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AN AUTOMATIC LINE VOLTAGE SWITCHING CIRCUIT

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ABSTRACT

The voltages found in line sockets around the world vary widely. Power supply designers have, most often, overcome this problem by the use of a doubler/bridge switch that can double the 120V nominal line and simply rectify the 240V nominal voltage.

A two device solution (comprising an integrated circuit and a customized triac) that will adapt the power supply to various line voltages around the world is described in the following paper. This circuit replaces a manual switch and could also open special markets. Other advantages of this integrated circuit solution are ease of circuit design, lower power dissipation, a smaller component count and additional safety features.

INTRODUCTION - THE DOUBLER/BRIDGE CIRCUIT.

AC line voltages the world over can be divided into two main categories :

a) 120V nominal, 60Hz systems. Electronic equipment is usually designed to run in the 90V - 132V range.

b) 240V nominal, 50Hz systems. Equipment has to be designed to run in the 187V-264V range.

A good reference for the various line voltages around the world is found in [1].

Power supplies built to run off these voltages have to be either wide range input or must use a doubler/bridge circuit. The disadvantage of the wide range input scheme - that all components have to meet worst case current and voltage requirements - makes such a solution popular only at less than 75W power levels. The popular doubler/bridge circuit is shown in Fig. 1. When the AC input voltage is 120V nom. (doubler mode) the switch S1 is closed. During the positive half cycle of the input voltage capacitor C1 is charged. During the negative half cycle of the input voltage, capacitor C2 is charged to the peak line voltage. When the line voltage is 240V nom. (bridge mode), the switch S1 is open and

Figure 1. Schematic Diagram of a Doubler/Bridge Circuit.
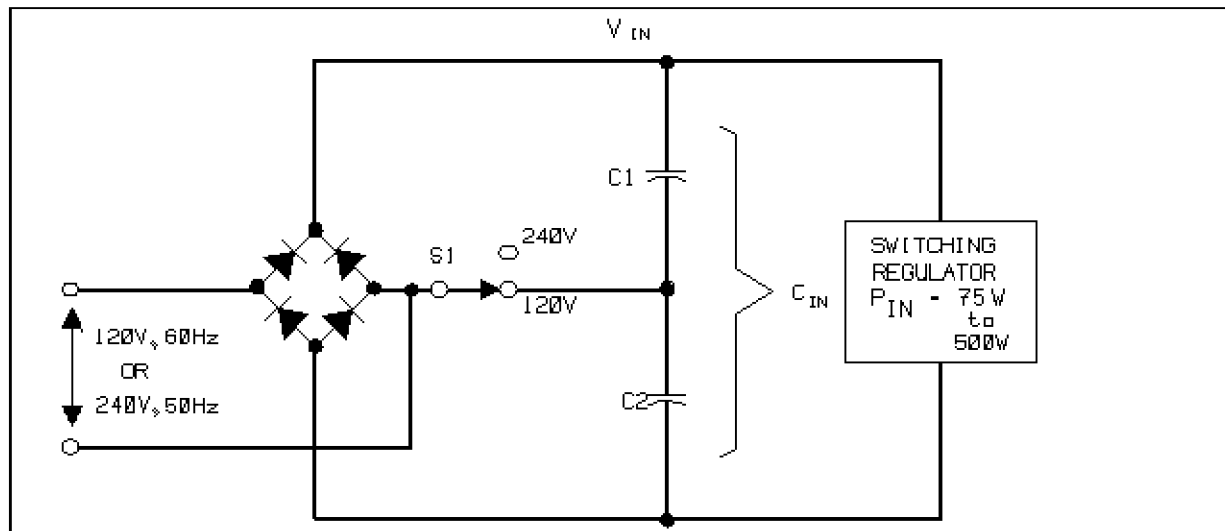
At power levels of over 500W, power factor correction circuits and three phase line input voltage circuits dominate. So, the automatic line voltage switching (AVS) circuit is used mostly in the 75W-500W power range.

The recent push to replace the mechanical switch S1 in Fig.1 with an automatic line voltage switching (AVS) circuit came from computer manufacturers. They found that the small additional cost of the AVS circuit is less than the costs of power supply failures incurred by inadvertently positioning the switch in the wrong position.

While many of the early AVS designs used relays, the triacs, with their superior reliability, small size and low cost are now more popular.

