UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE
Department of Electrical and Computer Engineering

EXPERIMENT 7 – LAMPS

OBJECTIVES

The purpose of this experiment is to introduce the concept of resistance change with temperature in commonly used metals, and observe the effects of these changes for the tungsten lamp as they take place in time.

MATERIALS/EQUIPMENT NEEDED

Digital Multimeter
Digital Oscilloscope
14 V Lamp
Resistors: 10Ω

INTRODUCTION

Tungsten is the metal used to make the filament in vacuum tubes and incandescent lamps for illumination (e.g. a 60 W incandescent light bulb). Tungsten (Wolframite) is not as good a conductor as copper, and has the highest melting point of all common metals (3370 0C). Thus, it is able to glow white-hot for extended periods without melting. Due to the huge change in temperature of a tungsten filament when it is switched on, there is a substantial increase in its resistance when it is white hot (tungsten, like most metals, has a positive temperature coefficient of resistance).

This results in a cold filament having a much lower resistance, and a high inrush of current at the moment of turn-on. In fact, manufacturers of 120 V_{AC} electrical switches rate them lower in amperage when they are used for turning on tungsten lamps. In this experiment, the peak current at time of turn-on will be measured using the single-shot display capability of the digital oscilloscope. In addition, the X-Y mode will be used to make a Volt-Ampere graph (I vs. V), showing the increase in resistance and decrease in current as the bulb goes from a cold start to a glowing white- hot.

Effect of Temperature on Resistance: In Experiment 2 - Basic Circuit Elements, students were exposed to the electrical quantities that relate to resistance, that is, voltage and current. Resistance is also affected by at least four physical factors, namely specific resistances of the material type, length, cross sectional area and temperature. In this experiment, the power dissipated by a tungsten lamp will be determined. The change in dissipated power will represent a change in temperature. It is this change in dissipated power and temperature, which will change the resistance of the components used. A tungsten lamp will be used to investigate the characteristics of a positive temperature coefficient material. Since power is directly proportional to temperature, the student will indirectly see the effect of the temperature on resistance.

Information on V-A Characteristics: A very important and frequently used way of describing how a two terminal device (e.g., resistor, diode) and a three-terminal device (e.g., transistor) behave is by making a graph of current through the device versus voltage across the device. This graph is known as a volt-amp characteristic, or V-A characteristic.

During the experiment the voltage across the device will be set to a certain value, and the current that flows will be measured. Then the voltage will be changed, and the process repeated. Since the data will be taken this way, the voltage is the independent parameter and the current that flows is dependent on the voltage. The independent variable is plotted on the horizontal axis (x-axis), and the dependent variable is plotted on the vertical axis (y-axis). These two axes are called the abscissa (horizontal) and the ordinate (vertical).

If we consider a fixed (color-coded) resistor has a certain resistance, which essentially does not vary when the resistor is used within its power rating (e.g., 1/2 Watt). Thus, the graph of current versus voltage is a straight line. Other two-terminal devices, like tungsten lamps, have resistances that vary widely with temperature. The graphs for <u>current versus voltage</u> for these devices are NOT a straight line. Since the resistance depends on temperature, temperature depends on power and power depends on the applied voltage, the resistance depends on voltage. Additionally, this voltage dependent resistance will change with time until thermal equilibrium is achieved.

In addition to the V-A graph, another useful visual description of how a two-terminal device behaves is a graph of resistance versus voltage. The resistance data for this graph can be calculated from the voltage and current measurement data. The curves of resistance versus voltage will show that fixed resistors have essentially a constant resistance independent of the applied voltage, and that the resistance of the tungsten bulb increases as voltage increases.

Circuit Explanation: The circuit in Figure 7-1 has a 10 Ω current-sensing resistor in series with the bulb. The negative side of the power supply is allowed to float while the node between the lamp and the sensing resistor is grounded. In this way lamp voltage and current can be simultaneously observed. By putting the oscilloscope in single-shot mode (directions in the procedure section) and triggering on the rise of the Channel 1 voltage, the in-rush of current, proportional to the voltage across the sensing resistor, can be captured as the switch is thrown.

