



University of British Columbia  
ELEC291/ELEC292

## Lab 4: Capacitance Meter and Photo Electric Heart Rate Monitor

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## Objectives

- Lab 4 requirements for ELEC291 and ELEC292.
- The 555 timer.
- Heart rate monitor circuit.
- Testing the EFM8 board.
- Attach an LCD to the EFM8 board.
- Read capacitors.
- C programming language:
  - Example: Measure frequency.
  - Example: Measure period.

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## Lab 4

- Two different labs depending on what course you are taking:
  - ELEC291: 555 timer/capacitance meter.
  - ELEC292: Heart Rate Monitor.
- You can work with a partner: only one circuit and code for two students. You can also work by yourself!
- If either you or your lab partner is registered in ELEC292, then both of you have to do the ELEC292 lab.

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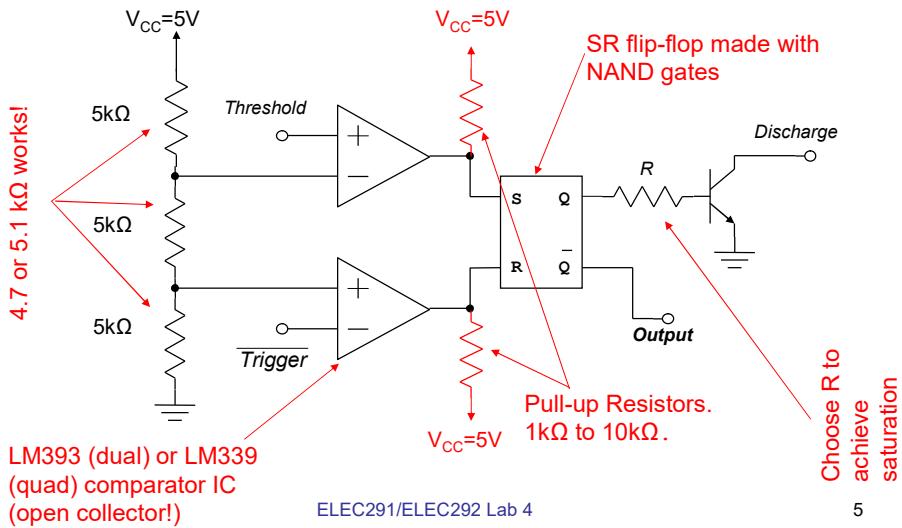
## ELEC291 Lab

- 555 Timer:
  - a) Build a 555 timer using discrete parts.
  - b) Use a real 555 timer or the one you made in part a) to measure capacitance:
    - Range: 1nF to 1 $\mu$ F.
    - Display value using LCD.
    - Program EFM8 board using C language.

