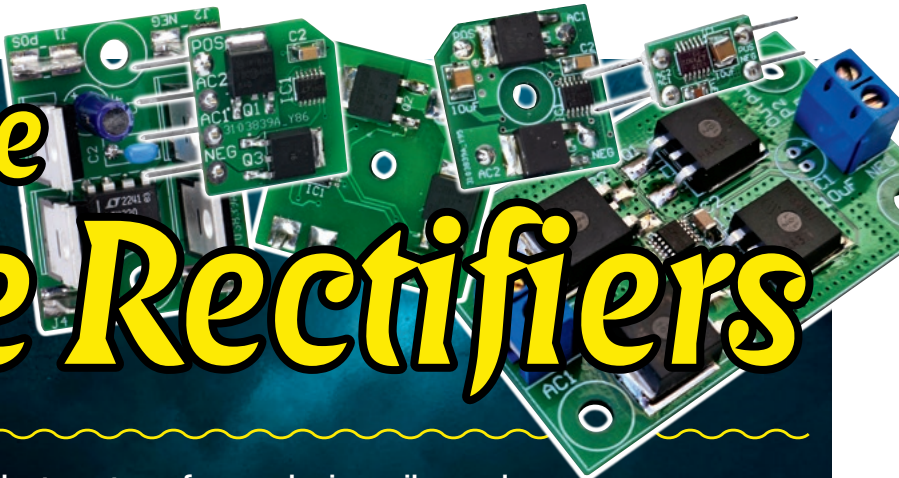




Ideal Diode Bridge Rectifiers

By Phil Prosser

Rectifiers have evolved a lot over the last century, from selenium piles and mercury arc rectifiers to vacuum tube diodes, then germanium and silicon diodes. Now, active rectifiers offer much greater efficiency than silicon diodes, running much cooler. We show you how to make up to six different Bridge Rectifiers depending on how much power you want.

In the simplest terms, an ‘ideal diode’ uses a power Mosfet with a control circuit to replace a rectifier diode. Combining four such devices gives you an ‘ideal bridge rectifier’.

While they are not truly ideal, they are much closer than a regular diode, with a forward voltage (and thus power loss and heat dissipation) typically around $\frac{1}{10}$ that of a normal diode.

This idea caught my attention because I realised it would allow us to build devices like power amplifiers or power supplies that operate more efficiently and deliver more power, as less is lost in the bridge. Bridge rectifiers used in large power amplifiers need a lot of heatsinking! They can dissipate tens of watts under heavy load.

That all changes with this design, which is a drop-in replacement for many existing bridge rectifiers.

When designing my Dual Hybrid Power Supply, (February & March

2022; siliconchip.au/Series/377), I wished I had the time to delve into these active bridges, as the power loss in a high-current DC power supply bridge is also significant. For example:

- The PB1004 10A bridge rectifier (Altronics Cat [Z0085](#)) has a forward voltage drop of over 1V at 5A, or 2V across the bridge. This means it is dissipating 10W at 5A.
- The KBPC3510 35A bridge rectifier (Altronics Cat [Z0091A](#)) drops 1V at 10A, resulting in a 2V loss and 20W dissipation at 10A.

The 2V drop is manageable, if annoying, by increasing the transformer voltage. However, transformers often come in 5V steps, meaning you might be wasting a lot of power to compensate for that relatively small voltage loss.

On the other hand, that 10-20W dissipation is troublesome, as it demands a substantial heatsink and forces

physical layout decisions to enable this heat to be dissipated.

Pros and cons

By comparison, if we use an LT4320 ‘ideal bridge’ controller and TK6R9P08QM power Mosfets, we will see 70mV maximum drop per device at 10A, which is a total of 1.4W or about $\frac{1}{10}$ th of the heat you get from a standard bridge rectifier!

So what is the catch, and why aren’t these used everywhere? I suspect there are a few reasons:

1. One of the complications that needs to be dealt with is generating the V_{GS} drive for the N-channel Mosfet, which requires a boost circuit to drive the gates well above the source voltages.

2. For a bridge, you need four power Mosfets and a controller, which increases parts count and cost.

3. The real benefits are accrued when rectifying lower voltages at high currents or if you cannot afford losses in your system (or when high efficiency is essential).

4. Because of how the control and switching works, for the simplest off the shelf solution, a dual-rail power supply (such as for a power amplifier) needs two bridges, each fed by one of the two secondary windings.

