ECE 4760: Laboratory 1

Digital Capacitance Meter.

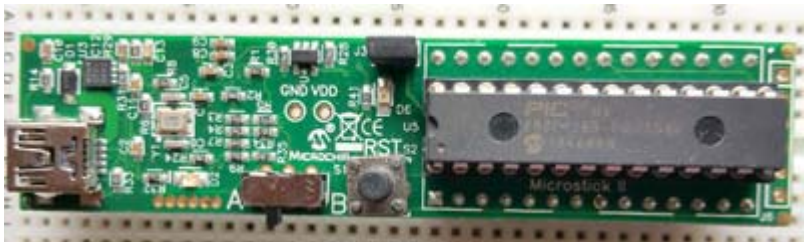
Introduction.

You will produce a digital capacitance meter (DCM) which displays the capacitance on the graphic LCD. The DCM will measure capacitances from 1 to 100 nF. But first you need to set up a board, arrange jumpers, learn how to connect peripheral devices and use the compiler.

Hardware

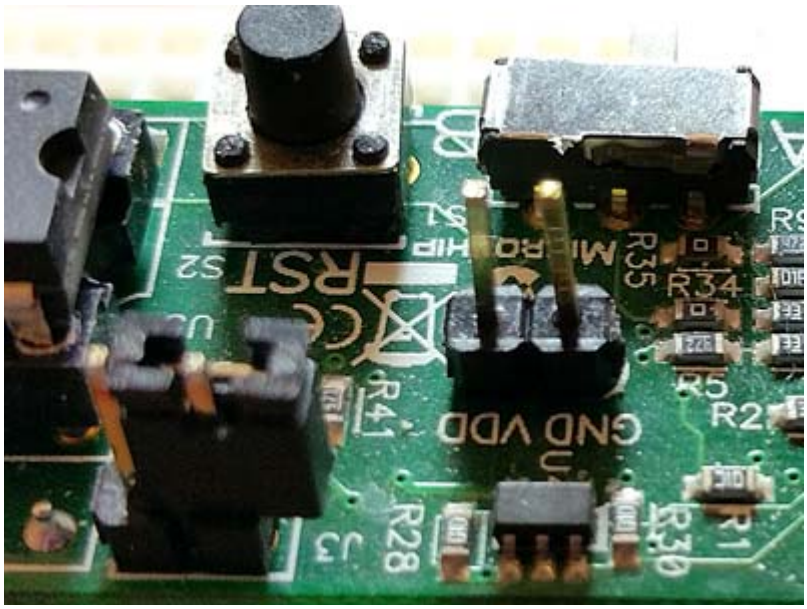
The hardware you will be using to support the PIC32 microcontroller is a small board providing:

- A target microcontroller (mcu) with onboard flash program memory, timers, ADC, and other peripherials.
- A 3.3 volt, 300 mA regulator. MCP1727 (DFN package marked CAAQ)
- A USB programming/debugging/power connection.
- A reset button and one user LED.
- A programming control switch. It MUST be set to the 'A' position as shown at the bottom-senter of the board.



In the initial testing phase of this lab, you are going to connect a TFT LCD screen to use for debugging and results.
The connections will be much like the photos on the TFT page, but you will get Vdd from the connection in the middle of the Microstick2.
You may want to solder a header pin there. Turns out that the GND and Vdd pins are not quite 0.1 inch apart, so you need to
bend the header slightly to make it fit. Also note that the jumper in the lower left of the image below is unmounted to turn off

the on-board LED.



Connections to MCU

The MCU peripherials can be configured to different pins, so some planning is necessary to fit the pieces together.
For this lab I suggest the following:

- TFT uses `pins 4,5,6, 22 and 25` (RB0, RB1, RB2, MOSI1, SCLK1)
  SCK: connected to RB14 on the PIC
  MOSI: connected to RB11 on the PIC
  CS: connected to RB1 on the PIC
  SDCS: left unconnected as I'm not using the microSD card for this
  RST: connected to RB2 on the PIC
  D/C: connected to RB0 on the PIC
  VIN: connected to 3.3V supply
  GND: connected to gnd
- Comparator 1 uses
  C1INA positive input `pin 7` (port B bit 3, or RB3)
  Negative input internally connected to IVref=1.2 +/- 0.06 volts
  C1OUT is in PPS output group 4, could use RPB9 which is `pin 18`
- Input capture 1
  IC1 signal is IC1 is in PPS input group 3, could use RPB13 which is `pin 24`

Software

Software you will use is freely downloadable and consists of:

- MPLABX version 3.05
- XC32 compiler version 1.40 (near bottom of page choose Downloads tab>Compilers)
- plib (near bottom of page choose Downloads tab>plibs)

