

**CORSO DI:**

**ELABORAZIONE DI SEGNALI BIOMEDICI**

**(LUCIDI DELLE LEZIONI V)**

**PROF. SERGIO CERUTTI**

Dipartimento di Bioingegneria

Politecnico di Milano

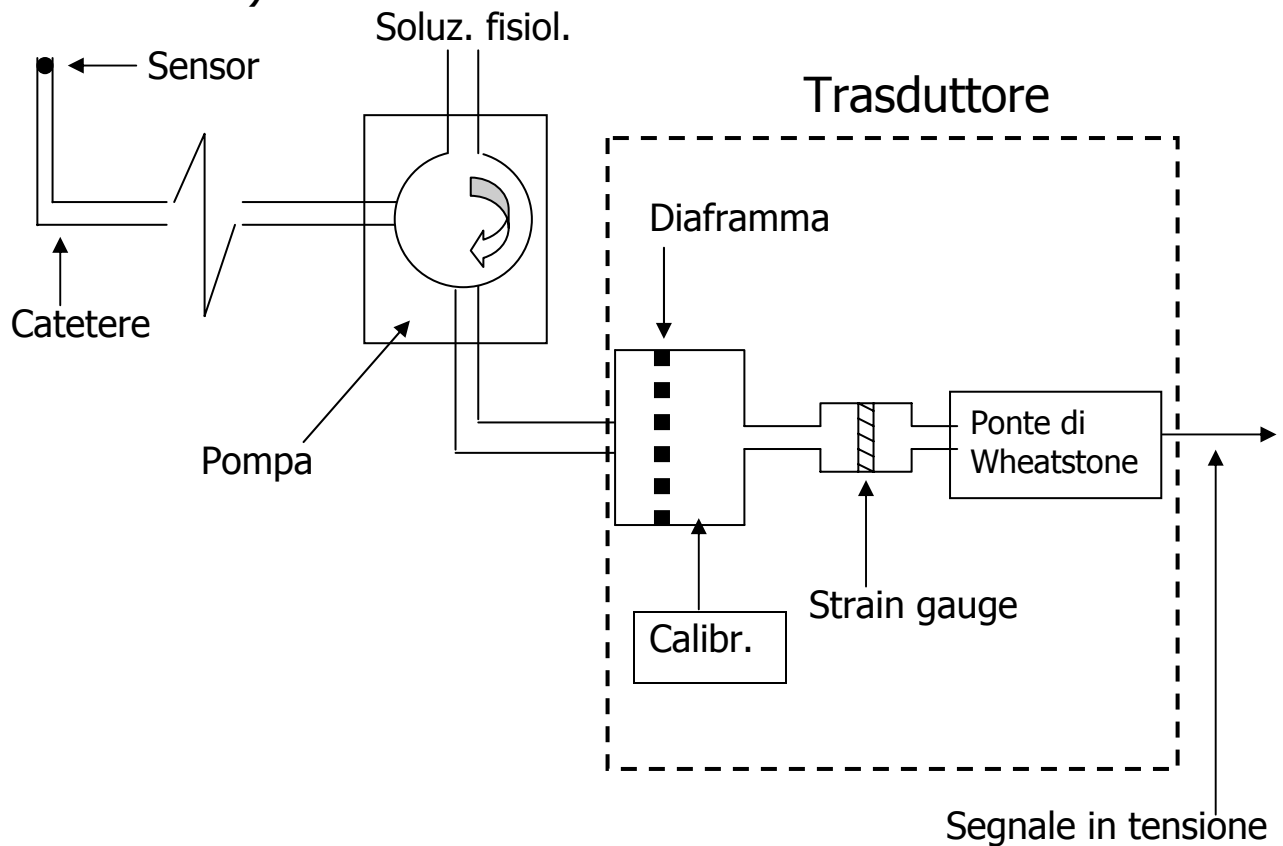
**OTTOBRE 2004**

# PRESSIONE ARTERIOSA

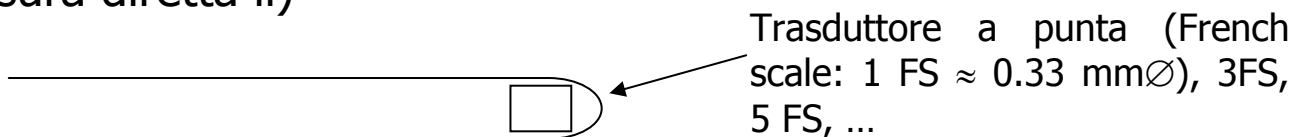
Brevi cenni sulla strumentazione e sui trasduttori (oggetto di studio in altri corsi di bioingegneria)

- Misura diretta
  - 1. con trasduttore esterno collegato tramite catetere a soluzione fisiologica
  - 2. con trasduttore interno montato sulla punta del catetere
  
- Misura indiretta
  - 1. Metodo di Riva-Rocci (suoni di Korotkoff)
  - 2. Metodo pletismografico (FINAPRES tecnica per il rilievo in continua della P.A.)

### Misura diretta i)



### Misura diretta ii)

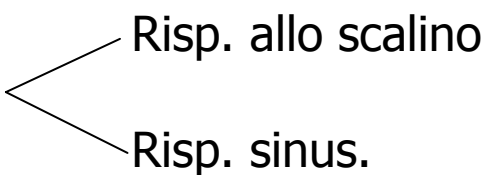


- Il trasduttore a punta presenta:
- ↑↑ risposta in frequenza
  - ↓ ritardo di risposta del sistema
  - ↑↑ costo
  - ↑ fragilità

Esistono anche trasd. a punta montati su fibra ottica (di solito con diametro maggiore), per ↑↑ sicurezza elettrica.

## **Banda passante:**

- i) fino a  $10 \div 20$  Hz
- ii) fino a  $100 \div 150$  Hz

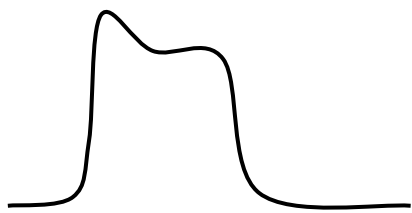
Metodi per determinare la banda : 

- Risp. allo scalino
- Risp. sinus.

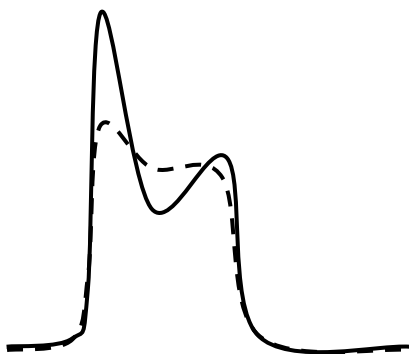
In genere è necessaria la frequenza fondamentale + almeno 10 armoniche  $\Rightarrow$  H.R.  $\approx 120$  bpm  $\equiv 2$  Hz (x 10) = 20 Hz

Se poi si vuole derivare il segnale per ricavare la  $dP/dt$  (che da una misura della contrattilità miocardica), si deve ampliare la banda (almeno 20 armoniche, Gersch 1971)

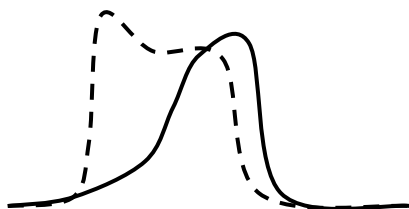
L'insieme trasduttore – linea arteriosa può essere schmatizzato come un sistema del secondo ordine, con i tre possibili comportamenti, come indicato:



