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## How To Use The Capacitive Sensing Module (CSM)

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### INTRODUCTION

This application note describes the use of the Capacitive Sensing Module (CSM) present on all PIC16F72X devices. The CSM simplifies the amount of hardware and software setup needed for capacitive sensing applications. Only the sensing pads on the PCB need to be added. It is recommended that application note AN1101, "Introduction to Capacitive Sensing" be read in order to understand the capacitive sensing concepts.

### CAPACITIVE SENSING MODULE

The CSM allows the user to design a capacitive sensing system without an external oscillator circuit.

The CSM has its own software-controlled oscillator. It can also monitor up to 16 inputs. In a typical application, the CSM is directly attached to pads on a PCB and covered by an insulating material. When the insulating material above a pad is touched by the user's fingertip, the capacitance of the pad increases, thus causing a frequency shift in the CSM. For more information on the CSM hardware, please refer to the device data sheet.

This module simplifies the software needed for capacitive sensing: it is only necessary to initialize a few registers and then set the appropriate method of measuring the change in frequency.

### MODULE INITIALIZATION

To initialize the CSM, the appropriate cap sense inputs must be initialized as analog inputs. Then, the CSM registers are set, as shown in Example 1.

### EXAMPLE 1: SETUP OF THE CAPACITIVE SENSING MODULE

```
TRISA = 0x30;
ANSELA = 0x30;           // CPS7, CPS6 initialized as analog inputs
TRISB = 0x3F;
ANSELB = 0x3F;           // CPS0-CPS5 initialized as analog inputs
TRISD = 0xFF;
ANSELD = 0xFF;           // CPS8-CPS15 initialized as analog inputs
CPSCON0 = 0x8C;          // Cap sense on, high range oscillator,
CPSCON1 = 0x00;          // Cap sense channel input 0 is selected
```

### FREQUENCY MEASUREMENT

Once these registers are set, the module will start oscillating. Now, the appropriate method of measuring the frequency needs to be set. There are several methods that can be applied:

- Use Timer0 as a timer resource for the CSM.
- Use Timer2 as a timer resource. Timer2 has a greater flexibility in defining the time base by using PR2 to set the desired time base.
- Use the WDT wake from Sleep event as the time base.

### FREQUENCY MEASUREMENT: TIMER1 GATE

All of these methods use the Timer1 gate input. Timer1 will act as a counter; it will increment at every rising edge of the Cap Sensing Module output frequency. The time base selected will start and stop the counter. The user can then read the value on Timer1, which would be a measure of the oscillator frequency. It is recommended to use Timer1 Gate in One-Shot mode to measure the full-cycle length of the chosen time base.

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The completion of the Timer1 Gate event, triggered by the chosen time base overflow, will generate a Timer1 Gate Interrupt. When servicing this interrupt, the value of TMR1 can be read to determine the oscillator frequency.

For more information on the Timer1 Gate hardware setup, please refer to the device data sheet.

## FREQUENCY MEASUREMENT: TIMER0 TIME BASE

To setup the Timer0 time base, the OPTION register as well as the interrupt flag and the enable bit need to be set accordingly during initialization. T1GSS (Timer1 Gate Source Select, T1GCON<1:0>), bits <1:0>, is set to '01' so the Timer0 overflow output becomes the Timer1 Gate Source. The setup code is shown on Example 2:

### EXAMPLE 2: TIMER0 TIME BASE SETUP

```
OPTION = 0xC3;      // fosc/4, hi-lo edge transition, 1:16 prescaler
TMR0IF = 0;        // clear TMR0 interrupt flag
TMR0IE = 1;        // enable TMR0 interrupt
T1CON  = 0xC5;     // Timer1 initialization
T1GCON = 0xE1;     // Timer1 gate init /Toggle Mode/TMR0 time base
TMR1GIF = 0;      // Clear Gate Interrupt Flag
TMR1GIE = 1;      // Enable Gate Interrupt
```

## FREQUENCY MEASUREMENT: TIMER2 TIME BASE

To setup the Timer2 time base, the T2CON register must be set with the desired prescalers. In addition, the user may want to load a value into PR2 register to

adjust the sensor scan rate. T1GSS (T1GCON <1:0>) is set to '10' so the Timer2 Match PR2 output becomes the Timer1 Gate Source. The setup code is shown on Example 3.

