NEW Product

RFF500/600/700 Series

Application Note 174

RoHS
2002/95/EC

ARTESYN TECHNOLOGIES

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1. Introduction

This application note describes the features and functions of Artesyn Technologies' RFF500/600/700 series of high power density, full-brick dc-dc converters. These encapsulated, single output modules are targeted specifically at the RF amplifier telecommunications power market with requirements for 28 V modules for usage within distributed power architectures.

The RFF500/600/700 series offers wide input voltage ranges of 18-36 Vdc and 36-75 Vdc and can operate over a baseplate temperature range of -40 °C to +100 °C. The modules are fully protected against overcurrent, overvoltage and overtemperature conditions. Standard features include remote ON/OFF and remote sense.

The series has been designed primarily for RF amplifier telecommunication applications. EN60950-1 and UL/cUL60950 safety approvals have been obtained or are in process, and a high level of reliability has been designed into all models through extensive use of conservative derating criteria. Automated manufacturing methods, together with an extensive qualification program, ensure that all RFF500/600/700 series converters are extremely reliable.

2. Models

The RFF500/600/700 series comprises 5 models, as listed in Table 1

Model	Input Voltage	Output Voltage	Output Current
RFF500-24S28Y	18-36 Vdc	28 V	17.9 A
RFF500-48S28Y	36-75 Vdc	28 V	17.9 A
RFF600-24S28Y	18-36 Vdc	28 V	21.4 A
RFF600-48S28Y	36-75 Vdc	28 V	21.4 A
RFF700-48S28Y	36-75 Vdc	28 V	25.0 A

Table 1 - Output Voltages

RoHS Compliance Ordering Information

RoHS 2002/95/EC

The 'Y' at the end of the part number indicates that the part is non Pb-free (RoHS 5/6 compliant). Pb-free RoHS 6/6 compliant versions may be available on special request, please contact your local sales representative for details.

Features

- Industry standard full-brick and footprint: 116.84 x 60.96 x 12.70 mm (4.60 x 2.40 x 0.5 inches)
- Low profile option: 10.16 mm (0.4 inches)
- Wide operating temperature range (-40 °C to +100 °C) baseplate
- No minimum load requirement
- Optically isolated remote ON/OFF control
- Remote sense compensation
- Constant switching frequency
- Brickwall overcurrent protection
- Continuous short-circuit protection
- Output overvoltage protection (OVP)
- Overtemperature protection (OTP)
- Input under/overvoltage lockout protection (U/OVLO)
- Power good signal (IOC) that can be changed to current monitor
- Low voltage auxiliary control power for remote ON/OFF control
- Voltage output trimmable from 60% to 105%
- Parallelable with active current share
- RoHS compliant

3. General Description

3.1 Electrical Description

A block diagram of the RFF500/600/700 48 V input converter is shown in Figure 1. High efficiency power conversion is achieved through the use of high density silicon and planar magnetics in a dual interleaved forward topology operating at a nominal frequency of 500 kHz. 28 V output converters utilize ultra fast recovery output diodes.

The regulated voltage on the output pins is governed by the voltage on the module's sense pins, +S and -S.

The output is adjustable over a range of 60 % to 105 % of the nominal output voltage, using the TRIM pin (referenced to -S).

The converter can be shut down via the remote ON/OFF inputs (-ON/OFF pins and +ON/OFF inputs) that are isolated from both the primary and secondary sides of the converter. The remote ON/OFF mode of operation is described in Section 4.7

The output is monitored for overvoltage conditions. The converter will shutdown at the overvoltage set-point if an overvoltage condition is detected at the output. After an overvoltage shutdown, the unit will remain in a low-dissipation non-operating condition until the input power or the RC enable pin is cycled (latching overvoltage). The converter is also protected against overtemperature conditions. If the converter is overloaded or the ambient temperature gets too high, the converter will shut down when the center of the baseplate reaches a temperature of approximately 110 °C. The converter will restart when the baseplate temperature falls below approximately 100 °C.

An internal filter smoothes the input current and reduces conducted and radiated EMI. Further improvement, including compliance with the most common conducted emission specifications, can be achieved through the use of an optional user-supplied external input filter.

