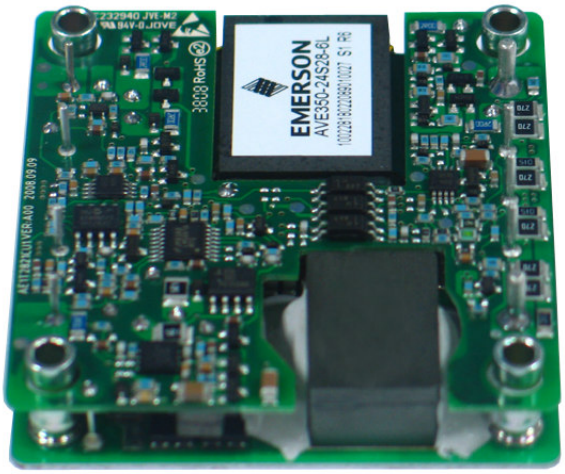
# AVE350-24S28

## 350 Watts

### Half-brick Converter

**Total Power:** 350 Watts
**Input Voltage:** 18 to 36 Vdc
**# of Outputs:** Single




## Special Features

- Delivering up to 12.5A output
- Ultra-high efficiency 94% typ. at half load
- Wide input range: 18V ~ 36V
- Excellent thermal performance
- No minimum load requirement
- RoHS 6 compliant
- Remote output sense
- Trim function: 50% ~ 118%
- Input under voltage lockout
- Output over current protection
- Output over voltage protection
- Over temperature protection
- Industry standard half-brick pin-out outline
- With baseplate
- Remote control logic optional
- Pin length optional

## Safety

UL 60950-1
CSA-C22.2
IEC/EN 60950-1
GB4943
TUV
CE Mark

## Product Descriptions

The AVE350-24S28 is a single output DC/DC converter with standard half-brick outline and pin configuration. It delivers up to 12.5A output current with 28V output voltage. Above 94% ultra-high efficiency and excellent thermal performance makes it an ideal choice to supply power to a power amplifier used in telecom and datacom applications. With the aluminium baseplate it can work under -40 $^{O}$C ~ +85 $^{O}$C without air cooling.

## Applications

Telecom/ Datacom

ARTESYN™
EMBEDDED TECHNOLOGIES

# Model Numbers

| Standard | Output Voltage | Structure | Remote ON/OFF logic | RoHS Status |
|---|---|---|---|---|
| AVE350-24S28-6L | 28Vdc | Baseplate | Negative | R6 |
| AVE350-24S28P-6L | 28Vdc | Baseplate | Positive | R6 |
| AVE350-24S28-6L/M | 28Vdc | Baseplate | Negative | R6 |
| AVE350-24S28P-6L/M | 28Vdc | Baseplate | Positive | R6 |

## Ordering information

| AVE350 | - | 24 | S | 28 | P | - | 6 | L | /M |
|---|---|---|---|---|---|---|---|---|---|
| ① | | ② | ③ | ④ | ⑤ | | ⑥ | ⑦ | ⑧ |

| | | |
|---|---|---|
| ① | Model series | AVE: high efficiency half brick series, 350: output power 350W |
| ② | Input voltage | 24: 18V ~ 36V input range, rated input voltage 24V |
| ③ | Output number | S: single output |
| ④ | Rated output voltage | 28: 28V output |
| ⑤ | Remote ON/OFF logic | Default: negative; P: positive logic |
| ⑥ | Pin length | 6: 3.8mm |
| ⑦ | RoHS status | L: RoHS, R6 |
| ⑧ | Mounting hole | Default: through hole; M: screw thread |

## Options

None

# Electrical Specifications

## Absolute Maximum Ratings

Stress in excess of those listed in the "Absolute Maximum Ratings" may cause permanent damage to the power supply. These are stress ratings only and functional operation of the unit is not implied at these or any other conditions above those given in the operational sections of this TRN. Exposure to any absolute maximum rated condition for extended periods may adversely affect the power supply's reliability.

Table 1. Absolute Maximum Ratings:

| Parameter | Model | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Input Voltage | | | | | | |
| Operating -Continuous | All | $V_{IN,DC}$ | - | - | 40 | Vdc |
| Non-operating -100mS | All | | - | - | 50 | Vdc |
| Maximum Output Power | All | $P_{O,max}$ | - | - | 350 | W |
| Isolation Voltage[1] | | | | | | |
| Input to output | Open frame module | | - | - | 1500 | Vdc |
| Input to baseplate | Baseplate module | | - | - | 1500 | Vdc |
| Output to baseplate | Baseplate module | | - | - | 500 | Vdc |
| Ambient Operating Temperature | All | $T_A$ | -40 | - | +85 | $^{O}$C |
| Storage Temperature | All | $T_{STG}$ | -55 | - | +125 | $^{O}$C |
| Voltage at remote ON/OFF pin | All | | -0.3 | - | 15 | Vdc |
| Humidity (non-condensing) | All | | - | - | 95 | % |

