MSDI- Multi-switch Detection Interface (多重开关状态检测接口) 在车身控制模块的应用

David Wang

Systems Engineer (INT-MSS)

Texas Instruments

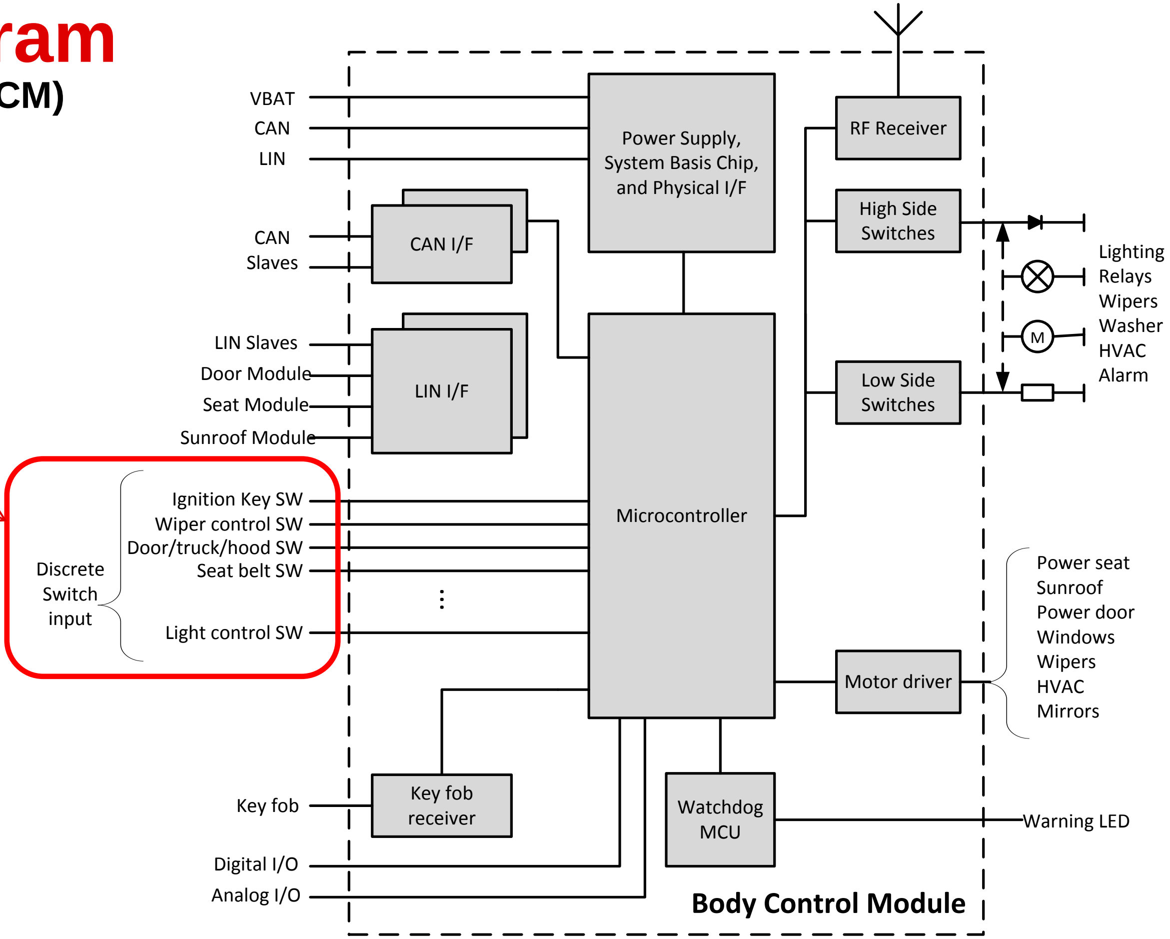
Detailed agenda

- Challenges in today’s Body Control Module (BCM) design
- How MSDI helps solve system-level challenges in BCM design
- Advanced features of the MSDI
- Conclusion

System block diagram

Automotive Body Control Module (BCM)

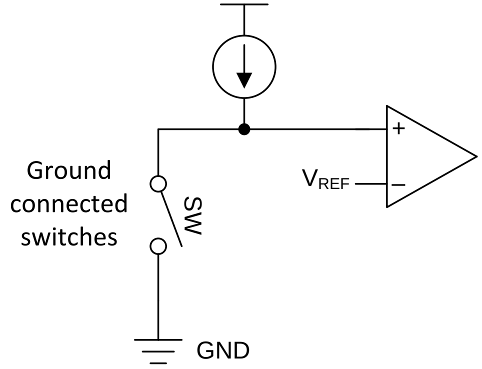
- There are a large number of switches (sometimes more than 100) in an advanced automotive system.
- Switch status detection is typically done discretely using the microcontroller's GPIOs



Switch detection concept

Automotive Body Control Module (BCM)

Digital switch (ON/OFF only)



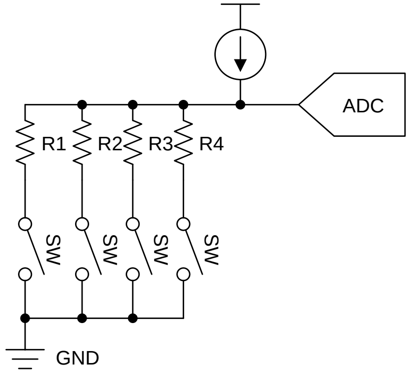
SEAT BELT SW

FR/RR FOG

TRUNK OPEN

DOOR UNLOCK

Analog (Resistor-coded) switch (Multi-threshold)



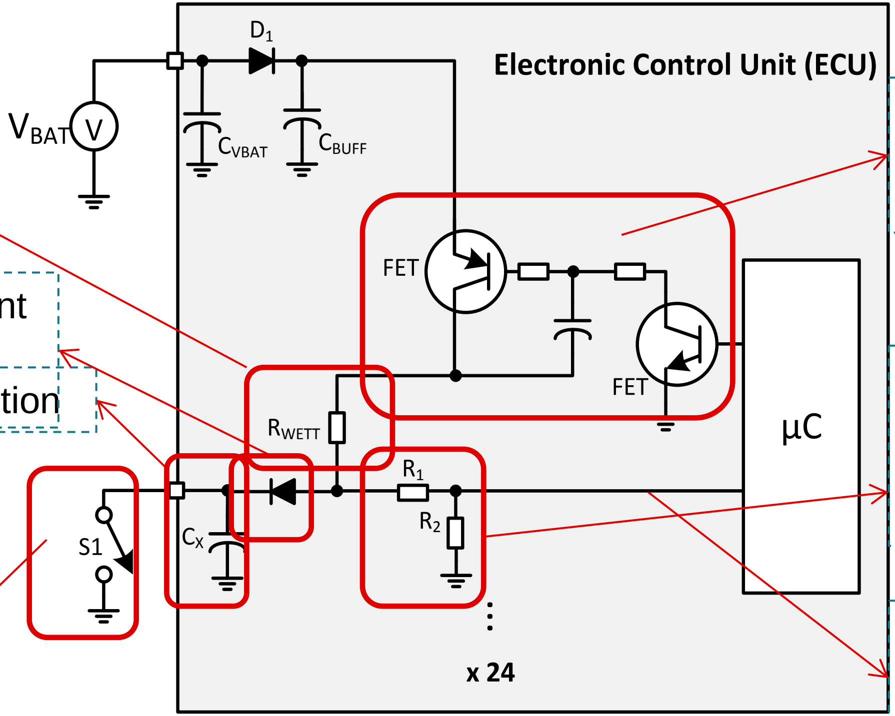
Key IN

TAIL / HEAD LAMP

Wiper

Discrete implementation

Switch/ contact status monitor



Wetting current adjustment resistor

Blocking diodes to prevent current
ba
in
ection

Components required to support each switch channel:

