Technical Note: RNP20021001

None-Inductive Thin Film Power Resistors, RNP10S, RNP20S and RNP50S

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1. PRODUCT OVERVIEW:

Nikkohm Thin Film Power Resistors (models RNP10S, RNP20S and RNP50S) are made by the deposition of nickel-chrome (Ni-Cr) onto the surface of an alumina substrate. The back of the substrate is metalized and soldered directly to a heat-dissipating copper plate (tab), which forms an outside surface of the resistor body. This provides excellent thermal efficiency as the heat generated within the resistor is effectively educted through the tab to the outside of the resistor, making it possible for a resistor of relatively small size to handle large amounts of electric power - as much as 10 to 50 watts in these models. Typical structure and dimensions are shown in figures 1 and 2.

Resistor performance characteristics and customer confidence have allowed Nikkohm to ship over 30 million units since product introduction in 1985.

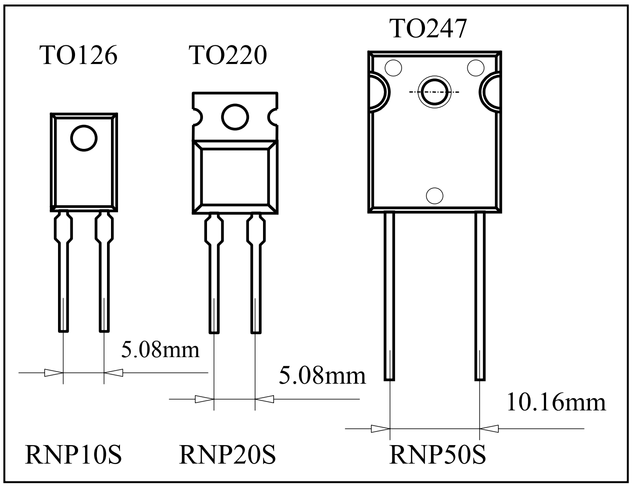

Figure 1. External view of RNP10S, RNP20S and RNP50S

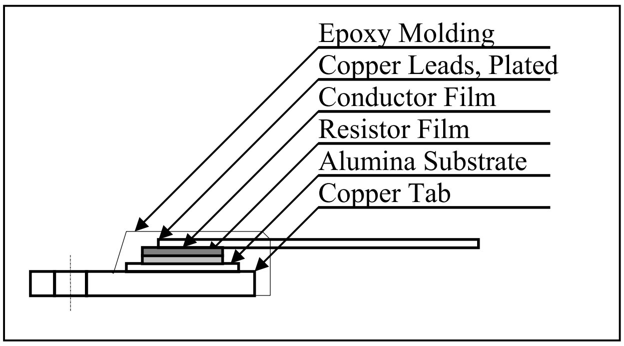

Figure 2. Typical structure of RNP resistors.

2. CHARACTERISTICS OF THE RNP-TYPE RESISTOR:

2.1. Resistance Range, Temperature Coefficient, and Resistor Tolerance:

The resistors can be technically made in any resistance value from 0.1ohms up to 51k ohms. The quickest and most efficient delivery cycles are available when values and tolerances are selected from the E24 Standard Value Table (Table 2). E24 is specified as 24 values per decade. 2.5 and 5.0 are contained additionally in Table 2 because our customers require 2.5 and 5.0 in many case. Power rating is defined in condition that the resistor is attached on a heat sink and that tab temperature of resistor is kept from –50C to +25C. Dielectric withstanding voltage is voltage between tab and leads.

Type	RNP10S		
Package	TO126		
Powerwith heat sink	10W (2.8C/W heat sink)		
Resistance(ohm)	0.1-0.91 E24	1.1-0.91 E24	10-51k E24
TCR (+/-ppm/C)	250ppm	250ppm	50ppm
Tolerance (+/-)	5%	5%	1%
Dielectric	1500VDC		
Thermal Resistance	5.9C/W		
Capacitance	2.7pF		

Table 1-1. Performance of RNP-10S.

Type	RNP20S		
Package	TO-220		
Power with heat sink	20W (2.8C/W heat sink)		
Resistance(ohm)	0.1-0.91 E24	1.0-9.1 E24	10-51k E24
TCR (+/-ppm/C)	250ppm	100ppm	50ppm
Tolerance (+/-)	5%	1%, 5%	1%
Dielectric	2,000VDC		
Thermal Resistance	3.3C/W		
Capacitance	2.8pF		

Table 1-2. Performance of RNP-20S.

