

# Michael Thomas Flanagan's Java Scientific Library

## ImpedanceSpectroscopy, ImpSpecSimulation and ImpSpecRegression Classes

<http://www.ee.ucl.ac.uk/~mflanaga/java>

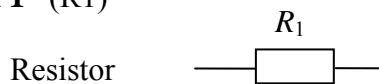
<http://www.ee.ucl.ac.uk/~mflanaga>

### EQUIVALENT CIRCUIT MODELS

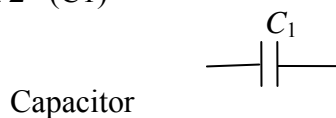
The 44 equivalent circuits, already coded within the ImpedanceSpectroscopy, ImpSpecSimulation and ImpSpecRegression classes, and the associated model numbers are listed below.

The list following the model number is the order in which the parameter values must be entered in the parameter array arguments in the relevant methods in the above classes.

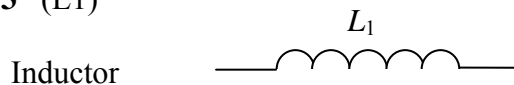
#### Model 1 (R1)



#### Model 2 (C1)



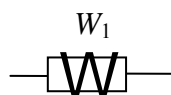
#### Model 3 (L1)



#### Model 4 (W1)

Warburg Impedance (infinite diffusion layer thickness)

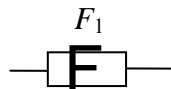
$$[Z = W/\sqrt{\omega} - jW/\sqrt{\omega}]$$



#### Model 5 (Fsigma1, Fdelta1)

Warburg Impedance (finite diffusion layer thickness)

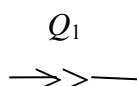
$$[Z = (\sigma/\sqrt{\omega})(1 - j)\tanh\{\delta(j\omega)^{1/2}\}]$$



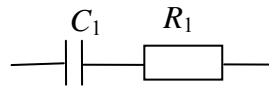
#### Model 6 (Qsigma1, Qalpha1)

Constant Phase Element

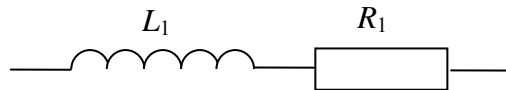
$$[Z = \sigma (j\omega)^{-\alpha}]$$



**Model 7** ( $R_1, C_1$ )



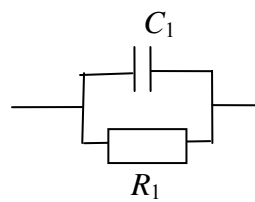
**Model 8** ( $R_1, L_1$ )



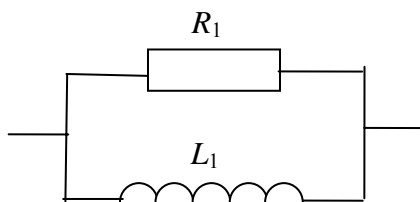
**Model 9** ( $L_1, C_1$ )



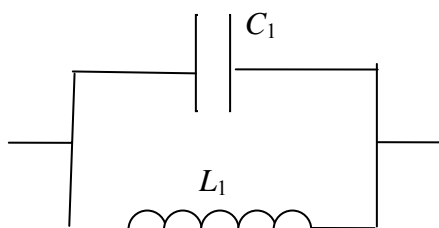
**Model 10** ( $R_1, C_1$ )



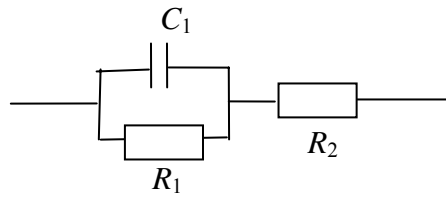
**Model 11** ( $R_1, L_1$ )



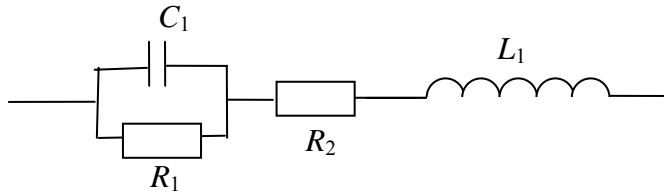
**Model 12** ( $L_1, C_1$ )



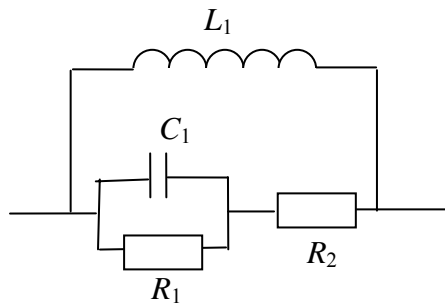
**Model 13** (R1, C1, R2)



