Home Appliance Controls Development using Model Based Design

Presented By: Priti Madurwar, Pranoti Joshi
Content

• About Whirlpool

• Model Based Development Process in Whirlpool

• Case Study: Universal Motor Controls Development

• Organisational Benefits through MBD
About Whirlpool

- World’s leading major Home Appliance company
- Founded over 100 years ago
- ~$21 billion in revenue in 2018
- 92,000 employees and 70 manufacturing and technology research centers
- 1 in 3 employees volunteer for taking care of our neighborhoods and the planet
Limitations of Traditional Software Development Process

The Waterfall Model

- Missing linkage between requirement and software code.
- Unfreeze requirements

- Squeezed timelines.
- Software Integration with cross regional teams in workforce.
- Less readability, difficult debugging
- Variation in implementation method from developer to developer.

- Setup & Maintenance Cost Involved.
- Difficult setup replication.
- Hardware availability.
- Safety of Tester.
MBD process in Whirlpool...Few years Ago

Control Model Development and Code Generation
- Model development in Simulink using Stateflow
- Primary level verification using Signal Builder and m-scripts.

Rapid Control Prototype
- Data acquisition during development phase of control model
- Model verification on machine without dependencies on other software components

MIL/SIL
- Design error checks
- Black Box & White Box Testing for control model
- Both Unit Level and Integrated Level Testing
- Coverage Report Analysis

PLANT MODEL FOR CLOSED LOOP MIL/SIL
- Leveraging physics based Plant Model for closed loop simulation

Requirements

Challenges
- Direct deployment on machine for testing
- Hardware dependency and setup issues
- Safety concerns
- Delayed testing due to other software dependencies

Challenges
- Unavailability of Model Requirements
- Unavailability of inputs that replicate system behaviour (Level Testing)
Current MBD Workflow in Whirlpool

Requirements

Plant Model

MIL/ SIL

Control Model

Rapid Control Prototype

Code Generation & Integration

Verification on machine

FMI Toolkit

Simulink V&V, SLDV

Stateflow, Fixed Point Designer

Stateflow, Fixed Point Designer

Embedded Coder

Whirlpool Corporation - Confidential
Summary of MBD algorithm in different Whirlpool products

![Algorithm Development / Platform Chart]

- Wet Inertia
- UMC
- UM Sensing
- TemperatureControl
- Shifter Feedback
- Sensed Drain
- Plugging
- OWI Calibration
- Defrost ADC
- Convective Defrost
- Airlock
- AGI Torque Detection

Platforms:
- Dishwasher
- HA
- Refrigeration
- VA
Universal Motor Controls Development

- Requirements breakdown
- Class Diagrams for Controller using SysML
- System Engineering Support for development of Universal Motor Plant Model
- Verification at Module level as well as integrated level.
Algorithm Modeling Using Stateflow & Simulink

- Algorithm requirements have been implemented as a Simulink® model
  - Floating/Fixed point, Fixed step size
  - Use most convenient tools (Simulink, Stateflow, MATLAB code blocks)
  - Use referenced model
  - Use of Data Dictionaries
  - Capturing Model Metrics
  - Traceability
Universal Motor and Washer Dynamics Plant Model

Plant Model Development

- Model Based System Engineering team support for Plant Model Development
- Use of Dymola/Modelica environment
- Calibration of Plant Parameters with Real Time Test Data

Open Loop Validation

Closed Loop Validation with Basic Control
Integration of Control Model and Plant Model

- Use of Functional MockUp units for leveraging Dymola Plant Models in Simulink
- Provides Capability to find robustness of the logic at system level.
- Allows to perform System Level verification

Simulink PSP Toolbox till 2016
Inbuilt Simulink FMI kit feature 2017 onwards
Verification and Validation

- **Simulink Model**
  - **Model Requirements in DNG**
  - **Prepare Test Cases for Simulink models linked with DNG Requirement**
  - **Test Case Generation in RQM**

- **Simulink Design Verifier**
  - **Automatic Design Error Check**

- **Simulink V&V**
  - **Test Harness**
    - Harness model allows testing the component in simulation
  - **Coverage Analysis**
    - Decision coverage, condition coverage, MC/DC coverage
  - **Test Report From Simulink Test**

- **Simulink Coverage & Test**
  - Raising defects in RTC and updating results in RQM
  - Produces report analysing Pass/Fail conditions.
Requirement Linking from Simulink to DNG

Configure Requirement Settings

Select Project Area from DNG

Selecting Requirement from DNG

DNG Link of requirement in Simulink

Simulink Implemented link in DNG

Simulink Requirement Toolbox
**Application of Simulink V&V & Design Verifier**

1. Cumulative coverage results on multiple tests

   ![Cumulative coverage results](image1)

2. Identified missing coverage

   ![Identified missing coverage](image2)

3. Traceability between DOORS requirements and Model

   ![Traceability between DOORS requirements and Model](image3)

**Simulink Validation & Verification**

- Check for risks of software design errors prior to implementation
  - Integer overflow, division by zero, range violations, dead logic

**Simulink Design Verifier**

Example: Modify block parameter

- Overflow Identified
- No risk of overflow
- Fix
Code Generation and Integration

Variant Subsystems

Auto-Code Generation

Interface Code

Delivery of complete package to the stream

Toolboxes Used:
Stateflow, Embedded Coder, Fixed Point Designer, Matlab coder, Simulink Coder

Achieving Optimized Code: (reference MATLAB EXPO 2018)

- Use of Model Advisor to apply and establish best Modeling practices
  - MAAB/MISRA C, ISO/IEC Standards etc
  - Simulink and Stateflow guidelines
- Model Advisor Guidelines
  > Model Design Standards for DO-178C/D0-331
  > Model Design Standards for EN 50128
  > Model Design Standards for IEC 61508
  > Model Design Standards for IEC 62304
  > Model Design Standards for ISO 26262
  > Model Design Standards for MAAB
  > Model Design Standards for JMAAB
  > Model Design Standards for MISRA C:2012
Advantages of Model Based Design

- Consistent design flow from conception to implementation using same language
- Detecting errors in early stages of Software Development
- Easy to deploy code in different projects by managing variant subsystems.
- Easy to handle change requests without impact on timelines.
- Very few defects in released softwares
- Early observation for unexpected emergent behavior.
- Good Test Management
Whirlpool Corporation ownership of the Hotpoint brand in EMEA and Asia Pacific regions is not affiliated with the Hotpoint brand sold in the Americas.
THANK YOU!

JOIN THE CONVERSATION

@WhirlpoolCorp
LinkedIn.com/company/Whirlpool-Corporation
WhirlpoolCorp.com