is nearly an order of magnitude higher than values measured following conventional thermal annealing at 900°C. For example, the maximum electron concentrations we have measured for samples annealed at 900°C for 30 s is 2-3 × $10^{18}$ $cm^{-3}$ for selenium and tellurium implants. The mobility of the laser-annealed samples is, however, lower than expected from the data of Sze and Irvin.[5] The reason for this is unclear but may be associated with the fact that samples have an ionised-defect concentration perhaps an order of magnitude higher than the measured free-electron concentration. Thus, the magnitude of the mobility could correspond to an ionised-defect concentration greater than about $10^{20}$ $cm^{-3}$. The fact that the peak electron concentration is deeper than the theoretical range may be due to the implanted ion diffusing during annealing.[1] Only the front half of profiles could be measured since the tail regions became too resistive over the period of one etch step (200-400 Å).

The deposition of the $Si_3N_4$ is effectively a pulsed thermal anneal at 750°C, and we have shown using Rutherford back-scattering that this process allows amorphous layers to recrystallise but that there is still significant damage near the sample surface. Thus, it is interesting to note that samples with and without $Si_3N_4$ coatings can give similar electrical results (Table 2). Also, it is significant that good electrical results were obtained for samples implanted at 200°C. These results indicate that the production of an amorphous layer is not a necessary requirement for successful annealing by absorption of laser energy.

Laser energy densities of 0·05 J/$cm^2$ or more removed much of the $Si_3N_4$ coating from samples, and in these areas the surface became rippled compared with the relatively smooth regions where $Si_3N_4$ still remained. The average amplitudes of the ripples for one sample were about ± 400 Å. These rippled areas may correspond to the parts of the sample which absorbed sufficient energy to melt.

*Conclusion:* Electron concentrations in the range 1-2 × $10^{19}$ $cm^{-3}$ have been obtained by laser annealing GaAs implanted with a dose of 1-5 × $10^{15}$ $cm^{-2}$ of selenium or tellurium ions. The implant temperature was room temperature or 200°C and it was not necessary to coat samples before annealing to achieve the high electrical activation.

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## References

1 GOLOVCHENKO, J. A., and VENKATESAN, T. N. C.: 'Annealing of Te-implanted GaAs by ruby laser irradiation', *Appl. Phys. Lett.*, 1978, 32, p. 147
2 RIMINI, E., BAERI, P., and FOTI, G.: 'Laser pulse energy dependence of annealing in ion implanted Si and GaAs semiconductors', *Phys. Lett.*, 1978, 65A, p. 153
3 CAMPISANO, S. U., CATALANO, I., FOTI, G., RIMINI, E., EISEN, F., and NICOLET, M. A.: 'Laser reordering of implanted amorphous layers in GaAs', *Solid-State Electron*, 1978, 21, p. 485
4 KULAR, S. S., SEALY, B. J., STEPHENS, K. G., CHICK, D. R., DAVIS, Q. V., and EDWARDS, J.: 'Pulsed laser annealing of zinc-implanted GaAs', *Electron. Lett.*, 1978, 14, pp. 85-87
5 SZE, S. M., and IRVIN, J. C.: 'Resistivity, mobility and impurity levels in GaAs, Ge and Si at 300 K', *Solid-State Electron.*, 1965, 11, p. 599

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## FORD-GIRLING EQUIVALENT CIRCUIT USING C.C.II

*Indexing terms: Active networks, Equivalent circuits, Inductance*

A new configuration equivalent to the well known Ford-Girling circuit and using c.c.II instead of the o.a. is given. Applications and advantages of the new realisation are discussed.

Several realisations are available for simulating a nonideal inductance using a single o.a.[1] One of the most popular realisations is the Ford and Girling circuit[2] shown in Fig. 1*a*. The purpose of this letter is to introduce an equivalent circuit to the Ford-Girling network using the second-generation current conveyor[3] c.c.II.

