NEW Product

RFB300/350 Series

Application Note 167

RoHS
2002/95/EC

ARTESYN TECHNOLOGIES

167 Rev. 03 / 26 April 2006

File Name: an_rfb300_350.pdf

1. Introduction

This application note describes the features and functions of Artesyn Technologies' RFB300/350 series of high power density, half-brick dc-dc converters. These encapsulated, single output modules are targeted specifically at the RF amplifier telecommunications power market with requirements for 12 V and 28 V modules for usage within distributed power architectures. The 12 V output model is also ideally suited for application as an intermediate bus converter.

The RFB300/350 series offers wide input voltage ranges of 18 Vdc to 36 Vdc and 36 Vdc to 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 and UL/cUL1950 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 de-rating criteria. Automated manufacturing methods, together with an extensive qualification program, ensure that all RFB300/350 series converters are extremely reliable.

2. Models

The RFB300/350 series comprises 4 models, as listed in Table 1

Model	Input Voltage	Output Voltage	Output Current
RFB300-24S28Y	18-36 Vdc	28 V	11 A
RFB300-48S28Y	36-75 Vdc	28 V	11 A
RFB350-48S12Y	36-75 Vdc	12 V	29.2 A
RFB350-48S28Y	36-75 Vdc	28 V	12.5 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 half-brick pin-out and footprint: 60.71 x 57.66 x 12.70 mm (2.39 x 2.27 x 0.5 inches)
- Low profile option: 10.16 mm (0.4 inches)
- Wide operating temperature range (-40 °C to +100 °C) baseplate
- Wide range output trim
- No minimum load requirement
- Remote ON/OFF control (primary referenced)
- 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)
- Available RoHS compliant

3. General Description

3.1 Electrical Description

A block diagram of the RFB300/350 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 single forward topology operating at a nominal frequency of 500 kHz. 28 V output converters utilize ultra-fast recovery output diodes, while the 12 V output model uses Schottky output rectifiers. Feedback isolation is achieved without the usage of optical isolators.

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

The output is adjustable over a range of 60% to 105% (110% for 12 V output model) of the nominal output voltage, using the Vadj pin (referenced to Vsense–).

The converter can be shut down via a remote ON/OFF input (RC pin) that is referenced to the primary side. This input is compatible with popular logic devices; a 'positive' logic input is supplied as standard, with 'negative' logic available as an option. Positive logic implies that the converter is enabled if the remote ON/OFF input is high (or floating), and disabled if it is low. Conversely, negative logic implies that the converter is enabled if the remote ON/OFF input is low, and disabled if it is high (or floating).

The output is monitored for over-voltage conditions. The converter will shutdown at the over-voltage set-point if an over-voltage condition is detected at the output. After an over-voltage shutdown, the unit will remain in a low-dissipation non-operating condition until the input power or the RC enable pin is cycled (latching over-voltage). The converter is also protected against over temperature 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.

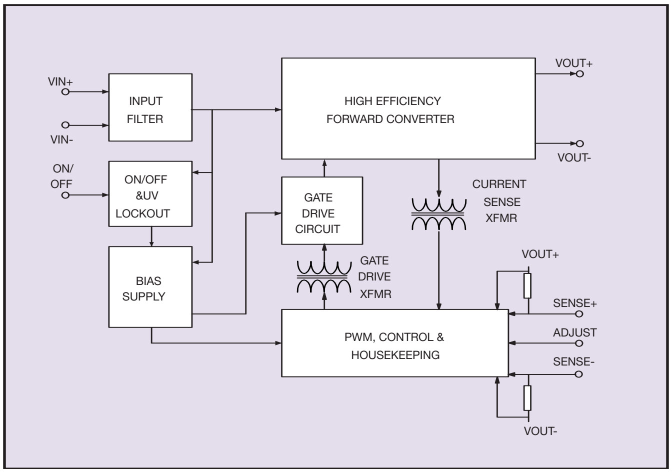


Figure 1 - Electrical Block Diagram

3.2 Physical Construction
The RFB300/350 converters are constructed using a multi-layer FR4 PCB in conjunction with a two layer T-clad aluminum board which is in thermal contact with the module baseplate. Heat dissipation of the power components is optimized, ensuring that control components are not unduly 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 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 RFB300/350'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:

- 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)
- Target application PCB design, especially ground planes. These can be effective heatsinks for the converter.
- Use of attached heatsink

The RFB300/350 can be operated from -40 °C to a maximum ambient baseplate temperature of +100 °C.

