Automotive and Industrial **Switch Monitoring Solution** Using Freescale's MSDI Family

AMF-ACC-T1675

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SEPT.2015

External Use

Agenda

- Introduction
- Switch Status Monitoring
- Introduction to Freescale's MSDI family
- MC33978 – Next generation MSDI device
- Comparison to Discrete Solutions
- Other Configurations
- MSDI Applications

INTRODUCTION

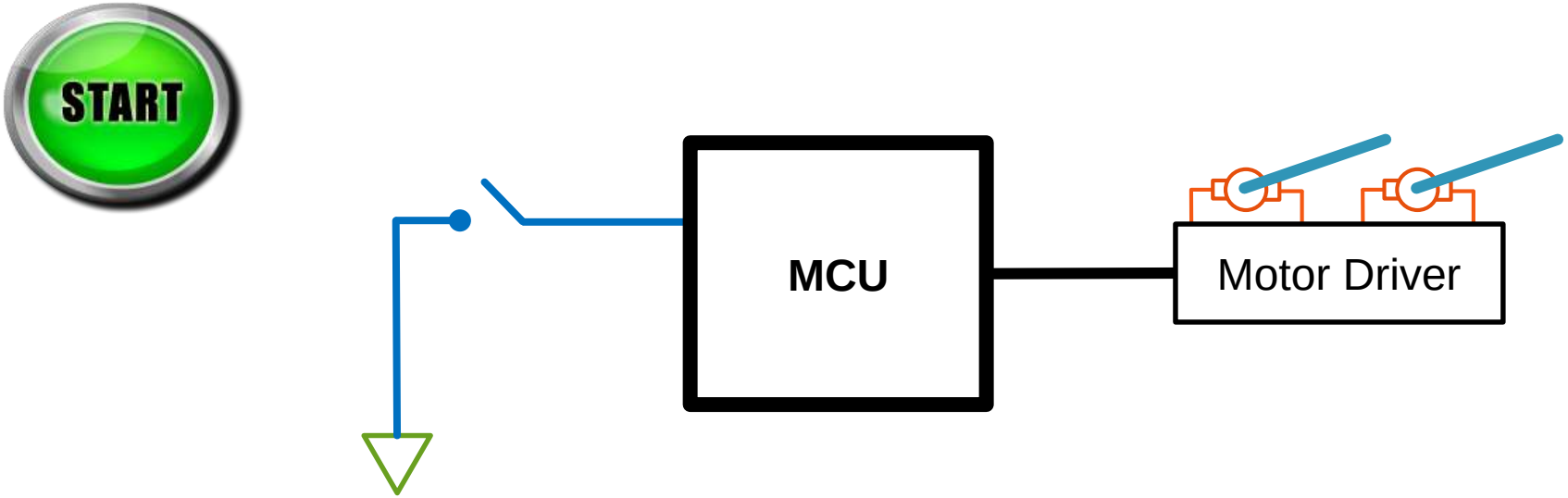
- Auto Systems no longer enabled actuators and functions mechanically, instead they are driven and controlled by MCUs, requiring proper sensing of contactors to enable or disable functions.

- Increasing technology is pushing for a greater number of mechanical contactors In auto and industrial applications while other key factors push for robustness, space efficiency and better price-per-features ratio to solve today's market needs.

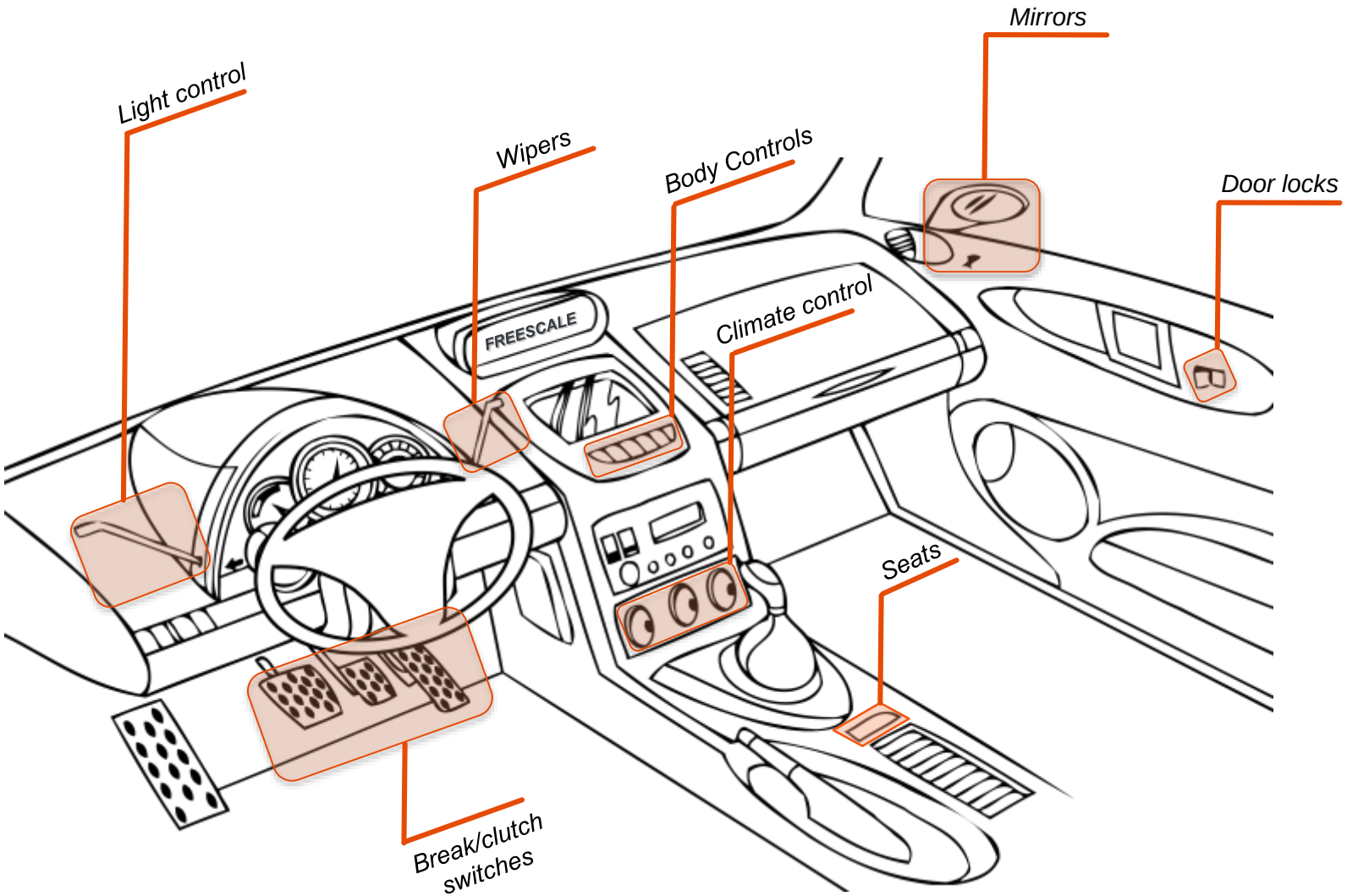
- To address such needs, Freescale developed and has been the industry leader in the automotive switch detection market for the past decade with the Multiple Switch Detection Interface family of devices.

Understanding Switch Status Monitoring

- A switch is normally open to indicate the OFF state of a given function.
- When the switch is shorted to Ground or Battery, an MCU detects the event and starts a function to enable the feature controlled by the switch.