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## 555 Timer Block Diagram



## 555 Timer astable (oscillator)

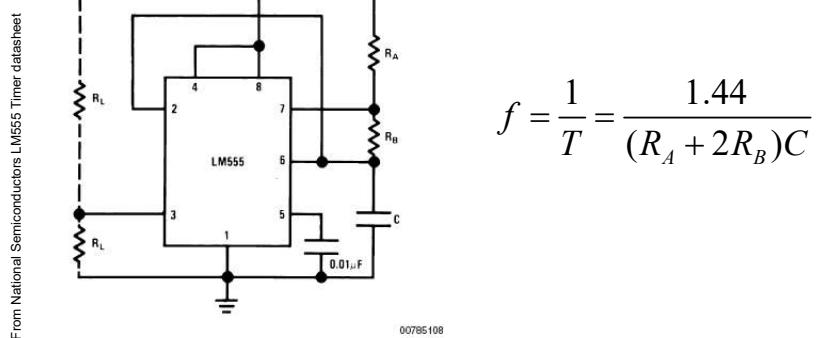
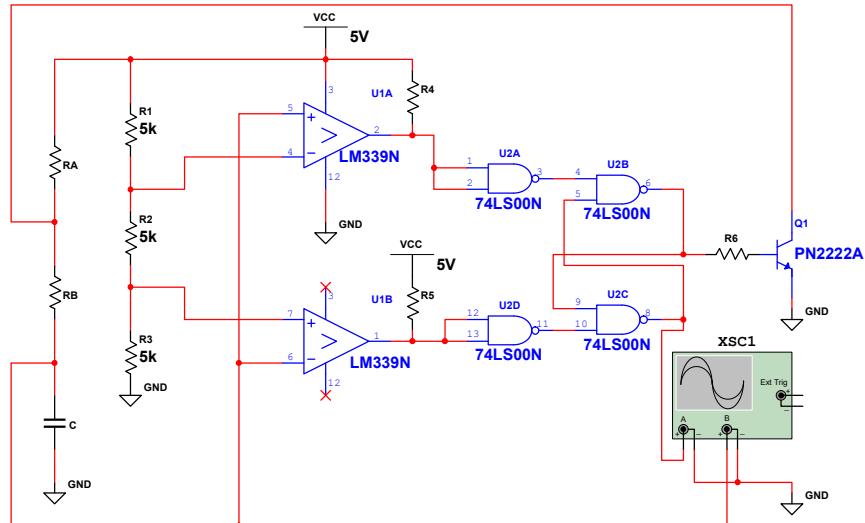


FIGURE 4. Astable

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## Tip: Simulate the Circuit!

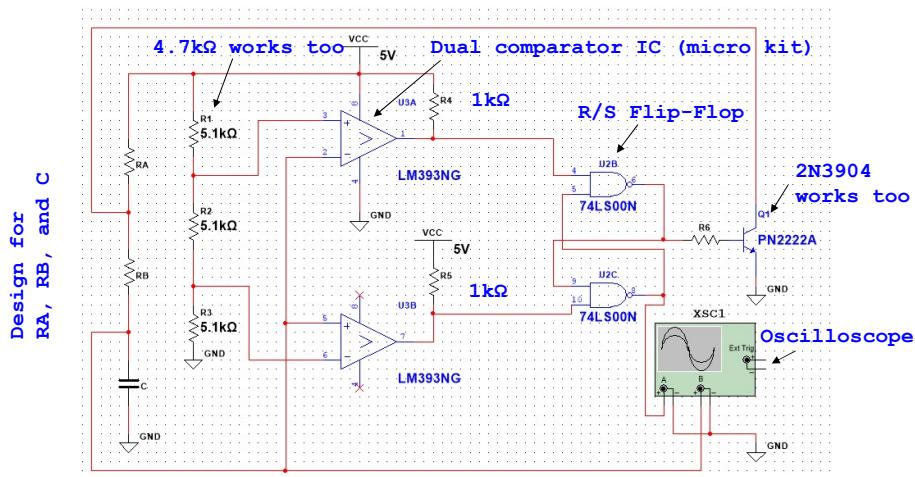


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## Tip: Simulate the Circuit!



Tip: build this one!

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## Multisim

- NI Multisim. Download from:

[http://courses.ece.ubc.ca/2020/NI\\_Circuit\\_Design\\_Suite\\_14\\_1\\_Education.exe](http://courses.ece.ubc.ca/281/2020/NI_Circuit_Design_Suite_14_1_Education.exe)

