MSP430FW42x ScanIF Demo Box Hardware and Software Description

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ABSTRACT

This application report describes the specific information of the demo box that detects the disc rotation using Scan Interface in MSP430FW42x. Both hardware and software are covered to help the developer understand the working principle of this demo box in a short time.

This document is based on *Rotation Detection With the MSP430 Scan Interface* (SLAA222). Detailed technical information can be found in that document.

Contents

1 The Demo Box 2
2 Demo Source Code 3
3 References 12
Appendix A Schematic 13

List of Figures

1 Demo Box 2
2 The LCD 3
3 Graphical Illustration for the Criteria of Updating SIFCNT1 6
4 Relationship Between the Excitation Level, the DAC Level and SIFxOUT 8
5 Value of SIFxOUT at the Same Excitation Level With Different DAC Value 8
6 Startup Calibration Flowchart 9
7 Coarse to Fine Calibration for System Startup 10
8 Relationship Between Different Parameters 11
9 Example of Run Time Calibration When Excitation Level Became Higher 12
10 Simplified Schematic of the Demo Box 13

List of Tables

1 Pin Connection 3
2 ScanIF Initialization 3
3 TSM Setup 5
4 State Table Setting of the Demo Source Code 7

1 The Demo Box

Figure 1 shows different parts of the demo box. The target demo board is equipped with an MSP430FW429 for ScanIF operation.

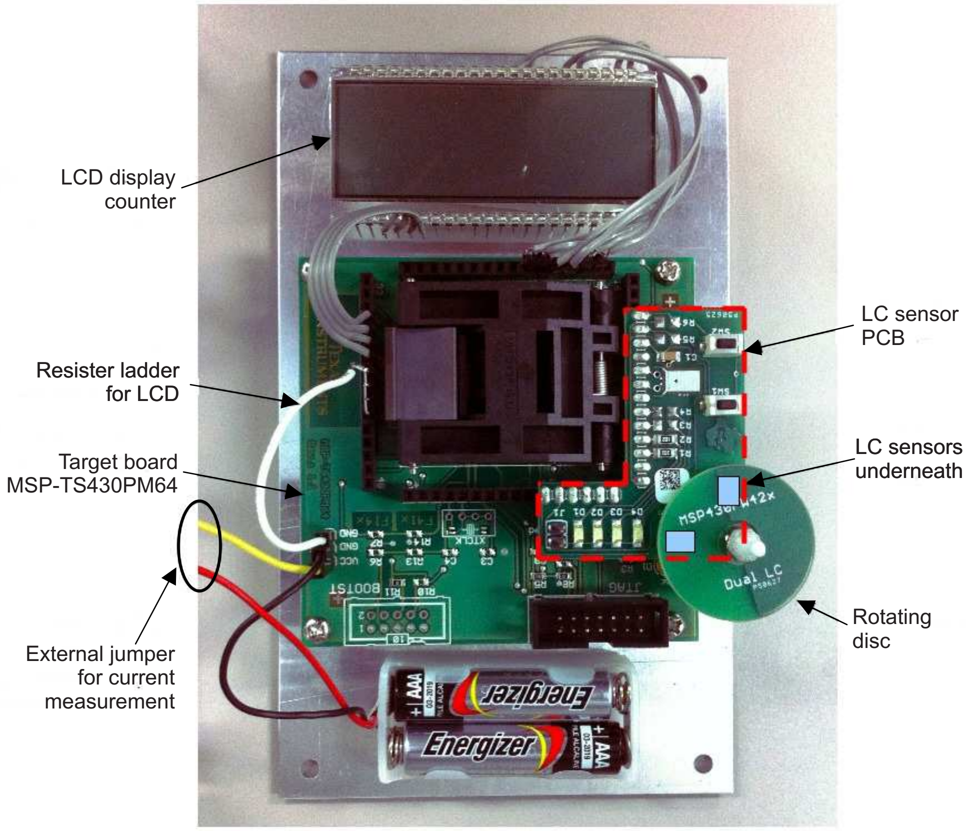


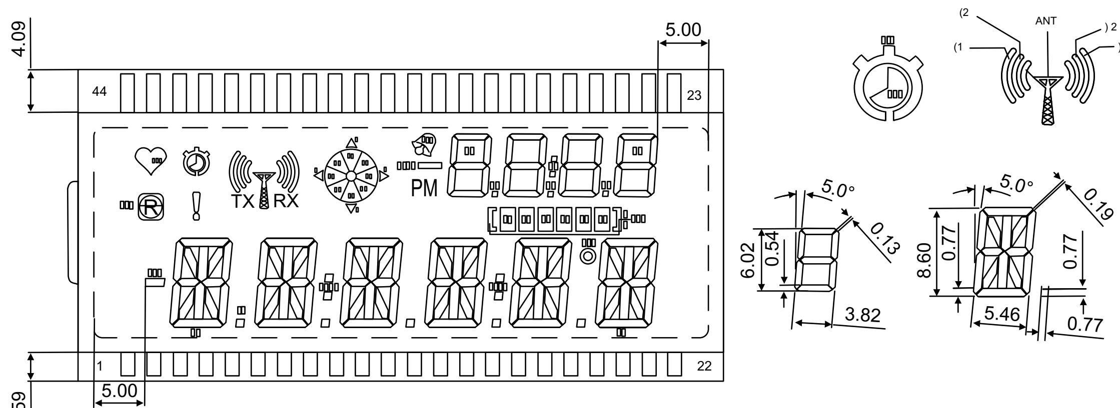
Figure 1. Demo Box

NOTE:

- To power the board, short the external jumper or connect the JTAG to the FET tool.
- To measure the current consumption (using battery power), connect the external jumper pin to a multi-meter.
- The JTAG and the battery share the same V_{CC}. Do not power the board using the JTAG and the battery at the same time.
- For the demo source code once the board is powered up, the LCD shows “CAL” for initialization. If there is nothing shown on the LCD, there may be some bad contacts between the MCU and the target board. Opening and closing the cover of the MCU socket should solve the problem.
- The LCD takes roughly 3 µA. Disconnect the LCD resister ladder to eliminate that current consumption. Of course, the LCD will not display numbers anymore.

1.1 LCD

The LCD layout is shown in Figure 2. Only the 3 digits on the left (A1, A2 and A3) are used and only the corresponding pins are connected to the MCU.



PIN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
COM0	A1M	A1D	AIDP	A1P	A2M	A2D	A2DP	A2P	A3M	A3D	A3DP	A3P	A4M	A4D	A4DP	A4P	A5M	A5D	A5DP	A5P	A6M	A6D
COM1	A1G	A1C	A1N	A1K	A2G	A2C	A2N	A2K	A3G	A3C	A3N	A3K	A4G	A4C	A4N	A4K	A5G	A5C	A5N	A5K	A6G	A6C
COM2	A1F	A1B	NEG	A1J	A2F	A2B	A2C0L	A2J	A3F	A3B	ANT	A3J	A4F	A4B	A4C0L	A4J	A5F	A6B	DEG	A5J	A6F	A6B
COM3	A1E	A1A	A1Q	A1B	A2E	A2A	A2Q	A2H	A3E	A3A	A3Q	A3H	A4E	A4A	A4Q	A4H	A5E	A5A	A5Q	A5H	A6E	A6A

PIN	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
COM0	RX	A6P				C0M0	BATT	[]	D4D	D4DP	D3D	D3DP	D2D	D2DP	D1D	DC0L	DNEG	U	PN	PNE	) 2	TMR2
COM1	A6N	A6K			C0M1		B2	B1	D4C	D4G	D3C	D3G	D2C	D2G	D1C	D1G	REC	R	PE	PSE	) 1	TMR1
COM2	TX	A6J		C0M2			B4	B3	D4B	D4F	D3B	D3F	D2B	D2F	D1B	D1F	PM	D	PS	PSW	(2	HRT
COM3	A6Q	A6H	C0M3				B6	B5	D4A	D4E	D3A	D3E	D2A	D2E	D1A	D1E	ALM	L	PW	PNW	(1	!

Figure 2. The LCD

Table 1. Pin Connection

LCD	1	2	5	6	9	10	25	26	27	28
MSP430F W42x	S6	S7	S8	S9	S10	S11	COM3	COM2	COM1	COM0

2 Demo Source Code

The source code is divided into 3 files: lcd.c, main.c and scanif.c. This section focuses on the operation of rotation detection using ScanIF only.

2.1 ScanIF Initialization

The initialization code is modified from *Rotation Detection With the MSP430 Scan Interface* (SLAA222). The main difference is that the demo source code adds test cycle settings for calibration. The setting is shown in Table 2. Some unrelated parameters are not shown.

Table 2. ScanIF Initialization

Register Setting	Bitwise Value	Meaning
SIFCTL2 = 0x0150;	SIFDACON = 0	DAC is controlled by TSM
	SIFCAON = 0	Comparator is controlled by TSM
	SIFCAINV = 0	Comparator output is non-inverted
	SIFCAX = 0	Comparator input from SIFCHx
	SIFVSS = 0	Sample capacitor is grounded to SIFVss
	SIFVCC2 = 1	AVcc/2 on
	SIFSH = 0	Sample and hold disabled
	SIFEN = 1	Excitation circuitry is enabled
	SIFTCH1x = 01	Test channel 1 is mapped to SIFCH1
	SIFTCH0x = 00	Test channel 0 is mapped to SIFCH0

Table 2. ScanIF Initialization (continued)

Register Setting	Bitwise Value	Meaning
SIFCTL3 = 0x4000;	SIFS2x = 01	SIF1OUT is the S2 source
	SIFS1x = 00	SIF0OUT is the S1 source
	SIFIS1x = 00	SIFIFG3 is set with each count, up or down, of SIFCNT1
SIFCTL4 = 0x33D0;	SIFCNT1ENM = 1	SIFCNT1 decrement is enabled
	SIFCNT1ENP = 1	SIFCNT1 increment is enabled
	SIFQ7EN = 0	Q7 is not used to determine next PSM state
	SIFQ6EN = 0	Q6 is not used to determine next PSM state
	SIFDIV3Bx = 111	TSM restart after 330 ACLK cycle. At 32768Hz, that would be 0.01sec. This reflects the sampling rate of the LC sensor.
	SIFDIV3Ax = 101	
SIFCTL5 = 0x0045;	SIFTSMRP = 0	Each TSM sequence is triggered by ACLK divider
	SIFCLKFQx = 1000	Internal oscillator frequency = Nominal
	SIFFNOM = 1	Internal oscillator frequency = 1MHz
	SIFCLKEN = 1	TSM high frequency clock source = internal oscillator

2.2 TSM Setup

The SIFTSMx is modified from the *Rotation Detection With the MSP430 Scan Interface* (SLAA222) source code for calibration. The setting is shown in Table 3.

