Electronic Transformers

Their anatomy and application

Dr. Thomas Scherer (Germany)

Low-voltage halogen lamps have grown in popularity since their launch in the 1980s. The same timeframe has seen the development of 'electronic transformers' that are compact, lightweight and economic. What makes them tick — and what other applications can we find for them?

When low-voltage halogen lamps first appeared their power supplies used conventional iron-cored transformers with 12 V AC secondaries. The same applied to those trendy suspension-wire light systems using three miniature 35-W spotlights dangling from parallel wires; the insubstantial airiness of these light fittings contrasted strongly with the weighty circular core of the 100 watt transformers that fed them. Humming hefty lumps of 12 V transformer did not make installation of built-in downlighters any easier either. It's little wonder therefore that the industry was forced to develop a slimmer and less weighty substitute for the time-served transformer with its bulky iron laminations and copper windings. So please pay respect now to the electronic transformer presented in **Figure 1**.

Anatomy

Today of course these tiny electronic transformers are all but universal. They have become so widespread and affordable that three vital questions demand an answer:

- What's actually inside these miracles of miniaturisation?
- What kind of output can we expect?
- What other applications could we dream up for these little gizmos?

No sooner said than done—and bought and dismantled. You probably guessed: inside the plastic case is nothing more than a switch-mode power supply (SMPS). Was this blindingly obvious? Not necessarily, because a close look at the printed circuit board (PCB) in **Figure 2** reveals that the electronics are less conventional than you might have guessed. Certainly we see some diodes, capacitors, an output transformer (right) and two high-voltage power MOSFETs (centre) more or less where you would expect these to be. But there are two surprises:

- For starters, the output does not appear to be provided with any rectification or electrolytics for smoothing.
- Secondly, next to the MOSFETs you might have expected a high-voltage electrolytic for filtering the rectified mains voltage.

For our first observation the obvious conclusion is that our halogen lamps must be run not on DC but on some kind of AC voltage! As far as the second is concerned, the input side of the SMPS must be supplied with a pulsating (rather than smoothed) DC voltage. Consequently we can expect the output waveform to resemble the 100 Hz output of a full-wave bridge rectifier, only the more so because the solitary 68 nF foil capacitor on the output of the diode bridge has far too little capacity to do a proper job of smoothing.

Both dodges make sense: direct current is not essential for lamp bulbs and the absence of rectification not only improves efficiency but also save hard cash. Omitting a high-voltage electrolytic saves both cost and space on the PCB. This elegance of design is matched by the fact that not a single IC is employed. On the rear side of the PCB (**Figure 3**) we discover apart from some SMD-resistors and capacitors merely three transistors and two diodes. The PCB looks a bit flimsy, being only 1 mm thick, but in fact it is made of sturdy epoxy material and not from brittle SRBP (Paxolin, Pertinax). In place of real fuses we have two thin PCB tracks drawn in zigzag fashion. The first 'what' question has now been answered.

Figure 1. An off-the-shelf 'electronic transformer' providing 60 W of power for low-voltage halogen lamps.

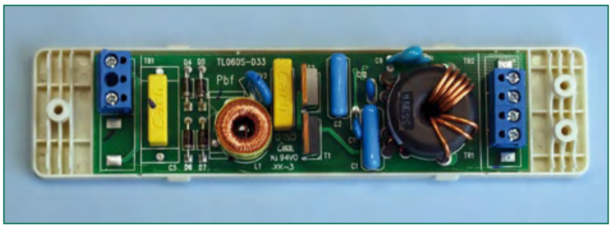

Figure 2. Inside the plastic case we find a straightforward switch-mode power supply using discrete components.

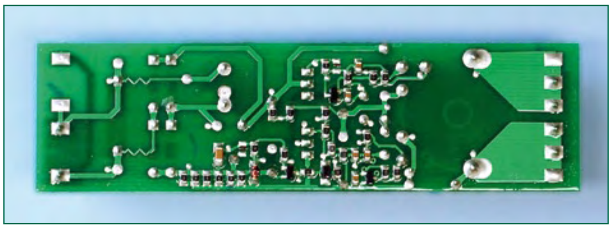

Figure 3. The rear side of the printed circuit board displays a spartan appearance, with no ICs and just a handful of semiconductors.

Curves

The array of components used indicates that AC must appear at the output. And it's a foregone conclusion that the signal there will be in the upper kHz region. Naturally.

Revealed and Explained

So you will be just as astonished as I was when I applied the 'scope to the output terminals. **Figure 4** shows a rather familiar waveform: it's the standard kind of 100 Hz ripple waveform you would naturally expect to see on the far side of a bridge rectifier. But not quite normal, because this waveform displays a mirror image either side of the horizontal.

