University of California, Davis
Electrical and Computer Engineering

EEC 1/89D

Introduction to Electrical and Computer Engineering

Part 1: Embedded Systems Programming

Using the TI Microcontroller, Energia, and ADALM2000

Lab 2: Serial Input/Output, Measuring Voltages with the ADALM, and Scopy software

Introduction:

a. Purpose/ Scope

In this lab we will continue the exercises from the previous lab. Last time, you were introduced the microcontroller, how to write a simple program, and how to interface with a breadboard. This week, we will continue to look at features of the MCU. You will also learn how to use the ADALM2000 (also known as M2K) from Analog Devices (AD). The M2K is a powerful tool which can be used as an oscilloscope, signal generator, multimeter, and power supply. You will use the ADALM as a voltmeter and power supply throughout the quarter.

b. Resources/Lab Materials

Lab Materials:

- 1x TI MSP432P401 LaunchPad Kit (Red kit)
- 1x ADALM2000 (M2k) with Scopy software
- 1x Breadboard
- 1x LEDs
- Jumper Wires
- 2x 330 Ohm resistor
- 2x 1k Ohm resistor
- 1x 10k Ohm resistor
- 1x Potentiometer (POT)

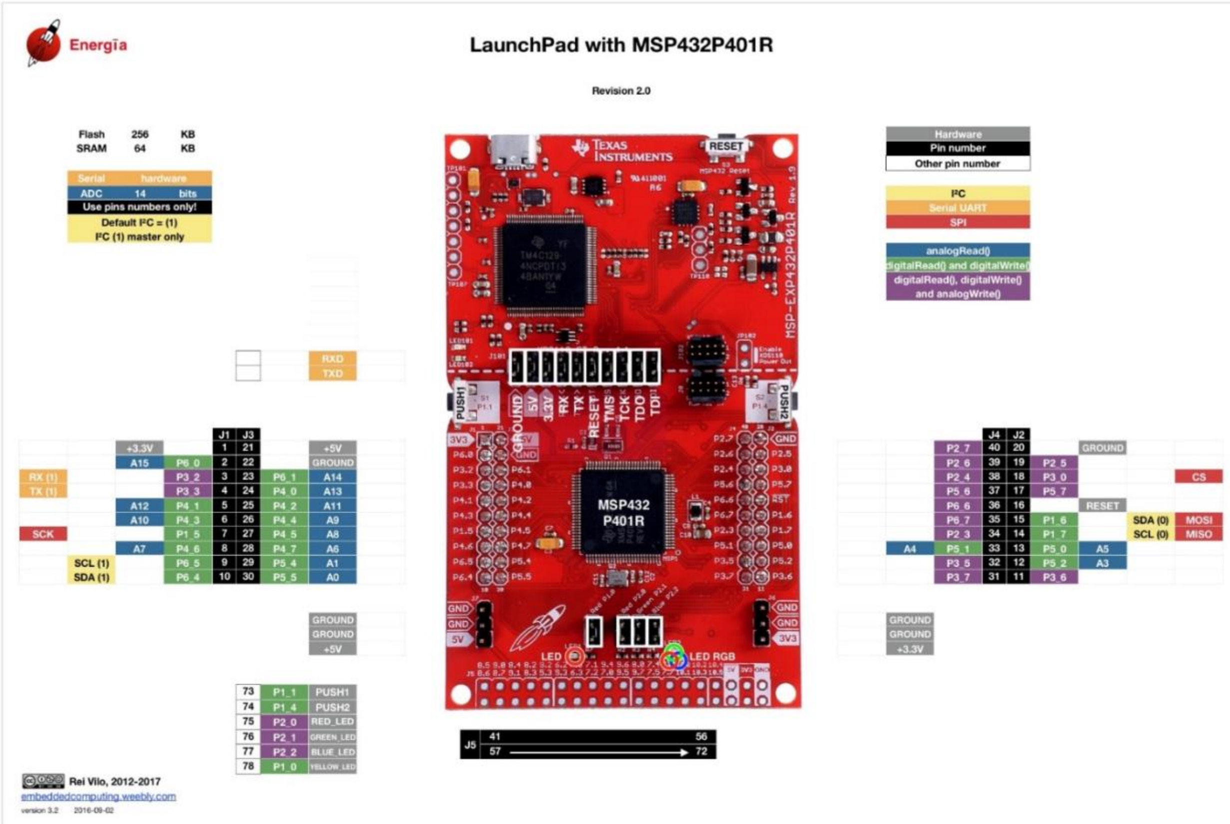


Figure 1. Pin layout of MSP432

ADALM2000 Set Up

1. Verify that you have all needed components. You should have received the following in the ADALM2000 kit:
    a. One ADALM2000 Active Learning Module
    b. One Micro USB cable
    c. One 20-pin **and** one 10-pin connector with jumper wires
    d. Male-male breadboard headers

Figure 2: Components in ADALM2000 kit

Exercise 1: Using the UART to Monitor Program Execution

Description: In this exercise, you will learn how to utilize the communication interface knows as the "UART" (pronounced you-Art) to communicate between the PC and the MCU. This is useful if you want to know values that you are reading into the MCU. For this class we will use this extensively to measure voltages in our circuits, but this can even be used to display messages in different parts of your code to inform you that a certain event has happened which is particularly helpful when trouble shooting. On a superficial level, the serial communication functionality will appear to be nothing more than writing text to a monitor, however, its utility will become more evident as you progress.

