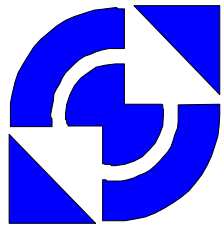
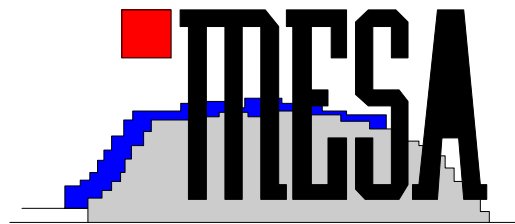

Reduction of the $1/f$ Noise induced Phase Noise in a CMOS Ring Oscillator by increasing the Amplitude of Oscillation

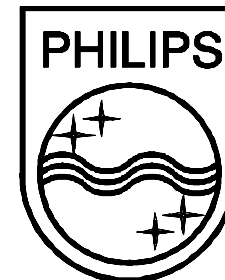
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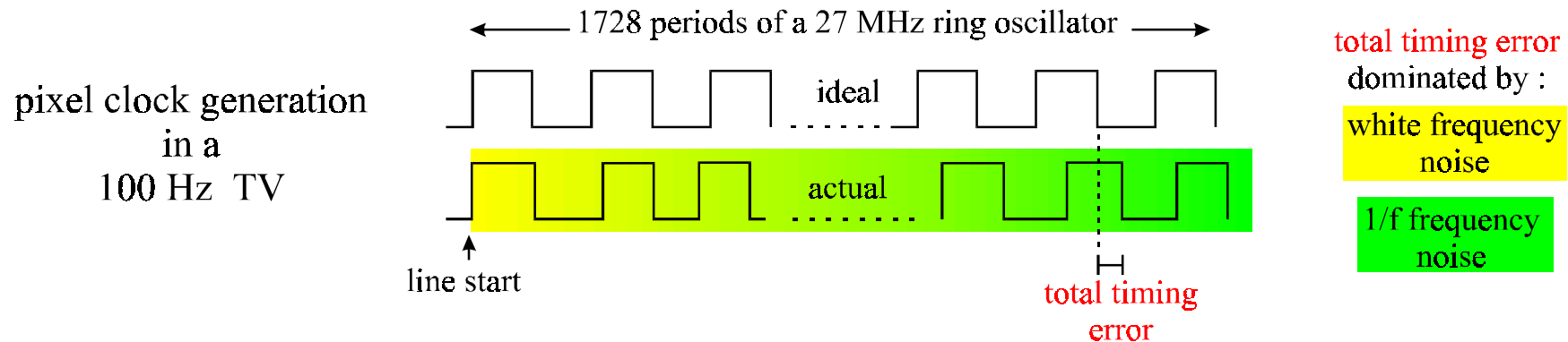


Philips
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Contents

- Introduction
- $1/f$ noise reduction by switching
- (How) does $1/f$ noise reduction appear in a ring oscillator ?
- Ring oscillator sideband noise measurement
- Conclusions

Introduction



$$\sigma_{\text{total timing error}} \sim \begin{cases} \sqrt{\# \text{ periods}} & \text{for white frequency noise} \\ \# \text{ periods} & \text{for } 1/f \text{ frequency noise} \end{cases}$$

