est frequency antenna made on GaAs to date. This chip antenna is mounted on a brass block which acts as the ground plane for the antenna, measuring 20 × 20 × 6mm. This corresponds to the length, width and depth of the brass block. The H-shaped GaAs patch antenna sits in the centre of this ground (Fig. 1). Owing to its high degree of size reduction, the gain of this antenna is about –10dBi reported in [5], as compared to +5dBi for a conventional half-wave patch antenna. To investigate the gain improvement of this antenna system, a parasitic radiator measuring 22 × 22mm was placed above the feed antenna at distance of 0.5–10mm. The parasite was truncated at a 2 vertex point with d = 5mm. It was then determined experimentally that the optimum coupling height was 2mm above the feed antenna. This setup arrangement provides an input matching of $S_{11} = -6$dB as opposed to that of $S_{11} = -23$dB reported in [5]. This poor matching performance is due to difficulties in obtaining an optimum bond onto the chip. The bandwidth of the GaAs antenna reported in [5] was measured at 0.67%. It was observed that when the parasite is applied very close to the feed antenna, detuning effects occur as the frequency shifts slightly to 6.02GHz. The measured gain of the antenna is shown in Fig. 2*a*, where the GaAs feed antenna is coupled with (solid line) and without (dash-dot line) the parasite. From the measured results, the chip antenna without the parasite has a gain of a –15dBi. This is again due to the poor wire bond properties. With the parasite at a height of 2mm from the feed antenna, a gain enhancement of ~16dB was observed, bringing the overall gain of the antenna close to 1dBi. Fig. 2*b* shows the relation of the gain of the antenna system with respect to the variation in coupling height. It was also observed that with the extension of the antenna ground plane behind the brass block (Fig. 2*a*, dotted line), an overall gain enhancement of 21dB was observed, bringing the final antenna gain to 6dBi. The measured radiation pattern at the optimum position of 2mm for both parasitic cases (normal ground and extended ground) are shown in Fig. 3.

Packaging design and assembly: It is well understood that packaging of a fragile semiconductor chip on a suitable carrier provides robustness, ease of handling, and also protects the device from environmental degeneration. There are currently several encapsulations and chip carrier standards being laid out by the JEDEC JC-11 committee [6]. Some of the more popular chip carriers are made of plastics and ceramics. In Fig. 4*a*, we show an assembly concept of the proposed chip carrier module. As the silicon/GaAs chip will perform all the processing, only a few connection pins are necessary on the lead frame. These are effectively for the supply voltage, ground and baseband signals. The parasitic patch antenna then sits on top of the carrier material, sealing the MMIC antenna chip. An alternative form of packaging using an alumina lid hermatic sealing is shown in Fig. 4*b*. The lid which seals the parasite within the package may also be used as a radome to further improve the gain [7].

Conclusion: A novel packaging technique for a complete RF front end module equipped with radiator has been proposed. A method of overcoming the problem of a small antenna using a parasitic element, which is implemented within the chip module, provides the necessary gain restoration. In principle, only the baseband signal, power supply and ground should be needed for such a configuration. It opens up the opportunity for such designs to be fully integrated on a silicon chip, hence keeping PCB board complexity to a minimum.

Acknowledgment: The authors would like to thank BT Advanced Communications Technology Centre for their funding of this project.

© IEE 2000 *19 July 2000*
Electronics Letters Online No: 20000996
DOI: 10.1049/el:20000996

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Synthetic impedance for implementation of piezoelectric shunt-damping circuits

A.J. Fleming, S. Behrens and S.O.R. Moheimani

Piezoelectric transducer (PZT) patches may be attached to structures to reduce vibration. The PZT patches essentially convert vibrational mechanical energy to electrical energy. The electrical energy can be dissipated via an electrical impedance. The authors introduce a method of implementing any arbitrary impedance, using a digital signal processor. The 'synthetic impedance' is demonstrated on a resonant simply supported beam.

Introduction: Piezoelectric material, in conjunction with appropriate circuitry, can be used as a mechanical energy dissipation device. By placing an electrical impedance across the terminals of the piezoelectric transducer (PZT), the passive network is capable of damping structural vibrations. If a simple resistor is placed across the terminals of the PZT, the PZT will act as a viscoelastic damper [1]. If the network consists of a series inductor-resistor *R–L* circuit, the passive network combined with the inherent capacitance C_p of the PZT creates a damped electrical resonance. The resonance can be tuned so that the PZT element acts as a tuned vibrational energy absorber [1]. This damping methodology is commonly referred to as passive shunt-damping. Passive shunt-damping is regarded as a simple, low-cost, light-weight, and easy-to-implement method for controlling structural vibrations. This methodology also guarantees stability, unlike some active control schemes that may result in closed-loop instability if the dynamics of the system are disturbed.

Flexible mechanical structures contain an infinite number of resonant frequencies (or structural modes), i.e. the structure is capable of vibrating at its natural frequencies. If the tuned energy absorber [1] is to be used to minimise vibration of a number of modes, rather than one mode, an equal number of PZT patches and resonant controllers would be required. This is clearly impractical. A method of damping multiple vibration modes using a single PZT has been reported [2]. This is shown in Fig. 1 for vibration control of two modes. This circuit consists of a 'current blocker' comprising one parallel capacitor-inductor *C–L* circuit that is placed in series with each parallel *R–L* shunt circuit designed for one structural mode. Depending on the number of structural modes to be shunt-dampened simultaneously, a different number of *C–L* networks are placed in series with the parallel *R–L* shunt branch.

