

Five Volt Fullwave Rectifier Tubes

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Tube#	Base	Filam. Volts	Filam.A mp.	Vdrop	Max. P mA	Max. P V	Notes
5AR4/GZ34	5DA	5.0	1.9	17	250	450	low Vdrop 5U4/5Y3
5AS4A	5T	5.0	3.0	50	275	450	improved 5U4
5AT4	5L	5.0	5.5	30	800	550	higher power 5U4
5AU4	5T	5.0	3.75	50	325	400	high power 5U4
5AW4	5T	5.0	3.7	46	250	450	long life 5U4
5AX4GT	5T	5.0	2.5	65	175	350	high power 5Y3
5AZ3	12BR	5.0	3.0	44	275	600	compactron 5U4
5AZ4	5T*	5.0	2.0	60	125	350	loctal 5Y3
5BC3	9QJ	5.0	3.0	53	300	500	compactron
5CG4	5L	5.0	2.0	?	125	400	
5DJ4	8KS	5.0	3.0	44	300	600	redesigned 5U4 (higher volts)
5R4G/GY	5T	5.0	2.0	67	250	750	high voltage 5U4
5R4GYA	5T	5.0	2.0	67	250	750	high voltage 5U4 (ruggedized)
5R4GYB	5T	5.0	2.0	63	250	900	high voltage 5U4 (ruggedized)
5T4	5T	5.0	2.0	45	225	450	metal 5U4
5U4G	5T	5.0	3.0	44	225	450	octal 5Z3
5U4	GA	5T	5.0	3.0	44	250	450
5U4	GB	5T	5.0	3.0	50	275	450
5V3	5T	5.0	3.8	47	350	425	higher power 5U4
5V3A	5T	5.0	3.0	42	415	550	5V3 reduced filament current
5V4G/GA	5L	5.0	2.0	25	175	375	octal 83V
5W4G/GT	5T	5.0	1.5	45	100	350	low power 5Y3
5X4G	5Q	5.0	3.0	58	225	450	5U4 different pinout
5X4GA	5Q	5.0	3.0	47	250	450	
5Y3G/GT	5T	5.0	2.0	60	125	350	octal 80
5Y4G/GT	5Q	5.0	2.0	60	125	350	5Y3 diff pinout
5Z3	5T	5.0	3.0	58	225	450	4pin 5U4
5Z4	5L	5.0	2.0	20	125	350	low drop 5Y3
80	4C	5.0	2.0	60	125	350	4pin 5Y3
82	4C	2.5	3.0	15	115	450	lower power type 83
83	4C	5.0	3.0	15	225	450	4pin mercury vapour
83V	4C	5.0	2.0	25	175	375	4pin 5V4
1641	8E	5.0	3.0	44	250	450	rabbit ear 5U4
5931	5T	5.0	3.0	47	300	600	industrial 5U4
6004	2AJ	5.0	2.0	60	120	375	rabbit ear 5Y3
6087	5L	5.0	2.0	50	125	350	
6106	5L	5.0	2.0	60	125	350	
6853	8HE	5.0	1.7	60	125	350	
RK60	8E	5.0	3.0	44	250	450	rabbit ear 5U4

Six Volt Fullwave Rectifier Tubes

Tube#	Base	Fvoltage	Famp	Vdrop	Max. P mA	Max. P V
6AX5GT	6S	6.3	1.2	50	125	350
6AX6G	7Q	6.3	2.5	21	250	350
6BW4	9DJ	6.3	0.9	40	100	325
6BY5G/GA	6CN	6.3	1.6	32	175	375
6CA4	9M	6.3	1.0	?	150	?
6W5G	6S	6.3	0.9	24	90	325
6X4	5BS	6.3	0.6	22	90	360
6X5	6S	6.3	0.6	22	80	360
6Z5	6K	6.3	0.8*	?	60	?
6ZY5G	6S	6.3	0.3	18	40	325
7Y4	5AB	6.3	0.5	22	70	325
7Z4	5AB	6.3	0.9	40	100	325
84/6Z4	4C	6.3	0.3	20	60	325
5993	5993	6.3	0.8	?	60	260
5852	6S	6.3	1.2	?	65	300
6202	5BS	6.3	0.6	22	55	325
6203	9CD	6.3	0.9	22	77	325
6325	6325	6.3	2.7	?	250	780
6754	9ET	6.3	1.0	?	90	325