The riddle is resolved in **Figure 5**: by speeding up the timebase we discover a squarewave signal of about 32 kHz at the output, which is very much what we might expect as the unrectified output of a switch-mode power supply. And as our SMPS is designed to provide a pulsating DC voltage rather than something smoothed and filtered, the output is overlaid with the 100 Hz waveform of the input. The signal of **Figure 4** consists therefore of a 32 kHz squarewave AC voltage amplitude-modulated at 100 Hz.

So, on now to our second 'what' question. Should we be concerned about the overtone frequencies of the 32 kHz squarewave signal, if it is fed to a couple of halogen lamps along two catenary (suspension) wires a metre long? Definitely, because this device would transmit a broad band of radio interference starting in the RF region and extending into medium wave territory. Disappointingly, there's no mention whatsoever of this either on the plastic case or in the instruction leaflet. Despite the pretty CE symbol displayed on the casing (and a number of international technical approval markings), a radiating electronic transformer of this kind should be better screened and ideally not used at all for catenary wire lighting.

Applications

Now just the final 'what' question remains. Having determined that an electronic transformer is best used only with screened (metal-cased) lamp fittings, we need to say something about the stability of the output voltage. The nominal voltage of 11.2 V (unloaded) drops to 11.0 V when supplying a 5 A load current. That's certainly a fraction less than the 11.5 V marked on the unit but of adequate stability for this voltage.

Because this kind of '12 V transformer' offers such good bang for our buck — models rated at 105 W (around 8.5 A) are available cheaply — it's well worth seeing if this bargain might have alternative applications. Most of these will demand direct current and we could simply rectify and smooth the output voltage. The high switching frequency means that four Schottky diodes of adequate rating would be preferable to a normal bridge rectifier. For smoothing at 30 kHz around 100 μF/A would be adequate — were it not for the 100 Hz amplitude modulation. So let's remove it altogether.

Figure 6 shows a temporary lash-up with a foil capacitor soldered on the rear side of the PCB, raising the capacity on the input side of the bridge rectifier to a good 700 nF. You can see how effective this is by looking at the output in **Figure 7**, where we see a signal with the 100 Hz component reduced visibly. We can improve on this: up to 50 W a high-voltage electrolytic rated 100 to 220 μF/385 V will be fine. At 100 W and more we would need to raise the capacity correspondingly. As can be seen with our modified electronic transformer in **Figure 8**, such a hefty capacitor

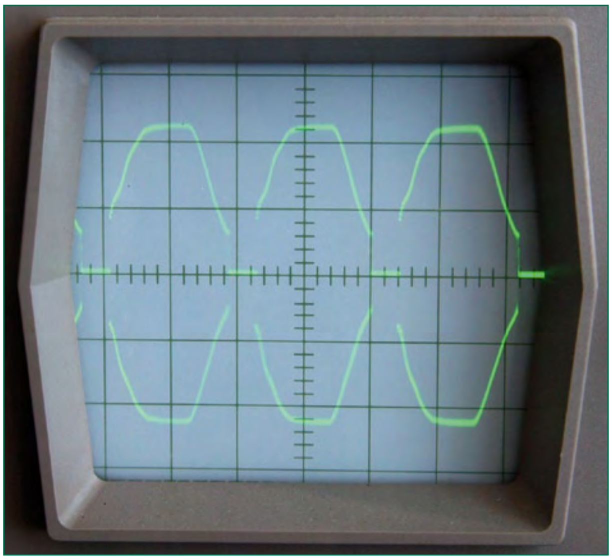

Figure 4.
Output signal waveform at a timebase of 5 ms/division.

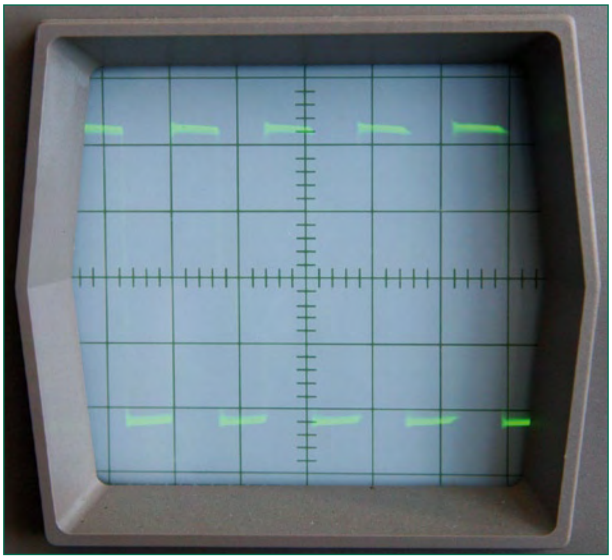

Figure 5.
With the timebase reset to 20 μs/division the high-frequency component becomes visible.

