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grooves; granular  
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and inductors fabricated  
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losses, thus enabling  
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a patterned quasi-distributed gap. A design methodology based on a simple model is proposed. Analysis of secondary effects is also developed. A design example for a 5 MHz buck power converter application is presented.

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We are developing high-  
frequency (8 MHz)

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for losses are presented. Special design considerations for the key dynamic voltage scaling enabler, called the dynamic DC-DC converter are given. The focus throughout is on low-power portable applications, where small size, low cost, and high energy efficiency are the primary design objectives.

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power converters in  
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Trends in the  
miniaturisation of  
electronic products,  
especially in the  
portable products area,

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has sparked considerable interest in the miniaturisation of the energy processing electronics i.e. the power conversion circuits such as the switched mode power supply (SMPS). Unlike digital electronics which have benefited from miniaturisation and integration in microelectronics, power

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electronics  
have not significantly  
reduced in size. This is  
directly due to the fact  
that power conversion  
requires energy storage  
components such as  
inductors and  
capacitors. The value of  
the inductors and  
capacitors required can  
be reduced if the  
switching frequency of  
the power converter is

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increased. In order to miniaturise the power converter, the switching frequency must be increased so that passive components can be miniaturised and integrated. Traditionally the inductive components have been difficult to integrate on chip. This work focused on the design and fabrication of integrated



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inductors-on-silicon for  
very high frequency  
power conversion (20  
{u2013} 100 MHz).

Initially an analytical  
model for micro-  
inductors which was  
developed in previous  
work was used to design  
inductors for operation  
up to 20 MHz. The  
designs selected for  
fabrication had a  
footprint area between 5

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{u2013} 9 mm<sup>2</sup> and a predicted device efficiency of 90% and above. These models were validated by finite element analysis before fabrication. The fabricated prototypes displayed a low loss of inductance to 20 MHz and current handling ability to 0.5 A. The micro-inductors were then interfaced with a

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high frequency dc-dc converter (20 {u2013} 100 MHz) developed by NXP Semiconductor, and achieved an inductor efficiency of 93% at 20 MHz. The maximum converter efficiency with the micro-inductor was measured to be 78.5%, which to date is highest quoted inductor-on-silicon device efficiency

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in a converter  
application at 20 MHz.  
Circuit equivalent  
lumped-element models  
of the micro-inductor  
for use in circuit  
simulation software  
were also developed.  
This equivalent circuit  
model includes elements  
such as capacitance,  
which are not accounted  
for in the previously  
developed analytical

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model. The initial micro-inductor devices performance was found to be comparable to commercial chip inductors for inductor efficiency when used in a converter. However, if the micro-inductor technology is to compete as a viable alternative to commercial devices, it needed to reduce its

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footprint area

dramatically. This was achieved by using an optimisation software engine to find the inductor designs with maximum efficiency for a given footprint area. The footprint of these optimised devices ranged from 0.5 {u2013} 2.5 mm<sup>2</sup> for a range of inductances to 200 nH. A range of

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optimised devices were fabricated and the measured optimised devices displayed a low loss of inductance to tens of MHz and good current handling capability. However, measured dc resistance was found to be substantially higher than design, due to issues in the fabrication process. The fabricated inductors

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also highlighted the trade-offs that are introduced in micro-inductor performance vs. footprint area. This design trade-off was also reflected in micro-inductor performance in a converter. An optimised 2.5 mm<sup>2</sup> area device was tested in a dc-dc converter at 20 MHz, which resulted in a slightly lower peak



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efficiency of 90.5% than  
the previous larger  
devices. The fabricated  
optimised micro-  
inductors achieve an  
inductance density  
(inductance per unit  
area) ranging from 66 -  
110 nH/mm<sup>2</sup> and  
display current handling  
ability of 500mA for the  
2.5 mm<sup>2</sup>, 250mA for  
the 1.3 mm<sup>2</sup> and

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150mA for the 0.5 mm<sup>2</sup> area device. For inductors aimed at power conversion applications, this work shows a significant improvement to what is reported in literature - in high frequency operation to tens of MHz, inductance density and current handling.

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Although they are some of the main components in the design of power electronic converters, the design of inductors and transformers is often still a trial-and-error process due to a long working-in time for these components.

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especially useful for senior undergraduate and graduate students in electrical engineering and electrical energy systems, and engineers working with power supplies and energy conversion systems who want to update their knowledge on a field that has progressed considerably in recent years.

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