More information

- Getting started with PIC32
- MPLABX IDE users guide
- 32 bit peripherials library -- **PLIB examples** **(ZIPPED)** -- (full Legacy PLIB 115 MB)
- 32 bit language tools and libraries including C libraries, DSP, and debugging tools
- XC32 Compiler Users Guide
- **MicrostickII pinout**
- PIC32MX250 **configuration options**
  - JTAG enable overrides pins 13, 14, and 15
  - Primary oscillator enable overrides pins 9 and 10
  - Secondary oscillator enalbe overrudes pins 11 and 12
- PIC32 reference manual
  (this is HUGE -- better to go to PIC32 page, then Documentation>Reference Manual and choose the section)
- **Specific pages from the PIC32 datasheet**
  1. PIC32MX250F128B **PDIP pinout** by pin
  2. PIC32MX250F128B ::: **Signal Names=>Pins** ::: **1**, **2**, **3**, **4**, **5**, **6**, **7** PDIP highlighted in green (for **PPS** see next tables)
  3. PIC32MX250F128B **Peripheral Pin Select (PPS) input table**
     example: UART receive pin ::: specify PPS group, signal, logical pin name
     `PPSInput(2, U2RX, RPB11);` //Assign U2RX to pin RPB11 -- Physical pin 22 on 28 PDIP
  4. PIC32MX250F128B **Peripheral Pin Select (PPS) output table**
     example: UART transmit pin ::: specify PPS group, logical pin name, signal
     `PPSOutput(4, RPB10, U2TX);` //Assign U2TX to pin RPB10 -- Physical pin 21 on 28 PDIP

Procedure

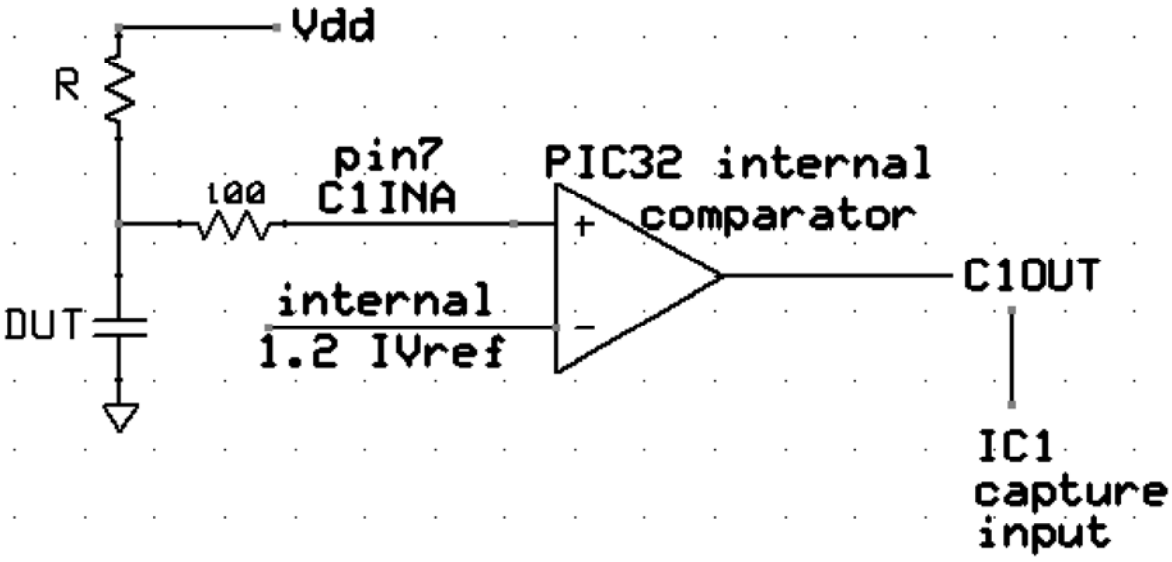
1. For most of the semester you will be useing the TFT LCD for output and debugging.
   Read the **TFT page**, then wire it up and run the run the test code.
   You will need to use some of the graphics library calls described there in this lab.
2. You may wnat to refer the the **ProtoThreads page** for the general threading setup.
   But note that the UART functions mentioned on that page were deleted for TFT compatability.
   The Protothreads page also has information on how to set up a **timer input event capture**, which you will need to do for this lab.
3. If you start by downloading and testing the project ZIP file on the TFT page, then you will have all the ProtoThreads libraries and TFT libraries.
4. Timing of all functions in this lab, ***and every exercise in this course*** will be handled by interrupt-driven counters, (including the builtin functions in ProtoThreads) and not by software wait-loops. This will be enforced because wait-loops are hard to debug and tend to limit multitasking. You may not use any form of a delay(mSec) function.
5. You can connect the **oscilloscope to the computer** with a USB cable (type-B connector) attached to the *back* of the oscilloscope (*not* the type-A connector on the front).
   To use the Tektronix software on the PC:
   1. Search for `OpenChoice Desktop` in the start menu, and start the program.
   2. When the main panel appears, choose `Select Instrument`.
   3. In the select dialog box, choose the `USB` device, and click `OK`.
   4. Back in the main panel, click `Get Screen`.

