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## **UNDERSTANDING SCR POWER CONTROLS**

When selecting SCR Power Controls, it is important to have a basic understanding of how SCRs work. This will help you select the right SCR for your application.

### **• HOW SCR POWER CONTROLS WORK**

A silicon controlled rectifier (SCR) is a solid state switching device which can provide fast, infinitely variable proportional control of electric power. Not only does this give maximum control of your heat process, but it can extend heater life many times over other control methods. Since the SCR is solid state, it can cycle on and off over a billion times, if properly used.

### **The advantages of SCR Controls over other temperature control methods**

- Improved response time
- Closer process control
- Extended heater life
- Reduced maintenance costs. No mechanical wear.
- Silent operation. No arcing and sparking.
- Reduced peak power consumption

Remember, a heating element is made of wire in most cases. If you use a mechanical relay to turn on your heater, it will cycle on or off within 30 seconds or longer. The heater will expand and contract, getting more and more brittle each time. This is called thermal shock. Temperature overshoot may also occur. Relays also arc, spark and will burn out on a regular basis.

Mercury displacement relays can cycle from 3-15 seconds. While it controls better than a mechanical contractor, overshoot and thermal shock will still occur. If cycled too fast, Mercury relays can overheat and explode causing Haz-Mat problems.

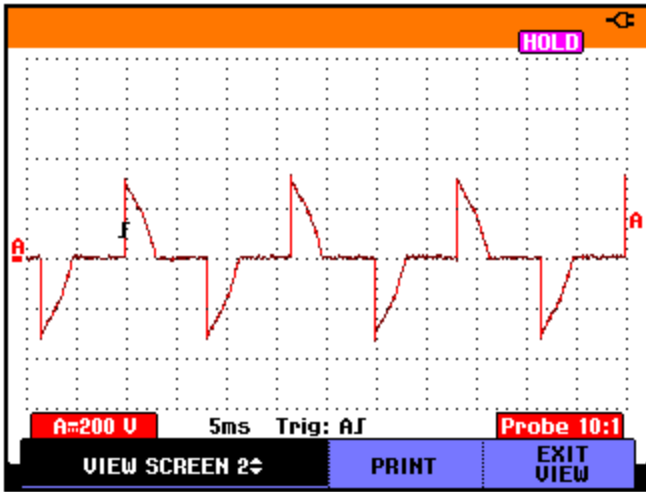
## **POWER CONTROL SELECTION GUIDE**

The SCR control can deliver electrical power to heaters in several ways: phase angle fired, zero voltage switched and on/off control.

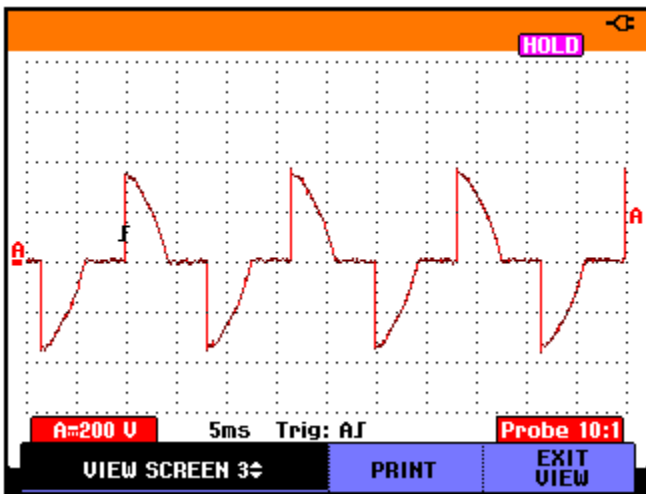
### **PHASE ANGLE FIRED**

These controls proportionally turn on a percentage of each power line half cycle. This gives smooth, infinitely variable application of power to the heaters. Imagine a light dimmer and how it provides power to a light bulb. This method will provide the most precise control of heaters. Phase angle fired SCR's will respond the fastest to load change and provide maximum heater life. It is the most precise method of control. Phase angle firing can increase heater *life up to seven times depending on heater type*. Phase angle firing also allows options such as soft start, voltage limit and current limit. These options are not available with any other means of control.

