Microprocessor I
Interfacing Ultrasonic Sensor with PIC18F

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Presentation Progress

Part 1: Fundamentals

1- Fundamentals of the Ultrasonic Sensor
2- Fundamentals of the PIC18F

Part 2: Implementation

1- Hardware Interfacing
2- The Main Program
3- TRIG Pulse Generator
4- ECHO Pulse In
5- Distance Calculation
6- Cyclic Delay Generator
7- Testing The Implementation

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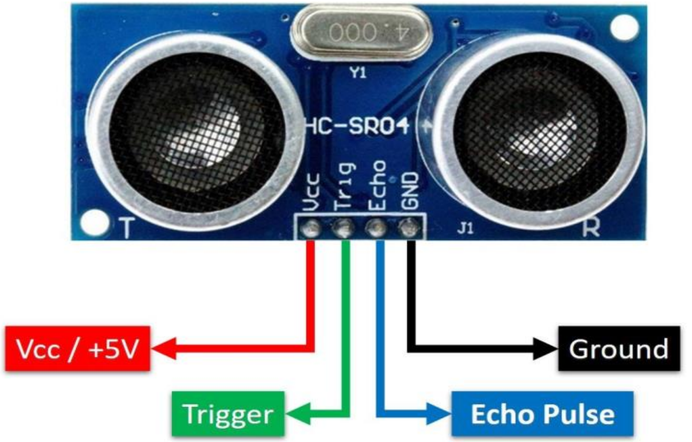
Fundamentals of Ultrasonic Sensor



Power Pins:

1- Vcc Pin: This pin is connected to a 5V voltage source.

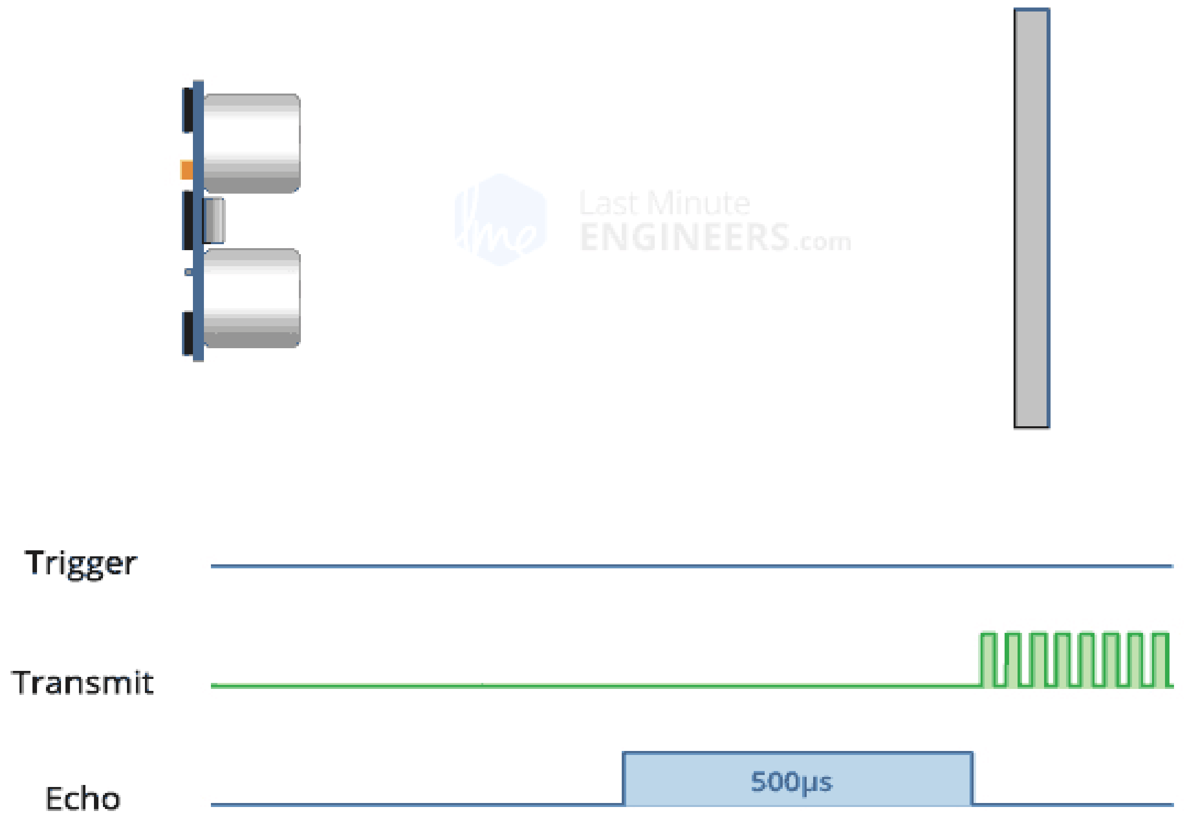
2- GND Pin: This pin is connected to the common ground.

