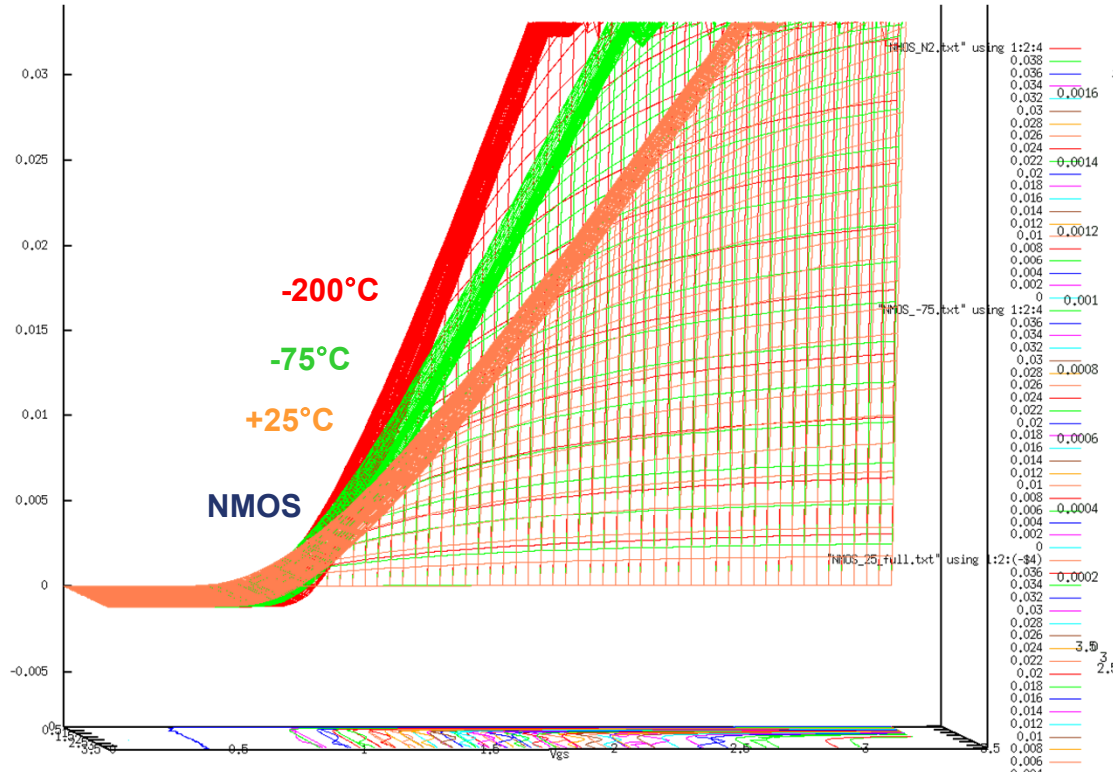
Front-end a basse (cryogenic) temperature

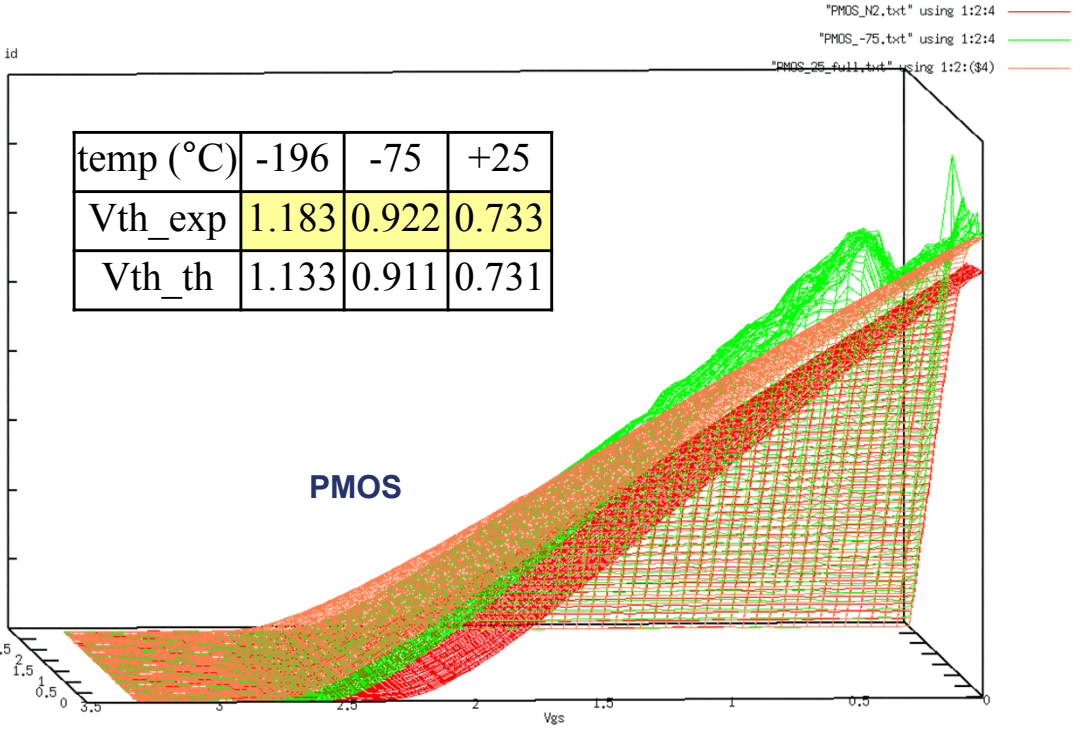
Cryogenic experience feedback

- MOS
- Resistance
- Capa…
- Delai inverseur
- 1/f noise
- Setup instrum
- Tips and traps
- Composants discrets