Typical Applications



System Considerations

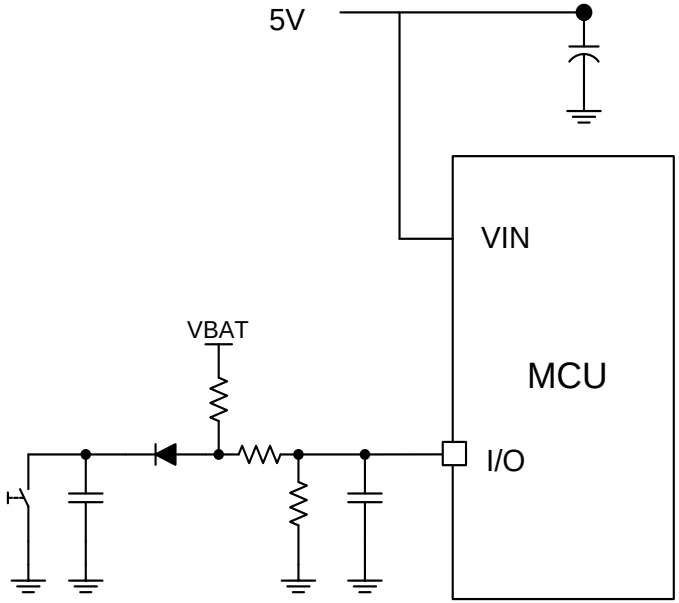
- When designing a switch status monitoring system, we should keep a few consideration in mind

  - Automotive systems operate with 12V (not compatible with 5V MCU I/Os)
  - Quality and reliability of switches (use of wetting techniques to reduce oxide accumulation on contactors.)
  - Limited number of I/Os to detect all switches in parallel.
  - Green solutions (Efficient and reliable power utilization)
  - Space constrain with growing systems
  - New Operating conditions and requirements such as operating voltage range, EMC protection and ISO compliance.

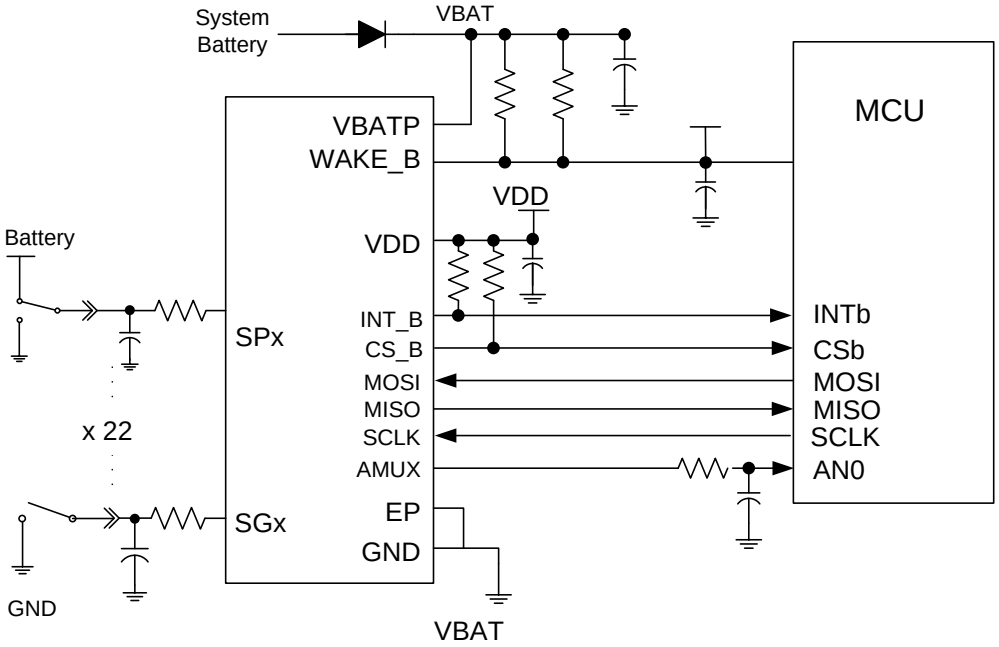
Switch Detection Monitoring

What options do we have?

- Implement discrete solutions using passive components.



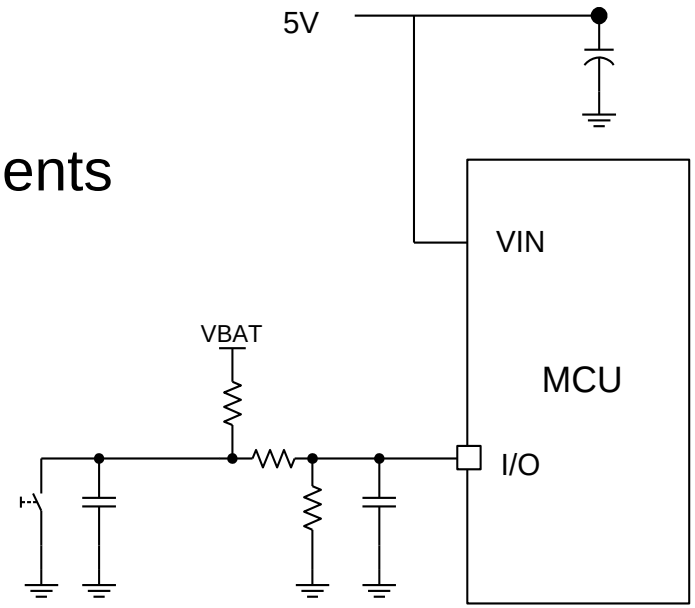
- Use Dedicated IC for switch status monitoring



Discrete solutions

- Discrete solutions are simple in their unity, however, these solutions leads to some “caveats” when dealing with new requirements.

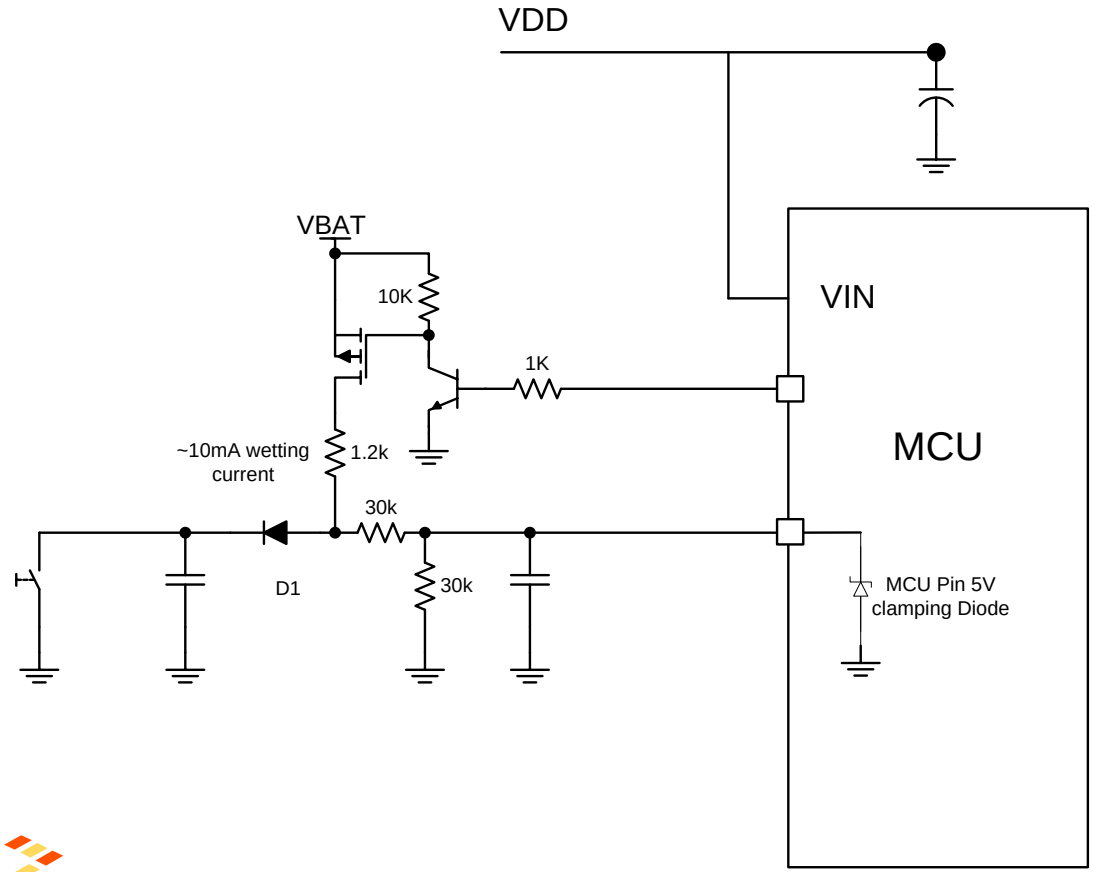
1. Limited operating voltage range
2. Poor reliability at high or low voltage
3. Poor protection against Battery transients
4. Limited functionality
5. High power consumption
6. Heavy used of MCU I/Os
7. Heavy use of board space
8. High component count



