Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
6.115 Microprocessor Project Laboratory Spring 2020

Final Project Tip
Detecting Light with the PSoC Transimpedance Amplifier (TIA)

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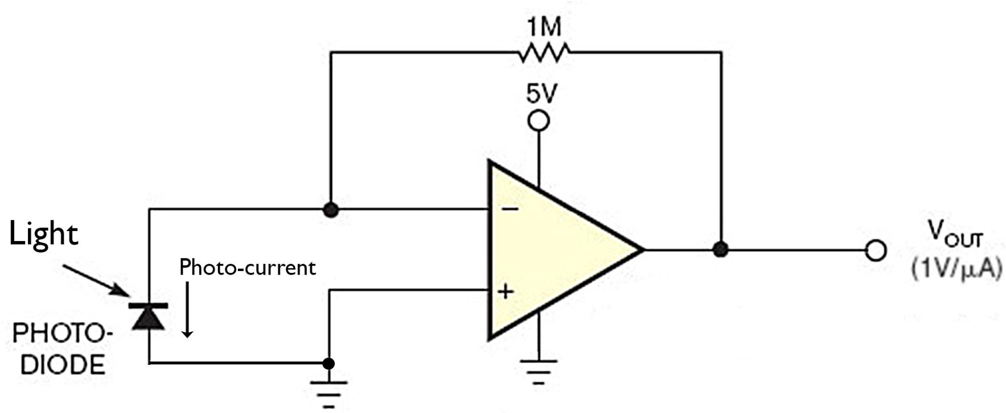
So why is the PSoC my "desert island part"?

Well, we obviously had very little time to assemble our Kovid Kit before we had to decamp from Cambridge. You probably do not have a lot of things you might have wanted for your final project. For example, it might be nice to have photodiodes or other photo detectors, like the kind used in the SpinDude tomography system that I showed you in lecture. Heck, it might be nice just to have a decent selection of resistors with more values than only 430 Ohms! What to do? We could bemoan our situation and give up, or we could snap our fingers and alter reality with the power of PSoC 5LP!

Did you know that an LED (from your Kovid Kit) can be used as a photodiode?

Yes, True Believers! If you put current IN to an LED it the right way, it glows. But, if you shine a light ON an LED, it will become a current source, and we can use the current that flows OUT to detect light level! Awesome. A typical circuit looks like this:




Notice that the photodiode is used in a strange way in this circuit. The voltage across the diode is near zero. The "photo-current" that flows down the diode is in the "reverse" or leakage direction. It is, therefore, a relatively small current. We would be lucky for a reasonably bright illumination to produce anywhere between one and twenty microamps (e.g., 1e-6 to 2e-5 amps). The op-amp circuit, sometimes called a "transimpedance amplifier (TIA)," makes it possible to detect this photo-current with a microcontroller. The TIA converts a current input to a voltage output. When the photo-current flows, the op-amp output voltage rises to drive current back through the feedback resistor (1 megaohm in the example) to balance the current at the inverting terminal. That is, the photo-current flowing down through the photodiode is balanced or fed by the current flowing "back" through the 1 megaohm resistor. Notice that this convenient circuit allows us to use a "single-sided" op-amp, which operates between a positive voltage (five volts in this case) and ground for its power supply rails.

Really cool! The problems are: we don't have a photodiode, and we don't have an op-amp, and we don't even have a 1 megaohm resistor. Hmmmmmm, what to do? Time to borrow a piece of magic from Creator and the mighty PSoC!


PSoC 5LP, available on your "Big Board" and also your "Stick", offers a TIA as a drag-and-drop part! And we can press an LED from our Kovid Kit into service as a photodiode! Here's my demo:

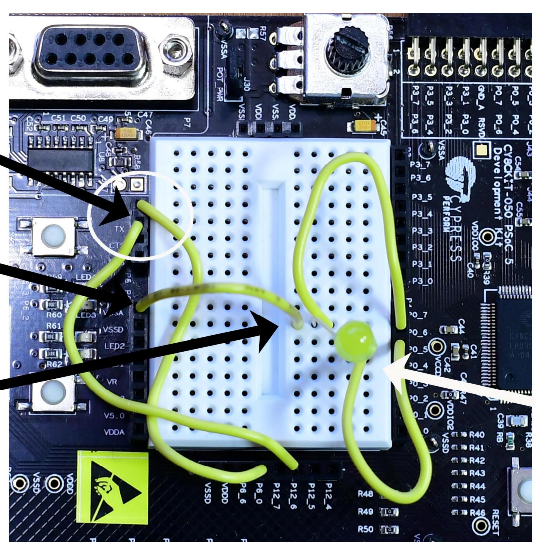
1. First, I added this wiring to my "Big Board". Be careful. Do NOT blow up your Big Board. You may be better off pressing your "Stick" into service for this experiment if you want to try it.