Figure 2. Discrete AVS Circuit Block Diagram
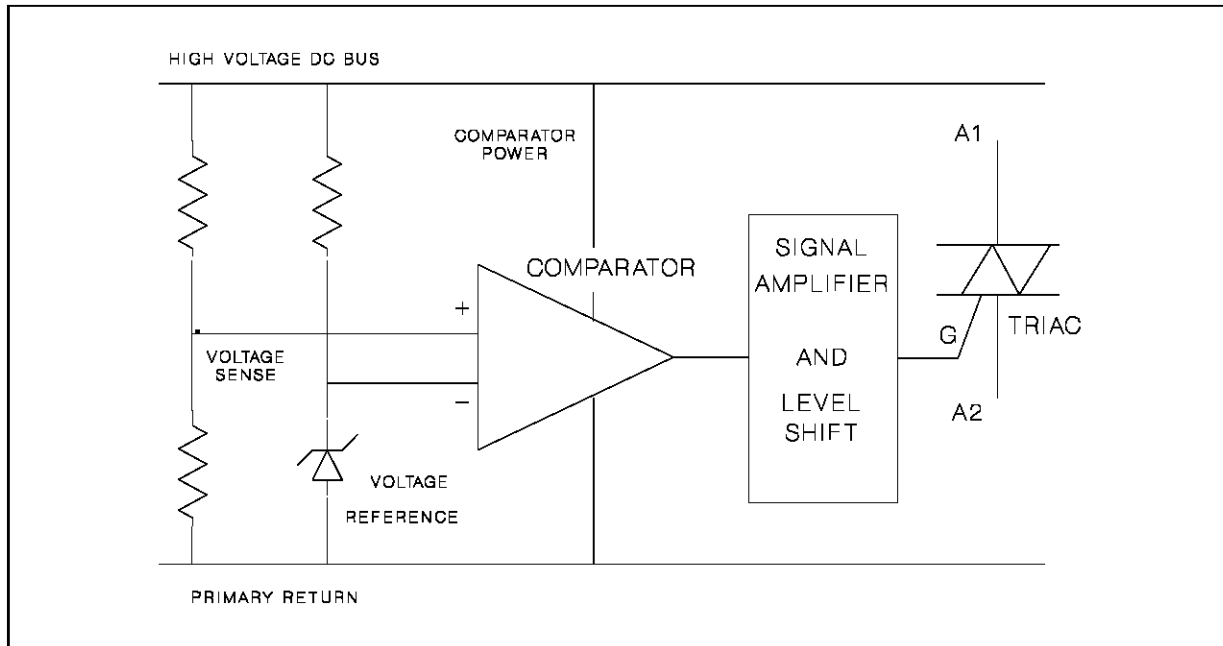
DISCRETE AUTOMATIC VOLTAGE SWITCHING CIRCUIT

Figure 2 shows a diagram of the various blocks comprising a discrete implementation of the AVS circuit. The line voltage selection circuit can be divided into three main functions:

1. Detection of peak line input voltage. Various schemes use resistive or capacitive dividers to measure the voltage across C1 and C2.

2. Comparison with a reference voltage that is generated with the help of a zener diode. A simple comparator can be implemented with two small signal transistors.

3. Drive for the triac. If the circuit is to be in the doubler mode, then the output signal of the comparator is boosted to provide the drive to turn the triac on. This interface circuitry can consist of a high voltage transistor and bias resistors.

DISCRETE VS INTEGRATED CIRCUIT AVS.

An IC based AVS circuit should be designed to overcome the disadvantages of the discrete solution that are listed below.

1. Power Dissipation.

This is critical because the entire supply current necessary for the operation of the AVS circuit comes from the high voltage bus. Every milliampere of current saved in the sensing, comparison and drive circuitry increases the efficiency of the entire system.

$$P_D(AVS)=k*(V_{AC})^2. (1)$$

is in the gate drive to the triac. This means that a sensitive gate triac is the best candidate for the switch S1 in Figure 1.

Discrete AVS solutions usually use between 5W and 12W.

2. Immunity to Input Line Voltage Transients.

Most power supplies today are designed to meet IEEE 587 or similar line transient specifications. We must choose a triac that withstands these transient voltages without any triggering. So we have to make a compromise between low gate drive requirements (I_{GT}) and good static dv/dt immunity. The gate drive circuit of the triac must also be designed to reduce any parasitic voltages at the gate. The gate non- trigger voltage (V_{GD}) of most triacs is about 0.2V.

