Lab 3 Appendix

Book Title: *Real-Time Environmental Monitoring: Sensors and Systems, Second Edition – Lab Manual*

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An example of commercial probe

To illustrate these concepts we will look at a commercial temperature transducer, the "107 Temperature Probe" manufactured by Campbell Scientific (Campbell Scientific Inc. 2014). It measures temperature of air, soil, or water in environmental monitoring stations, such a weather station. Its range of measurement is from -35C to 50C.

The 107 probe is based on a Thermistor with the parameters $a=8.27\times10^{-4}$; $b=2.08\times10^{-4}$; $c=8.06\times10^{-8}$. We can use the Steinhart-Hart model to illustrate the behavior of the resistance of the thermistor vs. temperature. Let us create a new function SHart

```
# Steinhart Hart
SHart <- function(Rtmax=4071.186,Rtmin=27.481,dR=-0.1){
 a <- 8.27 *10^-4; b <- 2.08 *10^-4; c <- 8.06*10^-8
 Rt.k <- seq(Rtmax,Rtmin,dR); Rt <- Rt.k*1000; nR <- length(Rt)
 T.K <- 1/(a+b*log(Rt)+c*(log(Rt))^3)
 T.C <- T.K - 273
 return(list(Rt.k=round(Rt.k,2),T.C= round(T.C,1)))
}
```

and call it to visualize the resistance vs temperature plot (Figure 3.1).

```
x <- SHart(Rtmax=4071.186,Rtmin=27.481,dR=-0.01)
plot(x$T.C,x$Rt.k,type="l",ylab="R (kΩ)",xlab="T (°C)")
x$Rt.k[length(x$T.C)]
x$T.C[length(x$T.C)]
```

We can appreciate the non-linear response over this broad range of temperature. This thermistor is connected in a voltage divider circuit (Figure 3.2). The output voltage corresponds to the drop across $R_f = 1$ kΩ resistor. In series with the thermistor the 107 has $R_1 = 249$kΩ resistor, which makes the current through the transducer have a low value. We create a new function ckt.div.Shart

```
ckt.div.SHart <- function(Rtmax=4071.186,Rtmin=27.481,dR=-0.01,Rf.k,R1.k,Vs){
 Rt.k <- SHart(Rtmax,Rtmin,dR)$Rt.k
 x <- SHart(Rtmax,Rtmin,dR)
 T.C <- x$T.C
 Rt.k <- x$Rt.k
 R <- R1.k + Rt.k + Rf.k
 Vout <- Vs*Rf.k/R
 Pow <- (Vs/R)^2*Rt.k
 return(list(T.C=T.C,Vout=round(Vout,5),Pow.mW=round(Pow,5)))
}
```

Now we can call it in lab3.R

```
Rf.k=1; R1.k=249; Vs=2.5; kt=1.5
x<- ckt.div.SHart(Rtmax=4071.186,Rtmin=27.481,dR=-0.01,Rf.k,R1.k,Vs)
plot(x$T.C,x$Vout,type="l",ylab="Vout (V)",xlab="T (°C)")
```

The excitation is the source voltage V_s. This code plots the response (Figure 3.3). Lastly, we can apply specs.transd and specs.plot

```
X<- specs.transd(x)
specs.plot(X)
```

to calculate sensitivity and linearity (Figure 3.4). Sensitivity is 0.09 mV/°C and linearity error is 9.59% of FS. For measurements in air, a radiation shield protects the transducer from heating by direct sun exposure.

Real Term

If running Windows you can use the RealTerm Serial capture program. Available from https://sourceforge.net/projects/realterm/ or https://osdn.net/projects/sfnet_realterm/downloads/Realterm/2.0.0.70/Realterm_2.0.0.70_setup.exe/

Download **RealTerm** and install on your computer. Run it. In the Port tab, set up your port to be the same one as the one used by the Arduino and at the same baud rate (Figure 3.5). Close your Serial Monitor and Plotter of the Arduino IDE if still open. Press Change to start data collection; you should see output collected (Figure 3.6). To hide the CrtlLf characters go to the Display tab and select Display As Ascii just below the uint16 (unsigned integer 16 bit) (Figure 3.7).

