S12 MagniV Designing Power Window Lifts with the S12VR

Overview

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SEP. 03. 2014
 Agenda

• MagniV solutions for motor control
• S12VR overview
• TRK-S12VR-WLFT Reference Design: Hardware
• Safety Measures for Power Window Lifts
• TRK-S12VR-WLFT Reference Design: Software
A Technology Sweet spot for Sensor and Actuators

Digital Logic
- S12, PWMs, Timers, SRAM, SPI, SCI, GPIO, Watchdogs, etc.

High-Voltage Analog
- Low Side & High Side Drivers, Voltage Regulator LIN/CAN Phy. etc.

Non-Volatile Memory
- Flash, EEPROM

Existing
- Low Leakage 180nm CMOS+NVM

40V UHV Devices

Existing
- 180nm CMOS+NVM

40V UHV Devices
Shrink Your Application

Traditional Solutions

- Standard MCU
- Multiple analog IC

System in Package

- Saves up 30% space
- Simplifies manufacturing
<table>
<thead>
<tr>
<th>S12VR Target Area</th>
<th>S12ZVM Target Area</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power Stage</strong></td>
<td><strong>Mechanical</strong></td>
</tr>
<tr>
<td>Relay-driven DC motors</td>
<td>H-Bridge driven DC motors</td>
</tr>
<tr>
<td>Relay</td>
<td>H-Bridge</td>
</tr>
<tr>
<td><strong>Mechanical</strong></td>
<td><strong>Construction</strong></td>
</tr>
<tr>
<td>Construction</td>
<td>Permanent magnets placed on rotor</td>
</tr>
<tr>
<td>Relay H-Bridge</td>
<td>Permanent magnets placed on stator</td>
</tr>
<tr>
<td>3-phase</td>
<td>Magnetic poles in rotor generated by current conducted coil</td>
</tr>
<tr>
<td><strong>Commutation</strong></td>
<td><strong>&amp; Control</strong></td>
</tr>
<tr>
<td>Technique</td>
<td>Advantage</td>
</tr>
<tr>
<td>Mechanical commutation by brushes in the rotor</td>
<td>Electronic Commutation takes place in the stator</td>
</tr>
<tr>
<td>6-step / block commutation to produce trapezoidal Phase voltage</td>
<td>Sinusoidal / vector control to produce sinusoidal phase voltage</td>
</tr>
<tr>
<td><strong>Topology</strong></td>
<td><strong>Advantage</strong></td>
</tr>
<tr>
<td>Advantage</td>
<td></td>
</tr>
<tr>
<td>Lowest cost</td>
<td></td>
</tr>
<tr>
<td>No mechanical component (reliability, electrification)</td>
<td>High Efficiency Power to weight ratio</td>
</tr>
<tr>
<td>No Relay noise</td>
<td>Power to weight ratio</td>
</tr>
<tr>
<td>PWM speed regulation</td>
<td>Reliability Noise</td>
</tr>
<tr>
<td></td>
<td>Best noise behavior</td>
</tr>
<tr>
<td></td>
<td>High speed &amp; precision</td>
</tr>
<tr>
<td></td>
<td>Highest efficiency &amp; torque</td>
</tr>
<tr>
<td></td>
<td>Power to weight ratio</td>
</tr>
</tbody>
</table>
MagniV Family for Motor Control

< 200W Motors

- **S12ZVM**
  - 16/32KB; 64pin; 50nC
- **S12ZVML**
  - 32-128KB; 64pin LIN with PHY, 100nC

> 200W Motors

- **S12ZVMC**
  - 64-128KB; 64pin 2nd 5V VREG for ext CAN, 100nC
- **S12ZVML**
  - 32-128KB; 64pin LIN with PHY, 100nC

**H-Bridge**

- **S12VR**
  - 48K-64KB; 32/48pin LIN with PHY; LS drivers
- **S12VR**
  - 16-32kB, 32pin LIN with PHY; LS-driver

**Relay-driven DC-motors**

- **S12VR**
  - 48K-64KB; 32/48pin LIN with PHY; LS-drivers
- **S12VR**
  - 16-32kB, 32pin LIN with PHY; LS-driver

**Production**
**Execution**
**Planning**
**Proposal**

- **LIN applications**
- **CAN applications**
- **PWM controlled apps**

- **Switch panel interface**
- **High temp option (AEC Grade 0)**

- **Family-concept for relay-driven DC-motor window lifter**
- **Covering low to high end**
- **Planned extension for future H-Bridge DC-WL**
S12 VR Family

