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Airbag Evaluation Platform

FTF-AUT-F0020

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Freescale and Bosch Collaboration

Two automotive leaders jointly enabling emerging markets with evaluation platforms

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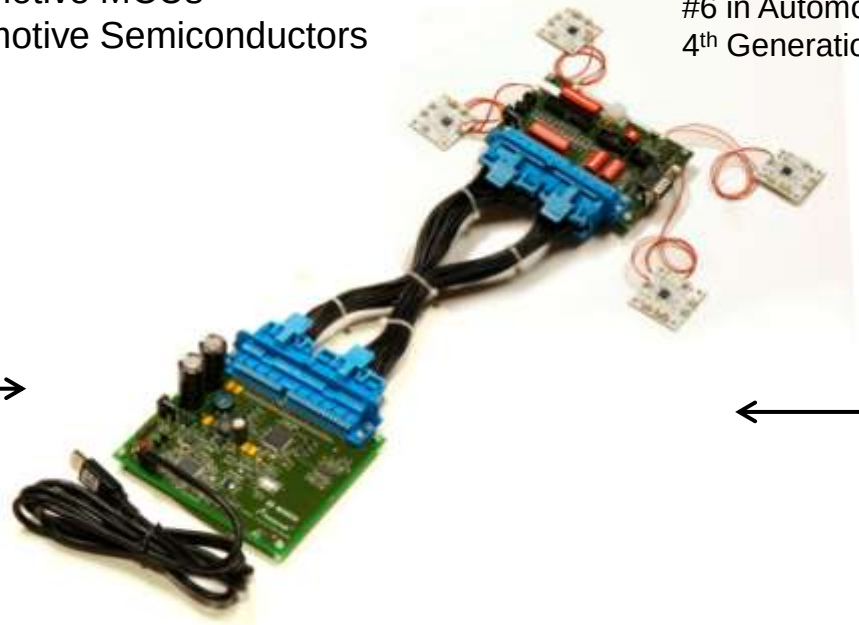
#1 in Automotive Accelerometers
#2 in Automotive MCUs
#3 in Automotive Semiconductors

BOSCH
Invented for life

#1 in MEMS Automotive Sensors
#6 in Automotive Semiconductors
4th Generation Airbag Chipsets



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Overview

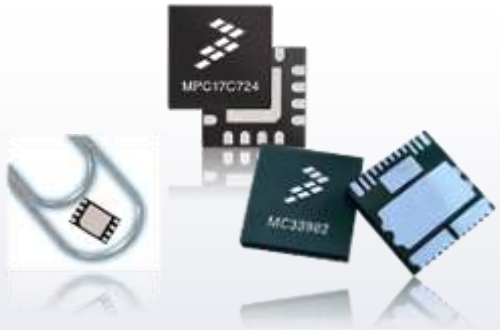
Freescale Automotive Solutions

Microcontrollers & Microprocessors

- Market-leading architectures
- Industry-leading flash technology
- Comprehensive tool and software ecosystem

Sensors

- 25 years experience designing & manufacturing automotive grade MEMS
- Leading integration capability



Analog

- Efficient integration of power, analog and digital on single chip
- Global design capability and a rich library of automotive analog IP

Comprehensive Software Enablement

Integrated, differentiated, production-ready hardware and software solutions

Freescale Runtime Software

AUTOSAR
MCAL & RTOS

Development Tools

CodeWarrior

Market Solutions

Xtrinsic

Qorivva

i.MX

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Portfolio Overview

Bosch Semiconductors & Sensors

Safe

Airbag systems
- Airbag system ICs
- System supply ICs
- Safety controllers
- Firing loop drivers
- Sensor interfaces
- Peripheral sensor devices
- (pressure and acceleration)
- Acceleration sensors
- Angular rate sensors
- Pressure sensors

Vehicle dynamics systems
- Angular rate sensors for VDC
- Acceleration sensors for VDC
- Combined inertial sensors for VDC
- Acceleration sensors for active suspension

In-vehicle communication
- CAN transceivers
- CAN controllers
- PSI5 receivers

Intellectual property
- IP modules

Clean & Economical

Engine management systems
- System basis ICs
- Power supply ICs
- Injection valve drivers
- Low-side power switches
- Multi-Purpose MOSFET Drivers
- A/D converters
- Sensor interfaces
- Ignition stage drivers
- Lambda probe interfaces
- H-bridges
- Barometric pressure sensors

Transmission control systems
- System basis ICs
- System watchdog ICs
- Current regulators
- Shunt evaluation
- Pressure sensors

Electric power steering
- Torque sensor for electric power steering

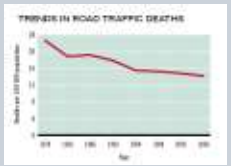
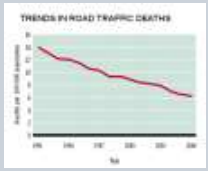
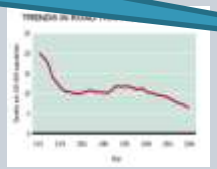
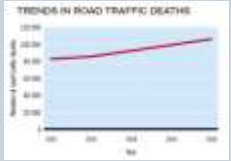
Electric drives control
- Power Modules for (H)EV inverters, Light electric vehicles and Power Steering

Alternator Electronics
- Press fit diodes
- Voltage regulators

Intellectual property
- IP modules

1.2 Million People Worldwide are Killed on the Road Every Year (*) or More Than 3,200 People Per Day …

… 90% of these casualties occur in developing countries

					
Country	**USA**	**Germany**	**Japan**	**China**	**India**
Population	306 million	83 million	128 million	1,336 million	1,189 million
Car Park	251 million	56 million	91 million	145 million	72 million
Road fatalities	~ 40,000	~ 5,000	~7,000	~ 90,000	~ 105,000
Death / 100k people	13.9	6.0	5.2	6.7	8.8
Death / 100k cars				**61.6**	**145**
Trend in road fatalities					

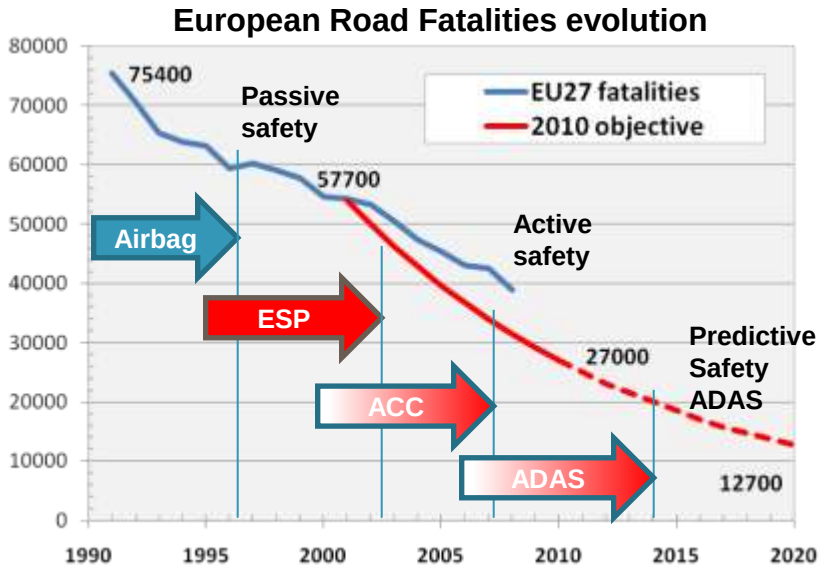
中华人民共和国道路交通安全法
Road Traffic Safety Law of the People's Republic of China

(*) and 50 million are injured

Source: http://www.who.int/violence_injury_prevention/road_safety_status/2009/en

Electronics Provide Improved Safety

- To decrease deaths on the road, a **"Safe System"** approach is required to save lives
- Introduction of **airbags** followed by **active safety** have significantly reduced fatalities in **developed countries**
- **Fast** deployment of **passive safety** systems such as front and side airbags in **emerging countries** is needed



Introducing the Airbag Evaluation Platform

Everything you need
to add your crash algorithm
and make it your airbag solution

Airbag Evaluation Platform
ECU & daughter cards

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Freescale-Bosch Collaboration: Safety for Everyone

Leveraging their global leadership positions and system expertise, the Freescale-Bosch collaboration provides customers with automotive evaluation platforms specifically designed for emerging markets.

Automotive Safety

- Airbags are ranked among the most efficient life saving passive safety applications.
- Increased demand for mobility in emerging markets makes airbags necessary for reducing injuries and fatalities.