Misc Volt Fullwave Rectifier Tubes

Tube#	Base	Fil. voltage	Famp	Vdrop	Max. P mA	Max. P V
0Z4	4R	none	none	?	110	880
82	4C	2.5	3.0	15	115	450
3DG4	5DE	3.3	3.8	32	400	325
12BW4	9DJ	12.6	0.45	40	100	325
12DF5	9BS	12.6	0.45	40	100	350
12X4	5BS	12.6	0.3	22	90	360
25X6	7Q	25.0	0.3	25	60	125
25Y5	6E	25.0	0.3	?	42	250
25Z5	6E	25.0	0.3	22	75	235
25Z6	7Q	25.0	0.3	22	75	235
26Z5	9BS	26.5	0.2	22	50	325
28Z5	6BJ	28.0	0.24	40	100	325
50AX6G	7Q	50.0	0.3	21	250	350
50X6	7AJ	50.0	0.15	22	75	235
50Y6	7Q	50.0	0.15	22	75	235
50Y7	8AN	50.0	0.15	22	75	235
50Z6	7B	50.0	0.3	?	75	235
50Z7	8AN	50.0	0.15	21	65	235
117Z6	7Q	117	0.075	15.5	60	235
5690	5690	12.6*	1.2	17	125	350

5U4 Compatible Fullwave Rectifier Tubes

Tube#	Base	F volt	F amp	V drop	Max. P mA	Max.P V	Notes
5AR4/GZ34	5DA*	5.0	1.9	17	250	450	low Vdrop 5U4/5Y3
5AS4A	5T	5.0	3.0	50	275	450	improved 5U4
5AU4	5T	5.0	3.75*	50	325	400	high power 5U4
5AW4	5T	5.0	3.7*	46	250	450	long life 5U4
5DJ4	8KS*	5.0	3.0	44	300	600	redesigned 5U4 (higher volts)
5R4G/GY	5T	5.0	2.0	67	250	750	ruggedized 5U4 (higher volts)
5R4GYA	5T	5.0	2.0	67	250	750	
5R4GYB	5T	5.0	2.0	63	250	900	
5T4	5T	5.0	2.0	45	225	450	metal 5U4
5U4G	5T	5.0	3.0	44	225	450	octal 5Z3
5U4GA	5T	5.0	3.0	44	250	450	
5U4GB	5T	5.0	3.0	50	275	450	
5V3	5T	5.0	3.8*	47	350	425	higher power 5U4
5V3A	5T	5.0	3.0	42	415	550	5V3 with reduced filament current
5931	5T	5.0	3.0	47	300	600	industrial 5U4

*Extra connections on base - may not be plug-in compatible in some circuits.

*Higher heater current requirement - may not work in many 5U4 circuits.

5Y3 Compatible Fullwave Rectifier Tubes

Tube#	Base	F volt	F amp	V drop	Max. P mA	Max.P V	Notes
5AR4/GZ34	5DA*	5.0	1.9	17	250	450	low Vdrop 5U4/5Y3
5AX4GT	5T	5.0	2.5*	65	175	350	high power 5Y3
5CG4	5L*	5.0	2.0	?	125	400	
5R4G/GY	5T	5.0	2.0	67	250	750	ruggedized 5U4 (higher volts)
5R4GYA	5T	5.0	2.0	67	250	750	
5R4GYB	5T	5.0	2.0	63	250	900	
5T4	5T	5.0	2.0	45	225	450	metal 5U4
5V4G/GA	5L*	5.0	2.0	25	175	375	octal 83V
5W4G/GT	5T	5.0	1.5	45	100	350	low power 5Y3
5Y3G/GT	5T	5.0	2.0	60	125	350	octal 80
5Z4	5L*	5.0	2.0	20	125	350	low drop 5Y3
6087	5L*	5.0	2.0	50	125	350	special 5Y3
6106	5L*	5.0	2.0	60	125	350	special 5Y3
6853	8HE*	5.0	1.7	60	125	350	

*Extra connections on base - may not be plug-in compatible in some circuits.

