University of British Columbia
ELEC291/ELEC292

Lab 4: Capacitance Meter and Photo Electric Heart Rate Monitor

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February 17, 2023

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.

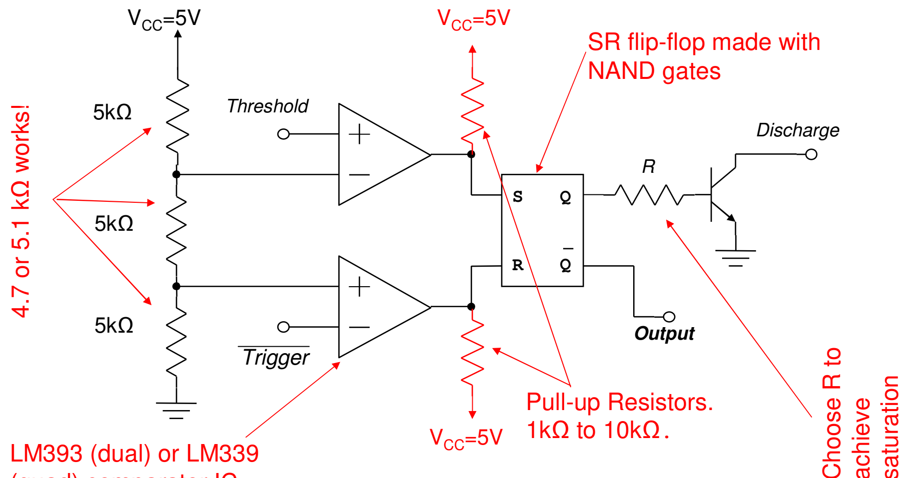
Lab 4

- 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 register in ELEC292, then both of you do the ELEC292 lab.

ELEC291 Lab

- 555 Timer:
  a) Build a 555 timer using discrete parts.
  b) Use a 555 timer to measure capacitance:
     - Range: 1nF to 1µF.
     - Display value using LCD.
     - Program EFM8 board using C language.

555 Timer Block Diagram



555 Timer astable (oscillator)

From National Semiconductors LM555 Timer datasheet

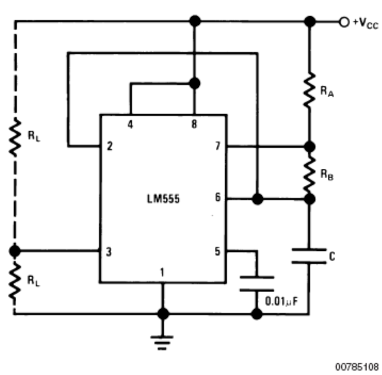
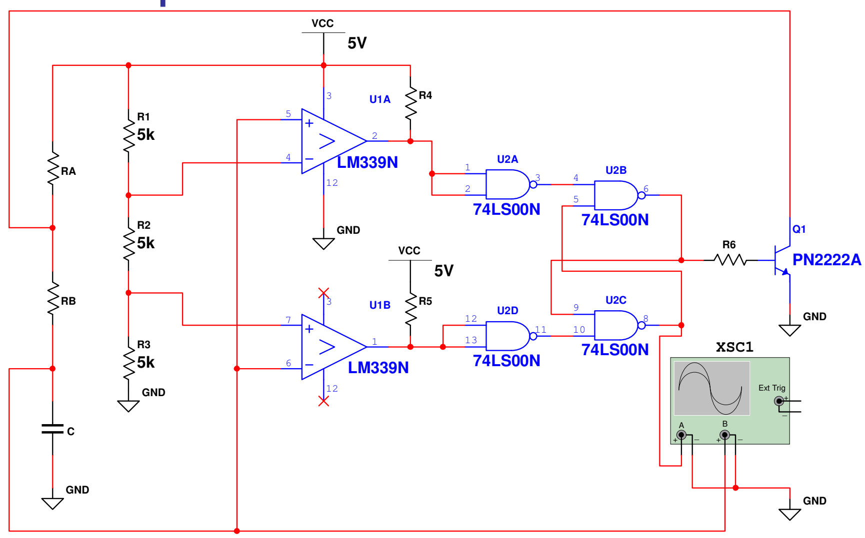