- 5 resistors
- 2 capacitors
- 1 diodes
- 2 FETs

monitored

FET + resistors for wetting current timing control

Resistor divider to scale down the input voltage for the µC to sample

1 µC GPIO for every switch to be monitored

Challenges with discrete implementation

1. High component count:

   Ex: BOM required to support 24 switches:

   - 78 resistors
   - 27 capacitors
   - 24 diodes
   - 6 FETs

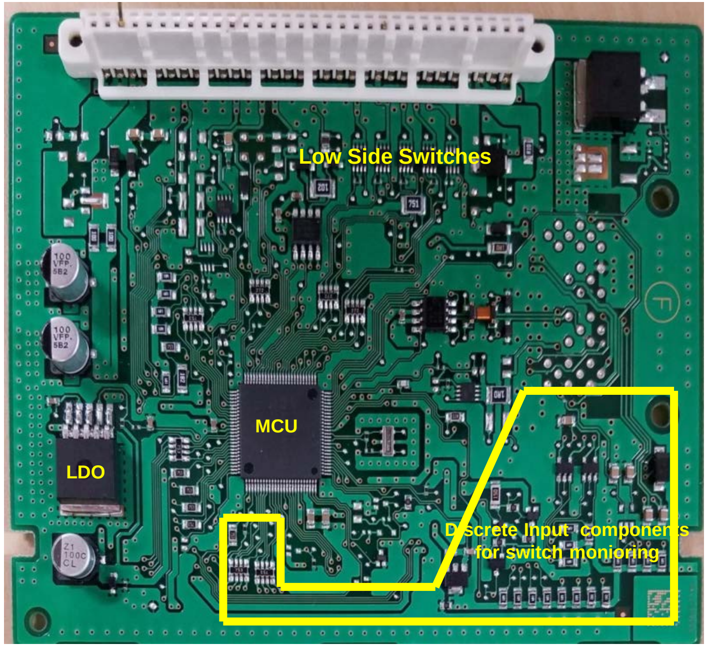
2. Large board area

3. High GPIO count➔ expensive µC:

   - # of GPIOs needed to support 24 channels: 28

4. High power consumption:

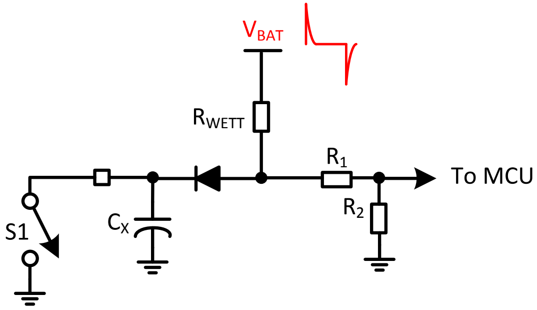
   - MCU needs to be active or constantly waken-up to support continuous switch monitoring， which consumes mA’s of current.



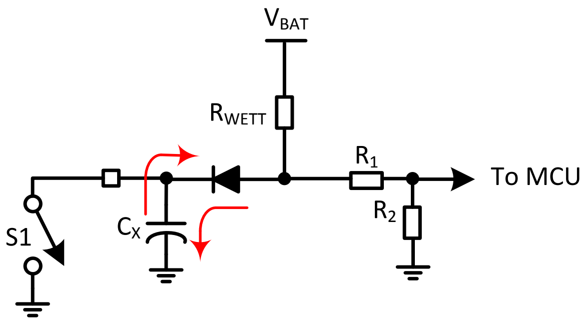
BCM example

Challenges with discrete implementation (continued)

5. Wetting current variation:
   - Voltage of an automotive battery could change rapidly due to cranking， load dump， transient loading spike， and jump start…etc.
   - Change in the V_{BAT} or supply voltage causes the wetting current (I_{WETT}) to change

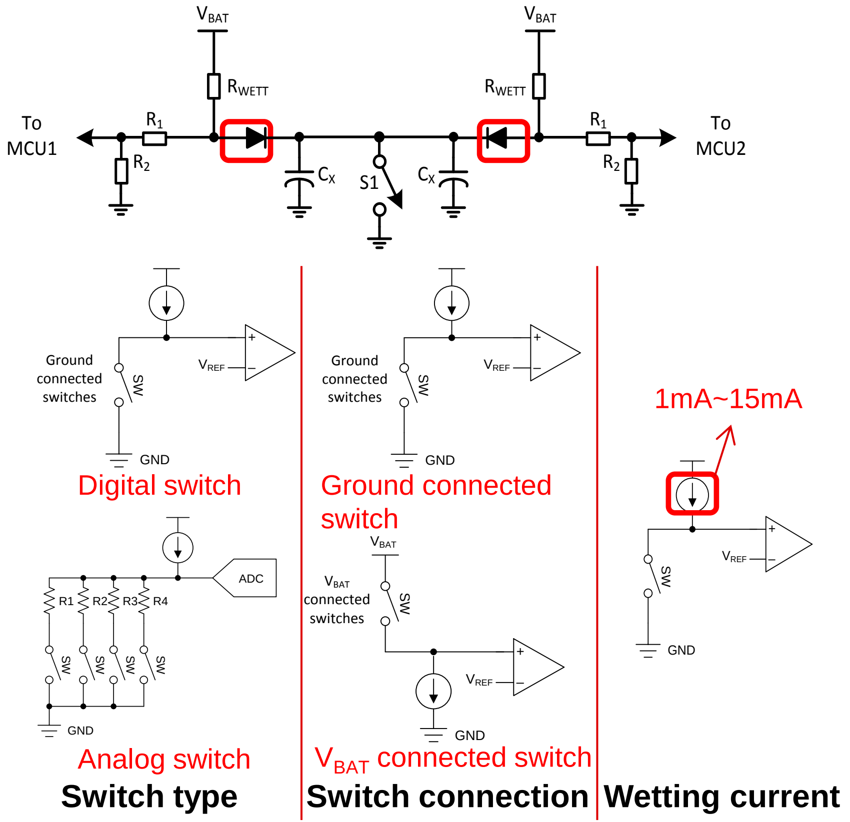


6. Large input ESD capacitors:
   - ESD capacitors is typically required to provide system level ESD protection for the MCU.
   - A large capacitor increase the charging/discharging time with I_{WETT}， which:
     1. Delays the switch response time
     2. Causes the MCU to stay active for longer



Challenges with discrete implementation (continued)

7. Expensive blocking diode:
    - Diodes are needed if the same switch is to be monitored by multiple MCUs for redundancy reasons to prevent current backflow.
8. Difficult to create portable designs:
    - Many aspects of switch design can change， including:
        - Switch type
        - Switch connection
        - Wetting current
        - Response time
    - It is difficult to create a portable reference design that can be adopted to various different use cases.



