The Voice Coil Actuator Story.

Who needs to read this?

Why we started with the development of our own Voice-Coil-Actuator may be of interest to some of our visitors. So if you want to know more about the how and why, please read on...

What is is used for?

When an instruction is received to move a piano or accordion key, or to hit a snare drum, something needs to make that movement. Our ancestors started out with a technology revolving around air and wooden and leather parts glued together. The best known device of such a design is a bellow. When air is blown into a bellow, it swells up pushing the 2 wooden planks away from each other, thus creating a movement. This is a very "analogue" way, with lots of advantages: very little background noise, very linear, very though and dependable over time. But it also has some drawbacks: it is relatively slow and you need a spring or gravity to return the bellow back to its starting position. It is also very difficult to exactly control the force and position, and it is a large and bulky system.

When electricity and its partner magnetism came into existence, it did not take long for the electromagnet to be invented. Apply power to a coil of copper wire and a magnetic field is created. If you put a metal core inside the coil you get movement as the metal core is attracted by the magnetic field. The electromagnet has advantages over the bellow: it is much smaller to incorporate in a design and you can control the magnetic force by applying more or less current to the coil. But again, there are disadvantages, like the need of a spring to return the metal core back to its starting position.

Worse is that the relation between force and traveled distance is not linear at all. In other words, with the same amount of current applied, the force is the weakest when the metal is the furthest away from the magnetic field, and the force gets exponentially stronger as the metal gets closer to the coil. This makes it very difficult to control. Just imagine that your arm can lift 1 kg when it's down, but that the strength would exponentially build up to 100 kg when your arm is up, it would be very difficult to handle a load and keep it in control.

The inertia of the mass of the (heavy) metal core means slow take-offs (moreover the electromagnet is at its weakest in the start position), and once moving, it's difficult to stop that same mass (adding to it that you have no stopping control whatsoever). So basically, this car is always stopped by hitting the tree due to lack of brakes.

Luckily, there is a solution to all these problems: the Voice Coil Actuator (VCA).

What ia a VCA, and how does it work?

The name comes from one of the most widely used applications: the loudspeaker. A coil moves the speaker's cone to amplify a voice, hence Voice Coil. Here the designers faced some serious problems. Re-create very fast sound waves (up to 20Khz, or 20.000 back and forward movements each second), and do this without the addition of any extra background (motor) noise.

So they invented the Voice Coil Actuator. The system is very simple in its basic form: a coil is positioned inside a permanent magnetic field. When current is applied to that coil, the coil creates a (second) magnetic field of itself which reacts with the permanent magnetic field, both fields pushing away from each other, or when the polarity of the current is reversed, pulling towards each other, thus creating a movement.

What are the pro's and con's?

The practical advantages of VCA's are difficult to exaggerate. The coil is moving in a magnetic field touching nothing, so there is absolutely no friction and background noise, also no wear on these parts. The heavy parts like the metal housing and magnets are stationary. The moving part is the coil, the lightest part in the setup. This means low mass with very fast movements as a result.

One of the biggest advantages is that a VCA is almost 100% linear! So regardless the position of the coil, the current applied will always result in the same force. This makes all the difference if you want to predict which power to apply to get a certain travel.

With all these advantages it is easy to think: This is it! But once you get busy trying to integrate these VCA's in your custom design, you soon discover the bumps in the road.

High cost.

The biggest challenge I found was also most surprising: the prices of these VCA's are very, very steep! How is it possible that a loudspeaker costing 50$ with all its parts (coil, metal parts, magnetic material, paper cone, rubbers and so on,) costs one tenth of only 3 parts of that same speaker: a coil, some metal housing and magnetic material? And those parts that cannot be used as is. You need to provide a guidance system, means to get the current to the moving coil, and assemble it all into a working unit.

Once you have a VCA up and running, you need to provide a driver like for a speaker, say an amplifier. And if you want this movement to mean anything to you, you need to incorporate a dependable motion encoder to measure the position of your load so that you can move your load to any position, fast and accurately. This calls for an intelligent feedback system that continuously measures the coil's position and controls the back/forward power to the coil, and this at least 2,000 times each second.

If you want to buy all these goodies from the shelf, you will spend many thousands of dollars for just one moving part. A far cry from the few Dollars it costs to make a bellow (remember, 2 pieces of wood and some leather) or electromagnet. Despite all the advantages of the VCA, the moment you come to that price conclusion, it hardly seems realistic to consider a VCA as a viable replacement for the existing systems.

How can the cost be lowered?

Well, we are now some years later, and we have done our homework on the VCA's. We learned a lot, we made many prototypes, and we finally came up with 2 designs (one linear and one rotary) that are now getting close to beta testing. They look very promising!

When it comes to the parts, we now know that 500$ for a coil, some metal parts and magnetic material is far too much if you only calculate the raw material. But we also found that there are many other factors which can increase the cost of the end

user's unit price.

- Legal expenses: You want to protect your work, but this can only be done by extremely expensive patents only protecting the guy who can pay the best layers. We did register our designs to be on the safe side, but we see no further advantage in expensive legal protection at the expense of our customers.
- Design expenses: If we look at the time we spent designing and if you need to pay engineers on your payroll top dollars for all this time, while this is not really a "mass production" device, the design cost will add a lot to the final unit price. These "high end" devices might also carry some certification allowing them to be used in medical equipment, a cost for the manufacturer which will also add to the final unit price.
- To high specification standards: When are specs good enough? The positioning they offer may be accurate within a millionth of an inch, good if you need that resolution to focus your space mirror, but who needs it if you want to hit a snare drum? Is there no market where positioning in one hundredth of an inch is more than sufficient?

Mind you, hitting a snare drum requires the strength of a human arm, and our organs will hit percussion instruments many million times. So the VCA we designed must be extremely well built, which they are. They only don't carry specs they don't need.

The electronics have made big advances in the last few years. Now you can find bridge-drivers (amplifiers) driving 10 amps costing a few $. There are now processors costing a few dollars with the processing power of a PC from not too many years ago.

We have put all this together into one complete working system, VCA's with integrated guidance, distance sensor, power driver and controller. A complete working device in the box costing less than the 500$ that other companies charge for a few loose parts.

We designed these VCA's for our own use, and we are excited to start integrating these amazing devices in our instruments. It will be one of the greatest advances in musical performance capabilities since our family started building organs more then 100 years ago.

Are there other possible uses for our VCA's outside our automated instruments?

We are convinced that many other designers find themselves in the same situation that we found ourselves in a few years ago: where can we find a HQ, low-cost VCA setup with the right specs for our use? Well, there might be some good news: we decided to offer these VCA's for sale as a separate product outside our musical instruments. And now that we have learned so much about VCA's, we can offer parts similar to other manufacturers if the quantities warrant the start-up cost.

We expect to get our two beta designs into production by the end of this year. If you are interested in acquiring these complete VCA's or VCA parts, please fill in the question form and we will see what we can do to help out!

The DECAP VCA design team.