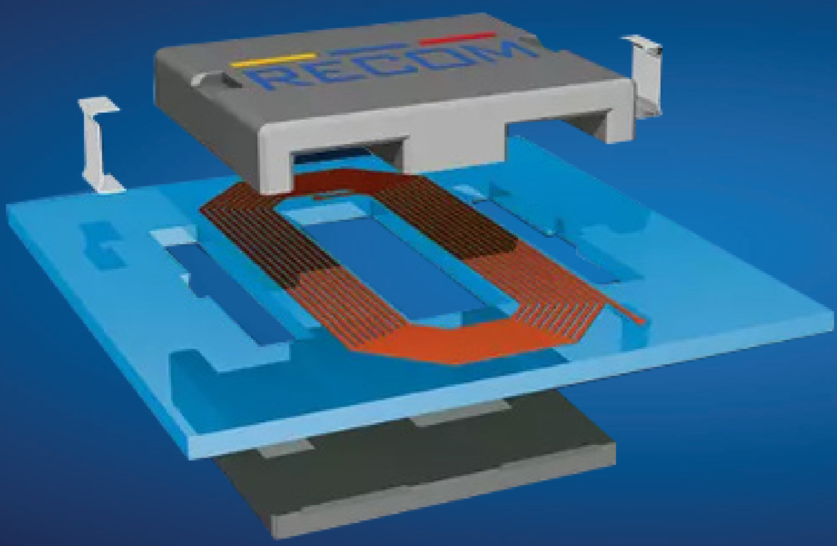
NEW ISOLATED DC/DC TOPOLOGY MAXIMIZES RELIABILITY WHILE MITIGATING COST & SUPPLYCHAIN DISRUPTION



Transforming Legacy Industry Essential: Optimal Balance, Flexibility, and Automation. Explore how a traditional industry staple has evolved for improved efficiency, reduced errors, and adaptable product roadmaps.

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ABSTRACT

Many different DC/DC converter topologies have been developed, each with unique characteristics. However, it is uncommon for a new design to transcend the limitations of established, proven architectures while introducing modern benefits — particularly in low-power applications.

In this whitepaper, we examine how a longstanding workhorse of the industry has been enhanced to deliver a more optimal balance of size, weight, power efficiency, and cost. At the same time, it enables flexible product roadmaps by supporting a broad range of input voltage options along with both isolated and regulated output capabilities. Adopting a topology compatible with automated transformer manufacturing also helps reduce manual intervention, thereby minimizing the risk of human error.

INTRODUCTION

The core of any isolated DC/DC converter is its transformer. Since transformers only operate with alternating current (AC), every isolated DC/DC converter fundamentally performs a DC-to-AC and then an AC-to-DC conversion process (Figure 1).

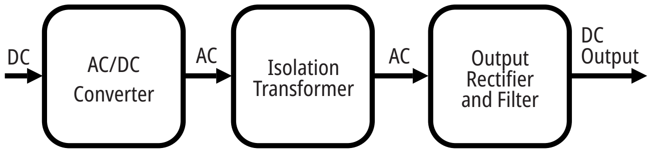

Figure 1: Isolated DC/DC converter block diagram

The most basic form of DC/AC conversion involves a free-running oscillator that produces a square wave across the primary winding of the isolation transformer. On the secondary side, the simplest AC/DC converter consists of a diode-capacitor network that rectifies and filters the waveform to produce a DC output voltage.

The simplest complete DC/DC converter design is the self-oscillating Royer topology-an unregulated push-pull converter (Figure 2):

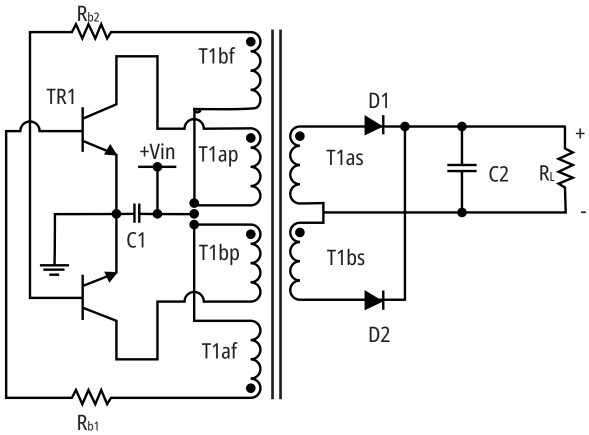

Figure 2: Royer Topology

This circuit includes only eight low-cost components in addition to the transformer: two transistors, two resistors, two diodes, and two capacitors. The transistors TR1 and TR2 are alternately switched on and off in antiphase by the two feedback windings T1af and T1bf, and the secondary winding output is rectified by diodes D1 and D2 before being smoothed by the output capacitor C2. For a full analysis of the Royer topology, refer to the DC/DC Book of Knowledge.