1 channel Switch to ground detection example

Discrete solutions

- Adding a diode (D1) helps increasing reverse current protection
- To add low power mode, extra components should be added to disable the current flow during low power. (no switch detect possible)

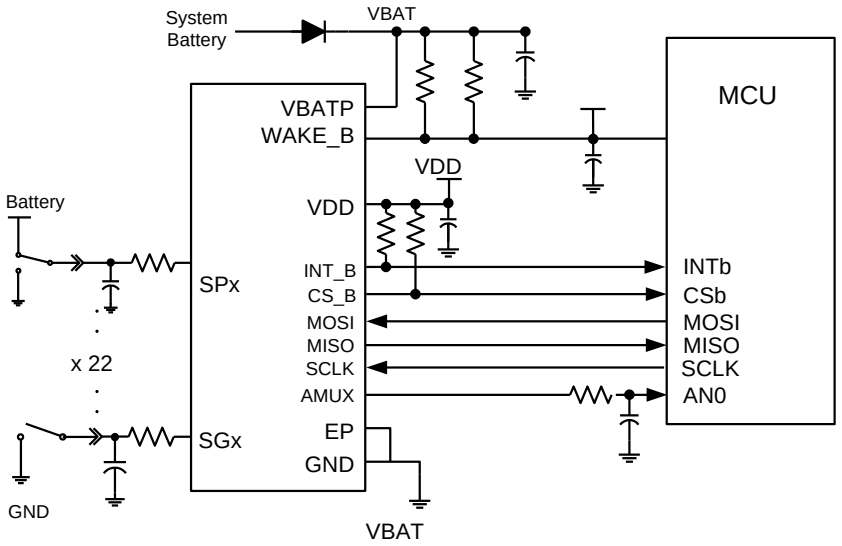


- Note: Discrete solution relies on MCU internal clamping diode for high VBAT operation

Introduction To Freescale Multiple Switch Detection Interface (MSDI) Family

Integrated Circuit Solution

- Multiple switch status monitoring through a single communication path (i.e SPI)
- Better operating ranges
- Better power consumption
- Fewer component required (less solder joints)
- Built in support for EMC and battery transients.
- Switch-to-Ground and Switch-to-Battery support
- Better space utilization



Freescale MSDI Family

- The product family consists of many devices
  - MC33993 (Legacy Device)
  - MC33972, MC33972A
  - MC33975, MC33975(A)
  - MC33978 (New Product Introduction 2014/15)

- MC33972(A), MC33975(A) and MC33978 devices is packaged in the Exposed pad 32SOIC.

- The MC33978 will also be packaged in a 5x5 QFN.

- The MC33978 is designed for robustness, wider operating conditions and flexibility.

MC33978 – Next Generation MSDI Device

22 Channel Switch Detection Interface

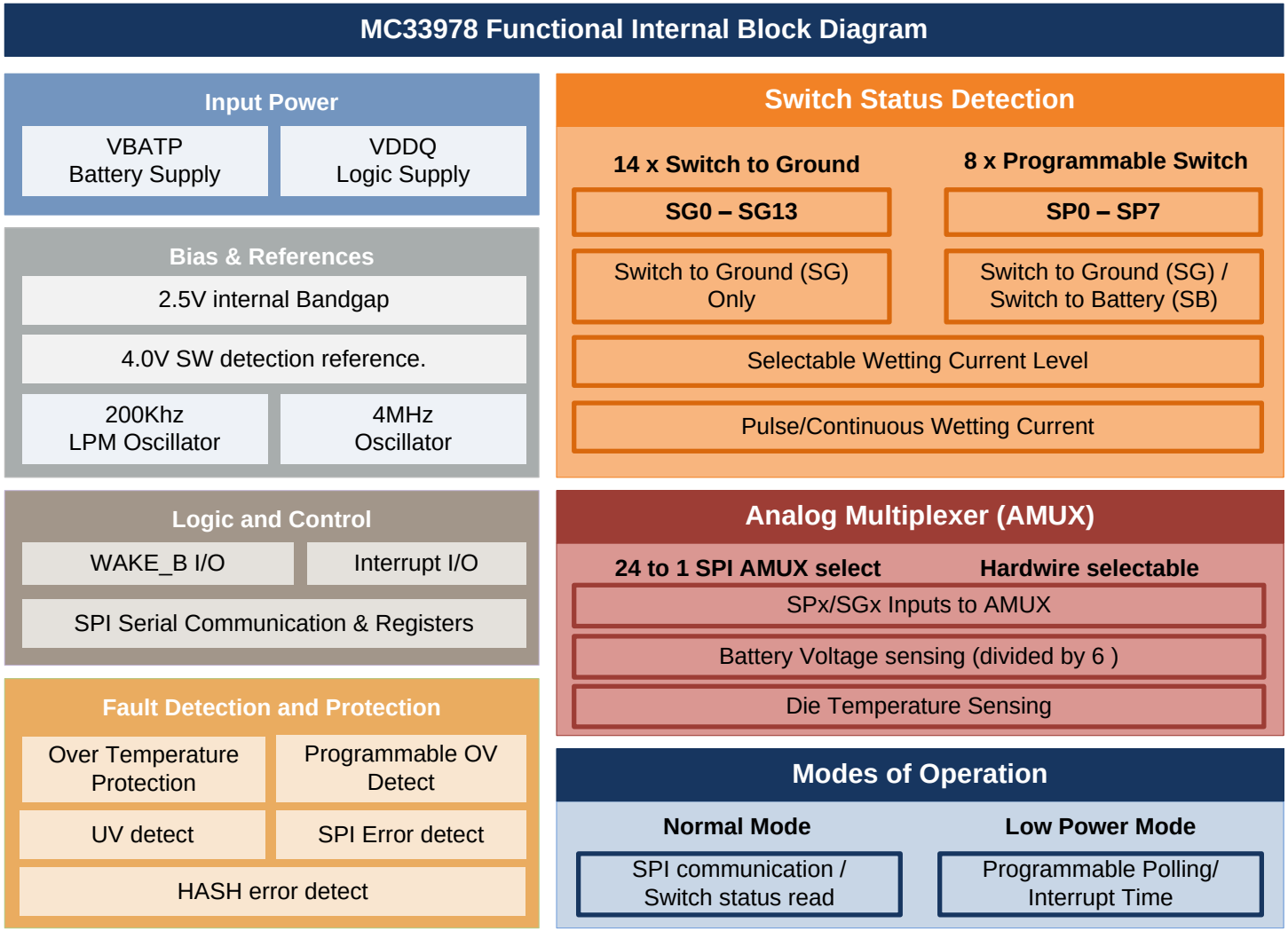
Next Gen switch detection solution for body, power train and industrial applications.

