

Input Sharing With the TIC12400-Q1

ABSTRACT

This application report shows how the TIC12400-Q1 device can support more digital switches with the same input count through use of input sharing. Included in this document are the concepts of input sharing, with design examples and results.

Table 1. Related Documentation

Device	Data Sheet
TIC12400-Q1	SCPS260

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1 Input Sharing Concept

1.1 Overview

In BCM designs today it is common for a single I/O to be monitoring a single switch input. The ADC of the TIC12400-Q1 can be used to expand the number of switch inputs monitored by a single I/O. This reduces the overall cost of the system by supporting more switches with the same number of I/O pins.

This is accomplished by adding a resistor to the digital switch input. Instead of the standard comparator monitoring seen in the left side of [Figure 1](#), the ADC is used to monitor both switches as shown on the right side of the image.

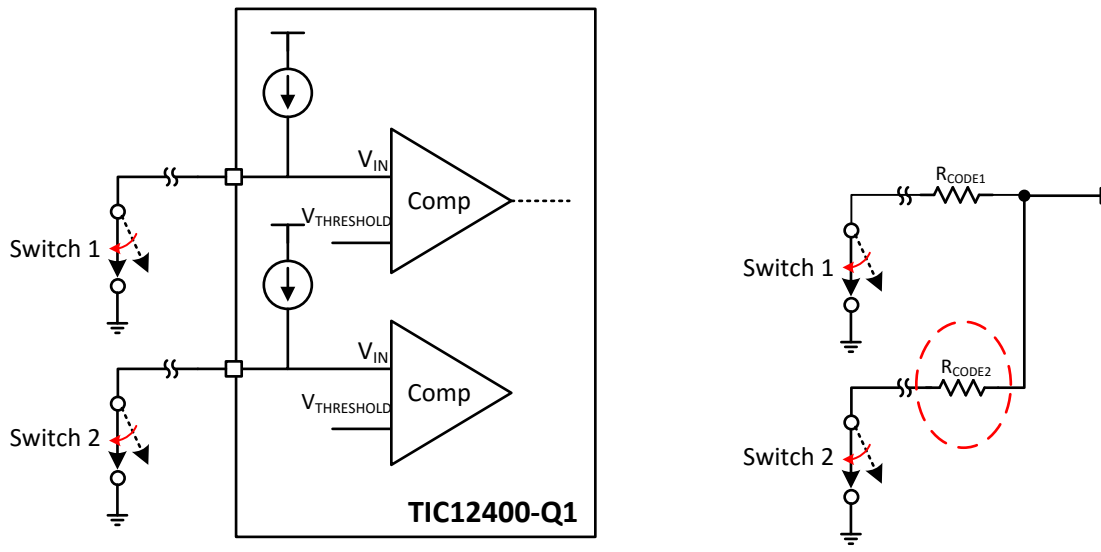


Figure 1. Input Sharing Concept

1.1.1 Calculating the Number of Inputs That can be Supported

Input sharing can be done in two ways with the ADC:

1. Use the available TIC12400 Q-1 Thresholds on channels with more than three thresholds available.
2. Manual interpretation of the ADC code and corresponding switch status.

To determine the best method, the system designer must consider if a wake-up interrupt is needed when there is a state change on a given input. When using input sharing there will be 4 switch states on an input. The TIC12400-Q1 can only send an interrupt if the switch voltage has crossed a threshold. [Figure 2](#) shows that three thresholds are required to distinguish between the four states.

	SW1	SW2	
State 1	Closed	Closed	
State 2	Closed	Open	← Threshold 1
State 3	Open	Closed	← Threshold 2
State 4	Open	Open	← Threshold 3

Figure 2. Thresholds

The TIC12400-Q1 supports more than three thresholds and channels IN18 to IN23, six total channels. Therefore, one TIC12400-Q1 can support $24 + 6 = 30$ switch inputs if a wake-up interrupt is required on all channels for a status change.

If a wake-up interrupt is not required on state change, the MCU can monitor the inputs periodically using the ADC code for that input and determine the switch state. This is discussed more in [Section 2](#). Without a required wake-up interrupt, the TIC12400-Q1 can utilize input sharing on all 24 inputs with 12 of the 48 having a wake-up interrupt (IN18 to IN23), yielding 48 supported switches with only 24 inputs.