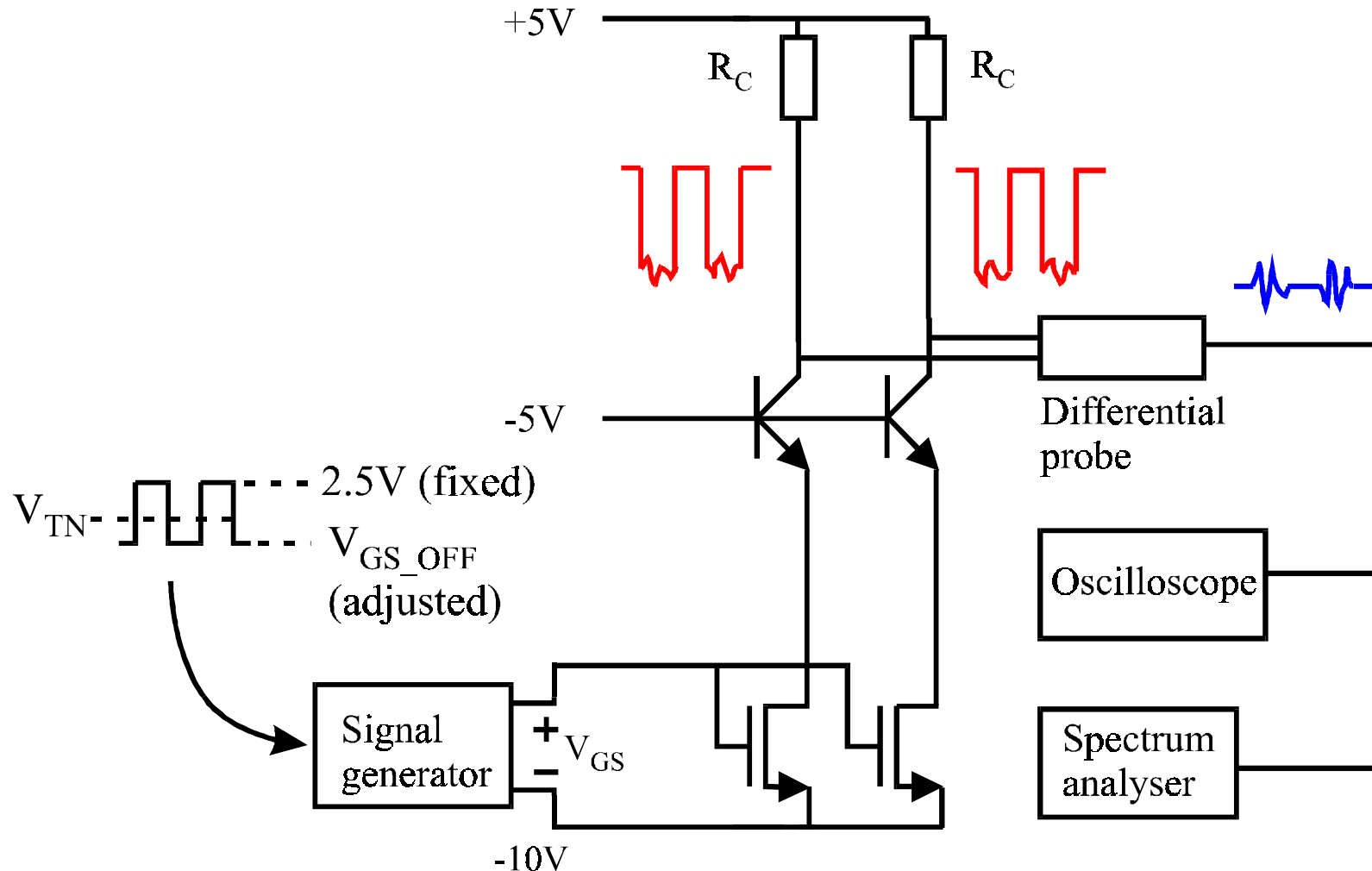
- total timing error mainly determined by the 1/f frequency noise of the ring oscillator
- measurement of ring oscillator : lower 1/f frequency noise than expected



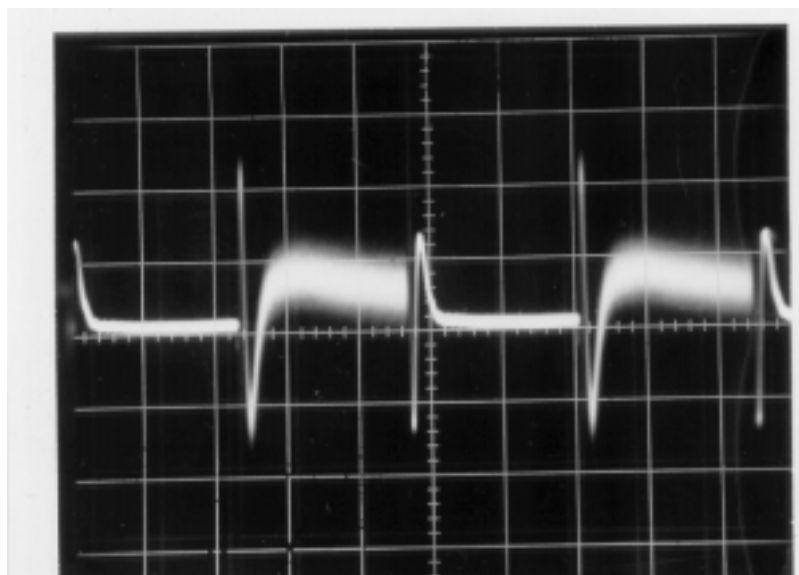
Does intrinsic MOS 1/f noise change due to periodical switching ?

