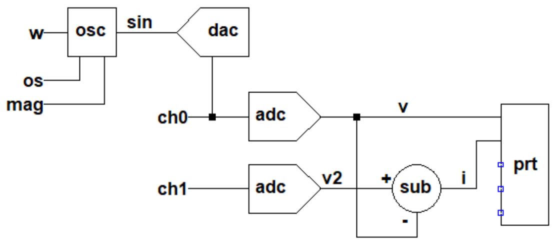
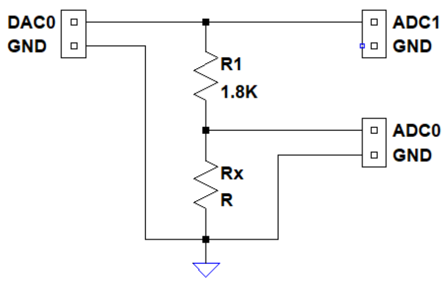
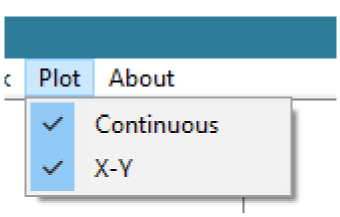
# X-Y Plotting

Our first example is plotting the linear characteristic of a resistor. This simple curve tracer uses the voltage drop across a resistor to sense current. The non-linearity of the ADC, not the resistor, will become evident in the test curves.

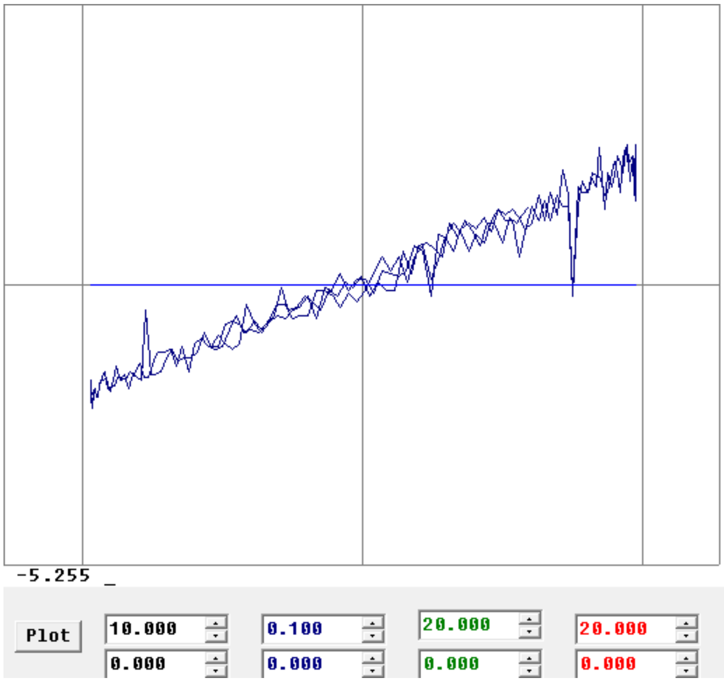


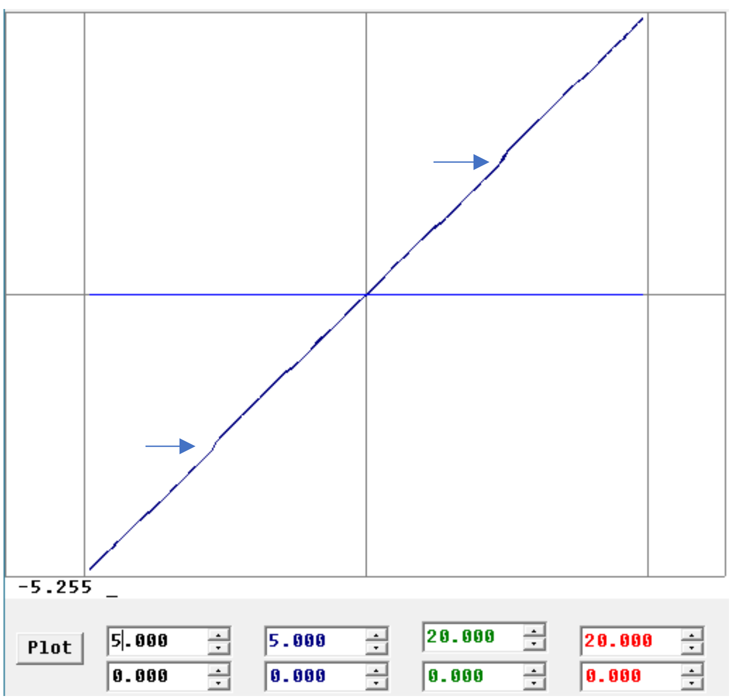

```
clr
osc w os mag sin
adc ch0 v
adc ch1 v2
dac sin ch0
sub v2 v i
prt v i
end
set dt 0.003
set w 10
set max 10000
set ch1 1
set mag 9.8
set avg 4
set fmt 3
```



