= M @-@ derived filter =

Parts of this article or section rely on the reader 's knowledge of the complex impedance representation of capacitors and inductors and on knowledge of the frequency domain representation of signals .

m @-@ derived filters or m @-@ type filters are a type of electronic filter designed using the image method . They were invented by Otto Zobel in the early 1920s . This filter type was originally intended for use with telephone multiplexing and was an improvement on the existing constant k type filter . The main problem being addressed was the need to achieve a better match of the filter into the terminating impedances . In general , all filters designed by the image method fail to give an exact match , but the m @-@ type filter is a big improvement with suitable choice of the parameter m . The m @-@ type filter section has a further advantage in that there is a rapid transition from the cut @-@ off frequency of the pass band to a pole of attenuation just inside the stop band . Despite these advantages , there is a drawback with m @-@ type filters ; at frequencies past the pole of attenuation , the response starts to rise again , and m @-@ types have poor stop band rejection . For this reason , filters designed using m @-@ type sections are often designed as composite filters with a mixture of k @-@ type and m @-@ type sections and different values of m at different points to get the optimum performance from both types .

= = Background = =

Zobel patented an impedance matching network in 1920 which , in essence , used the topology of what are now called m @-@ type filters , but Zobel did not name them as such or analyse them by the image method . This pre @-@ dated George Campbell 's publication of his constant k @-@ type design in 1922 on which the m @-@ type filter is based . Zobel published the image analysis theory of m @-@ type filters in 1923 . Once popular , M @-@ type filters and image parameter designed filters in general are now rarely designed , having been superseded by more advanced network synthesis methods .

= = Derivation = =

The building block of m @-@ derived filters , as with all image impedance filters , is the " L " network , called a half @-@ section and composed of a series impedance Z , and a shunt admittance Y. The m @-@ derived filter is a derivative of the constant k filter . The starting point of the design is the values of Z and Y derived from the constant k prototype and are given by

<formula>

where k is the nominal impedance of the filter , or R0 . The designer now multiplies Z and Y by an arbitrary constant m (0 < m < 1) . There are two different kinds of m @-@ derived section ; series and shunt . To obtain the m @-@ derived series half section , the designer determines the impedance that must be added to 1 / mY to make the image impedance ZiT the same as the image impedance of the original constant k section . From the general formula for image impedance , the additional impedance required can be shown to be

<formula>

To obtain the m @-@ derived shunt half section , an admittance is added to 1 / mZ to make the image impedance Zi? the same as the image impedance of the original half section . The additional admittance required can be shown to be

<formula>

The general arrangements of these circuits are shown in the diagrams to the right along with a specific example of a low pass section .

A consequence of this design is that the m @-@ derived half section will match a k @-@ type section on one side only . Also , an m @-@ type section of one value of m will not match another m @-@ type section of another value of m except on the sides which offer the Zi of the k @-@ type .

= = = Operating frequency = = =

For the low @-@ pass half section shown , the cut @-@ off frequency of the m @-@ type is the same as the k @-@ type and is given by
<formula>
The pole of attenuation occurs at ;
<formula>
From this it is clear that smaller values of m will produce <formula> closer to the cut @-@ off frequency <formula> and hence will have a sharper cut @-@ off . Despite this cut @-@ off , it also brings the unwanted stop band response of the m @-@ type closer to the cut @-@ off frequency , making it more difficult for this to be filtered with subsequent sections . The value of m chosen is usually a compromise between these conflicting requirements . There is also a practical limit to how small m can be made due to the inherent resistance of the inductors . This has the effect of causing the pole of attenuation to be less deep (that is , it is no longer a genuinely infinite pole) and the slope of cut @-@ off to be less steep . This effect becomes more marked as <formula> is brought closer to <formula> , and there ceases to be any improvement in response with an m of about 0 @.@ 2 or less .

= = = Image impedance = = =