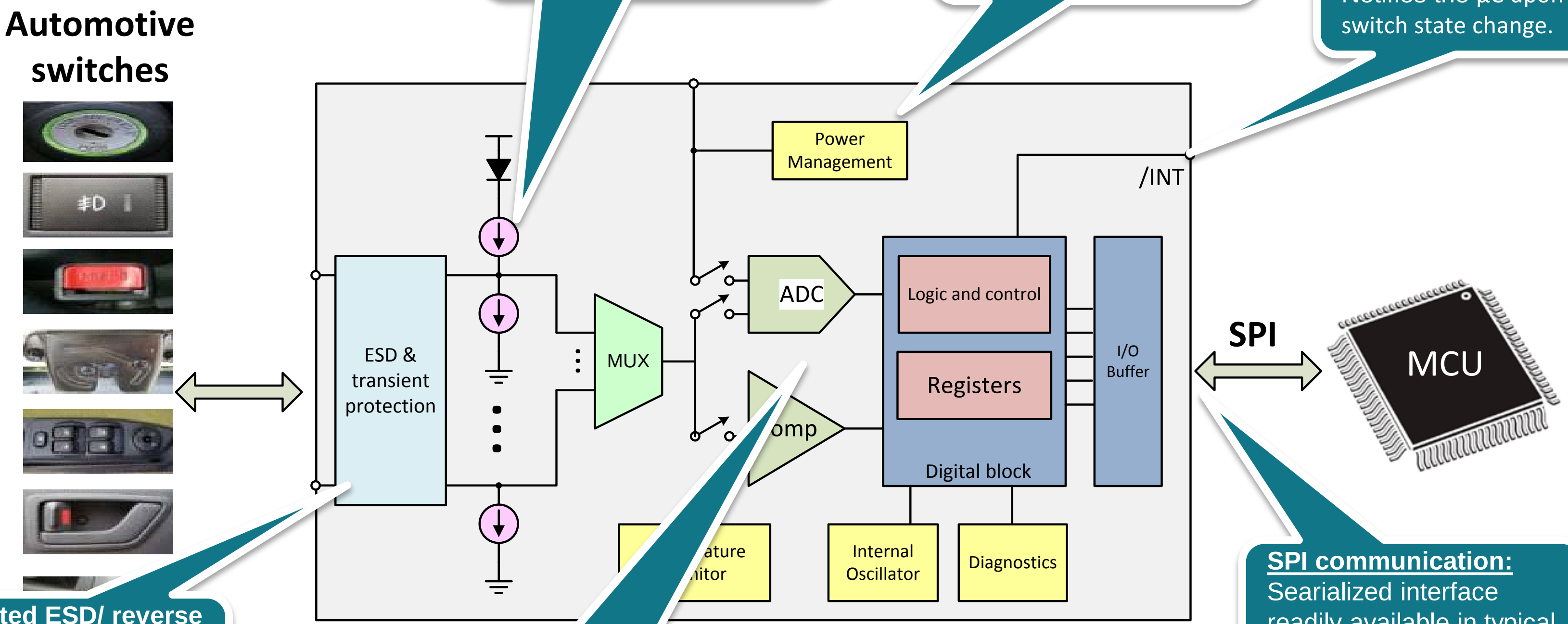
How MSDI solves system challenges

MSDI concept

Programmable channels:
Detect up to 24 switches with 10 channels supporting programmable configuration

Power management:
Maintain register settings when supply is as low as 2.8V

Interrupt generation:
Notifies the µC upon switch state change.



Integrated ESD/ reverse battery protection:
Minimize usage of external components.

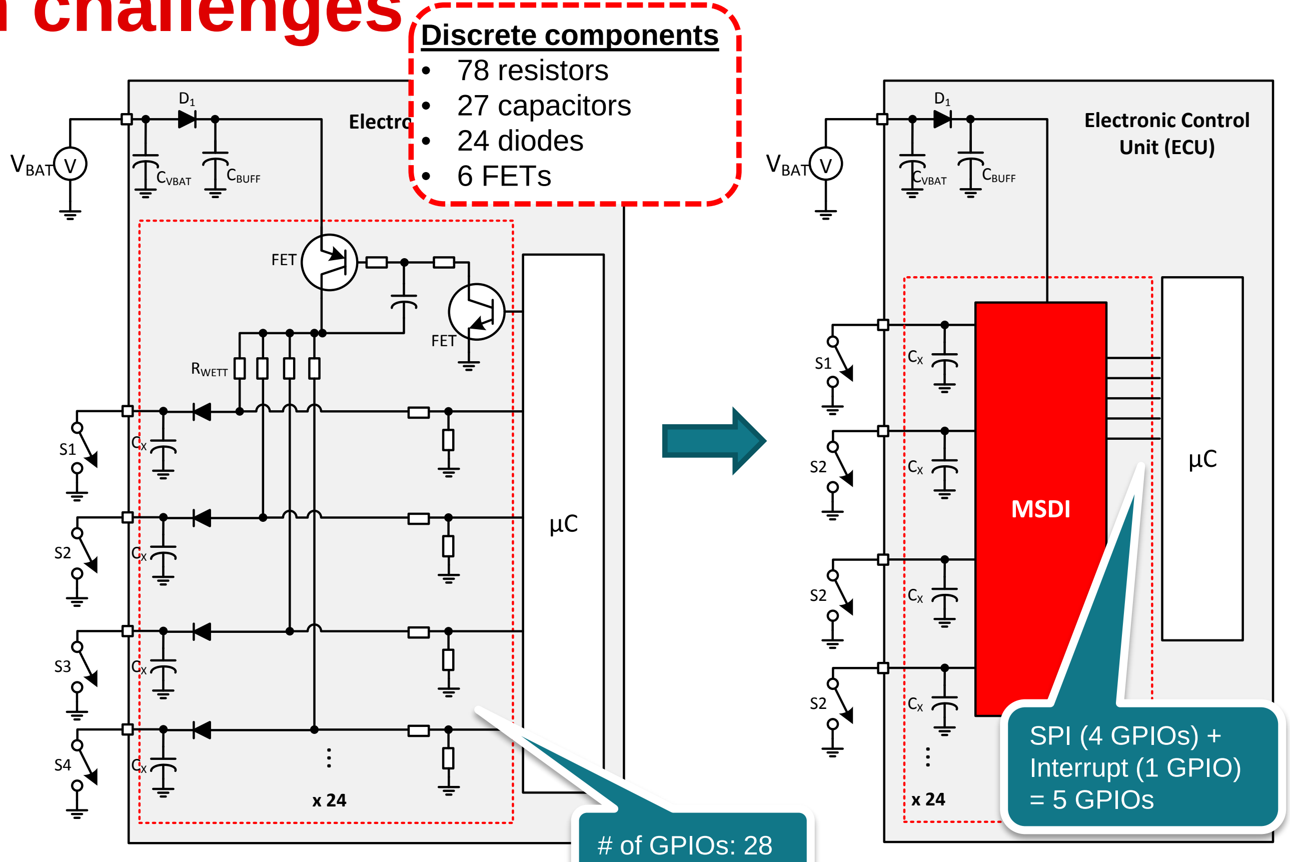
Integrated ADC and comparator: Allow detection of both analog and digital switches

SPI communication:
Searialized interface readily available in typical automotive systems

Solving system challenges

Discrete implementation challenges	
1	Large board area
2	High BOM count
3	High GPIO count
4	High power consumption
5	Wetting current variation
6	Large input ESD capacitors
7	Expensive block diodes
8	Difficult to create portable designs

MSDI implementation can save board area and BOM count by up to **40%**， and reduce # of µC GPIO usage significantly!