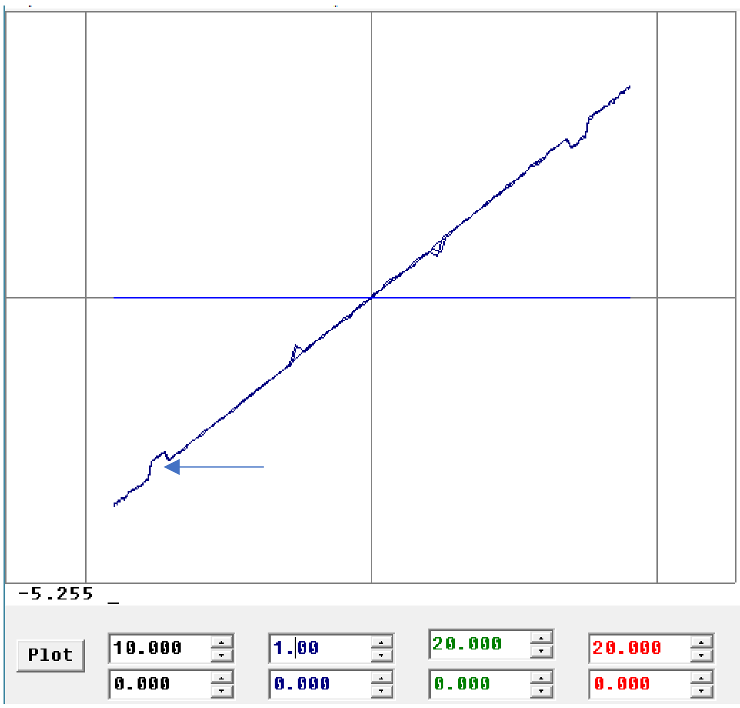

After loading and running the program, check Continuous Plot and X-Y Plot. (Don't forget to cal the ADCs)




The current for a 330K resistor is around 30uA at 10V. There is only a 54mV drop (about 10 LSBs) across the 1.8K resistor. This is about the largest resistor we can measure.

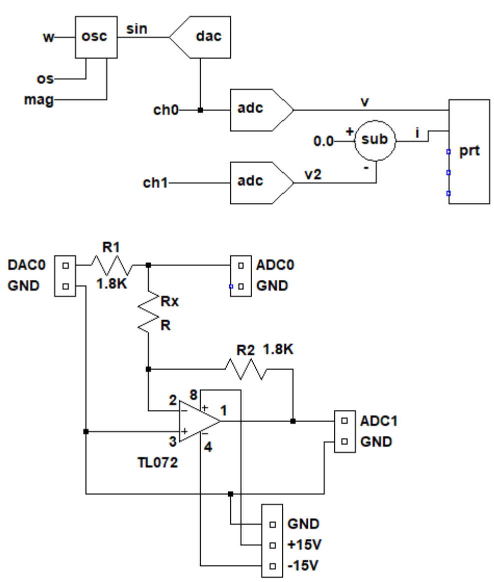



Using a resistor value equal to the 1800 ohm current sense resistor gives us the maximum ADC range for both current and voltage. A couple of non-linear kinks from the ADC are visible in the plot.