Table 3. TSM Setup

SIFTSM0 = 0x8800	**All off. Idle for 18xSMCLK**
(SIFTSM1 – 4: settings for SIFCH0)	SIFCHx = 00 SIFTESTS1 = 0 (Test cycle uses SIFDACR6 for DAC) SIFLCEN = 1 (LC enabled) SIFCLKON = 1 (Hi-Freq clock on)
SIFTSM1 = 0x002C	LC excitation for 1xSIFCLK SIFEX = 1 (Excitation)
SIFTSM2 = 0x0424	Wait for 1xACLK SIFACLK = 1 (use ACLK)
SIFTSM3 = 0x6934	Enable AFE for 14xSIFCLK SIFREPEATx = 13 SIFDAC = 1 (DAC on) SIFCA = 1 (Comparator on)
SIFTSM4 = 0x2174	Measurement for 5xSIFCLK SIFREPEATx = 4 SIFDAC = 1 SIFRSON = 1 (Enable output latch) SIFCA = 1
(SIFTSM5 – 8: settings for SIFCH1)	SIFCHx = 01 SIFTESTS1 = 1 (Test cycle uses SIFDACR7 for DAC) SIFLCEN = 1 (LC enabled) SIFCLKON = 1 (Hi-Freq clock on)
SIFTSM5 = 0x00AD	LC excitation for 1xSIFCLK SIFEX = 1 (Excitation)
SIFTSM6 = 0x04A5	Wait for 1xACLK SIFACLK = 1 (use ACLK)
SIFTSM7 = 0x69B5	Enable AFE for 14xSIFCLK SIFREPEATx = 13 SIFDAC = 1 (DAC on) SIFCA = 1 (Comparator on)
SIFTSM8 = 0x21F5	Measurement for 5xSIFCLK SIFREPEATx = 4 SIFDAC = 1 SIFRSON = 1 (Enable output latch) SIFCA = 1
SIFTSM9 = 0x0200	SIFSTOP = 1 (End of TSM sequence)

2.3 PSM Table Design

Rotation Detection With the MSP430 Scan Interface (SLAA222) points out that the 16-state table causes a bouncing problem and suggested a 32-state table. However, if the 16-state table is carefully designed, the bouncing problem can be solved so that the PSM table can be kept simple.

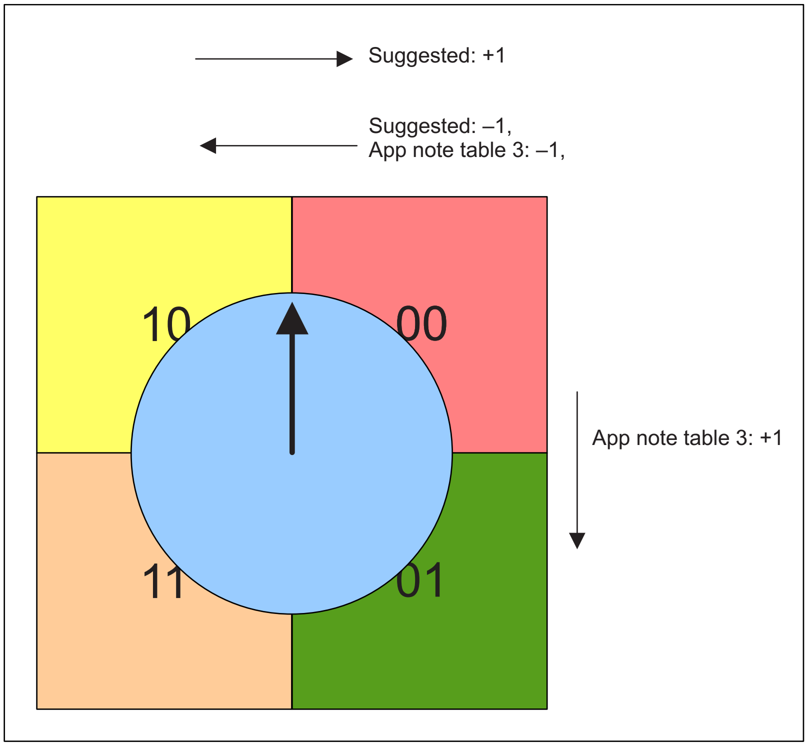


Figure 3. Graphical Illustration for the Criteria of Updating SIFCNT1

From Figure 3, imagine the blue circle is the rotating disc for rotation measurement. The arrow on the blue circle shows the rotating position. When that arrow is lying on any quadrates, the SCANIF gets the specific sensor state. For example, when the arrow lies on the yellow quadrate, S2 = 1 and S1 = 0. (State 10).

