**Memorandum**

**To:** Prof. David Kelley

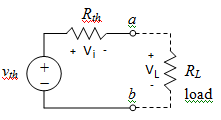
**From:** Yifan Ge, Andy Isola

**Date:** September 16, 2010 8:00am

**Subject:** ELEC 225 – Lab #2: Thévenin Equivalent Circuits

**Introduction**

The purpose of this lab was to investigate the function generator using Thévenin equivalent circuits (TEC’s) to find the function generator’s internal resistance and the relationship between the displayed voltage and the measured voltage output. The Thévenin equivalent circuit model is shown below in Figure 1 (from ELEC 225 Lab #2 handout for Fall 2010 by Prof. Kelley).We used this internal resistance value to design and build an attenuator circuit as shown in Figure 2 (from ELEC 225 Lab #2 handout for Fall 2010 by Prof. Kelley) to reduce the Thévenin equivalent voltage of the function generator.



**Figure 1.** TEC representation of the function generator.

*R1*

*R2*

*RL*

*vL*

−

+

*Rth*

*vth*

*a*

*b*

+

−

*c*

*d*

**Figure 2.** An attenuator circuit inserted between a Thévenin equivalent representation of a signal source and its load.

**Thévenin Equivalent Circuit Analysis**

Our primary goal was to determine Thévenin equivalent circuit of the function generator and the relationship of the displayed voltage and actual measured voltage.

In order to find the relationship of the displayed voltage and actual measured voltage, we set the function generator to output a 1.000Vpp, 1kHz sine wave. Interestingly, the measured output value from oscilloscope was 2.008V, which approximately doubled the displayed value. This voltage is also the open circuit voltage (*Voc*).

To determine the Thévenin equivalent circuit of the function generator, we need to find both the internal resistance (Thévenin equivalent resistance) and Thévenin equivalent voltage.

Since *Voc = Vth, Vth* = 2.008V.

Then we applied resistor loads of 1Ω, 100Ω, and 10kΩ, respectively, to the circuit. By finding the values of voltage across the internal resistor and current that flew through, we used Ohm’s law to identify the value of resistance.

For find out the current of the Thévenin equivalent circuit, the equation is .

Since *Rth* and *RL* are in series, using the voltage divider equation yields . Then, applying Ohm’s law, we have **(Eqn 1)**

By applying 1Ω, 100Ω, and 10kΩ to RL, we used the equations shown above to derive three possible values of *Rth*.

For the 1Ω resistor, we measured actual value of *RL*and *VL* (as shown in Figure.1).

*RL,1* = 1.2Ω ; *VL,1*= 43.0mV = 0.043V

Substituting *VL,1* to **Eqn 1**, we have

For the 100Ω resistor, we have

*RL,100* = 99.2Ω ; *VL,100* = 1.348V

Substituting *VL,100* to **Eqn 1**, we have

For the 10Ω resistor, we have

*RL,10k* = 9900Ω ; *VL,10k* = 2.006V

Substituting *VL,10k* to **Eqn 1**, we have

As we can see from the results, three possible values are different from each other. In order to decide which value is more close to actual resistance, we compared each value in the calculation. Since *VL,10k* is too close to *Vth* and *VL,10* is too small, *Rth,1* and *Rth,10k* are more likely to be inaccurate. Hence we decided, *Rth ≈ Rth,100* = 48.6Ω

Therefore, the Thévenin equivalent circuit of the function generator is shown in Figure 1 with

*Vth* = 2.008V and *Rth* = 48.6Ω

**The Attenuator Circuit Design**

The goal of this part of the lab is to design an attenuator circuit (as shown in Figure 2). The circuit has to satisfy *Vth,c-d* = 0.1*Vth,a-b* and *Rth,c-d* = *Rth,a-b*. First, we connected RL that has resistance similar to *Rth* to the circuit as shown in Figure 1. We have that

*RL* = 47.8Ω and *VL* = 0.990V

The *VL* is approximately equal to 1V, the displayed voltage on the function generator. Also *VL* is almost half of the *Vth* we have measured. As *VL* varies as we connect different resistor to circuit of Figure 1, the ratio of *VL* to *Vth* also varies as *RL* changes. However, as the voltage source is fixed, the ratio of *Vth* to the displayed value of the function generator stays the same.

Then we need to find the *R1* and *R2* value in Figure 2. Since *Vth,c-d* = 0.1*Vth,a-b* and *Rth,c-d* = *Rth,a-b*, we need to find expression for *Rth,c-d*, *Rth,a-b*, *Vth,c-d* and *Vth,a-b* in order to find two equation to solve for R1 and R2.

First, we shorted the voltage source to find *Rth,c-d* and *Rth,a-b*. We have

;

Then we used voltage divider to find *Vth,c-d* and *Vth,a-b*. We have

;

Hence, we have two equations

**(Eqn 2)** and **(Eqn 3)**

We used **Eqn 3** divide **Eqn 2** and got

which gives us

Substitute *R1* = 9*Rth* to **Eqn 3** and we have

which gives us

Finally, substitute *Rth* = 48.6Ω. And solve for the solutions. We have

*R1* = 437.13Ω ; *R2* = 53.97Ω

Then we picked resistors which have similar resistance to *R1*­ and *R2* to build the test circuit.

*R1,actual* = 426.4Ω ; *R2,actual* = 55.6Ω

We measured and got *Vth,c-d,measured* = *Voc,c-d* = 0.211V

This value is very close to *Vth,c-d,expected* = 0.1 *Vth* = 0.201V

To verify *Rth,c-d*, we connected a load Resistor *RL*, which has a resistance of 99.2Ω. Then we used a similar approach as we used for determining Thévenin equivalent resistance of the function generator. We measured *VL* = 0.141V. Thus, substituting *Vth,c-d* to *Vth* and *Rth,c-d* to *Rth*, we have

Therefore, the attenuator circuit is verified.

Finally, we removed the attenuator and set the displayed output voltage of function generator to 5Vpp. We measured *Voc* = *Vth* = 9.95V, which is approximately five times the value of *Vth* that we measure before.

Then we used **Eqn 1** to find the *Rth,new* by connect *RL* = 99.2Ω to the circuit. The measured value for *VL* is 6.65V

Hence, *Rth,new* remains unchanged.

**Data Summary**

In this lab we measured the voltages across several different resistor loads in order to find the Thévenin equivalent resistance of the function generator. The measured and calculated values associated with these measurements used to obtain *a* are included below in Table 1.

Table 1. Calculated and measured data for Rth equations.

|  |  |  |  |
| --- | --- | --- | --- |
| RL (nominal) (Ω) | 1 | 100 | 10000 |
| RL (actual) (Ω) | 1.20 | 99.2 | 9900 |
| VL (measured) (V) | 0.043 | 1.348 | 2.006 |
| Vth-VL (V) | 1.965 | 0.660 | 0.002 |
| I (A) | 0.0358 | 0.0136 | 0.000203 |
| Rth (Ω) | 54.9 | 48.6 | 9.87 |

**Conclusion**

This report summarizes our approach towards testing different resistor loads to determine the Thévenin equivalent resistance and voltage of the function generator provided. Using this result, we designed and constructed an attenuator circuit to normalize the output voltage of the function generator to match the displayed voltage output values while preserving its internal resistance.