The serial number assigned to UBC students is **M71X71786**

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## ELEC292 Lab

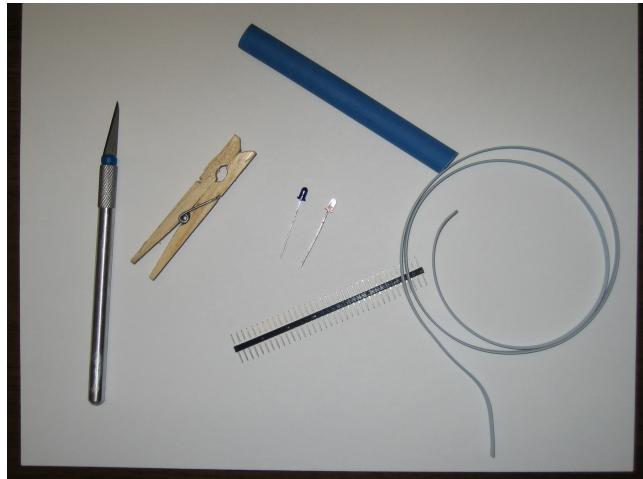
- Design, build, program, and test a microcontroller-based photoelectric heart rate monitor:
  - Build a photo-sensor finger-clip. Kit will be distributed NOW. Instructions posted in Canvas.
  - Assemble an amplifier/filter circuit.
  - Measure heart rate (BPM) and display using LCD.
  - Program EFM8 board using C language.

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## Finger Clip: before



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## Finger Clip: after



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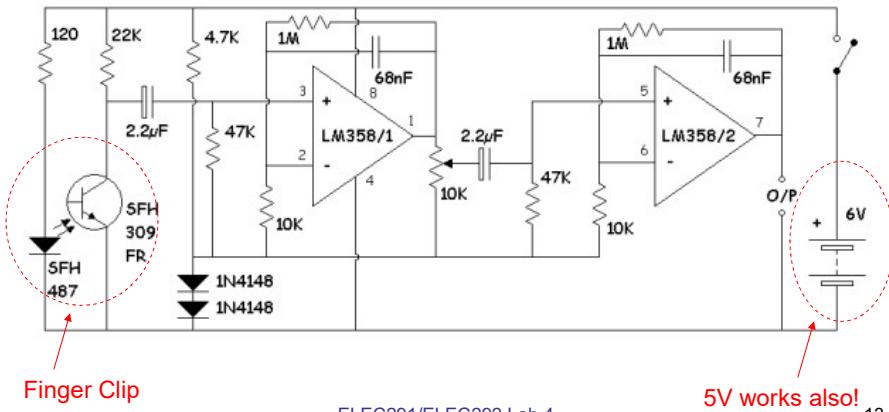
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# Amplifier/Filter

Original: [http://www.picotech.com/experiments/calculating\\_heart\\_rate/](http://www.picotech.com/experiments/calculating_heart_rate/)

Web archive: <https://web.archive.org/web/20210506185357/https://www.picotech.com/library/experiment/calculating-heart-rate>

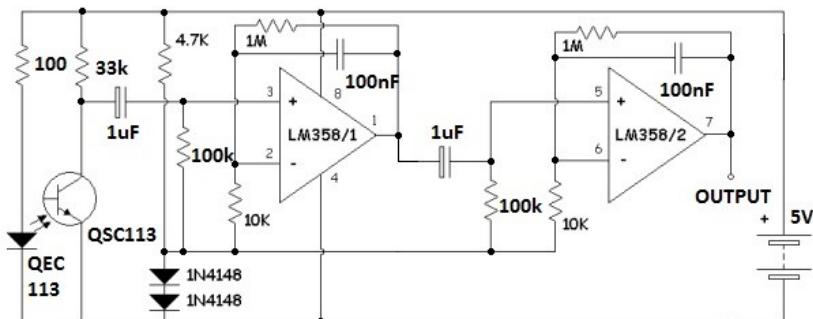


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## Modified Circuit Using Components at hand.