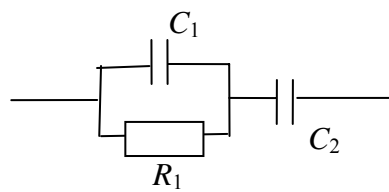
**Model 14** (R1, C1, R2, L1)



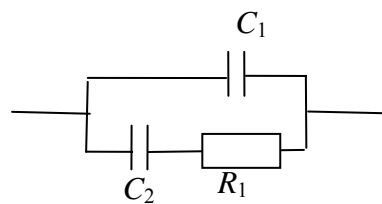
**Model 15** (R1, C1, R2, L1)



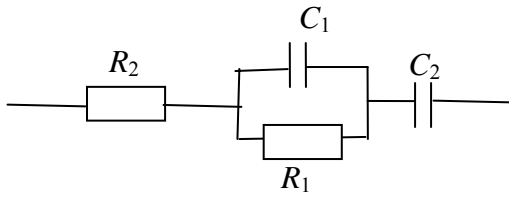
**Model 16** (R1, C1, C2)



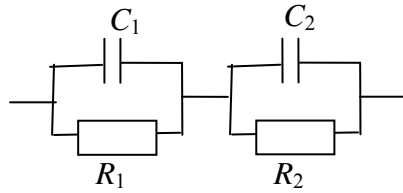
**Model 17** (R1, C1, C2)



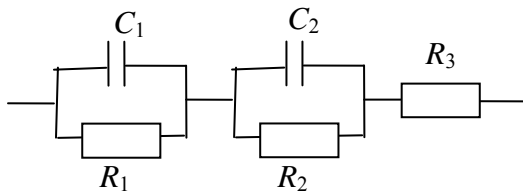
**Model 18** ( $R_1, C_1, R_2, C_2$ )



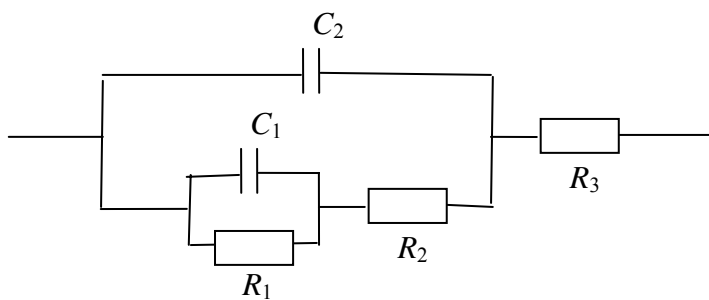
**Model 19** ( $R_1, C_1, R_2, C_2$ )



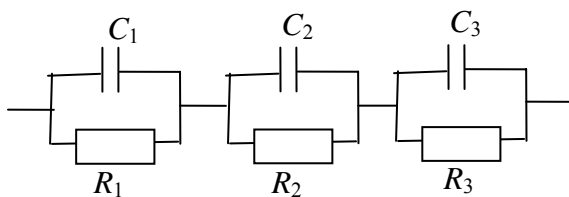
**Model 20** ( $R_1, C_1, R_2, C_2, R_3$ )



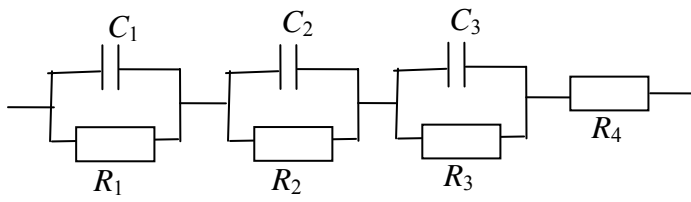
**Model 21** ( $R_1, C_1, R_2, C_2, R_3$ )



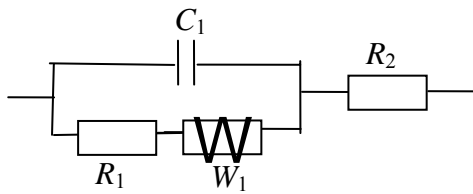
**Model 22** ( $R_1, C_1, R_2, C_2, R_3, C_3$ )



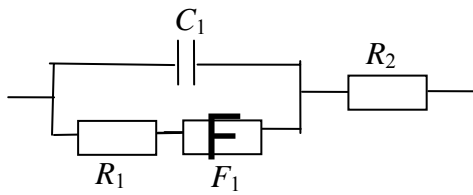
**Model 23** ( $R_1, C_1, R_2, C_2, R_3, C_3, R_4$ )



