University of British Columbia
ELEC291/ELEC292

Lab 4: Capacitance Meter and Photo Electric Heart Rate Monitor

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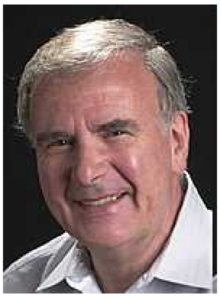
Hans R. Camenzind, the Inventor of the 555 timer



1934-2012

- https://www.youtube.com/watch?v=j3vpu67uu28
- https://www.youtube.com/watch?v=4rRf1V70eHE

Objectives

- Lab 4 requirements for ELEC291 and ELEC292.
- The 555 timer.
- Heart rate monitor circuit.
- Testing the F38x board.
- Attach an LCD to the F38x board.
- Read capacitors.
- C programming language:
  - Example: Measure frequency.
  - Example: Measure period.

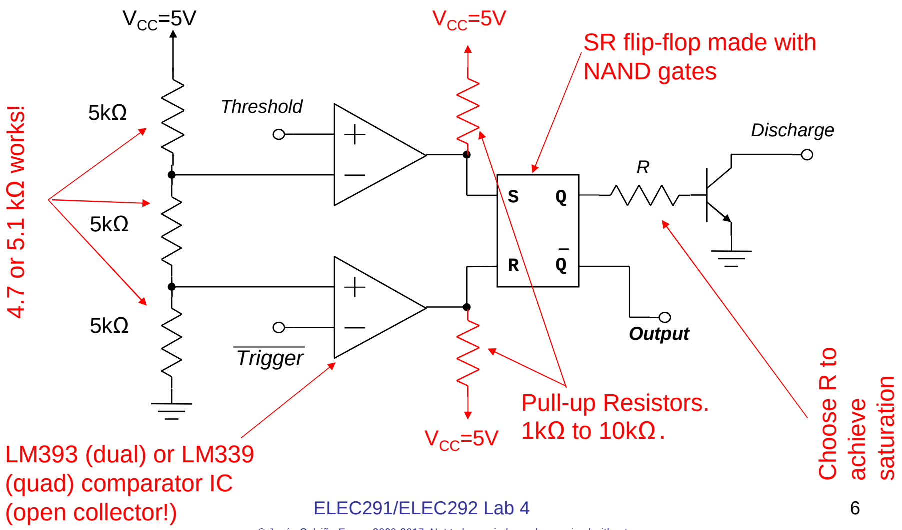
Lab 4

- 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.
- Due date: Thursday March 2nd.

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 F38x board using C language.

555 Timer Block Diagram



555 Timer astable (oscillator)

From National Semiconductors LM555 Timer datasheet

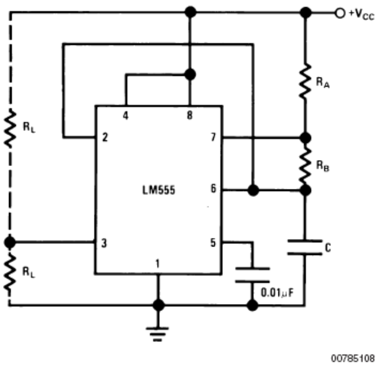
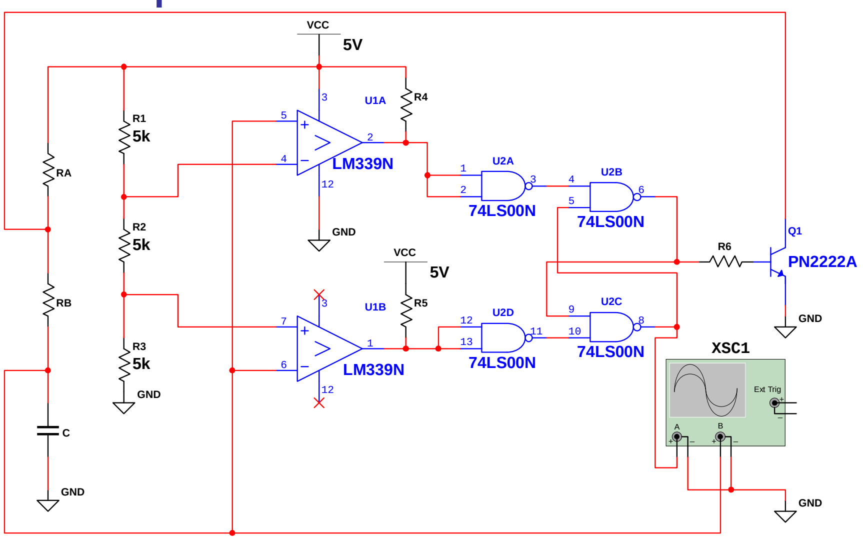