Procedure:

Part I: "Hello, World!"

It is a tradition for the first program someone writes when learning how to code to be a simple program that displays the message, "Hello, World!" on the screen. While we have already written a few programs, now is just as good a time as any to write this program.

1. There are two commands that are particularly important:

```
Serial.begin([baud rate])

Serial.println([message])
```

Copy the program written below into Energia but **do not execute** it.

```
//Exercise 1: UART monitor

void setup(){
  //Initialize serial communication to 115200 bits per second.
  Serial.begin(115200);
}

void loop(){
  Serial.println("Hello, World!");
  delay(10000); //prints statement to monitor every 10s
}
```

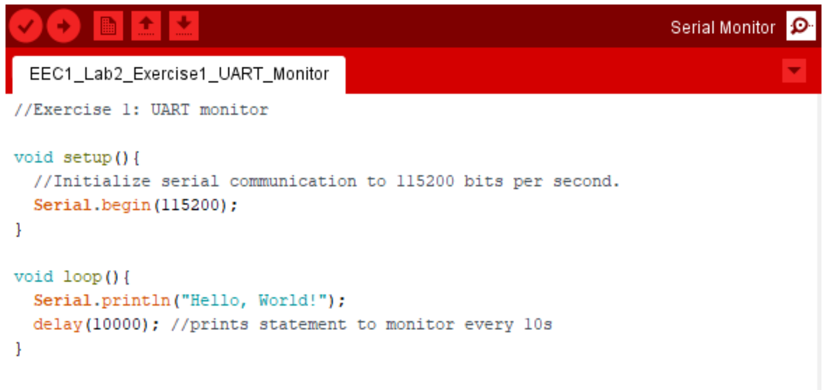
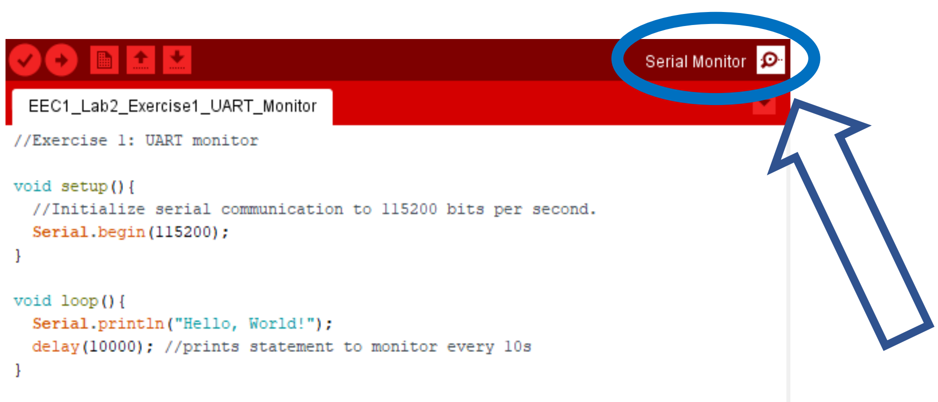


Figure 3. Code for exercise 1

The first command, `Serial.begin()` in the setup block tells the MCU that we will be engaging in serial communication with it and we specify the rate of communication between us using what is known as a baud rate. In our program, we are specifying a baud rate of 115200 which corresponds to a maximum serial transmission of 115,200 bits per second.

The second command, `Serial.println()` sends a message that you will be able to view in the serial monitor in a moment. This function displays the message or contents of what is given to the function on screen and then jumps to the next line. This command will be important for the remaining exercises and future labs.

2. Before executing the code, open the UART monitor shown in the image below and set the baud rate in the drop-down menu to 115200. This screen is what you will use to display any communication.