A Royer topology DC/DC converter offers several advantages: a low bill of materials (BoM), compact size (as small as <0.5cm^3), and high isolation (up to 4kVDC for 1 second). It is also easy to configure for dual ± output by adding an extra capacitor and reversing D2, making it ideal for powering dual-rail op-amps, analog-to-digital converters, or bipolar sensor circuits. The main drawback is that the output is unregulated, but with a stable supply voltage and a 10–100% load range, the output voltage typically remains within ±10%—an acceptable range for low-cost applications.

For low-power applications requiring galvanic isolation, it remains the most widely used DC/DC converter solution on the market.

MINIMUM COST BARRIER

Despite the success of Royer converters, there is a constant push from the market to drive costs even lower. The main fixed cost is the transformer construction (Figure 3). These are typically hand-wound on toroidal ferrite cores because their very small size (6mm outer diameter and 3mm inner diameter) makes them too small for traditional transformer winding machines.

Figure 3: Typical hand-wound miniature transformer

The material cost of the toroidal transformers (core, transformer wire) decreases with increased production volumes, but the assembly time per transformer remains fixed. This results in a minimum manufacturing cost—even at production volumes in the millions (Figure 4):

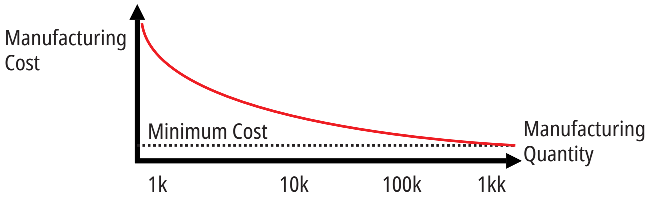

Figure 4: Manufacturing cost vs. quantity

With such a low BoM count, there are limited opportunities to reduce component costs further. Since much of the assembly work is manual (winding the transformers, soldering the transformer wire ends to the PCB), costs could be lowered by outsourcing to low-wage countries. However, as RECOM is a responsible employer and values the experience and skills of its operators, we insist on paying a fair wage.

The solution is to make a paradigm shift—adopting a different topology and transformer design that supports fully automated manufacturing.

NEXT GENERATION DC/DC CONVERTERS

For a transformer to work, it needs at least one turn on the primary and one on the secondary. In practice, many more turns are required, depending on the input and output voltage, as well as split center-tap primaries and secondaries. For the Royer topology, two additional feedback windings are also necessary. This requirement for six separate windings is what makes the Royer topology transformer so labor-intensive.

One alternative used by a competitor is to create the windings around the ferrite core using a multilayer PCB with vias, forming electrical connections from top to bottom to create the windings (Figure 5):

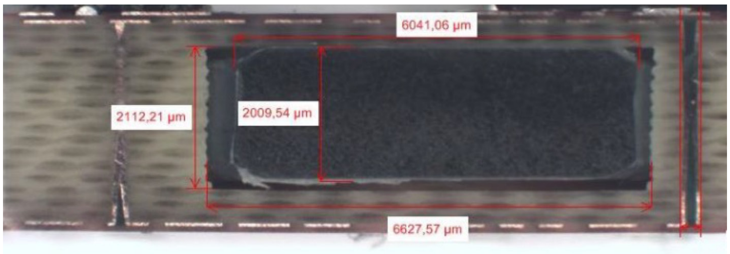

Figure 5: Competitor solution using PCB tracks and electrical vias to form the windings

While this solution does work, the high height-to-width ratio of the via connections (100:1) is technically challenging to achieve with high reliability, which increases production costs.

