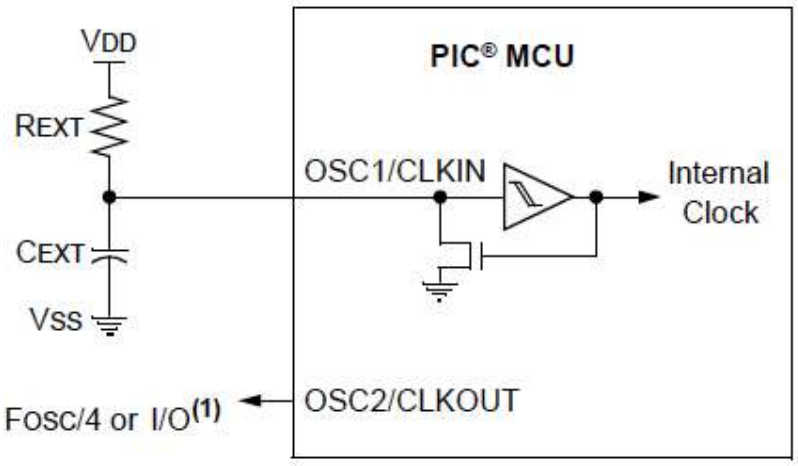
External RC Oscillator

The **External RC Oscillator** mode allows the PIC® MCU to be clocked by a simple Resistor-Capacitor (RC) combination. This offers a low cost option for the oscillator in applications that don't require precise timing and is especially useful for older devices that don't have an internal oscillator option.

The RC connects to the OSC1 pin. The OSC2 is not needed and can be used as a clock out pin or a general purpose I/O. The OSC2 pin option is selected by the **$\overline{\text{CLKOUTEN}}$** bit in a configuration word.

The External RC setup is shown in the figure below.



The RC Oscillator frequency is a function of the supply voltage (Vdd) for the device, the resistor (Rext) value and the capacitor Cext) value. Operating temperature also plays a key role in the accuracy of the RC created frequency.

Typical value ranges include:
For Vdd < 3 volts:
10k ≤ Rext ≤ 100k

For Vdd ≥ 3 volts:
3k ≤ Rext ≤100k

For Vdd: 2 - 5 volts:
Cext > 20pf

For REXT values below 2.2 kΩ, oscillator operation may become unstable, or stop completely. For very high REXT values (e.g. 1 MΩ), the oscillator becomes sensitive to noise, humidity and leakage. Thus, it's recommended to keep REXT between 3 kΩ and 100 kΩ.

Configuration Settings

The External RC Oscillator is selected with the Fosc bits in a configuration register.

REGISTER 4-1: CONFIG1: CONFIGURATION WORD 1

R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	U-1
FCMEN	IESO	$\overline{\text{CLKOUTEN}}$	BOREN<1:0>		—
bit 13					bit 8

R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	R/P-1
$\overline{\text{CP}}$(1)	MCLRE	$\overline{\text{PWRTE}}$	WDTE<1:0>		FOSC<2:0>		
bit 7							bit 0

bit 2-0 **FOSC<2:0>:** Oscillator Selection bits
111 = ECH: External Clock, High-Power mode (4-20 MHz): device clock supplied to CLKIN pin
110 = ECM: External Clock, Medium-Power mode (0.5-4 MHz): device clock supplied to CLKIN pin
101 = ECL: External Clock, Low-Power mode (0-0.5 MHz): device clock supplied to CLKIN pin
100 = INTOSC oscillator: I/O function on CLKIN pin
011 = EXTRC oscillator: External RC circuit connected to CLKIN pin
010 = HS oscillator: High-speed crystal/resonator connected between OSC1 and OSC2 pins
001 = XT oscillator: Crystal/resonator connected between OSC1 and OSC2 pins
000 = LP oscillator: Low-power crystal connected between OSC1 and OSC2 pins

The **$\overline{\text{CLKOUTEN}}$** bit is also in a configuration register and typically in the same register as the Fosc bits.

REGISTER 4-1: CONFIG1: CONFIGURATION WORD 1

R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	U-1
FCMEN	IESO	CLKOUTEN	BOREN<1:0>		—
bit 13					bit 8

R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	R/P-1
$\overline{\text{CP}}$(1)	MCLRE	$\overline{\text{PWRTE}}$	WDTE<1:0>		FOSC<2:0>		
bit 7							bit 0

bit 11 **$\overline{\text{CLKOUTEN}}$:** Clock Out Enable bit
If FOSC configuration bits are set to LP, XT, HS modes:
This bit is ignored, CLKOUT function is disabled. Oscillator function on the CLKOUT pin.
All other FOSC modes:
1 = CLKOUT function is disabled. I/O function on the CLKOUT pin.
0 = CLKOUT function is enabled on the CLKOUT pin

Note: On older devices the OSC2 clock out option is incorporated into the Fosc settings instead of a separate **$\overline{\text{CLKOUTEN}}$** bit to set.

bit 2-0 **FOSC<2:0>:** Oscillator Selection bits

111 = RC oscillator: CLKOUT function on RA4/OSC2/CLKOUT pin, RC on RA5/OSC1/CLKIN
110 = RCIO oscillator: I/O function on RA4/OSC2/CLKOUT pin, RC on RA5/OSC1/CLKIN
101 = INTOSC oscillator: CLKOUT function on RA4/OSC2/CLKOUT pin, I/O function on RA5/OSC1/CLKIN
100 = INTOSCIO oscillator: I/O function on RA4/OSC2/CLKOUT pin, I/O function on RA5/OSC1/CLKIN
011 = EC: I/O function on RA4/OSC2/CLKOUT pin, CLKIN on RA5/OSC1/CLKIN
010 = HS oscillator: High-speed crystal/resonator on RA4/OSC2/CLKOUT and RA5/OSC1/CLKIN
001 = XT oscillator: Crystal/resonator on RA4/OSC2/CLKOUT and RA5/OSC1/CLKIN
000 = LP oscillator: Low-power crystal on RA4/OSC2/CLKOUT and RA5/OSC1/CLKIN

Calculating Frequency

The OSC1 pin is a schmitt trigger input. The charge time to reach the Vih level will control the period of the signal and thus the frequency.

