An error does not become truth by multiplied propagation. ***Mahatma Gandhi***

see more at:
http://vixra.org/abs/1504.0183
http://vixra.org/abs/1506.0009 (still developing, not final)

All that glitters is not gold: Zero-point energy in the Johnson noise of resistors

L.B. Kish [1], G. Niklasson [2] and C.G. Granqvist [2]

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[2] *Department of Engineering Sciences, Ångström Laboratory, Uppsala University, Uppsala, Sweden*

Abstract. The quantum zero-point term in the Fluctuation-Dissipation Theorem (FDT) is incorrect otherwise perpetual motion machines can be constructed. We show two such perpetual motion machine concepts. We also point out that the Fermic-Dirac statistics of electrons forbids Johnson noise at zero temperature, which is another direct contradiction with the Callen-Welton result. The issue of a conceptual mistake in the Ginzburg-Pitaevski derivation of the FDT yields another proof that the zero-point term is incorrect.

Gunnar

Claes

Special thanks to:

Kyle Sundqvist (TAMU)

Some of the unsolved problems

- Low-temperature Johnson-noise experiments with wide-band (not-heterodyne) amplifiers.

- Creating a *clean* quantum theory of the Fluctuation-Dissipation Theorem, which includes the measurement setup, too.

- How to change hard wired beliefs when new aspects show that they cannot be correct?

Memory: Montreal, ICNF conference, 1987 (debate about the quantum 1/f noise model).

Laszlo Nico van Kampen

May 27, 1987

van Kampen's note about the debated quantum 1/f noise model during his lecture

Theory is good for you

van Kampen's note about the debated quantum 1/f noise model during his lecture

Theory is good for you

Provided the theory is correct

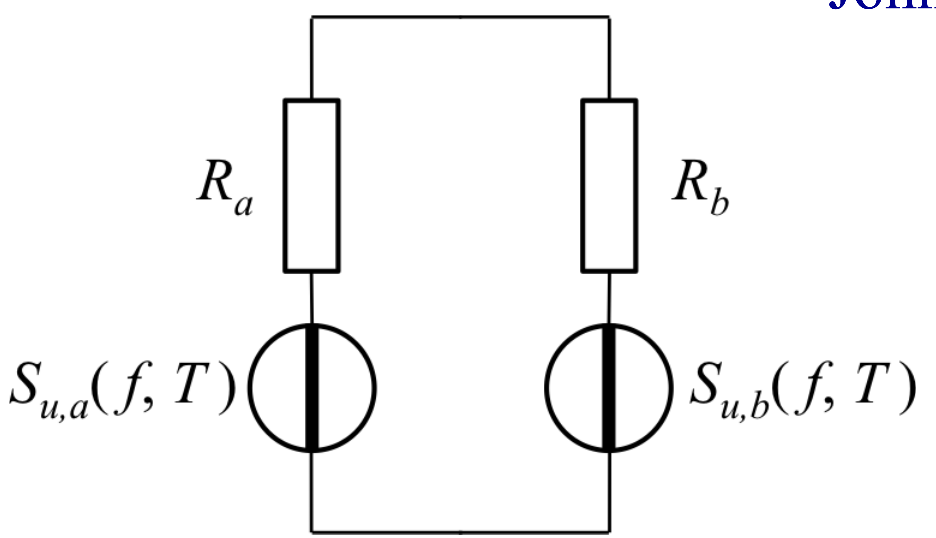
we add here a relevant item:

Experiment is good for you

we add here a relevant item:

Experiment is good for you

Provided its interpretation is correct



Johnson noise of resistors

Second Law of Thermodynamics:

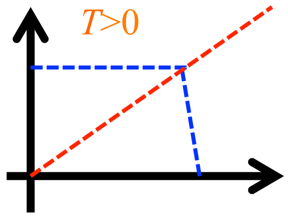
When $T_A = T_B$, $P_{A\to B}(f, \Delta f) = 0$

$$S_u(f, T) = R(f)Q(f, T) \qquad S_i(f, T) = G(f)Q(f, T)$$

$$P_{A\to B}(f, \mathrm{d}f) = (T_A - T_B)\,Q(f, T)\frac{R_A R_B}{(R_A + R_B)^2}\,\mathrm{d}f$$

Callen-Welton (quantum FDT), 1951:

$$S_{u,q}(f,T) = \underbrace{4Rhf\left[N(f,T)\right.}_{\text{Nyquist}}\left.+0.5\right]$$

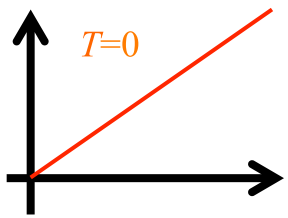


Planck quantum number $\quad N(f,T) = \left[\exp(hf/kT) - 1\right]^{-1}$

For $f \ll kT/h$, or $hf/k \ll T$, *classical* Johnson noise formula: $\quad S_u \cong 4kTR$

For $\boldsymbol{kT/h \ll f}$, or $\boldsymbol{T \ll hf/k}$, zero-point noise formula: $\quad S_{u,ZP} = 2hfR$

similar for current noise: $\quad S_{i,ZP} = 2hfG$



The meaning of the power-density spectrum of voltage is well-established and most of today's quantum schools believe in the explicit visibility of zero-point term in Johnson noise. (Otherwise the fluctuation-dissipation theorem for resistor noise is not more but just Nyquist.)