Data Pins:

1- Trig Pin: It is an input pin used to trig the sensor to transmit ultrasonic waves.

2- ECHO Pin: It is an output pin which generates a variable time pulse depending on the time the ultrasonic wave spends on its travel.

Fundamentals of Ultrasonic Sensor



$$Distance[cm] = \frac{v_{US} * t_{TRIG}}{2} = 0.01715 * t_{TRIG}\ [\mu s]$$

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Fundamentals of PIC18F

I/O Ports:

PIC18F458 has 5 Digital input ports each which has different number of pins as represented bellow

Port A:	RA0	RA1	RA2	RA3	RA4	RA5	RA6	
Port B:	RB0	RB1	RB2	RB3	RB4	RB5	RB6	RB7
Port C:	RB0	RB1	RB2	RB3	RB4	RB5	RB6	RB7
Port D:	RD0	RD1	RD2	RD3	RD4	RD5	RD6	RD7
Port E:	RE0	RE1	RE2					

Fundamentals of PIC18F

I/O Ports:

A pin **N** within a port **X** is declared as an input or an output pin using the SFR TRIS**X**.
BSF *TRIS**X***, ***N*** will set R**XN** as an input pin
BCF *TRIS**X***, ***N*** will set R**XN** as an output pin

To manipulate the state of an output pin we use the SFR PORT**X**
BSF *PORT**X***, ***N*** will set R**XN** value into 1
BCF *PORT**X***, ***N*** will set R**XN** value into 0

To check the state of an input pin we also use the SFR PORT**X**
BTFSS *PORT**X***, ***N*** will skip the next instruction if R**XN** value is 1
BTFSC *PORT**X***, ***N*** will skip the next instruction if R**XN** value is 0

Fundamentals of PIC18F

Timer 0:

PIC18F458 has an integrated 16 bits counter called Timer 0

One basic role of Timer 0 is to count an external event happening outside the microcontroller.

The number of times Timer 0 ticks are stored in two byte concatenated SFRs called TMR0H:TMR0L as represented bellow

TMR0H								TMR0L							
D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

Fundamentals of PIC18F

Timer 0:

To configure Timer 0 we use the SFR T0CON represented bellow

T0CON SFR:

TMR0ON	T0BIT	T0CS	T0SE	PSA	T0PS2	T0PS1	T0PS0

BSF *T0CON, TMR0ON* will start Timer 0
BCF *T0CON, TMR0ON* will stop Timer 0

BSF *T0CON, T0BIT* will configure Timer 0 as 8 bit counter
BCF *T0CON, T0BIT* will configure Timer 0 as 16 bit counter

BSF *T0CON, T0CS* will control the counter by an external clock
BCF *T0CON, T0CS* will control the counter by the internal clock

BSF *T0CON, T0SE* will configure Timer 0 as Falling edge counter
BCF *T0CON, T0SE* will configure Timer 0 as Rising edge counter

Fundamentals of PIC18F

Timer 0:

BSF *T0CON, PSA* will disable pre-scaler
BCF *T0CON, PSA* will enables pre-scaler

Pre- scaler scheme:

Scale	T0PS2	T0PS1	T0PS0
1:2	0	0	0
1:4	0	0	1
1:8	0	1	0
1:16	0	1	1
1:32	1	0	0
1:64	1	0	1
1:128	1	1	0
1:256	1	1	1

$T_{step} = \frac{4}{f_{osc}} * 2^{N+1}$ where $N = (T0PS2\!:T0PS1\!:P0PS0)_{10}$

