MOSFET BASED H-BRIDGE WINDOW LIFT IMPLEMENTATION

AMF-AUT-T2353

AGUSTIN DIAZ, JESUS SANCHEZ, JUAN ROMERO
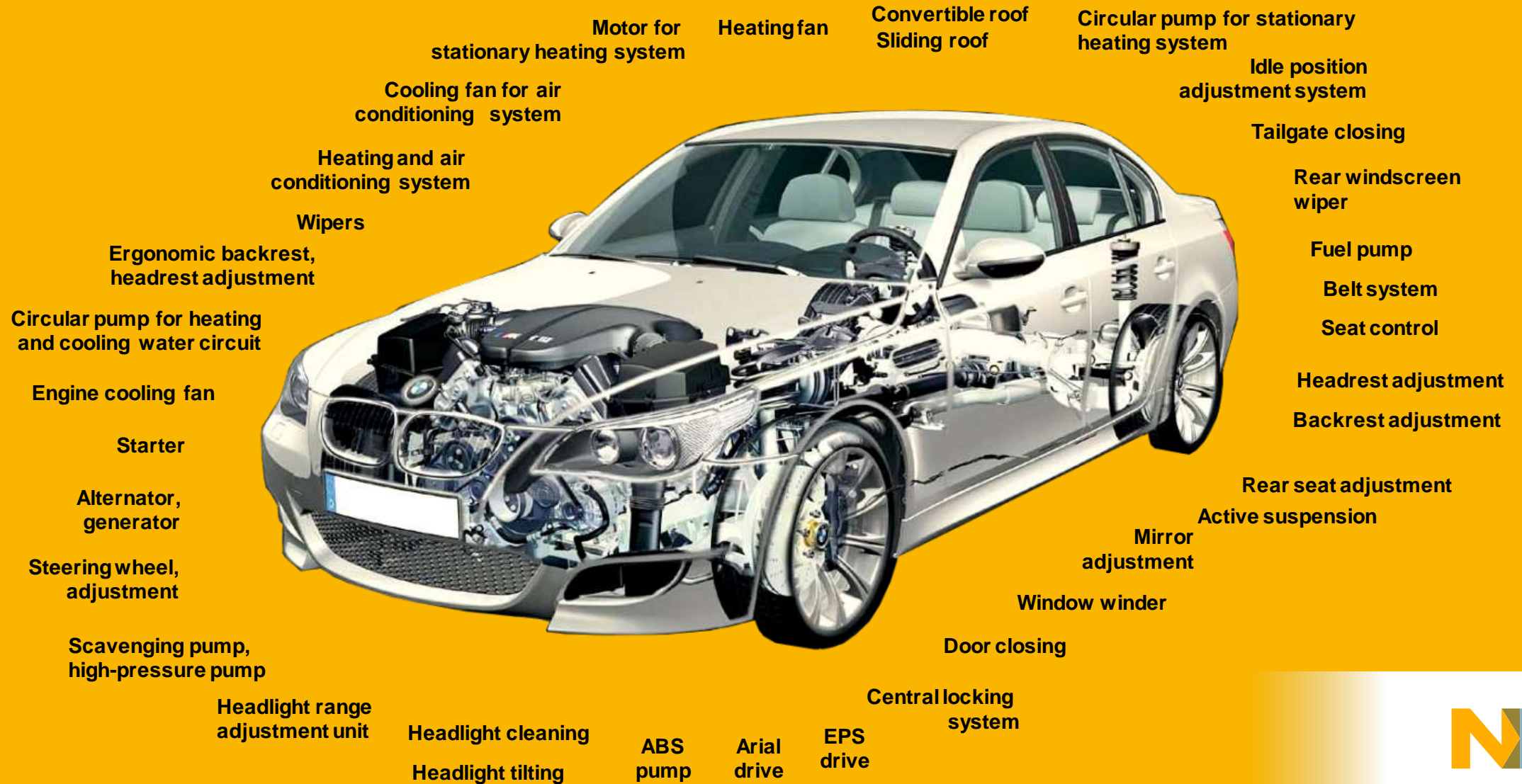
OCT, 2016

NXP

SECURE CONNECTIONS
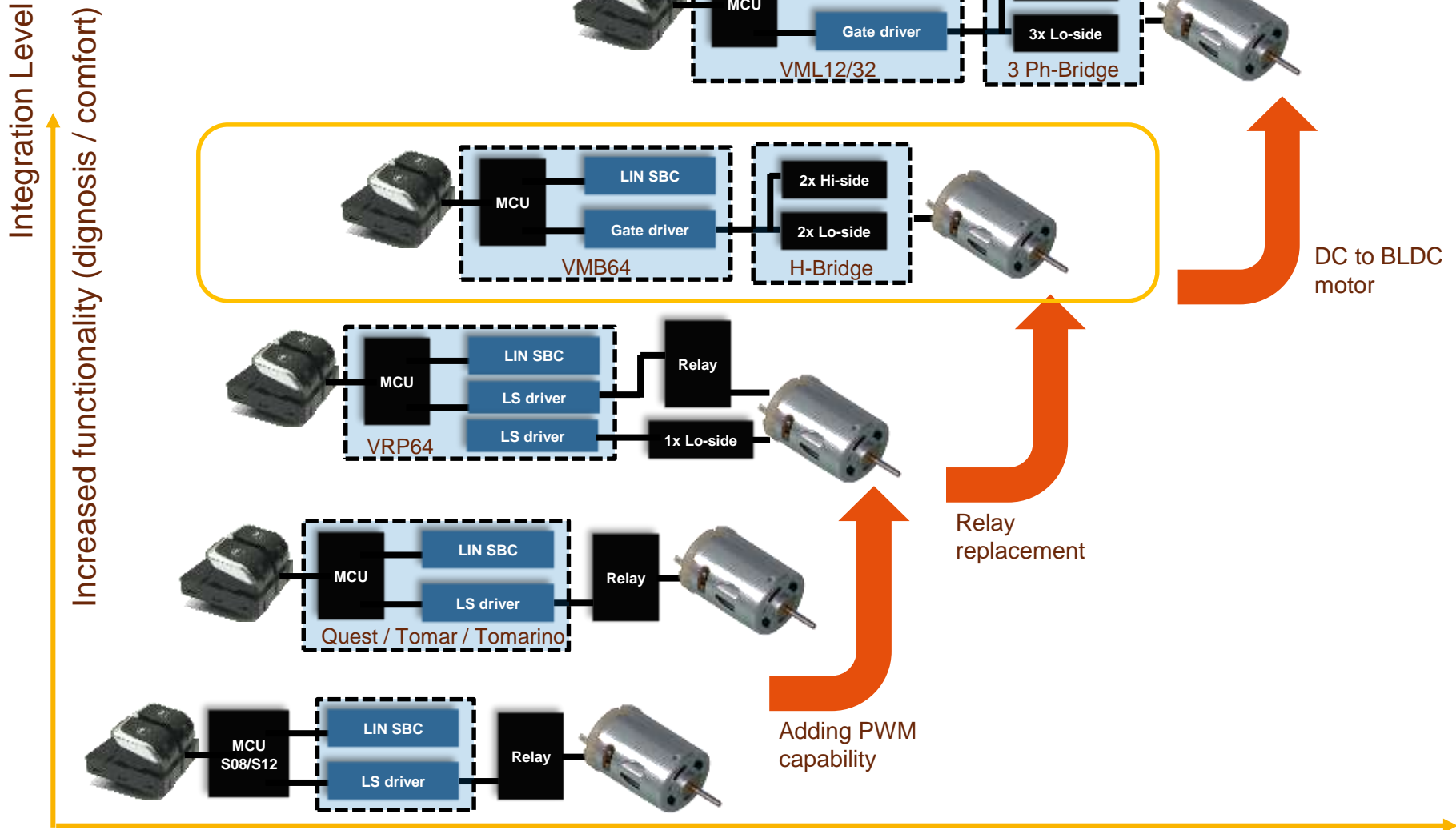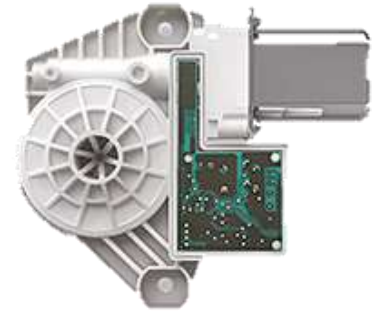FOR A SMARTER WORLD

Session Agenda

- Electric motor demands in Automotive
- Current/future brushed DC motor solutions
- MagniV portfolio for Motor Control
- Overview of S12ZVMB
- Live demo
- Conclusions

MOTOR CONTROL - 10 BILLION ELECTRIC MOTORS SHIPPED GLOBALLY IN 2013
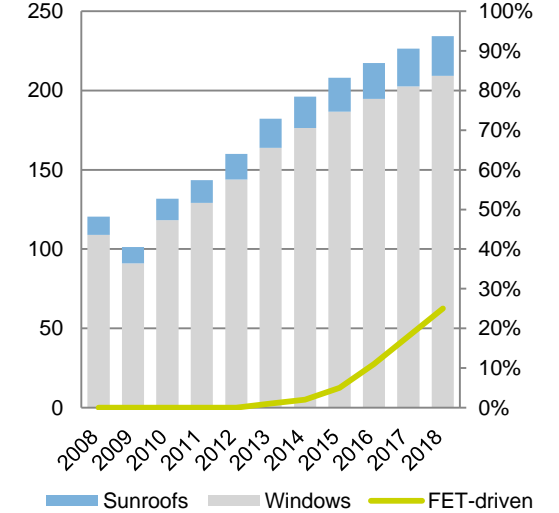## 2.5 BILLION IN AUTOMOBILES, 30 PER CAR AVERAGE

Motor for stationary heating system
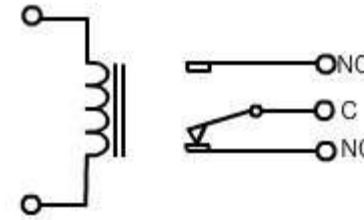
Heating fan

Convertible roof
Sliding roof

Circular pump for stationary heating system

Cooling fan for air conditioning system

Idle position adjustment system

Tailgate closing

Heating and air conditioning system

Rear windscreen wiper

Wipers

Fuel pump

Ergonomic backrest, headrest adjustment

Belt system

Circular pump for heating and cooling water circuit

Seat control

Engine cooling fan

Headrest adjustment

Backrest adjustment

Starter

Alternator, generator

Rear seat adjustment

Active suspension

Mirror adjustment

Steering wheel, adjustment

Window winder

Scavenging pump, high-pressure pump

Door closing

Central locking system

Headlight range adjustment unit

Headlight cleaning

ABS pump

Arial drive

EPS drive

Headlight tilting

NXP

Windowlifter / Sunroofs
Evolution

Relay based vs. Mosfet based DC motor control

Comparing	Relay	Mosfet
Ease of control	Very High	High
Maintenance of mechanism and motor	Mid	Low
Speed control	No	Yes
Acoustic noise	High	Mid
Board Dimensions (Z-axis)	High	Low
Switching Frequency	Low	High

