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MCAP-CR Simulation Software Ver.1.1
Operation Guide

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1. Software Specification

This software simulates loudspeaker system performance characteristics based on the driver's T/S parameters and MCAP-CR enclosure design. Characteristics are graphically shown. Characteristics include SPL response, sound pressure phase, impedance and group delay.

2. Design Specification of MCAP-CR Enclosure and Variable Numbering Rule

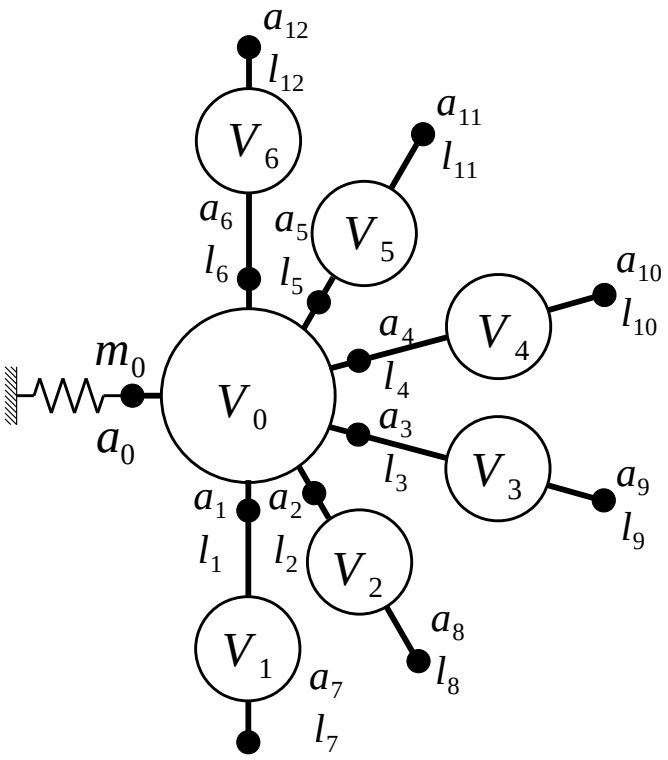


Fig.1 Design Values and Numbering Rule of MCAP-CR Enclosure

MCAP-CR enclosure consists of single main chamber (V_0) and some sub-chambers (V_1 - V_6 in Fig.1).
Each sub-chamber is connected with main chamber through duct, and has external duct.
Design values are given by Table 1.

Table 1 Enclosure Design

symbol	name	unit
V_0	main chamber volume	ℓ
V_1 etc.	sub-chamber volume	ℓ
a_1 etc.	duct crossectionall area	cm2
l_1 etc.	duct length	mm

If some of sub-chambers do not have external ducts, then approximate like below.
$a_k \gg a_0$
$l_k > 10000$

3. Driver's Specification Values

Specify the following specification values given by Table 2. Other values are not used in the program code.

Table 2 Driver's Specification Values

Symbol	Name	Unit	Variable Name in the Program Code	Remark
R	DC resistance	Ω	dcr	
Sd	Membrane piston area	cm2	sd	
mms	Moving mass	g	mms	
Qts	Comprehensive Q(Qts or Q0)	-	qts	
BL	Force Factor	N/A	BL	
f0	Lowest characteristic frequency	Hz	f0	in lieu of cms

4. Other Conditional Values

Friction coefficients between duct surface and air may be specified. Shown values are reference. Use better values if known. Left blank is considered zero.

5. Software Operation

This program is OpenOffice/LibreOffice Calc file(*.ods)-embedded macro program, coded with OpenOffice BASIC.
OpenOffice/LibreOffice Calc software disables macro program function as default. Change security setting if applicable. Refer to Appendix-2, if you change your security setting.

Executing the program:

(1) Open "parameter" sheet and input driver specification values and enclosure design values to light green cells.

(2) Click "CALCULATE ALL" button in the top right.

Then calculation process starts and finally shows message when the calculation became complete.
It is recommended to clear calculation results before recalculate changing some values This is recommendation to avoid leaving previous calculation results. Click "CLEAR RESULTS" button to delete previous calculation results. Input parameters still remain even if "CLEAR RESULTS" button is clicked.

Input all the necessary design values. This program ignores unused values.
Execution process continues around 1 minute if nv=2 depending on the user's environment. It takes longer and longer if you want bigger nv numbers. If the calculation is slower than expected, open "graphics" sheet and watch progress. Graphs are being updated in every calculation step (frequency).
The graphs' scales are manually specified. Users may change scale or choose automatic.

List of Sheets

Name	Description
parameters	Input specification and design value and execute the program.
stiffness	Stiffness matrix. Refer to white papers in http://mcap-cr.com for more details.
numerical_results	Calculation results are written.
graphics	Results are graphically shown.
debug	Used for debugging only. Do not delete this sheet. It cause errors.

6. Acknowledgement

I thank Mr. Yonemichi who developed this calculation algorithm and original spreadsheet applications.

