MOSFET Regulator/Rectifiers - The Why & The How

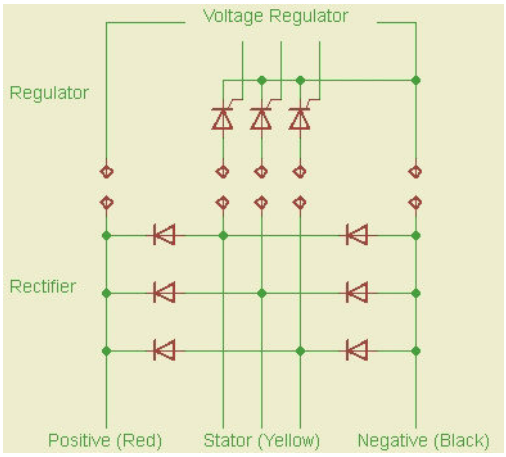
Ok, since there has been a couple of people asking lately, both on the forums and in PM, how to tell what R/R's are MOSFET, I compiled a list...

Also, since I'm making a list, why not include my explanation that's currently buried in another thread on WHY you want MOSFET's in your R/R...

Part 01 - How

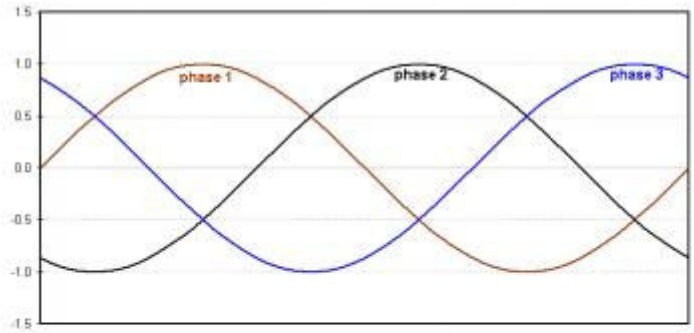
How does the R/R work?

The R/R consists of two parts, the Rectifier and the Regulator... This is a very simplified image of the R/R...

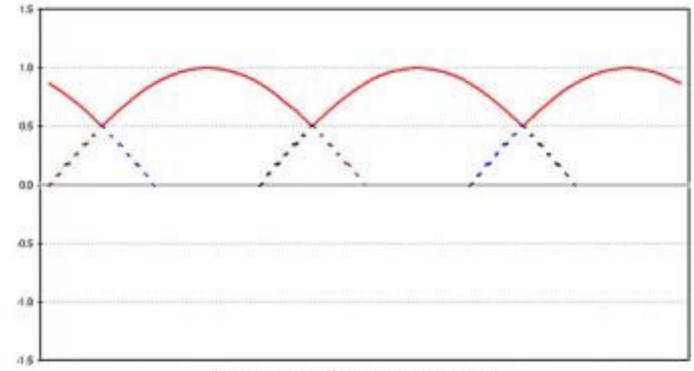


The Rectifier is always made up out of "normal" diodes, but there are different type's of diodes, in varying degree's of effiency...¨

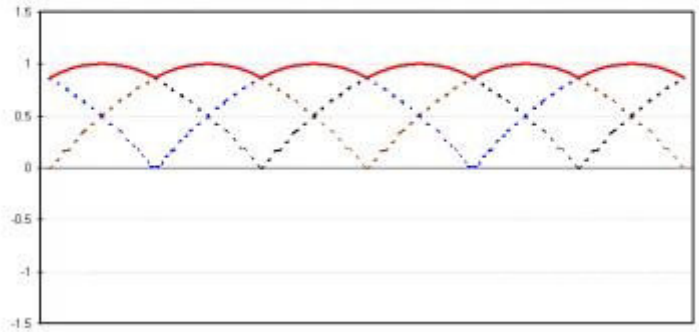
The Rectifier takes the AC voltage from the stator and converts it into DC voltage... That's accomplished by taking the "negative" part of the AC, and "re-routing" it with diodes so that it becomes "positive"... Simple explanation, simple physics, but not somehting we need to understand completely... Here is a picture to let you know in principle what the result is...