Normale

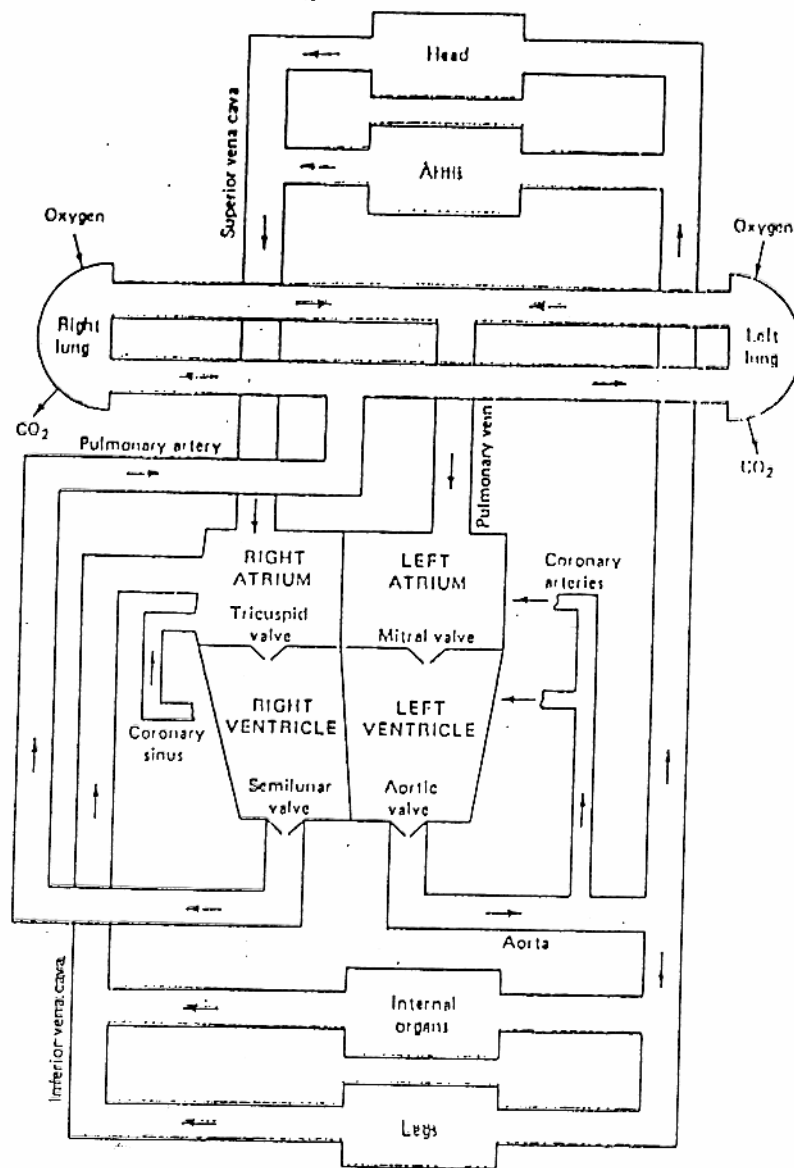


Sottosmorzato



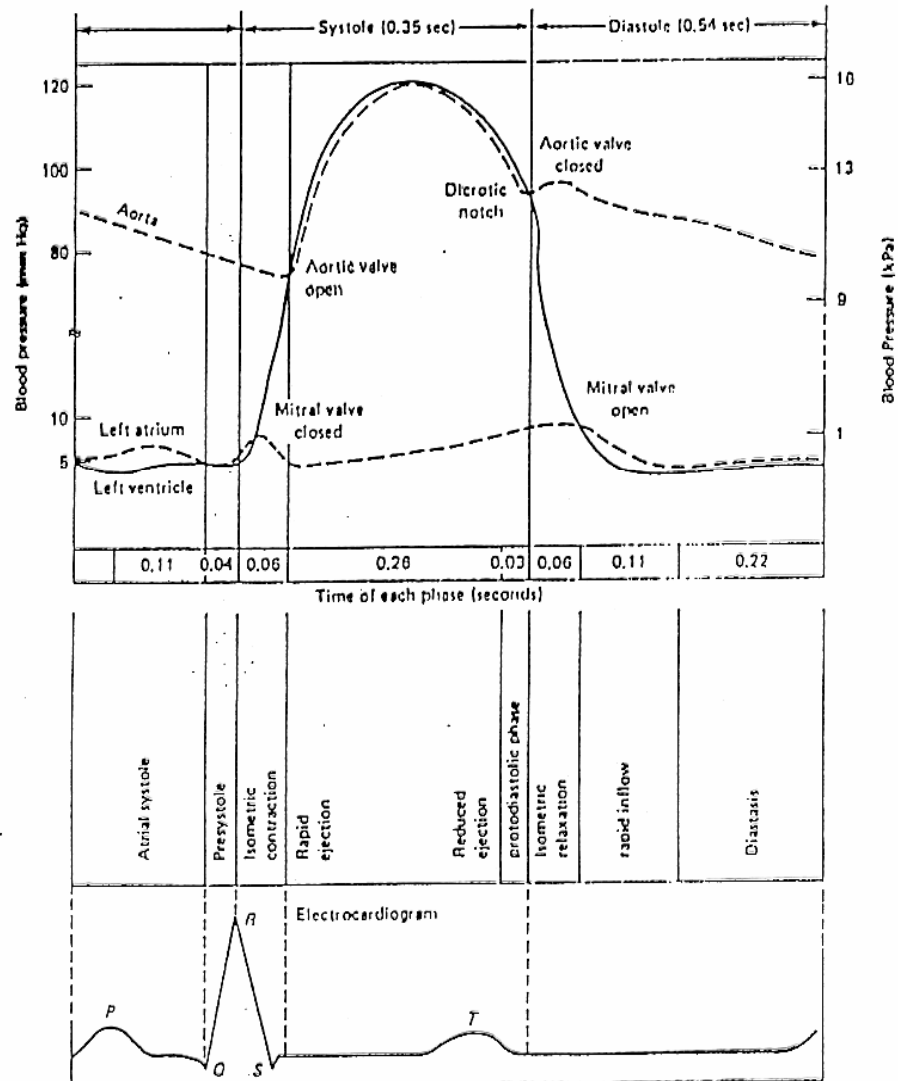
Sovrasmorzato

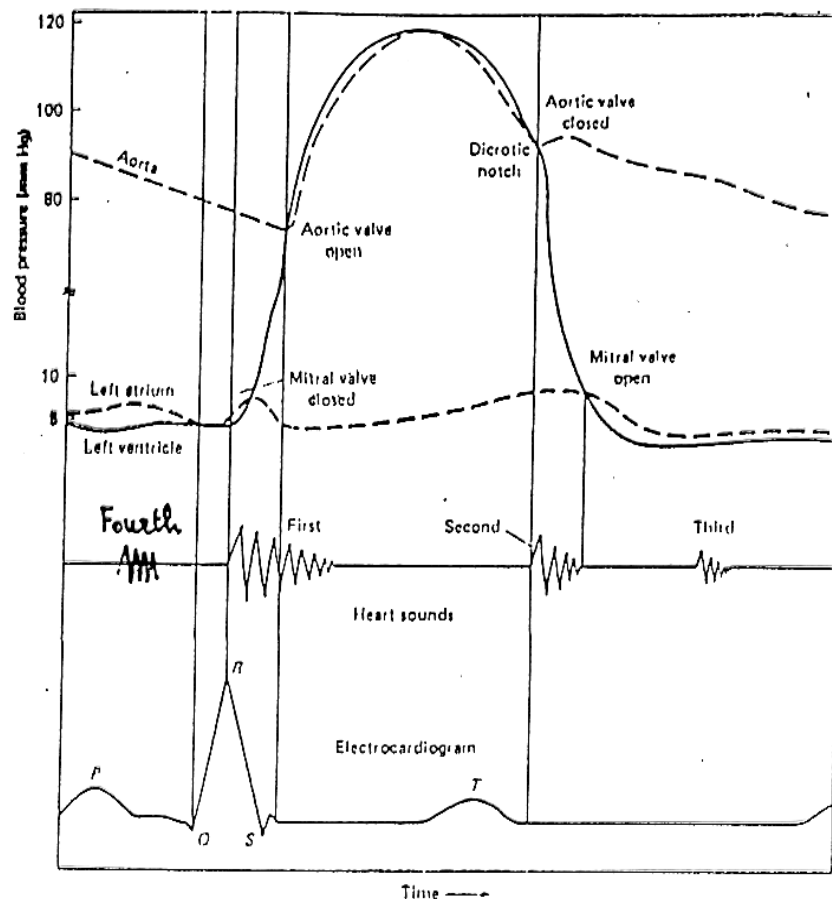
# MODELLO CIRCOLATORIO



Cardiovascular circulation.