5. Copy or save the image or data to your lab report.

Capacitance measurement

The approach we will use is to measure the time it takes for a RC circuit to charge a capacitor to a given level. Using the IVref internal voltage reference, then the level will be $v(t_{1.2})=1.2\pm0.06$. Since the internal reference has 5% possible error, you will need to measure the voltage for your chip. Specifically, we will use the internal analog comparator as shown in the following diagram to trigger a timer capture event. The `C1OUT` pin needs to be connected to one of the event capture channels, with `IC1` shown. Since R will be known, we can get C because the voltage on the capacitor $v(t)=Vdd(1-exp(-t/\tau))$ with $\tau=R*C$. The capacitor shown is the device you are trying to measure.You must choose R so that the capacitor charging time is not too short or too long. If it is too short you will lose measurement accuracy. It if is too long, the timer will overflow. The 100 ohm resistor limits discharging current when using pin 7 (B3) as an output. The following code snippet is sufficient to set up internal compare1 and read `C1OUT` with the oscilloscope.

```
//set up compare 1
CMP1Open(CMP_ENABLE | CMP_OUTPUT_ENABLE | CMP1_NEG_INPUT_IVREF);
PPSOutput(4, RPB9, C1OUT); //pin18
mPORTBSetPinsDigitalIn(BIT_3); //Set port as input (pin 7 is RB3)
```



One thread of your program will have to (in time order):

1. Drive C1INA (PortB3) to zero by making it an output and clearing the bit, then wait long enough to discharge the capacitor through 100 ohms. Since R and the 100 ohm resistor form a voltage divider, to dischage to zero volts with 1% accuracy, `R>100*(100ohms)`.
2. Convert C1INA (PortB3) to an input and start a timer connected to the chosen capture unit.. The capacitor will start to charge toward Vcc.
3. Detect when the voltage at C1INA (PortB3) is greater than than the IVref. That is, you will have to record when the comparator changes state. Do this by connecting the comapator output to the input capture IC1. Using input capture gives better timing accuracy and more dynamic range than polling or an interrupt.
4. Print capicitance to the TFT.
5. Repeat

I suggest that you organize the program as follows:

- **Protothreads** maintains the ISR-driven, millisceond-scale timing.
- **Capture ISR** copies IC1 into a variable. `capture1 = mIC1ReadCapture();` The actual IC1 capture is done in hardware.
- **Main** sets up peripherials and protothreads then just schedules tasks, round-robin.
- **Measure Thread**
  - Does step 1 above
  - Waits for the discharge using `PT_YIELD_TIME_msec(wait_time)`
  - Does step 2 above
  - Waits for capture event (step 3)
  - Computes the capacitance and updates the LCD.
  - waits for 200 mSec using `PT_YIELD_TIME_msec(200)`
- **Blink Thread** Blinks a circle on the LCD as a hearbeat, at 1/second.

Assignment

Timing of all functions in this lab, ***and every exercise in this course*** will be handled by interrupt-driven counters, not by software wait-loops.
ProtoThreads maintains a ISR driven timer for you! This will be enforced because wait-loops are hard to debug and tend to limit multitasking.

Write a Protohreads C program which will:

- The LCD should be updated every 200 mSec or so.
- An circle on the LCD should blink about 1/second.
- The capacitance should be measured as quickly as possible as described above.
- The range of capacitances to be measured is 1 nf to 100 nf.
- The program should detect whether a capacitance is present or not and display an appropriate message if no capacitor is present.
- If present, format the capacitance as an ASCII number and prints the message `C = xx.x nf` to the LCD. There should be exactly one digit shown after the decimal point.

When you demonstrate the program to a staff member, you should demonstrate that the capacitance is correct within the tolerance of the resistors you use. Your program should not need to be reset during the demo.

Your written lab report should include the sections mentioned in the policy page, and :

- How you converted time to capacitance
- A heavily commented listing of your code.
- A screen capture of the oscilloscope showing the charge/discharge waveform.
- Explain how you could make the meter autoranging.
