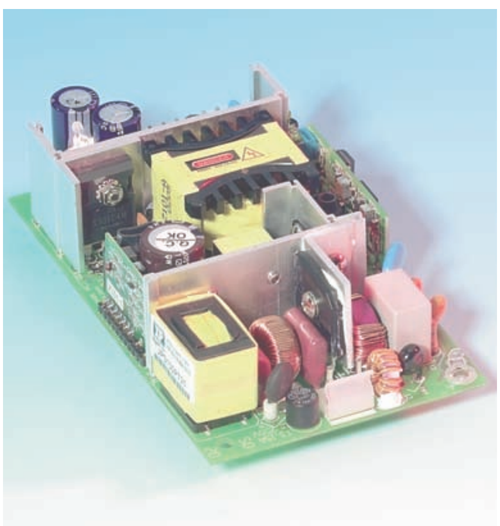
Synchronous Rectification Joins the Mainstream



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Introduction

Synchronous rectification delivers higher efficiency and therefore more compact power conversion equipment. Early products were aimed at the premium end of the market, with premium price tags. However, using patented technology and a new topology, it has proved practical to bring the benefits of synchronous rectification to a wider range of more price-sensitive applications, and this article illustrates how high efficiency power supplies are now available at 5 V and below, within a mainstream 130 W range.

What is synchronous rectification?

Rather than using output rectifier diodes to conduct when forward biased, synchronous rectification uses switched MOSFET transistors. The success of the technique has been driven by the rapid reduction in the cost of high current MOSFETs, combined with a significant reduction in the available 'ON' resistance values. The benefits become clear by considering losses at 20 A:

A diode with nominal 0.5 V forward voltage gives a power dissipation of:

20 x 0.5 = 10 W

Whereas a MOSFET 'ON' resistance of 14 mOhms at 100 °C, gives a power dissipation of:

20 x 20 x14 = 5.6 W

This results in a 4.4% increase in efficiency in a 100W power supply.

Although losses are nearly halved, it is worth noting that higher voltage MOSFETs typically have higher RDS values, so synchronous rectification is not ideal for all output voltages. The MOSFET must be switched, and conventional designs use relatively complex ICs to provide the timing and control necessary, often offering precision performance, but at a price. Of particular importance is synchronising the switching to ensure that only one switch is ever ON and to minimise switching losses and noise generation. We shall come back to these issues later, but let us review the core benefits of the technique.

What are the benefits of synchronous rectification?

Although efficiency is often used as the headline feature of PSUs, the benefits become much clearer by focusing on losses rather than efficiency. A change of 10% in efficiency from 80% to 90% represents losses dropping from 20 W to 10 W at 100 W. That represents half the power loss, and therefore half the waste heat. Even moving from 85% to 90% reduces losses from 15 W to 10 W, a 33 % reduction in waste heat.

Less dissipated power may mean no forced cooling and a reduction in the physical size of the power supply (PSU). In addition, when the PSU is mounted close to other electronics, it will not just be heating itself. Equipment failure rates typically double for every extra 10 °C increase in ambient temperature, so reduced PSU losses can improve overall system reliability. Less heat may also mean that the mounting or orientation of the PSU is less critical, since it is no longer vital to align special heatsinks with unimpeded airflow.

Because diode losses depend on I x VFD (where VFD is the diode forward volt drop), paralleled diodes does not reduce dissipation; therefore large diodes are needed at high currents. Conversely, MOSFET losses depend on I^2 x RDS (where RDS is drain-source ON resistance), so splitting current between two MOSFETs reduces each current by two and the dissipation in each device by two2, i.e. to a quarter, halving the total dissipation. The positive temperature dependence of RDS also means that MOSFETs tend to share current well. Being able to use multiple, smaller devices gives significant mechanical flexibility to adjust form factor, height etc, enables the use of lower cost devices.

The low voltage challenge

A quick check of most power supply ranges will underline the difficulties of delivering power at 5 V and below, and it is important to check the datasheet to see whether power ratings are reduced, significantly greater airflow is specified, or the designer is left to work out how to keep a heatsink below a certain maximum temperature.

