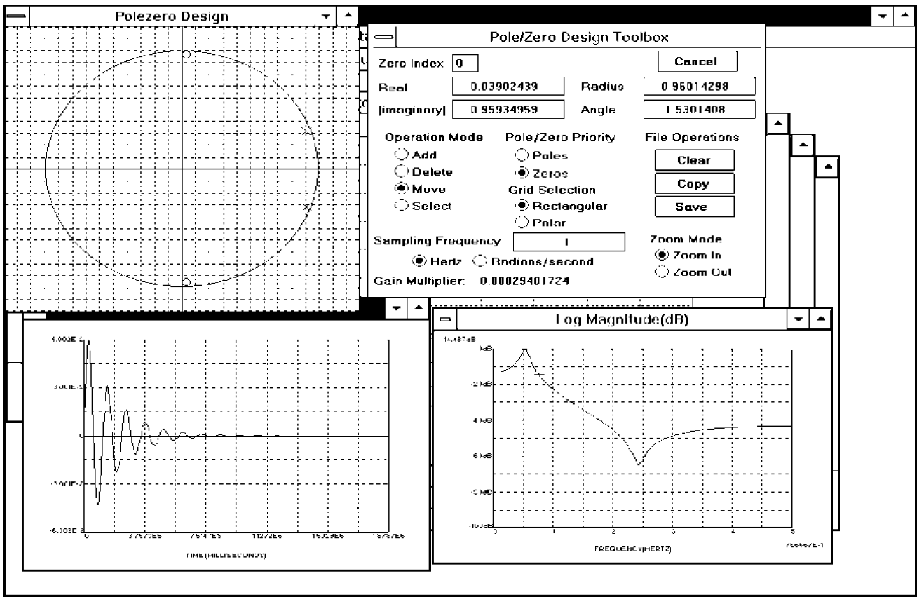
Filter design by pole/zero placement

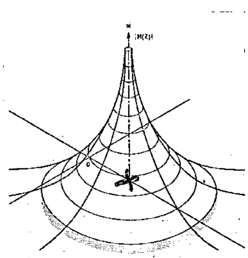


The ***QEDesign*** filter design software has a feature which allows for digital filter design by pole/zero placement.

What this means is, filters can be designed by placing and moving poles and zeroes on a pole/zero plot. The poles and zeroes are placed, deleted or moved using the mouse: the effects on filter response are calculated as soon as the pole or zero is released.

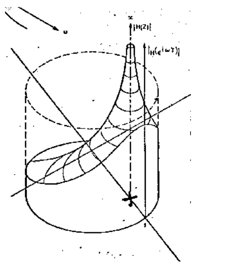
Much of the behaviour of digital filters can be deduced from the position of their poles. This is a happy circumstance, because it is easier to find the locations of the poles than it is to calculate the value of the transfer function H(z) for every value of z.

The effect of poles and zeroes can be visualised using the 'rubber sheet' analogy.



The transfer function H(z) is represented by a rubber sheet. At the poles, the sheet is stretched over upright poles: at the zeroes, the sheet is pinned down.

The shape of H(z) is pretty much defined by the positions of the poles and zeroes.



The filter frequency response is just the height of the rubber sheet on the unit circle.

Using the rubber sheet analogy to visualise the transfer function and its shape on the unit circle helps in gaining an intuitive understanding of some useful things about the effect of poles and zeroes, and their position, on the frequency response:

1) Poles cause bumps
2) Zeroes cause dips

The nearer to the unit circle, the sharper the feature.

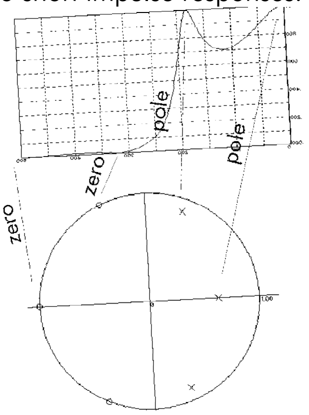
Pole and zero positions also tell something about the filter's transient response. Values of z off the unit circle represent transient terms:

1) inside the circle, transients decay
2) outside the circle, transients rise
3) on the circle, things stay the same

It is possible to imagine the effect of the poles upon the transient response (and hence the impulse response).

Each pole will give rise to a frequency component, whose frequency is found by projecting a line from the origin, through the pole, to the unit circle. The oscillation will decay: the rate of decay will be faster the further the pole is from the unit circle.

Poles near to the unit circle will give rise to long impulse responses, while poles far inside the unit circle will give rise to short impulse responses.



Using the new pole/zero placement feature certainly brings to life this close relation between pole/zeroes and the frequency/impulse response. If nothing else, it is definitely a useful way to increase intuitive understanding of what is going on.

Some electrical engineers will also be sufficiently familiar with poles and zeroes to use the new feature directly as a filter design method: although I think one would need to be pretty knowledgeable to jump straight in at this point. It should certainly be possible to use the new feature for sensible 'fine tuning' of a filter response, and this might prove especially useful with quantised coefficients (which tend to perturb the actual pole/zero locations away from the ideal).

Fordwater, Pond Road, Woking, Surrey GU22 0JZ
Telephone: (01483) 740138 Fax: (01483) 740136 email: bores@bores.com Web: http://www.bores.com