Go to the Capture tab, write the path and name of capture.txt file. Select TimeStamp as YMDHS. You do not need to select delimiter comma because the Arduino will be writing the comma delimiters. You can use Start: Overwrite or Append (on successive restarts) (Figure 3.8)

Press Stop Capture when you are done. You can resume by pressing Start: Append.
Now open the file capture.txt in Geany (Figure 3.9) and should be able to see that you have the file with your data. It will be updated as new data comes in.

When using RealTerm, you could add the comma as a delimiter at the capture phase, and in this case it would be sufficient to use the **heat-fan-read-sensor-plot** if you wish to so. For consistency, we will assume that we add the comma in the Arduino script.

Figure captions

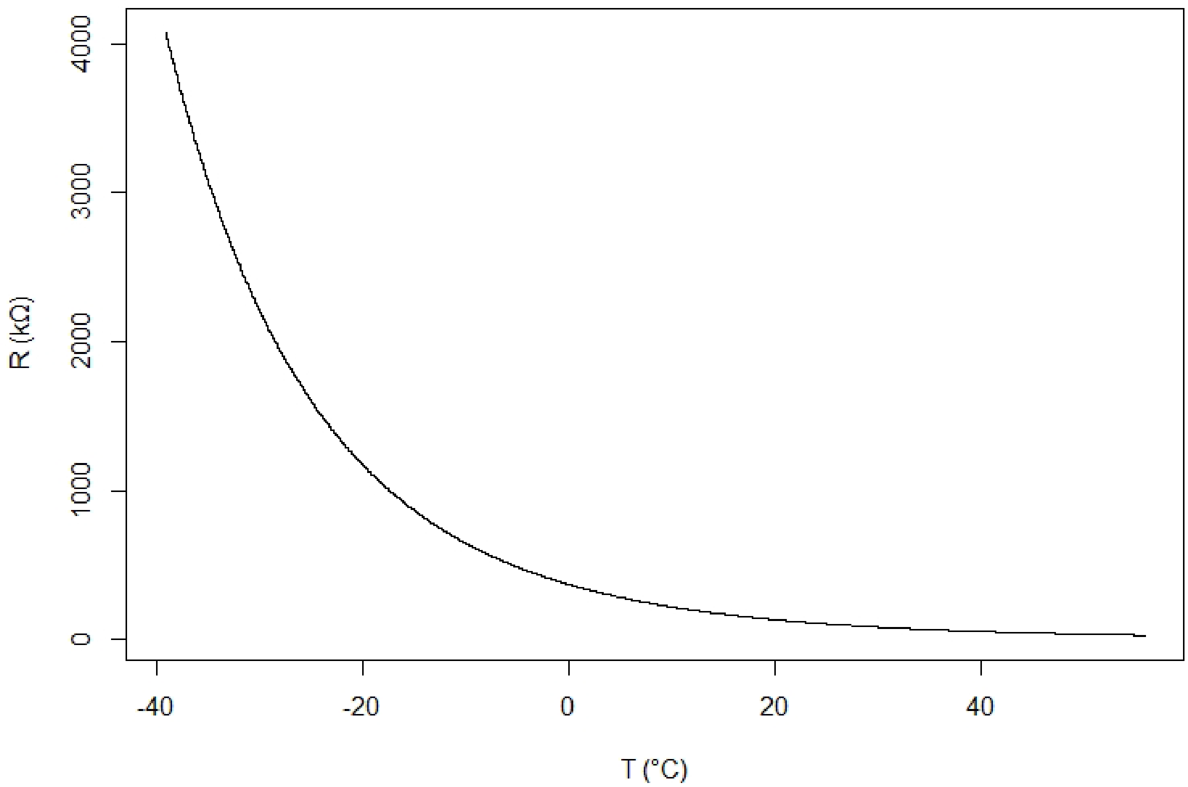

Figure 3.1 Thermistor in 107 probe; temperature response

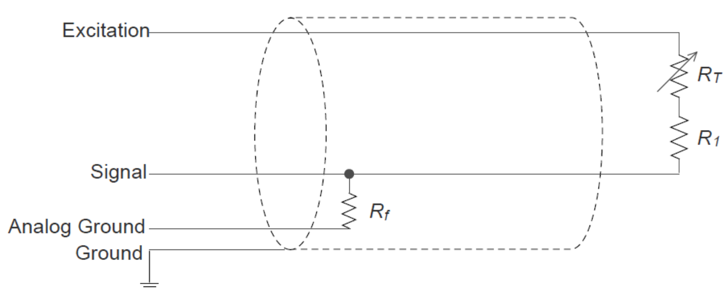

Figure 3.2 Circuit implemented in the Campbell Scientific 107 temperature probe. R_T is a thermistor, Rf is 1 kΩ, R1 is 249kΩ. Both R1 and Rf are low tolerance resistors (0.1%). Adapted

from Campbell Scientific Documentation.

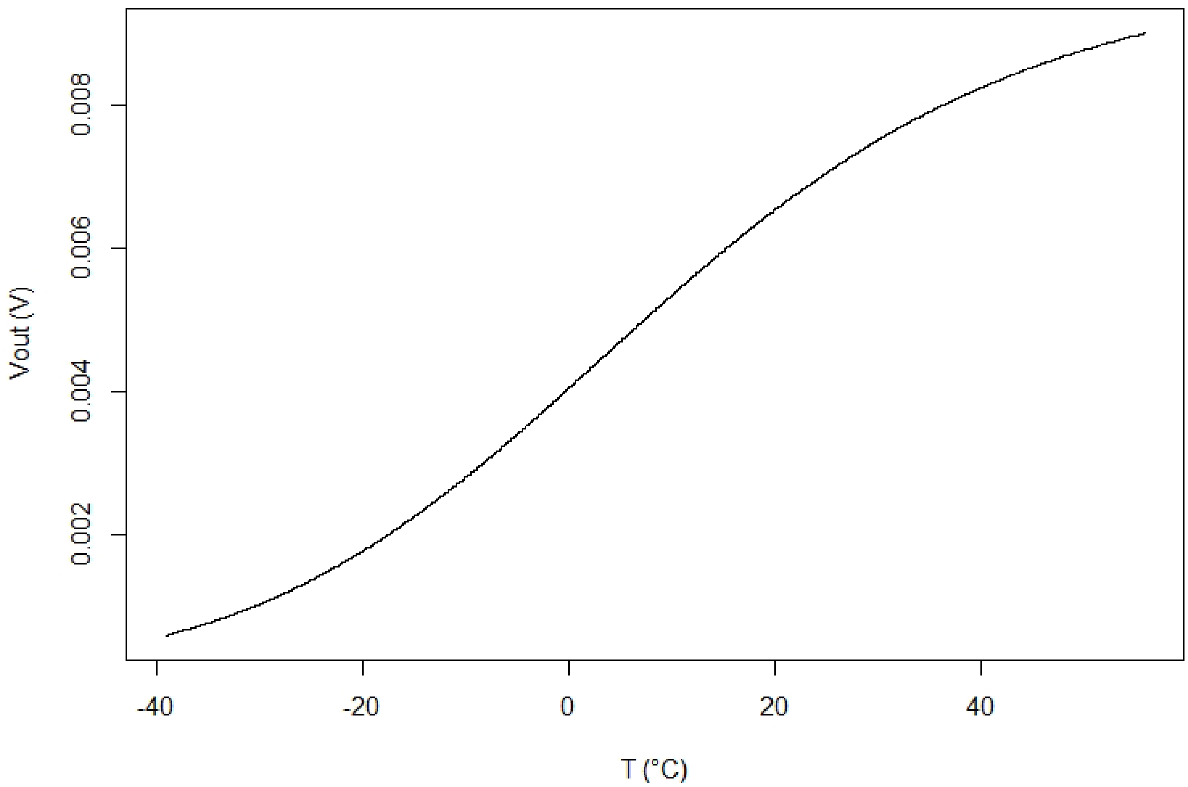

Figure 3.3 Transducer output vs. temperature.

