AN 22.12

CAP1114 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 CAP1114 RightTouch® capacitive sensor. The LED control timing parameters are discussed in AN21.3 CAP1114 LED Configuration Options.

AUDIENCE

This application note assumes that the reader is familiar with hardware design and the Microchip CAP1114 data sheet.

REFERENCES

CAP1114 Data Sheet

NOMINAL VALUES

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

SENSING CYCLE TIMING PARAMETERS

When the CAP1114 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. 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 and the individual channel sampling time. The minimum sensing cycle time is 35ms. If sampling can be completed in less than 35ms, the device is idle for the remainder of the 35ms sensing cycle, after which it starts the next sensing cycle. Note that the device does not enter a lower power state when it is idle.

The parameters that affect the CAP1114 sensing cycle timing are shown in Table 1.

TABLE 1: CAP1114 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 Enable Register 21h and Grouped Sensor Channel Enable Register 41h	1-14 sensor inputs	all sensor inputs enabled
		Number of sensor inputs enabled in Sleep State	Sleep Channel Control Register 29h and Grouped Sensor Channel Enable Register 41h	1-14 sensor inputs	no sensor inputs enabled
T_{SS}	Sensor Input Sampling Time	Sampling time for each sensor input	Sampling Channel Select Register 4Eh and Sampling Configuration Register 4Fh	8 choices from 0.32ms to 40.96ms	2.5ms (see Note 1)

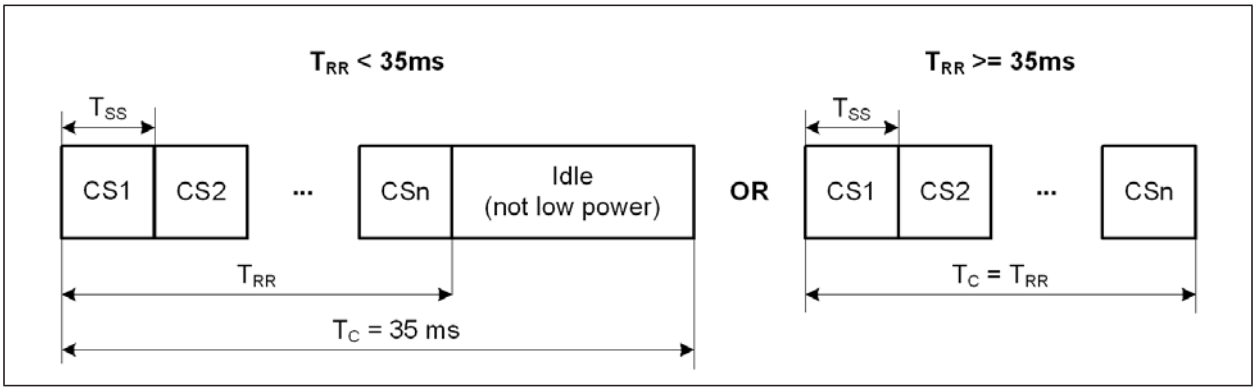
TABLE 1: CAP1114 SENSING CYCLE TIMING PARAMETERS (CONTINUED)

Symbol	Parameter	Description	Control	Options	Default
T_{RR}	Round Robin Cycle Time	Sampling time for all enabled sensor inputs during each round robin sampling cycle.	Calculation: $T_{RR} = T_{SS} * CSx$		35ms (Fully Active State)
T_C	Sensing Cycle Time	Time to complete a sensing cycle	Calculation: T_C = 35 ms or T_{RR} (whichever is longer)		35ms (Fully Active State)

Note 1 It is recommended that the default be used (see Sensor Input Sampling Time on page 2).

Figure 1 shows a graphical representation of the parameters.

FIGURE 1: *CAP1114 Sensing Cycle Time*



Additional Considerations

POWER STATES

There are four operating states for the CAP1114: Fully Active, Sleep, Inactive, and Deep Sleep. In both the Inactive and Deep Sleep states, the device is not monitoring any capacitive touch sensor inputs, so sensing cycle timing is not applicable.

For both the Fully Active and the Sleep states, the timing parameters are the same, with the exception of identifying which sensors are enabled. The Sensor Enable Register 21h determines whether the group sensor inputs and which of the individual sensor inputs are enabled in the Fully Active state. The Sleep Channel Control Register 29h determines whether the group sensor inputs and which of the individual sensor inputs are enabled in the Sleep state. If the group sensor inputs are enabled (bit 7 in register 21h or 29h), the Grouped Sensor Channel Enable Register 41h determines which of the individual group sensor inputs are enabled.

