A wearable intelligent system for the health of expectant mom's and their children

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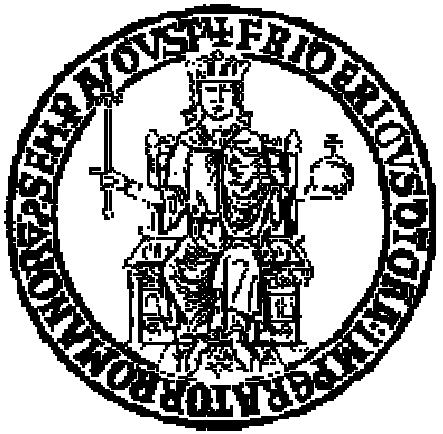
UNIVERSITÀ DEGLI STUDI DI PAVIA

FACOLTÀ DI INGEGNERIA

LABORATORIO DI MICROCALCOLATORI

Obiettivi

Progetto di Ricerca di Interesse Nazionale



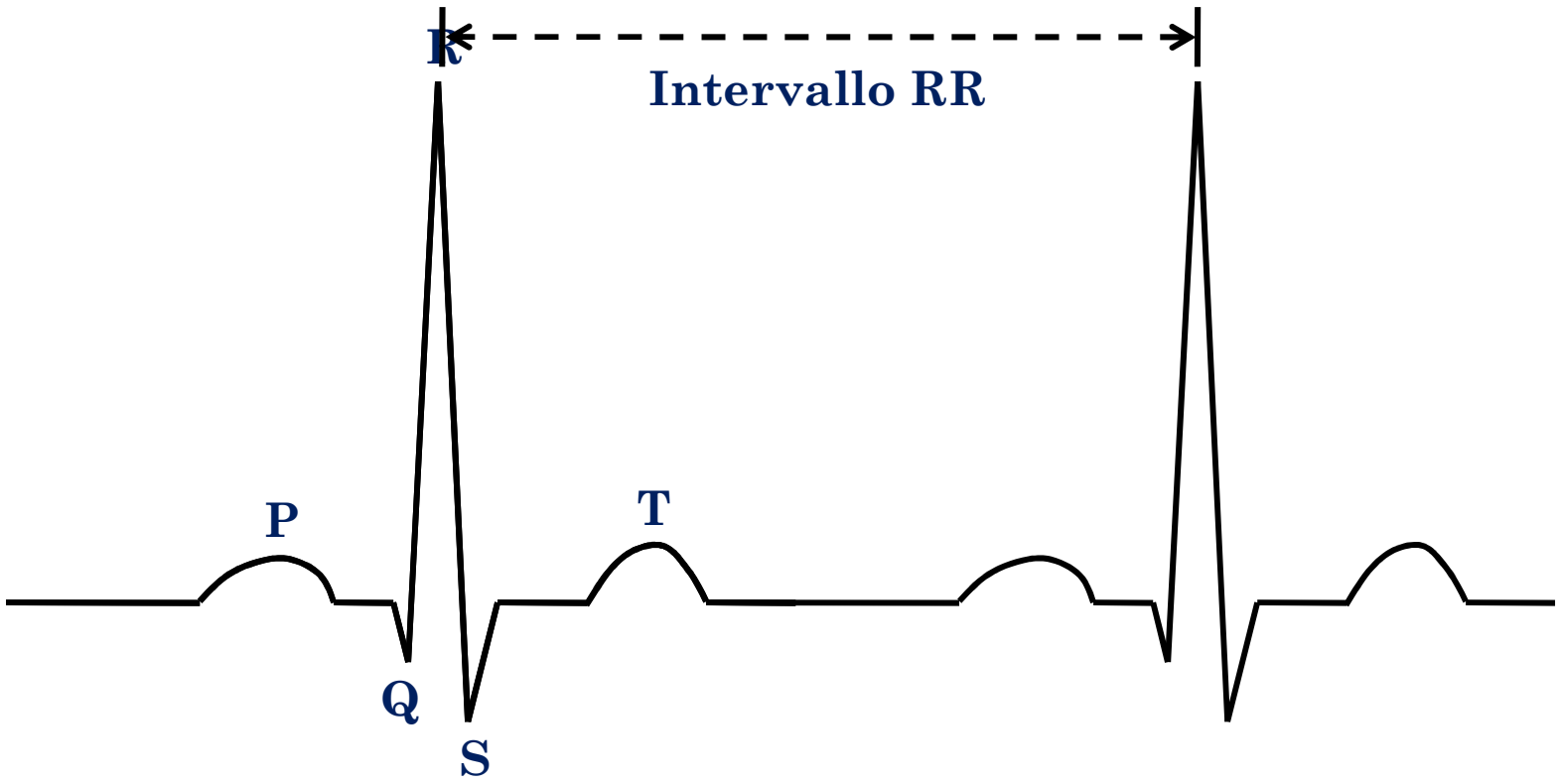
Realizzare un sistema indossabile
a basso costo e basso consumo
per misure cardiotocografiche fetali in tempo reale

→ embedded

Sommario

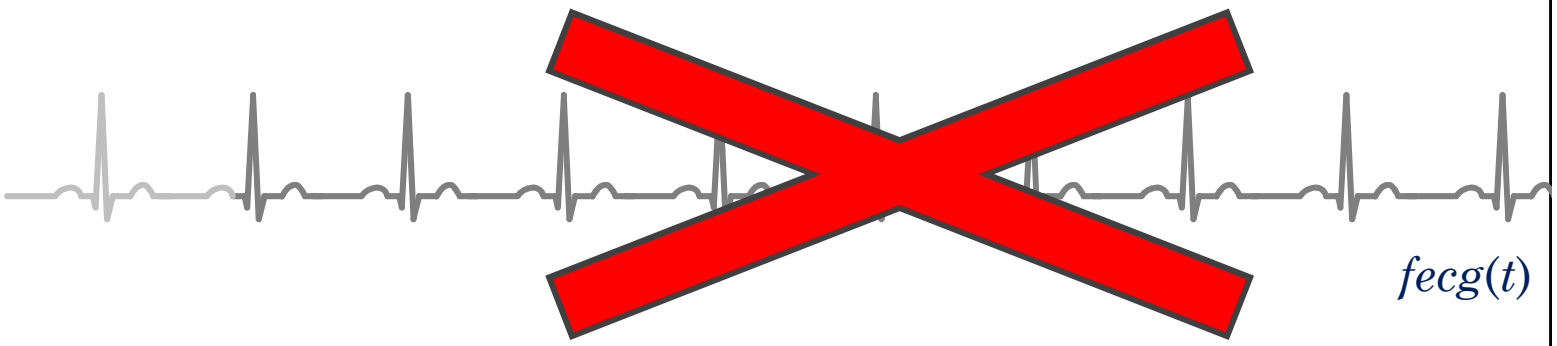
- ECG Fetale
- Algoritmi per la stima del FECG
- Infomax
- Implementazione su FPGA Stratix II
- Conclusioni

Frequenza Cardiaca (HR)

