AN 22.13

CAP1188 Device Family Sampling and Cycle Timing

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OVERVIEW

This application note describes the capacitive sensing cycle timing and recalibration timing parameters used in the CAP1188 family of RightTouch® capacitive sensors: CAP1188, CAP1166, CAP1133, CAP1128, CAP1126, and CAP1106. The LED control timing parameters are discussed in AN21.4 CAP1188 Family LED Configuration Options.

AUDIENCE

This application note assumes that the reader is familiar with hardware design and the Microchip data sheet for the device of interest.

REFERENCES

Data Sheet for the RightTouch device of interest

NOMINAL VALUES

Nominal values are used in this document. Actual values may vary by ±20%.

DOCUMENT AND DEVICE DIFFERENCES

In this document, the CAP1188 is used to illustrate timing examples. The CAP1166, CAP1133, CAP1128, CAP1126, and CAP1106. devices have the same timing parameters; however, they vary in terms of the number of capacitive touch sensor inputs. In calculations, they can be considered the same as the CAP1188, but with some of the sensors disabled.

TABLE 1: RIGHTTOUCH DEVICE SENSOR INPUTS

Device	Number of Capacitive Sensor Inputs
CAP1188	8
CAP1166	6
CAP1133	3
CAP1128	8
CAP1126	6
CAP1106	6

SENSING CYCLE TIMING PARAMETERS

When a CAP1188 RightTouch family device is active, it automatically initiates a sensing cycle (also referred to as the polling cycle) and repeats the cycle every time it finishes. The cycle polls through each enabled capacitive touch sensor input starting with CS1. It takes the designated number of samples on the channel and averages the result by the number of samples before updating the measurement. After each sensor input is polled, its measurement is compared against a baseline “not touched” measurement. If the delta measurement is large enough, a touch is detected and an interrupt can be generated.

The time it takes to complete a sensing cycle is dependent upon the number of channels enabled, the number of samples per channel, and the sample time. The sensing cycle time is programmable: 35ms, 70ms (default), 105ms, or 140ms. If sampling can be completed in less than the programmed sensing cycle time, the device is idle (placed in a lower power state) for the remainder of the sensing cycle, after which it starts the next sensing cycle.

The parameters that affect the CAP1188 device family sensing cycle timing are shown in Table 2.