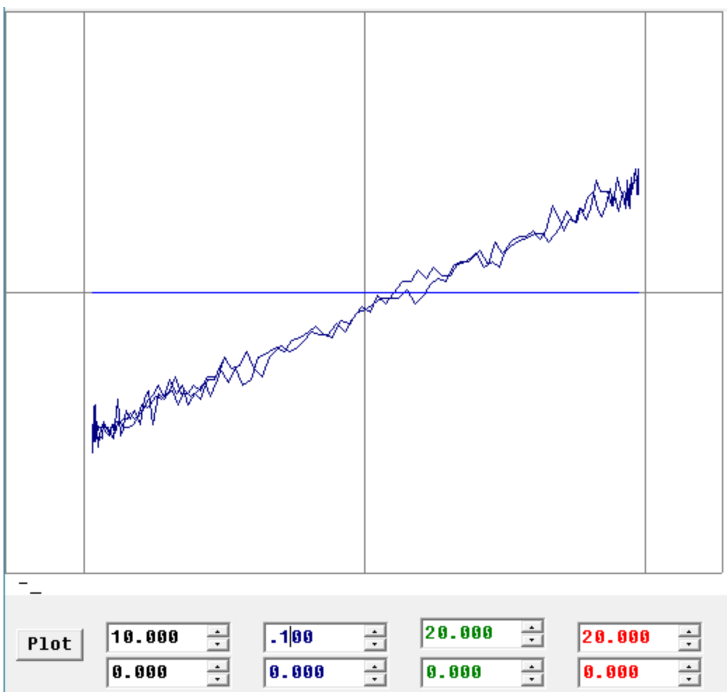



A 22K test resistor exacerbates the ADC non-linearity. At the large divot, there is about a half of volt difference between the current and voltage. As the measurement sweeps past a differential non-linearity, ADC0 will have a measurement about 4 LSBs low and ADC1 will have a measurement about 4 LSBs high. This results in a jump of 8 LSBs or about 0.039V/1800 = 21.6uA. Full scale is about 420uA.

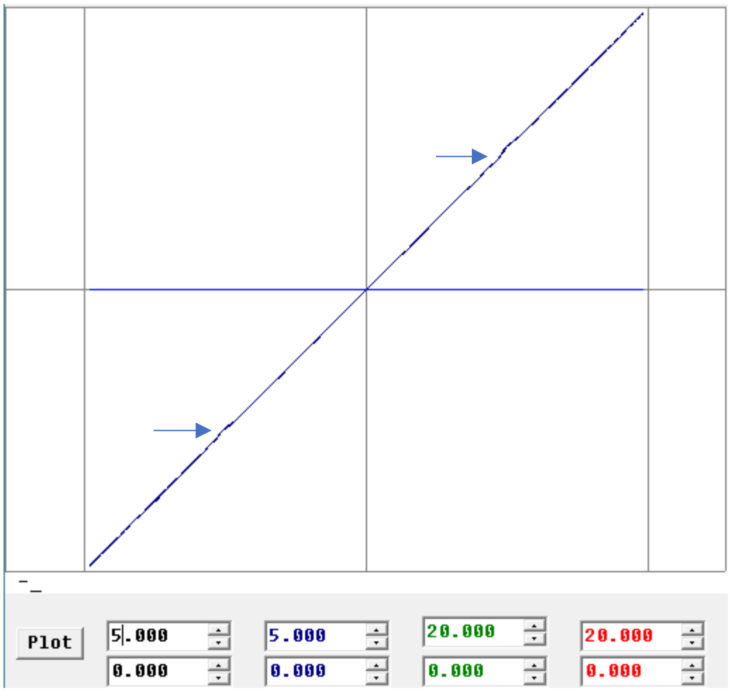
We can't improve the ADC non-linearity but we can take advantage of linear regions of operation. Changing the current measurement to a virtual ground op amp circuit scales the current with the voltage. It is small for large resistances and large for small resistances. This is the opposite of the voltage drop sensor.



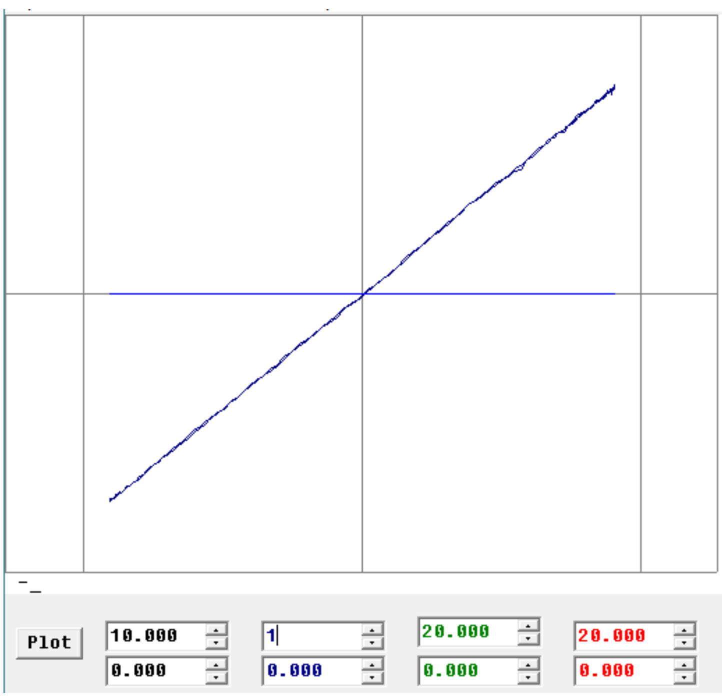
```
clr
osc w os mag sin
adc ch0 v
adc ch1 v2
dac sin ch0
sub 0 v2 i
prt v i
end
set dt 0.003
set w 10
set max 10000
set ch1 1
set mag 9.8
set avg 4
set fmt 3
```




The virtual ground current measurement results in a lower noise curve for the 330K resistor.