Note 1 - 1mA for 60s, slew rate of 1500V/10s

## Input Specifications

Table 2. Input Specifications:

| Parameter | Conditions[1] | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Operating Input Voltage, DC | All | $V_{IN,DC}$ | 18 | 24 | 36 | Vdc |
| Turn-on Voltage Threshold | $I_O = I_{O,max}$ | $V_{IN,ON}$ | 16 | 17 | 18 | Vdc |
| Turn-off Voltage Threshold | $I_O$ = Lomax | $V_{IN,OFF}$ | 15 | 16 | 17 | Vdc |
| Lockout Voltage Hysteresis | $I_O = I_{O,max}$ | | 0.5 | - | - | V |
| Maximum Input Current ($I_O = I_{O,max}$) | $V_{IN,DC} = 18V_{DC}$ | $I_{IN,max}$ | - | - | 22 | A |
| No-load input current | | $I_{IN}$ | - | - | 0.25 | A |
| Standby Input current | Remote OFF | $I_{IN}$ | - | - | 0.02 | A |
| Recommended Input Fuse | Fast blow external fuse recommended | | - | - | 30 | A |
| Input filter component values (C\L) | Internal values | | | 28\0.56 | | µF\µH |
| Recommended External Input Capacitance | Low ESR capacitor recommended | $C_{IN}$ | - | 470 | - | uF |
| Input Reflected Ripple Current | Through 12uH inductor | | - | 50 | 300 | mA |
| Operating Efficiency | $T_A$=25 °C<br>$I_O = I_{O,max}$<br>$I_O = 50\%I_{O,max}$ | η | -<br>- | 92.7<br>94 | -<br>- | %<br>% |

Note 1 - Ta = 25 °C, airflow rate = 400 LFM, Vin = 48Vdc, nominal Vout unless otherwise noted.

## Output Specifications

Table 3. Output Specifications:

| Parameter | | Conditions[1] | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Factory Set Voltage | | $V_{IN,DC}$ = 24$V_{DC}$ $I_O$=50%$I_{O,max}$ | $V_O$ | 27.72 | 28 | 28.28 | Vdc |
| Output Voltage Line Regulation | | All | %$V_O$ | - | 0.05 | 0.5 | % |
| Output Voltage Load Regulation | | All | %$V_O$ | - | 0.1 | 0.5 | % |
| Output Voltage Temperature Regulation | | All | %$V_O$ | - | 0.005 | 0.02 | %/$^O$C |
| Total output voltage range (Over sample, line, load, temperature & life) | | All | $V_O$ | 27.16 | 28 | 28.84 | V |
| Output Voltage Trim Range | | All | $V_O$ | 14 | - | 33 | V |
| Output voltage remote sense range | | All | | - | - | 0.5 | V |
| Output Ripple, pk-pk | | 20MHz bandwidth | $V_O$ | - | 100 | 300 | $mV_{PK-PK}$ |
| Output Current[1] | | | $I_O$ | 0 | - | 12.5 | A |
| Output DC current-limit inception[2] | | | $I_O$ | 13.5 | - | 17.5 | A |
| $V_O$ Load Capacitance[3] | | High frequency and low ESR is recommended | $C_O$ | 470 | 680 | 4000 | uF |
| $V_O$ Dynamic Response | Peak Deviation<br>Settling Time | 50% ~75%~50% slew rate = 0.1A/us | $\pm V_O$<br>$T_s$ | -<br>- | 600<br>700 | -<br>- | mV<br>uSec |
| Turn-on transient | Rise time | $I_O$ = $I_{max}$ | $T_{rise}$ | - | 60 | 100 | mS |
| | Turn-on delay time | $I_O$ = $I_{max}$ | $T_{turn-on}$ | - | 20 | 40 | mS |
| | Output voltage overshoot | $I_O$ = 0 | %$V_O$ | - | 0 | 1 | % |
| Switching frequency | | All | $f_{SW}$ | 200 | 220 | 240 | KHz |

Note 1 - Ta = 25 $^O$C, airflow rate = 400 LFM, Vin = 48Vdc, nominal Vout unless otherwise noted.
Note 2 - Module can work in 30V/13.3A stably
Note 3 - Hiccup: auto-restart when over-current condition is removed.
Note 4 - High frequency and low ESR is recommended.

## Output Specifications

Table 3. Output Specifications, con't:

| Parameter | | Conditions[1] | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Remote ON/OFF control (positive logic) | Off-state voltage | All | | -0.3 | - | 0.8 | V |
| | On-state voltage | All | | 2.4 | - | 15 | V |
| Remote ON/OFF control (negative logic) | Off-state voltage | All | | 2.4 | - | 15 | V |
| | On-state voltage | All | | -0.3 | - | 0.8 | V |
| Output over-voltage protection[4] | | All | $\%V_O$ | 125 | 135 | 150 | % |
| Output over-temperature protection[5] | | All | T | 105 | 110 | - | $^OC$ |
| Over-temperature hysteresis | | All | T | 5 | - | - | $^OC$ |
| MTBF | | Board@25$^OC$, normal input/output Bellcore, TR332 method 1, case 3 | | - | 1.0 | - | $10^6$ h |

Note 5 - Hiccup: auto-restart when over-voltage condition is removed.
Note 6 - Auto recovery.