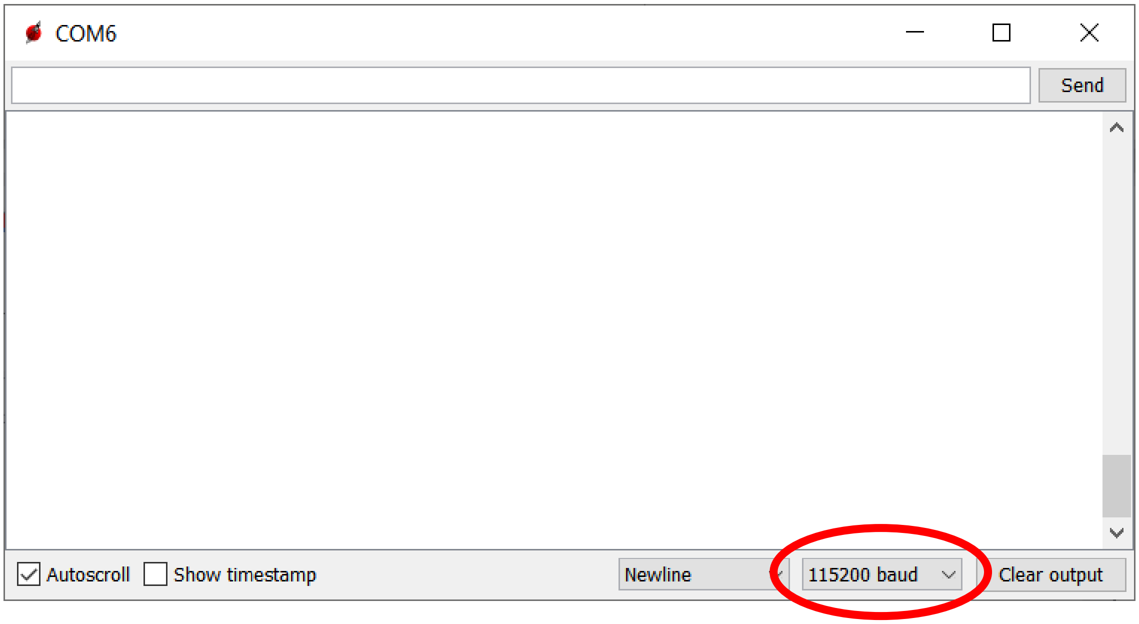


Figure 4. Image to show how to open up the serial monitor and select the correct baud rate

3. Execute the program and you will see your message print to screen. It may take a few seconds before it appears as the program is starting up. After the first print, the code is set to delay for 10000 ms before executing again which is to ensure your UART monitor isn't filled with the print statement.

Hint: if you don't see anything, make sure your baud rate is correct, you may also have to try another COM port.

<u>Part II:</u> Print the colors switched between during exercise 2

<u>Procedure:</u> Using the information in part A, go back to exercise 2 from lab 1 where you wrote a program to switch between LED colors on the MCU board. In your code, first initialize serial communication in the setup block. In the loop block, have your code only switch back and forth between the red LED and the green LED. While each LED is on, print the word "Red" or "Green" to the UART monitor depending on which LED is on.

SUBMISSION: copy **ONLY** the loop() block of your code into the Canvas submission box when prompted to.

Exercise 2: Measure a Voltage with the ADALM

Links:
Scopy software downlink: [Link]
Video tutorial for ADALM2000 (M2K) and Scopy Software: [Link]

Description: This exercise is arguably the most important of the lab. It is standard when working with electrical circuits to measure the currents and voltages at different components. In a laboratory setting, you will have easy access to tools such as voltmeters and oscilloscopes, however, here you will use the M2K's voltmeter function.

Procedure:
1. Download the Scopy software compatible with your computer from the link provided above. Run the .exe file to install the software. Be sure to check the box that says Install drivers for ADALM2000.
2. Watch the video tutorial to familiarize yourself with other features of the ADALM2000.
3. Connect your ADALM2000 via USB port shown in Figure 5 below.

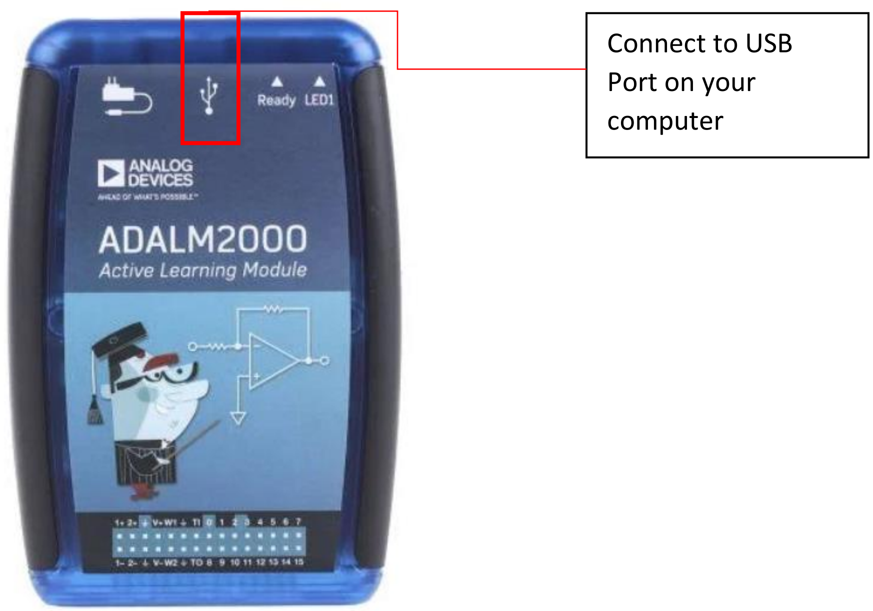


Figure 5. ADALM2000 (M2K)

4. **IMPORTANT**: Connect and calibrate the ADALM2000 while it is **not connected** to any circuit or device. Open the Scopy software on your computer, your M2K icon should appear. Then click on Connect which will also calibrate the ADALM2000. The left-hand side lists the tools available (see Figure 6.)