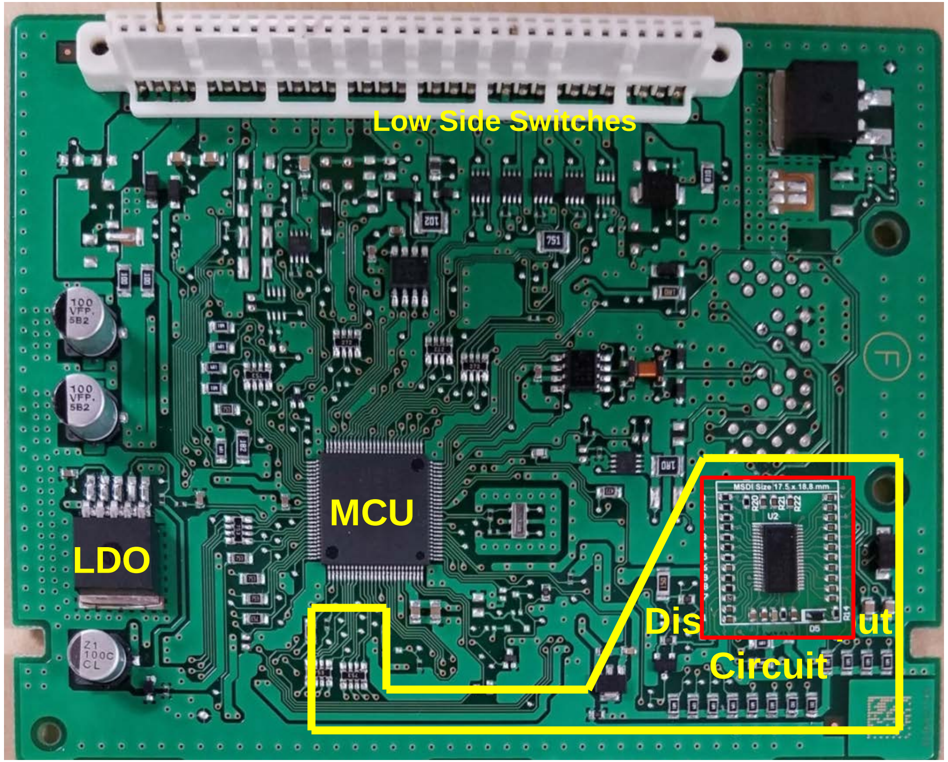


Discrete implementation

MSDI implementation

Solving system challenges

Discrete implementation challenges	
1	Large board area
2	High BOM count
3	High GPIO count
4	High power consumption
5	Wetting current variation
6	Large input ESD capacitors
7	Expensive block diodes
8	Difficult to create portable designs

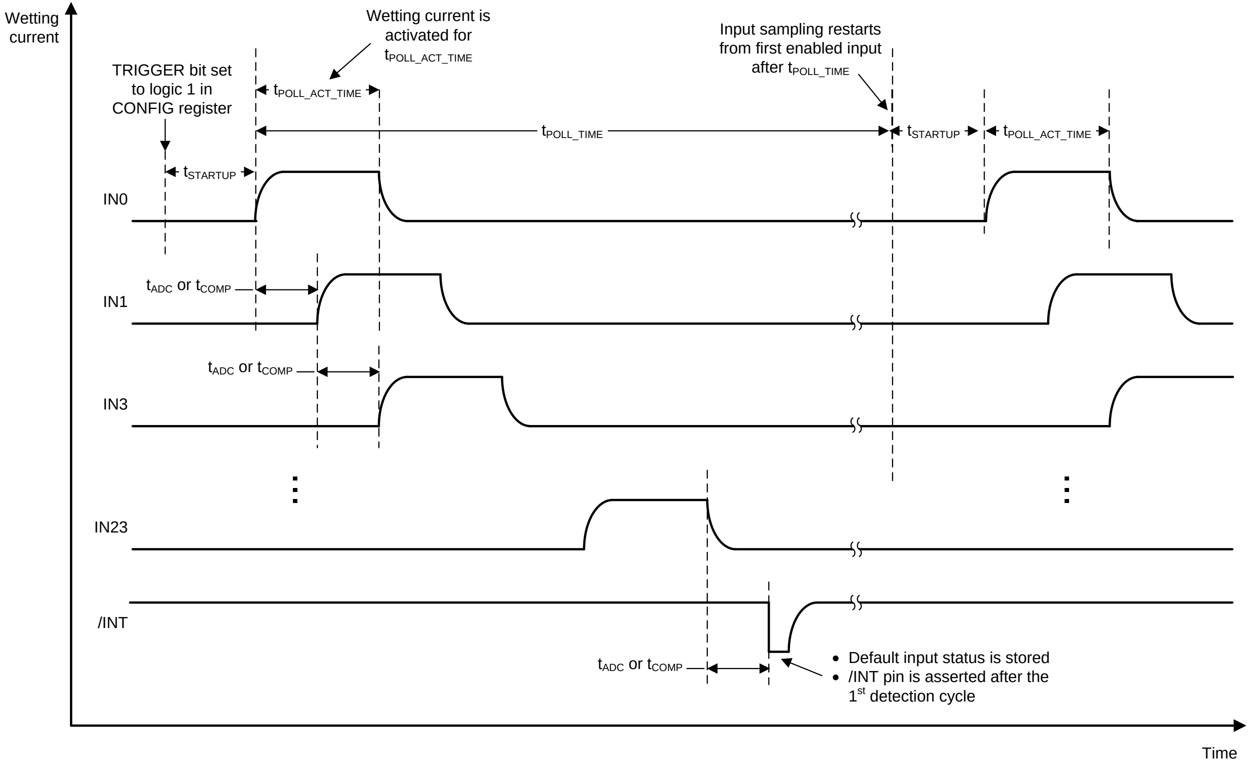


Size: 17.5mmX18.8mm

Solving system problems (continued)

Discrete implementation challenges	
1	Large board area
2	High BOM count
3	High GPIO count
4	High power consumption
5	Wetting current variation
6	Large input ESD capacitors
7	Expensive block diodes
8	Difficult to create portable designs

Polling mode allows significant power savings by enabling the wetting current only for a short direction for voltage sampling!