SOME HISTORY. Interesting history-survey by Derek, though a bit incomplete and *we disagree about some claims*, see below. Also, at UPoN 1996; and in the introduction of a special issue in Chaos (1998).

IEEE TRANSACTIONS ON EDUCATION, VOL. 39, NO. 1, FEBRUARY 1996

Simple Derivation of the Thermal Noise Formula Using Window-Limited Fourier Transforms and Other Conundrums

Derek Abbott, *Member, IEEE,* Bruce R. Davis, *Member, IEEE,* Nicholas J. Phillips, and Kamran Eshraghian

(permission: Derek Abbott)

The zero-point noise cannot exist because, in that frequency range, kT/h << f , processes are reversible and noise would require irreversibility.

D. K. C. Macdonald, Physica 28, 409 (**1962**)

Incorrect statement, it is not valid in general. For example optical absorption is irreversible while ***kT/h << f*** *.*

The available (observable) noise power should include only the Nyquist term and any other quantum term associated with the detector or receiver.

$$S_{u,q}(f,T) = 4Rhf\left[N(f,T) + \cancel{\mathbf{0.5}}\right]$$

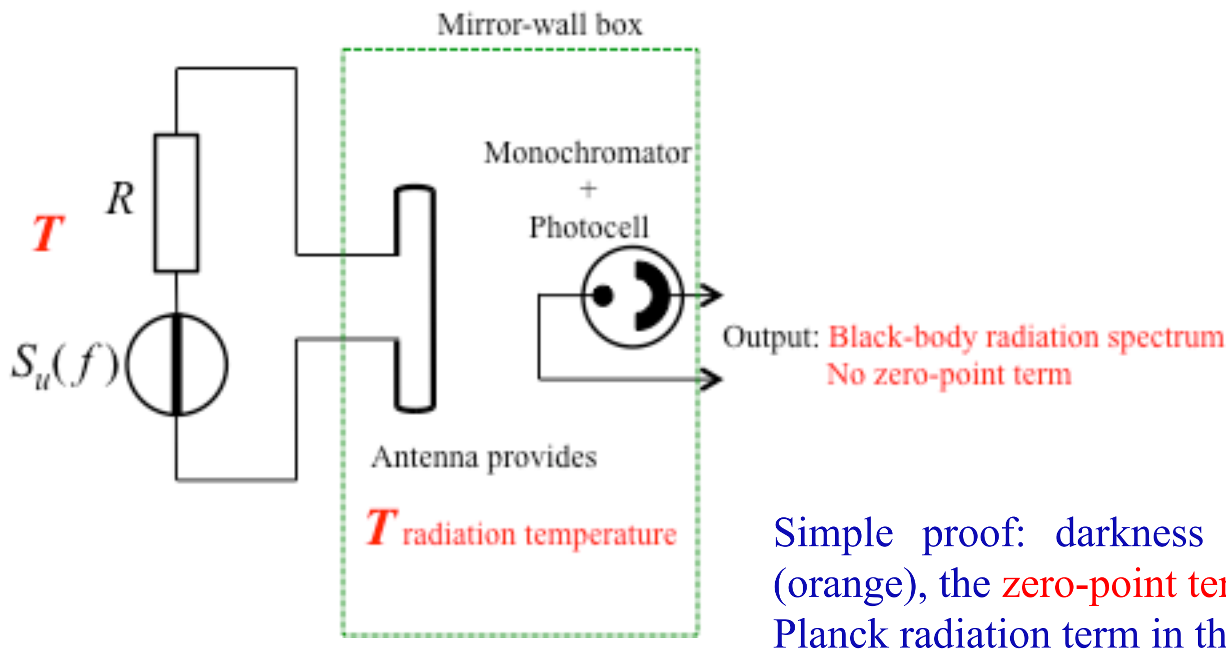
I.A. Harris, Electron. Lett. 7, 148 (**1971**) (at National Buro of Standards)

(based on J. Weber, "Quantum theory of a damped electrical oscillator and noise", Phys. Rev. 90, 977 (**1953**) and H. Heffner, "The Fundamental Noise Limit of Linear Amplifiers", Proc. IRE 50, 1604 (**1962**))

Looks like these early people had the truth.

Why zero-point noise cannot exist: Black-body radiation, Photocell vs antenna

G. Grau and W. Kleen, Solid-State Electron. 25, 749 (**1982**)



Werner Kleen 1967

In 1988, I stayed at his house, in Munich for a few days but he was not interested in the zero-point problem, anymore.

Simple proof: darkness in a dark room. At 600 nm (orange), the zero-point term is 30 times greater (!) than the Planck radiation term in the sunshine.

This scheme is a more rigorous derivation of the Nyquist formula than Nyquist's own derivation, which contains some ad-hoc steps not fully justified.

Correct claim and it has not been answered by the "zero-point noise people".

Fluctuation of the zero-point energy ?