Automotive Expertise

- Freescale and Bosch, two global automotive leaders, working in partnership to enable emerging market customers to provide greater occupant safety through airbag evaluation platforms

Validated Design

Airbag Evaluation Platform:

- Speeds time to market
- Affordable
- Meets the latest automotive quality standards
- Complete bill of materials with jointly developed firmware

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Freescale-Bosch Airbag Evaluation Platform - Features & Benefits

Features	Airbag Evaluation Platform	Benefits
Collaboration	Two leading automotive semiconductor suppliers jointly enabling emerging markets with evaluation platforms	Scalable platform solutions covering all major market segments
Quality	Products designed specifically for the automotive market Zero defect methodology AECQ100 qualification	Assured quality
Interoperability	Validated interoperability and safing concept between Freescale Qorivva MCU and Bosch Airbag ASSP, operating with sensors from both partners	Customer choice
Time to Market	Full system development environment available, including hardware (schematics, layout, BoM) and firmware (application example) on which customers can build their own airbag application (crash algorithm)	Fast time to market
Support	Both companies offer regional support in local languages	Local technical support
Scalable Solution	Both Freescale Quorivva MCU and Bosch Airbag ASSP families available with targeted performance and feature sets	Scalable platform solutions covering all major market segments
Highly Integrated Solution	Evaluation platform consists of three major components	Cost efficient solution

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Freescale-Bosch Continuing Collaboration

Airbags

Powertrain

Steering

Automotive Evaluation Platform Common Features

- MCUs
- Sensors
- Analog products
- Communication interfaces
- Bosch ASSPs and sensors
- Jointly developed firmware

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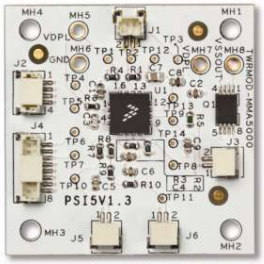
Key Characteristics of the Airbag Evaluation Platform

- **Freescale MPC560xP 32-bit Qorivva MCU family**
  - Scalable MCU family for safety applications
  - e200z0 Power Architecture core @ 64 MHz
  - Scalable Memory , up to 512 KB Flash
  - LQFP Package
- **Bosch CG1xx Airbag ASSP family**
  - Power supply control
  - Satellite sensor interfaces (PSI5)
  - Up to 12 firing loops integrated
  - Analog interfaces
  - Safing Block
- **Working with Sensors from Freescale and Bosch**
- **Benefit for the customer**
  - Safing Concept validated with Bosch and Freescale sensors
  - Fast time to market using airbag application skeleton
  - ECU level debug and test over serial communications interfaces
  - Fully supported application level debug and test using microcontroller system



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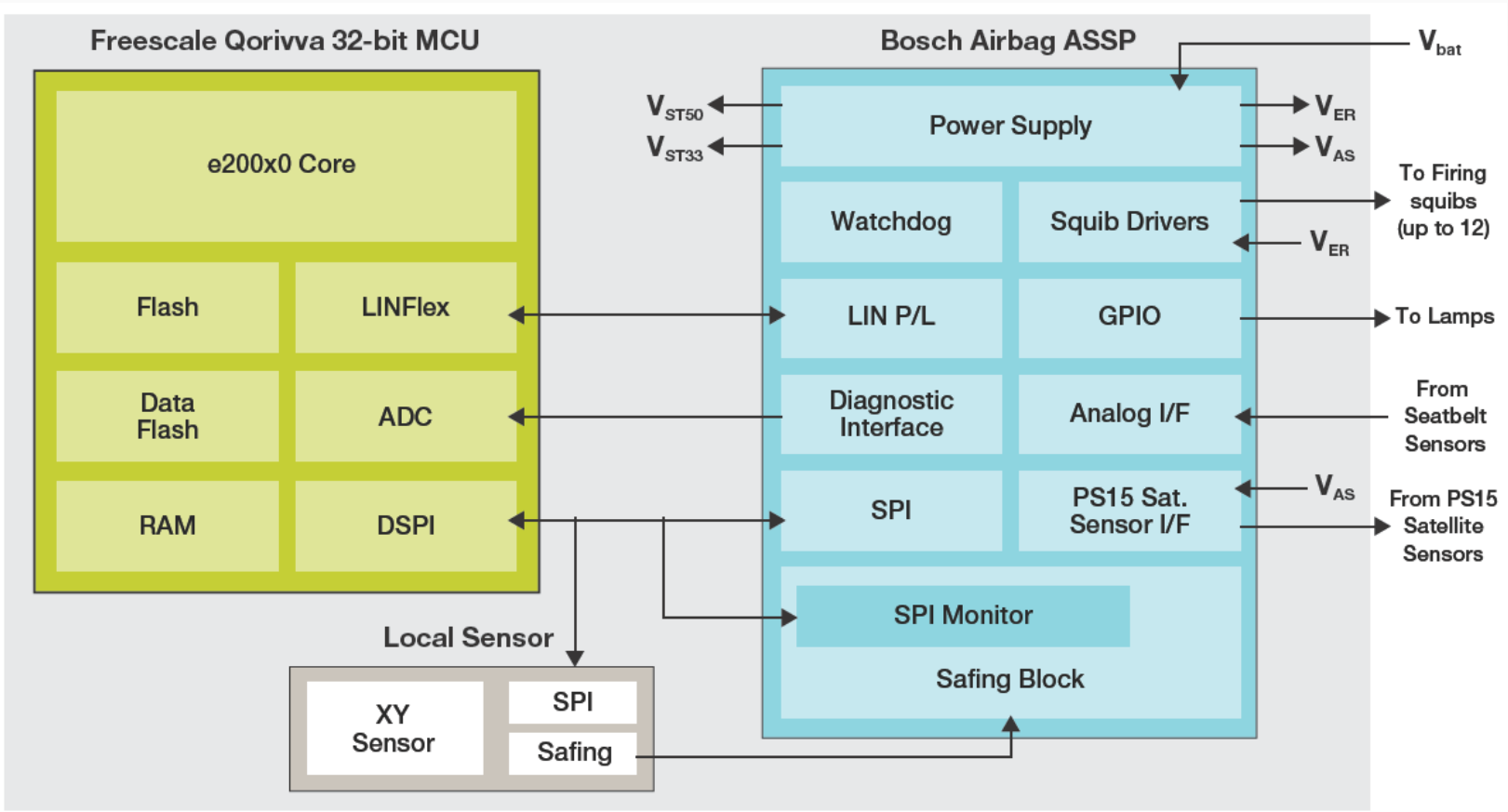
Platform

Airbag Evaluation Platform



Qorivva MPC50xP Automotive Microcontroller

- Power Architecture® technology
  - High-performance 64 MHz e200z0h CPU
  - 32-bit Microcontroller with Variable Length Encoding (VLE)
- Fail safe protection
  - Programmable watchdog timer
  - Junction temperature sensor
  - Non-maskable interrupt
  - Fault collection unit
- Capacity
  - As much as 512 KB on-chip code flash memory
  - 64 KB for EEPROM emulation (data flash),with ECC, with erase/program controller
  - As much as 40 KB on-chip RAM with ECC
- One of the Freescale SafeAssure solutions

http://www.freescale.com/webapp/sps/site/homepage.jsp?code=SAFETYPRGRM

Bosch CG147 Airbag System Chip

- Advanced Airbag System Basis Chip
  - Power Supply for the complete ECU
  - 4 independent PSI5 channels
  - Asynchronous and Synchronous Mode for PSI5
  - Up to 12 Firing Loops integrated
  - Up to 6 analog interfaces
  - Safing with 3 watchdogs
  - High speed SPI interface to MCU

Freescale Sensors

Central Acceleration Sensor

MMA65xx: Dual Axis XY SPI Airbag Sensor

- 12-bit resolution
- Mid-G accelerometer (up to 120Gs)
- Twelve selectable independent low-pass filters
- Optional offset cancelation
- 6x6 mm