MOS

- T ↘ , la mobilité μ augmente ➔ gm ∝ μCox augmente
- T ↘, Vth ↗



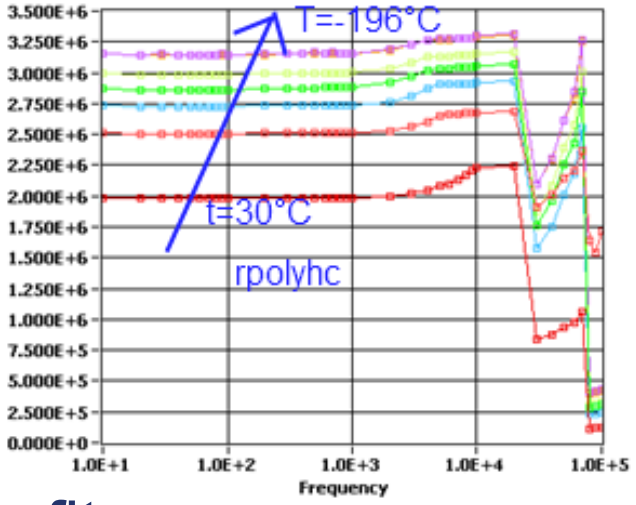


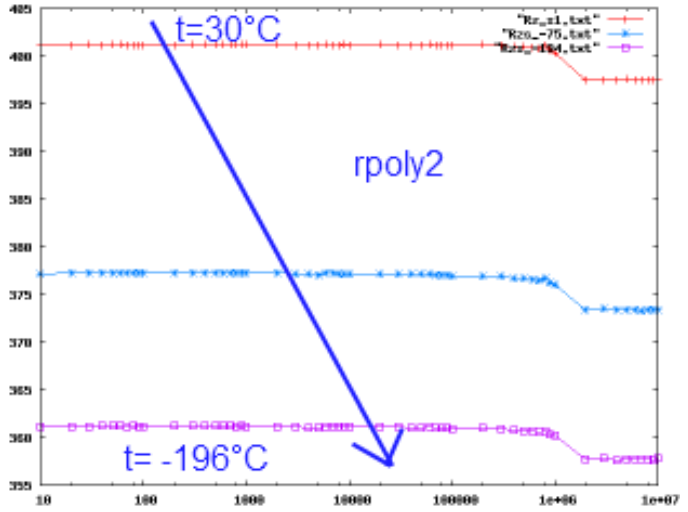
temp (°C)	-196	-75	+25
Vth_exp	1.183	0.922	0.733
Vth_th	1.133	0.911	0.731

Resistance

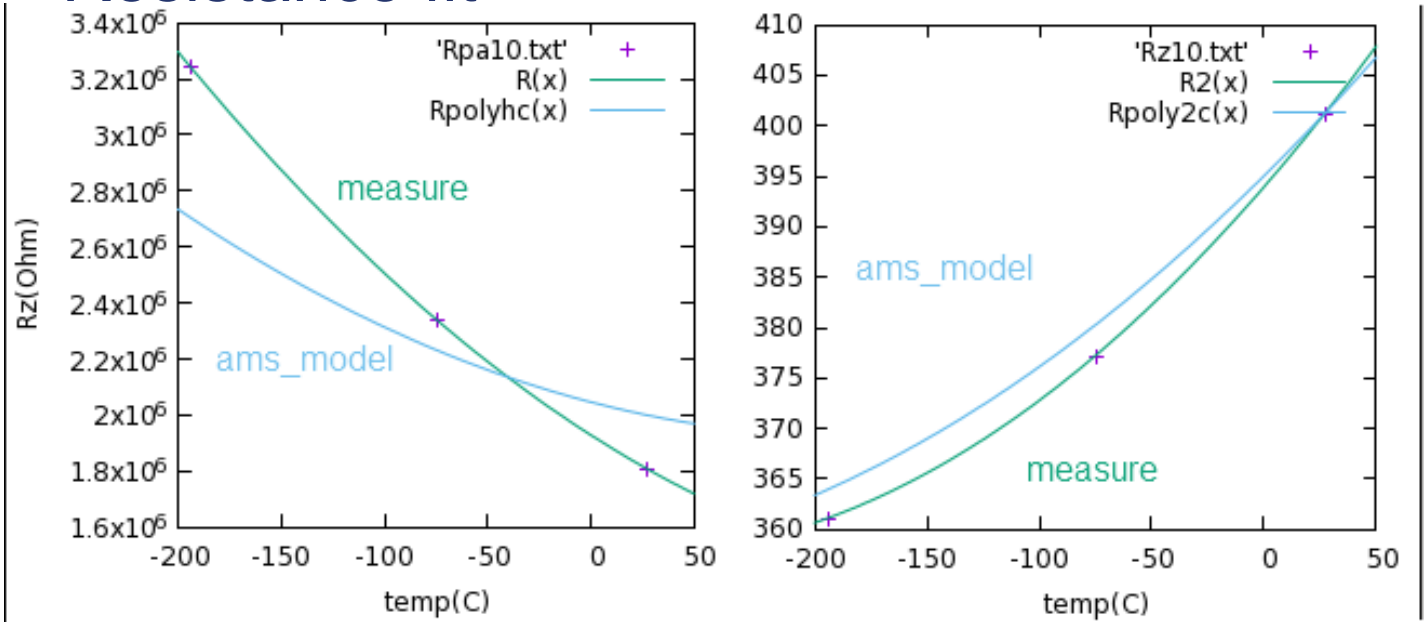
$$R(T) = R(T0)\cdot\left(1 + TCR1(T - T0) + TRC2(T - T0)^2\right)$$

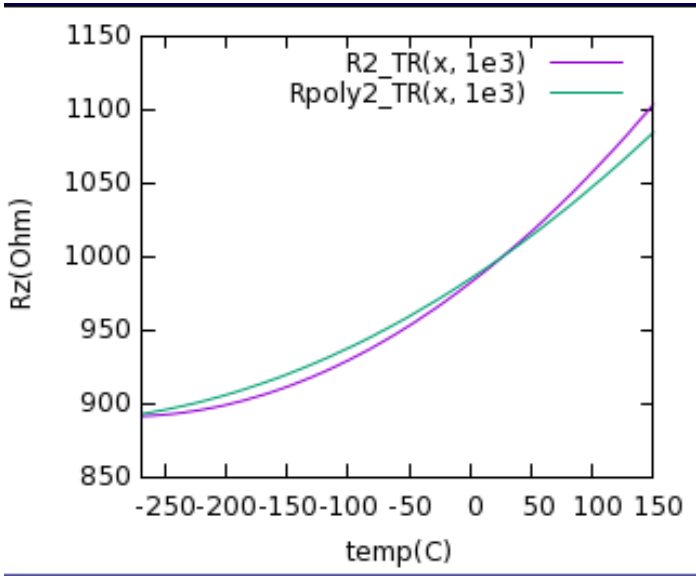
T0	RT0		TCR1 ($10^{-3}\Omega$/K)		TCR2 ($10^{-6}\Omega$/K)	
27	spec.	exp	spec.	exp	spec.	Exp
rpoly2	350Ω	360Ω	0.59	0.70	7.7	1.17
rpolyhc	2MΩ	1.8MΩ	-0.75	-2.37	3.82	5.70