The number of digital inputs supported by a single TIC12400-Q1 using input sharing can be calculated if the required number of wake-up channels is known. If the number of required wake-up channels is WAKE_UP, the total number of channels the TIC12400-Q1 can support is governed by the following equation. Total channels supported = $NUM_{WAKE_UP} + (36 - (NUM_{WAKE_UP} - 12) \times 2)$.

In summary, a quick combination of inputs using the previous formula is shown in [Table 2](#) and [Table 3](#).

Table 2. Single TIC12400-Q1 Number of Supported Inputs

Number of Wake-up Interrupt Inputs	Non-Wake-up Inputs
30	0
12	36
13	34
0	48

Table 3. Two TIC12400-Q1 Number of Supported Inputs

Number of Wake-up Interrupt Inputs	Non-Wake-up Inputs
60	0
24	72
25	70
0	96

2 Design Example

This section presents an input sharing design example using the TIC12400-Q1 device.

2.1 Design Requirements

Implement the following design requirements:

1. Design R1 and R2 such that only one input of the TIC12400-Q1 is needed to monitor the switch status for SW1 and SW2.
2. Support wake-up interrupt capability on the input.
3. Meet the following parametric requirements:
 - Minimum supply voltage: 10 V
 - Wetting current setting: 10 mA
 - Input ESD cap: 15 nF
 - Worst-case switch resistance: $R_{SW} = 100 \Omega$
 - Sampling frequency: 2 ms

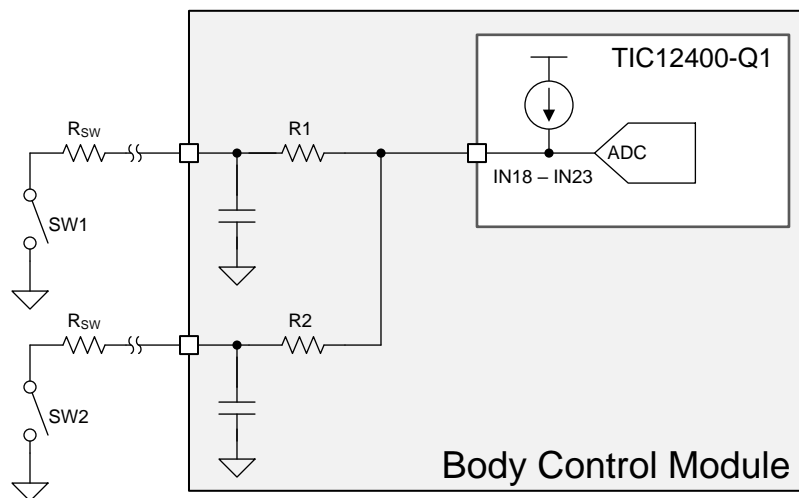


Figure 3. BCM With Input Sharing

2.1.1 Design Procedure

2.1.1.1 Equivalent Resistance Calculations

The first step is to calculate the equivalent resistance equation that SW1 and SW2 create when toggled on and off.

Table 4. Switch Status and R_{EQ}

Switch State	SW1 Status	SW2 Status	R_{EQ}
State 1	ON	ON	$R_{SW1} // R_{SW2}$
State 2	ON	OFF	$R1 + 100$
State 3	OFF	ON	$R2 + 100$
State 4	OFF	OFF	∞

2.1.1.2 Resistor Selection

Assume that $R2 > R1$. The ADC dynamic range is 0 V to 6 V, with 6 V corresponding to ADC code 1023. Designing the system to have 3 different thresholds that separate the 4 switch states is the goal.

The first calculation for R2 uses the rule that the input voltage must be less than the dynamic range of the ADC. The input voltage = Wetting Current $\times R_{EQ}$. ADC dynamic range = 6 V. This gives the equation $10 \text{ mA} \times (R2 + 100) \leq 6 \text{ V}$, simplified to $R2 \leq 500 \Omega$. Select $R2 = 300 \Omega$, R1 must be less than R2 and R1 = 150 Ω is picked.