4.2 Overtemperature Protection (OTP)
The RFB300/350 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 RFB300/350 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 the 12 V model is trimmable from 60% to 110% of the nominal voltage setpoint. The output voltage on 28 V models is trimmable from 60% to 105% of the nominal voltage setpoint. 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 an auxiliary control loop running in parallel to the main control loop. However, unlike the main loop, the OVP loop senses the 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 120-125% of the nominal output voltage setpoint 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 RC enable pin to "OFF" and then back to "ON".

4.5 Safe Operating Area
The Safe Operating Area (SOA) of the RFB300/350 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 output current may need to be derated so that the output power does not exceed 308 W or 350 W depending upon the model.

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

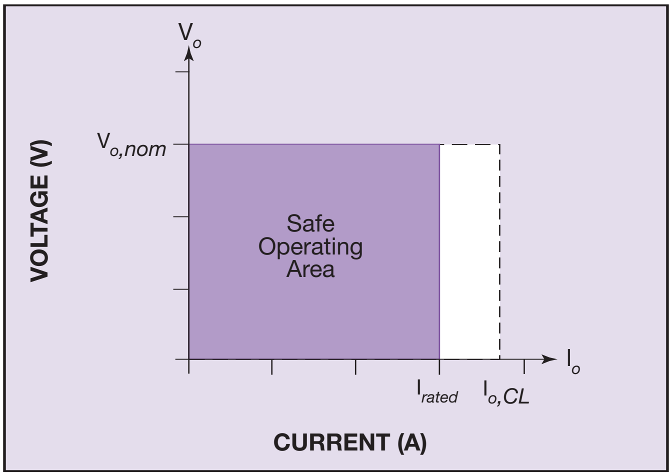


Figure 2 - Maximum Output Current Safe Operating Area

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 RFB300/350 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 115% of rated full load for all models. The maximum short-circuit current will be 130% 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 input allows external circuitry to put the RFB300/350 converter into a low dissipation sleep mode. Active-high remote ON/OFF is available as standard and active-low logic can be specified as an option by adding the suffix '-R' to the part number.

Active-high units of the RFB300/350 series are turned on if the remote ON/OFF pin is high (or floating). Pulling the pin low will turn off the unit. Active-low units are turned on if the remote ON/OFF pin is low. Pulling the pin high (or leaving it floating) will turn off the unit. The signal level of the remote ON/OFF input is defined with respect to Vin–.

To simplify the design of the external control circuit, logic signal thresholds are specified over the full temperature range. The maximum remote ON/OFF input open circuit voltage, as well as the acceptable leakage currents, are specified in the RFB300/350 Datasheet. The remote ON/OFF input can be driven in a variety of ways as shown in Figures 3, 4 and 5. If the remote ON/OFF signal originates on the primary side, the remote ON/OFF input can be driven through a discrete device (e.g. a bipolar signal transistor) or directly from a logic gate output. The output of the logic gate may be an open-collector (or open-drain) device. If the drive signal originates on the secondary side, the remote ON/OFF input can be isolated and driven through an optocoupler.