TABLE 2: SENSING CYCLE TIMING PARAMETERS

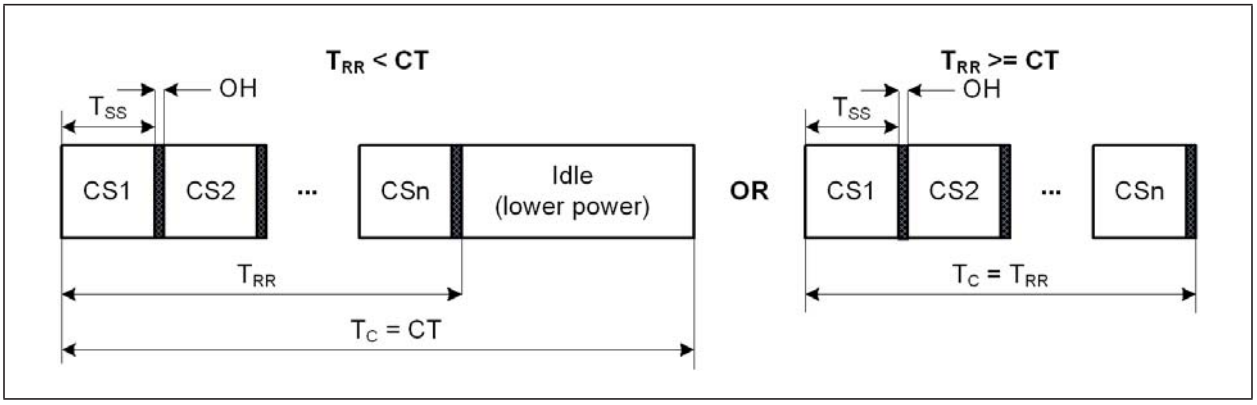
Symbol	Parameter	Description	Control	Options	Default
CSx	# of enabled sensor inputs	Number of sensor inputs enabled in Fully Active State	Sensor Input Enable Register 21h	any or all sensor inputs	all sensor inputs enabled
		Number of sensor inputs enabled in Standby State	Standby Channel Register 40h	any or all sensor inputs	no sensor inputs enabled
AVG	Sensor Input Samples	Number of consecutive samples taken for each sensor input in Fully Active state	Averaging and Sampling Config Register 24h bits 6-4, AVG[2:0]	8 choices from 1 to 128	8
		Number of consecutive samples taken for each sensor input in Standby state	Standby Configuration Register 41h bits 6-4, STBY_AVG[2:0]		
ST	Single Sample Time	Time to take a single sample in Fully Active state	Averaging and Sampling Config Register 24h bits 3-2, SAMP_TIME[1:0]	320us, 640us, 1.28ms, and 2.56ms	1.28ms
		Time to take a single sample in Standby state	Standby Configuration Register 41h bits 3-2, STBY_SAMP_TIME[1:0]		
T_{SS}	Sensor Input Sampling Time	Sampling time for each sensor input	Calculated: ST * AVG		10.24ms
OH	Overhead	Time to switch sensor inputs	Calculation: 0.55 * CSx		4.4ms (CAP1188 or CAP1128), 3.3ms (CAP1166, CAP1126, or CAP1106), 1.65ms (CAP1133)
T_{RR}	Round Robin Cycle Time	Sampling time for all enabled sensor inputs during each round robin sampling cycle.	Calculation: $T_{RR} = (T_{SS} * CSx) + OH$		86.32ms (CAP1188 or CAP1128), 64.74ms (CAP1166, CAP1126, or CAP1106), 32.34ms (CAP1133)

TABLE 2: SENSING CYCLE TIMING PARAMETERS (CONTINUED)

Symbol	Parameter	Description	Control	Options	Default
CT	Programmed Cycle Time	Programmed, desired goal for cycle time in the Fully Active state	Averaging and Sampling Config Register 24h bits 1-0, CYCLE_TIME[1:0]	35ms, 70ms, 105ms, and 140ms	70ms
		Programmed, desired goal for cycle time in the Standby state	Standby Configuration Register 41h bits 1-0, STBY_CY_TIME[1:0]		
T_C	Sensing Cycle Time	Time to complete a sensing cycle	Calculation: T_C = CT or T_{RR} (whichever is longer)		86.32ms (CAP1188 or CAP1128), 70ms (CAP1166, CAP1133, CAP1126, or CAP1106)

Figure 1 shows a graphical representation of the parameters that affect the CAP1188 device family sensing cycle timing.

FIGURE 1: *CAP1188 Device Family Sensing Cycle Time*



Additional Considerations

POWER STATES

There are three operating states for the CAP1188 device family: Fully Active, Standby, and Deep Sleep. In the Deep Sleep state, the device is not monitoring any capacitive touch sensor inputs, so sensing cycle timing is not applicable.

As noted in Table 2, "Sensing Cycle Timing Parameters", separate controls are available for the sensing cycle parameters in the Fully Active and the Standby states. To minimize power consumption in the Standby state, see Table 3.

TABLE 3: STANDBY SETTINGS FOR MINIMUM POWER CONSUMPTION

Register	Bits	Value	Description
Standby Channel Register 40h			disable unnecessary sensor inputs
Averaging and Sampling Config Register 24h	bits 6-4, AVG[2:0]	000b	set the average number of samples per channel to 1
Standby Configuration Register 41h	bits 3-2, STBY_SAMP_-TIME[1:0]	00b	set single sample time to the lowest setting of 320us
Standby Configuration Register 41h	bits 1-0, STBY_CY_-TIME[1:0]	11b	set the maximum cycle time of 140ms

SINGLE SAMPLE TIME AND COUNTS

Single sample time is the time allowed to take a single sample for a sensor input. Base count and delta count are both proportional to the single sample time. For example, changing the single sample time from 1.28ms to 2.56ms effectively doubles the number of base counts (see Table 4) as well as the number of delta counts. This is because the device is taking the sample over a period that is twice as long so it can accumulate twice as many counts.