3. Effect of Line Sags and Surges.

Line voltages are generally considered to vary about +/- 10% from their nominal values. The 120V nominal can be as high as 132V and the 208V nom. can fall to 187V. Between 132Vac and 187Vac, there exists a window, in which we have to design the threshold voltage of the comparator in Fig. 2. Additional ('strife', etc.) test requirements can reduce this window to a smaller 140V to 170V. An analysis of worst case component tolerances is critical in AVS design.

Ultimately, however, there will always be line voltage waveforms that will fool an automatic voltage selection scheme. One can think of situations where, say, a large motor will pull the line voltage down below the threshold voltage during startup. A good AVS system will monitor the line voltage and protect the power supply . In some applications, the bridge mode (240V mode) is considered the fail safe mode and if the unit starts off in the bridge mode, it should not be able to change modes till the power is recycled.

SGS-THOMSON AVS10 SOLUTION.

We at SGS-THOMSON studied the possibility of an integrated circuit solution for this application. The cost constraints ruled out any exotic single chip solutions and forced us to opt for an 8 pin DIP IC for sensing and a TO-220 triac as the power switch. This IC+triac solution, called AVS10, also offers optimal protection against noise.

In order to maximize the design flexibility and reduce turn around time, we chose a semi-custom solution called ANACA. A 12V CMOS ANACA process used offers mixed analog/digital standard cell capability.

OPERATION OF THE AVS10 CIRCUIT

A typical application diagram for the AVS10 in a power supply is shown in Fig. 3.
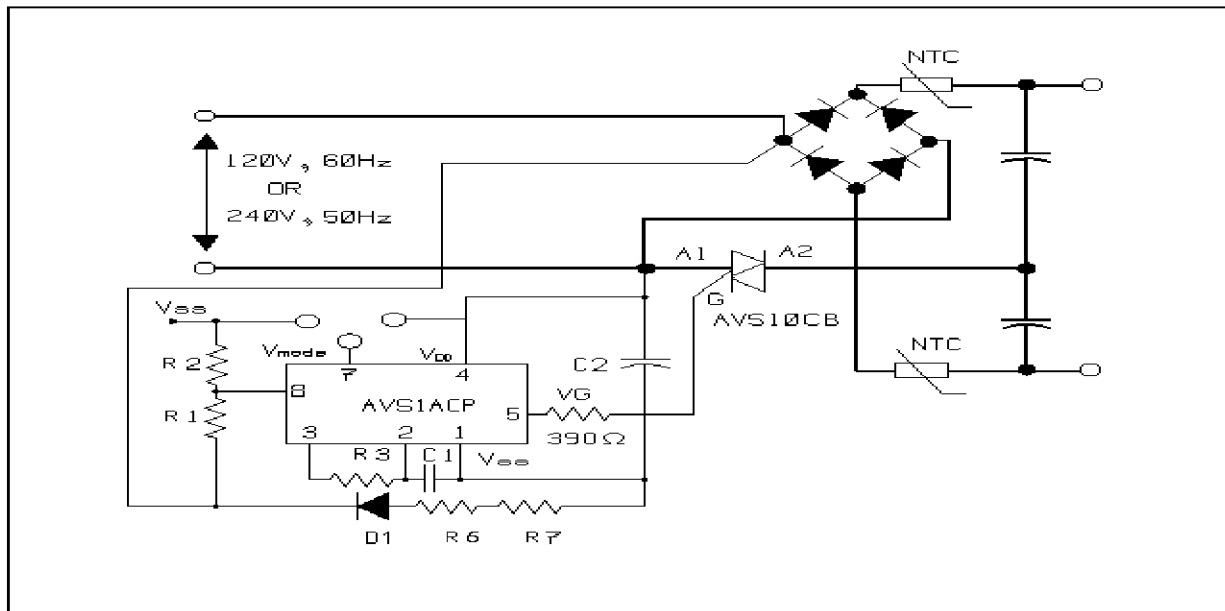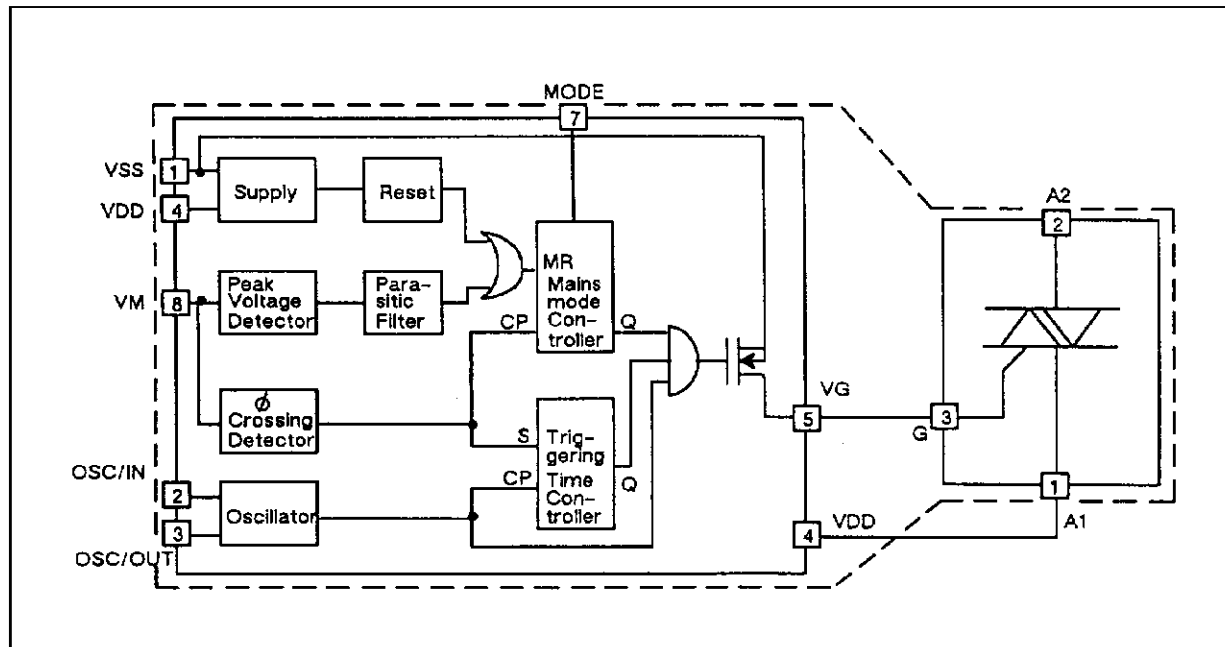
Figure 3.   AVS10 Application Schematic Diagram