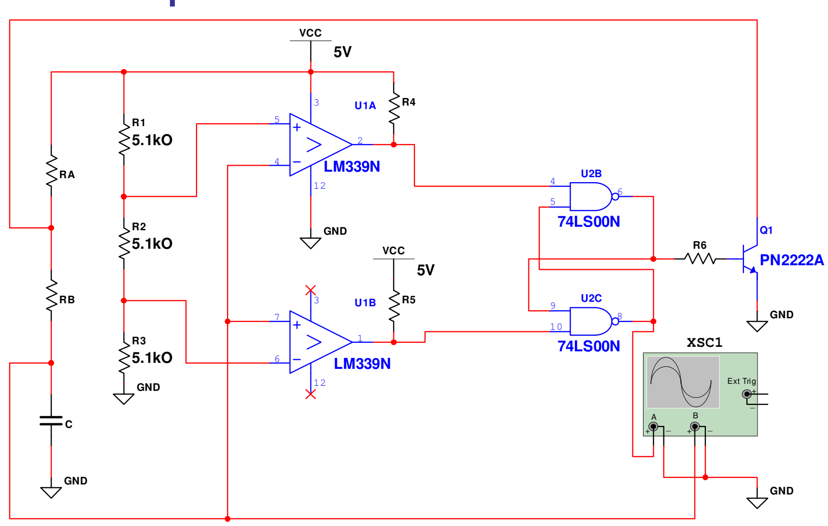
FIGURE 4. Astable

$$f = \frac{1}{T} = \frac{1.44}{(R_A + 2R_B)C}$$

Tip: Simulate the Circuit!



Tip: Simulate the Circuit!



Multisim

- NI Multisim. Download from:

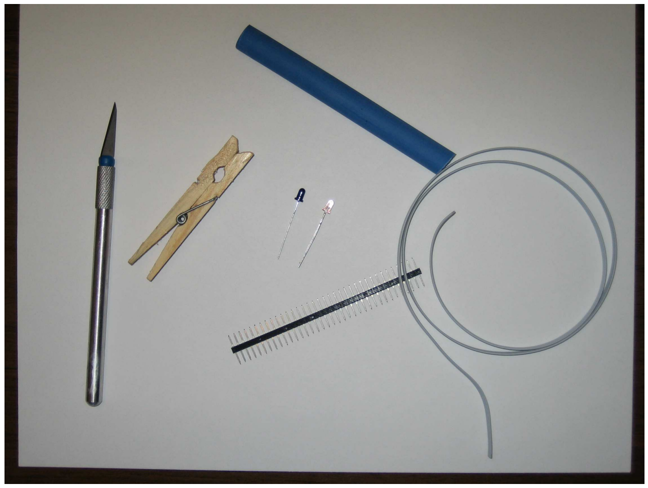
  http://courses.ece.ubc.ca/281/2020/NI_Circuit_Design_Suite_14_1_Education.exe

  The serial number assigned to UBC students is M71X71786

ELEC292 Lab

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

Finger Clip: before



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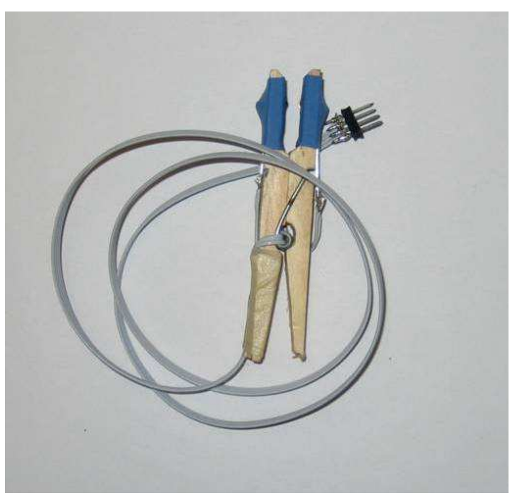
Finger Clip: after



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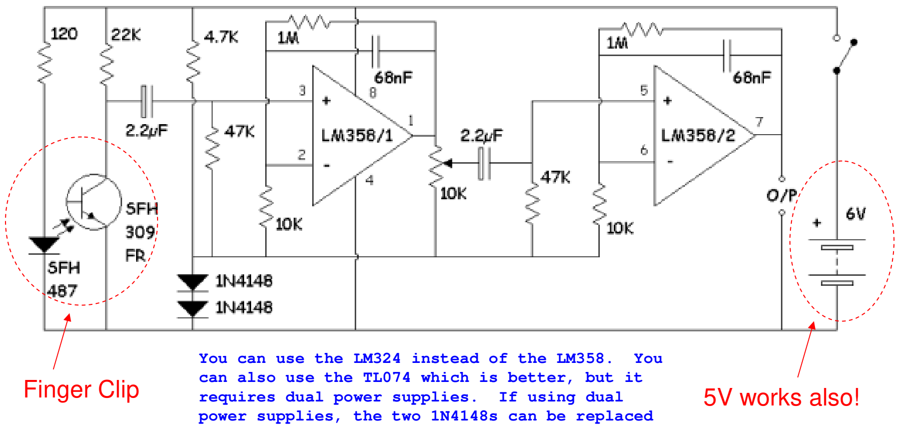
Amplifier/Filter