TABLE 4: NOMINAL BASE COUNTS FOR SAMPLE TIME

Sample Time (ms)	Nominal Base Counts
2.56	25,600
1.28	12,800

Thresholds are also proportional to the single sample time. If the sample time is increased, thresholds need to be adjusted to avoid false touch detections. This is because a threshold set for sample time of 1.28ms is based on a certain number of delta counts (X) exceeding the threshold. When single sample time is increased to 2.56ms, the number of delta counts doubles (2X) and the threshold becomes too low and is easily exceeded, resulting in false detections.

PROXIMITY SENSING CYCLE TIMING PARAMETERS

When the goal is to detect proximity, the Standby state sensing cycle parameters should be used. Table 5 shows an example of proximity settings.

TABLE 5: EXAMPLE OF PROXIMITY SETTINGS

Symbol	Parameter	Description	Control	Option	Value
CSx	# of enabled sensor inputs	Number of sensor inputs enabled in Standby State	Standby Channel Register 40h	sensor input 1 enabled	01h
AVG	Sensor Input Samples	Number of consecutive samples taken for each sensor input in Standby state	Standby Configuration Register 41h bits 6-4, STBY_AVG[2:0]	32	101b
ST	Single Sample Time	Time to take a single sample in Standby state	Standby Configuration Register 41h bits 3-2, STBY_SAMP_TIME[1:0]	2.56ms	11b
T_{SS}	Sensor Input Sampling Time	Sampling time for each sensor input	Calculated: ST * AVG		81.92ms
OH	Overhead	Time to switch sensor inputs	Calculation: 0.55 * CSx		0.55ms
T_{RR}	Round Robin Cycle Time	Sampling time for all enabled sensor inputs during each round robin sampling cycle.	Calculation: $T_{RR} = (T_{SS} * CSx) + OH$		82.47ms
CT	Programmed Cycle Time	Programmed, desired goal for cycle time in the Standby state	Standby Configuration Register 41h bits 1-0, STBY_CY_TIME[1:0]	35ms	00b
T_C	Sensing Cycle Time	Time to complete a sensing cycle	Calculation: T_C = CT or T_{RR} (whichever is longer)		82.47ms

RECALIBRATION TIMING

Each sensor input is digitally recalibrated at an adjustable rate. By default, the recalibration routine stores the average 64 previous measurements and periodically updates the base count “Not Touched” setting for the capacitive touch sensor input. This routine is disabled automatically if a touch is detected so the touch does not factor into the base count setting.

Note:	Automatic recalibration only works when the delta count is below the active sensor input threshold. It is disabled when a touch is detected.

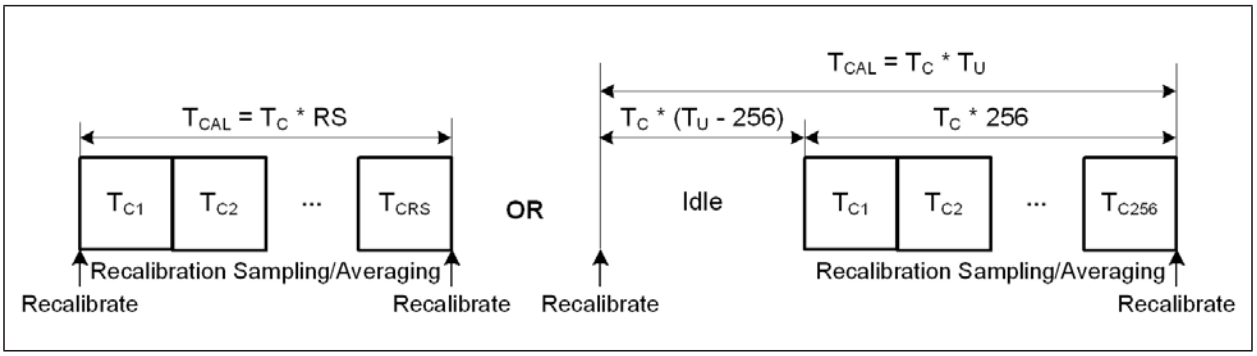
The parameters that affect the CAP1188 RightTouch family recalibration timing are shown in Table 6.