W. Kleen, ICNF proc (**1985**) :

In a stable system, the zero-point energy does not fluctuate thus in cannot emit any energy thus it cannot generate a noise.

True. Dirac had the same notion and said "the line-width of the zero-point state is infinitely narrow, thus its lifetime is infinite". (Peter Rentzepis)

D. Abbott, et al, IEEE Trans Education 39, 1 (**1996**):

He writes <u>zero-point fluctuations</u> as the source of zero-point noise.

In any case, Kleen is right; such an effect cannot be he source of the zero-point noise observed in some experiments.

FDT derivations are incorrect

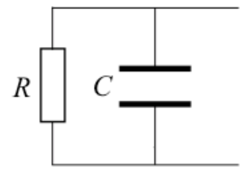
Recently, L. Reggiani, et al. [Fluct. Noise Lett. 11, 1242002 (**2012**)] criticized the FDT derivations. Excerpt from their conclusions:

"... the FDT holds at the resonant frequencies of the physical system under test ***only***. Outside the resonant frequencies, the formalism of δ-functions does not allow to determine the frequency interrelation between the spectrum of fluctuations, $S_{xx}(\omega)$, and the imaginary part of the susceptibility, $\mathrm{Im}[\alpha(x)]$.
As a consequence, the commonly adopted interpretation of the QFDT as a universal spectral relation between $S_{xx}(\omega)$ and $\mathrm{Im}[\alpha(x)]$, which is continuous in the whole frequency range $[0,\infty]$ and holds for an arbitrary physical system, is invalid/incorrect."

So, when the measurement frequency is a "resonance frequency" of the system, the old FDT results are still accepted to be correct. For general cases, they show a new formula, which is not easy to evaluate. *Their results support a non-zero zero-point noise, at least at the resonance frequencies of the system.*

Renormalization arguments

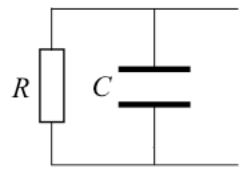
L.B. Kish, Solid State Comm. 67, 749 (**1988**): *zero-point noise would cause divergent energy in a shunt capacitor due to the zero-point noise term, so it should be renormalized*



Abbott, et al, IEEE Trans Education 39, 1 (**1996**): *zero-point energy is infinite thus it should be renormalized but not the "zero-point fluctuations".*

However, renormalization considerations are not the organic part of quantum theory, so they should be avoided, if possible.

Perpetual motion machine issues



L.B. Kish, Solid State Comm. 67, 749 (**1988**): *If the zero-point noise exists, perpetual motion machines could be constructed by moving capacitor plates. Realization of such was not shown that time.*

Valid assumption; in this talk, we will show two such machines; which proves that the zero-point noise cannot objectively be present in the resistors.

D. Abbott, et al, UPoN'96 proc (**1996**): *Perpetual motion machines with capacitors are no problems because the Casimir force (and zero-point energy) is a conservative field.*

This is a correct claim, however it is irrelevant because the conceptual perpetual motion machines do not utilize the Casimir force, see proof below.

The experiments: Josephson-junction heterodyne detection (spectral analysis by frequency mixing to DC)

VOLUME 47, NUMBER 17 PHYSICAL REVIEW LETTERS 26 OCTOBER 1981

Observation of Zero-Point Fluctuations in a Resistively Shunted Josephson Tunnel Junction

Roger H. Koch, D. J. Van Harlingen,[a] and John Clarke
Department of Physics, University of California, Berkeley, California 94720, and Materials and Molecular Research Division, Lawrence Berkeley Laboratory, Berkeley, California 94720

(Received 27 July 1981)

The spectral density of the voltage noise has been measured in current-biased resistively shunted Josephson junctions in which quantum corrections to the noise are expected to be important. The experimental data are in excellent agreement with theoretical predictions, demonstrating clearly the contribution of zero-point fluctuations that are generated in the shunt at frequencies near the Josephson frequency and mixed down to the measurement frequency.

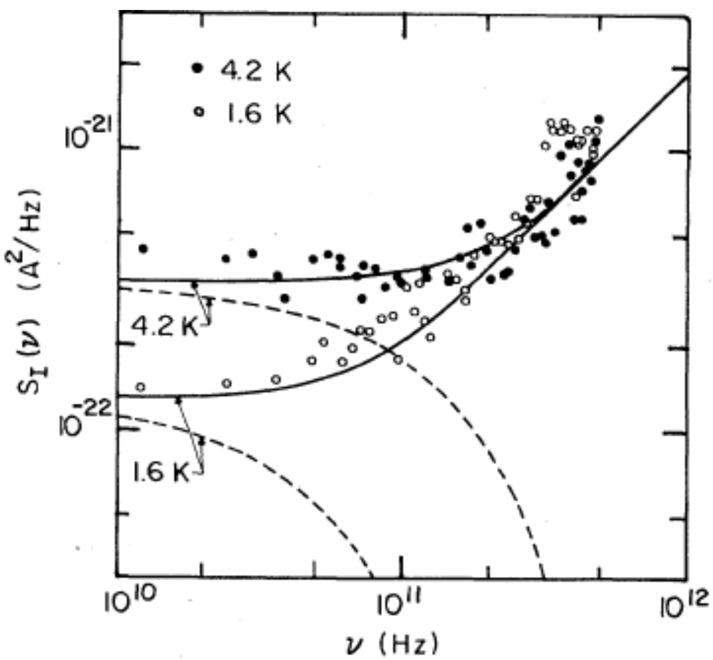


FIG. 3. Measured spectral density of current noise in shunt resistor vs the Josephson frequency $\nu = 2eV/h$ at 4.2 K (solid circles) and 1.6 K (open circles). Solid lines are predictions of Eq. (2), while dashed lines are $(4h\nu/R)[\exp(h\nu/k_BT)-1]^{-1}$.