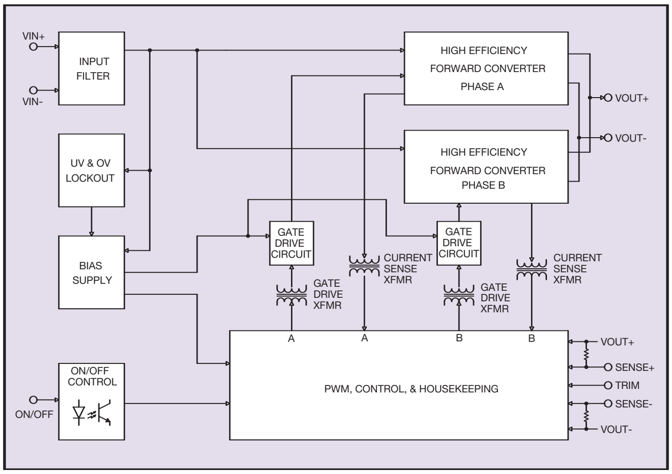

Figure 1 - Electrical Block Diagram

3.2 Physical Construction

The RFF500/600/700 converters are constructed using a multi-layer FR4 PCB in conjunction with a two layer T-clad board that forms the module baseplate. Heat dissipation of the power components is optimized, ensuring that control components are not thermally stressed. The multi-layer board is used for most of the low power dissipation components, while the high power components, including magnetics and power semiconductors, are T-clad mounted to provide excellent thermal conductivity to the converter baseplate. This baseplate is the primary path for removal of heat from the module. The baseplate is configured so that an external heatsink may be attached if desired.

4. Features and Functions

4.1 Wide Operating Temperature Range

The RFF500/600/700's ability to accommodate a wide range of ambient temperatures is the result of its high power conversion efficiency and resultant low power dissipation, combined with the excellent thermal performance of the mechanical package. The maximum output power that the module can deliver depends on a number of parameters, primarily:

- Use of attached heatsink
- Input voltage range
- Output load current
- Air velocity (forced or natural convection)
- Mounting orientation of target application PCB, i.e. vertical/horizontal mount, or mechanically tied down (especially important in natural convection conditions)

The RFF500/600/700 can be operated from -40 °C to a maximum ambient baseplate temperature of +100 °C.

4.2 Overtemperature Protection (OTP)

The RFF500/600/700 is equipped with non-latching, overtemperature protection. A temperature sensor monitors the operating temperature of the converter. If the temperature exceeds a threshold of 110 °C (typical) at the center of the baseplate, the converter will shut down, disabling the output. When the baseplate temperature has decreased by approximately 10 °C the converter will automatically restart.

The RFF500/600/700 might experience overtemperature conditions during a persistent overload on the output. Overload conditions can be caused by external current faults. OTP might also be entered due to a loss of control of the environmental conditions (e.g. an increase in the converter's ambient temperature due to a failing fan).

4.3 Output Voltage Adjustment

The output voltage on 28 V models is trimmable from 60% to 105% of the nominal voltage set-point. Details on how to trim all models are provided in Section 8.4.

4.4 Output Overvoltage Protection

The overvoltage protection (OVP) feature is used to protect the module and the user's circuitry in the event that a fault occurs in the main control loop. Faults of this type include feedback component failure, an open-circuit sense resistor or error amplifier failure. The unit is also protected in the event of the output being trimmed above the recommended maximum specification.

The OVP circuit consists of a differential amplifier and comparator that senses the actual voltage at the output power terminals of the module. The sensed voltage is compared to a separate OVP reference and a compensated error signal is generated that causes the converter to shut down when the overvoltage threshold is reached. The OVP threshold level is typically set at 112-125% of the nominal output voltage set-point for each model.

After an OVP shutdown, the converter will remain latched in a low power dissipation non-operating condition. The converter can be restarted by either turning the input power source off and back on again or by toggling the enable pin to "OFF" and then back to "ON".

4.5 Safe Operating Area

The Safe Operating Area (SOA) of the RFF500/600/700 converter is Shown in Figure 2. Assuming the converter is operated within its thermal limits it can deliver rated output current I_{rated}. Note, however, that when the unit output voltage is trimmed up. The maximum output current will need to be reduced so that the output power does not exceed 500 W, 600 W and 700 W depending upon the model.

The module will still deliver I_{rated} when trimmed down.

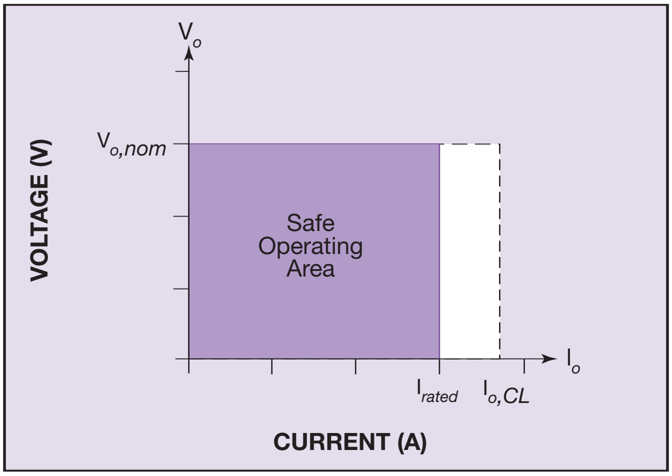

Figure 2 - Maximum Output Current Safe Operating Area

It should be noted that the SOA shown in Figure 2 is valid only if the converter is operated within its thermal specification. See Section 8.2 for more detail.

