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# ICP-20100 User Configurable Operation Mode and IIR Filter



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## 1 ICP-20100 VERSIONS

In this document, we differentiate between ICP-20100 versions A and B.

Refer to the ICP-20100 Datasheet, Section 5.4 ASIC Identification for a way to detect the ICP-20100 version.



## 1 MODE4 CONFIGURATION

In ICP-20100 Mode4 operation, the pressure OSR can be programmed using the register field OSR\_PRESS\_REG in register MODE4\_OSR\_PRESS, and the temperature OSR can be programmed using the register field OSR\_TEMP\_REG in register MODE4\_CONFIG1. This document explains how to calculate the MODE4 settings.



## 2 BARREL SHIFTER AND ADJUSTABLE GAIN

#### 2.1 BARREL SHIFTER

The barrel shifter needs to be configured in MODE4 as a function of the selected OSR. This should be done for pressure and temperature independently by configuring register fields BS\_SHIFT\_VAL\_PRESS and BS\_SHIFT\_VAL\_TEMP of register MODE4\_BS\_VALUE according to Table 1\_and Table 2.

BS_SHIFT_VAL_PRESS	Condition for Pressure
0	2 <sup>12.5</sup> < OSR <sub>PRESS</sub> <= 2 <sup>13</sup>
1	$2^{12} < OSR_{PRESS} \le 2^{12.5}$
2	$2^{11.5} < OSR_{PRESS} <= 2^{12}$
3	$2^{11} < OSR_{PRESS} \le 2^{11.5}$
4	$2^{10.5} < OSR_{PRESS} <= 2^{11}$
5	$2^{10} < OSR_{PRESS} \le 2^{10.5}$
6	$2^{9.5} < OSR_{PRESS} \le 2^{10}$
7	$2^9 < OSR_{PRESS} \le 2^{9.5}$
8	$2^{8.5} < OSR_{PRESS} <= 2^9$
9 - 15	reserved

Table 1. Barrel Shifter Values for Pressure

BS_SHIFT_VAL_TEMP	Condition for temperature
6	OSR <sub>TEMP</sub> =2 <sup>10</sup>
8	OSR <sub>TEMP</sub> =2 <sup>9</sup>
1-5.7.9-15	reserved

**Table 2. Barrel Shifter Values for Temperature** 

Values higher than 8 are not possible on version A and will be saturated to 8.

The following formula is equivalent to Table 1 for pressure

BS\_SHIFT\_VAL\_PRESS = round\_down(26-2\* $log_2(OSR_{PRESS})$ )

#### 2.2 ADJUSTABLE GAIN

The adjustable gain block for MODE4 needs to be configured for pressure by programming the registers GAIN\_FACTOR\_PRESS\_MODE4\_LSB and GAIN\_FACTOR\_PRESS\_MODE4\_MSB according to the following formula:

The value GAIN\_FACTOR\_PRESS\_MODE4\_INIT is the value of the register GAIN\_FACTOR\_PRESS\_MODE4 after start-up.

Example values are listed in Table 3.

(Note that the GAIN\_FACTOR\_PRESS\_MODE4\_INIT value for MODE4 is device dependent and needs to be read from the register and not taken from Table 3).

GAIN_FACTOR_PRESS_ MODE4_INIT (hex)	OSR <sub>MODE4</sub> (OSR_PRESS_REG <sub>MODE4</sub> )	BS_SHIFT_VAL_ PRESS <sub>MODE4</sub>	GAIN_FACTOR_PRESS_ MODE4 (hex)
1.4450 (0xB8F6)	2368 (73)	4	1.0809 (0x8A59)
1.4450 (0xB8F6)	1088 (33)	6	1.2800 (0xA3D7)
1.4450 (0xB8F6)	512 (15)	8	1.4450 (0xB8F6)

**Table 3. Adjustable Gain Value Examples** 





If the calculated GAIN\_FACTOR\_PRESS\_ MODE4 is larger than or equal to 2.0, BS\_SHIFT\_VAL\_ PRESSMODE4 value needs to be incremented with 1 until the GAIN\_FACTOR\_PRESS\_ MODE4 is smaller than 2.0.



#### 3 MODE CONFIGURATION

This section provides MATLAB sample code on how to configure measurement mode MODE4. The following terminology is used in this code for register map references:

```
regMap.Register Name.Register Field Name.Write(Value)
```

where "Register\_Name" is the register name; "Register\_Field\_Name" is the name of the register field in the register; "Write" is a write operation for the specified register field; "Value" is the value being written to the specified register field.