## AVE350-24S28 Performance Curves

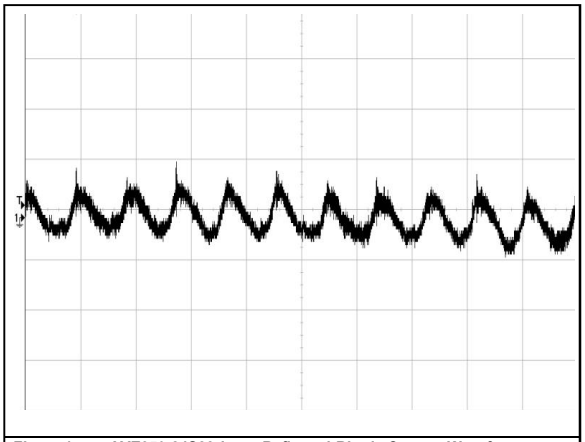


Figure 1: AVE350-24S28 Input Reflected Ripple Current Waveform (5uS/div, 10mA/div)

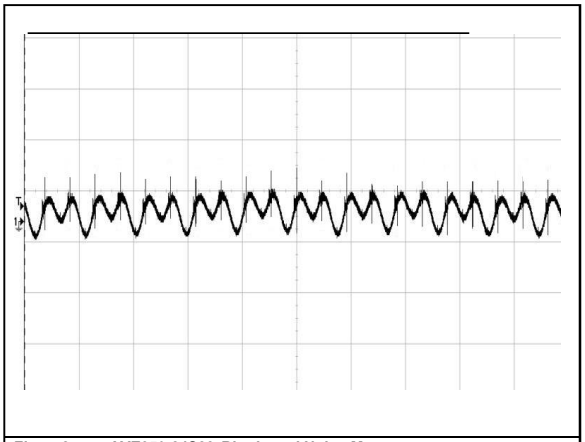


Figure2: AVE350-24S28 Ripple and Noise Measurement (10us/div, 100mV/div)

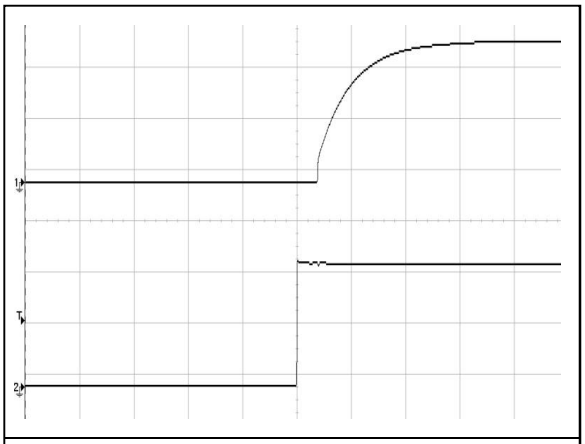


Figure 3: AVE350-24S28 Output Voltage Startup Characteristic (50ms/div)

Ch 1: Vo (10V/div) Ch 3: Vi (10V/div)

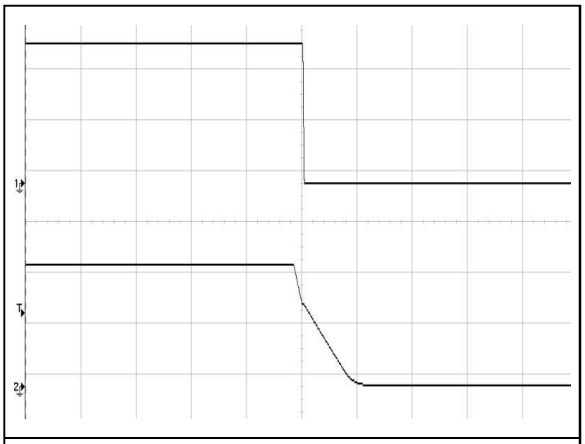


Figure 4: AVE350-24S28 Turn Off Characteristic (50mS/div)

Ch 1: Vo (10V/div) Ch 3: Vi (10V/div)

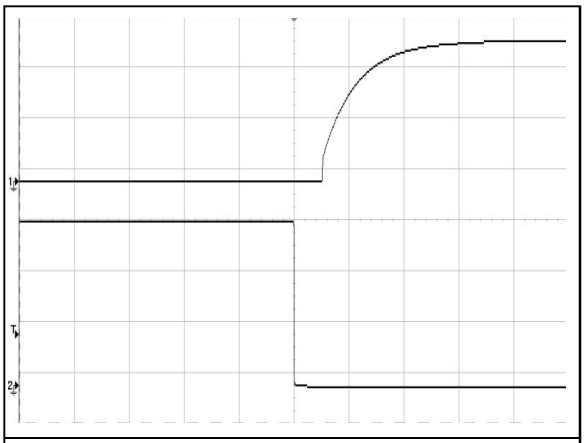


Figure 5: AVE350-24S28 Remote ON Waveform (50mS/div)