Differentiating Points

- Reduced VPWR standby current
- Extended VPWR operating range for start/stop system compatibility
- Selectable wetting currents to support broader application requirements
- Fast polling of selected inputs enables fast wake-up while maintaining low sleep current
- Analog multiplexer with SPI or hardwire control – minimizes SPI traffic
- Integrated battery sense option helps reduce BOM cost
- Integrated Die temperature Sense through AMUX
- Simplified input de-bounce in hardware reduces software complexity
- Enhanced device robustness

	MC(Z)33972	MC(Z)33975	MC33978
Schedule	In Production	In Production	Production: 1Q 2015
Inputs	22	22	22
Sleep Current	100uA	100uA	<40uA
Temp Sensor	--	--	YES
Battery Sensor	--	--	YES
Wetting Current	16mA	32mA	2 to 20mA
AMUX	22 to 1	22 to 1	24 to 1
Package	32 SOIC	32 SOIC	32 SOIC & 32 QFN

MC33978 - 22 Channel Switch Detection Interface with programmable wetting current



MC33978 Benefits

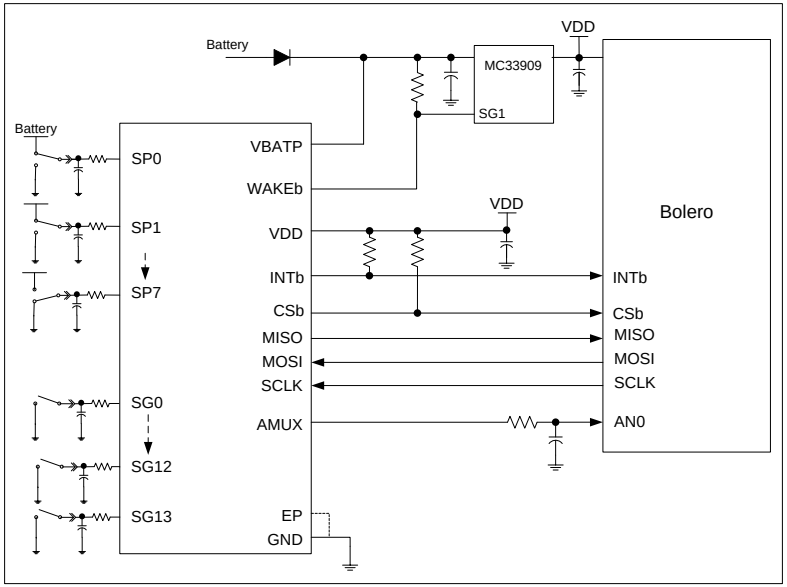
Features	Benefits
Advanced Wakeup Features	Monitor for event, even if the system is powered down
Temperature Sensor	BOM reduction by integrating the temp sensor
Battery Sense	BOM reduction by integrating the battery monitor
Robustness, EMC, ESD	Operates even in the presence of dramatic transients
Analog Multiplexer	Extends functionality by allowing MCU direct access to analog
Hi/Lo-side current sources	Supplies current to the input pins for wetting current (eg, switch)
4.5V to 40V operation	Ensures performance during crank, load dump, 24 volt systems, etc.

MC33978 - 22 Channel Switch Detection Interface

Product Features

- Detects 22 switch inputs:
  - 14 switch-to-ground inputs
  - 8 programmable inputs (switch to battery or ground)
- Direct Interface to a MCU using a 3.3V/5.0V SPI protocol
- Selectable wake-up on change of state
- 24-1 analog multiplexer
- WAKE_B pin to control power supply enable
- INT_B pin for active interrupt on change of switch state.

Performance	Typical Values
Flexible I/O Inputs	22
Switch Input Voltage	-14 to 38V
Operating Voltage	4.5 to 26 V (Vpwr)
Wetting Current 33978	2-20mA
ControL/Communication	SPI
Q Current	40uA
Operating Temp	-40°C ≤ TA ≤ 125°C

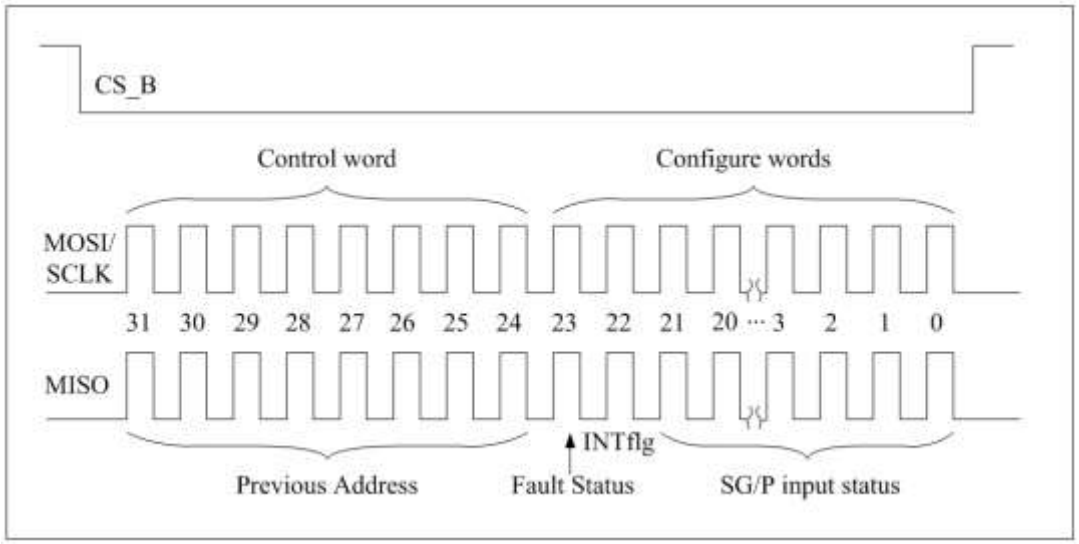


Typical Applications

- Automotive
  - Body electronics
  - Power train
- Industrial
  - Relay closure detection
  - Industrial control
  - Security systems

SPI Communication

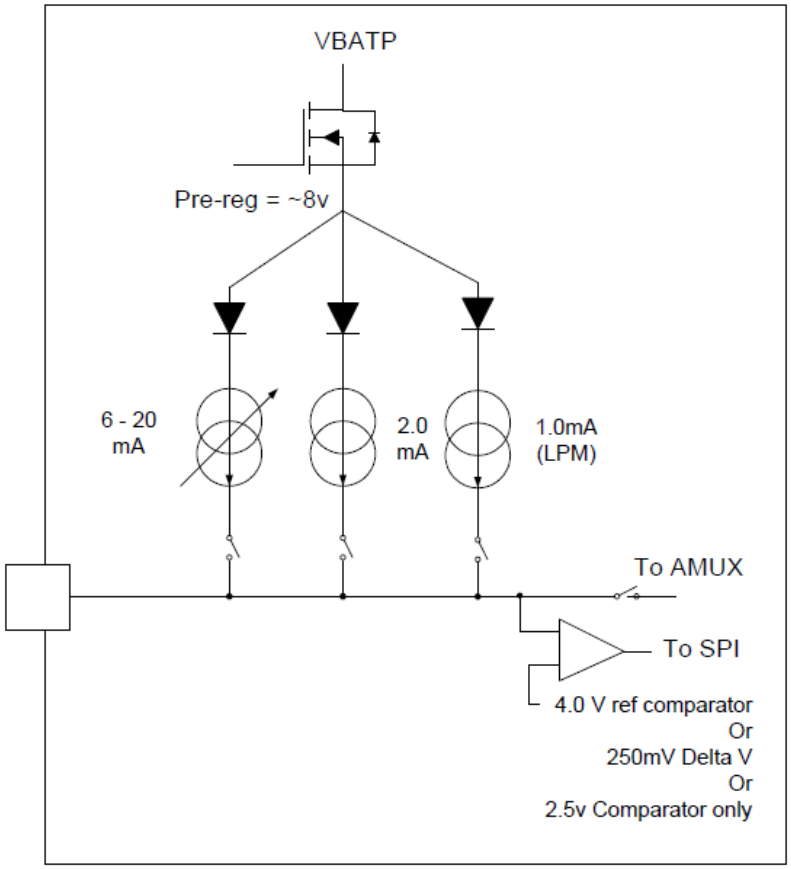
- 32-bit SPI words including:
  - Modulo 32-bit requirement
  - HASH Error Detection
- Daisy Chain capable



