Application of tube replacement and Rectifiers

International Rectifier's Solid State Tube Replacements are designed to replace vacuum and mercury vapor tube rectifiers. Each unit is a silicon rectifier assembly molded in a tube-type case. The tube replacement is equipped with the identical pin locations and connections as the tube it is designed to replace. Advantages of IR tube replacements include long life, no warm up, high temperature operation, low heat generation, and resistance to mechanical shock.

In some cases it may be necessary to add resistance to the circuit to protect the load from excess voltages or to protect the tube replacement from surge currents.

SPECIFIC REPLACEMENT INFORMATION

ST-1 and ST-5 are similar devices except that ST-5 offers increased internal pin spacing required for high altitude operation.

ST-8 and ST-14 have resistance added to the internal circuitry to protect from excessive surge currents.

ST-9 and ST-10 differ only in mounting so that ST-9 replaces tube 8008 and ST-10 replaces 872A. In both cases pin #2 is connected to cathode. In some special applications, it may be necessary to modify the circuit wiring before installation.

ST-9, ST-10, ST-11, ST-12, and ST-15 incorporate shunting resistors and capacitors to increase transient voltage protection of the tube replacement.

LOAD VOLTAGE LIMITING RESISTANCE

When replacing gas or mercury vapor tubes, it is not necessary to increase total circuit resistance to simulate tube voltage drop. The slight increase in output voltage is generally not large enough to damage other circuit components. However, it is necessary to add a series resistance when replacing high vacuum rectifiers; otherwise the resulting higher output voltage could damage other circuit components.

CALCULATING THE RESISTOR FOR LIMITING LOAD VOLTAGE

To calculate the required series resistance:

$$R_D = \frac{V_{F(tube)}}{I_{FM}} \quad (1)$$

Where: $V_{F(tube)}$ = Forward voltage drop of vacuum tube being replaced

I_{FM} = Peak output current of tube.

R_D = Series voltage dropping resistor.

The value of $V_{F(tube)}$ may be obtained from the tube rating sheets or from operational characteristics curves. The value of I_{FM} may be approximated for most cases by multiplying the dc output of the tube (I_o) by four. (If very large peak currents are expected, a more accurate calculation of I_{FM} should be made.)

Thus: $$R_D \approx \frac{V_{F(tube)}}{4 \times I_o} \quad (2)$$

To calculate the power rating of the resistor:

$$P = (I_{F(rms)})^2 \times R_D \quad (3)$$

Where: R_D = Resistance calculated in Equation 2.

$I_{F(rms)}$ = The RMS current through the resistor.

It will be necessary to estimate the value of $I_{f(RMS)}$ because of the current wave form. A good approximation is made by multiplying the average current by three.

Thus: $$P = (3 \times I_o)^2 \times R_D = 9\, R_D\, I_o^2 \quad (4)$$

EXAMPLE

When IR's ST-2 is used to replace a 5U4 vacuum tube operating at 300VRMS and 200mAdc, the forward voltage drop, from the tube rating tables, is approximately 45Vdc. Therefore;

$$R_D = \frac{V_{F(tube)}}{4 \times I_o} = \frac{45}{4 \times .200} = 56 \text{ Ohms}$$

$$P = 9\, R_D\, I_o^2 = 9 \times 56 \times (.200)^2 = 20 \text{ Watts}$$

Thus a 60Ω, 20 Watt resistor should be connected between the cathode tube pin and the filter and load circuit.

SURGE PROTECTION

When tube replacements are used with capacitive loads and when no voltage limiting resistance is added to the circuit, the tube replacement must be protected from current surges by a current limiting series resistance. This resistance must limit the surge current to a value which the tube replacement can withstand. IR's ST-15 affords a 200 Amp one-cycle surge rating, while all other IR tube replacements offer a one-cycle surge rating of 50 Amps.

CALCULATING SURGE CURRENT PROTECTION

The required surge limiting resistance is computed from:

$$R_{(surge)} = \frac{E_{pf}}{I_{FM(surge)}} \quad (5)$$

Where: E_{pf} = Peak value of the transformer phase voltage.

$I_{FM(surge)}$ = Maximum allowable surge current rating (peak Amperes).

$R_{(surge)}$ = Resistance of surge limiting resistor.

