Allan Linton-Smith looks at an exciting speaker development from Europe: MEMS speakers

How many speakers can you fit on a 5 cent coin?

MEMS, or Micro Electrical-Mechanical Systems, represents a significant breakthrough in electronics technology.

We're looking here at the USound UT-P-2017 MEMS loudspeaker. Using integrated circuit (IC) fabrication and device packaging processes, an Austrian audio/semiconductor company, USound GmbH (www.usound.com) managed to pack a fully-functioning speaker into a device just 6.7 x 4.7 x 1.6mm – and weighing just 47mg.

If you're having difficulty converting the measurement to reality, look at this rectangle – ▭ – that's the actual size of this speaker!

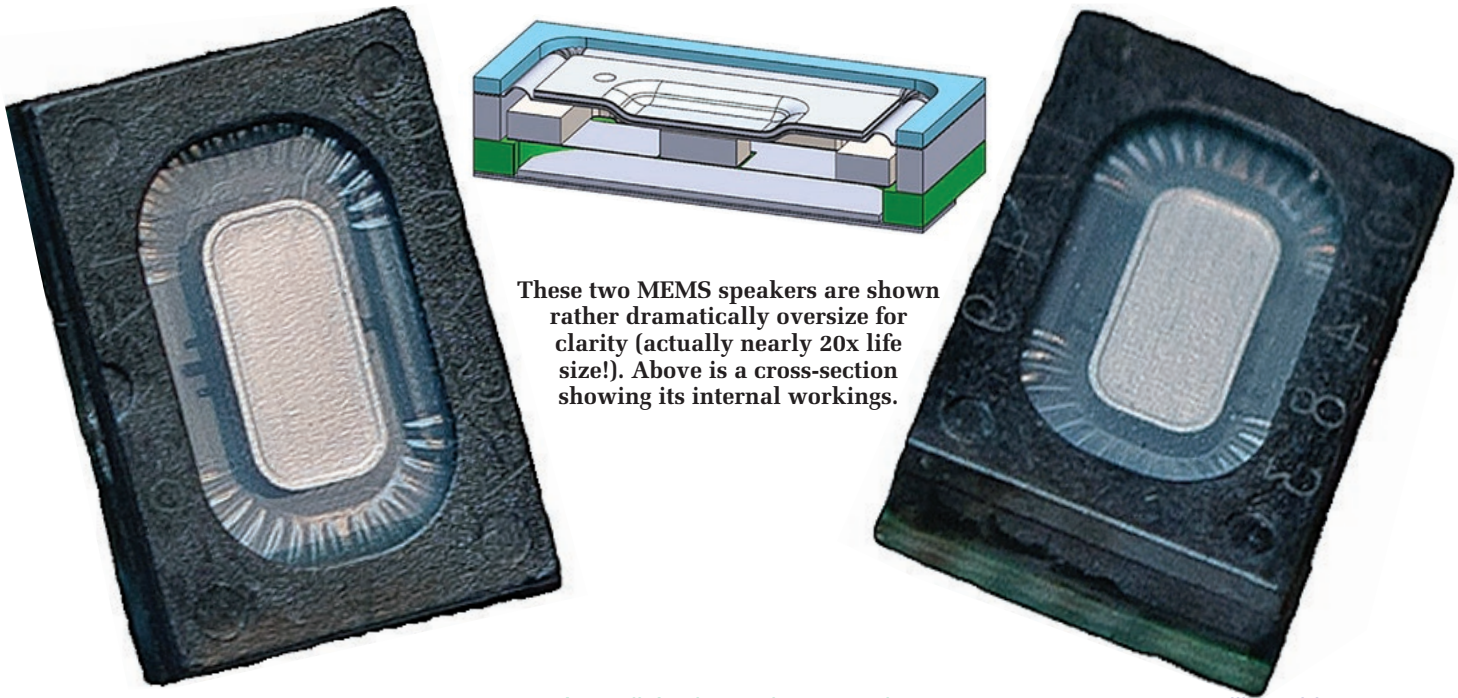
The manufacturer claims it is not only suitable for earwear, hearing aids, smartphones and the like but for much larger projects – such as a full-scale free field tweeter mounted in large hifi speakers!