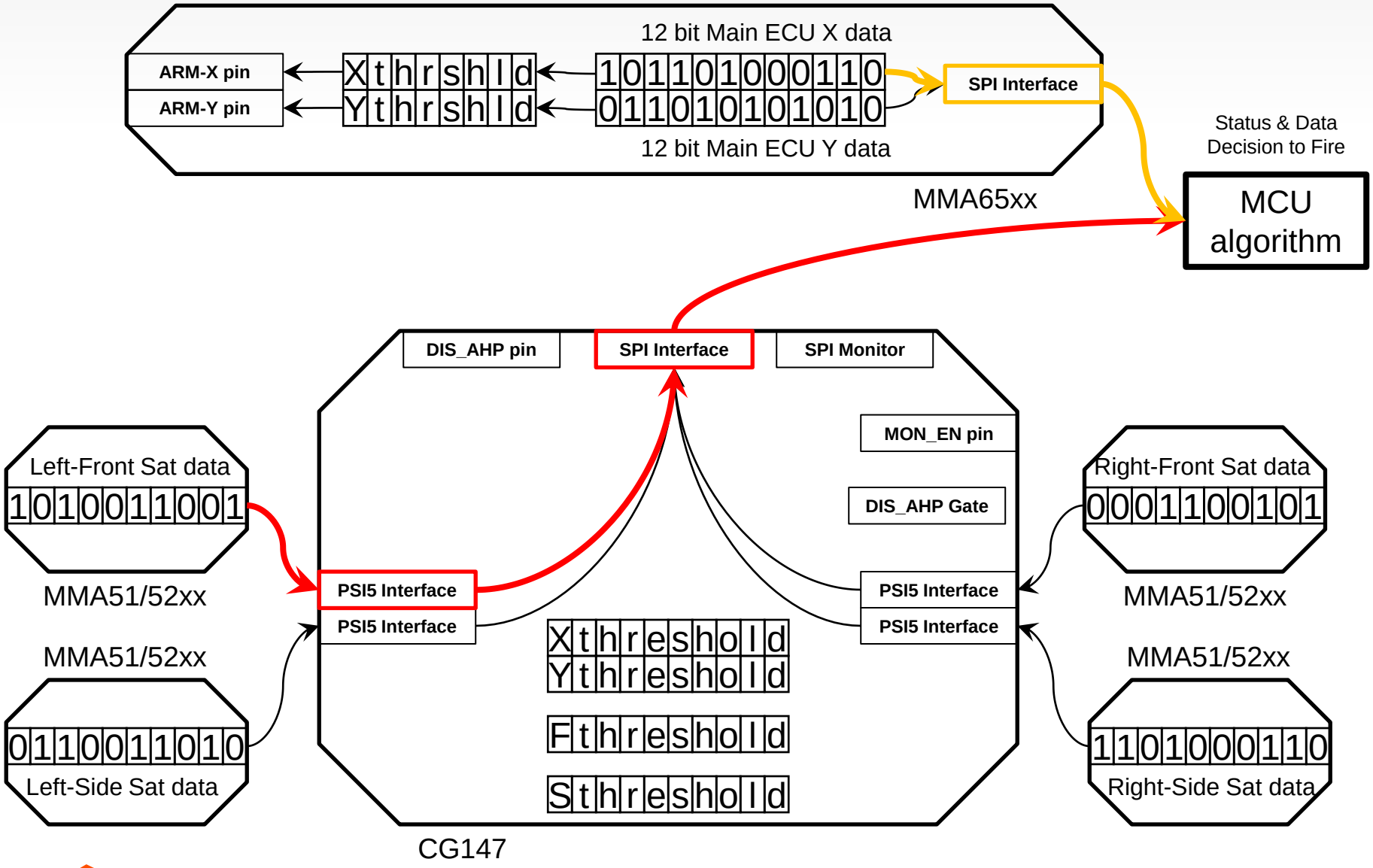
Satellite Acceleration Sensor

MMA51xx: Single Axis Z PSI5 Airbag Sensor

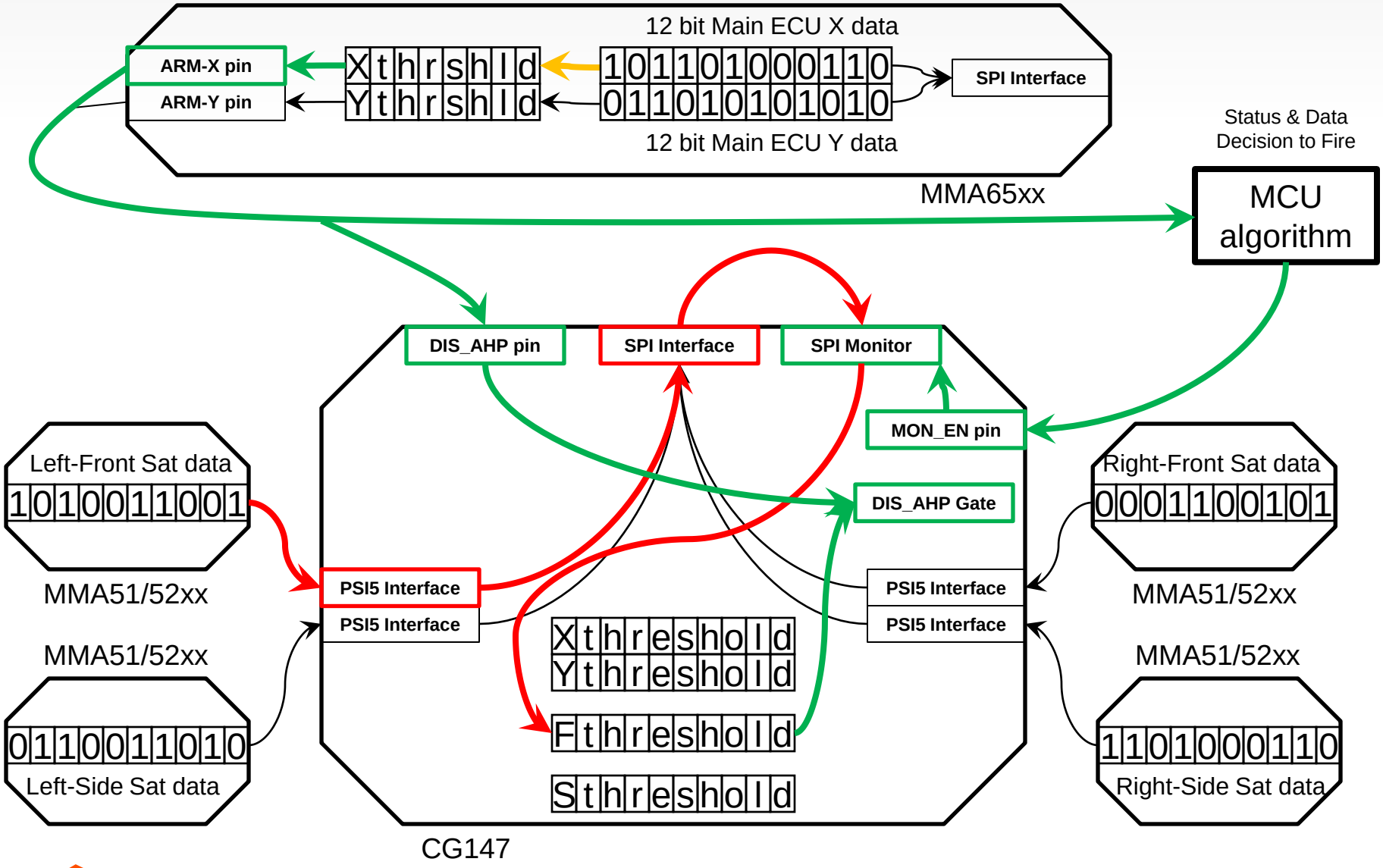
MMA52xx: Single Axis X PSI5 Airbag Sensor

- 10-bit resolution
- Hi-G accelerometer (up to 480Gs)
- 3- or 4-Pole Low-pass filter
- 16 usec sampling rate
- 6x6 mm

Impact Detection Data Path Example



Safing Data Path Example



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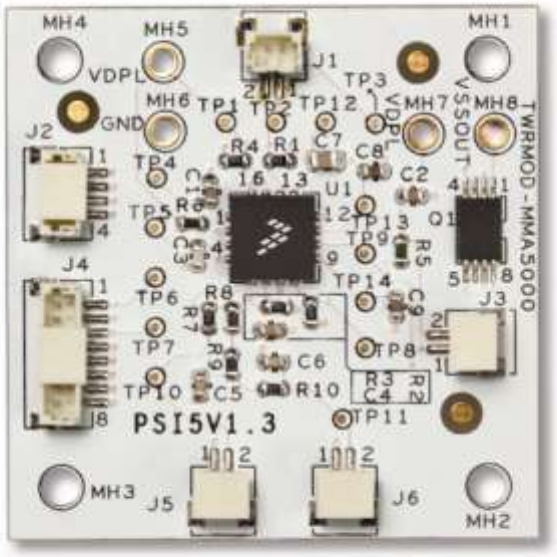
PSI5