The arrows outside the square shows the different increment and decrement criteria based on two implementations: the implementation in *Rotation Detection With the MSP430 Scan Interface* (SLAA222) and the suggested implementation. The pointing direction of the arrows refers to the direction where the disc is rotating and that state change updates the SIFCNT1 value. For example, suggested: + 1 means when the disc rotates from state 10 to state 00, the SIFCNT1 will be +1.

It shows that in the application report implementation, the increment and the decrement of the counter is done on different disc position. For the *Quadrature Transitions for 2-Sensor Implementation* table in *Rotation Detection With the MSP430 Scan Interface* (SLAA222), if the disc rotates back and forth between 00 and 01, the state change of 00->01 increases the counter by 1. But it will not decrease by 1 when the state changes from 01 to 00. That will cause only +1 in this situation, which is the bouncing problem on 16- state table stated in *Rotation Detection With the MSP430 Scan Interface* (SLAA222).

To solve that problem, set the increment and the decrement on the same position. In order to design the state table, pair up the previous state and the current state, so that the increment and the decrement can be occurred at the same position.

Table 4 shows the state table setting of the demo source code.

Table 4. State Table Setting of the Demo Source Code

Look Up Position (Offset by Current S1 S2)	Previous State		Current State		State Table Value							Next Look Up Position	Moving Direction
	Q3	Q0	S1	S2	Q6	Q3	Q0	Q2 (-1)	Q1 (+1)	Binary (Q6 ...Q0)	Byte Code		
P0	0	0	0	0	0	0	0	0	0	000 0000	0x00	P0	No movement
	0	0	0	1	0	0	1	0	0	000 0001	0x01	P1	Turn Right
	0	0	1	0	0	1	0	1	0	000 1100	0x0C	P2	Turn Left (-1)
	0	0	1	1	1	1	1	0	0	100 1001	0x49	P3	Error (Opposite)
P1	0	1	0	0	0	0	0	0	0	000 0000	0x00	P0	Turn Left
	0	1	0	1	0	0	1	0	0	000 0001	0x01	P1	No movement
	0	1	1	0	1	1	0	0	0	100 1000	0x48	P2	Error (Opposite)
	0	1	1	1	0	1	1	0	0	000 1001	0x09	P3	Turn Right
P2	1	0	0	0	0	0	0	0	1	000 0010	0x02	P0	Turn Right (+1)
	1	0	0	1	1	0	1	0	0	100 0001	0x41	P1	Error (Opposite)
	1	0	1	0	0	1	0	0	0	000 1000	0x08	P2	No movement
	1	0	1	1	0	1	1	0	0	000 1001	0x09	P3	Turn Left
P3	1	1	0	0	1	0	0	0	0	100 0000	0x40	P0	Error (Opposite)
	1	1	0	1	0	0	1	0	0	000 0001	0x01	P1	Turn Left
	1	1	1	0	0	1	0	0	0	000 1000	0x08	P2	Turn Right
	1	1	1	1	0	1	1	0	0	000 1001	0x09	P3	No movement

2.4 Calibration

The demo source code consists of two different calibration codes. One is for system initialization and one is for run time calibration. The basic principle of both calibration codes are the same.

Figure 4 and Figure 5 show the relationship between the LC excitation level, the DAC value, and the measured output SIFxOUT. The SIFxOUT is the comparator output of the DAC and the LC excitation. When the LC excitation stays at a certain level, if the DAC value is above the excitation level (DAC value 1), the SIFxOUT becomes 0. If the DAC value is below the excitation level (DAC value 2), the SIFxOUT becomes 1.

Based on this relationship, the MCU can find the excitation level (threshold value) by adjusting the DAC value and check the SIFxOUT. For rotation detection, there are two excitation levels: with and without metal covers the LC sensors. The excitation level is lower when there is metal covers the LC sensors and it is higher when there is no metal covers the LC sensors.