$$S_{u,q}(f,T) = 4Rhf\left[N(f,T) + \mathbf{0.5}\right]$$

Uncertainty principle

W. Kleen, Solid-State Electron. 30, 1303 (**1987**). :

The observed zero-point noise in the KVC experiments is not coming from the resistor but it is the amplifier noise due the phase-particle number (energy-time) uncertainty noise of quantum amplifiers (masers, Heffner, 1963)

The effect is indeed there and it disqualifies the Josephson junction experiments as proofs of zero-point noise. However, it cannot not prove that the zero-point noise itself does not exist in the resistor.

D. Abbott, et al, IEEE Trans Education 39, 1 (**1996**):

*Zero-point noise is there and it is **required** by the uncertainty principle.*

However, we will see there are situations when the relevant uncertainty principle is not applicable, see below..

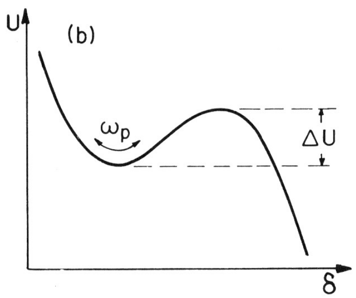
Negative experiments

1981, the same Richard Voss, who went around with the 1/f noise in music show later.

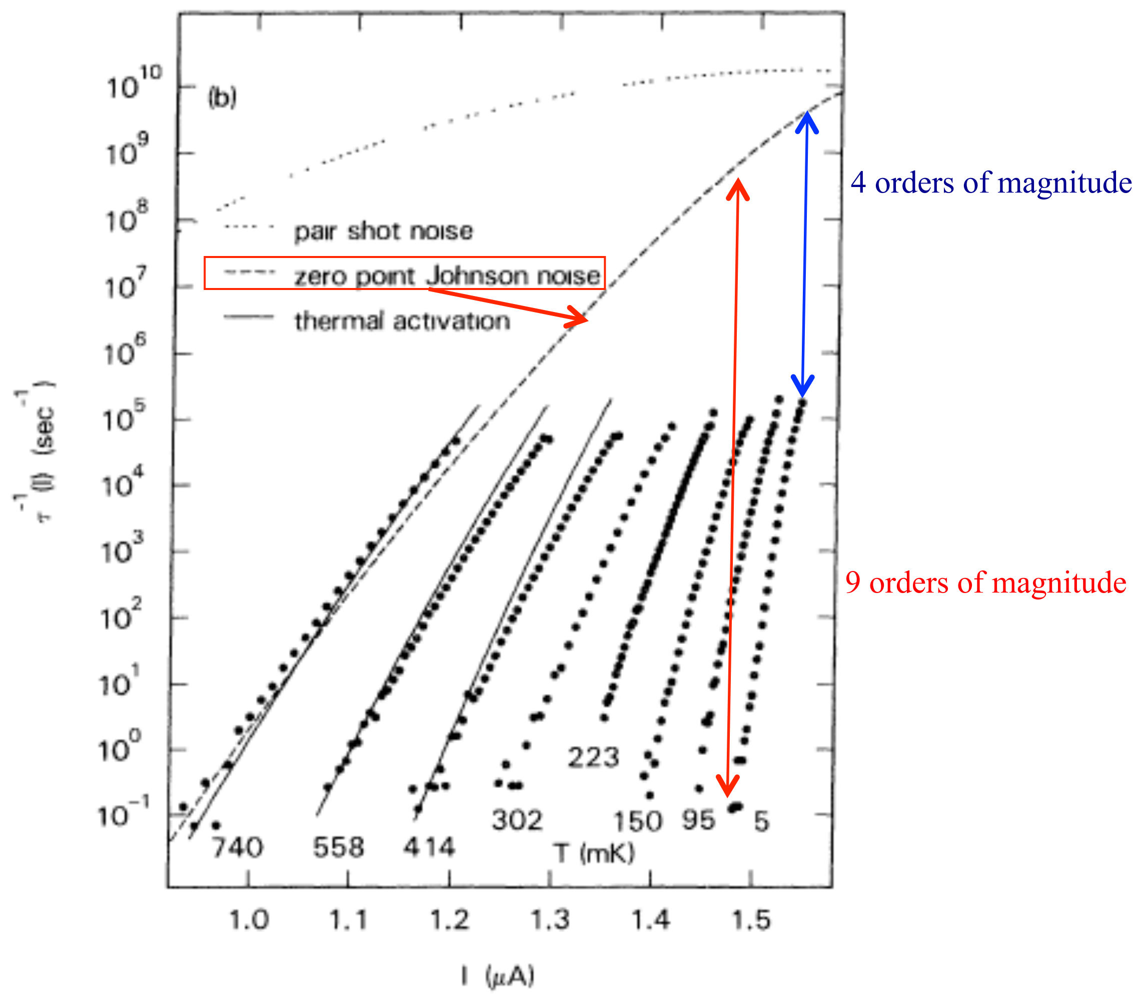
PHYSICAL REVIEW B VOLUME 24, NUMBER 12 15 DECEMBER 1981

