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FLICKER NOISE IN MOSFETs MADE BY THE DMOS PROCESS†

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Abstract—Signetics SD 200 MOSFETs show a $1/f^\alpha$ spectrum with $\alpha \simeq 1.0$ at low frequencies and $\alpha \simeq 0.6$ at high frequencies, with a turnover at about 50 kHz. The noise resistances in these two branches seem to be related but show a different current dependence. These features may be associated with the "diffused" MOS (DMOS) process by which they are manufactured.

Huang and van der Ziel[1] found that flicker noise in Signetics SD 200 MOSFETs varied as about $1/f^{0.6}$ above 1 MHz, which explained why the flicker noise extends to far above 100 MHz for these devices.

We have extended the noise measurement to much lower frequencies, and found that the spectrum was of the form const/f^α, with $\alpha \simeq 1$ at low frequencies and $\alpha \simeq 0.6$ at high frequencies. A typical result is shown in Fig. 1, where it is seen that α changes from the *l.f.* value 0.93 to the *h.f.* value 0.65, with the change occurring at about 50 kHz.

The question is now whether these are two completely unrelated spectra or whether a relationship between the *l.f.* and the *h.f.* noise exists. To that end we measured the noise resistance R_n of a large number of SD 200 at 1 kHz and at 1 MHz and plotted log R_n (1 MHz) vs log R_n (1 kHz). If the two spectra varied independently from sample to sample, the measured points should scatter widely. The results are shown in Fig. 2; while there is some scatter, there is a definite linear relationship between these two noise resistances, indicating that R_n (1 MHz) and R_n (1 kHz) varied simultaneously rather than independently.

In a third experiment we measured R_n (1 MHz) and R_n (1 kHz) for various samples as a function of current and plotted log R_n (1 MHz) vs log R_n (1 kHz) with the current as a parameter. If the two sections of the spectrum had the *same* current dependence, there would be a linear relationship. As Fig. 3 indicates, there is a more or less quadratic relationship between R_n (1 MHz) and R_n

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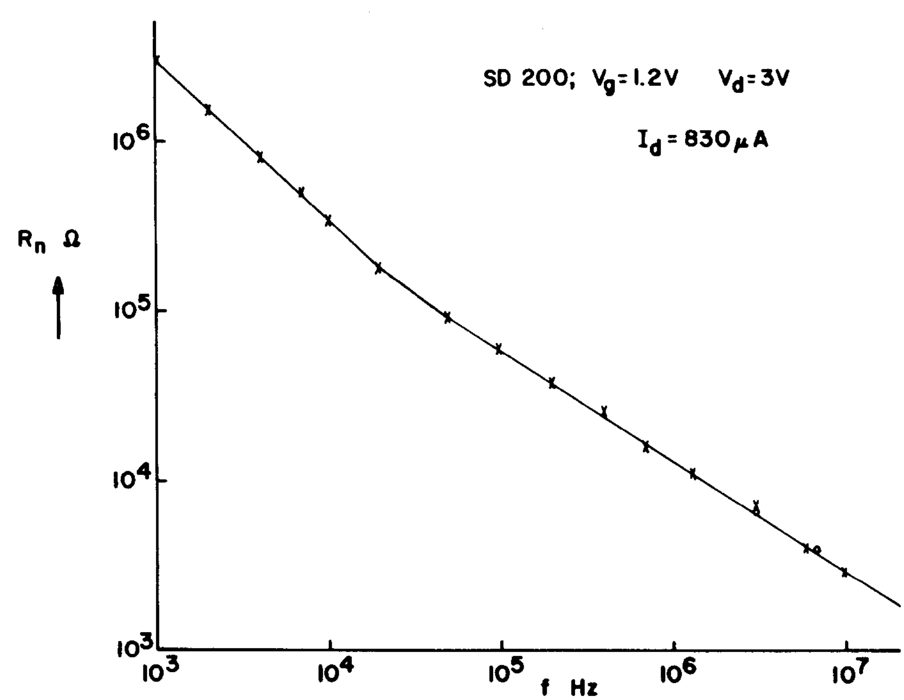

Fig. 1. Typical noise spectrum of an SD 200 device at $V_g = 1.2$ V; $V_d = 3$ V, $I_d = 830\,\mu$A. R_n in ohms vs frequency in Hz.