This value of resistance includes the resistance offered by the transformer secondary phase winding.

The power rating of the resistor is calculated as in Equation 4; but R_D is replaced with $R_{(surge)}$:

$$P = 9\, R_{(surge)}\, I_o^2 \quad (6)$$

EXAMPLE:

Using the same conditions as in the previous example, the 300VRMS operating voltages must be converted to the peak operating voltage.

$$E_{pf} = 300 \times \sqrt{2} = 425V$$

Then the resistance must be computed:

$$R_{(surge)} = \frac{E_{pf}}{I_{FM(surge)}} = \frac{425}{50} = 8.5 \text{ ohms}$$

The transformer resistance can now be subtracted from the required series resistance:

$$R_{(surge)} - R_{transformer} = 8.5 - 1.0 = 7.5 \text{ ohms}$$

(The transformer resistance listed is for example only.)

Now the power rating of the resistor can be calculated:

$$P = 9\, R_{(surge)}\, I_o^2 = 9 \times 7.5 \times (.200)^2 = 2.7 \text{ Watts}$$

Thus a 7.5Ω, 3 Watt resistor should be connected in series with the tube replacement to limit surge currents to the rectifier.

It should be recognized that where the calculated value of the series voltage dropping resistor R_D is greater than the required value for the surge limiting resistor $R_{(surge)}$, it is not necessary to include both in the circuit. Only R_D would be necessary.

INTERNATIONAL RECTIFIER

Semiconductor Division, 233 Kansas Street, El Segundo, California 90245, Phone (213) 678-6281
Field offices and distributors in major cities around the world

Furthermore, when a surge limiting resistor is necessary, it may be placed in either of the two locations indicated in Figure 1

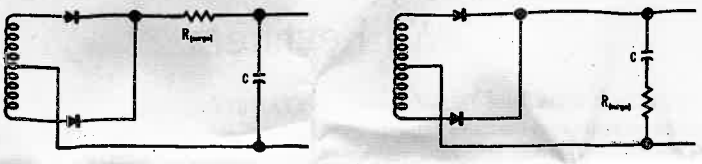
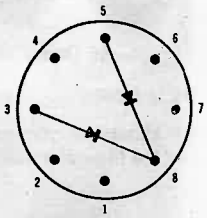
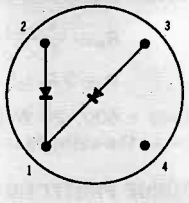


