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CCP Module

Dpt. Enginyeria de Sistemes, Automàtica i Informàtica Industrial

The PIC18 CCP units

- A PIC18 device may have one, two, or **five (K22)** CCP modules.
- CCP stands for **Capture**, **Compare**, and **Pulse Width Modulation**.
- Each CCP module can be configured to perform capture, compare, or PWM function.
- In **capture** operation, the CCP module copy the contents of a 16 bit timer into a capture register on a signal edge.
- In **compare** operation, the CCP module compares the contents of a CCPR register with that of a Timer (1, 3 or 5) in every clock cycle. When these two registers are equal, the associated pin may be pulled to high, or low, or toggled.
- In **PWM** mode, the CCP module can be configured to generate a waveform with certain frequency and duty cycle. Timers 2/4/6 are related with the PWM hardware.

Capture/Compare/PWM (CCP) Modules

- PIC18F45K22 has 5 CCP Modules.
- Each CCP module requires the use of timer resource.
- In capture or compare mode, the CCP module may use either Timer1, Timer3 or Timer5 to operate.
- In PWM mode, either Timer2, Timer4 or Timer6 may be used.
- The operation of a CCP module is controlled by the CCPxCON register (to select the mode), the CCPTMRS0 and CCPTMRS1 registers (to select the operating timer) and the 16-bits data register CCPRx (CCPRxH and CCPRxL).
- A device pin (CCPx pin) can be associated to CCP module operation (with appropriate TRIS configuration).

CCPxCON Register

14.5 Register Definitions: ECCP Control

REGISTER 14-1: CCPxCON: STANDARD CCPx CONTROL REGISTER

U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	—	DCxB<1:0>		CCPxM<3:0>			
bit 7							bit 0

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
u = Bit is unchanged	x = Bit is unknown	-n/n = Value at POR and BOR/Value at all other Reset
'1' = Bit is set	'0' = Bit is cleared	

bit 7-6 **Unused**

bit 5-4 **DCxB<1:0>:** PWM Duty Cycle Least Significant bits

Capture mode:
Unused

Compare mode:
Unused

PWM mode:
These bits are the two LSbs of the PWM duty cycle. The eight MSbs are found in CCPRxL.

bit 3-0 **CCPxM<3:0>:** ECCPx Mode Select bits

0000 = Capture/Compare/PWM off (resets the module)
0001 = Reserved
0010 = Compare mode: toggle output on match
0011 = Reserved

0100 = Capture mode: every falling edge
0101 = Capture mode: every rising edge
0110 = Capture mode: every 4th rising edge
0111 = Capture mode: every 16th rising edge

1000 = Compare mode: set output on compare match (CCPx pin is set, CCPxIF is set)
1001 = Compare mode: clear output on compare match (CCPx pin is cleared, CCPxIF is set)
1010 = Compare mode: generate software interrupt on compare match (CCPx pin is unaffected, CCPxIF is set)
1011 = Compare mode: Special Event Trigger (CCPx pin is unaffected, CCPxIF is set)
TimerX (selected by CxTSEL bits) is reset
ADON is set, starting A/D conversion if A/D module is enabled(1)
11xx =: PWM mode

Note 1: This feature is available on CCP5 only.

CCPTMRS0/1 (Timer select) Register

REGISTER 14-3: CCPTMRS0: PWM TIMER SELECTION CONTROL REGISTER 0

R/W-0	R/W-0	U-0	R/W-0	R/W-0	U-0	R/W-0	R/W-0
C3TSEL<1:0>		—	C2TSEL<1:0>		—	C1TSEL<1:0>	
bit 7							bit 0

bit 7-6 **C3TSEL<1:0>:** CCP3 Timer Selection bits
00 = CCP3 – Capture/Compare modes use Timer1, PWM modes use Timer2
01 = CCP3 – Capture/Compare modes use Timer3, PWM modes use Timer4
10 = CCP3 – Capture/Compare modes use Timer5, PWM modes use Timer6
11 = Reserved

bit 5 **Unused**

bit 4-3 **C2TSEL<1:0>:** CCP2 Timer Selection bits
00 = CCP2 – Capture/Compare modes use Timer1, PWM modes use Timer2
01 = CCP2 – Capture/Compare modes use Timer3, PWM modes use Timer4
10 = CCP2 – Capture/Compare modes use Timer5, PWM modes use Timer6
11 = Reserved

bit 2 **Unused**

bit 1-0 **C1TSEL<1:0>:** CCP1 Timer Selection bits
00 = CCP1 – Capture/Compare modes use Timer1, PWM modes use Timer2
01 = CCP1 – Capture/Compare modes use Timer3, PWM modes use Timer4
10 = CCP1 – Capture/Compare modes use Timer5, PWM modes use Timer6
11 = Reserved

REGISTER 14-4: CCPTMRS1: PWM TIMER SELECTION CONTROL REGISTER 1

U-0	U-0	U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0
—	—	—	—	C5TSEL<1:0>		C4TSEL<1:0>	
bit 7							bit 0

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
u = Bit is unchanged	x = Bit is unknown	-n/n = Value at POR and BOR/Value at all other Resets
'1' = Bit is set	'0' = Bit is cleared	

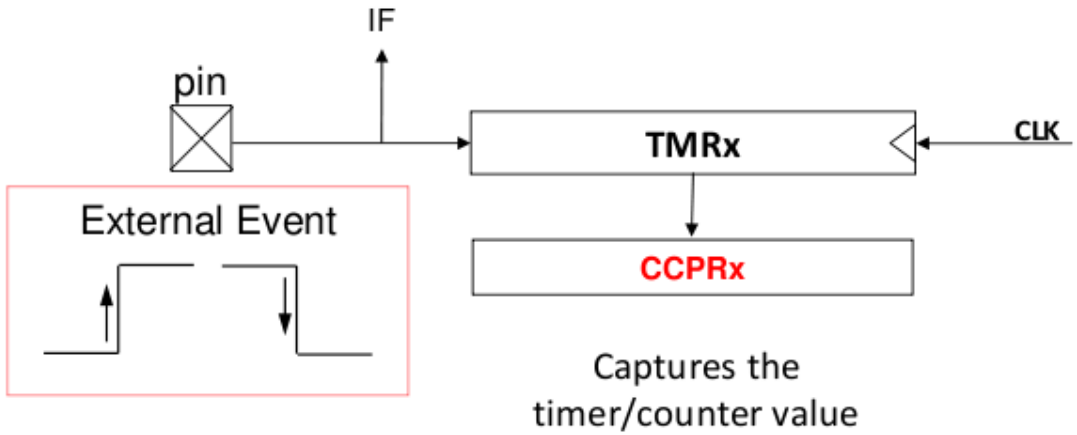
bit 7-4 **Unimplemented:** Read as '0'

bit 3-2 **C5TSEL<1:0>:** CCP5 Timer Selection bits
00 = CCP5 – Capture/Compare modes use Timer1, PWM modes use Timer2
01 = CCP5 – Capture/Compare modes use Timer3, PWM modes use Timer4
10 = CCP5 – Capture/Compare modes use Timer5, PWM modes use Timer6
11 = Reserved

bit 1-0 **C4TSEL<1:0>:** CCP4 Timer Selection bits
00 = CCP4 – Capture/Compare modes use Timer1, PWM modes use Timer2
01 = CCP4 – Capture/Compare modes use Timer3, PWM modes use Timer4
10 = CCP4 – Capture/Compare modes use Timer5, PWM modes use Timer6
11 = Reserved

Capture Function

Capture Function



Gives a reference on the instant in which the event takes place
(Application: measure the period of a given signal)

Capture Mode

- Main use of CCP is to capture **event** arrival time

- An event is represented by a signal edge.