2.1.1.3 ADC Code Calculations

Now use the I_{WETT} specification for 10 mA from [TIC12400-Q1 24-Input Multiple Switch Detection Interface \(MSDI\) With Integrated ADC and Adjustable Wetting Current for Automotive Systems](#), $9.2 \text{ mA} < I_{WETT} < 13.4 \text{ mA}$, to find V_{IN} and the corresponding ADC code for each of the switch states where $V_{IN} = I_{WETT} \times R_{EQ}$. $R_{EQ} = (R_{SW1} \times R_{SW2}) / (R_{SW1} + R_{SW2})$. $R_{SWn} = 100 + R_n$.

Table 5. Single TIC12400-Q1 Number of Supported Inputs

Switch State	SW1 Status	SW2 Status	R_{EQ}	V_{IN}	ADC Code
State 1	ON	ON	154 Ω	1.42 V–2.06 V	242–351
State 2	ON	OFF	250 Ω	2.3 V–3.35 V	392–572
State 3	OFF	ON	400 Ω	3.68 V–5.36 V	627–914
State 4	OFF	OFF	∞	> 6 V	1023

2.1.1.4 ADC Threshold Selection

Pick the threshold to be the mid-point between two neighboring states using Equation 1:

$$\text{Threshold} = ((\text{State } n \text{ maximum ADC code}) + (\text{State } n+1 \text{ minimum ADC code})) / 2 \tag{1}$$

- Threshold 1: 372
- Threshold 2: 600
- Threshold 3: 968

2.1.1.5 Polling Time Selection

Select a T_{POLL} of 2 ms and a $T_{POLL_ACT} = 64 \mu\text{s}$ to satisfy the design timing requirement.

2.1.1.6 Channel Selection and Program Timing Settings

To satisfy the design requirement to generate a wake-up interrupt on state change, use an input that has three thresholds. The channels that support three or more thresholds are input channels 18–23. Choose channel IN18. Use the GUI to help create register map settings that correspond to the input design requirements.

Corresponds to code 273, 600 and 968

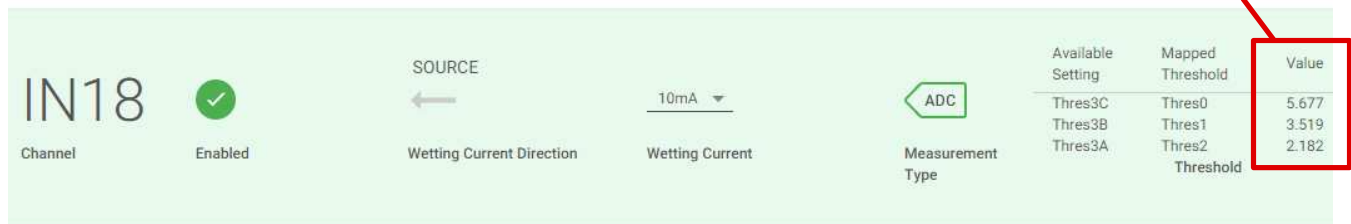


Figure 4. GUI Channel Selection

Next, choose the correct polling time settings.

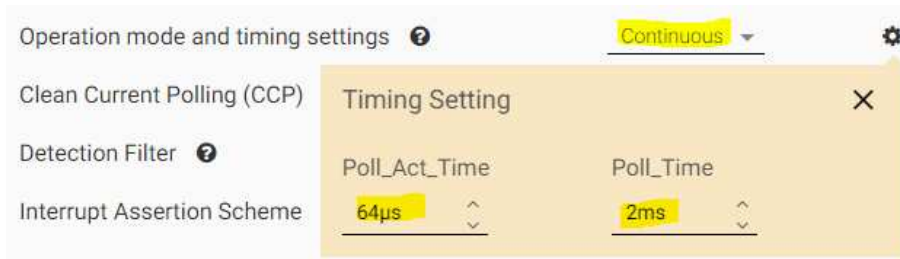


Figure 5. GUI Polling Time Settings

Finally the interrupt settings must be set and the auto scaling must be disabled.

