After you get a good score in simulation, you should debug on the real board. Because of the complexity of the system and the possibility of hardware errors, we strongly suggest you perform the same three tests: 1) just the ADC; 2) ADC and display; and 3) ADC, display and SysTick.

Part e) There are many ways to build a transducer. If your potentiometer has tabs, then you will need to gently bend them so the pot will plug into the breadboard. Be careful not to bend the pins. I suggest you consult a data sheet for your potentiometer to verify which pins refer to the three pins shown in Figure 14.1. The data sheet for the Bourns PTA series of slide pots can be found at BournsPTASlidePotentiometer.pdf (/c4x/UTAustinX/UT.6.01x/asset/BournsPTASlidePotentiometer.pdf). The next video shows how I bent the tabs on my slide pot.

HOW TO BEND TABS ON THE SLIDE POT

0:00 / 2:15 1.0x

DR. JONATHAN VALVANO: In this video, we're

going to show you how to configure the slide pot, the potentiometer,

to do this lab.

Most of the potentiometers have these extra tabs.

Now, notice that there are two types of pins on here.

The pins labeled one, two, and three, those are the important pins.

Don't bend those.

But these other big fat tabs we don't need.

So I'm going to bend them out of the way.

So I grab my suppliers, I hold on tight, and I bend it out of the way.

Now, notice I didn't bend pin one, two, or three.

Help

I just bent one of these tabs.

So I'm going to take all the tabs that I don't need to

and I'm going to bend them out of the way.

And that was two.

Take this one, bend it out of the way.

Take this one, bend it out the way.

OK.

So now I have left three pins.

Pin three is going to be connected to plus 3.3.

Pin one will go to ground, and pin two will

be connected to the analog-to-digital input.

And as we saw, we're going to use PE2, which is analog channel one.

So now I can flip this over and plug it into the protoboard.

Notice that pin (three) is going to be tied to 3.3,

and down here we have pin one going to the ground-- that's this one--

and pin two is going to the analog-to-digital input.

And so now we have our slide pot here, which

can be used to create our analog voltage.

One last important step is we're going to convert this pot to a distance

measure by attaching a scale to it.

And so if I define the measurement point as right here, that

is 0 millimeters, 5 millimeters, 10 millimeters-- you see,

my edge is right here at 10 millimeters-- 15, and lastly 20.

Now some pots have more or less millimeters,

but they all go from one side to the other.

And so now I've created the transducer, which I can use to measure distance.

Have fun building it.

Help

If your pot does not plug into the breadboard, attach three wires to the pins by soldering or twisting solid wire very tightly on the three pins.

You will need a mechanical definition for “true” distance. A cursor in Figures 14.8 and 14.9 was created by twisting a solid wire around the armature. I glued the metric ruler onto the slide pot positioning the ruler so the zero-position of the slide pot (closest to pin 1) lined up with the zero-position of the ruler. I defined truth as the position of the cursor over the ruler. Feel free to define truth as however you wish. For example, you could skip the cursor and define truth as one edge of the armature itself. If you are gluing, be careful not to get glue into the potentiometer. The potentiometer may have places where it is nonlinear. So you may have to run the grader until your find a set of points that are linear enough. The full scale range may be any value from 1.5 to 10.0 cm, depending on your potentiometer. The full scale range does not matter.

The real board uses the PD3 analog input to measure voltage, so Vin (pin 2 of the potentiometer in Figure 14.1) must be connected to both PE2 (or PE3 or PE5) for your measurement and to PD3 for the real-board grader measurements.

