The maths of model flying: Resolution

Remember when your amplifier had a volume control? You turned it to some value between 0 and 10, or 11 if your name was Eric Clapton. You could choose a value anywhere in between. There was an infinity of possible values. The position of the knob is an analogy to the sound level, so is called an analogue system. 0 is off, 10 is full and for example 6.55 is somewhere in between. You can choose EXACTLY the level you want. It’s not like that now as you will soon see. In the same way a vinyl disk has a groove that swings from side to side again with an infinity of displacements.

Lets look at a transmitter. It will have switches, sticks, knobs and sliders. There are on-off switches that allow just two positions or states, on and off. Clever stuff this innit? Then there the ones with a mid-position as well, so have three states. Both types of switch simplify all possibilities into two or three states. We call this a resolution of two or three. What about the knobs and sliders? These are analogue as they have an infinity of positions. However the transmitter electronics can’t cope with that so rounds off the positions to the nearest of a series of numbers. We could have just ten possible values but in the context of a rudder stick that would only give five possible possible positions in each direction. This is almost back to the days of single channel radio where the rudder was either full right or left or centralised. A resolution of 3. So each knob, stick or slider has a maximum and a minimum but how many positions in between depends on how many states the electronics rounds to in between.

Back to the amplifier. The knob does not have a maximum or minimum position. It just turns and turns - one way for louder and the other for quieter. Or it might just be a pair of real or screen buttons or even a knob that just clicks. And you often seem to be unable to find the exact volume you want.

Why. Because now everything is digital. Inside the electronics in the amplifier is a number that gives the current volume but that number has a limited number of steps between off and maximum. The number is turned into a voltage that is applied to the transistors, probably FETs, to set how much the signal is amplified, known technically as gain.

Computers can’t count
Well, they can but not up to ten like we can on our fingers.

The volume number is stored as a binary number, that is just a series of 1 and 0 digits. We normally count in tens that the maths experts call decimal or denary. Suppose we have a three digit decimal number 532. Taking them in reverse order:

2 This means two ones
3 This means three tens
5 This means five hundreds

In binary the values double with each left step rather than going up by ten times as in decimal.
Take the number 110101
The rightmost 1 is a one
The next 0 means no twos
The next 1 means a four
The next 0 means no eighths
The next 1 means a sixteen

The last 1 means a thirty-two

So we have counted to 32 + 16 + 4 + 1 or 53 in decimal
The decimal number 532 from above will be 1000010100. Have a go at confirming that.
If you want a quick course in how different number bases work listen to Tom Lehrer's song 'New Math'. Remember there are 10 types of people. Those who understand binary and those who don't.

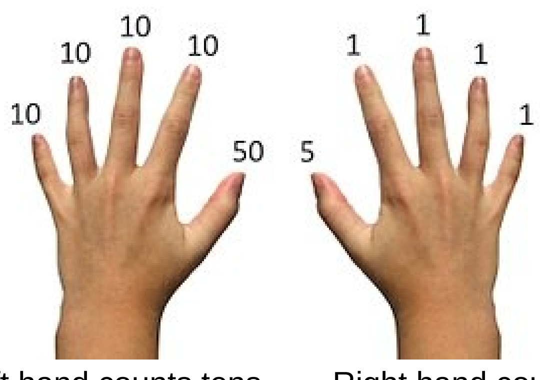
Remember that the vinyl disk was analogue. On a CD or DVD or in an MP3 or MP4 file the sounds are recorded as a series of digital numbers that appear to merge together when played into a continuous sound.

Better ways of counting on our fingers

There is a story told about an explorer who landed on an island unknown to his country. In the usual, at best, patronising way that such people often adopted, he made fun of the inhabitants, probably after giving them all diseases. In this case it was their counting system. He said they counted 1, 2, then 'Lots'. Some have argued that they might have been using a sophisticated binary system. If an extended finger is a 1 and a curled finger is a 0 then you can count up to 2^{10} -1 or 1023 on ten fingers.

There is a traditional decimal counting system in Korea called chisanbop that can count large numbers on two hands. The right hand counts the ones and the left the tens.