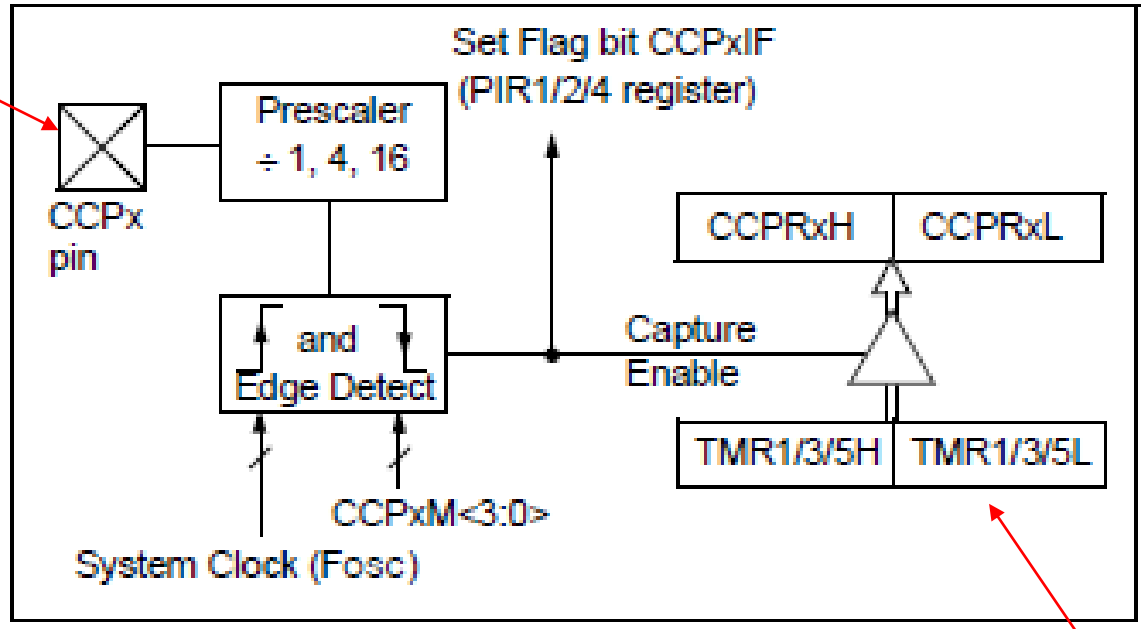
The PIC18 event can be one of the following:

1. every falling edge
2. every rising edge
3. every 4th rising edge
4. every 16th rising edge

Capture Unit

FIGURE 14-1: CAPTURE MODE OPERATION BLOCK DIAGRAM

CCPx Pin must be configured as an Input

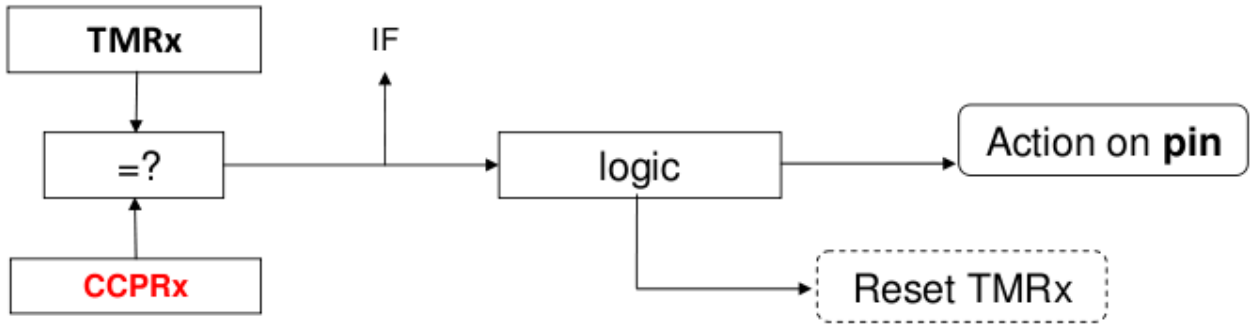


TimerX must be active and configured (prescaler, CLK source) properly.

The five capture units operate independently

Compare Function

Compare Function



Generates equally spaced time intervals
(Application: Delays, Pulse Trains)

Compare Mode

- 16-bit CCPRx register is compared against one of the Timers(1/3/5).

- When they match, one of the following actions may occur on the associated CCPx pin:

1. driven high
2. driven low
3. toggle output
4. remains unchanged

Software Interrupt Mode

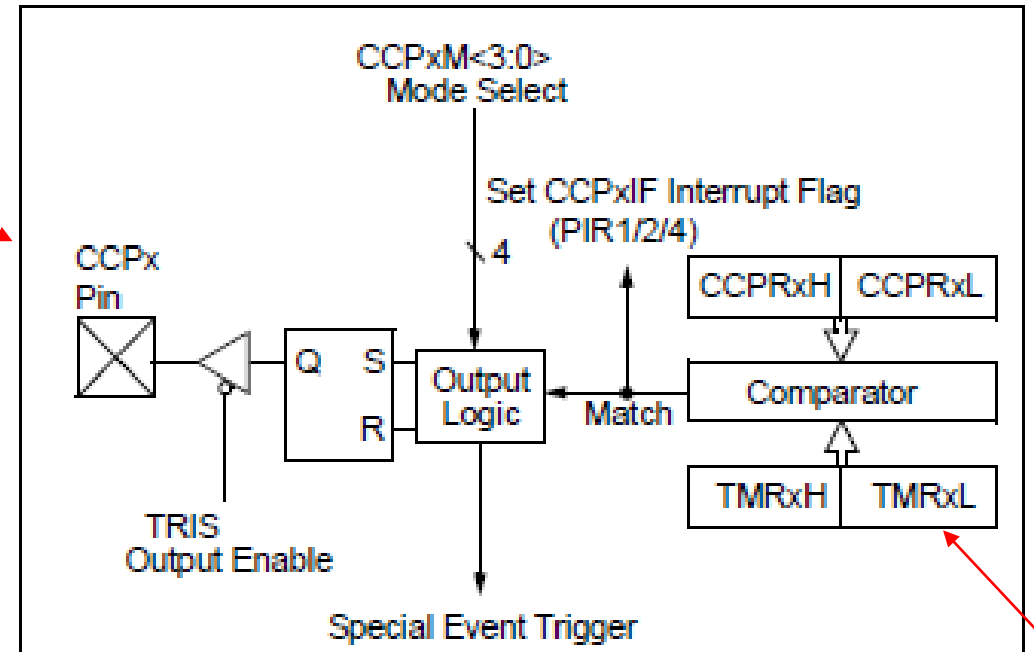
When Generate Software Interrupt mode is chosen (1010), the CCPx module does not assert control of the CCPx pin.

