MPR121 Proximity Detection

INTRODUCTION

MPR121 is a feature rich, second generation touch sensor controller after Freescale's initial release of the MPR03x series device. Like MPR03x, MPR121 has a unique feature that all the electrode inputs can be internally connected together so that all the surface touch sensing area on the inputs are "summed" together to act as a single large electrode pad. This can effectively increase the total area of the sensing conductor for non-contact near proximity detection for hand approaching.

OVERVIEW

Capacitive proximity detection uses the same principle as capacitive touch sensing. Each MPR121 input sensing channel can be used as contactless proximity detection as well as finger touch detection if each sensing pad is designed properly and relevant register are set properly.

Typically a smaller pad size is used for finger touch button detection; while a larger pad size is necessary for contactless near proximity detection. On the other side, it's true that in most portable application design there is no dedicated big surface area left for proximity detection as the touch sensing buttons occupy all the available surface area. To make proximity detection at the same time of touch detection without additional dedicated large sensing pad, MPR121 has an internal input multiplexor which can connect all input sensing channels together so that all the touch sensing surface areas on the input pads are "summed" together effectively acting as a single large sensing pad.

Using this scheme in typical applications, the 12 channels can be used for 12 key buttons touch sensing, and the surface area of all the pads can also used for proximity detection (e.g., hand approaching).

PROXIMITY DETECTION REGISTER SETTING

Like each independent touch sensing detection, the 13th Proximity Detection electrode also has its own register configurations, other than that, all the concepts applied to the proximity detection are the same as touch sensing detection.

1.0 Enable Proximity Sensing

Proximity detection (a/k/a area detection mode) is enabled by configuring the Electrode Configuration Register (0x5E), see Table 1. In MPR121, this adds an area detection step (the 13th pseudo Electrode) before all the independent electrodes touch sensing detect sequence. Once configured, we refer to this area detection as the 13th Proximity Detection electrode.

Table 1. Electrode Configuration Register 0x5E (Reset Default: 0x00)

Bit	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Read / Write	CL[1]	CL[0]	AD[1]	AD[0]	EC[3]	EC[2]	EC[1]	EC[0]
Reset	0	0	0	0	0	0	0	0

AD1	AD0	EC3	EC2	EC1	EC0	Description
0	1	x	x	x	x	Area Detection by connecting ELE0~1.
1	0	x	x	x	x	Area Detection by connecting ELE0~3.
1	1	x	x	x	x	Area Detection by connecting ELE0~11.

2.0 Proximity Data Register and Baseline Register

Eleprox Electrode Registers (0x1C, 0x2D) contain the 10-bit raw data of the capacitance-voltage measurement value for the 13th Proximity Detection electrode.

Table 2. Eleprox Electrode Register 0x1C, 0x2D (Reset Default: 0x00, 0x00)

0x1C	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
	D7	D6	D5	D4	D3	D2	D1	D0

0x1D	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
	—	—	—	—	—	—	D9	D8

Eleprox Baseline Value Register (0x2A) contains the 8 MSBs of the 10-bit baseline value for the 13th Proximity Detection electrode. Writing to Baseline Value Register updates the 8 MSBs of baseline value and clears the 2 LSBs to zero. The Baseline Value Registers can only be written when in Shutdown Mode, but the current values may be read at any time.

Table 3. Eleprox Baseline Value Register 0x2A (Reset Default: 0x00)

0x2A	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
	D9	D8	D7	D6	D5	D4	D3	D2

3.0 Proximity Sensing Status Indication

MPR121 provides a single proximity sensing status bit (ELE[12] in table below) in the Touch Status Register. This status bit changes as a result of internal detection algorithm using the proximity raw data with the proximity baseline value and proximity touch/release threshold setting. When ELE[12] is set, the proximity is deemed as detected, and undetected when ELE[12] is 0.

Table 4. Status Register 0x00, 0x01 (Reset Default: 0x00)

0x00	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
	ELE[7]	ELE[6]	ELE[5]	ELE[4]	ELE[3]	ELE[2]	ELE[1]	ELE[0]

0x01	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
	OVCF	0	0	ELE[12]	ELE[11]	ELE[10]	ELE[9]	ELE[8]

The update rate of this status bit will be determined by sampling rate and detection debounce setting. The status bit will not immediately change if the Debounce Register is non zero. This Debounce Register is globally effective to prevent possible flick noise for both touch and proximity sensing. The value in the Debounce Register determines how many numbers of sample intervals are needed to pass at the touch/release threshold before the status bit is finally changed.

Table 5. Debounce Register 0x5B (Reset Default: 0x00)

0x5B	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
	X	DR[2]	DR[1]	DR[0]	X	DT[2]	DT[1]	DT[0]

On ELEPROX status bit change, the interrupt pin will be asserted.

