# Caratterizzazione elettrica di DAC e ADC dell'ASIC *CHIPIX65 Demonstrator*

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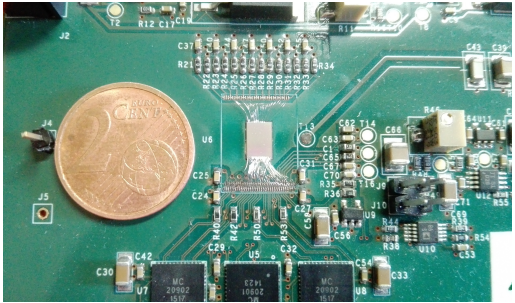
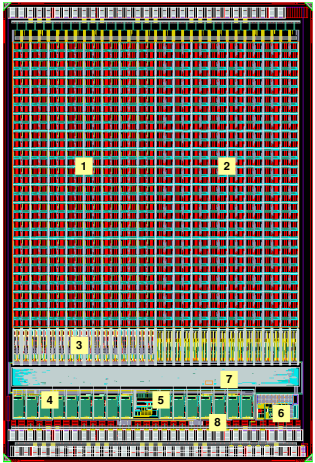
# Sommario dell'attività svolta



1. **Stage**: Sviluppo **DAQ**
2. Caratterizzazione **DACs**
3. Caratterizzazione **ADC**
   - linearità
   - risposta in frequenza

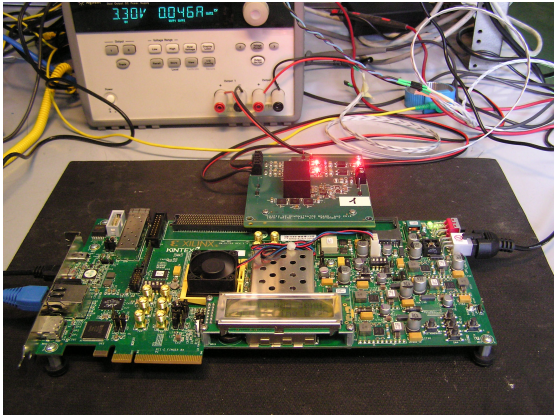
# CHIPIX65 Demonstrator




- tecnologia CMOS *65 nm*
- array di 64×64 pixels
- 50 $\mu$m $\times$ 50 $\mu$m pixel
- 10-bit DACs per correnti/tensioni di bias per Front-End dei pixels (**4**)
- 12-bit ADC di monitoring (**6**)

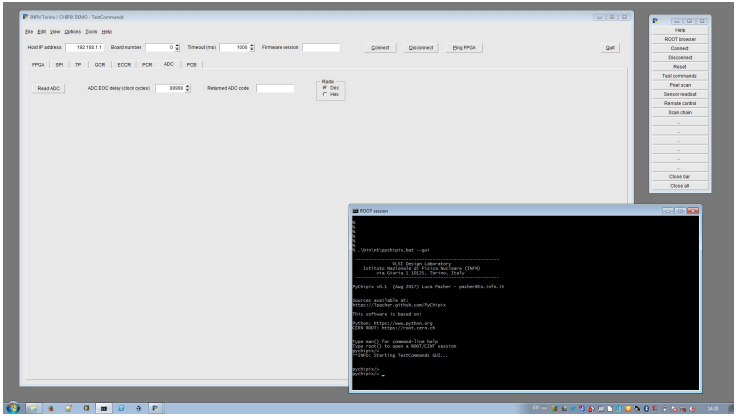
**3.5 mm $\times$ 5.1 mm**

# Test Setup




- CHIPIX Demonstrator Board *(INFN Sez. di Torino)*
- Alimentatore Stabilizzato
- *FPGA Kintex7 Xilinx*
- Connessione *Ethernet/UDP*
- Multimetro (Keithley 2240)
- Generatore funzioni d'onda 14-bit/50 MHz (Keithley 3390)