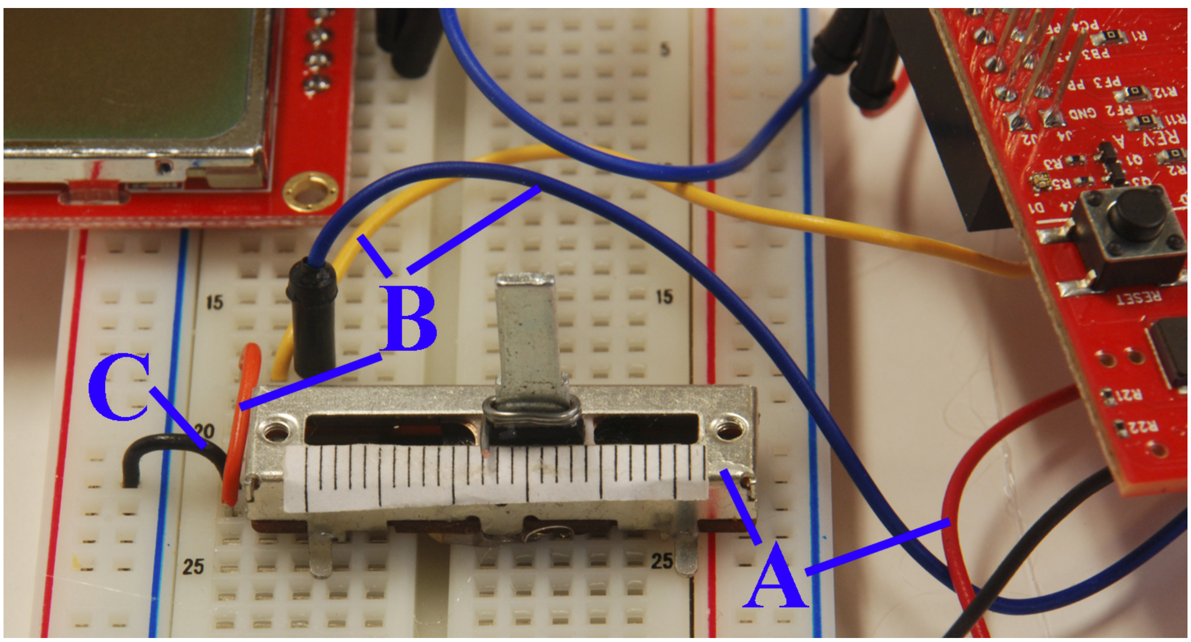

Figure 14.8. Hardware setup for Lab 14, showing the slide pot. In this system the label A is +3.3V, which is also connected to pin 3 of the potentiometer. The label B is pin 2 of the potentiometer, which is also connected both to PE1 and PD3. Label C is ground, which is also connected to pin 1 of the potentiometer.

Help

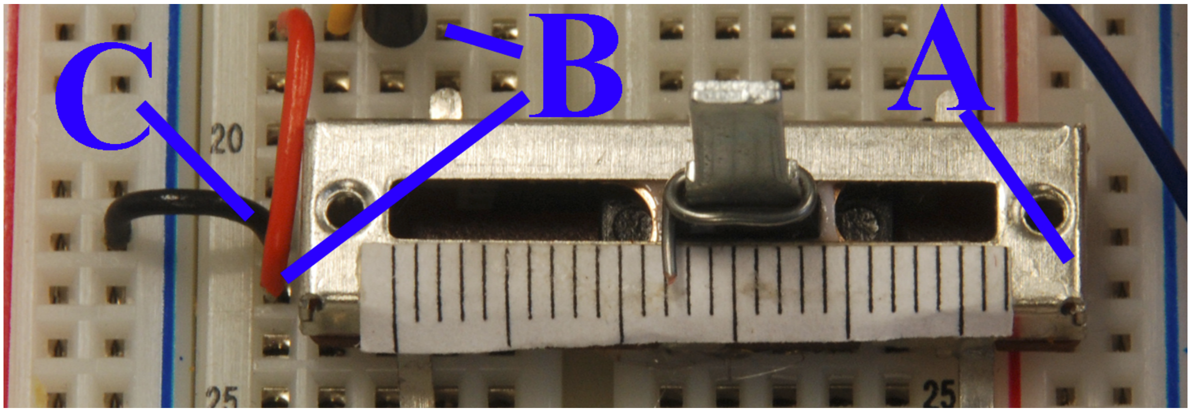

Figure 14.9. Top view of the slide pot. Notice the wire twisted around the armature creating a cursor at which the "true" distance is defined.

Part f) Because of imperfections in the ADC and the slide pot, you will have to calibrate your system. I ran one of the test programs and collected this data, where Truth has units 0.001 cm.

Truth	ADCdata
500	784
1000	1878
1500	2980

Next I calculated the two slopes. If the slopes are not about the same, I suggest you retake the data

Slope = (1000-500)/(1878-784) = 0.457

Slope = (1500-1000)/(2980-1878) = 0.453

The average slope is about (0.457+0.453)/2 = 0.455. Next I calculated three offsets

Offset = 500-0.455*784 = 143

Offset = 1000-0.455*1878 = 145

Offset = 1500-0.455*2980 = 143

The average offset (*B*) is about (143+145+143)/3 = 144. This means I should calculate

Distance =0.455***ADCdata** +144

I calculate the constant *A* as 0.455*1024 = 466. The equation the software will calculate is

Distance = ((466***ADCdata**)>>10) +144

Expect your data to be different, but the process will be the same.