5. Your rectified output voltage rail needs to stay above 9V, or bad things happen (more on that later).

The best use cases for an ideal diode bridge rectifier are where space and capacity to dissipate power are limited, where voltage drop from the transformer is undesirable and where

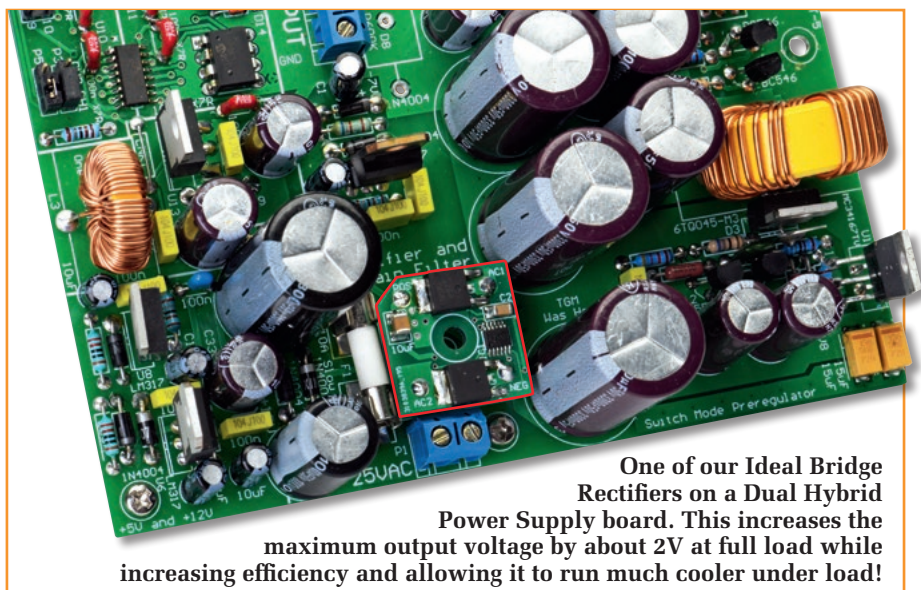
Lessons learned during the design process

The design of these modules served as a reminder on the need for attention to detail and the value of peer review. I did the bulk of the PCB layout while I was on holidays, and since there were only seven parts, what could go wrong? Plenty.

When I was making the CAD library for the LT4320 IC, I stuck the ‘pin’ that denotes the thermal pad for the IC in the wrong spot. This led me to assume it connected to the positive pin rather than the negative, where it belonged. I then laid out seven variants of this board from the schematic, all with the pad connected to the wrong output.

I now know that the LT4320 will work for several minutes with the thermal pad tied to the wrong pin, but after that, it will blow up, take out your Mosfets and short your transformer! I found the bug after blowing many fuses, \$100 worth of bits, wasting a couple of days, and my whole budget of four-letter words.

To add insult to injury, I had to respin all the different prototype boards, another \$100 lesson. Ouch! All for about 2mm of misplaced PCB trace.



lower voltages at higher currents need to be rectified.

In terms of using Mosfets to replace diodes, it is interesting to note the growing use of 'synchronous' switch-mode converters. In this case, the usual schottky diodes are replaced with power Mosfets. Many synchronous switch-mode controllers include an output to drive the diode replacement Mosfets, resulting in increased efficiency.

Design approach

Given the desire to investigate this technology, our efforts turned to an integrated solution. We wanted an option that could be used in a range of projects and showcase the potential of this technology, without making construction too tricky or the device too expensive.

A survey of ideal diode controller ICs shows that many are intended for hot-swap and redundant power supply applications. In this case, multiple power supplies are combined in an 'OR' function so that if one supply fails, the other picks up the load. Supply currents can be very high in a server application, so reducing diode losses is critical.

We also found several controllers for automotive applications, in alternators and circuit protection. These are generally intended for single-rail applications and are not suited to more general AC rectification. In particular, most utilise the diode to operate the circuit itself. This limits their application as generic diode replacements.

The range of available parts in this field is growing, so new ICs that are useful in a range of applications are coming on the market. In this project, we show how to use the most available controller IC and build a range of 'ideal diode bridge rectifiers' that can replace conventional diode bridges in various projects.

The controller we have selected is the LT4320, as this allows simple and compact boards to be built, ranging from tiny SOT-23 Mosfet based bridges through DPAK (TO-252) to very high current TO-220 based through-hole versions. Where might each of these be used?

- The SOT-23-based bridge is only $9 \times 15\text{mm}$ and can be used inline on the DC power supply lead to a device or soldered in place of a small bridge. This can make the power lead for your device polarity agnostic without affecting its operation noticeably.
- Our boards using DPAK SMD Mosfets can replace the common 5mm pitch 19mm SIL bridge or rectangular bridges with corner pins or spade connectors (see the photo above) and handle high currents.

- There are also two 'standalone' versions that are basically just small boards you can mount in a chassis to provide the rectification function. One uses TO-220 Mosfets and other through-hole parts and can handle very high currents, limited mainly by the PCB itself!

There are a few limitations or requirements we need to work with that initially may sound onerous. However, in a real-world application,

the following are not that hard to meet:

- The LT4320 works in a 'single-rail' configuration only.
- For an audio amplifier, you need to rectify the outputs of the two secondary windings independently. You then connect the negative output from one bridge to the positive output from the second bridge to get your split supply, usually at the main capacitor bank.
- We have achieved pin compatibility for all the larger bridge types. But DIP-8 and W02/W04 type bridges are a bit small for us to match, so if replacing one of those, you will need to mount the SOT-23 version on leads.
- The minimum output voltage allowed is 9V DC, while the maximum is 72V peak. This means that we should limit the AC input to 40V RMS to provide reasonable safety margins. We must ensure that the rectified output's minimum voltage does not drop below 9V during operation.