# LEGAME TRA ECG E CURVE DI PRESSIONE





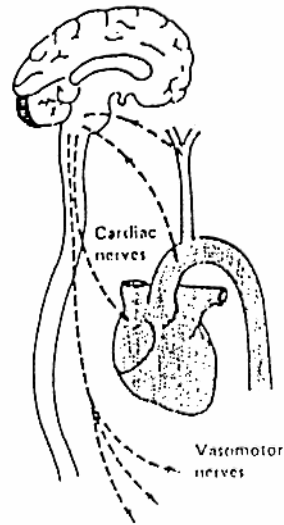
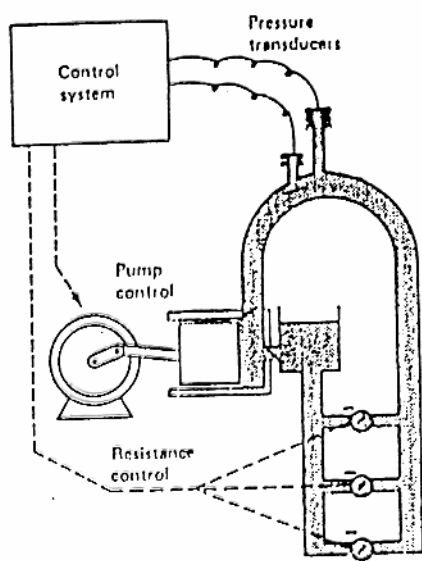
## SUONI:

Relationship of heart sounds to function of the cardiovascular system.

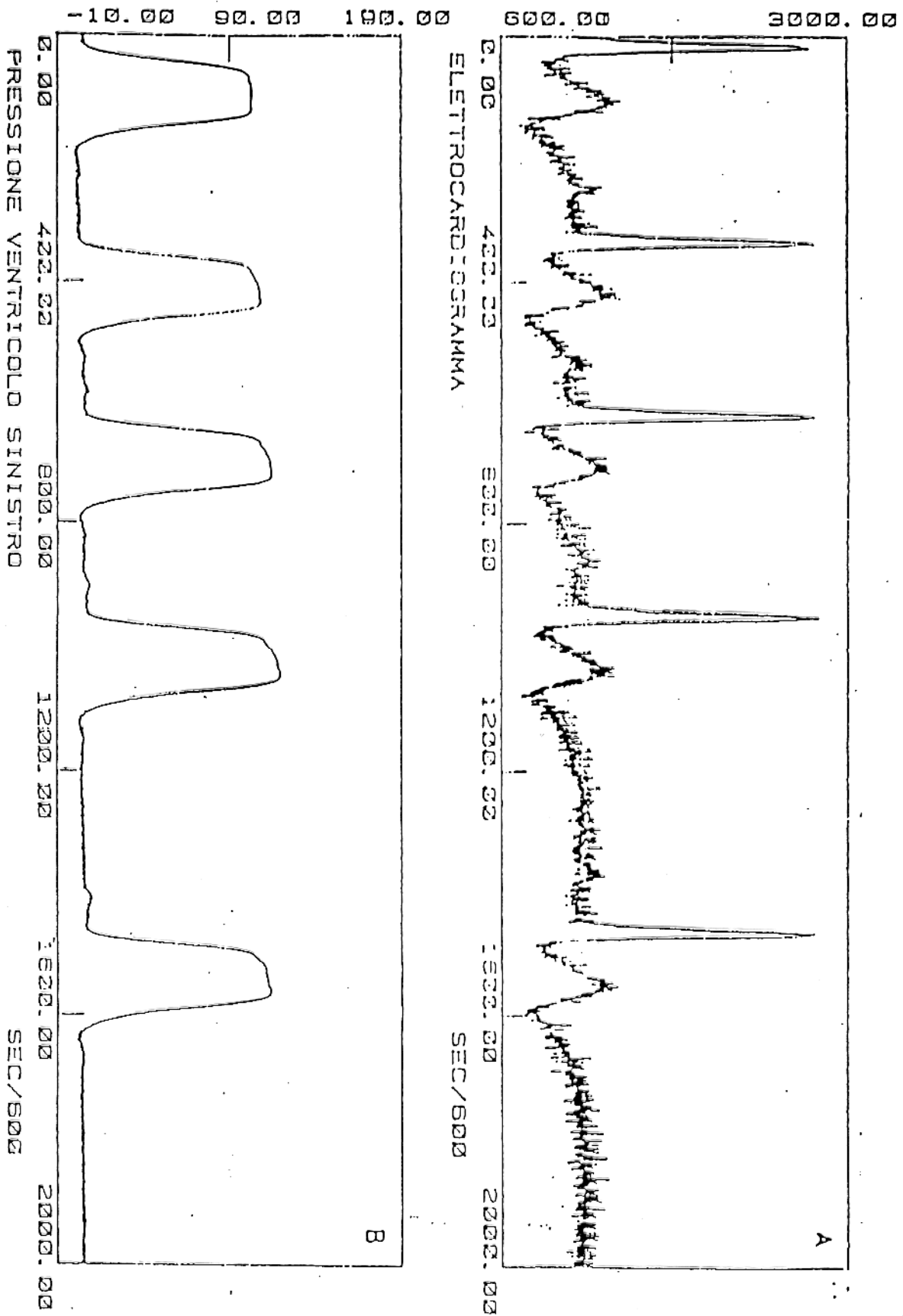
- I) oscillazione del sangue all'inizio della sistole ventr. (si chiudono le valvole mitrale e tricuspide – tra A-V), oscillaz. su radice aorta e valvole polmonari
- II) decelleraz. e inversione flusso in aorta ed arteria polmonare (chiusura valvole semilunari : tra ventricoli )
- III) repentina fine del riempimento dei ventricoli e degli atri
- IV) sistole atriale (gli atri si contraggono). Si può rilevare chiaramente solo con il fonocardiogramma.