http://www.picotech.com/experiments/calculating_heart_rate/

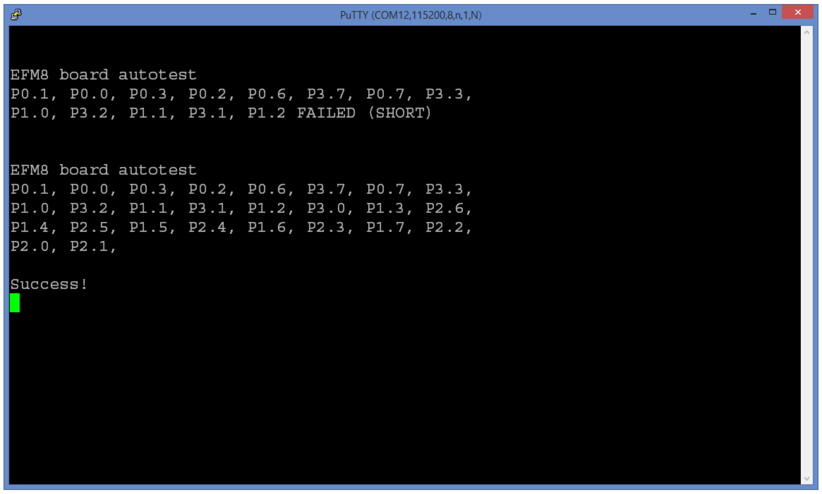


`You can use the LM324 instead of the LM358. You can also use the TL074 which is better, but it requires dual power supplies. If using dual power supplies, the two 1N4148s can be replaced with a connection to ground and the 4.7k resistor is not needed.`

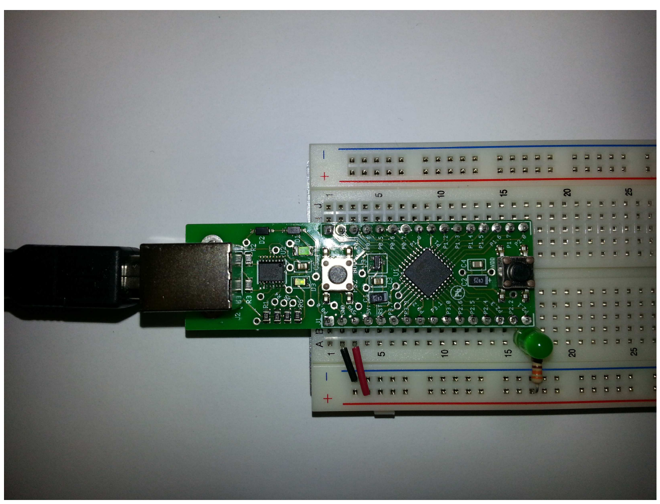
Testing The EFM8 Board

- 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:

Testing The EFM8 Board

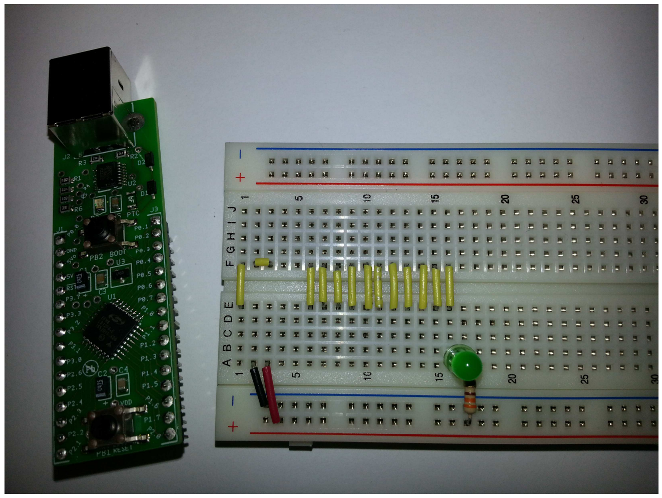


Testing The EFM8 Board

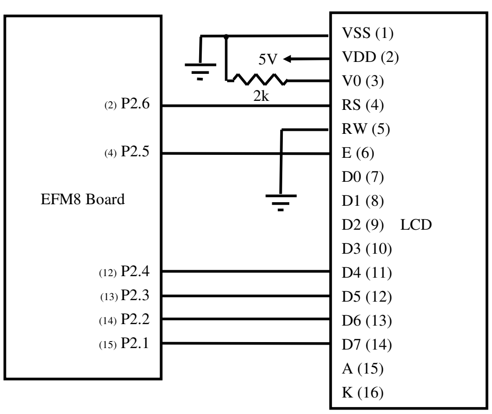


Testing The EFM8 Board

After testing the circuit, remove the ‘test’ wires from the breadboard!

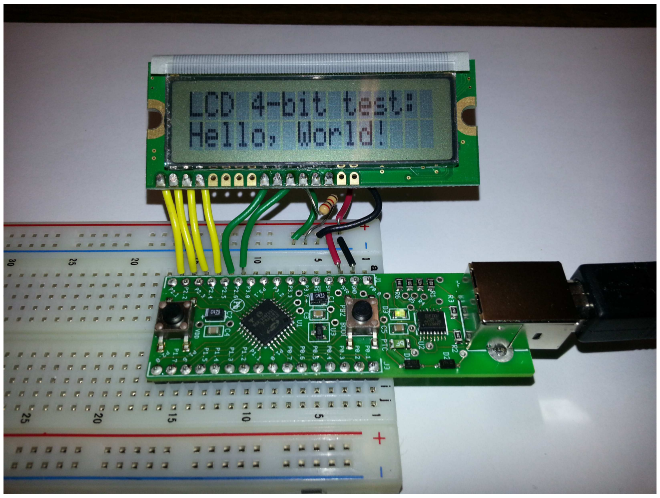


Attaching LCD to EFM8 board



- 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.