Ch 1: Vo (10V/div) Ch 2: Remote ON (2V/div)

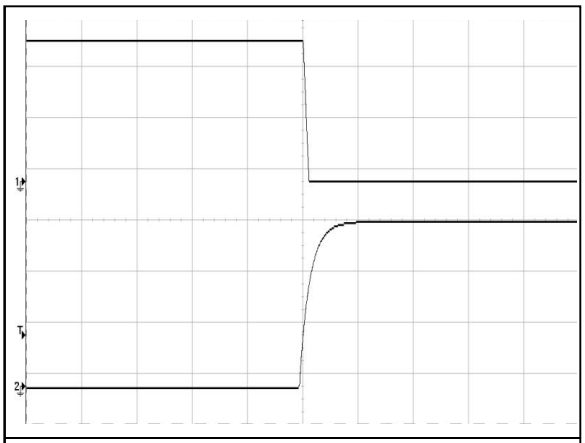


Figure 6: AVE350-24S28 Remote OFF Waveform (10mS/div)

Ch 1: Vo (10V/div) CH 2: Remote OFF (2V/div)

## AVE350-24S28 Performance Curves

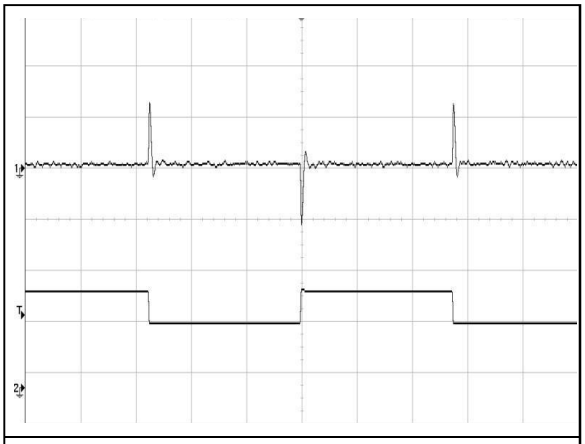


Figure 7: AVE350-24S28 Transient Response (2mS/div)
50%~75%~50% load change, 0.1A/uS slew rate
Ch 1: Vo (200mV/div) Ch 2: Io (10A/div)

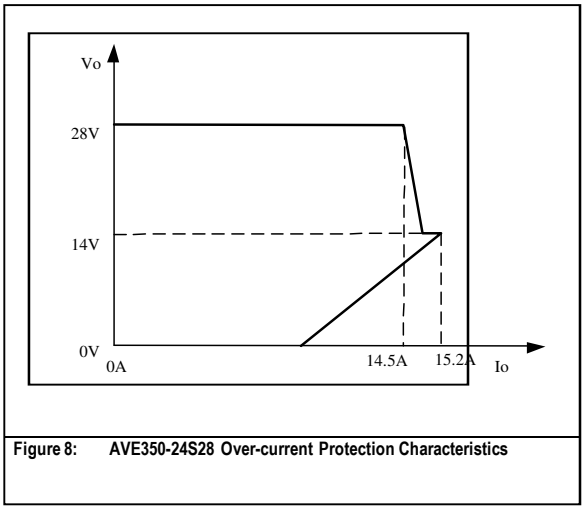



Figure 8: AVE350-24S28 Over-current Protection Characteristics

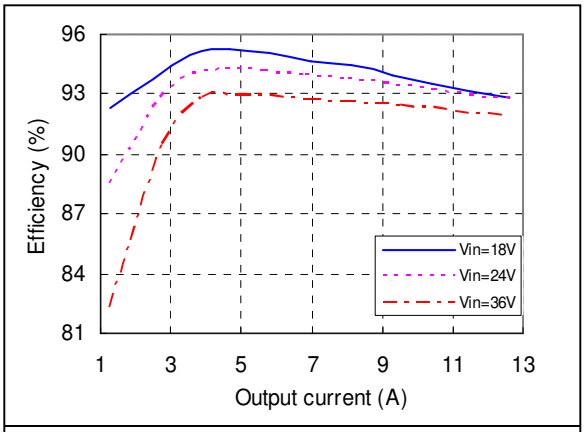
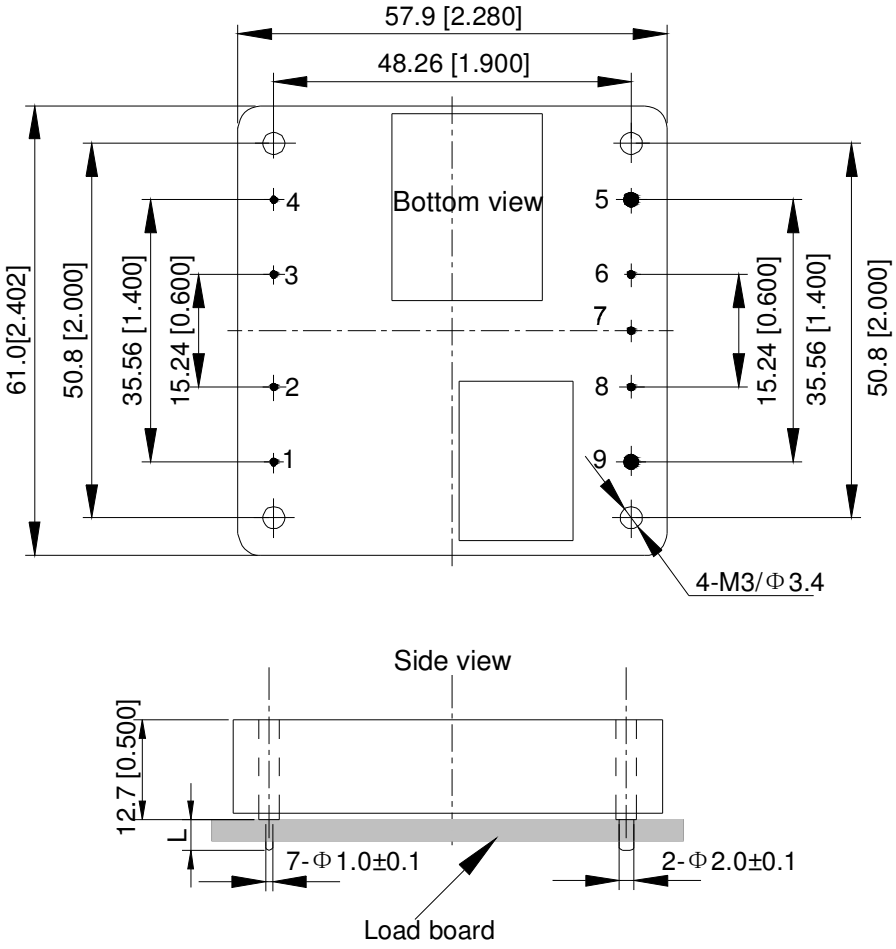



