TB3142

ADC Channel Switching Effect on I/O Pins

Author: Anthony Stram
Microchip Technology Inc.

INTRODUCTION

The analog functionality on microcontrollers can create complex interactions with the digital portion of the circuitry and the running firmware. The application can have undesired interactions unless the analog features are understood. This technical brief will describe the most common I/O issues that arise when switching between ADC channels.

BACKGROUND

Digital logic is utilized in controlling the analog channel multiplexer (MUX). As an artifact of using digital logic to switch between analog (ADC) channels, signals from different device pins can momentarily be connected. Two unrelated I/O pins can become connected when the ADC input channels are switched. The I/O can connect for the amount of time it takes the signal to propagate through the MUX to trigger the ADC channel to change. This connection can last up to 40 ns, which is longer than the minimum rise and fall times of the I/O pin logic, causing a glitch on the connected pins. This is enough time to have an effect on the pins since the rise and fall times of the pins are 15 to 30 ns. The effects of the glitch can last longer than 40 ns due to the time it takes for the pins to change their state back to their prior level.

As an example, if switching between ADC inputs AN2 and AN5, RB4 and RC0 could become connected for the duration of the switching time. Having RB4 set as an input that is driven half way between logic-high and logic-low can cause the glitch to be seen on RC0 if it is set as an output. When the two connected pins are at the same logic level, the glitch is minimized to less than 10 mV. In the extreme case where both pins are at differing logic levels, the glitch can be above 160 mV.

Another source of glitches can arise from switching the channels of the ADC itself. These glitches can be seen externally if the ADC input channel is also an input to an active comparator or op amp on the device. Three different sources of glitches can occur. Switching ADC channels changes the voltage across the ADC sample and hold capacitor (cap), which can cause glitches due to the potential differences across the cap. Depending on the external voltage level applied across the cap, the glitch can be positive or negative in nature. A second glitch can occur while the first glitch is recovering. This second glitch is due to the cap being disconnected from the pin electronics. The third glitch happens when the conversion is complete and the cap is re-connected to the pin electronics.

WORKAROUND

Digital Inputs

When using the I/O pins as digital input, there are a few choices to avoid the ADC channel switching issues. If the input pin is being polled, an option is not to switch ADC channels while in the polling loop. If polling is not used, then the input pin should not be checked for a state change right after issuing an ADC channel switch. Insert a `NOP` (no operation) instruction after the channel change, and then check the input for state change. The better option, if only dealing with a state change, is software debouncing the input. Check the input several times, counting up the number of times a particular state is registered. Once enough counts of the state change are recorded, then the state variable can be changed. This way, any ADC channel switching glitches get filtered out of the possible state change.

Digital Outputs

Using the digital pin as an output can cause spurious glitches to external circuitry during the ADC channel switching. The output pin, when driven high or low, can see a glitch corresponding to the opposite direction of the driven state. As an example, if the output is driven high, then a negative going glitch of up to 200 mV below the high state can appear on the pin. This glitch can last anywhere from 15 to 40 ns depending on the settling time of the switching logic.

The main ways to reduce or eliminate the issue are to reduce the energy in the glitch, make external circuits immune to the glitch, or to filter out the glitch entirely. First, try adding a resistor to the output pin to limit the current in the glitch so that it will not appreciably affect external circuits. External circuits that have Schmitt Trigger inputs would be immune to the glitch due to their inherent hysteresis. Another option is to filter out the glitch.

A low-pass RC filter on the output pin will reduce or even eliminate any glitches from reaching the external circuitry. Several factors need to be accounted for in choosing the R and the C component values of the filter. The RC time constant should be longer than the time period of the glitch (t > 40 ns) to filter out the glitch.

EQUATION 1: RC TIME CONSTANT

$$t = R \times C$$

It is recommended to be careful with the frequency response of the RC low-pass filter, so that it does not interfere with the external circuit. At a minimum, the cut-off frequency should be a decade higher frequency than the highest frequency signal that the application will output on that pin.

EQUATION 2: CUT-OFF FREQUENCY

$$f_c = \frac{1}{2\pi RC}$$

As an approximation, using the glitch rise and fall times of 15 to 40 ns (tr) would give a frequency of interest in the range of 8 to 24 MHz (BW). This is a rough idea of the highest frequency component in the glitch based on the equation relating bandwidth to rise time.

EQUATION 3: BANDWIDTH TO RISE TIME RELATION

$$BW = \frac{0.35}{t_r}$$

Note: t_r = the 10-90% rise time of a square wave
BW = the bandwidth of the signal

Analog Inputs

The first and second analog glitches can be reduced or eliminated by precharging the sample and the hold capacitor using the DAC. Set the DAC to a voltage level close to the expected voltage the ADC will sample to reduce the glitch. Charging the sample and the hold capacitor needs to be done before switching external ADC channels. If a close approximation of the voltage is known, then the DAC can be used to precharge the cap to a similar potential.

The third analog glitch is removed by switching the ADC to a different channel after the conversion is started, but before the conversion is complete. Start by selecting the conversion channel. Then start the conversion. Next, switch the ADC to the next channel to convert. Finally, the conversion completes and the process can be started over again.