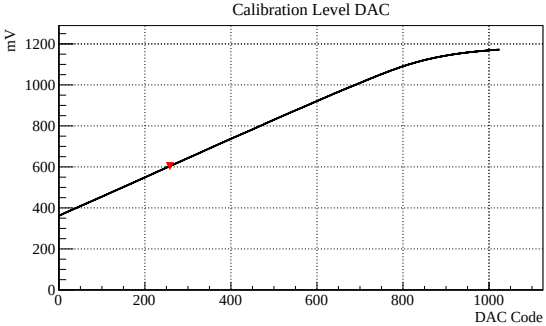
# PyCHIPIX *DAQ*

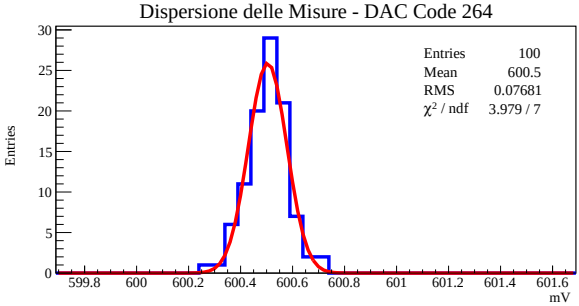



Progetto dello **stage**

- DAQ per l'automatizzazione delle misure
- **ROOT** interpretato con Python

# Caratterizzazione DAC



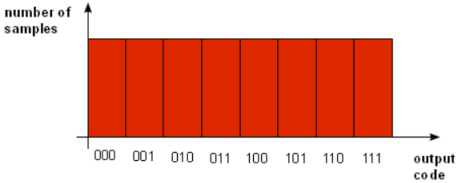



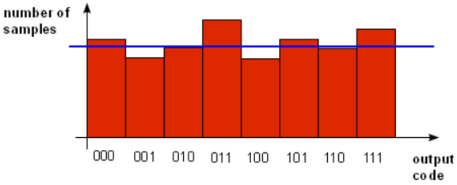

- DAC **Calibration Level** : Carica di calibrazione dei pixels
- **100 Misure ripetute** su singolo DAC Code ( $\approx$ 5 ore, controllo remoto Ketihley 2440)
- **Fit gaussiano** sull'istogramma delle misure
- RMS Noise $\approx$ 0.1 mV, cfr. passo DAC Code $\approx$ 0.8 mV $=$ 40 $e^-$

# Caratterizzazione ADC: linearità

- Metodo **Code Density** : confronto frequenze attese ($f_i$) e osservate ($\hat{f}_i$)

  $\Longrightarrow$ es. 3-bit ADC, *Rampa Lineare:* $V_{in}(t) = kt$




**Idealmente**

$$W_i = LSB$$

$$\hat{f}_i = f_i$$

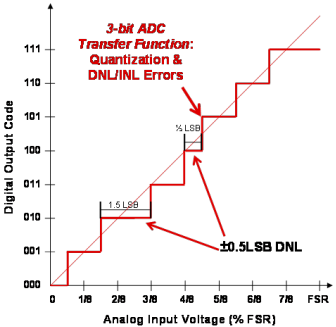
**Realmente**

$$W_i = LSB\,(1 + \alpha_i)$$

$$\hat{f}_i = f_i\,(1 + \alpha_i)$$

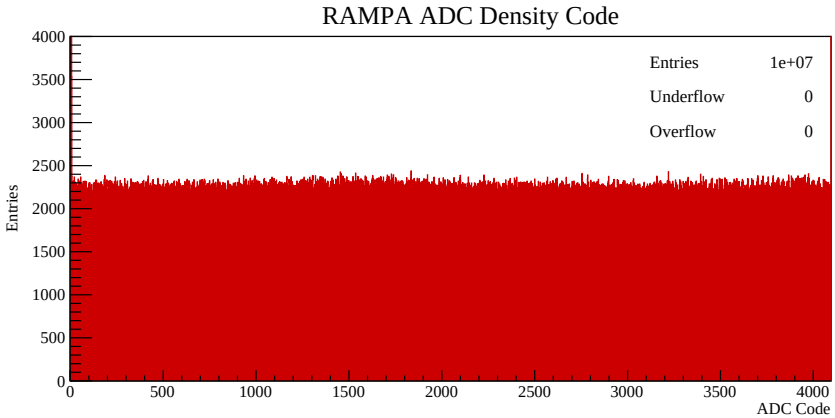
# ADC: Non Linearità Differenziale (DNL) e Integrale (INL)