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# Testing The EFM8 Board

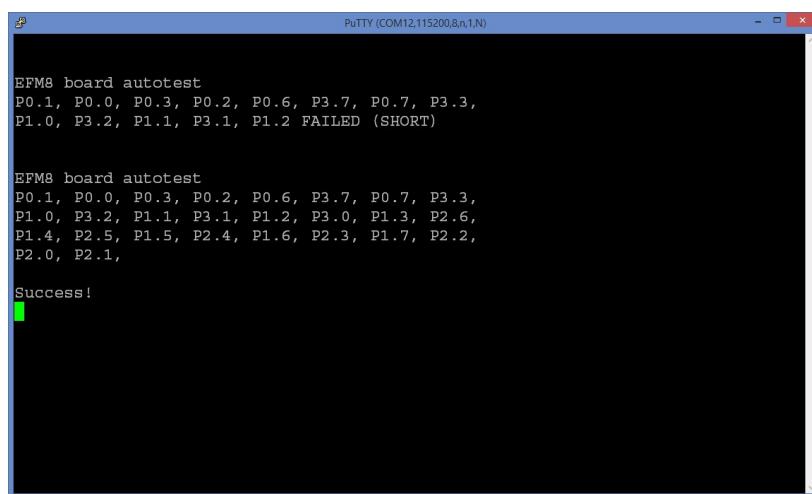
- Testing program available in Connect.
- Make the following connections:
  - P0.0 and P0.1
  - P0.2 and P0.3
  - P3.7 and P0.6
  - P3.3 and P0.7
  - P3.2 and P1.0
  - P3.1 and P1.1
  - P3.0 and P1.2
  - P2.6 and P1.3
  - P2.5 and P1.4
  - P2.4 and P1.5
  - P2.3 and P1.6
  - P2.2 and P1.7
  - P2.1 and P2.0
- Attach a resistor + LED to pin P2.1.
- Open PuTTY, run the test program:

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# Testing The EFM8 Board



```
EFM8 board autotest
P0.1, P0.0, P0.3, P0.2, P0.6, P3.7, P0.7, P3.3,
P1.0, P3.2, P1.1, P3.1, P1.2 FAILED (SHORT)

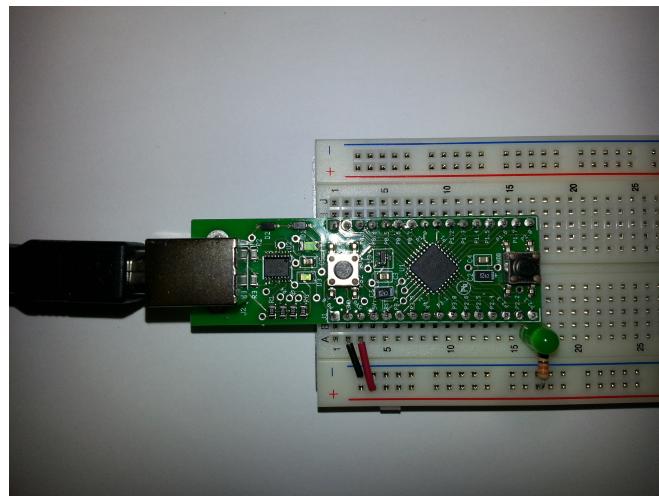
EFM8 board autotest
P0.1, P0.0, P0.3, P0.2, P0.6, P3.7, P0.7, P3.3,
P1.0, P3.2, P1.1, P3.1, P1.2, P3.0, P1.3, P2.6,
P1.4, P2.5, P1.5, P2.4, P1.6, P2.3, P1.7, P2.2,
P2.0, P2.1,
Success!
```

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## Testing The EFM8 Board



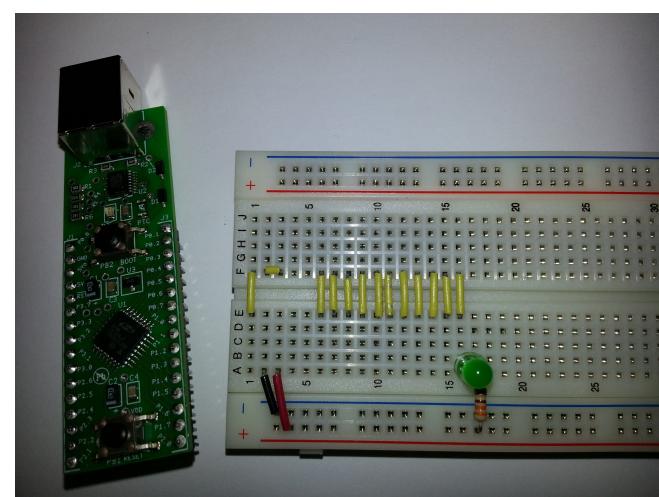
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## Testing The EFM8 Board