7. Program License

Appendix-1 Simulation Algorithm

This simulator program was developed as OpenOffice BASIC application. Calculation is based on Mr. Yonemichi's algorithm.
Refer to white papers of http://mcap-cr.com/mcap/documents.html for MCAP-CR models.

Calculation procedure is outlined below:

(1) Calculate stiffness matrix for vibration model, applying user-input values.
(2) Calculate real and imaginary parts of displacement response matrix for each frequency.
(3) Multiply displacement response matrix by force vector then calculate complex displacement response.
(4) Multiply complex displacement vector by angular velocity.
(5) Calculate complex sound pressure 1m apart from the loudspeaker system for each moving mass including driver and air in the duct.
(6) Summate complex sound pressure values then calculate real SPL.
(7) Calculate phase angle of complex sound pressure number.
Later make the phase curve smooth shifting 180° at discontinuous points.
(8) Calculate group delay from the phase angle.

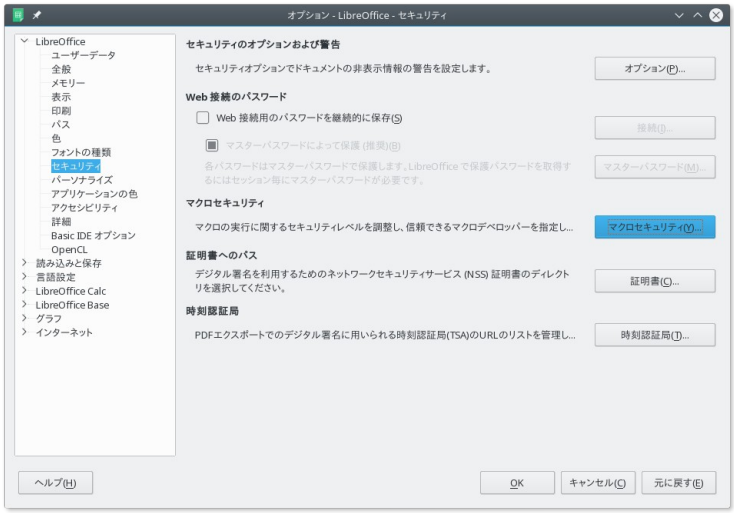
Equations used in the program code

Name	Formulae	Variable name
Displacement response matrix	Let displacement response matrix be $\boldsymbol{G}+i\boldsymbol{D}$. Then let $\boldsymbol{L} = \boldsymbol{A}+i\boldsymbol{B}$ $\boldsymbol{A} = \boldsymbol{K}-\omega^2\boldsymbol{M}$ $\boldsymbol{B} = \omega\boldsymbol{C}$. Therefore $\boldsymbol{G} = \Re\boldsymbol{L}^{-1} = (\boldsymbol{A}+\boldsymbol{B}\boldsymbol{A}^{-1}\boldsymbol{B})^{-1}$ $\boldsymbol{D} = \Im\boldsymbol{L}^{-1} = -\boldsymbol{A}^{-1}\boldsymbol{B}\boldsymbol{G}$	A RM(i,j) B IM(i,j) G RP(i,j) D IP(i,j)
Displacement	Let $\boldsymbol{f}$ be driving force vector, then real part of displacement vector is: $\boldsymbol{x_R} = \boldsymbol{G}\boldsymbol{f}$. Similarly, imaginary vector is $\boldsymbol{x_I} = \boldsymbol{D}\boldsymbol{f}$.	force "force" is applied to membrane only, therefor scholar variable is used for force. XR(j) & XI(j)
Velocity	Complex velocity vector $\boldsymbol{v_C}$: $\boldsymbol{x_C} = \boldsymbol{x_R}+\boldsymbol{x_I}$,where $\boldsymbol{v_C}=i\omega\boldsymbol{x_C}$	Complex variables are separated to real and imaginary variables.
Sound pressure	$p_{Ck}=-2\pi f_e^2\rho a_k(x_{Rk}+ix_{Ik})$	SPR(j), SPI(j) total sound pressure: TSPR, TSPI
Impedance	$Z=\frac{V_e R_{DC}}{\lvert V_e-BL\,v_{0C}\rvert} = \frac{V_e R_{DC}}{\lvert RI\rvert}$	Z
Group delay	$\tau_g=-\frac{d\phi}{d\omega}$	GD

See OpenOffice BASIC macro program for details.

Appendix-2 Security Setting to Enable Macro Program (Example: LibreOffice Calc)

This is am example of LibreOffice Calc. OpenOffice Calc is similar. For Linux OS, LibreOffice is recommended, while OpenOffice is recommended for Windows OS.



Choose “Option” from Tool pull-down menu. Then choose - “security” - “macro”.

Security levels are shown. Then choose (M) or (L). (M) is recommended option. Macro programs sometimes include malicious codes.

After changing this macro security, open the program file, the enable macro, if you trust me.

Once macro is enabled, this program becomes usable.