3-PHASE AC



3-PHASE HALF-WAVE RECTIFICATION



3-PHASE FULL WAVE RECTIFICATION

In the end, what the Rectifier produces is DC voltage that ripples around the 20-35V mark somewhere, depending on RPM...

The Rectifier part of the R/R produces heat from the diodes, but in terms of the total losses and heat production, this part is ridiculously small compared to the Regulator part... But, it is still affected by the total heat amount...

The second part, the Regulator, sit's like a spider in the net, looking at what the Rectifier does, and by shorting one of the three phases to ground for short bursts, it keeps the output voltage at the desired voltage for the bike...

The "diodes" that are used for switching the current to ground on and off are either thyristors, basically a diode with a third leg that acts as a switch, or MOSFETS, which are transistors functioning in a similar capacity. (and transistors are made up out of diodes in their most basic form)

Regardless of what type of "switch" you use, the act of switching it on or off casues large amounts of heat, and when fully on, shorting things to ground, that causes even

more heat... That heat is usually much, much more than what the Rectifier produces... But both parts are equally affected by the heat...

Part 02 - Heat

What does heat do to the components?

The heat makes diodes of *all* types age faster, and if you have enough heat, the diode starts to change characteristics, making it less exact...

The loss of precision creates wilder swings between high voltage and low voltage, making the Regulator have to work harder to maintain the output voltage where it's supposed to be... And the harder it works, the more heat it produces, and then it looses even more precision... That creates a pretty steep downwards cycle...

The result of the ageing is obvious, first it becomes even less exact... Then it fails, when it cant keep up... And a diode can fail in two ways...

One, it can act as a fuse and stop conducting... The result of that is that the R/R produces lower voltage than specified and cant keep the battery fully charged... That slowly kills the battery, but the bike keeps working a good while before you notice anything...

Two, it fails by conducting both ways, or in the case of the switching diodes (thyristors) "leaking" when it's supposed to be shut off... That makes the R/R produce wildly varying voltage, lower or higher depending on what combination of diodes are currently conducting, something that again makes the R/R work harder... This results in the battery being overcharged, the bike doing "weird things", like popping fuses or randomly dying...

And eventually, the diode or thyristor short circuits, conducting both ways, or becoming unable to turn off... The result of that is a boiled over battery, smoldering electronics and a big hefty bill for repairing your bike...

But there are other things creating heat... One is corrosion on terminals in the wiring harness... It's bad in all places, but more catastrophic in the connector for the R/R, since it's already hot there... Soldering the terminals instead of crimping them makes it easier to keep them free of corrosion... Making sure that there is no way for moisture to get in there is another good tip...

Part 03 - The difference

What is the difference between a thyristor and a MOSFET based R/R?

The switches in the Regulator part are either type, but they both do the same thing... The rapidly turn on and off, shortcircuiting power to ground to keep voltage constant... That's called "Shunting", and almost every type of bike R/R used now is made this way...

Every time you short circuit something, it creates heat, just from the short circuit... That's the same for both types... But, the difference is in *how you switch!*

On a thyristor based R/R the most heat isn't from the shortcircuit, it's from the switching... A thyristor is basically a diode with a separate leg, acting as a switch... But the switch has a delay... The thyristor relies on the current flowing through it, to keep it open...

Basically the switch opens the door a crack, and then waits for the current to crash into the door, slamming it open... Closing it is similar... You slowly, slowly push the door closed enough until the current looses power and cant hold the door open, slamming it shut...

As a result, the thyristor is horribly inexact and inefficient... It takes time to switch, and it creates huge amounts of heat while doing it...

The MOSFET is a bit more intelligent... It doesn't rely on the current for opening the door, and it doesn't try to close it slowly... Instead the switch is really a switch... Switching it on means it starts to conduct fast, and switching it off means it stops almost as fast... That creates a lot less heat, and makes it more exact... A lot more exact...

Part 04 - what to do about it...

Well, the smart move is to get a new MOSFET based R/R... You just need to know what type R/R is MOSFET based...

Now this is where a lot of you will start crying... Sorry...