$$DNL_i = \frac{\hat{f}_i}{f_i} - 1 \implies INL_i = \sum_{k=1}^{i} DNL_k$$




- $LSB = \frac{V_{Ref}}{2^N}$
- Buona ADC Commerciale:
  $|DNL| < \mathbf{0.5}\ LSB$

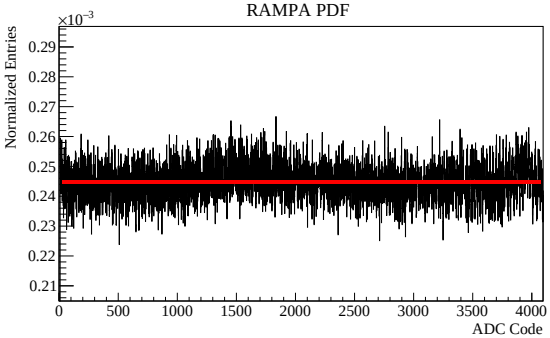
# Code Densitiy RAMPA - ACQUISIZIONE

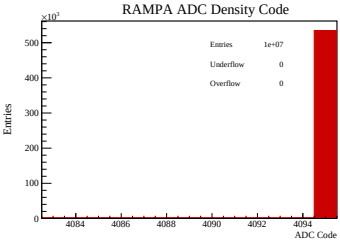


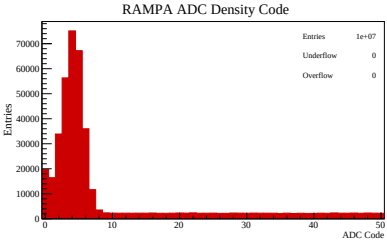

- Rampa Lineare a Dente di Sega
- $\nu = 0.314159\ Hz$
- $V_{ref} = 900$ mV
- frequenza di campionamento: $100 Hz$
- durata presa dati: 2 *giorni*
- Nessun errore di comunicazione

# Densità Codici RAMPA - ANALISI /1

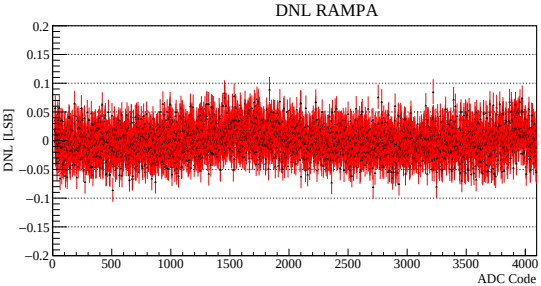
- Selezione Codici
- Normalizzazione Code Density
- Confronto PDF: $\mathrm{PDF}(\mathbf{code}) = \dfrac{1}{code_{MAX} - code_{MIN}}$