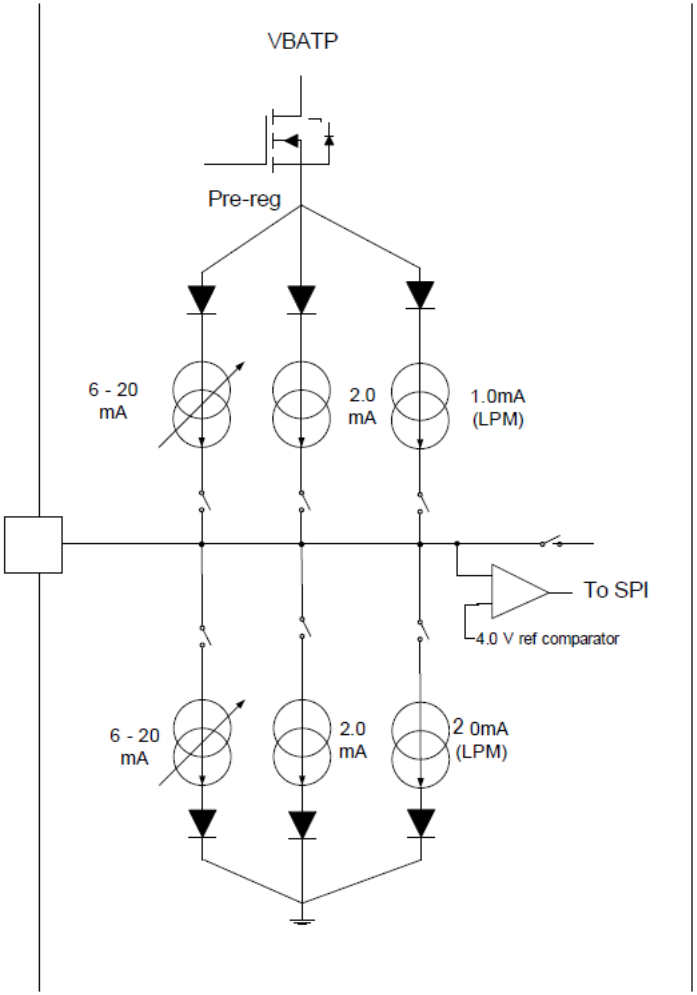
SPI Registers

Register #	Register Name	Address							Rb/W
0	SPI Check	0	0	0	0	0	0	0	0
02/03	Device Configuration Register	0	0	0	0	0	0	1	0/1
04/05	Tri-state SP Register	0	0	0	0	0	1	0	0/1
06/07	Tri-state SG Register	0	0	0	0	0	1	1	0/1
08/09	Wetting Current Level SP Register	0	0	0	0	1	0	0	0/1
0A/0B	Wetting Current Level SG Register 0	0	0	0	0	1	0	1	0/1
0C/0D	Wetting Current Level SG Register 1	0	0	0	0	1	1	0	0/1
16/17	Continuous Wetting Current SP Register	0	0	0	1	0	1	1	0/1
18/19	Continuous Wetting Current SG Register	0	0	0	1	1	0	0	0/1
1A/1B	Interrupt Enable SP Register	0	0	0	1	1	0	1	0/1
1C/1D	Interrupt Enable SG Register	0	0	0	1	1	1	0	0/1
1E/1F	Low-power Mode Configuration	0	0	0	1	1	1	1	0/1
20/21	Wake-up Enable Register SP	0	0	1	0	0	0	0	0/1
22/23	Wake-up Enable Register SG	0	0	1	0	0	0	1	0/1
24/25	Comparator Only SP	0	0	1	0	0	1	0	0/1
26/27	Comparator Only SG	0	0	1	0	0	1	1	0/1
28/29	LPM Voltage Threshold SP Configuration	0	0	1	0	1	0	0	0/1
2A/2B	LPM Voltage threshold SG Configuration	0	0	1	0	1	0	1	0/1
2C/2D	Polling Current SP Configuration	0	0	1	0	1	1	0	0/1
2E/2F	Polling Current SG Configuration	0	0	1	0	1	1	1	0/1
30/31	Slow Polling SP	0	0	1	1	0	0	0	0/1
32/33	Slow Polling SG	0	0	1	1	0	0	1	0/1
34/35	Wake-up Debounce SP	0	0	1	1	0	1	0	0/1
36/37	Wake-up Debounce SG	0	0	1	1	0	1	1	0/1
39	Enter Low-power Mode	0	0	1	1	1	0	0	1
3A/3B	AMUX Control Register	0	0	1	1	1	0	1	0/1
3E	Read Switch Status	0	0	1	1	1	1	1	0
42	Fault Status Register	0	1	0	0	0	0	1	0
47	Interrupt Request	0	1	0	0	0	1	1	1
49	Reset Register	0	1	0	0	1	0	0	1

Wetting Current SG



Wetting Current SP



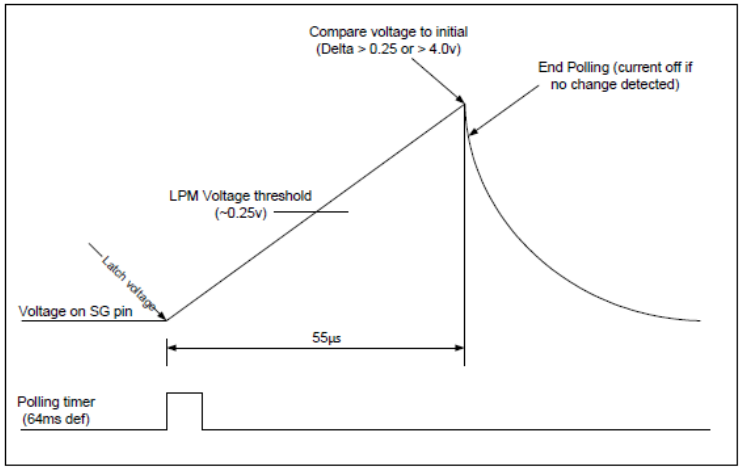
Low-Power Mode

- Entered via SPI Command
- Lowest Power Consumption Mode
- Several Possible Ways to Wake
  1. Interrupt Timer
  2. Selectable Falling Edge of INTB, CSB, WakeB
  3. Input Change of State (if enabled)

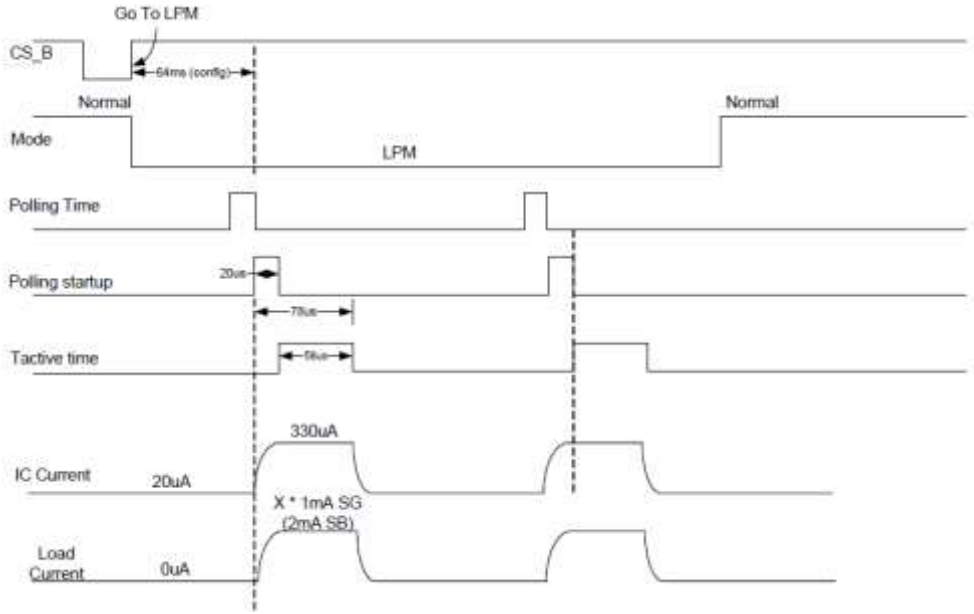
Low-Power Polling Mode

- Periodic Momentary Activation of Selectable Switch Inputs to Test for Closure
- 16 selectable Polling Times From 0ms – 64ms
  - Non-critical Input polling times can be increased x 4.

