



## Observing & Measuring The In-rush Current Of A Tungsten Lamp, or, Why Bulbs Burn Out When They Are Turned On

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### Purpose:

Tungsten is the metal used to make the filament in vacuum tubes and lamps for illumination (e.g. a 60 W Edison-base bulb). Tungsten (Wolframite) is not as good a conductor as copper ( $RHO_w/RHO_{Cu} = 3.25$ ), and has the highest melting point of all common metals (3370 °C). 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 (abruptly?) 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).

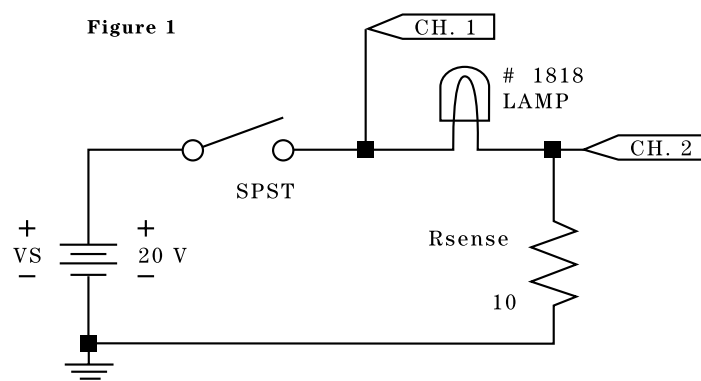
This results in a cold filament having a much lower resistance, and a high inrush of current at the moment of turn-on. In fact, manufacturers of 120VAC electrical switches rate them lower in amperage when they are used for turning on tungsten lamps. In this experiment, we will measure the peak current at time of turn-on, using the single-shot display capability of the Agilent -54601A digitizing 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 glowing white-hot.

### Equipment Required:

- Agilent 54600 - Series Oscilloscope

### Circuit Explanation:

The circuit below has a 10 ohm current-sensing resistor in series with the bulb. By putting the oscilloscope in single-shot mode, and by triggering on the rise of voltage on Channel 1, the voltage across the circuit (bulb + resistor) and the sensing resistor voltage alone (which is proportional to bulb current) can be captured when the switch is first thrown.





To make the graph of I vs. V, the oscilloscope is put in X-Y mode. Channel 1 is connected to the supply voltage and becomes the X-axis, while the Channel 2 voltage is the circuit current (multiplied by 10 ohm) and becomes the Y-axis.

**Procedure A - Observing And Measuring Lamp In-rush Current At Turn-on:**

- 1) Return the oscilloscope to its default settings by pressing the SETUP hardkey, and then the DEFAULT SETUP softkey. Put the SPST switch into the **open** position. The power supply **ON** button should be in (which is the **on** position), the 0 to +20 V supply should be set for maximum, and the current limit knob should be set for maximum (fully clockwise, I<sub>max</sub> (or approximately equal to) 450 mA).
- 2) Connect Channel 1 and Channel 2 as indicated in the schematic, using 10X probes. **Be sure to make the probe setting correct (10X) by using the PROBE softkey for Channels 1 & 2 (press 1 to select channel 1, and then press the PROBE softkey as needed to toggle between a divide by 1 or 10 or 100 probe).**
- 3) Set the **Volts/Div** control for channel 1 to 10 V/Div. Press the trigger **mode** hardkey, and then the **normal** trigger mode softkey. Set the trigger **level** control for something more than 0 V and less than 20 V (e.g. 10 V). The trigger slope is positive (this is the default slope). Adjust the **Time/Div** control on the front panel for 10 ms/div. Press the **Main/Delayed** hardkey, and the **Time Ref** softkey to make the reference time be at the left.
- 4) Firmly slide the SPST switch to its **ON** position. The sweep of the oscilloscope should be triggered once, and a new trace recorded (see Figure 2 for a typical display). Adjust the **position** controls for Channels 1 & 2 to separate the traces. If more than one trigger occurs for a single press of the **ON** button, choose the trigger **mode** hardkey, and then the **single** trigger mode softkey. You will have to press the **Run** hardkey after each trigger to “arm” the sweep.
- 5) Press the **Stop** hardkey, and then press the **Display** hardkey followed by the **Vectors On** softkey. Notice that Vectors On essentially “connects the dots”, giving a better display of the traces for Channels 1 and 2. Notable is the “droop” of the supply voltage (Channel 1), due to the instantaneous current demanded by the bulb exceeding the maximum power supply current limit value. Notice that as the bulb warms up, and its resistance increases, its current drops (Channel 2) and supply voltage returns to + 20 V.
- 6) Measure the approximate time required for this lamp to reach steady-state. From the frozen display, measure the supply voltage and the sensing resistor voltage at two different times: the instant current begins to flow, and in steady-state. Record these values in the table below, and calculate the bulb resistance at these two times.

**Measurement of Bulb Resistance**

	V <sub>Source</sub>	V <sub>Rsense</sub>	I = V <sub>Rsense</sub> / R <sub>sense</sub>	R <sub>total</sub> = V <sub>Source</sub> / I	R <sub>bulb</sub> = R <sub>total</sub> - R <sub>sense</sub>
Turn-On					
Steady-state					



- 7) If you want to have some insight into why lamps generally burn out at the instant they are turned on, compute the instantaneous lamp power =  $I^2(R_{\text{bulb}})$  at turn-on and in steady-state.