Solving system problems (continued)

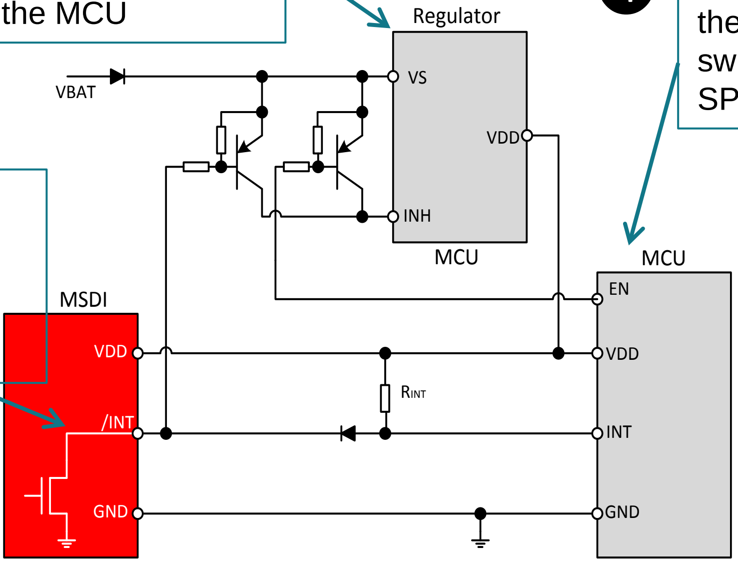
	Discrete implementation challenges
1	Large board area
2	High BOM count
3	High GPIO count
4	High power consumption
5	Wetting current variation
6	Large input ESD capacitors
7	Expensive block diodes
8	Difficult to create portable designs

The MSDI can monitor switch input autonomously and consumes only an average of 70µA of current (polling mode) ， compared to a typical µC's 3mA→ a **98%** saving!

3 Interrupt generation can be used to wake-up the power regulator， which in turn re-activated the MCU

2 When switch change state is detected， interrupt will be asserted.

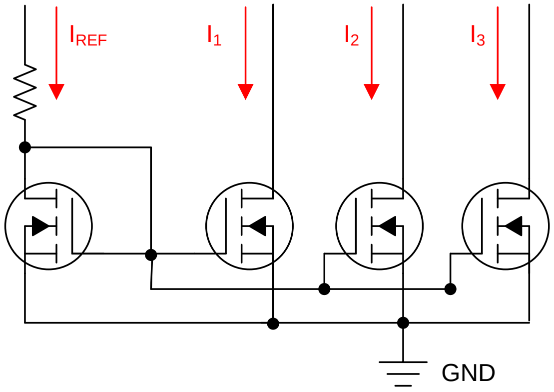
4 Once re-activated， the MCU can read the switch status using SPI



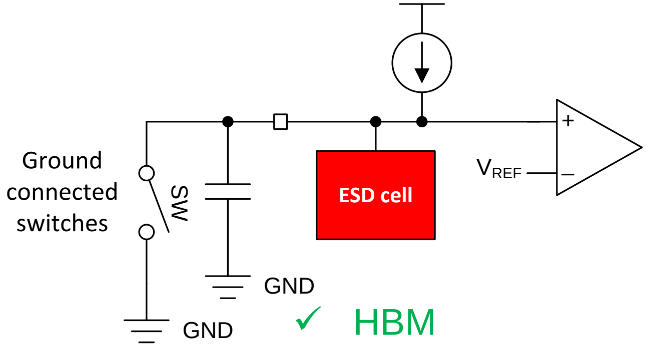
1 The MCU can be put to sleep to reduce power consumption.

Solving system problems (continued)

Discrete implementation challenges	
1	Large board area
2	High BOM count
3	High GPIO count
4	High power consumption
5	Wetting current variation
6	Large input ESD capacitors
7	Expensive block diodes
8	Difficult to create portable designs



The MSDI is designed with current mirror architecture，making the wetting current output relatively insensitive to supply and load fluctuations.

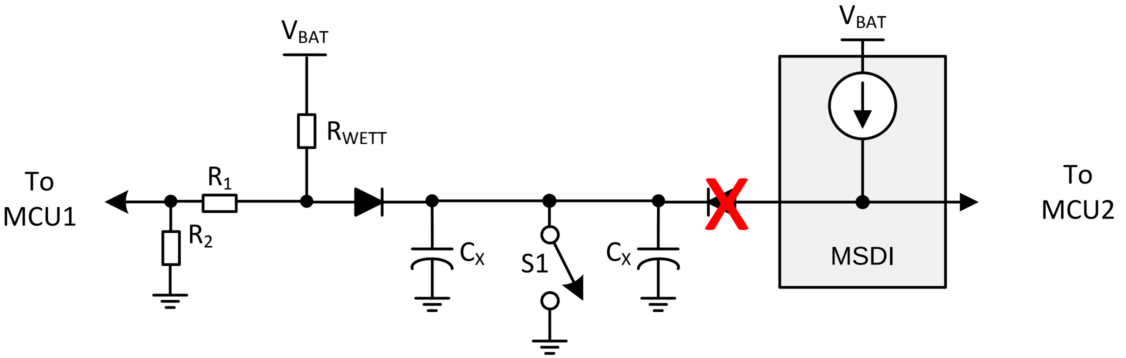


- ✓ HBM
- ✓ CDM
- ✓ Contact Discharge
- ✓ Air Discharge

All of MSDI’s input pins have integrated ESD protection，reducing the need for a large external capacitor.

Solving system problems (continued)

Discrete implementation challenges	
1	Large board area
2	High BOM count
3	High GPIO count
4	High power consumption
5	Wetting current variation
6	Large input ESD capacitors
7	Expensive block diodes
8	Difficult to create portable designs

