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Knitted Coil for Inductive Plethysmography

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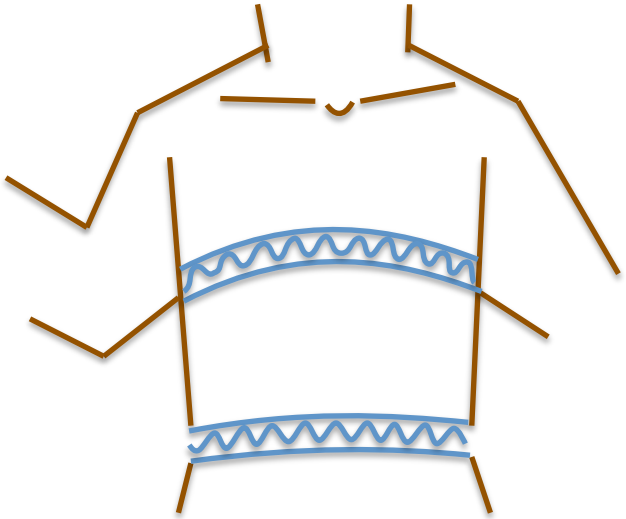
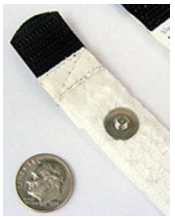
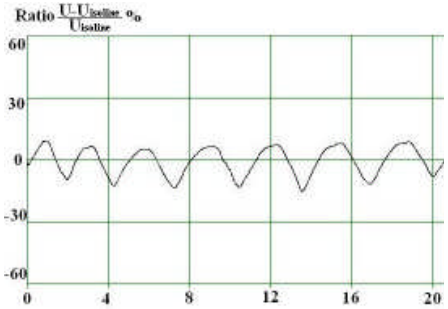
Inductive plethysmography



Based on: Physiological Measurement 24(1):149-63

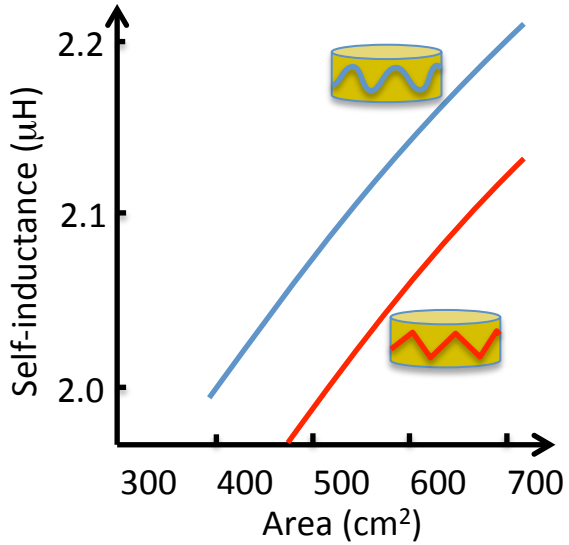


Elektronika ir Elektrotechnika · 01/2008



0161-7567/88 The American Physiological Society, p.1749

$$L = \mu_0 \cdot \sqrt{(A/\pi)}\{\ln[8\sqrt{(A/\pi)}/\rho] - 7/4\}$$



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Knitted coil 1

RESPIBELT M. Catrysse et al. Sensors and Actuators A 114, pp 302-311 (2004)