Low-Power Polling Mode



Low-Power Mode Polling Check



Timing

AMUX OPTIONS

- All Inputs are SPI Selectable
  - input voltage divided by 6
- Battery Sense (± 5% on SG)
- Die Temperature
- Eight Inputs Selectable for Fast Direct Selection using SG1,2 & 3

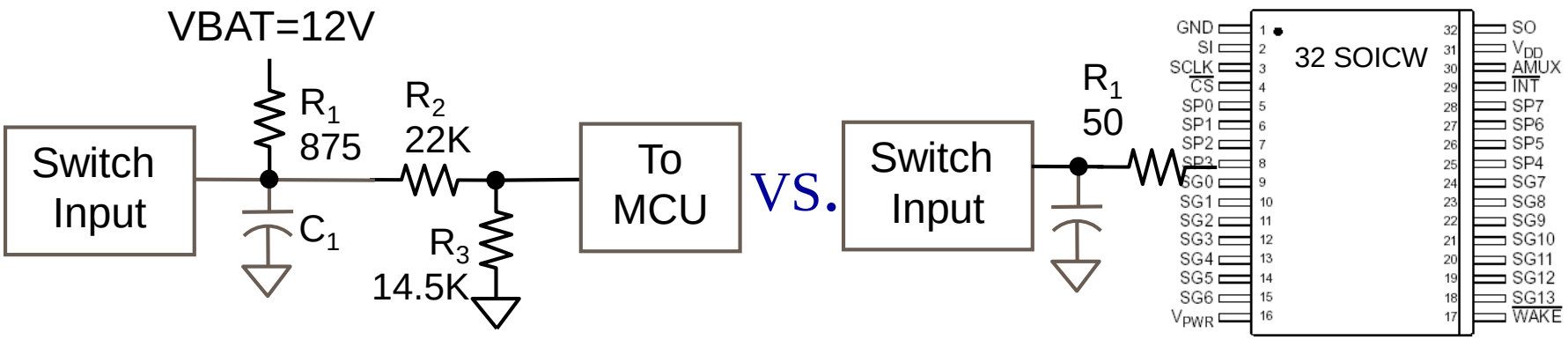
EMC Results

- ISO 7637-2 and CI-220 Transient Test Results

ISO Pulse	CI-220	Test Level	Pulse Duration	Status	Comments
1	E	100 V	50 Pulses	PASSED	R=50 ohm, C=47 nF
2a	F	150 V	50 Pulses	PASSED	R=50 ohm, C=47 nF
3a	-	-150 V	60 Seg	PASSED	R=50 ohm, C=47 nF
3b	-	100 V	60 Seg	PASSED	R=50 ohm, C=47 nF
5b	G	36 V	50 Pulses	PASSED	R=50 ohm, C=47 nF
-	A1	-450V	60 seg	PASSED	R=50 ohm, C=47 nF
-	A2	-400 V	60 Seg	PASSED	R=50 ohm, C=47 nF
-	B1	300 V	60 seg	PASSED	R=50 ohm, C=47 nF
-	C	-450 V	60 seg	PASSED	R=50 ohm, C=47 nF

Comparison to Discrete Solution

Comparison to Discrete Solution



	Discrete Switch Input	MC33978 Switch Input
Power Dissipation	**Poor**	**Good**
Operating Voltage Range	**Poor**	**Excellent**
Board Space Utilization	**Poor**	**Good**
Number of Solder Joints	**Poor**	**Excellent**
Ground Offset Protection	**Good**	**Excellent**
Quiescent Current with Wake up	**Poor**	**Excellent**

Power Dissipation

Power Dissipation at 16.0 V supply, 875 ohm pull up resistor and 22 switches closed.

Discrete solution

$P_{discrete} = V^2/R * \#\ of\ Closed\ Switches$

$P_{discrete} = 0.292\ W * 22$

$P_{discrete} = 6.43\ W$

MC33978

$P_{33978} = V*I* \#\ of\ Closed\ Switches$

$P_{33978} = 16*2mA* 22$

$P_{33978} = 0.704\ W$

Power dissipation is reduced because of reduction from wetting current to sustain current.

Operating Voltage Range

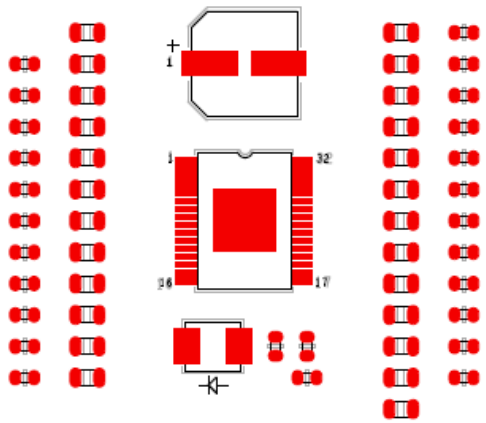
VBAT Voltage Range	Discrete Switch Input	MC33978 Switch Input
4.5V to 6.0V	Cannot guarantee Switch state at MCU pin	Good, (functional) Lower Switch Current
6.0V to 9.0V	Ok	Excellent, Ground Offset Protection
9.0V to 12.56	OK, Ground Offset Protection Relays on MCU clamping diode	
12.56V to 16.0V	Good, Creates MCU Current Injection	Excellent
16.0V to 28V	MCU Current Injection Excessive Heat Pulsing required	Excellent Double battery support
28 to 36V	MCU Current Injection Excessive Heat Pulsing required	Good, (Functional) Load dump support