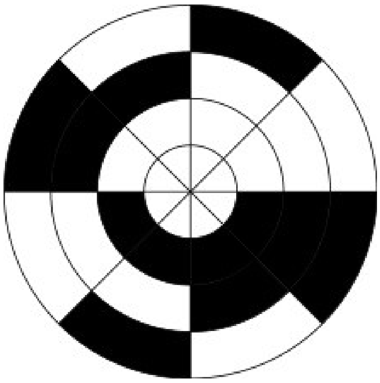
You hold your hands fingers extended above a table. You right hand counts the 1s. Start with your little finger. For the first count lower your little finger onto the table. Lower the next three finger in turn as you count to four. To count the next lower thumb for five and raise the other fingers. Lower them again as you count to nine. On the next count raise them all and drop the little finger on your left hand to show ten. Try it out. You will soon get the hang of it. When all of your fingers are on the table you have counted to ninety-nine. Not quite as good as binary but better than our method.



Left hand counts tens   Right hand counts ones

Enough already!

How is the volume number created and changed? It will probably start at the volume you had when you switched off or perhaps a default number. As you turn or click to increase the volume the binary number goes up by 1. Its easy to see how a click becomes an extra 1 but what about the rotary control? We use a rotary encoder. A flat disk one might look like this.



This a three bit encoder using a system called Gray Code. Suppose we have three light sensors, one for each ring, and we bounce light off the disk. A white patch will send light into a sensor and oddly in this case give a 0. Black gives 1. There are eight segments. Start with the fully white segment you get three 0s. Turn 45 degrees clockwise. The outer patch gives a 1 and the others 0s. The next step gives a 1 in the twos and 0 for the rest. If the disk turns so the digital numbers get smaller the circuitry turns the volume number down and vice versa.

You are ahead of me. Yes, because there is no contact with the disk and the sensors are electronic, this type of encoding can be very fast. It is used for all kinds of rotary sensing. So far as I know it isn't yet used in our servos nor transmitter controls though I might be wrong.

Pictures and sounds
Pictures and sounds are now mostly digitised. This means that the images and sounds are turned into 1s and 0s. At the same time they are compressed to reduce the size of files, using mysterious techniques called things like jpeg and mp3. These techniques are mind-bogglingly complicated. On my website, at peterscott.website, is my technical explanation, which is written in plain English. Click the Audiovisual screen button.

Play arduino

If the above ideas pique your interest why not try them out? You can buy low cost electronic kits that allow you to experiment. I think the biggest and best is the arduino that has the benefit of being low cost and easy to get hold of. It is the subject of another article. I recommend it very highly.

Resolution in our radio control systems

The more aerobatic our models are the more important resolution becomes. A high speed model is much more sensitive to small changes in the position of the control surfaces. 3D models have large control surfaces that can make large swings in very short times. You probably aren't aware of it when you are flying these models but take a look at someone who is. You will see constant, tiny stick movements.

Typical values

A quick scan of forums and specifications reveals that 1024 (10 bit) is the most common. Ten bit actually gives a maximum value of 1023 but the extra step in the zero. More expensive models can have 2048, thus halving the size of each servo step. A few have

4086. An average trim click gives about four steps. Note that some transmitters only use about two-thirds of the possible levels by default. When you add in expo which expands part of the range you can well finish up with quite coarse steps when close to neutral.

In the same way servos vary in their resolutions, with the best using 12 bits (4086). The whole system – transmitter, receiver and servo – is only as good as the lowest resolution in the chain. Also remember that a servo travels 60º in each direction as the pulse goes from 1 to 2 ms. So the resolution actually applies to the whole 120º movement. If you add this all up you can see you have far fewer steps than you might think.

For a 1024 step system:
If the transmitter uses 67% of the range there will be about 690 steps.
The servo moves in both directions. In one direction there are 345 steps.
In terms of angle this means about 0.2º per step.
Suppose you set your control surface throw to 10º.
That means only 50 steps.
Now you might use expo which would coarsen that further for the extreme deflection.

Last edit 1 March 2023