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Hardware Interfacing

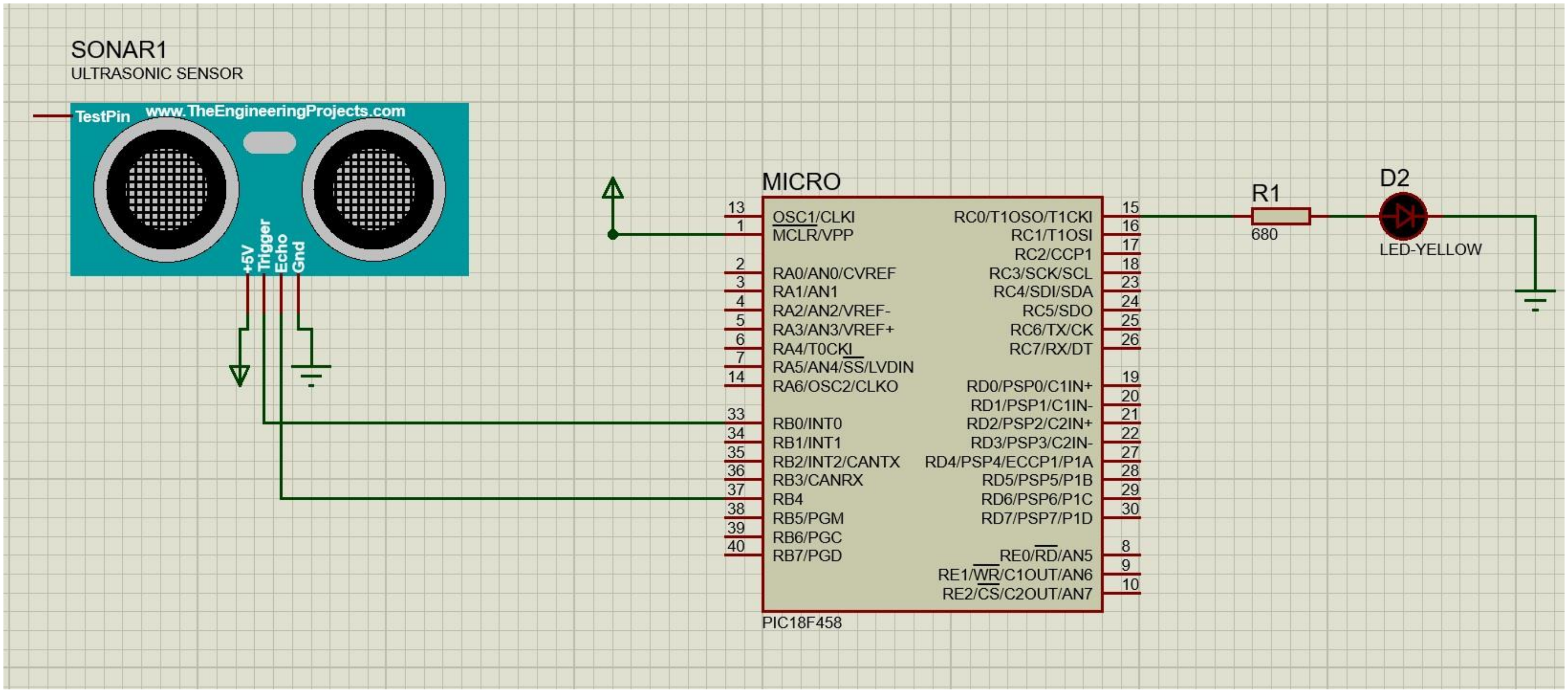
I/O Pins used:

Port A:	RA0	RA1	RA2	RA3	RA4	RA5	RA6	
Port B:	RB0	RB1	RB2	RB3	RB4	RB5	RB6	RB7
Port C:	RC0	RC1	RC2	RC3	RC4	RC5	RC6	RC7
Port D:	RD0	RD1	RD2	RD3	RD4	RD5	RD6	RD7
Port E:	RE0	RE1	RE2					

Pin *RB0* is connected to *TRIG* pin of the sensor. It is configured as an output pin.
Pin *RB4* is connected to *ECHO* pin of the sensor. It is configured as an input pin.
Pin *RC0* is connected to a *LED*. It is configured as an output pin.

Hardware Interfacing

The Connections:



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The Main Program

Main Code:

Initially: Configure the I/O ports and Timer 0

Step 1: Generate 10 μs pulse on pin RB0 (TRIG pin)

Step 2: Count the duration for which pin RB4 (ECHO pin) is High

Step 3: Calculate the Distance

Step 4: wait for 10 ms

Step 5: Set pin RC0 (LED) if an object is detected

Repeat step 1 indefinitely

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TRIG Pulse Generator

TRIG Pulse Generator Code:

```
TRIG_PULSE2 MOVLW 0x08
            MOVWF C3
            BSF PORTB, 0
AGAIN       DECF C3
            BNZ AGAIN
            BCF PORTB, 0
            RETURN
```

```
TRIG_PULSE   BCF PIR1, TMR2IF
             BSF PORTB, 0
             BSF T2CON, TMR2ON
LOOP         BTFSS   PIR1, TMR2IF
             BRA LOOP
             BCF PORTB, 0
             RETURN
```