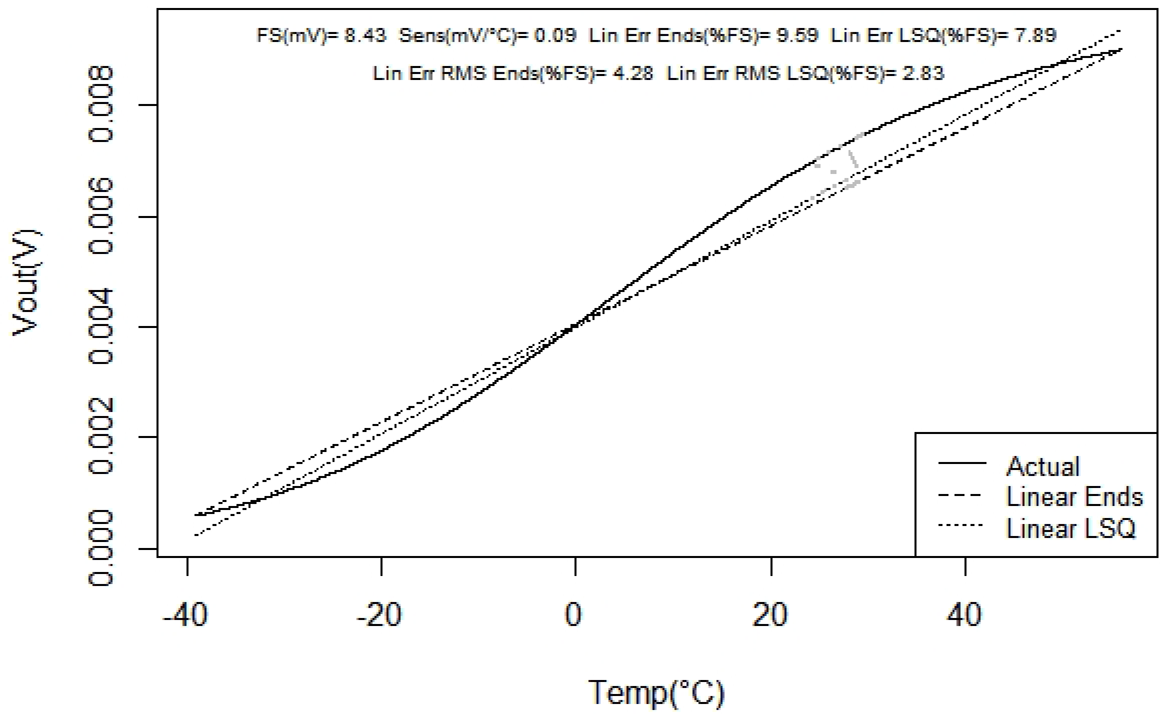

Figure 3.4 Vout of 107 probe with annotations for sensitivity and linearity.