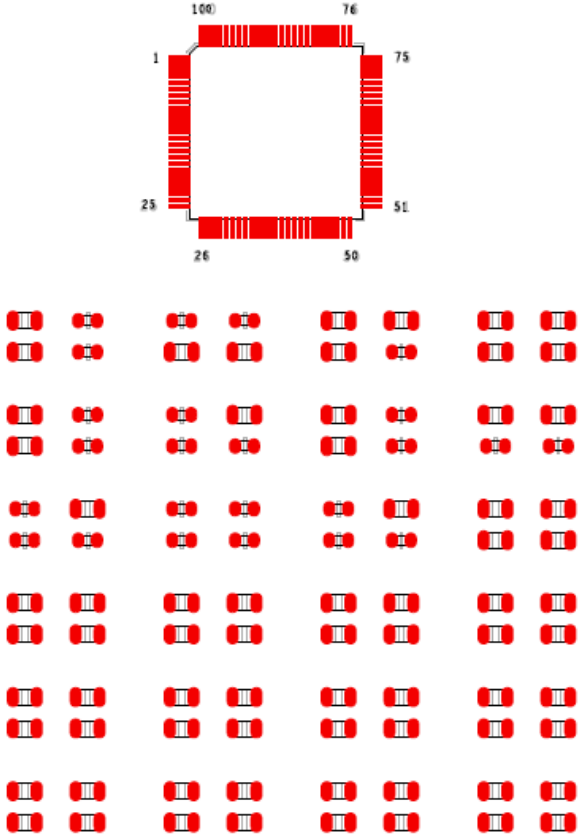
Board Space Utilization

MC33978

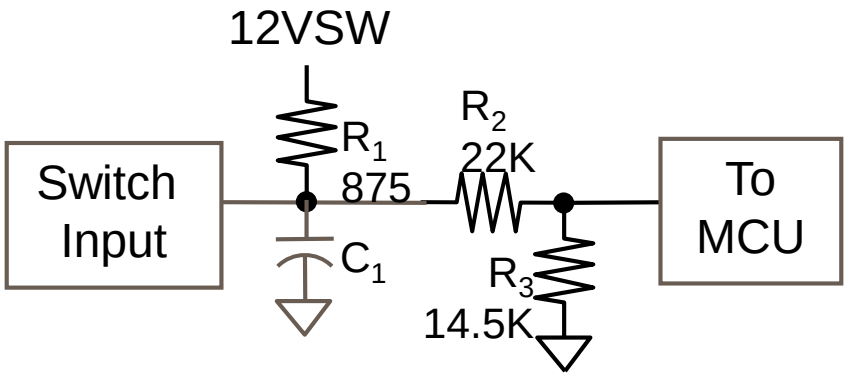
VS

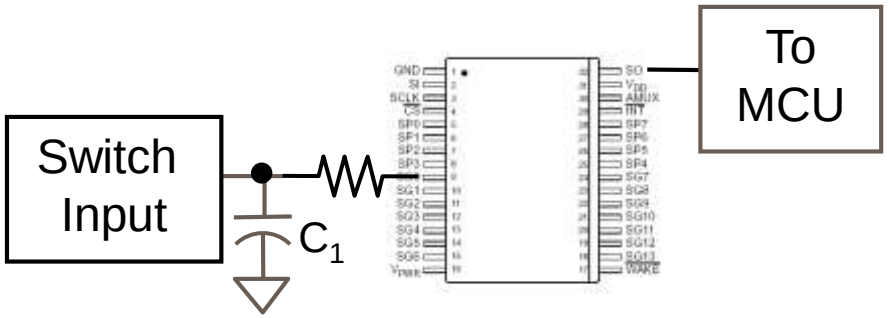
Discrete Solution





Number of Solder Joints



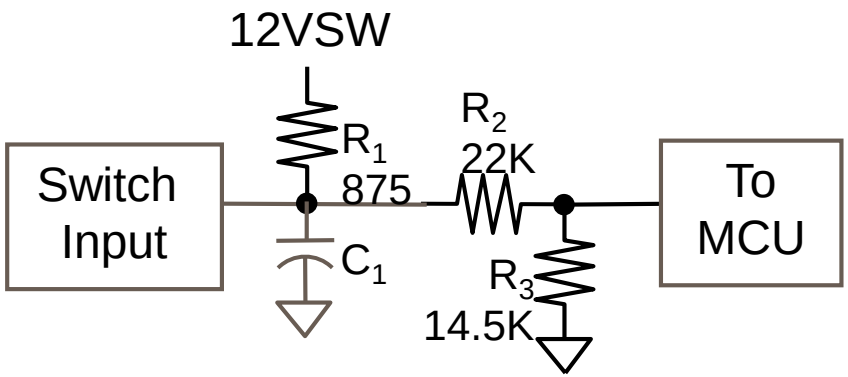


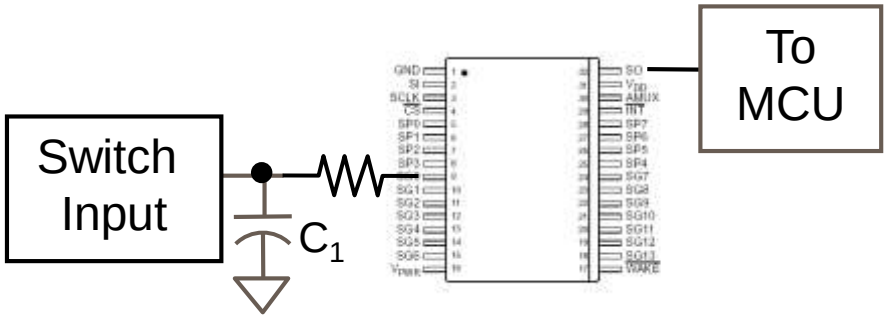
Discrete Solution
8 Joints/input * 44 inputs
= 352 Solder Joints

Higher inspection and Manufacturing cost!

Silicon Solution
5 Joints/Input*44 inputs +
Power and GND and SPI
= 220 + 2 + 4
= 226 Solder Joints.

Quiescent Current





Discrete Solution

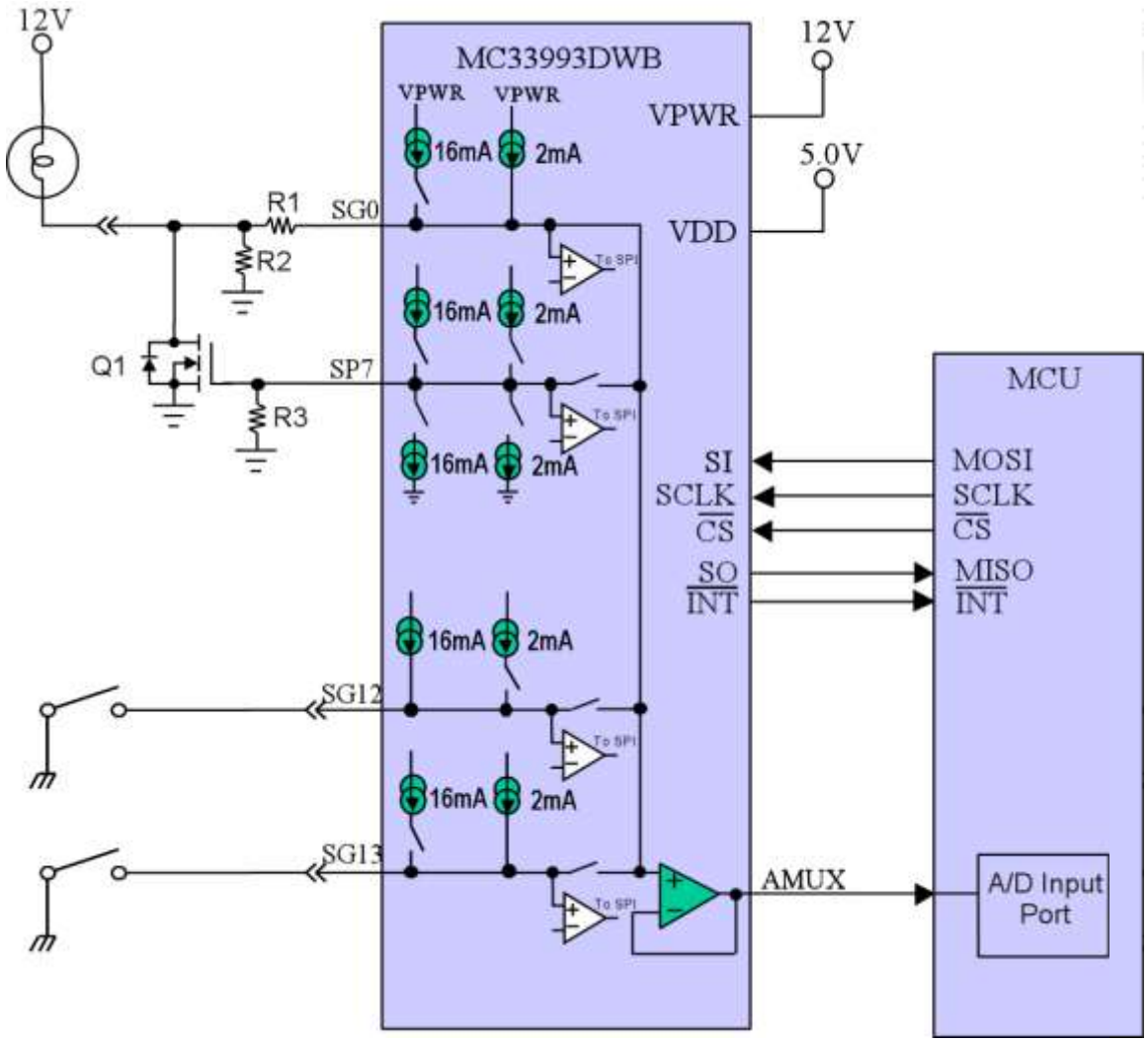
Q current under MCU control. Typical system are capable of 500uA to 1 mA with wake up