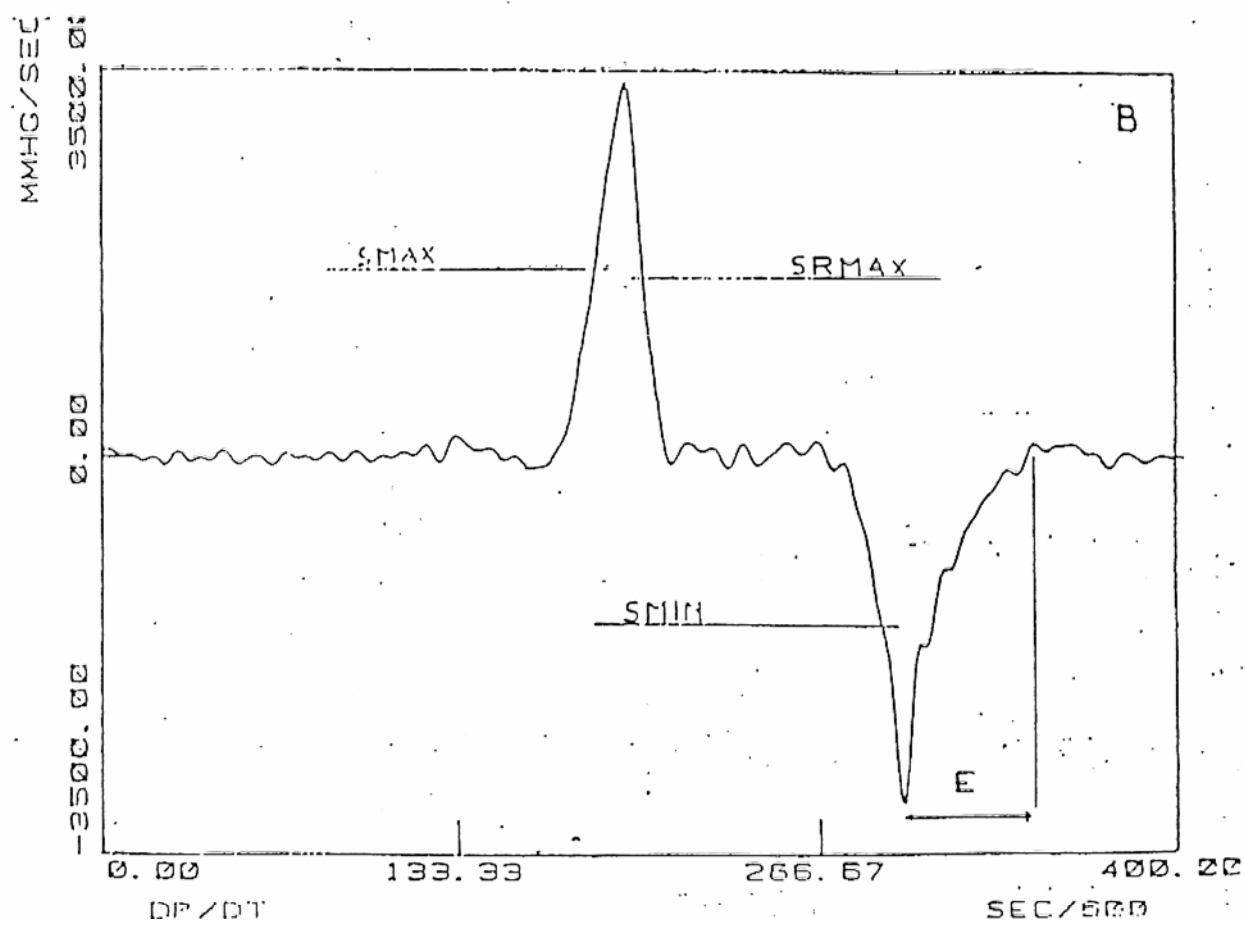
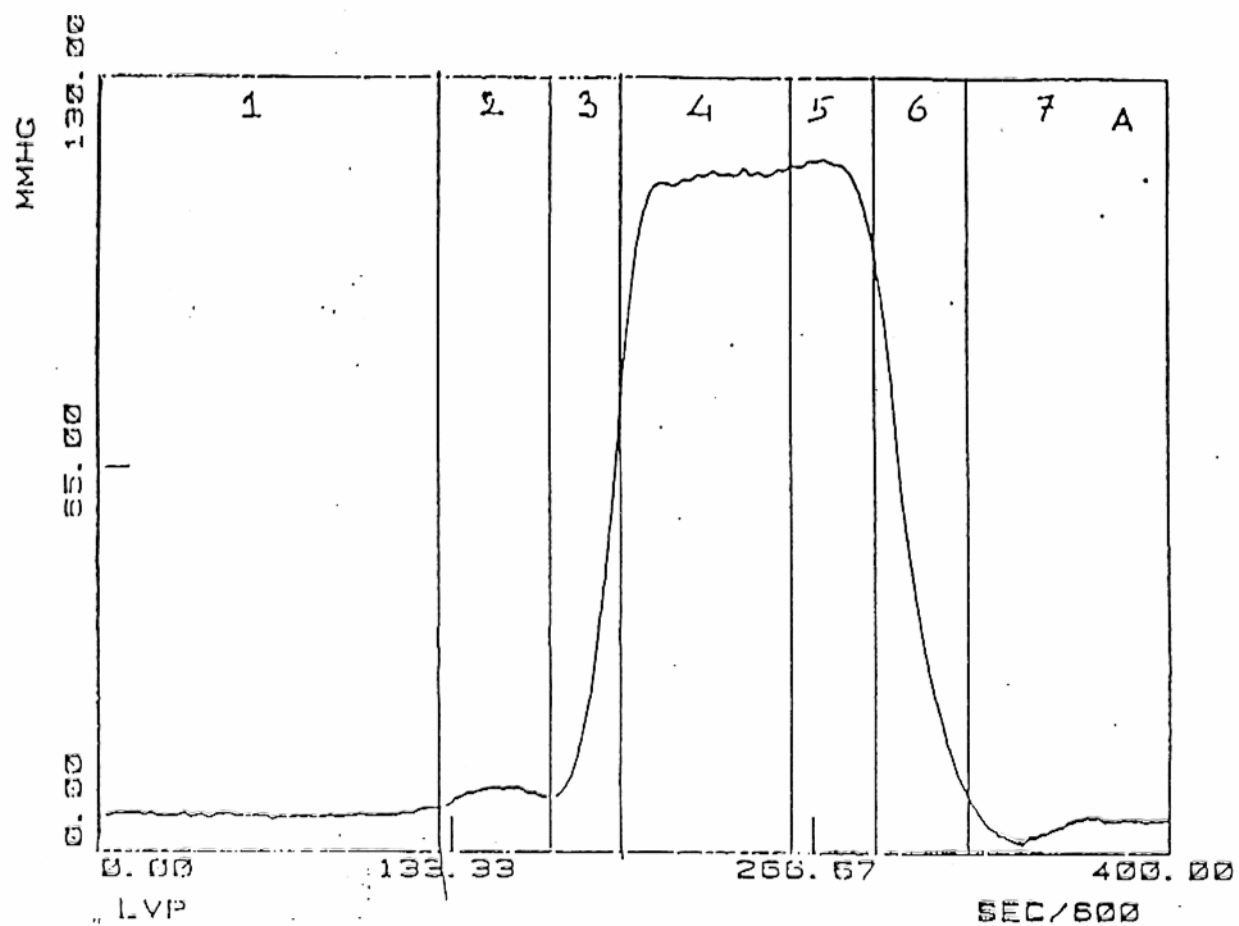