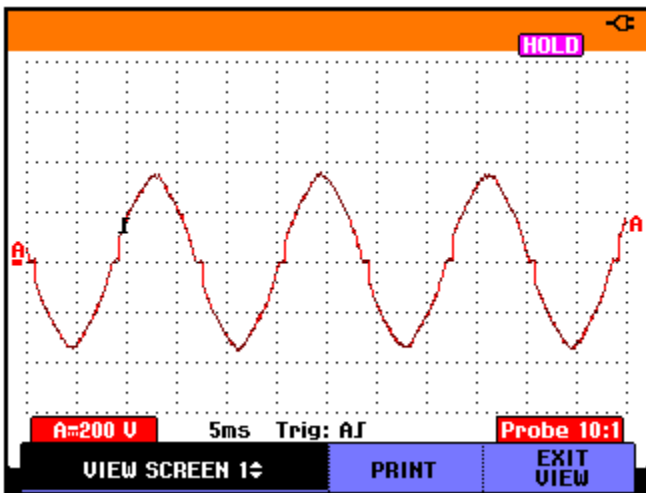
Graphs below shows **phase angle fired** voltage output on a 240V power line.



Graph shows 25% output or 60V RMS.



Graph shows 50% output, 120V RMS.

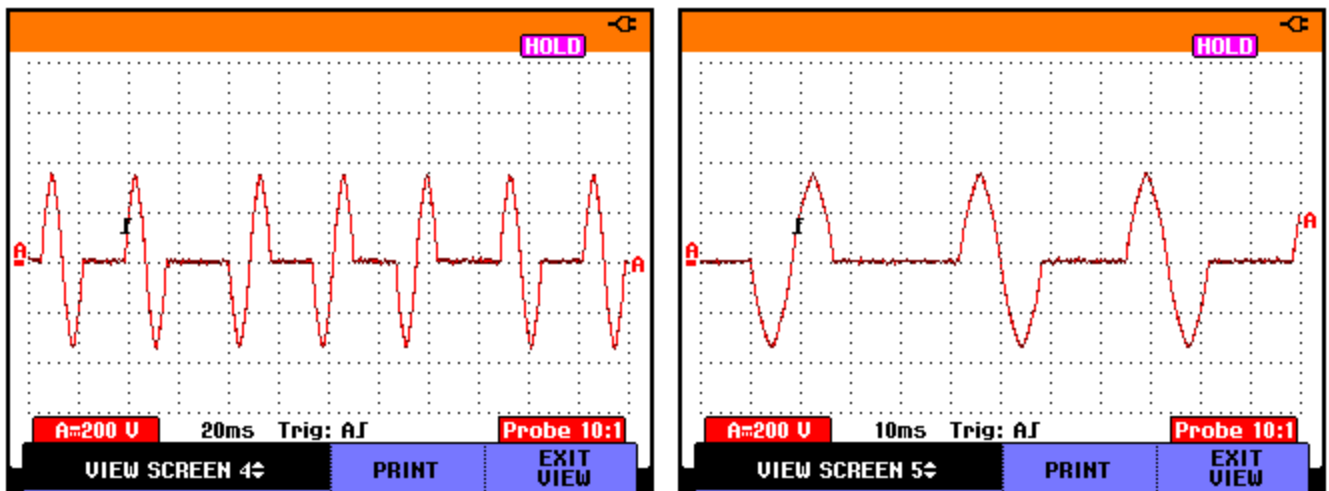


Graph shows 99.5% output or 238.8V RMS

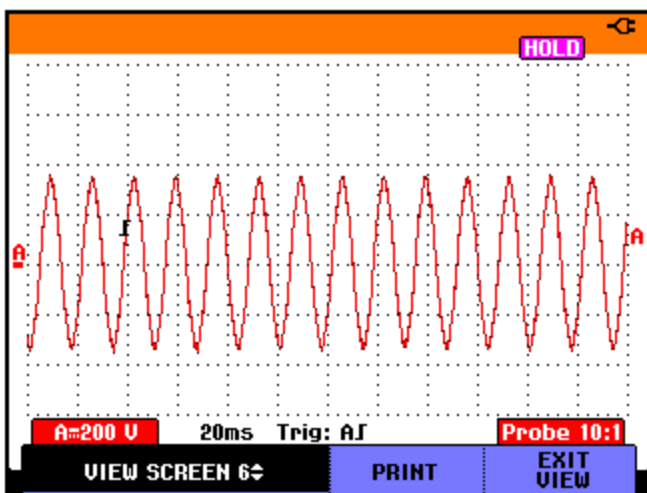
## ZERO VOLTAGE SWITCHED

Zero voltage switched controls proportionally turn on and off each full cycle of the power line cycle. By varying the number of AC power line cycles, the SCR provides power to the heaters. With a variable time base, the optimum number of cycles turned on/off is achieved. The switching is done at fractions of a second during the zero voltage crossing of the power line cycles. For IR heating