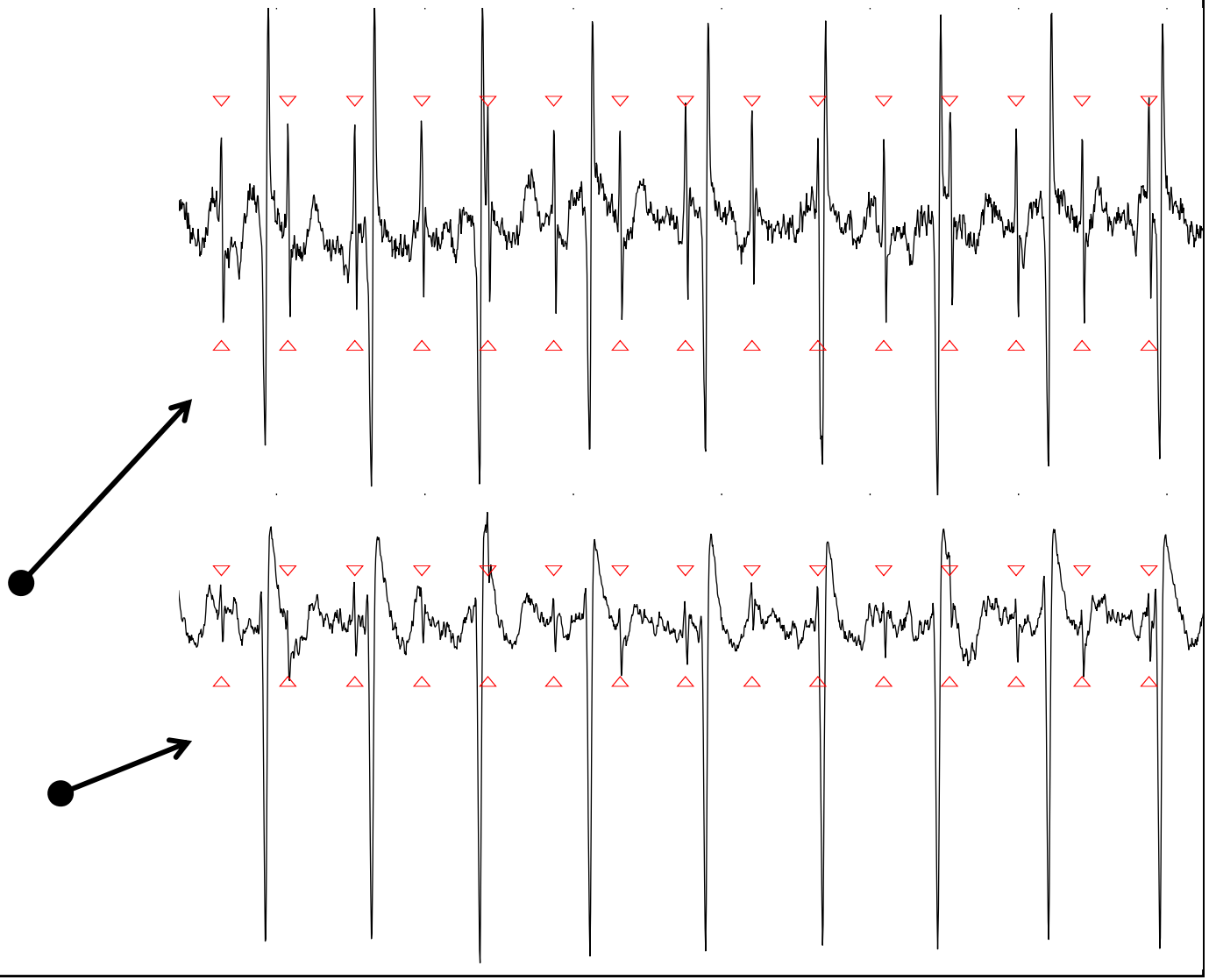


Complesso QRS

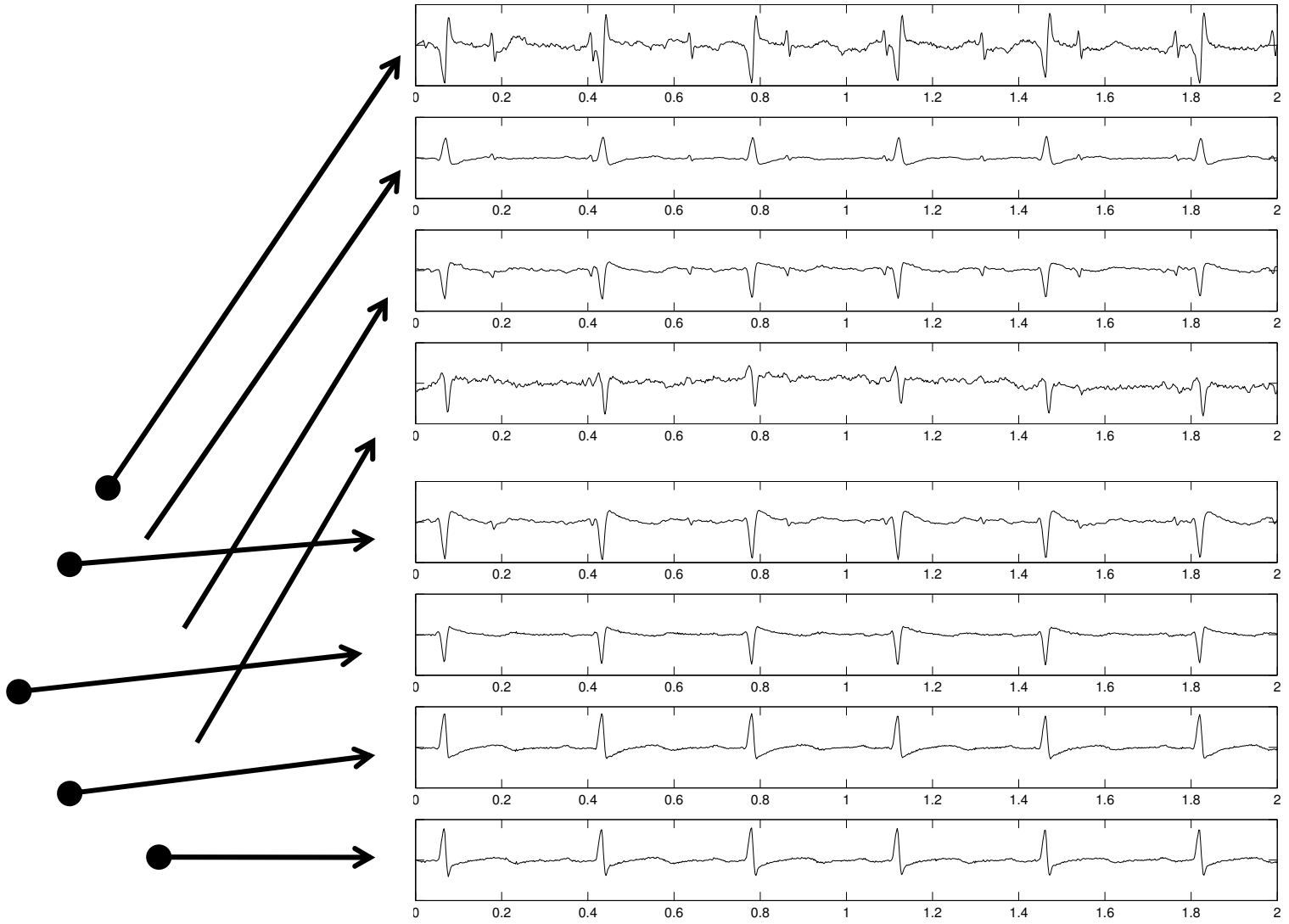
ECG Fetale (FECG)