# CONTROL OF ARTERIAL BLOOD PRESSURE

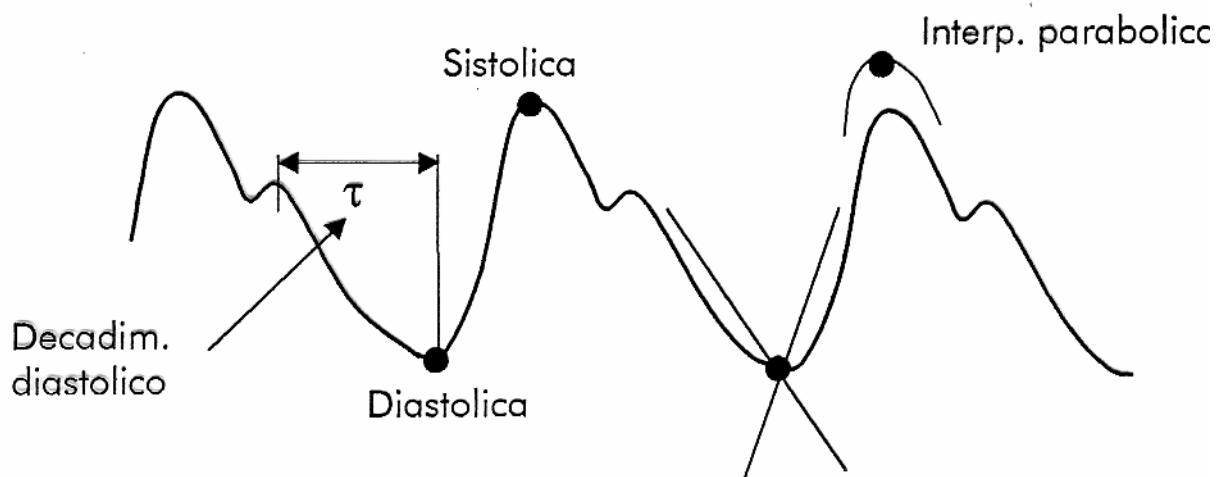


MMHG

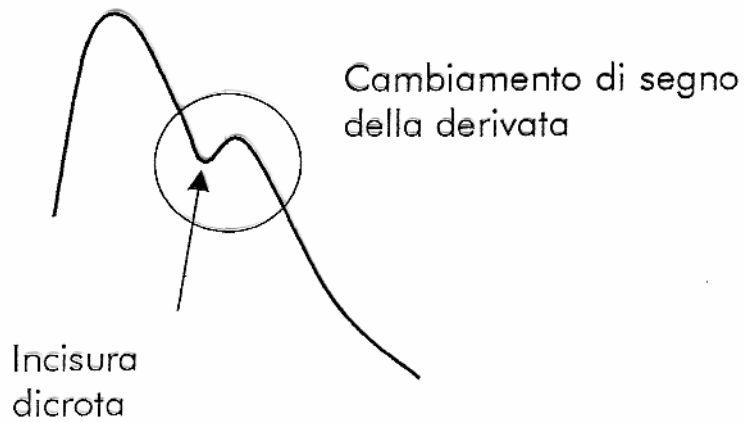




## Riconoscimenti sul segnale pressorio



Valori battito-battito  $\{s(i)\}$ ,  $\{d(i)\}$ ,  $\{m(i)\}$ ,  $\{p(i)\}$



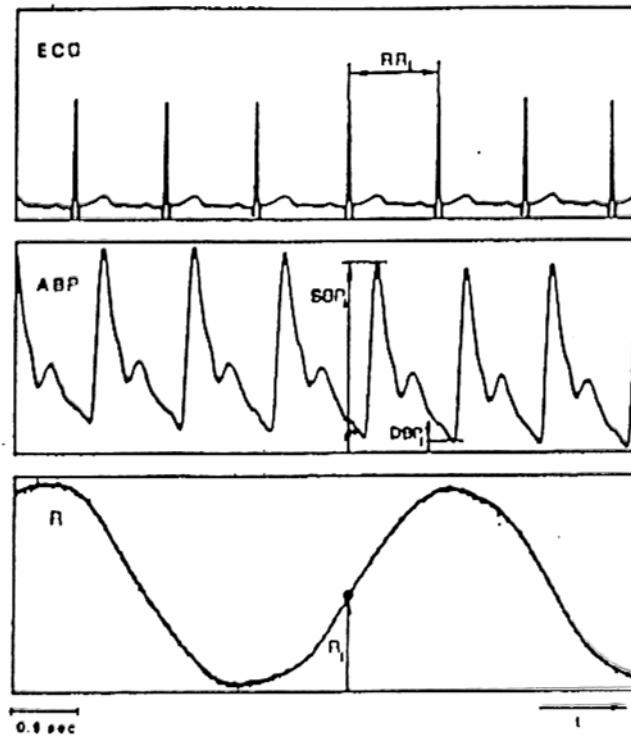


Figure 1. ECG, arterial blood pressure (ABP) and respiration (R) contemporaneously recorded as a function of time (t). The relevant cycle-by-cycle parameter extraction is indicated at l-th cycle: RR interval, systolic blood pressure (SBP), diastolic blood pressure (DBP) and respiration. (See text)

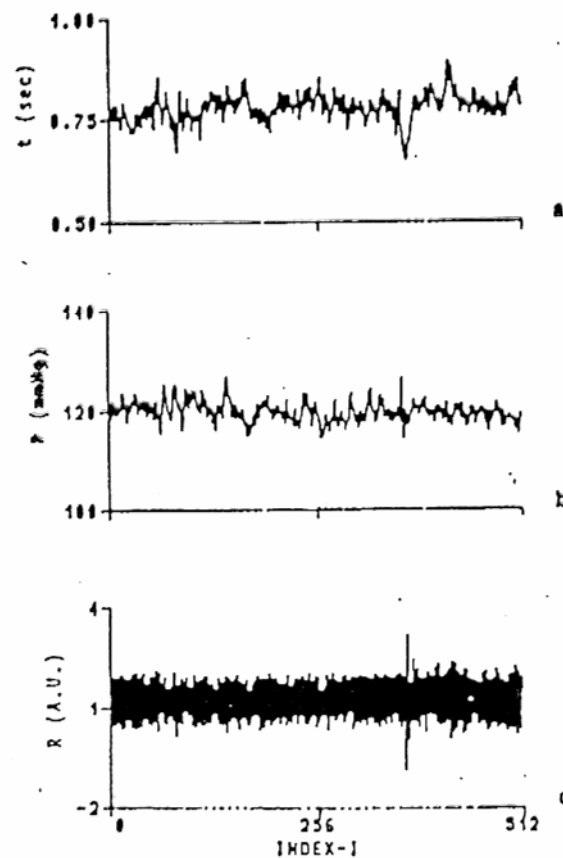


Figure 2. Variability signals from raw signals in Figure 1: tachogram (a), systogram (b) and respirogram (c), as a function of index I.

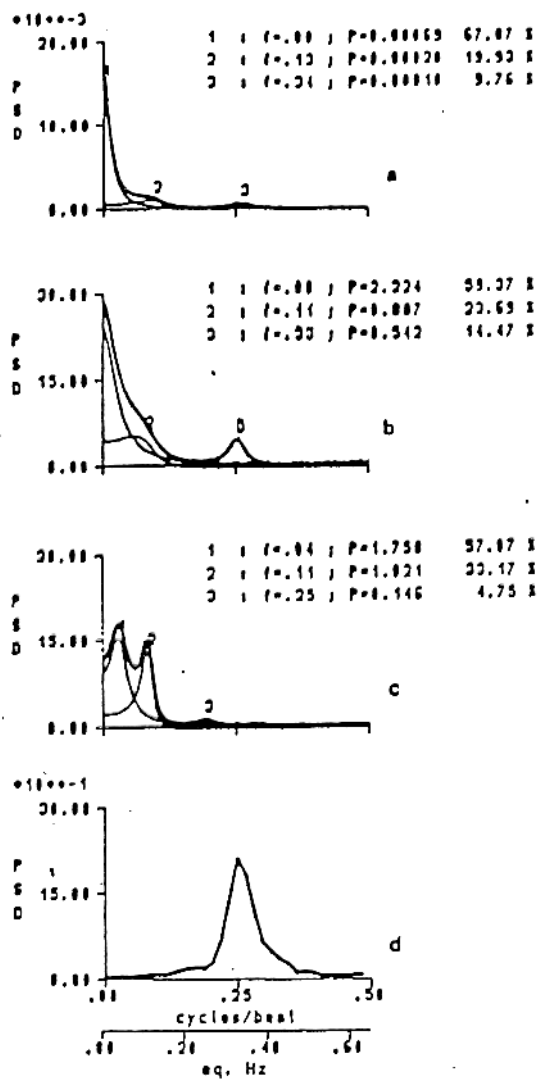


Figure 3. Power spectral density (PSD) of tachogram (a), systogram (b), diastogram (c) and expiration (d). (a), (b) and (c) are estimated via AR modelling and (d) via the periodogram calculation. The horizontal axis has a double scale (c/b and eq Hz, see text). The spectral components are also shown for (a) (b) (c) with their central frequency (in eq. Hz) and power in absolute and percentage value.

