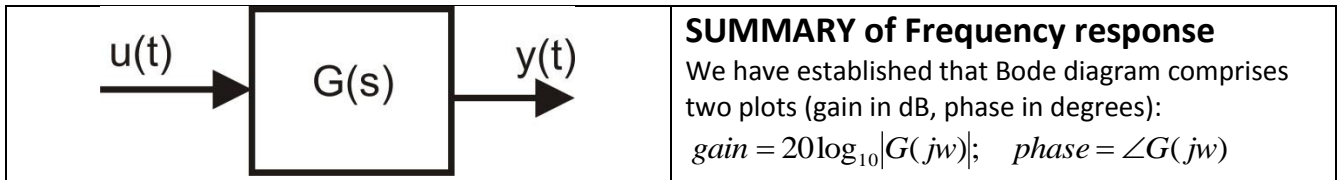


# Modelling and control summaries



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## Bode 9: Bode with several simple factors



### ADDITIVE PROPERTIES OF BODE DIAGRAMS

The previous note presented Bode diagrams for single factors. This note shows how one can use those plots in combination with rules of logarithms to form plots for systems with multiple factors (poles/zeros).

$\angle GM = \angle G + \angle M$	$\angle \frac{G}{M} = \angle G - \angle M$	<p><b>Multiplying/dividing factors leads to addition/subtraction in BOTH bode plots!</b></p>
$20\log GM  = 20\log G  + 20\log M $	$20\log\left \frac{G}{M}\right  = 20\log G  - 20\log M $	

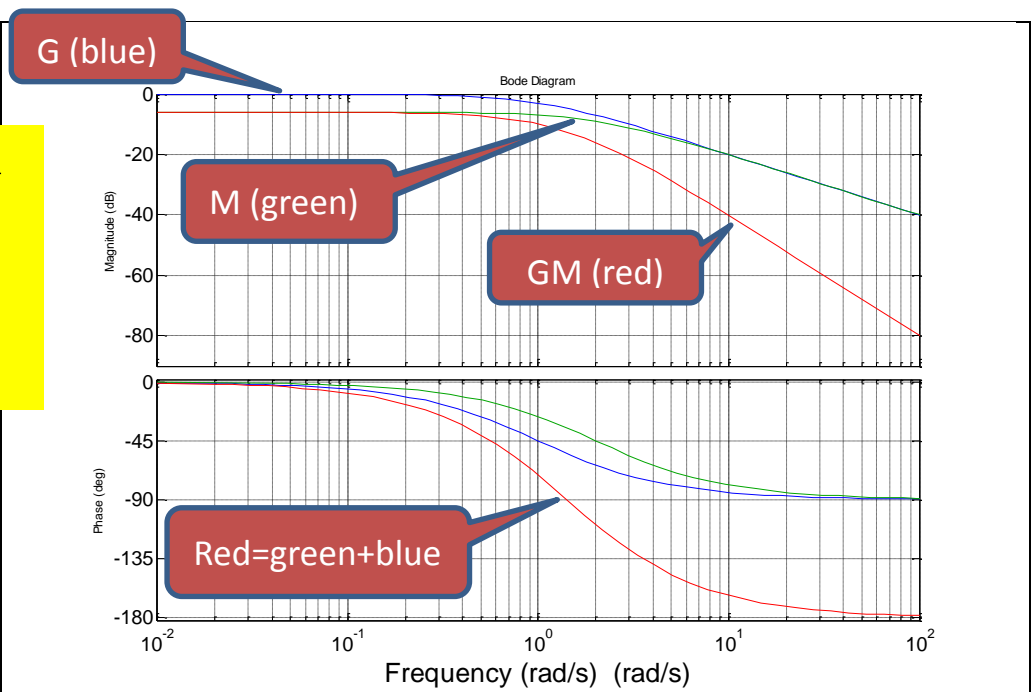
#### Example 1

$$GM = \frac{1}{(s+1)(s+2)}$$

$$G = \frac{1}{s+1}$$

$$M = \frac{1}{s+2}$$

One can determine the Bode for GM by adding the Bode plots for G and M.



**REMARK:** The additive property is useful and will be used later in design. However, as seen in the next example, it can be somewhat clumsy for constructing the original plots and is not a good way of constructing a plot with multiple factors.

### Example 2

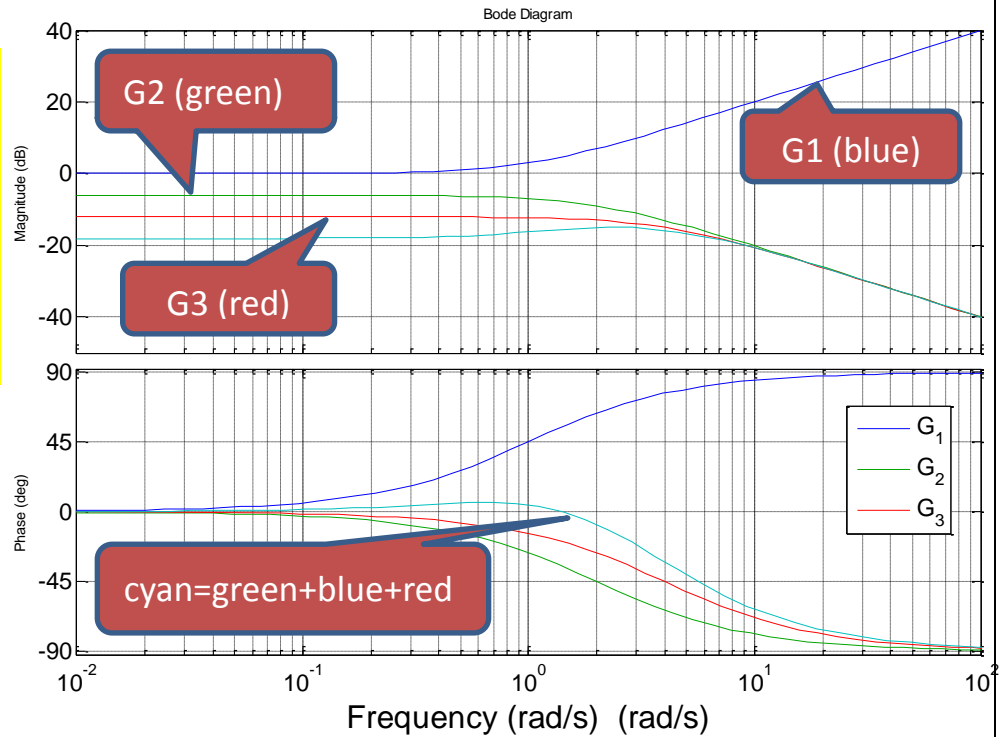
$$G_1 G_2 G_3 = \frac{s+1}{(s+4)(s+2)}$$

$$G_3 = \frac{1}{s+4}$$

$$G_2 = \frac{1}{s+2}$$

$$G_1 = s+1$$

One can determine the Bode for  $G_1 G_2 G_3$  by adding the individual Bode plots.



### SUMMARY

1. Sketching diagrams for simple factors is easy.
2. Adding together two sketches is manageable.
3. Once there are a large of factors, producing all the factor sketches and adding together is no longer straightforward.
4. **We need an alternative sketching method which is more efficient.**
5. **Remember, sketching should be quick and simple. If you have time, use a computer!**

Next, the notes show how asymptotic methods form a convenient and simpler way to obtain a sketch for a system with multiple factors; remember the focus is on methods one can do quickly and without needing substantive computation.