Relay

Mosfet

NXP

Motor Control Portfolio

	8 - 128 KB	256 - 512 KB	1 - 2 MB	> 2 MB
32bit PowerPC Motor Control Portfolio with ISO26262 support		**MPC560xP** 2 64MHz, PWM	**MPC5744P** 4 2 x 200MHz,1M-2.5M, PWM **MPC567xK** 3 2 x 180MHz, SPE, Enet, PWM **MPC5643L** 4 2x 120MHz, PWM	
32bit PowerPC General Purpose		**MPC560xB** 64MHz, PWM		
MagniV Motor Control Portfolio with HV integration	**S12ZVM** 2 16K – 128K GDU, LIN Phy **S12VR** LIN, LINPHY, 2xLS, 2xHS,			
General Purpose with Motor Control Capabilities	**KEA** M0+, PWM, CAN **S12G** S12G, PWM, CAN			

Application Examples

- EPS
- Door Module
- Seat Module
- Oil Pump
- Water Pump
- Fuel Pump
- Cooling Fan
- HVAC Blower
- Window Lift
- Sunroof
- Sliding Doors
- Wipers

32bit PowerPC
16bit MagniV
32bit ARM M0+
16bit S12G

High temp 150C ambient

Target Safety Level (ISO26262)
Level 2 = ASIL-B
Level 3 = ASIL-C
Level 4 = ASIL-D

OVERVIEW / ADVANTAGES OF S12ZVMB

S12ZVMB Family

LIN based Integrated H-Bridge driver

- Key Features:
  - S12Z CPU @ 32MHz bus speed
  - VREG + 5V/20mA switchable sensor supply
  - LIN PHY, LIN2.1 / 2.2 / J2602 compliant
  - High Voltage Inputs (HVI) with internal connection to ADC for analog 12V measurements
  - High-Side Drivers for switch panel and LED
  - H-Bridge Gate Pre-Driver for 4-NMOS control (Gate Charge 50-80nC)

- Target applications:
  - Windowlift / Sunroof
  - LIN-controlled Valves for gases / liquids (EGR-control)
  - Seat-position, Lordosis
  - Belt pretentioner, prefetcher

|					
LIN -PHY		**Pierce Osc.**		**Temp Sense**	**10-Bit LADC**
SCI 1	**SCI 0**	**RCosc. +/-1.3%**	**PLL**	**Current Sense (Op-Amp)**	
SPI		**S12Z 32MHz Bus**		**2 HS Drivers**	
BDM BDC	**KWU** / **Win Wdog**	**48-64kB Flash (ECC)**		**GDU 4ch** MOS-FET-Predriver	
TIM 16b 8+4ch		**512B EEPROM (ECC)**	**4 kB RAM (ECC)**	**Charge Pump**	
6ch PMF (PWM)	**PTU**			**VREG**	**VSUP sense**
1# EVDD		**3 HV Inputs**		70mA	

(GPIO spans left column)

- Digital Components
- MCU Core and Memories
- 5V Analog Components
- High-Voltage Components

Options:
- Package: 48-LQFP; 64 LQFP
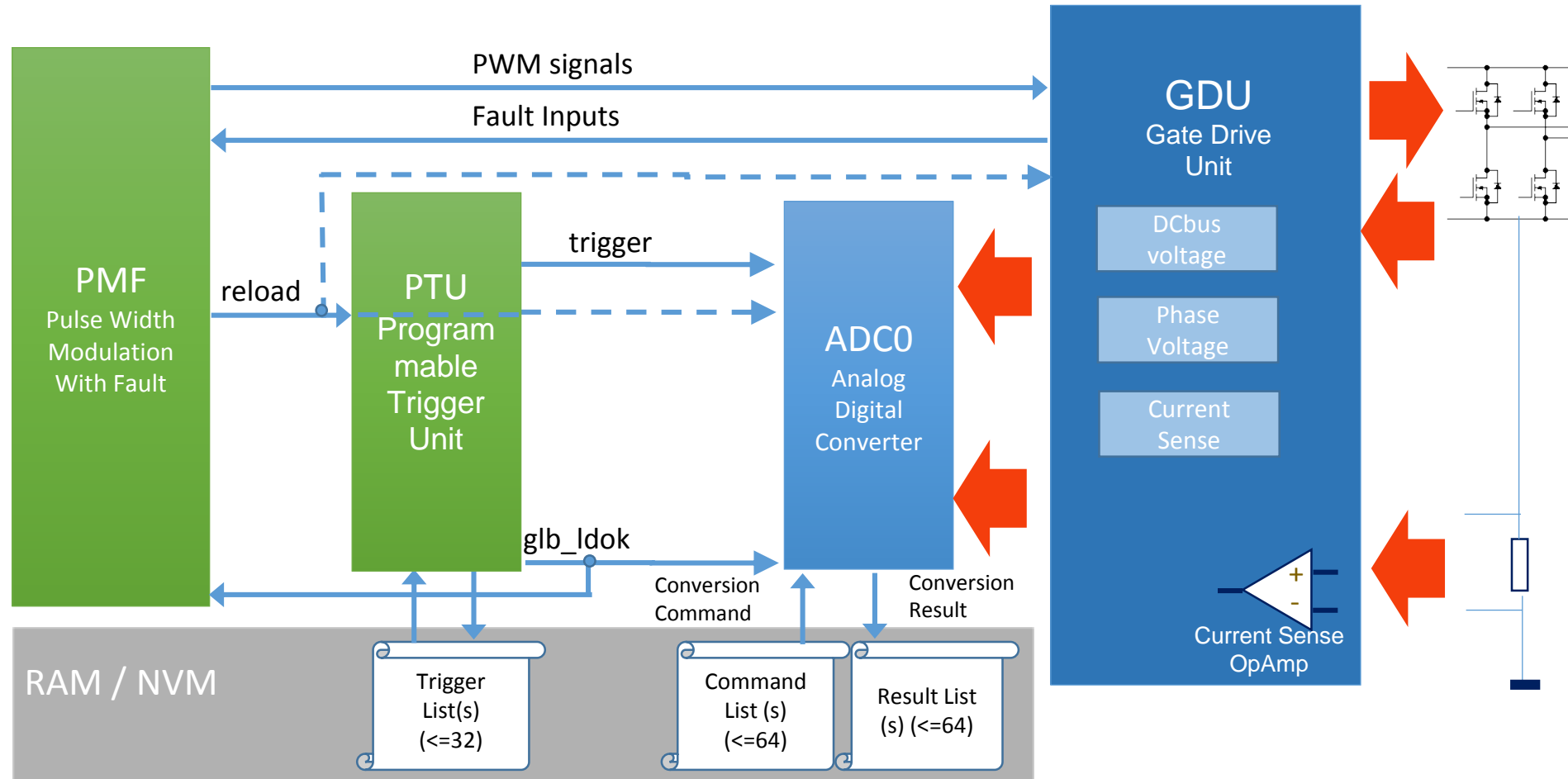- Memory: 48 … 64kB Flash
- Temperature: V / M / W
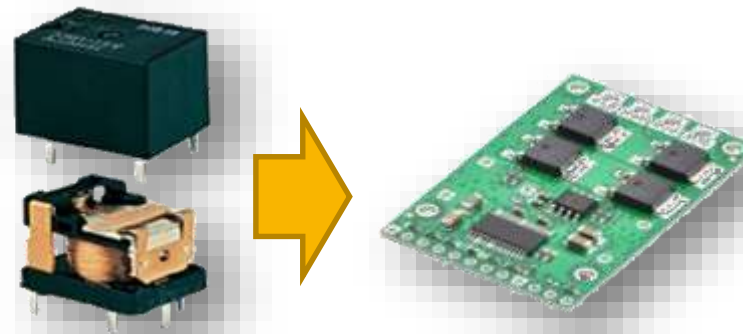
S12VMBx in Windowlifter - Application Use-case
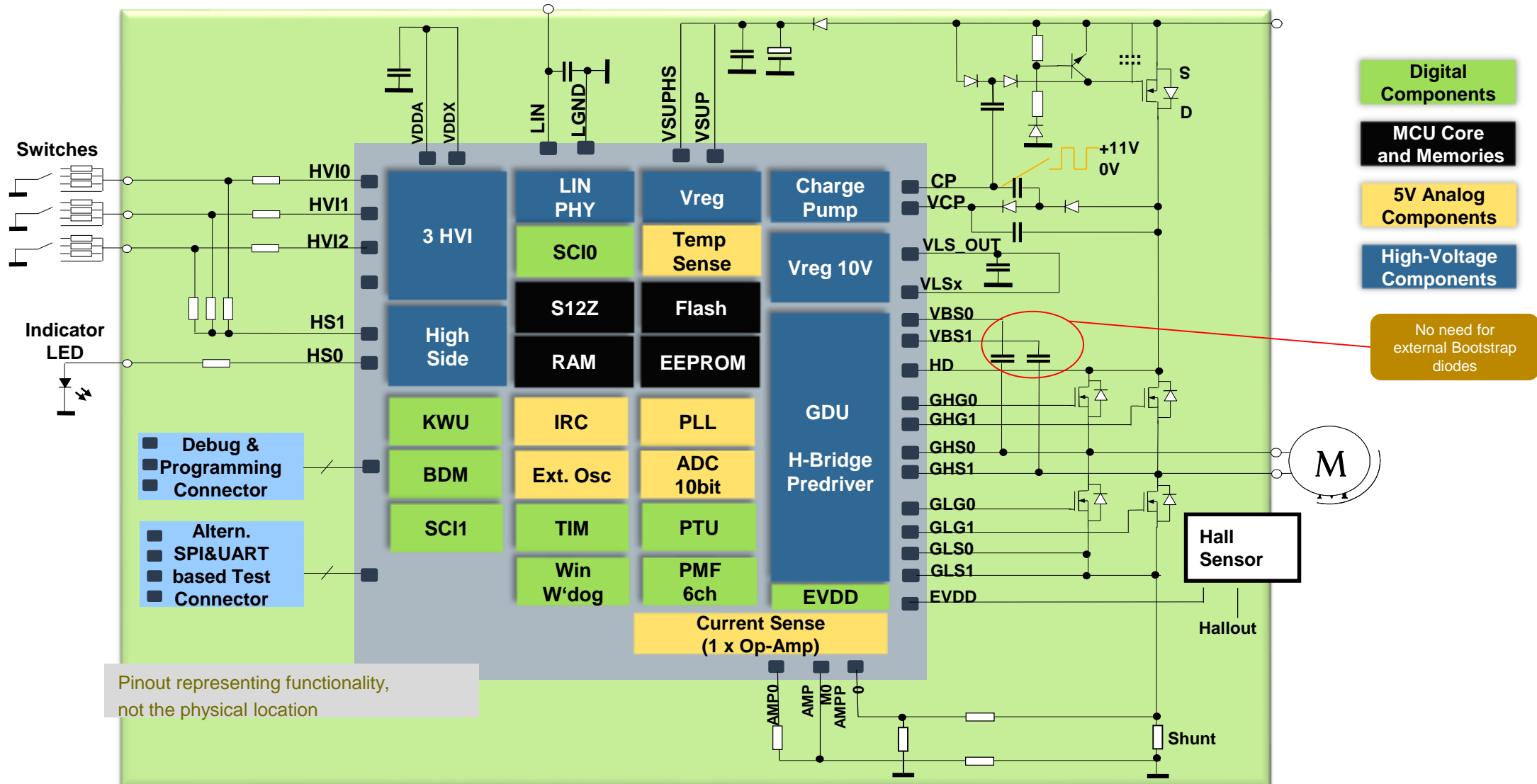
# Motor control peripherals integration

Pulse Width Modulator Module (PMF)

- 6 PWM channels, 3 independent counters

- Up to 6 independent channels or 3 complementary pairs

- Based on core clock (max. 64MHz)

- Complementary operation:

- Dead time insertion

- Top and Bottom pulse width correction

- Double switching

- Separate top and bottom polarity control

- Edge- or center-aligned PWM signals

- Integral reload rates from 1 to 16 cycles

- H-bridge configuration supported.