S12 CPU with an integrated Voltage regulator, LIN physical layer and HS/LS-drivers for Relay-driven Window Lift motor
S12VR Family
Relay based DC Motors

Key Features:

- **S12 (25 MHz max) 16-bit CPU** compatible with the S12G family and MM912 solutions.
- **Voltage Regulator** operating directly from car battery (No ext regulator needed) capable to drive 20mA to drive off chip components (E-Vdd)
- **LIN Physical Layer**: LIN 2.x / J2602 compliant; +/- 8kV ESD capability
- **True 512B EEPROM** with ECC, 4 byte erasable
- **2 Low-Side drivers** with active clamps to drive relays (inductive load) for bi-directional brushed DC Motors
- **Up to 2 HS drivers**: for indicator LED and Switch supply
- **Up to 4 High Voltage Inputs**: 12V Inputs, ESD-protected, wake-up/interrupt capability, 12V analog inputs routed internally to ADC through selectable divider ratio.
- **On chip RC Oscillator**: trimmed to +/- 1.3% tolerance over full temperature range

Target Applications

- Automotive **power window lift** / **sunroof** with anti-pinch
- Any **relay driven DC motors**
- **LIN slaves** with space constraints

Family options:

- Flexible Flash Options: 16kB to 64kB Flash
- Packaging: 32-LQFP or 48-LQFP
- C / V / M Temperature options (up to 125°C Ta)
Overview of S12VR Family

- **2 UARTs**
  - One linked to LIN Phy, 2nd as reardoor communication or indep. test Interface

- **LIN Physical Layer**
  - LIN2.2 and SAE J2602 compliant

- **S12 CPU**
  - 16-bit, compatible with S12G Family and existing SiP Solutions.

- **On chip RC OSC**
  - Factory-trimmed to +/-1.3%, meets LIN -needs

- **ADC** - up to 6 ext. Ch.
  - +4 int. channels for temp sense, supply monitors, HV inputs, internal ref Voltages

- **Up to 2 HS drivers**
  - For LED and Switch supply

- **2 Low-Side Drivers**
  - Protected LS Drivers to drive relays directly

- **Voltage Regulator**
  - 5V/70mA for the whole system

- **Supply- and Battery-sensing**
  - Voltage sense before (VSENSE) and after protection diode (VSUP)

- **Packaging Options**
  - 32LQFP and 48LQFP

Other features:

- **Up to 16 Wakeup pins**
  - Combined with Analog Input pins and HV pins

- **4ch 16bit Timer**
  - Hall inputs, SW timing

- **8ch PWM**
  - Routable to HS and LS outputs, for LED dimming

- **External Supply**
  - 5V / 20mA switchable for local (same PCB), over current protected. Eg. supplying Hallsensors

- **4 High Voltage Inputs**
  - 12V Inputs for Switch Monitoring Routable to ADC

- **EEPROM**
  - 4 byte erasable 100k program/erase cycles

- **Flash (48/64kB)**
  - 512B erasable, 10k p/e cycles
  - Can be used for Data (parameter, config, calibr.)

- **TIM 16b 4ch**
  - PWM 8ch 8b or 4ch 16b

- **GPIO**
  - VSENSE (battery)

- **PWM 8ch 8b or 4ch 16b**

- **BDM**

- **KWU**

- **Win Wdog**

- **Electrical Characteristics**

- **Supply- and Battery-sensing**

- **Packaging Options**
  - 32LQFP and 48LQFP
Overview of S12VR Family – Analog Modules

- **LIN Physical Layer**: LIN2.2 and SAE J2602 compliant
- **Up to 2 HS drivers**: For LED and Switch supply
- **2 Low-Side Drivers**: Protected LS Drivers to drive relays directly
- **Voltage Regulator**: 5V/70mA for the whole system
- **Supply- and Battery-sensing**: Voltage sense before (VSENSE) and after protection diode (VSUP)

