MULTISIM DEMO 9.2: MODELING A (VERY) LOW-PASS FILTER IN MULTISIM

In the study of electrical circuits, our minds often drift upwards in frequency. We dream of Hz, kHz, MHz, GHz…possibly even THz. But what about mHz, or even strange things like cHz (centi-Hertz)? These are signals which have periods greater than one second, and hence frequencies less than 1 Hz. We'll look at those below.

In some gasoline tanks in cars, the gas is measured using a potentiometer with a shaft attached to a float which sits in the gas tank. Depending on level of the gasoline in the tank, the float sits at different vertical positions, and this would rotate the potentiometer accordingly. (See Fig. 9.2.1 below.) The change in resistance generated by the potentiometer rotation is used to generate a output signal voltage. But have you ever noticed if you're driving with an open container of liquid and you go over a poorly-maintained road where there's a lot of bumps your drink will slosh around and possibly spill? Obviously the same thing is happening in the gas tank; the gas is splashing around causing the float to move up and down, jerking the potentiometer back and forth and resultantly changing the voltage up and down. But your gas meter remains relatively stable. Why doesn't the gas-gauge jump all over like your 72 oz. soft drink? The answer is a smoothing filter.

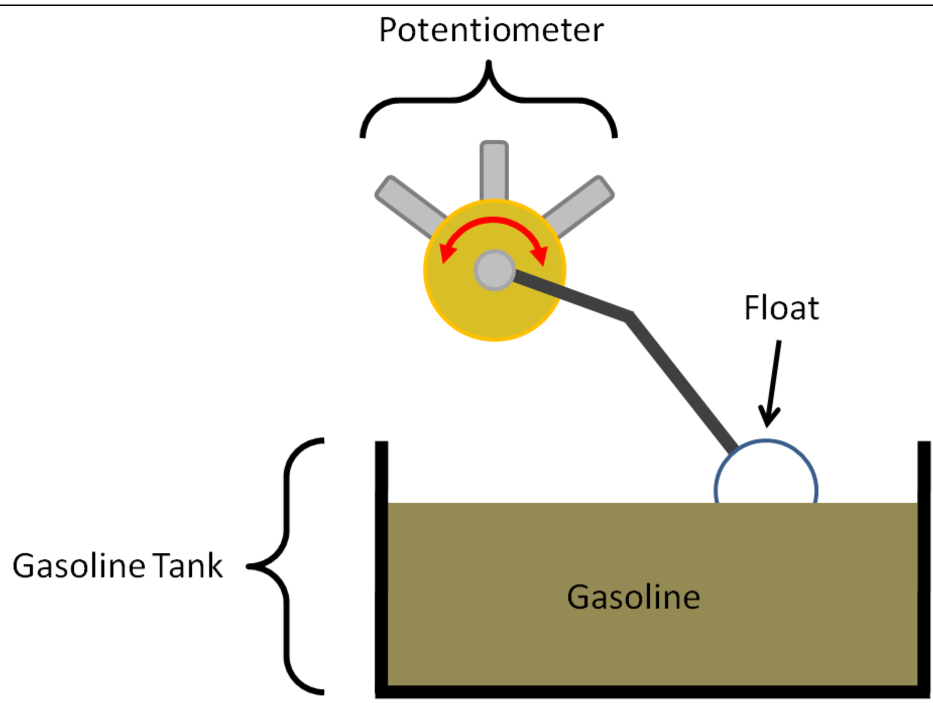

Figure 9.2.1 Simple schematic of gas tank with float-potentiometer measurement system.

While vehicles with gasoline generally utilize some sort of float/potentiometer combination to measure fuel levels, modern aircraft use a form of capacitor which uses the fuel as a dielectric. A metal tube and a metal rod placed inside the tube form a cylindrical capacitor. Fuel fills up between the two conductors, and since the dielectric constant of fuel is different from air, the fuel level affects the capacitance of the cylindrical capacitor. This capacitor value is used in a variable oscillator. As a result, the frequency of oscillation reflects the fuel level in the aircraft.

A smoothing filter, which is essentially a really-low-pass filter will block quick changes (high frequencies) in the gas level and only pass long-term changes (low frequencies) in gas level. Let's assume that we want a filter that will pass changes in gas level that last longer than 30 seconds, but block changes which are of a shorter duration than that. As a result, we need to pass frequencies only below 0.033 Hz.