# PARAMETRI SPETTRALI

Analisi bivariata:  $x(k), y(k)$

$$x(k) \rightarrow Y(z), \quad y(k) \rightarrow Y(z)$$

Autospettro di Y:  $P_y(f_m)$

$$P_y(f_m) = \frac{1}{N \cdot \Delta t} \left| \Delta t \cdot \sum_{k=0}^{N-1} y(k) \cdot e^{-2j\pi k \Delta t} \right|^2 = \frac{1}{N \cdot \Delta t} |Y(F_m)|^2$$

Cross-spettro X-Y:  $P_{xy}(f_m)$

$$P_{xy}(f) = \frac{1}{N \cdot \Delta t} X(f) \cdot Y^*(f) = G_{xy}(f) \cdot e^{j\Phi_{xy}(f)}$$

$G_{xy}(f)$  = cross-spettro dei moduli

$\Phi_{xy}(f)$  = cross-spettro delle fasi

Coerenza quadratica:  $k_{xy}^2(f)$

$$k_{xy}^2(f) = \frac{G_{xy}(f)^2}{P_x(f)P_y(f)} \quad (\text{mediata su pi\`u spezzoni})$$

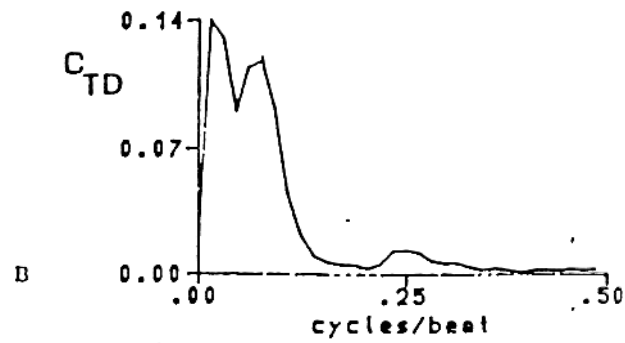
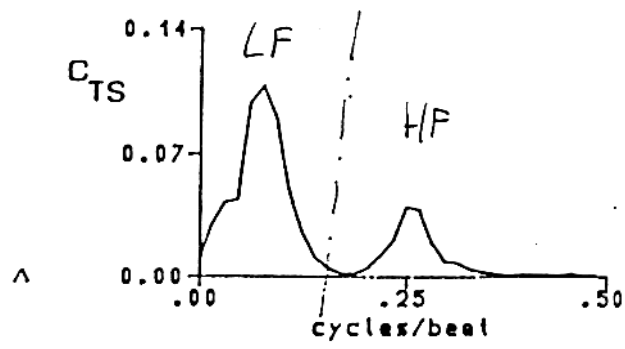


Figure 4. Cross spectral moduli (T = tachogram, S = systogram, D = diastogram).

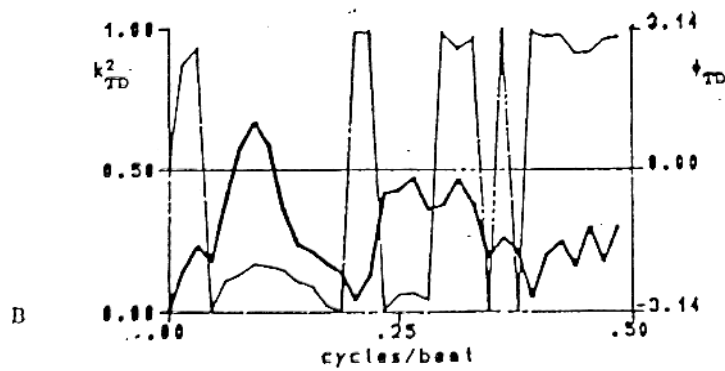
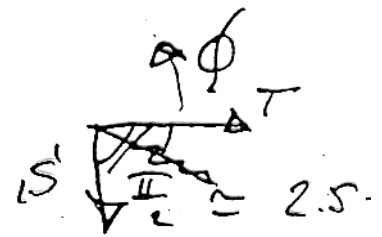
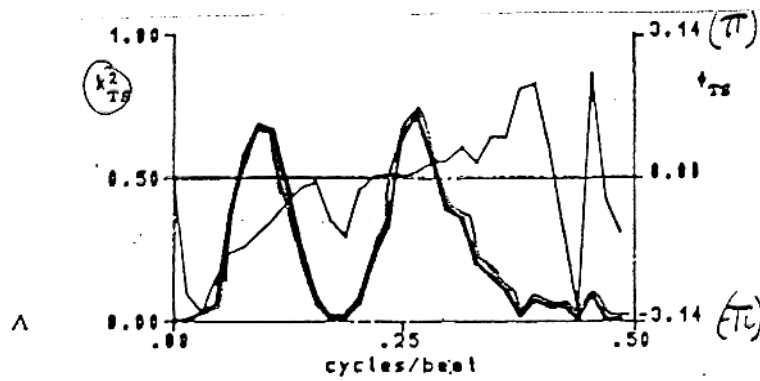
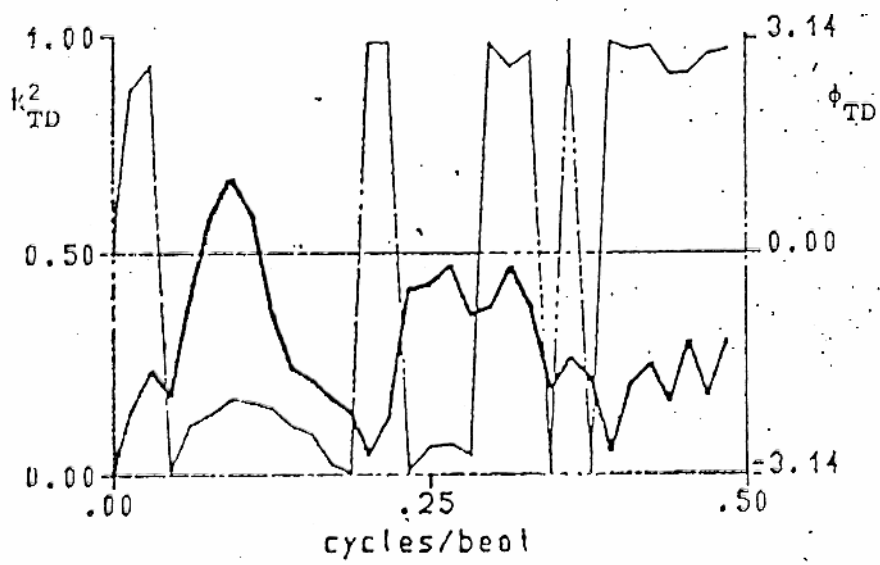
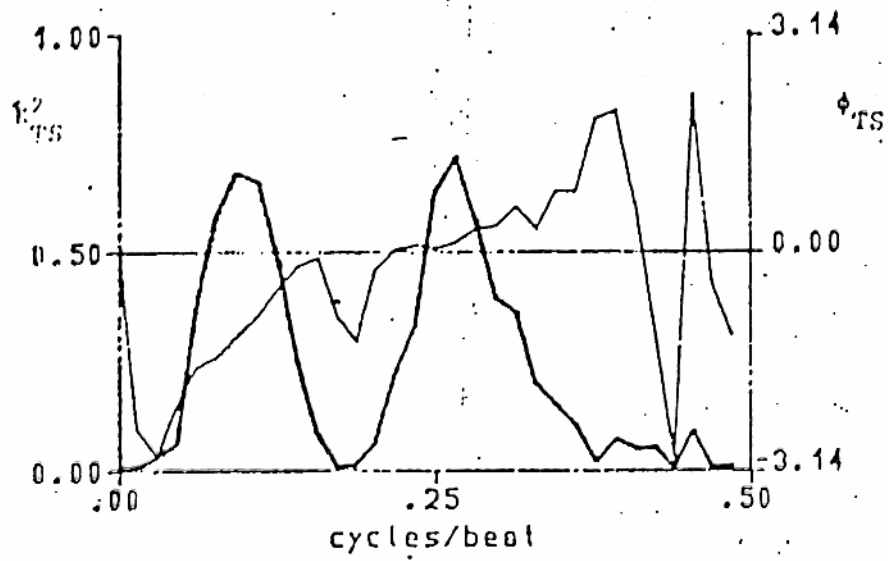
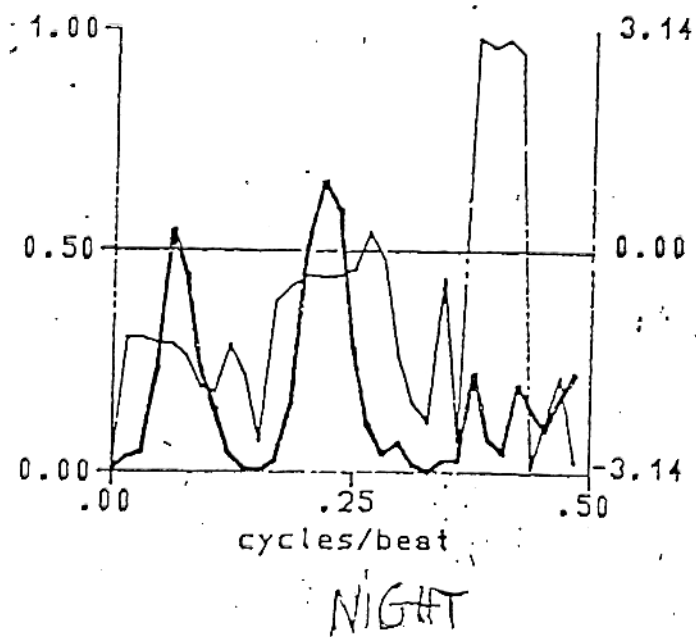
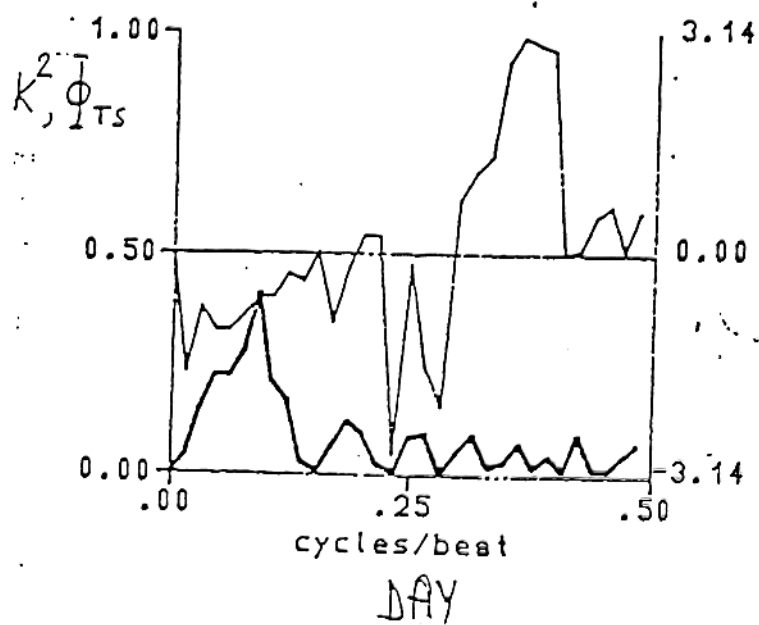