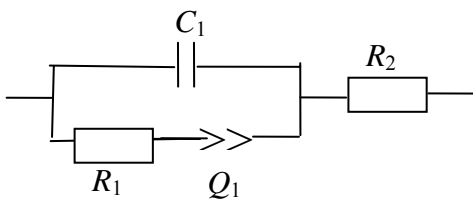
**Model 24** ( $R_1, C_1, W_1, R_2$ )



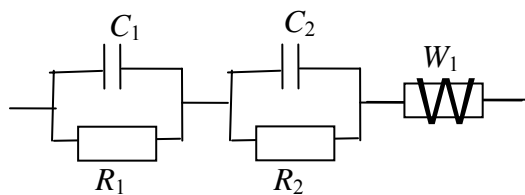
**Model 25** ( $R_1, C_1, F_{\text{sigma1}}, F_{\text{delta1}}, R_2$ )



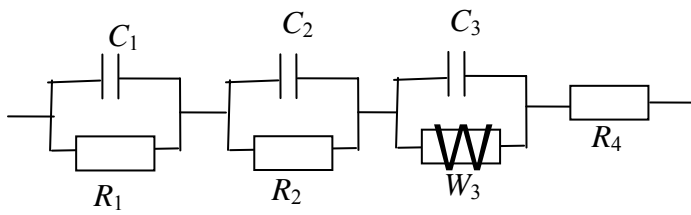
**Model 26** ( $R_1, C_1, Q_{\text{sigma1}}, Q_{\text{alpha1}}, R_2$ )



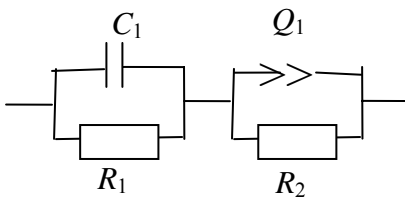
**Model 27** ( $R_1, C_1, R_2, C_2, W_1$ )



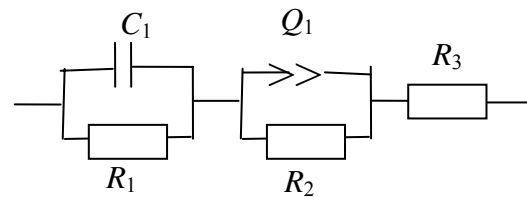
**Model 28** ( $R_1, C_1, R_2, C_2, W_3, C_3, R_4$ )



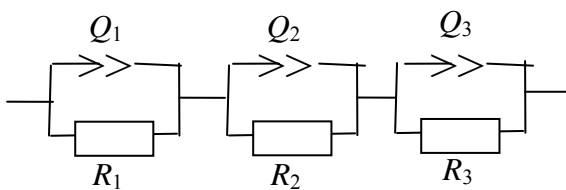
**Model 29** ( $R_1, C_1, R_2, Q_{\text{sigma1}}, Q_{\text{alpha1}}$ )



**Model 30** ( $R_1, C_1, R_2, Q_{\text{sigma1}}, Q_{\text{alpha1}}, R_3$ )

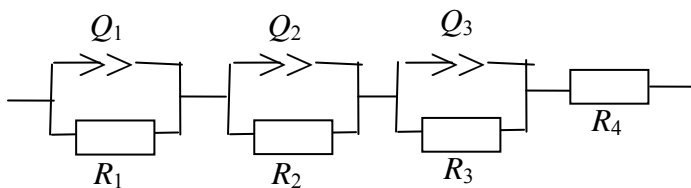


**Model 31** ( $R_1, Q_{\text{sigma1}}, Q_{\text{alpha1}}, R_2, Q_{\text{sigma2}}, Q_{\text{alpha2}}, R_3, Q_{\text{sigma3}}, Q_{\text{alpha3}}$ )



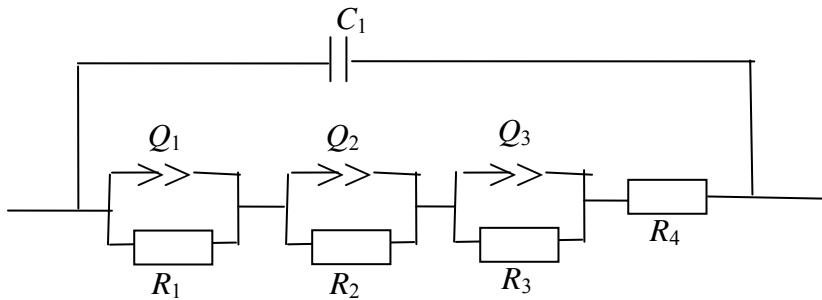
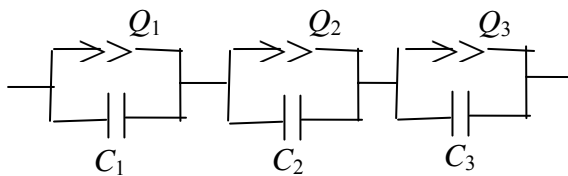
**Model 32**