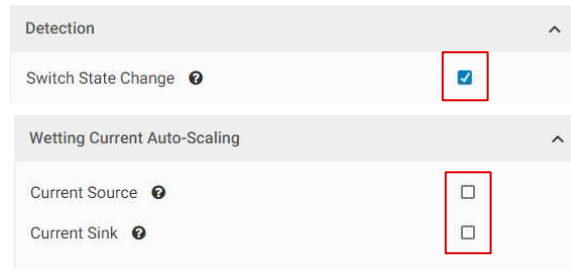


Figure 6. GUI Interrupt and Current Source Settings

3 Design Results

This section presents the results obtained from the design example using input sharing with the TIC12400-Q1 device.

3.1 Board Setup

Use the TIC12400-Q1 EVM to test a design on IN18 to make sure the system behavior matches the design requirements.

The *EVM Switch Board* resistors were changed to mimic the total switch resistance for SW2: 400 Ω , and SW1: 150 Ω .

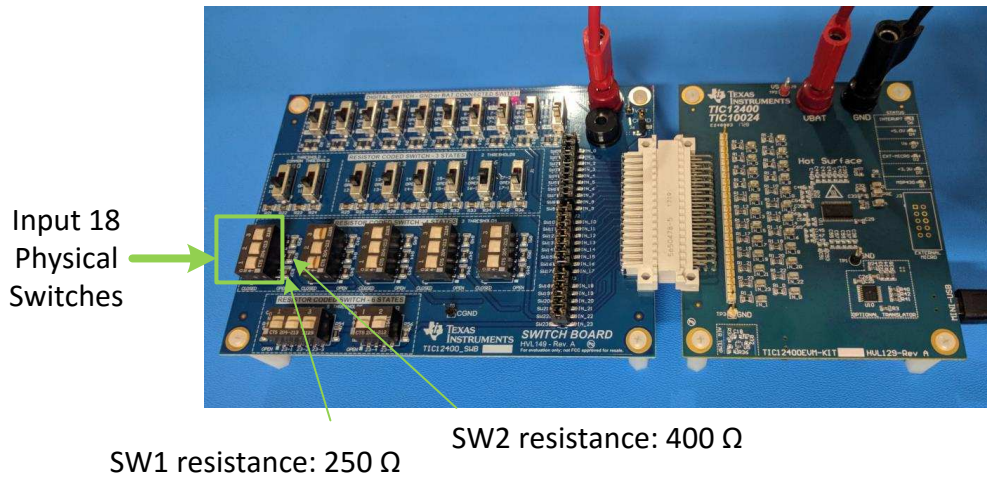


Figure 7. EVM Board Setup

3.2 GUI Results

Using the real-time status tracker of the GUI, toggle the external switches and verify that the state changes match expectations.

The results show that the TIC12400-Q1 is able to differentiate the four unique switch states properly and report that information back to the GUI.

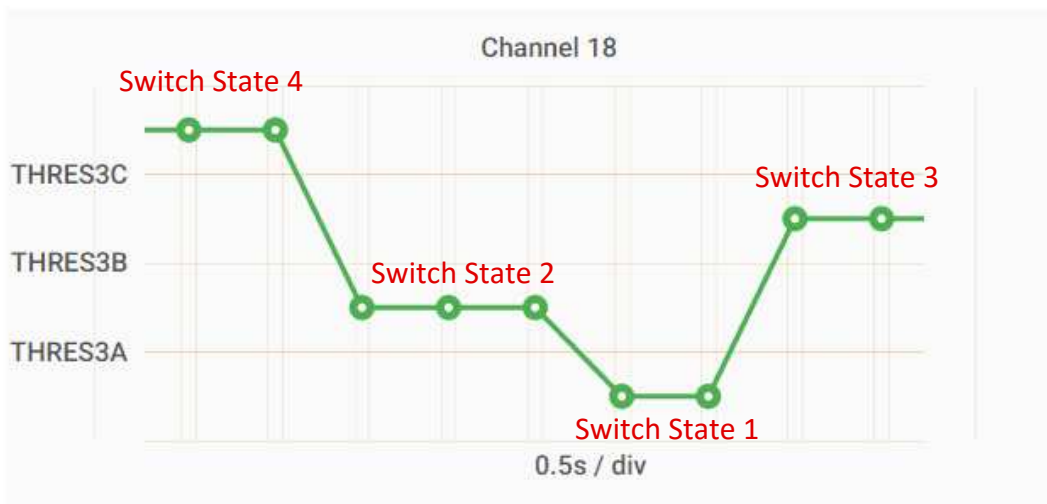


Figure 8. GUI Switch State Changes

3.3 Bench Characterization Results

Testing under a thermal stream at ambient temperatures of -40°C , 25°C , and 125°C , obtains the resulting data. The measured values are well bound by the thresholds that were selected during the design procedure and give confidence that the system will perform as expected across temperature.