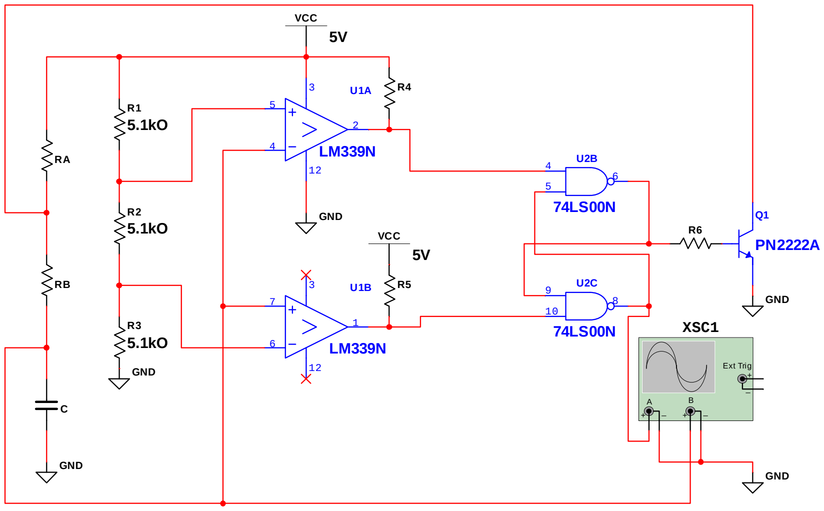
FIGURE 4. Astable

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

Tip: Simulate the Circuit!



Tip: Simulate the Circuit!



Multisim

- NI Multisim. Download from:

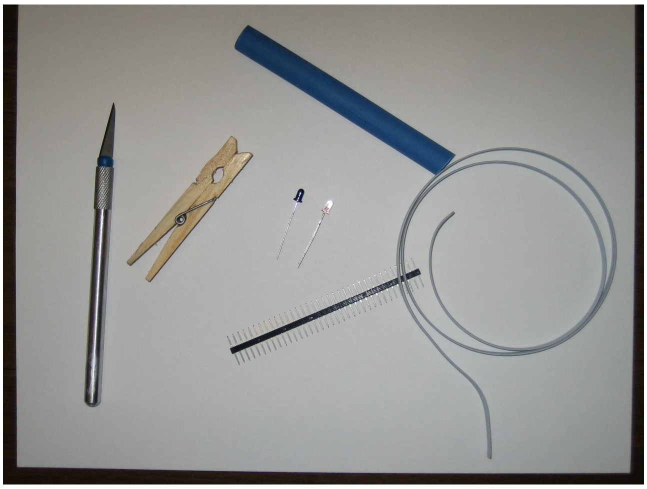
  http://download.ni.com/evaluation/labview/ekit/other/downloader/NI_Circuit_Design_Suite_14_0_Education.exe

  The serial number assigned to UBC students is M71X71786

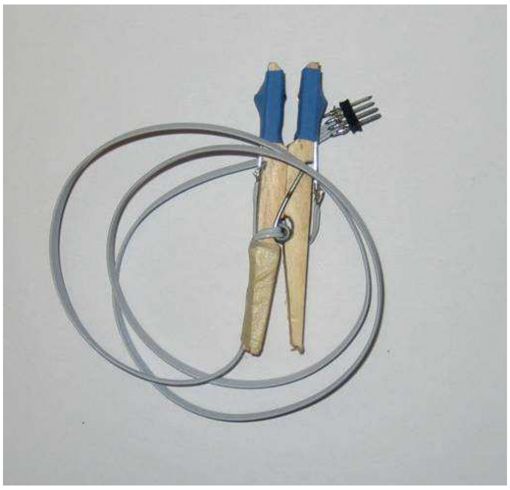
ELEC292 Lab

- 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 F38x board using C language.