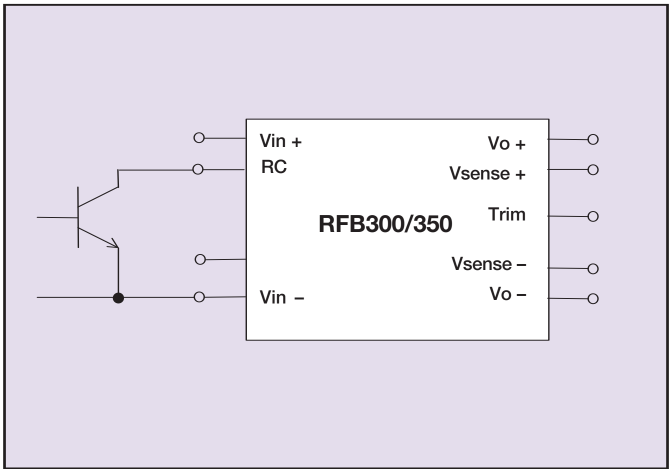


Figure 3 - Remote ON/OFF Input Drive Circuit for Non-Isolated Bipolar

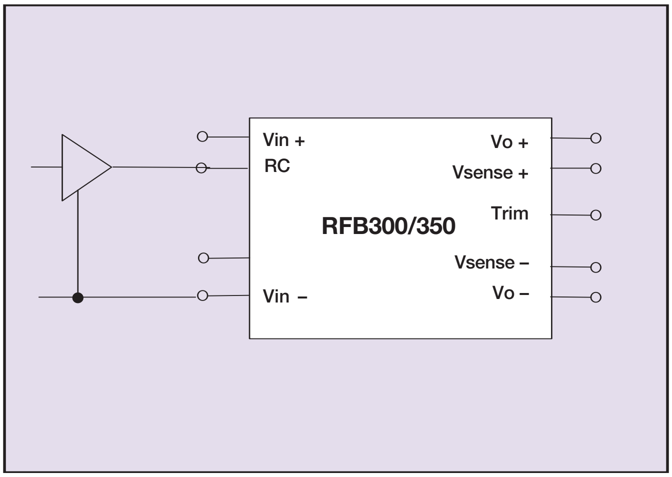


Figure 4 - Remote ON/OFF Input Drive Circuit for Logic Drive

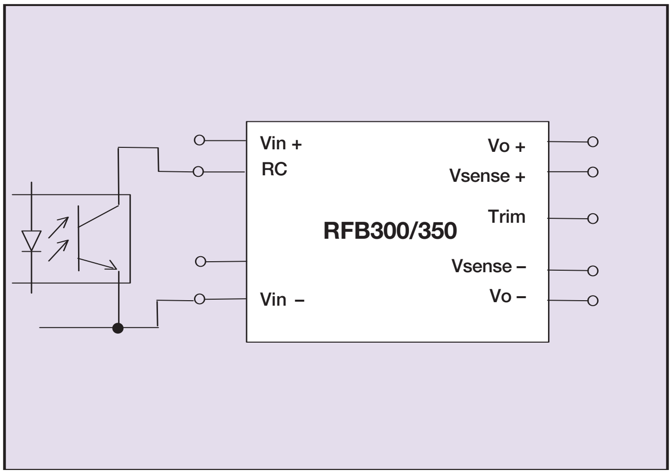


Figure 5 - Remote ON/OFF Input Drive Circuit using an Optocoupler to maintain the isolation barrier from primary to secondary

5. Safety

5.1 Isolation

The RFB300/350 series has been designed in accordance with EN60950, CAN/CSA-C22.2 No. 60950-00 and UL60950 'Safety of Information Technology Equipment'.

The RFB300/350 dc-dc converter 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 RFB300/350 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:

- RFB300-48S28Y 15 A
- RFB350-48S12Y 20 A
- RFB350-48S28Y 20 A
- RFB300-24S28Y 30 A

6. EMC

The RFB300/350 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 RFB300/350 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 RFB series of dc-dc converters:

- Locate the EMI filter as far away from the RFB 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 18 AWG, 10 Turn windings on opposite sides of a Magnetics Inc ZW-41605-TC (or equivalent) core. Place common mode capacitors (0.01 µF 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 µF of ceramic capacitance after each choke. Multiple parallel 1 µF capacitors work best for this purpose. An optional 1 µF 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 µF 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 RFB300/350 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 RFB300/350 series is intended for Pin Through Hole (PTH) mounting to the user's PCB. The RFB series features an efficient thermal design with low thermal resistance between many of the pins and the converter's baseplate. 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 RFB 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 RFB is also compatible with normally used preheat cycles.

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

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

Table 2 - Wave Solder Test Conditions

7.2 Water Washing
The RFB300/350 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
RFB300/350 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 RFB300/350 should be mounted to the end-use printed cicuit board in accordance with Application Note 103. The threaded inserts on the threaded baseplate version of the converter are insert molded, 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. 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.