PSI5 Key Features

- PSI5 is an open standard
- Two wire interface for power and signaling
- Bi-directional messaging up to 189kbits/s
- Up to 189kbit/s sensor to ECU
- ECU to sensor dependant on bus sync period
- Single-ended output drive operation
- Low cost wiring implementation – twisted pair
- Up to 4 sensors per interface (at 189kbit/s)
- Typically 1-3 sensors used per interface at 125kbit/s

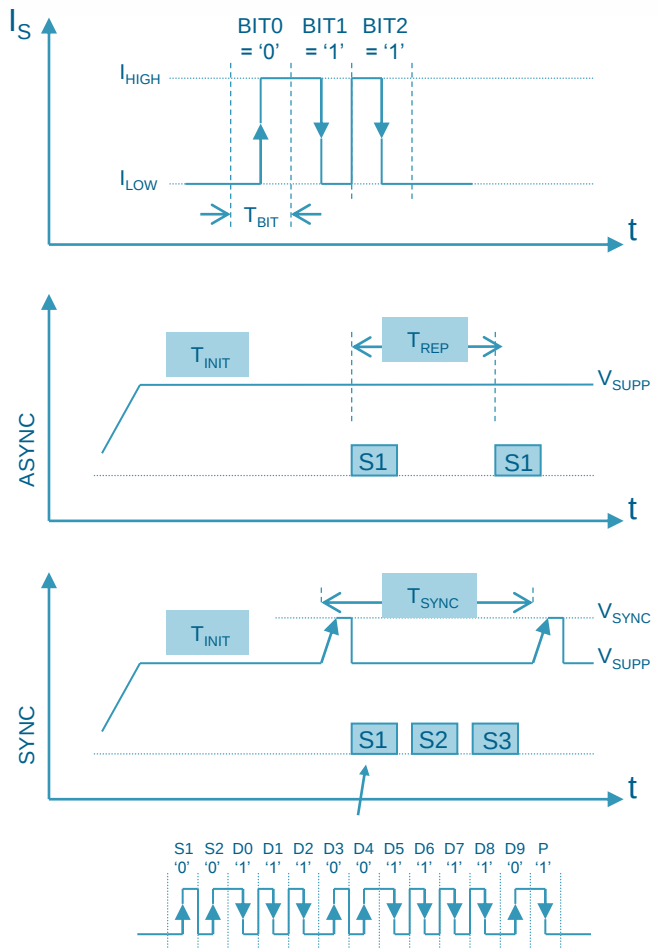


Airbag System Satellite Sensors

PSI5 Data Transfer

Sensor to ECU – Manchester Encoded Current Modulation

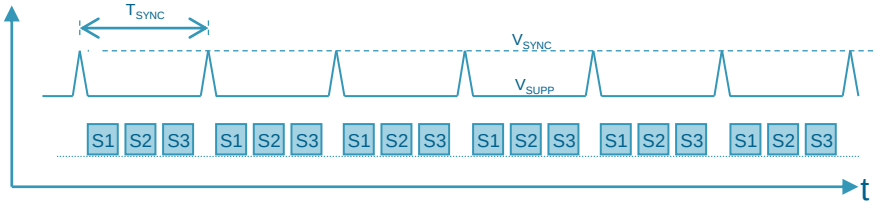
- Current modulated data transfer from sensor to ECU
- Manchester encoded
- High noise immunity
- Asynchronous Mode
- Single sensor (point-to-point mode)
- Sample rate set by sensor (typ 228µs)
- Synchronous Mode
- Multiple sensors (bus mode)
- Voltage modulated sync pulse from
- ECU to sensors sets sample rate
- VSYNC typically 2 * VSUPP
- Example configuration:
- P10P – 500/3L
- 3 sensors connected in parallel, 125kbit/s data rate
- Sample rate 2kHz (TSYNC = 500µs)
- 2 start bits, 10 data bits, parity



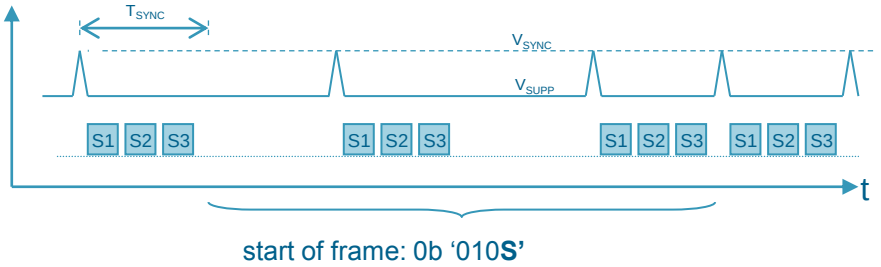
PSI5 Data Transfer
ECU to Sensor – Voltage Modulation

- ‘sync’ pulse used for bit encoding
- sync pulse present, logic high ‘1’
- sync pulse absent, logic low ‘0’
- Command word data rate depends on network sync period (TSYNC)
- For typical TSYNC = 500us, command
- Word data rate is 2kbps
- Start of frame pattern signals that a command is being sent to sensors
- During a command phase, sensor can respond to the sync pulse in normal way when it is present

Uni-directional data transfer – normal operation



Bi-directional data transfer – start of frame



start of frame: 0b ‘010**S’**

PSI5 Feature Summary

Feature	PS15 (V1.3)	Comment
Maximum data rate	189kbit/s	Typically 125kbit/s used
Bi-directional data	yes	ECU to sensor data rate restricted to sync period
Differential data	No	Two wire interface
Bus architecture	parallel/ daisy-chain	Daisy-chain option dependant on sensor
Number of sensors	4 max (1-3 typical)	189Kbit/s only
Cost	low	Power and data over two wires
Power consumption	low	Synchronous operation, low average power consumption

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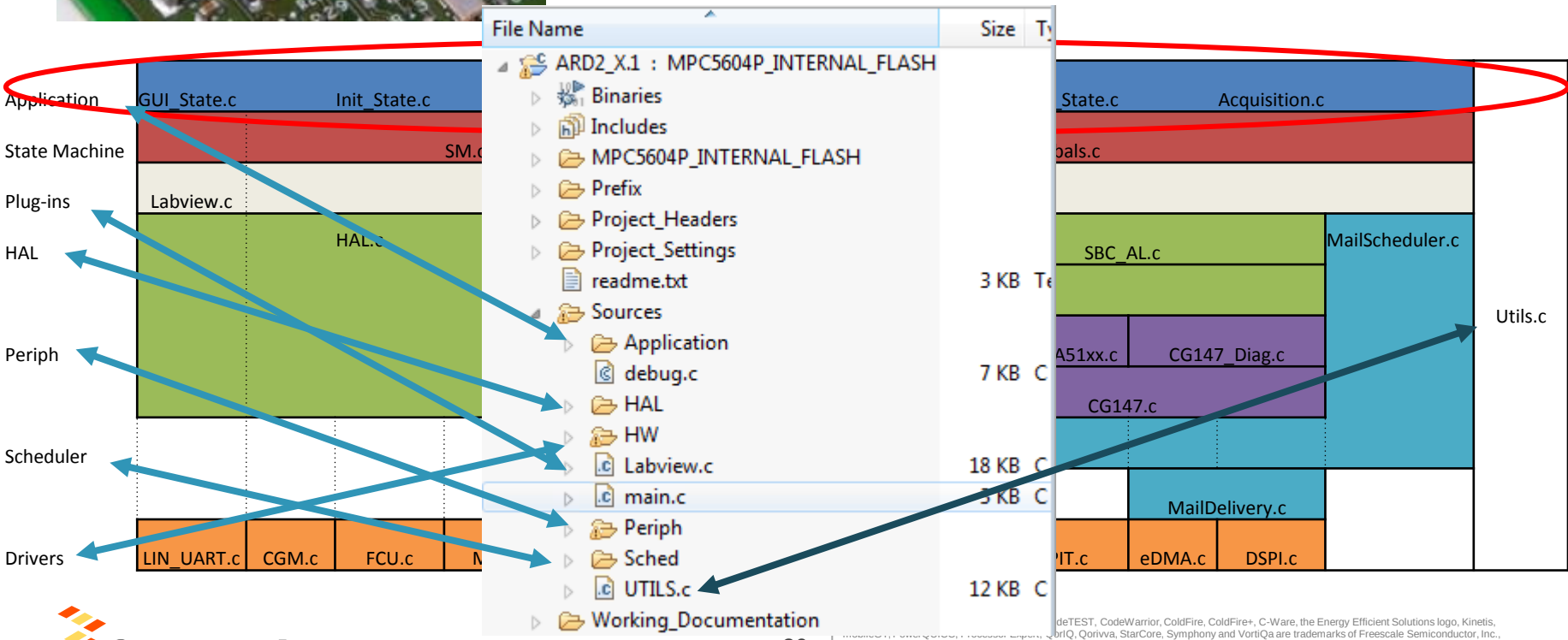
Software

