Application Note

Designing With TMUX1308A-Q1: Settling Time and The Impact on Your System

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ABSTRACT

Designs where various sensors are used to monitor different subsystems, tend to be complex due to the numerous amounts of signal paths. A common approach to reduce size and simplify the system is to use an analog multiplexer (mux) to route signals from different sensors into a single ADC. However, due to the break-before-make feature of most muxes, when switching between different channels the drain floats for a short period of time, causing the output voltage signal to slightly drop. Once the switch channel is connected to the new source the signal begins to settle. If the ADC samples before the signal can recover this can lead to an error. Furthermore, this implementation usually includes passive components, such as resistors and capacitors, on the input of the mux which can increase that delay and as a result can increase the ADC error count. For this type of application accurate sensor performance can be very critical. Reducing the input RC caused by the additional components on the input can minimize this delay and settling time: allowing the system to measure these sensors more frequently. Another option is to implement a multiplexer with improved functionality reducing settling time and improving system performance. The TMUX1308A-Q1 is designed to provide such a design.

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Trademarks

1 Introduction

Modern systems often rely on numerous sensors to monitor various subsystems, making efficient signal processing essential. To manage and simplify the routing of signals from many sensors to an ADC, a typical design is to use a multiplexer. However, when the mux switches to different channels, a short delay occurs when the drain is floating causing the output signal to slightly drop. During this time the ADC continues sampling which can lead to an error if a sample occurs in this down period when the drain is floating. This application is often seen in automotive, specifically in zone & body control modules, which involves managing the overvoltage risk from short to battery conditions that exceed the mux voltage limitations. To protect this and reduce signal distortion, resistors and capacitors are implemented on the inputs, resulting in an increased RC delay. The TMUX1308-Q1 is commonly used for this use case due to the configuration. Recently the TMUX1308A-Q1 was released as a direct replacement, but with improved functionality; greatly reducing settling time and ADC error count.

2 Application

In applications where an ADC is sampling data from multiple sensors, a single multiplexer can provide a design for routing and passing the signals. The TMUX1308-Q1 and TMUX1308A-Q1 devices can support up to eight sensors due to the devices configuration as shown in Figure 2-1. The devices switch between different sensor inputs and select which data is sent to an ADC.

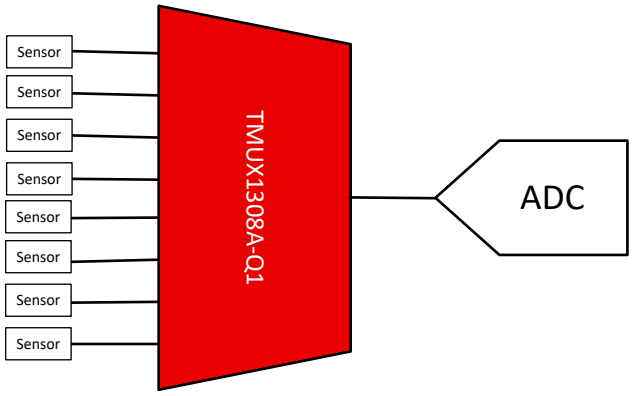

Figure 2-1. TMUX1308-Q1 ADC Application

This is heavily used in zone and body control modules where the potential for an overvoltage event is present, or the need to interface with a 48V battery system. A voltage divider has to be implemented on the inputs, to lower the voltage to a level where the mux can operate in. In addition to the resistors, capacitors tied to ground are used on each source to stabilize the signal. On the drain side there is also capacitance from the ADC, which greatly impacts the settling time.