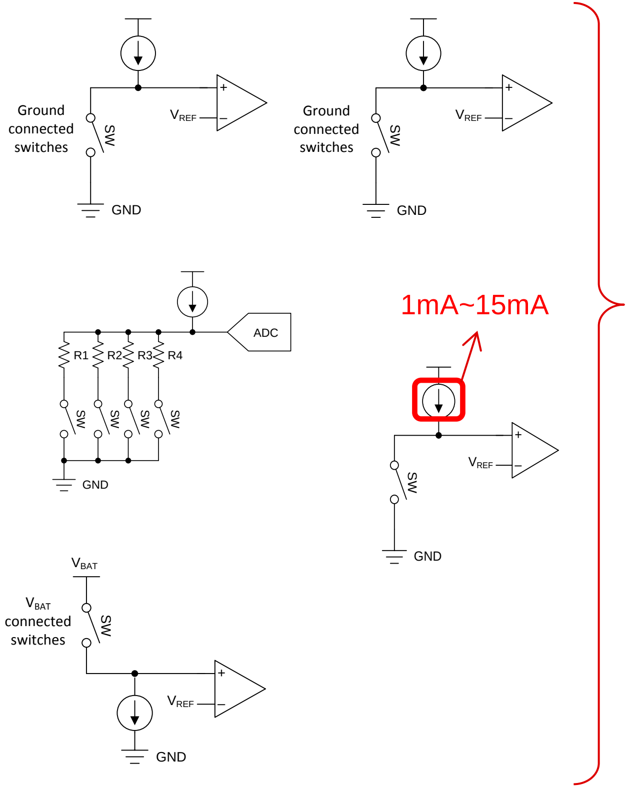


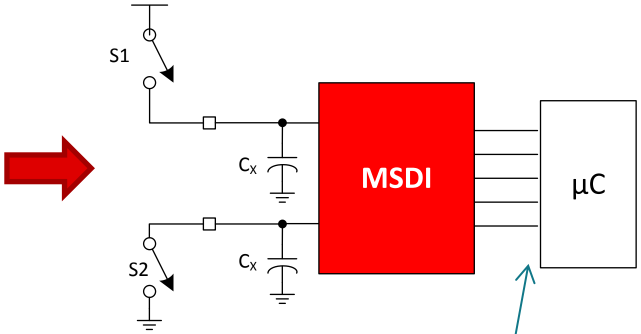
The MSDI's current mirror structure only allows current to flow in one direction， eliminating the need of expensive external blocking diodes.

Solving system problems (continued)

	Discrete implementation challenges
1	Large board area
2	High BOM count
3	High GPIO count
4	High power consumption
5	Wetting current variation
6	Large input ESD capacitors
7	Expensive block diodes
8	Difficult to create portable designs

MSDI is highly programmable， allowing system designers to create portable and simplified hardware designs.

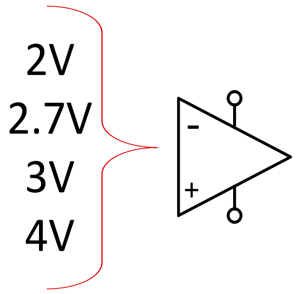




All settings can be configured through register settings.

MSDI advanced features

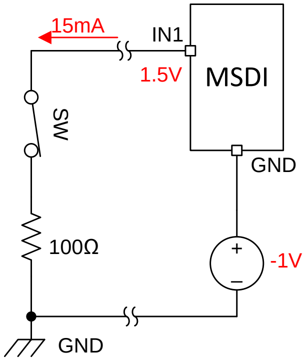
Adjustable comparator detection threshold



Comparator threshold can be set to 2V， 2.7V， 3V， or 4V

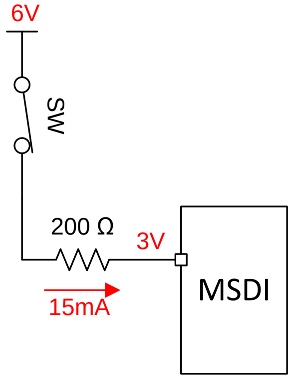
Benefits of using TIC12400-Q1:

- Adjustable comparator threshold allows the system designer to use MSDI to mitigate non-idealities in switch detection systems.



Example 1

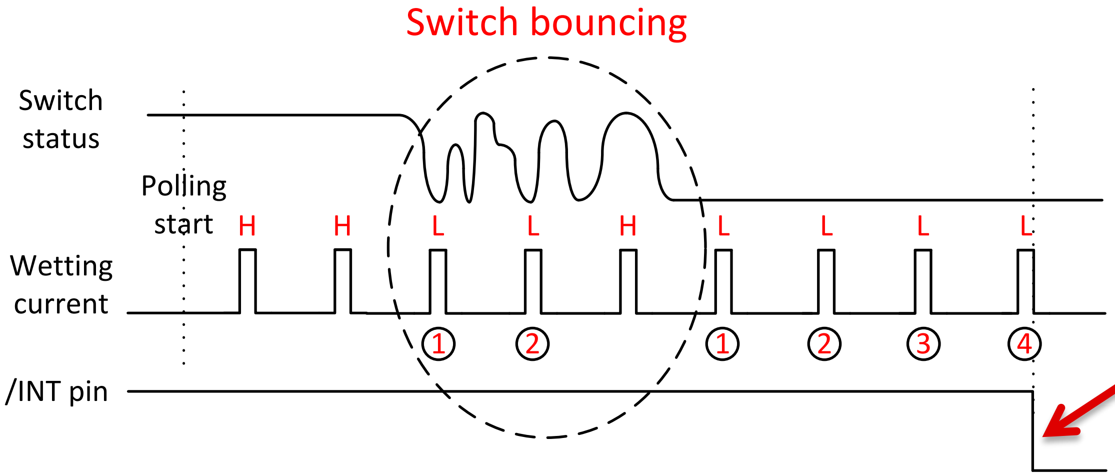
Negative ground shift scenario→ higher detection threshold is required



Example 2

Battery connected switch with series resistor→ lower detection threshold is required

Detection filter (DET_FILTER)



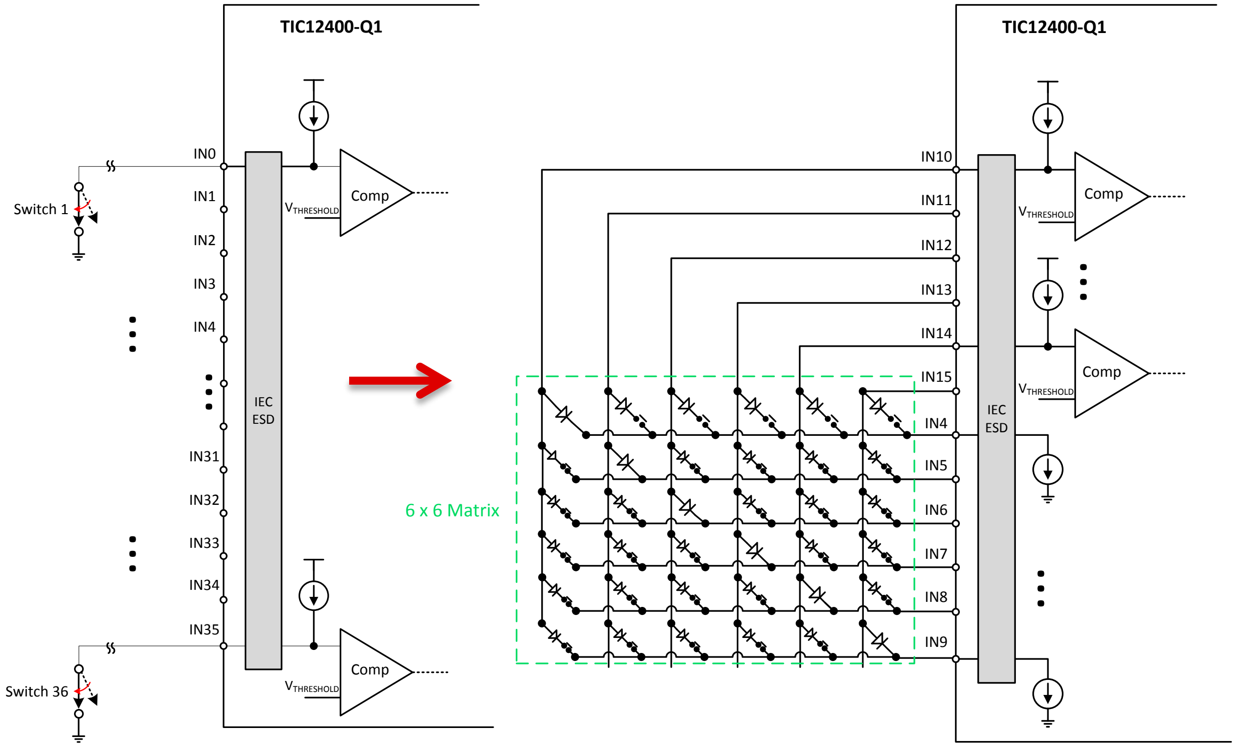
- If the Interrupt filter feature is enabled， the TIC12400-Q1 issues an interrupt only if the switch state stays the same with respect to the threshold for a pre-programmed number (2， 3， or 4) of polling cycles.