4.0 Proximity Detection Touch/Release Threshold

Similar to the touch/release threshold for touch detection, the proximity detection also has a pair of touch/release threshold setting registers. The programmable threshold setting range is 0~63 count, representing the delta change below the baseline value when touched or released. The Threshold should be set according to the system SNR requirement and also provide adequate headroom for mass production variation. For normal application, set Touch Threshold slightly larger than Release Threshold so that there is no flick detection.

Example: Touch Threshold = 0x08, Release Threshold = 0x05.

Table 6. Eleprox Touch Threshold Register 0x59 (Reset Default: 0x00)

0x59	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
	D7	D6	D5	D4	D3	D2	D1	D0

Table 7. Eleprox Release Threshold Register 0x5A (Reset Default: 0x00)

0x5A	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
	D7	D6	D5	D4	D3	D2	D1	D0

5.0 Proximity Baseline Filter Setting

As with the touch detection, the proximity detection also dedicates register sets for baseline filter control. These include the maximum half delta for rising/falling, the noise half delta for rising/falling/touched, the noise count limit for rising/falling/touched, and filter delay for rising/falling/touched. Table 8 shows an example setting for proximity sensing, the concept is to have quickest response on baseline rising (when hand takes away) and slowest response on baseline falling (when hand approaching). Refer to Freescale application note AN3891 for detailed description on baseline system.

Table 8. Proximity Baseline Filter Registers 0x36~0x40 (Reset Default: all 0x00)

Register Name	Register Address	Example Setting
ELEPROX Max Half Delta Rising	0x36	0xFF
ELEPROX Noise Half Delta Amount Rising	0x37	0xFF
ELEPROX Noise Count Limit Rising	0x38	0x00
ELEPROX Filter Delay Limit Rising	0x39	0x00
ELEPROX Max Half Delta Falling	0x3A	0x01
ELEPROX Noise Half Delta Amount Falling	0x3B	0x01
ELEPROX Noise Count Limit Falling	0x3C	0xFF
ELEPROX Filter Delay Limit Falling	0x3D	0xFF
ELEPROX Noise Half Delta Amount Touched	0x3E	0x00
ELEPROX Noise Count Limit Touched	0x3F	0x00
ELEPROX Filter Delay Limit Touched	0x40	0x00

6.0 Electrode Configuration for Proximity Sensing

Same as touch sensing, the proximity sensing requires that the charging current and time for the 13th Proximity Detection electrode to be properly set. This can be done in 3 ways:

1. Globally setting the AFE Configuration Register (0x5B) and Filter Configuration Register if recent current setting and time setting is zero.
2. Set by using Eleprox Electrode Current Register (0x6B) and Charge Time Register (0x72).
3. Using Auto-Configuration function to automatically set charge current and charge time for this 13th Proximity Detection electrode.

It's recommended that Auto-Configuration is used for design efficiency if proximity sensing works properly in this way. Refer to Freescale application note AN3889 for details of the Auto-Configuration function.

7.0 AFE and Filter Configuration Register

The last two registers relevant to proximity detection are the AFE Configuration Register and Filter Configuration Register. These two registers set the numbers of samples for the 2 level filters and the sampling interval for the second level filter.

Table 9. Filter Configuration Registers 0x5D (Reset Default: 0x24)

0x5D	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
	CDT[2:0]			SFI[1:0]		ESI[2:0]		

Table 10. AFE Configuration Registers 0x5C (Reset Default: 0x10)

0x5C	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
	FFI[1:0]		CDC[4:0]					

The FFI[1:0], SFI[1:0] and ESI[2:0] bits in the registers are those related to the first filter, second filter and sample interval respectively. These two registers are powered up with default setting of 0x24 and 0x10 respectively. The default setting is already workable for proximity sensing, but since ESI[2:0] is 100, the sampling interval is at 16 ms. If lower power consumption is desired, the user can adjust it to the value to find a balance between the proximity detection response time current consumption. For a detailed explanation on these registers, please refer to Freescale application note AN3890.

OTHER DESIGN CONSIDERATIONS

1. Remember the paralleled plate capacitor model when considering the proximity detection. Larger sensing area (the effective sensing area formed by the sensing pad and material under detection, e.g. the surface area of hand projected to the sensing pad) gives longer proximity sensing distance.
2. The electric energy store in the capacitance (thus the strength of the sensing field) is proportional to the square of the voltage potential applied. Setting the auto-configure target level as high as possible will help extend the proximity sensing range.
3. Since increasing the sensing pad area also has the problem of making it easier to receive the electric noise. It’s possible that the original solid sensing pad can be replaced by a series of circles or x hatch patterns.

Refer to Freescale application note AN3863 for more detailed discussion on electrode and layout design considerations.

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