- Resistance fit

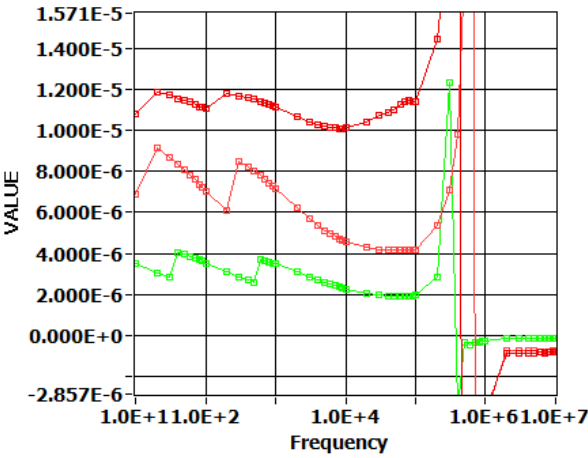


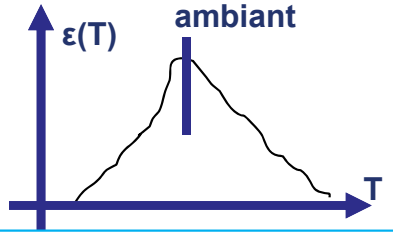


Capa…

- CMS : COG/NPO => valeur max (de taille :1210)➔ 100nF
- Tantale : à éviter, PB de vieillissement
- Capa CMS X5R X7R, YUV …
  - **quand t°C diminue C diminue,**

- Capa intégré [OK]
- Danger techno ‘high kè’ K=ε(T)/ ε_0
  - **Modif de la capa à froid➔vth ↗**





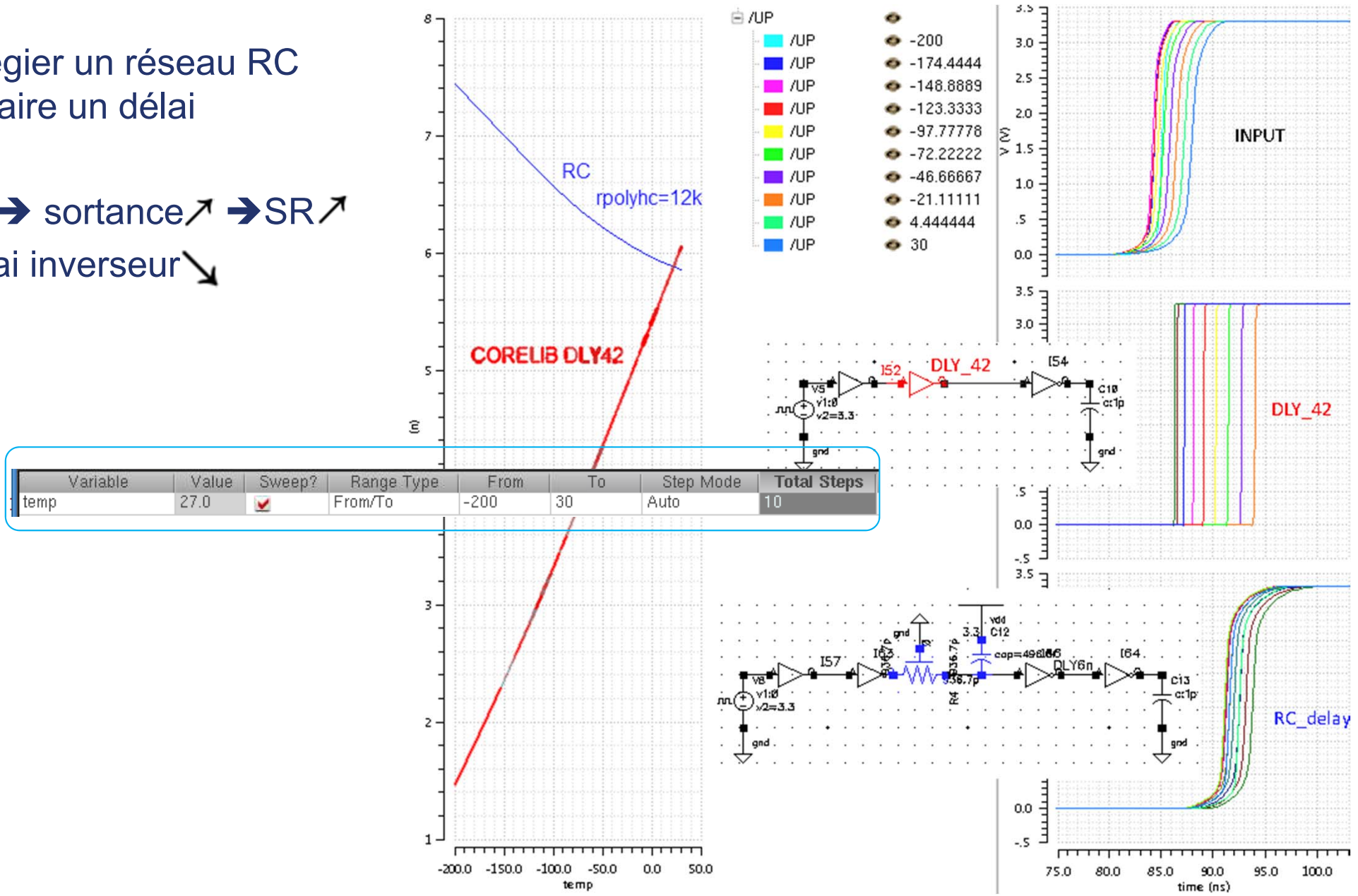
Capacitor type	Measured capacitance (100 nF at 300 K)		f \ T	Measured ESR		
	77 K	4 K		300 K	77 K	4 K
X7R ceramic	21.3 nF	3.4 nF	1 kHz	76 Ω	574 Ω	5.6 MΩ
			10 kHz	1.5 Ω	64 Ω	400 kΩ
			100 kHz	0.3 Ω	7.6 Ω	62 kΩ
Y5V ceramic	1.8 nF	0.9 nF	1 kHz	93 Ω	3940 Ω	3910 Ω
			10 kHz	1.8 Ω	410 Ω	360 Ω
			100 kHz	0.6 Ω	50 Ω	40 Ω
NPO ceramic (NPO/COG/COH)	100.2 nF	99.7 nF	1 kHz	2.1 Ω	2 Ω	3 Ω
			10 kHz	0.3 Ω	0.4 Ω	0.1 Ω
			100 kHz	0.2 Ω	0.02 Ω	0.05 Ω
Polyester	71.8 nF	15.3 nF	1 kHz	42 Ω	37 Ω	340 Ω
			10 kHz	1.8 Ω	40 Ω	36 Ω
			100 kHz	0.8 Ω	19 Ω	18 Ω
PPS	92 nF	83.2 nF	1 kHz	21 Ω	4.4 Ω	3.1 Ω
			10 kHz	1.1 Ω	0.2 Ω	0.25 Ω
			100 kHz	0.2 Ω	0.02 Ω	0.3 Ω