**After testing the circuit,  
remove the 'test' wires  
from the breadboard!**

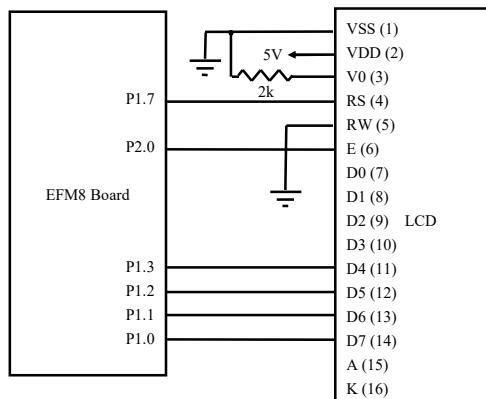


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## Attaching LCD to EFM8 board



- Example configures LCD in 4-bit mode. Saves pins and wires!
- Standard Hitachi HD44780 controller
- Pin assignments arbitrary, but source code must match wiring
- Pins 7, 8, 9, 10, 15, 16 not connected.

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## Attaching LCD to EFM8 board



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## Attaching LCD to EFM8 board

- Example provided EFM8\_LCD\_4bit.c:  
Configures and uses a Hitachi compatible LCD  
in 4-bit mode.

Pins used in the example:

```
#define LCD_RS P1_7
// #define LCD_RW Px_x // Not used in this code. Connect to GND
#define LCD_E P2_0
#define LCD_D4 P1_3
#define LCD_D5 P1_2
#define LCD_D6 P1_1
#define LCD_D7 P1_0
```

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## Capacitor Types

- Ceramic. Small values, small size, good price, good tolerance (lowest around  $\pm 1\%$ )
- Electrolytic. Large value, high tolerance ( $\pm 10\%$  minimum), don't age well, big size, very temperature sensitive.
- Tantalum. Large value, low voltage, small size, expensive, lowest tolerance around  $\pm 5\%$ .
- Mica. Best capacitors ever! Lowest tolerance around  $\pm 0.5\%$ . Very small values. VERY expensive, around 4\$ each!
- Polyester Film. Wide range values, inexpensive, good tolerance, price depends on tolerance and voltage rating
- Glass.

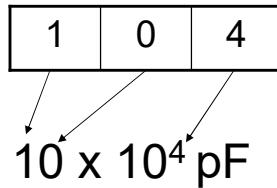
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## How to read Capacitor Codes

- Large capacitors have their values printed on them, for example  $10\mu\text{F}$ ,  $50\text{V}$ ,  $85\text{C}$ .
- Most small capacitors use a three number code system:



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## How to read Capacitor Codes

- Tolerance is indicated by a letter after the value:

E	$\pm 0.5\%$
F	$\pm 1\%$
G	$\pm 2\%$
H	$\pm 3\%$
J	$\pm 5\%$
K	$\pm 10\%$
M	$\pm 20\%$
N	$\pm 30\%$
P	+100% , -0%
Z	+80%, -20%

If tolerance is not indicated assume it is 'Z': +80%, -20%.

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## How to read Capacitor Codes

- Examples:
  - 103J
    - $10 \times 10^3 \pm 5\% = 0.01\mu\text{F} \pm 5\%$
  - 681
    - $68 \times 10^1 +80\%, -20\% = 680\text{pF} +80\%, -20\%$
  - 104Z
    - $10 \times 10^4 +80\%, -20\% = 0.1\mu\text{F} +80\%, -20\%$
  - 224M
    - $22 \times 10^4 \pm 20\% = 0.22\mu\text{F} \pm 20\%$
  - 473K
    - $47 \times 10^3 \pm 10\% = 47\text{nF} \pm 10\%$

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## 8051's Timers/Counters

- The original 8051 had only two timers/counters: 0 and 1.
- Newer 8051 microcontrollers (like the AT89LP51RB2) usually have:
  1. The 8051 timers/counters: timers 0 and 1
  2. The 8052 timer/counter: timer 2
  3. The Programmable Counter Array (PCA)
- The EFM8LB1 has 6 Timers / Counters + 5-channel PCA!