1/f noise reduction by switching

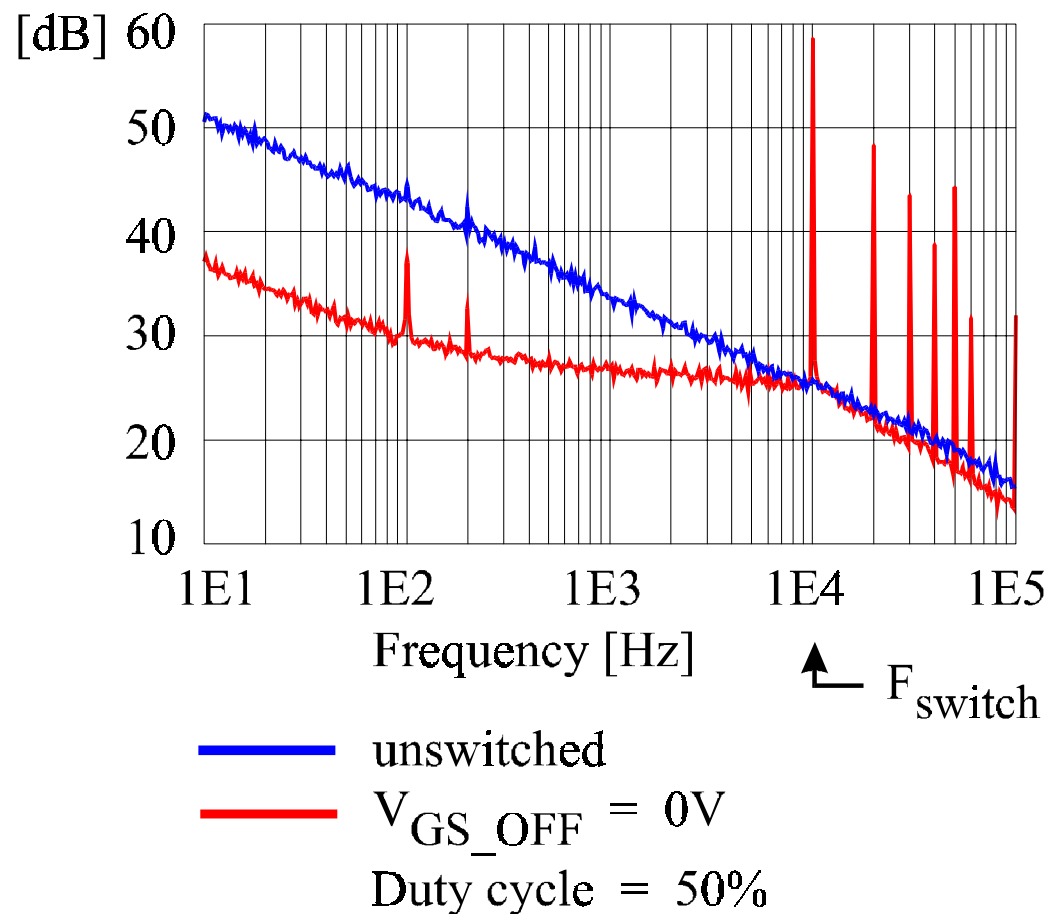
measurement setup



Baseband measurement result

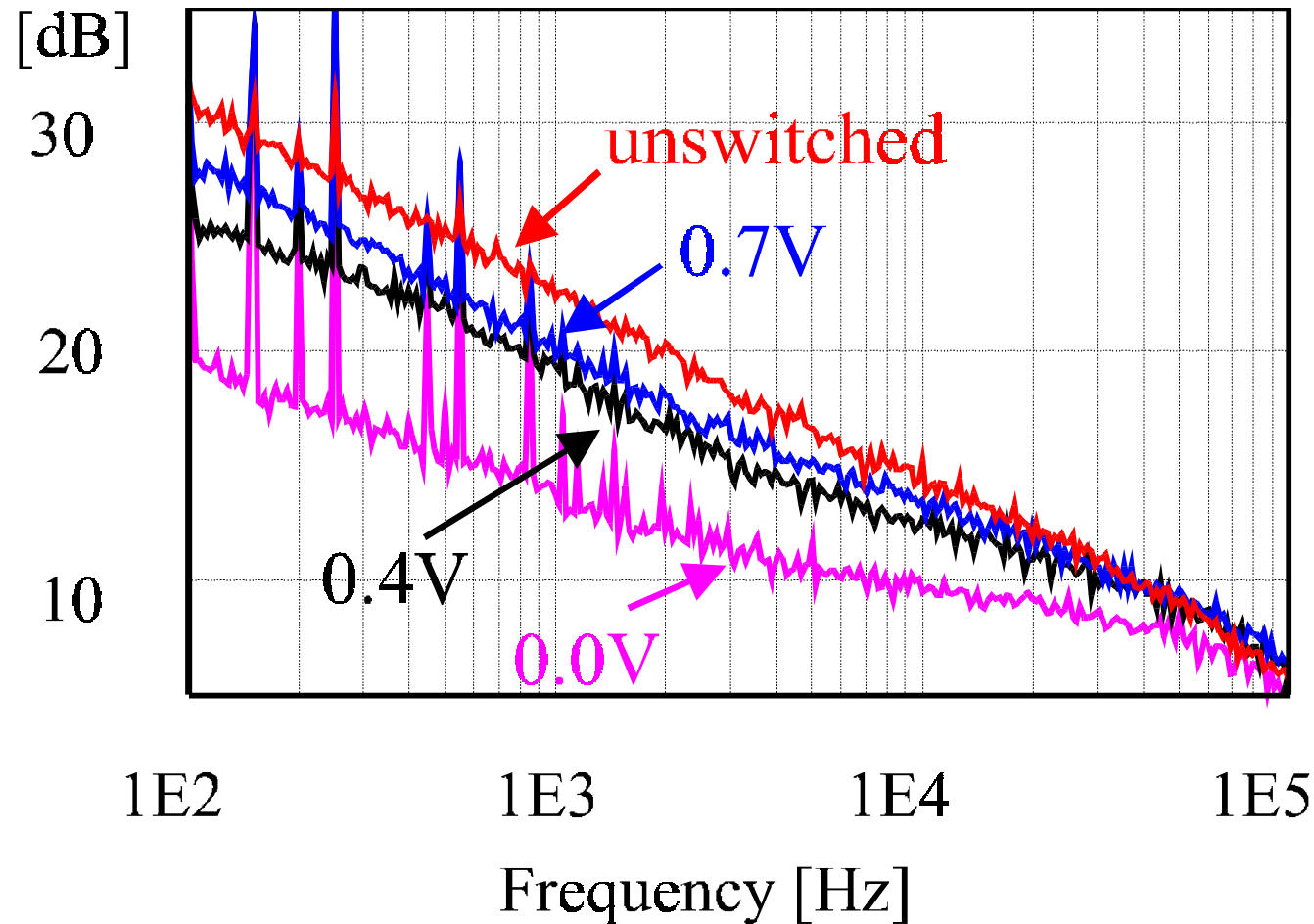


↑ 2mV/DIV
→ 20µs/DIV
probe gain : 5x



switching of MOS transistor → reduction of *intrinsic* 1/f noise
[see also : Bloom and Nemirovsky, Applied Physics Letters 1991]