Figure 9: AVE350-24S28 Efficiency Curves Vo=28V

Tc: temperature test point on baseplate, Ta=25 °C, Tc<40 °C

# Mechanical Specifications

## Mechanical Outlines




Unit: mm[inch]

Bottom view: pin on upside

Tolerance: X.Xmm±0.5mm[X.X in.±0.02in.]
X.XXmm±0.25mm[X.XX in.±0.01in.]

## Pin Length Option

| Device code suffix | L |
|---|---|
| -4 | 4.8mm±0.2 mm |
| -6 | 3.8mm±0.2 mm |
| -8 | 2.8mm±0.2 mm |
| None | 5.8mm±0.2 mm |

## Pin Designations

| Pin No | Name | Function |
|---|---|---|
| 1 | Vin+ | Positive input voltage |
| 2 | CNT | Remote ON/OFF control |
| 3 | Case | NC |
| 4 | $V_{in}$- | Negative input voltage |
| 5 | $V_o$- | Negative output voltage |
| 6 | S- | Negative sense |
| 7 | Trim | Output voltage trim |
| 8 | S+ | Positive sense |
| 9 | Vo+ | Positive output voltage |

# Environmental Specifications

## EMC Immunity

AVE350-24S28 series power supply is designed to meet conducted emission's requirements of EN55022 Class A with external filter.

## EMC Filter Configuration

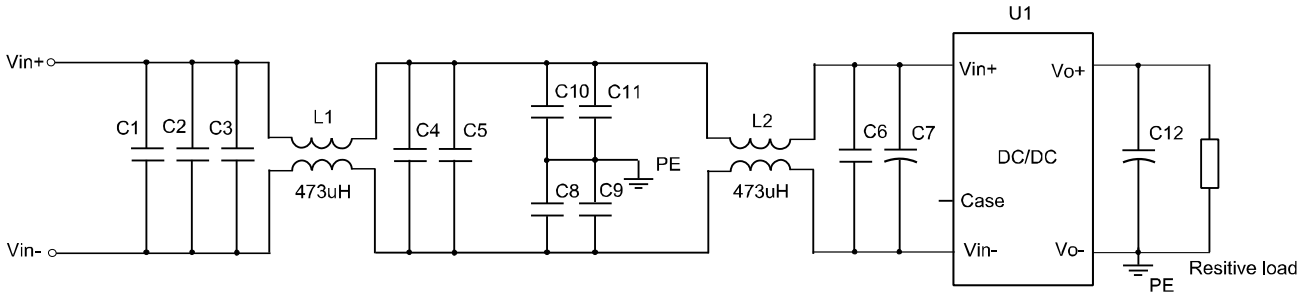



Figure 10 EMC test configuration

U1: Module to test, AVE350-24S28

C1 ~ C5: 1uF/100V X7R ceramic capacitor, P/N: C3225X7R2A105KT (TDK) or equivalent caps

C6: 0.1uF/100V X7R ceramic capacitor, P/N: 12101C104JAT2A (AVX) or equivalent caps

C8 ~ C11: 0.22uF/630V X7R ceramic capacitor, P/N: 2220CC224KA11A (AVX) or equivalent caps

C7: 470μF/100V electrolytic capacitor, P/N: UPW2A471MHD (Nichicon) or equivalent caps

C12: 680uF/63V electrolytic capacitor, P/N: UPW1J681MHD(Nichicon) or equivalent caps

PE: Connect to Vo-

Case：Not connected

## Safety Certifications

The AVE350-24S28 Series power supply 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. This product is only for inclusion by professional installers within other equipment and must not be operated as a stand alone product.