Figure 4. AVS10 Block Diagram

About 80% of the power lost in the AVS scheme The series circuit of D1, R6, R7 and C2 provide power for the chip. Pin 1, Vss, is a shunt regulator that provides a -9V (nom.) output. R1 and R2 are resistive divider precision resistors that are a measure of the input line. The voltage at Pin 8 varies with the input line. Thus the voltage at Pin 8 is not only a measure of the peak input voltage, but it can also sense line voltage zero crossing. Pins 2 and 3 are inputs to an oscillator. The resistor R3 and C1 set the oscillator frequency. Pin 5 drives the gate of the triac through a 390Ω resistor. Pin 7 offers the user a choice of two different modes of operation. The block diagram of the IC is given in Fig. 4.

1. Decreased Power Dissipation.

Decreased power dissipation is an important advantage of the AVS10. While most discrete AVS schemes need 5W to 12W of power, the AVS10 uses about 2W. This performance is thanks to an innovative gate triggering scheme (Patent Pending). The gate current is made up of a pulse train that has a typical duration of around 23μs (45kHz+/-5%). The duty cycle of the pulses is typically 10%. The values of R2 and C3 in Fig. 3 are chosen to give us the pulse frequency.

2. Immunity To Voltage Transients.

The triac of the AVS10 is a sensitive gate triac that is specified to remain off when subjected to dv/dt of 50V/μs. Circuit layout is critical in preventing false dv/dt turn on of the triac [2]. The IC of the AVS10 circuit has a built in digital filter that suppresses the effect of all spikes of less than 200μs duration.