4.6 Brickwall Current Limit and Short-Circuit Protection

All RFF500/600/700 models have a built-in brickwall current limit function and full continuous short-circuit protection. Thus the V–I characteristic in current limit, as indicated by the dashed line in Figure 2, will be almost vertical at the current limit inception point, I_{limit} . This means that the output current should be almost constant irrespective of the output voltage during overload. The current limit inception point is influenced by the ambient temperature and line voltage, and also has a parametric spread. The current limit inception point is typically 117% of rated full load for all models. The maximum short-circuit current will be 13% of the rated full load current. The brickwall current limit scheme has many advantages, including increased capacitive load start-up capability.

Note that none of the module specifications are guaranteed when the unit is operated in an overcurrent condition. The unit will not be damaged in an overcurrent condition because it will be protected by the OTP function, but the converter's lifetime may be reduced.

4.7 Remote ON/OFF

The remote ON/OFF inputs allow external circuitry to put the RFF500/600/700 converter into a low dissipation sleep mode. Remote ON/OFF control is available as standard and has one mode of operation. The converter will be active as long as a current (1 to 20 mA) is flowing between -ON/OFF and +ON/OFF and inactive when no current is flowing. Because the Remote control pins are isolated up to 1.5 kV, the voltage to drive this current can be derived from the input, the outputs, or an external supply, or the Aux. pin with appropriate resistor. The maximum forward current allowable without damage is 20 mA and the maximum reverse voltage is 6 Volts. These limitations need to be factored-in when selecting the value of the current limiting resistor. Figures 3 and 4 show various ways that the remote ON/OFF control can be implemented.

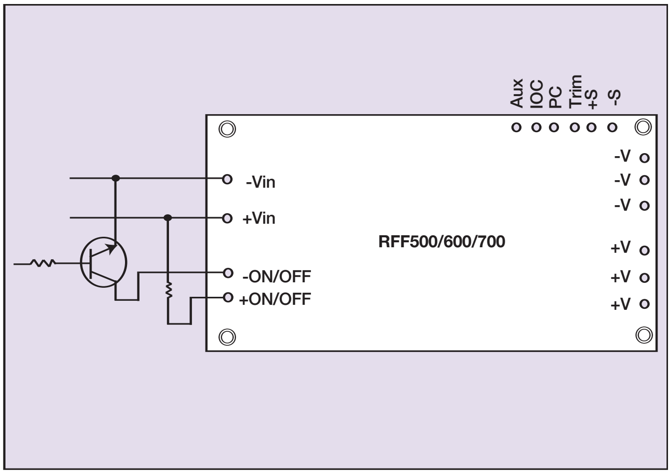

Figure 3 - Remote ON/OFF Input Drive Circuit Reference to the Input R Recommended Resistor Value = 30 kΩ (1/2 W) for RFF with 48 V input, 10 kΩ for RFF with 24 V input

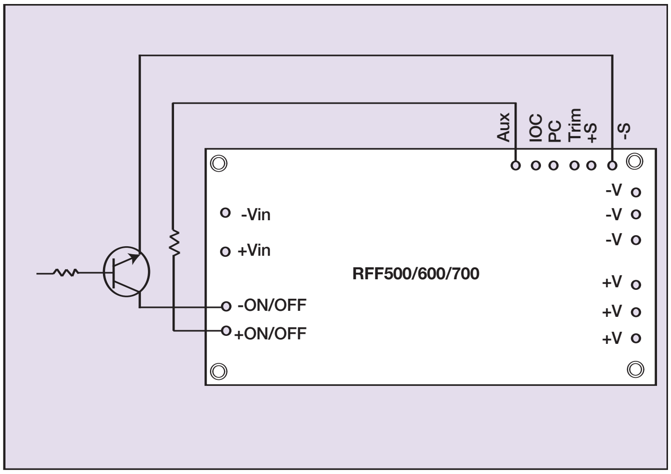

Figure 4 - Remote ON/OFF Input Drive Circuit Referenced to the Output -S and Powered by the Aux. Pin, Recommended Resistor Value = 2 kΩ (1/8 W)

4.8 Inverter Operation Good (IOC) Signal

The RFF500/600/700 series has a pin labelled IOC, which indicates normal or abnormal operation of the converter. The signal is an open-collector output referenced to the –S terminal (maximum sink current is 5 mA and maximum applied voltage is 35 V). The signal is low when the converter is operating normal and is high when the converter stops or is operating abnormally.

The IOC signal becomes unstable when the converter is in overcurrent protection (OCP), is operating under light loads in a parallel configuration, or is operating under dynamic load operation.

4.9 Auxiliary Power Terminal (AUX)

The pin labelled AUX will output a continuous voltage of 7-10 Vdc with a maximum output current of 20 mA referenced to –S terminal. Shorting the AUX pin to any of the converter terminals could cause the converter to be damaged.