Silicon Solution

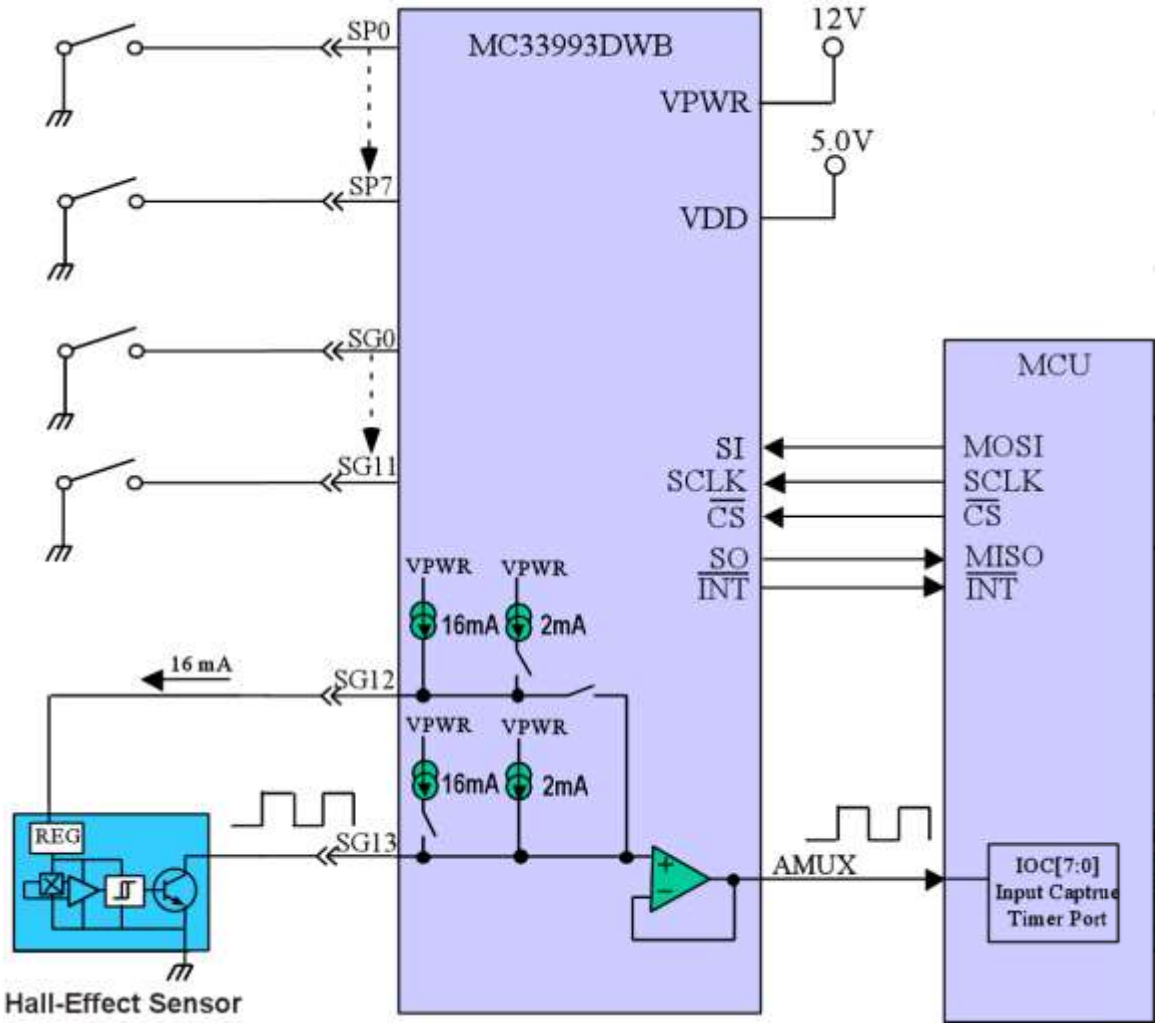
Q current under chip control. Typical Q current per chip is 40 uA on VBATP + 10uA on VDDQ.

Other Configurations

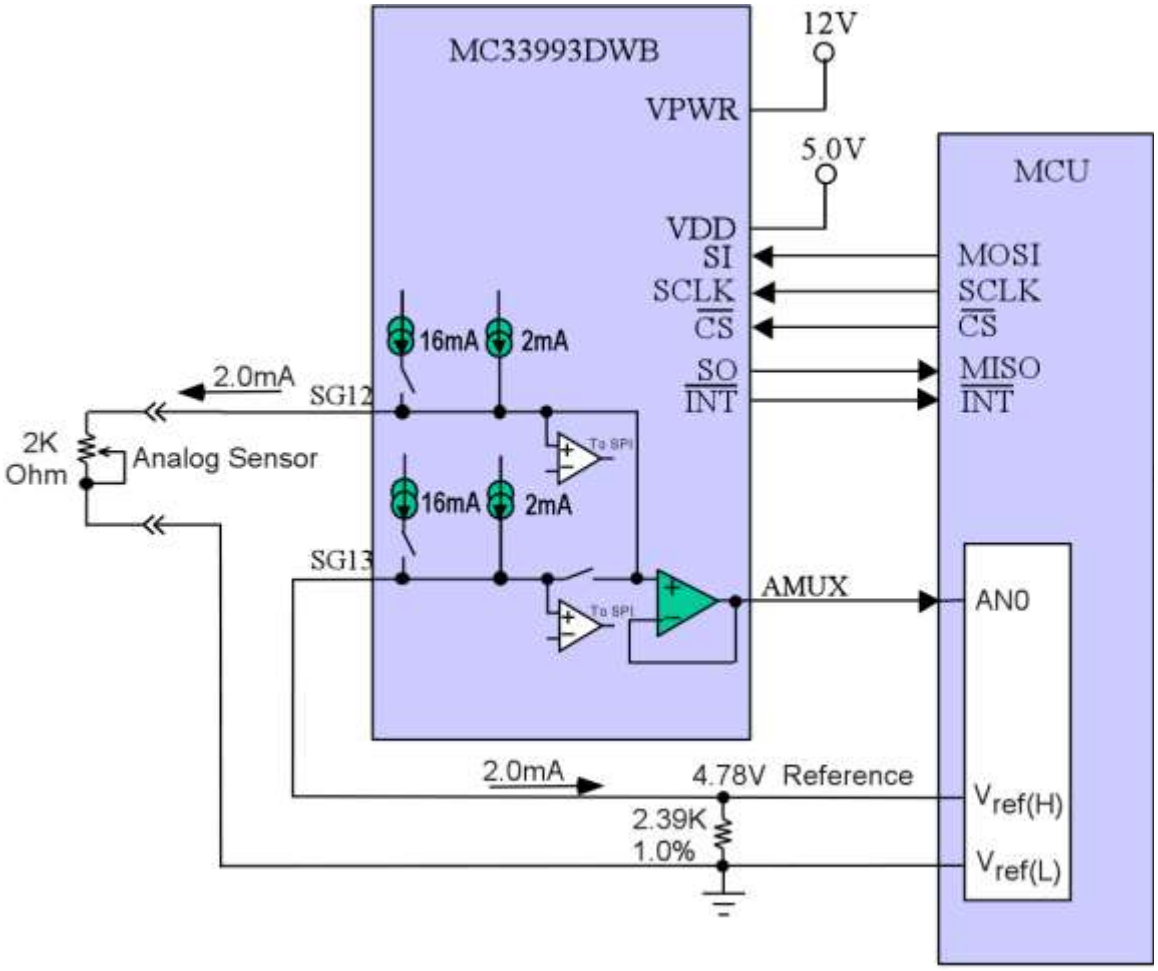
Circuit Application: MOSFET Driver/Monitor



Circuit Application: Sensor Supply and Monitor



Circuit Application: Sensor Supply and Monitor With Ratio metric Conversion



MSDI Applications

Product Applications

- AUTOMOTIVE
  - Smart Junction Box Controllers
  - Electrical Body Modules
  - Power train Engine Controllers
- INDUSTRIAL
  - Machine Tool Controls

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