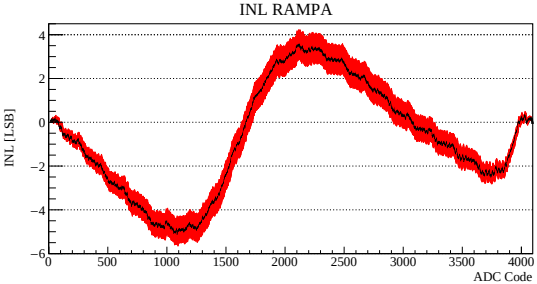



# Densità Codici RAMPA - ANALISI /2

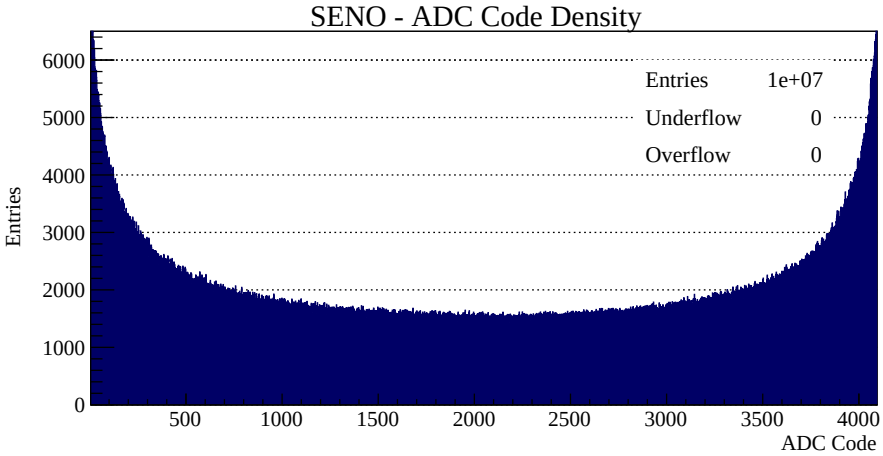



$|DNL| < 0.1\ LSB$



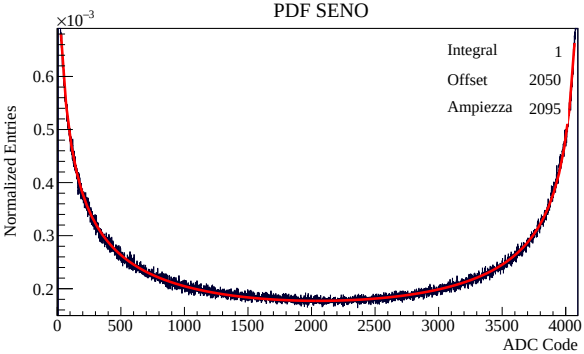

$-5$ LSB $< INL <$4 LSB

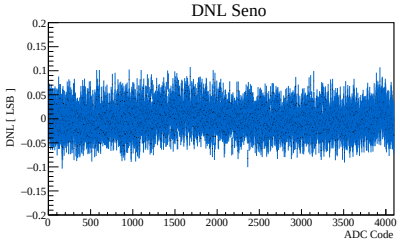
# Densità Codici SENO - ACQUISIZIONE

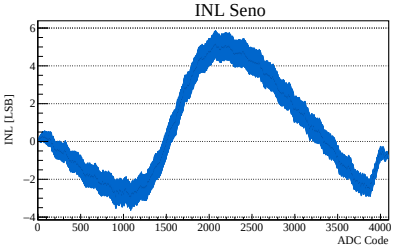



- Funzione Sinusoidale
- $\nu = 0.314159\ Hz$
- $A = 900$ mV
- frequenza di campionamento: $100 Hz$
- durata presa dati: 2 *giorni*
- Nessun errore di comunicazione