Type	RNP50S		
Package	TO-247		
Power with heat sink	50W(1.2C/W)		
Resistance (ohm)	0.1-0.91 E24	1-9.1 E24	10-51k E24
TCR (+/-/C)	250ppm	100ppm	50ppm
Tolerance	+/-5%	+/-5%	+/-1%
Dielectric	2,500VDC		
Thermal Resistance	1.3C/W		
Capacitance	5.0pF		

Table 1-3. Performance of RNP-50S

Type	RNP10		
Package	TO220		
Power with heat sink	10W (2.8C/W)		
Resistance (ohm)	0.01-0.91 E6	1.0-9.1 E24	10-51k E24
TCR (+/-/C)	250ppm	100ppm	50ppm
Tolerance	5%	1%, 5%	1%
Dielectric	2,000VDC		
Thermal Resistance	3.3 C/W		
Capacitance	2.7pF		

Table 1-4. Performance of RNP-10

1.0	1.1	1.2	1.3	1.5	1.6	1.8	2.0	2.2	2.4	(2.5)
2.7	3.0	3.3	3.6	3.9	4.3	4.7	(5.0)	5.1	5.6	6.2
6.8	7.5	8.2	9.1							

Table 2. Standard value decade table.
(Modified E24 Table.)

2.2. Rated Power and Heat Dissipation:

Power consumed by the resistor is dissipated in the form of heat. Heat generated within the resistive film is educed primarily by conduction through the alumina substrate, through the tab, and into the heat sink on which the resistor is mounted, as illustrated in Fig. 3. The heat sink, itself, is generally either air cooled or water cooled. An aluminum alloy board is often conveniently used as an air-cooled heat sink. When the resistor is mounted on a heat sink with 2.8C/W or 1.2C/W of thermal resistance and electrical power is consumed by the resistor, the temperature rise on the resistive film and the temperature rise on the tab relative to the power consumed are as shown in Fig.4 (a), (b) and (c).

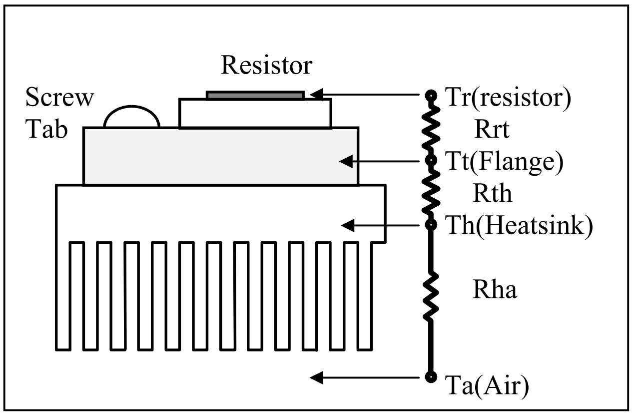

Figure 3. Heat resistance (Rt) and temperature (T).

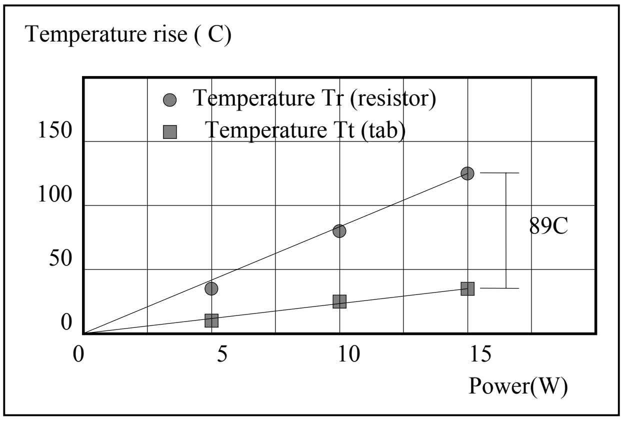

Figure 4 (a). Temperature rise of RNP-10S which was put on heat sink of 2.8 C/W.

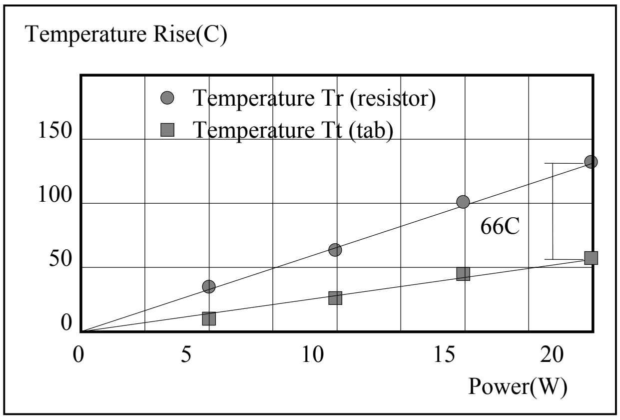

Figure 4 (b). Temperature rise of RNP-20S which was put on heat sink of 2.8 C/W.