**LIN PHY**
- SCI 1, SCI 0
- S12 25MHz Bus
- 48-64kB Flash (ECC)
- 512B EEPROM (ECC)

**GPIO**
- BDM, KWU, Win
- TIM 16b, 4ch
- PWM 8ch, 8b or 4ch 16b
- 1# EVDD

**Pierce Osc.**: +/−1.3%
- PLL

**Temp Sense**: 10-Bit ADC

**4 High Voltage Inputs**: 12V Inputs for Switch Monitoring Routable to ADC

**VSENSE (battery)**
- VSENSE
- 70mA
## S12VR Package & Feature Options

<table>
<thead>
<tr>
<th>Product Name</th>
<th>S12VR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
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</tr>
<tr>
<td>Package 32 LQFP</td>
<td>32 LQFP</td>
</tr>
<tr>
<td>Package 32 LQFP</td>
<td>32 LQFP</td>
</tr>
<tr>
<td>Package 48 LQFP</td>
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<td>Low Side Drivers</td>
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<td>SPI modules</td>
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<tr>
<td>Pin Pitch</td>
<td>0.8mm</td>
</tr>
<tr>
<td>Pin Pitch</td>
<td>0.5mm</td>
</tr>
</tbody>
</table>

0.8mm pitch allows routing signals between pins for PCB space- & layer-savings
S12VR Development Tools and Enablement

**HARDWARE:**
- **S12VR64EVB:** S12VR Evaluation Board ($149,-)
- **TRK-S12VR-WLFT:** Window lifter reference design
- **USBMULTILINKBDM:** In-Circuit Debugger/Programmer

**COMPILER, DEBUGGER:**
- **CW_V5.1HCS12_VR64SP:** CodeWarrior for HCS12(X) v5.1 VR64 Service Pack
- **ZAP 6812 ICD:** Cosmic ZAP HCS12 BDM Debugger.

**APPLICATION NOTE, REFERENCE DESIGN, MIDDLEWARE:**
- **AN4540** Comparison Between the MC9S12VR and MM912_634
- **AN4650** Functional Differences between Tomar 2.1 (2N05E) & Tomar 3 (0N59H)
- **FSL_LIN_2.1_DRIVER:** LIN 2.1 / J2602 Driver

**TRAINING:**
- **AN4448:** MC9S12VR Family Demonstration Lab Training
Achieved LIN2.2/SAE J2602-2 Physical Layer Conformance

Test Report

Device Under Test
- Object Family: S12VR54
- Manufacturer: Freescale Semiconductor
- Type: LIN Transceiver
- Sample marking: S12VR54MLF.DE27457.1 SN021

Customer
- Order No.: P13_0142
- Name: Freescale Semiconductor México
- Address: Periférico Sur 8110 Col. El Marín Tlahuacuca, Jal. 45509 Mexico

Number of Pages: 40 from ww 20/3/2013 until ww 20/3/2013

Test Method / Test Requirement
- LIN Conformance Test Specification
- LIN OSI Layer 1 - Physical Layer
- For LIN devices with Rx and Tx access. For the LIN Physical Layer Specification. Revision 2.2 (December 31th, 2013)

Performed Tests and References
- The Test Results refer to the delivered device.

For detailed information see chapter Test List at the following pages.

Approved by
- L. Kukla, Project Manager

Test performed by
- P. Hoffmann, Project Engineer

Test Report

Device Under Test
- Object Family: S12VR54
- Manufacturer: Freescale Semiconductor
- Type: LIN Transceiver
- Sample marking: S12VR54MLF.DE27457.1 SN021

Customer
- Order No.: P13_0141
- Name: Freescale Semiconductor México
- Address: Periférico Sur 8110 Col. El Marín Tlahuacuca, Jal. 45509 Mexico

Number of Pages: 30 from ww 18/3/2013 until ww 18/3/2013

Test Method / Test Requirement
- LIN Conformance Test Specification
- "SAE J2602-2 LIN Network for Vehicle Application Conformance Test. SAE J2602-2 issued NOV 2012"

Performed Tests and References
- The Test Results refer to the delivered device.

For detailed information see chapter Test List at the following pages.

Approved by
- L. Kukla, Project Manager

Test performed by
- J. Eversmeier, Project Engineer
LINPHY EMC Certifications

IBEE

BMW

Volkswagen

Porsche

Ford

GM

Chrysler

Audi

Mooser
S12VR Detailed Analog Module Explanation
Low Side Drivers

Features

- Power N channel enhancement MOSFETs that can be used to activate coils
- 2 LSD are included no matter what package is selected. Thus, up/down control is possible in any case.
- It is included an over current protection circuit with automatic shutdown (not shown in the picture)
- 2 zener diodes are included to protect the MOSFET from the BEMF generated when switching off the coils.
Low Side Drivers

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Figure 14-1. LSDRV Block Diagram
Low Side Drivers

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- 2 zener diodes are included to protect the MOSFET from the BEMF generated when switching off the coils.
Low Side Drivers