To make the graph of I versus V, the oscilloscope is put in the X-Y mode, Channel 1 is connected to the positive side of the power supply and becomes the X-axis, while Channel 2 is connected to the negative side of the power supply, is inverted and becomes the Y-axis. The bulb current is proportional to the voltage across the sensing-resistor as measured by Channel 2, and is given by $I = V/10\Omega$.

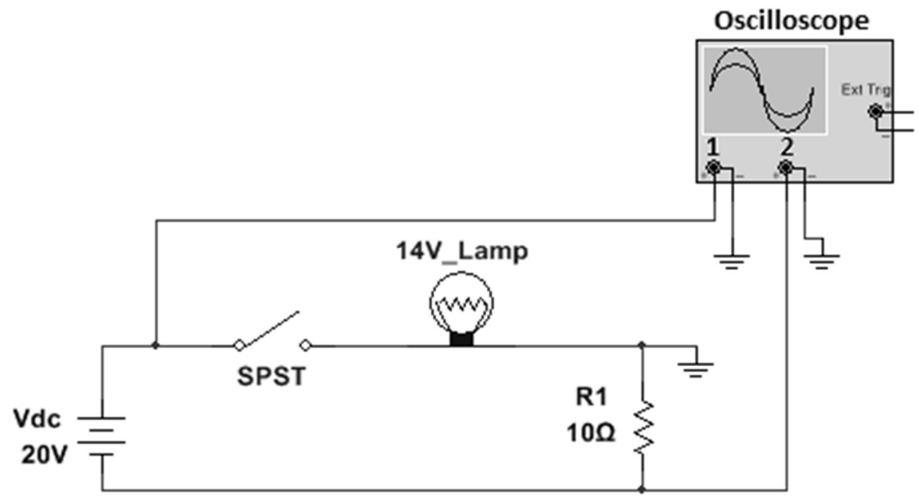

Figure 7-1 Lamp circuit setup (Note: invert channel 2 readings on oscilloscope)

PRELAB

1. The ideal voltage source often appearing in electrical schematics and used in circuit analysis problems, actually is not physically possible. Voltage sources such as batteries and laboratory power supplies will have a reduced terminal voltage that depends on the amount of current delivered by the source and the voltage regulation of the source. This reduction in terminal voltage will increase with increasing load current and is often approximately accounted for by a sourcing resistance (internal resistance) placed in series with an ideal voltage source to create an equivalent circuit representing the voltage source (as shown in Figure 7-2 below). Assuming that V_T is $0.9*V_{ideal}$ and R_L is 10Ω, calculate the value of the sourcing resistance R_S.

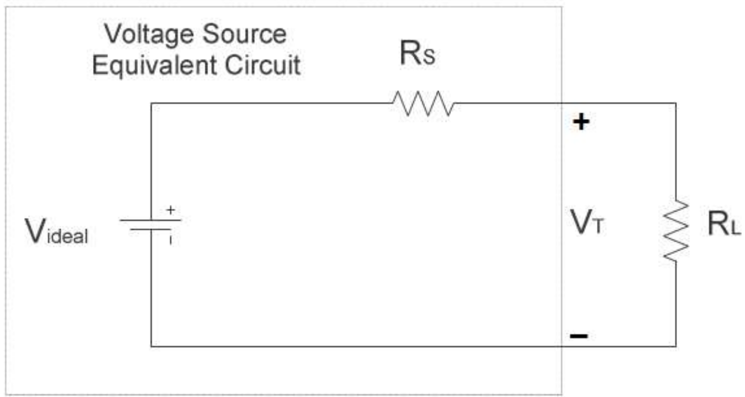

Figure 7-2 Voltage source equivalent circuit feeding a load resistor R_L

2. For the circuit in Figure 7-1 and the voltage curves of Figure 7-3, obtained from that circuit, determine the voltage across the lamp and the voltage across the 10Ω resistor; the steady-state current is simply the voltage across the 10Ω resistor divided by 10Ω. Using the above values determine the steady-state resistance of the lamp.