Here’s my “Big Board” wiring!

Ignore these two wires, they are “leftovers” for the serial Kable....

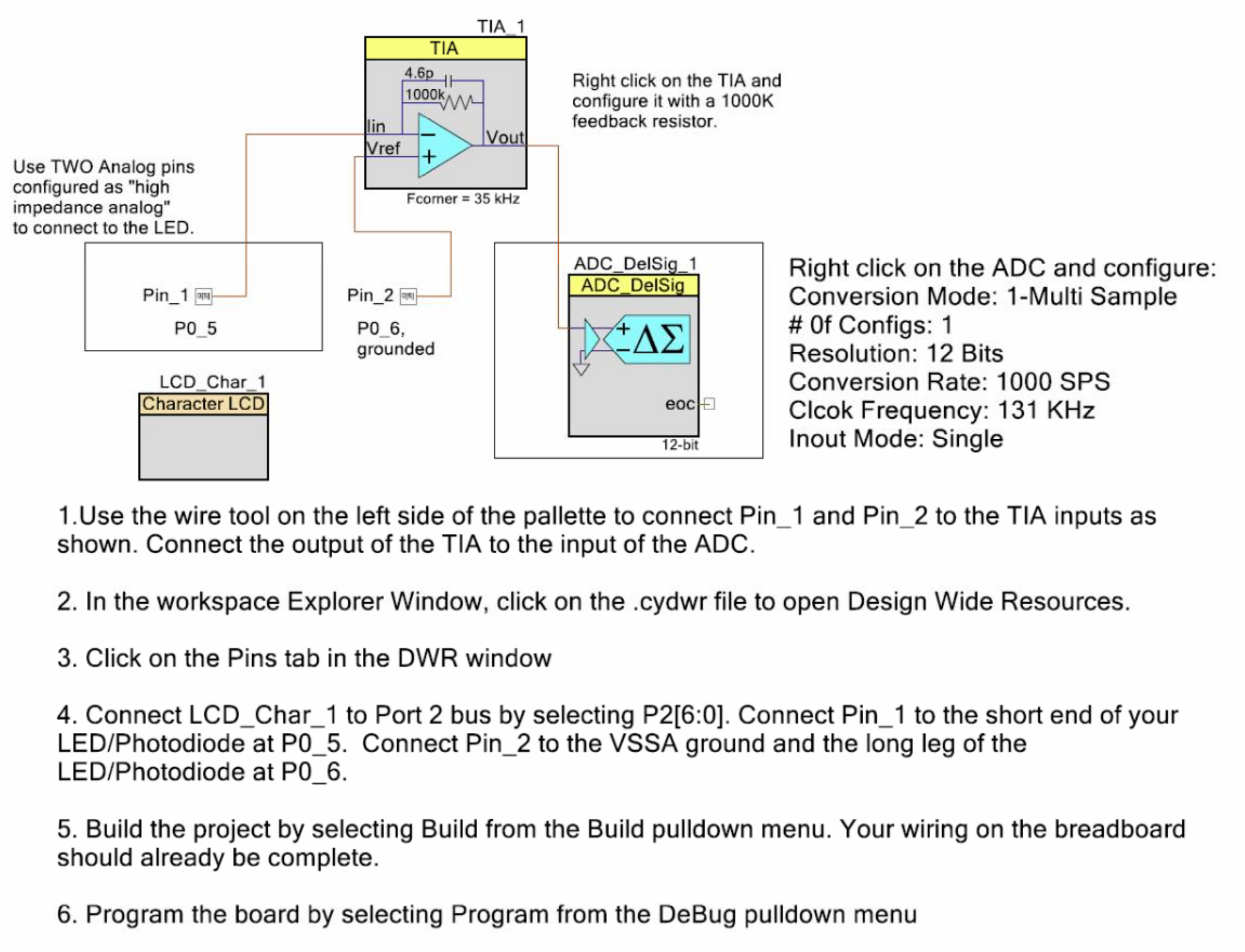
This wire goes from “VSSA,” which is analog ground, to a breadboard row.