Pair shot noise and zero-point Johnson noise in Josephson junctions

Richard F. Voss and Richard A. Webb
IBM Thomas J. Watson Research Center, Yorktown Heights, New York 10598



Transition rates $\tau^{-1}(I)$ with theoretical predictions.



Their conclusion was the potential well models of Josephson junctions with Langevin type formulation were inappropriate. *The possibility that the zero-point noise did not exist was not mentioned.*

A. van der Ziel's negative experimental outcome for direct (non-heterodyne) microwave photonic measurements.

They did not see the zero-point term via direct (non-heterodyne) measurements of *Hanbury Brown-Twiss* type microwave circuitry at 1 Kelvin temperature and up to 95 GHz frequency, even though this frequency limit at this temperature is about 5 times beyond the kT/h classical/quantum boundary and their accuracy to measure noise-temperature was 0.1 Kelvin.

C.M. Van Vliet, Equilibrium and non-equilibrium statistical mechanics, (World Scientific 2008).

A. van der Ziel, Proc. ICNF, Washington DC, 1981.

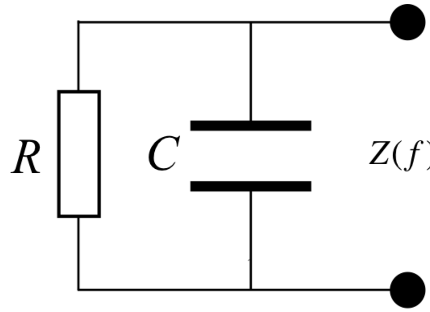
I guess they saw only the black body radiation and then gave it up when the KVC experiments came out in PRL ...

Aldert van der Ziel Laszlo

Montreal, ICNF, May 27, 1987

THIS TALK: If Callen-Welton (FDT) usual interpretation of objectively present zero-point noise is correct, we can create at least 2 different types of perpetual motion machines, that is *the Second Law is violated*. One is with a *fixed* capacitor, and another one with a *moving capacitor plate*.

Consider the mean energy due to the zero-point noise term in a capacitor shunting a resistor:

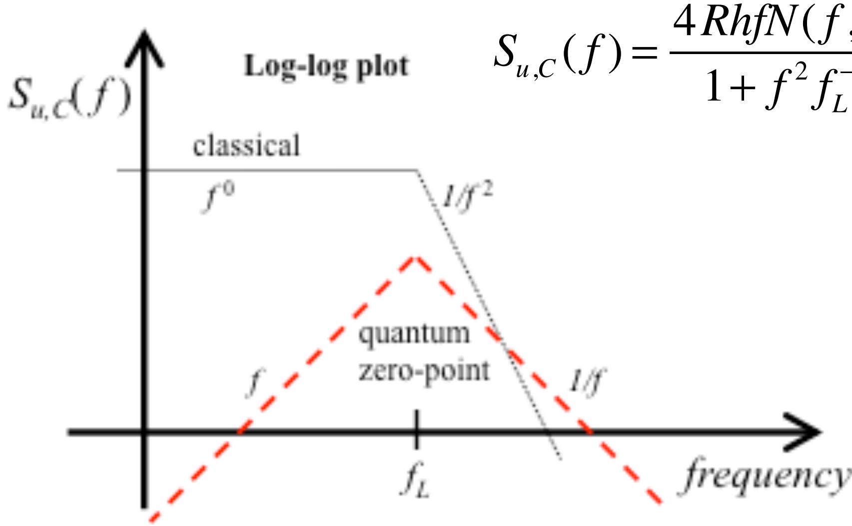


$$Z(f) = \frac{R}{1 + \mathbf{j}\frac{f}{f_L}}$$

$$\mathrm{Re}[Z(f)] = R\left(1 + f^2 f_L^{-2}\right)^{-1} \qquad f_L = (2\pi RC)^{-1}$$

$$S_{u,q}(f,T) = 4\,\mathrm{Re}[Z(f)]hf\left[N(f,T) + \mathbf{0.5}\right]$$

$$N(f,T) = \left[\exp(hf/kT) - 1\right]^{-1}$$



$$S_{u,C}(f) = \frac{4RhfN(f,T)}{1 + f^2 f_L^{-2}} + \frac{2Rhf}{1 + f^2 f_L^{-2}}$$

$$\langle E_C \rangle = 0.5C\langle U_C^2(t) \rangle = 0.5C\int_0^{f_c} S_{u,C}(f)\,df$$

For $T \longrightarrow 0$, the classical term exponentially vanishes because of N(T)

thus:

$$\left\langle U_{C,q}^2(t) \right\rangle = \int_0^{f_c} \frac{2hfR}{1+f^2 f_L^{-2}} df = hRf_L^2 \ln\left(1+\frac{f_c^2}{f_L^2}\right)$$

and the mean energy at zero Kelvin is:

$$\boxed{\left\langle E_C \right\rangle = \frac{h}{8\pi^2 RC} \ln\left(1+4\pi^2 R^2 C^2 f_c^2\right)}$$

Because it depends on the resistance, perpetual motion machines can be constructed.