*Higher heater current requirement - may not work in many 5Y3 circuits.

Four Pin Fullwave Rectifier Tubes

Tube#	Base	F volt	F amp	V drop	Max. P mA	Max. P V	Notes
5Z3	4C	5.0	3.0	58	225	450	4pin 5U4
80	4C	5.0	2.0	60	125	350	4pin 5Y3
83	4C	5.0	3.0	15	225	450	4pin mercury vapour
83V	4C	5.0	2.0	25	175	375	4pin 5V4

Note: There are many more rectifier tube types that were made and some are still being made. The above list is not intended to include them all, nor does it include rectifier tubes intended for half-wave rectification nor does it include signal diodes.

Why use a different rectifier tube?

Normally the best replacement tube is to use the same type tube number as originally designed for the circuit. These days it is sometimes the case that the original tube is not available, hard to find, or very expensive. Many times substitutions can be used that may be more readily available, or lower cost, yet still perform in the circuit as well as the originally designated tube type.

There are two basic fullwave power rectifier tubes that you will likely encounter. The 5Y3 family, and the 5U4 family. The 5Y3 family is the oldest fullwave rectifier design. The 5Y3 design goes all the way back to the 1920s (type 80 tube) and is still being made today. The original design was the type 80 tube. When the octal base format came into use, the type 80 tube had an octal base put on it and the type became the 5Y3. You can swap between the tubes using a base adapter.

The original type 80 tube came in a globe/balloon style. Later the type 80 was switched to the ST shape which is more rugged because it supports the internal elements. Long after the end of design life for the type 80 tube, it was made available in the GT style for replacement use. This was really just a 5Y3GT with a four pin base.

When the 5Y3 came out, all they did was to put an octal base on the type 80 tube. At this time, the type 80 tubes were using the ST shaped glass, so the first 5Y3 tubes, which were called 5Y3G, also used the ST shape. Later on as equipment manufacturers demanded smaller tubes, the 5Y3 was packed into the smaller GT style. Beyond that, the design remains largely the same as when the type 80 tube was first introduced.

Originally if more power than the type 80 tube could provide was needed, you needed to design in two or more tubes. The main reason for requiring two tubes was that the heat disipation for a fullwave rectifier of that power would be too much to handle in the standard size tube. To deal with this, the type 83 tube was designed.

The type 83 tube uses mercury vapour (the same gas in florescent lights) to reduce the internal resistance. Doing so reduces the amount of power disipated by the tube and thus the heat generated. This allows a high power fullwave rectifier to be placed in the same package as the original type 80 tube.

The down side to this is that the mercury creates its own set of problems. The toxic aspects of mercury were not considered to be as big an issue at that time as it is now. However there are other problems. The primary problem is that mercury is a liquid at room temperature. That causes it to condense onto the internal tube elements. If voltage is applied to the plates before the heater has warmed up the tube (and turn the mercury into gas), the mercury can cause internal shorting or arcing to occur. This can cause damage to the tube and to the circuits in which it is used.

Note: there is a tube type called 83-V. It is unfortunate that they selected the "83" number for it as it is rather different than a type 83 tube. It is closer to a type 80 tube but with a reduced internal resistance. The reduced resistance is achieved by placing the cathode/heater and plate closer together. This makes it much harder to manufacture and more susceptible to shorting out. A shorted power rectifier tube can cause a lot of damage to the circuits in which it is used.

There were various attempts made to deal with the mercury problem in the type 83 tube. One solution was the 5Z3 tube. The 5Z3 tube uses a larger glass bulb and larger plates to handle the higher power. It also has a bigger heater so that it can emit more electrons that are required for the higher power levels. The end result is a tube with twice the plate current as a type 80 or 5Y3 tube and slightly more plate voltage. For high power amplifiers, radios and TVs, this was just what was needed.