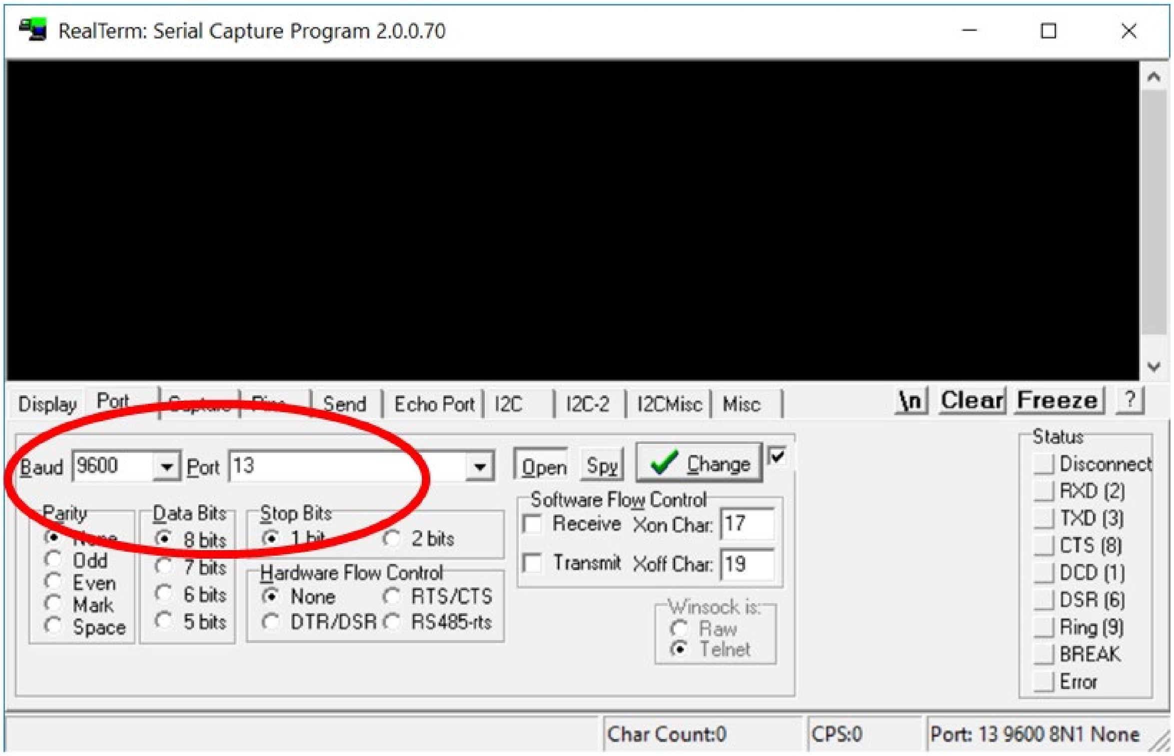

Figure 3.5 Setup Port in Realterm.

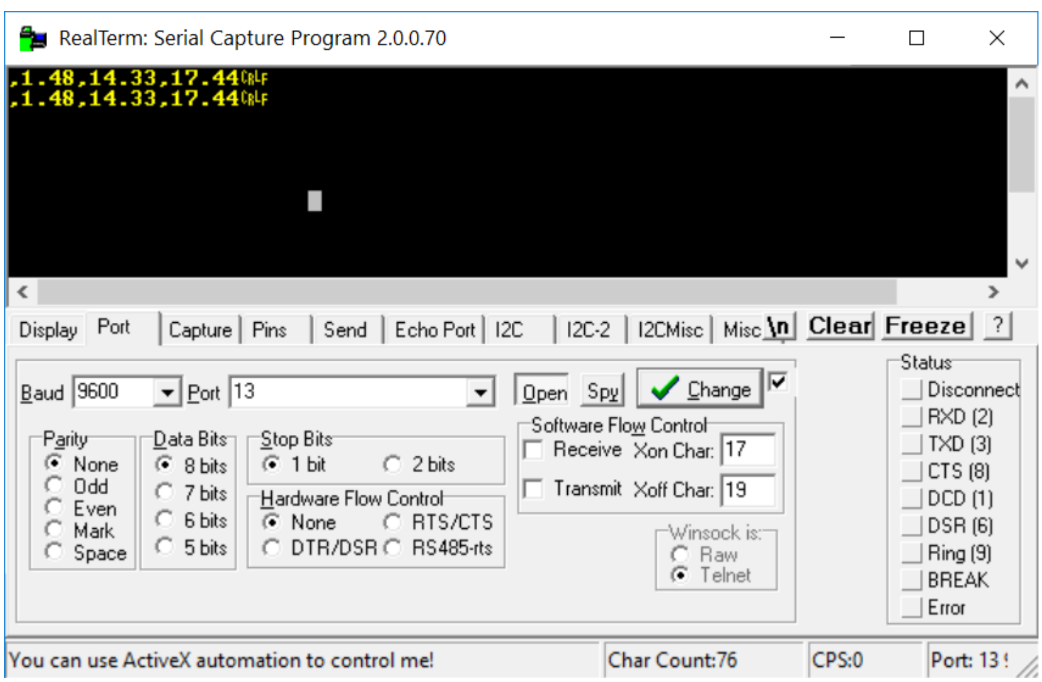

Figure 3.6 Press Change to start collection.