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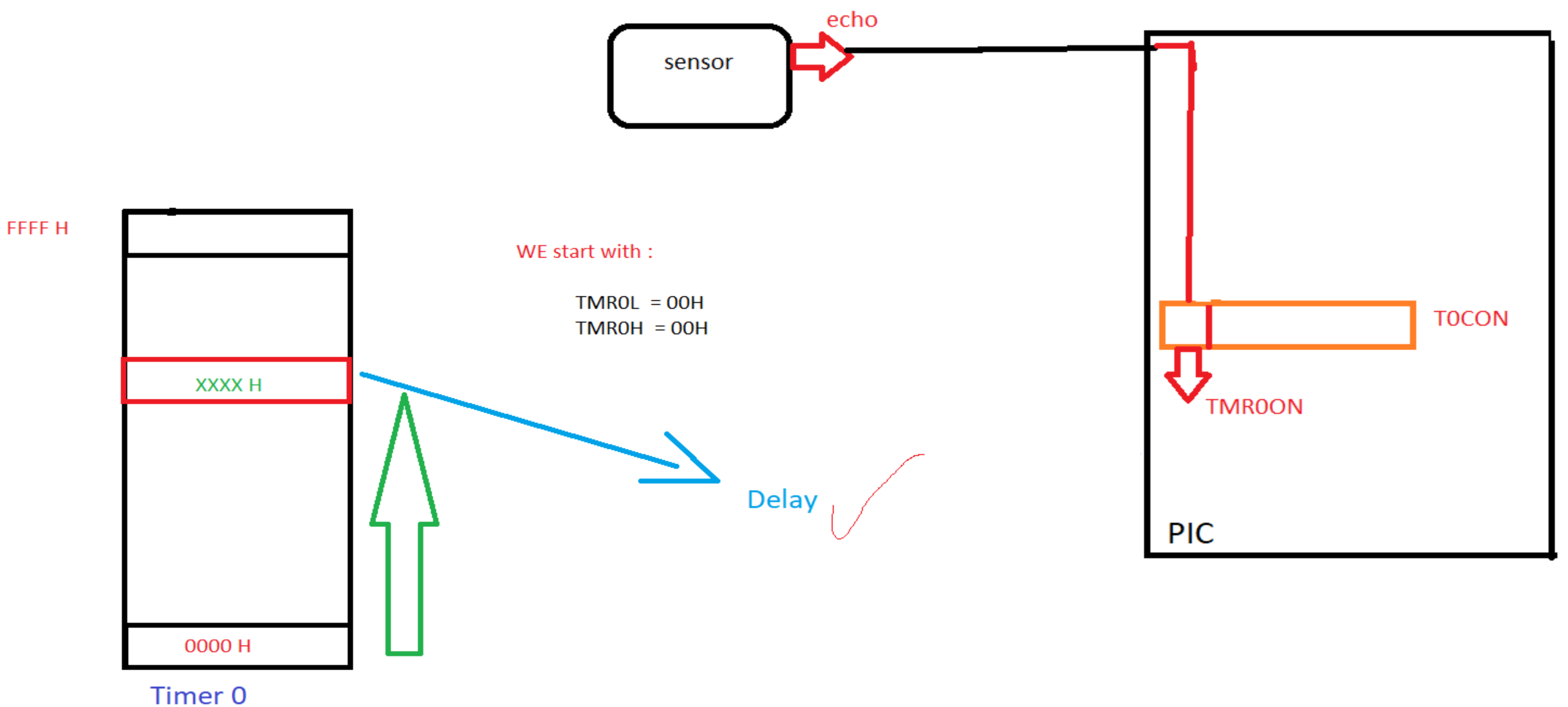
ECHO Pulse In

ECHO Pulse In Principle:



ECHO Pulse In

ECHO Pulse In Principle:

Initially: Configure Timer 0.
T0CON = 00H

Step 1: initiate the counter into zero.
TMR0H:TMR0L = 0000H

Step 2: Continuously test RB4 pin. If echo pulse goes High, enable the counter.
if (RB4 == 1)   TMR0ON = 1

Step 3: Continuously test RB4 pin. If echo pulse goes Low, disable the counter.
if (RB4 == 0)   TMR0ON = 0

Step 4: Collect the number of steps in a temporary Register Pair.
A1:A0 = TMR0H:TMR0L

ECHO Pulse In

Timer0 Configuration:

We configured T0CON SFR of Timer 0 as shown bellow:

T0CON SFR:

TMR0ON	T0BIT	T0CS	T0SE	PSA	T0PS2	T0PS1	T0PS0
RB4	0	0	0	0	0	0	0

TMR0ON will be set and reset according the value the digital pin RB4 (ECHO)

T0BIT is set to 0 since we are configuring Timer 0 as 16 bit counter.