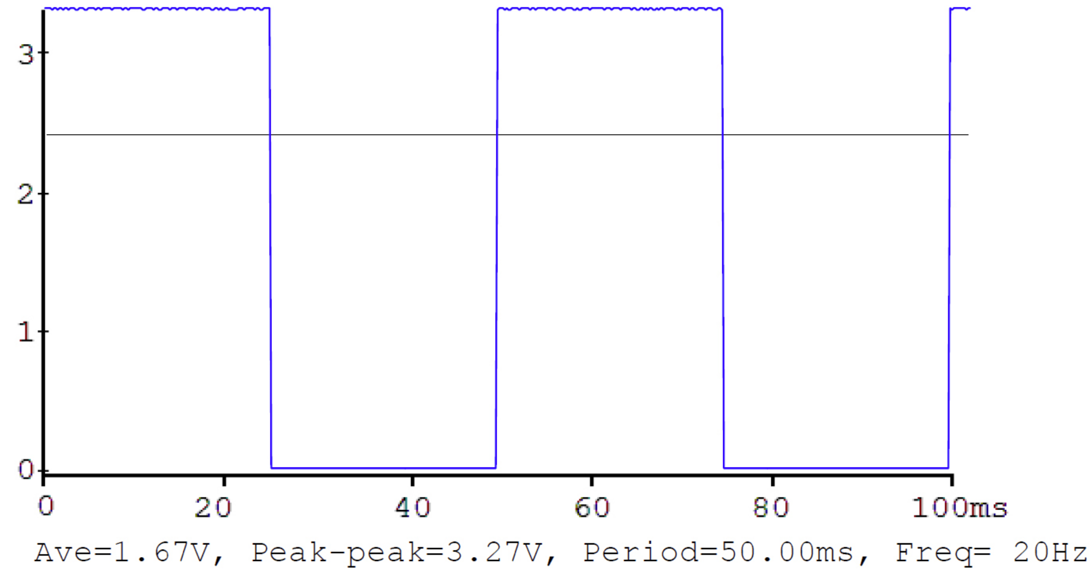

Figure 14.10. Zoomed out debugging screen shows SysTick interrupting every 25 ms on the real board.

Part g) One by one repeat the testing of the modules on the real board. Just like the simulator, the goal is to get the value of Distance, as seen in a Watch window, to match the true distance on the slide pot. The real board grader looks at linearity rather than accuracy, so you do not need to spend a lot of time making the real system accurate.

The TExaS voltmeter, PD3, can be used for debugging on the real board. However, the UART cannot be used for both the oscilloscope and as a character display at the same time. Remember the microcontroller must be running for the voltmeter and the oscilloscope to be operational. You will be able to use the TExaS oscilloscope to see zoomed-out execution profile like Figure 14.6, but not zoomed in like Figure 14.7 because this oscilloscope takes data only at 10 kHz. Figure 14.10 shows the SysTick ISR is indeed running at 40 Hz on the real board.

REAL BOARD GRADER

PROFESSOR JONATHAN VALVANO: All right.

Let me show you how to get a grade in Lab 14.

When you're done debugging, we're going to run the grader.

I've built the system here.

	0:00 / 4:04	1.0x			

Help

Here's my slide pot.

And it's important to note, when it's time to grade,

I'm going to take pin 2 here of the slide pot

and connect it to PE2, which is going to be my A/D converter for the program.

But then we have PD3, which is also connected to that same pin.

So your program will measure the voltage on the A/D converter using PE2.

In my program, we'll measure the voltage on PD3,

but it will be the same voltage.

During the grading process, I'm going to be sliding this slide pot up and down.

All right.

Over here in edX, on the Real Board Grader page,

I'm going to take this 4-digit here, Copy,

and then I'm going to go over to Keil.

We're going to be running on the Real Board, so we checked our Options.

I make sure TExaS is the operating system.

I make sure that I'm running in the Real Board debugger.

OK.

We build it.

Since it's on the Real Board, we've got to download the code.

We go over to the debugger, and so now I'm debugging the Real Board.

The window that I need to see here is the TExaS Grader 2.1.

So I'll open that window.

And as all the other labs, in order to be grading on the Real Board,

I need to be running.

OK?

So I'm going to push the Run button here.

Interesting to know is as I slide the slide pot from one

end all the way to the other end, you can

see this is the voltage here on PD3, the grader we'll be grading you on.

All right.

I know that I'm in Lab 14.

That's good.

I'm going to paste in that number I got from edX, paste it right here, Paste.

Get rid of that.

I don't need that.

Help

I've pasted in that number.

And now I'm going to hit the Grading button here.

Click the Grading button.