Table 4. Safety Certifications for AVE350-24S28 series power supply system

| Document | File # | Description |
|---|---|---|
| UL60950,CSA-C22.2 | | US and Canada Requirements |
| EN60950-1 | | European Requirements |
| IEC60950 | | International Requirements |
| GB4943 | | Chinese Requirements |
| CE | | CE Marking |

## Operating Temperature

The AVE350-24S28 series power supplies will start and operate within stated specifications at an ambient temperature from -40 $^{O}$C to 85 $^{O}$C under all load conditions. The storage temperature is -55 $^{O}$C to 125 $^{O}$C.

## Thermal Considerations

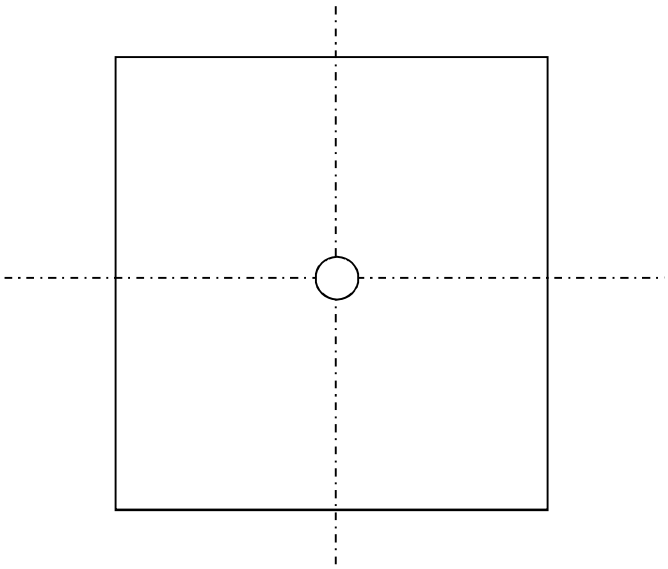


Figure 11 Temperature test point on baseplate

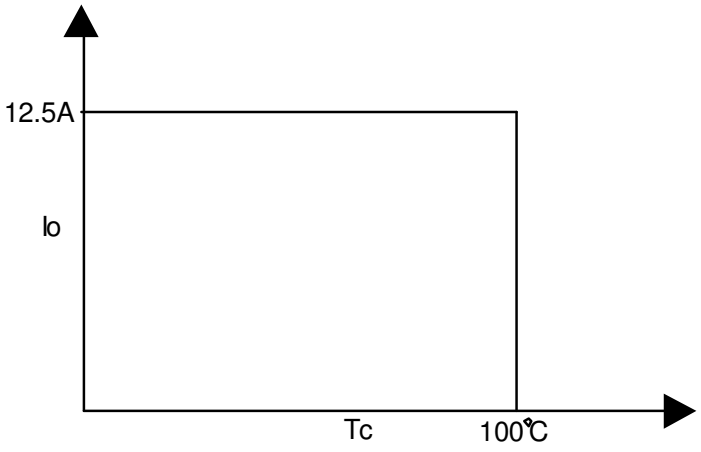



Figure 12 Output power derating, 24$V_{in}$

$T_c$: Temperature test point on baseplate, see Figure 11 for test configuration

## Qualification Testing

| Parameter | Unit (pcs) | Test condition |
|---|---|---|
| Halt test | 4-5 | $T_{a,min}$-10 $^{O}$C to $T_{a,max}$+10 $^{O}$C, 5 $^{O}$C step, $V_{in}$ = min to max, 0 ~ 105% load |
| Vibration | 3 | Frequency range: 5Hz ~ 20Hz, 20Hz ~ 200Hz, A.S.D: 1.0$m^2/s^3$, -3db/oct, axes of vibration: X/Y/Z. Time: 30min/axes |
| Mechanical Shock | 3 | 30g, 6ms, 3axes, 6directions, 3time/direction |
| Thermal Shock | 3 | -40 $^{O}$C to 100 $^{O}$C, unit temperature 20cycles |
| Thermal Cycling | 3 | -40 $^{O}$C to 85 $^{O}$C, temperature change rate: 1$^{O}$C/min, cycles: 2cycles |
| Humidity | 3 | 40 $^{O}$C, 95%RH, 48h |
| Solder Ability | 15 | IPC J-STD-002C-2007 |

# Application Notes

## Typical Application

Below is the typical application of the AVE350-24S28 series power supply.