http://hal-obspm.ccsd.cnrs.fr/hal-00623399/document

Delai inverseur

Privilégier un réseau RC
pour faire un délai

gm ↗➔ sortance↗ ➔SR↗
➔délai inverseur↘



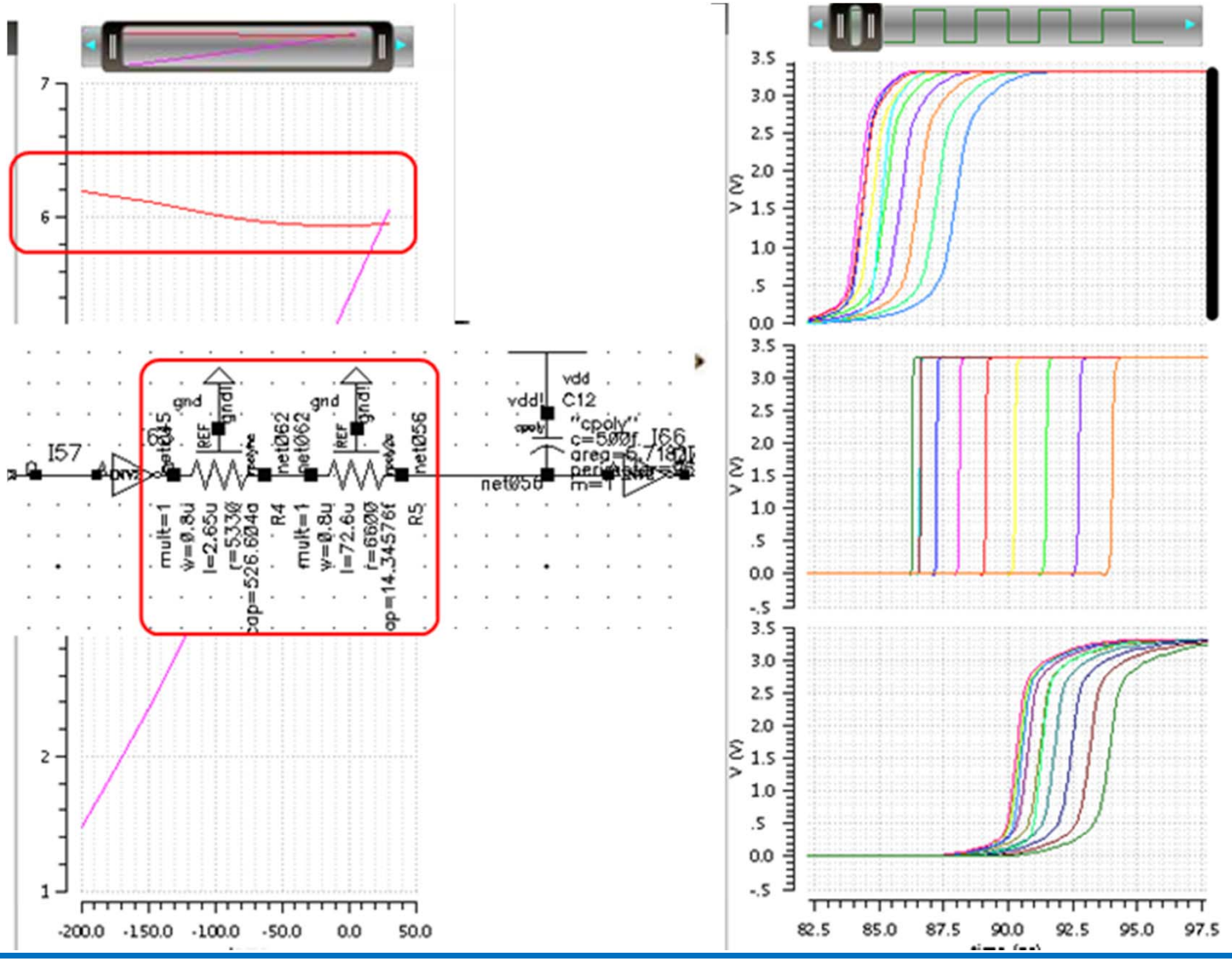
delai ~constant de -200°C à 30°C

- En jouant sur les variations inverse de rpoy2 et rpolyh en température

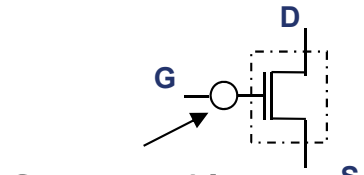
Au premier ordre pour conserver R_{total} constant :

Rpolyh=Rpoly2*0.59/0.75
Rtot=12k=5.33k + 6.6k

➔tau=1/2/3.14/(12k*500f)=6ns
~constante sur [-200°C +30°C]