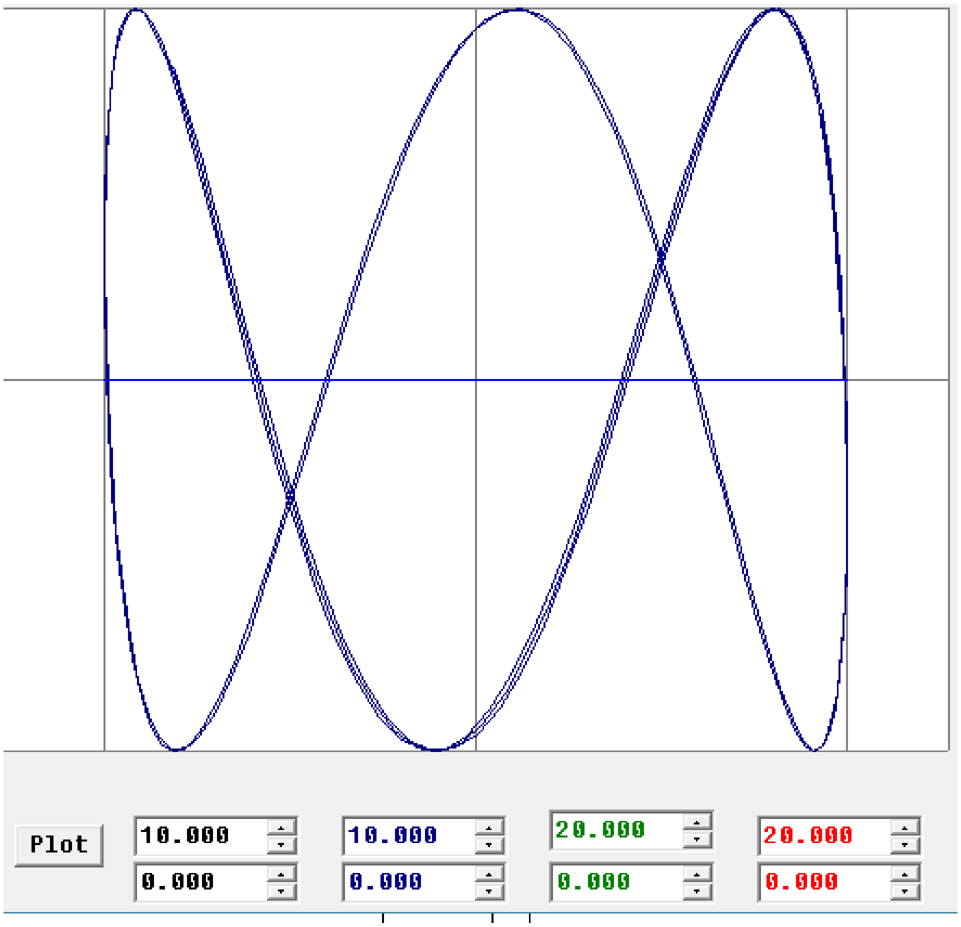



The 1800 ohm resistor still has some kinks in the curve but they are smaller.



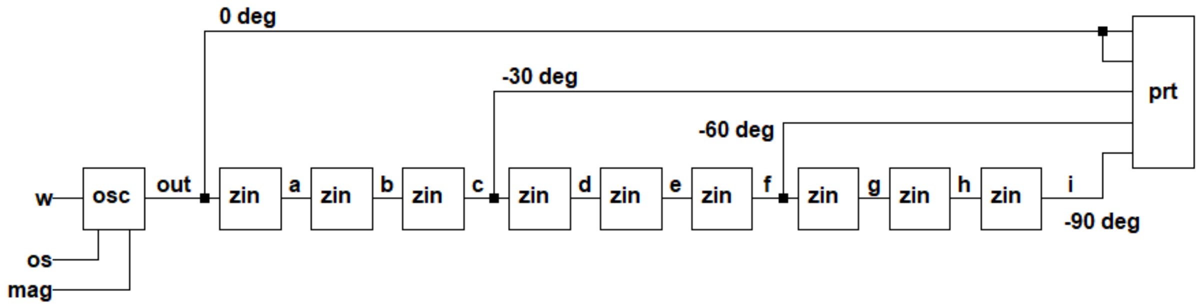

The divots for the 22K are gone.

