Bob’s TechTalk #14
by Bob Eckweiler, AF6C

Ohm's Law (Part IV of IV)

Practical Ohm's Law

In our last discussion of Ohm's Laws we learned how to derive all twelve equations. This month let's look at some practical examples for these equations. First we'll choose the proper resistor to use with a new AlInGaP high intensity LED (See Sidebar). Next, we'll handle that dreaded phone call many people get. Finally we'll look at building a load bank to test that new 12 Volt 25 Amp power supply you just bought surplus.

Example One: The Bright LED

You want to attach an indicator light to your 28VDC power supply so you will remember to turn it off when it's not needed. You don't want to use an incandescent bulb since they seem to burn out at the wrong time. Also, you want an indicator that is bright over a wide angle so you can see it from across your work area. You choose a new AlInGaP light emitting diode (LED).

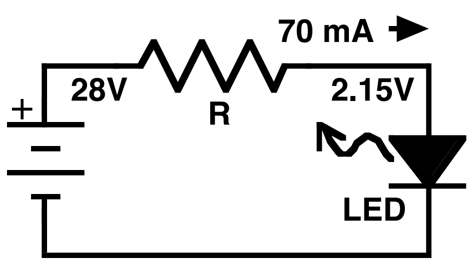

Figure 1

A quick check of its specifications reveals that the diode drops 2.15 volts at its rated forward current of 70 milliamperes. Since the LED is a current device, you must select the proper resistor to limit the current through the device to 70 ma. from the 28.00 VDC source. The resistor must also be chosen to handle the power it is dissipating. From Figure one we see that the resistor must drop 25.85 volts when 70 ma is passing through it. Using equation (3) [Equations are from the February 2002 Tech Talk (#13) article on Ohm's Law]:

$$\begin{aligned} R &= E/I \\ &= (28.0 - 2.15) / 0.070 \\ &= 25.85 / 0.070 \\ &= 369 \text{ ohms} \end{aligned}$$

The nearest 5% resistor value is 360 ohms. Using equation (2) the actual current would be closer to 72 ma. A better choice may be to use the next larger 5% resistor value, 390 ohms; this results in a lower current of 66 ma. which trades off some brightness for more life and reliability.

Are we done? NO! All resistors dissipate power when voltage is applied across them. If we put in a resistor that can't handle this power it will soon fail. If it fails open the LED goes out; if it fails shorted the LED burns out! Neither is desirable. Use equation (12) (from Feb.) to find the power dissipated in the 390 ohm resistor:

$$\begin{aligned} W &= E2 / R \\ &= (25.85 \times 25.85) / 390 \\ &= 668.2 / 390 \\ &= 1.7 \text{ watts} \end{aligned}$$

If you used a common quarter-watt or half-watt resistor, a new fragrance would be in the air soon after you turned your power supply on. You could use a two-watt resistor, which would give a small 17% safety factor. But since this resistor will see continuous duty, a larger safety factor would be added insurance. One excellent solution would be to use two 750 ohm 2-watt resistors in parallel. This would give:

$$R = (750 \times 750) / (750 + 750)$$

= 750 / 2
= 375 ohms

I = 25.85 / 375
= 69 ma.
(very close to the desired 70 ma.)

W = (25.85 x 25.85)/750
= 0.9 watts
(in each resistor)
A very conservative 120% safety factor.

W(total) = 0.9 + 0.9
= 1.8 Watts
for both resistors.

Example Two:
"Dad [Mom] [Honey], The Car Won't Start."

Eventually, we all hear or say those words in one flavor or another. Often the problem is that the lights or other battery- draining device was left on; other times the battery has reached the end of its life. Rarely it is an expensive component (starter motor, etc.) that has failed. What do you do? In our scenario you've just gotten the call and are puzzled. Your wife swears she didn't leave the lights on and the battery is only a year old. Also, she has reported a few times lately that the car was "starting funny". Armed with that information, a few simple tools, jumper cables, your trusty multimeter and some Tech Talk knowledge you head to the mall where the car sits. Upon arriving, the first thing you do is try to start the car. All you hear is a rapid clicking as you turn the key and you notice that the overhead light dims to almost nothing in rhythm with the clicking.

Figure two is a simple schematic a starter circuit. Some resistors have been added that aren't really resistors but are part of the circuit none-the-less. R(bat) is the internal resistance of the battery; R(term) is the resistance of the connection between the battery post and the clamp on battery connector. R(wire) is the resistance of the wire. These resistances are normally VERY SMALL!

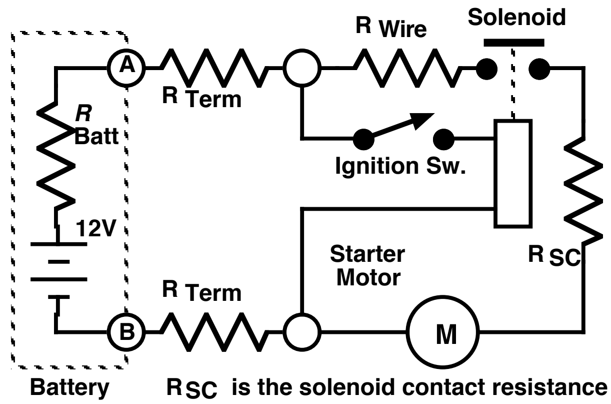

Figure 2

The first thing you do is measure the battery voltage across the battery posts; 13.1 volts - the battery is not dead.

You'd like to check the battery under load, so you ask your wife to turn on the headlights. They light, but dimly. Again you measure the battery voltage right on the battery posts (Points A). The meter reads just a bit lower than it did before but it is too small to read the difference; 13.09 volts you surmise. The problem is not the battery.