### EXAMPLE 3: TIMER2 TIME BASE SETUP

```
T2CON = 0x04;      // T2ON, prescaler & postscaler = 1:1
T2CON = 0x01;      // adjust prescaler
PR2   = 0xB4;      // w/pres.1:1, 0xB4 sets 125us scan rate.
TMR2IF = 0x00;
TMR2IE = 0x01;
T1CON  = 0xC5;     // Timer1 init
T1GCON = 0xE2;     // Timer1 gate init/ Toggle Mode
                // set T1GSS for Timer2 match PR2
TMR1GIF = 0;      // Clear Gate Interrupt Flag
TMR1GIE = 1;      // Enable Gate Interrupt
```

## FREQUENCY MEASUREMENT: WDT TIME BASE

To set up the Watchdog Timer (WDT) as the time base, one has to set T1GSS (T1GCON <1:0>) to '11' and set TMR1GE. A Timer1 Gate Interrupt will be generated every time the Watchdog Timer overflows. The Timer1 Gate Interrupt will be generated even with WDT disabled in the Configuration Word. The PSA bit in the OPTION register may be set to select the prescaler for the WDT.

**EXAMPLE 4: WATCHDOG TIMER TIME BASE SETUP**

```

OPTION = 0xCB;           // Prescaler assigned to WDT
T1CON  = 0xC5;           // Timer1 init
T1GCON = 0xE3;           // Timer1 Gate Enabled / WDT time base
TMR1GIF = 0;             // clear gate Interrupt flag
TMR1GIE = 1;             // enable gate interrupt

```

**WDT TIME BASE DURING SLEEP**

The CSM is able to continue oscillating during Sleep mode. While in Sleep mode, if the Timer1 Gate is active, Timer1 will continue to count until Watchdog Timer (WDT) overflows and wakes the device.

**EXAMPLE 5: WATCHDOG TIMER TIME DURING SLEEP MODE**

```

CLRWDT();               // Reset Watchdog
SLEEP();                 // Enter Sleep mode
                        // The first wakeup Gate is enabled and timer1 will
                        // start counting.

SLEEP();                 // Second wakeup, Gate is disabled, and timer1 gate
                        // will interrupt.

```

This mode is useful in applications where putting the device in Sleep mode to conserve power is desired. The designer can set the Capacitive Module Oscillator in low setting for low-power consumption during Sleep. Once the unit wakes from Sleep and detects a change in capacitance, due to a finger or hand in close proximity to the sensor, then the program can be set to another time base to detect the actual button pressed and perform the desired function.

**ISR: SETTING THE NEXT INPUT**

Once the interrupt has been serviced and the frequency value read, the next sensor to be tested should be set. This is easily done by incrementing the value of index and setting this new value into CPSCON1<3:0>, as illustrated in Example 6 below:

**EXAMPLE 6: SETTING THE NEXT INPUT CHANNEL**

```

index = (++index) & 0x0F;
CPSCON1 = index;

```

This is to be done if the 16 inputs are being read sequentially. Otherwise, or for other multi-input configurations, the appropriate input value must be loaded into CPSCON1. Please refer to AN1104, “Capacitive Multi-Button Configurations”, for more information on this topic.

**ISR: RESTART TIMERS**

When using the CSM, Timer1 needs to be reset at the end of ISR. This will clear the TMR1 value and restart the timer (see Example 7).

**EXAMPLE 7: RESTARTING THE TIMERS**

```

TMR1ON = 0;             // Stop Timer1
TMR1L  = 0x00;          // Reset Timer1
TMR1H  = 0x00;
TMR1ON = 1;             // Restart Timer1

```

**SCAN RATE**

When using the CSM, the designer has a choice on what scan rate to use. It will be based on the time base used. For example, if Timer0 is used, then the scan rate for a single button will be defined by:

**EQUATION 1:**

$$T_{scan} = 256 \times (4 \times T_{osc}) \times PS$$

If Timer2 is used, then the scan rate is:

**EQUATION 2:**

$$T_{scan} = PR2 \times (4 \times T_{osc}) \times PS$$

It becomes apparent that Timer2 offers a greater flexibility in the scan rate based on the value placed in PR2 and the pre- and postscaler values.

If WDT is used, then the scan rate will depend on what the watchdog postscaler is set to.

The scan rate needs to be considered when scanning multiple inputs. For example, when running the internal oscillator of the device at 8 MHz and scanning 16 buttons, the TMR0 overflows every 128 us and TMR1GIF every 256 us. This translates to a total scan time of 4.9 msec. All values are nominal times.

## OSCILLATOR FREQUENCY

In addition to the scan rate, the capacitive sensing circuit oscillator frequency must be considered. The Oscillator offers the option of high, medium and low oscillating frequencies based on the current source/sink levels. The designer must decide the appropriate frequency based on the time base to be used and the desired sensitivity to the sensor.

## BUTTON DETECTION ALGORITHMS

There are several button detection algorithms to consider:

- Explicit Trip, Fixed Hysteresis
- Percentage Trip
- Percentage One at a Time, Always Average.