The circuit in Fig. 9.2.2 should accomplish this. The values of the components are chosen because they are good, realistic component values. 4700 μF is a bread-and-butter capacitor that you'll find in any well-stocked electronics laboratory (or should at least). Build it, and simulate it with a Bode plotter as shown. You should get a plot similar to that in Fig. 9.2.3.

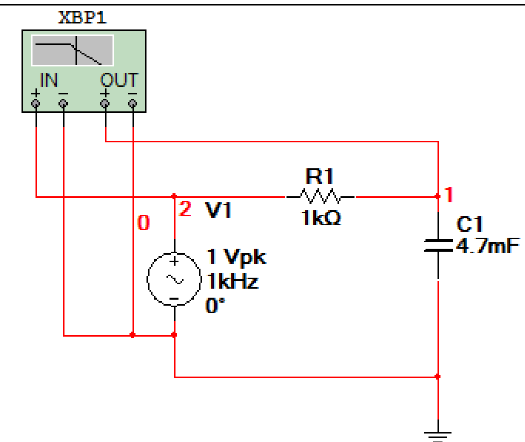

Figure 9.2.2 Simple schematic of a ultra-low pass filter.

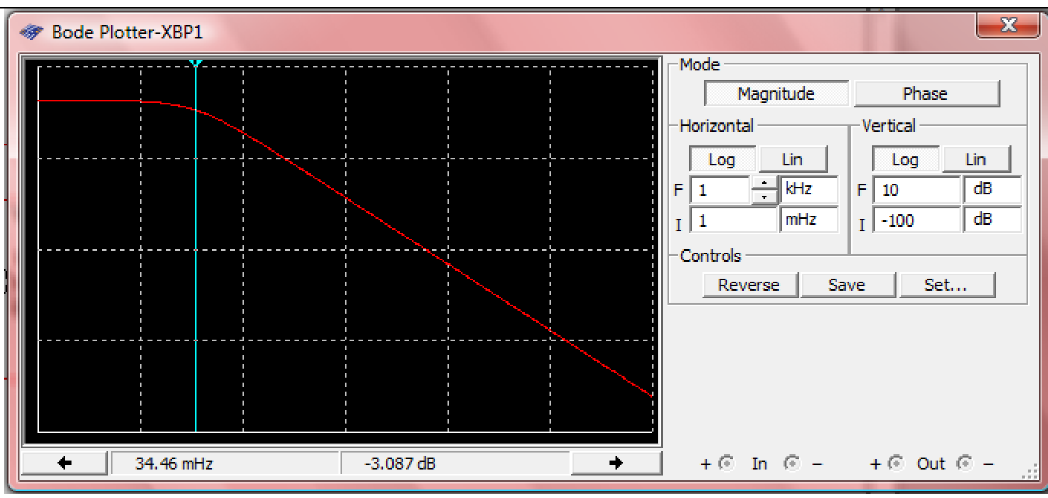

Figure 9.2.3 Bode plotter output of the Ultra-low-pass filter. Note the corner frequency of 34.46 mHz.

As we can see, the 3 dB frequency is 34.46 mHz. which corresponds to a cutoff period of about 29 seconds. That will do for our smoothing filter.

Now let's incorporate this thing into a gasoline gauge in Multisim. Build the circuit shown in Fig. 9.2.4. In this circuit, the potentiometer, (which is controlled by the level of gasoline in the in the tank), is hooked up so that it forms a voltage divider. (The 10 kΩ resistor R3 ensures that we don't drain the capacitor too quickly if the gasoline drops all the way down.) The output of the voltage divider is fed into the input of the ultra-low-pass filter which we just simulated with the Bode Plotter. The multimeter, which measures the output of the filter, serves as our fuel gauge (We'll assume that we have one of those nice expensive cars with a digital fuel gauge.)