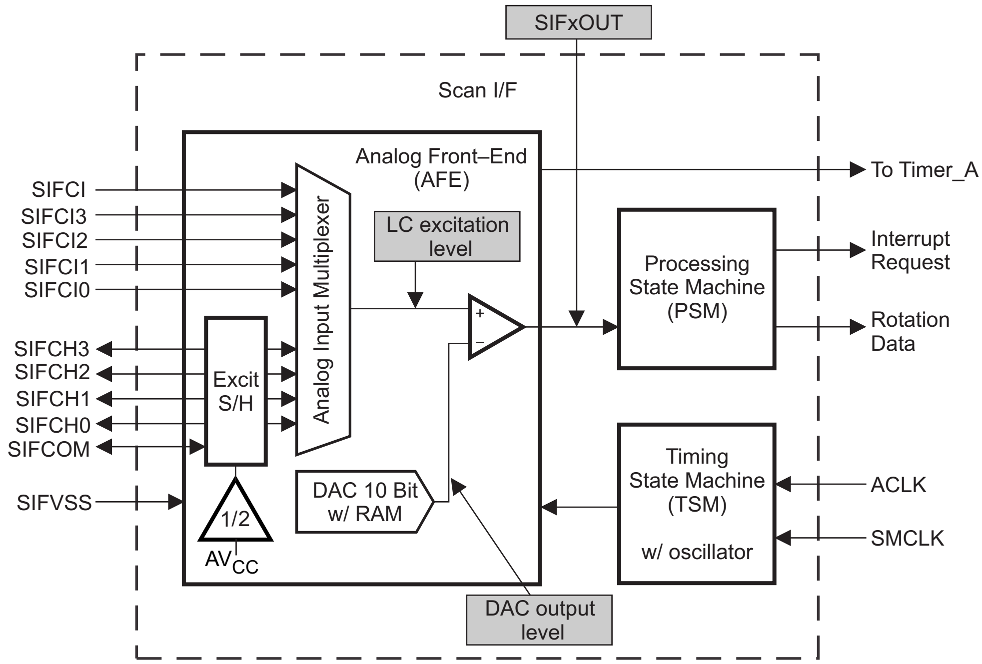


Figure 4. Relationship Between the Excitation Level, the DAC Level and SIFxOUT

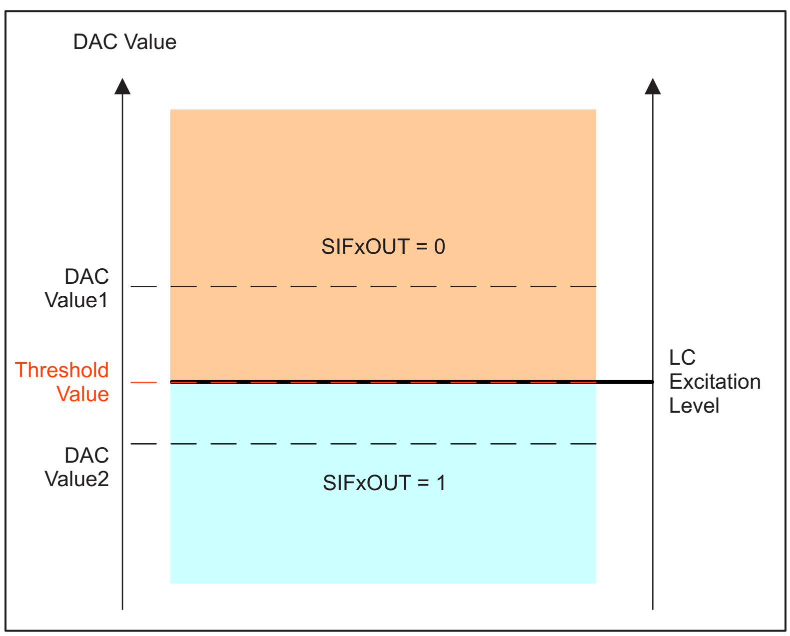


Figure 5. Value of SIFxOUT at the Same Excitation Level With Different DAC Value

2.4.1 System Initial Calibration

When the system starts up, there is no reference for the LC excitation levels. If there is no predefined value, it is not able to determine whether or not the LC sensor is covered by metal. In this situation, the system should find out the excitation level of those two states.

After the ScanIF setup, it sets different DAC values to SIFDACR(0-4) and check the SIFxOUT on each sampling cycle. The calibration starts from coarse step size to fine step size in order to minimize the number of iteration. The calibration step is shown in Figure 6.