MCU Software: Architecture

- Custom State-Machine running under Airbag-Application
- Abstraction layer for peripherals (CG147 and Sensors)
- Periodic tasks taken care of by a custom scheduler
- Drivers for used hardware modules



MCU Software: Airbag State Machine

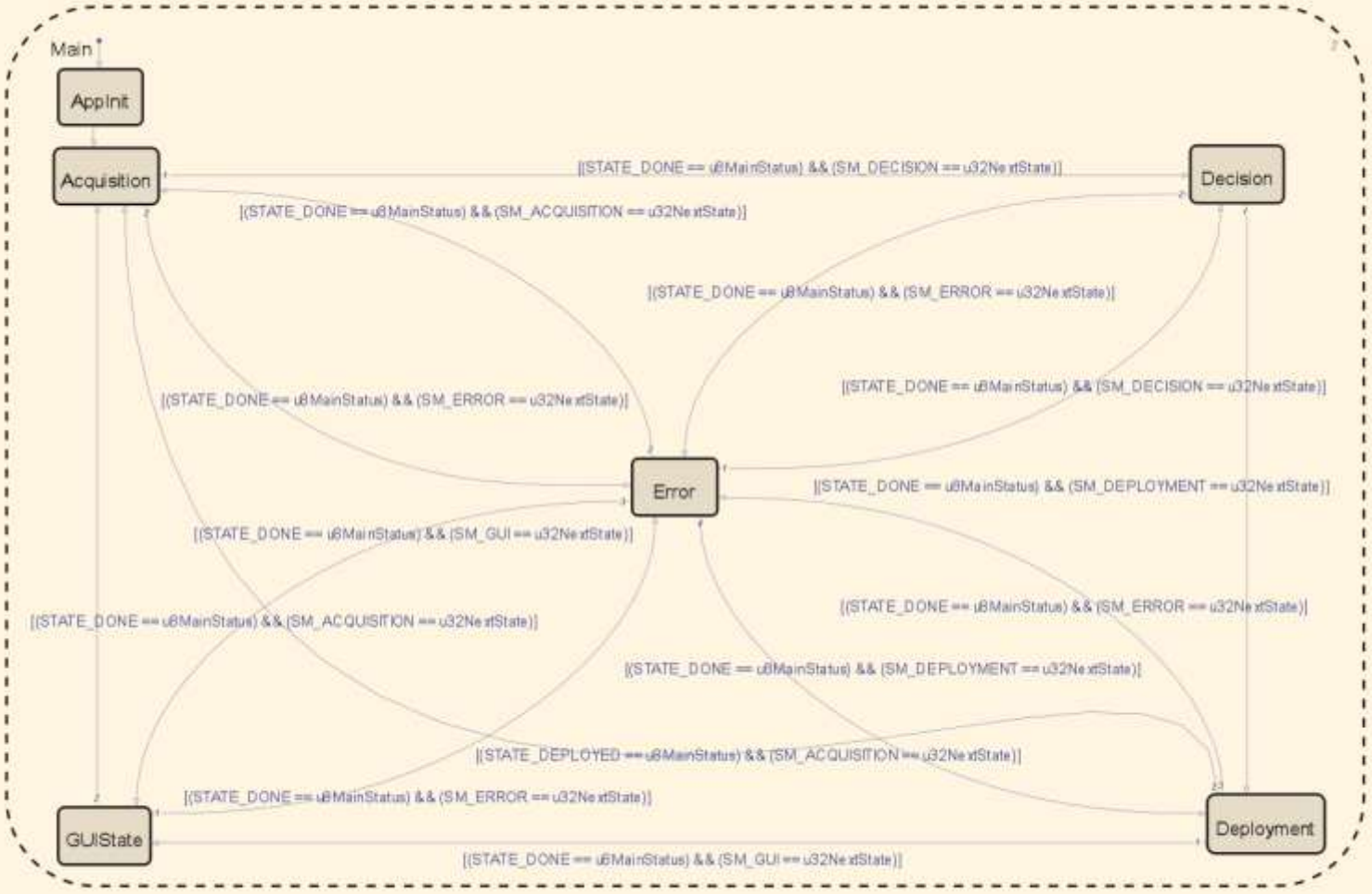
6 States:

1 run-once:
- AppInit

4 cyclic:
- Acquisition
- Decision
- Deployment
- GUIState

1 Error

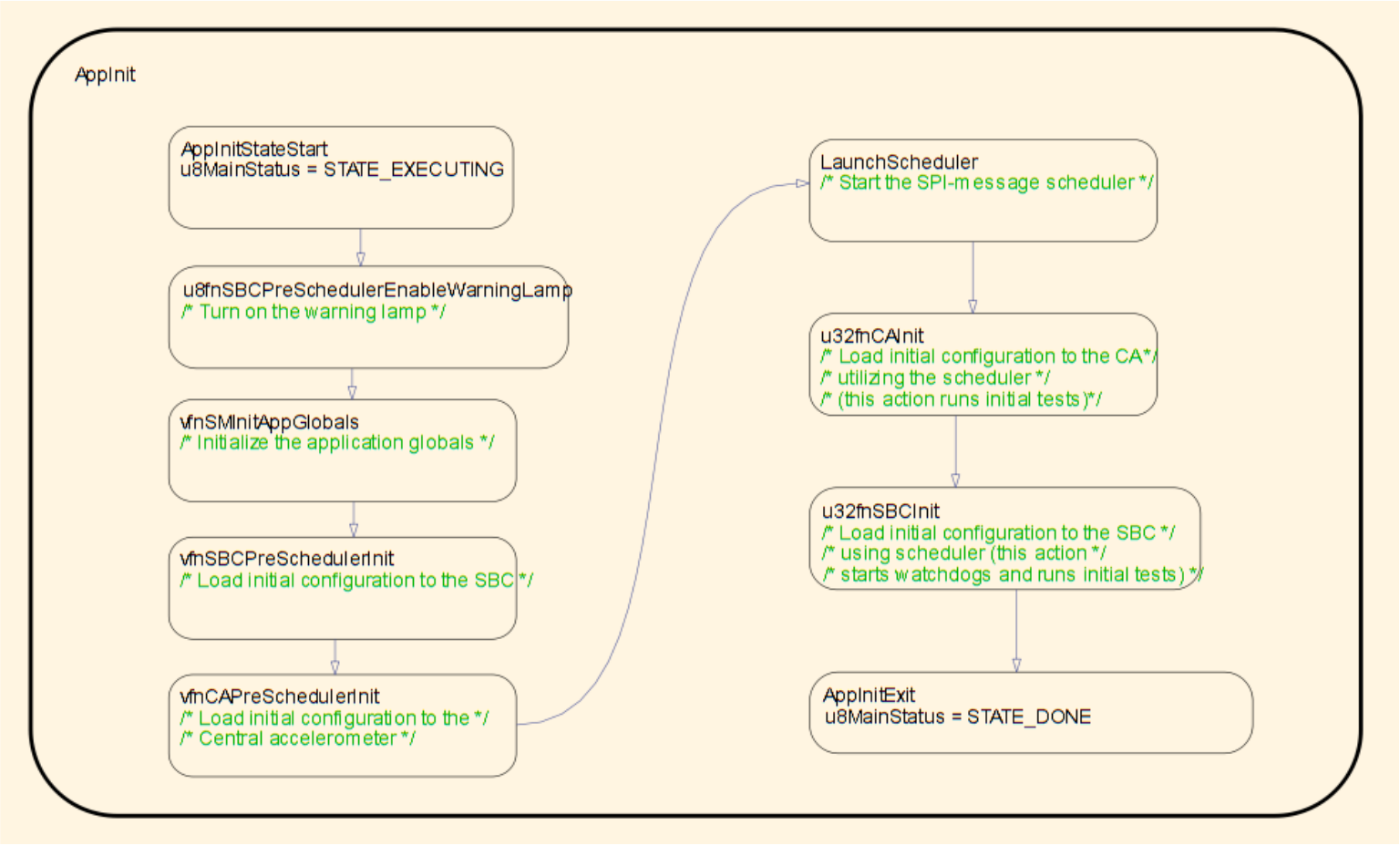
A complete cycle must be executed in 500 usec!