There are a number of problems associated with this technique, the foremost being the complexity and size of the circuit required to implement the total impedance. Typically the shunt circuit requires large inductor values (up to 1000s of Henries), therefore Riordan gyrators [3] are required to implement the inductor elements. Gyrator circuits are large in size and are sensitive to component tolerances. Also, PZTs are capable of generating large voltages for moderate structural excitations, therefore the gyrators must be constructed from high-voltage operational amplifiers. Furthermore, the required number of operational amplifiers required to shunt-dampen two structural modes could be > 32 op-amps.

In this Letter we introduce a method for implementing an impedance of arbitrary order and complexity. This 'synthetic impedance' is used in place of shunt-damping networks to provide effective vibrational damping without the problems associated with direct circuit implementations.

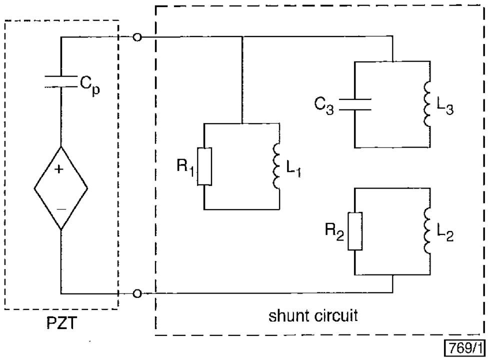

Fig. 1 *Simplified shunt-damping circuit of* [2]

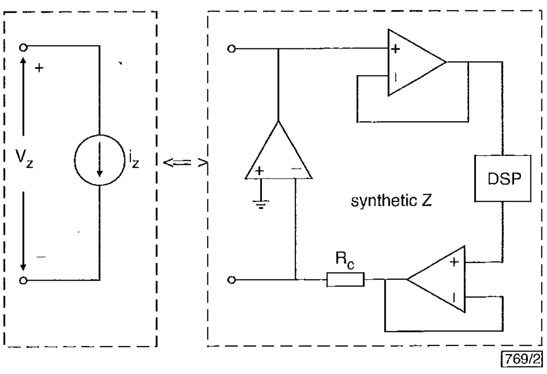

Fig. 2 *Synthetic impedance*

Synthetic impedance: We define a synthetic impedance as a two-terminal device that establishes some arbitrary relationship between voltage v_z and current i_z at its terminals. The functionality of the device is shown in Fig. 2, where: $i_z(t) = f(v_z(t))$. This can be made to synthesise any network of physical components by fixing i_z as the output of a linear transfer function of v_z, $I_z(s) = Y(s)V_z(s)$, where $Y(s) \equiv 1/Z(s)$ and $Z(s)$ is the desired impedance to be seen from the terminals. A DSP system *dSPACE* is used to simulate the required transfer function $Y(s)$ in real time, as shown in Fig. 2.

Application: To validate the shunting simulated impedance, experiments were carried out on a simply supported piezoelectric laminated beam, i.e. a mechanically resonant structure. The resonant beam structure consists of a uniform aluminum beam of rectangular cross-section with experimentally pinned boundary conditions at both ends. A pair of piezoelectric ceramic patches (PIC151) are attached symmetrically to either side of the beam surface. One of the patches is used as an actuator and the other as a shunting layer, i.e. sensing layer.

The synthetic impedance can now be used in place of the passive network shown in Fig. 1. The desired impedance is first calculated, then the corresponding admittance transfer function is implemented on the *dSPACE* DSP system.

The simply supported beam is excited by applying a voltage signal V_a to the piezoelectric actuator. To determine the damping performance of the synthetic impedance, the frequency response of the beam from the structural excitation voltage to the structural displacement at a point on the beam surface can be measured, i.e. $d(x, s)/V_a(s)$. The frequency response is captured using a polytec scanning vibrometer (PSV-300). The uncontrolled and damped frequency response $d(x, s)/V_a(s)$ of the beam is plotted in Fig. 3. Results show that the synthetic impedance dampens two structural modes of the piezoelectric laminated beam by 18 and 20dB.

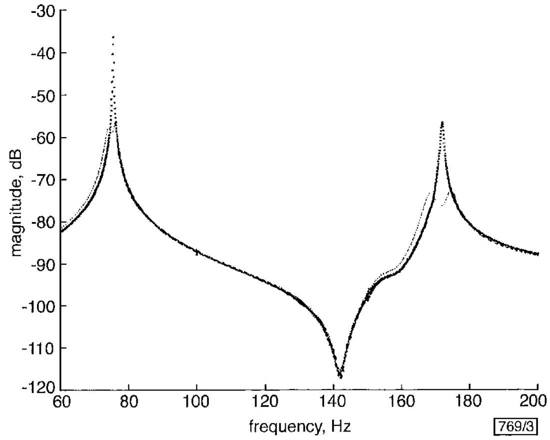

Fig. 3 *Frequency response of piezoelectric laminated simply supported beam*

··········· experimental (undamped)
——— experimental (damped)

Conclusions: A method has been presented for implementing a simulated impedance required for effective shunt-damping of a resonant structure. This technique has alleviated some of the practical problems associated with shunt-damping. The arbitrary impedance has also created the opportunity for more advanced passive control solutions. This includes passive controllers that adapt to structural variations, i.e. adaptive controllers.

Acknowledgments: This research was supported by the Centre for Integrated Dynamics and Control and the Australian Research Council.

23 June 2000
Electronics Letters Online No: 20001083
DOI: 10.1049/el:20001083

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30Gsample/s time-stretch analogue-to-digital converter

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High speed analogue-to-digital conversion using a photonic time-stretch preprocessor followed by an electronic digitiser is demonstrated. The preprocessing increases the effective sampling rate and input bandwidth of the digitiser. The system exhibits 30Gsample/s sampling rate with 26dB signal-to-noise ratio over a 4GHz bandwidth.