How it works

Its operation is similar to a diode bridge but with a controller IC that turns the Mosfets on when required to minimise losses. Fig.1 is the circuit diagram while Fig.2 shows how current flows during the two main phases when the bridge is conducting.

The Mosfets are arranged so the current flows from their source to drain terminals in regular operation, the opposite to a standard common-source Mosfet switch application. This is so that the current flows through the Mosfet body diodes in the forward direction.

Therefore, in the absence of the controller, current would flow through those body diodes. However, there would be a high typical 1V forward drop at high currents, similar to a silicon power diode.

During operation, the LT4320 determines which of the input voltages (IN1

& IN2) is lower and switches on either Q3 or Q4 full to connect the input terminal with the lower voltage to the negative rail and hence the negative output.

The controller switches Mosfet Q1 or Q2 on when current flows through them, reducing the effective forward voltage to about 20mV. The drop is set by the controller; if the LT4320 detects a differential greater than 20mV between the highest AC input voltage

and the output terminal, it switches the respective Mosfet on harder.

If the Mosfets have a relatively high $R_{DS(ON)}$ figure resulting in more than 20mV across the Mosfet, it will be switched on fully, and the input/output differential will be higher than 20mV.

The gate drive to the Mosfets is not very 'strong' in that a fairly low current is supplied. This reflects the application for this IC in low-frequency

(50/60Hz mains) or for the MT4320-1 (to 600Hz) operation.

With a 9V DC output voltage and the top Mosfet (Q1 or Q2) V_{GS} at 2V, the pullup current is only 500 μ A. Our recommended DPAK SMD Mosfet, the TK6R9P08QM, has an input capacitance of 2.7nF. So the gate voltage will change at a rate of 180mV/ μ s.

That is terribly slow compared to most Mosfet applications, but for mains-frequency operations, if each Mosfet is on for 10% of the cycle, that's 2ms. The switch-on time of 20 μ s or so is only 1% of that period. The losses are minimal because this switching is just as the mains cycle crosses over.

The 1 μ F ceramic capacitor across the OUTP and OUTN pins is important for the correct circuit operation as it prevents the output voltage from changing too rapidly. It should be kept as close to the LT4320 as possible.

The Ideal Bridge Rectifier can operate from 9-72V. If the rectified output goes below 9V, the LT4320 will not drive the Mosfet gates, and rectification falls back to the body diodes in the Mosfets. This is OK at startup, but we must ensure the rectified rail remains above 9V afterwards. We will come back to this later on.

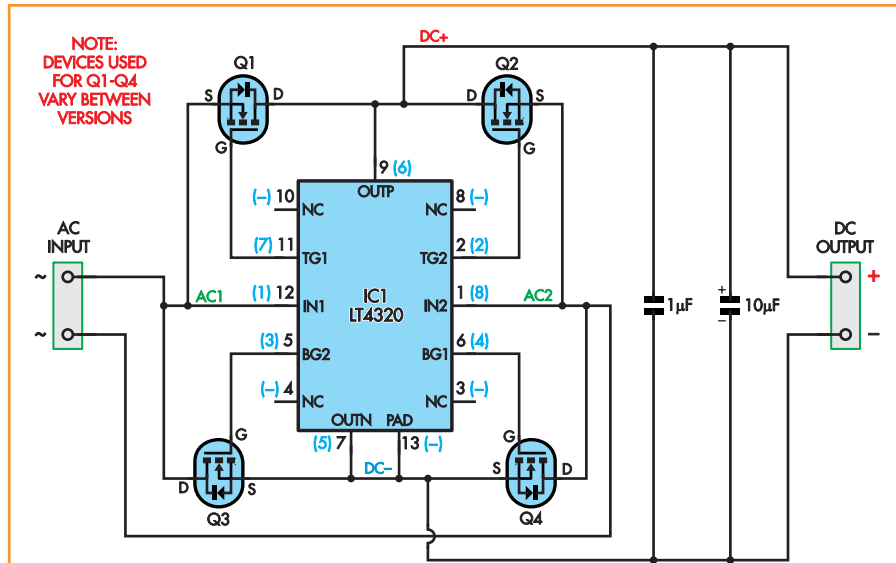
During tests where we were hammering the bridge and applied a load so severe that the output voltage dropped below 9V, we found that the Mosfets were getting hotter than we expected. However, that's a fairly unusual situation for a real bridge rectifier.

Parts selection

There were a few things to keep in mind when choosing the Mosfets for this design. We have tested the devices specified in the parts list and in the panel titled "Ideal Bridge Rectifier PCBs", although there is no doubt that many others would work. Besides being in the correct package for the board, they need sufficiently high voltage and current ratings, low on-resistances (for highest efficiency) and a gate-source threshold voltage in the correct range.

For the latter, the recommendation is that it should be more than 2V. This is required to ensure that the controller can switch the Mosfet off quickly, to keep efficiency high.

Many modern Mosfets have a low gate threshold to allow them to be controlled by lower voltage circuits (often



IDEAL BRIDGE RECTIFIERS BASIC CIRCUIT

Fig.1: the circuit is slightly more complex than a conventional bridge rectifier. Pin numbers in black are for the MSOP-12 package while those in brackets in cyan are for DIP-8. Dashes in parentheses indicate pins that don't exist on the DIP-8 package.