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# The EFM8LB1

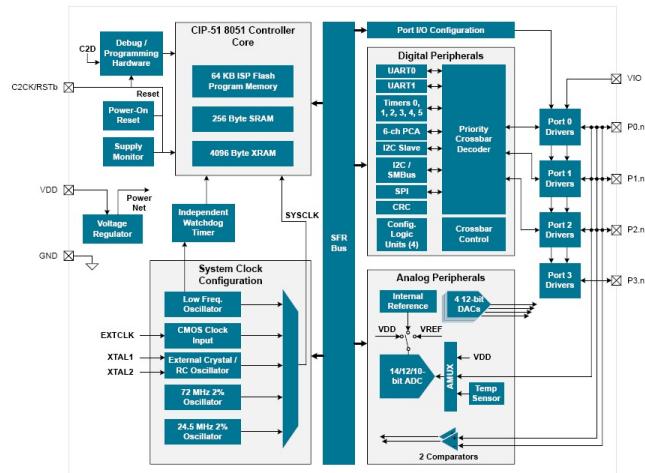


Figure 1.1. Detailed EFM8LB1 Block Diagram

Reference manual is  
329 pages only!

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## TMOD timer/counter mode control register (Address 89H)

Timer 1				Timer 0			
GATE	C/T*	M1	M0	GATE	C/T*	M1	M0

Bit	Name	Description	
7 & 3	GATE	1: uses either INT0 or INT1 pins to enable/disable the timer/counter	
6 & 2	C/T*	0: timer; 1: counter (pins T0 and T1)	
All the other pins!	M1	M0	
	0	0	13-bit timer/counter
	0	1	16-bit timer/counter
	1	0	8-bit auto-reload timer/counter
	1	1	Special mode

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## TCON: timer/counter control register. (Address 88H)

TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0
-----	-----	-----	-----	-----	-----	-----	-----

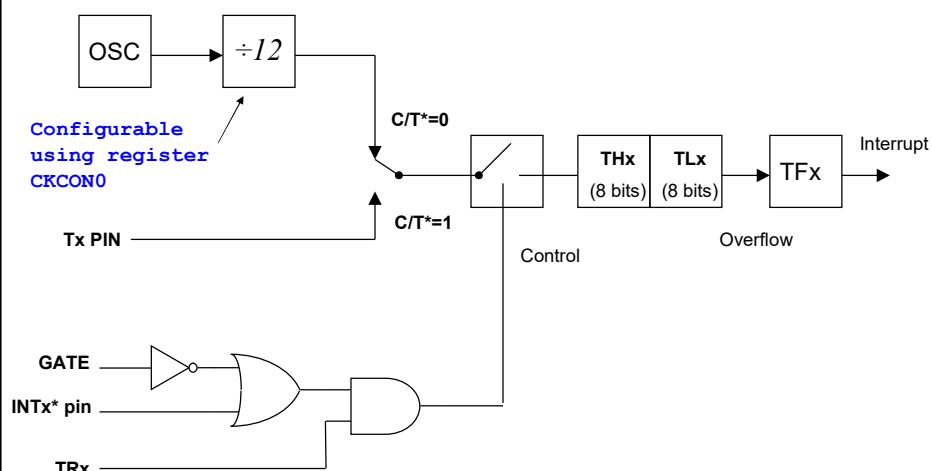
Bit	Name	Description
7	TF1	Timer 1 overflow flag.
6	TR1	Timer 1 run control.
5	TF0	Timer 0 overflow flag.
4	TR0	Timer 0 run control.
3	IE1	Interrupt 1 flag.
2	IT1	Interrupt 1 type control bit.
1	IE0	Interrupt 0 flag.
0	IT0	Interrupt 0 type control bit.