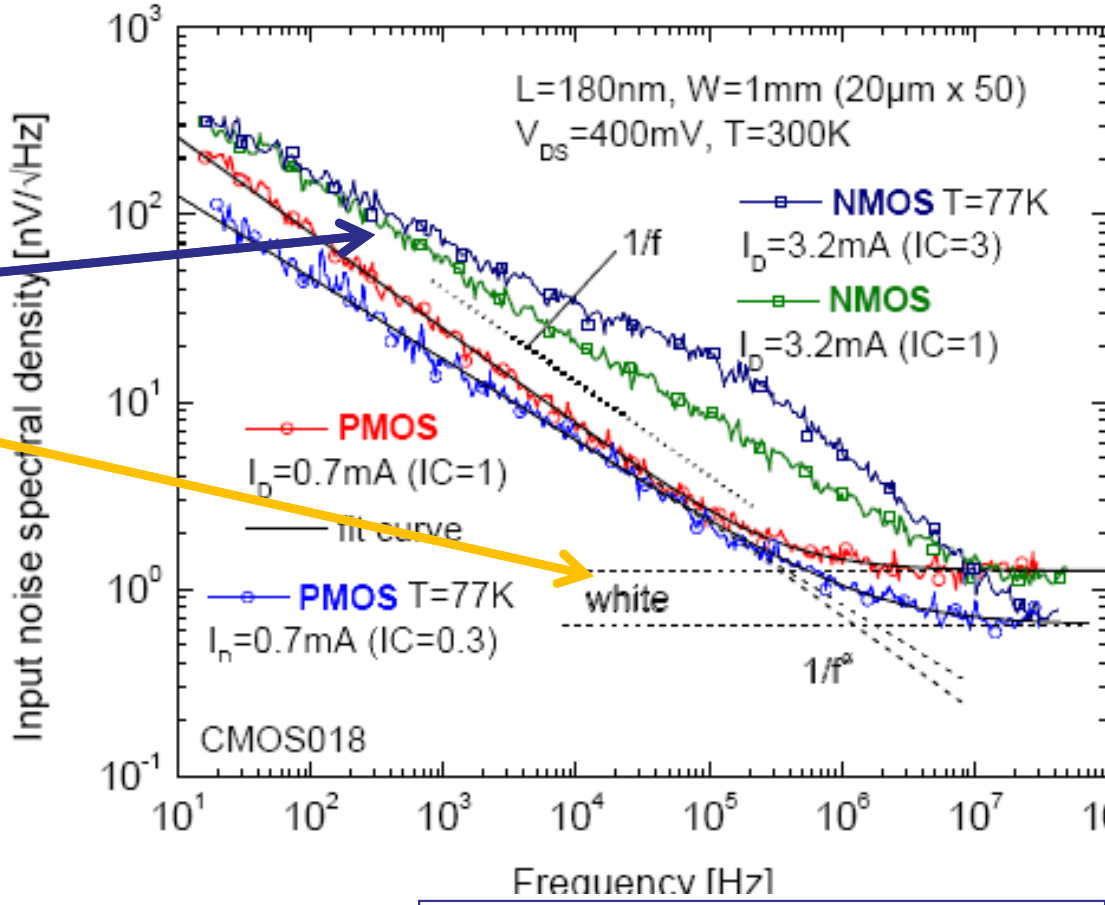


1/f noise



S_{inTot} [V²/Hz]

$S_{inTot} = 4kTR_N$ $\quad R_N = \frac{\rho}{WL}\frac{f}{} + \frac{n}{g_m}$



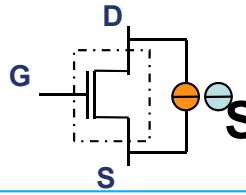
Radeka, De Geronimo NSS2010

- Nécessité de contraindre le simulateur pour prévoir des pentes de bruit en 1/f plus contraignantes.
- Sinon, les résultats sont éloignés des prédictions…

➔ Augmenter L : la largeur des transistors à W/L constant ➔ augmentation de la surface

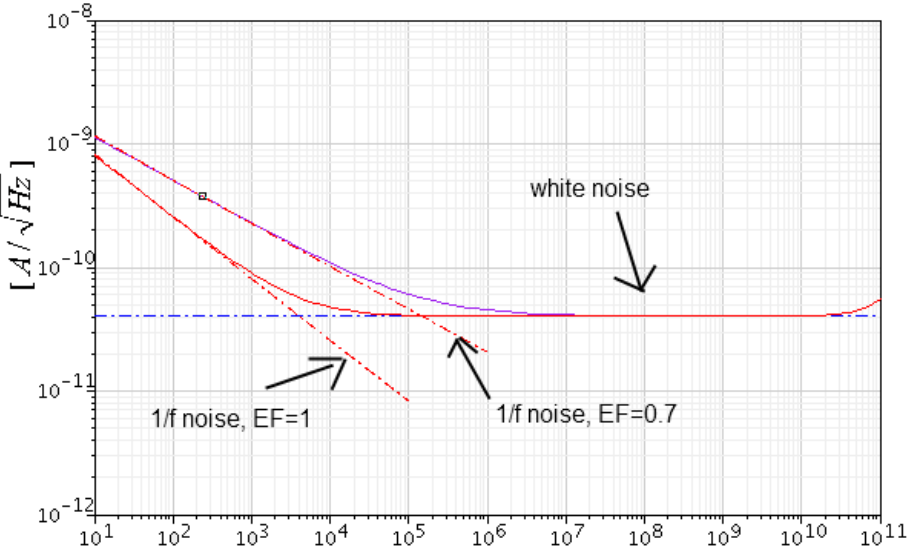
$$S_{If} = \frac{K_f . I_d^{AF}}{C_{ox} WL . f^{EF}}$$ [A²/Hz]

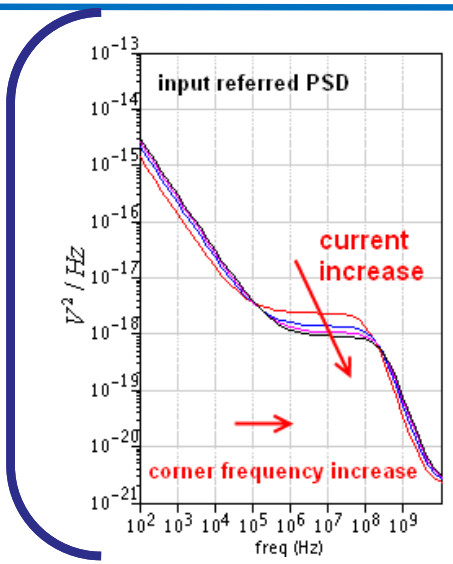
$$S_{Ith} = \frac{2}{3} 4kTg_m$$ [A²/Hz]