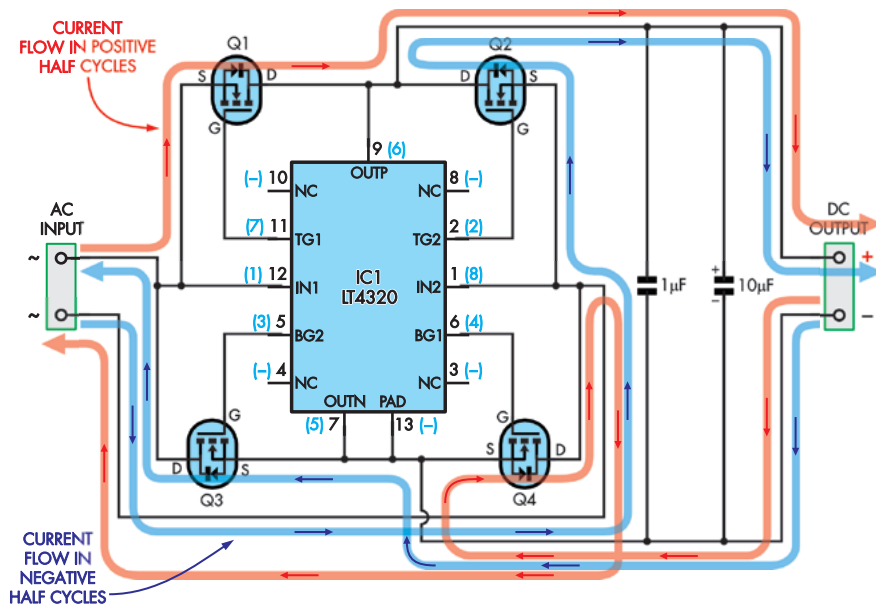


Fig.2: during part of the mains waveform, when the upper AC input voltage is higher than the lower, IC1 switches on Q1 & Q4 and current flows via the red paths. During the opposite part of the waveform, the upper AC input voltage is lower, Q2 & Q3 are on and current flows via the blue paths.

called ‘logic-level’ Mosfets), making them unsuitable. These can sometimes be spotted as they tend to have a lower maximum V_{GS} rating, below the $\pm 20V$ to $\pm 30V$ that used to be typical. However, there are still logic-level Mosfets with a higher V_{GS} rating, so you need to check the data sheet.

As for the current rating, in a bridge rectifier, the current usually only flows while the reservoir capacitors are charging. With very large capacitor banks and a low internal impedance transformer, this can be pretty short, resulting in peak charging currents much greater than the average (or “DC”) current being drawn from the power supply.

The recommendation is that the Mosfets have a DC rating triple the average direct current. Therefore, we have selected Mosfets with higher current ratings than you might expect are necessary.

However, we tried not to go overboard with this as ultra-high-current Mosfets tend to have a high gate capacitance. The LT4320 does not have a strong gate drive capability, so that would slow switch-on and switch-off, resulting in increased losses.

The $V_{DS(MAX)}$ rating should be well above the voltage at which you want to operate the bridge, with a solid margin to allow for ringing and spikes. We looked for a minimum rating of 80V, although our SOT-23 version is limited to 40V.

Mosfet heating is primarily determined by the average current and their $R_{DS(ON)}$. For the TK6R9P08QM DPAK Mosfet we use in many module versions, the typical $R_{DS(ON)}$ is specified as $5.5m\Omega$ for $V_{GS} > 10V$.

The LT4320 delivers about 11V to the gates for voltages greater than 13V. For an average current of 10A, this results in 550mW dissipation in each conducting Mosfet, or 275mW per Mosfet for an AC input, which is easily manageable, and the boards only get warm.

For a current of 20A, this dissipation increases to about 1W per Mosfet, making them very warm indeed, at which point you should consider building the TO-220 version.

The recommended TO-220 Mosfet has an $R_{DS(ON)}$ of $4.2m\Omega$ at full drive and, at 40A, will drop 160mV; it would be closer to 1.2V in a regular bridge at this sort of current. The power dissipation in each Mosfet would be 3.5W for

Ideal Bridge Rectifier PCBs

For maximum flexibility, we have produced six different PCBs that implement essentially the same circuit, as follows:

#1 Square 28mm metal bridge using 6.3mm spade connectors

Compatible with KBPC3504

PCB code: 18101241 (28 × 28mm with a central mounting hole)

Current & voltage handling: 10A continuous (20A peak), 72V

Connectors: 6.3mm spade lugs, 18mm tall

IC1 package: MSOP-12 (SMD)

Mosfets: TK6R9P08QM,RQ (DPAK/TO-252 SMD)

Operates at 10A continuously and much higher currents intermittently but will get hot. In a long-term 8A test, it reached 79°C in free air.