TABLE 6: RECALIBRATION TIMING PARAMETERS

Symbol	Parameter	Description	Control	Options	Default
T_C	Sensing Cycle Time	Time to complete a sensing cycle	Calculation: T_C = CT or T_{RR} (whichever is longer) (see Table 2, "Sensing Cycle Timing Parameters")		86.32ms (CAP1188 or CAP1128), 70ms (CAP1166, CAP1133, CAP1126, or CAP1106) (Fully Active State)
T_U	Update Time	Amount of time (in sensing cycle periods) that elapses before the base count is updated.	Recalibration Configuration Register 2Fh bits 2-0, CAL_CFG[2:0]	256, 1024, 2048, or 4096	N/A
RS	Recalibration Samples	Number of samples that are measured and averaged before the base count is updated		16, 32, 64, 128, or 256	64 samples
T_{CAL}	Calibration Cycle Time	Time interval between two recalibration updates	$T_{CAL} = T_C * RS$ OR $T_{CAL} = T_C * T_U$		5.52s (CAP1188 or CAP1128) 4.48s (CAP1166, CAP1133, CAP1126,or CAP1106

Table 2 shows a graphical representation of the parameters.

FIGURE 2: *Recalibration Time*



Calibration cycle time can be based on the number of recalibration samples or the update time. The values for both are stored in the same register bits: Recalibration Configuration Register 2Fh bits 2-0 CAL_CFG[2:0]. If the number of samples is less than 256, calibration cycle time equals the number of samples selected times the sensing cycle time. This method has the shorter recalibration times.

If the number of samples is 256, calibration cycle time is equal to the update time. This method results in longer recalibration times.

When the update time is greater than 256 sensing cycles, a delay is added which postpones update of the base count. This delay, or idle period, is the update time minus 256, with the result multiplied by the sensing cycle time. For example, if the sensing cycle time is the default of 86.32ms and the update time is 1024 (CAL_CFG[2:0] set to 101b), the base counts registers will be updated every 88.39s (86.32 x 1024). The recalibration routine is completed every 22.1s (86.32 x 256). The idle time will be 66.29s ((1024-256) x 86.32), which is 3/4 of the time interval between base count updates (66.29 / 88.39).

Additional Considerations

POWER STATE TRANSITIONS

The device will recalibrate all enabled sensor inputs that were disabled when it transitions from the Standby power state to Fully Active. Likewise the device will recalibrate all enabled sensor inputs when waking out of Deep Sleep or coming out of reset.

ON DEMAND RECALIBRATION

Each individual capacitive touch sensor input can be recalibrated at any time by setting the corresponding bit in the Calibration Activate Register 26h. After the register is updated, the recalibration routine will not start until the currently active sensing cycle completes. The analog recalibration takes approximately 4ms for each sensor input selected for recalibration. The digital recalibration takes 16 samples (using the single sample time) for each sensor input selected for recalibration, averages them, and then updates the base counts. Notice that the programmed number of samples is ignored. In addition, the programmed cycle time is ignored, so there's no delay if the selected sensor input can be sampled in less time than the programmed cycle time.

During on demand recalibration routine, the sensor inputs will not detect a press, and the Sensor Input Base Count Registers values will be invalid. Also during this time, any press on the corresponding sensor inputs will invalidate the recalibration. To calculate this time, use the equations in Table 7.