Special Event Trigger

The CCPx modules can also generate this event (mode 1011) to reset TMR1/3/5 depending on which timer is the base timer. When this mode is selected CCP5 will start an ADC conversion, if the ADC is enabled.

Compare Unit

FIGURE 14-2: COMPARE MODE OPERATION BLOCK DIAGRAM



Special Event Trigger function on

- ECCP1, ECCP2, ECCP3, CCP4 and CCP5 will:
  - Reset TimerX – TMRxH:TMRxL = 0x0000
  - TimerX Interrupt Flag, (TMRxIF) is not set

Additional Function on

- CCP5 will
  - Set ADCON0<1>, GO/$\overline{\text{DONE}}$ bit to start an ADC Conversion if ADCON<0>, ADON = 1.

CCPx Pin must be configured as an Output

TimerX must be active and configured (prescaler, CLK source) properly.

Example: use CCP Compare to Generate Sound

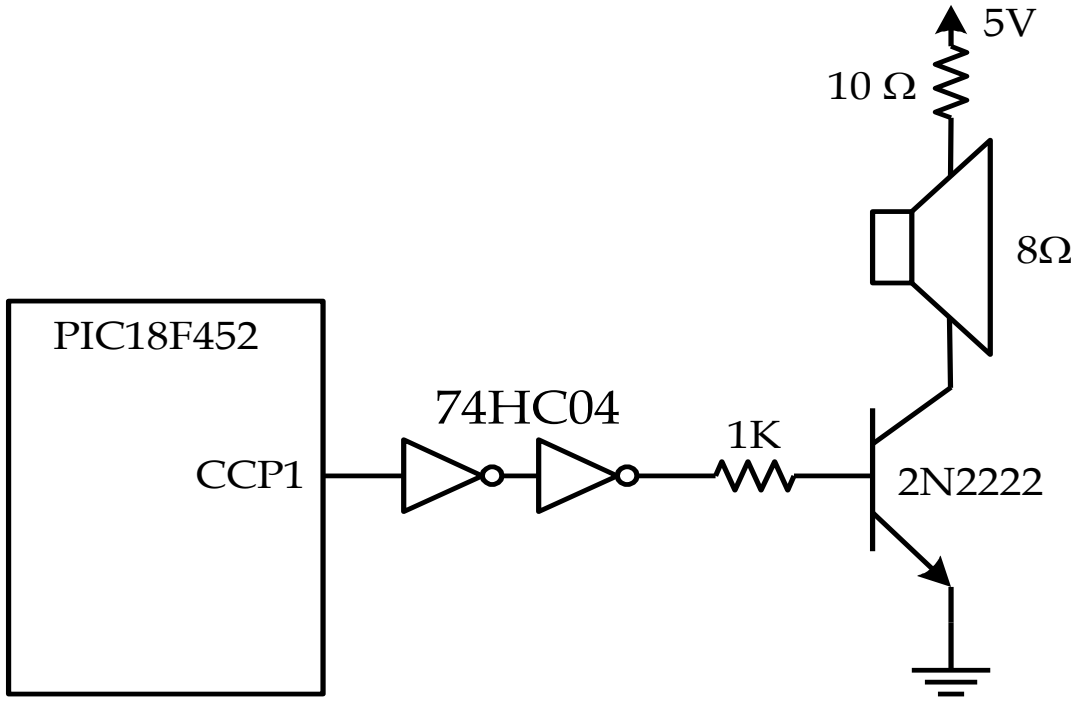


Figure 8.22 Circuit connection for siren generation

Pitch table

	Frequency (Hz)							
Note	Octave 0	Octave 1	Octave 2	Octave 3	**Octave 4**	Octave 5	Octave 6	Octave 7
C	16.351	32.703	65.406	130.813	**261.626**	523.251	1046.502	2093.005
C#,Db	17.324	34.646	69.296	138.591	**277.183**	554.365	1100.731	2217.461
D	18.354	36.708	73.416	146.832	**293.665**	587.330	1174.659	2349.318
D#,Eb	19.445	38.891	77.782	155.563	**311.127**	622.254	1244.508	2489.016
E	20.061	41.203	82.407	164.814	**329.626**	659.255	1318.510	2367.021
F	21.827	43.654	87.307	174.614	**349.228**	698.456	1396.913	2637.021
F#,Gb	23.124	46.249	92.449	184.997	**369.994**	739.989	1474.978	2959.955
G	24.499	48.999	97.999	195.998	**391.995**	783.991	1567.982	3135.964
G#,Ab	25.956	51.913	103.826	207.652	**415.305**	830.609	1661.219	3322.438
A	**27.500**	**55.000**	**110.000**	**220.000**	**440.000**	**880.000**	**1760.000**	**3520.000**
A#,Bb	29.135	58.270	116.541	233.082	**466.164**	932.326	1664.655	3729.310
B	30.868	61.735	123.471	246.942	**493.883**	987.767	1975.533	3951.066

Example code:

For the circuit in Figure 8.22, write a program to generate a simple song assuming that f_{OSC} = 4MHz.

Solution:

Two tables are used by the program. 1) Table of numbers to be added to CCPR1 register to generate the waveform with the desired frequency. 2) Table of numbers that select the duration of each note. CCP1 module is used to generate te signal -compare mode toggle CCP1 pin on match-. TIMER0 is used for note duration.

