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	$2^{12.5} < OSR_{PRESS} <= 2^{13}$
1	$2^{12} < OSR_{PRESS} <= 2^{12.5}$
2	$2^{11.5} < OSR_{PRESS} <= 2^{12}$
3	$2^{11} < OSR_{PRESS} <= 2^{11.5}$
4	$2^{10.5} < OSR_{PRESS} <= 2^{11}$
5	$2^{10} < OSR_{PRESS} <= 2^{10.5}$
6	$2^{9.5} < OSR_{PRESS} <= 2^{10}$
7	$2^{9} < OSR_{PRESS} <= 2^{9.5}$
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	$OSR_{TEMP}=2^{10}$
8	$OSR_{TEMP}=2^{9}$
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:

$$GAIN\_FACTOR\_PRESS\_MODE4 = GAIN\_FACTOR\_PRESS\_MODE4\_INIT * 256^2 / ((OSR\_PRESS\_REG_{MODE4}+1)^2 * 2^{BS\_SHIFT\_VAL\_PRESS_{MODE4}})$$

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_{MODE4} (OSR_PRESS_REG_{MODE4})	$BS\_SHIFT\_VAL\_PRESS_{MODE4}$	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
    % off
    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 fields should 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 1st order filter with programmable cut-off frequency from $0.1*f_{ODR}/2$ to $f_{ODR}/2$. The output of the IIR filter can be represented as:

$$Output_{Filtered} = (1-k) / (1 - k*Output_{Filtered\_Previous}) * Input$$

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_{ODR})
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.

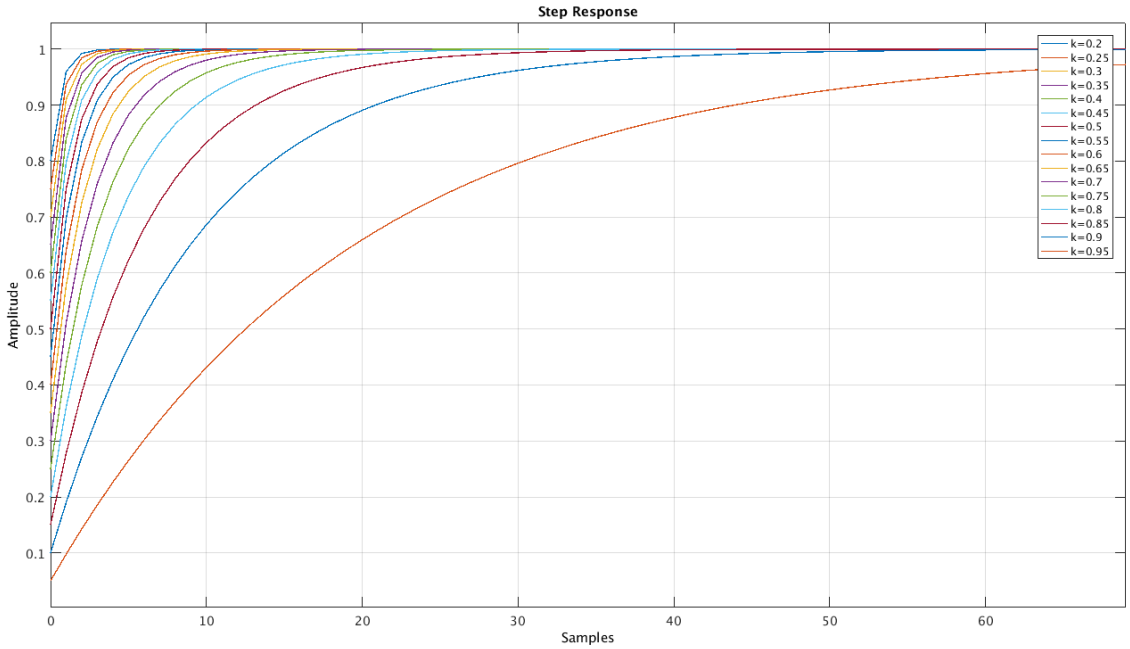

Figure 1. IIR Filter Step Response for Different k Values

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.

Version A		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	OSR_TEMP_REG				
2E	46	3E	62	MODE4_ODR_LSB	R/W	ODR_REG_LSB							
2F	47	3F	63	MODE4_CONFIG2	R/W	-	KEEP_HFOSC_ON	KEEP_DVDD_ON	ODR_REG_MSB				
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
7:0	OSR_PRESS_REG	Configures Over Sampling Ratio (OSR) for pressure measurement 00000000: No pressure measurement 00000001 to 11111111 are valid settings OSR_{PRESS} = (OSR_PRESS_REG + 1) * 2^5 For example, if OSR_PRESS_REG is set to 1, the corresponding OSR_{PRESS} 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

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

BIT	NAME	FUNCTION
7:0	ODR_REG_LSB	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) For example, ODR_REG = 0 corresponds to ODR of 8 kHz; ODR_REG of 8191 corresponds to ODR of 0.98Hz

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
6	KEEP_HFOSC_ON	DVDD and HF oscillator control in between measurements 0: Full power-off/power-on sequence if KEEP_DVDD_ON field equals 0 1: Avoid lengthy power cycle timings by keeping the Power management and HF oscillator on between 2 measurements
5	KEEP_DVDD_ON	DVDD control in between measurements (this setting is ignored when KEEP_HFOSC_ON field is set to 1) 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
4:0	ODR_REG_MSB	Output Data Rate (ODR) MSB 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) 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

BIT	NAME	FUNCTION
7:4	BS_SHIFT_VAL_TEMP	The gain of the temperature chain barrel shifter equals $2^{bs\_shift\_val\_temp}$. 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 $2^{bs\_shift\_val\_press}$. 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 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 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

BIT	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

COMPLIANCE DECLARATION DISCLAIMER

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