#2 Square 21mm plastic bridge with 13mm pitch pins

Compatible with PB1004

PCB code: 18101242 (22 × 22mm with a central mounting hole)

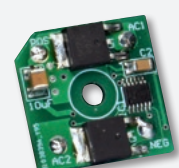
Current & voltage handling: 10A continuous (20A peak), 72V

Connectors: solder pins on a 14mm grid (can be bent to a 13mm grid)

IC1 package: MSOP-12 (SMD)

Mosfets: TK6R9P08QM,RQ (DPAK/TO-252 SMD)

A PB1004 leaded bridge replacement, typically capable of 5-10A. We used these to upgrade our Dual Hybrid Power Supply module.



#3 5mm pitch SIL

Compatible with KBL604

PCB code: 18101243 (23 × 20mm)

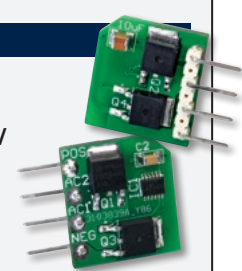
Current & voltage handling: 10A continuous (20A peak), 72V

Connectors: solder pins at 5mm pitch

IC1 package: MSOP-12 (SMD)

Mosfets: TK6R9P08QM,RQ (DPAK/TO-252 SMD)

The 5mm pitch SIL bridge rectifier drop-in replacement module.



#4 Tiny inline bridge

Width of W02/W04

PCB code: 18101244 (9 × 15mm)

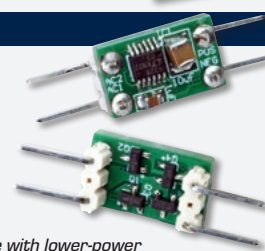
Current & voltage handling: 2A continuous, 40V

Connectors: solder pins 5mm apart at either end

IC1 package: MSOP-12 (SMD)

Mosfets: SI2318DS-GE3 (SOT-23 SMD)

The baby of the crew, the SOT-23 based version optimised for putting inline with lower-power circuits. These Mosfets are rated at 40V & 3.9A, but we reckon a safer limit would be 1.5-2.0A.



#5 Standalone SMD version

PCB code: 18101245 (59 × 36mm with mounting holes in 49 × 26mm rectangle)

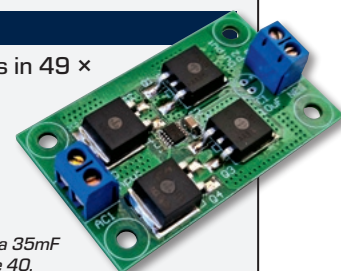
Current & voltage handling: 20A continuous, 72V

Connectors: 5mm screw terminals at either end

IC1 package: MSOP-12 (SMD)

Mosfets: IPB057N06NATMA1 (D2PAK/TO-263 SMD)

The D2PAK version, which I have tested for half an hour at 12V AC and 8A (into a 35mF capacitor with a 2Ω load across it). You can see this being stress tested on page 40.



#6 Standalone through-hole version

PCB code: 18101246 (38 × 28mm with 70μm-thick copper and mounting holes 29mm apart)

Current & voltage handling: 40A continuous, 72V

Connectors: 6.3mm spade lugs, 18mm tall

IC1 package: DIP-8 (through-hole)

Mosfets: TK5R3E08QM,S1X (TO-220 through-hole)

The TO-220 version is a bit of a beast and, along with the D2PAK version shown above, it will easily handle 8-10A RMS continuously. It uses a DIP-8 controller IC and allows you to mount a heatsink to the Mosfets if you want to rectify some serious currents. All the images here are not shown to scale.

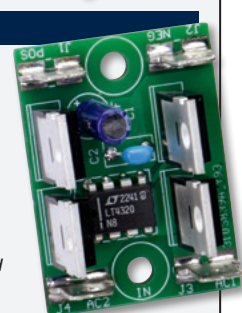




Fig.3: the cyan trace is the positive portion of the incoming AC waveform, yellow is the filtered DC output, while mauve is the positive Mosfet gate drive. The cyan AC trace is offset by -2V; otherwise, the mauve trace would obscure it much of the time.

Fig.4: a similar setup to Fig.2, but this time, we're monitoring the gate of one of the low-side Mosfets (mauve). You can see how it's switched on with a duty cycle close to 50%, synchronised with the zero crossings of the AC waveform.

an AC input, which is significant but manageable with small heatsinks. In this case, a regular diode-based bridge would get toasty, as it would dissipate 48W per diode!

The LT4320 IC comes in an SMD (MSOP-12) and through-hole (DIP-8) version. These are available from all the major component suppliers and will be included in the SILICON CHIP kits.

For the Mosfets, we have tried to stick to standard parts, with DPAK (TO-252) being our overall preference as they are large enough to handle a decent amount of dissipation (~1W) without being so large that they take up a lot of space. The other Mosfets we've used come in TO-220 packages (for really high current applications)

and the tiny SOT-23 (for when space is tight).

By sticking to these standard footprints, you can use alternative parts if necessary.

PCB design

Most of the modules we present use surface-mounting parts to fit into the space we have. We have also resorted to placing components on both sides of the PCB, as doing that was essential to match some of the common bridge rectifier form factors.

For higher-current modules, we need to be conscious of the current rating of the PCB traces. To fit the parts onto the KBPC3504 form-factor board, along with the very wide tracks that a 30-40A rating warrants, is quite

a challenge. Our version manages to keep all high-current tracks short and thick, but that forced the layout to be slightly larger than the original rectifier.