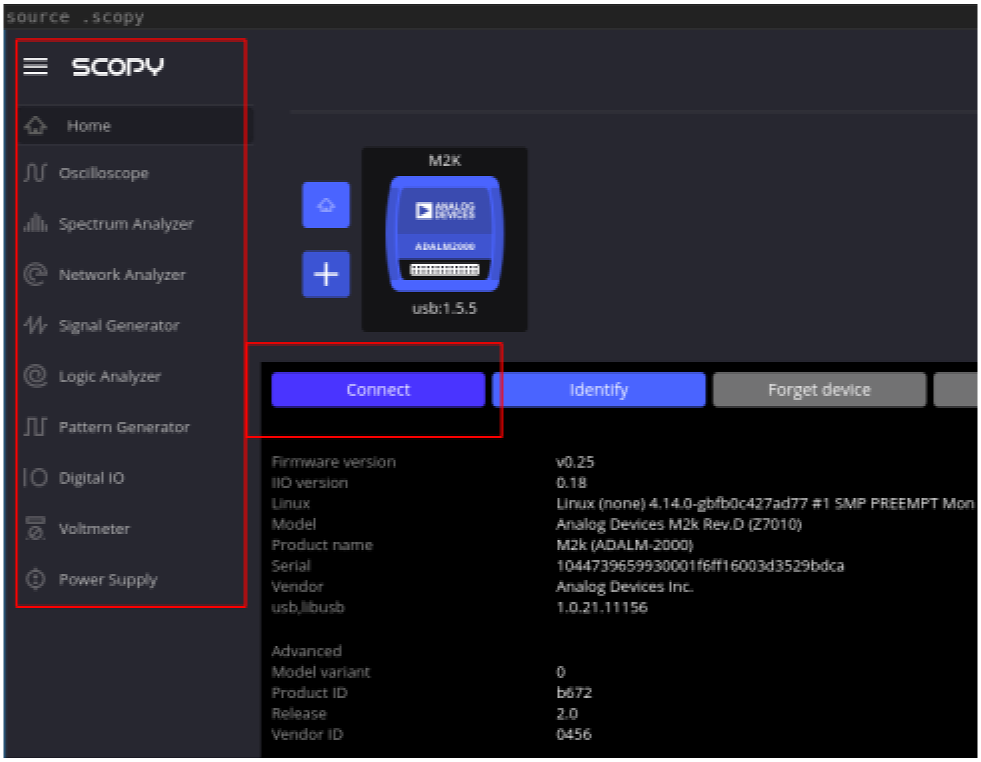


Figure 6. Scopy Connect and Tools Menu

5. There are two wire harnesses in your ADALM2000 kit. Attach the smaller of the two on the left side of the ADALM2000 as shown in Figure 8a to the highlighted pins shown in Figure 7b.

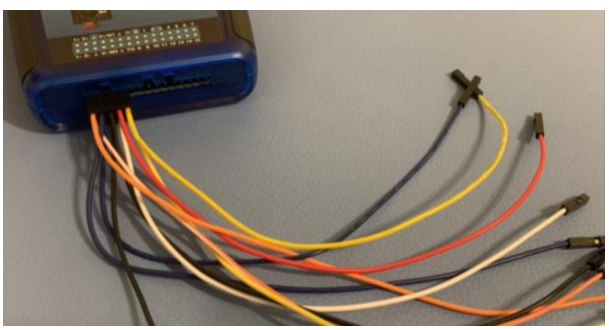


Figure 7a. ADALM2000 extension wires. Figure 7b: ADALM2000pins and labels.

The 10 pins on the left side are the analog pins on the M2K. Below is a description of each pin.

1+ and 1-	A positive and negative probe for an Analog Input (voltage) for Channel 1
2+ and 2-	A positive and negative probe for an Analog Input (voltage) for Channel 2
V+	A voltage source capable of up to 5 volts above the computer’s ground reference
V-	A voltage source capable of up to 5 volts below the computer’s ground reference
W1 and W2	Two analog output signals, each relative to the computer’s ground

Remember to use the wire extensions that plug into the ADALM2000 pins so that you have a solid mechanical connection to all pins. Do not use jumper wires to connect directly to the pins, use the extensions as shown in Figure 7a. Also make sure to use the headers that came with your ADALM to make solid mechanical contact between the M2K wires and the breadboard. See Figure 8.

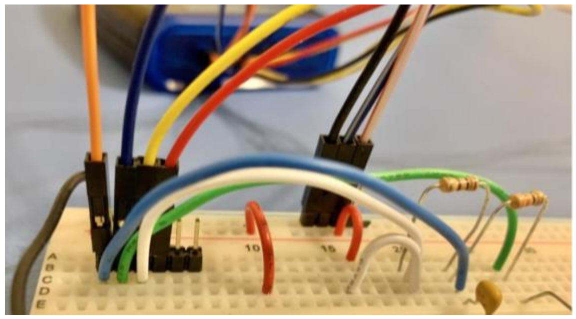


Figure 8. Extension wires plugged into headers on a breadboard.
(Note: this photo is NOT a circuit from this class.)