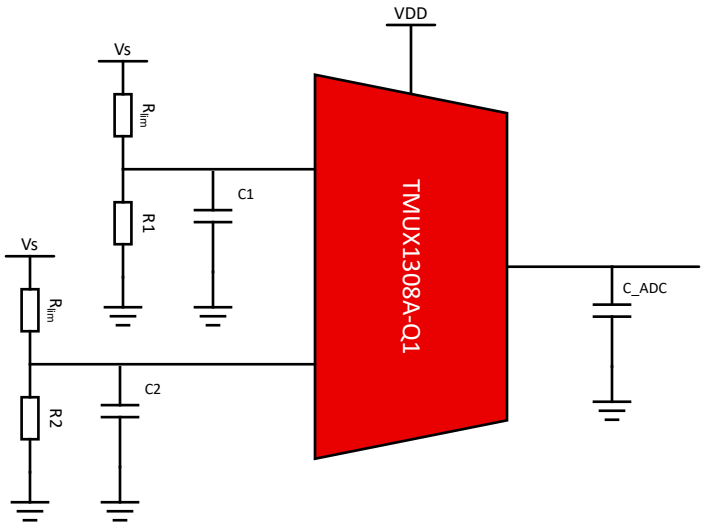

Figure 2-2. RC Components on the I/Os of the MUX

Most multiplexers have a feature called *Break before Make*. This is a safety feature that prevents two inputs from connecting when the device is switching. The output first breaks from the on-state switch before making the connection with the next on-state switch.

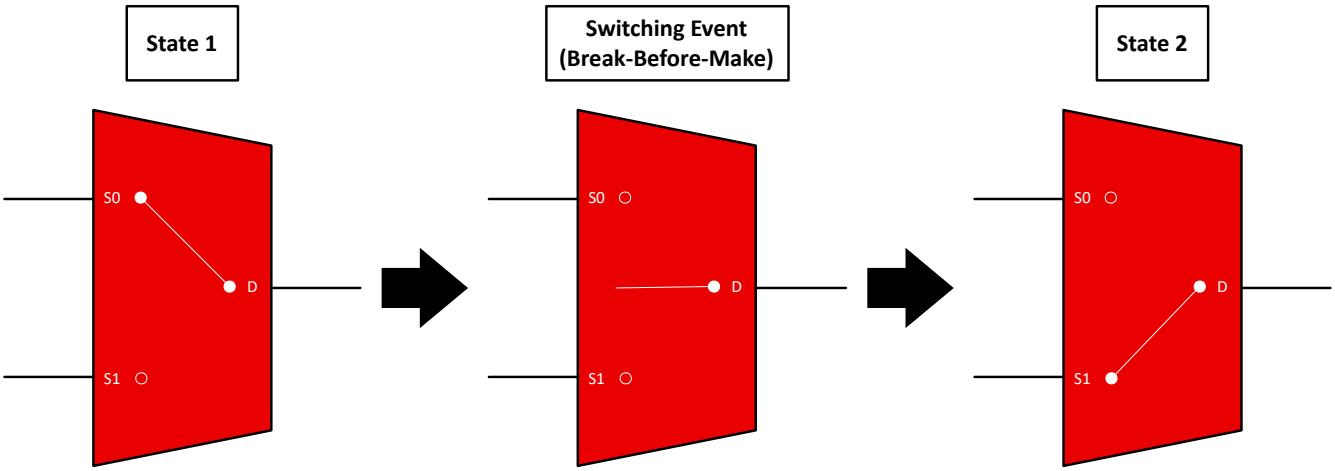

Figure 2-3. Break-Before-Make

This creates a slight delay where there is a down time when there is no connection between the source and drain. This can cause ADC reading errors, since the voltage level of the signal drops for a short period of time causing the ADC to read wrong voltage values. Having an additional RC load on the source pins can increase the time the output of the mux takes to recover which can result in inaccuracies on the ADC input. The time this takes for the signal to recover to the peak, referred to as the settling time (t_{st}), is directly affected by the series resistance and capacitance on the source pins as seen in Figure 2-4. The capacitance on the source and drain can affect how low the signal can dip, while the resistance can impact how fast this can settle back to the original state. Combined together is your total settling time.

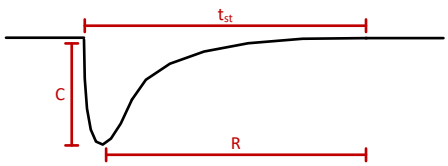

Figure 2-4. Settling Time Graph

3 Settling Time Tests and Results

The TMUX1308A-Q1 is the next generation upgrade over the TMUX1308-Q1. This is a direct drop in replacement with improved current injection control and faster settling time. To show this, lab measurements were gathered comparing the worst-case settling time of the TMUX1308-Q1, a common competitor device, and the TMUX1308A-Q1. Test setup shown in Figure 3-1.