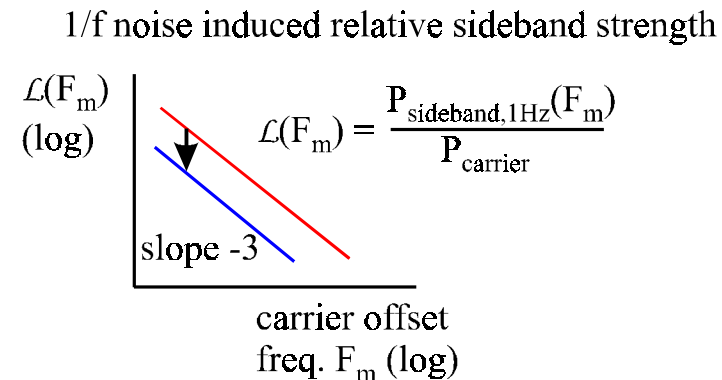
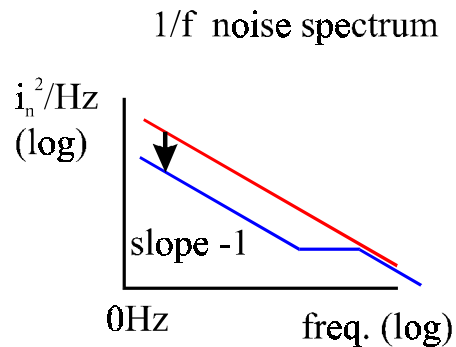
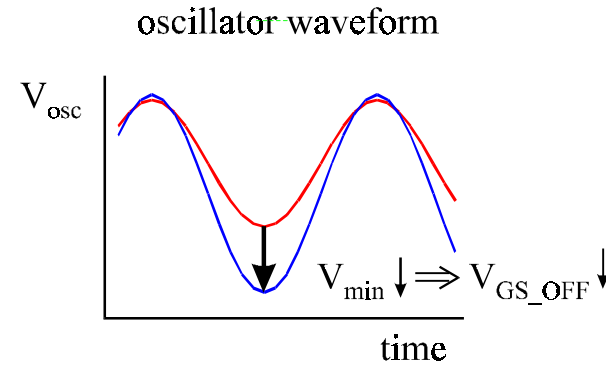
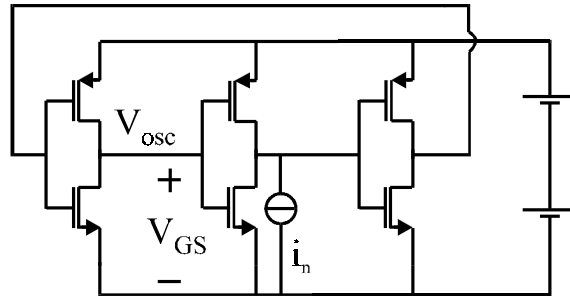
How does V_{GS_OFF} affect the 1/f noise spectrum ?