An alternative to long vias is to implement the windings as spirals on the PCB layers and clip two halves of the ferrite core around the PCB—a method known as planar transformer construction (Figure 6):

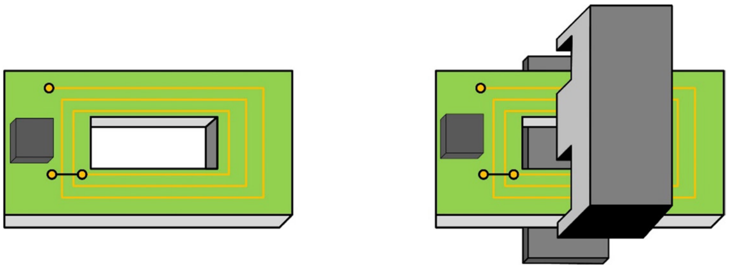

Figure 6: Planar transformer construction

Since most of the PCB layer area is occupied by the primary and secondary spiral windings, there is limited space to add the two feedback windings required for the Royer topology. Furthermore, the Royer topology relies on positive feedback to enhance switching speed and depends on core saturation to interrupt the feedback loop on each cycle, making it incompatible with planar transformer designs.

To adopt a planar transformer approach—where the PCB containing the windings can be mass-produced and the transformer fully assembled through automation—the Royer topology must be abandoned.

The alternative is a push-pull transformer driver IC, which integrates an oscillator, control logic, a MOSFET power stage, and additional features such as over-current and over-temperature protection (Figure 7):

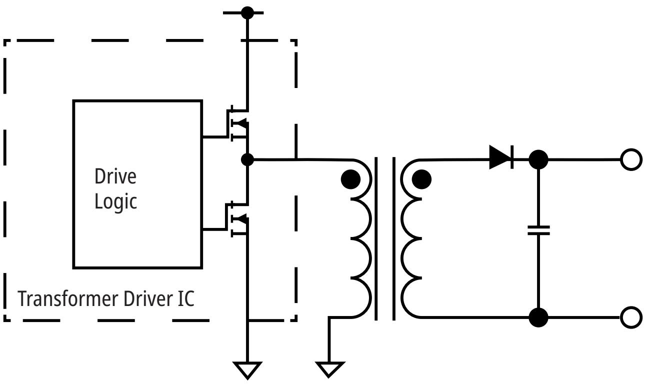

Figure 7: Push-pull transformer IC with planar transformer

While the transformer driver IC provides benefits like a wider input voltage range and reduced EMI, at low volumes the IC alone can cost more than a complete Royer DC/DC converter. However, at very high production volumes, economies of scale drive down the BoM cost to the point where the overall production cost becomes lower than that of the simpler Royer design (Figure 8):

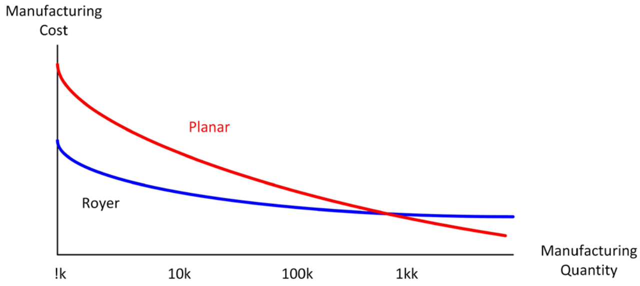

Figure 8: Royer vs Planar topology manufacturing cost

SUMMARY

	ROYER	PLANAR
BoM cost	Lowest possible	Higher
Transformer construction	Time-consuming, manual	Fully automated
Assembly cost	Fixed, even with high volume	Reduces with increasing volume
Line regulation (± 10% input voltage variation)	Unregulated (± 8%)	Regulated (<5%)
Load regulation (10-100%)	Unregulated (± 10%, rising to +25% with no load)	Regulated (< ±5%)
Short circuit protection	No	Yes
Efficiency	75-84%	>85%
Isolation	4kVDC/1s	4kVDC/1s
Operating temperature	Industrial (-40°C to +85°C)	Automotive (-40°C to +105°C)
Performance consistency	Good	Excellent
Overall cost (high volume)	Low	Lower

CONCLUSION

The transition from Royer to planar transformer-based topologies enables manufacturers to meet modern requirements for cost-efficiency, automation, and reliability. As demand for scalable, high-performance solutions grows, adopting these next-generation converters presents a clear competitive advantage.

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