The limitations of PCB track losses for sub-3V supplies are leading to the widespread adoption of point-of-load regulation, but there is still a significant requirement for 5 V and 3.3 V PSU modules that are easy to use, compact, reliable and low-loss. By focussing on meeting this need at low cost, XP has introduced a new topology incorporating synchronous rectification and several patented innovations to reduce noise and provide power factor correction to further simplify system design. The JPS130 power supply uses the new topology.

Synchronous rectification for the mainstream

Given the need to control MOSFET switching, most existing designs use complex control chips, often delivering sophisticated control and performance features, but placing the core benefits of synchronous technology outside the budget of mainstream systems. These control systems typically combine both input and output control in a single device.

However, by separating the input and output control [See Figure 1] and ensuring that the primary DC bus voltage is held stable, limiting the range of duty cycle within the switching power stage, the output MOSFETs can be switched using relatively simple, and therefore inexpensive, control. Since this input stage can drive either a conventional diode output, or a synchronous rectifier output, it is possible to produce a single range that matches the output section to the rated voltage, i.e. synchronous rectification for 5 V and 3.3 V units and conventional output rectifier diodes for higher voltages, maximising volume cost advantages.

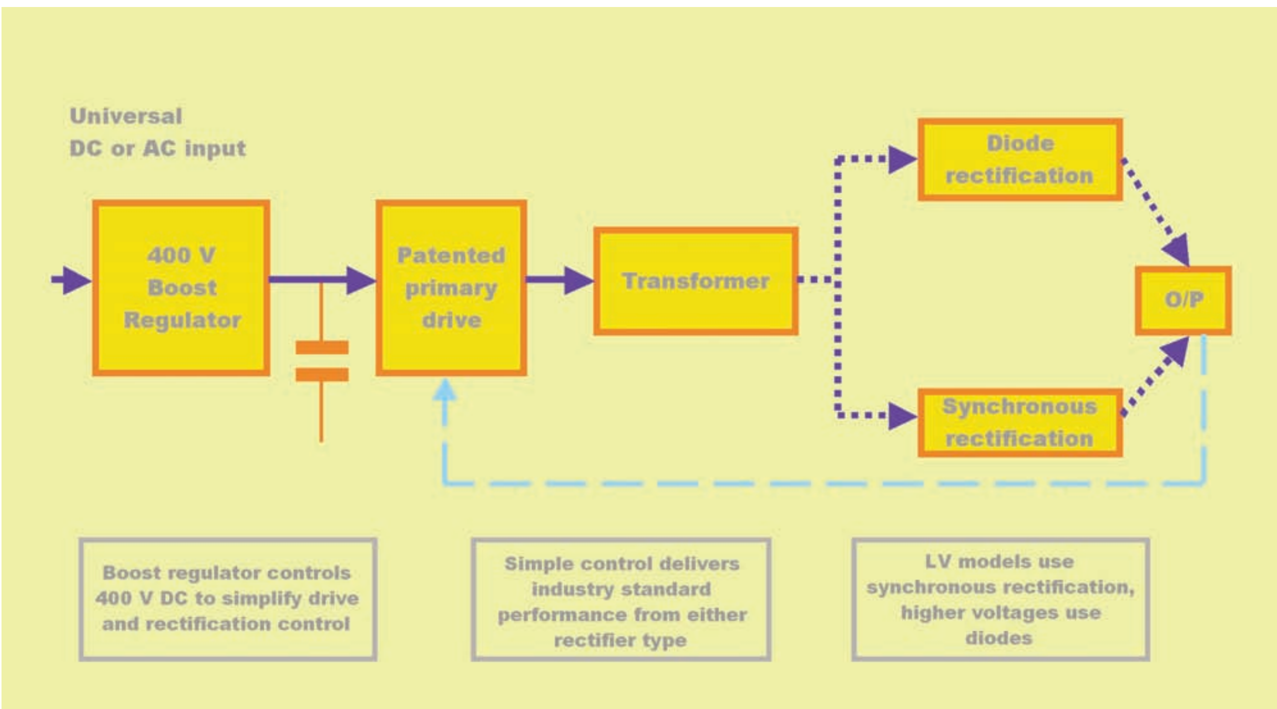


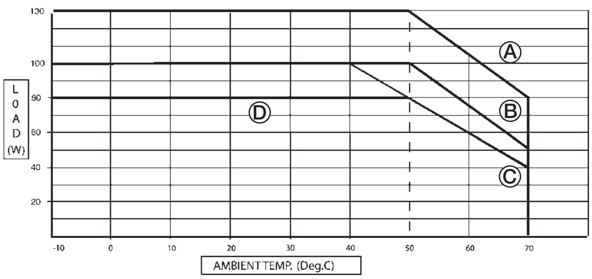
Figure 1.