Figure 5. Phase spectra (light line) and squared coherence  $k^2$  (heavy line) referred to cross spectra of Figure 4



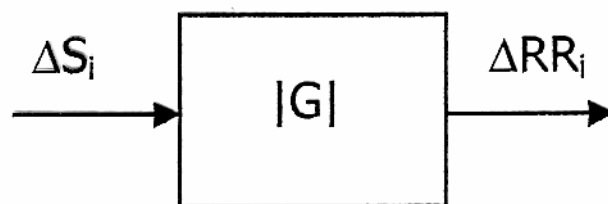


# SOGGETTO IPERTESO

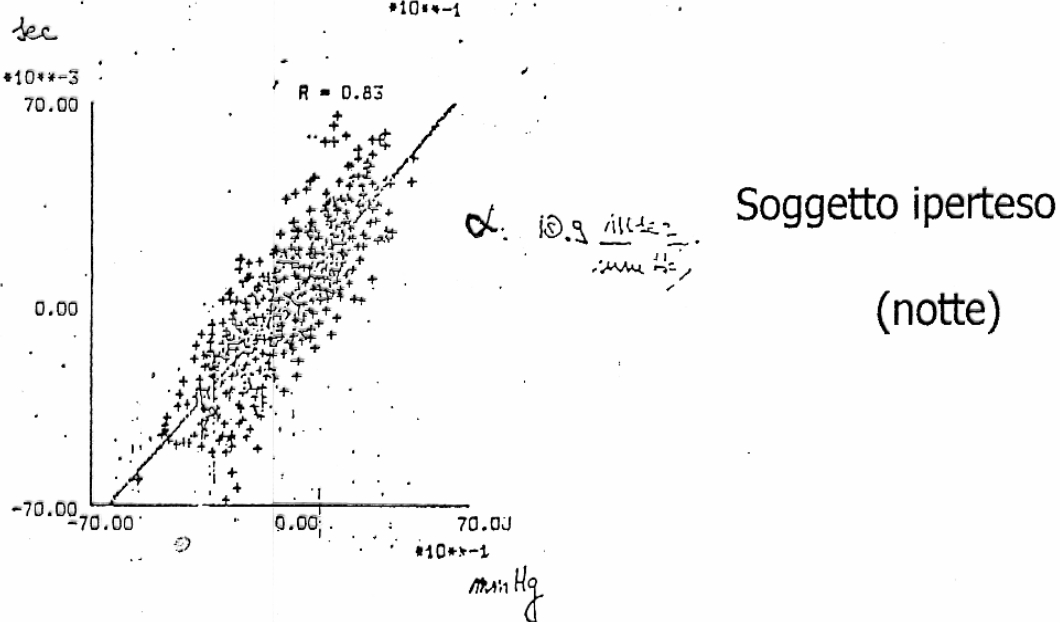
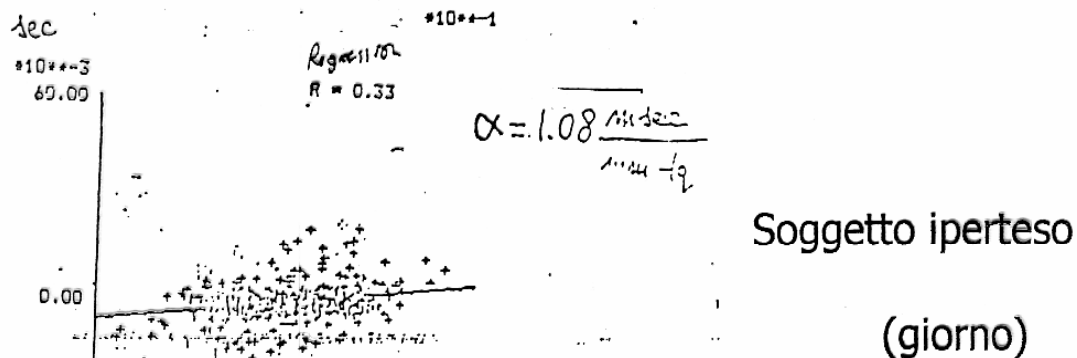
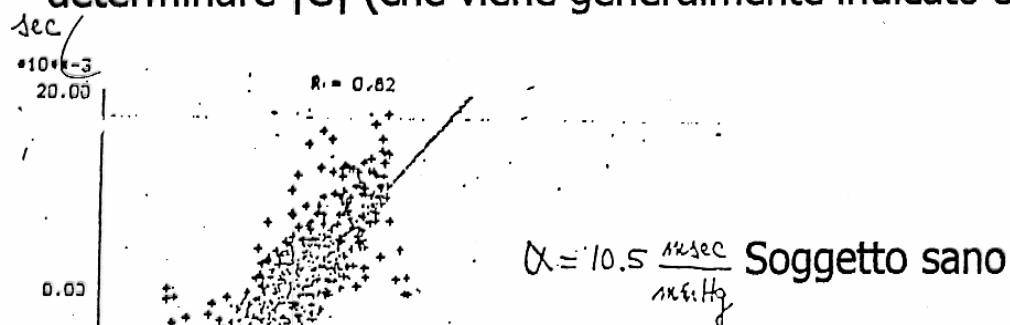


## Relazioni di interesse clinico tra $\Delta P$ e $\Delta RR$ (guadagno barocettivo)

Modello generale:



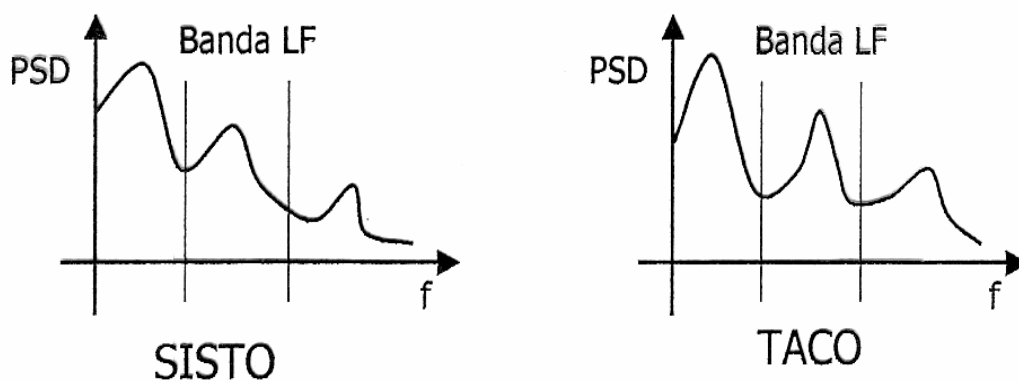
Rappresentazione tramite un diagramma  $\Delta P$  vs  $\Delta RR$  per determinare  $|G|$  (che viene generalmente indicato con  $\alpha$ )



In sede clinica si effettua il test alla Fenilefrina (farmaco vasocostrittore che provoca un aumento di pressione). Tale test provocativo permette di determinare  $\alpha$ .

Lo studio delle variazioni  $\Delta P$  vs  $\Delta RR$  battito-battito ha il vantaggio di non perturbare le caratteristiche emodinamiche del sistema.

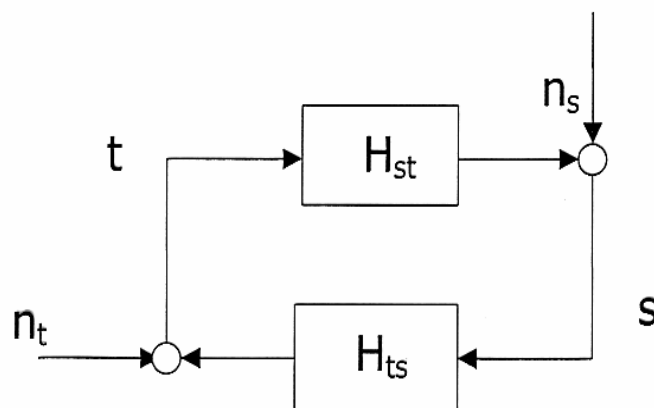
$\alpha$  può essere anche calcolato dallo spettro dei due segnali (rispettivamente pressione e tacogramma), come indicato:



$$\alpha = \sqrt{\frac{P_{LF}(RR)}{P_{LF}(S)}} \quad [\text{m} \cdot \text{sec/mmHg}]$$

Tale calcolo di  $\alpha$  viene effettuato ovviamente ad anello aperto  
(non ci sono retroazioni da  $\Delta RR$  che agiscano su  $\Delta P$ ).

Un modello più sofisticato permette di calcolare  $\alpha$  ad anello chiuso, tenendo conto delle retroazioni.

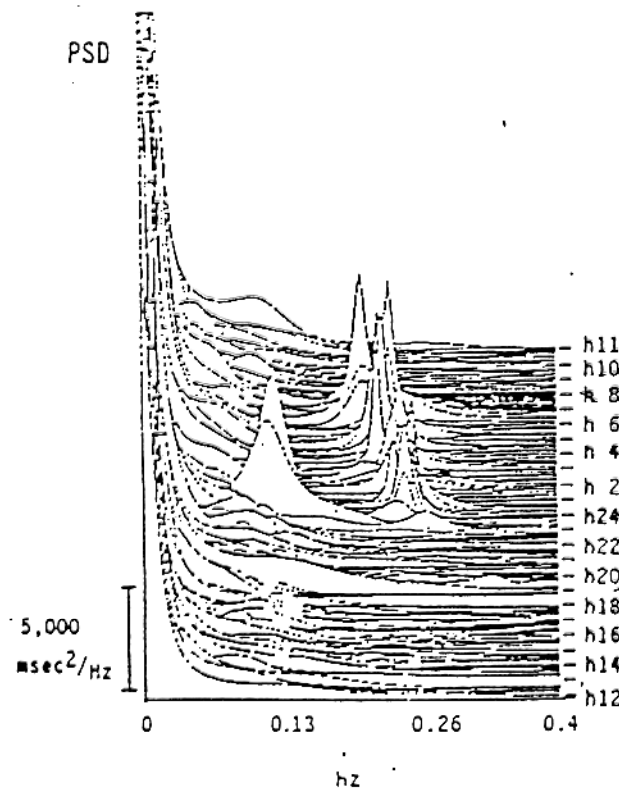


$\alpha \equiv |H_{ts}|$  ad anello chiuso (Baselli et al., 1988)

CSA – Compressed Spectral Array di spettri batch (512 punti)  
 ottenuti sulle 24 ore ( $\approx 120.000$  battiti per un soggetto sano)

### Soggetto sano

a)



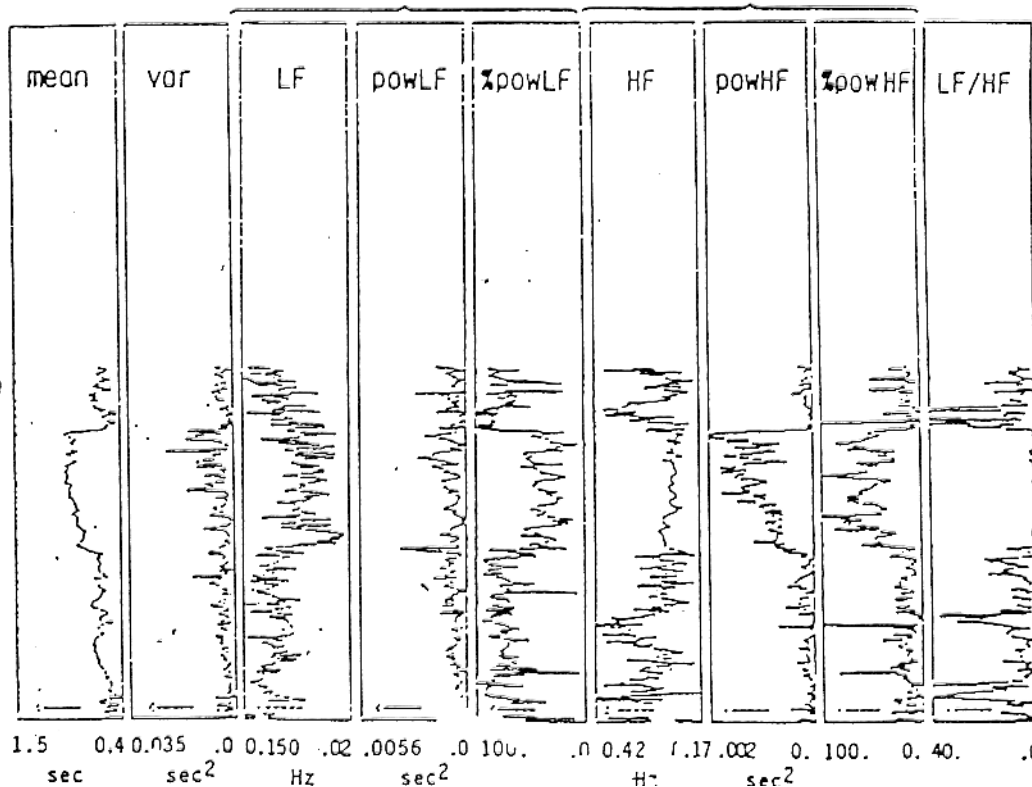
b)

c)

d)

e)

f)



# CSA

## Soggetto iperteso

a)