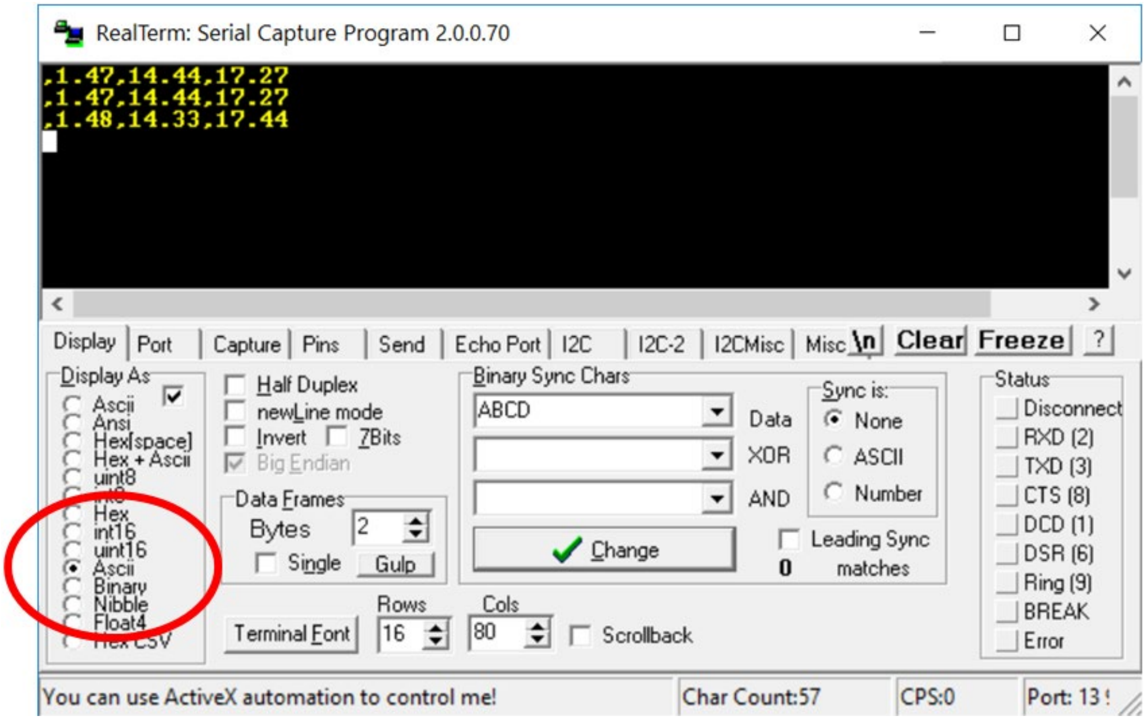

Figure 3.7 Select unint16, Ascii to hide the ctrlLf character.