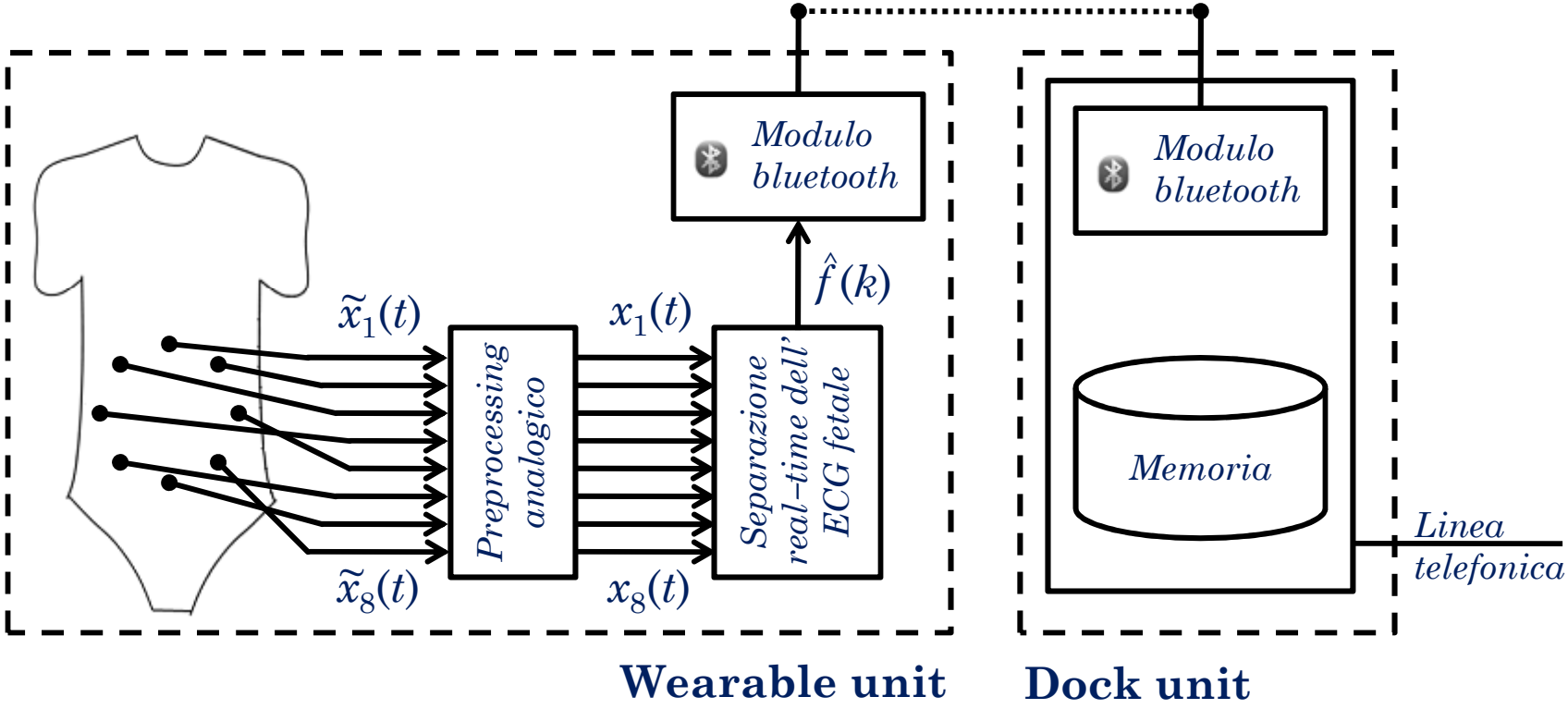
Misurazioni addominali



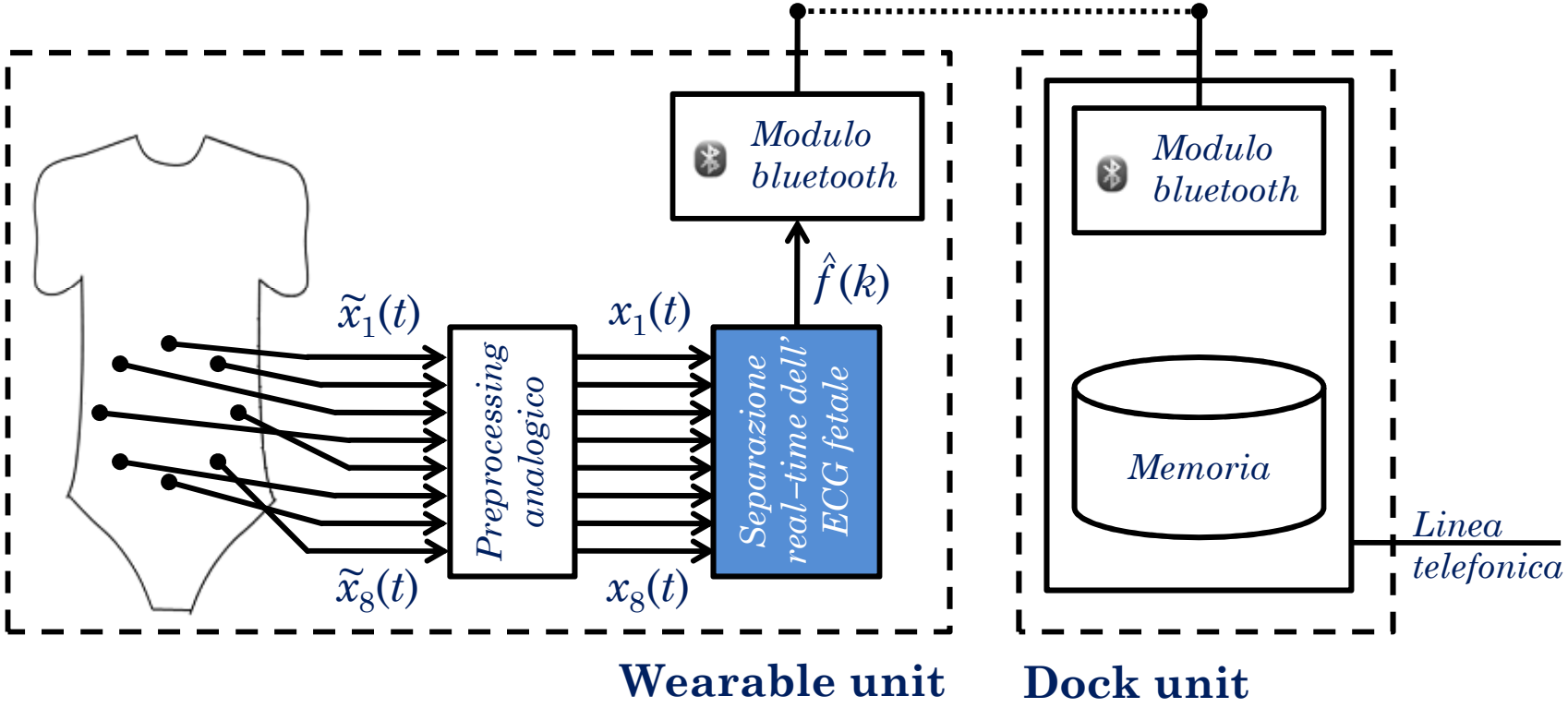
Misurazioni addominali



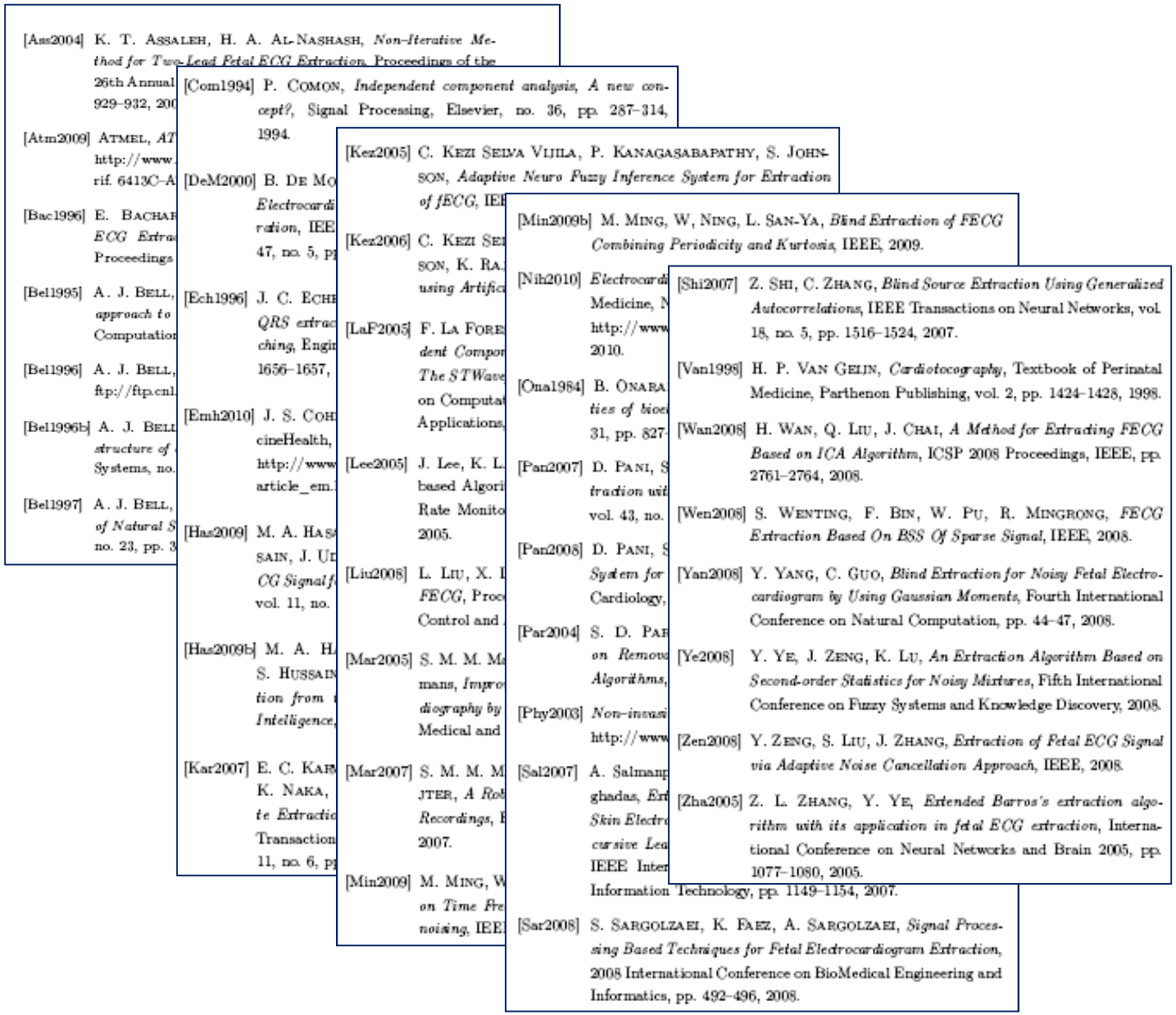
Sistema proposto



Sistema proposto



Algoritmi per la stima del FECG



[Ass2004] K. T. Assaleh, H. A. Al-Nashash, *Non-Iterative Method for Two-Lead Fetal ECG Extraction*, Proceedings of the 26th Annual 929–932, 200

[Atm2009] Atmel, *AT* http://www. rif. 6413C–A

[Bac1996] E. Bachar *ECG Extra* Proceedings

[Bel1995] A. J. Bell, *approach to* Computatio

[Bel1996] A. J. Bell, ftp://ftp.cnl.

[Bel1996b] A. J. Bell *structure of* Systems, no.

[Bel1997] A. J. Bell, *of Natural S* no. 23, pp. 3

[Com1994] P. Comon, *Independent component analysis, A new concept?*, Signal Processing, Elsevier, no. 36, pp. 287–314, 1994.

[DeM2000] B. De Mo *Electrocardi ration*, IEE 47, no. 5, pp

[Ech1996] J. C. Eche *QRS extrac ching*, Engi 1656–1657,

[Emh2010] J. S. Coh cineHealth, http://www article_em.

[Has2009] M. A. Has sain, J. Ul *CG Signal f* vol. 11, no.

[Has2009b] M. A. H S. Hussain *tion from Intelligence*,

[Kar2007] E. C. Kar K. Naka, *te Extractio* Transaction 11, no. 6, pp

[Kez2005] C. Kezi Selva Vijila, P. Kanagasabapathy, S. Johnson, *Adaptive Neuro Fuzzy Inference System for Extraction of fECG*, IE

[Kez2006] C. Kezi Se son, K. Ra. *using Artifi*

[LaF2005] F. La Fore *dent Compo The STWave* on Computat Applications,

[Lee2005] J. Lee, K. L based Algori Rate Monito 2005.

[Liu2008] L. Liu, X. *FECG*, Proc Control and

[Mar2005] S. M. M. Ma mans, *Impro diography by* Medical and

[Mar2007] S. M. M. M jter, *A Rob Recordings*, 2007.

[Min2009] M. Ming, W *on Time Fre noising*, IEE