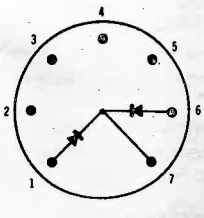
Fig. 1



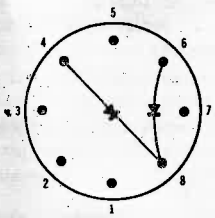
1N1237 ST-3
Octal Base



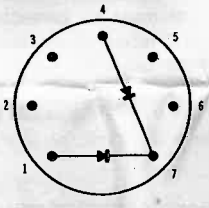
1N1150A, ST-4
A4-9 Base



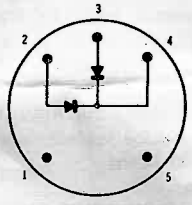
ST-1, ST-1A
E7-1 Base



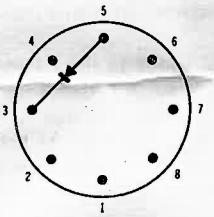
1N1238, 1N1239
ST-2, ST-2A
Octal Base



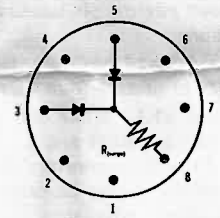
1N2490, ST-5
E7-1 Base



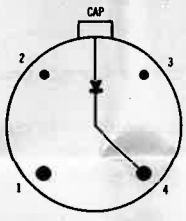
ST-6
A5-11 Base



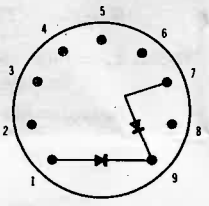
ST-7
Octal Base



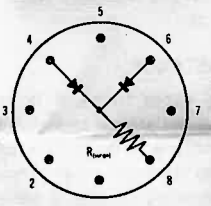
ST-8
Octal Base



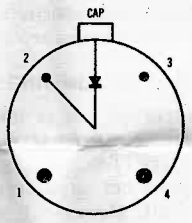
ST-7A, ST-11, ST-12
Base①



ST-13
E9-1 Base



ST-14
Octal Base



ST-9, ST-10, ST-15
Base②

TYPICAL RATINGS AND CHARACTERISTICS

IR Number	JEDEC Number	V_{RWM}—Working Peak Reverse Voltage per Leg (Volts)	$V_{r(rms)}$—Max. RMS Input (Volts)	$I_{O(AV)}$—Max. dc Output Current @ 70°C (mA)	$I_{FM(surge)}$—Max. Peak One-Cycle, Non-Recurrent Surge Current (A)	V_F—Average Forward Voltage Drop per Leg (Vdc) @ 0.5 Adc	Max. Dimensions L	Max. Dimensions D	Replaces Tubes
ST-1	1N2630	1,500*	1,050*	85*	50	1.8	1.75	0.87	6X4, 12X4
ST-1A	1N570	1,500*	1,050*	75*	50	1.8	(See Fig. 2)		MIL-6X4, MIL-12X4
ST-2	1N2631	1,600*	1,130*	600*	50	1.8	2.65	1.25	5AW4, 5AX4, 5AZ4, 5T4, 5U4, 5Y3, 6004
—	1N1238	1,600*	1,130*	750*①	50	3.0	2.65	1.25	5AV4, 5AW4, 5AZ4, 5T4, 5U4, 5V4, 5W4, 5Y3, 5Z4
ST-2A	1N2632	2,800*	1,950*	200*	50	2.7	2.65	1.25	5R4, 5R4W
—	1N1239	2,800*	1,950	500*①	50	6.0	3.75	1.38	5R4
ST-3	1N2633	1,600*	1,130*	600*	50	1.8	2.65	1.25	0Z4, 5X4, 6AX5, 6W5, 6X5, 6ZY5, 5839, 5852
—	1N1237	1,600*	1,130	750*①	50	3.0	2.65	1.25	0Z4, 5X4, 5Y4, 6AX5, 6X5
ST-4	1N2634	1,600*	1,130*	600*	50	3.6	2.65	1.25	5Z3, 80, 82, 83, 83V
—	1N1150A	1,600*	1,130	750*①	50	3.0	2.65	1.25	5Z3, 80, 82, 83, 83V
ST-5	1N2635	1,500*	1,050*	85*	50	3.6	1.75	0.87	High Altitude 6X4 & 12X4
—	1N2490	1,600*	1,130	500*①	50	3.0	1.50	0.87	6X4
ST-6	1N2636	1,500*	1,050*	85*	50	3.6	2.45	1.19	84/6Z4
ST-7	1N1262	4,500*	3,200	250*①	50	4.5	3.75	1.38	6AU4, 6AX4, 6BL4, 6W4, 12AX4, 17AX4, 25W4
ST-7A	1N2637	10,400	7,300*	250*	50	11.0	5.05	1.38	3B28, 249B, 866, 866A
ST-8	—	1,250	880	80	50	6.2②	1.10	1.40	0Z4, 6X5
ST-9	—	10,000	7,000	1,250	50	14.0	8.05	2.31	8008
ST-10	—	10,000	7,000	1,250	50	14.0	8.18	2.31	872A
ST-11	—	7,500	5,300	125	50	8.1	4.20	1.20	816
ST-12	—	40,000	28,000	100	50	54.0	7.90	2.40	8020
ST-13	—	1,275	900	130	50	1.8	2.00	0.82	6BW4, 12BW4
ST-14	1N2389	1,600	1,130	600	50	5.3③	1.50	1.44	5AV4, 5AW4, 5AX4, 5T4, 5U4, 5V4, 5W4, 5Y3, 5Z4, 6004
ST-15	—	15,000	10,600	1,750	200	15.0	9.65	3.88	673

JEDEC registered value (applicable on JEDEC types only). ① @ 100°C ③ Including internal current limiting resistor.

① Tube replacement	Base
ST-7A	A4-10
ST-11	A4-5
ST-12	A4-10

② Tube replacement	Base
ST-9	A4-18
ST-10	A4-29
ST-15	A4-18