Description: In this exercise you will be reading in a voltage from a variable resistor known as a potentiometer (trim-pot) using the voltmeter feature of the ADALM and the Scopy software.

A trim-pot is a three pin device with a knob that allows you to change the resistance. The knobs you see in many electrical devices are actually one of these trim-pots and are used in embedded systems to determine the intensity of a parameter set by the user. Thus, we can see that while this is a simple system, it is also a very practical one with wide applicability. Remember it next time you increase the volume on the radio.

Figure 9. Precision trim-pot

Procedure:

1. Connect the ADALM to your computer, open Scopy, and then build the circuit illustrated below. The blue square in Figure 10 is a depiction of the potentiometer shown in Figure 9.

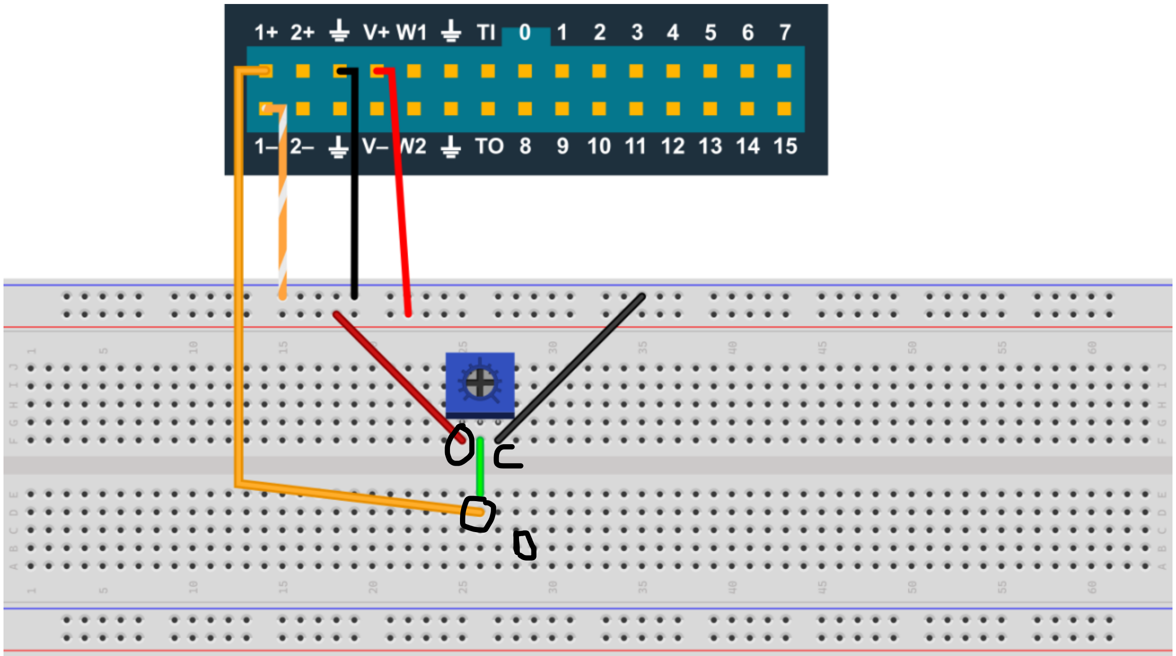


Figure 10. Diagram of circuit for exercise 2

2. In Scopy, click on the Power Supply tab then apply the settings shown in Figure 11. Set the Positive output to 5V by typing “5v” and pressing Enter (Or use the dial or the “+” and “–” buttons). **Don’t enable the output until you are certain your wiring is correct** based on Figure 10. Once you enable the output in a later step, if the VDC Measure voltage is not close to 5 volts, your circuit is using too much power and has a wiring problem.

Figure 11. Scopy Power Supply Settings

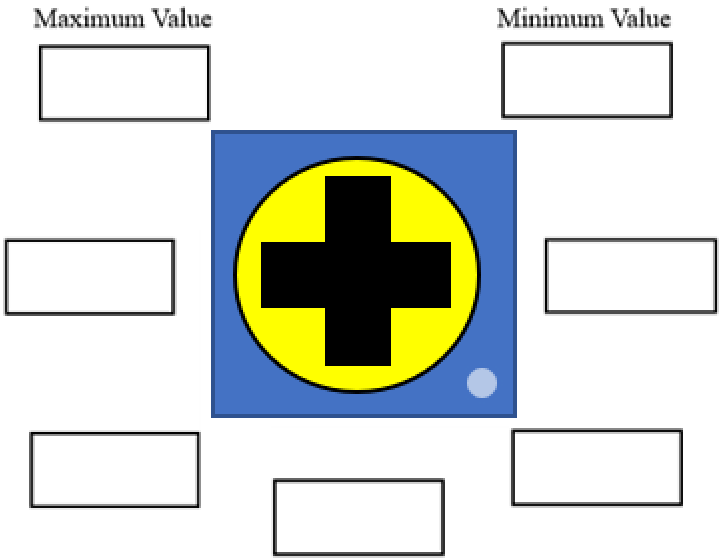
3. In Scopy, click on the Voltmeter tab then apply the settings shown in Figure 11. On the righthand side, under Channel 1, select DC (Direct Current), set Range to Auto, turn off History. To test that your voltmeter is working properly, if you measure the value CD (voltage at C - voltage at D). To do this, connect your 1+ pin (orange wire voltage probe) to point C and your 1- pin (orange wire with white stripe voltage probe) to the middle pin of the potentiometer. Click **Enable** on the Positive output of the Power Supply tab. Then click **Run** on the top right of the Voltmeter to measure the voltage. If the voltage reading changes when you turn the potentiometer, it is working properly.

