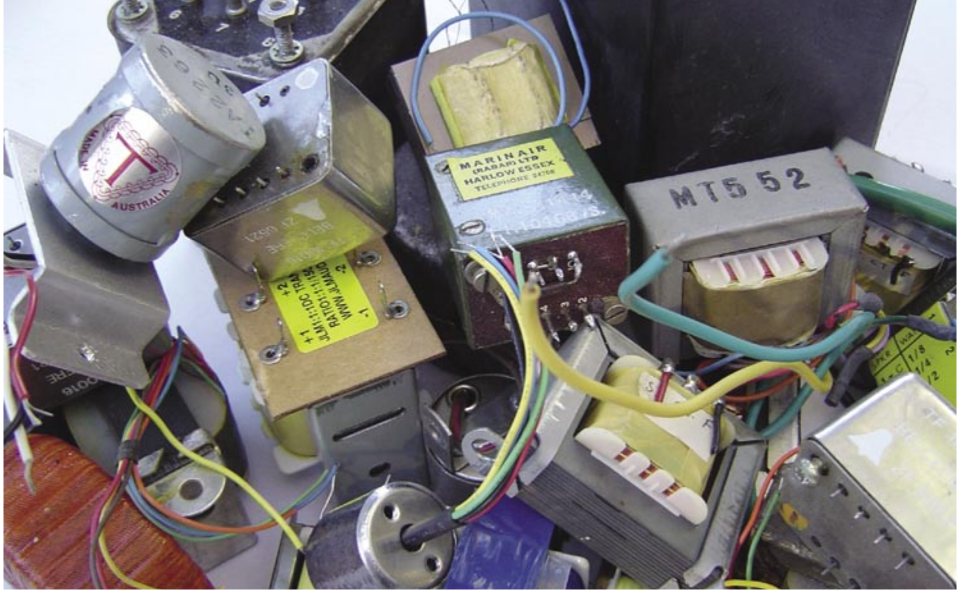
ON THE BENCH
TRANSFORMERS

Ever wondered what a transformer does and why it's synonymous with 'warmth'?

Text: Rob Squire



▶ As the winter chill grips Southern Australia, keeping warm becomes a high priority. Of course, in the audio world we're all trying keep warm all year round – getting some 'warmth' into our recordings seems to be increasingly something many of us want. From my side of the workbench, 'warmth' is often a hard concept to quantify. Often a client will ask for my description of how a particular unit 'sounds' and providing an answer is usually something I try to steer clear of. "You let me know how you think it sounds," is my typical response. You see, I think we're often talking about subtle and subjective qualities and my impressions may not be yours. And by giving my impression I may affect *your* impression… the psychology of audio shouldn't be underestimated!

How then does all this relate to transformers? Well, audio transformers have some easily quantifiable qualities and in exploring these qualities we can find some particular characteristics that may just be the key to generating some of this so-called 'warmth'. So let's kick things off by examining first of all what transformers actually are.

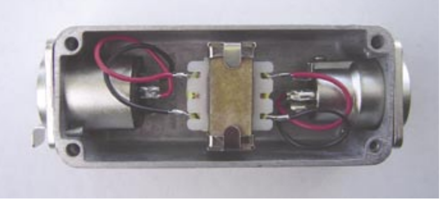
EVENFLOW

Back in Issue 53 I wrote about impedance and in that article inductors were mentioned as one of the fundamental passive components in electronics. Inductors usually consist of a coil of wire. If we take two such inductors and place them together in such a way that they share their magnetic field we create a *transformer*. In this configuration the two coils are said to be *magnetically coupled* and a current flowing through one coil will induce a voltage across the second. In essence, a transformer provides a *transfer of energy*. This simple concept has a number of significant outcomes and this is why transformers are such important devices in electronics, used in everything from power generation and distribution to delivering a useful output from ribbon mic transducers.

ISOLATION

One of the first things that becomes apparent from the construction of a transformer is that the two coils of wire are electrically isolated from each other. This is called *galvanic isolation*. Electrical current cannot flow directly from one coil to the other; effectively the two coils are insulated from one another. Despite this isolation, alternating signals can pass from one coil to the other through their magnetic coupling. Thus, one of the uses of transformers is to isolate one electrical circuit from another. This is exploited in 'mains' transformers that are found in virtually all mains-operated equipment. There's a transformer inside a plug pack, even switch-mode power supplies contain a transformer, which isolates the mains circuit from the equipment. This isolation provides an important safety aspect to equipment running on a potentially lethal mains supply.