Benefits of using TIC12400-Q1:

- Noise immunity: The DET_FILTER can be used as a debouncing mechanism to eliminate the impact of switching noise during switch toggle.
- Simplicity: No firmware intervention is required.

Matrix polling

- The Matrix Mode is a special polling scheme to support up to 36 switches using only 12 input channels.
- 3 different matrix configurations are possible: 4x4 (16 switches) ， 5x5 (25 switches) ， or 6x6 (36 switches).



Benefits of using TIC12400-Q1:

- Supporting up to 36 switches using only 12 input channels.
- Matrix polling is autonomous once enabled. No software control is required.

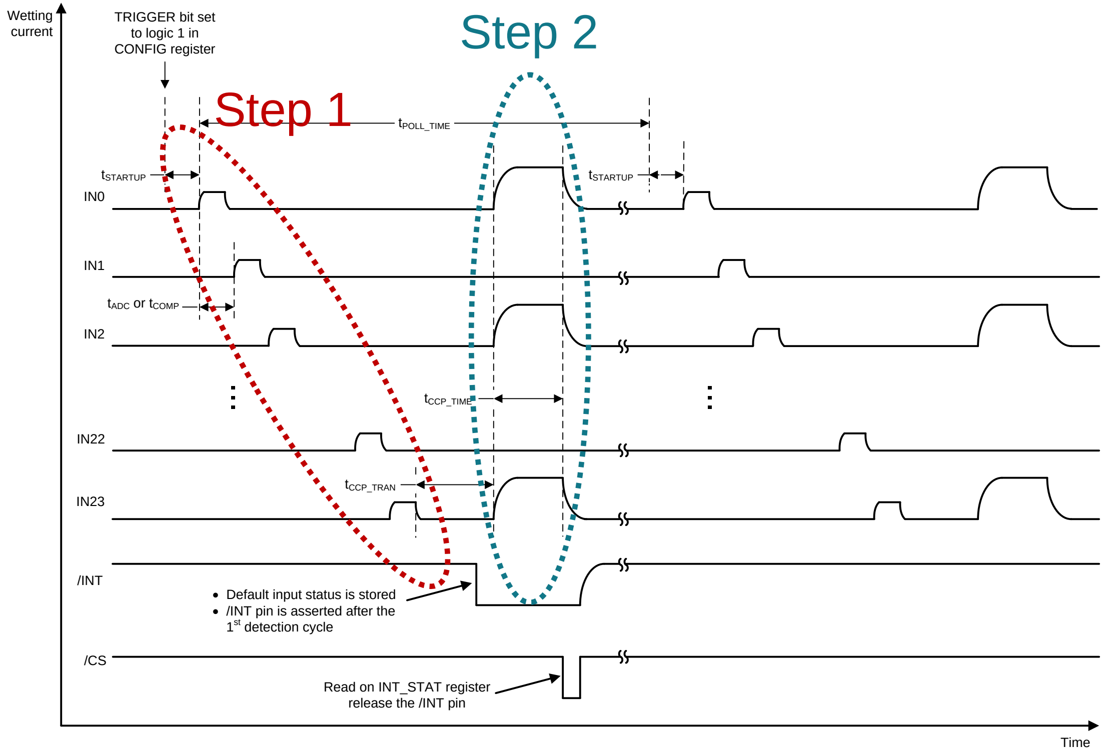
Clean current polling (CCP)

- CCP consists of two steps:

1. Regular polling for switch status sampling.
2. Clean current pulse for switch contact cleaning.

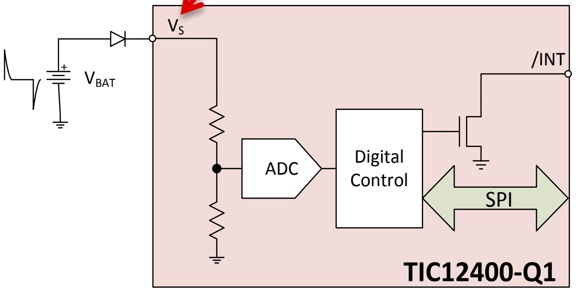
Benefits of using TIC12400-Q1:

- Detection current and clean current can both be utilized within the same polling cycle ，simplifying the system design significantly.

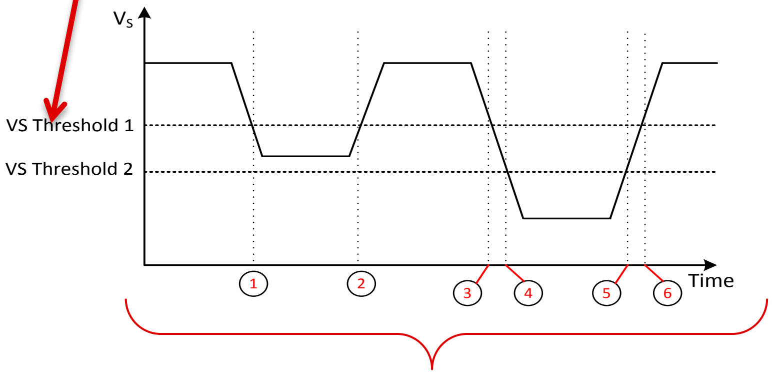


Battery supply measurement

The supply voltage is routed to the ADC as part of the polling sequence.



Up to 4 separate VS threshold can be set to monitor the supply voltage



Interrupt will be generated to alert the system. It can be masked base on low to high or high to low transition.