* GUIState is exclusive to the demo and not representative of a real application

MCU Software: Airbag State Machine: AppInit

Boots everything & performs startup tests



List of startup tasks

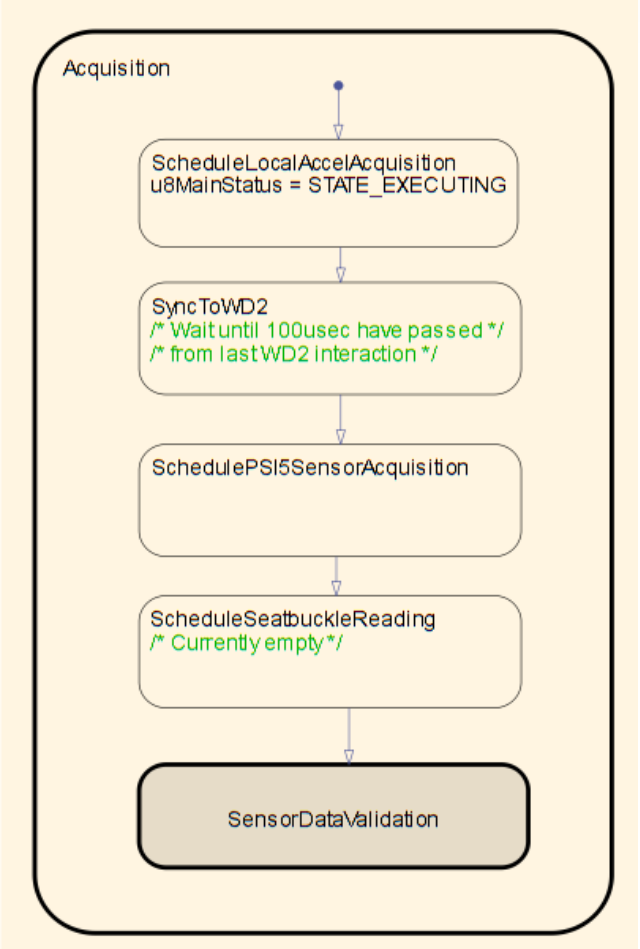
- **SBC:**
  - Initialize watchdogs
  - Startup PSI 5 lines
    - Gather PSI5 satellite data
    - Verify received satellite data vs. expected
  - Test capacitor power retention
  - Test internal ADC & MUX vs. reference levels
  - Verify squib status

- **Central accelerometer**
  - Pre-self test offset verification
  - Power-on self-test (MEMS deflection)
  - Post-self test offset verification

- **MCU**
  - Fault Collection Unit (FCU) is turned on and routed to a pin with a LED.

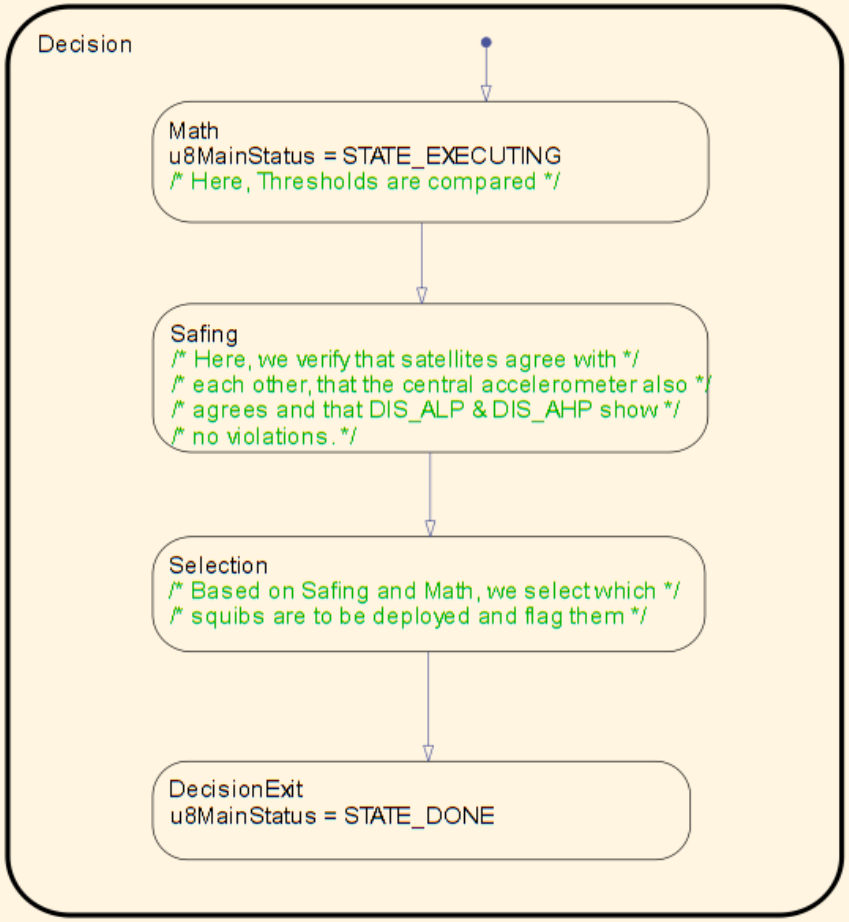
MCU Software: Airbag State Machine: Acquisition

- Gathers satellite sensor data
- Obtains central accelerometer readings
- Could be edited to recollect seatbelt data



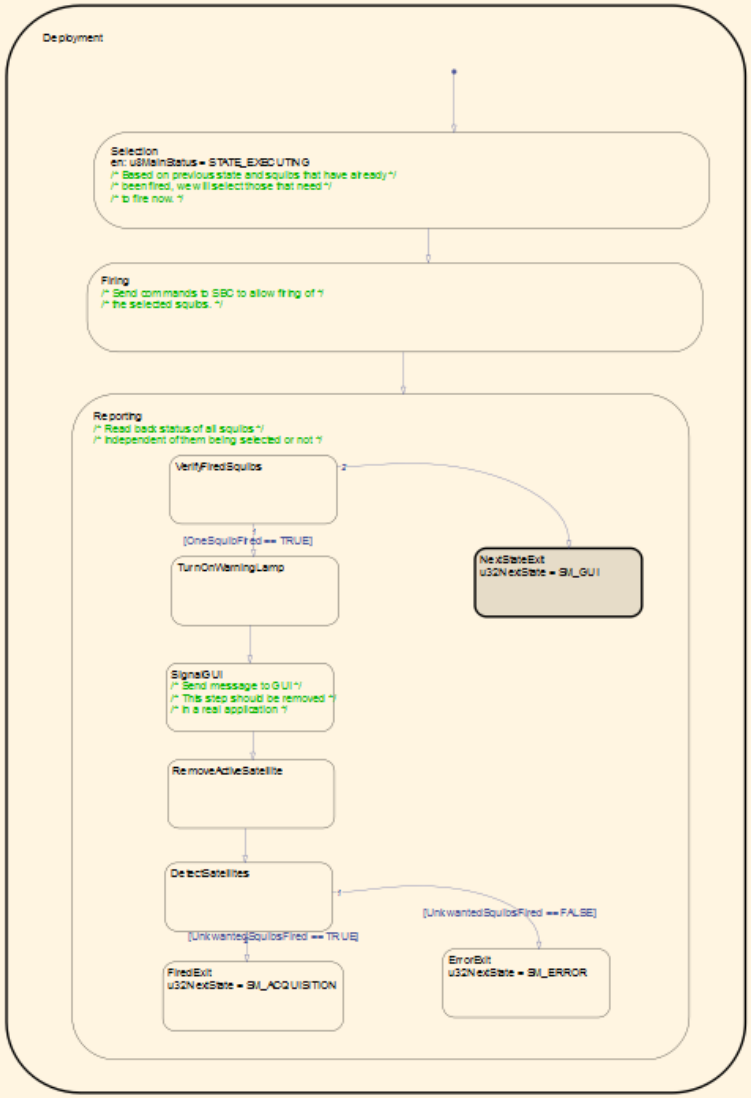
MCU Software: Airbag State Machine: Decision