There is no specific 'rating' for PCB traces; there are guidelines, but too many variables exist to realistically put a simple, accurate number to a track width. Still, voltage drop and heating must be considered. In the limiting case, tracks can fuse or melt.

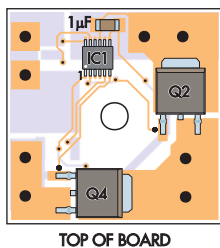
We have specified '2oz' (70µm thick) copper traces on the TO-220 PCB, twice as thick as a standard '1oz' (35µm) PCB. This will halve resistive losses in the PCB at the price of it being a lot harder to solder due to the thick copper acting as a heatsink (although that will have benefits during operation, drawing heat away from components faster).

It is evident that at high currents, even an 'ideal diode' warrants careful attention to power ratings, losses and dissipation. But these are reduced to a level where a practical solution can be developed. We recommend that you pay careful attention to losses and heat if you use this at really high currents. At least verify that the chosen module doesn't get overly hot at your expected maximum current draw.

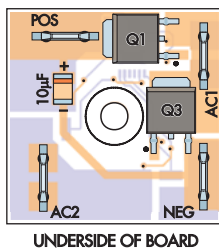
Waveforms & verification

Figs.3 & 4 show the input, output and gate drive waveforms for the Ideal Bridge Rectifier operating at 4A RMS. Note that the AC input is offset -2V to allow a clearer view – there is so little voltage drop across the Mosfet that the output visually 'tracks' the input AC much of the time. The gate drive is over 10V, so the Mosfet is switched fully on.

To illustrate the low voltage drop across the power Mosfet even at 4A, Fig.5 shows the input and output waveforms with no offset.

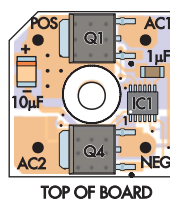


TOP OF BOARD

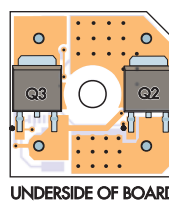


UNDERSIDE OF BOARD

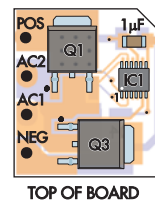
Q1 – Q4: TK6R9PO8QM, RQ or IPD50N06S4-09 or TK5R1P08QM, RQ



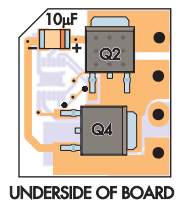
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UNDERSIDE OF BOARD

Figs.6-11: use these overlay diagrams to guide the component placement on each version. The four smaller PCBs have components on both sides. Generally, it's best to fit all the SMDs on one side, then all the SMDs on the other, then any remaining through-hole parts. Note that while we've specified non-polarised ceramic 10µF capacitors for the first four variants, tantalums are shown in case you want to use them, in which case they must be orientated as shown.

Having built the modules, we decided to run some extreme tests as we didn't want our readers to make them only to have them blow up! We loaded the 28mm bridge design (KBPC3504 compatible) to draw 5A RMS from a toroidal transformer and left it running for several hours. The Ideal Rectifier stabilised at 42°C. Ramping the current to 8A led to it reaching 72°C, which is not unreasonable for the current.

Swapping in a regular KBPC3504 at 4A without heatsinking, it reached 79°C after a few minutes.

As shown earlier, we 'upgraded' our Dual Hybrid Power Supply with Ideal Rectifiers, which saves 10W of heat per board at full output or 20W in total. For this, we used the PB1004 format modules and soldered them on leads directly to the PCB, as at 5A, they do not get hot enough to demand a heatsink.

During testing, we had a test setup with a 12V AC output transformer, an Ideal Bridge Rectifier and a 22mF capacitor. Things were going great until we reduced the load resistance to somewhere near 1Ω, and the output voltage dropped below 9V due to the capacitor discharging between cycles.

The LT4320 stopped driving the Mosfets, and instead of there being 20mV across them, there was suddenly about 1V across the body diodes at about 15A. The smoke quickly escaped from the DPAK Mosfets. We recommend that you avoid that situation.

Construction

With so few parts on the board, construction is straightforward. Refer to the PCB overlay diagram(s) for whichever version(s) you are building, shown in Figs.6-11.

The principal challenge is that for all but the TO-220 version, we're using the LT4320 IC in an MSOP-12 package



Fig.5: the same waveforms as in Fig.2 but without the -2V offset on the AC input. The IPP083N10N Mosfets on this board stabilised at 38°C in the lab. The dummy load, on the other hand, measured 130°C.

with a thermal pad on its base. This thermal pad makes this part a tad harder to solder than your average SOIC/SOP SMD part. There are two (or three) practical soldering options:

1. Using a reflow oven. If you already own one of these, chances are you are all over how to mount the part. Each oven has its own quirks, so we will leave this to you.

2. Use a toaster oven as a 'bodge'. You can read articles on turning a toaster oven into a reflow oven (April & May 2020; siliconchip.au/Series/343), but there is also a 'quick and dirty' method that works.