[Min2009b] M. Ming, W, Ning, L. San-Ya, *Blind Extraction of FECG Combining Periodicity and Kurtosis*, IEEE, 2009.

[Nih2010] *Electrocardi* Medicine, N http://www 2010.

[Ona1984] B. Onara *ties of bioe* 31, pp. 827-

[Pan2007] D. Pani, S *traction uit* vol. 43, no.

[Pan2008] D. Pani, S *System for* Cardiology,

[Par2004] S. D. Par *on Remov Algorithms*,

[Phy2003] *Non-invasi* http://www

[Sal2007] A. Salmanp ghadas, *Ext Skin Electro cursive Lea* IEEE Inter Information Technology, pp. 1149–1154, 2007.

[Sar2008] S. Sargolzaei, K. Faez, A. Sargolzaei, *Signal Processing Based Techniques for Fetal Electrocardiogram Extraction*, 2008 International Conference on BioMedical Engineering and Informatics, pp. 492–496, 2008.

[Shi2007] Z. Shi, C. Zhang, *Blind Source Extraction Using Generalized Autocorrelations*, IEEE Transactions on Neural Networks, vol. 18, no. 5, pp. 1516–1524, 2007.

[Van1998] H. P. Van Gelin, *Cardiotocography*, Textbook of Perinatal Medicine, Parthenon Publishing, vol. 2, pp. 1424–1428, 1998.

[Wan2008] H. Wan, Q. Liu, J. Chai, *A Method for Extracting FECG Based on ICA Algorithm*, ICSP 2008 Proceedings, IEEE, pp. 2761–2764, 2008.

[Wen2008] S. Wenting, F. Bin, W. Pu, R. Mingrong, *FECG Extraction Based On BSS Of Sparse Signal*, IEEE, 2008.

[Yan2008] Y. Yang, C. Guo, *Blind Extraction for Noisy Fetal Electrocardiogram by Using Gaussian Moments*, Fourth International Conference on Natural Computation, pp. 44–47, 2008.

[Ye2008] Y. Ye, J. Zeng, K. Lu, *An Extraction Algorithm Based on Second-order Statistics for Noisy Mixtures*, Fifth International Conference on Fuzzy Systems and Knowledge Discovery, 2008.

[Zen2008] Y. Zeng, S. Liu, J. Zhang, *Extraction of Fetal ECG Signal via Adaptive Noise Cancellation Approach*, IEEE, 2008.