Steel cylindrical coil

stainless steel yarn

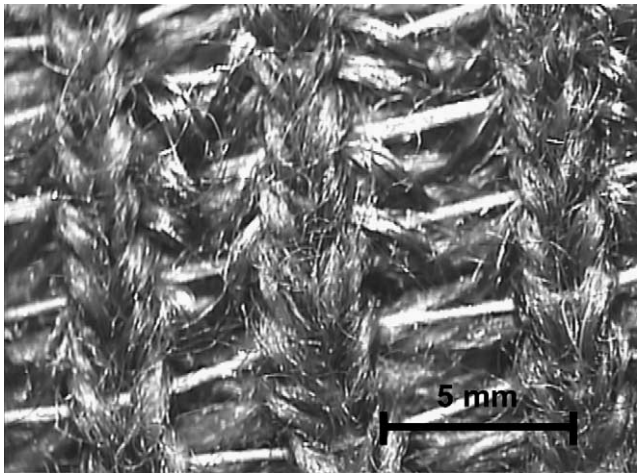
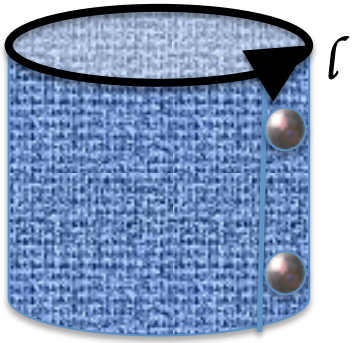
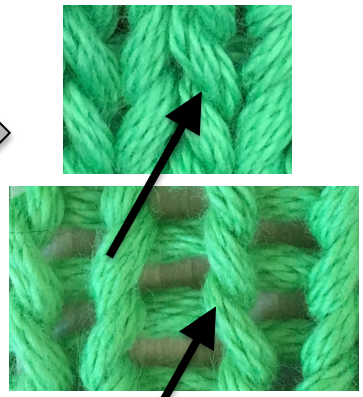


Fig. 8. Detail of the Respibelt respiration sensor.

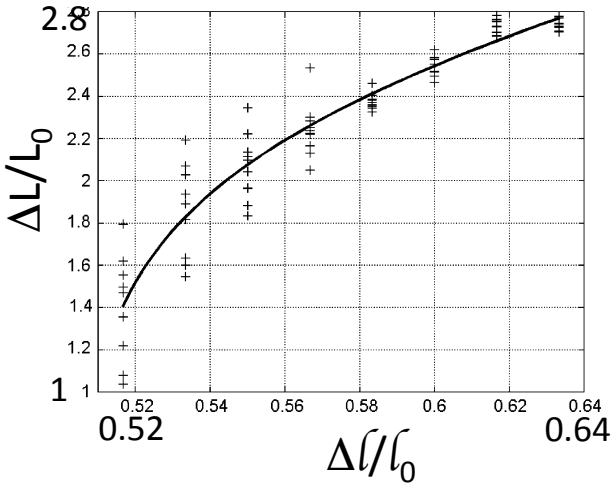
L

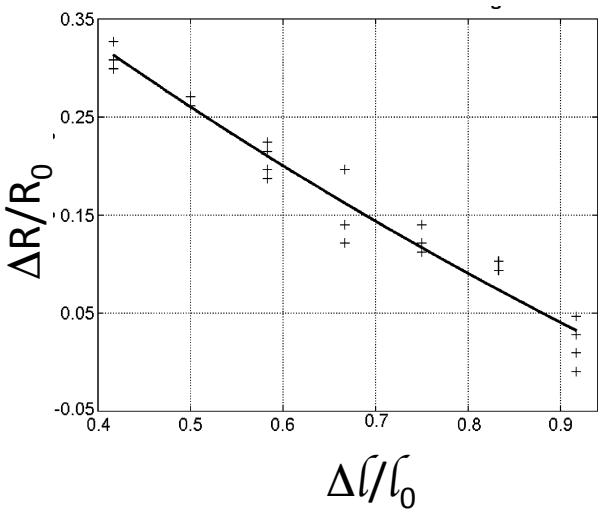


R



Cross-over points





ℓ_0 = 60 cm
L_0 = 0.38 μH
R_0 = 10.7 Ω

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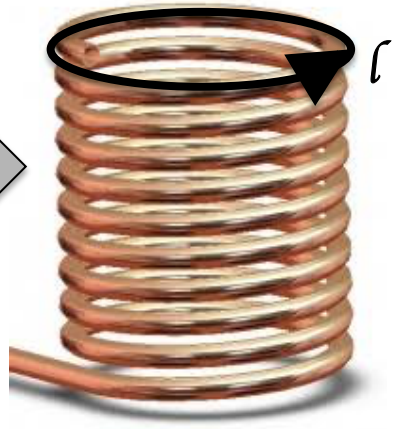
Knitted coil 2