Figure 12. Scopy Voltmeter Settings

Now answer the following questions on Canvas:

QUESTIONS:

1. In a number of cases, we would like the response of the system to an input such as a knob, to be linear. This means that when the knob is all the way to one end it should be off, when it is at the other end it should be at maximum intensity, and when it is in the middle it should be at half intensity. However, this is not always the case. Below you will see a drawing of the potentiometer at different positions. Place the knob in each of these positions and record the value displayed on the UART monitor. Is the trim-pot linear?


Maximum Value
Minimum Value

Exercise 3: Using your ADALM2000 (M2K) as a differential voltmeter

Description: This exercise and the next one are very important. It is standard when working with electrical circuits to measure the currents and voltages at different components. In a laboratory setting, you will have easy access to tools such as voltmeters and oscilloscopes, however, here we are limited to what our MCU can measure. In this exercise you will program your MCU to work as a voltmeter which you will use often in future labs.

Modify your circuit such that the trim-pot is no longer included. From the ADALM2000, the 1- pin and the 1+ pin will be your voltage probes that you will place at different locations of the circuit to measure the voltage. This is shown more explicitly in Figure 13.

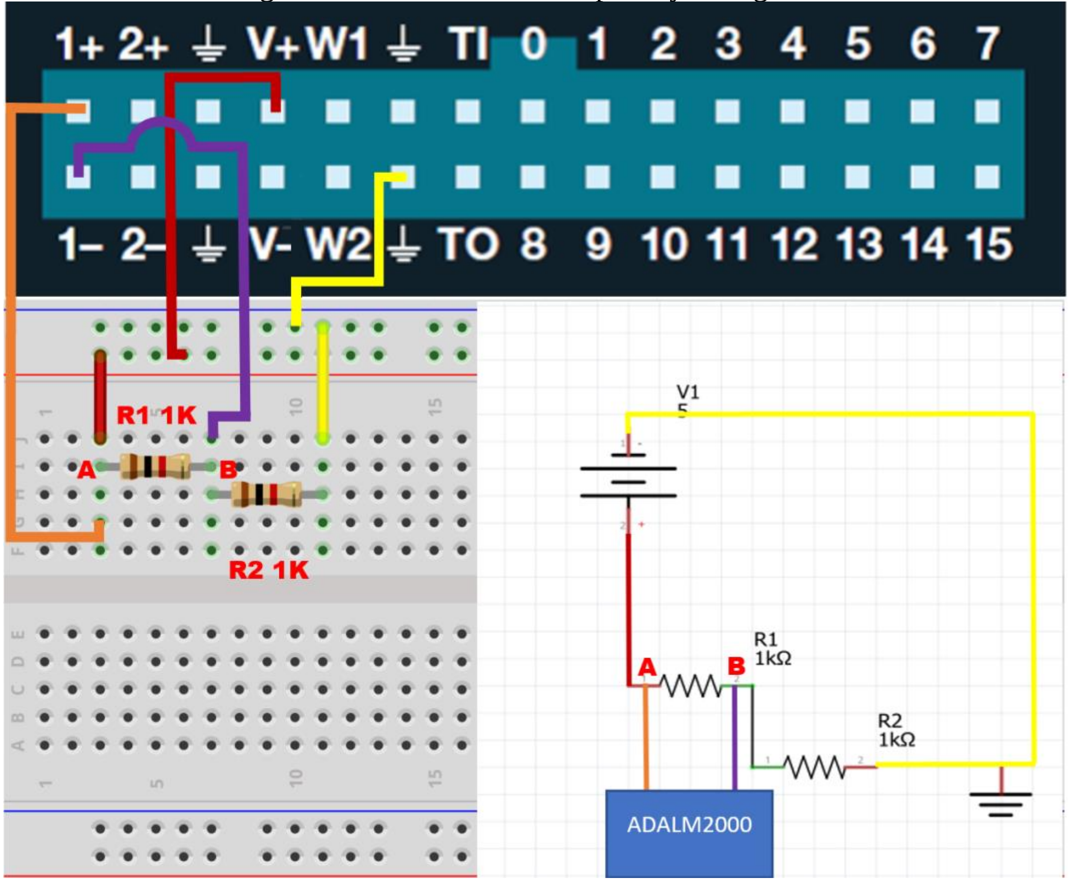


Figure 13. Measuring R1 in a series 2-resistor circuit

Procedure:

In Figure 13, a 5V DC voltage from the ADALM2000 is placed across two equal resistors, R1 and R2 in series. The channel 1 probes (port 1+,1-) from ADALM2000 are connected parallel to resistor R1 (ADALM2000 and R1 share the same nodes A and B) to measure the voltage drop across R1. The voltage across R1 should be approximately half of the voltage supplied.