The 5Z3 uses the same base and pin out as the type 80 tube, so it is actually possible to put a 5Z3 in a type 80 socket. Normally this should be avoided though, the 5Z3 uses a 3amp heater whereas a type 80 tube uses a 2amp heater. Putting a 5Z3 in a type 80 circuit will likely cause the power transformer to overheat and fail. Conversely, putting a type 80 tube in a 5Z3 circuit will likely overdrive the type 80 tube causing it to fail very quickly.

Like the type 80, when the octal socket came into use, the 5Z3 had an octal base put on it and it became the 5U4. The "G" style 5U4 is the original 5Z3 ST shaped tube using an octal base. Also like the 5Y3, the tube was reduced in size by using a GT bulb. The 5U4GT bulb is much larger than the 5Y3GT bulb to accommodate the larger 5U4 plates.

There are two basic 5U4GT tubes. The 5U4GA and the 5U4GB. The GA is simply the old 5U4G crammed into a smaller GT bulb. The GB is a GA with an improved design (slightly more power output).

Originally the 5U4GB design was called the 5AS4 (ST version) and later the 5AS4A (GT version). Due to lack of sales and multiple inventory issues for a tube that was essentially the same as the 5U4, manufacturers decided to name it the 5U4GB and retire the 5U4, 5U4GA and 5AS4 tubes. You will often see tubes labeled 5U4GA/GB or 5U4GB/5AS4A indicating that they are intended for replacement of those tube types.

For new designs the differences are not normally a problem, and for most radio and TV designs the differences are minor enough to not make a difference. For some audio amplifiers the slight differences in design can result in a shift of voltages enough to make a noticeable difference in the way the amplifier sounds. In a properly designed amplifier the different tubes should not cause damage to the amplifier. Switching between the various types can be a way to tweak the amplifier for a different sound. The general rule of thumb is that a tube with more voltage drop will make the amplifier sound more mellow and one with less voltage drop will sound more firm. However the nature of the beast is that the actual results will depend heavily on the amplifier design and the other tubes used in the amplifier.

Another aspect is that a used tube can make a difference in the sound of an amplifier. As a tube ages, the number of electrons emitted from the cathode is reduced. This has the effect of increasing the voltage drop across the tube. The result is that an old amplifier with well used tubes can sound more mellow than a new amplifier of the same design.

Over the years other tubes have been designed that take their history from the original type 80 and type 5Z3 tubes. Some were designed to have lower voltage drop, others to have more or less maximum plate current and or plate voltage.

One of the more popular replacement versions is the 5T4 which is a metal version of the 5U4/5Y3 tube. Because it uses a 2 amp heater but has the voltage and current rating of a 5U4, the 5T4 can be used in place of either a 5U4 or

a 5Y3 in most circuits. The 5T4 tube is no longer made, but there are still a lot of them available as the military used them extensively. Because of the metal envelope, the tube is very rugged.

The main problem is that since it is metal, you cannot see inside the tube to see if it is gassy, arcing or the heater is not working. Also it is taller (the same bottle as the metal 6L6) than the 5Y3, so it may not physically fit in circuits using the 5Y3.

Another popular replacement version with a 2 amp heater that allows it to be used in either 5U4 or 5Y3 circuits is the 5R4 tube. The 5R4 also has a significantly higher plate voltage and a low loss base. The GYA and GYB versions are highly ruggedized for aircraft use. The main problem is that the higher plate voltage also means a higher voltage drop across the tube. Also the GYA and GYB versions have large heavy bases as a part of the ruggedization.

A popular tube still being made is the 5AR4/GZ34. This is basically an improved redesigned 5U4/5Y3 tube. It has a 1.9amp heater and plate voltage and current similar to the 5U4 so it can be used in either circuit. However it has a much lower voltage drop so care should be used to be sure that the circuit can handle the extra current surge. This tube is usually best used in a circuit that is designed to handle the low voltage drop. The other potential problem with this tube is that it has an internal connection on pin 1 which can potentially cause problems with some circuits. Don't use this tube unless you know that the circuit can handle it.