(1)

$$Time = (Rext * Cext) ln[Vdd/(Vdd - Vih)]$$

(2)

$$Fosc = 1/Time$$

(3)

$$InstructionClock = Fosc/4$$

So a RC value is selected to result in the instruction clock rate that is desired for the application.

The data sheet electrical specifications for the device will specify the Vih threshold but in most devices Vih = 0.9*Vdd as seen in the sample data sheet section below.

Param No.	Sym	Characteristic	Min	Typ†	Max	Units	Conditions
	VIL	**Input Low Voltage**					
		I/O ports:					
D030		with TTL buffer	VSS	—	0.15 VDD	V	For entire VDD range
D030A			VSS	—	0.8V	V	4.5V ≤ VDD ≤ 5.5V
D031		with Schmitt Trigger buffer	VSS	—	0.2 VDD	V	
D032		MCLR, OSC1 (in RC mode)	VSS	—	0.2 VDD	V	
D033		OSC1 (in XT and LP modes)	VSS	—	0.3V	V	**(Note 1)**
		OSC1 (in HS mode)	VSS	—	0.3 VDD	V	
		Ports RC3 and RC4:		—			
D034		with Schmitt Trigger buffer	VSS	—	0.3 VDD	V	For entire VDD range
D034A		with SMBus	-0.5	—	0.6	V	For VDD = 4.5 to 5.5V
	VIH	**Input High Voltage**					
		I/O ports:		—			
D040		with TTL buffer	2.0	—	VDD	V	4.5V ≤ VDD ≤ 5.5V
D040A			0.25 VDD + 0.8V	—	VDD	V	For entire VDD range
D041		with Schmitt Trigger buffer	0.8 VDD	—	VDD	V	For entire VDD range
D042		MCLR	0.8 VDD	—	VDD	V	
D042A		OSC1 (in XT and LP modes)	1.6V	—	VDD	V	**(Note 1)**
		OSC1 (in HS mode)	0.7 VDD	—	VDD	V	
D043		OSC1 (in RC mode)	0.9 VDD	—	VDD	V	
		Ports RC3 and RC4:					

Example

Here is an example using the values below for the RC oscillator.

Vdd = 5v
Vih = Vdd * 0.9 = 4.5v
Rext = 10k
Cext = 22pf

The calculations show the charge time of the RC circuit to reach the Vih level is 506 nanoseconds.

(4)

$$Time = (10k * 22pf)ln[(5v/(5v - 4.5)] = 506nanoseconds$$

(5)

$$OscillatorFrequency(Fosc) = 1/Time = 1/506nanoseconds = 1.976Mhz$$

(6)

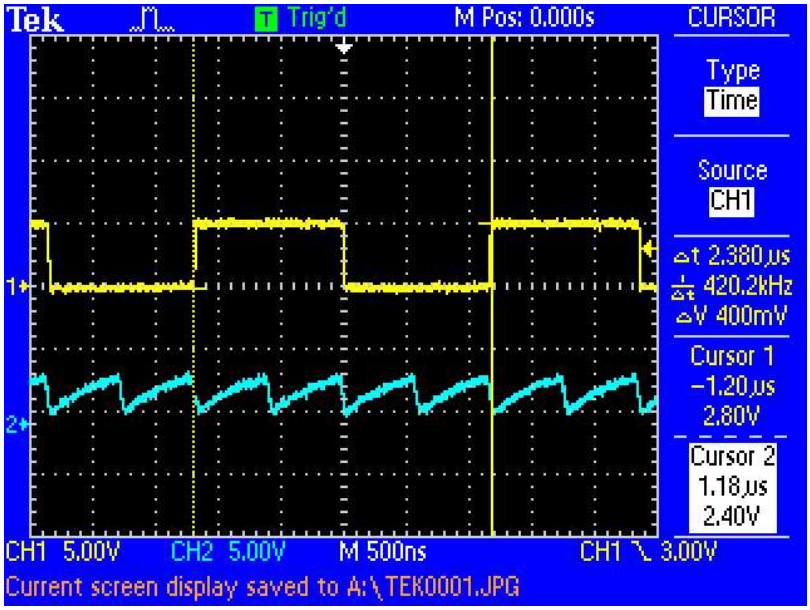
$$InstructionClock = Fosc/4 = 494Khz$$

Using these values in an actual circuit with a PIC16F690, the scope plot shows the RC charge and discharge waveform in blue. The configuration is set to send the instruction clock ($\overline{\text{CLKOUTEN}}$ = 1) out the OSC2 pin. The clock out signal is captured in the yellow waveform.

The actual Vdd = 4.67v.
Rext = 10k +- 10%
Cext = 22pf +- 20%

The results show parameters in the range of the calculated values but certainly off due to the variations in the components.

The measured frequency is a 420 Khz instruction clock based on an RC charge time of around 595 nanoseconds.



Yellow - Instruction Clock (CLKOUT on OSC2 pin)
Blue - RC charge/discharge signal

For more information on 8-Bit oscillator options visit the **8-Bit Oscillator Options (/8bit:osc)** article.