For how to interpret resistor color codes, see Section 3.2.

1. Connect to the circuit to +5V from channel 1 of the DC power supply, the top red wire in Figure 13.

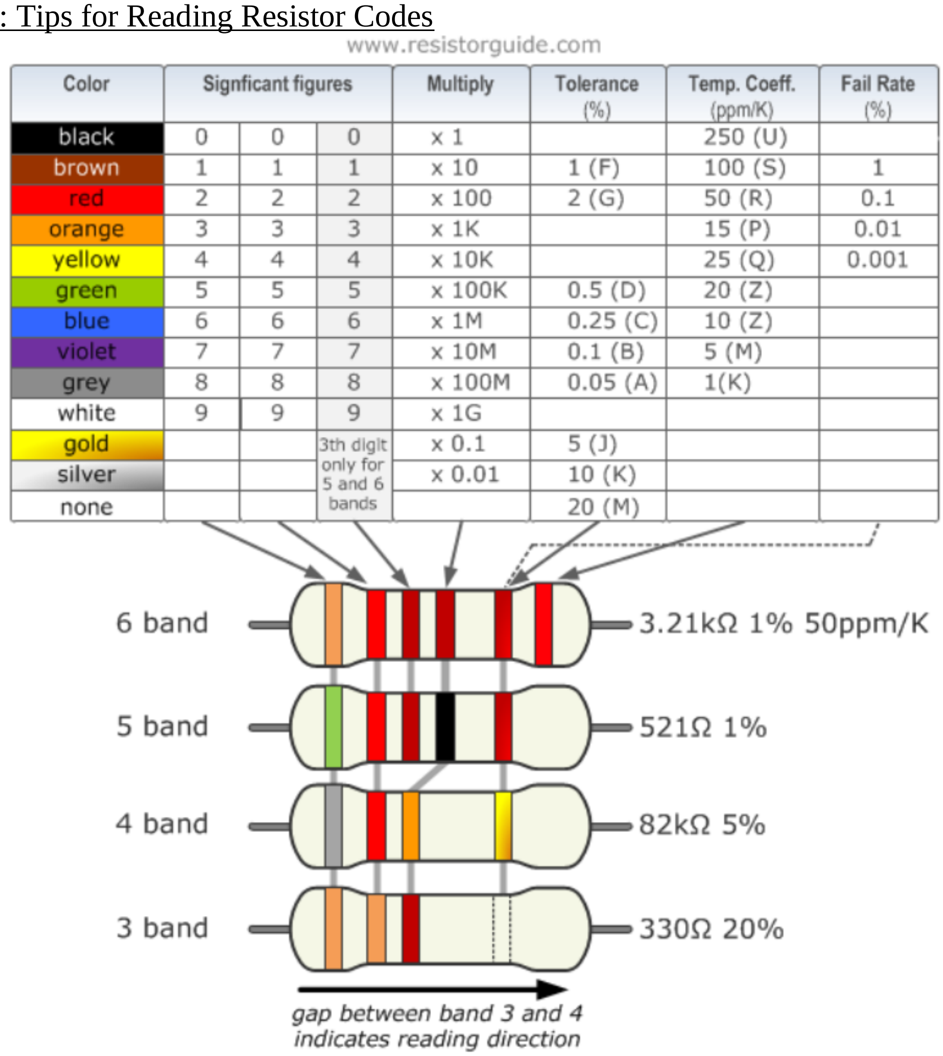
2. Connect the ground of the circuit to negative terminal from channel 1 of the DC power supply, the black wire in Figure 13.
3. Enable the channel 1 output of the power supply, then use the ADALM Voltmeter to measure the voltage across each resistor:
4. In Scopy, apply the same settings to the Power Supply (+5V) and Voltmeter tabs as for Exercise 2. Again, do not enable the power supply output until you are certain the wiring is correct based on Figure 13.
5. Measure the voltage across R1. Repeat this step by moving the 1+ and 1- pins to the measure across the other resistor and complete the table below.