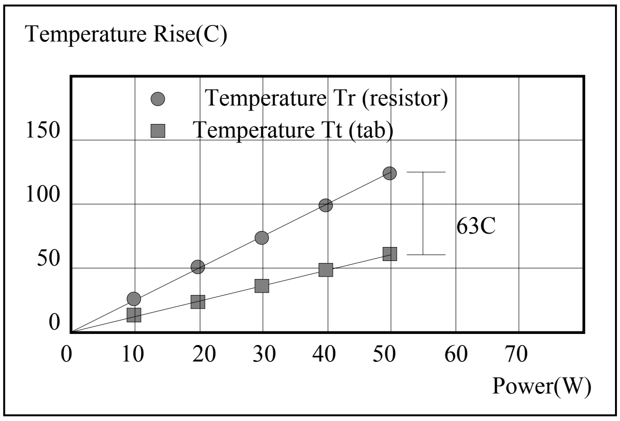

Figure 4 (c). Temperature rise of RNP-50S which was put on heat sink of 1.2 C/W.

The resistor temperature measurement, is made using a non-contacting thermal image processor and which subtracts the temperature of the surrounding environment thus yielding a direct measurement of temperature rise rather than absolute temperature.

The thermal resistance between the resistance film and the tab can be found by subtracting the two curves in each graph of Fig.4. It can be seen, for example, that at 20 watts (Fig.4b) of RNP20S thermal resistance, Rrt is 3.3C/W - which constitutes the combined thermal resistance of the alumina substrate and the thermal resistance of the junction between the tab and the alumina substrate. Thermal resistance of RNP10S and RNP50S show 5.93C/W (Fig.4a) and 1.26C/W (Fig.4c). The thermal resistance between resistor and tab are determined by the area of each substrates. Increasing the substrate area would proportionally decrease thermal resistance.

Derating curves are derived from the thermal resistance and maximum operating temperature allowed for the resistor material. In Ni-Cr thin film resistor, maximum operating temperature will ordinary be 155C. The derating curve indicates a relation between applied power and tab temperature. With zero power applied the resistance film temperature would be the same as the tab temperature and ambient temperature, and this must be kept at 155C or less. As applied power is gradually increased, the heat generated in the film is not completely educted through to the ambient because of thermal resistance of all of the materials and resistor temperature will be increased. Because of the thermal resistance between the resistor and the tab, the tab temperature must be adequately controlled at a lower temperature than the resistor in order to keep the resistor below 155C. The relation between the tab temperature and applied power is expressed as heat resistance Rrt which is obtained from temperature rise measurements.

Figure 5 shows the derating curves for RNP10S, RNP20S and RNP50S with the power applied along the vertical axis and the tab temperature along the horizontal axis. As the power is increased, the resistor film temperature rises above the tab temperature and therefore the tab temperature must be reduced in order to keep the film temperature below the 155C maximum allowable temperature. Or, conversely, at elevated temperatures (above 25C) the power must be reduced from the maximum 25C power rating to keep the resistor film operating temperature below its approved limit of 155C. The slope of the derating curve is obtained from the heat resistance.

In the case of RNP20S, the heat resistance between resistor film and tab, Rrt is 3.30C/W. Starting from a point of zero power at +155C a dotted line can be made with the Rrt as shown in Fig. 5b. A cross point of +25C shows the rated power of about 38 watts using common power rating standard. Applying a considerable safety margin, the RNP20S is rated at 20W.

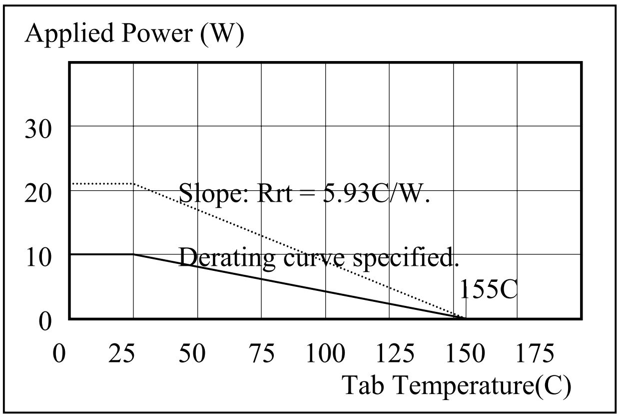

Figure 5a. Derating curve, RNP10S.

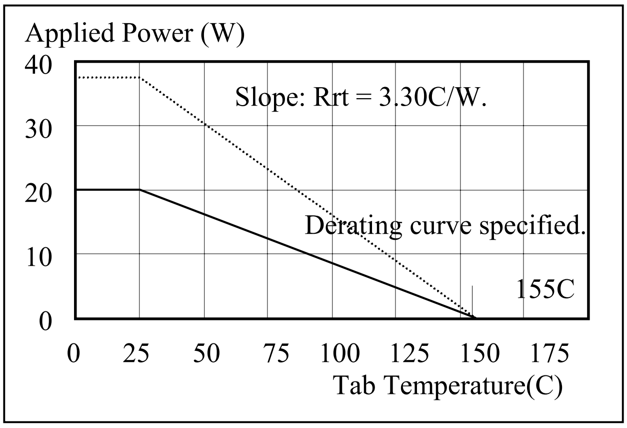

Figure 5b. Derating curve, RNP20S.

