# **Equivalent Meter Resistance**

# This installation of N.E.R.D discusses meter resistance. The equipment referenced here is found in the Undergraduate Electronics Lab at the University of Houston. Topics covered in this document are as follows.

**Voltage Measurements**

 **Equivalent Circuit**

 **Effect of Voltmeter Resistance**

**Current Measurements**

 **Equivalent Circuit**

 **Effect of Ammeter Resistance**

# **Voltage Measurements**

***Equivalent Circuit***

Voltage measurements are made by connecting a voltmeter in parallel with the voltage to be measured. We will suppose, to be specific, that we want to measure the voltage *v*2 across resistor R2 in the circuit in Figure 1.

**Figure 1** We wish to measure the voltage *v*2 using a voltmeter.

The measurement process is illustrated in Figure 2. The figure on the left shows the voltmeter in place. The figure on the right shows the voltmeter modeled using an equivalent resistance Rmv. As we will see, the presence of Rmv changes the value of *v*2, which we know call *v*meas. Note that *v*meas is not the same as *v*2, because of the voltmeter resistance.

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**Figure 2 Left**: Schematic representation of the placement of a voltmeter (V) to measure the voltage *v*meas. **Right**: A resistor Rmv has been used to model the voltmeter as an equivalent resistance.

We explore the effect of the meter resistance by noting that R2 has been replaced by the parallel combination of R2 and Rmv. The circuit with the equivalent resistance is shown in Figure 3.

The equivalent resistance Req is calculated from

$$R\_{eq}=R\_{2}//R\_{mv}$$

$ =\frac{R\_{2}R\_{mv}}{R\_{2}+R\_{mv}}$ .

**Figure 3** Circuit schematic accounting for the parallel equivalent resistance of R2 and Rmv.

***Effect of Voltmeter Resistance***

In thinking about resistor combinations, we know that Req will be less than either R2 or Rmv. From the voltage divider equation we see that the voltage vmeas will therefore be less *v*2. This introduces an error in measuring *v*2.

**The error introduced by the voltmeter will be small if Rmv >> R2.**This can be seen by looking at the expression for Req. In the limit that Rmv is infinite (an ideal voltmeter), Req = R2. Therefore a good voltmeter has a large equivalent resistance Rmv. Even if it does, however, there may be circumstances where we need to measure a voltage across a large resistance. In that case, we should expect an error that may be significant. But if we know the voltmeter resistance and the resistance whose voltage we are trying to measure, we can calculate, or at least estimate, the expected error.

**The multimeter in the ECE Lab is an Agilent 34405A. The internal resistance of this meter when used as a voltmeter is 10[M] for all full-scale measurement values.**

# **Current Measurements**

***Equivalent Circuit***

Current measurements are made by connecting an ammeter in series with the current to be measured. We will suppose, to be specific, that we want to measure the current *i*2 through resistor R2 in the circuit in Figure 4.

**Figure 4** We wish to measure the current *i*2 using an ammeter.

The measurement process is illustrated in Figure 5. The figure on the left shows the ammeter in place. The figure on the right shows the ammeter modeled using an equivalent resistance Rma. As we will see, the presence of Rma changes the value of *i*2, which we know call *i*meas. Note that *i*meas is not the same as *i*2, because of the ammeter resistance.

**Figure 5 Left**: Schematic representation of the placement of a voltmeter (V) to measure the voltage *v*meas. **Right**: A resistor Rmv has been used to show that the voltmeter introduces an equivalent resistance to the circuit.

We explore the effect of the meter resistance by noting that we have introduced a series resistance Rma. We can think of this as having added the meter resistance to R2, so that now we have an equivalent resistance that is the series combination of R2 and Rmv. This is illustrated in Figure 6.

The equivalent resistance Req is calculated from

$$R\_{eq}=R\_{2}+R\_{ma}$$

**Figure 6** Circuit schematic accounting for the series equivalent of R2 and Rma.

***Effect of Ammeter Resistance***

In thinking about resistor combinations, we know that Rmv will be large than R2. As a result, the current *i*meas will be less *i*2. This introduces an error in measuring *i*2.

**The error introduced by the ammeter will be small if Rma << R2.**This can be seen by looking at the expression for Req. In the limit that Rma is zero (an ideal ammeter), Req = R2. Therefore a good ammeter has a small equivalent resistance Rma. Even if it does, however, there may be circumstances where we need to measure a current through a small resistance. In that case, we should expect an error that may be significant. But if we know the ammeter resistance and the resistance whose current we are trying to measure, we can calculate, or at least estimate, the expected error.

**The multimeter in the ECE Lab is an Agilent 34405A. The internal resistance of this meter when used as an ammeter is specified as less than 20[] at 10[mA] scale, 2[] at 100[mA] scale, and 0.5[] at 1[A] scale.**