- Decides if a satellite has observed a crash
- Verifies this decision against the central accelerometer
- Selects which squibs shall be fired based on previous information



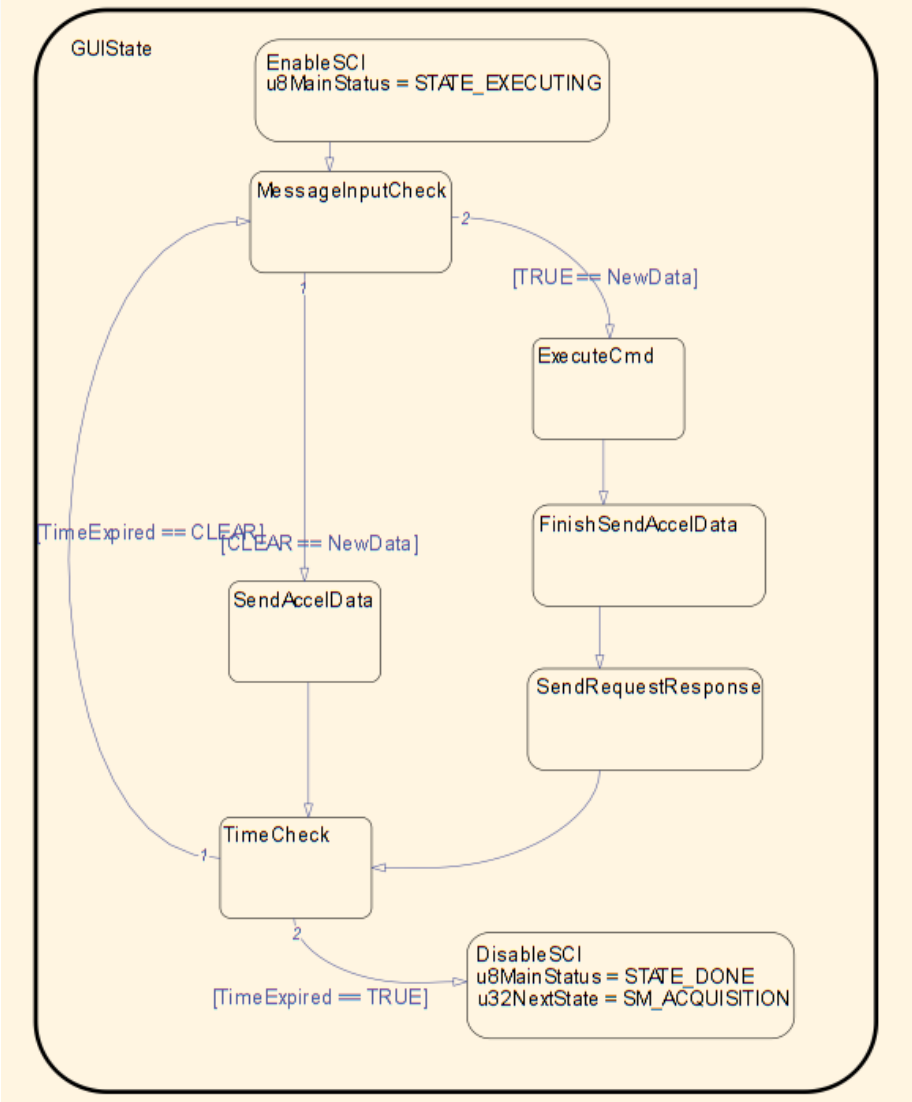
MCU Software: Airbag State Machine: Deployment

- Based on the result of the previous state, fires a squib
- Verifies that either no squib has been fired, or that only the correct squibs have been fired by asking the SBC directly



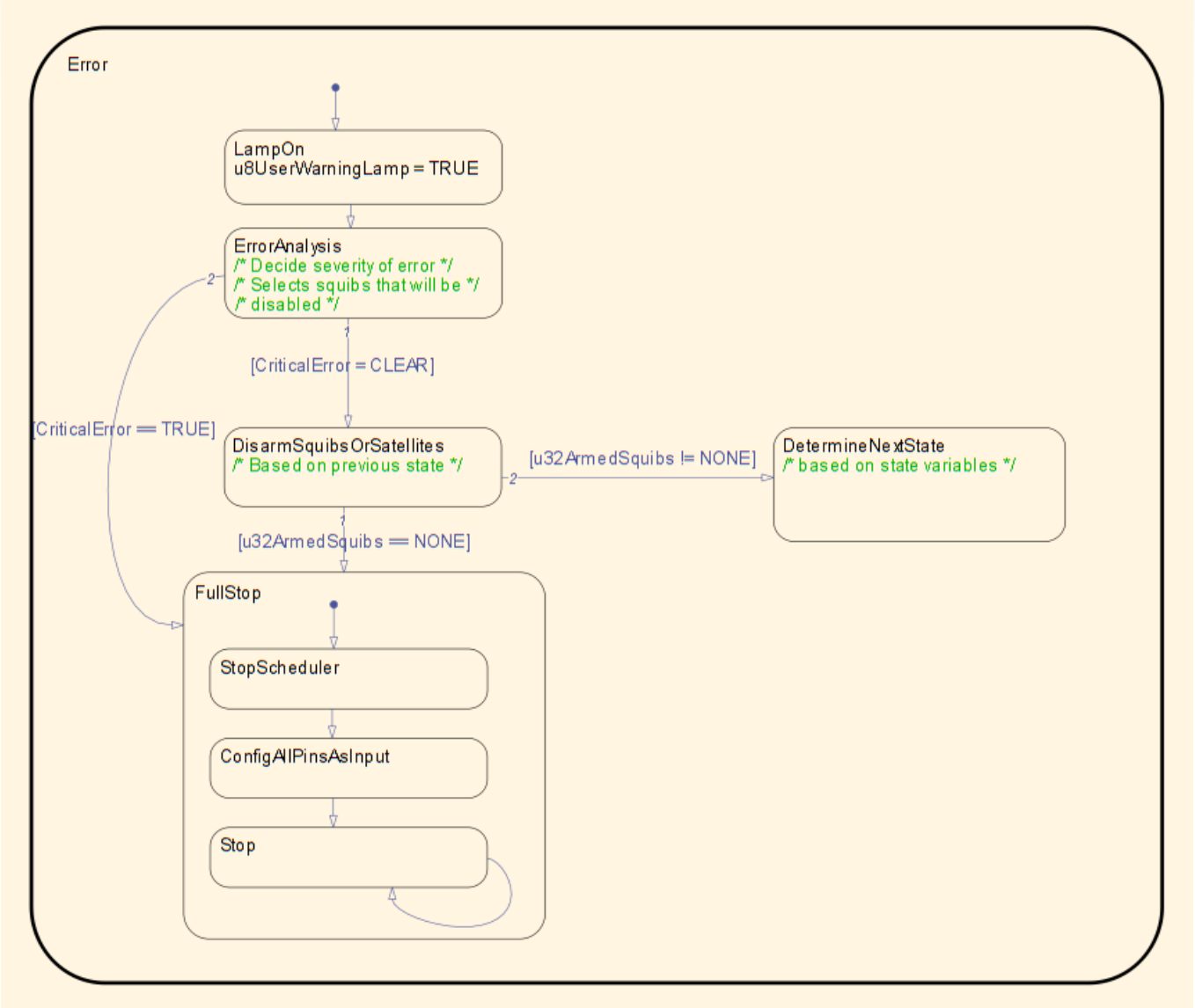
MCU Software: Airbag State Machine: GUIState

- State exclusively developed for demo
- Real application would perform system tests instead
- Sends data back to the GUI and/or acts on commands received from the GUI
- Executes in a 100 usec window unless a command has been received