Heat generator from zero-point noise (if the zero-point noise in the FDT is correct)

It is an ensemble of ***M*** Units, each one containing two different resistors and one capacitor controlled by the same flywheel in asynchronous way. The capacitors in the Units are periodically alternated between the two resistors by centrally controlled switches, in a synchronized fashion, that makes the relative control energy negligible.
See, LBK, "Johnson noise engines", Chaos, Solitons & Fractals 44, 114 (**2011**)

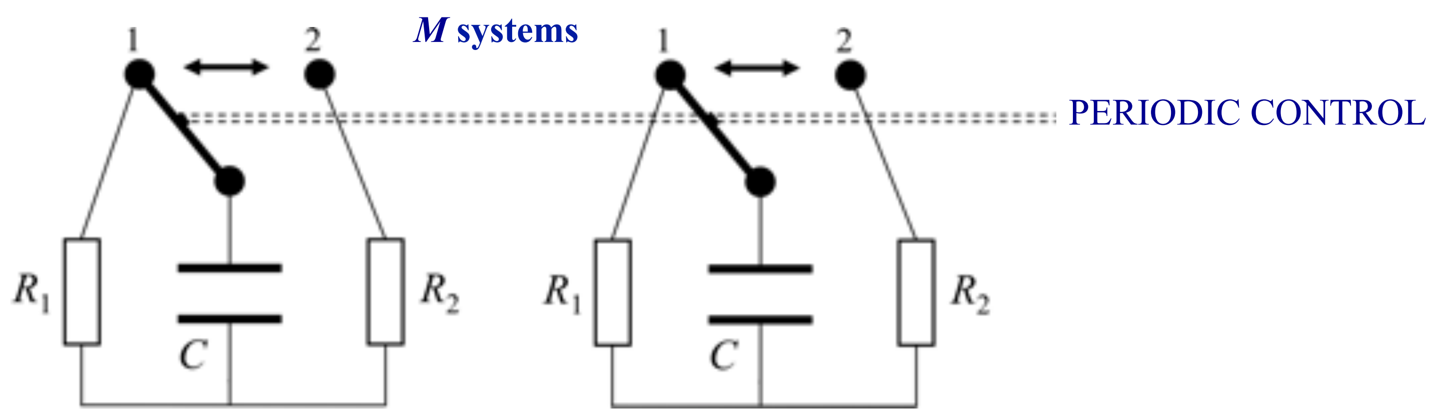
The duration of the period is much longer than any of the RC time constants thus the capacitors are "thermalized" by the zero-point noise in each state. Suppose, $R_1 < R_2$.

Then at each 1 ➔ 2 transition

$$\boxed{0 < E_h = M\frac{h}{8\pi^2 C}\left[\frac{\ln\left(1+4\pi^2 R_1^2 C^2 f_c^2\right)}{R_1} - \frac{\ln\left(1+4\pi^2 R_2^2 C^2 f_c^2\right)}{R_2}\right]}$$

energy is dissipated in R_2 .

This energy is coming from the zero-point noise of R_1. It can be used to drive the flywheel that controls the system.