The USound MEMS device

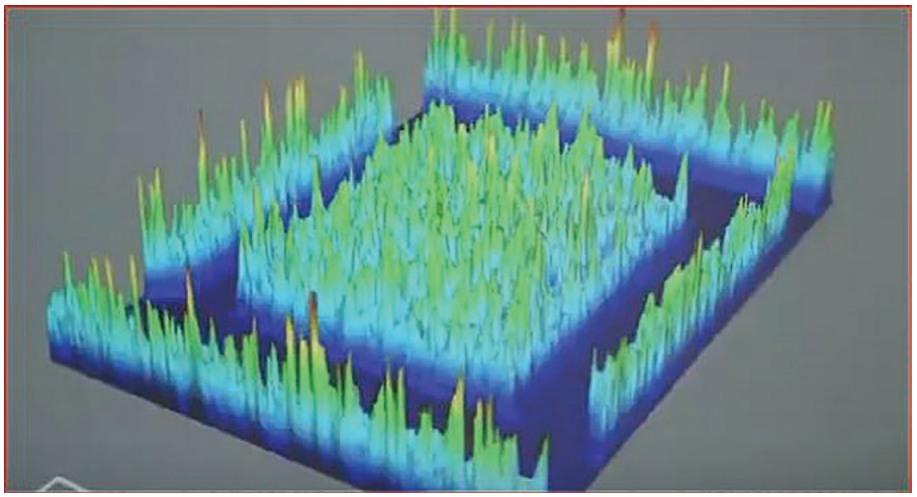
USound first brought this very-low-profile MEMS microspeaker to market towards the end of last year. It was initially targeted at wearables, headsets, embedded speakers and the like.

While this is described as a piezo tweeter, they were able to overcome the limitations of traditional piezo transducers, producing microspeakers with significantly improved sound pressure levels (SPLs) and low distortion as well. The UT-P-2017 offers a frequency range of 2kHz to 20kHz

Previous versions of piezo microspeakers available were not successful because of their limited excursion and lack of adequate bottom-end and midrange output.



These two MEMS speakers are shown rather dramatically oversize for clarity (actually nearly 20x life size!). Above is a cross-section showing its internal workings.



USound's MEMS speaker 3D doppler holograph from their development and testing phase. Note how the sound is emitted uniformly from the microspeaker.

One application suggested by the manufacturer is in "wearable" audio, such as these sunglasses. They have full-range stereo MEMS speakers plus a microphone built in. You can use them in place of earbuds for your smartphone! Prescription lenses are also available if you need them. They are available for around 300 Euros from USound (see website for details).

However, now they have successfully evolved with larger and thinner ceramics and the force of the ceramic element is high, enabling a cantilever to increase excursion and increase sound levels.

They are also easy to mount commercially because they can be soldered in place by reflow soldering techniques, which is how most miniature electronic SMD components are incorporated. They are in fact an SMD speaker!

Fortunately they can also be soldered to manually, but you have to have a steady hand and handle the device carefully according to the manufacturers datasheet: **www.usound.com/wp-content/uploads/2019/12/1912_Adap-UT-P-2017-Datasheet.pdf**

These little speakers can be made far more easily than conventional moving coil miniature speakers which require manual manufacturing steps. It has been estimated that MEMS speakers will require 1,000 times less manufacturing time to produce!

We obtained some of the USound MEMS speakers from DigiKey (part no 2000-1013-ND).

They were a bit expensive at about $AU21.50 each, including freight to Australia. The price has since come down a little (despite a falling Aussie dollar) and naturally, if you buy in any sort of quantity, there are good discounts.

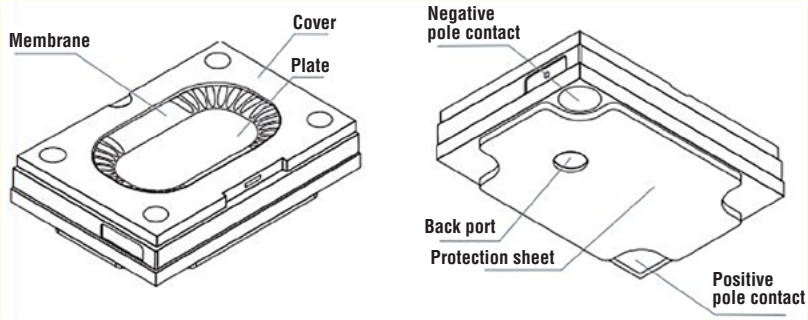
Incidentally, there is another model available from Digikey, the USound UT-P-2016 which is a full-range, in-ear speaker with a relatively flat 20Hz-9kHz (we hope to also look at this one soon).