Another popular redesigned tube that is still in production is the 5DJ4. This tube is essentially a 5U4 with higher plate voltage and current. It also has extra connections on the base which can be a potential problem. Like the 5AR4, don't use this tube unless you know that the circuit can handle it. Serious damage can potentially occur in some circuits.

If you need the higher voltage or current of the 5DJ4 but the extra connections on the base are a problem, consider the 5831. The 5831 has similar characteristics but with the standard 5U4 pinout.

Generally you should stay away from the 5AU4 or 5AW4 tubes as replacements for a 5U4. These tubes have 20% higher filament current which can cause the power transformer to overheat if it is not designed to take the extra load. If you know that the transformer can handle the extra current, then you can use them.

The 5AU4 is designed to have more current output and the 5AW4 is designed to have a longer life. Unless you have a specific need for one of these tubes, you should consider one of the other tubes as a substitute. Neither of these tubes is being made anymore.

The 5V3 is another one of the troublesome tube numbers. There are two versions of the tube, the 5V3 and the 5V3A. The 5V3 should be avoided as a 5U4 replacement because it has a 20% higher heater current which can potentially damage the power transformer.

The 5V3A has the same heater current as the 5U4 and can be safely used as a substitute. The main advantage of the 5V3 is that it has a higher plate current and voltage, so it can be used in more demanding circuits (or last longer in undemanding circuits).

However given the serious difference between the 5V3 and 5V3A types, extreme care must be used that you don't accidentally put the wrong tube in a circuit that cannot handle it.

For circuits that use a 5Y3, there are a few more options available for substitution.

For low voltage drop, as well as the 5AR4, there are the 5V4 and 5Z4 tubes. The 5V4 tube comes in the older ST style "G" glass and in the newer "GT" style glass. The 5V4 is an octal version of the four pin 83-V tube. The 5Z4 also comes in the ST and GT styles, but has slightly lower voltage drop (20v vs 25v). These tubes don't have quite

as much plate voltage as the 5AR4, but will work in a circuit designed for the 5Y3 as long as the lower voltage drop is not a problem. The 5CG4 is rare, but is essentially a 5V4 type tube in a small GT package.

The 5W4 tube is a lower power version of the 5Y3. It uses less power so it runs cooler and lasts longer, but it may not work in all circuits due to the lower plate current rating.

There are also three special industrial/military versions of the 5Y3.

The 6087 is the same as the 5Y3 but is in a low loss base and rugged construction for mobile and aircraft use.

The 6106 is a highly specialized version of the 5Y3 tube. It is a Bendix Red Bank tube. These tubes were designed for the military to withstand the most punishment that could be thrown at a tube. These are the best 5Y3 tubes ever made.

The 6853 is an industrial version of the 5Y3. It has a lower filament current so that it lasts longer. The rest of the characteristics are the same as a normal 5Y3.

Note: How can a tube with a lower filament current have the same or more power output as a tube with a higher current? The answer is in the cathode. The cathode is coated with special rare earth oxides which is the source of the emitted electrons. The chemistry of the coating determines how many electrons are emitted for a given amount of heat generated by the filament.

How to decide if you can use a different tube type.

The commonly used replacement tubes for the 5U4 and 5Y3 tubes are listed in the 5U4/5Y3 Compatible Fullwave Rectifier Tubes tables above.

The first thing to check is the filament voltage and current. The replacement tube should have the same filament voltage. The filament current should be equal to or less than the original design.

Lower filament current usually means the tube is not able to handle the same power levels as the original design, but not always. The plate characteristics need to be checked to see if it will work.

Higher filament currents should be avoided as they can cause the power transformer to overheat and fail unless it is designed to handle the higher current requirement.

Note: If the rectifier tube is used in a series strung heater circuit, then the voltage and current ratings for the tube must be exactly the same as the original tube. Generally for those types of circuits it is best to stay with the original tube number. Normally you won't encounter a series strung heater circuit unless it is a radio or TV.

