Technical Note #1

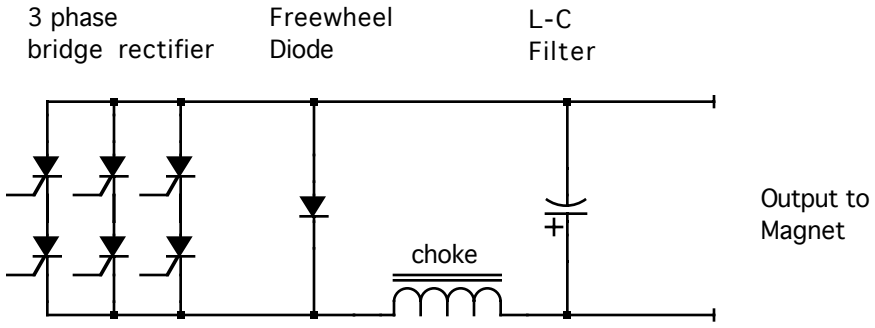
Connection of the Freewheel Diode

Power Circuit Operation

There has been discussion as to the proper location of the freewheel diode in SCR type magnet power supplies. When the power supply is connected to large inductive loads then this diode becomes a very important part indeed. Freewheel diodes are used to:

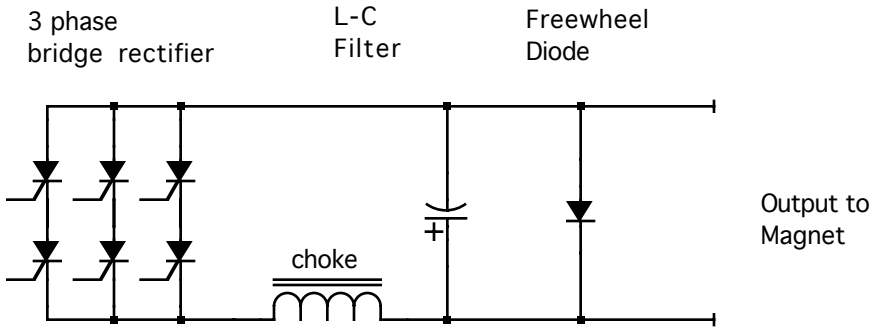
* Provides a path for energy stored in the magnet inductance ($\frac{1}{2}$ LI^2)
* Prevents reverse voltage across capacitors
* Force one-quadrant operation of the rectifier

In past years we have used one-quadrant SCR controllers that required that the freewheel diode be connected across the bridge (as shown below). The choke inductance is typically very small compared to the magnet inductance, so one can consider the choke to be in series with, and part of the magnet circuit. As can be seen, the freewheel diode will discharge the combined magnet- choke energy.



This arrangement is not ideal, however, because the capacitor is not protected directly by the diode. Any voltage that appears across the choke could appear as an added voltage across the capacitor. Depending on the exact L-C ratio and the slewing rates of the current, potentially damaging reverse voltages could appear across the capacitor.

Our newer power supplies use a 2 quadrant controller, this allows an alternate method of using the freewheel diode. By connecting it across the magnet terminals, magnet energy is still discharged, and the capacitor is protected against reverse voltage. Now the stored choke energy (again, proportionally small) is returned to the power line via second quadrant operation of the rectifier.



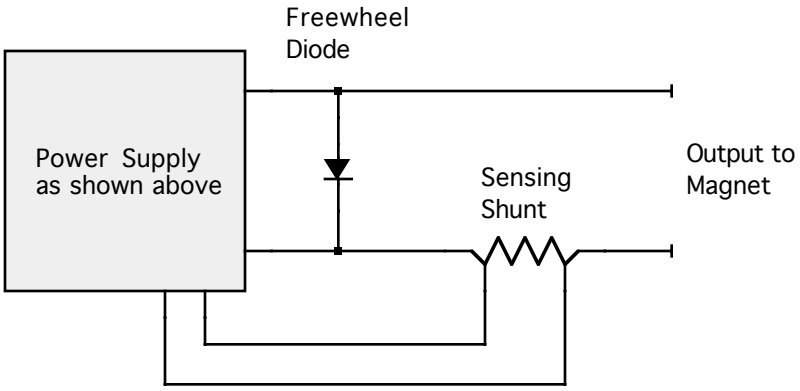
All things considered, this is the better way to apply a freewheel diode.

Regulator Operation

To further expound in this issue, one must consider the impact of the freewheel diode on the regulation circuit. By adding the shunt directly in the output lead, one very important feature is achieved.

* There are no "sneak paths" for current to flow - shunt current is absolutely the same as magnet current

This is certainly desirable, and many people insist on using this method.

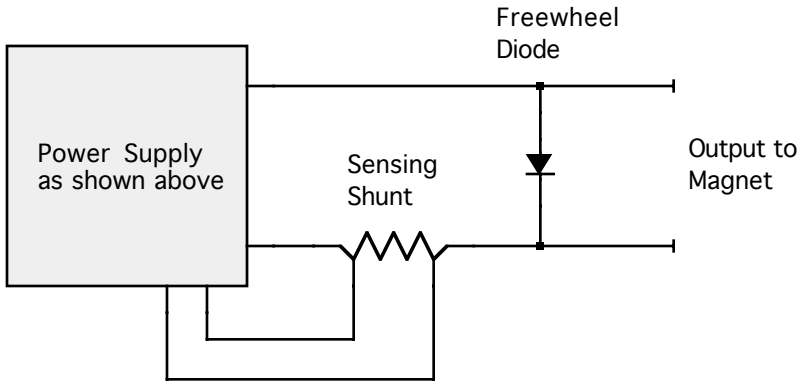


Said another way, the shunt current is equal to the magnet current, but may be different from the power supply current. As one can see, as magnet discharge energy flows through the diode, it also flows through the shunt. Because the magnet only discharges in this manner during slews down (to lower currents), the power supply is "fooled" into thinking that there is more current than it *itself* is commanding. The power supply responds to this by slewing to its fully zero condition. Keep in mind that actual magnet current is still flowing through the diode / shunt. From the regulators point of view, during this slew down it cannot keep control of its own output (as it believes it from the shunt) and overcompensates while trying to gain control. After the magnet current drops below the power supply set point, the supply can increase its current up from zero and regain control at the new current.

This connection results in the power supply - freewheel diode changing rapidly between their full on and full off states during slew downs.

By connecting the freewheel diode truly at the magnet terminals, as shown below, the power supply can always controls is own current. The magnet discharge energy will share between the diode and the power supply. There is not the condition, as noted above where the diode - power supply share "all or nothing". This is better, in that nothing has to change from a fully off to a fully on again situation.

Some may argue that in normal operation, the diode may conduct current away from the magnet, and the current regulation will suffer. However, if one really looked at the numbers, the reverse currents of even the leakiest diodes are insignificant.



Conclusion

When used with inductive loads the freewheel diode provides several benefits. Although several possible configurations are similar in their behavior, the best configuration seems to be with the diode directly across the magnet terminals, after the current sensing shunt.