4.10 Current Sharing Terminal (PC)

The PC terminal is utilized when 2 or more converters are paralleled. Connecting these pins together on paralleled units causes the units to equally share the load. See Section 8.5 for more applications details.

5. Safety

5.1 Isolation

The RFF500/600/700 series has been designed in accordance with EN60950, CAN/CSA-C22.2 No. 60950-00 and UL60950 ‘Safety of Information Technology Equipment’.

The RFF500/600/700 series is intended for inclusion in other equipment and the installer must ensure that it is in compliance with all the requirements of the end application.

The dc-dc converter is designed with operational insulation. For many applications, models with operational insulation will be sufficient, provided that one pole of the output is connected to protective earth. Units with operational isolation are less costly and will have 1-2% higher efficiency than the equivalent model with basic isolation.

The galvanic isolation is verified in an electric strength test during production; the test voltage between input and output is 1.5 kVdc. Also, note that the flammability ratings of the terminal support header blocks and internal plastic constructions meet UL94V-0.

5.2 Input Fusing

In order to comply with safety requirements, the user must provide a fuse in the unearthed input line if an earthed input is used. The reason for putting the fuse in the unearthed line is to avoid earth being disconnected in the event of a failure. If an earthed input is not being used, the fuse can be placed in either input line.

A slow-blow/anti-surge 200 V HRC (High Rupture Capacity) fuse should be used for all models. The maximum current rating of the fuse is:

- RFB500-24S28Y 80 A
- RFB500-48S28Y 40 A
- RFB600-24S28Y 80 A
- RFB600-48S28Y 40 A
- RFB700-48S28Y 40 A

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6. EMC

The RFF500/600/700 converters have been designed in accordance with the EMC requirements of ETSI 300 386-1. Final compliance is determined at the end product level, and additional filtering external to the converter will usually be required to meet the most commonly used levels of EMC performance.

6.1 Conducted Emissions

The applicable standard for conducted emissions is EN55022 (FCC Part 15). Conducted noise can appear as both differential-mode and common-mode noise currents. Differential-mode noise is measured between the two input lines, with the major components occurring at the converter's fundamental switching frequency and its harmonics. Common-mode noise, a contributor to both radiated emissions and input conducted emissions, is measured between the input lines and system ground and can be broadband in nature. The RFF500/600/700 series of converters uses capacitors to internally bypass much of the common-mode noise. Common-mode noise currents flowing in the application circuitry will therefore be greatly minimized. Furthermore, the converters have an internal filter on the input to reduce the demands on an external conducted emissions filter.

In order to pass the conducted emission levels specified in EN55022 class A or B, an external EMI filter is required. The following recommendations are provided to assist with the development of this EMI filter for the RFF series of dc-dc converters:

- Locate the EMI filter as far away from the RFF module, and as close to the power entry of the system enclosure as possible. This will allow the filter to attenuate in accordance with its impedance characteristic rather than being compromised by radiated field pick-up.
- Include 2 common mode stages in the filter design. The common mode chokes may consist of two separate 13 AWG, 8 Turn windings on opposite sides of a Magnetics Inc ZW-42507-TC (or equivalent) core. Place common mode capacitors (0.01 uF in parallel with 1000 pF) after both chokes. Do not place capacitors before the first choke unless they are located directly at the power entry to the system chassis, and far away from the brick. Also, the capacitors after the second choke should be located close to the brick. The rest of the filter should follow rule #1 above.
- Include 2 differential mode stages in the filter design. The leakage inductance of the common mode chokes can be used for this purpose. Include approximately 10 uF of ceramic capacitance after each choke. Multiple parallel 1 uF capacitors work best for this purpose. An optional 1 uF can be placed close to the system power entry before the first choke. The capacitors located after the second choke should be as close to the brick as possible.
- Include at least 500 uF of bulk electrolytic after the second choke to stabilize the source impedance and to clamp EN61000-4-5 transients. It may also be a good idea to include an appropriately rated MOV (metal oxide varistor) before the first choke to protect the ceramic capacitors from excessive externally applied voltage surges.

6.2 Radiated Emissions

The radiated emissions performance is measured at the product level and is influenced significantly by the packaging of the converter into the end equipment. The high density layout and attention to packaging details within the RFF500/600/700 converters will typically allow the applicable radiated emissions specifications to be met at the system level if generally accepted design and layout practices are used. Such practices include usage of ground planes under fast-transition high current conductors, adequate decoupling capacitors at the loads, and usage of the recommended capacitance across the input of the converter.

7. Use in a Manufacturing Environment

7.1 Resistance to Soldering Heat

The RFF500/600/700 series is intended for Pin Through Hole (PTH) mounting to the user's PCB. The RFF series features an efficient thermal design with large copper pins for current carrying capacity. The resultant thermal mass may present difficulties when attempting to manually solder the unit to the PCB with a soldering iron. Instead, Artesyn recommends soldering the unit to the PCB using one of the two following methods.