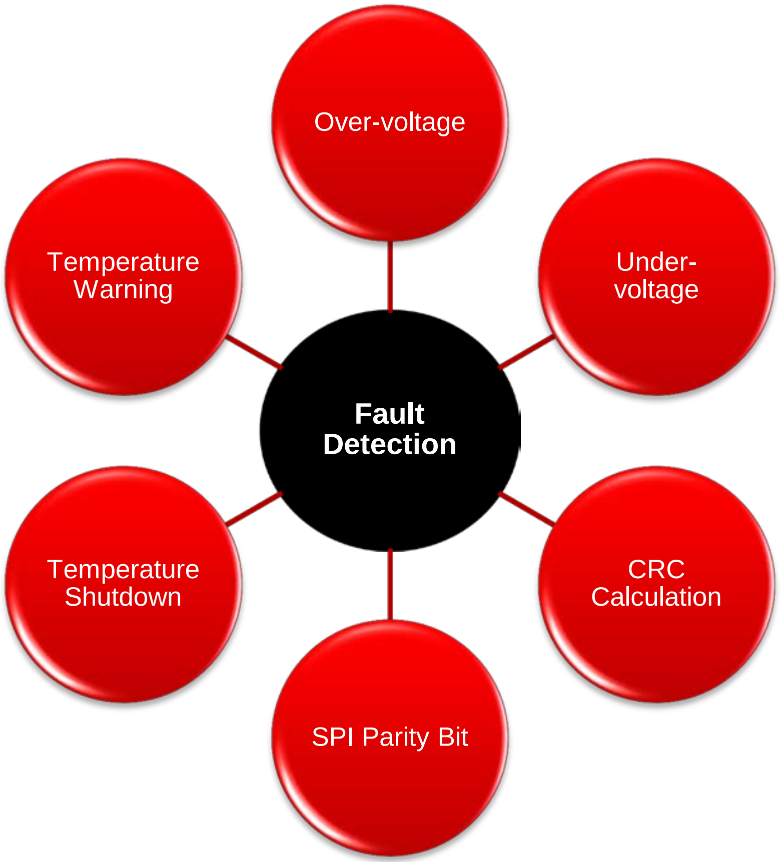
Benefits of using TIC12400-Q1:

- Accuracy: Ensure the switch detection result is accurate and not impacted by the low battery voltage (especially critical for resistor-coded switches).

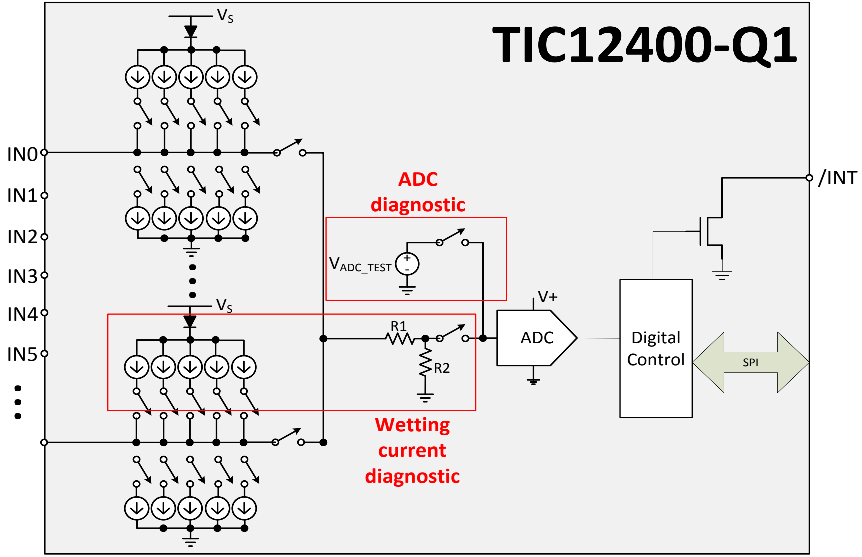
Fault detection

Benefits of using TIC12400-Q1:

- Robustness: The TIC12400-Q1 informs the microcontroller upon occurrence of a fault to make sure the system has robustness operation.



Wetting current and ADC diagnostic

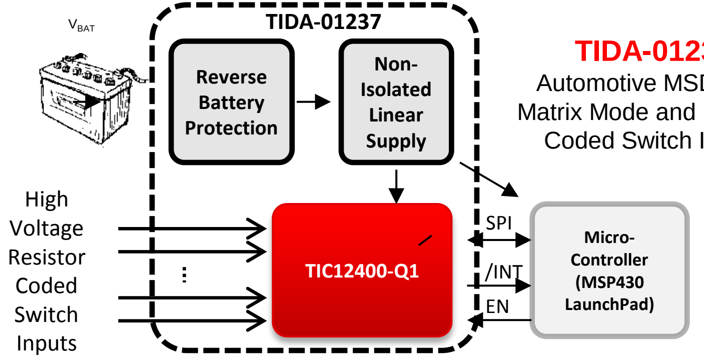


Benefits of using TIC12400-Q1:

- Wetting current diagnosis: Make sure the wetting current is flowing accurately.
- ADC self-diagnostic: Make sure the ADC is converting properly.

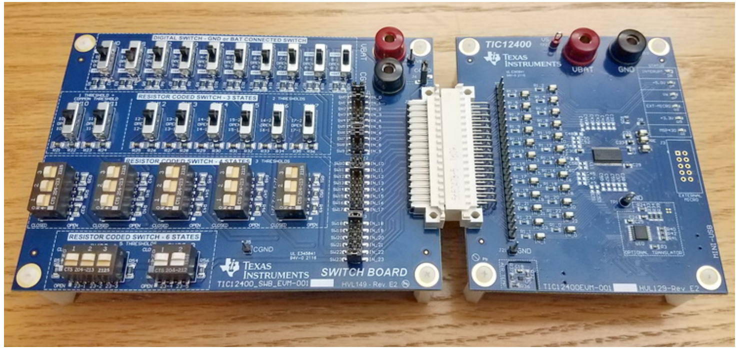
Conclusion

TIC12400-Q1| Tools and Collaterals

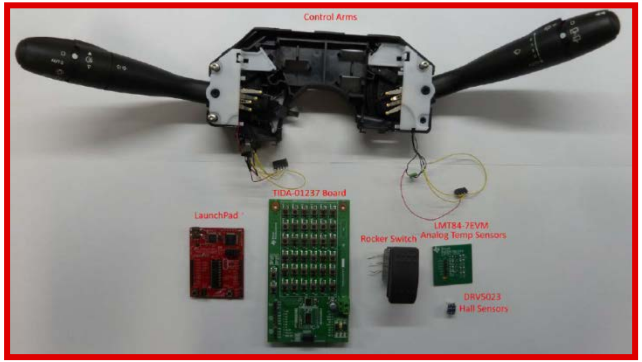


TIDA-01237
Automotive MSDI with Matrix Mode and Resistor Coded Switch Inputs

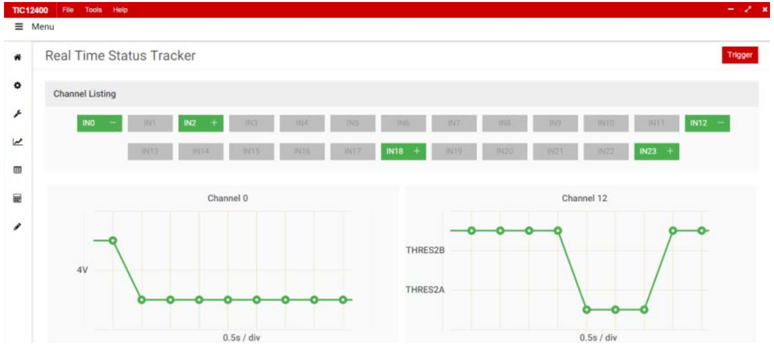
TI Design



EVM + switch load board



TIDA-01237



GUI software

Texas Instruments