Use Recommendation in Window Lifters

- Use one LSD to drive the motor up and the other to drive it down.
- Example:
  - When activating LS0 turn off LS1 to move the motor up
  - When activating LS1 turn off LS0 to move the motor down
Low Side Drivers

Use Recommendation in Window Lifters

- Use one LSD to drive the motor up and the other to drive it down.
- Example:
  - When activating LS0 turn off LS1 to move the motor up
  - When activating LS1 turn off LS0 to move the motor down
High Voltage Input

Features

- Can be used as a digital or analog input that can be operated at battery voltage level.
- A voltage divider is included to allow routing the divided voltage to an ADC channel.
- Direct mode used to bypass the voltage divider.
- Internally it has a 40K ohm resistor and externally the required 10k resistor provide a low leakage path.

![HVI Block Diagram](image)
High Voltage Input

Features

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High Voltage Input

Use Recommendation in Window Lifters

- Use them to read the state of switches connected to battery voltage level.
- Use them to awake the MCU from stop when a relay fault is detected.
High Voltage Input

Use Recommendation in Window Lifters

- Use them to read the state of switches connected to battery voltage level.
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High Side Driver

Features

- Power P channel enhancement MOSFETs that can be used to activate resistive loads.
- 1 HSD included in the 32LQFP package and 2 in the 48LQFP
- An over current protection with automatic shutdown feature is included
- VGS limited by zeners
High Side Driver

Features

- Power P channel enhancement MOSFETs that can be used to activate resistive loads.
- 1 HSD included in the 32LQFP package and 2 in the 48LQFP
- An over current protection with automatic shutdown feature is included
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High Side Driver

Features

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- 1 HSD included in the 32LQFP package and 2 in the 48LQFP
- An over current protection with automatic shutdown feature is included
- VGS limited by zeners
High Side Drivers

Use Recommendation in Window Lifters

- Use one HSD to drive a search light.
- Use the second HSD to power the ajar switch.
High Side Drivers

Use Recommendation in Window Lifters

- Use one HSD to drive a search light.
- Use the second HSD to power the ajar switch.
LINPHY

Features

- LSD transistor used as LIN physical layer.
- Internal selectable slave pull up device.
- Slew rate control
- Over current shutdown with mask feature
- TxD Dominant timeout with automatic shut down feature.
- Can be configured to generate a wake up pulse during stop mode that can be passed to the SCI to awake the MCU.
- Compliant with LIN PHY Layer 2.2 spec
- Compliant with SAE J2602-2 LIN Standard
LINPHY

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- Compliant with LIN PHY Layer 2.2 spec
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LIN wake up

23us after the falling edge at the SCI RX, the bus clock becomes available, then other peripheral modules are transitioned to run mode and CPU fetches the RXEDG interrupt.

About 3.4us after the LIN bus reaches its recessive level (~60% of VSUP), the SCI RX falling edge occurs.

No LIN wake up

* is tWUFR period

SCI Rx
(internal signal)

LIN bus

MCU state

STOP

RUN
FMVSS Powered Window Lift Required Safety Measures
FMVSS 118

- ECUs driving power-operated window, partition and roof panels must meet the requirements of the FMVSS:

1. The system is restricted to close the window only if specific conditions are met (see FMVSS for a detail of all conditions), or

2. The system implements an automatic reversal system. This system must stop and reverse the direction of the window either before contacting, or before exerting a squeezing force of 100N

- The Objective of these measures is to minimize the likelihood of death or injury from accidental operation
Self Reversal Systems

• For self reversal systems, the system needs to be able to compute the force exerted by the window during its operation or detect the proximity of an object obstructing the window

• Typical implementations:
  1. Sense the current in a DC motor while it moves
     • Torque is proportional to the current flowing on the motor
     • Current ripples can be used to detect the window position
  2. Use a hall encoder to detect the position and speed of the motor
     • The torque can be computed with the measured speed and the measured voltage at the terminals of the motor
  3. Use infrared reflection to detect obstructing objects before contacting them
Considerations when Designing Powered Window Lifts
Do NOT exceed MCU’s maximum operating ratings!