SPECIFICATIONS: U SOUND UT-P-2017

PARAMETER	SPECIFICATION
Fundamental resonance	2.9kHz (15V pk-pk)
Q @ Fundamental resonance	0.7 (15V pk-pk)
Effective membrane surface	12mm²
VAS	40mm³
Front volume (inside speaker)	5.6mm³
Back volume (inside speaker)	20mm³
Capacitance (1kHz 15V_{pp})	40nF
Power consumption, 60dB white noise	27mW
Power consumption, 60dB pink noise	32mW
Max DC voltage	15V
Max AC voltage	15V pk-pk
Max frequency	40kHz
Overall dimensions, LxWxH	6.7 x 4.7 x 1.56mm
Total weight	47mg

The specifications show that the parameters are really tiny compared to larger, "normal" tweeters – and let's face it, ANY other tweeter is bigger than this one! Remarkably, the tiny size is really an advantage because the membrane can easily respond to more than 30kHz.

For a general description by the manufacturer go to: **www.youtube.com/watch?v=aAYrFVKW1XM**



The MEMS speaker is miniscule, measuring only 6.7x4.7 mm and weighing just 47 milligrams! Fortunately it can be soldered to connecting wires – but you have to have a steady hand and handle the device carefully.

MEMS impedance

Basically what we have here is a sort of electrostatic speaker, although in reality it is described as a "piezo silicon" device.

It acts like a capacitor and is very efficient; however, as with most of its big brothers, it requires a higher voltage input than dynamic speakers – but requires less current and therefore less power.

One drawback is that some amplifiers don't like capacititive loads, which may cause "ringing" or spurious oscillations.

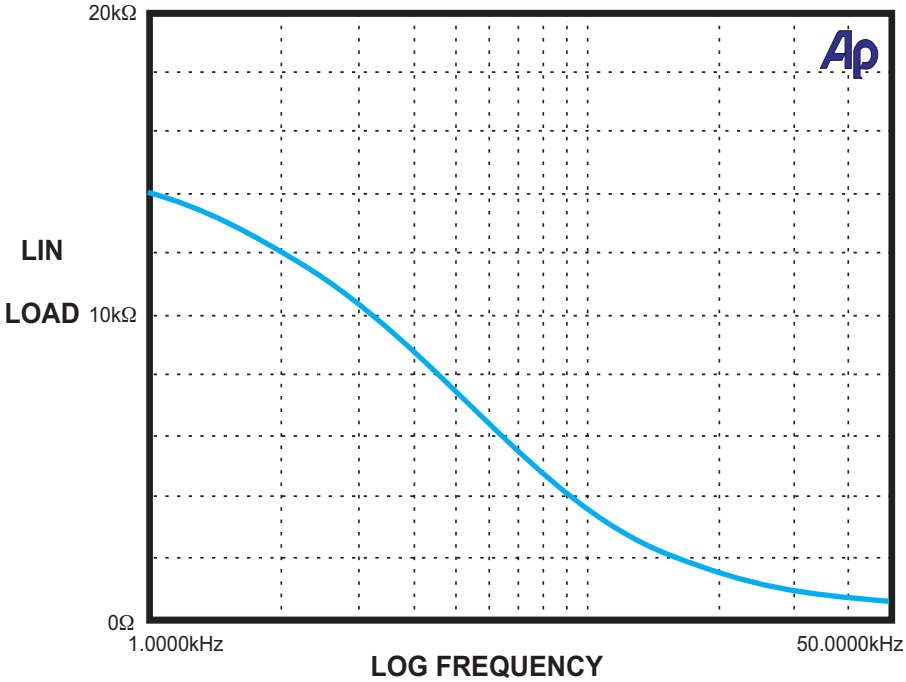


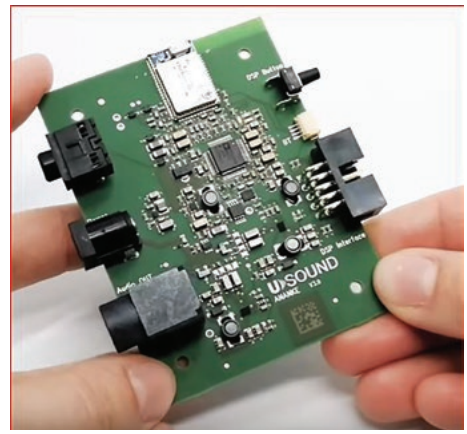
Fig.1: the impedance vs frequency curve shows a very high impedance across the range, only dropping under 1kΩ over 25kHz. This makes it suitable to be driven from just about any amplifier, including many preamplifiers or headphone amplifiers, but Class-D amplifiers are not recommended.