Please refer to sections 11 and 12 for information about the registers/register fields shown in the sample code.

```
function PowerMode (self)
    %% PowerMode: function to move into power mode
    global regMap
    %% Move to power mode if not already inside
    if (regMap.MODE SELECT.POWER MODE.read==0)
        fprintf('Moving into power mode...\n')
        regMap.MODE SELECT.POWER MODE.write(1);
        pause (0.001);
    end
end
function Configure mode4(self)
    %% Configure_mode4: sample code on how to configure mode4 mirror registers
    % after a reset of the device
    global regMap
    self.PowerMode;
    %% Configure the mode4 mirror registers
    % Configure OSR for pressure and temperature according to the needs. Following
    % example programs OSR press=177 and OSR temp=15
    regMap.MODE4 OSR PRESS.OSR PRESS REG.write('0xb1');
    regMap.MODE4 CONFIG1.OSR TEMP REG.write('0x0f');
    % Configure the need of FIR and/or IIR filter. In this example, they are switched
    regMap.MODE4 CONFIG1.FIR ENABLE.write(0);
    regMap.MODE4 CONFIG1.IIR ENABLE.write(0);
    % Configure the ODR. In this example, the ODR is set to 25Hz (ODR=320)
    regMap.MODE4 ODR LSB.ODR LSB.write('0x40');
    regMap.MODE4_CONFIG2.ODR_MSB.write('0x01');
    % Following \overline{\mathsf{fields}} shoul\overline{\mathsf{d}} be reset to avoid activity between 2 measurements
    regMap.MODE4 CONFIG2.KEEP DVDD ON.write(0);
    regMap.MODE4 CONFIG2.KEEP HFOSC ON.write(0);
    % Calculate the barrel shifter values based on section 6.4.1
    regMap.MODE4_BS_VALUES.BS SHIFT VAL PRESS.write('0x1');
    regMap.MODE4 BS VALUES.BS SHIFT VAL TEMP.write('0x8');
    % Calculate the additional gain values based on section 6.4.2
    regMap.GAIN FACTOR PRESS LSB.write('0x56');
    regMap.GAIN FACTOR PRESS MSB.write('0x0b');
end
```

Table 4. MATLAB sample code to configure MODE4



## 4 IIR FILTER

The ICP-20100 includes an IIR filter in the signal path, to filter out pressure glitches due to sudden pressure changes caused by events such as slamming door or wind blowing on the sensor. The IIR filter is a 1<sup>st</sup> order filter with programmable cut-off frequency from  $0.1*f_{\text{ODR}}/2$  to  $f_{\text{ODR}}/2$ . The output of the IIR filter can be represented as:

Output<sub>Filtered</sub> = 
$$(1-k) / (1 - k*OutputFiltered Previous)*Input$$

where Input is the pressure sensor value input to the IIR filter and k is an unsigned 16-bit value ranging between 0 and 1. K can be programmed by writing to register fields K\_LSB and K\_MSB in registers IIR\_K\_FACTOR\_LSB and IIR\_K\_FACTOR\_MSB, respectively. As k approaches 1, the cut-off frequency reduces. The lower the cut-off frequency, the closer 1-k gets to zero and quantization noise increases.

Example values of k and corresponding cut-off frequencies are shown in following table:

k (hex)	k (dec)	k (equivalent value)	Cut-off frequency (*f <sub>ODR</sub> )
0x0000	0	0	transparent
0x3333	13107	0.2	0.351
0x4000	16384	0.25	0.269
0x4CCD	19661	0.3	0.220
0x5999	22937	0.35	0.185
0x6666	26214	0.4	0.157
0x7333	29491	0.45	0.134
0x8000	32768	0.5	0.115
0x8CCC	36044	0.55	0.098
0x9999	39321	0.6	0.083
0xA666	42598	0.65	0.069
0xB333	45875	0.7	0.057
0xBFFF	49151	0.75	0.046
0xCCCC	52428	0.8	0.036
0xD999	55705	0.85	0.026
0xE666	58982	0.9	0.017
0xF332	62258	0.95	0.008

Table 5. IIR Filter Cut-Off Frequencies for Different k Values

The step response for different k values is shown in Figure 1.



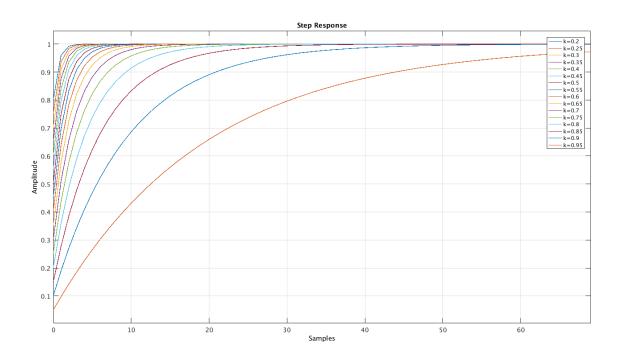


Figure 1. IIR Filter Step Response for Different k Values



## **5 REGISTER MAP**

This section lists the additional registers for ICP-20100 that are needed to configure MODE4.