# Densità Codici SENO - ANALISI

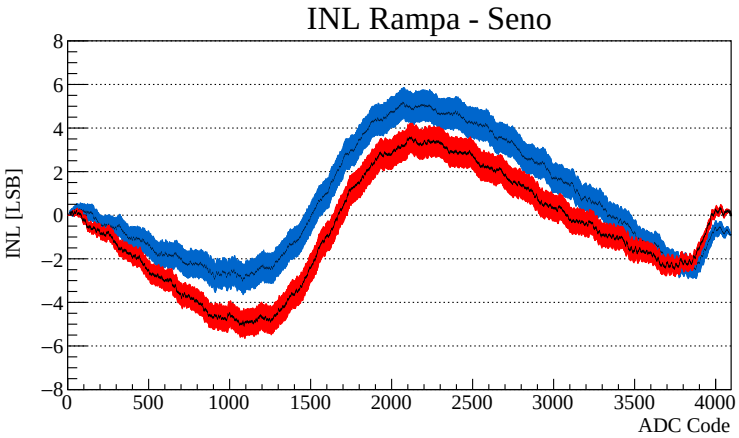


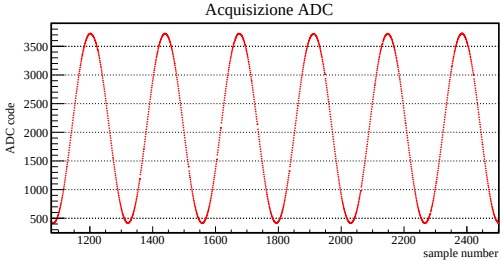

- Ottimizzazione PDF tramite FIT
- $P(\mathbf{code}) = \left[\arcsin \frac{\mathbf{code} - \mathit{Offset}}{\mathit{Ampiezza}} - \arcsin \frac{\mathbf{code} - 1 - \mathit{Offset}}{\mathit{Ampiezza}}\right]$

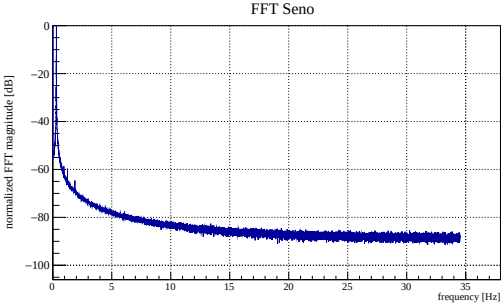
# Densità Codici CONFRONTO INL



# Risposta in frequenza: Analisi di Fourier /1

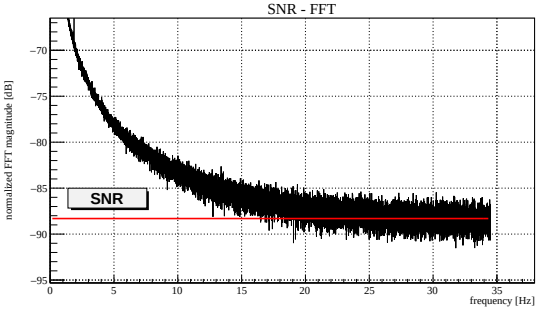
- **D**iscret **F**ourier **T**ransform
- $x(\mathbf{t}) \implies x(nT_S) \implies X_{\mathbf{k}} = \sum_{n=0}^{N-1} x(nT_S)\, e^{-jk2\pi\frac{n}{N}} \implies$ **F**ast **F**ourier **T**ransform



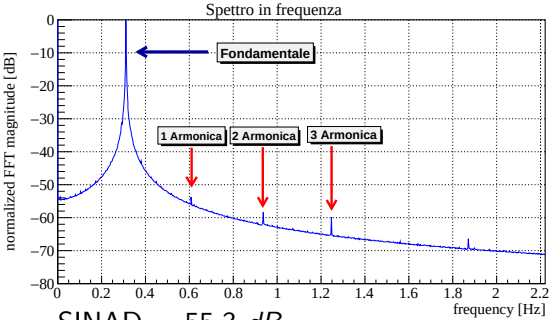




- frequenza di campionamento $= \dfrac{1}{T_S} \approx 70\text{Hz}$

# Risposta in frequenza: Analisi di Fourier /2




$SNR = 88.4\ dB$




$SINAD = 55.3\ dB$

$$Effective\ Numbers\ Of\ Bits = \frac{SINAD - 1.76}{6.02} = 8.9 \implies atteso : 9.5$$

# Conclusioni

- Sviluppo di un software efficiente per l'acquisizione di misure articolate basato su librerie open-source
- Analisi dati utilizzando metodologie specifiche per la caratterizzazione di convertitori DAC e ADC
- Ottimo accordo tra prestazioni attese e misurate nell'ASIC CHIPIX65
- Questi risultati saranno presentati e pubblicati ad IEEE/NSS 2017