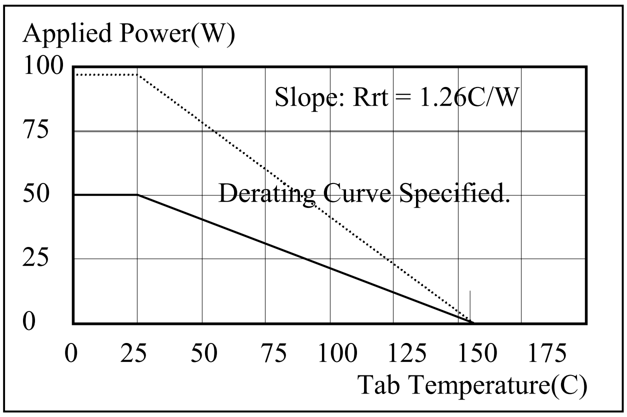

Figure 5c. Derating curve, RNP50S.

These derating curves are based on tab temperature, but when resistor is installed into equipment, the heat resistance between tab and heat sink as well as the heat resistance between the heat sink and the ambient air will also be factor to consider. For example an RNP20S attached on a heat sink of Rht=5C/W, the heat resistance Rth will commonly be about 0.1C/W, and the total heat resistance from resistor film to air will be 8.4C/W (=3.30+0.1+5.0). When using the common standard maximum ambient temperature is 50C (Ta), the temperature difference

between Tr and Ta is 8.4C/W, available maximum rating power will be obtained as 12.5W:
= (155-50) / 8.4.

It will be noted that the specified rated power of 20W of RNP20S at 25C is not applicable at 50C, and therefore the heat resistance and the maximum operating temperature will be important factors in the thermal management.

The heat resistance of heat sink will be as shown in Figure 6a and Figure 6b. Usually, the heat-sink is not used exclusively for the resistors but is shared by the semiconductors as well. Finally, the thermal design calculations should be verified by actual temperature rise measurements on each component to experimentally confirm the thermal conditions in the specific electronic equipment.

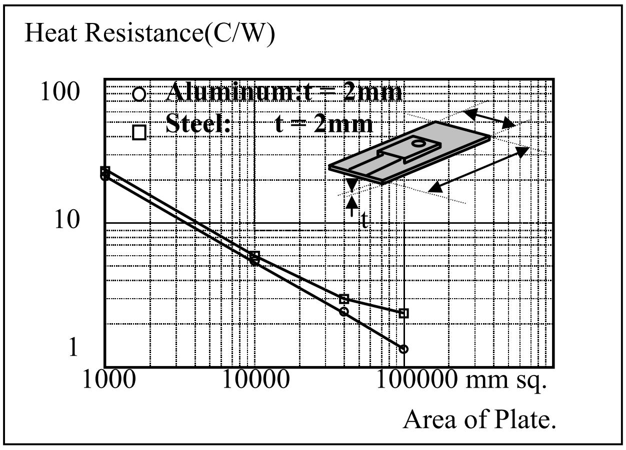

Figure 6a. Heat resistance of plate-type heat sink.

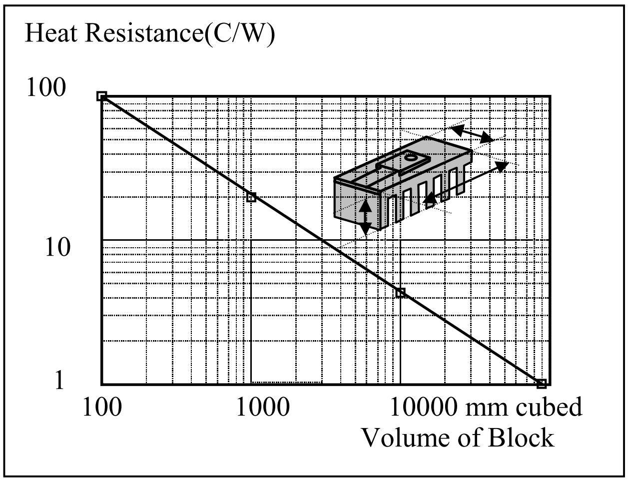

Figure 6b. Heat resistance of block type heat sink.

2.3. Impedance vs. Frequency, and Equivalent Circuits:

Impedance measurements at various frequencies result in the curves shown in Fig.7a, 7b, 7c. The graphs show the root-mean-square value of impedance measured for various resistance values in different models of RNP-Type resistors. An equivalent circuit of the RNP-Type resistor is approximated by Fig.8 (a) in resistance value of 100ohms or more, and in Fig.8 (b) for resistance values of 10ohms or less. The reactance component of the equivalent circuit is affected by the lead length. In the following explanations the measurement points are at the base of the stand-off on each lead, the points at which the leads would be attached to the printed circuit board. In resistor values between 50 and 100ohms, the inductive and capacitive reactance are mutually canceled and the frequency response is purely resistive with a smooth flat frequency characteristic from D.C. to several hundred Mega hertz. The RNP resistor can be used economically in high frequency applications. In the applications, resistor values of 50ohm, 75ohm and 100ohm are used in many cases.