If you are a fan of the old TV series the Outer Limits, you may remember the Lissajous pattern displayed on an oscilloscope. It is created by using a sine wave for the X input and a Y sine wave that is a multiple frequency of the X input. To get it to animate, the Y frequency is slightly higher than an integer multiple of X.



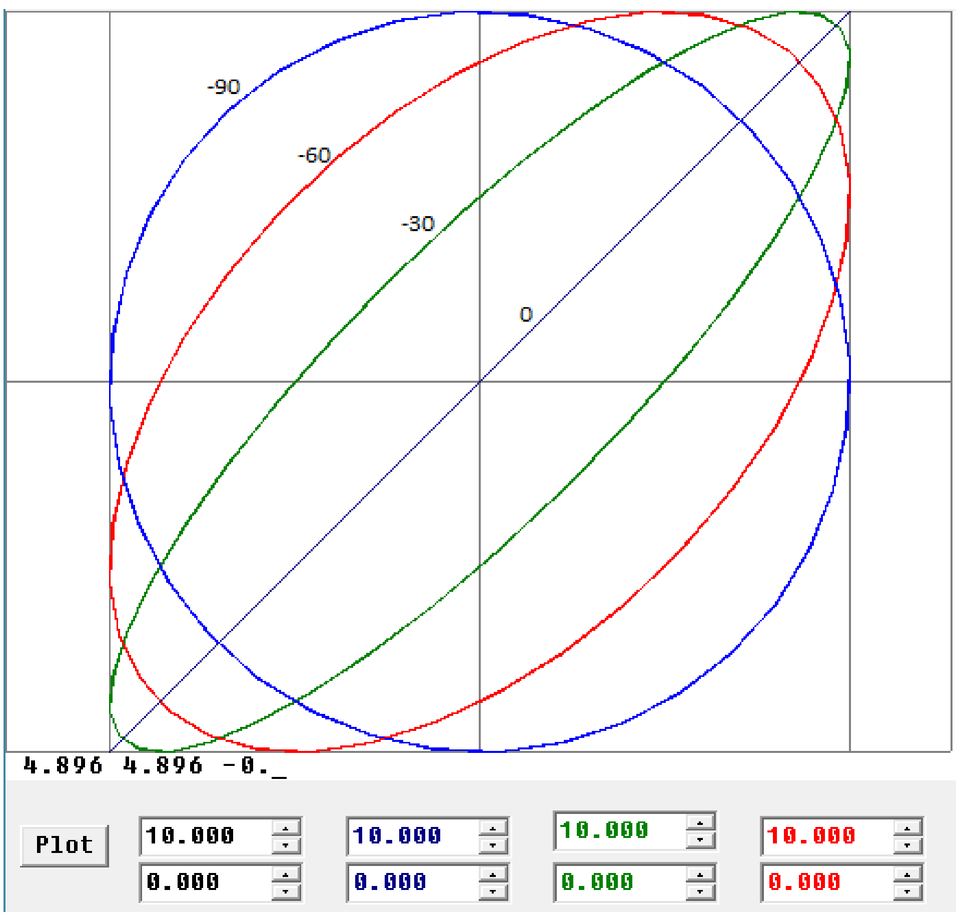

**clr**
**osc w os mag out**
**osc w2 os mag ou2**
**prt out ou2**
**end**
**set dt .003**
**set max 999999**
**set fmt 3**
**set w 20**
**set w2 60.1**
**set mag 10**

Lissajous patterns were used to measure the phase relationship between two signals of the same frequency. The easiest way to generate a phase shift is with the unit delay zin ($z^{-1}$). It takes a lot of delays to make small degree steps. We use nine delays for 10 degree steps. This step size generates a relatively smooth curve.




w = 2 * pi / ( 4 * 9 * dt)

9 = # of zin delays



```
clr
osc w os mag out
zin out a
zin a b
zin b c
zin c d
zin d e
zin e f
zin f g
zin g h
zin h i
prt out out c  f i
end
set dt .005
set max 999999
set fmt 3
set w 34.9
set mag 10
```