The user can detect the version of the device by reading register VERSION.

Vers	sion A	Version B		Version B											
Addr (Hex)	Addr (Dec.)	Addr (Hex)	Addr (Dec.)	Register Name	Serial I/F	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0		
2C	44	3C	60	MODE4_OSR_PRESS	R/W	OSR_PRESS_REG									
2D	45	3D	61	MODE4_CONFIG1	R/W	-	IIR_ENABLE	FIR_ENABLE		09	SR_TEMP_R	EG			
2E	46	3E	62	MODE4_ODR_LSB	R/W	R/W ODR_REG_LSB									
2F	47	3F	63	MODE4_CONFIG2	R/W	-	KEEP_HFOSC_ON	KEEP_DVDD_ON		0	DR_REG_M	SB			
30	48	40	64	MODE4_BS_VALUE	R/W	BS_SHIFT_VAL_TEMP BS_SHIFT_VAL_PRESS									
78	120	88	136	IIR_K_FACTOR_LSB	R/W	K_LSB									
79	121	89	137	IIR_K_FACTOR_MSB	R/W	K_MSB									
82	130	92	146	GAIN_FACTOR_PRESS_MODE4_LSB	RW	GAIN_PRESS_LSB									
83	131	93	147	GAIN_FACTOR_PRESS_MODE4_MSB	RW	GAIN_PRESS _MSB									



## **6 REGISTER MAP DESCRIPTION**

This section describes the function and contents of each register.

# 6.1 MODE4\_OSR\_PRESS

Name: MODE4\_OSR\_PRESS

Address: 44 (0x2C) Version A; 60 (0x3C) Version B

Serial IF: R/W Reset value: 0xFF

BIT	NAME	FUNCTION
		Configures Over Sampling Ratio (OSR) for pressure measurement 00000000: No pressure measurement
7.0	OCD DDECC DEC	00000001 to 11111111 are valid settings
7:0	OSR_PRESS_REG	OSR <sub>PRESS</sub> = (OSR_PRESS_REG + 1) * 2 <sup>5</sup>
		For example, if OSR_PRESS_REG is set to 1, the corresponding OSR <sub>PRESS</sub> value
		is 64

# 6.2 MODE4\_CONFIG1

Name: MODE4\_CONFIG

Address: 45 (0x2D) Version A; 61 (0x3D) Version B

Serial IF: R/W Reset value: 0x1F

Reset	value. UXII	
BIT	NAME	FUNCTION
7	-	Reserved
		IIR Filter Selection
6	IIR_ENABLE	0: Bypass the IIR filter
		1: Enable the IIR filter
		FIR Filter Selection
5	FIR_ENABLE	0: Bypass the FIR filter
		1: Enable the FIR filter
		Configures Over Sampling Ratio (OSR) for temperature measurement
	OSR_TEMP_REG	00000: No temperature measurement
4:0		01111 and 11111 are valid settings. All other settings are not supported
4.0		$OSR_{TEMP} = (OSR\_TEMP\_REG + 1) * 2^{5}$
		For example, if OSR_TEMP_REG is set to 1, the corresponding OSR <sub>TEMP</sub> value
		is 64

## 6.3 MODE4\_ODR\_LSB

Name: MODE4\_ODR\_LSB

Address: 46 (0x2E) Version A; 62 (0x3E) Version B

Serial IF: R/W Reset value: 0x40

Output Data Rate (ODR) LSB  ODR_REG is a 13-bit quantity, with values from 0 to 8191. 8 LSBs are in register MODE4_ODR_LSB, 5 MSBs are in register MODE4_CONFIG2  ODR(Hz) = 8000/(ODR_REG + 1)	BIT	NAME	FUNCTION
For example, ODR_REG = 0 corresponds to ODR of 8 kHz; ODR_REG of 819: corresponds to ODR of 0.98Hz	7:0	ODR_REG_LSB	ODR_REG is a 13-bit quantity, with values from 0 to 8191. 8 LSBs are in register MODE4_CONFIG2 ODR(Hz) = 8000/(ODR_REG + 1) For example, ODR_REG = 0 corresponds to ODR of 8 kHz; ODR_REG of 8191