PROCEDURE

Measuring Lamp In-rush Current at Turn-on

1. Construct the circuit of Figure 7-1. Initially put the SPST switch in the open position.
2. Turn the power supply ON, adjust the supply voltage to 20V.
3. Connect Channel 1 and Channel 2 of the oscilloscope as indicated in Figure 7-1.
4. Set the vertical scale for both channels at 5Volts/Div and the time base for 10ms/Div.
5. Set the zero point for channel 1 in the center of the display and the zero point for channel 2 (Y-axis) one division above the bottom.
6. Set the horizontal position so the zero time arrow is one division from the left of the screen.
7. Using the trigger menu select Channel 1, DC coupling and normal falling edge triggering. Set the trigger level just under 20 Volts on Channel 1.
8. Under the Channel 2 menu invert the y-axis so a positive displacement will correspond to a positive current.
9. Press the single sequence key, and throw the SPST switch to its ON position. The sweep of the oscilloscope should be triggered once, and a new trace displayed (see Figure 7-3 for a typical display).

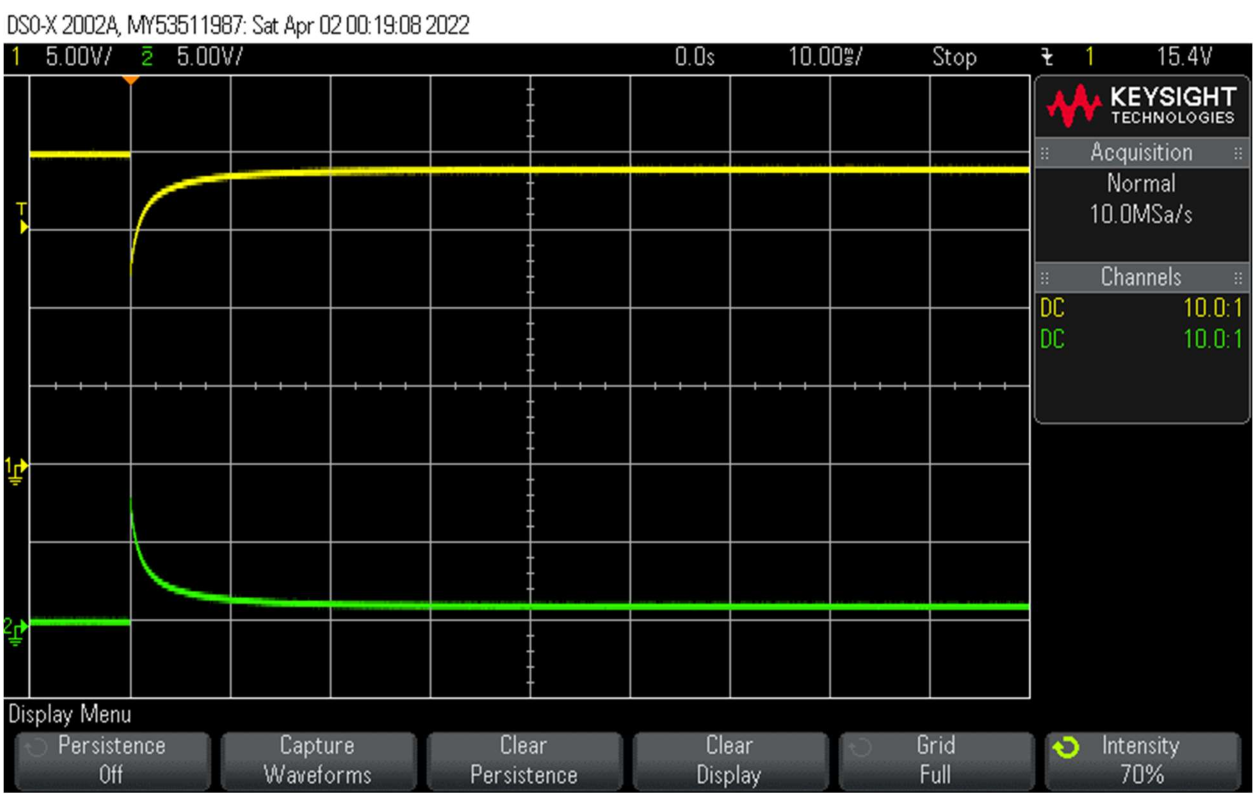

Figure 7-3 Lamp voltage and current vs. time, showing in-rush current and reduced voltage during in-rush