[Zha2005] Z. L. Zhang, Y. Ye, *Extended Barros's extraction algorithm with its application in fetal ECG extraction*, International Conference on Neural Networks and Brain 2005, pp. 1077–1080, 2005.

Algoritmi per la stima del FECG

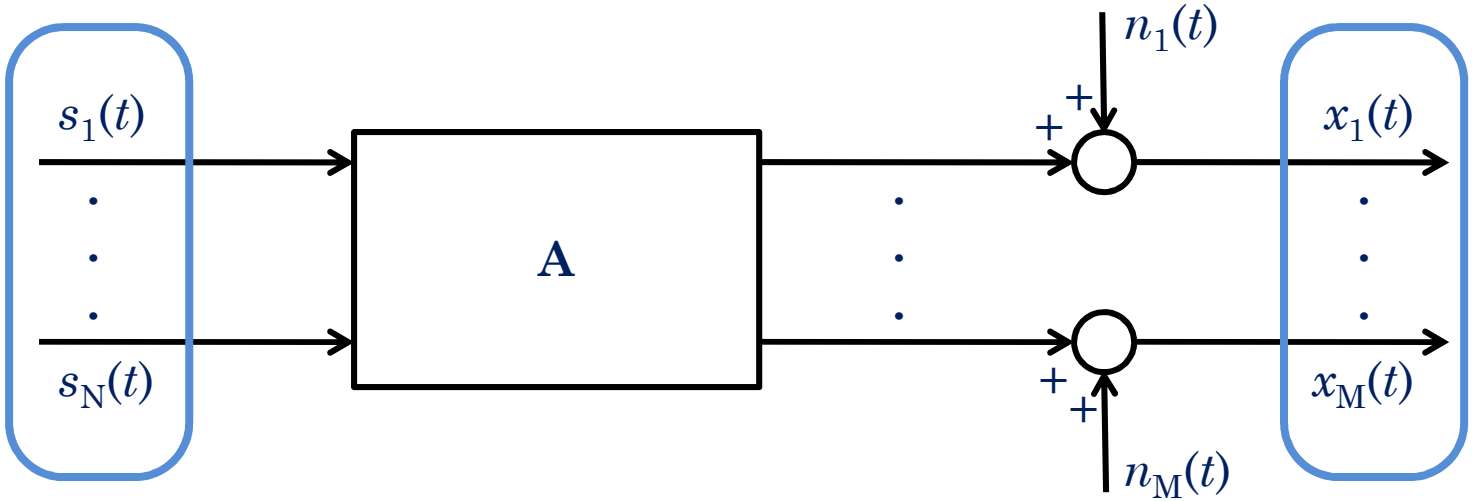
Infomax

Sviluppato da Bell e Sejnowski nel 1995.

Inizialmente utilizzato per separare mix audio, è stato applicato in vari campi.

Fa parte della famiglia *independent component analysis*.

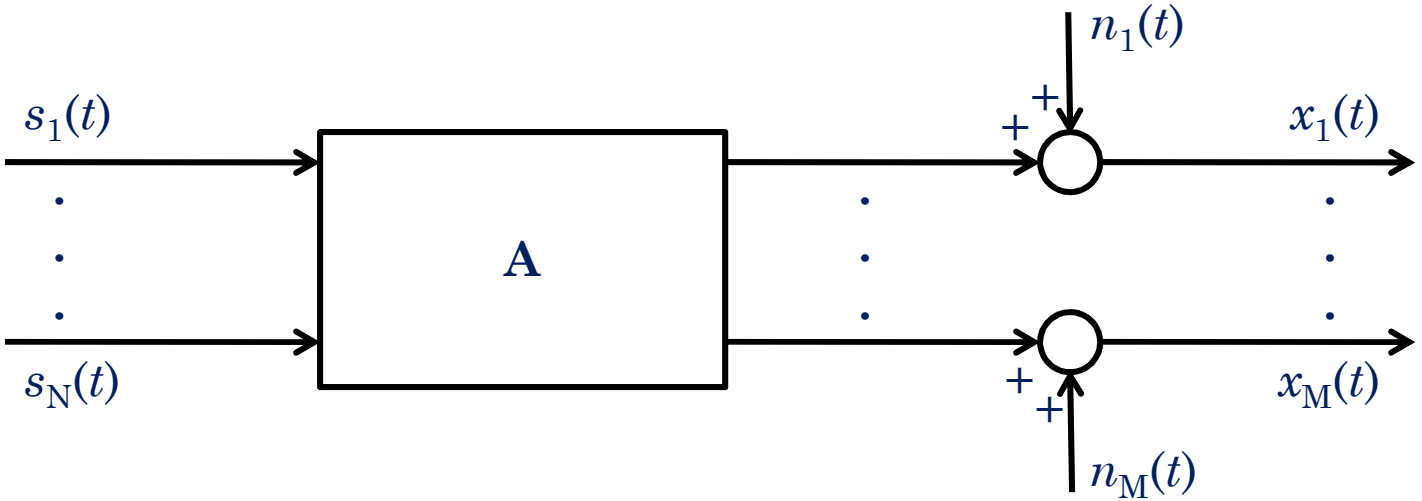
Modello



- ECG fetale
- ECG materno
- alimentazione di rete
- respiro
- movimento
- rumore di contatto dell'elettrodo
- rumore ambientale

Misure addominali

Modello



$$\boldsymbol{x}(t) = \mathbf{A}\boldsymbol{s}(t) + \boldsymbol{n}(t)$$

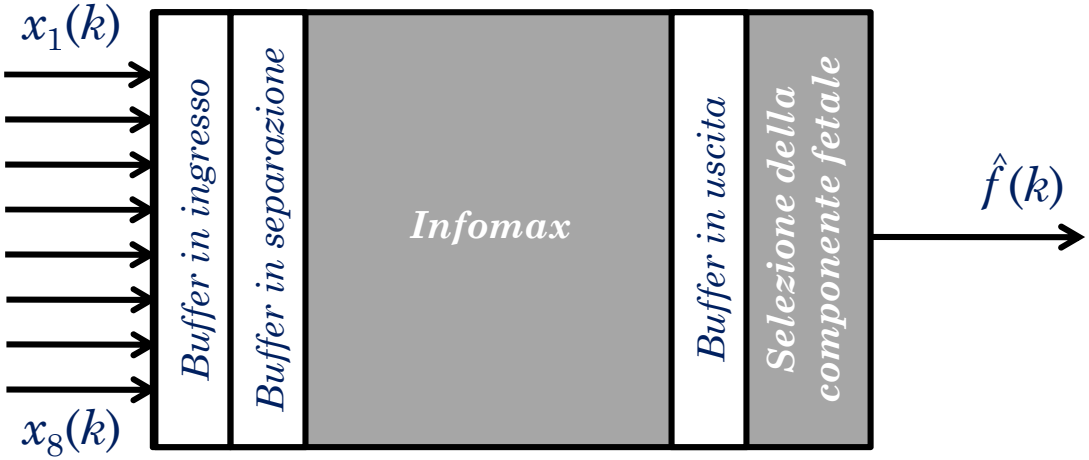
$$\boldsymbol{s}(t) = \mathbf{A}^{-1}\boldsymbol{x}(t)$$

$$\hat{\boldsymbol{s}}(t) = \hat{\mathbf{A}}^{-1}\boldsymbol{x}(t) = \mathbf{W}(t)$$

approssimazione iterativa

Infomax nell'unità di separazione

Sono necessari alcuni *buffer*, per rendere la separazione *online*.