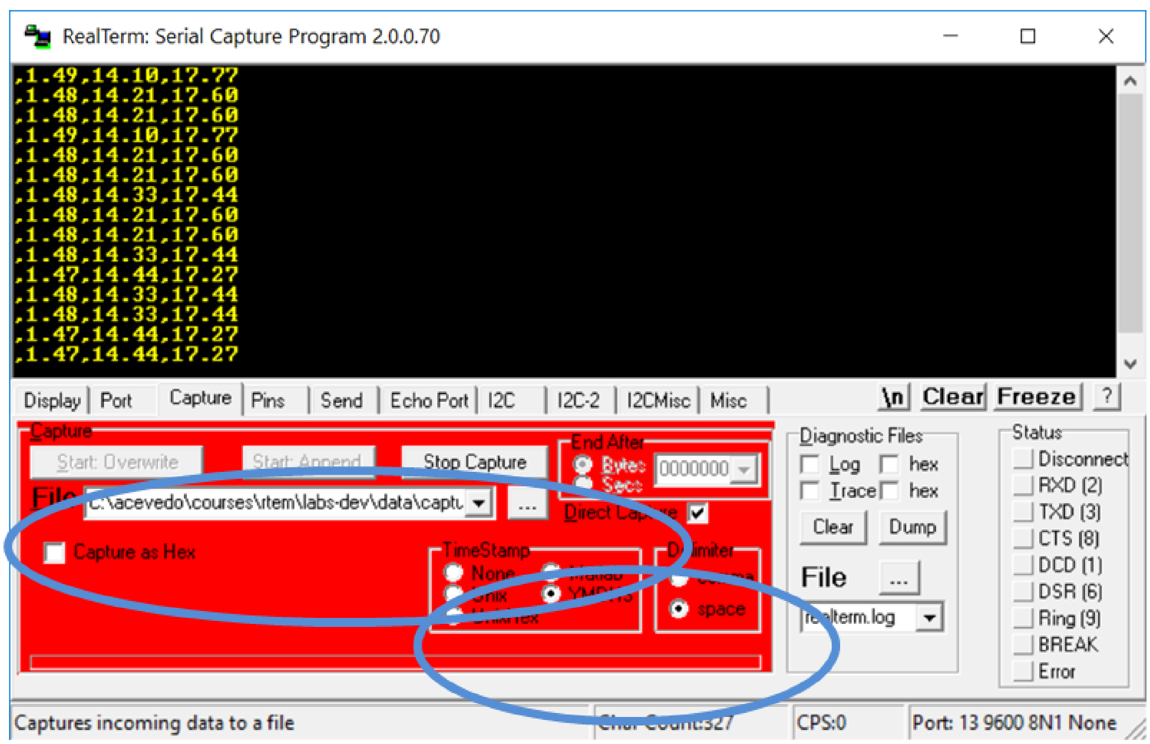

Figure 3.8 Capturing txt file.

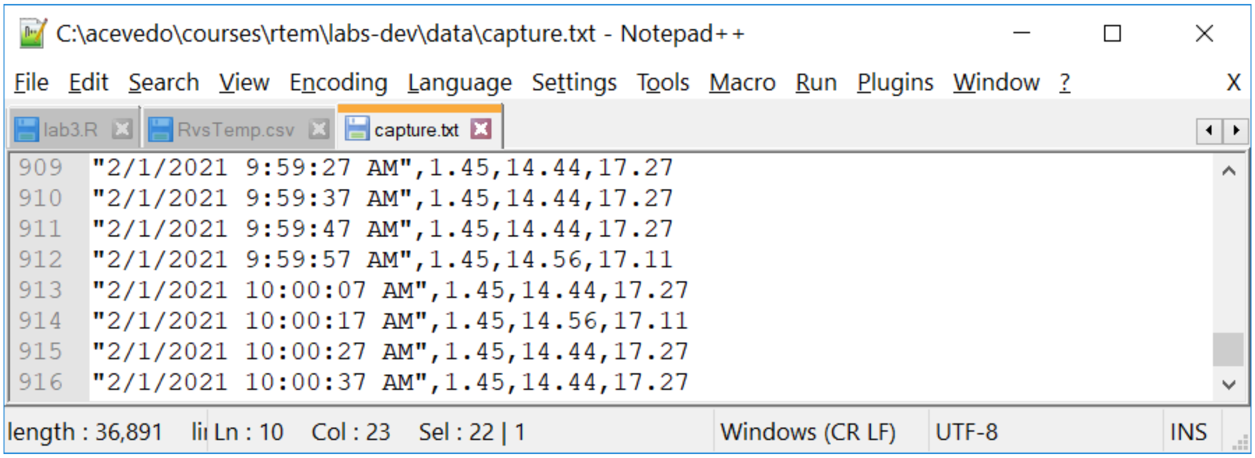

Figure 3.9 Capture txt file.

References

Campbell Scientific Inc. 2014. *Model 107 Temperature Probe. Instruction Manual*: Campbell Scientific Incpp.