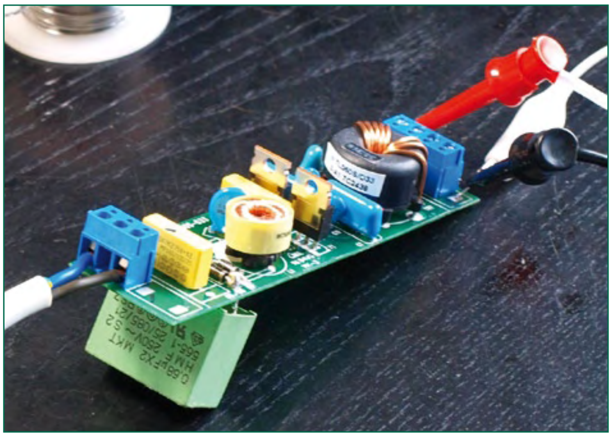

Figure 6.
In this experiment a plastic foil capacitor has been soldered in cascade with the input rectifier to raise the filter capacitance value.

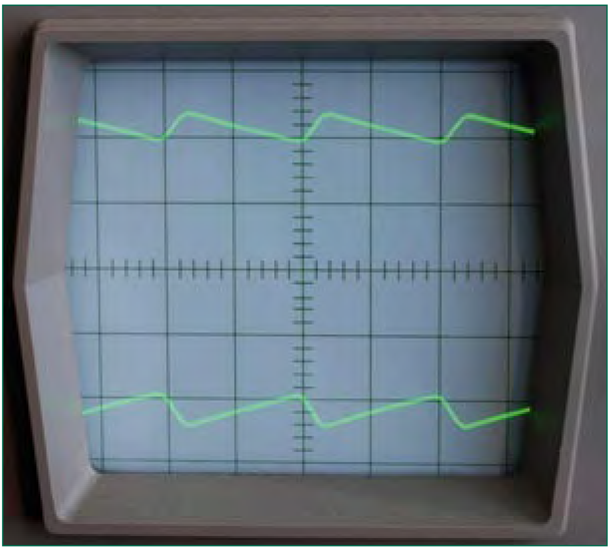

Figure 7.
Improved smoothing on the input side lowers the amount of 100 Hz modulation on the output.

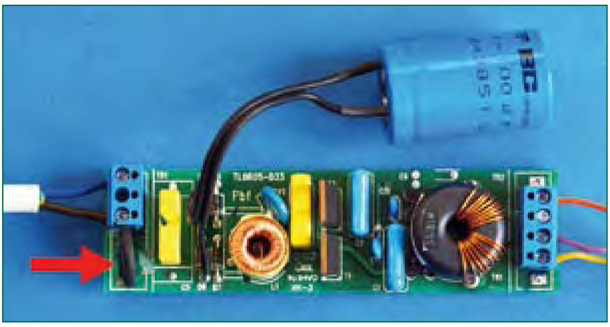

Figure 8.
This modified 60 W transformer has been fitted with a 100 µF filter capacitor (above) and an NTC thermistor (arrowed). The output transformer (right) has additionally been rewound with 2 x 8 turns to produce two 15 V secondaries.

naturally will no longer fit inside the unit's plastic casing. If you are adding a high-voltage electrolytic of this kind for smoothing you will also need to fit a thermistor (NTC) with around 22 Ω cold resistance to the mains lead (arrowed in red) in order to keep the switch-on inrush within bounds.

Adequate smoothing on the output is achieved with an electrolytic rated at 1000 µF/25 V. The 25 V voltage rating is necessary because the output's peak value can rise to around 16 V. With these two modifications made, we have now created an affordable SMPS that delivers around 15 V direct current.

In **Figure 2** the eight turns of the secondary winding of the output transformer are clearly visible. As the primary winding is extremely well insulated with a layer of plastic, this enables us to remove the secondary winding and substitute something different to produce different voltages. On the models we looked at each turn produced 2 V or so. You could for example wind two enamelled copper wires in parallel and produce a winding with a precise centre tap, which would enable you to achieve full-wave rectification with just two diodes. That would save one diode path and reduce losses in the process.

Conclusion? An electronic transformer makes an ideal basis for a cheap, lightweight power supply. And 'green' too — the example illustrated develops a measured efficiency of 90 % when operating with its nominal load!

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Warning!

Any experimentation involving mains voltages demands extreme care and absolute respect for electrical safety guidelines and separation distances.