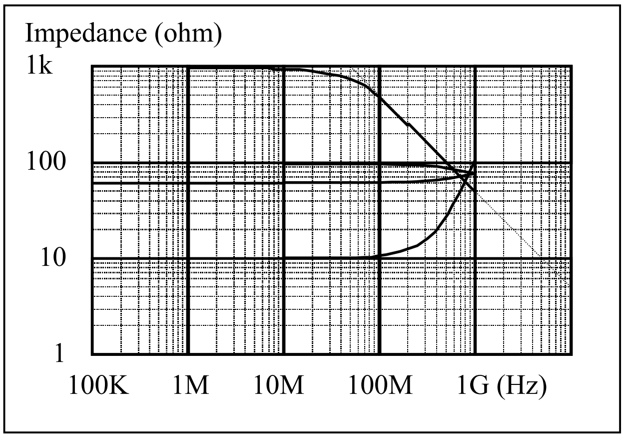

Figure 7a. Frequency characteristics of RNP10S.

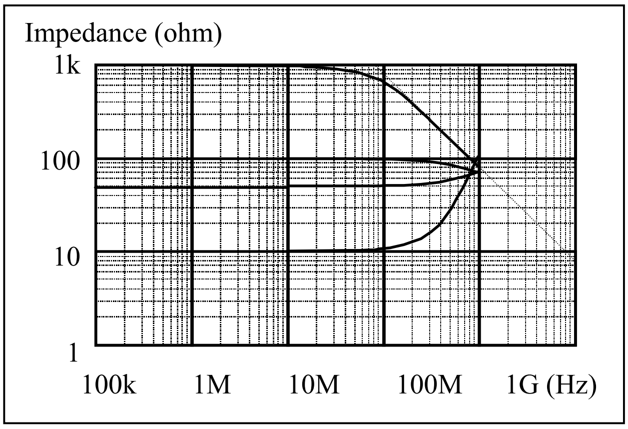

Figure 7b. Frequency characteristics of RNP20S.

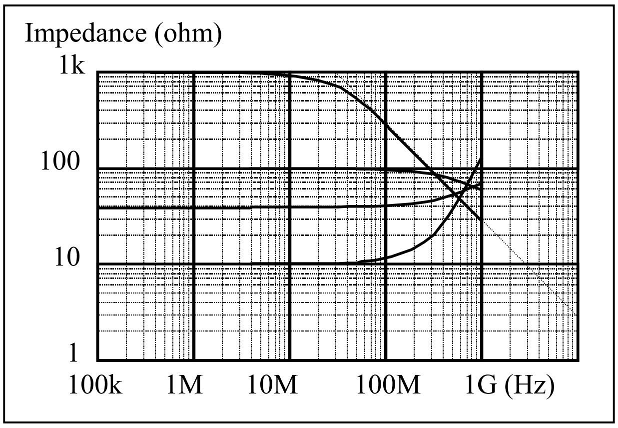

Figure 7c. Frequency characteristics of RNP50S.

Moreover, in resistance ranges above 100ohms, wide-band high performance circuits can be achieved without adding compensating circuitry because the capacitive characteristic of the resistor will be compensated by circuit wiring stray inductance.

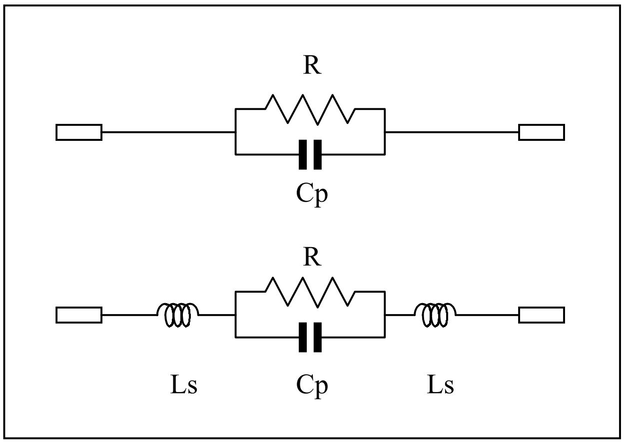

Figure 8a. Equivalent circuit for higher resistance than 100ohm. (upper)
Figure 8b. Equivalent circuit for lower resistance than 10ohm. (lower)

2.4. Short Term Overlord:

Conditions of short term overload are commonly defined as 2.5 times rated power applied for 5 second. The RNP resistor can handle very large power pulses without damage when the pulse widths are 1 milli second or less. In some applications, such as in snubber resistors or in the interface circuit which receives noise pulses, it is possible that the resistor receive short pulse width impulses with peak power greater than rated power. Typically, snubber resistors might experience power overloads at duration of several micro seconds or shorter.

