with defects in the generated code.”
Dr. Robert Turner, ABB

ABB Accelerates the Delivery of Large-Scale, Grid-Connected Inverter Products with Model-Based Design

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Challenges

- Difficult to fit modern algorithms into low-cost production hardware
  - Limited ROM, RAM, stack, and speed
- Not known a priori during design, what embedded device is required
  - Need optimal implementation
- Hand coding is process bottleneck
  - Adds bugs, delays, iterations

“The advantages of Model-Based Design over hand-coding in C can’t be overestimated.” Kazuhiro Ichikawa, Ono Sokki

Ono Sokki Reduces Development Time for Precision Automotive Speed Measurement Device
Solutions

Optimization Techniques:
1. Use optimal settings
2. Minimize data sizes
3. Target vector engines
4. Select best processor(s)
5. Reduce data copies
6. Optimize Using Min & Max Values
7. Reuse components
8. Identifying clones in model
1. Use Optimal Settings

Select your most important code generation objective.

- Execution efficiency
- RAM efficiency

Key Feature: Embedded Coder Quick Start
2. Optimize Data Types

Key Feature: Single Precision Converter
3. Target vector engines

Key Feature: Code Replacements
PIL Benchmark Results for ARM Cortex-A

Run Format: [ANSI or Ne10], [gcc no opt or gcc -02], ARM 1Ghz Cortex A8

Example: FIR Filter
4. Select best processor(s) for your application

- Portable code: any device for algorithm code generation

- Support packages for target-specific system executable generation
  - ARM … Zynq

- Hardware vendors offer their own target packages
  - ADI, Infineon, Microchip, NXP, Renesas, TI, STMicroelectronics
Results for PMSM Motor Control for ARM cores - Average and Max Execution Time

Processor Benchmarks for Task0 of pmsmfoc

- **Cortex-A8**, 1 GHz, Linux OS, NE10 DSP Libs
- **Cortex-M7**, 216 MHz, Bare metal, CMSIS DSP Libs
5. Reuse data

```c
void Subsystem(void)
{
    ...
    for (i = 0; i < 100; i++) {
        Reuse[i] = 2.0F * Reuse[i] * 20.0F;
    }
    fcn3(&Reuse[0]);
}
```

Key Feature: Reusable Storage Classes
6. Optimize Using Min & Max Values

- These minimum and maximum values usually represent environmental limits, such as temperature, or mechanical and electrical limits, such as output ranges of sensors.

- Software uses the minimum and maximum values to derive range information for downstream signals in the model.

- This derived range information is used to determine if it is possible to streamline the generated code by, for example:
  - Reducing expressions to constants
  - Removing dead branches of conditional statements
  - Eliminating unnecessary mathematical operations

- This optimization results in:
  - Reduced ROM and RAM consumption
  - Improved execution speed
Configure Model

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6. Optimize Using Min & Max Values

Code generation

Optimize using the specified minimum and maximum values

\[ r_{tb\_Sum} = U_1 + U_2; \]

\[
/* \text{Gain: '<S9>/Gain' incorporates:} \\
* \text{Import: '<Root>/U3'} \\
*/
\]

\[ r_{tb\_Sum2} = \text{Code\_Optimization\_P.Gain\_Gain} \times U_3; \]

\[
/* \text{RelationalOperator: '<S9>/Relational\_Operator' incorporates:} \\
*/
\]

\[ r_{tb\_RelationalOperator} = (r_{tb\_Sum} \leq r_{tb\_Sum2}); \]

\[
/* \text{Switch: '<S9>/Switch1' incorporates:} \\
*/
\]

if (r_{tb\_RelationalOperator}) {
\[
/* \text{Sum: '<S9>/Sum4' incorporates:} \\
* \text{Import: '<Root>/U1'} \\
* \text{Import: '<Root>/U2'} \\
* \text{Import: '<Root>/U3'} \\
*/
\]

\[ r_{tb\_Sum2} = (U_1 + U_2) + U_3; \]
}

else {
\[
/* \text{Product: '<S9>/Product' incorporates:} \\
* \text{Import: '<Root>/U1'} \\
* \text{Import: '<Root>/U2'} \\
* \text{Import: '<Root>/U3'} \\
*/
\]

\[ r_{tb\_Sum2} = U_1 \times U_2 \times U_3; \]
}
7. Reuse components

Key Features: Subsystem Reuse and Simulink Functions
8. Detecting Clones in model

Key Feature: Simulink Clone Detection
8. Thrift Logic (Prove)

Key Feature: Polyspace Code Prover
Solution Summary

Optimization Techniques:
1. Use optimal settings
2. Minimize data sizes
3. Target vector engines
4. Select best processor(s)
5. Reduce data copies
6. Reuse components
7. Thrift logic

“The code generated with Embedded Coder required about 16% less RAM than the handwritten code used on a previous version of the ECU; the code met all project requirements for efficiency and structure.” Mario Wünsche, Daimler

Daimler Designs Cruise Controller for Mercedes-Benz Trucks
1. Use Optimal Settings

- Select your most important code generation objective.
  - Execution efficiency
  - RAM efficiency

What to consider:
- Based on your selection, the Quick Start configures your model with the best optimizations for your specified code generation objective.
- After Quick Start code generation is complete, you can fine-tune your optimization settings using the Code Generation Advisor.

Key Feature: Embedded Code Quick Start

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2. Optimize Data Types

Key Feature: Single Precision Converter

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3. Target vector engines

- PIL Benchmark Results for ARM Cortex-A
  - Embedded Code ANSI-C
  - Embedded Code ARM-C (N-CCG optimized)

4. Select best processor(s) for your application

- Portable code for any device
- Support packages for target-specific system executables
- ARM, Zynq
- Hardware resources offer

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6. Optimize Using Min & Max Values

- Code generation
  - Optimize using the specified minimum and maximum values

7. Reuse components

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8. Detecting Clones in model

Key Feature: Reusable Storage Classes

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Key Feature: Simulink Clone Detection

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Key Takeaways

Simulink and Embedded Coder new optimizations let you:

1. Reduce costs by minimizing hardware resources
2. Create innovative products by maximizing algorithm content
3. Expand code generation use to more applications (e.g., Mitsuba Uses Embedded Coder for NEC 78K 8-bit microcontroller)

“When we generated code with Embedded Coder, the team we handed it off to knew it was gold” Maria Radecki, BAE Systems

BAE Systems Delivers DO-178B Level A Flight Software on Schedule with Model-Based Design
Additional Customer References and Production Applications

Honeywell Aerospace, USA
Certified Flight Control Processor

FLIR Systems, USA and Sweden
Thermal Imaging FPGA

Festo AG, Germany
Robotic PLC

GM, USA
Powertrain ECU

Alstom Grid, UK
HDVC Power DSP

Baker Hughes, Germany
Oil and Gas Drill Processor

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Generating Optimized Code for Embedded Microcontroller Algorithms

- **Testing Generated Code in Simulink**
  - This one-day course provides a working introduction to designing and testing embedded applications with Simulink Coder™ and Embedded Coder. Themes of simulation speedup, parameter tuning in the deployed application, structure of embedded code, code verification, and execution profiling are explored in the context of Model-Based Design.

- **Embedded Coder for Production Code Generation**
  - This three-day course focuses on developing models in the Simulink environment to deploy on embedded systems. The course is designed for Simulink users who intend to generate, validate, and deploy embedded code using Embedded Coder.
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