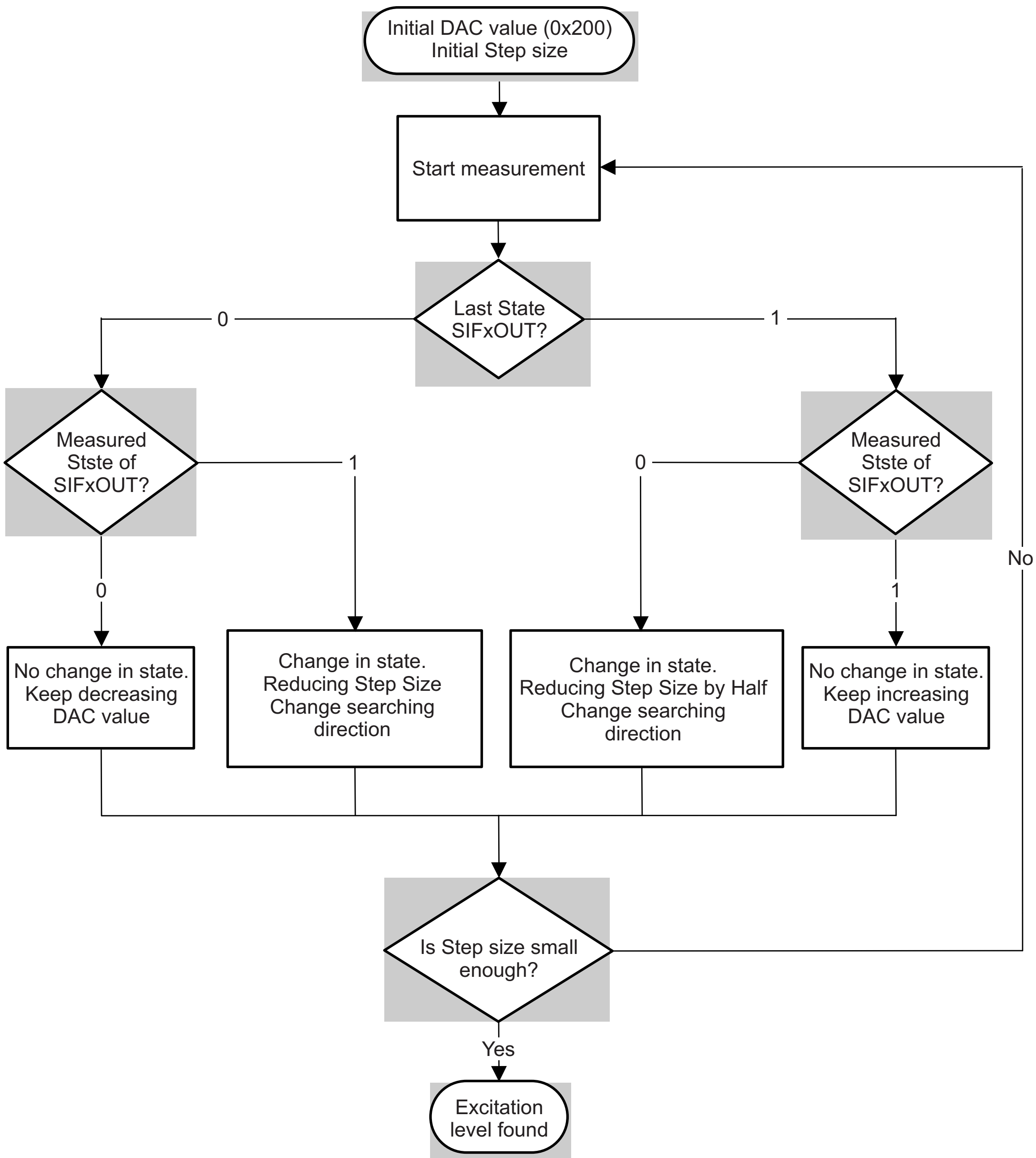


Figure 6. Startup Calibration Flowchart

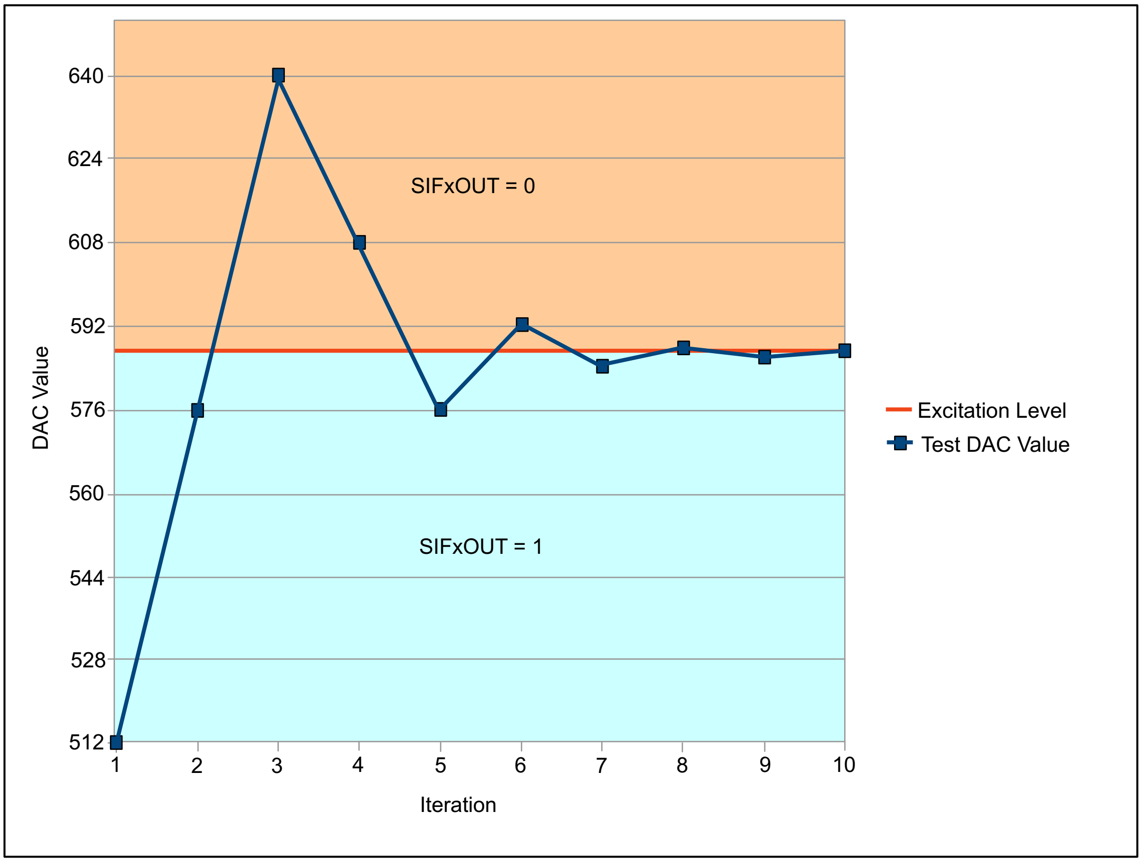


Figure 7. Coarse to Fine Calibration for System Startup

The threshold is continuously found. The maximum and the minimum value are recorded. When the disc rotates, the MCU eventually finds the thresholds of two states. The two states are determined by the difference (separation) of the maximum and the minimum value. If the difference is large enough, it is said that the two states are found. The final DAC value, SIFDACR0/2 and SIFDACR1/3 are calculated by averaging the upper and the lower threshold, plus hysteresis.