In the pulse operation of the resistor, the resistor consumes both the mean power averaged over an entire period of pulse sequence and the instantaneous power for short pulse duration. The mean power might be restricted within specified rated power and will induces slow temperature rise of resistor. Also, the peak power of pulse, or pulse energy, may cause partial damage in the resistor film as the hot-spot. The pulse energy will vaporize small area of resistor film in a moment. Pulse durability of resistor seems not to be related with resistor temperature, remarkably.

Fig. 9 shows the results of pulse overload testing on the RNP type resistor and shows one of typical destructive limit of pulse operation.

In Fig. 9 the curves show the results of tests at different peak power pulses with pulse widths from 1 microseconds to 10 milliseconds, within 1 second cycles.

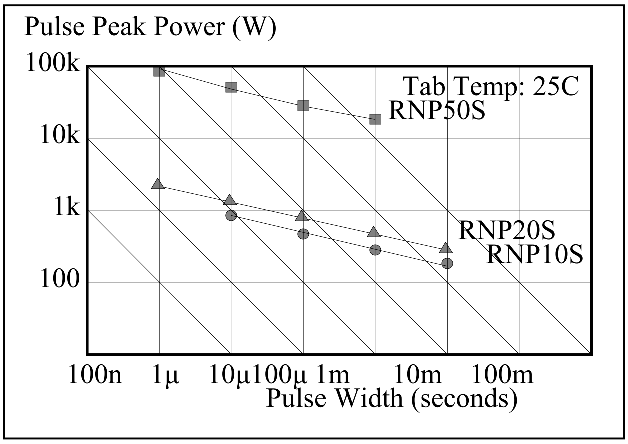

Figure 9. Pulse energy durability.

Resistance changes were measured after 10 cycles of exposure; damage is assumed to have begun if the resistor changes +/-0.1% or more.

In other applications, such as in braking resistors in motor control circuits or as inrush-current protection resistors in the power supplies which receive pulses of several hundred milliseconds intervals, the RNP can handle up to 2 or 3 times its rated power.

2.5. Dielectric Withstanding Voltage (DWV):

The structual drawing in Fig 2 shows that the alumina substrate between the resistance film and the external tab completely insulates the RNP type resistor from the tab. Therefore, the resistor can be mounted directly to a heat-sink without requiring electrical insulation. The dielectric withstanding voltage is determined by the thickness of the alumina substrate (0.63mm) and the dielectric withstanding voltage of the alumina (10 KV/mm). A dielectric withstanding voltage test is performed on 100% of the product in the manufacturing process and a standard of 1500-2500volts DC, depending on style, is guaranteed.

3. APPLICATIONS:

3.1. Load Resistor for the Video Output Circuit in High Resolution Monitors:

The circuit is shown in Fig.10. In the video color output circuit the signal amplitude is 70 volts applied to the CRT in monitor applications, 200 volts in projection TV applications, and in the wide band amplifier large signal amplitudes up to hundreds of Megahertz are necessary. In such applications the cascade-type power transistor amplifier with common base circuitry can achieve better gain-phase characteristics than feedback type circuits. In this circuit the high frequency performance of the collector load resistor is critical to the amplifier characteristics and the resistor will determine picture quality. The RNP type resistor makes a very good collector load resistor in these applications and because this resistor is the same type package as the power transistor used for the cascade amplifier, stray inductance generated by wiring them into the circuit can be greatly reduced. The RNP type resistor is used for CRT monitors, projection TV, advanced TV, video signal processing, video signal measurements, etc.

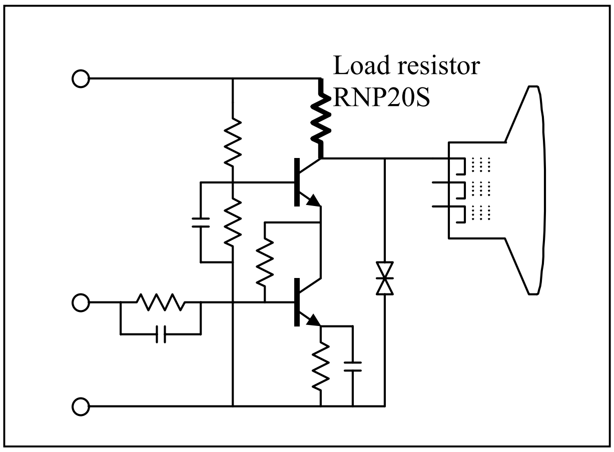

Figure 10. Video output circuit in high resolution monitors:

3.2. Damping Resistor of High-output Circuit in Monitors.

Usually, inductive components in analog circuits have a small amount of stray capacitance and the circuits resonate at specific frequencies. As shown in Fig.11, a deflection circuit and its driver create a linear magnetic field in the deflection coil. However, an inconvenient ringing waveform is also created by the combination of coil inductance and stray capacitance. The ringing wave form causes picture non-linearity towards the edge of the screen and the picture quality becomes inferior. A damping resistor is effectively used to improve picture quality but the high frequency characteristics of the damping resistor are important. The high frequency performance of the RNP type resistor make it well suited for this application.