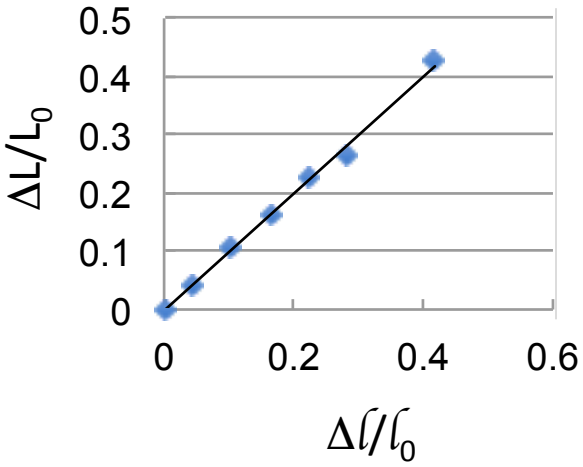
Integrated coil K. Fobelets

Elastic yarn + thin insulated Cu wire

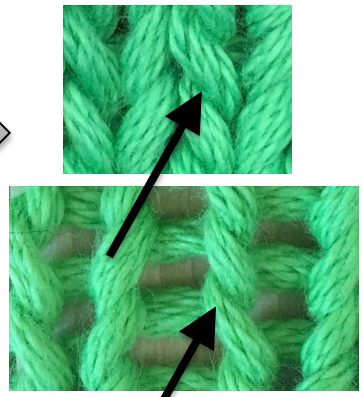
L

Cu helical coil





R



$\Delta R/R_0\ (\Delta\ell/\ell_0) = 0$

ℓ_0 = 49.5 cm
L_0 = 12.48 μH
R_0 = 11.3 Ω

Cross-over points

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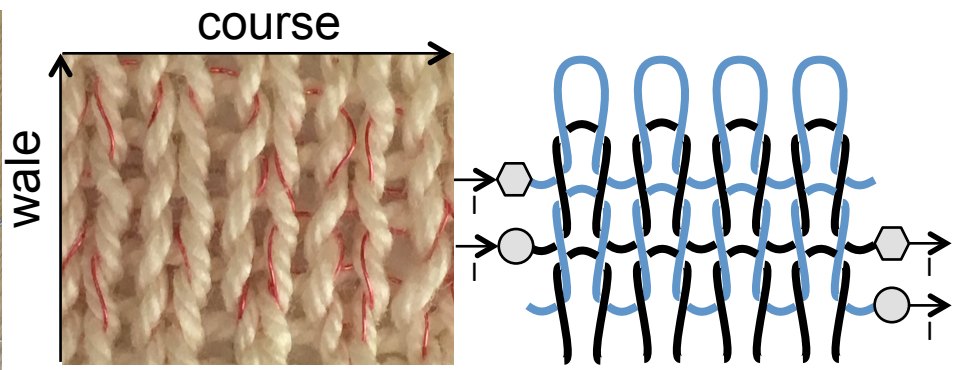
Characteristics of a knitted coil

Knit requirements: round knit, thin insulated metal wire and *N* small

Knitting in the round



Continuity of current flow

No seams = no electrical connections

K. Fobelets et al, IEEE Sensors Journal 19(18), pp. 7835 – 7840 (2019)

$$R \approx \underbrace{\rho_{Cu}^{A} \times l \times N}_{\text{Classical coil}} + \underbrace{\rho_{Cu}^{A} \times 2 \times d_n \times N_s(l, d_n) \times N}_{\text{Wales in knit}}$$