Example XC8

```
#include   <xc.h>
#define    base       3125  // counter count to create 0.1 s delay
#define    NOTES      38    // total notes in the song to be played

#define    C4         0x777 // semioperiod
#define    F4         0x598 // for each
#define    G4         0x4FC // note freq
#define    A4         0x470
#define    B4         0x3F4
#define    C5         0x3BC
#define    D5         0x353
#define    F5         0x2CC

unsigned int half_cycle;

const unsigned int per_arr[38]={ C4,A4,G4,A4,F4,C4,C4,C5,
                                 B4,C5,A4,A4,F4,D5,D5,D5,
                                 C5,A4,C5,C5,B4,A4,B4,C5,
                                 A4,F4,D5,F5,D5,C5,A4,C5,
                                 C5,B4,A4,B4,C5,A4};

const unsigned char wait[38] = { 3,5,3,3,5,3,3,5,
                                 3,3,5,3,3,5,3,3,
                                 5,3,3,3,2,2,3,3,
                                 6,3,5,3,3,5,3,3,
                                 3,2,2,3,3,6};
```

```
void  delay (unsigned char xc);

void interrupt high_ISR(void)
{
        if (PIE1bits.CCP1IE && PIR1bits.CCP1IF) {
                PIR1bits.CCP1IF = 0;
                CCPR1 += half_cycle;
        }
}


void interrupt low_priority low_ISR (void)
{
}
```

```
void main (void)
{    int i, j;

     TRISCbits.TRISC2 = 0;   /* configure CCP1 pin for output */
     T3CON = 0x81;   /* enables Timer3 in 16-bit mode, Timer1  for CCP1 time base */
     T1CON = 0x81;   /* enable Timer1 in 16-bit mode */
     CCP1CON = 0x02;   /* CCP1 compare mode, pin toggle on match */
     IPR1bits.CCP1IP = 1;   /* set CCP1 interrupt to high priority */
     PIR1bits.CCP1IF = 0;   /* clear CCP1IF flag */
     PIE1bits.CCP1IE = 1;   /* enable CCP1 interrupt */
     INTCON |= 0xC0;       /* enable high priority interrupt */

     for (j = 0; j < 3; j++) {     /* Play song several times */
          i = 0;
          half_cycle = per_arr[0];
          CCPR1 = TMR1 + half_cycle;
          while (i < NOTES) {
               half_cycle = per_arr[i];   /* get the cycle count for half period of the note */
               delay (wait[i]);           /* stay for the duration of the note */
               i++;
          }
          INTCON &= 0x3F;   /* disable interrupt */
          delay (11);               /* Pause before replay song */
          INTCON |= 0xC0;    /* re-enable interrupt */
     }
}
```

```
/* The following function runs on a PIC18 demo board running with a 4 MHz crystal  */
/* oscillator. The parameter xc specifies the amount of delay to be created        */
/* ------------------------------------------------------------------------------*/
void delay (unsigned char xc)
{
        switch (xc){
                case 1:         /* create 0.1 second delay (sixteenth note) */
                        T0CON = 0x84; /* enable TMR0 with prescaler set to 32 */
                        TMR0 = 0xFFFF - base; /* set TMR0 to this value so it overflows in 0.1 second */
                        INTCONbits.TMR0IF = 0;
                        while (!INTCONbits.TMR0IF);
                        break;
                case 2:         /* create 0.2 second delay (eighth note) */
                        T0CON = 0x84; /* set prescaler to Timer0 to 32 */
                        TMR0 = 0xFFFF - 2*base; /* set TMR0 to this value so it overflows in 0.2 second */
                        INTCONbits.TMR0IF = 0;
                        while (!INTCONbits.TMR0IF);
                        break;
                case 3:         /* create 0.4 seconds delay (quarter note) */
                        T0CON = 0x84; /* set prescaler to Timer0 to 32 */
                        TMR0 = 0xFFFF - 4*base; /* set TMR0 to this value so it overflows in 0.4 second */
                        INTCONbits.TMR0IF = 0;
                        while (!INTCONbits.TMR0IF);
                        break;
```

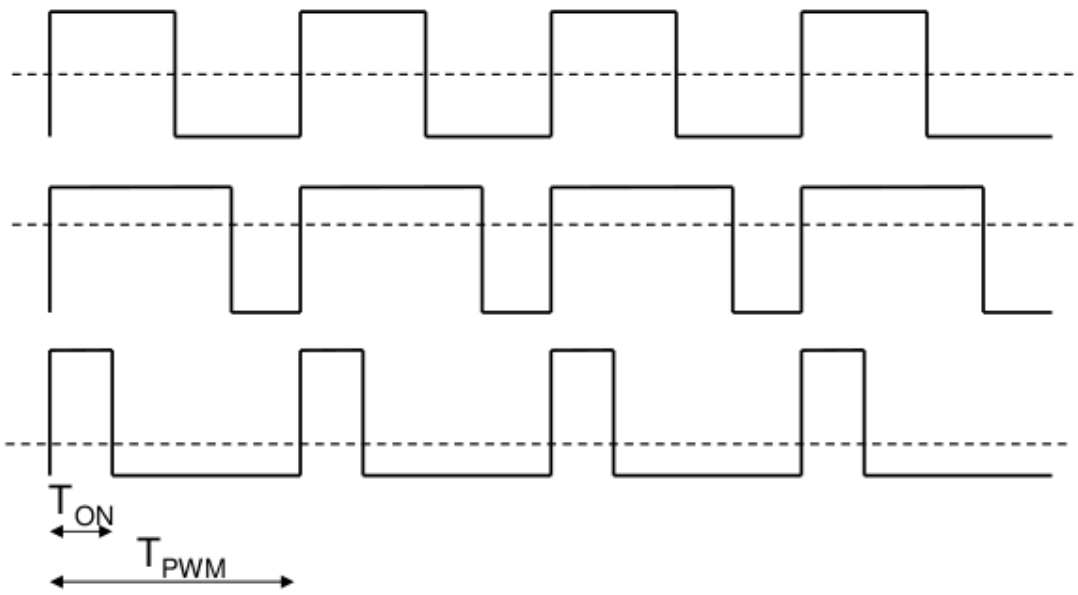
```
            case 4:         /* create 0.6 s delay (3 eighths note) */
                T0CON = 0x84; /* set prescaler to Timer0 to 32 */
                TMR0 = 0xFFFF - 6*base; /* set TMR0 to this value so it overflows in 0.6 second */
                INTCONbits.TMR0IF = 0;
                while (!INTCONbits.TMR0IF);
                break;
            case 5:         /* create 1.2 second delay (3 quarter note) */
                T0CON = 0x84; /* set prescaler to Timer0 to 32 */
                TMR0 = 0xFFFF - 12*base; /* set TMR0 to this value so it overflows in 1.2 second */
                INTCONbits.TMR0IF = 0;
                while (!INTCONbits.TMR0IF);
                break;
            case 6:         /* create 1.6 second delay (full note) */
                T0CON = 0x84; /* set prescaler to Timer0 to 32 */
                TMR0 = 0xFFFF - 16*base; /* set TMR0 to this value so it overflows in 1.6 second */
                INTCONbits.TMR0IF = 0;
                while (!INTCONbits.TMR0IF);
                break;

            default:
            break;
        }
}
```