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## Timer/Counter 0 or 1 in Mode 1

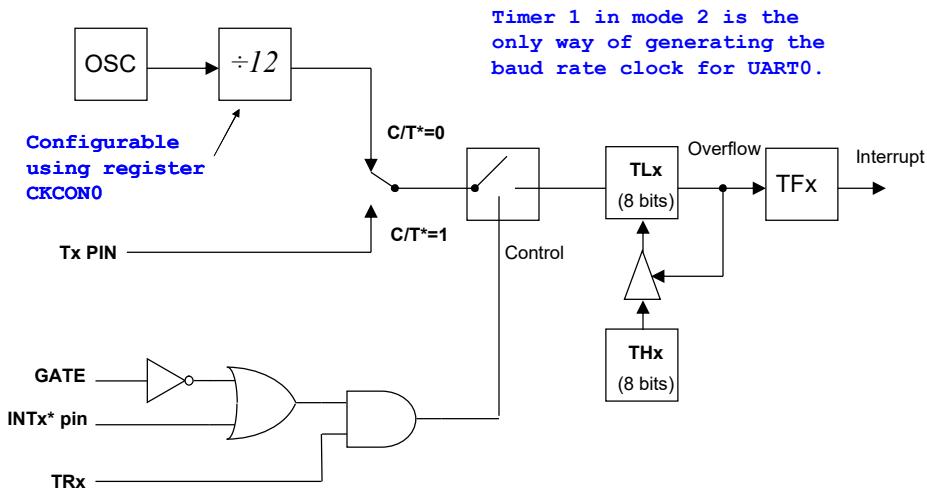


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## Timer/Counter 0 or 1 in Mode 2



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## Using a Counter to Measure Frequency

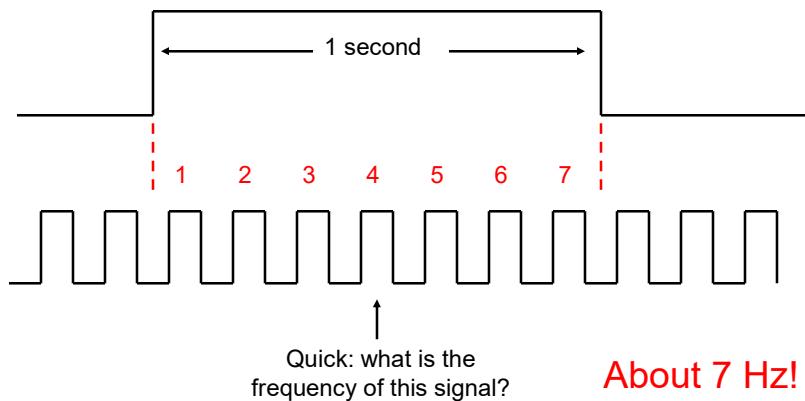
- By definition “frequency” in Hz is the number of pulses in one second, so:
  - 1) Set up the counter to count pulses in one of the pins in the microcontroller.
  - 2) Reset the counter to zero.
  - 3) Enable the counter.
  - 4) Wait one second.
  - 5) Disable the counter. The counter register (THx, TLx) has the frequency in Hz!

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## Using a Counter to Measure Frequency



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## FreqEFM8.c

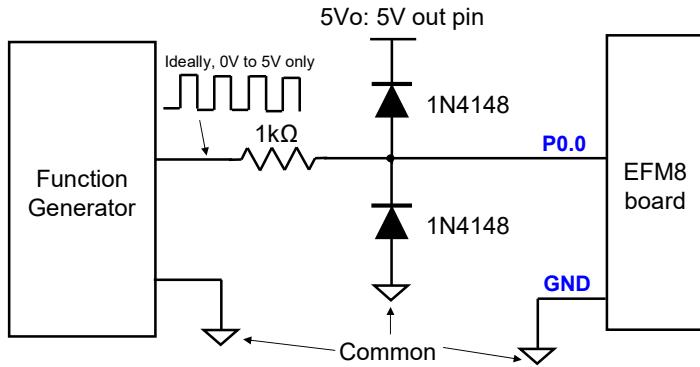
- Available on Canvas

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## Testing FreqEFM8.c with Lab Function Generator



A voltage limiter will prevent over-voltages that will damage your board!