Finger Clip: before

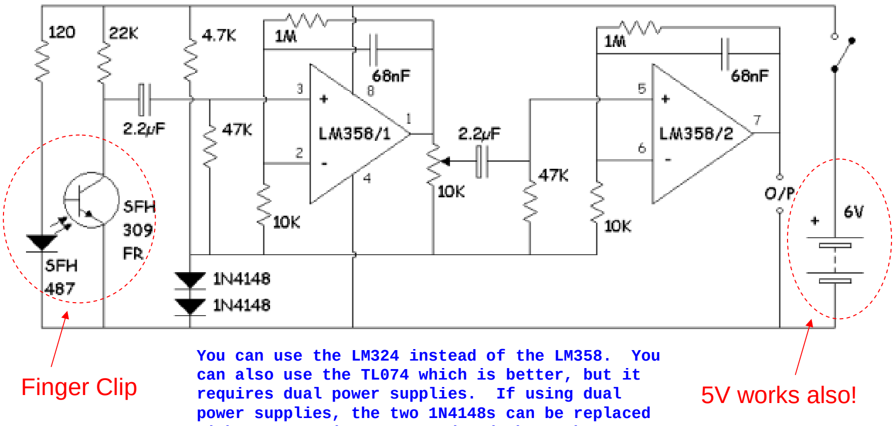


Finger Clip: after



Amplifier/Filter

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

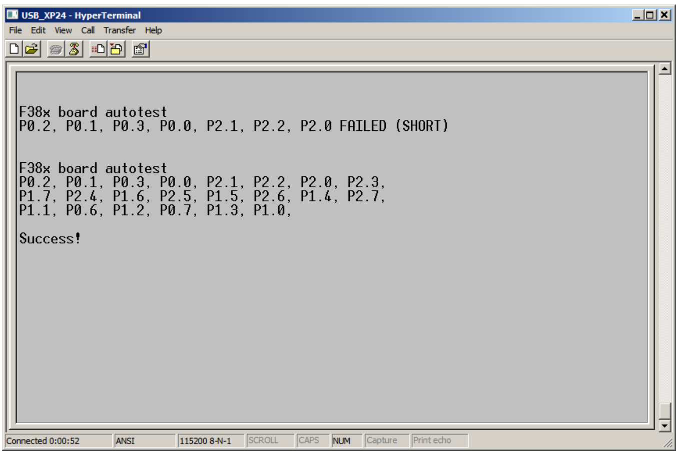


You can use the LM324 instead of the LM358. You can also use the TL074 which is better, but it requires dual power supplies. If using dual power supplies, the two 1N4148s can be replaced with a connection to ground and the 4.7k resistor is not needed.

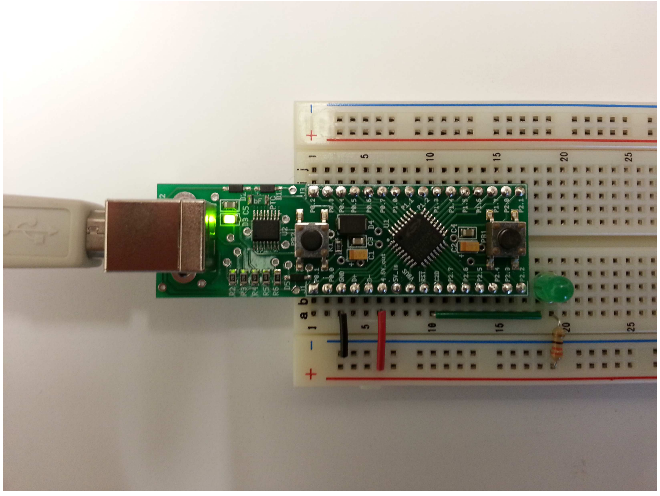
Testing The F38x Board

- Testing program available in Connect.
- Make the following connections:
  - P0_1 and P0_2
  - P0_0 and P0_3
  - P2_2 and P2_1
  - P2_3 and P2_0
  - P2_4 and P1_7
  - P2_5 and P1_6
  - P2_6 and P1_5
  - P2_7 and P1_4
  - P0_6 and P1_1
  - P0_7 and P1_2
  - P1_0 and P1_3
- Attach a resistor + LED to pin P3.0, marked as C2D in the F38x board.
- Open PuTTY, run the test program:

Testing The F38x Board

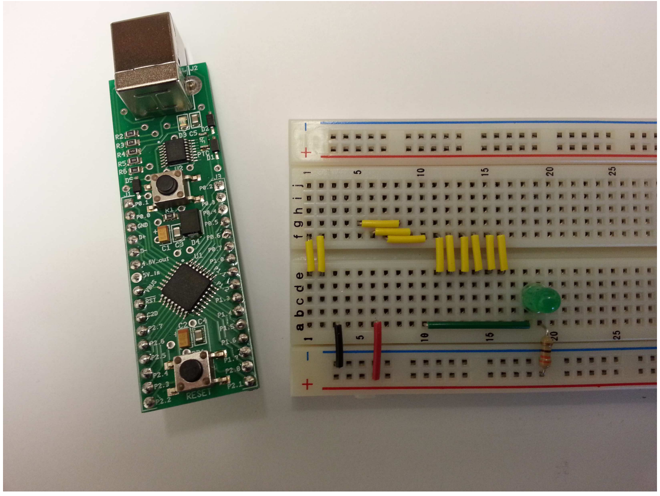


Testing The F38x Board



ELEC291/ELEC292 Lab 4 17

Testing The F38x Board



ELEC291/ELEC292 Lab 4 18

Attaching LCD to F38x board

Attaching LCD to F38x board

- Two examples in C:
  - LCD_4bit_F381.c: Configures and uses a Hitachi compatible LCD in 4-bit mode.
  - LCD_8bit_F381.c: Configures and uses a Hitachi compatible LCD in 8-bit mode.

LCD_4bit_F381.c

Pins used in the example:

```
#define LCD_RS P2_2
#define LCD_RW P2_1 // Not used in this code
#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
```


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 C8051F38C has 6 Timers / Counters + 5-channel PCA!

The C8051F38C

SILICON LABS

C8051F380/1/2/3/4/5/6/7/C

Full Speed USB Flash MCU Family

Analog Peripherals
- **10-Bit ADC (C8051F380/1/2/3/C only)**
  - Up to 500 ksps
  - Built-in analog multiplexer with single-ended and differential mode
  - VREF from external pin, internal reference, or V_{DD}
  - Built-in temperature sensor
  - External conversion start input option
- **Two comparators**
- **Internal voltage reference (C8051F380/1/2/3/C only)**
- **Brown-out detector and POR Circuitry**

USB Function Controller
- USB specification 2.0 compliant
- Full speed (12 Mbps) or low speed (1.5 Mbps) operation
- Integrated clock recovery; no external crystal required for full speed or low speed
- Supports eight flexible endpoints
- 1 kB USB buffer memory
- Integrated transceiver; no external resistors required

High Speed 8051 µC Core
- Pipelined instruction architecture; executes 70% of instructions in 1 or 2 system clocks
- Up to 48 MIPS operation
- Expanded interrupt handler

Memory
- 4352 or 2304 Bytes RAM
- 64, 32, or 16 kB Flash; In-system programmable in 512-byte sectors

Digital Peripherals
- 40/25 Port I/O; All 5 V tolerant with high sink current
- Hardware enhanced SPI™, two I²C/SMBus™, and two enhanced UART serial ports
- Six general purpose 16-bit counter/timers
- 16-bit programmable counter array (PCA) with five capture/compare modules
- External Memory Interface (EMIF)

Clock Sources

Data sheet is 321 pages only!

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

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

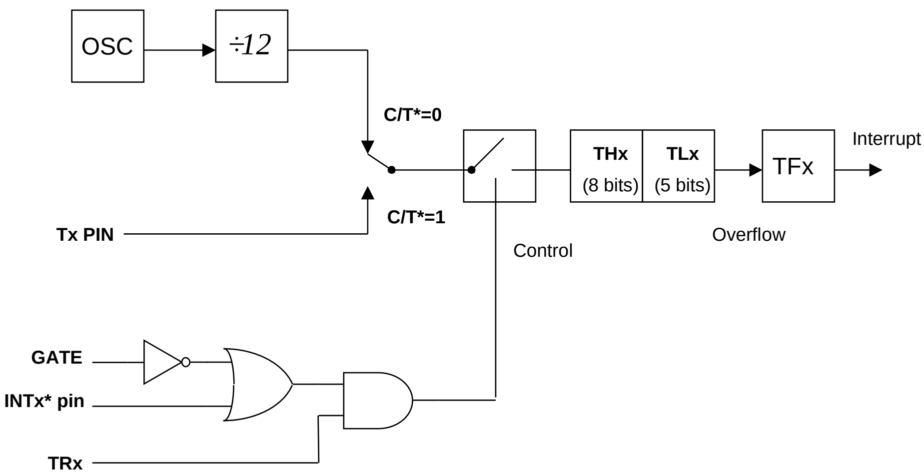
Bit	Name		Description
7 & 3	GATE		1: uses either INT0 or INT1 pins to enable/disable the timer/counter
6 & 2	C/T*		0: timer; 1: counter (pins T0 and T1)
All the other pins!	M1	M0	
	0	0	13-bit timer/counter
	0	1	16-bit timer/counter
	1	0	8-bit auto-reload timer/counter
	1	1	Special mode