PWM function

Pulse Width Modulation (PWM) Function

Generates (automatically) a PWM signal



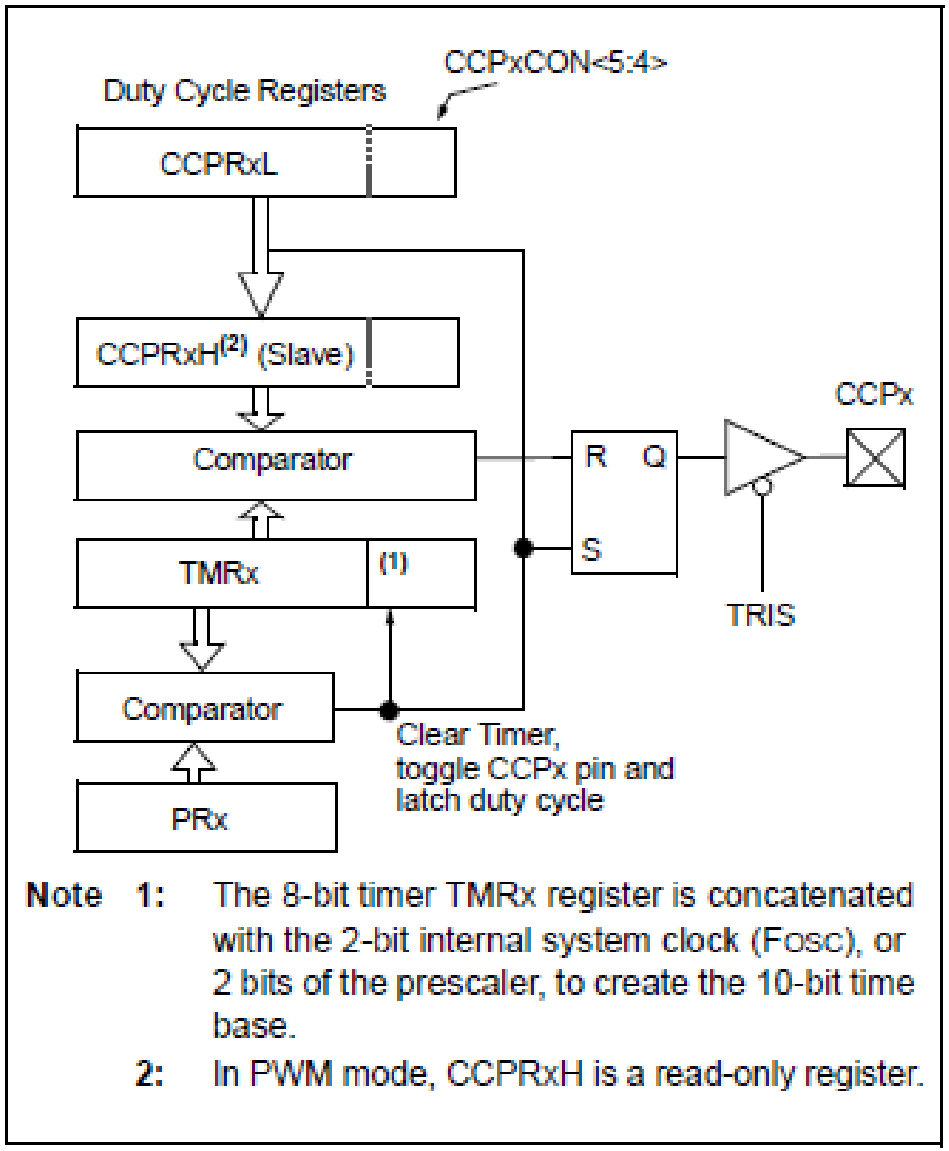
Period = T_{PWM}

Frecuency, $F_{PWM} = 1/ T_{PWM}$

Duty Cycle = $(T_{ON} / T_{PWM}) \times 100$

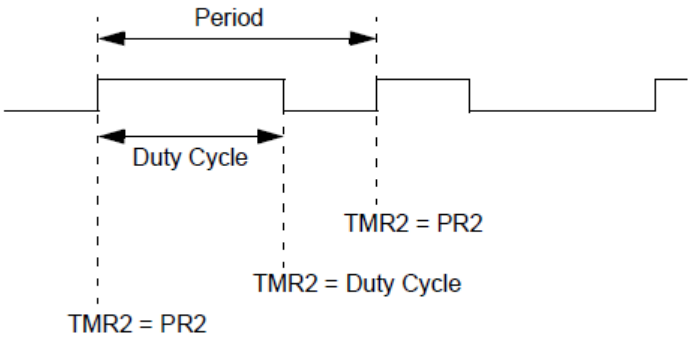
PWM Mode

FIGURE 14-4: SIMPLIFIED PWM BLOCK DIAGRAM



Note 1: The 8-bit timer TMRx register is concatenated with the 2-bit internal system clock (FOSC), or 2 bits of the prescaler, to create the 10-bit time base.

2: In PWM mode, CCPRxH is a read-only register.



Period & Duty cycle

Pwm formulas:

EQUATION 14-1: PWM PERIOD

$$PWM\ Period = [(PRx) + 1] \bullet 4 \bullet Tosc \bullet (TMRx\ Prescale\ Value)$$

Note 1: Tosc = 1/Fosc

EQUATION 14-2: PULSE WIDTH

$$Pulse\ Width = (CCPRxL:CCPxCON<5:4>) \bullet Tosc \bullet (TMRx\ Prescale\ Value)$$

EQUATION 14-4: PWM RESOLUTION

$$Resolution = \frac{\log[4(PRx + 1)]}{\log(2)}\ bits$$

EQUATION 14-3: DUTY CYCLE RATIO

$$Duty\ Cycle\ Ratio = \frac{(CCPRxL:CCPxCON<5:4>)}{4(PRx + 1)}$$

TABLE 14-7: EXAMPLE PWM FREQUENCIES AND RESOLUTIONS (FOSC = 32 MHz)

PWM Frequency	1.95 kHz	7.81 kHz	31.25 kHz	125 kHz	250 kHz	333.3 kHz
Timer Prescale (1, 4, 16)	16	4	1	1	1	1
PRx Value	0xFF	0xFF	0xFF	0x3F	0x1F	0x17
Maximum Resolution (bits)	10	10	10	8	7	6.6

TABLE 14-8: EXAMPLE PWM FREQUENCIES AND RESOLUTIONS (FOSC = 20 MHz)

PWM Frequency	1.22 kHz	4.88 kHz	19.53 kHz	78.12 kHz	156.3 kHz	208.3 kHz
Timer Prescale (1, 4, 16)	16	4	1	1	1	1
PRx Value	0xFF	0xFF	0xFF	0x3F	0x1F	0x17
Maximum Resolution (bits)	10	10	10	8	7	6.6

TABLE 14-9: EXAMPLE PWM FREQUENCIES AND RESOLUTIONS (FOSC = 8 MHz)

PWM Frequency	1.22 kHz	4.90 kHz	19.61 kHz	76.92 kHz	153.85 kHz	200.0 kHz
Timer Prescale (1, 4, 16)	16	4	1	1	1	1
PRx Value	0x65	0x65	0x65	0x19	0x0C	0x09
Maximum Resolution (bits)	8	8	8	6	5	5

Programming recipe.

1. Disable the CCPx pin output driver by setting the associated TRIS bit.
2. Select the 8-bit TimerX resource, (Timer2, Timer4 or Timer6) to be used for PWM generation by setting the CxTSEL<1:0> bits in the CCPTMRSx register.(1)
3. Load the PRx register for the selected TimerX with the PWM period value.
4. Configure the CCP module for the PWM mode by loading the CCPxCON register with appropriate values.
5. Load the CCPRxL register and the DCxB<1:0> bits of the CCPxCON register, with the PWM duty cycle value.
6. Configure and start the 8-bit TimerX resource:
   - Clear the TMRxIF interrupt flag bit of the PIR2 or PIR4 register.
   - Configure the TxCKPS bits of the TxCON register with the Timer prescale value.
   - Enable the Timer by setting the TMRxON bit of the TxCON register.
7. Enable PWM output pin:
   - Wait until the Timer overflows and the TMRxIF bit of the PIR2 or PIR4 register is set.
   - Enable the CCPx pin output driver by clearing the associated TRIS bit.

