Hi, my name is Alex Hazama from Breccia Digital. And in this short video, we're going to talk about power supply and input, filter interaction, stability, instability issues and Middlebrook's instability criteria. Let's say you have this on your filter and you connect it to a power supply and there are times whereby the power supply is perfectly stable, but as soon as you connect the input filter, the loop starts to go unstable. Professor Middlebrook did a study on this and he came up with the notion that the in order for the input filter not to interact with the power supplies, a control loop, the input impedance of the power supply and then operating on the closed conditions must be much higher than the output impedance of the f the filter. Now, measuring of the output impedance of the filter is not that difficult measure the input impedance of the power supply is not as straightforward. That is because in order for the power supply to operate, you're going to have to put some capacitors on the inputs and of course, that is part of the filter and not part of the power source, power supply. Luckily, we can estimate these actually quite easily. The equation for the input impedance of the power supply is the Vin squared times efficiency divided by output power as shown in Steve Sumners book. And there's Zout of the filter, which is a simple L.C filter. Zout is equal to the square root of L over C. You can see right now that the larger the L the bigger Zout. And what we are trying to avoid is that Zout value ever gets close to Zin. Now, given that the cutoff frequency of the filter is one over two pi square root of L.C by selecting the appropriate value of C as smaller value of L large amounts of C, you could actually reduce Zout and we will discuss all of these later when we design a filter. So what happens if this Zout gets close to Zin? Well, I have done a simulation. Here you see the classic body plot of a voltage mode power supply, this is the voltage buck converter. The blue trace is the loop before I have added the filter. You can also see the face. It's all nice and beautiful exactly like you expect. Then the red trace is a filter that I have. I have designed specifically so that at its kind of frequency where it resonates, the impedance of the filter starts interacting with the impedance of the pass play. And you can clearly see the loop response crosses the zero dB axis several times and that is a recipe for instability. You can also see from the face the red trace on the face collapses at the cut off frequency or the resonance frequency of the filter, which in this case is around seven kilohertz. Now, if your loop is crossing the zero dB axis several times, you'll have to meet the stability criteria every time. And that is why this causes instability problem. Of course, this is a simulation because in real life, the power supply will go unstable at this point and then you will not be able to plot it very we however, what we are going to do is we are going to make a measurement of a real power supply and we're going to connect to it a listen in order to add some impedance. A listen is effectively a filter with lots of inductance and lots of capacitance. So what happens is when we attach to listen, it will interact with the loop and then we will use the body 100 in order to measure the loop. And you will clearly see that the beautiful loop that we have before addition of this huge amounts of inductance will dip as soon as we connect to listen. After I suggested earlier, we were going to connect a listen whilst measuring the loop and see the impact of the filter inside of listen, the huge inductors that we have inside of the control loop. At the moment, I am not using the listen. You can see that I've got my power supply over here. I've got the body 100. I have got the injection transformer. And the power supply is being my converter is being powered directly from the bench. And here you can see that I've got a classic look of a beautiful control loop. I have got a crossover frequency of around ten kilohertz. I've got about 55 degrees of phase margin. You can see the resonant little pole of the LC filter of the buck convertor. It is operating in multimode and you can see how nicely the phase is behaving. This is before adding the listener into the equation. So as we suggested earlier on when I connect a listen which is just like a filter, the output impedance of this will become too close to the input impedance of the power supply. And I expect to see a dip in the game plot and I expect the phase to start changing. So I'm not going to disconnect it my buck converter from the bench power supply and now going to power it through the listen. So if I connect it now to the listen you will see now, here we go. So now on this red trace, this is the resonant frequency of the L.C inside the listen, you can see that the loop, again, has dipped. But look at what's happening with the phase. The phase is going wildly up and down. And that is because now Zout of this LC network is interacting with a control loop of the power supply, just like Professor Middlebrook's suggested. Now, this is not approaching zero on purpose because otherwise it would go unstable and I could not actually show you anything as the power supply would kick into a protect mode. But you can clearly see that it's dipping down. And of course, at this point crosses the zero axis that is where your input filter makes your power supply unstable.