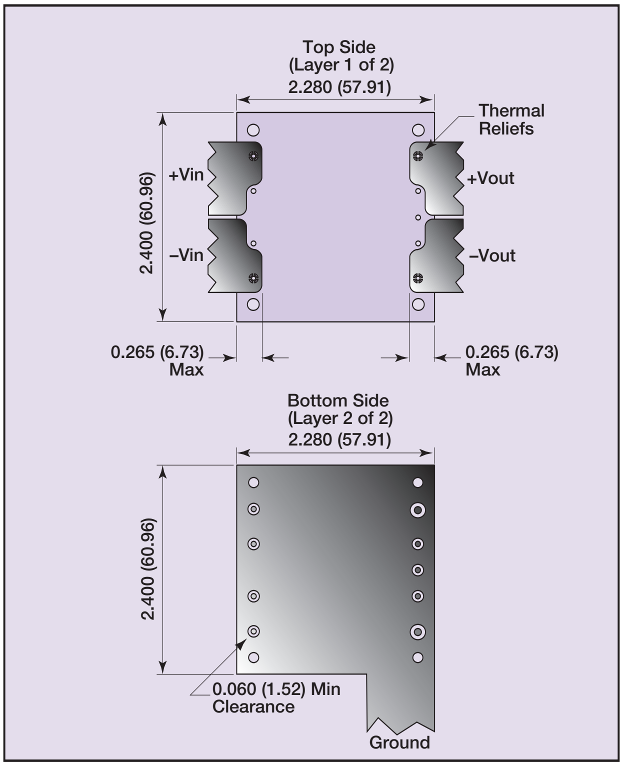
8. Applications

8.1 Optimum PCB Layout

While the primary thermal interface for the RFB300/350 units is the baseplate, the PCB acts as a partial heat sink and draws some heat from the unit via conduction through the pins. 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).

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 6. However the end user must ensure that other components and metal in the vicinity of the RFB300/350 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 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 6 - Recommended Footprints

8.2 Optimum Thermal Performance

The electrical operating conditions of the RFB300/350, 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 °C. 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 V_{adj} pin and either the V_{sense+} or V_{sense-} pin. With an external resistor R_{adj_down}, between V_{adj} and V_{sense-} , the output voltage setpoint decreases. Conversely, connecting an external resistor, R_{adj_up} , between V_{adj} and V_{sense+}, the output voltage set point increases. This is shown in Figures 7 and 8.

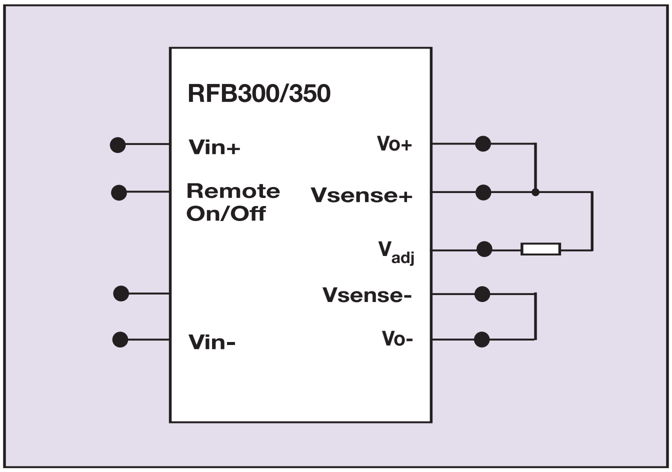


Figure 7 - Trimming Output Voltage - Trim up

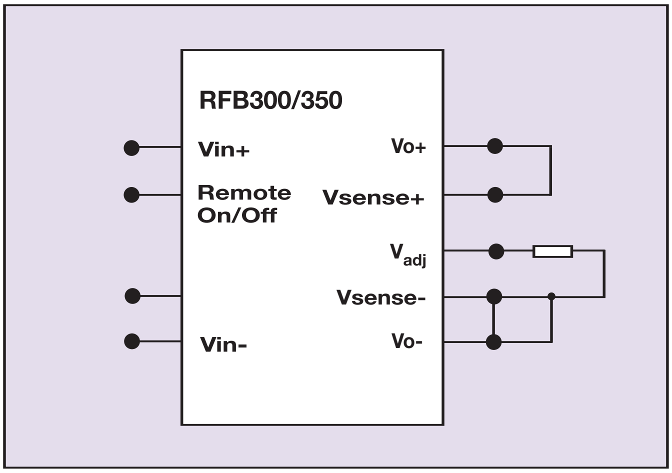


Figure 8 - Trimming Output Voltage - Trim Down

The relevant trim equations to derive the appropriate trim resistance for the RFB300/350 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 half brick modules and is plotted in Figures 9 and 10.