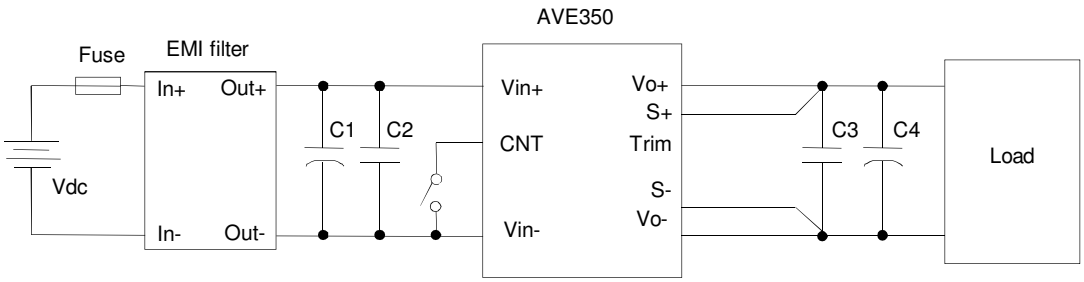



Figure 13 Typical application

C1: 470μF/100V electrolytic capacitor, P/N: UPW2A471MHD (Nichicon) or equivalent caps

C2, C3: 1μF/100V X7R ceramic capacitor, P/N: C3225X7R2A105KT0L0U (TDK) or equivalent caps

C4: 680μF/63V electrolytic capacitor, P/N: UPW1J681MHD(Nichicon) or equivalent caps

Note: If ambient temperature is below -5° C, additional 680μF electrolytic capacitor (Low ESR ) is needed for output.

Fuse: External fast blow fuse with a rating of 30A. The recommended fuse model is 314030 from LITTLEFUSE.

## Remote ON/OFF

Either positive or negative remote ON/OFF logic is available in AVE350-24S28. The logic is CMOS and TTL compatible. The following figure is the detailed internal circuit and reference in AVE350-24S28.

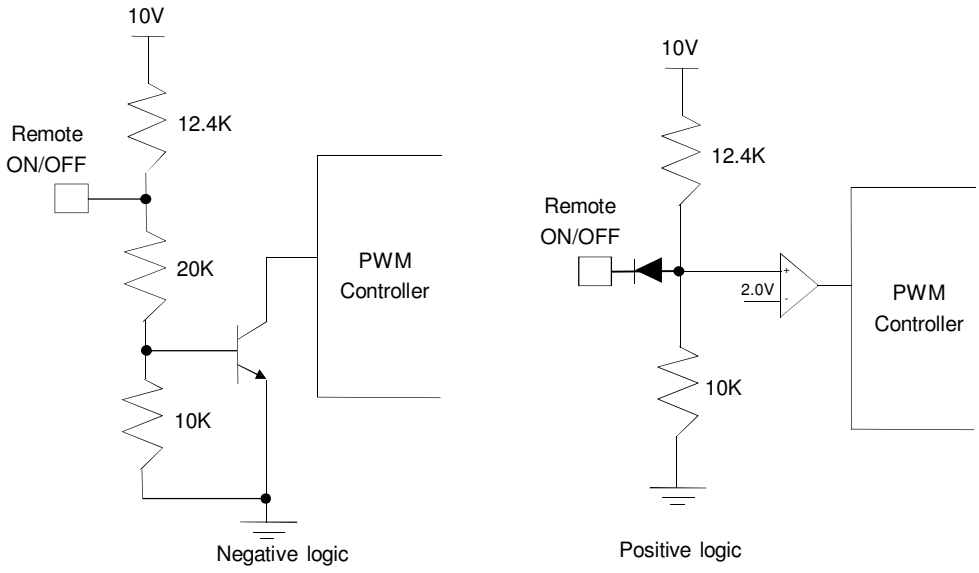



Figure 14 External Remote ON/OFF circuit

## Trim Characteristics

Connecting an external resistor between Trim pin and Vo- pin will decrease the output voltage. While connecting it between Trim and Vo+ will increase the output voltage. The following equations determine the external resistance to obtain the trimmed output voltage.

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

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

△%: Output e rate against nominal output voltage.

$V_{nom}$: Nominal output voltage

For example, to get 33V output, the trimming resistor is

$$R_{adj\_up} = (\frac{33}{1.225 \times (33-28)/28} - \frac{100\% + 2 \times (33-28)/28}{(33-28)/28}) = 143.26k\Omega$$

The output voltage can also be trimmed by potential applied at the Trim pin.

$$V_o = 11.43 \times V_{trim} + 14$$

Where $V_{trim}$ is the potential applied at the Trim pin, and $V_o$ is the desired output voltage.

When trimming up, the output current should be decreased accordingly so as not to exceed the maximum output power and the minimum input voltage should be increased as shown in Figure 15