( $R_1, Q_{\text{sigma1}}, Q_{\text{alpha1}}, R_2, Q_{\text{sigma2}}, Q_{\text{alpha2}}, R_3, Q_{\text{sigma3}}, Q_{\text{alpha3}}, R_4$ )

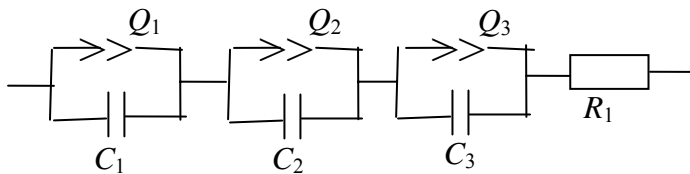


**Model 33**

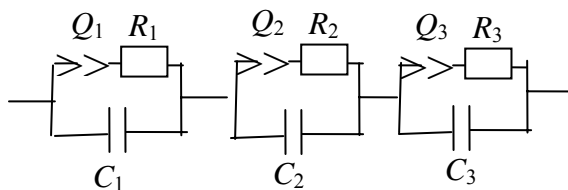
( $R_1$ ,  $Q_{\sigma 1}$ ,  $Q_{\alpha 1}$ ,  $R_2$ ,  $Q_{\sigma 2}$ ,  $Q_{\alpha 2}$ ,  $R_3$ ,  $Q_{\sigma 3}$ ,  $Q_{\alpha 3}$ ,  $R_4$ ,  $C_1$ )

**Model 34** ( $C_1$ ,  $Q_{\sigma 1}$ ,  $Q_{\alpha 1}$ ,  $C_2$ ,  $Q_{\sigma 2}$ ,  $Q_{\alpha 2}$ ,  $C_3$ ,  $Q_{\sigma 3}$ ,  $Q_{\alpha 3}$ )**Model 35**

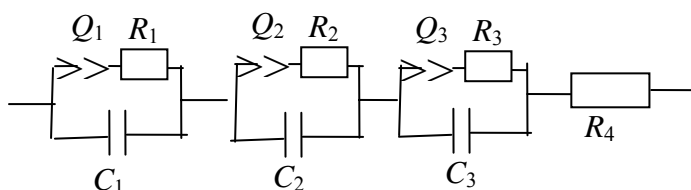
( $C_1$ ,  $Q_{\sigma 1}$ ,  $Q_{\alpha 1}$ ,  $C_2$ ,  $Q_{\sigma 2}$ ,  $Q_{\alpha 2}$ ,  $C_3$ ,  $Q_{\sigma 3}$ ,  $Q_{\alpha 3}$ ,  $R_1$ )

**Model 36**

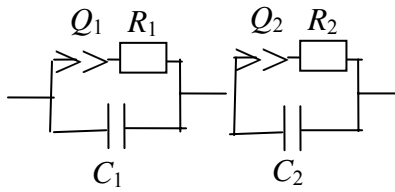
( $R_1$ ,  $Q_{\sigma 1}$ ,  $Q_{\alpha 1}$ ,  $C_1$ ,  $R_2$ ,  $Q_{\sigma 2}$ ,  $Q_{\alpha 2}$ ,  $C_2$ ,  $R_3$ ,  $Q_{\sigma 3}$ ,  $Q_{\alpha 3}$ ,  $C_3$ )

**Model 37**

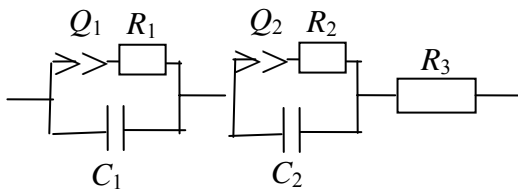
( $R_1$ ,  $Q_{\sigma 1}$ ,  $Q_{\alpha 1}$ ,  $C_1$ ,  $R_2$ ,  $Q_{\sigma 2}$ ,  $Q_{\alpha 2}$ ,  $C_2$ ,  $R_3$ ,  $Q_{\sigma 3}$ ,  $Q_{\alpha 3}$ ,  $C_3$ ,  $R_4$ )