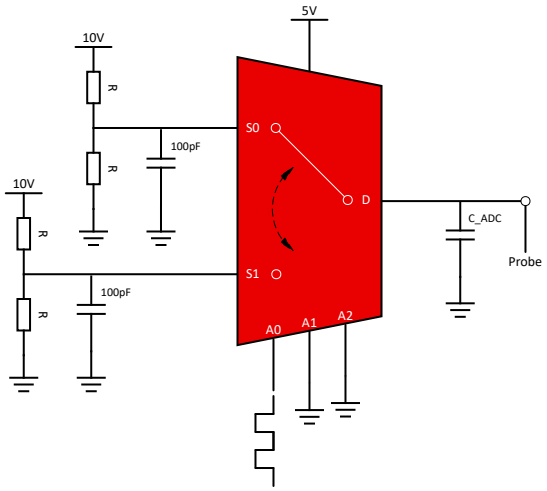

Figure 3-1. Lab Measurement Setup

The test conditions used for the experiment were the same for all three devices. There was 10V on the input with two resistors of the same value creating a voltage divider that reduces the voltage in half. Measurements are collected with the resistor values 4.7kΩ, 10kΩ, 22kΩ, and 47kΩ. The capacitance is fixed at 100pF. The device is powered by 5V, two of the address pins A1 and A2 are grounded, while A0 has a square wave input to toggle the two sources continuously. Lastly, the drain pin is probed to show the settling time of the signal. As seen from Table 3-1, the TMUX1308A-Q1 outshines the other two parts.

Table 3-1. Settling Time Test Conditions and Results

	R1(Ω)	R2(Ω)	Cs (pF)	Vs (V)	VDD(V)	TMUX1308A-Q1 t_{st} (µS)	TMUX1308-Q1 t_{st} (µS)	Comp-1 t_{st} (µS)
Condition 1	4.7k	4.7k	100	10	5	3.5	5	4
Condition 2	10k	10k	100	10	5	4	10.5	11
Condition 3	22k	22k	100	10	5	7.5	15	15
Condition 4	47k	47k	100	10	5	11.5	24	22

The following images show a settling time comparison between the three devices in voltage and 12-bit ADC error bits over time. In the voltage vs time graphs, the TMUX1308A-Q1 slightly dips and then recovers much faster than the other two devices. Resulting in a small and short disturbance in the voltage signal read by the ADC. Compared to the other two multiplexers, the TMUX1308A-Q1 greatly reduces the voltage distortion imparted on the sensor output signal being measured by the ADC. In the ADC error bits vs time graphs, the error amount is much lower compared to the other two parts. This is due to the fast recovery of the signal from the TMUX1308A-Q1.

As mentioned earlier, since this is a zone & body control module application the voltage supply can go up to 60V. This can result in requiring a current limiting resistor (R_{lim}) to prevent too much current feeding into the clamping circuit. To limit the voltage down to an operable condition, different resistor values need to be used for different voltage input levels.

Table 3-2. R_{limit} Values for <6V Through the Switch

V_{input}(V)	R_{lim}(Ω)
12	1.6k
18	3k
19	3.3k
24	4.7k
36	10k
48	13k
60	15k

Using the 36V input condition as an example, a 10kΩ limiting resistor needs to be implemented. With this resistor, the TMUX1308A-Q1's settling time is reduced to 4uS.