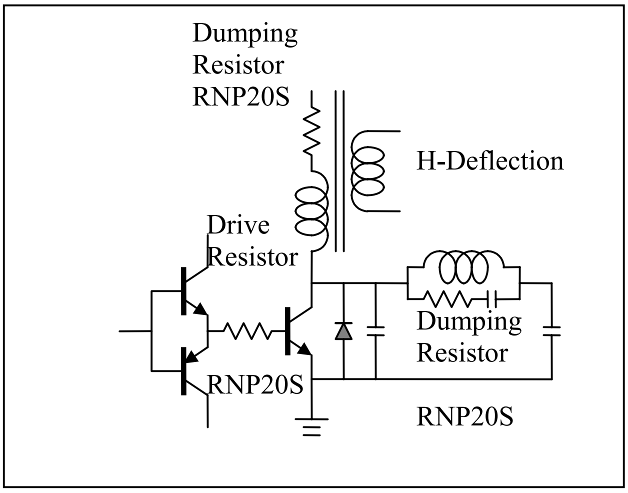

Figure 11. Deflection circuit.

3.3. Snubber Resistor for Switching Circuits:

A Typical switching power supply circuit is shown in Fig.12. A power supply with an output of 1KW or more uses a large switching transformer, which has large inductance as well. The snubber circuit in a switching power supply contains resistors, capacitors, and diodes. The snubber circuit protects the switching transistors (power MOS and IGBT) to prevent damage caused by the surge voltage. With pulse rise and fall times being 0.1 nanoseconds or less the frequency component of energy is concentrated within several hundred Megahertz. It is not possible to quantitatively express the energy involved because the wave forms change depending upon the switching frequency and the output current of the power supply. However, the high frequency characteristics of the RNP-type resistors have been proven to be excellently applied as snubber resistors in switching power supplies. The resistors are used in the power supply units of large computers, telephone/network switching systems, radio communication systems, and other broadcasting systems.

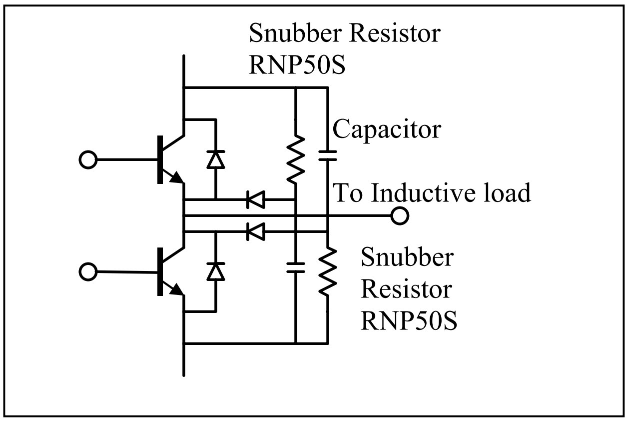

Figure 12. Snubber Resistor in SW-PS.

3.4. Other Applications:

The RNP resistor is also used as a current detecting emitter resistor in a low power circuit to detect the current flowing into the transistor. In large-scale power supplies the RNP resistor is used as the gate resistor of the gate-drive circuit of the IGBT. In high frequency applications the RNP resistor is used as a concentration resistor in a Wilkinson amplifier or as a high power terminating resistor. In pulse generators RNP resistors are used as impedance matching resistors.

4. REMARKS:

4.1. Heat Sink:

Although the rated power of RNP20S is still 2 watts in free air (no heat sink), the better frequency response of general Vishay thin film resistors (RP12-1W, RP202-2W) makes them a better choice in lower power high frequency applications.

The heat sinking capability versus power is shown in Fig.6 for natural air cooling. Also, it is common that a single heat sink is shared by multiple heat generating devices such as power transistors along with the RNP type resistors. In these cases it is necessary to confirm the temperature rises by actual measurement in operation. Measure the temperature of RNP20S resistors at the tab, and measure the temperature RNP10S and RNP50S resistors on the mounting screw.

4.2. Torque of Mounting Screw:

When the RNP resistor is mounted on a heat-sink by screw, a tightening torque of 5 kgf-cm is recommended. Note that the temperature rise of the resistor and the cooling effect of the heat sink are significantly affected by the torque on the mounting screw. Fig.13 shows the temperature rise on each part of the resistor at different levels of screw torque.