- Individual software-controlled PWM outputs

- Programmable fault protection

**Complementary Mode**
with / without dead time insertion
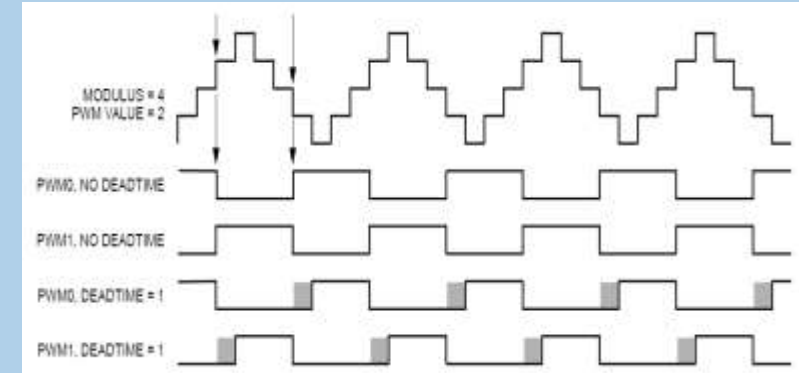
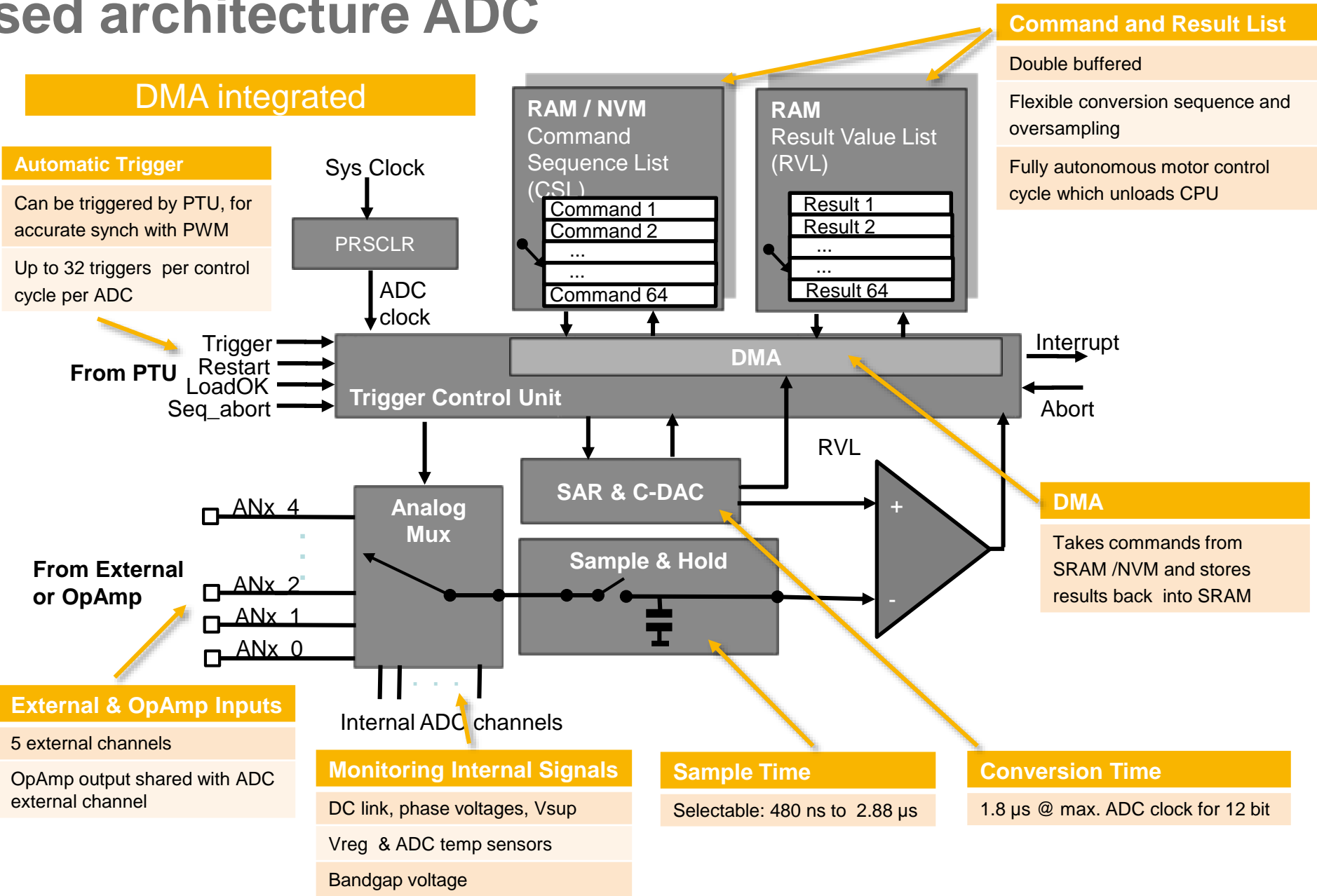**Double-Switching Mode**
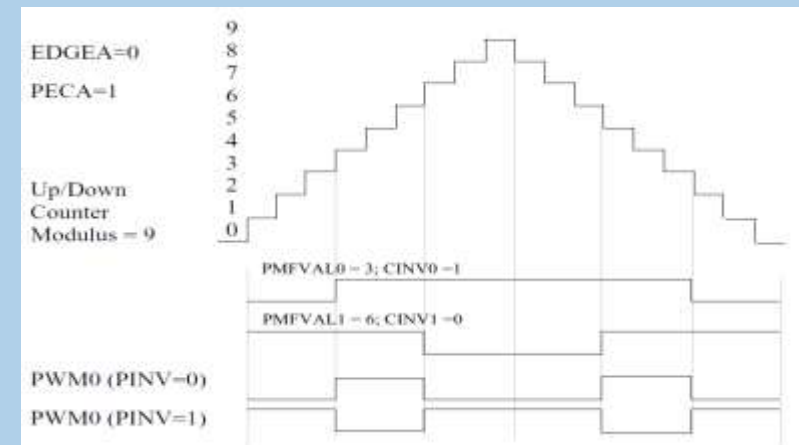
Programmable Trigger Unit (PTU)

Completely avoids CPU involvement to trigger ADC during the control cycle

- One 16-bit counter as time base
- Up to 32 trigger events per trigger generator
- Trigger Value List stored in system memory
- Double buffered list, so that CPU can load new values in the background
- Software generated "Reload" & trigger event
- synchronized with PMF and ADC to guarantee coherent update of all control loop modules
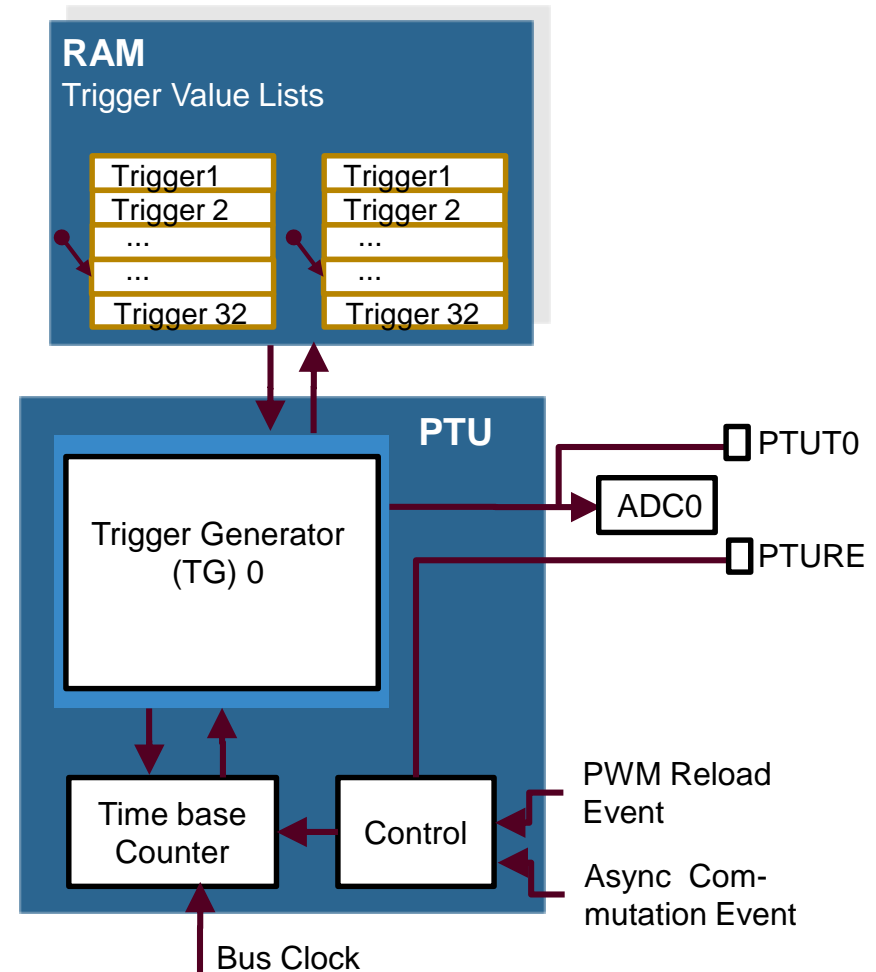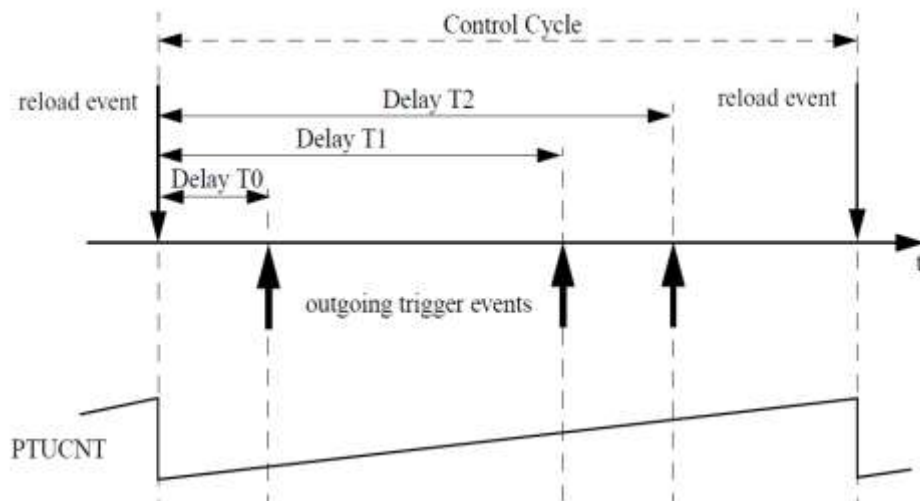
List based architecture ADC