All right.

Just like the other graders, it will check

to make sure your configurations are right,

checking the A/D converter, the SysTick, and the PLL.

And now it's going to take five points.

It doesn't matter where these five points are.

They just have to be a different place.

So slide to the first point and press the switch.

I'm pressing switch 1 now.

It took a point.

Now, it says slide to the second point.

So what I'm doing is I'm moving my slide pot to another spot.

You see the voltage change right there.

And press the switch again.

And said now move it to a third spot.

So I move it again.

You notice the voltage down here changes.

Doesn't matter where I move it to, I just got to move it.

There's the fourth point.

Move it again.

Again, it doesn't have to be in all one direction.

Push it again.

Slide it one more time and push the button.

And after the five points are captured, it will perform a linear regression

and calculate the r squared value, in this case, 0.99.

That's very, very linear.

So I got full credit.

So I take this ASCII string here, Copy, go back to edX, paste it in this window

here, and push the Check button.

And there I go.

I got my 40 points.

All right, good luck.

Help

You do not need a display to pass the real-board grader. However, you must connect PD3 to the analog input, potentiometer pin 2. There are three steps to the real board grader:

0) Initialization tests will look specifically to make sure SysTick is interrupting at 40Hz. In particular, there is only one value the grader will accept for the SysTick RELOAD register;
1) The grader will check to see if the ADC is initialized properly and the channel you have selected in the dialog window matches the channel you configured the ADC. You must use ADC0. However, you may use channel 0, 1, or 8. You must use sequencer 3, and software start;
2) The grader will measure the linearity of the system, which is the measured position (the value you put into **Distance**) as a function of the voltage on PD3 (measured by the grader). You must store your position measurements into the global **Distance**. You will be asked to move the slide pot to five different positions. It is important that these five positions be different, but they do not need to vary by a constant amount. Every time the grader asks for a new point, move the slide pot either up or down. When you have moved the slide pot to a new position you will push the SW1 button on the LaunchPad and the grader will collect a (voltage, Distance) point. After five points are collected, the grader will calculate the correlation coefficient of the linear regression on these five points, r^2. To pass your system must have a correlation coefficient, $r^2>0.96$. The following program shows the function the real board grader used to calculate r^2. For more information on linear regression, see http://en.wikipedia.org/wiki/Simple_linear_regression (http://en.wikipedia.org/wiki/Simple_linear_regression).

```
unsigned long checkLinearity( long x0, long y0,
       long x1, long y1,
       long x2, long y2,
       long x3, long y3,
       long x4, long y4){
   long r2, sumx, sumy, sumxy, sumx2, sumy2, n;
   long numerator25, denominator0_25;
   // divide by 2^n until numerator is less than sqrt(2^31-1)=46,340
   n = 0;
   sumx = (x0 + x1 + x2 + x3 + x4);
   sumy = (y0 + y1 + y2 + y3 + y4);
   sumxy = ((x0*y0)+(x1*y1)+(x2*y2)+(x3*y3)+(x4*y4)); // sum of x*y
   sumx2 = ((x0*x0)+(x1*x1)+(x2*x2)+(x3*x3)+(x4*x4)); // sum of x^2
   sumy2 = ((y0*y0)+(y1*y1)+(y2*y2)+(y3*y3)+(y4*y4)); // sum of y^2
   numerator25 = 5*sumxy - sumx*sumy;
   while(((numerator25>46340) || (numerator25<-46340)) && (n<8)){
     x0 = x0>>1; x1 = x1>>1; x2 = x2>>1; x3 = x3>>1; x4 = x4>>1;
     y0 = y0>>1; y1 = y1>>1; y2 = y2>>1; y3 = y3>>1; y4 = y4>>1;
     n = n + 1;
     sumx = (x0 + x1 + x2 + x3 + x4);
     sumy = (y0 + y1 + y2 + y3 + y4);
     sumxy = ((x0*y0)+(x1*y1)+(x2*y2)+(x3*y3)+(x4*y4)); // sum of x*y
     sumx2 = ((x0*x0)+(x1*x1)+(x2*x2)+(x3*x3)+(x4*x4)); // sum of x^2
     sumy2 = ((y0*y0)+(y1*y1)+(y2*y2)+(y3*y3)+(y4*y4)); // sum of y^2
     numerator25 = 5*sumxy - sumx*sumy;
   }
   denominator0_25 = (5*sumx2 - sumx*sumx)*(5*sumy2 - sumy*sumy)/100;
   r2 = numerator25*numerator25/denominator0_25;
   return r2;
 }
```

Help

Help