A circuit is described using an LM1875 power amplifier chip which is modified to cope with this speaker.

The nominal impedance is quoted as 161Ω – however, you can see from the impedance graph that this speaker has a smoothly declining impedance, typical of a capacitor, but at the same time it avoids impedance troughs and peaks which are usual with most other speakers. The result is better quality, smoother sound.

The impedance vs frequency curve from our test setup shows a very high impedance across the range of 1kHz to 50kHz – from 13.9kΩ down to 0.44kΩ. It only drops under 1kΩ over 26kHz.

This makes it suitable to be driven from just about any amplifier, including many preamplifiers or headphone amplifiers. However, we would be cautious with class-D amplifiers because of their heavy high frequency output (usually significant above 20kHz) which may overload the microspeaker because of its incredibly high frequency response which is significant – from 3kHz to an incredible 40kHz!



For future experimental work you can obtain a USound evaluation kit. Full details are included on their website. Also watch the whole thing on www.youtube.com/watch?v=9GInWhqHRFU

Power supply

For this speaker to function it requires a 15V supply (which may of course already be available in the power supply of an amplifier).

Bear in mind that 15V is the maximum allowed and the speaker will

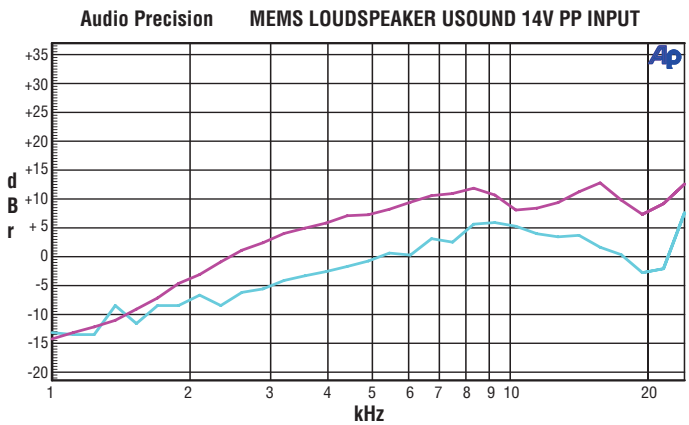


Fig.2: frequency response of the USound MEMS loudspeaker is quite smooth at its near-maximum of 14Vpp (4.95V RMS) and is close to the manufacturer's test data which was also taken at a nearfield distance of 3cm. The top trace (purple) was taken on the tweeter axis and the bottom trace (cyan) is 30° off axis. Zero dBr was set at 1Pa which represents a sound pressure level of 94dB, so the peak is an SPL of 106dB. The speaker had no problem in reproducing 102dB at 24kHz! The same circuit was used as for Fig.1 with the recommended DC bias of 15.0V.

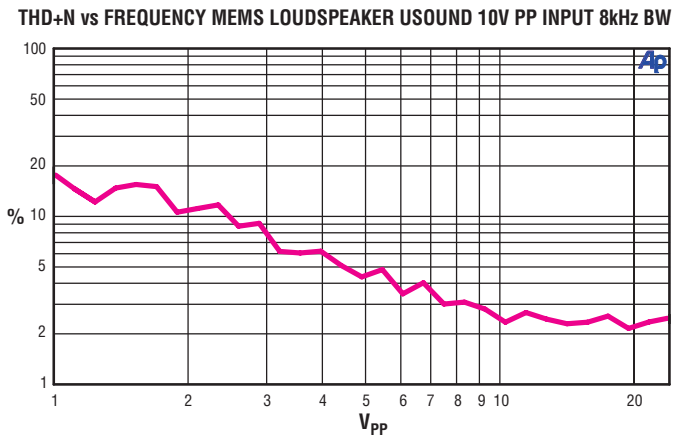


Fig.3: THD+N vs input (Volts$_{pk-pk}$). Distortion drops significantly as the voltage increases up to its rated maximum of 15V or 5.32V RMS. Note that the lowest distortion is achieved from approx 7-15V which is easily handled by most audio amplifiers. We used a bandwidth of 80kHz and a fixed frequency of 8kHz because this is a tweeter and the conventional 1kHz is not recommended. Also bear in mind that even our lab-grade Bruel and Kjaer mics contribute about 0.4% distortion to these measurements so it is pretty impressive!