The older Yamaha YZF-R1 R/R is a popular swap for the VTR... It greatly reduces failures... But... *It isn't a MOSFET R/R...* That means it will eventually fail...

Don't get me wrong, it's still a very good upgrade, it's infinitely more robust than the crappy OEM one... And since it's specified for 50W, and the VTR is specified for 35W, it's not working hard too keep up with demand, and that makes it age slower... So it will happily keep working twice the time an OEM one or a cheap OEM copy will... A MOSFET based R/R should never, *ever fail from heat!*

But, again... *It's not an MOSFET...* So it does create heat... And it does age...

So, now that you are all throwing your new replacement R/R's in disgust... Let's figure out how to find those that ***are MOSFET...***

Part 05 - Finding an MOSFET R/R...

The "easy" way of knowing if a R/R is MOSFET based, is to look at the markings...

Almost all R/R's for motorcycles are made by Shindengen, and they supply all the manufacturers... Honda, Kawasaki, Yamaha and Suzuki and others...

A MOSFET R/R has a marking with FH-*** on it... The numbers tell the specific output and such... and an older thyristor based R/R is marked SH-*** same here, numbers tell the output... SH stands for shunt, and FH for "FET based shunt"...

Ie MOSFET...

Now, it's pretty common that the sellers on eBay doesn't list an image with the markings, or write out the type... So here is a list of known MOSFET based R/R's... Keep in mind that the list is a work in progress, you might get an unsuitable R/R if you go by the list alone, look at the markings for FH-***...

Code:

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Kawasaki
ZX-6R 2007-> Cut-n-splice... Either solder, or get both connectors from
eastern beaver...
ZX-10 2004->
ZX14 2006->
Concours 2008-> Both MOSFET and non-MOSFET available, beware! (And the
tyristor based one seems to need a larger load than the VTR to work)

Yamaha
FZ1 2007->
YZF-R1 2007->
YZF-R1 2004-2006 - Works, but has large fins, making it hard to fit...
FJ1300 2007->
Wildstar 1300 2007->

Honda
CBR 1000RR 2004-2007 - Both MOSFET and non-MOSFET available, BEWARE! Cut-n-
splice
CBR 1000RR 2008-> Odd connectors, no plugs available, use spade
connectors...
CBR 600RR 2003-2006 - Both MOSFET and non-MOSFET available, BEWARE! Cut-n-
splice
CBR 600RR 2007-> Cut-n-splice
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All the Yamaha R/R's use the type of connectors that you can get from www.easternbeaver.com and those are waterproof... That makes it easy to splice the new wiring in, and making sure you don't get moisture and resistance from that...

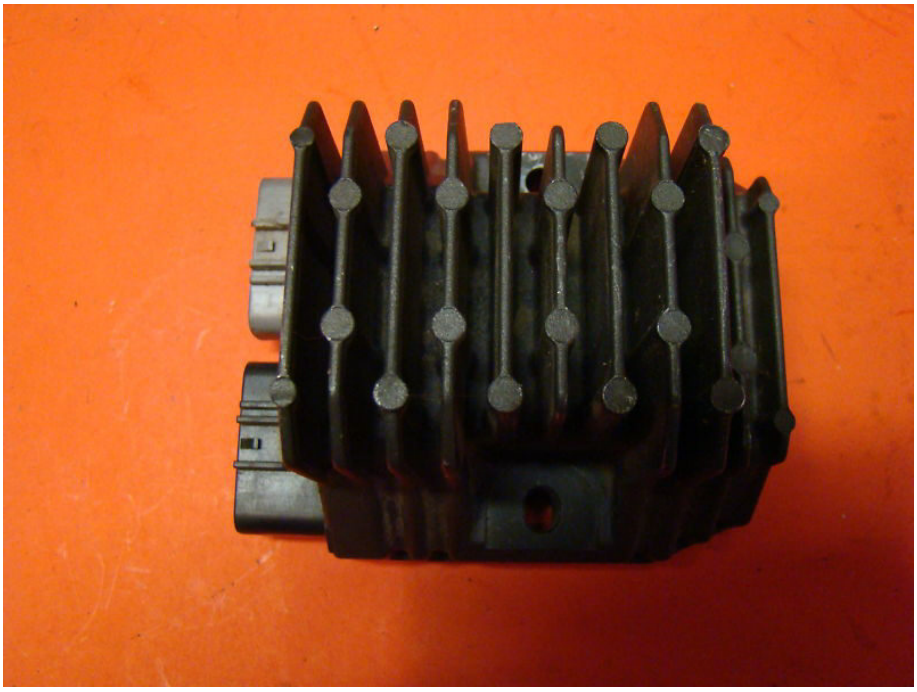
Some of the Kawasaki one's use the same plugs as the Yamaha's, some are the cut-n-splice variety like the Honda's...