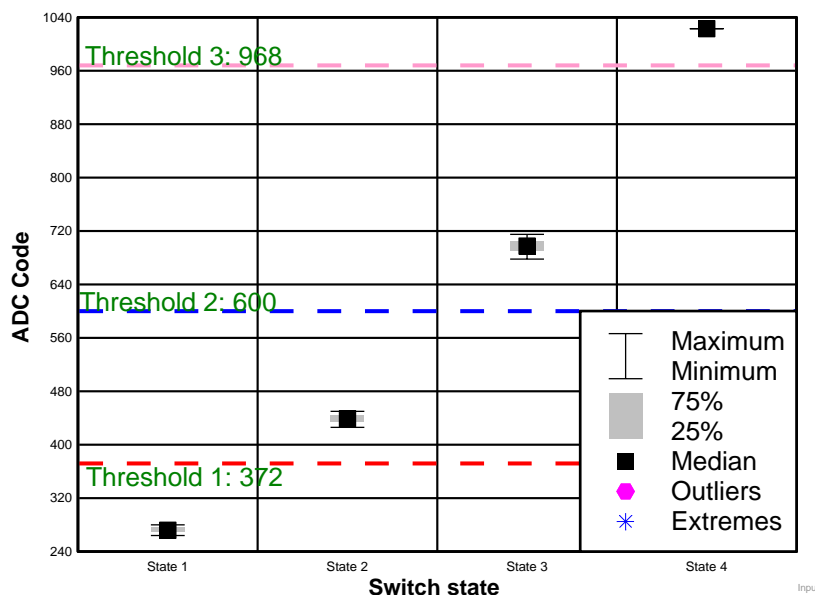


Figure 9. Switch State Verification Across Temperature

3.4 Oscilloscope Verification

To further validate the performance of the system, use an oscilloscope to manually verify the expected behavior.

The scope capture in [Figure 10](#) shows that at every change of the V_{IN18} voltage across a threshold, an interrupt is generated as expected.

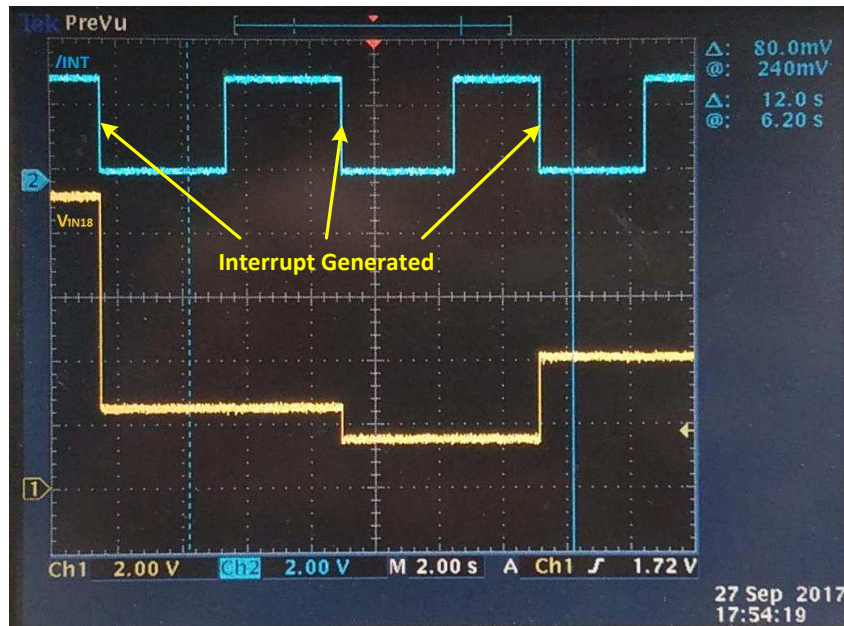


Figure 10. Continuous Current Measurement

The polling current measurement scope capture in [Figure 11](#) shows how during a polling cycle the voltage is captured with the current source on as the switch status is changed.