DMA integrated

Command and Result List

Double buffered

Flexible conversion sequence and oversampling

Fully autonomous motor control cycle which unloads CPU

Automatic Trigger

Can be triggered by PTU, for accurate synch with PWM

Up to 32 triggers per control cycle per ADC

Sys Clock

PRSCLR

ADC clock

RAM / NVM
Command Sequence List (CSL)

| Command 1 |
| Command 2 |
| ... |
| ... |
| Command 64 |

RAM
Result Value List (RVL)

| Result 1 |
| Result 2 |
| ... |
| ... |
| Result 64 |

Trigger
Restart
LoadOK
Seq_abort

From PTU

Trigger Control Unit

DMA

Interrupt

Abort

RVL

SAR & C-DAC

+

-

ANx_4

Analog Mux

From External or OpAmp

ANx_2
ANx_1
ANx_0

Sample & Hold

DMA

Takes commands from SRAM /NVM and stores results back into SRAM

External & OpAmp Inputs

5 external channels

OpAmp output shared with ADC external channel

Internal ADC channels

Monitoring Internal Signals

DC link, phase voltages, Vsup

Vreg & ADC temp sensors

Bandgap voltage

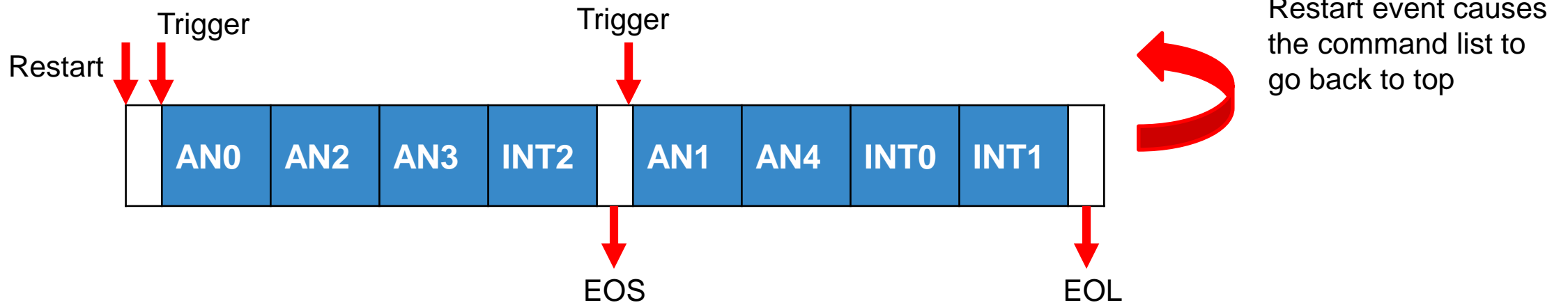**Sample Time**

Selectable: 480 ns to 2.88 µs

Conversion Time

1.8 µs @ max. ADC clock for 12 bit

Conversion Flow – Restart Mode

- **Restart mode** is ideal for **motor control applications**.
- **Internal or external (from other peripherals) trigger signals**.
- PTU can trigger the ADC **generate a delay** in the measurement. **This will allow the ADC to measure the current with right timing**.
- Everything is done by hardware so CPU does not suffer any load.

Timing

- **The interconnection between PMF,PTU and ADC** allows **accurate timing** for current measurements.

- Reload signal of the PMF restarts the PTU counter and ADC commands flow.

- **PTU control the time** between reload of PMF and ADC measurements.

- Everything is done by hardware. **No load for the CPU**.
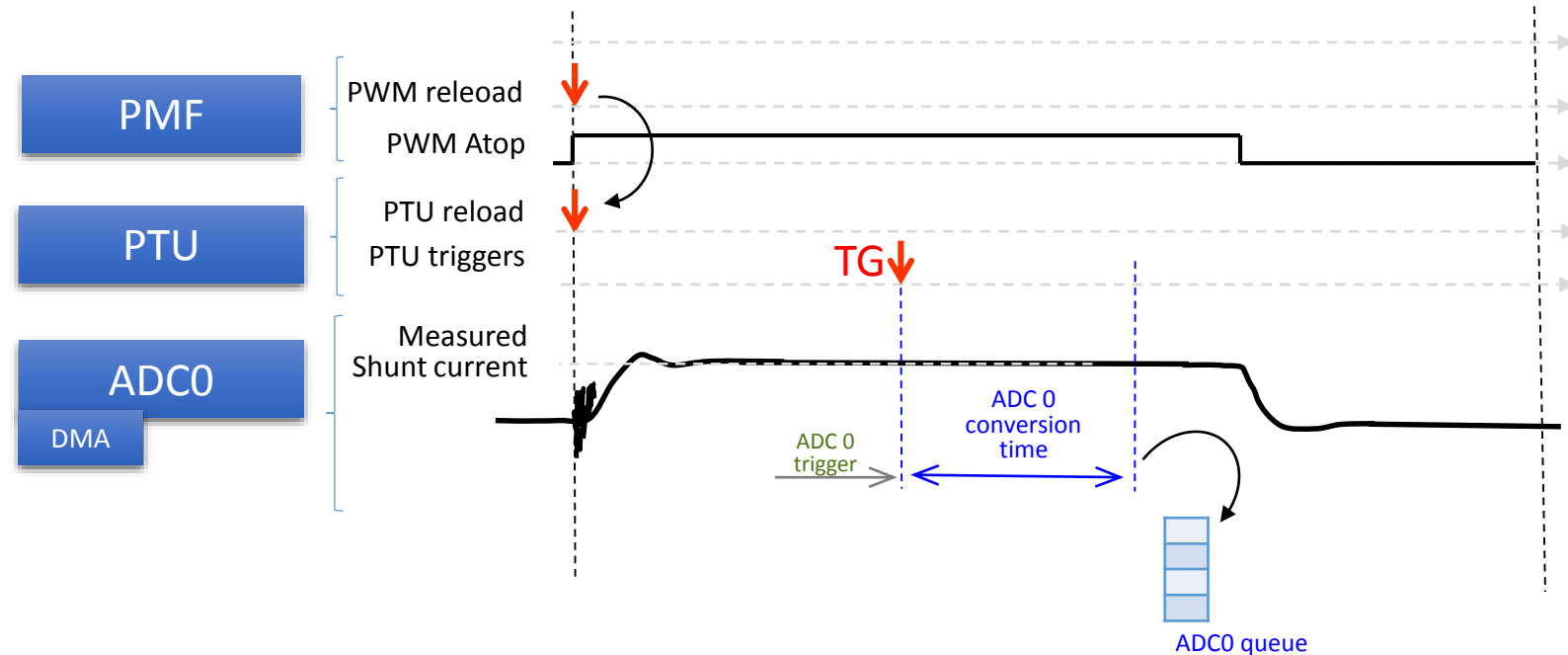
The importance of measuring at the right time

Reload event

High-side

Shunt resistor voltage

ADC measurement

PTU selectable delay
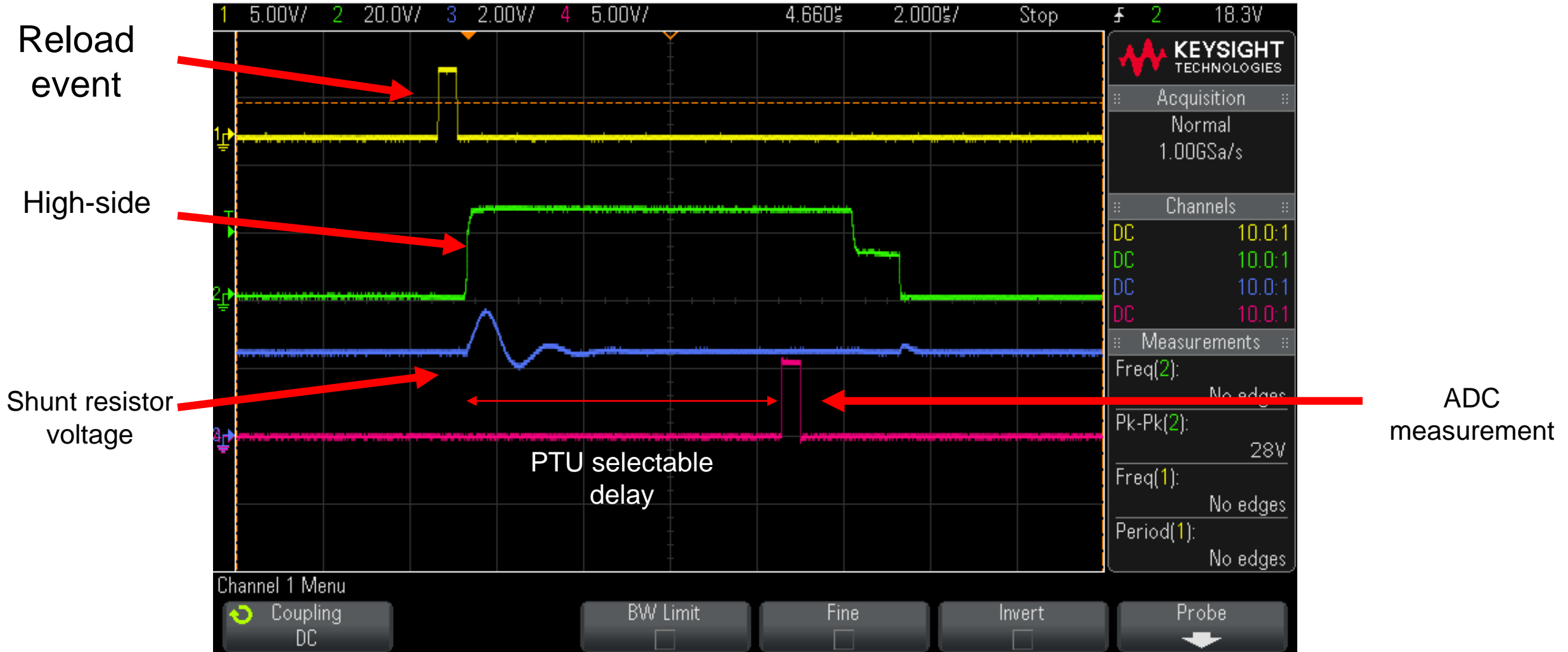
Gate Driver Unit (GDU)