After the calibration is done, the sampling rate can be lowered by modifying SIFCTL4 in order to lower the power consumption.

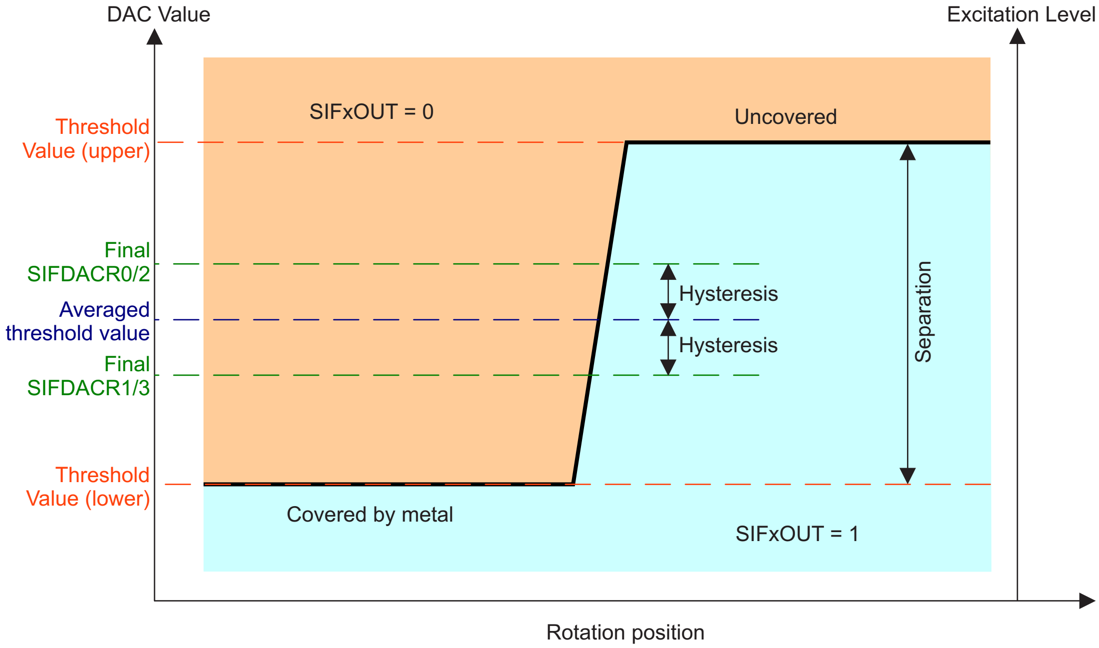


Figure 8. Relationship Between Different Parameters

2.4.2 Run Time Calibration

When the system runs, the calibration is done by using test cycle insertion (TCI) method. The TCI mechanism is built inside the ScanIF module. It inserts test cycles between normal cycles that allows for easy integration of calibration to occur without impacting the normal measurement cycle.

The TCI method uses SIFDACR6/7 for DAC output and SIFTCHxOUT for the measured result. It makes sure that the testing process will not affect the normal operation.

In the demo code, it starts searching for upper threshold by setting the testing DAC value SIFDAC6/7 to the stored upper threshold. It inserts test cycle and gets the SIFTCHxOUT for SIFDAC6/7. When SIFxOUT is 1, it also checks SIFTCHxOUT. If SIFTCHxOUT is 0, it shows that the excitation level became lower. So SIFDAC6/7 decreases and the test is done again, until SIFTCHxOUT becomes 1. Alternately, if SIFTCHxOUT is 1, it means that the excitation became higher. So SIFDAC6/7 increases and the test is done again, until SIFTCHxOUT becomes 0. The final SIFDAC6/7 is the new upper threshold. The same action is then being done for lower threshold by setting the initial SIFDAC6/7 to the stored lower threshold and by checking the SIFTCHxOUT when SIFxOUT is 0.

Once the new upper and the lower threshold have been found, the averaged threshold can be updated.