CONCLUSION

Care should be taken when switching between ADC channels as the switching logic can inadvertently connect I/O pins. Using the recommendations above, most of the effects caused by channel switching can be mitigated. Modern MCUs with digital and analog components in close proximity can cause many previously unseen issues, but by following a few simple guidelines a robust application can be realized.

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

QUALITY MANAGEMENT SYSTEM CERTIFIED BY DNV

== ISO/TS 16949 ==

Trademarks

The Microchip name and logo, the Microchip logo, dsPIC, FlashFlex, flexPWR, JukeBlox, KEELOQ, KEELOQ logo, Kleer, LANCheck, MediaLB, MOST, MOST logo, MPLAB, OptoLyzer, PIC, PICSTART, PIC^{32} logo, RightTouch, SpyNIC, SST, SST Logo, SuperFlash and UNI/O are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

The Embedded Control Solutions Company and mTouch are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Analog-for-the-Digital Age, BodyCom, chipKIT, chipKIT logo, CodeGuard, dsPICDEM, dsPICDEM.net, ECAN, In-Circuit Serial Programming, ICSP, Inter-Chip Connectivity, KleerNet, KleerNet logo, MiWi, motorBench, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICkit, PICtail, RightTouch logo, REAL ICE, SQI, Serial Quad I/O, Total Endurance, TSHARC, USBCheck, VariSense, ViewSpan, WiperLock, Wireless DNA, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

ISBN: 978-1-63277-765-2

Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
http://www.microchip.com/support
Web Address:
www.microchip.com

Atlanta
Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Austin, TX
Tel: 512-257-3370

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Cleveland
Independence, OH
Tel: 216-447-0464
Fax: 216-447-0643

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Novi, MI
Tel: 248-848-4000

Houston, TX
Tel: 281-894-5983

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110

Canada - Toronto
Tel: 905-673-0699
Fax: 905-673-6509

ASIA/PACIFIC

Asia Pacific Office
Suites 3707-14, 37th Floor
Tower 6, The Gateway
Harbour City, Kowloon

Hong Kong
Tel: 852-2943-5100
Fax: 852-2401-3431

Australia - Sydney
Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing
Tel: 86-10-8569-7000
Fax: 86-10-8528-2104

China - Chengdu
Tel: 86-28-8665-5511
Fax: 86-28-8665-7889

China - Chongqing
Tel: 86-23-8980-9588
Fax: 86-23-8980-9500

China - Dongguan
Tel: 86-769-8702-9880

China - Hangzhou
Tel: 86-571-8792-8115
Fax: 86-571-8792-8116

China - Hong Kong SAR
Tel: 852-2943-5100
Fax: 852-2401-3431

China - Nanjing
Tel: 86-25-8473-2460
Fax: 86-25-8473-2470

China - Qingdao
Tel: 86-532-8502-7355
Fax: 86-532-8502-7205

China - Shanghai
Tel: 86-21-5407-5533
Fax: 86-21-5407-5066

China - Shenyang
Tel: 86-24-2334-2829
Fax: 86-24-2334-2393

China - Shenzhen
Tel: 86-755-8864-2200
Fax: 86-755-8203-1760

China - Wuhan
Tel: 86-27-5980-5300
Fax: 86-27-5980-5118

China - Xian
Tel: 86-29-8833-7252
Fax: 86-29-8833-7256

ASIA/PACIFIC

China - Xiamen
Tel: 86-592-2388138
Fax: 86-592-2388130

China - Zhuhai
Tel: 86-756-3210040
Fax: 86-756-3210049

India - Bangalore
Tel: 91-80-3090-4444
Fax: 91-80-3090-4123

India - New Delhi
Tel: 91-11-4160-8631
Fax: 91-11-4160-8632

India - Pune
Tel: 91-20-3019-1500

Japan - Osaka
Tel: 81-6-6152-7160
Fax: 81-6-6152-9310

Japan - Tokyo
Tel: 81-3-6880- 3770
Fax: 81-3-6880-3771

Korea - Daegu
Tel: 82-53-744-4301
Fax: 82-53-744-4302

Korea - Seoul
Tel: 82-2-554-7200
Fax: 82-2-558-5932 or
82-2-558-5934

Malaysia - Kuala Lumpur
Tel: 60-3-6201-9857
Fax: 60-3-6201-9859

Malaysia - Penang
Tel: 60-4-227-8870
Fax: 60-4-227-4068

Philippines - Manila
Tel: 63-2-634-9065
Fax: 63-2-634-9069

Singapore
Tel: 65-6334-8870
Fax: 65-6334-8850

Taiwan - Hsin Chu
Tel: 886-3-5778-366
Fax: 886-3-5770-955

Taiwan - Kaohsiung
Tel: 886-7-213-7828

Taiwan - Taipei
Tel: 886-2-2508-8600
Fax: 886-2-2508-0102

Thailand - Bangkok
Tel: 66-2-694-1351
Fax: 66-2-694-1350

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4450-2828
Fax: 45-4485-2829

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Dusseldorf
Tel: 49-2129-3766400

Germany - Karlsruhe
Tel: 49-721-625370

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Italy - Venice
Tel: 39-049-7625286

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

Poland - Warsaw
Tel: 48-22-3325737

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820

07/14/15