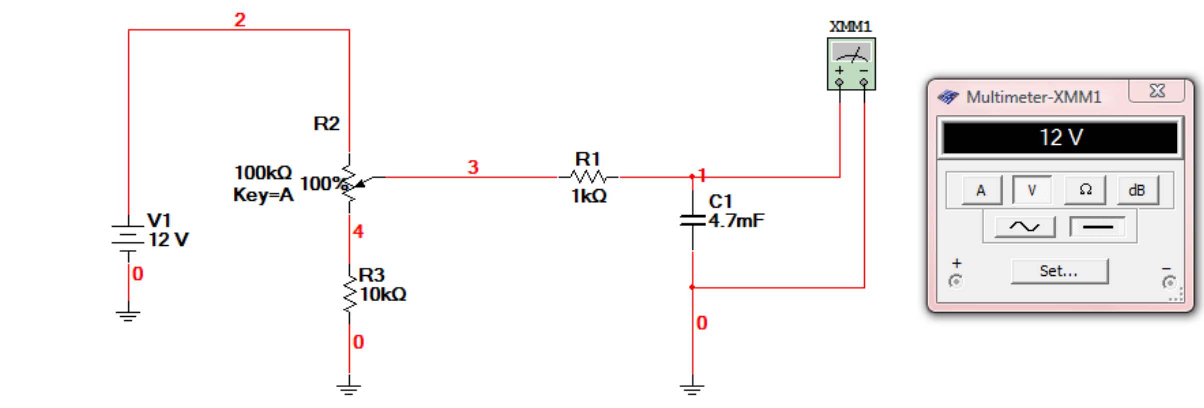

Figure 9.2.4 Gas Tank circuit reading a full tank.

We are going to simulate this circuit in the Interactive Simulation mode, and we want it to run in real time (1 second of our lives equals one second in the simulation). Depending on your processor speed, you may need to adjust the time step size of the Interactive Simulation by going to Simulate>Interactive Simulation Settings and adjusting it to that shown in Fig. 9.2.5. If the computer you are working on is really slow (or if you have a lot of applications running) you may need to increase TMAX even more than what is shown.

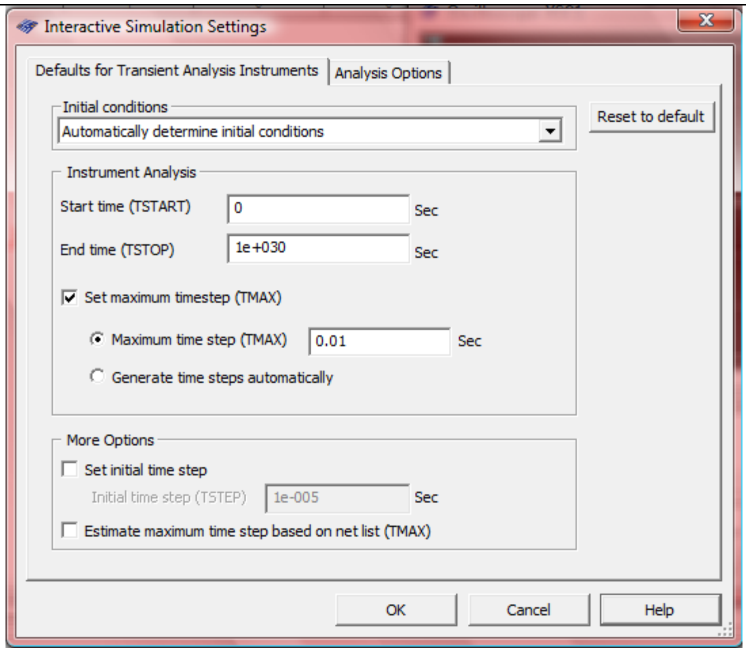

Figure 9.2.5 Adjusting TMAX in the Interactive Simulation Settings Window.

Before starting the Interactive Simulation, turn the gas all the way up (remember to have the potentiometer aligned correctly as shown in order for 100% to properly correspond to the correct side of the voltage divider.

100% corresponds to a full tank of gas. When you begin the simulation, the tank will register as full (12 V) (See Fig. 9.2.4). Now change it back and forth some, changing the potentiometer by 50% or so every few seconds. You should see no big differences or changes.

Stop the simulation by pressing , and adjust the gas tank potentiometer to 50%. Now start the simulation again. It should look like Fig. 9.2.6.