For volume production applications, the RFF series can be attached using typical wave soldering profiles. Artesyn has verified compatibility using tin/lead solder at a maximum temperature of 250 ºC with a typical solder wave dwell time of 3 seconds and a maximum dwell time of 6 seconds. The RFF is also compatible with normally used preheat cycles.

For selective soldering and rework applications, the RFF may be attached by using a small area standing solder pot or wave rework equipment. This option allows using the RFF series with SMT components on both sides of the PCB.

Temperature	Time	Temperature Ramp
260 °C ±5 °C	10 s±1	Preheat 4 °C/s to 160 °C. 25 mm/s rate

Table 2 - Wave Solder Test Conditions

7.2 Water Washing

The RFF500/600/700 converters are encapsulated but not considered to be hermetically sealed. Water washing during the manufacturing process may be used with caution, but prolonged immersion or soaking should be avoided.

7.3 ESD Control

RFF500/600/700 units are manufactured in an ESD controlled environment and supplied in conductive packaging to prevent ESD damage occurring before or during shipping. It is essential that they are unpacked and handled using approved ESD control procedures. Failure to do so could affect the lifetime of the converter.

7.4 Mounting Brick Type Converters to System PCB

The RFF500/600/700 should be mounted to the end-use printed circuit board in accordance with Application Note 103. The inserts are pressed into the T-clad, which gives added strength during mounting. Use an M3 screw of the proper length through the PCB to attach the power module. The clearance hole version contains no threads and allows for user-supplied M3 mounting hardware to extend through the PCB and an optional heatsink. Please contact Artesyn Technologies if further assistance is needed with regard to PCB mounting.

7.5 Heat Sink Mounting

Depending on the thermal requirements of the application, and the available space, heatsinks can provide increased thermal performance. A converter with threaded inserts can be screw-mounted on the end-use PCB, and can also have a heatsink attached to its top by another set of M3 screws. Alternatively, a single set of longer M3 screws can extend through the PCB, power module and heatsink when using the clearance hole version of the converter. The industry standard footprint allows the use of many types of off-the-shelf heatsinks. A thermally conductive pad or silicone grease should be used between the power converter and the heatsink to maximize thermal conductivity. In addition to the four outside inserts for heatsink mounting screws which are standard with most full-brick converters, the RFF500/600/700 family of converters have a fifth screw insert located in the center of the converter. Adding a fifth screw between the heatsink and converter will in most applications improve thermal conductivity by reducing the interface thermal resistance. If multiple converters are to be mounted to a single heatsink or cold plate, care must be taken during assembly. Application Note 103 provides additional detail on the attachment of heatsinks. Please contact Artesyn Technologies if further information is required.

8. Applications

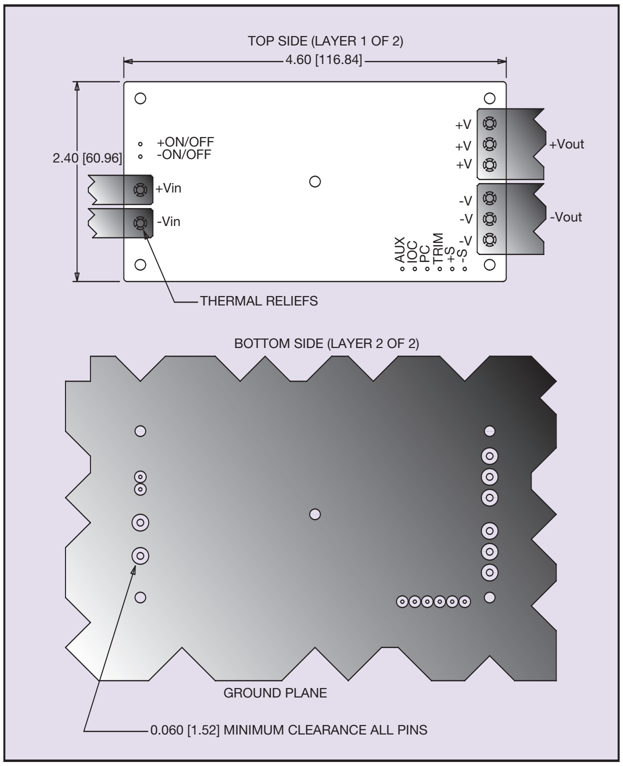
8.1 Optimum PCB Layout

It is recommended that power and return planes be used. A three-wire system including a chassis or system ground is also possible, and a ground plane is beneficial. These planes also act as partial EMC shields (note that EMC compliance at the system level may also depend on an optional user-supplied EMC filter).

