where k is Boltzmann's constant, f_1 and f_2 lower and upper frequency limits of the channel, and f the frequency of the measurement. If $\overline{v_s^2} = \overline{v_r^2}$, T_s is written as

$$T_s = \frac{\int_{f_1}^{f_2} R_s/(1 + 2\pi f R_s C_s)^2)\, df}{\int_{f_1}^{f_2} R_r/(1 + 2\pi f R_r C_r)^2)\, df} T_r \qquad (2)$$

If the two channels of measurement are equivalent, and the time constants R_sC_s and R_rC_r are made equal, T_s is expressed as T_rR_r/R_s.

2.1. *Balancing of the noise signal.*

The following method was adopted to detect the balance between $\overline{v_s^2}$ and $\overline{v_r^2}$. The thermal noise was amplified by a low noise preamplifier with double triode (7308) cascode circuits, and was discriminated so as to pass the pulses exceeding an established constant gate voltage v_g by means of the Schmitt circuit. $\overline{v_s^2}$ was balanced to $\overline{v_r^2}$ by integrating the pulse counts for a unit duration of time for both the discriminated noise pulses of $\mathrm{Re}\,(Z_s)$ and $\mathrm{Re}\,(Z_r)$. Since the thermal noise is a white one, the number N of pulses, exceeding the gate voltage v_g for a unit time, is expressed as follows [5].

$$N = \sqrt{\frac{1}{3}(f_1^2 + f_1 f_2 + f_2^2)}\, \exp\left(-\frac{v_g^2}{2\overline{v}_s^2}\right) \qquad (3)$$

This relation is shown by the broken line in Fig. 1 in which f_1 and f_2 are assumed to be 20 kHz and 300 kHz respectively, and C_s is to be 200 pF. If we take about 700 Ω as the equivalent noise resistance of the preamplifier used, the observed value agrees to the theoretical one.

The relative error $\Delta R/R$ of the observed values is estimated from the statistical error of the fluctuation of N. This relation serves to find the appropriate range for the sensing resistance.

Care must be taken to ensure that both the amplification and detection of the two noise signals are identical. This was accomplished by employing the same channel, which carried the two signals in time separation. In this pulse-counting method, the accuracy of the contact times (the duration of the integrating time) governs the total accuracy of the thermometry. The solid state switching circuit employed here is controlled by the crystal clock with the relative error of 2×10^{-5}.

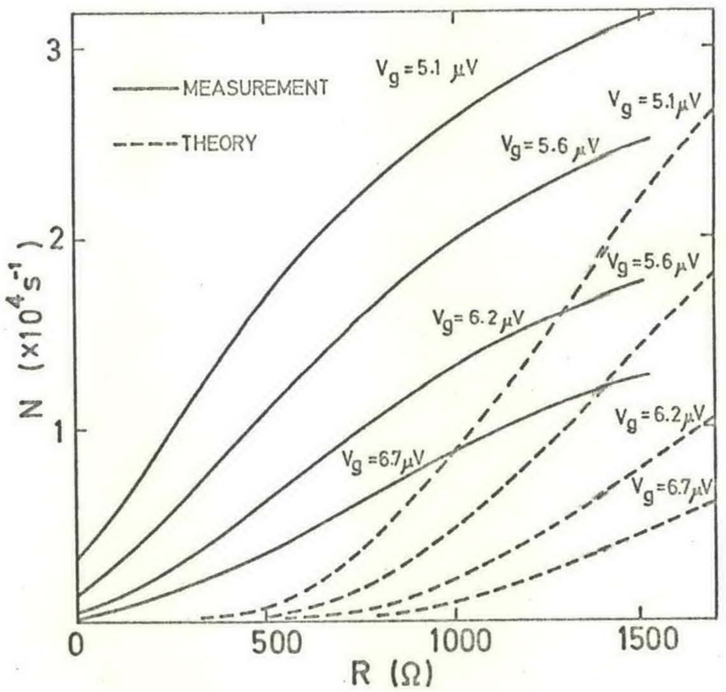

FIG. 1
Relationship between input resistance and pulse count rate.