Radios commonly used series strung heaters to reduce cost by eliminating the power transformer. Some very low cost TVs did the same thing.

Normally though series strung radios used halfwave rectifier tubes specifically designed for radio work and TVs. Although in later years those that used series strung heaters sometimes used solid state rectifiers instead. Generally, if the rectifier is a 5U4 or 5Y3 tube, it is unlikely that the circuit is series strung as the tube normally requires a power transformer with a separate filament winding for the tube.

The next thing to check is the maximum plate voltage. The maximum plate voltage should be at least as high as the tube you are replacing.

If you know the maximum voltage that will be encountered is less than the tube rating, you may be able to use a lower rated tube, but care must be used as an underrated tube may arc internally causing potential circuit damage if the plate voltage rating is exceeded.

Next you will want to check the maximum plate current capability. Like the plate voltage rating, the maximum plate current rating should be equal to or greater than the tube being replaced. With plate current there is greater flexibility as often the maximum rating of the tube is seldom reached. You may be able to get away with a lower rated tube. The problem that can be encountered here is the tube may be over driven causing shorter life for the tube and possible power supply collapse. Usually this isn't as damaging as when the tube experiences internal arcing, but in some circuits it may potentially be a problem. If you are not sure, always go with equal to or better current rating for the plates.

Finally, look at the tube voltage drop. This is normally a characteristic that is not as much a problem. In radios and TVs it often has little or no impact as they are typically designed to handle the variance. In amplifiers, it can affect how the amplifier sounds. Especially amplifiers that use fixed bias and little or no inverse feedback.

When considering the voltage drop, keep in mind that the rated voltage drop is normally given for the maximum voltage and current rating for the plate. The actual voltage drop in use will depend on the current flow through the plate and the voltage applied. The voltage drop for a given voltage and current will also depend on the construction of the tube. Some tubes will have a higher variability of the voltage drop as the current changes and others will have less of a change.

Generally a tube with a lower voltage drop design will have less of a change in the voltage drop with a change in the plate current. A well used tube will generally exhibit a larger change in voltage drop with a change in the plate current.

Also keep in mind that the rectifier tube is an important part of the power supply filter. Using a tube with lower resistance can potentially cause an increase in hum and increases the current surge on the filter capacitor which can potentially reduce its life expectancy. While using a tube with a higher resistance can cause the circuit voltage to sag (lower output voltage) which can cause an increase in signal distortion.

Usually it is not advisable to replace a regular rectifier tube with a gas rectifier, nor to use a regular rectifier tube in a circuit designed for a gas rectifier. The circuit requirements for the gas rectifier tube is significantly different than for a regular rectifier tube. Doing so can potentially cause increased hum, increased distortion, reduced power supply life, or even circuit failure.

One of the characteristics of a gas rectifier (such as a mercury rectifier) is that they tend to exhibit less of a change in the voltage drop. Mercury vapour tubes are very stable in this regard (which is the primary reason that Hickok used the type 83 tube in their tube tester). Neon, Xenon, and Argon are other gases that are popular to use in gas rectifiers.

The purpose of the gas is to provide a plasma inside the tube which reduces the internal resistance during operation. This characteristic comes with a price though. The gas will not ionize (turn into plasma) until a relatively high voltage is developed across the tube. This is typically between 50 volts and 150 volts. The exact voltage at which the ionization starts is dependant upon a number of factors, including temperature of the tube, the type and amount of gas used, and the internal construction of the tube (distance between the plate and cathode). Once the ionization occurs the tube resistance drops rapidly (within microseconds). This causes a strong current surge which can disrupt or harm the circuits if they are not designed to handle this situation. This can be especially harmful to high value electrolytic capacitors as the rapid increase in voltage can cause a high current surge into the capacitor as the circuit tries to charge up the capacitor. This can cause the capacitor to overheat which can result in it venting some or all of its electrolyte. This damages the capacitor. Usually resulting in the capacitance being

reduced, or in extreme cases the capacitor will explode. It is best to have inductive or resistive loading in the rectifier circuit when using a gas rectifier to protect the capacitor from being damaged by the current surge.