The trim up equation is plotted in Figures 11 and 12 for the 12 V and 28 V output converters.

The RFB300/350 can also be trimmed either above or below the nominal output voltage by means of a voltage applied between the V_{adj}pin and the V_{sense}- pin. The voltage source applied to the V_{adj} pin for a desired output voltage is defined in the following equation and shown in Figure 13.
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 in voltage (i.e. 12 V or 28 V)

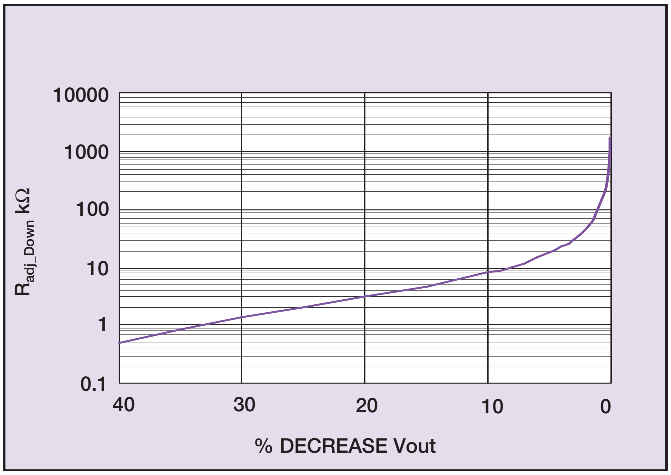


Figure 9 - Trim-Down Curve - Large Change
(resistor from V_{adj} to V_{sense}-)

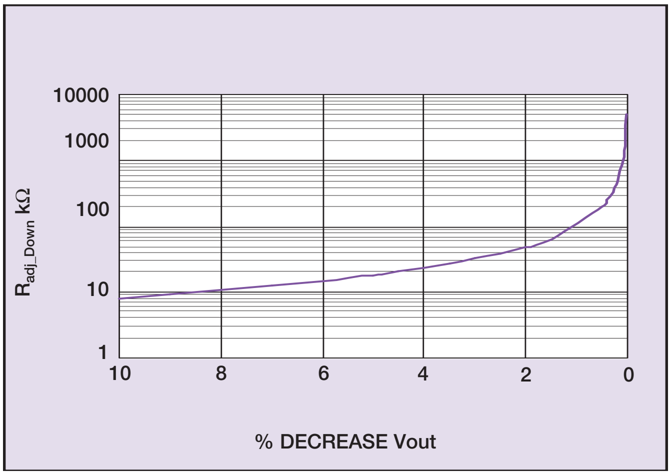


Figure 10 - Trim-Down Curve - Small Change
(resistor from V_{adj} to V_{sense}-)

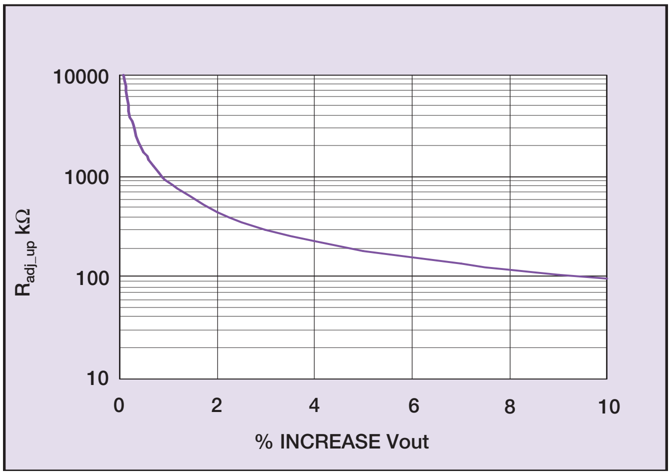


Figure 11 - Trim-Up Curve 12 V Output
(resistor from V_{adj} to V_{sense}+)