In some applications, it is recommended that an input bypass capacitor be inserted between input terminals as close to the converter as possible. This capacitor may be necessary because the added inductance caused by long power leads or input filter chokes between the power source and the converter may make the converter unstable. A low impedance (ESR < 0.7 Ω) electrolytic capacitor with a value of 330 μF, 100 V is suggested for all models.

A recommended layout for an end user's double-sided PCB that maintains the creepage and clearance requirements discussed in the safety section of this application note, is presented in Figure 5. However the end user must ensure that other components and metal in the vicinity of the RFF500/600/700 meet the spacing requirements to which the system is approved. Low resistance and low inductance PCB layout traces should be used where possible, particularly when high currents are flowing (e.g. on the converter's input and output).

VIEW IS FROM TOP SIDE



THERMAL RELIEF IN CONDUCTOR PLANES
IPC-D-275 SECTION 5.3.2.3

ALL DIMENSIONS IN INCHES (mm)
ALL TOLERANCES ARE ±0.10 (0.004)

Figure 5 - Recommended Footprints

8.2 Optimum Thermal Performance

The electrical operating conditions of the RFF500/600/700, namely:

- Input voltage, V_{in}
- Output voltage, V_o
- Output current, I_o

determine how much power is dissipated within the converter. The following parameters further influence the thermal stresses experienced by the converter:

- Ambient temperature
- Air velocity
- Thermal efficiency of the end system application
- Parts mounted on system PCB that may block airflow
- Real airflow characteristics at the converter location

The maximum acceptable operational temperature measured at the thermal reference point at the center of the baseplate is 100 ºC. Since the thermal performance is heavily dependent upon the final system application, the user needs to ensure the thermal reference point temperature is kept within the recommended temperature rating. It is recommended that the thermal reference point temperatures are measured using a thermocouple or an IR camera. In order to comply with stringent Artesyn derating criteria the baseplate temperature should never exceed 100 °C. Please contact Artesyn Technologies for further support.

8.3 Remote Sense Compensation

The remote sense compensation feature minimizes the effect of resistance in the distribution system and facilitates accurate voltage regulation at the load terminals or another selected point. The remote sense lines will carry very little current and hence do not require a large cross-sectional area. However, if the sense lines are routed on a PCB, they should be located close to a ground plane in order to minimize any noise coupled onto the lines that might impair control loop stability. A small 100 nF ceramic capacitor can be connected at the point of load to decouple any noise on the sense wires. The module will compensate for a maximum drop of 500 mV between the converter output voltage and sense point voltage. Remember that when using remote sense compensation all the resistance, parasitic inductance and capacitance of the distribution system are incorporated into the feedback loop of the power module. This can have an effect on the module's compensation capabilities, affecting its stability and dynamic response.

8.4 Output Voltage Adjustment

The output can be externally trimmed within the limits defined in the datasheet by connecting an external resistor between the TRIM pin and either the +S or -S pin. With an external resistor R_{adj_down}, between TRIM and -S, the output voltage set-point decreases. Conversely, connecting an external resistor, R_{adj_up}, between TRIM and +S, the output voltage set point increases. This is shown in Figures 6 and 7.

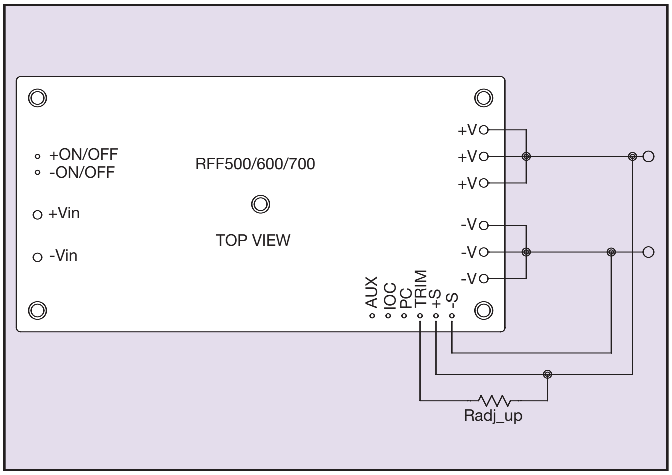


Figure 6 - Trimming Output Voltage - Trim-up

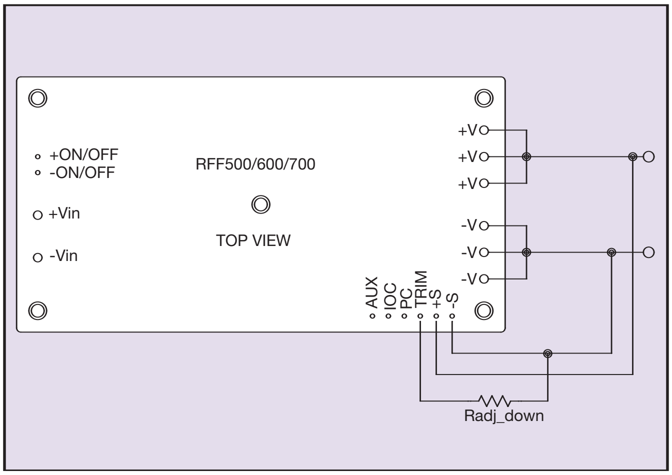


Figure 7 - Trimming Output Voltage - Trim-down

The relevant trim equations to derive the appropriate trim resistance for the RFF500/600/700 are as follows:

$$R_{adj\_down}\ (k\Omega) = 100\%/\Delta\% - 2$$

$$R_{adj\_up}\ (k\Omega) = \frac{V_o\ (100\% + \Delta\%)}{1.225 \times \Delta\%} - \frac{100\% + 2 \times \Delta\%}{\Delta\%}$$

Where:

V_o	is the nominal output voltage of the module
$\Delta\%$	desired percentage change in output voltage
R_{adj_down}	is the resistor required to achieve the desired (trimmed down) output voltage
R_{adj_up}	is the resistor required to achieve the desired (trimmed up) output voltage

The trim-down equation is the industry standard equation for full brick modules and is plotted in Figures 8 and 9.

The trim-up equation is plotted in Figure 10.

The RFF500/600/700 can also be trimmed either above or below the nominal output voltage by means of a voltage applied between the TRIM pin and the -S pin. The voltage source applied to the TRIM pin for a desired output voltage is defined in the following equation and shown in Figure 11.

Where:

$$V_{trim} = \frac{2.45\,V_o}{V_{o\,nom}} - 1.225$$

V_{trim}	is the applied trimming voltage in volts
V_o	is the desired output voltage in volts
$V_{o\,nom}$	is the nominal output voltage in volts (i.e. 28)

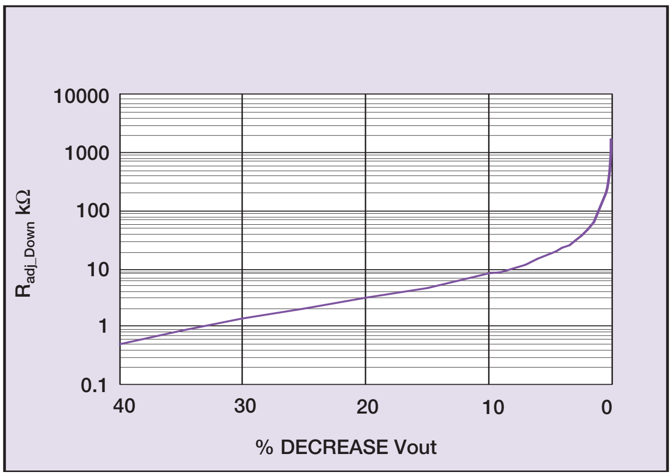


Figure 8 - Trim-down Curve - Large Change (resistor from TRIM to -S)

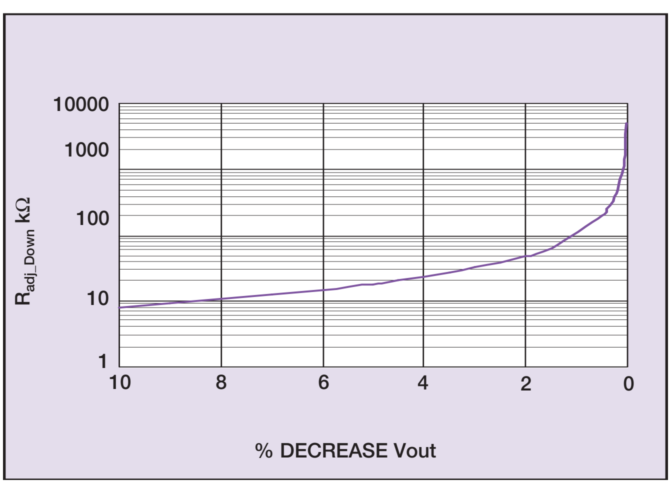


Figure 9 - Trim-down Curve - Small Change (resistor from TRIM to -S)

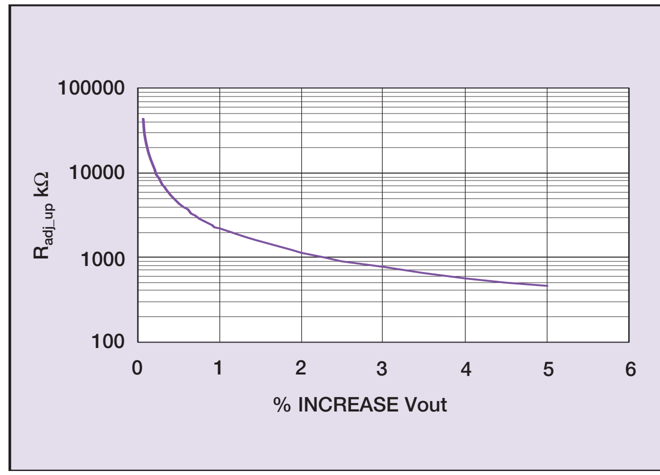


Figure 10 - Trim-up Curve (resistor from TRIM to +S)