The “long” (+) leg of the LED, VSSA, and a wire to P0_6 are all connected on this breadboard row....

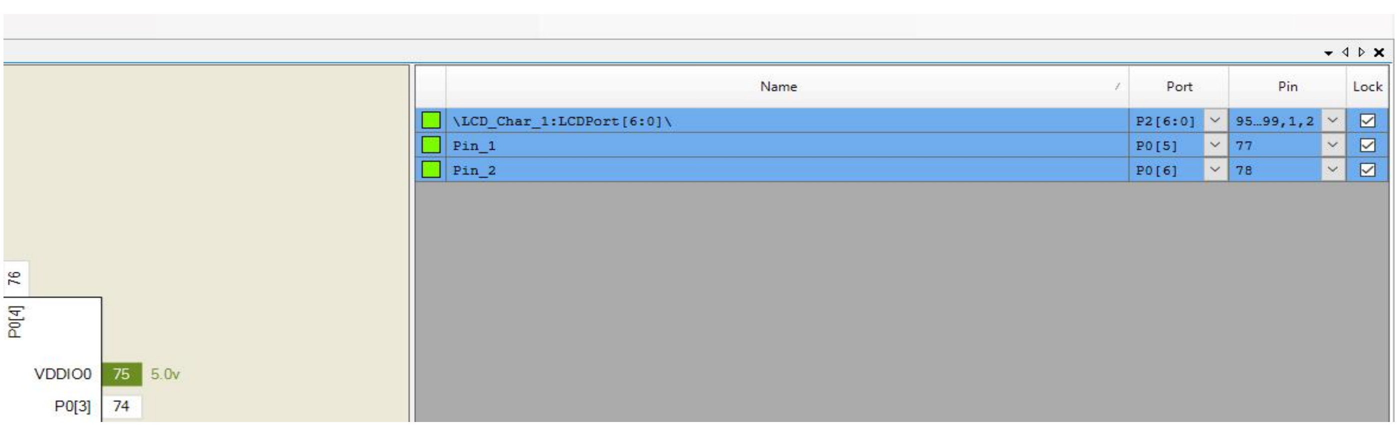


The “short” (-) leg of the LED and a wire to P0_5 are both connected on this breadboard row BELOW the VSSA row.

2. I MODIFIED my "Exercise 2" project from the 6.115 course webpage. The original project, which you work on in Exercise 4 of the second take-home lab, allows you to read the voltage from a potentiometer using an ADC and then display the ADC output on the LCD. Here, I modified the "TopDesign" so that I was no longer reading the POT. Instead, I'm reading the output of a PSoC 5LP TIA connected in between the external LED/Photodiode and the ADC. Take a look:



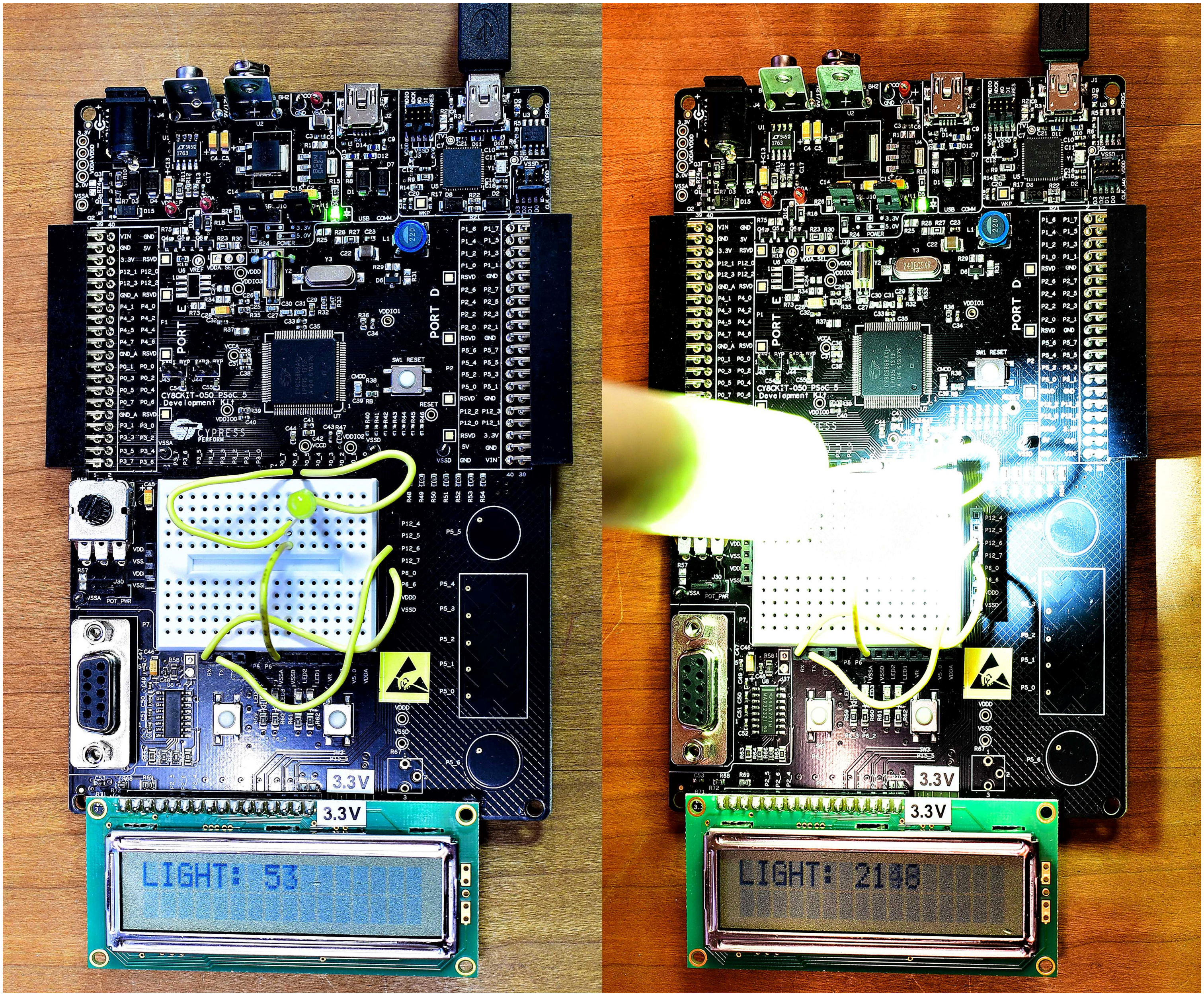

3. Here are the pin assignments in the Design Wide Resources:



4. No 1 megaohm resistor on your desert island? No problem. The TIA has it built in as one of its configuration choices. Just snap your fingers....
5. And here's a look at the code... It's very similar to Exercise 2, I've just added a command for "TIA_1_Start()" to fire up the TIA hardware:

```
#include <device.h>

uint16 adcResult = 0;

void main()
{
      unsigned char j = 50;                     // milliseconds delay


      LCD_Char_1_Start();                             // initialize lcd
      LCD_Char_1_ClearDisplay();
      LCD_Char_1_PrintString("LIGHT: ");

      ADC_DelSig_1_Start();                     // start the ADC_DelSig_1
      ADC_DelSig_1_StartConvert();        // start the ADC_DelSig_1 conversion

    TIA_1_Start();                    // Fires up the transimpedance amp hardware...

    for(;;)
    {
            if( ADC_DelSig_1_IsEndConversion(ADC_DelSig_1_WAIT_FOR_RESULT) )
            {
                  LCD_Char_1_Position(0, 7);
                  LCD_Char_1_PrintString("      "); // clean up the previous display
                  LCD_Char_1_Position(0, 7);
                  adcResult = ADC_DelSig_1_GetResult16(); // read the adc and
      if (adcResult & 0x8000)
            {
            adcResult = 0;       // ignore negative ADC results
            }
            else if (adcResult >= 0xfff)
            {
            adcResult = 0xfff;      // ignore high ADC results
            }
                  LCD_Char_1_PrintNumber(adcResult);
                  CyDelay(j);                           // delay in milliseconds
            }
    }
}
```

6. When I blast the project into my "Big Board," I get the behavior shown below, with and without a flashlight:




Sweeeet..........