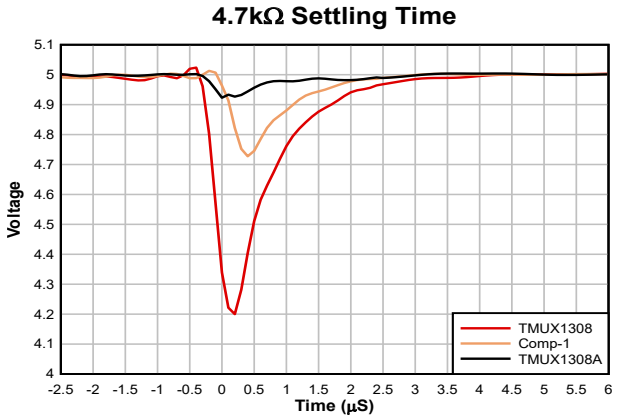

Figure 3-2. 4.7kΩ Voltage Settling Time

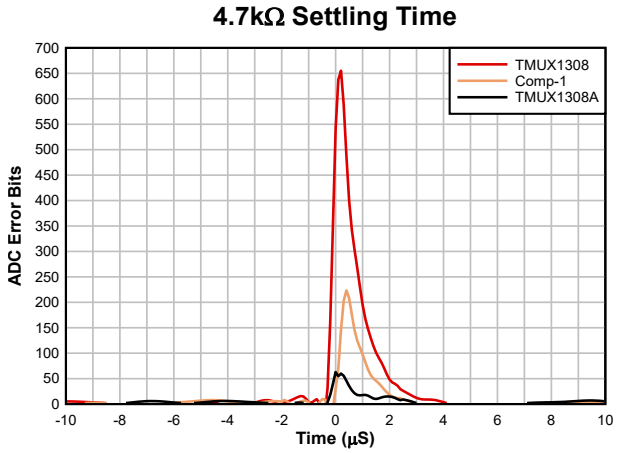

Figure 3-3. 4.7kΩ 12-bit ADC Error Bits Settling Time

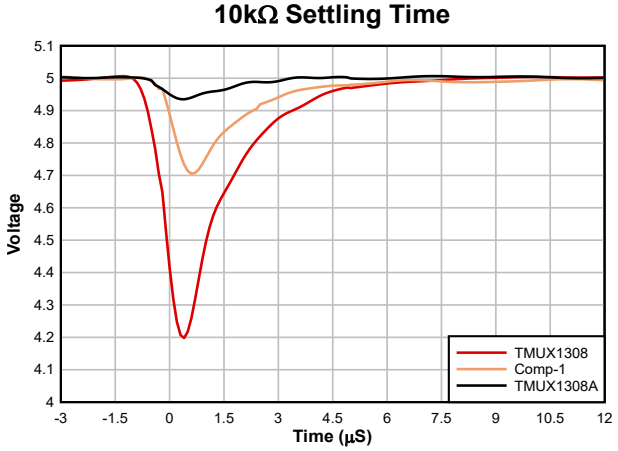

Figure 3-4. 10kΩ Voltage Settling Time

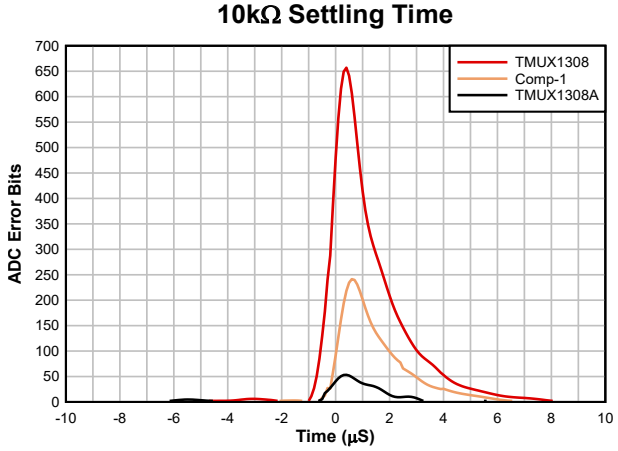

Figure 3-5. 10kΩ 12-bit ADC Error Bits Settling Time

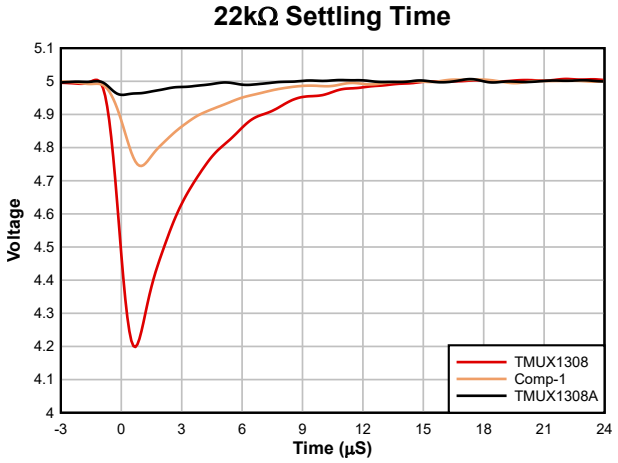

Figure 3-6. 22kΩ Voltage Settling Time

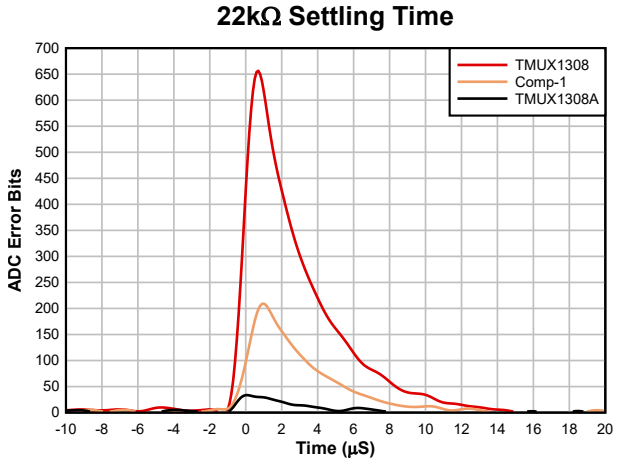

Figure 3-7. 22kΩ 12-bit ADC Error Bits Settling Time

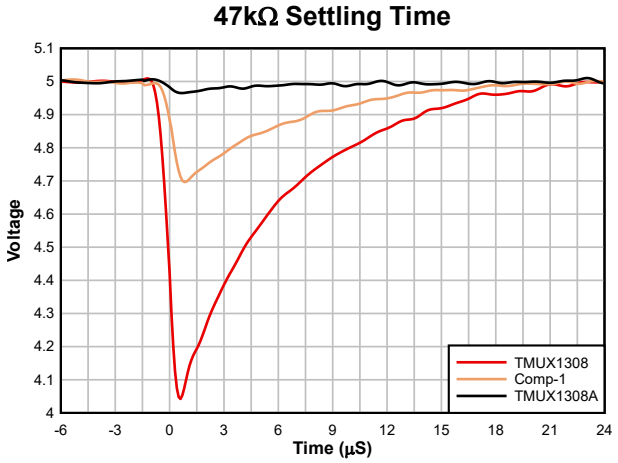

Figure 3-8. 47kΩ Voltage Settling Time

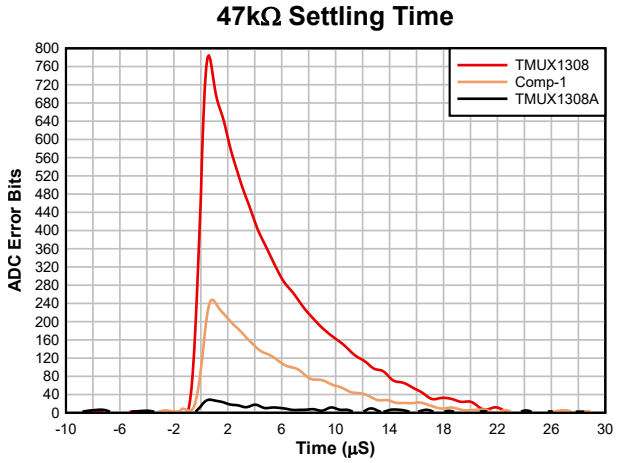

Figure 3-9. 47kΩ 12-bit ADC Error Bits Settling Time

4 Summary

The TMUX1308A-Q1 has a much faster settling time compared to the two other devices. Implementing this in sensor ADC applications can greatly reduce errors and improve system functionality. The TMUX1308A is available in both industrial and automotive rated versions. This allows to quickly cycle through multiple sensor signals, resulting in faster ADC sampling compared to the counterparts.

5 References

- Texas Instruments, *TMUX1308A-Q1 Automotive 5V, Bidirectional 8:1, 1-Channel Multiplexer With Injection Current Control & 1.8V Logic*, product page
- Texas Instruments, *TMUX1308A 5V, Bidirectional 8:1, 1-Channel Multiplexer With Injection Current Control & 1.8V Logic*, product page
- Texas Instruments, *Zonal Architecture and MCU I/O Expansion*, application brief
- Texas Instruments, *Short to Battery Protection with TI Analog Switches and Multiplexers*, application note

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