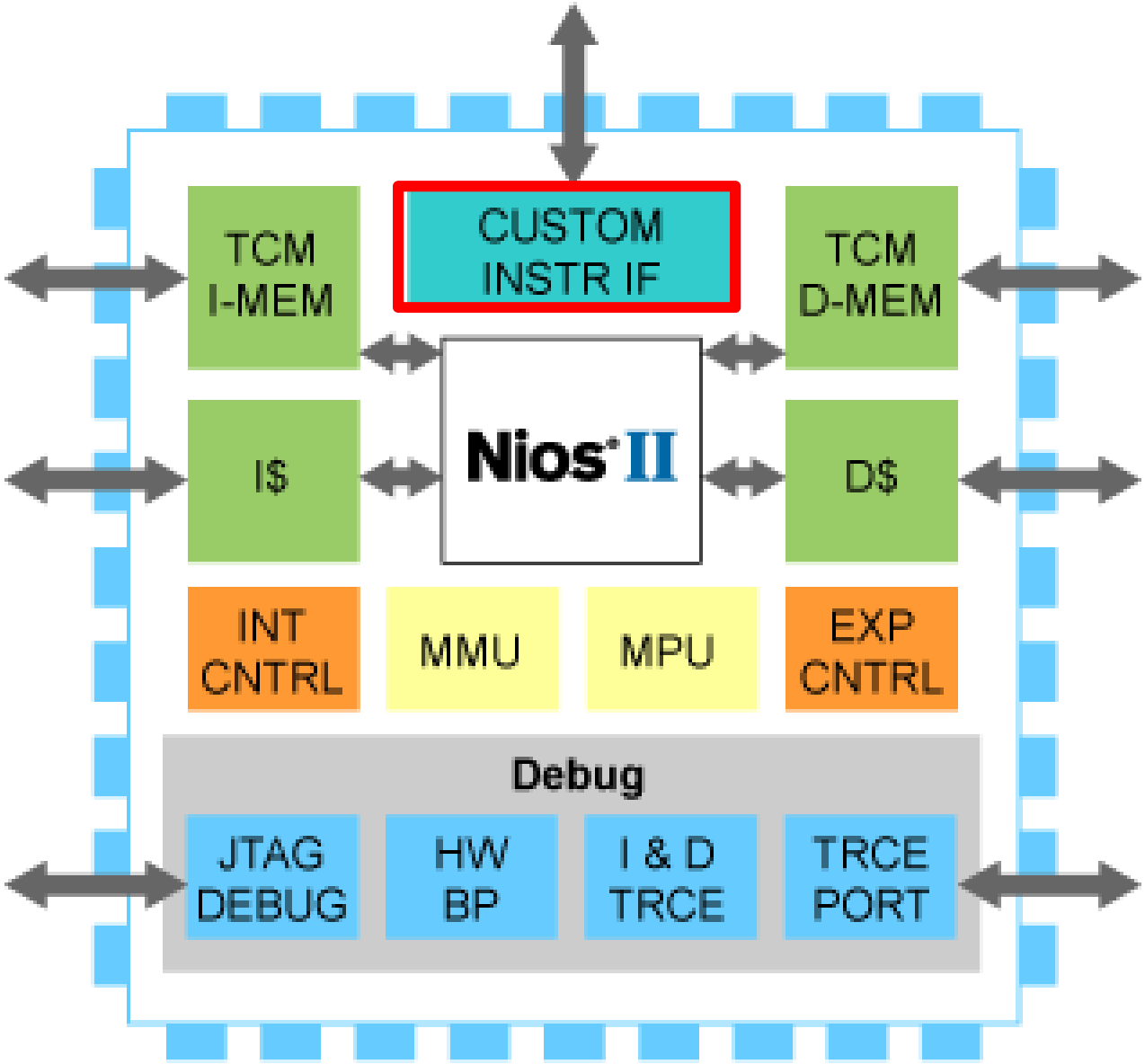


Sono state fatte alcune prove, con il segnale suddiviso in segmenti di 1024 campioni.

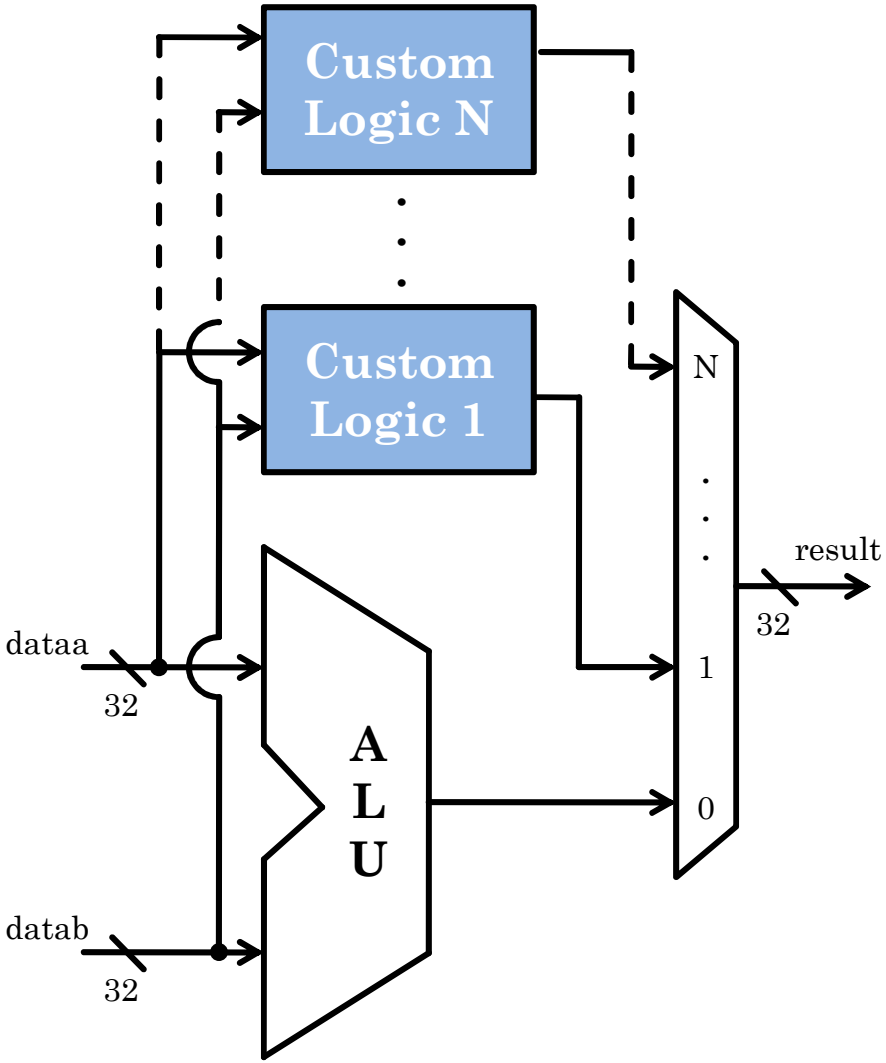
Altera Nios II Development Kit

- FPGA Altera Stratix II EP2S60
- 16 MB di memoria Flash;
- 2 MB di memoria sincrona SRAM;
- 32 MB di memoria SDRAM di tipo DDR;
- oscillatore a 50 MHz;
- interfaccia Ethernet;
- *display* a sette segmenti;
- otto *led*;
- quattro pulsanti;
- interfaccia JTAG.