You can use normal spade connectors on these, instead of the connectors and save you some money... But it qualifies as monumentally stupid... 

The Honda R/R's are different... They all come with Honda's own plugs... Not waterproof, and stupid design to boot... Cut them off and replace them with good quality waterproof & high amperage connectors, or just solder the wiring and use shrinktube to keep it moisture free...

Example of the ZX10/ZX14 Kawasaki one and 2007 -> R1...

Example of the "older" 2004-2006 R1... Works the same, just big and hard to fit under the tail cowling:



Two CBR 600RR regulators... Both fit 2003-2006... But one is *not* a MOSFET one... Looks a bit different, but only trust the markings...

CBR 1000RR regulator 2008->... Please note the stupid connectors... Start soldering... Olders look different, and apparently there are non MOSFET one's as well as MOSFET before 2008, so beware...:

Part 06- why old R/R's and new batteries doesn't mix well...

As a result of this, a typical thyristor based R/R will produce 13.5-14.5V if it's healthy... And in semi healthy condition usually 13.2-14.8V... But depending on the temperature in the R/R, RPM and how fast the RPM changes it will swing wildly between these values at random...

A MOSFET based R/R in new condition usually provides 13.5-14.5V, and in semi healthy condition (which takes about 20-30 times longer than the thyristor's to age into) the same 13.2-14.8V...

But... And that's a pretty important but... The MOSFET R/R tends to go towards middle voltage at just off idle RPM, and then towards lower voltage at high RPM, with only small peaks towards higher voltage usually when the RPM's change... Also the swings are slower, more controlled...

A SLA want's 13.8-14V or soo to charge, a GEL usually want's 14.1-14.2V to charge... Most SLA's "boil" and get reduced lifetime if the spend to much time above roughly 14.2V, same goes for GEL's at 14.5V... Drop to low and they simple stop charging... Just below optimal charging and you get "maintainance mode" as in most chargers...

This means that as long as the battery is in good condition it has no problems coping with a semi reliable R/R of either type... But a thyristor based R/R will age it sooner, and ages itself sooner... And then you get problems...

A MOSFET based R/R keeps the battery lasting longer, keeps the voltage more constant, which is good for the ECU/CDI, the electronics in the gauges, the fuses and also keeps the lightbulbs in your headlight happy since it likes just above 14V to make peak light output (provided you have decent wiring too it)...

Both types will make fireworks and smoke when they battery boils over if a diode in

the Rectifier decides to go wide open, and both will stop charging the battery if it fuses... But a MOSFET Regulator takes a very, very long time to go "bad" enough to create the heat needed for damaging the Rectifier diodes... Corroded connectors are obviously something that affects both equally in terms of resistance/heat...

Now for the LiFePo's... They like to be charged at 13.6-14.4V, and very, very optimally at around 13.8V... They highly dislike going above 14.4V since that charges them very rapidly with no real way for them to dissapate the heat, and charging to much at lower than 13.4V will build up internal resistance which reduces lifetime...

So a thyristor based R/R in peak condition will work decently... But *only* in peak condition... A MOSFET one will work even in semi decent condition since it rarely peaks and if it does it's a short time... It might reduce lifetime, but it's unlikely to blow stuff up...

The LiFePo's are no more volatile than SLA or GEL batteries when they go *poof,* infact they tend to make less damage since the chemicals don't eat through aluminium, and also since they contain much smaller volumes of chemicals simply becuase they are much smaller... But the margin for error is a bit less...