11V LDO

supplies the LS drivers

charges bootstrap cap for the HS drivers

Voltage Monitoring

HD High Voltage Monitor @ typ. 21/27.3 V

VLS Low Voltage trip point: 6.2 .. 7V

Integrated Dividers
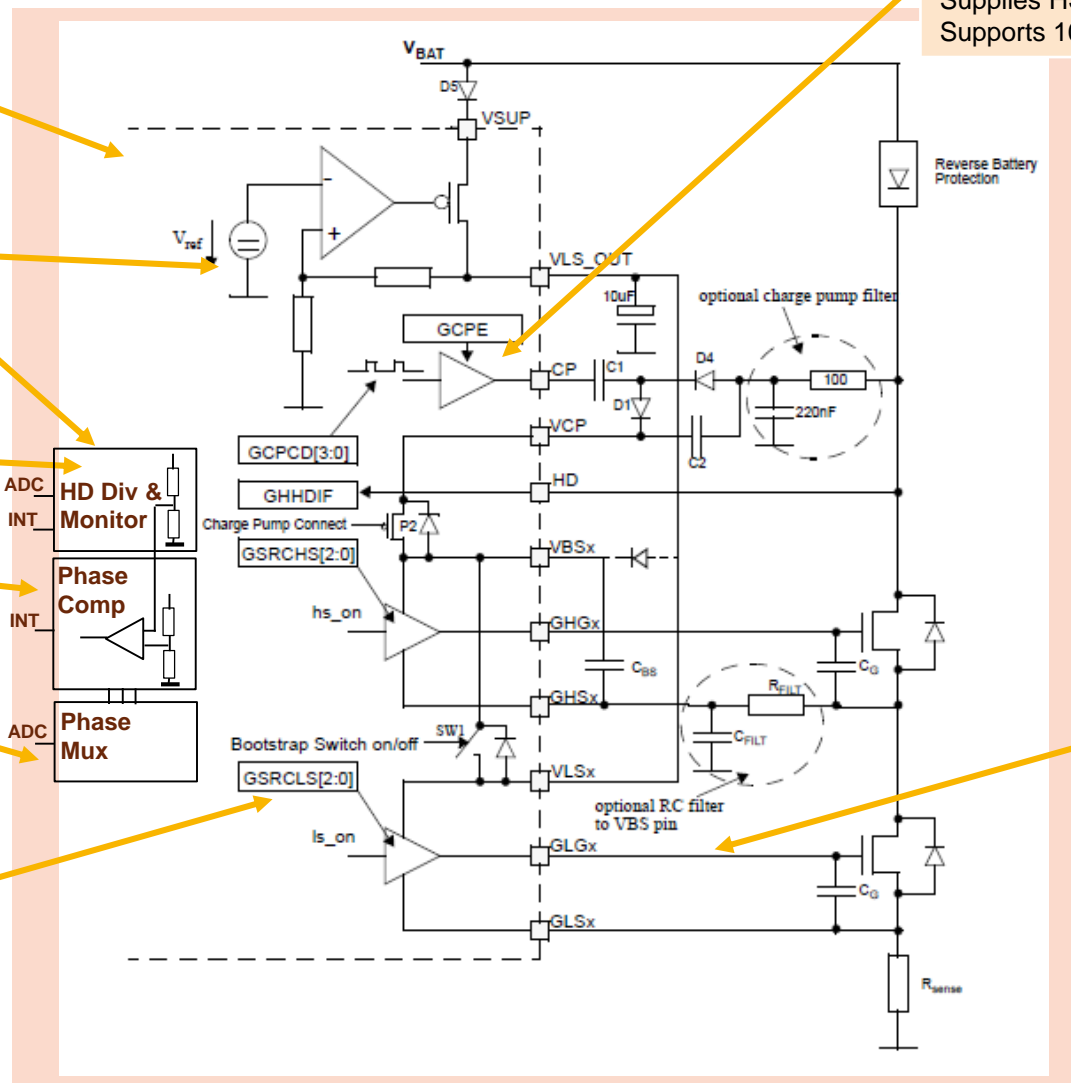
HD: divider 12 ; HS : divider 6

Phase Comparators

Compares HS against DCbus/2 in HW

Phase Multiplexer

Switched in each sector

Slew Rate Control

Output current limitation of Iout via selectable Iref

8 selectable slew rates

Charge Pump

Supplies HS Gate Drive
Supports 100% duty cycle

Drive Strength

Typ 50 nC

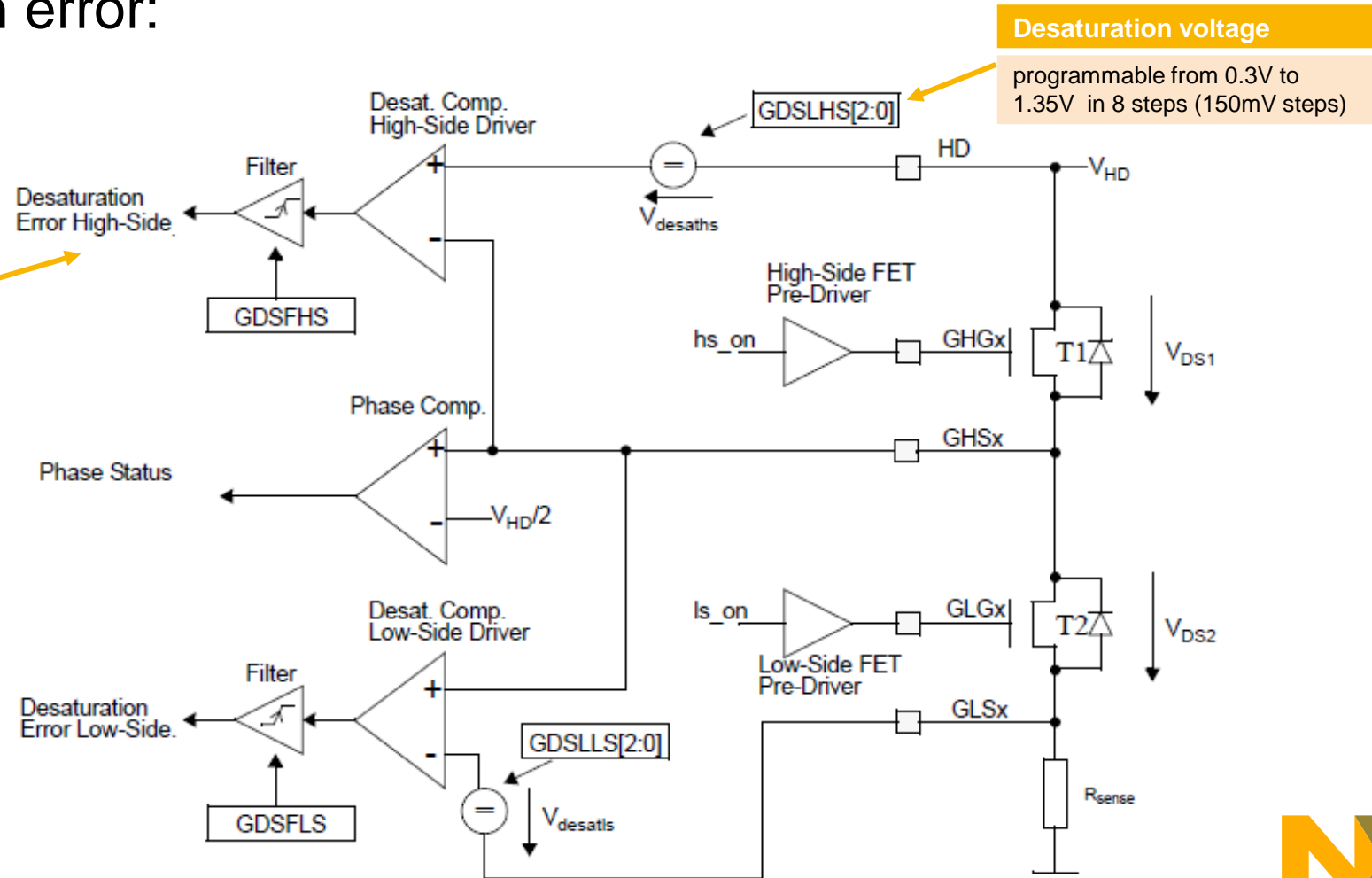# V$_{DS}$ Monitoring & Overcurrent Protection

- After turning on (any) high-side or low-side transistor, the HSx voltage is monitored
- In case of de-saturation error:
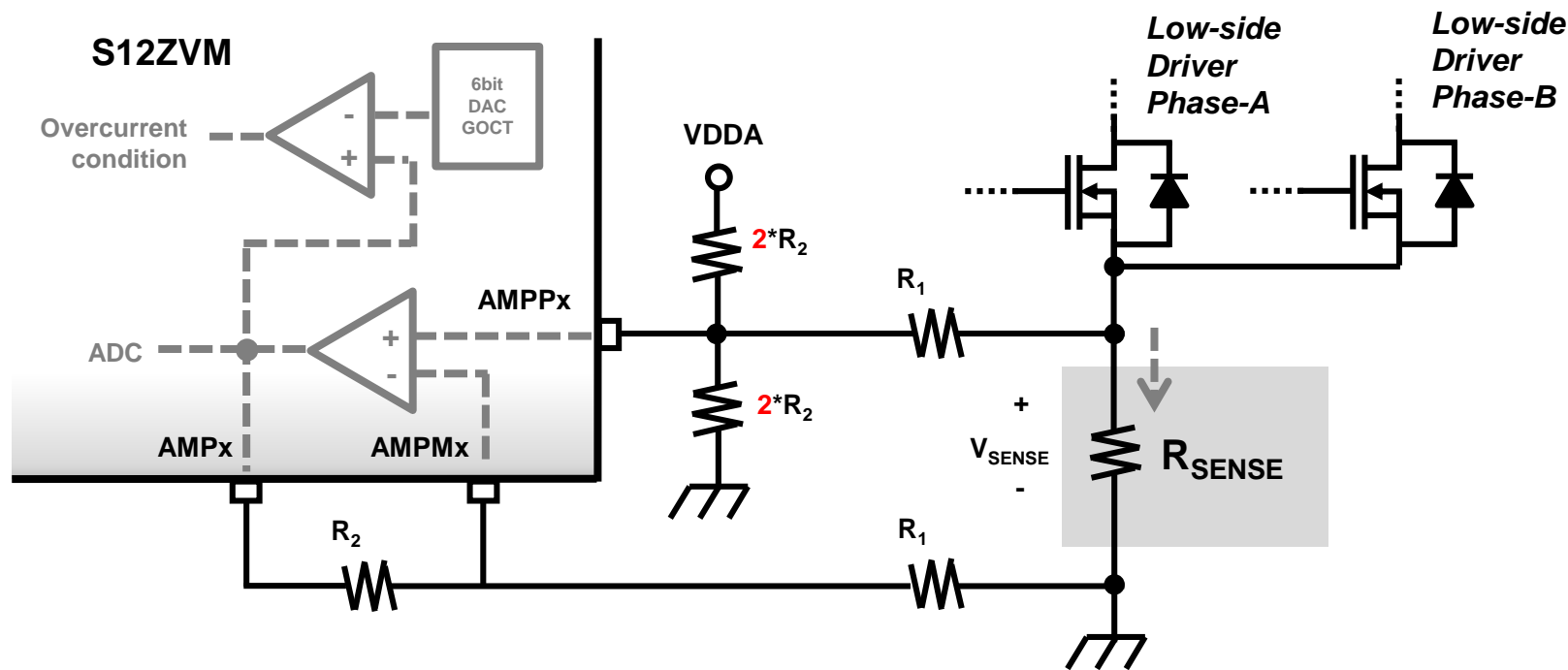 - →LS/HS switched off
  - →Optional interrupt