Quickly you move the meter leads to the battery cable clamps; whoa, here the meter reads a lowly 7 volts. You immediately wiggle the cable and are greeted by a sizzling noise, the lights flicker and the meter jumps between 7 and 13 volts. You ask your wife to turn the lights off and the meter returns to 13.1 volts. A few minutes with your tools and you've removed the battery terminal, cleaned the corrosion out and reinstalled everything.

This time, when you turn the key the car starts like new and your wife decides to go back into the store to buy you something special for dinner! What happened here? One of the R(term) resistances became higher due to corrosion, a common occurrence with car batteries. How high? Typical low-beam headlights (along with the associated tail and marker lights draws on the order of eight to ten amperes. Assuming 10 amperes, a battery voltage of 13 volts and that all the other extraneous resistances are zero, this amounts to a resistance of just 1.1 ohms (Can you use ohm's law to get this answer?)

When the key is turned the solenoid (which doesn't require a lot of current) closes switching the starter motor into the circuit. The 0.2-ohm starter motor that would normally draw about 50 amperes is suddenly in series with this 1.1-ohm terminal resistance. The result is a voltage divider circuit, which we studied in a previous Tech Talk. The starter motor is seeing less than 20% of the voltage it normally would see. Also, the solenoid sees that same voltage which is too low to keep the contacts in, and they open disconnecting the starter motor and causing the solenoid to contact again; thus the rapid clicking sound.

This is just one of many scenarios. If, after turning on the lights, the voltage at the battery posts drops substantially then R(batt) is dropping the voltage and the battery is probably defective. If the battery, with no load, measures low then it is either discharged, defective or the car's charging system is malfunctioning. Look at each resistance in figure two and think about what would happen if any of them became too large.

Example Three:
A Load to Test Your Power Supply.

You're in your garage. It's late night on the third Friday of October. You've just come home from the local radio club auction with a surplus 12-volt power supply. It's rated at 25 amperes and will be ideal to run your mobile rig when it's out of the car. Before you hook it up to your expensive rig you want to be sure it operates. You plug it in, turn it on see the voltmeter rise to a nominal 14 volts. With your old oscilloscope you look for AC ripple on the output. It's just a few millivolts and you begin to think you've acquired a real prize. Carefully you tweak the voltage adjusting control as you look on your trusty meter; you set it right on 13.8 volts - the ideal voltage for equipment designed to run off a 12-volt car battery under charge.

Everything looks ideal, but how will it perform with a 25- ampere load? What can you use as a test load? A few moments with you calculator and Ohm's law and you find you need a 0.56-ohm 350-watt power resistor. Darn, there was one at the auction, but you didn't bid on it, thinking; "What would I ever use THAT for?" Looking in your junk box you find numerous low resistance 100-watt resistors. Can you use them? Maybe!

Each power resistor has a specified resistance and a specified wattage. These are usually marked on the resistor body. Using ohms law you can calculate the maximum voltage and current the resistor can handle using equation (9) for the voltage and equation (10) for the current. (I often tag these values on power resistors). For 100-watt one, two and five-ohm resistors these voltages and currents are 10V/10A, 14.1V/7.1A, and 22.3V/4.5A respectively. Remember that these are maximum values above which you will exceed the 100- watt power rating of the resistor. The one-ohm resistor can only handle 10 volts so we can't use them unless we series them; the two-ohm resistors will just handle the voltage, but since this is a short test we will ignore any safety factor. We can place three 2-ohm 100-watt resistors in parallel across the power supply. At 13.8 volts each will draw 6.9 amperes for a combined 20.7 amperes. The resistors can be applied one at a time so the power supply can be checked at 6.9 and 13.8 amperes too. To get the load up to 25 amperes, we still need to draw another 4.3 amperes. We can add the fiveohm resistor to raise the total current By 2.76 amperes to 23.46 amperes. This should be close enough, but if your motto is: "Perfect is close enough" then you need to draw another 1.54 amperes. The maximum voltage for a 10-ohm 25-watt resistor is 15.8 volts. We have one, so lets add it in parallel with the others. At 13.8 volts it draws an additional 1.38 amperes; our total is now 24.84 amperes. We're now less than 1% from 25 amperes, way within the tolerance of typical power resistors.

At all currents the power supply performed well and you are very satisfied. By now it's way past midnight and you think about bed; but you suddenly realize it's nice and warm in the garage for an October night and you pull out the next treasure you picked up at last night's auction...!

This concludes the Bob's TechTalk series on Ohm's Law.

73, from AF6C

This article is based on the TechTalk article that originally appeared in the June 2002 issue of RF, the newsletter of the Orange County Amateur Radio Club - W6ZE.

AlInGaP LED Sidebar:

Recently, a new type of light emitting diode (LED) came on the market. This LED was designated as AlInGaP (for its material elements...chemical symbols for Aluminum-Al, Indium-In, Gallium-Ga, and Phosphorus-P). These LEDs have colors between red and yellow and are much brighter than standard LEDs. They also have a higher forward voltage drop - 2+ volts versus about 1.6 volts, and a higher current requirement - 50 to 70 ma. versus 20 to 30 ma.

To give you a rough idea of the improvement in brightness, a high efficiency red LED (old type) with a viewing angle of 36 degrees has an intensity of 8.7 mcd. at 20 ma.

Compare that to:

The AlInGaP LED has a viewing angle of 90 degrees and an intensity of 1250 mcd. at 70 ma. Quite an improvement!!!