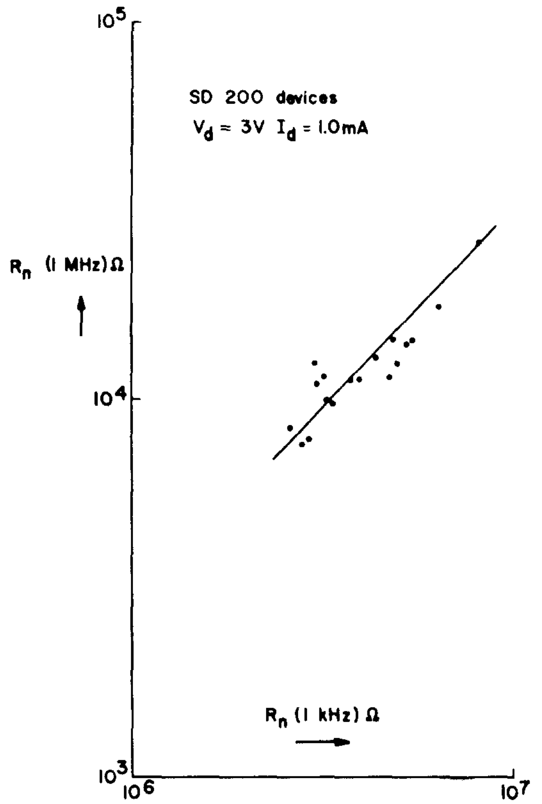

Fig. 2. R_n (1 MHz) plotted vs R_n (1 kHz), both in ohms, for a large number of SD 200 devices operated at $V_d = 3$ V, $I_d =$ 1.0 mA.

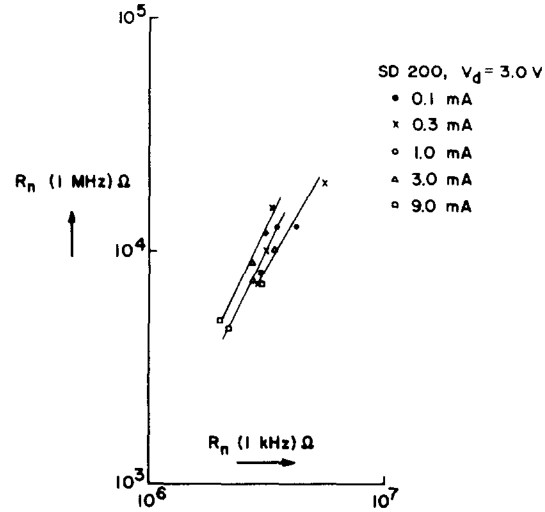

Fig. 3. R_n (1 MHz) plotted vs R_n (1 kHz), both in ohms, with the drain current as a parameter, for a few SD 200 devices operated at $V_d = 3.0$ V.

(1 kHz), or, since the only varying parameter is the *current*, it follows that the two sections of the spectrum have a different current dependence. It should be clear from these data that the theories of flicker noise in MOSFETs must be modified to explain these results. It is presently not quite clear how that should be done. But we may have a hint. It can be observed that SD 200 devices are made by the DMOS process, where D stands for "diffused". This diffusion process, operated on a weakly doped p-type substrate ($\bar{p}$), yields an $n^+ - p - p^- - n^+$ structure, with a very short p-region and a much longer $\bar{p}$-region. Here the adjacent n^+-source and the p-region are diffused in at the same time (hence the name DMOS). The rather strongly doped p-region gives by inversion an n-channel with a turn-on voltage of $+1$V; it is responsible for the high transconductance and the excellent high-frequency operation. The $\bar{p}$-region gives by inversion an n-channel in series with the other channel, and has a turn-on voltage of -1V. It might thus be possible that the two $1/f$ noise regimes could be attributed to the two regions of the channel. This should be studied in greater detail by making two types of devices, n-channel MOSFETs with strongly doped p-type substrates and n-channel MOSFETs with weakly doped p-type substrates, and comparing the generated flicker noise.

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REFERENCE

1. C. H. Huang and A. van der Ziel, *Solid-St. Electron.* **18**, 885 (1975).