$V_{GS_ON} = 2.5V$
 $F_{SWITCH} = 2MHz$
Duty cycle = 50%

$V_{GS_OFF} \downarrow \Rightarrow$ intrinsic 1/f noise \downarrow

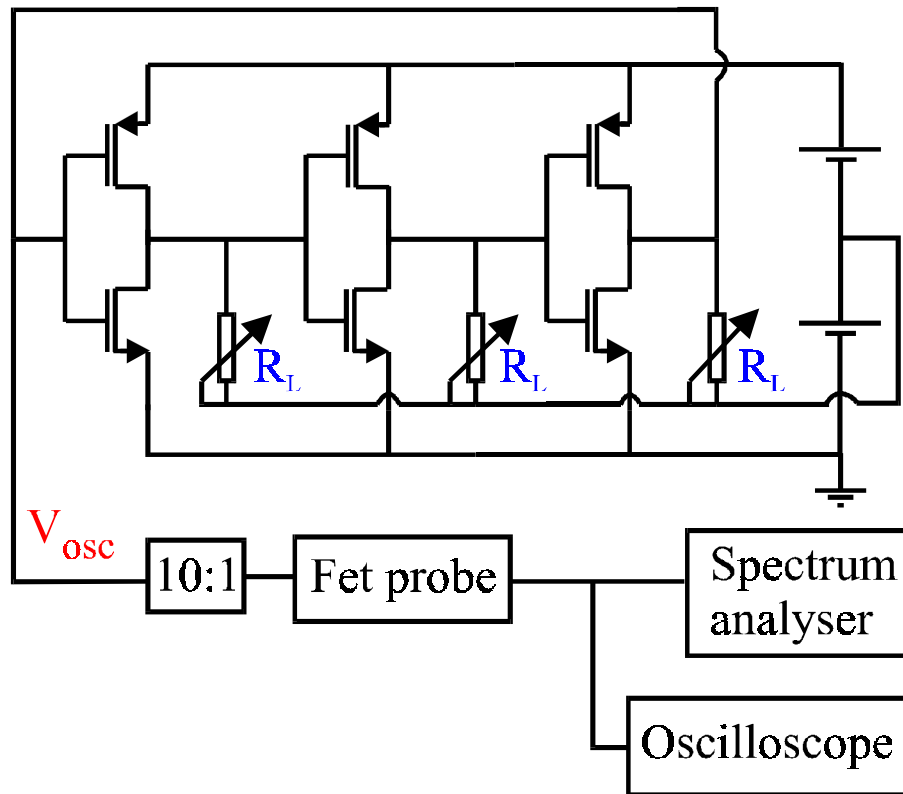
(How) does 1/f noise reduction appear in a ring oscillator ?



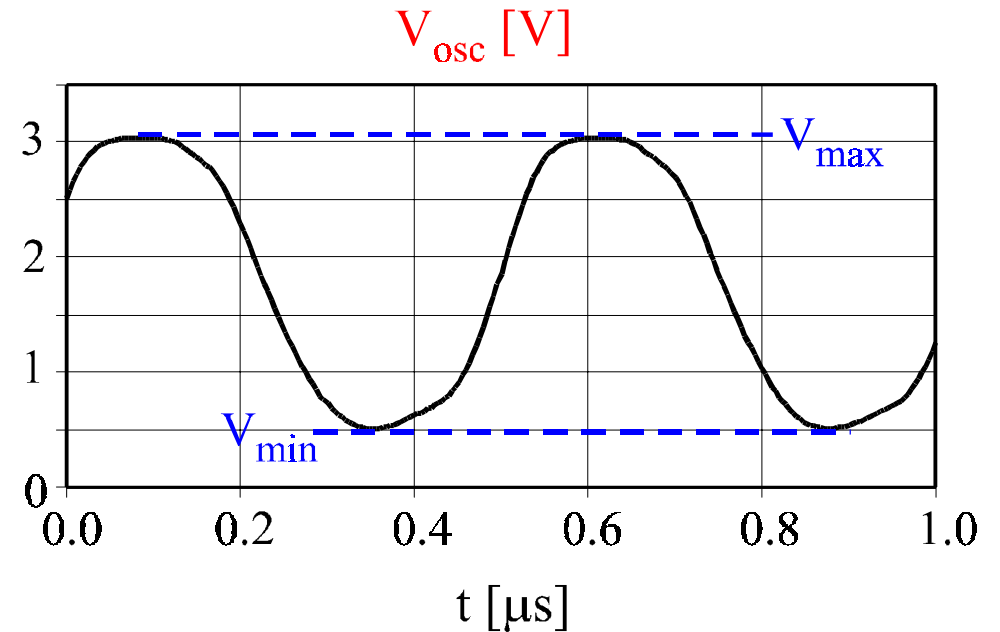
without 1/f noise reduction : $V_{\min} \downarrow \Rightarrow$ relative sideband \leftrightarrow
 with 1/f noise reduction : $V_{\min} \downarrow \Rightarrow$ relative sideband \downarrow