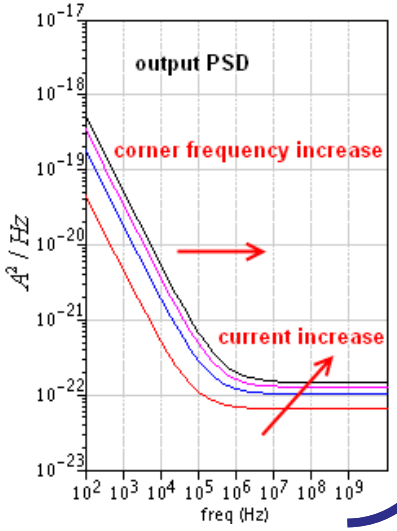


Output referred noise

S_{outTot} [A²/Hz]



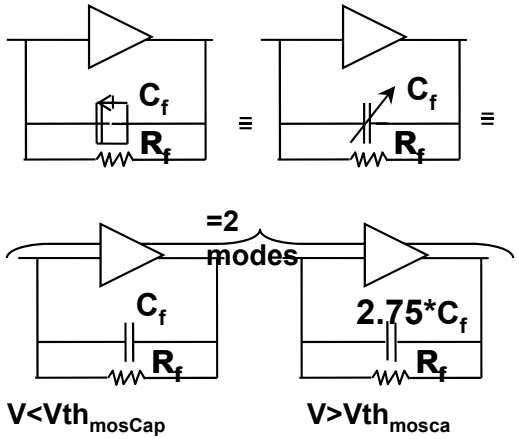


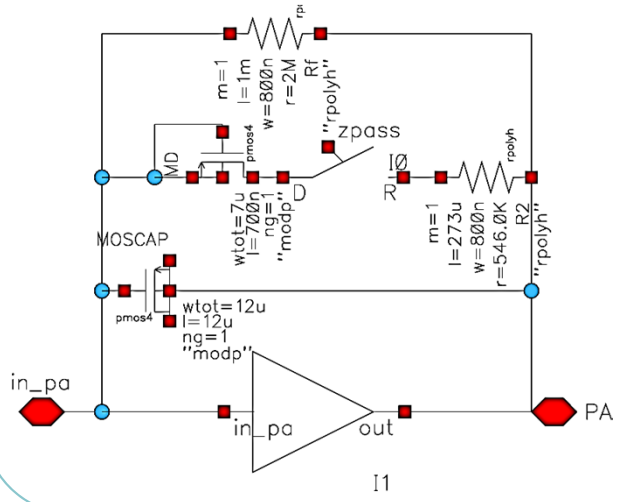


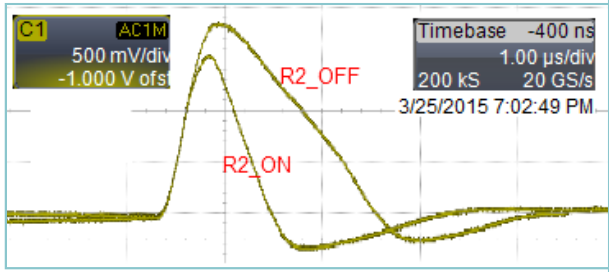
S_{outTot} [A²/Hz]=gm².S_{inTot}[V²/Hz]

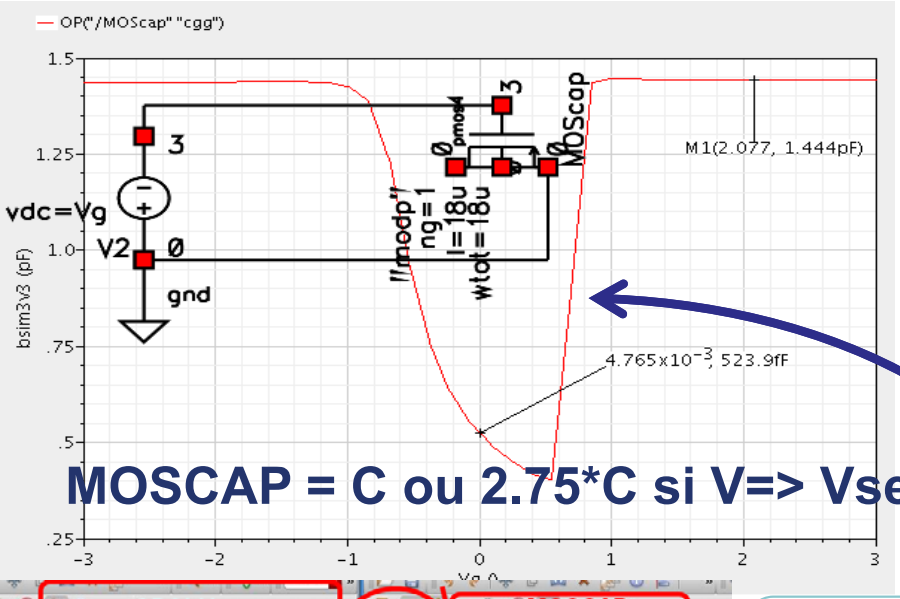
temp ↘	↘
gm ↗	↗
$f_{con}IN = \left(\frac{K_f . I_d^{AF} . g_m}{C_{ox} WL . \frac{2}{3} 4kT} \right)^{\frac{1}{EF}}$ ↗	$f_{con}OUT = \left(\frac{K_f . I_d^{AF}}{C_{ox} WL . \frac{2}{3} 4kTg_m} \right)^{\frac{1}{EF}}$ ↘