Attaching LCD to EFM8 board



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 P2_6
// #define LCD_RW Px_x // Not used in this code. Connect to GND
#define LCD_E  P2_5
#define LCD_D4 P2_4
#define LCD_D5 P2_3
#define LCD_D6 P2_2
#define LCD_D7 P2_1
```

Capacitor Types

- Ceramic. Small values, small size, good price, good tolerance (lowest around ±1%)
- Electrolytic. Large value, high tolerance (±10% minimum), don't age well, big size, very temperature sensitive.
- Tantalum. Large value, low voltage, small size, expensive, lowest tolerance around ±5%.
- Mica. Best capacitors ever! Lowest tolerance around ±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.

How to read Capacitor Codes

- Large capacitors have their values printed on them, for example 10μF, 50V, 85C.
- Most small capacitors use a three number code system:

1	0	4

10×10^4 pF

How to read Capacitor Codes

- Tolerance is indicated by a letter after the value:

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

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

How to read Capacitor Codes

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

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!

The EFM8LB1

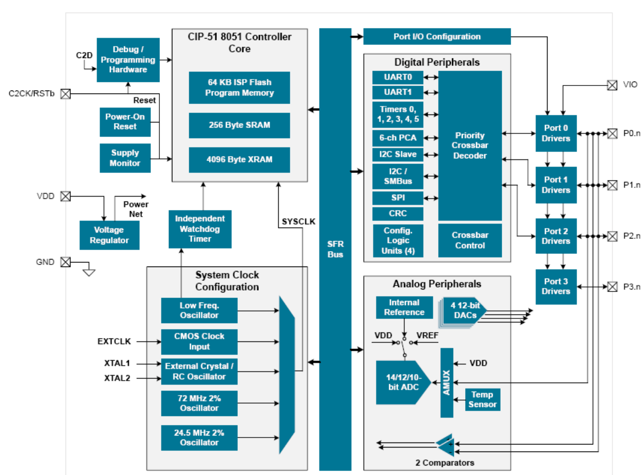


Figure 1.1. Detailed EFM8LB1 Block Diagram

Reference manual is 329 pages only!

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

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

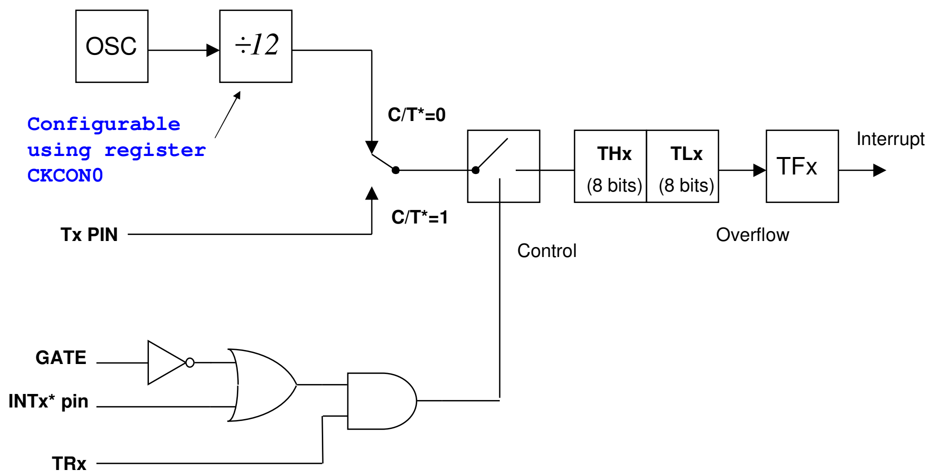
Bit	Name		Description
7 & 3	GATE		1: uses either INT0 or INT1 pins to enable/disable the timer/counter
6 & 2	C/T*		0: timer; 1: counter (pins T0 and T1)
All the other pins!	M1	M0	