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

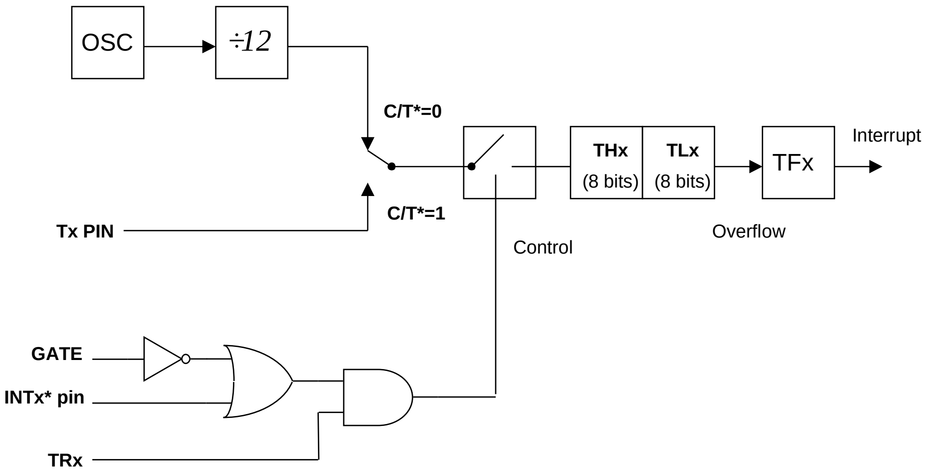
TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0

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.

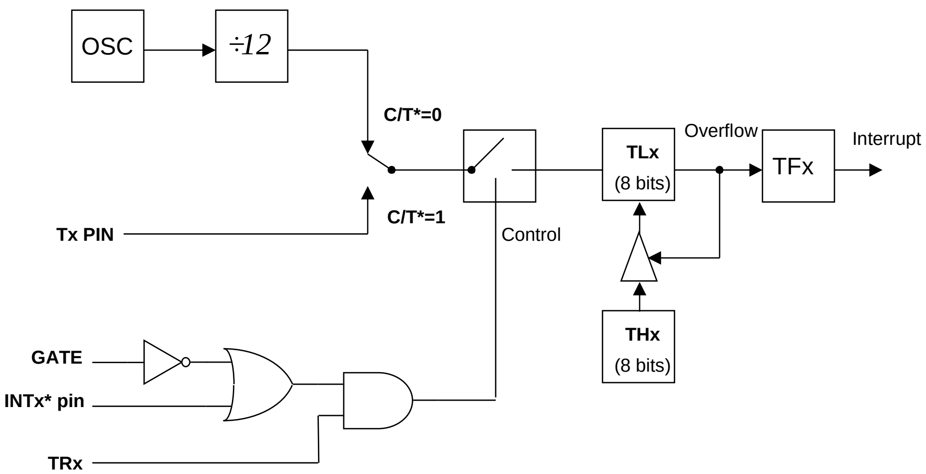
Timer/Counter 0 or 1 in Mode 0



Timer/Counter 0 or 1 in Mode 1



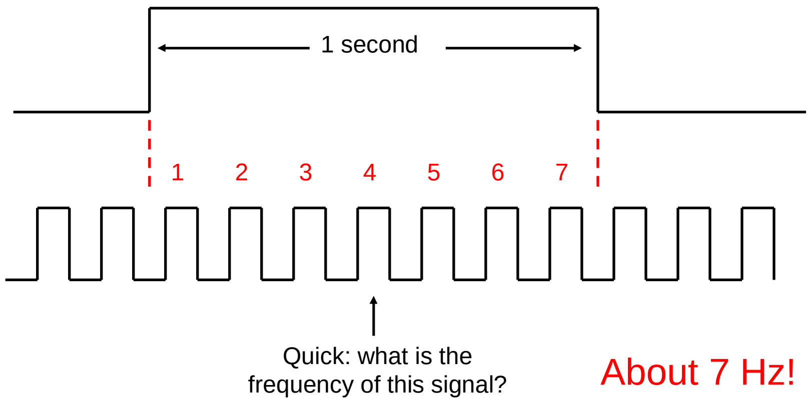
Timer/Counter 0 or 1 in Mode 2



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!