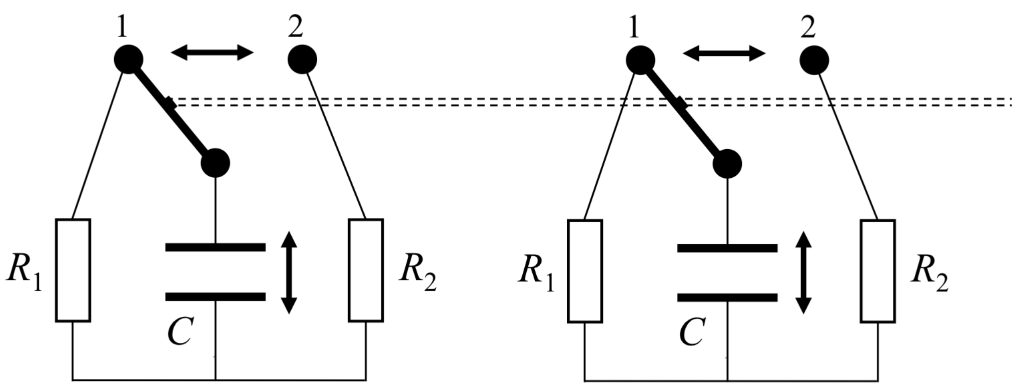


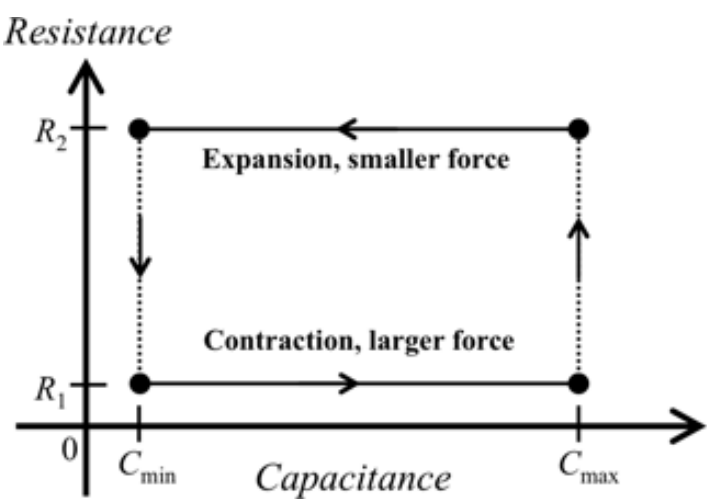
Two-stroke engine (and heat generator) from zero-point noise (if the FDT is correct)

The engine has M parallel cylinders with identical elements and parameters as in the heat generator. The plate-capacitors have a moving plate, which acts as a piston. The moving plates are coupled to a flywheel, which moves them in a periodic, synchronized fashion. When the plate distance reaches its nearest and farthest distance limits respectively, the switch alternates the driving resistor. *During contraction and expansion, we have R_1 and R_2, respectively.*

The mean force in the plate-capacitors is: $$\langle F(x)\rangle = \frac{\langle E_C\rangle}{x} = \frac{1}{x}\frac{h}{8\pi^2 RC(x)}\ln\left[1+4\pi^2R^2C^2(x)f_c^2\right]$$

With $R_1 < R_2$, at any given plate distance x (and corresponding capacitance value), the force is stronger during contraction than during expansion.





The heat-generation effect also kicks in, that is, heat is generated in R_2, similarly to the first perpetual motion machine.

NOTE: Casimir effect in the capacitor is irrelevant!

In the perpetual motion machines introduced above the Casimir effect can always be made negligible by the proper choice of the range of distance x between the capacitor plates during operation.

The Casimir-pressure in a plain capacitor decays with x^{-4}, which implies that

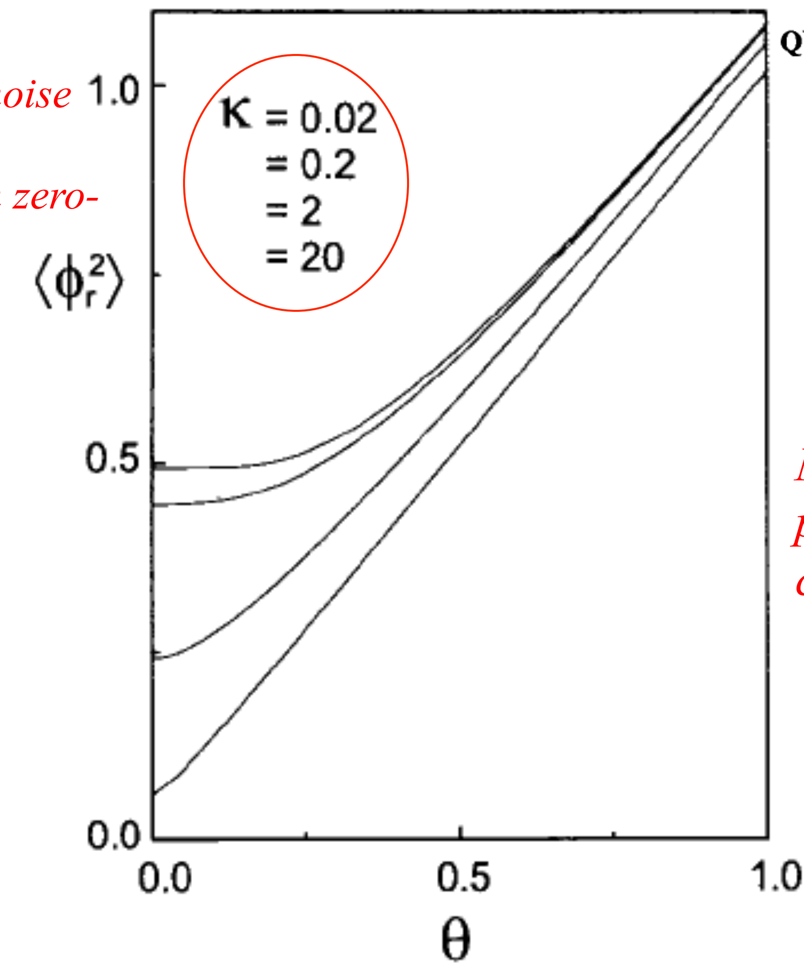
the Casimir force at fixed capacitance value decays with x^{-3}

see G. Bressi, et al, Phys. Rev. Lett. 88, 041804 (2002).

At the same time, the force due to the zero-point noise decays as $\boldsymbol{x^{-1}}$.

Already former theories RLC resonators contain of hidden perpetual motion machines:

Different magnetic noise energy at different resistances! All from zero-point noise!