A suggested bookshelf speaker arrangement developed by USound using MEMS microspeaker tweeters and conventional woofers. USound have a YouTube video for a blow-by-blow guide of how you can put them together. NOTE: As well as the conventional 8" woofer you will need 40 MEMS speakers to get the required volume! Full instructions are also available from their website, including recommended construction techniques, dimensions and recommended amplifiers and crossovers.

work quite happily at lower voltages, as long as the input peak-to-peak voltage does not exceed the DC voltage.

Lower voltages will naturally limit the power output and the sound pressure level.

Another option (which the manufacturer recommends) is a boost converter (see boost circuit diagram). USound operates from a 1.8-5.5V DC source and delivers a 15V DC output with 100mV ripple.

This IC is a tiny SMD suitable for in-ear applications but for a free field application, larger DC-DC converters or DC supplies within other amplifiers can be used to obtain the required power supply.

USound performance

One big advantage of a tiny item like this is that it allows a frequency response to a level only bats and dogs might be able to hear (getting some ideas are you?) because the membrane is so small and therefore can move very fast.

Also, because it is effectively a capacitor, its impedance has no significant peaks or troughs so it will be easy to drive.

It won't require a lot of signal and virtually any amplifier, even a preamplifier will be OK as long as it can deliver up to 5.3V RMS (15V peak-to-peak).

USound speaker practical applications

A hi-fi bookshelf speaker system was developed by USound using MEMS microspeaker tweeters and conventional 8-inch woofers.

Excellent instructions are available from their website including plans, recommended construction techniques, dimensions and recommended amplifiers and crossovers.

They even include detailed information to make the tweeter horn via 3D printing. They also describe a superb step by step guide to building this on YouTube: **www.youtube.com/watch?v=kx_JiYMPaZ8**

This speaker, also designed by USound, has 3x20 MEMS tweeters in a 360° arrangement for full "spaced out" sound. The woofer is a 2.5-in driver in a small box to provide the bass and lower midrange support. The effect is considered to be very unusual!

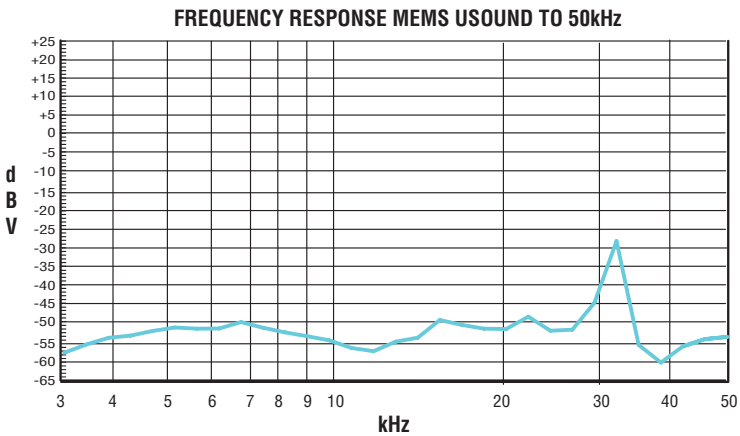


Fig.4: this THD+N vs frequency graph shows its response goes to an astounding 50kHz with a large peak at 32kHz, probably due to standing waves and/or resonance with the generator. It is remarkably flat to 50kHz and our B&K microphone responds to this frequency but is not calibrated above 40kHz. Note the manufacturer claims its response goes up to 80kHz and even bats and dogs probably won't hear it! Unfortunately we can't hear it or detect it either!