Desaturation voltage

programmable from 0.3V to 1.35V in 8 steps (150mV steps)

4 Desaturation Comparators

One HS and one LS per phase

Current Measurement & Overcurrent Protection

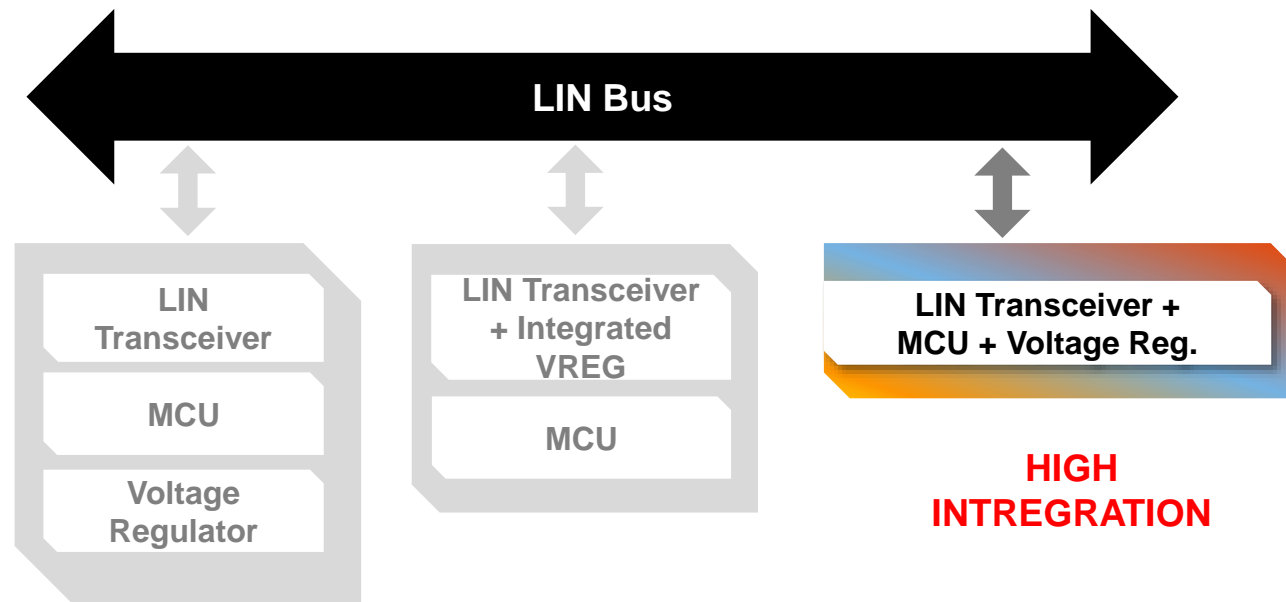$$V_{AMP} = \left(\left(\frac{R_2}{R_1} \right) V_{SENSE} \right) + 2.5V$$

- Low side, current sense amplifier.
- Internal Op-Amps (w/offset compensation) each one linked to an ADC channel.
- Gain / offset selected by external resistors.
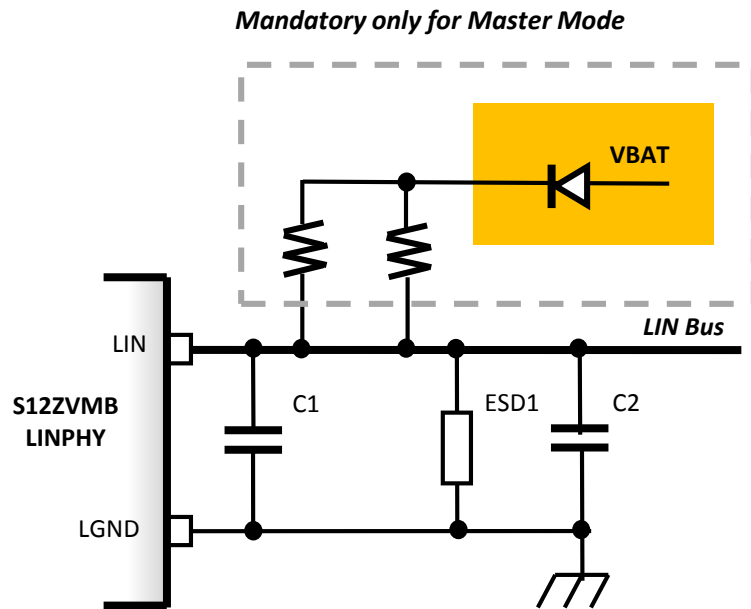- Integrated overcurrent comparator

LIN INTERFACE

LIN Physical Layer
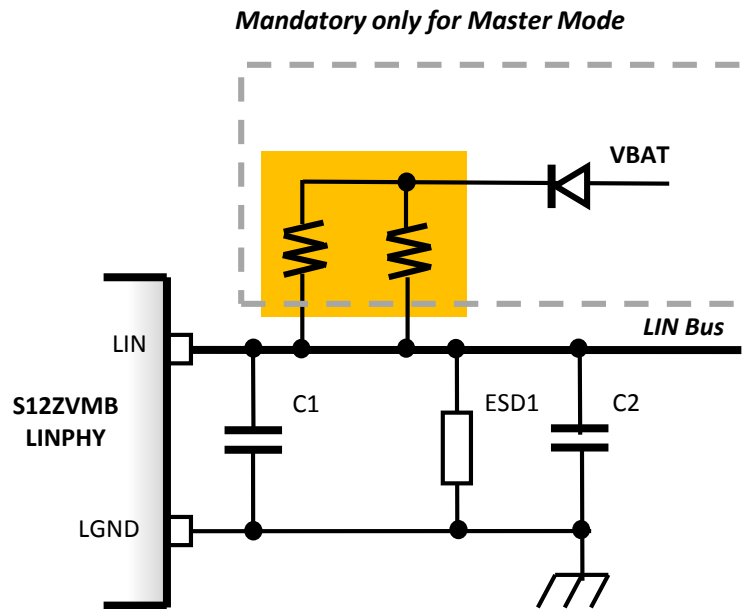

- NXP offers a complete line of products to meet the needs of high-performance CAN embedded applications.

- MagniV MCUs as **S12ZVMB** has an **on-chip** LIN physical transceiver and a dedicated power supply using an external ballast transistor for its. Having this module on-chip helps reduce the total amount of components required to implement LIN communication.
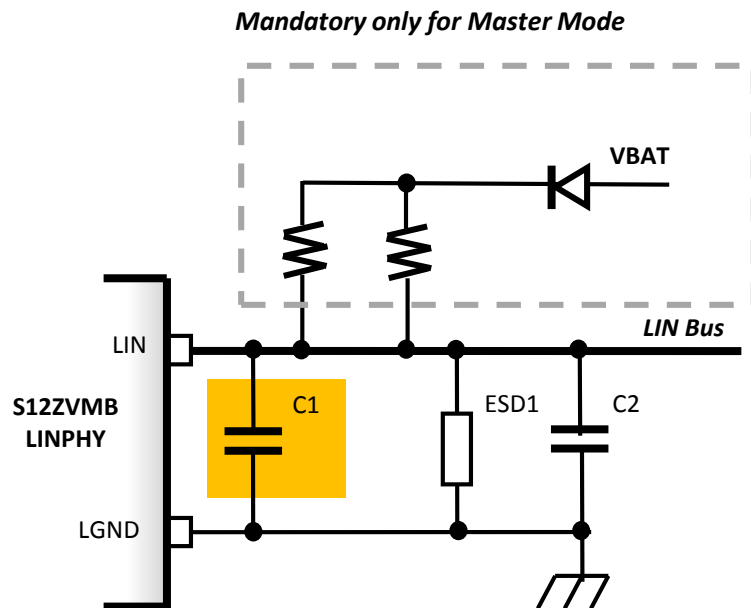
LIN Interface

Mandatory only for Master Mode

Reference	Part	Mounting	Remark
DMLIN	Diode	Mandatory only for master ECU	Reverse Polarity protection from LIN to VSUP.
RMLIN1 and RMLIN2	Resistor: 2kΩ Power Loss: 250mW Tolerance: 1% Package Size: 1206 Requirement: Min Power loss of the complete master termination has to be ≥ 500mW	Mandatory only for Master ECU	For Master ECU If more than 2 resistors are used in parallel, the values have to be chosen in a way that the overall resistance RM of 1kΩ and the minimum power loss of the complete master termination has to be fulfilled. For Slave ECU RMLIN1 and RMLIN2 are not needed on the PCB layout