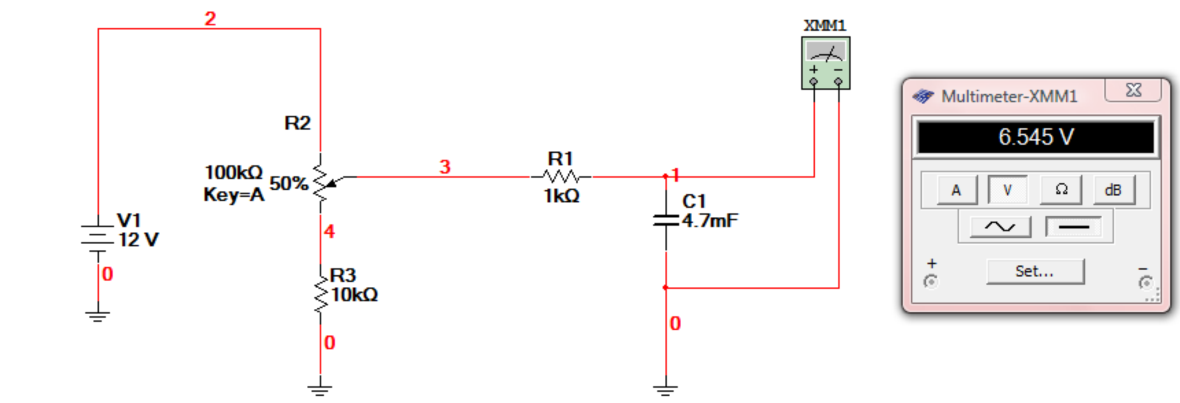

Figure 9.2.6 Gas tank circuit reading a half-tank.

So we're starting at half a tank. Now change the potentiometer up and down some like you did previously. Leave it 75% for a few seconds. Does it change much? No it shouldn't. The signals are too high of a frequency to get passed. The circuit will react pretty slowly. If you do leave it at different value for a long time, the output will eventually reach the proper value.

Now stop again, set the gas tank to 15%, and restart the simulation. The output should look like that in Fig. 9.2.7. Set it to 0% and let it sit for a few minutes. Eventually the "gauge" will read 0V.

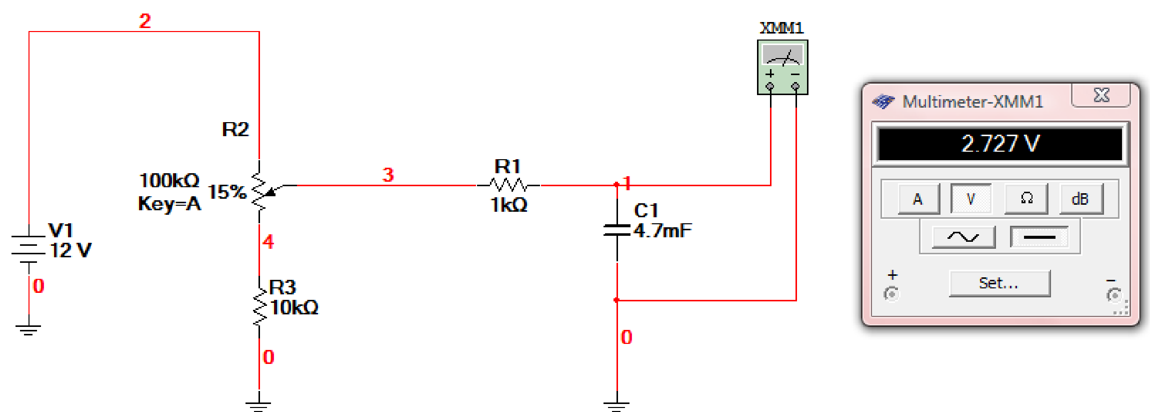

Figure 9.2.7 Gas tank circuit reading less than a quarter-of-a-tank (15%).

When the author ran the simulations it took at least several minutes to hit the zero point. But it did eventually hit zero…you just have to be patient.

From the zero point, you can also increase the gas gauge all the way, and as expected, the gauge will only slowly respond to the change. This is why when you fill your automobile with fuel at the pump the gauge doesn't always slam right to "F" when you start the car. It may need some time to reach the maximum value.

The point of this simulation is to show a real-world application of a filter in a frequency range which we do not often think about.