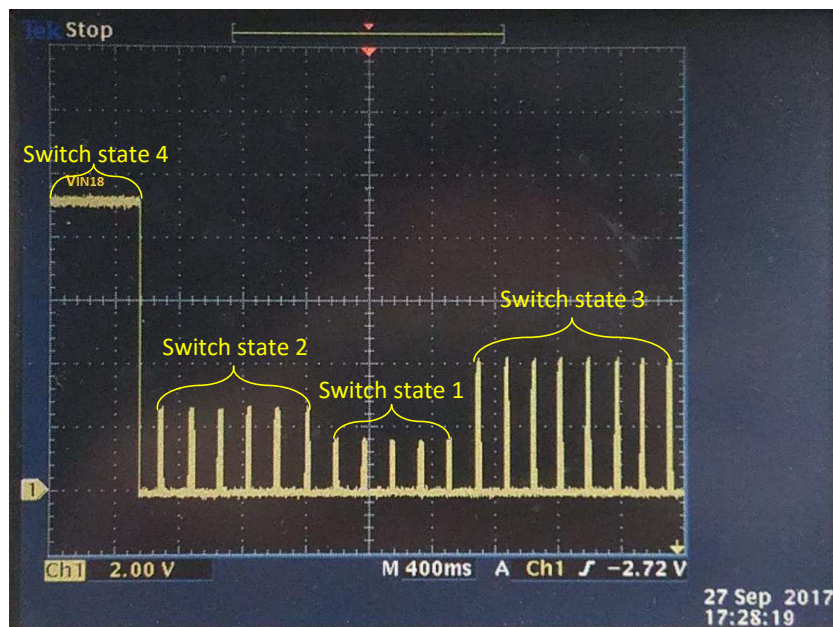


Figure 11. Polling Current Measurement

The polling cycle can also be verified by zooming in on the individual measurements. Figure 12 shows that the expected poll time of 2 ms and a startup time of 400 μ s can be measured to precisely 2.4 ms actual behavior. This confirms the system is behaving as anticipated and that our design is correct.

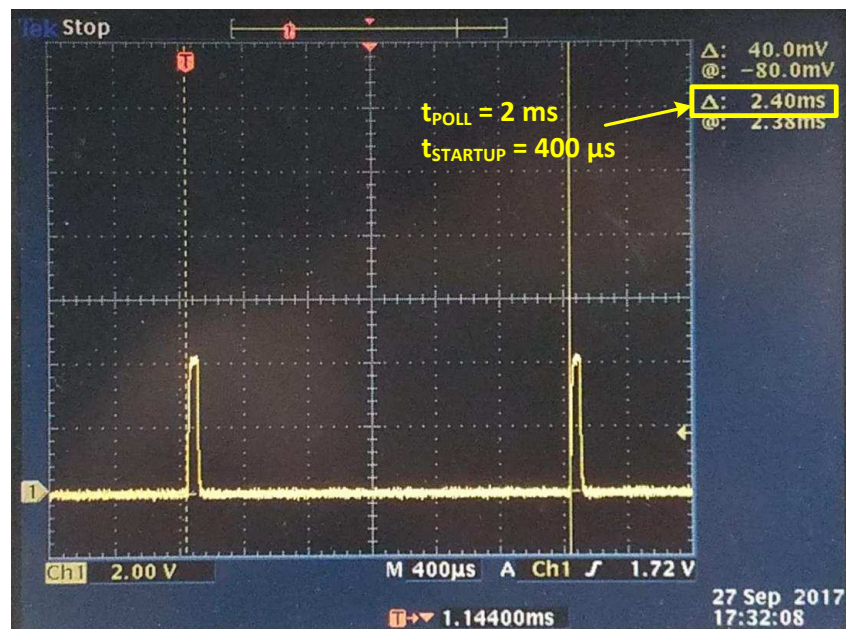


Figure 12. Polling Cycle Measurement

3.5 Conclusion

The measurement results show that the TIC12400-Q1 was successfully able to differentiate between the 4 unique switch states with plenty of margin using properly-designed external-code resistors. This allowed a single input to monitor 2 digital switches as intended.

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