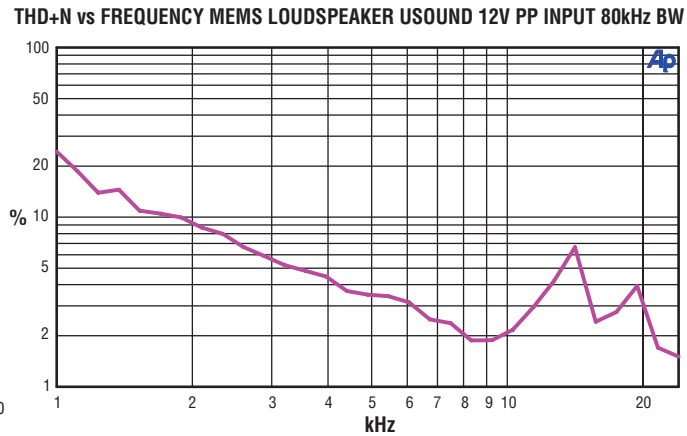
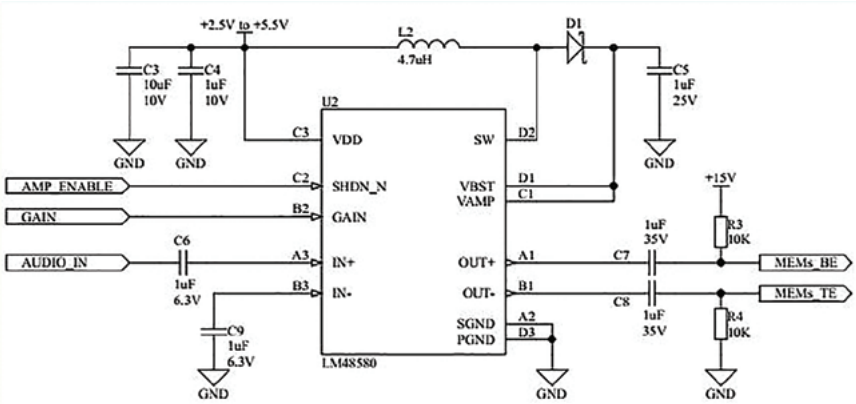
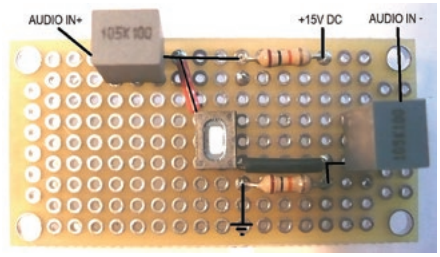


Fig.5: Total Harmonic Distortion plus noise (THD+N) vs frequency shows that our "mockup" results are as the manufacturer designed. It has a fairly low distortion in the 5-10kHz range and is very low at 20-24kHz. This speaker would use a high pass filter at 3kHz or higher to be in its "happy" range. Measurements were taken from our mocked up board and the Bruel & Kjaer microphone was mounted near field at 3cm from the speaker. The results are quite acceptable and the distortion levels are comparable to a full blown dynamic speaker.



The boost converter recommended by USound operates from a 1.8-5.5V dc source and delivers a 15V DC output with 100mV ripple. This IC is a tiny SMD type, suitable for earware, but for a free-field application there are probably easier ways to obtain the required voltage.



Our perforated board mock-up to allow us to evaluate the UT-P-2017 MEMS loudspeakers. We found that they performed very close to their published specifications.

We did "try out" the USound MEMS speakers but have not yet had time to re-create their built-up units. However, we may have a look at them in the future.

This stereo speaker system uses 20 microspeakers in each box in a vertical horn arrangement and presumably puts out significant sound.

There is another speaker system which requires 40 microspeakers in each box with a bigger woofer.

Another innovative speaker designed by USound has 20 MEMS tweeters in a thin metal tube which is angled slightly.

Three of these tubes surround a small woofer in a 360° arrangement for full spaced-out sound. The woofer is a 2.5-in driver in a small box to provide the bass & lower midrange support.

The effect is considered to be very unusual and spooky!

All sorts of innovations come to mind when you can have a thin tweeter and mount it on a flat surface and the obvious one is for earphones, earbuds and headphones. But there are many other novel uses and for this particular unit which is designed for free sound or open sound.

Virtually anywhere you have restricted space and power or you require close proximity sound is a good candidate.

Other applications

Because these microspeakers can be mounted on flat surfaces, they could find a ready market in computer tablets, laptops etc, vehicle dashboards and aero cockpits, instruments, calculators, books, talking magazines (SILICON CHIP?), supermarket shelf talkers, white goods and many similar applications.

Motor vehicle tweeters

Another likely market will be to solve an age-old problem in motor-vehicles.

Tweeters in cars are often "buried" – either in the dash, in doors, etc. Due to this, high frequency sound is often blocked by seats, front seat occupants, headrests and more.

So back seat passengers usually don't get quality audio.

But with flat MEMS tweeters, mounted, for example, above everyone's heads in the headlining, everyone could get to hear uninterrupted, full frequency sound! SC