Isolation for audio signals can also be an important function of a transformer, not so much for our physical safety, but perhaps for our sanity when confronted by a rig of equipment that's plagued with hums and buzzes. A common source of hum and buzz in an audio chain is currents flowing through multiple ground paths. With careful attention to wiring, ground (or earth) loops *can* be avoided, but every now and then we get a situation that's difficult to solve, and a transformer can provide the solution. Because of a transformer's electrical isolation and ability to pass alternating currents they're great for passing audio from one unit to another while separating the ground of the two units. Therefore, a suitable transformer (or pair of them) installed in a small box with XLR connectors presenting the inputs and outputs can be an invaluable tool to have lying around the studio.



Above is an example of an audio isolation box where pins 2 and 3 of the XLRs connect to the transformer, while pin 1 (the ground pin) is left disconnected, thus separating the grounds. In this example an M0710 transformer from Altronics has been used. This is a surprisingly good line-level transformer. Its only shortcoming is its poor ability to drive low impedance loads. However, in a typical line level and line impedance situation (10 to 20KΩ) it can be just the ticket for ground isolation.

RATIOS

Considering a transformer consists of two coils of wire, it immediately becomes apparent that the two coils can consist of different numbers of 'turns,' as they're called. We call the coil that is driven by a source, the *primary* and the other coil the *secondary*. Since the same voltage is induced in each turn of each winding, the ratio of primary turns to secondary turns yields a *transformation* of the voltage from the source applied to the primary, to a voltage on the secondary that's proportional to the turns ratio. Thus, if we have 500 turns on the primary and 1000 turns on the secondary we have a turns ratio of 1:2, and one volt applied to the primary will yield two volts on the secondary. This is a form of signal gain, but there's no free lunch, as they say! The transformer can't *add* energy or power to the signal – it doesn't possess magical powers. What's traded off is *impedance*.

Our transformer with a 1:2 ratio giving a voltage gain factor of two (or 6dB) is also transforming the impedance of the source. The impedance is transformed by the square of the turns ratio, so the 1:2 transformer has a secondary impedance four times (two squared) the impedance presented to the primary by the source. Think of it this way: if we took a microphone with a typical output impedance of 200**Ω** and used a transformer on its output to get the 40dB of gain that may be required to bring the signal up to line level, we'd need a transformer with a turns ratio of 1:100. This would transform the 200**Ω** output impedance of the microphone to 2M**Ω** – much higher than an electric guitar pickup – thus making it very difficult to connect to anything in the studio. All this also assumes 'perfect' transformers, which don't actually exist in the real world. A real transformer has a variety of losses and imperfections that would make a 1:100 transformer with anything like good audio performance a near impossibility to manufacture.

Practical transformers do exist and are used with ratios of 1:4 at the front end of microphone preamps, where the impedance implications are manageable and, indeed, exploited by designers to optimise signal-to-noise performance in the amplifier stages.

IMPERFECTIONS

Did I mention imperfection? Transformers, like many electronic parts, have a theoretically 'perfect' model, and then the real-world scenario with various shortcomings and quirks. It's some of these real-world qualities that can make transformers interesting and useful audio devices, beyond their ability to simply isolate and convert voltages.

Transformers cannot pass DC (direct current), only alternating signals. They're natural high-pass filters, which makes them gifted at removing sub-bass frequencies, and thus transformers can help clean up audio that's contaminated with air conditioner and road rumble. At the other end of the audio spectrum, at some point in their frequency response they begin to roll off at 12dB per octave. For any half decent audio transformer this will be at supersonic frequencies, say beyond 50kHz, but once again, this can work to our advantage by helping to remove frequencies outside the audio band. The high-frequency response is affected by the design of the transformer with higher turn ratios requiring more intensive winding techniques to keep the response flat and extended. The loading placed on the secondary of a transformer also affects this high frequency behaviour, and designers often trade off the flatness of the high frequency response against the transformer's supersonic frequency extension, beyond 20kHz. (Sometimes a bit of a bump around 16 to 20kHz isn't such a bad thing… a bit of 'air' anyone?)

LISTEN TO THAT DISTORTION

Where things get really interesting is in a transformer's distortion attributes (I know you were all wondering when I'd get back on track and bring 'warmth' back into the article!).

It's pretty easy to demonstrate that transformers have a 'sound' to them. That sound ranges around subjective impressions such as 'warm', 'fat', 'crunchy' or indeed 'cuddly' – as was introduced to the audio lexicon by Brad Watts back in Issue 53… you get the idea. Manufacturers of some of the leading audio transformers often work very hard to minimise these interesting imperfections and top quality transformers are pretty transparent – and 'transparency' certainly has its place.

But for our purposes here, it's time to turn on the soldering iron and explore what can be readily achieved with a pair of low-cost transformers. Remember your *impressions* are the important consideration here.

> "Cheaper transformers tend to distort more, so for our purposes here, this is a good thing."