LARZIC_2014

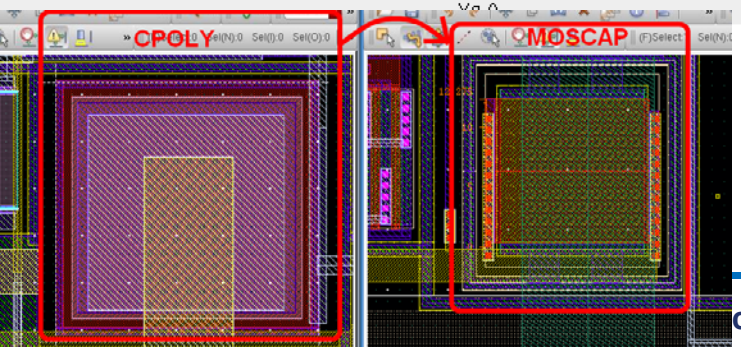






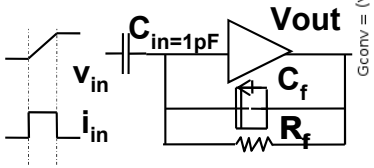


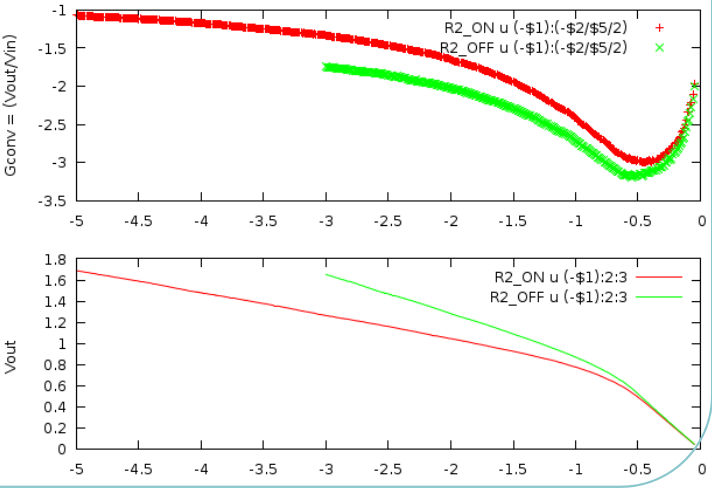
MOSCAP = C ou 2.75*C si V=> Vseuil



Sens de la MOSCAP choisit pour avoir la transition la plus franche

Gconv={2.5 ..1.5}[V/V] à travers 1pF
={2.5 ..1.5}[mV/fC]



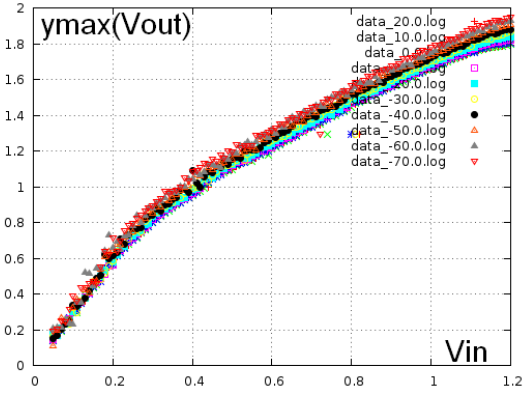


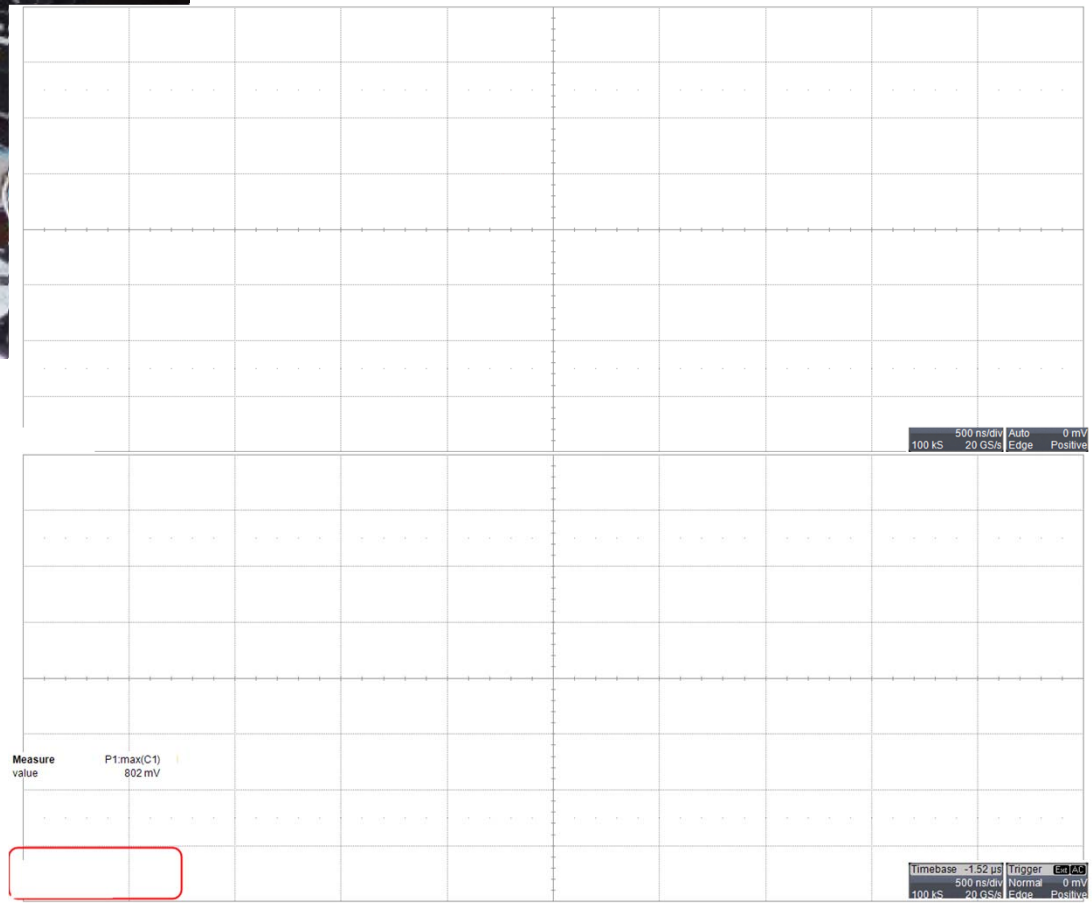
Setup instrum’