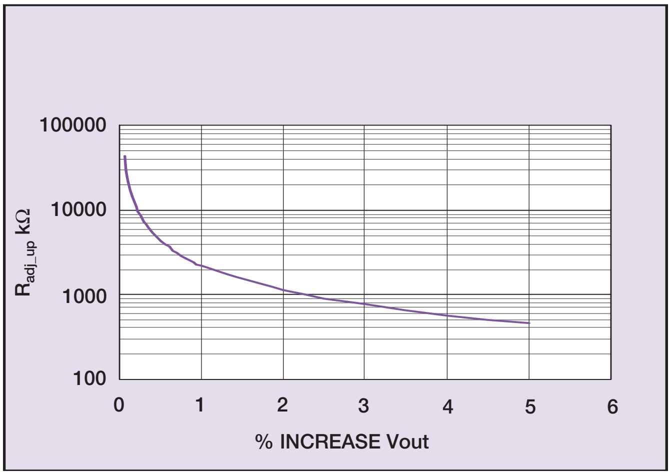


Figure 12 - Trim-Up Curve 28 V Output
(resistor from V_{adj} to V_{sense}+)

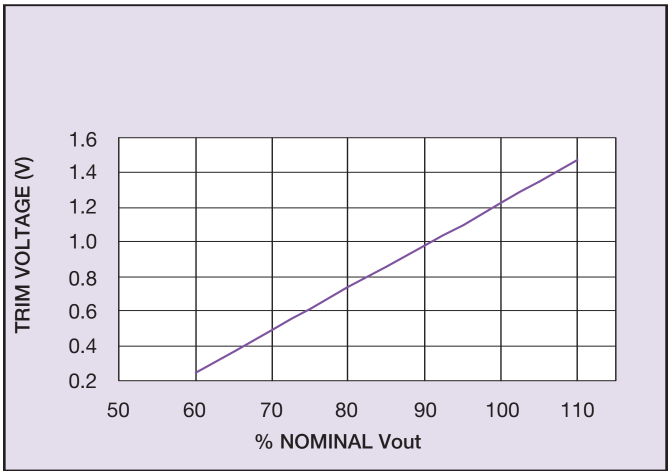


Figure 13 - Voltage Trimming Curve
(Note: 28 V models may be trimmed to 105% max.)

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 RFB300/350 series does not include any current sharing circuitry, and parallel operation of multiple converters is not recommended. If module paralleling is unavoidable, ORing diodes must be used to decouple the outputs. Droop resistors will support some passive current sharing. It should be noted that both measures will adversely affect power conversion efficiency. If higher currents are required than are available from the RFB series, the RFF series of converters may be considered as a solution.

Multiple RFB300/350 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 RFB300/350 series has been designed for stable operation without the need for external 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 for 28 V output models and 4,700 µF for 12 V output models. 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 14 has been used for both input reflected/terminal ripple current and output voltage ripple and noise measurements on the RFB300/350 series converters. The input ripple current measurement setup is compatible with ETS 300 386-1.

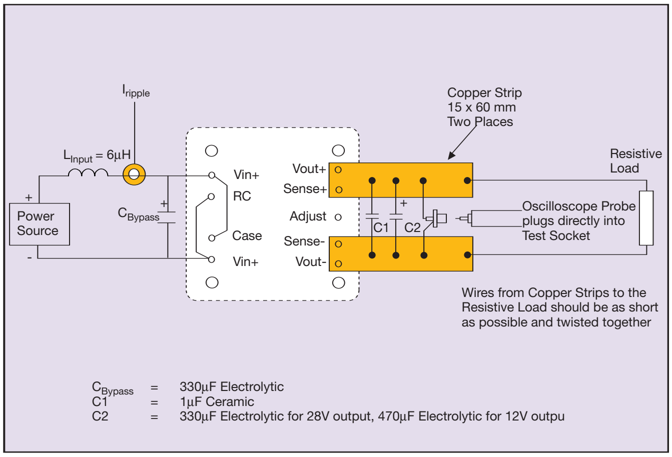


Figure 14 - Input Reflected Ripple Current and Output Voltage Ripple and Noise Measurement Set-Up