Distortion in an audio transformer is inversely related to frequency; the distortion increases as the frequency decreases. The distortion also increases smoothly with increasing signal level. This distortion consists primarily of lower-order harmonics, usually a mixture of second, third, fourth and fifth harmonics, which add musically related multiples to the original frequencies. A second harmonic being one octave up from the original tone, a third being up an octave and a fifth. It's this frequency-dependent nature that contributes to the 'sound' of transformers, adding harmonics at the low frequencies, thereby adding to their perceived loudness, while being relatively transparent at higher frequencies and thus avoiding harshness. Cheaper transformers tend to distort more, so for our purposes here, this is a *good* thing.

If we take a transformer like the one you might find in a cheap transistor radio and simply add input and output connectors, we have a cheap device that requires no power, is bulletproof and can be just the ticket for fattening up a kick drum, or driven hard to add some crunch to recordings. This transformer starts adding perceptible harmonics around 0dBu, so it's ideal for hitting at typical line levels; control the level to the transformer to massage the amount of harmonics added!

An analogue microprocessor! Here, the cheap little transformer – an M0222 – has been thrown into the same case as used in the previous isolation box example. Is this the smallest and cheapest effects box around?

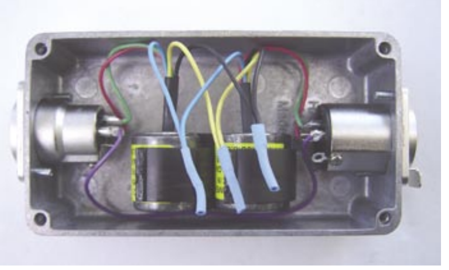
SOME LIKELY CANDIDATES

There is a range of cheap transformers available through general electronics outlets such as Altronics, Jaycar and Dick Smith that were never meant to see inside our pristine recording studios. As it turns out, these can be perfect for building an audio processor.

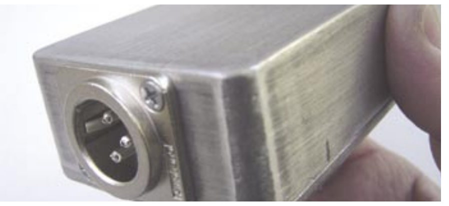
Some likely candidates, such as those used in the example above, are: the M0222 from Dick Smith and Altronics (same part number, different suppliers – must mean something!); the MM2534 from Jaycar; or the M1005 from Altronics. The M1015 from Altronics or MA-1512 also work well but can get pretty ugly at low frequencies, so these could be ideal for adding some real grunge. Interestingly, all these transformers have a pretty decent frequency response so you won't be throwing away top end in search of 'warmth'.

STEP UP

To deal with signals at the initial recording stage requires a slightly more complex approach. JLM audio (www.jlmaudio.com) sells a very good transformer that's designed with a 1:4 step-up ratio, making it suitable to include in a complete microphone preamp design. Taking advantage of this transformer with an existing mic preamp requires strapping two of them together back-to-back. Doing this preserves the input impedance of the mic preamp through to the output of the microphone, and connecting the centre winding tap on each transformer allows phantom power to pass through from the preamp to the microphone. This approach, while more expensive, yields a quality to preamps that otherwise may perform technically well but lack personality or character.



Two JLM 1:4 transformers wired back-to-back to place between a microphone and preamp. The wiring is straightforward: join the black, yellow and blue wire from one transformer to its same coloured mate from the second transformer. One XLR is a male type and connects its Pin 2 to a red wire and Pin 3 to a green wire on one transformer. The other XLR is a female type and connects in the same way to the second transformer. Connect Pin 1 from each XLR together, ensure that the joined wires are insulated from each other with heat-shrink or similar and you're done!



One end of the finished product in a die-cast box.

TRANSFORM YOUR SOUNDS

What you've read here is simply an introduction to audio transformers and doesn't pretend to even *begin* to cover all their complexities and applications. If you're interested in more information there are some excellent white papers available from Jensen that will add substantially to this article (www.jensentransformers.com/apps_wp.html), and future installments of On The Bench will undoubtedly delve into this subject further.

And before I forget, a word of warning: like any coil of wire, a transformer makes a great pickup for stray magnetic fields. This is why transformers designed for low-level signal (such as microphones) are encapsulated in a metal can. At line level, the accidental pickup of hum and buzz from mains wiring, lighting and other equipment is less of an issue but can still present problems. The thing to remember here is that a metal case helps – steel is better than aluminum – and distance is your friend. Magnetic fields fall off with the square of the distance, so increasing the distance between the transformer and other mains-powered equipment (including plug packs) can yield a significant improvement. Good Luck. ■