Buy a super-cheap toaster oven (we often see these for sale under \$50) and stick a K-type thermocouple alongside your board. Apply solder paste to the pads and carefully place the parts on top. Preheat the PCB to 100°C in the oven, then turn the oven up to maximum. Watch closely until the temperature hits 220°C. At this point, you should have seen the solder flow. Immediately turn the oven off and open the door.

3. Use a hot air gun. That is how we built all the prototypes, to convince ourselves that it would work for you (see the photo overleaf). Even though we have a reflow oven, we often use the hot air gun as it is quick and easy

(they're also surprisingly inexpensive). We used this technique just for the LT4320, leaving the easier capacitors and Mosfets to be hand-soldered. The key steps are:

- a | Apply a small amount of solder paste to each pad and the central thermal pad. Do not overdo this; a modest smear is sufficient. We use 60/40 tin/lead solder paste as it melts at a lower temperature, making it generally easier to work with. Nothing is stopping you from using lead-free solder, but remember that it requires higher temperatures.

- b | Place the LT4320 using tweezers. There should be sufficient solder paste to stick in place, but not so much that it squishes everywhere.

- c | Check that the LT4320 is the right way around. Double-check, as this is by far the most expensive part in this project.

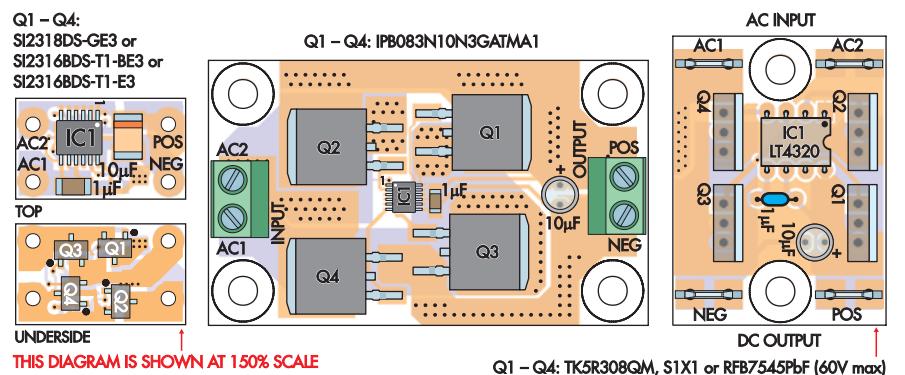
- d | Put the board on a heat-resistant surface, such as a PCB off-cut. Do not use your desk as it will get quite hot!

- e | Set your hot air gun to about 300°C.

- f | Apply heat to the board in a gentle waving motion from about 15cm away, so the board around the IC is heated reasonably evenly. We want to preheat the board to something in the region of 100°C over a minute or so.

- g | Once the board is well warmed up, bring the hot air gun to about 5-10cm from the board and work around the IC. Have your tweezers handy; if the IC moves a lot, you might need to nudge it back into position. Having said that, surface tension will typically pull it into place if you're blowing the air directly from above.

- h | Watch the solder paste. As the board approaches 220°C, you will see the paste changing from dull granular material to a shiny liquid. The change is significant, so you shouldn't miss it.





My poor wirewound nichrome dummy load reached 320°C while the Mosfets on the D2PAK standalone module only reached 67°C.



Soldering the MSOP-12 LT4320 IC using a low-cost hot air ‘rework’ station. These are invaluable for all sorts of jobs; they make it especially easy to desolder SMDs. In this case, the killer feature is the ability to heat the IC enough to solder the pad underneath.

i | As the solder melts, it also creates a lot of surface tension and will pull the IC into position.

j | Do not overheat the board. Once all the solder has reflowed, take the heat gun away.

k | Allow the board to cool naturally. Do not put any liquid on the board to accelerate the cooling.

l | You might see several pins with solder bridges across them. Fold some solder wick across the tip of your iron and ‘dab’ the pins to melt the bridge into the wick. Adding a little flux paste to the bridge first usually helps. With a little practise, this is quick and easy. We get quite a few bridges to fix as we are too generous with the solder paste!

For the remaining SMD parts, a regular soldering iron works fine. We generally tack down one of the SMD leads and make sure the part is straight. For the two-pin passives, all that’s left is to solder the second lead.

For the Mosfets, apply the iron to the source (main tab) at the junction of the tab and the PCB pad. Put a small amount of solder between the iron and the tab and wait until the solder flows.

Once both the pad and the component lead are hot, the solder will flow freely under the component. After that, you can solder the remaining small pins.

The 6.3mm spades, screw connectors or wire leads are through-hole parts, so solder them as usual.

Testing

Testing the Ideal Bridge Rectifier is not complex and can be undertaken at low power.

First, connect a 220Ω 1W resistor across the output, or an alternative resistor with a power rating that can withstand the DC voltage we will apply in the following steps. Connect a multimeter across the test resistor with the meter’s positive line to the positive output of the ideal bridge rectifier.

Connect a 12V DC power supply to the input of the Ideal Bridge Rectifier and verify that the output gives a +12V reading on the meter. Verify that the voltage drop is less than 100mV. Then swap the polarity of the input voltage and verify that the output is still giving a +12V reading on the meter, and the voltage drop is still less than 100mV.