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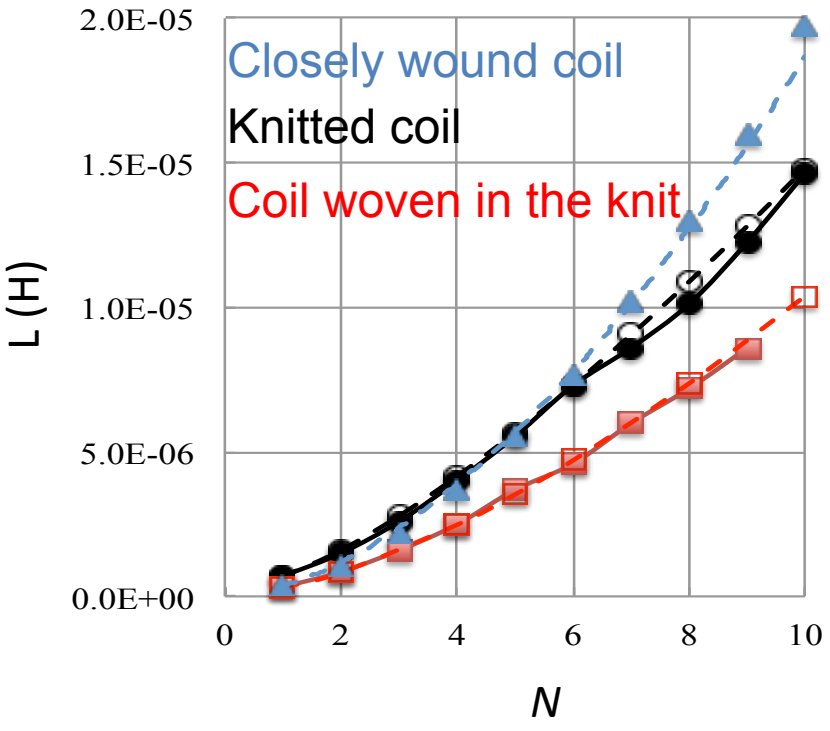
Characteristics of a knitted coil

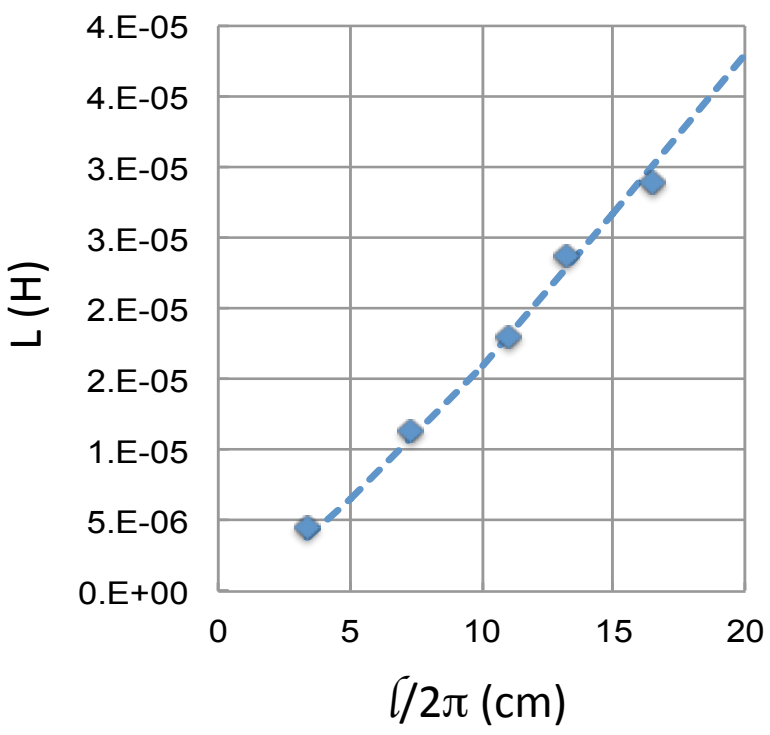
K. Fobelets et al, IEEE Sensors Journal 19(18), pp. 7835 – 7840 (2019)