3. Operating In The Failsafe Mode. $V_{mode} = V_{SS}$.

The mode pin on the AVS10 IC, Pin 7 determines the behavior of the circuit if it is turned on into a line surge/sag situation. If Pin 7 is tied to V_{SS} (Pin 1), the AVS10 circuit is in a failsafe mode. This means that if the device is turned into a bridge mode, it will remain in the bridge mode, even if the voltage were to suddenly dip into the 110V range.

4. Operation In Reactive Mode. $V_{mode} = V_{DD}$.

If Pin 7, the mode pin, is tied to V_{DD}, then the device will switch between bridge and doubler modes if the input voltage changes. If the 110V input changes to 220V, then the AVS10 turns the triac off by the next mains cycle. If the 220V input falls to 110V, the AVS10 circuit has a validation period of 8 mains cycles (when it verifies that the voltage is still at 110V) after which the triac turns on. Thus, safety features are built into

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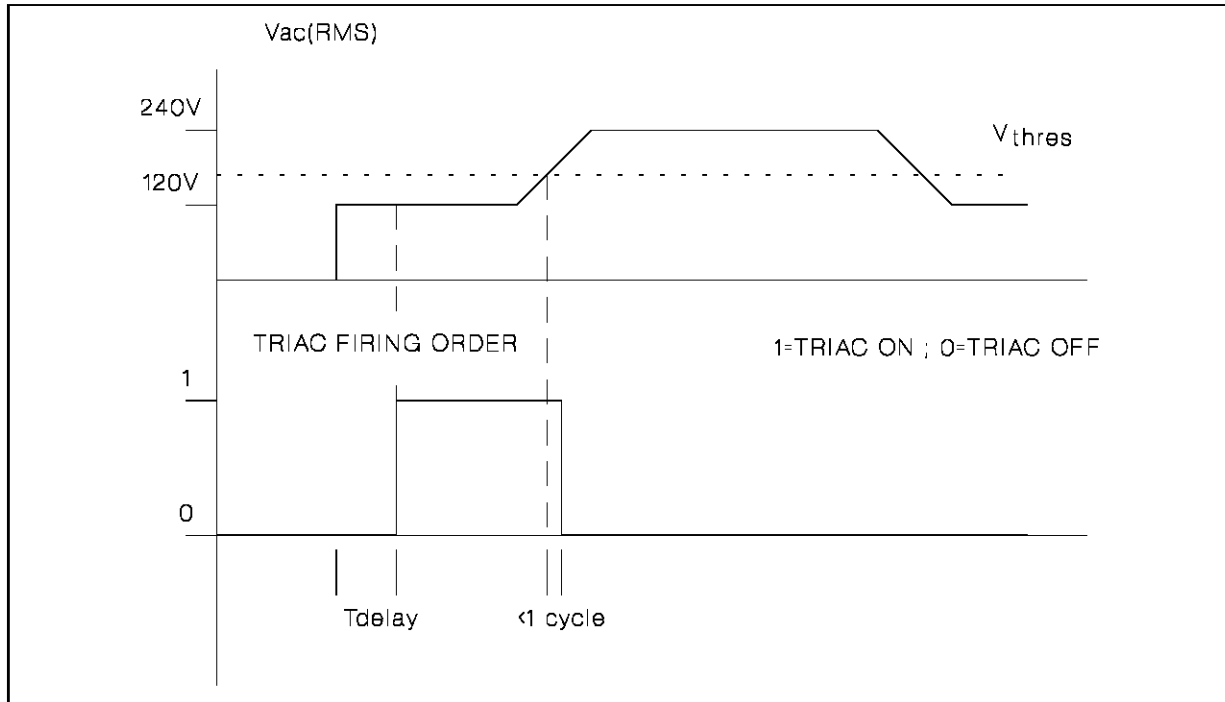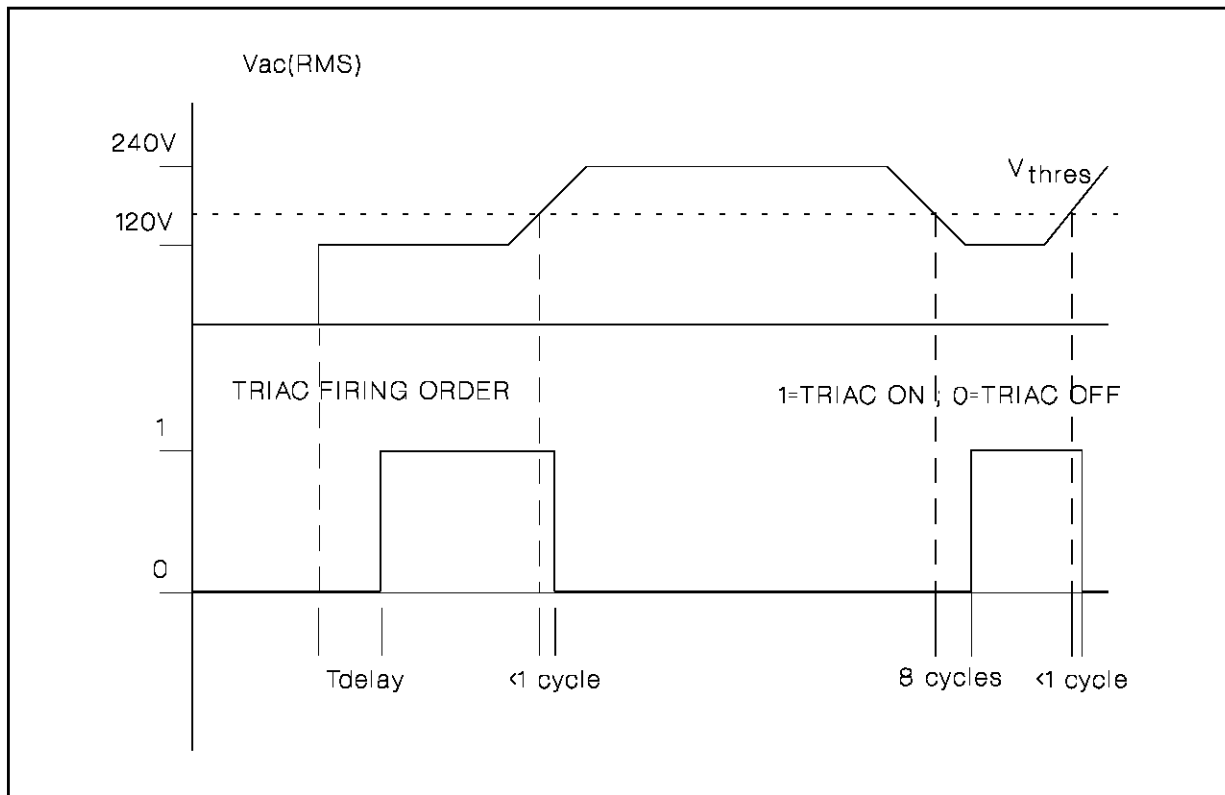**MICROELECTRONICS**