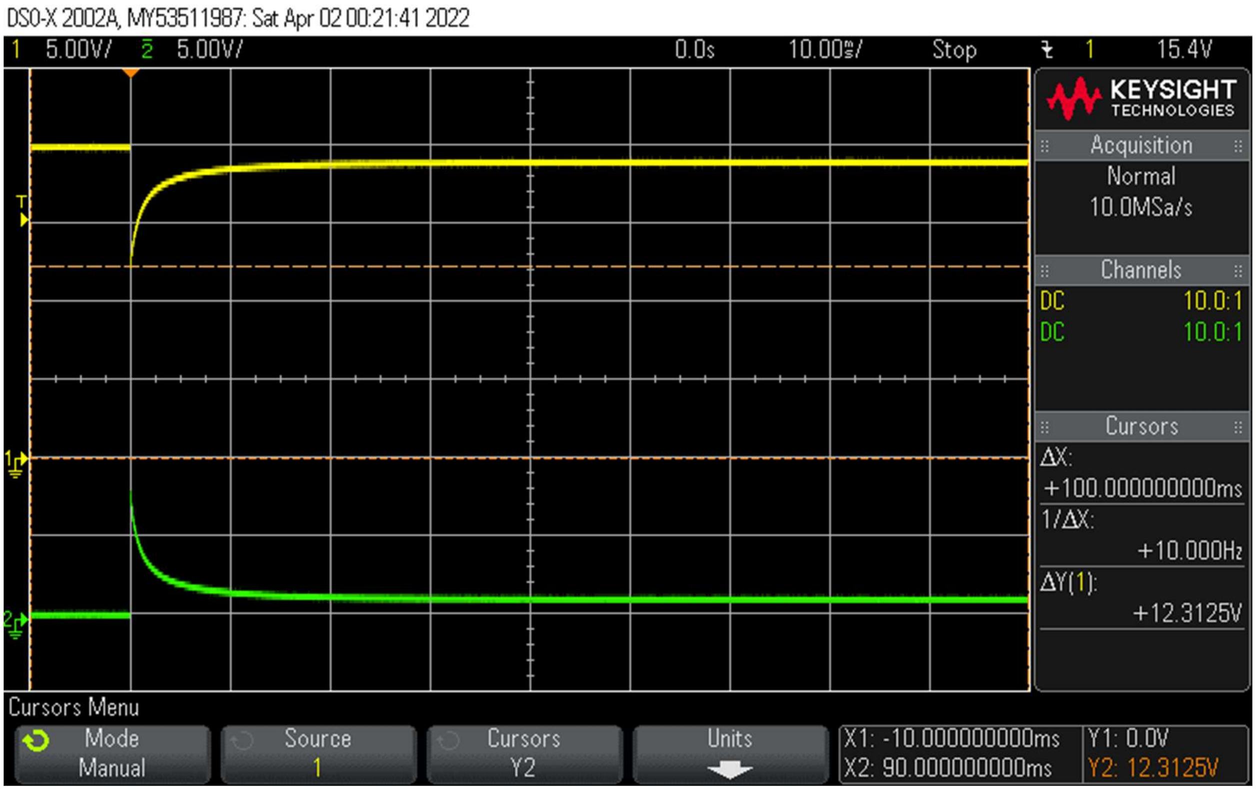

Figure 7-4 Turn-On V_{lamp} voltage

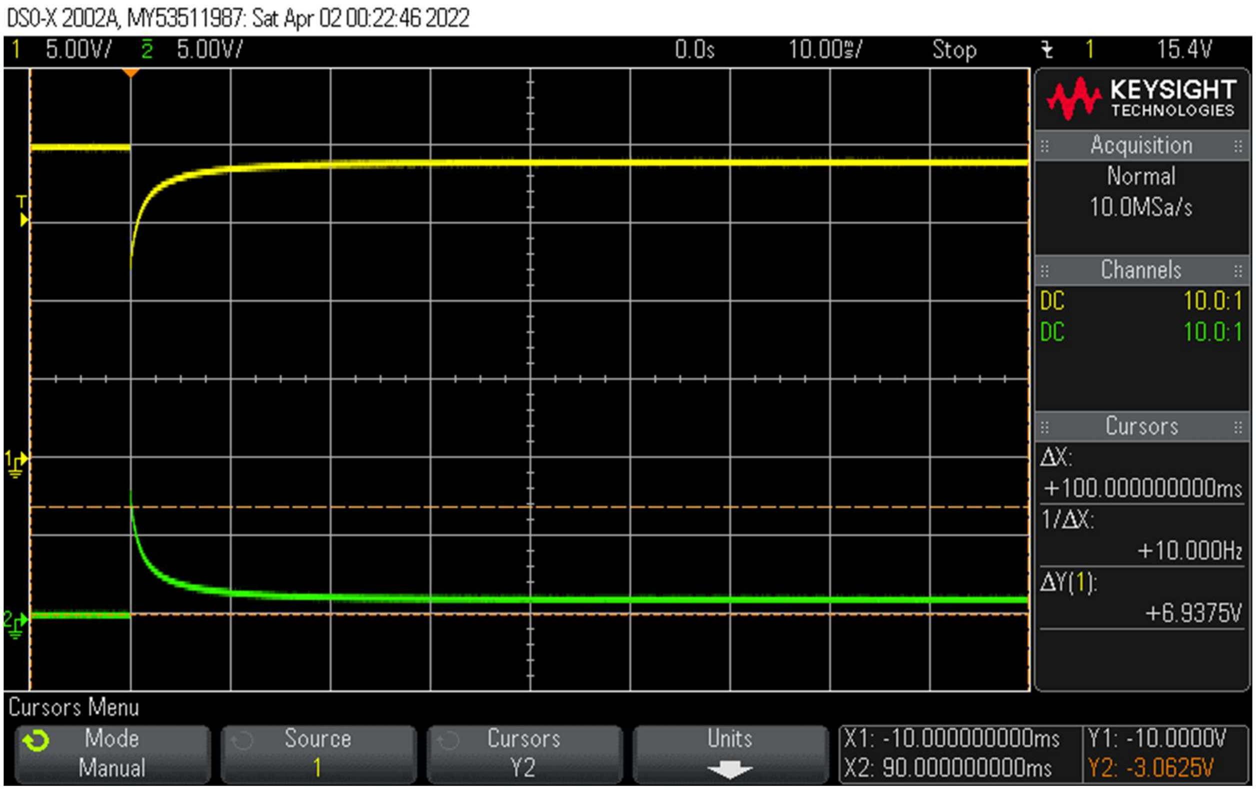

Figure 7-5 Turn-On V_{Rsense} voltage

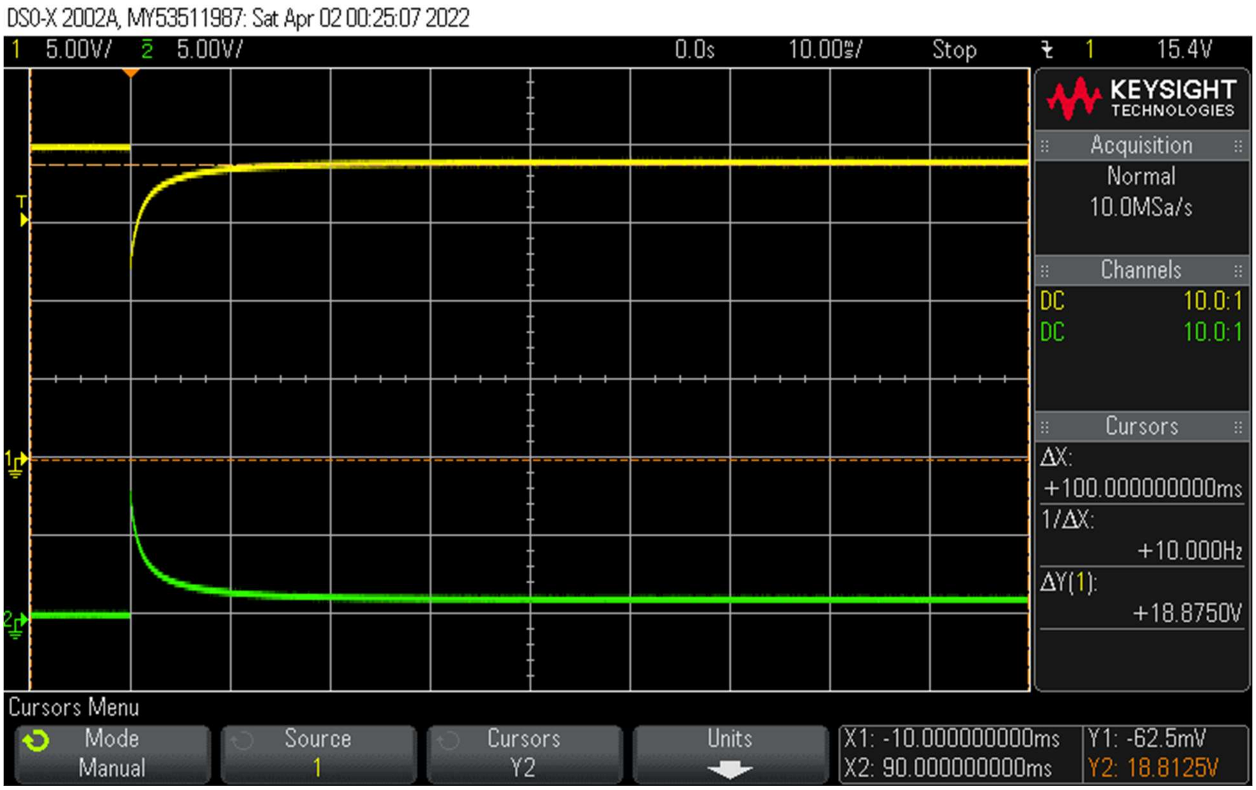

Figure 7-6 V_{lamp} Steady-State voltage

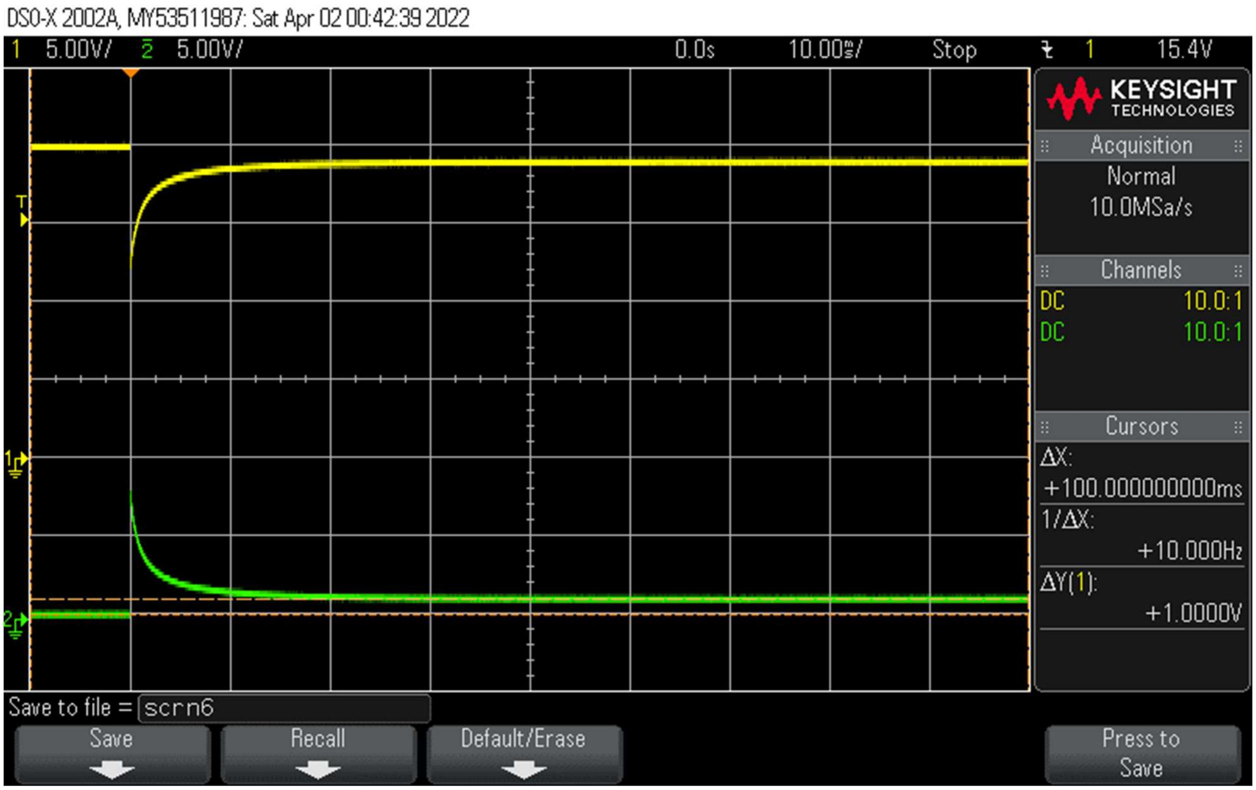

Figure 7-7 V_{Rsense} Steady-State voltage

10. It is possible for switch bounce to occur, multiple triggering is likely if this happens, and it may be necessary to repeat this procedure several times or to carefully make the connection manually to get a clean single trace. If required, repeat step 9 without the switch and manually connect. Can you get rid of the bouncing signal?
11. Observe that the initial bulb voltage (Channel 1) is reduced by the inrush current. However, as the bulb warms up, its resistance increases, its current drops (Channel 2) and the bulb voltage (Channel 1) returns to nearly + 20 V.
12. Measure the approximate time required for this lamp to reach steady-state.