Resistors	**Voltages**
R1	
R2	

Table 2: 2-Resistor Circuit Results

6. Ask the Teaching Assistants to verify your values.

Section 3.2: Tips for Reading Resistor Codes


www.resistorguide.com

Color	Signficant figures			Multiply	Tolerance (%)	Temp. Coeff. (ppm/K)	Fail Rate (%)
black	0	0	0	x 1		250 (U)	
brown	1	1	1	x 10	1 (F)	100 (S)	1
red	2	2	2	x 100	2 (G)	50 (R)	0.1
orange	3	3	3	x 1K		15 (P)	0.01
yellow	4	4	4	x 10K		25 (Q)	0.001
green	5	5	5	x 100K	0.5 (D)	20 (Z)	
blue	6	6	6	x 1M	0.25 (C)	10 (Z)	
violet	7	7	7	x 10M	0.1 (B)	5 (M)	
grey	8	8	8	x 100M	0.05 (A)	1(K)	
white	9	9	9	x 1G			
gold			3th digit only for 5 and 6 bands	x 0.1	5 (J)		
silver				x 0.01	10 (K)		
none					20 (M)		

Figure 15: Reading resistors

Here are some general tips for reading the color code:
The reading direction might not always be clear. Sometimes the increased space between bands 3 and 4 provide an indication of the reading direction. Also, the first band is usually the closest to a lead. A gold or silver band (the tolerance) is always the last band.

It is a good practice to check the manufacturer's documentation to be sure about the color coding system used. When in doubt, measure the resistance with a ohmmeter. In some cases this might even be the only way to figure out the resistance; for example when the color bands are burnt off.

<u>Exercise 4:</u> Differential measurements on a series 5-resistor circuit

<u>Description:</u> This exercise is more practice using the differential probes of the ADALM2000 (M2K) to measure voltages of components not connected to either ground or the power supply nodes of the circuit.

1. Construct the following series 5-resistor circuit on your breadboard. The resistor values are 330Ω, 1kΩ, 330Ω, 10kΩ, and 1kΩ.

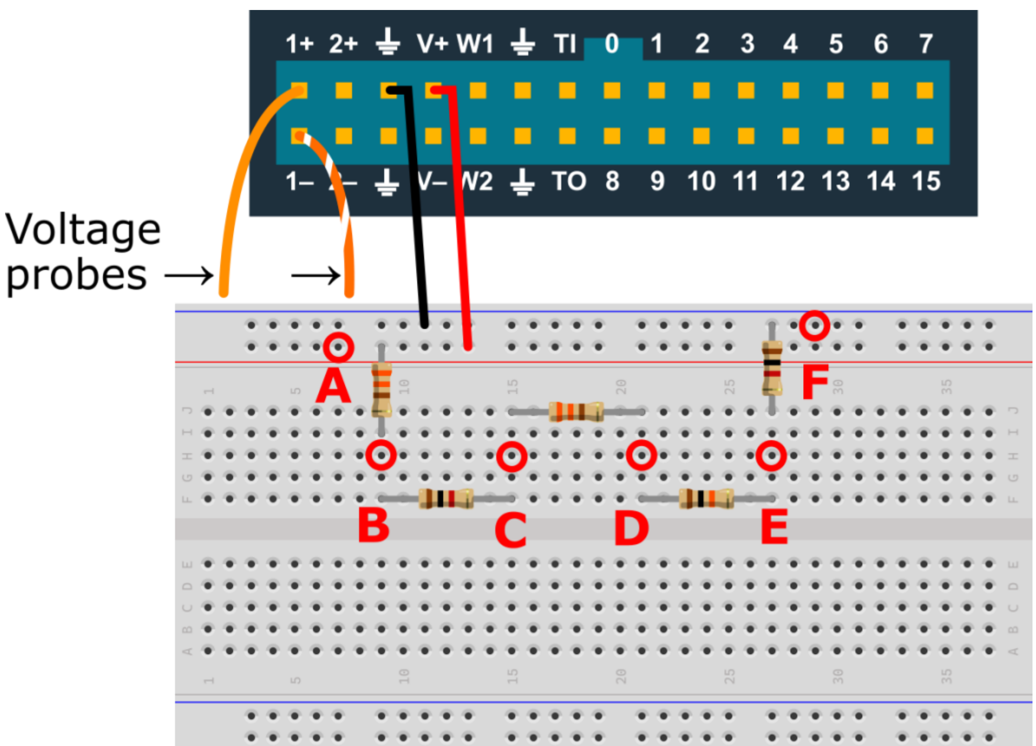


Figure 15. Diagram **of series 5-resistor** circuit to test voltmeter.
The orange wires **1+** and **1**– are the voltage probes.

Notice the orange wires dangling from the ADALM, pins "**1+**" and "**1**–". This are your voltage probes you will be using for the following steps. Each end of the resistors is labeled by the points A through F. It is often useful to measure the difference in voltage from one end of the device to the other to see how much energy was consumed by the resistor. Again make sure the Power Supply is set to +5V.

2. With this in mind, at this step you will place the voltage probes on both sides of each resistor at the different labeled points and record the voltages in a table.
3. To test that your voltmeter is wired properly and the circuit is powered correctly, if you measure the value CD (voltage with the "**1**+" wire at node C and the "**1**–" wire connected to node D), the Scopy Voltmeter should read 0.130 volts.

Questions: Complete the table below. Submit your answers on Canvas.

Measurement Points:	Voltage:
AB	
BC	
CD	0.13V
DE	
EF	
AC	
CF	
AF	