TABLE 7: ON DEMAND RECALIBRATION TIMING PARAMETERS

Symbol	Parameter	Description	Control	Options	Default
CSx	# of enabled sensor inputs	Number of sensor inputs enabled in Fully Active State	Sensor Input Enable Register 21h	any or all sensor inputs	all sensor inputs enabled
		Number of sensor inputs enabled in Standby State	Standby Channel Register 40h	any or all sensor inputs	no sensor inputs enabled
ANA_CAL	Analog Recalibration Time	Time to complete the analog recalibration	ANA_CAL = CSx * 4ms		32ms (CAP1188 or CAP1128) 24ms (CAP1166, CAP1126, or CAP1106), 12ms (CAP1133)
RS	Recalibration Samples	Number of samples that are measured and averaged before the base count is updated	none - this value is fixed		16 samples

TABLE 7: ON DEMAND RECALIBRATION TIMING PARAMETERS (CONTINUED)

Symbol	Parameter	Description	Control	Options	Default
ST	Single Sample Time	Time to take a single sample in Fully Active state	Averaging and Sampling Config Register 24h bits 3-2, SAMP_TIME[1:0]	320us, 640us, 1.28ms, and 2.56ms	1.28ms
		Time to take a single sample in Standby state	Standby Configuration Register 41h bits 3-2, STBY_SAMP_TIME[1:0]		
OH	Overhead	Time to switch sensor inputs	Calculation: 0.55 * CSx		4.4ms (CAP1188 or CAP1128), 3.3ms (CAP1166, CAP1126, or CAP1106), 1.65ms (CAP1133)
DIG_CAL	Digital Recalibration Time	Time to complete the digital recalibration	DIG_CAL = (CSx * RS * ST) + OH		168ms (CAP1188 or CAP1128) 126ms (CAP1166, CAP1126, or CAP1106), 63ms (CAP1133)
T_{OD_CAL}	On Demand Recalibration Time	Time to complete on demand recalibration (see Note 1)	T_{OD_CAL} = DIG_CAL + ANA_CAL		200ms (CAP1188 or CAP1128) 150ms (CAP1166, CAP1126, or CAP1106), 75ms (CAP1133)

Note 1 On demand recalibration time does not take into account the delay due to recalibration not starting until the currently active sensing cycle has completed.

NEGATIVE DELTA COUNTS RECALIBRATION

It is possible that the device loses sensitivity to a touch. This may happen as a result of a noisy environment, an accidental recalibration when the pad is touch but the delta counts do not exceed the threshold, or other environmental changes. When this occurs, the base count for a sensor input may generate negative delta count values. The NEG_DELTA_CNT[1:0] bits in the Recalibration Configuration Register 2Fh can be set to force a recalibration after a specified number (8, 16 (default), or 32 (default)) of consecutive negative delta readings.

Note: During this recalibration, the device will not respond to touches.

DELAYED RECALIBRATION

It is possible that a “stuck button” occurs when something is placed on a button which causes a touch to be detected for a long period. By setting the MAX_DUR_EN bit in the Configuration Register 20h, a recalibration can be forced when a touch is held on a button for longer than the duration specified in the MAX_DUR[3:0] bits in the Button Sensor Input Register 22h.

Note: Delayed recalibration only works when the delta count is above the active sensor input threshold. If enabled, it is invoked when a sensor pad touch is held longer than the time indicated by the MAX_DUR[3:0] setting.

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APPENDIX A: DATA SHEET REVISION HISTORY

TABLE A-1: REVISION HISTORY

Revision Level and Date	Section/Figure/Entry	Correction
REV A	REV A replaces SMSC version Rev. 1.1 (11-06-12)	
Rev. 1.1 (11-06-12)	Added Microchip logo; modified company disclaimer.	
Rev. 1.1 (05-09-11)	Sensing Cycle Timing Parameters on page 2 and Proximity Sensing Cycle Timing Parameters on page 4	Added overhead (OH). As a consequence recalibration cycle timing default for CAP1188 and CAP1128 changed from 5.24s to 5.52ms (updated in Table 6, "Recalibration Timing Parameters").
	Table 7, "On Demand Recalibration Timing Parameters"	Added overhead (OH).
Rev. 1.0 (02-03-11)	Formal document release	

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