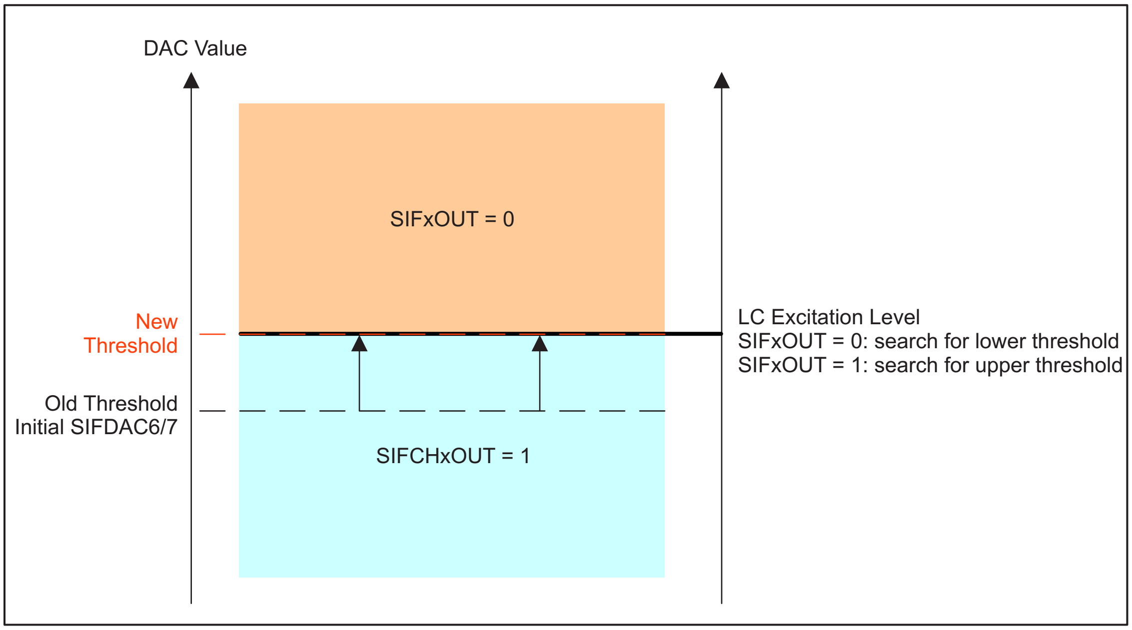


Figure 9. Example of Run Time Calibration When Excitation Level Became Higher

3 References

Rotation Detection With the MSP430 Scan Interface (SLAA222)

Appendix A Schematic

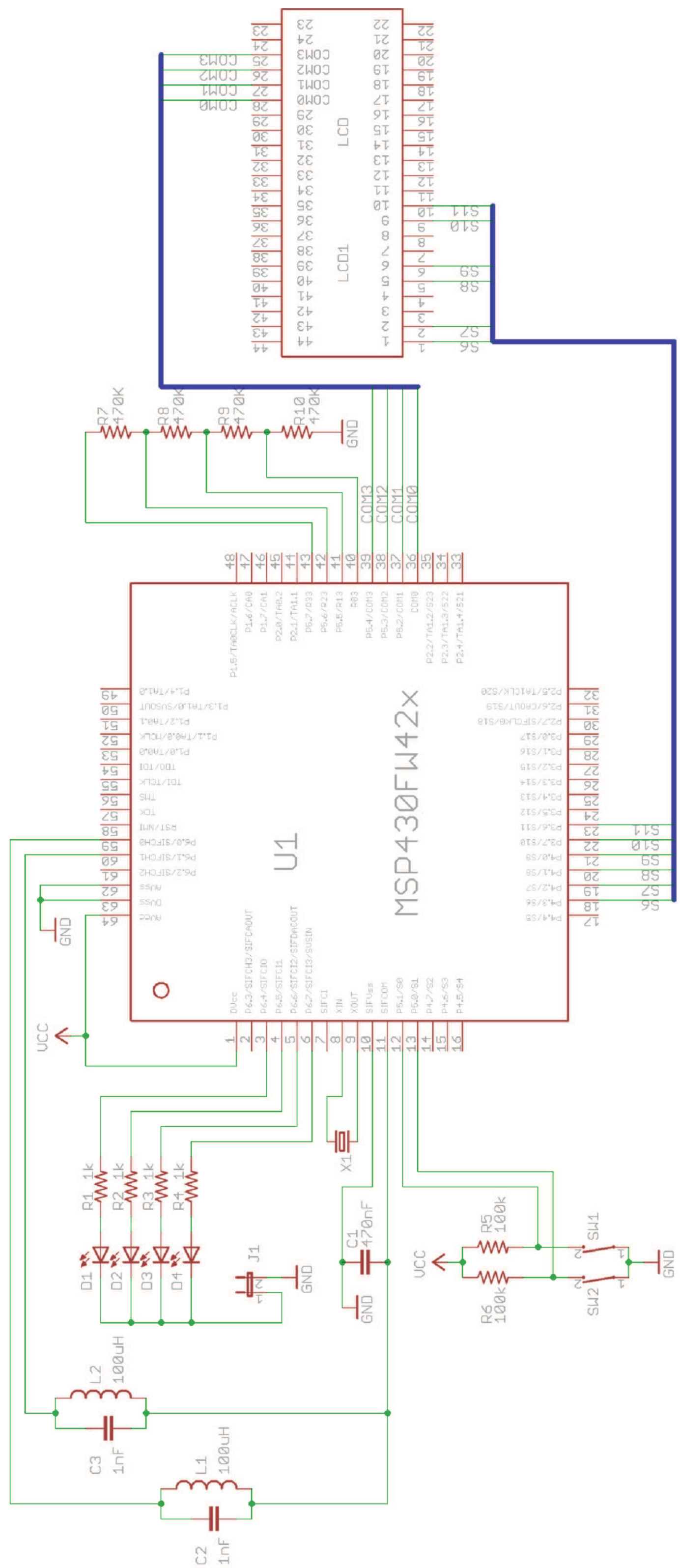


Figure 10. Simplified Schematic of the Demo Box

Products		**Applications**	
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