SENSOR INPUT SAMPLING TIME

Sensor input sampling time is the time allowed for sampling each sensor input.

The Sampling Channel Select Register 4Eh determines whether sensor inputs are sampled in 2.5ms (which requires 35ms if all sensor inputs are enabled) or whether they are sampled based on the Sampling Configuration Register 4Fh settings, which increases the sampling time. The default is to use the 2.5ms sampling time.

APPLICATION NOTE: It is recommended that the defaults be used. Changing the settings in registers 4Eh and 4Fh adds complexity. For example, instead of a Round Robin Cycle Time calculation of $T_{RR} = T_{SS}$ x CSx, there will be two T_{SS} values: one for the default sample time and one for the increased sample time. Each of these T_{SS} values will be multiplied by the number of sensors using that setting:
$T_{RR} = (T_{SS\_DEF} * CSx_{DEF}) + (T_{SS\_OVER\_SAMP} * CSx_{OVER\_SAMP})$.

Using the Sampling Configuration Register, sensor sampling time can be set from 0.32ms to 40.96ms. Changing the sampling time will have several effects. It affects the nominal base counts (see Table 2). If sample time is decreased, it reduces the number of delta counts for an equivalent touch, which decreases the effective sensitivity of that particular channel, so that a touch requires a larger delta C. Thresholds will need to be adjusted accordingly. Increasing sample time will increase the sensing cycle time (and all timing associated with the sensing cycle time, such as recalibration, repeat rate, and maximum duration).

TABLE 2: NOMINAL BASE COUNTS FOR SAMPLE TIME

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

TOUCH DETECTION SAMPLES

The Button Queue Control Register 1Eh determines the number of consecutive samples for which a single sensor input is above the Sensor Threshold before a touch is detected as well as when it is released. This can be set from 1 to 7 samples, with the default being 3 samples.

The time in which a touch or release can be detected is determined by this number of samples multiplied by the sensing cycle time.

PROXIMITY SENSING CYCLE TIMING PARAMETERS

There are additional sensing cycle timing parameters when the CS1 sensor input is operating in Proximity Mode, as shown in Table 3.

Note: Although additional sensors can be enabled when the CS1 input is in Proximity Mode, it is not recommended. Therefore, Table 3 only shows the sensing cycle timing parameters when CS1 is the only sensor enabled and is set to Proximity Mode.

TABLE 3: EXAMPLE OF PROXIMITY SETTINGS

Symbol	Parameter	Description	Control	Option	Value
CS_P	Proximity Mode	Enables Proximity Mode for sensor input CS1	Proximity Control Register 42h bit 7, CS1_PROX	enabled	1b
AVG	Sensor Input Samples	Number of consecutive samples taken for CS1 in Proximity Mode	Proximity Control Register 42h bits 4-3, PROX-_AVG[1:0]	16 (default), 32, 64, 128	00b (default)
ST	Single Sample Time	Sampling time for CS1 sensor input	Sampling Configuration Register 4Fh	8 choices from 0.32ms to 40.96ms	000b (2.5ms default)
T_{SS}	Sensor Input Sampling Time	Sampling time for CS1 sensor input	Calculated: ST * AVG		40.96ms
T_{RR}	Round Robin Cycle Time	Sampling time for all enabled sensor inputs (i.e. CS1) during each round robin sampling cycle.	Calculation: $T_{RR} = T_{SS} * CSx$		40.96ms
T_C	Sensing Cycle Time	Time to complete a sensing cycle	Calculation: $T_C = T_{RR}$		40.96ms

If other sensor inputs are enabled while in Proximity Mode, the sensing cycle time will increase by slightly less than the time calculated using the method above. This is because the normal sensor timing cycle calculations already include time for 1 sample. Therefore, if AVG is set to 16 for CS1 in Proximity Mode, the increase in sampling time is 16-1 times ST. Table 4 shows a comparison of the sensor timing cycle for CS1 in proximity mode only with ST set to 2.5ms and the

time that would need to be added to the calculated sensing cycle time when additional inputs are enabled. To determine the sensing cycle time for CS1 in Proximity Mode with additional sensors enabled, use the parameters in Table 1, "CAP1114 Sensing Cycle Timing Parameters" and then add the increase time.

TABLE 4: PROXIMITY MODE SENSOR TIMING CYCLE INCREASE

ST = 2.5ms		
AVG (PROX_AVG[1:0])	**Sensing Cycle Time with Only CS1 Enabled**	**Sensing Cycle Time Increase if Additional Inputs Enabled**
16	40.96ms	38.4ms
32	81.92ms	79.36ms
64	163.84ms	161.28ms
128	327.68ms	325.12ms

RECALIBRATION TIMING

Each sensor input is digitally recalibrated at an adjustable rate. By default, the recalibration routine stores the average 256 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.