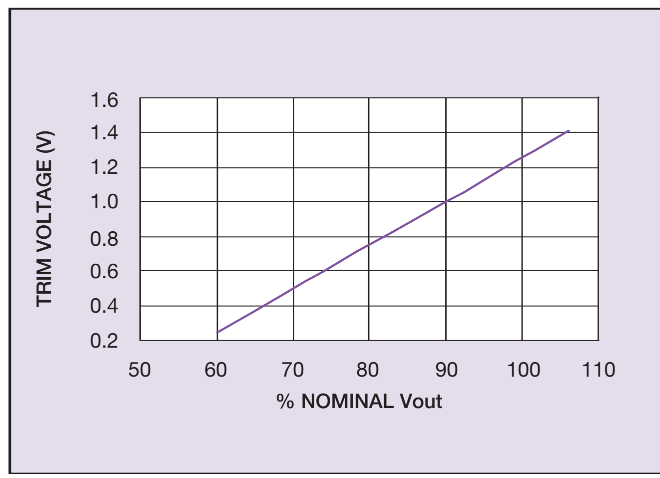


Figure 11 - Voltage Trimming Curve (Note: models may be trimmed to 105% max.)

Note that when the output voltage is trimmed up by a certain percentage, the output current may have to be derated so that the maximum output power rating is not exceeded.

8.5 Parallel and Series Operation

The RFF500/600/700 series are designed so they can be paralleled. When paralleled, the load current can be equally shared between the converters by connecting the PC pins together. A maximum of 11 converters of the same model can be connected in this way. If all parallel converters' output voltages are adjusted within 1%, each converter can output up to 95% of their rated current.

Multiple RFF500/600/700 converters can be connected in series but this is not expected to be a common application and may result in an increased level of common-mode EMI. Contact your local Artesyn Technologies representative for further information.

8.6 Output Capacitance

The RFF500/600/700 series has been designed for stable operation with a minimum of 330 μF of capacitance at the output terminals. However, when powering loads with large dynamic current requirements, improved voltage regulation can be obtained by inserting capacitors as close as possible to the load. The most effective technique is to locate low ESR ceramic capacitors as close to the load as possible, using several capacitors to lower the overall ESR. These ceramic capacitors will handle the short duration high frequency components of the dynamic current requirement. In addition, higher values of electrolytic capacitors should be used to handle the mid-frequency components.

It is equally important to use good design practices when configuring the DC distribution system. Low resistance and low inductance PCB layout traces should be utilized, particularly in the high current output section. Remember that the capacitance of the distribution system and the associated ESR are within the feedback loop of the power module. This can have an effect on the module's compensation capabilities and its resultant stability and dynamic response performance. With large values of capacitance, the stability criteria depend on the magnitude of the ESR with respect to the capacitance. As much of the capacitance as possible should be outside the remote sensing loop and close to the load. Note that the maximum rated value of output capacitance is 3,300 μF. Contact your local Artesyn Technologies representative for further information if larger output capacitance values are required in the application.

8.7 Reflected Ripple Current and Output Ripple and Noise Measurement

The measurement set-up outlined in Figure 12 has been used for both input reflected/terminal ripple current and output voltage ripple and noise measurements on the RFF500/600/700 series converters. The input ripple current measurement set-up is compatible with ETS 300 386-1.

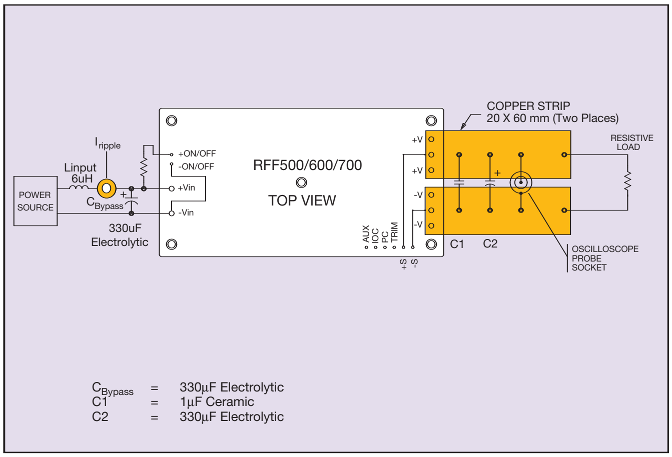


Figure 12 - Input Reflected Ripple Current and Output Voltage Ripple and Noise Measurement Set-Up

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