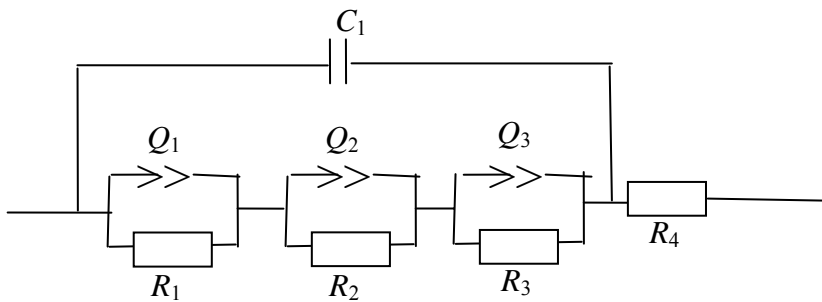
**Model 38** ( $R_1, Q_{\sigma 1}, Q_{\alpha 1}, C_1, R_2, Q_{\sigma 2}, Q_{\alpha 2}, C_2$ )



**Model 39** ( $R_1, Q_{\sigma 1}, Q_{\alpha 1}, C_1, R_2, Q_{\sigma 2}, Q_{\alpha 2}, C_2, R_3$ )

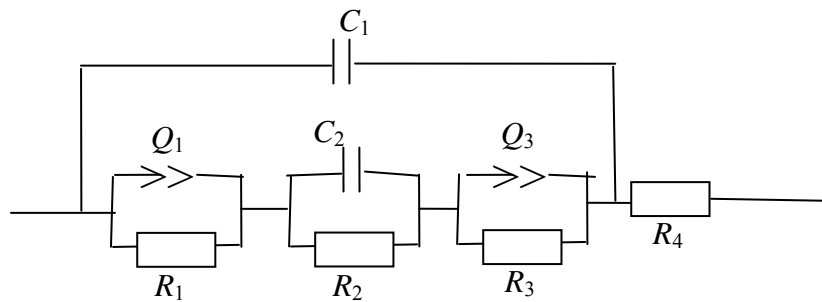


**Model 40** ( $R_1, Q_{\sigma 1}, Q_{\alpha 1}, C_1, R_2, Q_{\sigma 2}, Q_{\alpha 2}, C_2, R_3$ )



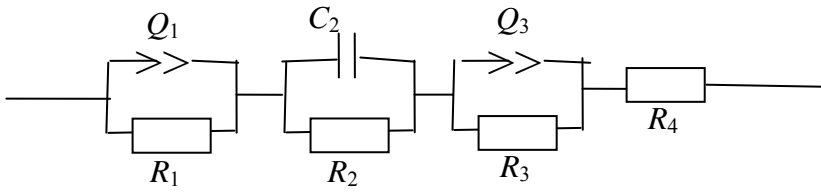
**Model 41**

( $R_1, Q_{\sigma 1}, Q_{\alpha 1}, R_2, Q_{\sigma 2}, Q_{\alpha 2}, R_3, Q_{\sigma 3}, Q_{\alpha 3}, R_4, C_1$ )



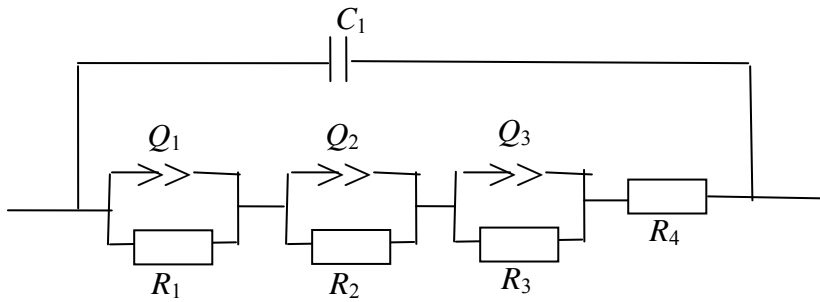


**Model 42** ( $R_1, Q_{\sigma 1}, Q_{\alpha 1}, R_2, C_2, R_3, Q_{\sigma 3}, Q_{\alpha 3}, R_4$ )



**Model 43**

( $R_1, Q_{\sigma 1}, Q_{\alpha 1}, R_2, Q_{\sigma 2}, Q_{\alpha 2}, R_3, Q_{\sigma 3}, Q_{\alpha 3}, R_4, C_1$ )



**Model 44** ( $R_1, Q_{\sigma 1}, Q_{\alpha 1}, R_2, Q_{\sigma 2}, Q_{\alpha 2}, R_3, C_1$ )