Light dimmer

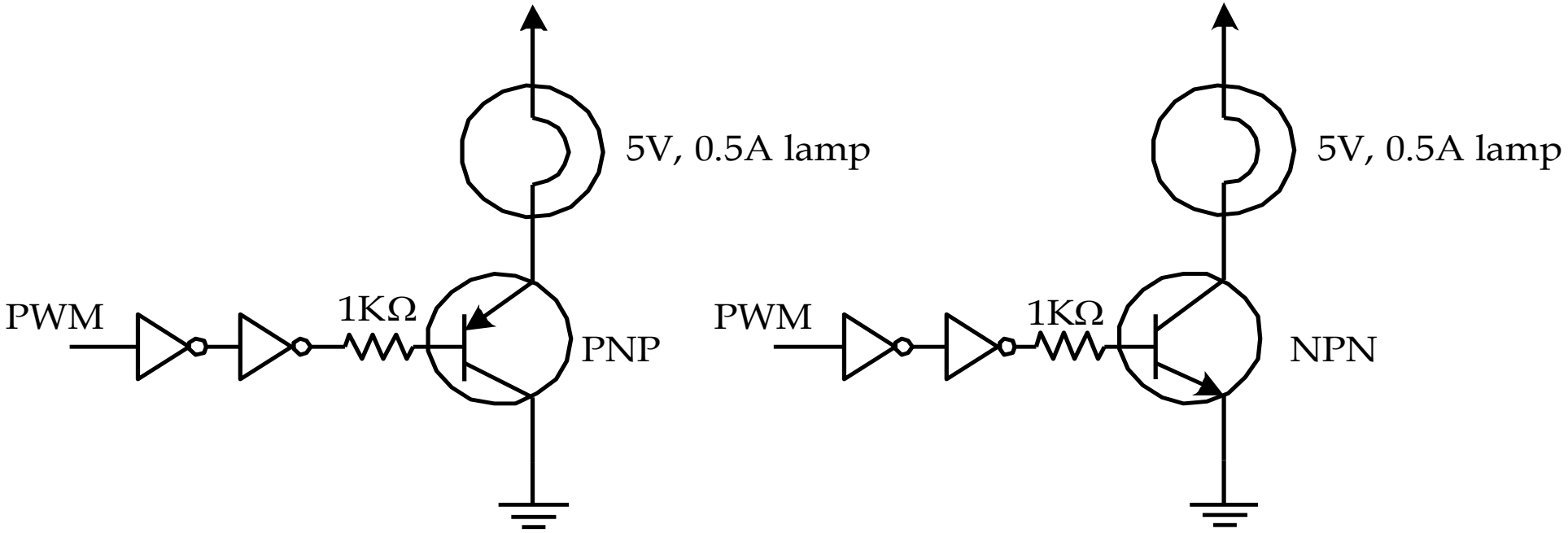


Figure 8.25 Using PWM to control the brightness of a light bulb

DC Motor Control

- DC motor speed is regulated by controlling its average driving voltage. The higher the voltage, the faster the motor rotates.
- Changing motor direction can be achieved by reversing the driving voltage.
- Motor braking can be performed by reversing the driving voltage for certain length of time.
- Most PIC18 devices have PWM functions that can be used to drive DC motors.
- Many DC motors operate with 5 V supply.
- DC motors require large amount of current to operate. Special driver circuits are needed for this purpose.
- A simplified DC motor control circuit is shown in Figure 8.26.