Table A-2. Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Num</th>
<th>Rating</th>
<th>Symbol</th>
<th>Min</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Voltage regulator supply voltage</td>
<td>$V_{SUP}$</td>
<td>-0.3</td>
<td>42</td>
<td>V</td>
</tr>
<tr>
<td>2</td>
<td>LINPHY supply voltage</td>
<td>$V_{SUP}$</td>
<td>-32</td>
<td>42</td>
<td>V</td>
</tr>
<tr>
<td>3</td>
<td>High side driver supply voltage</td>
<td>$V_{SUPHS}$</td>
<td>-0.3</td>
<td>42</td>
<td>V</td>
</tr>
<tr>
<td>4</td>
<td>Voltage difference $V_{DDX}$ to $V_{DDA}$</td>
<td>$\Delta V_{DDX}$</td>
<td>-0.3</td>
<td>0.3</td>
<td>V</td>
</tr>
<tr>
<td>5</td>
<td>Voltage difference $V_{SSX}$ to $V_{SSA}$</td>
<td>$\Delta V_{SSX}$</td>
<td>-0.3</td>
<td>0.3</td>
<td>V</td>
</tr>
<tr>
<td>6</td>
<td>Digital I/O input voltage sources</td>
<td>$V_{IN}$</td>
<td>-0.3</td>
<td>6.0</td>
<td>V</td>
</tr>
<tr>
<td>7</td>
<td>HVI PL[3:0] input voltage</td>
<td>$V_{Lx}$</td>
<td>-27</td>
<td>42</td>
<td>V</td>
</tr>
<tr>
<td>8</td>
<td>High-side driver HS[1:0]</td>
<td>$V_{PHS0/1}$</td>
<td>0</td>
<td>$V_{SUPHS} + \alpha/2$</td>
<td>V</td>
</tr>
<tr>
<td>9</td>
<td>Low-side driver LS[1:0]</td>
<td>$V_{PLS0/1}$</td>
<td>0</td>
<td>40</td>
<td>V</td>
</tr>
<tr>
<td>10</td>
<td>EXTAL, XTAL</td>
<td>$V_{ILV}$</td>
<td>-0.3</td>
<td>2.16</td>
<td>V</td>
</tr>
<tr>
<td>11</td>
<td>Instantaneous maximum current</td>
<td>$I_{D}$</td>
<td>-25</td>
<td>25</td>
<td>mA</td>
</tr>
<tr>
<td>12</td>
<td>Instantaneous maximum current on PP2 / EVDD</td>
<td>$I_{EVDD}$</td>
<td>-80</td>
<td>25</td>
<td>mA</td>
</tr>
<tr>
<td>13</td>
<td>Instantaneous maximum current</td>
<td>$I_{DL}$</td>
<td>-25</td>
<td>25</td>
<td>mA</td>
</tr>
<tr>
<td>14</td>
<td>Storage temperature range</td>
<td>$T_{Stg}$</td>
<td>-65</td>
<td>155</td>
<td>°C</td>
</tr>
</tbody>
</table>

1. Beyond absolute maximum ratings device might be damaged.
2. $V_{DDX}$ and $V_{DDA}$ must be shorted
3. EXTAL and XTAL are shared with PE0 and PE1 5V GPIO’s
4. All digital I/O pins are internally clamped to $V_{SSX}$ and $V_{DDX}$, or $V_{SSA}$ and $V_{DDA}$.
Load Dump and Fast Transients

Introduction

1. In Automotive it refers to the disconnection of the vehicle battery from the alternator while the battery is being charged.
2. Due to such disconnection other loads will see a voltage peak.
3. ISO7637 (and SAE J1113-11) specify standard shapes of pulses against which automotive electronic components must be designed.
4. Other ECU cables connected in the same harness than the Battery/Alternator will establish a capacitive/inductive coupling. Thus they will be affected also by fast transients.
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![Diagram of Load Dump and Fast Transients]

- **Coupled voltage at the pin**
- **Open circuit**
- **Load dump at VBAT**
- **Battery**
- **ECU**
- **Sensor**
- **Alternator**
Load Dump and Fast Transients

Introductions

1. Modules with connections to VBAT (or VSUP) will be directly affected by transients. Involved pins might be HSD, LSD, HVI, VSENSE, VSUP and LINPHY.

2. 5V pins will be affected also if they are routed thru cables running in parallel to VBAT.
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Load Dump and Fast Transients

**Recommendations**

1. Limit the maximum voltage at VBAT by using a transient suppressing device (for example use a TVS). **On load dumps it is recommended to have a centralized external Load dump module.** Max voltage at VSUP is 42V.

2. To limit the injected current at 5V pins, add RC filters (low pass filters) at input pins routed outside the board.

3. When possible limit the transient at HVIs and VSENSE by forming a low pass filter with the 10K ohm required resistor and a capacitor.