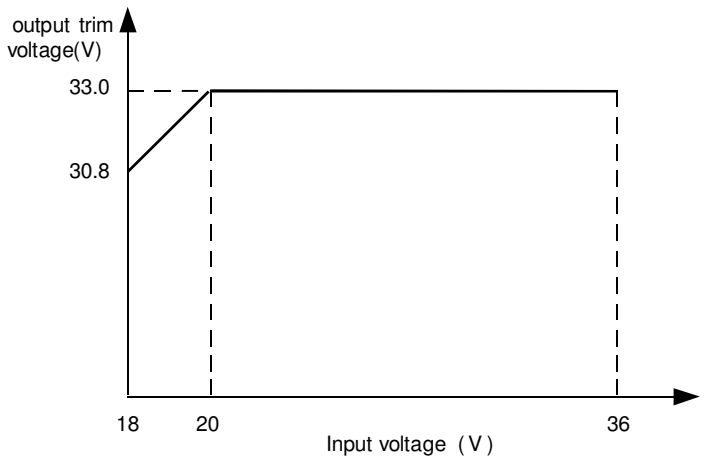



Figure 15 Output trim voltage vs. input voltage

## Trim Characteristics, Con't

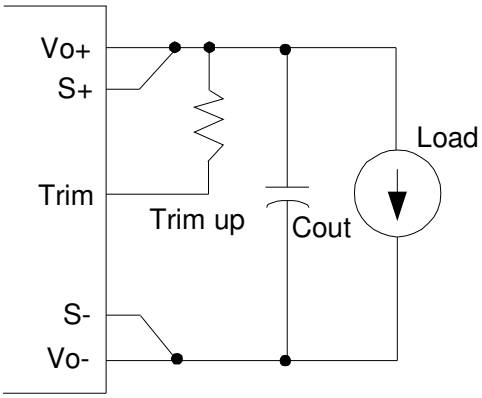



Figure 16 Trim up

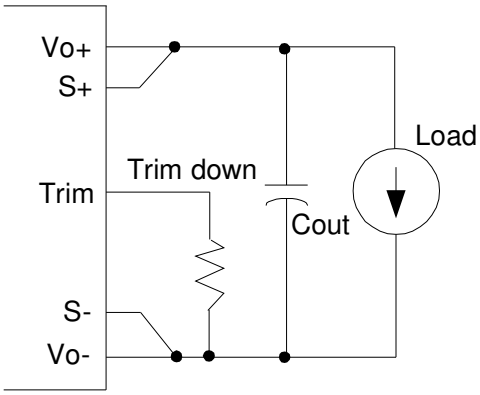



Figure 17 Trim down

## Input Ripple & Output Ripple & Noise Test Configuration

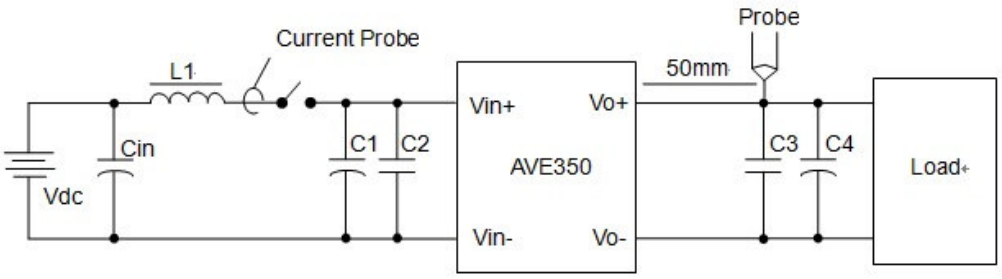



Figure 18 Input ripple & output ripple & noise test configuration

Vdc: DC power supply

L1: 12uH

Cin: 220uF/100V typical

C1 ~ C4: See Figure 13

Note - Using a coaxial cable with series 50ohm resistor and 0.68uF ceramic capacitor or a ground ring of probe to test output ripple & noise is recommended.

## Soldering

The product is intended for standard manual or wave soldering.

When wave soldering is used, the temperature on pins is specified to maximum 260 $^{O}$C for maximum 7s.

When soldering by hand, the iron temperature should be maintained at 300 $^{O}$C ~ 380 $^{O}$C and applied to the converter pins for less than 10s. Longer exposure can cause internal damage to the converter.

Cleaning of solder joint can be performed with cleaning solvent IPA or similative.

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## Hazardous Substances Announcement (RoHS of China R6)

| Parts | Hazardous Substances | | | | | |
|---|---|---|---|---|---|---|
| | Pb | Hg | Cd | $Cr^{6+}$ | PBB | PBDE |
| AVE350-24S28 | x | x | x | x | x | x |

x: Means the content of the hazardous substances in all the average quality materials of the part is within the limits specified in SJ/T-11363-2006

√: Means the content of the hazardous substances in at least one of the average quality materials of the part is outside the limits specified in SJ/T11363-2006

Artesyn Embedded Technologies has been committed to the design and manufacturing of environment-friendly products. It will reduce and eventually eliminate the hazardous substances in the products through unremitting efforts in research. However, limited by the current technical level, the following parts still contain hazardous substances due to the lack of reliable substitute or mature solution:

1. Solders (including high-temperature solder in parts) contain plumbum.
2. Glass of electric parts contains plumbum.
3. Copper alloy of pins contains plumbum

# Record of Revision and Changes

| Issue | Date | Description | Originators |
|---|---|---|---|
| 1.0 | 07.02.2014 | First Release | G.Xue |
| 1.1 | 10.15.2014 | Add condition | G.Xue |
| 1.2 | 09.17.2015 | Change Pin3 from “pin connected to baseplate” to “NC” | G.Xue |

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