Fig. 1*b* represents the new circuit, where c.c.II is defined by:

$$\left.\begin{aligned} i_c &= -i_a \\ i_b &= 0 \\ v_a &= v_b \end{aligned}\right\} \qquad (1)$$

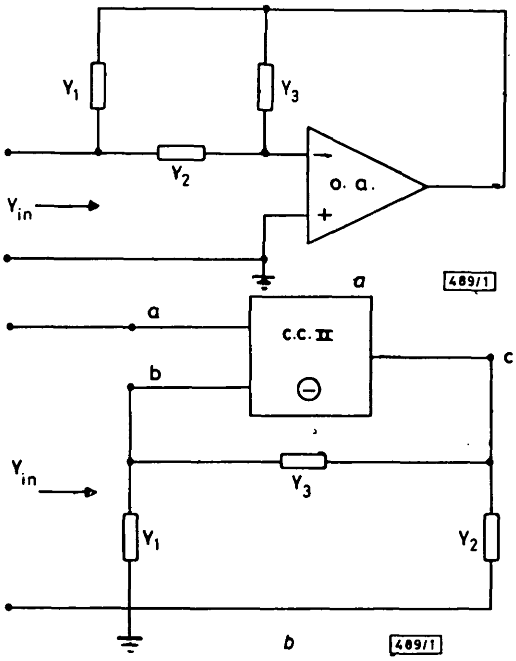


Fig. 1

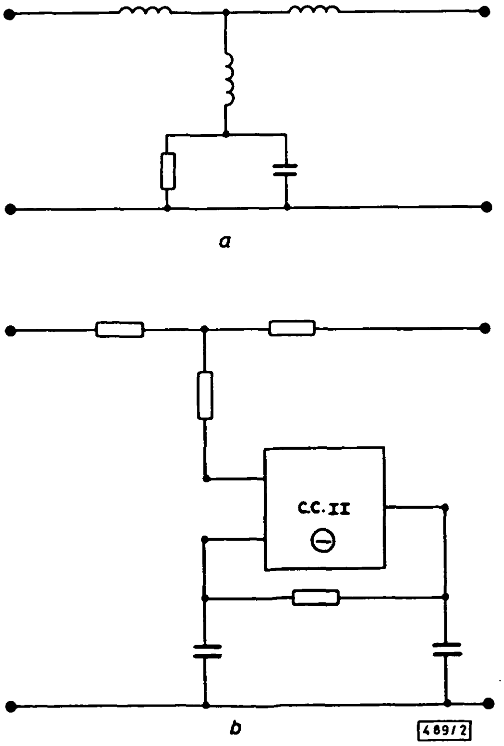


Fig. 2

Analysis of the circuit yields the following input admittance:

$$Y_{in} = Y_1 + Y_2 + \frac{Y_1 Y_2}{Y_3} \qquad (2)$$

It is seen that this is the same input admittance as in the Ford-Girling circuit.

The circuit may be used to realise a nonideal inductance consisting of an ideal inductance in parallel with a resistor by using a capacitance for $Y_3$ and conductances for $Y_1$ and $Y_2$.

The advantage of the proposed circuit is found when it is employed to realise a supercapacitance [frequency-dependent negative conductance (f.d.n.c.)] in parallel with a capacitance. This is obtained practically by using a conductance $G$ for $Y_3$ and capacitances $C_1$ and $C_2$ for $Y_1$ and $Y_2$. Thus the two capacitors are grounded, whereas in the Ford-Girling realisation using an o.a. both capacitors are floating.

*Application:* This simulated nonideal f.d.n.c. is very practical for realising lowpass filter sections with transmission zeros in the open left-half plane,[4] as shown in Fig. 2*b*. This circuit is derived from that in Fig. 2*a* using Bruton's transformation.[5]

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## References

1 DUTTA ROY, S. C.: 'On operational amplifier simulation of grounded inductance', *AEU*, 1975, **29**, pp. 107–115
2 FORD, R. L., and GIRLING, F. E. J.: 'Active filters and oscillators using simulated inductance', *Electron. Lett.*, 1966, **2**, p. 52
3 SEDRA, A., and SMITH, K. C.: 'A second generation current conveyor and its applications', *IEEE Trans.*, 1970, **CT-17**, pp. 132–134
4 HEINLEIN, W. E., and HOLMES, W. H.: 'Active filters for integrated circuits' (Oldenbourg Verlag, Munich), chap. 9, p. 522
5 BRUTON, L. T.: 'Network transfer functions using the concept of frequency dependent negative resistance', *IEEE Trans.*, 1969, **CT-16**, pp. 406–408

*0013-5194/78/220721-02$1.50/0*

## ERRATA

HOWARD, D., and HALL, T. J.: 'Interaction of high-frequency sound with fibre-guided coherent light', *Electron. Lett.*, 1978, **14**, pp. 620–621

On p. 620, column 1, penultimate line, Reference 7 should be Reference 6.

MOGHE, S. B., GUTMANN, R. J., CHUDZICKI, M. J., and BORREGO, J. M.: 'Effect of neutron and gamma irradiation on the low-frequency noise in GaAs m.e.s.f.e.t.s', *Electron. Lett.*, 1978, **14**, pp. 637–639

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