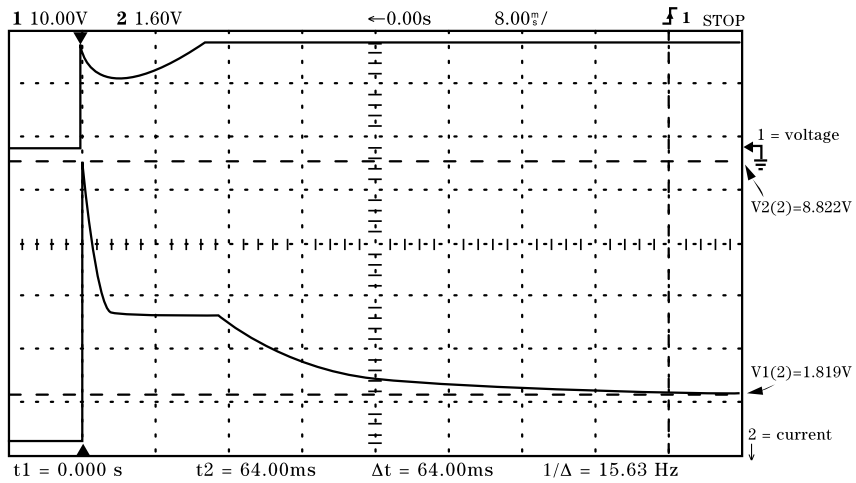
**Procedure B - Making & Analyzing A Graph Of Lamp Current Vs. Lamp Voltage:**

- 1) Keep the circuit and the probe locations as they were in procedure A. Turn down the supply voltage to 0 V. Change the oscilloscope settings as follows:

Channel 1 V/Div to 2V (X-axis)      Channel 2 V/Div to 500 mV (Y-axis)

Horizontal Mode to XY Channel 1 & 2 position to make a dot in lower left corner (0 A, V)

- 2) 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 back to 0 V.
- 3) Now press the **Auto-store** hardkey and repeat step 2. Now the dot leaves a line stored behind it. Slowly lower the supply voltage back to 0 V. Press the **Erase** hardkey.
- 4) Press the power supply **ON** button, to turn it off. Turn the supply voltage knob fully clockwise (maximum, (or approximately equal to) 20 V). Press the power supply **ON** button, to turn it on. Now, slowly reduce the supply voltage to 0 V. The display should look like Figure 3. 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, but the slope increased (the slope is the conductance,  $I/V$ , of the lamp). A colder lamp has more conductance = less resistance.



Chan	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	On	10.00 V	18.44m V	DC	Off	Off	10:1
Chan 2	On	1.6000 V	-6.375 V	DC	Off	Off	10:1
Chan 3	Off	100.0mV	0.000 V	DC	---	---	1:1
Chan 4	Off	100.0mV	0.000 V	DC	---	---	1:1

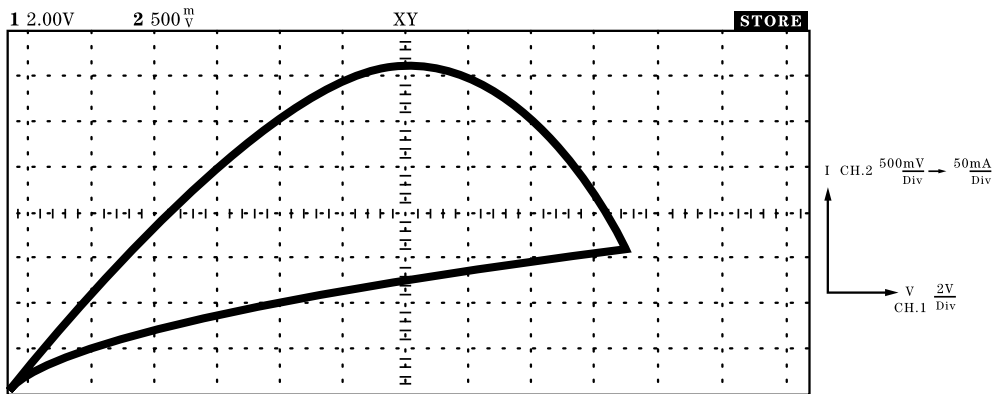
Horizontal	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	Normal	8.000ms/	0.000 s	Left	-----	-----

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
Trigger	Normal	Ch 1	6.250 V	200.0ns	Pos	DC	Off	Off

Display Mode: Normal

Cursors: t1=0.000 s t2=64.00ms V1(2)=1.819 V V2(1)=8.822 V

Figure 2 - Source Voltage and Current vs. Time, Showing Tungsten Lamp In-rush Current



Chan	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	On	2.000 V	-13.19 V	DC	Off	Off	10:1
Chan 2	On	500.0 V	-1.969 V	DC	Off	Off	10:1

Horizontal	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	XY	-----	-----	-----	-----	-----

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
Trigger	AutoLv1	Ch 1	0.000 V	200.0ns	Pos	DC	Off	Off

Display Mode: Normal

Figure 3 - Current vs. Voltage for Tungsten Lamp