Solid State Fullwave Rectifier Tube Replacements

An alternative to using a vacuum tube replacement is to use a solid state tube replacement. Most of the replacements available use a pair of silicon diodes to replace the vacuum tube rectifier elements.

The silicon rectifier has several big advantages. One is that they will normally last for the life of the device they are used in. Also since they don't require a heater to boil electrons off the cathode material, they use far less power and don't generate the heat like vacuum tube rectifiers.

They do have one disadvantage though, they have very little internal resistance. This can potentially cause trouble in some vacuum tube circuits. The low resistance can cause higher surge currents in the rectifier circuit which can shorten the life of electrolytic capacitors.

It can also cause an increase in hum bleed-thru since the internal resistance of the vacuum tube rectifier is normally included as a part of the power supply filtering in a tube circuit.

Some solid state tube rectifier replacements account for this by including a resistor in the circuit to emulate the internal resistance of the original tube. However the resistor is an added source of heat and makes the replacement more expensive to make, so most do not include the resistor. If the circuit can handle the solid state rectifier, it can provide more power because of the reduced power loss compared to a vacuum tube.

If you can handle a soldering iron, it is easy to make a solid state 5Y3 or 5U4 tube replacement. First get an octal plug. This can be bought from a tube supplier, or can be obtained by removing one from a dead tube. Next you will need two 1N4007 diodes. These are available from most electronics suppliers. Just about any diode with a current rating of at least one amp and a voltage of 1000V or higher will work.

Note: Diodes require higher ratings than tubes because they are not as forgiving as tubes. A tube can normally withstand a momentary event that exceeds it's rating without permanent damage. Solid state diodes cannot, they will fail immediately. Because of that, the diode rating needs to be selected such that it will never be possible for it to be exceeded. The general rule of thumb is to use at least double the voltage and current rating as the design calls for.

To construct the rectifier tube replacement, connect the anode of one diode to pin 4 and the cathode to pin 8. Connect the anode of the other diode to pin 6 and the cathode also to pin 8.

For a four pin rectifier, connect one diode anode to pin 2 and the other diode anode to pin 3. Connect the cathodes of the diodes to pin 4.

Congratulations, you now have a solid state tube replacement. However, you aren't done yet.

As was noted above, solid state rectifier tube replacements have much lower internal resistance compared to vacuum tube rectifiers. This can cause problems and potentially even damage to the circuits if they are not designed to handle this difference.

There are two ways to fix this. One is to modify the circuit by placing a resistor in series with the plate supply transformer center tap and ground. The other way you can fix this is by adding the resistor in series with the cathodes of the diodes and pin 8 (pin 4 on 4pin tubes).

The advantage of placing the resistor in the solid state rectifier tube replacement is that you are not modifying the circuit so that you can easily plug a regular vacuum tube in the circuit again without removing the added resistor from the circuit. The disadvantage of placing the resistor in the solid state rectifier tube replacement is that the resistor will get hot and will have dangerous voltages on it. It is strongly recommended that you properly insulate the solid state rectifier tube replacement so that you do not accidentally touch the exposed lethal voltages on the connections.

Design note: The recommended design for 5U4 and 5Y3 tubes is to take power off pin 8 of the filament. A few designs take the power from pin 2. This may result in increased hum because of the filament voltage getting into the DC power. To fix this, you can either rewire the circuit to take power from pin 8, or move the cathodes of the diodes in the solid state tube replacement to pin 2. Do not short pins 2 and 8 as this will short out the heater supply and damage the circuits.

For the four pin rectifiers, the wiring is even less consistent than with the octal circuits. You may need to move the cathodes to pin 1 instead of pin 4. As with the octal tube replacement, do not short pins 1 and 4 or you will damage the circuits.

For Radios and TVs the pin used to take power off the tube is usually not important as any hum generated will likely not be noticable as it will be filtered by the power supply capacitor. In audio circuits it may be an issue, especially in guitar amplifiers which are often operated at their maximum output levels.