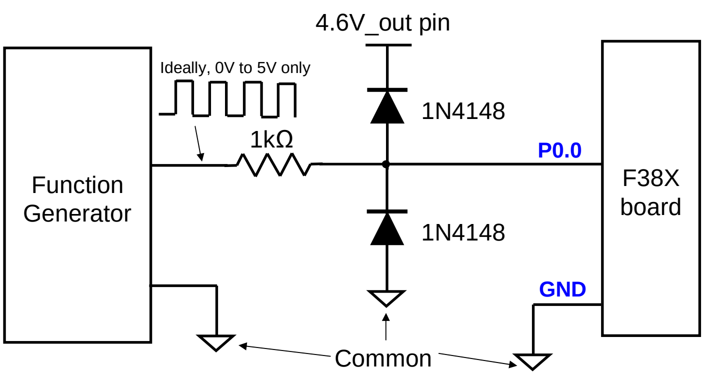
Using a Counter to Measure Frequency



Freq38x.c

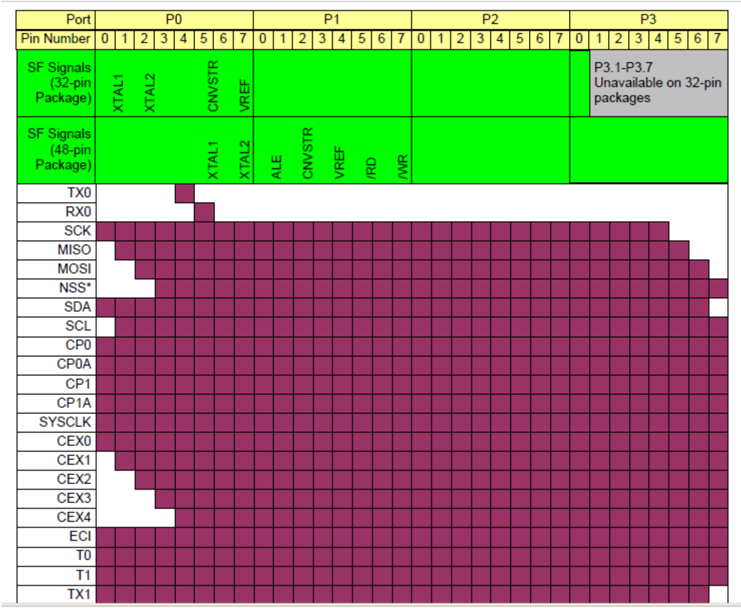
- Available on Connect

Testing Freq38x.c with Lab Function Generator



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

The Crossbar (Figure 20.3 in data sheet)



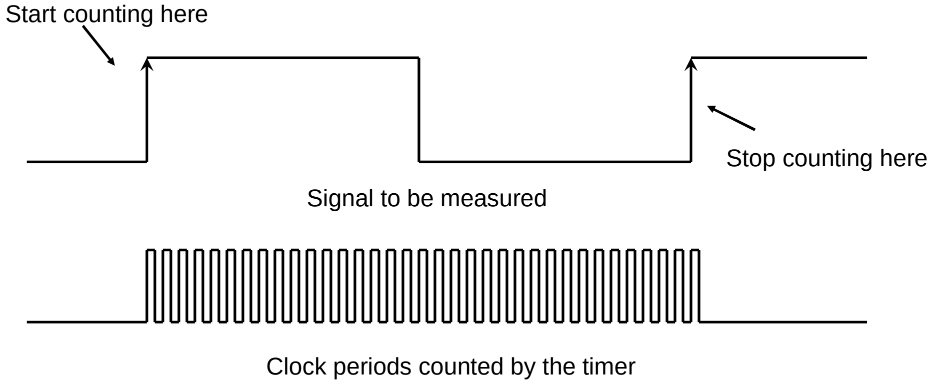
Measure Period Using a Timer in the 8051

- 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 F38x board (48MHz), the period of the signal would be approximately T=(35/48E6)*12=8.75µs

Maximum measurable period?

65535*12/48MHz=16.38ms

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

Period38x.c

- Available on Connect