13. From the frozen display, measure the bulb voltage and the sensing resistor voltage at two different times: (1) at the instant current begins to flow and (2) in steady-state. Record these values in Table 7-1, and calculate the bulb resistance at these two times.
14. To gain insight into why lamps generally burn out at the instant they are turned on, compute the instantaneous lamp power = I^2*(R_{bulb}) at turn-on and in steady-state.

Making & Analyzing a Graph of Lamp Current vs. Lamp Voltage

1. Keep the circuit and probe locations as they were in the previous part and close the switch.
2. Turn the supply voltage to 0 V, and change the oscilloscope settings as follows: Channel 1 to 2V/Div, Channel 2 to 500mV/Div,
3. Set the Horizontal Mode to X-Y, and Channel 1 & 2 positions to make a dot in lower left corner of the screen.

4. Slowly raise the supply voltage from 0 V to +20 V. Note that the dot moves upward and to the right. Slowly lower the supply voltage to 0 V.
5. Now set the display persistence to ∞ persist and repeat step 4. As the dot moves across the screen it leaves a trace. Observe the retrace as you slowly lower the supply voltage to 0 V. Record the image from the oscilloscope.
6. Adjust the power supply to 20V, and then turn the power supply OFF. Clear the screen and select ∞ persist. Turn the power supply ON, and then, after the trace reaches its maximum displacement, turn the power supply OFF.
7. You can see that the bulb current (Y-axis) climbed rapidly, then dropped off to its steady-state value. As the supply voltage was reduced, the bulb current decreased almost linearly with voltage, indicating a constant V/I or resistance at steady-state. Starting with the cold lamp, the current initially increased more rapidly with voltage, indicating a lower resistance following turn on, but an increasing resistance as the steady-state temperature was reached.
8. Save this waveform.
9. Next, adjust the supply voltage to obtain the steady-state lamp voltages in Table 7-2. Make the required measurements and calculations to complete the table.

DATA/OBSERVATIONS

Table 7-1: Lamp resistance at turn-on and steady-state

	V_{lamp}	V_{Rsense}	$I = V_{Rsense}/10\Omega$	$R_{lamp} = V_{lamp}/I$
Turn-On				
Steady-State				

Table 7-2: Readings for 14 V lamp

V_{lamp}	I_{lamp}	R_{lamp}	**Power**
2			
4			
6			
8			
10			
12			
14			

INSTRUCTOR'S INITIALS: ____________ DATE: ____________

POST-LAB

1. Plot current versus voltage and resistance versus voltage for the 14V lamp.
2. Discuss the in-rush current of the Tungsten lamp.
3. Using the curves obtained during the experiment repeat problem 2 of the Pre Lab.
4. Also, from these curves obtain the values of lamp voltage and lamp current at a point during the in-rush time (i.e., somewhere between 2 to 5 ms). Repeat problem 2 of the Pre Lab with these values. How does the inrush value of lamp resistance compare with the steady-state value?
5. From the data taken in this experiment, is it possible to estimate the internal resistance of the source? If yes, what is the value?

Be sure to include all items from the post-lab exercise above in your written lab report.