Ring oscillator sideband noise measurement

Phase noise measurement setup



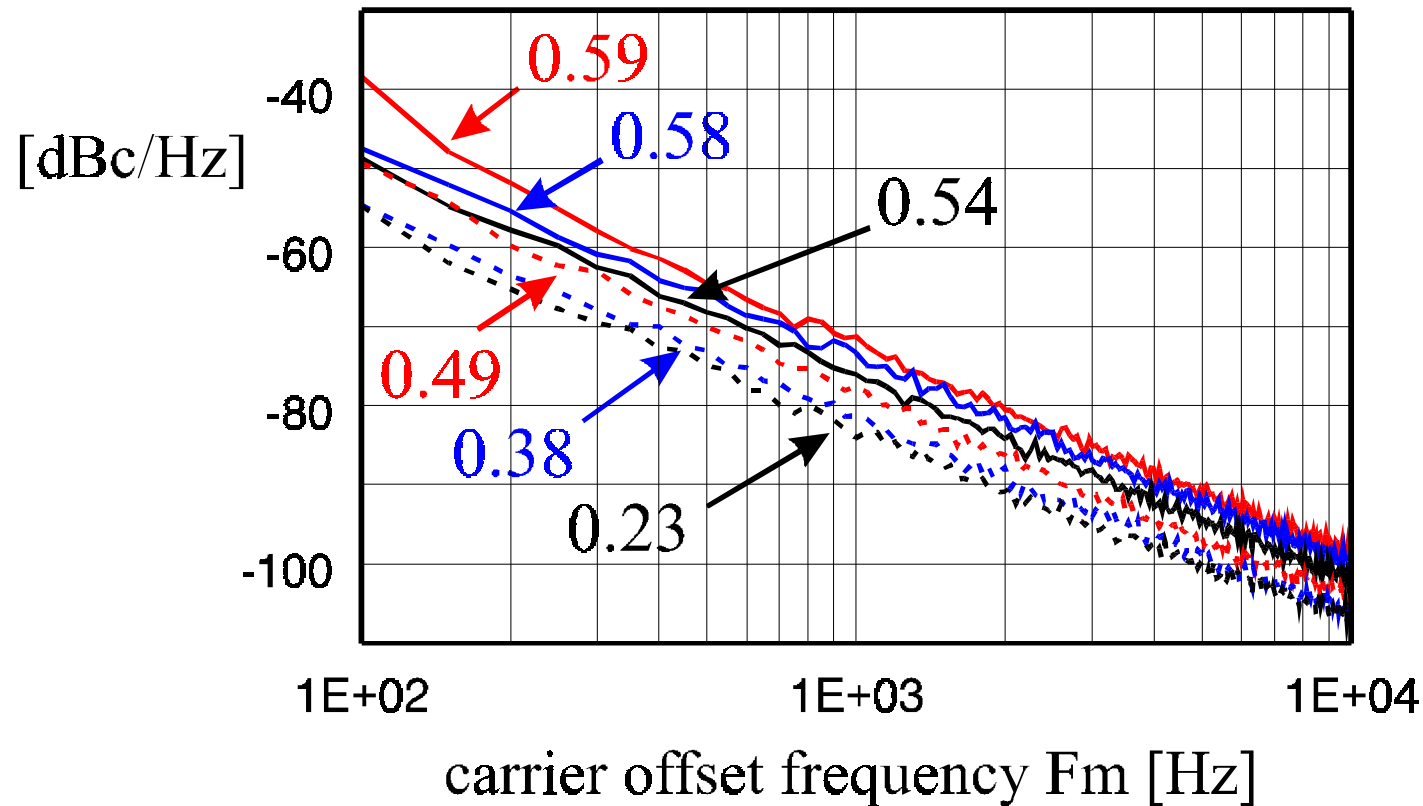
Typical waveform



V_{osc_pp} adjusted by means of R_L

Measured 1/f noise induced relative sideband strength

$10 \log(\mathcal{L}(F_m))$ at different V_{\min} ; $F_{\text{osc}} = 1.70 - 1.87$ MHz



$V_{\min} \downarrow \Rightarrow 1/f$ noise induced relative sideband strength \downarrow

Conclusions

- periodically switching a MOS transistor between an ON and OFF state leads to a reduction of intrinsic 1/f device noise
- $V_{GS_OFF} \downarrow$ (*especially for values well below V_T*) \Rightarrow intrinsic 1/f device noise \downarrow
- CMOS ring oscillator :
increasing the amplitude of oscillation can lead to a decrease in the 1/f noise induced relative sideband strength