Measurement

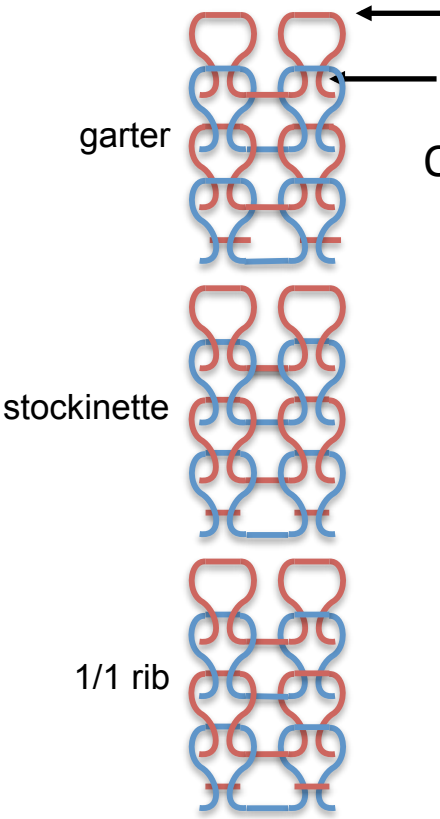
number of turns



unstretched radius of knit



Influence of the stitch type



Overlap depends on stitch type & stretch

$$L \approx \frac{\mu_0}{4\pi}\left(\oiint \frac{dx_1 \bullet dx_2}{|x_1 - x_2|}\right)$$

Inductance depends on overlap

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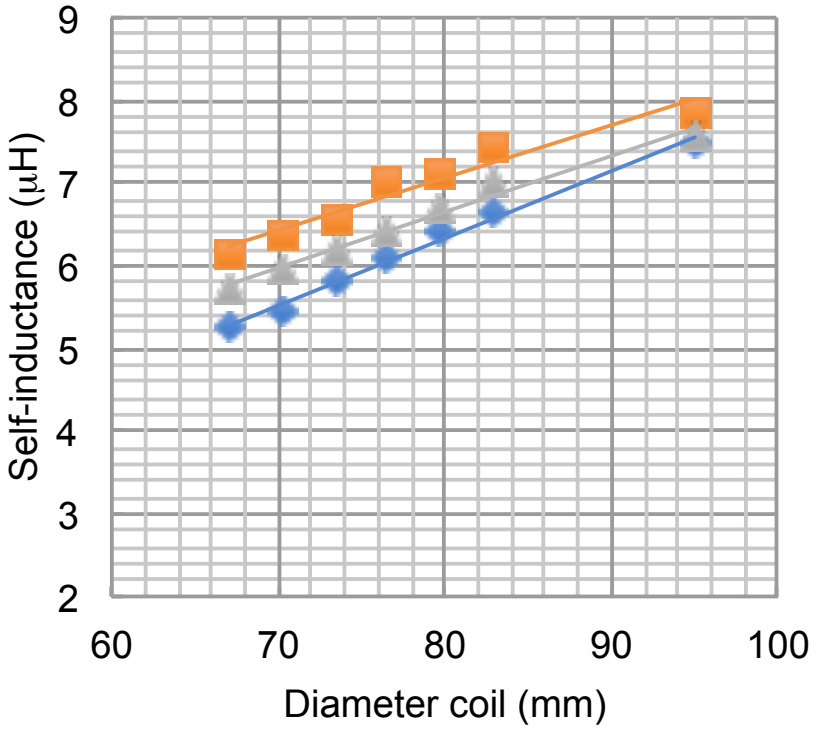
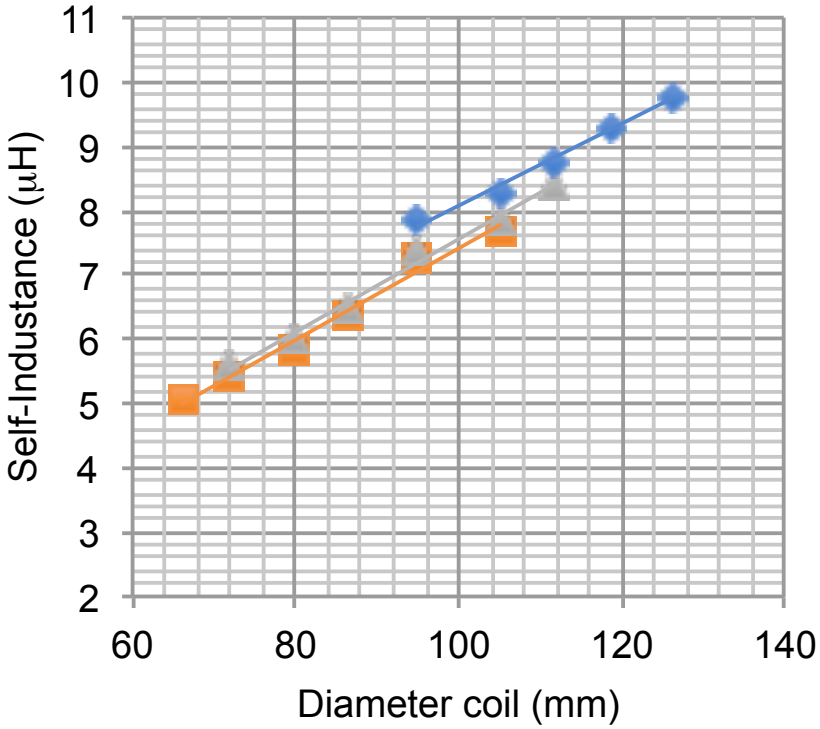
Influence of knit parameters on stretch response