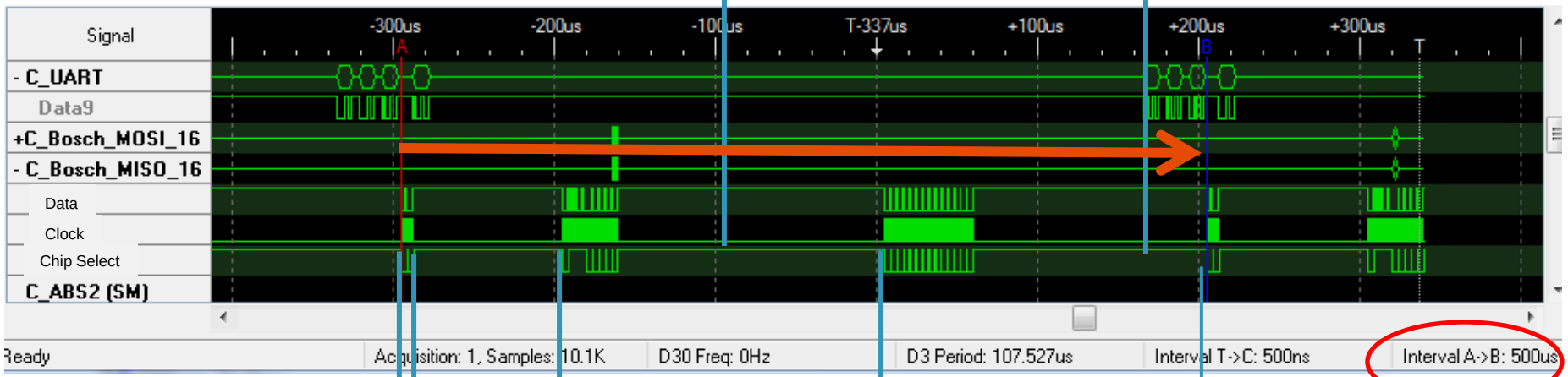
MCU Software: Airbag State Machine: Error State

- State where errors are treated
- Going once through this state forces the warning lamp on (and will stay on)
- May or may not exit the state, depending on severity of error



SPI Bus & its relationship with the State Machine

Timing diagram for SPI Bus running 4 synchronous PSI5 Satellites



SPI Bus

Decision State

GUI State

Start

Watch Dog2/3

Acquisition State

Deployment State

End

Start

* Deployment State will not necessarily deploy airbags, but it will always be executed

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Implementation Details

CG147 Watchdog Treatment Strategy

Watchdog 1:

- **Requirement:** 2MHz clock signal
- **Solution:**
  - Dedicated PLL setting using CLKOUT pin in MCU
  - Setup during AppInit state, never to be touched again

Watchdog 2 & 3:

- **Requirement:** CG147 shall request a specific word from MCU every 500 usec for Watchdog 2, and < 100 msec for Watchdog 3
- **Solution:**
  - Scheduler using periodic interrupts every 100 usec calculates when to send request/response to CG147

Scheduler & Watchdog 2 & 3

Uses *Periodic Interrupt Timer* (PIT) set to 100 usec

- PIT will generate an interrupt when the programmed time expires

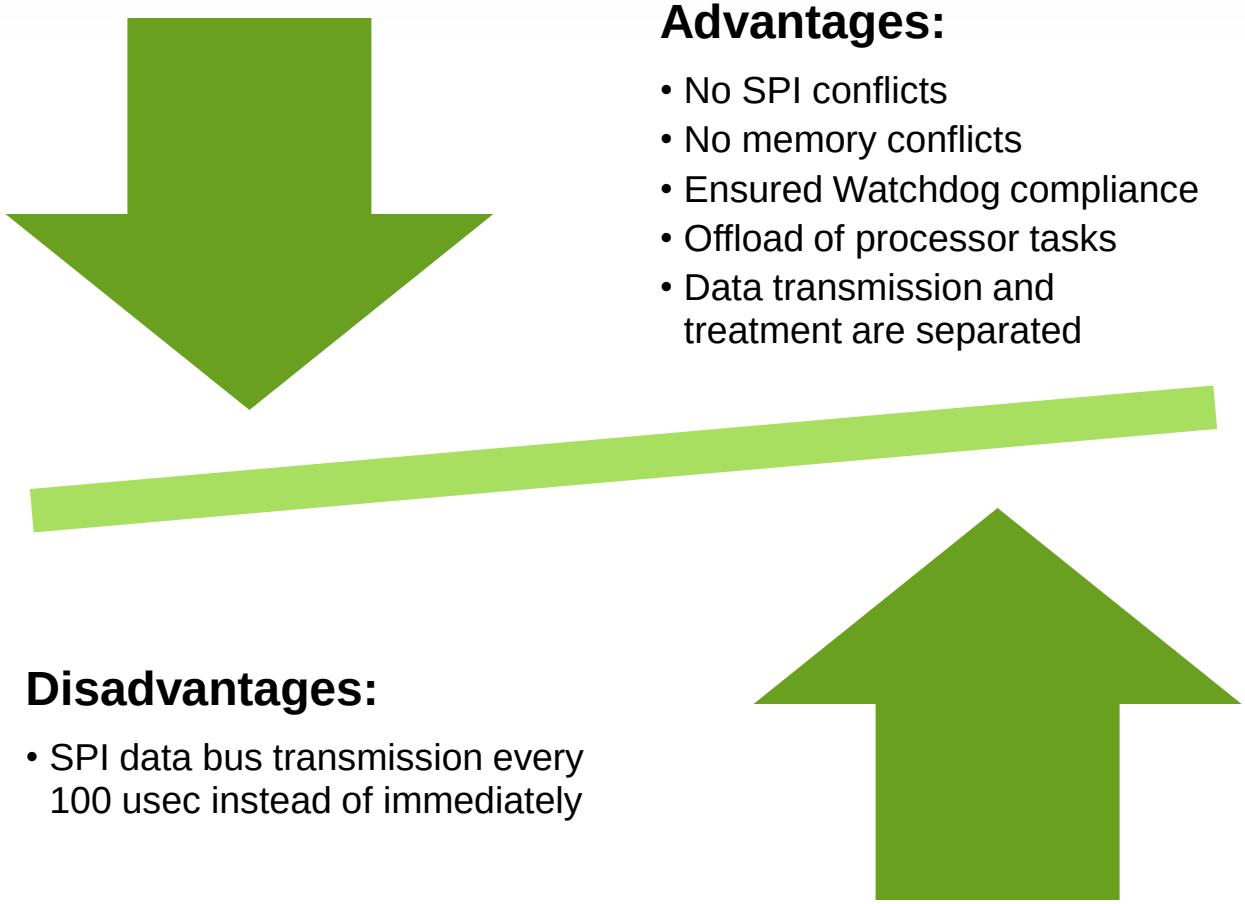
Every 5 interrupts, a new Watch Dog 2 word will be placed in the output buffer

Every 900 interrupts , a new Watch Dog 3 word will be placed in the output buffer

Scheduler & SPI in general

- What happens if Watchdog Interrupt occurs at the same time as an SPI transfer?
- To avoid this issue, ALL SPI transfers shall be performed through a software-managed output buffer
- The Enhanced Direct Memory Access (eDMA) hardware module will periodically take the buffered data and output it through the SPI
- Therefore, SPI data is always placed on a buffer, and output when the next PIT interrupt occurs
- All this is managed by the MailDelivery and MailScheduler files (refer to slide 15)

Scheduler Advantages and Disadvantages



Advantages:

- No SPI conflicts
- No memory conflicts
- Ensured Watchdog compliance
- Offload of processor tasks
- Data transmission and treatment are separated

Disadvantages:

- SPI data bus transmission every 100 usec instead of immediately

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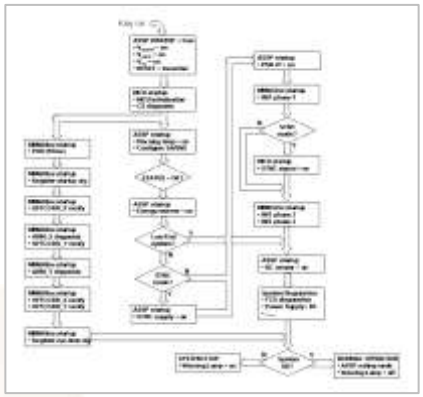
Summary

Airbag Evaluation Platform Deliverables

- Freescale/Bosch Airbag Evaluation Platform Board
- Platform Board Schematics, Layout and BoM
- Airbag System Evaluation Firmware
- Quick Start Guide
- Code Warrior Development Studio DVD-ROM
- Freemaster Demonstrator GUI Project
- Evaluation Platform Resource DVD-ROM (data sheets, application notes, …)



Summary

Freescale and Bosch are enabling a cost effective, robust, state-of-the-art, proven airbag solution for emerging markets

- Emerging markets such as Brazil, China and India are quickly adopting airbags:
  - Local legislation, Consumer demand, NCAP ratings
- Airbags are the most efficient life saving passive safety application
- Nearly 100% of all cars sold in the developed countries are equipped with airbags

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Additional Resources

- http://www.freescale.com/automotive
- http://www.freescale.com/arp
- http://www.bosch-semiconductors.de/en/airbagsystems/airbagsystems.asp

Q&A

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