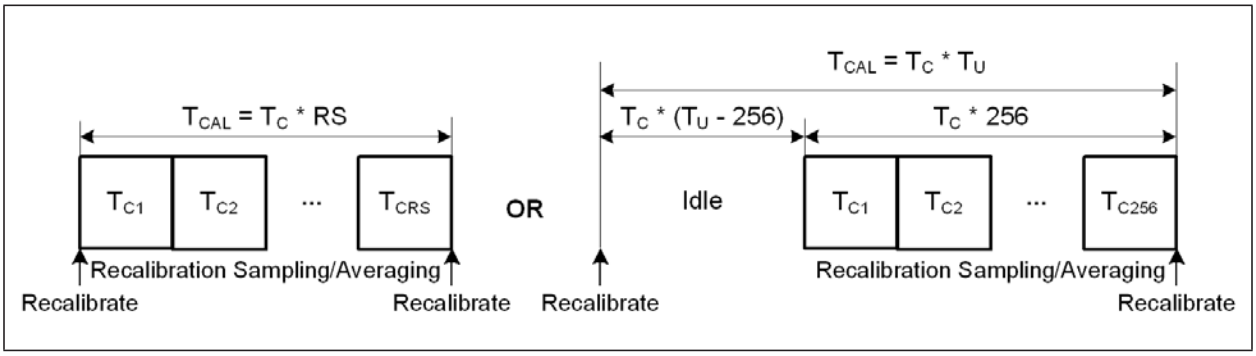
The parameters that affect the CAP1114 recalibration timing are shown in Table 5.

TABLE 5: RECALIBRATION TIMING PARAMETERS

Symbol	Parameter	Description	Control	Options	Default
T_C	Sensing Cycle Time	Time to complete a sensing cycle	Calculation: T_C = 35 ms or T_{RR} (whichever is longer) (see Table 1, "CAP1114 Sensing Cycle Timing Parameters")		35ms (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, 4096, or 7936	256 sensing cycles
RS	Recalibration Samples	Number of samples that are measured and averaged before the base count is updated		16, 32, 64, or 256	256 samples
T_{CAL}	Calibration Cycle Time	Time interval between two recalibration updates	$T_{CAL} = T_C * RS$ OR $T_{CAL} = T_C * T_U$		8.96s

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 35ms and the update time is 1024 (CAL_CFG[2:0] set to 100b), the base counts registers will be updated every 35.84s (35 x 1024). The recalibration routine is completed every 8.96s (35 x 256). The idle time will be 26.88s ((1024-256) x 35), which is 3/4 of the time interval between base count updates (26.88 / 35.84).

Additional Considerations

POWER STATE TRANSITIONS

The device will recalibrate all enabled sensor inputs that were disabled when it transitions from the Sleep 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 Registers 26h and 46h. 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 programmed sensor input sampling time) for each sensor input selected for recalibration, averages them, and then updates the base counts.

During on demand recalibration routine, the sensor inputs will not detect a press, and the Sensor 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 6.

TABLE 6: 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

TABLE 6: ON DEMAND RECALIBRATION TIMING PARAMETERS (CONTINUED)

Symbol	Parameter	Description	Control	Options	Default
ANA_CAL	Analog Recalibration Time	Time to complete the analog recalibration	ANA_CAL = CSx * 4ms		56ms
RS	Recalibration Samples	Number of samples that are measured and averaged before the base count is updated	none - this value is fixed		16 samples
T_{SS}	Sensor Input Sampling Time	Sampling time for each sensor input	Sampling Channel Select Register 4Eh and Sampling Configuration Register 4Fh	8 choices from 0.32ms to 40.96ms	2.5ms (see Note 1)
DIG_CAL	Digital Recalibration Time	Time to complete the digital recalibration	DIG_CAL = CSx * RS * T_{SS}		573ms
T_{OD_CAL}	On Demand Recalibration Time	Time to complete on demand recalibration (see Note 2)	T_{OD_CAL} = DIG_CAL + ANA_CAL		629ms

Note 2 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_B (for sensor inputs 1-7) and/or MAX_DUR_EN_G (for the group) bits 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_B[3:0] bits in the Button Configuration Register 22h (for sensor inputs 1-7) or MAX_DUR_G[3:0] bits in the Group Configuration 2 Register 24h (for the group).

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_B[3:0] setting for individual sensor inputs or MAX_DUR_G[3:0] setting for grouped sensor inputs.

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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. 1.0 (02-03-11)	Formal document release	

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