Figure 6. Timing diagram - $V_{mode} = V_{SS}$

Figure 5. Timing Diagram - $V_{mode} = V_{dd}$

the AVS10 circuit. Typical timing diagrams for the two modes are given in Figs. 5 and 6.

A detailed account of how to set the input voltage threshold is found in [2].

5. Additional Safety Features.

Additional steps are taken to enhance the safety of design include starting up always into the bridge mode. There is a delay of around 250 ms at start up before the AVS10 goes into the doubler mode.

Hysteresis is also built into the comparator to prevent small line voltage variations from causing toggling between bridge and doubler modes. Only a voltage variation of over 10% of the line voltage can cause the AVS10 to change modes.

CONCLUSION

This paper describes an efficient way of implementing an automatic doubler/bridge circuit. The primary use of this circuit is in 75W to 500W SMPS. Other innovative uses are possible. One example would be industrial motor drives which can be designed to accept either 120V line-to-neutral or 208V line-to-line input.

The main advantages of the AVS10 solution are:

1. High Efficiency. Losses are just 2W vs. 5W-10W for discrete schemes.

2. Safety. Uses digital spike suppression, hysteresis, validation of range, a failsafe mode and good control over the triac triggering.

3. Space Optimization., small supply resistor. Good reliability.

4. Ease of Use. Eliminates manual line selection errors.

5. Suitable solution for various power range:
   AVS10 up to 300W
   AVS12 up to 500W.

REFERENCES.

[1] PSMA Handbook of Standardized Terminology for the Power Sources Industry.
Appendix C.

[2] SGS-THOMSON technical note 'How To Use The AVS Kit'.

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