QUANTUM FLUCTUATIONS IN ELECTRICAL CIRCUITS

Michel H. Devoret

Service de Physique de l'Etat Condensé
CEA-Saclay, F91191 Gif-sur-Yvette, France

(1997)

Magnetic versions of the above perpetual motion machines can be constructed if the FDT is correct!!!

Fig. 10. Variations of the dimensionless variance $\langle \phi_r^2 \rangle = \langle \Phi^2 \rangle / (\hbar Z_0)$ of flux fluctuations of the LCR circuit as a function of the dimensionless temperature $\theta = k_B T / \hbar\omega_0$ for different values of the dimensionless damping coefficient $\kappa = (2RC\omega_0)^{-1}$.

This is a possible end of the talk because:

When the laws of physics are violated, the game is over...

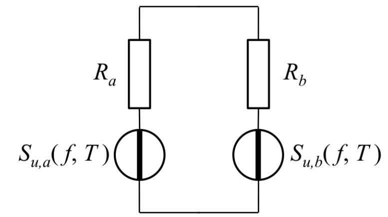
But due to Kyle's strong loyalty to Callen-Welton, we were drawn to consider other arguments, too. Research in progress.

Kyle Sundqvist (TAMU)

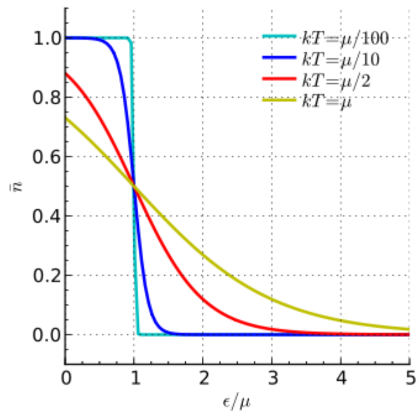
NOTE: Due to the perpetual motion issues, it is not a question if the "objective zero-point noise" interpretation of Callen-Welton's theory is wrong. The only question is **where**.

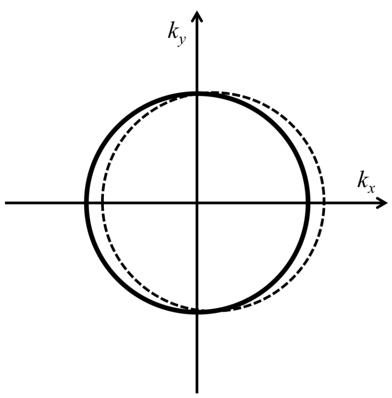
UNSOLVED PROBLEM. In the CW derivation there is no mathematical indication that the 0.5 term should ***not*** be objectively observable, **to be seen by arbitrary measurements.**

Because the Second Law requires zero mean power flow between two resistors of arbitrary materials, it is enough to show **in only a single chosen system that the Callen-Welton derivation is incorrect**. For the sake of simplicity, we take a metallic conductor with non-zero residual resistivity.



- The claim of zero-point current noise contradicts to the Fermi-Dirac statistics in metallic conductors (with defect scattering) when the temperature is approaching zero. Then all states are occupied up to the Fermi surface and no states can be occupied above. *That prohibits any current, including noise current, in this situation.*





Quantum Nyquist formula and the applicability ranges of the Callen-Welton formula

V. L. Ginzburg and L. P. Pitaevskiĭ

P. N. Lebedev Physics Institute, Academy of Sciences of the USSR; S. I. Vavilov Institute of Physics Problems, Academy of Sciences of the USSR

Usp. Fiz. Nauk **151**, 333–339 (February 1987)

We discuss Yu. L. Klimontovich's objections to the generally accepted derivations of the fluctuation-dissipation theorem and his proposed additional restrictions on the applicability of this theorem. We demonstrate that Yu. L. Klimontovich's arguments contradict the basic principles of statistical physics and hence cannot be correct.

1. Let us recall the problem at hand.

In an electrical circuit described by the equations

$$L\frac{dI}{dt}+RI+\frac{q}{C}=\mathscr{E},\qquad \frac{dq}{dt}=I, \tag{1}$$

the varying frequency ω, whereas in the $\hbar\omega\gg kT$ expression (2) falls off exponentially as the frequen creases.*) Obviously, reaching the quantum regime r lowering the temperature T and (or) going to hig quencies ω. We believe that the quantum regime

They use the same kind of calculations for a serial RLC circuit as we do for the perpetual motion machine calculations. They show that, with the Callen-Welton zero-point noise spectrum result, the energy in the weakly-damped LC resonator is equal to the energy of the of the quantum linear harmonic oscillator, that is, at zero temperature, and *small resistance*, this energy converges to the zero-point energy of the oscillator, $hf_0/2$.

However, there is a problem. In the large resistance and small inductance limit, *they would get our results and a perpetual motion machine with it!* Thus the assumption that the zero-point noise is in the resistor in this passive situation must be dropped.

Conclusion: it is not possible to derive the zero-point energy of the oscillator with this unphysical assumption that the zero-point voltage noise in the resistor is objectively present there. ***The agreement in the small resistance limit is only an accident.***

End of presentation. Questions?

When the laws of physics are violated, the game is over...