If this does not work:

- Check all solder connections.

- Check the orientation of the LT4320 IC.
- If using TO-220 Mosfets, check their orientations.
- If building the through-hole board, check the orientation of the electrolytic capacitor.
- Check your test setup; is the power supply in current limiting? Check the input voltage.

Using it

Among the six different modules, you will likely find a ‘drop in’ solution. The SIL and 19mm pin bridges should solder straight to a PCB that’s designed for a regular bridge rectifier.

For an audio amplifier, you would ideally mount two of the standalone versions in the chassis and run individual windings to each.

Remember that the LT4320 operates from 9V to 72V. If your output voltage falls below this, the LT4320 will not drive the Mosfets, and the bridge will only operate using the body diodes. That is OK to get the circuit started, but at high currents, the dissipation can be very high.

This is only a concern if your design uses low rail voltages, or you are likely to do something as silly as we did and drive the rectifier so hard that your capacitor discharges massively between 50Hz cycles. That won’t happen in a typical power supply or power amplifier.

Conclusion

The Ideal Diode Bridge Rectifier can significantly improve the efficiency of just about any circuit that requires a rectifier for only a modest increase in the device’s overall cost.

Best of all, for devices like power supplies and audio amplifiers, you can get even more output voltage or power than you would with a standard diode-based rectifier.

Don’t forget, though, that for applications like an audio amplifier with split rails (positive and negative), unlike a diode-based rectifier, you will need two of these devices, one for each supply rail. The transformer also needs to have two separate secondary windings. That’s because the control chip only monitors the voltage across the upper two Mosfets.

With six different designs in a range of sizes, current and voltage ratings, you’re bound to find one that suits your application. 

Parts List – Ideal Diode Bridge Rectifier

Common parts for versions #1 to #4 (from Mouser, DigiKey or element14)

- 1 LT4320IMSE#TRPBF ideal bridge controller IC, MSOP-12 (IC1)
- 1 1µF 100V X7R M3216 SMD ceramic capacitor [CL31B105KCHNNNE]
- 1 10µF 100V X7S M3225 SMD ceramic capacitor [GRM32EC72A106KE5K]

#1 28mm spade version

- 1 double-sided PCB coded 18101241, 28 × 28mm
- 4 6.3mm PCB-mounting vertical spade connectors [Altronics H2094, pack of 10]
- 4 TK6R9P08QM,RQ, IPD50N06S4-09 or TK5R1P08QM,RQ N-channel Mosfets, DPAK/TO-252 (Q1-Q4)

#2 21mm square PCB pin version

- 1 double-sided PCB coded 18101242, 22 × 22mm
- 1 10cm length of 1.5mm diameter tinned copper wire
- 4 TK6R9P08QM,RQ, IPD50N06S4-09 or TK5R1P08QM,RQ N-channel Mosfets, DPAK/TO-252 (Q1-Q4)

#3 5mm pitch SIL version

- 1 double-sided PCB coded 18101243, 23 × 20mm
- 1 10cm length of 1.5mm diameter tinned copper wire
- 4 TK6R9P08QM,RQ, IPD50N06S4-09 or TK5R1P08QM,RQ N-channel Mosfets, DPAK/TO-252 (Q1-Q4)

#4 Mini SOT-23 version

- 1 double-sided PCB coded 18101244, 9 × 15mm
- 1 10cm length of 0.7-1mm diameter tinned copper wire
- 4 SI2318DS-GE3, SI2316BDS-T1-BE3 or SI2316BDS-T1-E3 N-channel Mosfets, SOT-23 (Q1-Q4)

#5 Standalone D2PAK SMD version

- 1 double-sided PCB coded 18101245, 59 × 36mm
- 2 mini horizontal terminal blocks, 5mm or 5.08mm pitch
- 1 LT4320IMSE#TRPBF ideal bridge controller IC, MSOP-12 (IC1)
- 1 1µF 100V X7R M3216 SMD ceramic capacitor [CL31B105KCHNNNE]
- 1 10µF 100V radial electrolytic capacitor, 2.5mm pitch, ≤6.3mm diameter [Kemet ESL106M100AE3AA]
- 4 IPB083N10N3GATMA1 N-channel Mosfets, D2PAK/TO-263 (Q1-Q4) [ESL106M100AE3AA]

#6 Standalone TO-220 through-hole version

- 1 double-sided PCB coded 18101246, 38 × 28mm, with 70µm-thick copper
- 4 6.3mm PCB-mounting vertical spade connectors [Altronics H2094, pack of 10]
- 1 LT4320IN8#PBF ideal bridge controller IC, DIP-8 (IC1)
- 4 TK5R3E08QM,S1X (80V) or RFB7545PbF (60V) N-channel Mosfets, TO-220 (Q1-Q4)
- 1 1µF 100V X7R radial ceramic capacitor, 5mm pitch [RDER72A105K2M1H03A]
- 1 10µF 100V radial electrolytic capacitor, 2.5mm pitch, ≤6.3mm diameter [Kemet ESL106M100AE3AA]