N = 5, N_s = 54, *stitch type*



Rib
Garter
Stockinette

N = 5, stockinette, N_s



54
60
100

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Influence of knit parameters on stretch response

N = 5, N_s = 54, ^1N_S = 100, Yarn type and needle size

Sensitivity: $\Delta L/\Delta D$

$\Delta L/\Delta D$ (μH/mm)	Rib	Garter	Stockinette
Viscose 3.5 mm	0.064	0.068	0.081
Cotton 3 mm	0.059		0.062
Cotton 7.5 mm	0.053		0.053
Viscose 3.5 mm[1]	0.072		0.084

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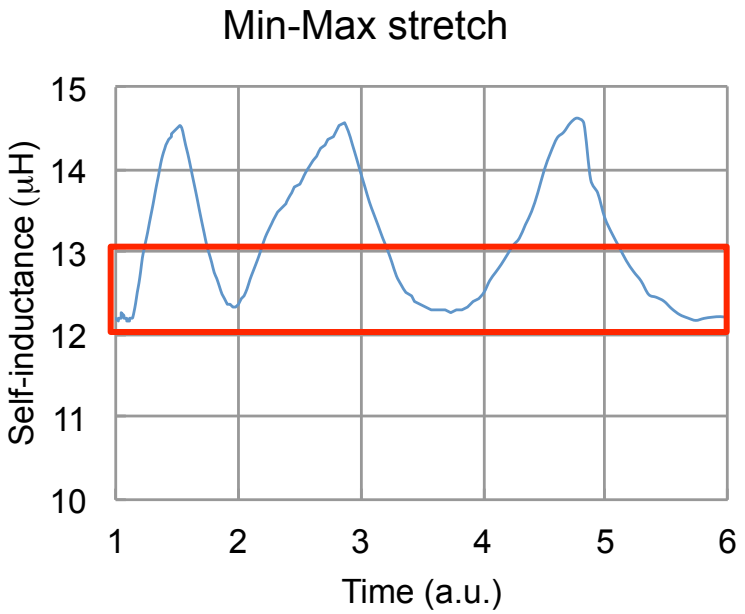
Simulated breathing with baby romper



44 cm < ℓ < 53 cm

Sleeping healthy baby 44 cm + 3 cm

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Conclusions

- A round knit with thin Cu insulated wire and yarn:
  - Behaves as a helical coil
  - Retains drape, elasticity and wearability
  - Does not require electrical contacts at seams
  - Gives reproducible characteristics
  - Gives linear response
- Rib knits give the highest inductance but stockinette the highest sensitivity
- The combination with elastic yarn is the best choice for inductive plethysmography.
- Feasibility as inductive breathing sensor for babies demonstrated.
- Improvement of the electrical conductivity of the thin conductor is required for improving performance.