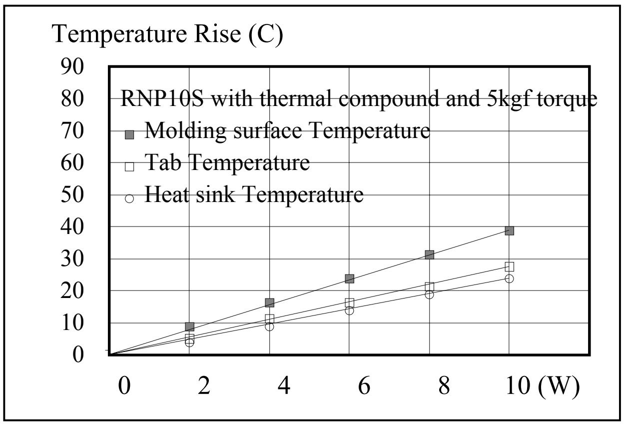

Figure 13a. Temp. rise of RNP10S attached on 2.8C/W heat sink with thermal compound and 5kgf torque.

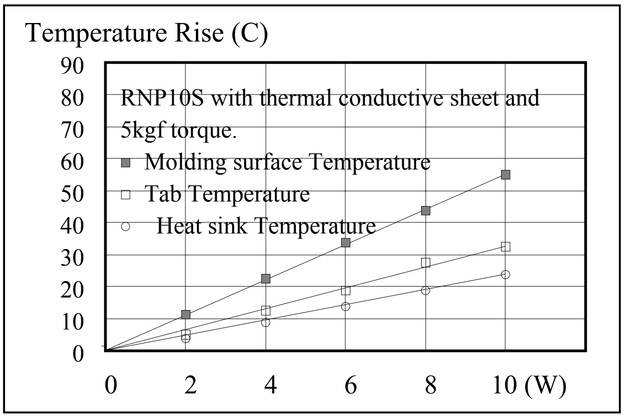

Figure 13b. Temperature rise of RNP10S attached on 2.8C/W heat sink with thermal conduction sheet

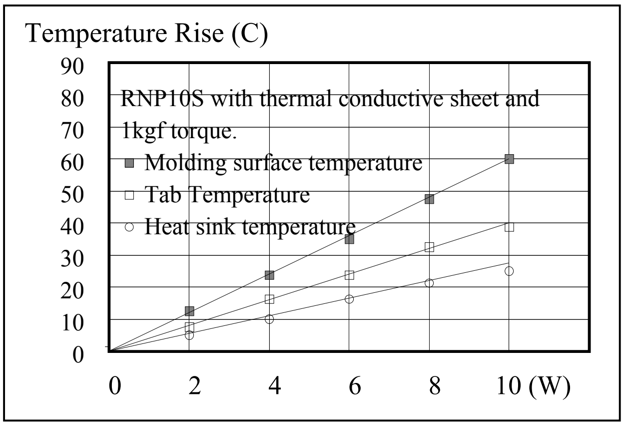

Figure 13c. Temperature. rise of RNP10S attached on 2.8C/W heat sink with thermal conductive sheet and 1kgf torque.

When an aluminum alloy plate is used as the heat sink and the resistor is mounted with a clip instead of a screw, it is important to measure and characterize the actual temperature rise for the specific installation to be sure that the temperature rise remains within specification limits. This is important because the mechanical force pressing the resistor against the heat sink vanes greatly with different clips.

4.3. Insulation of Tab:

When RNP type resistors are used it is not necessary to place an electric insulator between the tab and the heat sink. As shown in Fig.2 and 3, in all the RNP10S, the RNP20S and the RNP50S the resistive film is already insulated from the metal tab. Therefore, it is recommended that no additional insulation be used because it will unnecessarily diminish the cooling efficiency of the assembly.

4.4. Silicon Compound for Heat Conduction:

It is recommended that a heat conducting silicon compound be used between the metal tab of the RNP resistor and the heat-sink on which it is mounted. The silicon compound fills the small surface irregularities of the heat sink and the tab, increasing the thermal conductivity between them and thereby improving the thermal efficiency of the cooling operation. When the silicon compound is used the advantages is as shown in Fig13.

4.5. Series Connection of Resistors:

In an application where frequency characteristics are important and two resistors are to be connected, it is recommended that the resistors be chosen as series resistors instead of parallel. The stray capacitance of the resistors is not increased when connected in series and the cut-off frequency will be the same as single resistor.

5. Acknowledgment.

This technical note has been issued with our customer’s rich intelligence, and English explanation was helped with great effort of the stuffs who work within the Vishay Group. We thank them all for their goodwill and friendliness.

We would be very happy to hear of any questions or comments about this technical paper, please contact the author or skilled stuffs of Nikkohm directly to:

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