## 6.4 MODE4\_CONFIG2

Name: MODE4\_CONFIG2

Address: 47 (0x2F) Version A; 63 (0x3F) Version B

Serial IF: R/W Reset value: 0x01

BIT	NAME	FUNCTION
7	-	Reserved
		DVDD and HF oscillator control in between measurements
6	KEEP HFOSC ON	0: Full power-off/power-on sequence if KEEP_DVDD_ON field equals 0
	KEEI _III 036_014	1: Avoid lengthy power cycle timings by keeping the Power management and
		HF oscillator on between 2 measurements
		DVDD control in between measurements (this setting is ignored when
	KEEP_DVDD_ON	KEEP_HFOSC_ON field is set to 1)
5		0: Full power-off/power-on sequence
		1: Reduce the startup time for next measurement to 0.125 ms by keeping
		the DVDD LDO and BG on
		Output Data Rate (ODR) MSB
	ODR_REG_MSB	ODR_REG is a 13-bit quantity, with values from 0 to 8191. 8 LSBs are in
4:0		register MODE4_ODR_LSB, 5 MSBs are in register MODE4_CONFIG2
4.0		$ODR(Hz) = 8000/(ODR\_REG + 1)$
		For example, ODR_REG = 0 corresponds to ODR of 8 kHz; ODR_REG of 8191
		corresponds to ODR of 0.98 Hz

## 6.5 MODE4\_BS\_VALUE

Name: MODE4\_BS\_VALUE

Address: 48 (0x30) Version A; 64 (0x40) Version B

Serial IF: R/W Reset value: 0x60

	14.45.07.00	
BIT	NAME	FUNCTION
7:4	BS_SHIFT_VAL_TEMP	The gain of the temperature chain barrel shifter equals 2 <sup>bs_shift_val_temp</sup> . This gain is needed to compensate for lower gain values due to lower OSR selection.  Values higher than 8 are not possible and are saturated to 8  The following formula can be used to calculate the barrel shifter value in order to get a normalized DSP input value  Refer to 6.4 for selecting the correct value
3:0	BS_SHIFT_VAL_PRESS	The gain of the pressure chain barrel shifter equals 2 <sup>bs_shift_val_press</sup> . This gain is needed to compensate for lower gain values due to lower OSR selection. Values higher than 8 are not possible and are saturated to 8  The following formula can be used to calculate the barrel shifter value in order to get a normalized DSP input value  Refer to 6.4 for selecting the correct value



#### 6.6 IIR\_K\_FACTOR\_LSB

Name: IIR\_K\_FACTOR\_LSB

Address: 120 (0x78) Version A; 136 (0x88) Version B

Serial IF: R/W Reset value: 0x00

BIT	NAME	FUNCTION
7:0	K LSB	Pressure IIR filtering to reduce noise effects
7.0	K_L3B	Unsigned 16-bits value, with 0 integer bits and 16 fractional bits

## 6.7 IIR\_K\_FACTOR\_MSB

Name: IIR\_K\_FACTOR\_MSB

Address: 121 (0x79) Version A; 137 (0x89) Version B

Serial IF: R/W Reset value: 0x00

BIT	NAME	FUNCTION
7:0	K_MSB	Pressure IIR filtering to reduce noise effects
7.0		Unsigned 16-bits value, with 0 integer bits and 16 fractional bits

#### 6.8 GAIN\_FACTOR\_PRESS\_MODE4\_LSB

Name: GAIN\_FACTOR\_PRESS\_MODE4\_LSB

Address: 130 (0x82) Version A; 146 (0x92) Version B

Serial IF: R/W

Reset value: Device dependent

BIT	NAME	FUNCTION
7:0	GAIN_PRESS_LSB	8 least significant bits of the additional gain factor for MODE4 pressure
		measurement
		Unsigned 16-bits gain value, with 15 fractional bits

## 6.9 GAIN\_FACTOR\_PRESS\_MODE4\_MSB

Name: GAIN\_FACTOR\_PRESS\_MODE4\_MSB

Address: 131 (0x83) Version A; 147 (0x93) Version B

Serial IF: R/W

Reset value: Device dependent

nesset values 2 street dependent			
ВІТ	NAME	FUNCTION	
7:0	GAIN_PRESS_MSB	8 most significant bits of the additional gain factor for MODE4 pressure	
		measurement	
		Unsigned 16-bits gain value, with 15 fractional bits	



## 7 REVISION HISTORY

Revision Date	Revision	Description
10/05/2020	1.0	Initial Release
12/22/2021	1.1	Cosmetic updates
02/11/2022	1.2	Added version B



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