4. If the module will be subject to transients that require more dissipation power than the one already included in the device add additional suppressing devices.
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![Diagram showing a transient suppressed with a RC filter with 10K ohm resistor and 220pF capacitor](image)
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Specific Challenges when Designing for DC motors
Mid Freq. Transients During the Motor Activation

1. Several customers detect transients with a frequency content between 10MHz and 50MHz when activating a brushed DC motor.

2. Car manufacturers require the system to remain with no resets during the injection of these transients. E.g. The open Ford test requirement EMC-CS-2009.1. Test CI-220 pulse C-1
Mid Freq. Transients During the Motor Activation

• To filter such frequencies users can put a Low Pass LC Filter connected between VBAT and GND:
Mid. Freq. Transients During the Motor Activation

- Below it is shown in yellow the high frequency transient in the input and in green the output of the filter. For this filter as L element it was used 2 BLM18AG102SH1 inductors from Murata connected in parallel (1K ohm impedance each @100MHz) and 2 680pF capacitors connected in series. Green plot shows how the transients are removed.
TRK-S12VR-WLFT Characteristics

- **S12VR Package**: 32-pin LQFP

- **Motor type**: DC, 7A typ.

- **Feedback**: Hall Encoder, voltage applied at the Motor

- **PCB**: 2-layer board, assembly on top side only.
  2.4in x 1.9in (including demo switch and push-buttons)
  BOM parts = 42 (not including headers, switch and push-buttons)
Simplified Board Description
System Hardware Description

- VSUP: A low Vf Diode protects VSUP from reverse battery conditions. 2 10uF/50V/1210 capacitors are used to decouple transients in the 100KHz to 1MHz range.
- VSENSE: A 10K resistor and a 6.8nF/50V/0402 cap make a low pass filter for stable VBAT System Measurements.
- Motor Actuator: The relay takes typically ~1.3ms to open/close the terminals (max 5ms). During this time, the TVS1 can clamp transients caused by the rapid decrement in the current in the coils.
- The Relay is activated by 2 LSDs. No relay discharge coil diode were included given the fact that the LSDs already include an internal active clamp.
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A 1uF capacitor provides voltage stability against input transients in the 100KHz to 1MHz range.
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- The up/down switch is powered thru the HSD. This allows automatic power off during low current mode. HS0 can provide up to 50mA to switches.
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![SWITCHES](image.png)
Knowledge Needed to Implement Anti-pinach Detection

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![Graph showing motor speed vs. elevator friction and torque with no obstacle and stall conditions]
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Pinch Detection

- Using the measured motor speed, voltage in the motor and the expected speed at a determined position, it is possible to determine the force exerted by the window to a determined obstacle.

- By establishing a speed maximum period at a determined position and voltage, it is possible to determine if the exerted force was reached.
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**Pinch Detection**

- Expected speed is determined every time the speed signal toggles. And voltage can be averaged during that time.
- A synchronized timer channel is used to trigger an action when the minimum speed was reached without a speed toggle.
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Recommended SW Module’s Dependence

Mod A depends on Mod B
Hardware Interaction Layer Content

• Routines to control the S12VR HW Modules used in power window lifts
  
  – ADC Internal/External Channels
  – P-Flash/EEPROM Interaction
  – IFR Content Reading
  – Switches Routines
  – EVDD Control
  – Low Power Control
  – Timer/HVI/HSD/LSD/RTI/COP
Hardware Abstraction Layer Content

- Routines manipulating the HIL to perform Power Window Lifts tasks to:
  - enter low power mode
  - initialize calibrations
  - initialize HAL
  - activate the Self Reversal Routine
  - handle the speed and direction
  - self calibrate
  - perform tasks while powering down (save window position)
  - control system mode based on System Power Supply Voltage
  - execute tasks every 50ms.
  - initialize RAM
Recommended Software Subsystems

- **Speed and Direction:** Tracks the window position and the measured period of the speed signal.
- **Voltage at the Motor:** Reads the voltage at the motor up/down terminals.
- **Expected Speed at 12V:** Uses the Speed and Direction subsystem to provide an expected speed. It depends on stored calibrations.
- **Pinch Detection:** Uses the information from the subsystems above to determine the deviation from the computed speed and triggers the self-reversal subsystem when a threshold is passed.
- **Self-Reversal:** When triggered, it controls the self reversal of the window. It either stops after a certain amount of distance is reversed or after the initial window position was reached.