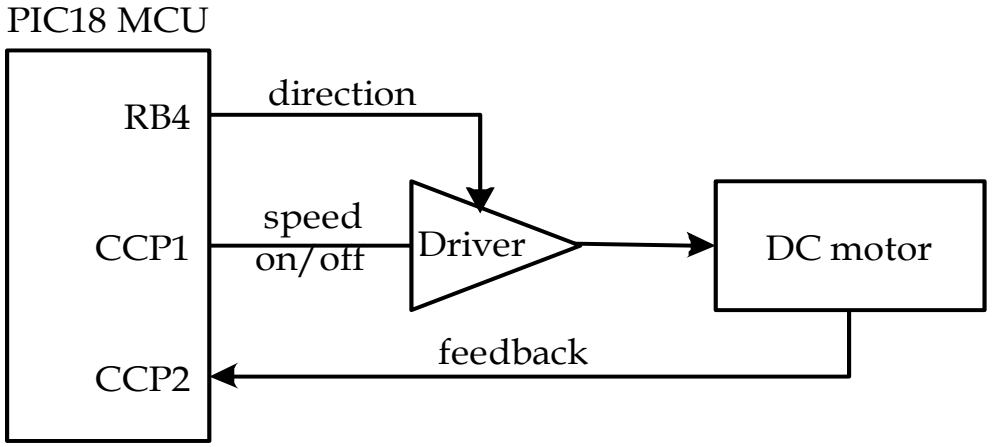


Figure 8.26A simplified circuit for DC motor control

DC Motor Driver

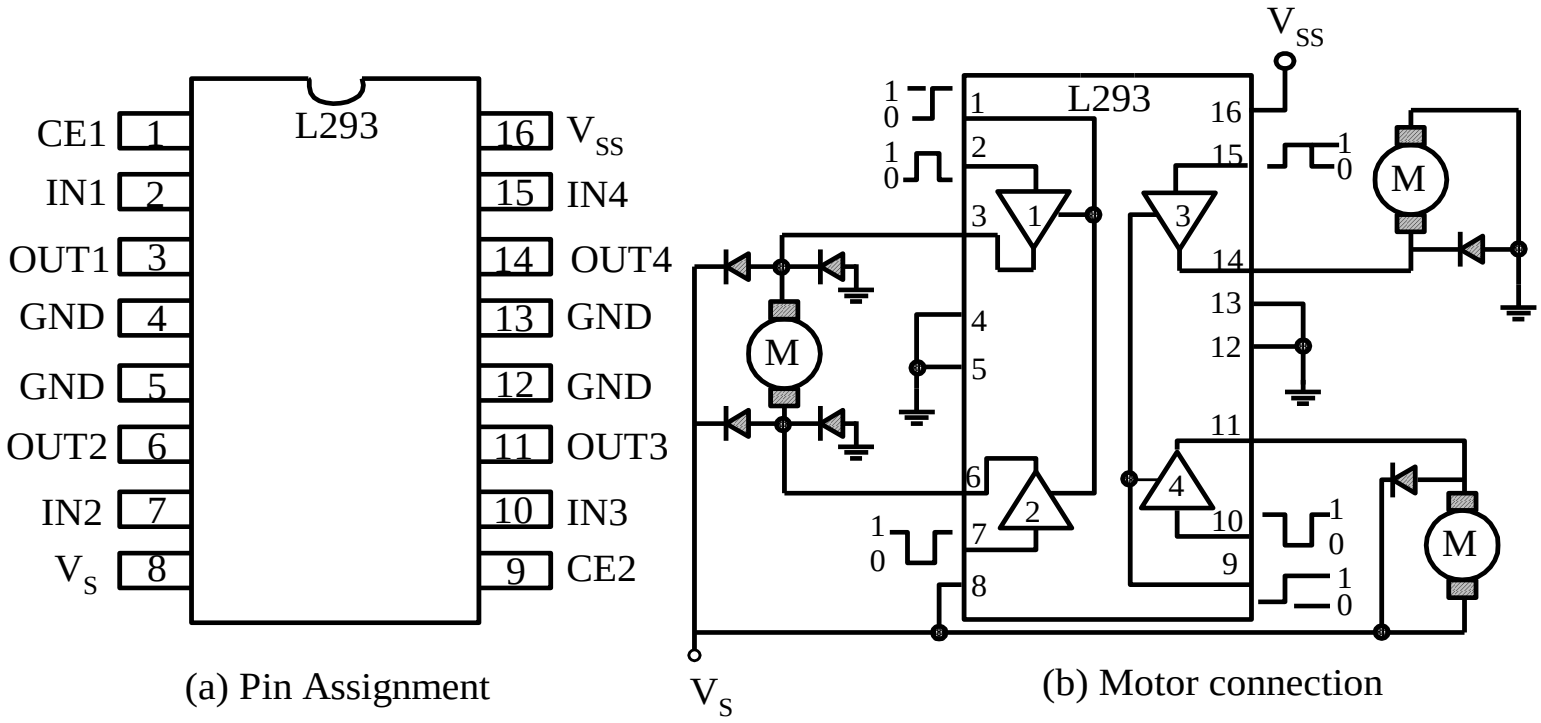


Figure 8.27 Motor driver L293 pin assignment and motor connection

Speed sensor

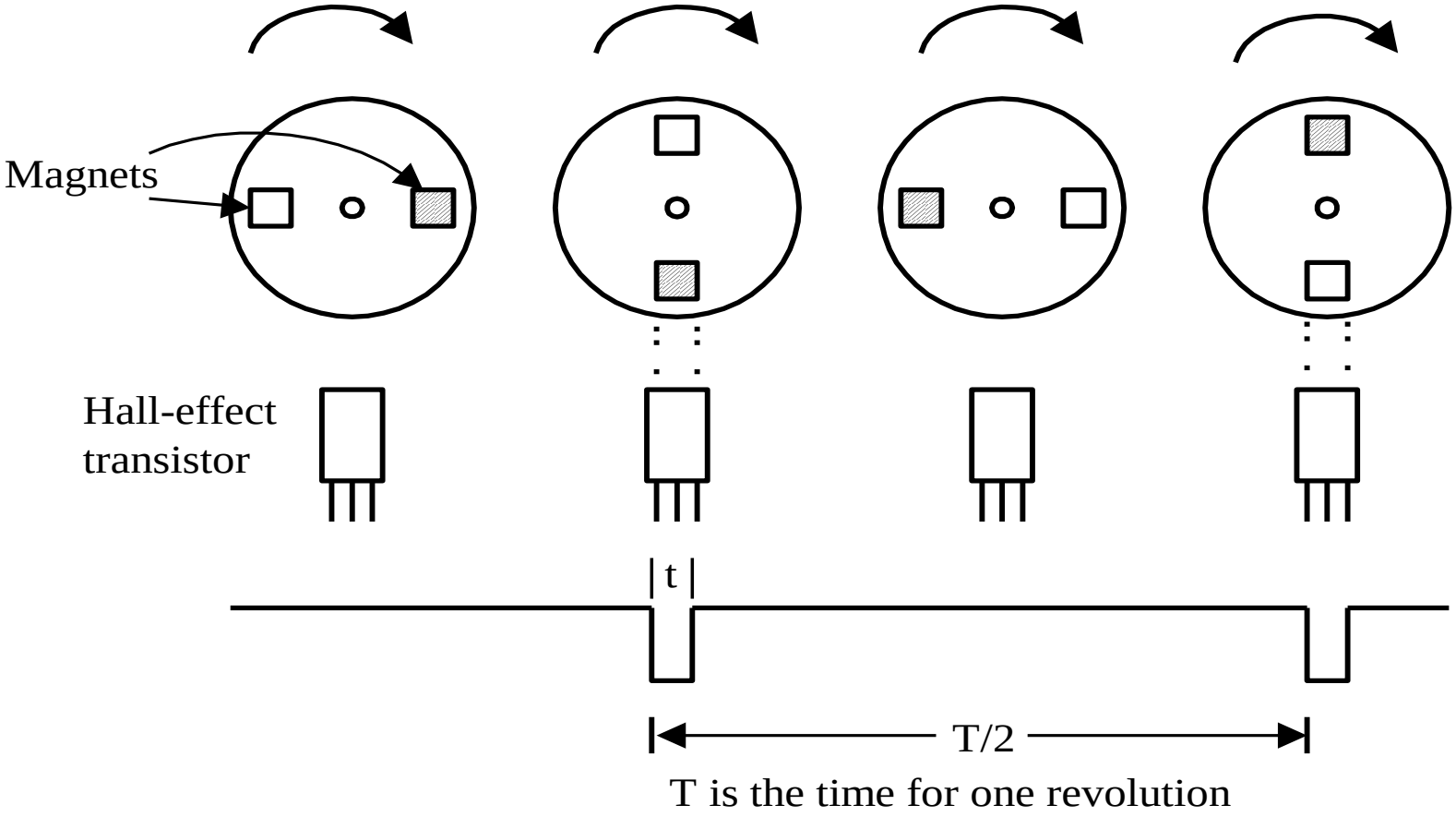
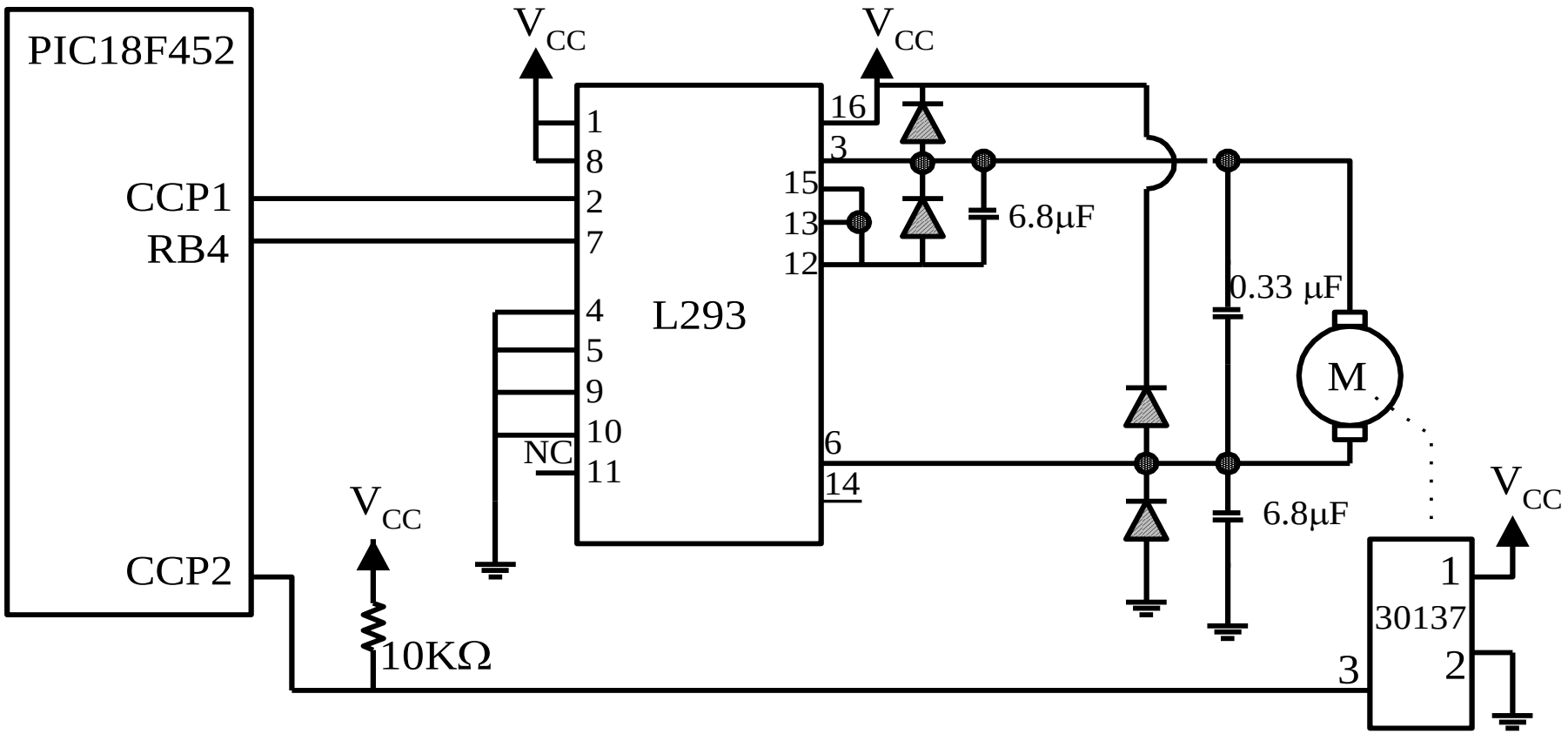