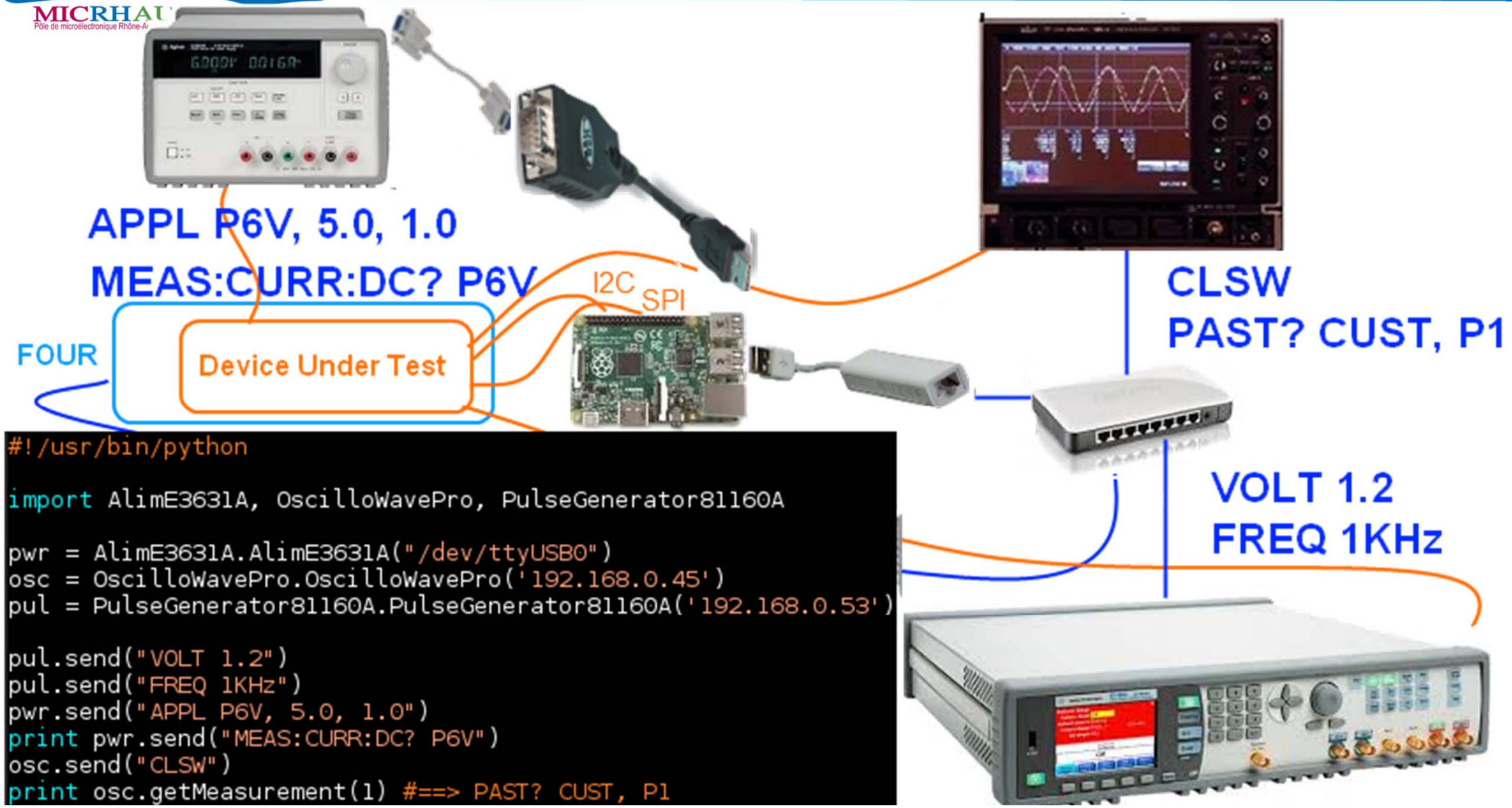
- **BOM :**

four (-70°C +180°C) , géné, Alim, ohmMetre (pt100), rpi…

- **LN2 à l’air libre ➔ pas d’obligation de cryostat fermé**
- **TODO : circulation LN2 pour test asservit de -200°C -70°C dans four asséché**







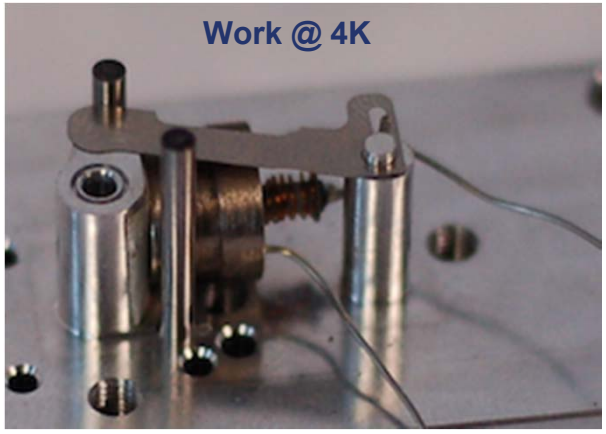

```
#!/usr/bin/python

import AlimE3631A, OscilloWavePro, PulseGenerator81160A

pwr = AlimE3631A.AlimE3631A("/dev/ttyUSB0")
osc = OscilloWavePro.OscilloWavePro('192.168.0.45')
pul = PulseGenerator81160A.PulseGenerator81160A('192.168.0.53')

pul.send("VOLT 1.2")
pul.send("FREQ 1KHz")
pwr.send("APPL P6V, 5.0, 1.0")
print pwr.send("MEAS:CURR:DC? P6V")
osc.send("CLSW")
print osc.getMeasurement(1) #==> PAST? CUST, P1
```

Merci beaucoup à Loup BALLEYGUIER pour son aide sur les drivers, (CDD→juin 2015)

➔ https://github.com/ebecheto/testbench

Composants discrets

- GPIO expander [OK] , testé dans LN2 : NXP, Ti
- LDO [OK], mais PSRR diminue, testé : TPS73233
  - Paper : *Evaluation of Voltage Reference Circuits and N-Channel Field Effect Transistors at Low Temperatures*, Richard.L.Patterson@grc.nasa.gov
- dream_twepp2014.pdf → régulateur intégré !
- DC/DC ? [non testé]
- Relai,Moteur [pass/fail]

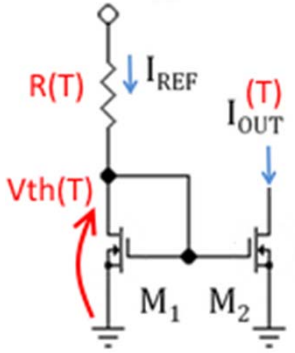


Tips and traps

- Eviter les connecteurs à ressort (JLCC) ➔ souder les ASIC et les connecteurs
- Si condensation lors d'un réchauffement ➔ eau possible sous les composants

/!\ auto-echauffement | conduct. therm. LN2 : 24mW/m^{-1}K^{-1} |

- Préférer un Bandgap à un miroir de courant simple
- PSRR ➔ circuits différentiels



Conclusion cryo

- Bsim Models : Res, cap, Vth [OK]
- /!\ power supply /!\
- Digital design should work.
- 1/f noise …
- Il existe actionneur ➔ moteur