LIN Interface

Mandatory only for Master Mode

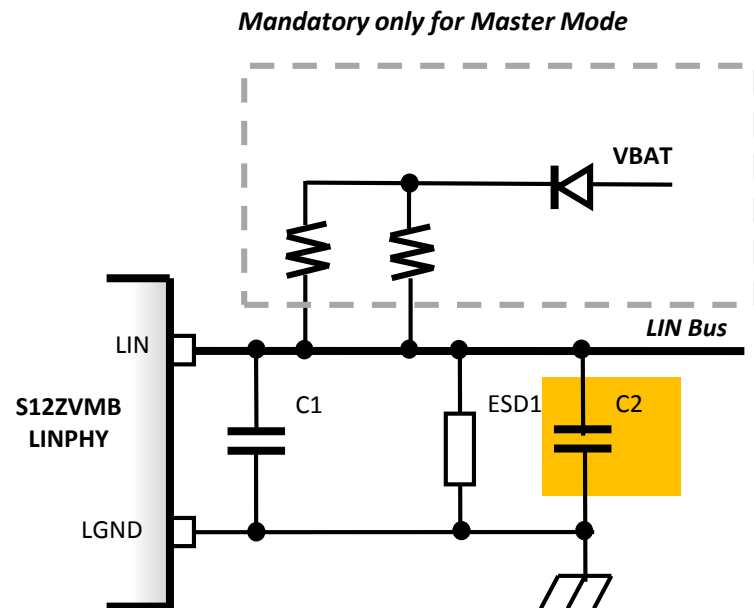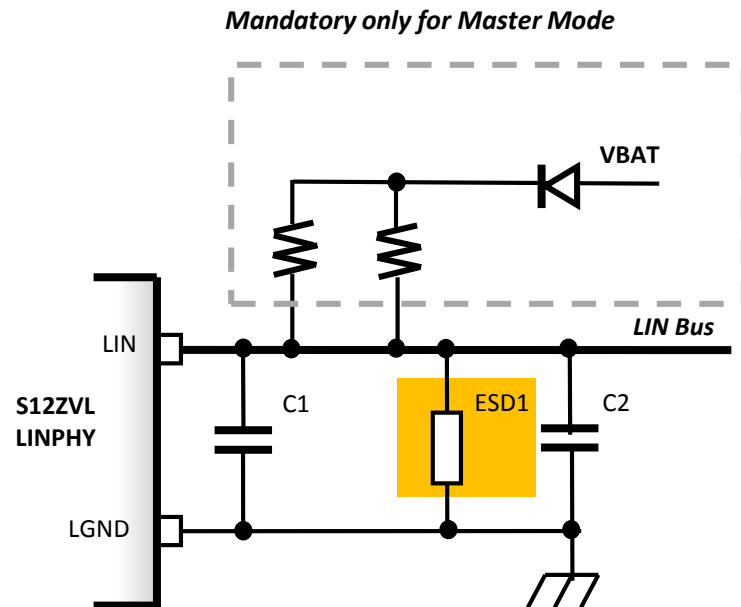| Reference	Part	Mounting	Remark
DMLIN	Diode	Mandatory only for master ECU	Reverse Polarity protection from LIN to VSUP.
RMLIN1 and RMLIN2	Resistor: 2kΩ Power Loss: 250mW Tolerance: 1% Package Size: 1206 Requirement: Min Power loss of the complete master termination has to be ≥ 500mW	Mandatory only for Master ECU	For Master ECU If more than 2 resistors are used in parallel, the values have to be chosen in a way that the overall resistance RM of 1kΩ and the minimum power loss of the complete master termination has to be fulfilled. For Slave ECU RMLIN1 and RMLIN2 are not needed on the PCB layout

LIN Interface

Mandatory only for Master Mode

Reference	Part	Mounting	Remark
C1	Capacitor: Master ECU: ≥560pF Slave ECU: 220pF Tolerance: 10% Package Size: 0805 Voltage: ≥50V	Mandatory	The value of the master node has to be chosen in a way that the LIN specification is fulfilled.
C2	Capacitor: Package Size: 0805	Optional	Mounting of the optional part only allowed if there is an explicit written permission of the respective OEM available. Placed close to the connector.

LIN Interface

Mandatory only for Master Mode

Reference	Part	Mounting	Remark
C1	Capacitor: Master ECU: ≥560pF Slave ECU: 220pF Tolerance: 10% Package Size: 0805 Voltage: ≥50V	Mandatory	The value of the master node has to be chosen in a way that the LIN specification is fulfilled.
C2	Capacitor: Package Size: 0805	Optional	Mounting of the optional part only allowed if there is an explicit written permission of the respective OEM available. Placed close to the connector.

LIN Interface

Mandatory only for Master Mode

Reference	Part	Mounting	Remark
ESD	ESD Protection • Zener • MOV • TVS	Optional	Layout pad for an additional ESD protection part. Mounting of the optional part only allowed if there is an explicit written permission of the respective OEM available. Place close to the connector.

ENABLEMENT

S12ZVMB – Development Tools and Enablement

HARDWARE:

- EVB for ~$200:
  - Prototype-EVB boards available now (X-S12ZVMBEVB)

- USBMULTILINKBDM: In-Circuit Debugger/Programmer

COMPILER, DEBUGGER:

- Codewarrior
- Cosmic

Run time Software:

- LIN driver will be available free of charge (before product launch)

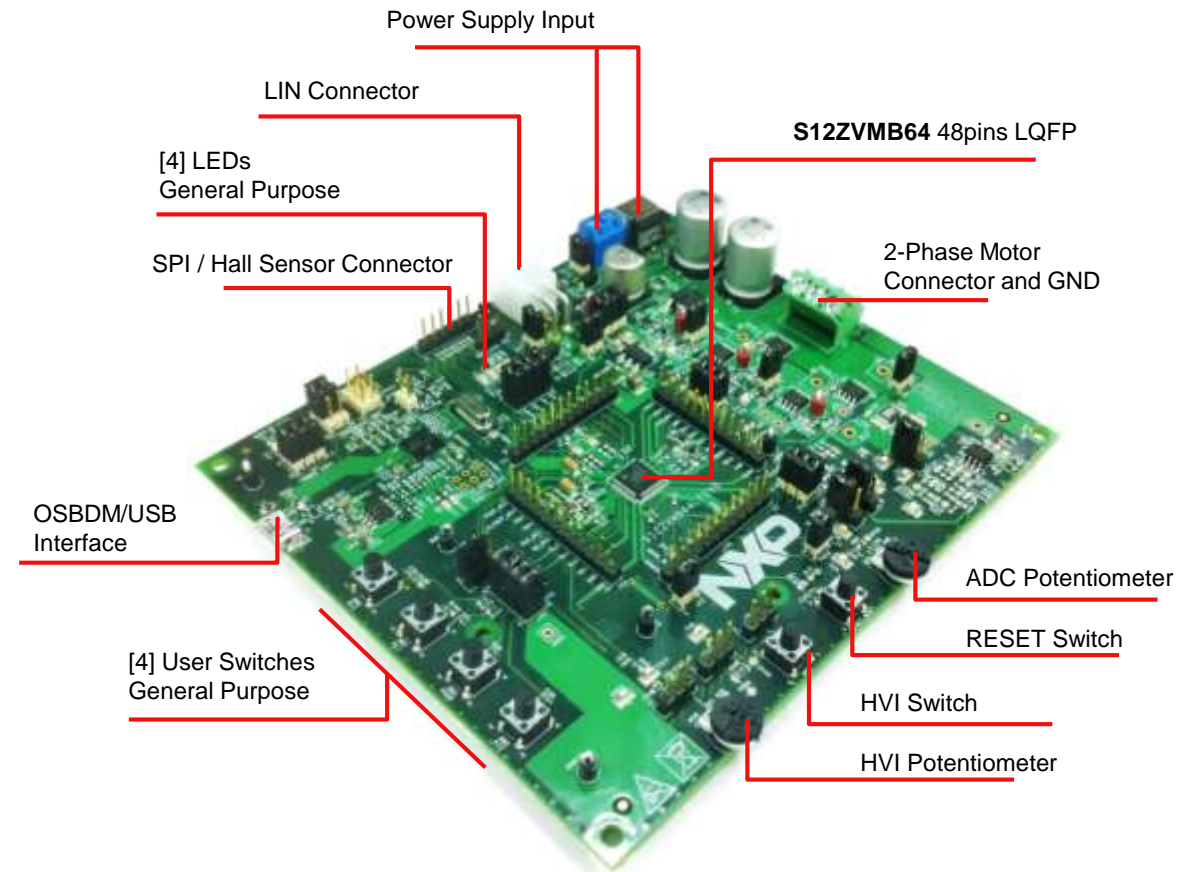**APPLICATION NOTE, REFERENCE DESIGN, MIDDLEWARE:**

- Window lifter reference design
- Window lifter Demo
- Hardware Design Guidelines for S12ZVM Microcontrollers
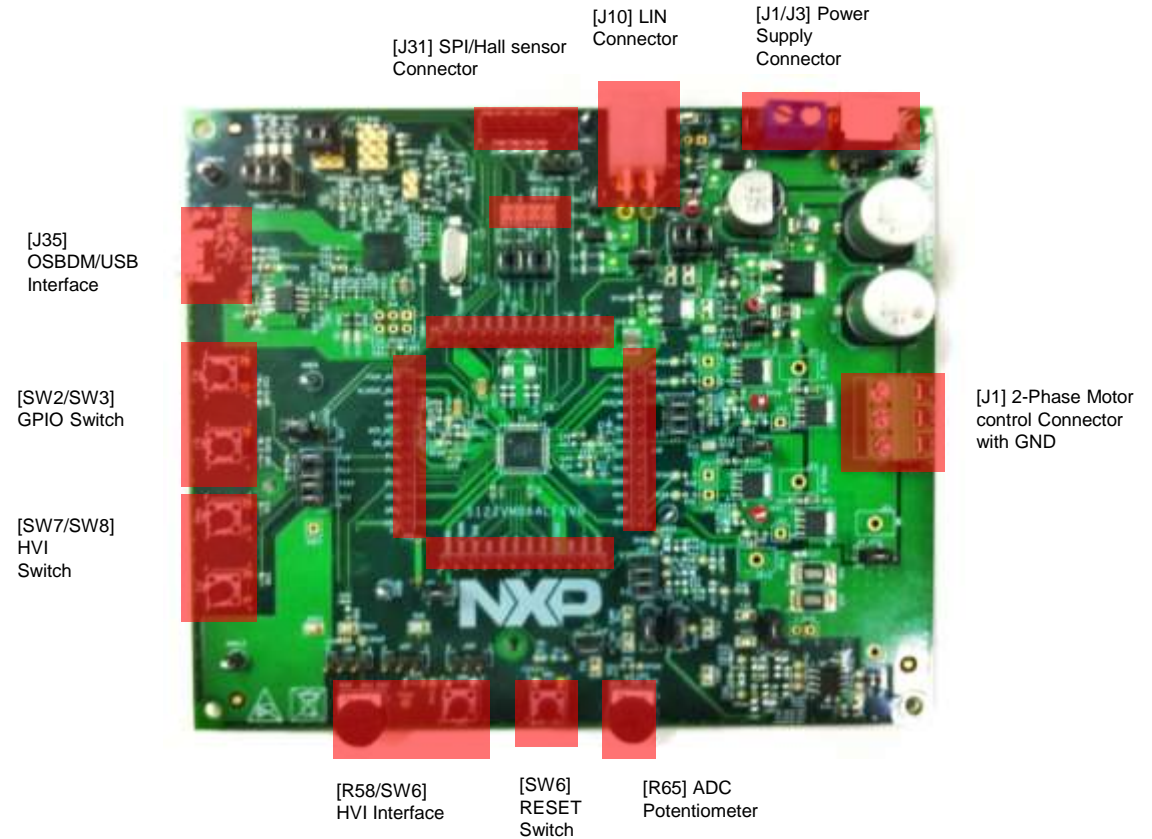
Get to know the S12ZVMB64 EVB

The **S12ZVMBEVB** is a development board for the MagniV S12ZVMB64 Mixed Signal MCU and provides rapid and fully integrated single chip solution to drive external power MOSFETs for 2Phase DC Motor drive applications.