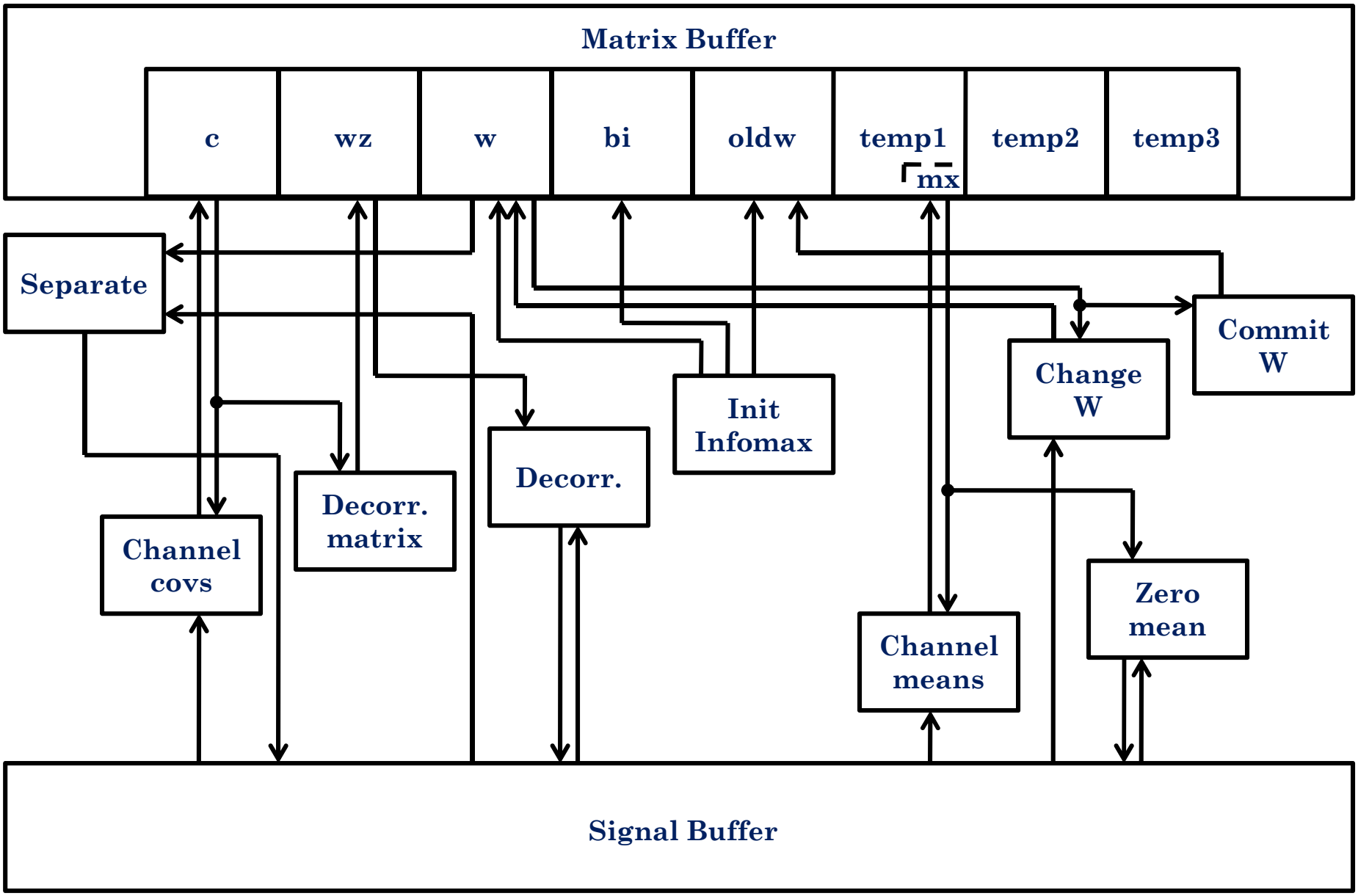
Custom Instructions



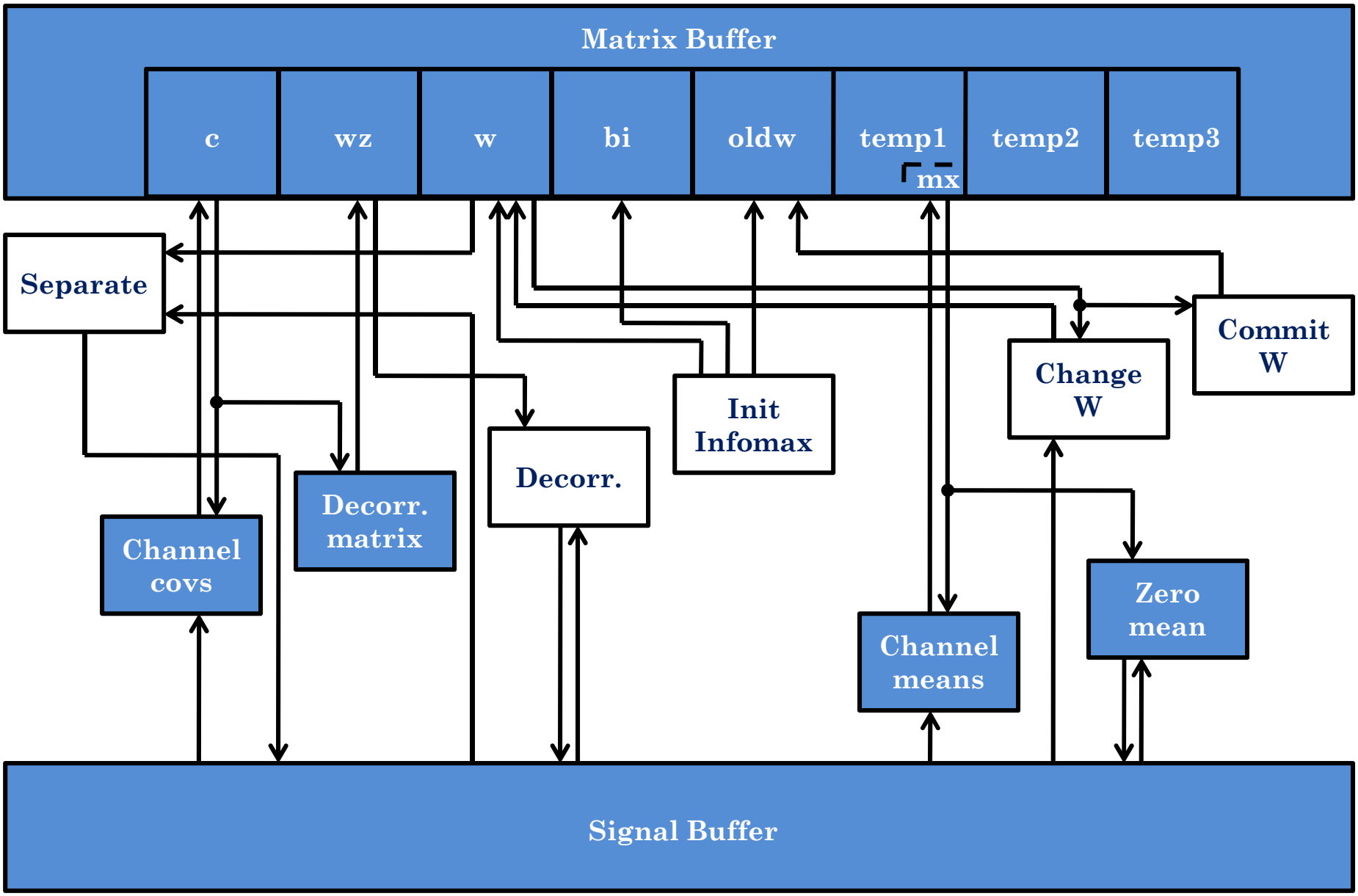
Custom Instructions



Infomax su FPGA Stratix II

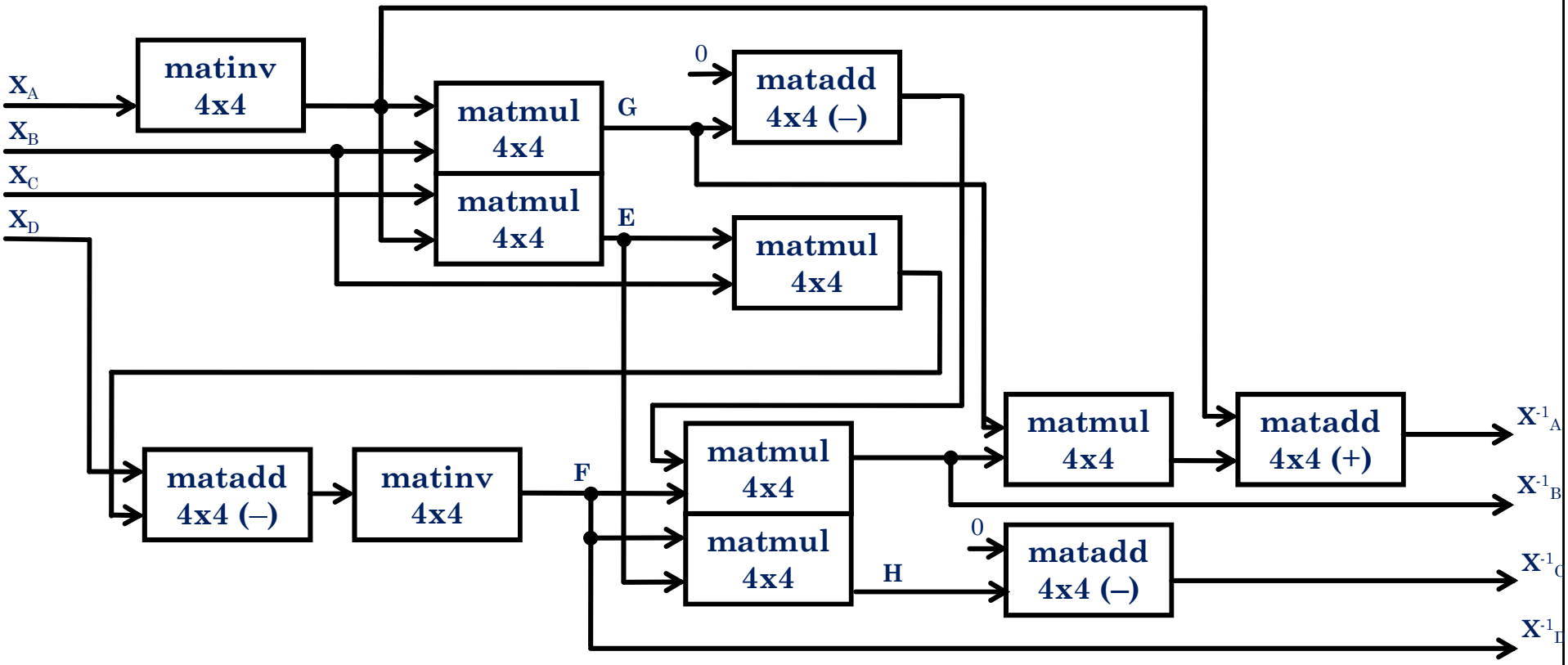


Infomax su FPGA Stratix II



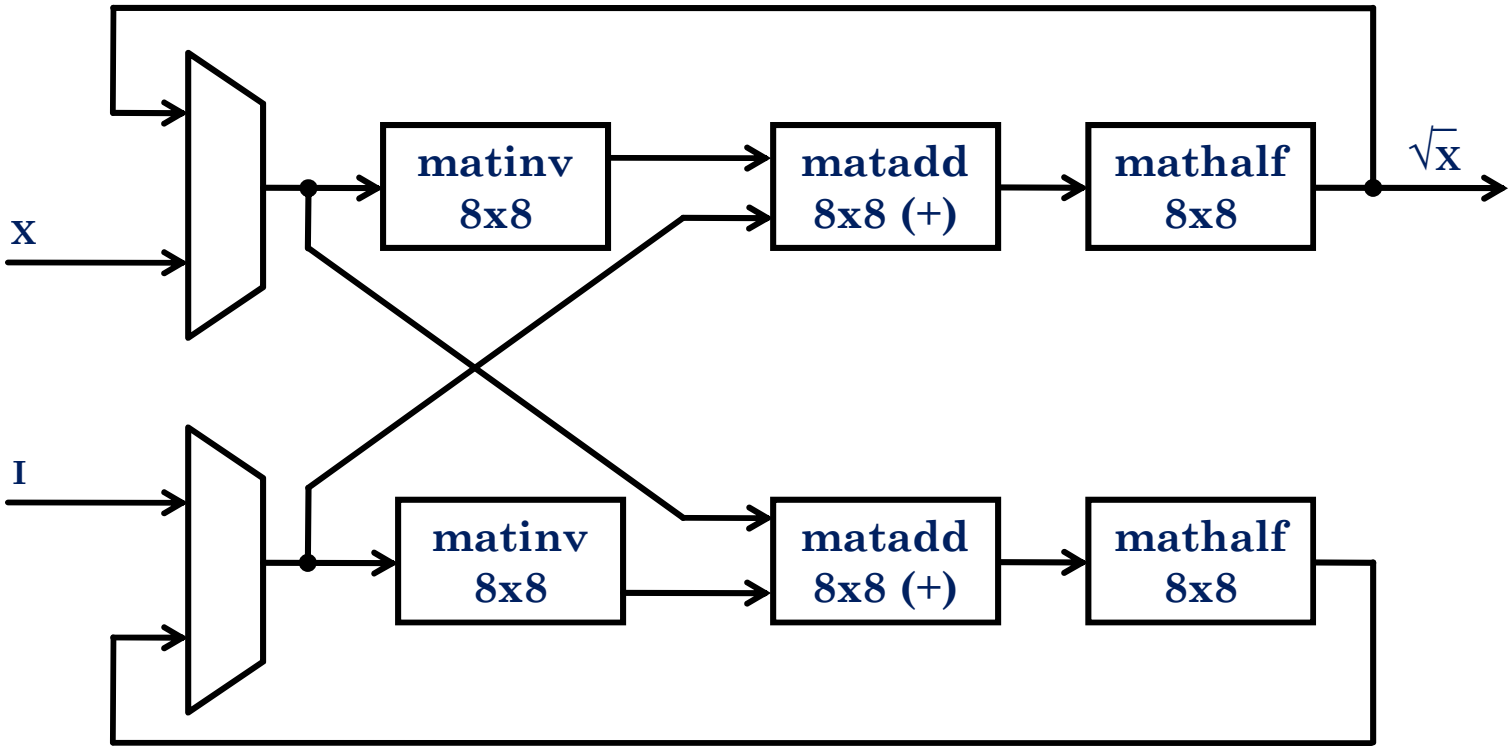
Infomax su FPGA Stratix II

matinv8x8



Infomax su FPGA Stratix II

matsqrt8x8



Risultati su FPGA Stratix II

8.54 ms << 652 ms

Tempo di esecuzione totale di quanto sviluppato su FPGA. (50MHz)

Tempo di esecuzione della stessa parte su ARM 9. (400MHz)

Conclusioni

È stato individuato un algoritmo efficace per la separazione del FECG.

È stata progettata una soluzione FPGA.

Di questa è stata sviluppata una parte, nettamente migliore in termini di efficienza rispetto all'equivalente implementazione software.

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