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The Crossbar (Figure 11.4 in reference manual)

Port	0	1	2	3	4	P0	5	6	7	0	1	2	P1	3	4	5	6	7	0	1	2	3	4	5	6	P2	0	1	2	3	4	5	6	P3	0	1	2	3	4	5	6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
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AC565			DAC566			DAC567			DAC568			DAC569			DAC570			DAC571			DAC572			DAC573			DAC574			DAC575			DAC576			DAC577			DAC578			DAC579			DAC580			DAC581			DAC582			DAC583			DAC584			DAC585			DAC586			DAC587			DAC588			DAC589			DAC590			DAC591			DAC592			DAC593			DAC594			DAC595			DAC596			DAC597			DAC598			DAC599			DAC600			DAC601			DAC602			DAC603			DAC604			DAC605			DAC606			DAC607			DAC608			DAC609			DAC610			DAC611			DAC612			DAC613			DAC614			DAC615			DAC616			DAC617			DAC618			DAC619			DAC620			DAC621			DAC622			DAC623			DAC624			DAC625			DAC626	
<td

## Measure Period Using a Timer in the 8051

- We can measure the period of a wave in integer numbers of the timer clock period.  
Some math may be required!
- Works quite well for slow signals.
- Measuring period could be way faster than measuring frequency.

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## Measure Period Using a Timer in the 8051

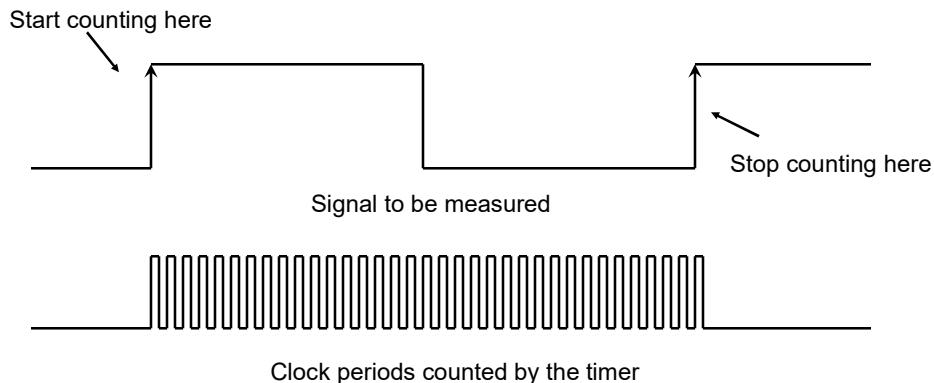
- To measure period we have to:
  - 1) Set up the timer.
  - 2) Connect the signal to be measured to any available pin. Also, set the pin as input.
  - 3) Reset the timer to zero.
  - 4) Wait for the input signal to transition from zero to one.
  - 5) Start the timer.
  - 6) Wait for the input signal to transition from zero to one.
  - 7) Stop the timer! The timer SFRs (THx, TLx) have the period in timer-input-period units!

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## Measure Period Using a Timer in the 8051



Signal period is about 35 timer periods. For a EFM8 board (@72MHz), the period of the signal would be approximately  $T=(35/72E6)*12=5.833\mu s$

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## Maximum measurable period?

$$65535*12/72\text{MHz}=10.92\text{ms}$$

To measure bigger periods, we need to keep count of the timer overflow.

(Of course, you could also work with a slower clock, for Example 12 MHz)

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## PeriodEFM8.c

- Available on Canvas