Figure 8.28 The output waveform of the Hall-effect transistor

Motor control system



All diodes are the same and could be any one of the 1N4000 series

Hall-effect switch

Figure 8.29 Schematic of a PIC18-based motor-control system

Clockwise or counterclockwise Rotation

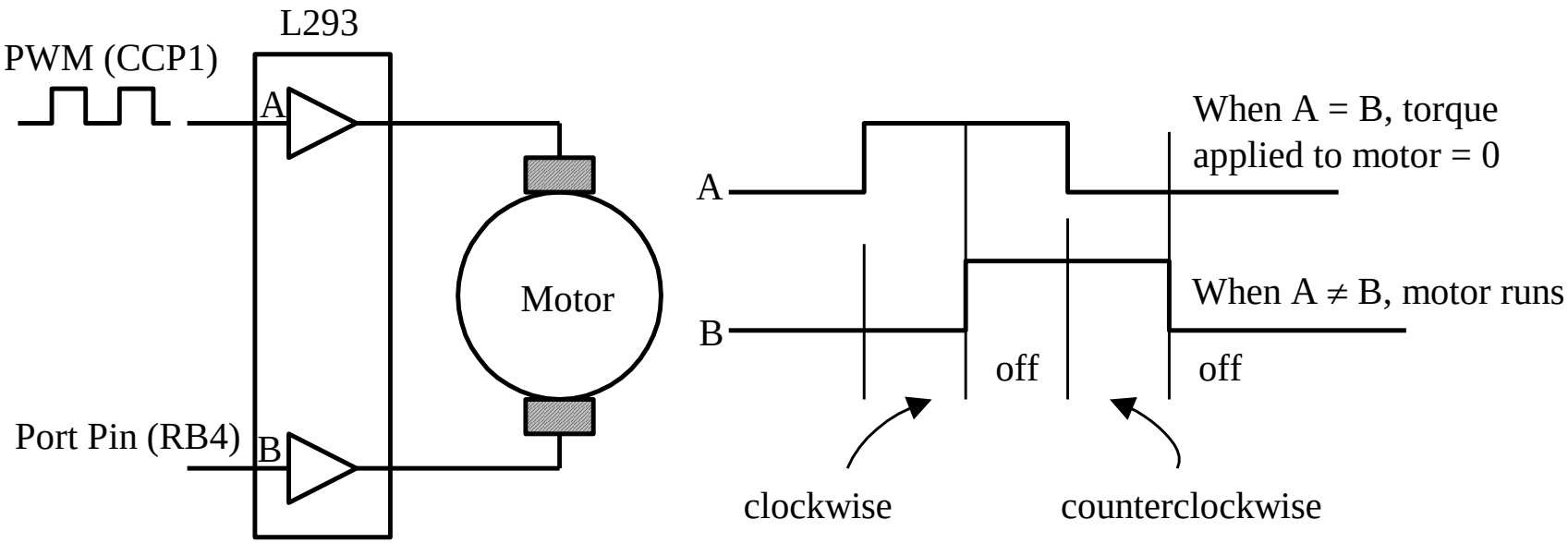
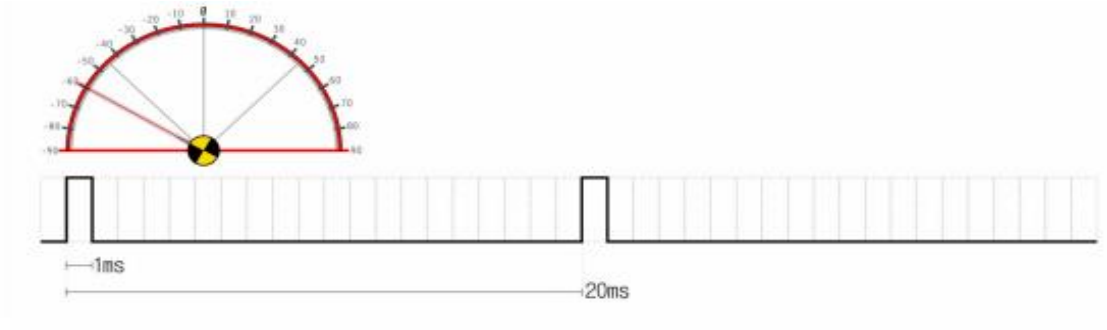


Figure 8.30 The L293 motor driver

Servomotors



(a)

(b)