

## THE DC ELECTRIC CONDUCTIVITY CALCULATION BY THE SERIES FOR THE MEMORY FUNCTION

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*In this work we have shown that the memory function formalism of the response transport theory, reduces to the expression that we already have obtained earlier from the Kubo formula. In that way the Laurent series expansion into scattering parameter  $g$ , is applicable to this formalism.*

In paralel with the Kubo formula<sup>1)</sup>, there exists another version of the linear response transport theory, which is usually called the memory function formalism<sup>2,3)</sup>, and in which the electric conductivity  $\sigma(z)$  is expressed by the memory function  $\Sigma(z)$  as follows:

$$\sigma(z) = \left(\frac{1}{V}\right) \left(\frac{e}{m}\right)^2 \frac{(-i \langle P_x | P_x \rangle)}{(z - \Omega + i \cdot \Sigma(z))}, \quad (1.1)$$

where

$$\Sigma(z) = - \int_{-\infty}^0 dt e^{izt} \langle e^{iLQt} QF_x | QF_x \rangle \langle P_x | P_x \rangle^{-1} \quad (1.2)$$

The quantity  $QF_x$  is the so called orthogonal projection of the internal force  $F_x$  that affects the system of carriers, and the expression (1.2) for  $\Sigma(z)$  is the Laplace transform of the orthogonal forces time correelation function.

In the derivation to be performed, we use the next relations valide for the superoperators of Liouvillean  $L$ , Projection operator  $p$ , Orthogonal projection operator

Q, and frequency  $z^{2,3}$ ):

$$\frac{1}{(z-LQ)} = \frac{1}{(z-L)} - \frac{1}{(z-LQ)} LP \frac{1}{(z-L)}, \quad (1.3)$$

$$P^2 = P, \quad Q^2 = Q, \quad PQ = 0, \quad F_x = iLP_x. \quad (1.4)$$

and also the Hermitean character of L, P, and Q. It that way the expression (1.2) for  $\Sigma(z)$  can be reduced to the next equation:

$$-imNE(z) = i \cdot \alpha(z) - \left(\frac{1}{2}\right) \Sigma(z) \alpha(z), \quad (1.5)$$

where we have introduced the abbreviation  $\Sigma(z)$ :

$$\alpha(z) = \left\langle F_x \left| \frac{(-1)}{(z-L)} \right| F_x \right\rangle. \quad (1.6)$$

The term  $\alpha(z)$  really is the Laplace transform of the full forces  $|F_x\rangle$  time correlation functions as follows:

$$\alpha(z) = \int_{-\infty}^0 dt e^{izt} \langle F_x(t) | F_x \rangle. \quad (1.7)$$

From (1.5) one gets for  $\Sigma(z)$ :

$$\Sigma(z) = \frac{z \cdot \alpha(z)}{(-i \cdot \alpha(z) - mNz)} \quad (1.8)$$

Now let us observe equation (1.8) for  $z \rightarrow 0$ . Since we suppose that the dc conductivity is finite,  $\sigma(0) < \infty$ , from equation (1.1) we immediately conclude that here must be  $\Sigma(0) \neq 0$ , and therefore the right side of the equation (1.8) must be nonvanishing for  $z \rightarrow 0$ . It is easy to conclude that the right side of the equation (1.8) will be nonvanishing if and only if the next relation is fulfilled:

$$(-i \cdot \alpha(z) - mNz) = v(z), \quad (1.9)$$

where  $v(z)$  is a function of  $z$  which with  $z \rightarrow 0$ , tends to zero like  $z^2$ . The equation (1.9) implies  $\alpha(z) \rightarrow 0$ , for  $z \rightarrow 0$ . From the equation (1.9)  $z$  is:

$$z = \left(\frac{1}{mN}\right) (-i\alpha(z) - v(z)). \quad (1.9)$$

Inserting this  $z$  into the equation (1.8), we get for  $\Sigma(z)$ :

$$\Sigma(z) = \frac{\alpha(z)(i\alpha(z) + v(z))}{mN(i\alpha(z) + mNz)}. \quad (1.10)$$

The right side of the equation (1.8) or equivalently (1.10), for  $z \rightarrow 0$  are indeterminate ratios of the form  $0/0$ , and after applying L'Hospital rule twice in succession to (1.10) we find for  $\Sigma(0)$  the expression:

$$-\Sigma(0) = \left(\frac{2}{mN}\right) \frac{(\alpha')^2}{(\alpha'')}, \quad (1.11)$$

where  $\alpha'$  and  $\alpha''$  are the first and the second derivatives in  $z$  of  $\alpha(z)$  as given by the expression (1.7), taken for  $z = s + +0$ . Inserting  $\Sigma(0)$  as given by (1.11) into the expression (1.1) we get the expression for  $\sigma(0) = \alpha$ , that we already have got in our previous work<sup>4)</sup> which may be developed into a Laurent series in the scattering parameter  $g$ .

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#### References

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