The input section is designed as a boost sub-system, enabling the design to maintain the DC line across the universal range of 85 – 264 VAC, from 47 – 63 Hz, with built-in active power factor correction to give a typical power factor >0.9 and enabling the low-cost output stage to deliver industry-standard performance. All the usual features such as over-current and over-voltage protection, remote sense and high MTBF are achieved, but there are some additional issues needed to make the PSU simple and economical to use.

Hidden Costs

Most system designers have met the additional cost of having to provide forced airflow, with attendant concerns such as fan reliability and excessive noise, so performance should be simple to understand. The same size module is rated at 130 W in 18 CFM air, and 100 W for convection cooling, whether 48 V or 5 V output, thanks to the use of synchronous rectification for the 5 V model and below, and unlike other ranges where 5 V and 3.3 V have the same output current, the JPS130 3.3 V model delivers 25 % extra current at 25 A, compared to 20 A for the 5 V unit. As can be seen from Figure 2, convection cooling enables 100 W up to 50 °C ambient for 48, 24, 15 and 12 V models, and up to 40 °C for 5 V, with 80 W available up to 50 °C from the 3.3 V model.

Figure 2



Ⓐ **JPS130 with 18 CFM fan.**

Ⓑ **JPS130PS12, PS15, PS24, PS48 with convection cooling & JPS130PS03 with 18 CFM fan.**

Ⓒ **JPS130PS05, PT30, PT31 with convection cooling.**

Ⓓ **JPS130P03 with convection cooling.**

Figure 2.

Power supplies are critical to equipment EMC performance, but although system performance will naturally depend on issues such as loading and wiring, it is clear that if a power supply only just meets the required EMC standards, any locally created noise is likely to cause problems. The lower the EMI noise of the PSU, the easier it will be to achieve EMC compliance for the whole system, and since switching contributes significantly to EMI noise as well as providing another component of power loss, this aspect of PSU design is key.

Ring-free zero voltage switching

Since the paper by Henze et al (See Reference 1) zero voltage switching (ZVS) has been widely explored as a way to deliver compact, efficient power conversion. Resonant circuits typically required either a large gap for the main transformer core, or an external inductor, but parasitic ringing between leakage inductance and stray capacitance introduce additional losses and unwanted noise. Since the paper by Henze et al (See Reference 1) zero voltage switching (ZVS) has been widely explored as a way to deliver compact, efficient power conversion. ZVS power stages employ resonant circuits, which typically require either a large gap for the main transformer core, or an external inductor, but parasitic ringing between leakage inductance and stray capacitance introduce additional losses and unwanted noise. By using a patented ZVS switching circuit, which automatically clamps ringing for both inductive and capacitive components, a 6dB improvement in noise has been achieved, reducing power losses, lowering the reverse voltage rating for the secondary rectification and increasing the practical operating frequency. These benefits apply whether the output is synchronous rectification (5 V or 3.3 V) or conventional diodes (12 V and above) and contributes to the 6.7 W/in3 power density for the 5 V to 48 V models.

Synchronous rectification for all

When introduced, synchronous rectification was a revolution, but perhaps it is time for system designers to move on and focus on what a given power supply will do for their system and the overall design process. With this new topology, the technology is now affordable for mainstream systems, so designers can return to looking at the fundamentals of their system needs, rather than viewing synchronous rectification as a ‘holy grail’.

Although efficiency is a common headline specification, comparing the actual power loss will give a better comparison between the system-level impacts of different PSUs, and provide a more valuable insight into factors such as cooling requirements and overall reliability. It is also important to address issues such as EMC margins and input power factor to ensure that the final system meets international standards for EMC immunity and emissions.

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