The particular differentiating features of this family are the enhanced S12Z core, the combination of an ADC synchronized to PWM signals using a Programmable Trigger Unit (PTU) and the integration of "high-voltage" analog modules, including the voltage regulator (VREG), Gate Drive Unit (GDU) and a Local Interconnect Network (LIN) physical layer.

Power Supply Input

LIN Connector

S12ZVMB64 48pins LQFP

[4] LEDs General Purpose

2-Phase Motor Connector and GND

SPI / Hall Sensor Connector

OSBDM/USB Interface

ADC Potentiometer

RESET Switch

[4] User Switches General Purpose

HVI Switch

HVI Potentiometer

S12ZVMBEVB Peripheral List

Interface	ID	Description
Power Supply and protection	J1	Power supply Connector [+12V]
	J3	Power supply Connector [+12V]
	D2	Power LED indicator, ON when VBAT [+12V]is connected to the board
	D3	Power LED indicator, ON when HD [+12V] is connected to the Motor control interface
	D4	MCU Power LED Indicator. ON when VDDX is regulating to +5V
User Peripherals	SW2	User switch (Active high)
	SW3	User switch (Active high)
	SW7	User HVI switch (Active low)
	SW8	User HVI switch (Active low)
	SW6	HVI Switch connected to VSUP/GND
	SW1	RESET Switch
	R58	Potentiometer connected to HVI
	R65	Potentiometer connected to ADC port AN3
	D13	UserLED - Green
	D14	UserLED - Green
	D15	UserLED - Green
	D16	UserLED - Green
Motor Control	J21	2-Phase Motor control Connector with GND
Communication and Programming Interfaces	J35	OSBDM/USB Connector
	D17	OSBDM PWR LED, ON when OSBDM is successfully enumerated as USB device.
	D18	OSBDM STATUS LED. ON when OSBDM is successfully transmitting as USB device.
	J10/J9	LIN Interface
	J6	LIN Master Enable
	J33	Header selector for OSBDM_RXD/TXD
	J31	SPI/Hall sensor lines with 5.0V and GND

[J31] SPI/Hall sensor Connector

[J10] LIN Connector

[J1/J3] Power Supply Connector

[J35] OSBDM/USB Interface

[SW2/SW3] GPIO Switch

[J1] 2-Phase Motor control Connector with GND

[SW7/SW8] HVI Switch

[R58/SW6] HVI Interface

[SW6] RESET Switch

[R65] ADC Potentiometer

Window Lift – Reference Design

- **Features**
  - Smallest possible, of 2 or 4 layer PCB with components only on the top.
  - BDM Interface .Connector HDR 2x3 100mils
  - Hall Sensor/SPI. Connector HDR 2x3 100mils
  - LIN based communication. Including bootloader functionality in the 2nd phase of SW development)
  - Overcurrent protection via an external current sense resistor.
  - Antipinch functionality enabled with the combination of both the hall-effect sensor feedback and the current sensing feedback.
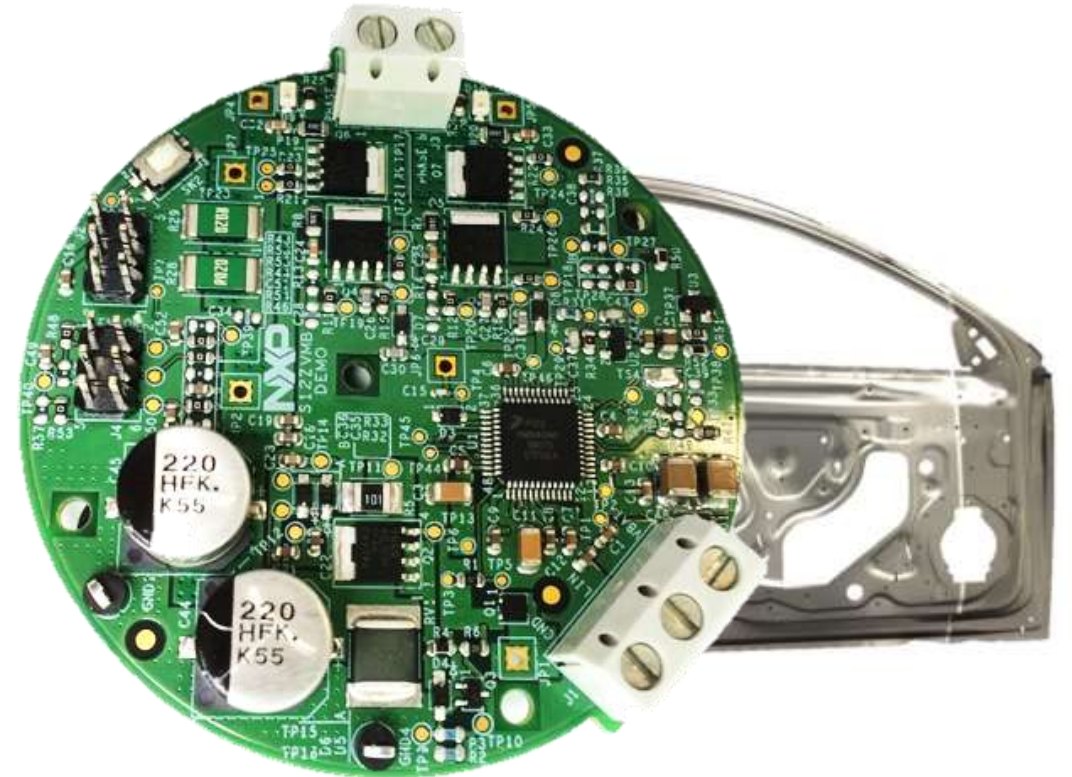
Window Lift – Reference Design
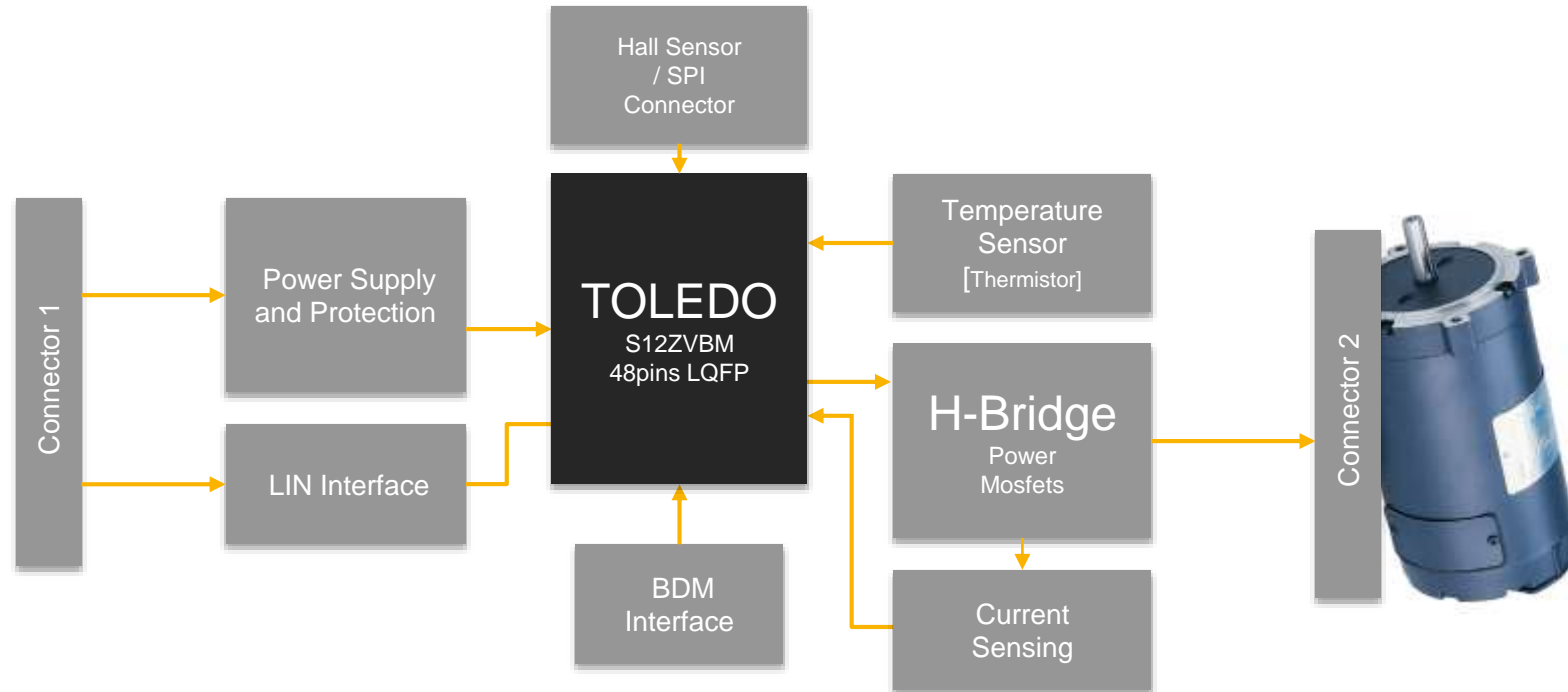
S12ZVMB Window lift ref. design

- Car window is being virtually simulated
- Buttons to move the motor up, down or stop it.
- Current and encoder pulse width values are being plotted.
- Calibration routine enabled
- SW enabled with Anti-pinch algorithm.

S12ZVMB: Window Lift Demo   v1.0

Erase calibration | Status | LIN enabled | Plot Selector
⦿ Current value
⦿ Pulse Width

Motor Current

motor current [mA]
threshold value [mA]

Time[ms]

S12 MagniV Benefits

S12 MagniV solutions deliver optimal **system cost** and
physical footprint for sensor and actuator applications**.**

✓ **Reduced PCB Space**
Up to 30%

✓ **Improved manufacturing efficiency**
Replacing typically 3 IC by 1 MagniV reduces assembly and test cost while quality improves

✓ **Reduced Bill Of Material (BOM)**
Fewer components to purchase, handle, store and qualify

✓ **Simplified motor control that speeds up time-to-market**
Save up to 6 months on development, validation and ISO26262 implementation
• Abstract the complexity of 3-phase motor control software development
• Production ready Automotive quality SW and Tools
• SafeAssure program

SECURE CONNECTIONS
FOR A SMARTER WORLD