For further information on these algorithms, please read AN1103 “*Software Handling for Capacitive Sensing.*”

## CONCLUSIONS

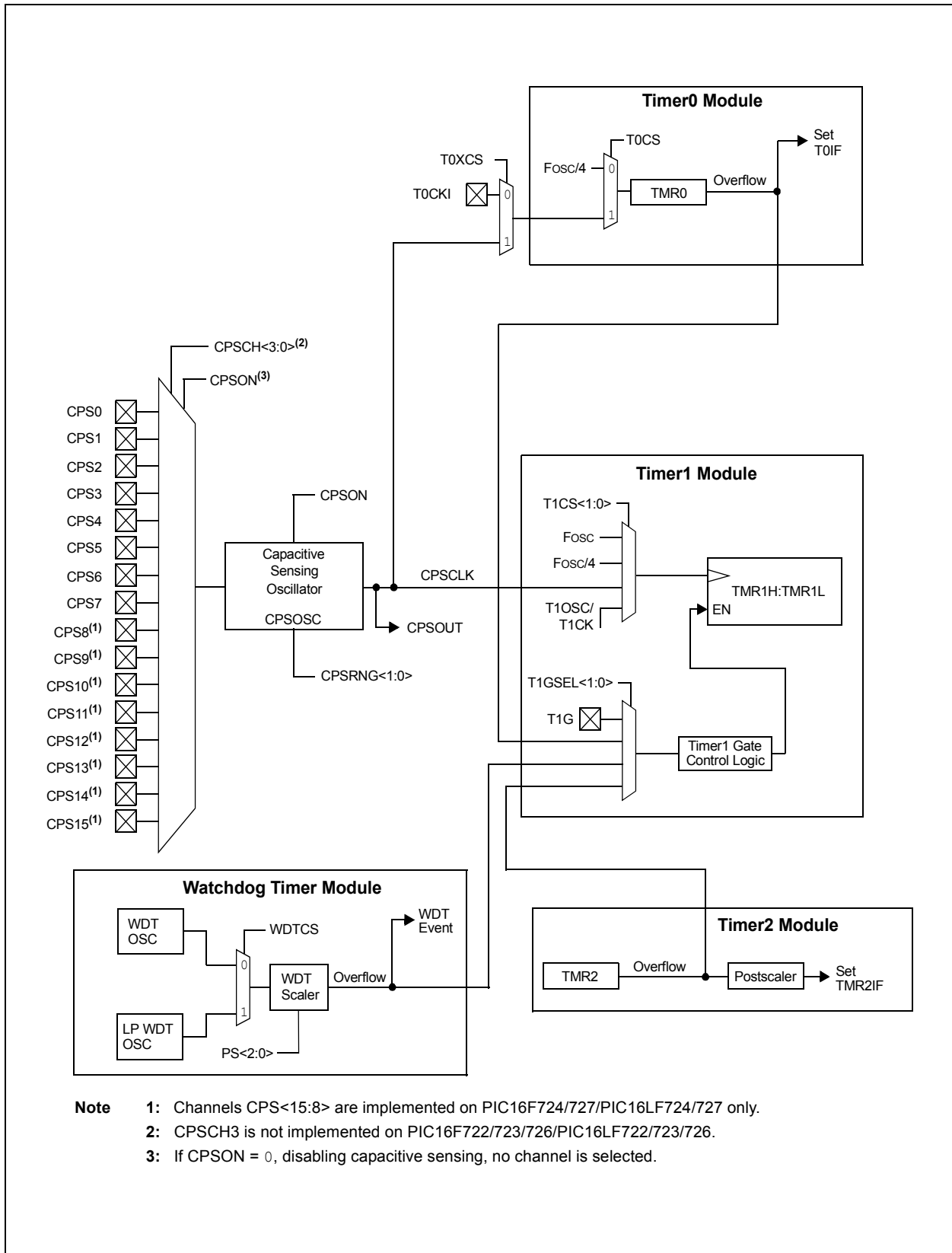
This application note has demonstrated the configuration and use of the CSM. Three time base solutions have been discussed. Usage of the Timer1 Gate has been shown to provide a powerful tool for the CSM oscillator frequency measurement. Another practical feature is the use of the WDT to wake up from Sleep mode and trigger the Timer1 Gate. This feature is useful in applications where power conservation is a concern.

The software provided with this application note gives the user a guideline on how to implement and use the capacitive sensor module. It will give users a starting point in which to develop their own capacitive sensing applications.

## REFERENCES

- AN1101 – “*Introduction to Capacitive Sensing*” (DS01101)
- AN1102 – “*Layout and Physical Design Guidelines for Capacitive Sensing*” (DS01102)
- AN1103 – “*Software Handling for Capacitive Sensing*” (DS01103)
- AN1104 – “*Capacitive Multi-Button Configurations*” (DS01104)

## APPENDIX A: CAPACITIVE SENSING BLOCK DIAGRAM



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NOTES:

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