	0	0	13-bit timer/counter
	0	1	16-bit timer/counter
	1	0	8-bit auto-reload timer/counter
	1	1	Special mode

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

TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0

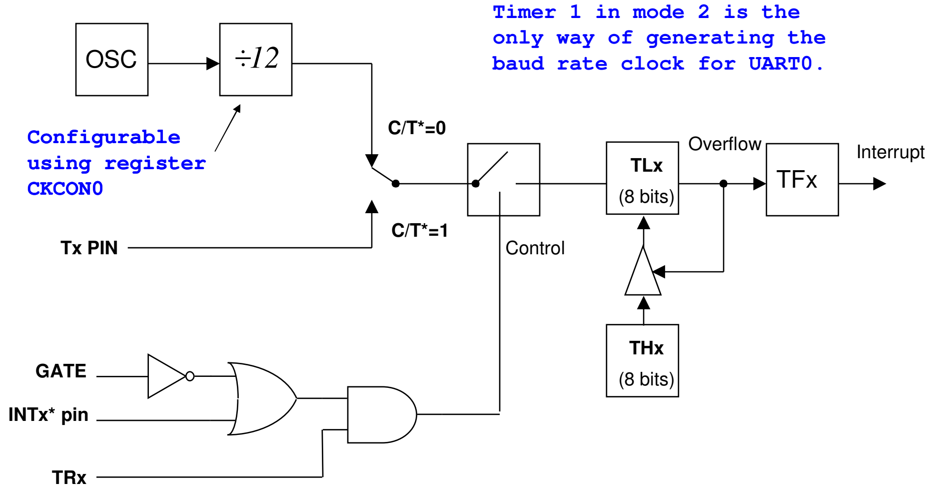
Bit	Name	Description
7	TF1	Timer 1 overflow flag.
6	TR1	Timer 1 run control.
5	TF0	Timer 0 overflow flag.
4	TR0	Timer 0 run control.
3	IE1	Interrupt 1 flag.
2	IT1	Interrupt 1 type control bit.
1	IE0	Interrupt 0 flag.
0	IT0	Interrupt 0 type control bit.

Timer/Counter 0 or 1 in Mode 1



Timer/Counter 0 or 1 in Mode 2

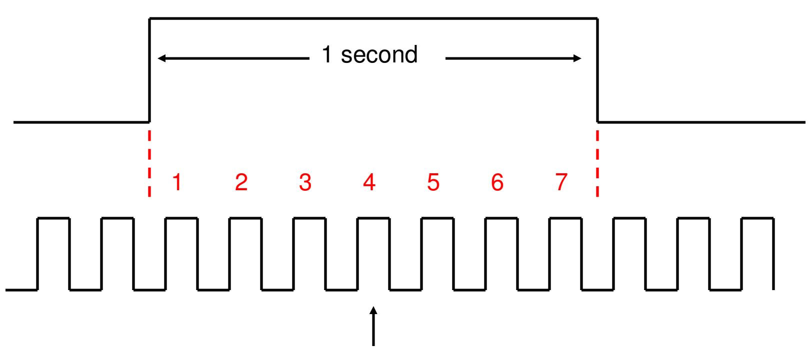
Timer 1 in mode 2 is the only way of generating the baud rate clock for UART0.



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!

Using a Counter to Measure Frequency



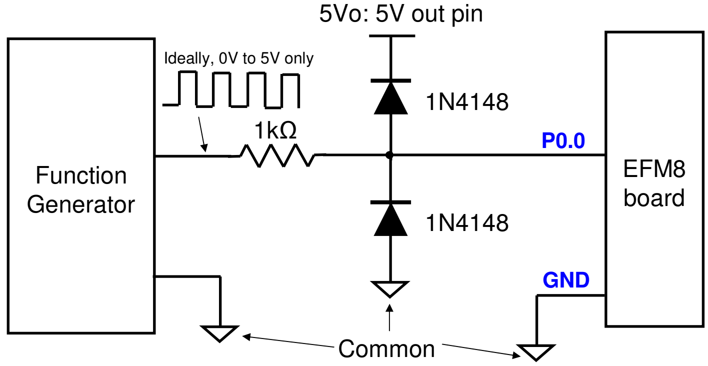
Quick: what is the frequency of this signal?

About 7 Hz!

FreqEFM8.c

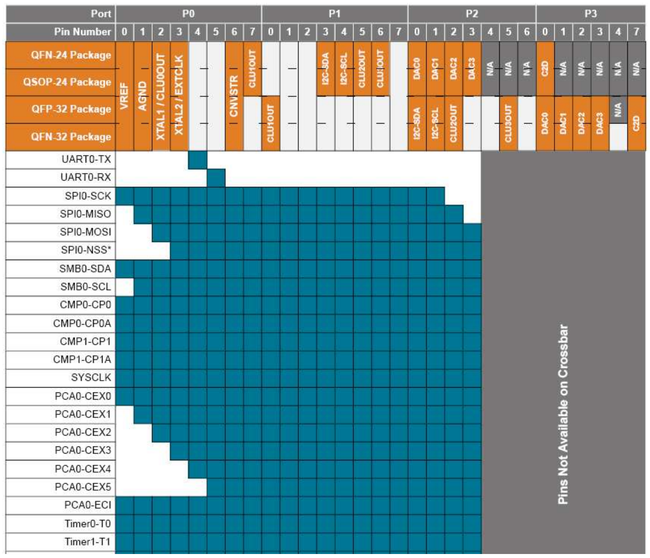
- Available on Canvas

Testing FreqEFM8.c with Lab Function Generator



A voltage limiter will prevent over-voltages that <u>will</u> damage your board!

The Crossbar (Figure 11.4 in reference manual)



If nothing else is enabled, T0 is assigned to P0.0.

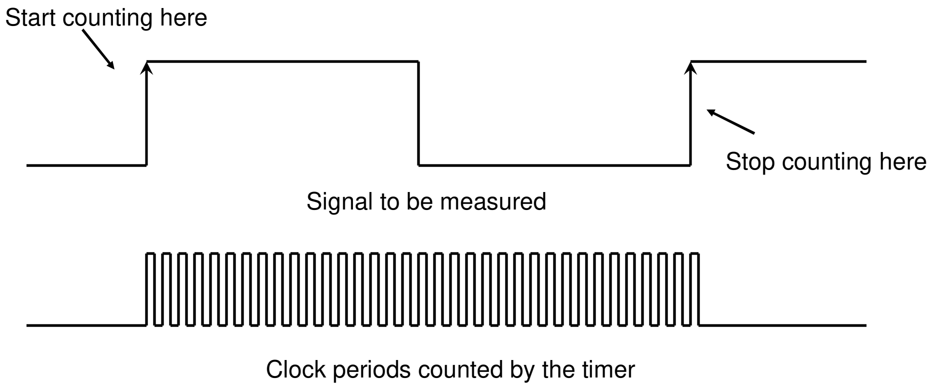
Measure Period Using a Timer in the 8051

- 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.

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 <u>any</u> 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!

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=5.8333µs

Maximum measurable period?

65535*12/72MHz=10.92ms

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)

PeriodEFM8.c

- Available on Canvas