While in some cases you may be able to get away without using the resistor, in others it may be wise to use it to prevent damage to the circuits or change in the characteristics of the circuit. The chart below provides some suggested values to use. As with all things like this, these are only suggested values. The actual ideal values will be specific to the circuit and use.

Selecting the resistor for the solid state rectifier tube replacement.

5AR4	20 ohms	10 watts
5AS4	20 ohms	10 watts
5AU4	30 ohms	10 watts
5AW4	150 ohms	10 watts
5AX4	47 ohms	2 watts
5DJ4	100 ohms	10 watts
5T4	150 ohms	10 watts
5U4G/GA	150 ohms	10 watts
5U4GB	20 ohms	10 watts
5V4(all)	100 ohms	5 watts
5W4(all)	47 ohms	2 watts
5Y3(all)	47 ohms	2 watts
5Z4	47 ohms	2 watts
80	47 ohms	2 watts
82	10 ohms	2 watts
83	10 ohms	2 watts
83V	47 ohms	2 watts
5Z3	150 ohms	10 watts

Note: replacement of the 5R4 with a solid state tube replacement is not recommended without careful review of the circuit in which it is used. If the 5R4 is being used in a circuit where the 5U4 would normally be installed, use the 5U4 resistor.

Note: Silicon rectifier diodes have a typical voltage drop of between 0.5volt and 1.0volt. This can be averaged to 0.75volts for the math. Divide this by the current flow to get the effective resistance. Thus for a 250mA tube circuit you would get $0.75 / 0.25 = 3$ ohms. This is much lower than the 150 ohms of a normal 5U4 tube.

Another way to determine the resistor is to install a new tube in the circuit and set it up to use the maximum amount of power it would normally use. Measure the voltage between ground and the power take-off pin (typically pin 8 for octal, pin 4 for 4pin types). Mark this voltage down as a reference.

Note: these voltages don't have to be super accurate. A 5% tolerance for this type of work is more than adequate. Most tube circuits are designed to handle tolerances of 10% to 20% or even more.

Remove the rectifier tube and install the solid state tube replacement using a variable resistor with the appropriate wattage for the resistor. Set the resistor value to the value listed in the table. Again apply power and set up the circuit for the maximum normal load. While measuring the power takeoff voltage, adjust the resistor to achieve the same voltage as obtained with the new tube. Turn off the power, remove the variable resistor from the circuit and measure the resistance of the variable resistor for the obtained setting (be sure not to disturb the setting). This is the value of resistor that should be used with the circuit. (You can use the next closest standard resistance value available.) The wattage is determined by multiplying the square of the maximum current in amps times the resistance. Then use the next higher wattage resistor. Thus for a 5U4 circuit rated at 225mA using a 150 ohm resistor; $0.225 * 0.225 * 150 = 7.6$ watts. For this you would use a 10watt resistor.

Generally try to pick a wattage 20% to 50% higher to prevent the resistor from overheating and burning up. Do not use a resistor with less wattage or it will overheat. Do not use a resistor with too high of a wattage either. A part of the purpose of the resistor is to act as a safety valve in case the diodes short out. The resistor should burn out before the shorted diode destroys the rest of the circuits. Always be sure to provide adequate ventilation for power resistors so that the heat can escape. Also keep them away from other parts that can be damaged by the heat.

Unfortunately, where the normal failure for a tube is to fail open, the normal failure for a solid state diode is to short out. This can potentially cause nasty damage to the circuits.

Warning: Use extreme caution when working with tube circuits. Do not do this work if you are not qualified to do it. The voltages in tube circuits are lethal and can kill you.

Also see the companion files:

<http://www.fourwater.com/files/rectnotes.txt>

<http://www.fourwater.com/files/gasrect.txt>

<http://www.fourwater.com/files/voltreg.txt>

<http://www.fourwater.com/tubeinfo.htm>

Mike at MDBVentures.com

<http://www.MDBVentures.com> - Great prices on great tubes!