T0CS will bet set to 0 since we are using the internal clock of the PIC.
i. e: $f_{osc} = 10MHz$

T0SE will bet set to 0 since we are configuring Timer 0 as rising edge counter.

ECHO Pulse In

Timer0 Configuration:

PSA will bet set to 0 since we will use a pre-scaler

Choice of Pre- scaler :

Scale	T0PS2	T0PS1	T0PS0
1:2	0	0	0
1:4	0	0	1
1:8	0	1	0
1:16	0	1	1
1:32	1	0	0
1:64	1	0	1
1:128	1	1	0
1:256	1	1	1

$N = (000)_{10} = 0$ so $T_{step} = \frac{4}{f_{osc}} * 2^{N+1} = \frac{4}{10\ MHz} * 2^{0+1}$ = 0.8 μs

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Distance Calculation

Simplification of Distance Formula:

$$Distance[cm] = \frac{v_{US}[cm/\mu s] * t_{TRIG}[\mu s]}{2} = \frac{0.0343[cm/\mu s] * t_{TRIG}[\mu s]}{2}$$

$$Distance[cm] = 0.01715[cm/\mu s] * t_{TRIG}\ [\mu s]$$

But we have: $T_{step} = 0.8\ \mu s$

And: $t_{TRIG}[\mu s] = Steps * T_{step}[\mu s]$

so: $Distance[cm] = 0.01715[cm/\mu s] * 0.8[\mu s] * Steps$

Conclusion: $Distance[cm] = 0.01372 * Steps$

Distance Calculation

Implementation of Distance Formula:

True value:
(0.01372)dec = (0,0000 0011 1000 001101...)bin

Approximated value (to 16 decimal point)
(0,0000 0011 1000 0011)bin = (0.013717 ...)dec

The approximation gave a 1.7 per 100 000 relative error

Multiplying the Approximated number by 2^16:
(0,0000 0011 1000 0011)bin x 2^16 = (0000 0011 1000 0011)bin = (383)hex = (899)dec

Calculating the Maximum Distance The Sensor Can Measure:

0000 0011 1000 0011 => 0383
1010 1111 1100 0100 => AFC8
0000 0010 0110 1001 0100 1011 0101 1000 => 0269 4B58

(0000 0010 0110 1001, 0100 1011 0101 1000)bin = (0269, 4B58)hex = (617,29)dec

Distance Calculation

Implementation of Distance Formula:

```
        A1 A0                A1 A0 =TMR0H TMR0L
        B1 B0                B1 B0 = 0383H
        -------
        K1 K0                K1 K0 = B0 x A0
     L1 L0                   L1 L0 = B0 x A1
     S1 S0                   S1 S0 = B1 x A0
T1 T0                        T1 T0 = B1 x A1
----------------
D3 D2 D1 D0
```

D0 = K0

D1 = K1 + L0 + S0

D2 = L1 + S1 + T0 + CARRY1

D3 = T1 + CARRY 2

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Cyclic Delay Generator

Cyclic Delay Code:

```
DEL_10MS_M2 MOVLW 0x64
            MOVWF C1
AGAIN1      MOVLW 0x52
            MOVWF C2
AGAIN2      DECF C2, F
            BNZ AGAIN2
            DECF C1, F
            BNZ AGAIN1
            RETURN
```

```
DELAY_10MS  MOVLW 0x9E
            MOVWF TMR1H
            MOVLW 0x58
            MOVWF TMR1L
            BSF T1CON,  TMR1ON
LOOP3       BTFSS PIR1, TMR1IF
            BRA LOOP3
            BCF T1CON, TMR1ON
            RETURN
```

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Testing The Implementation

Method:

According to the specifications, the sensor can measure a distance up to **617 cm**.
In our implementation, we choose to set the sensor's range to **512 cm**.

As we can see: (512)Dec = (0200)hex

So its sufficient to compare the 4th byte ***D3*** of the Distance calculated with number **2H** to assert whether an object has entered the range of the sensor. Accordingly, pin ***RC0*** must be set or reset.

If ***D3*** is strictly less than **2** then ***RC0*** = 1
Otherwise ***RC0*** = 0

Eg 1: let us assume that D3:D2:D1:D0 = 0130H then pin ***RC0*** *is set HIGH (LED is ON)*
Eg 2: Assume this time that D3:D2:D1:D0 = 0210H then pin ***RC0*** *is set LOW (LED is OFF)*

Testing The Implementation

Display Code:

```
DISPLAY     MOVLW 02
            CPFSLT S3
            BRA OFF
            BSF PORTC,0
            BRA SKIP
OFF         BCF PORTC ,0
SKIP        RETURN
```