with a fast element, you would see the elements flickering. On a ceramic heater, or more massive medium wave heater you can control within very tight tolerances.

**Zero voltage switching** controls proportionally turn on and off each full cycle of the power line. By varying the number of AC power line cycles, the SCR provides power to the heaters. With a variable time base, the optimum number of cycles turned on/off is achieved. This method produces less RFI line noise than phase angle fired SCRs. Power factor is 100%, while harmonic distortion is limited. Chart below shows 25% power output using variable time based zero voltage switching.



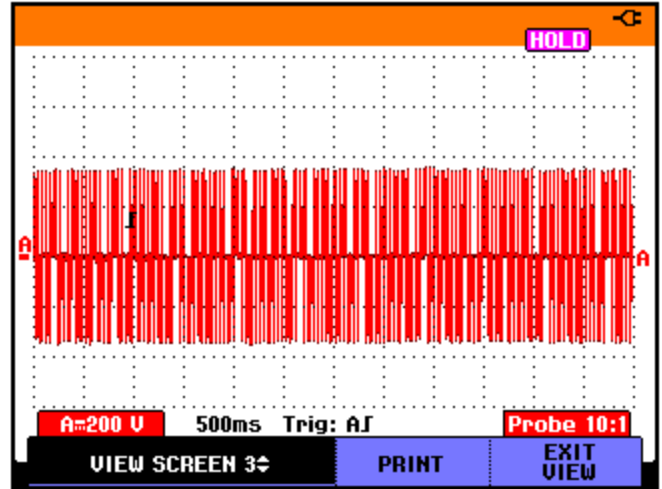
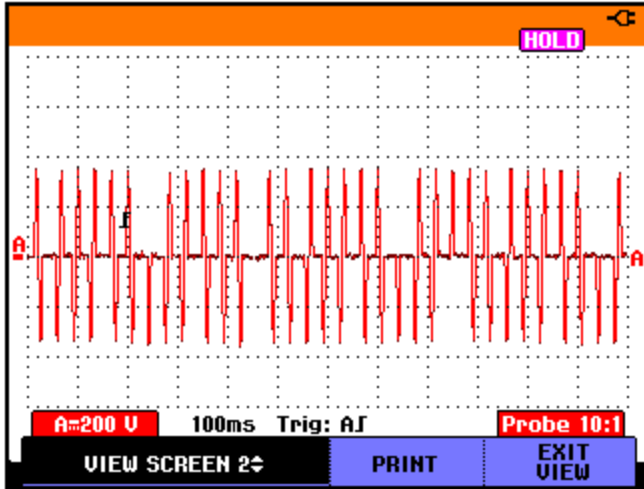
Avatar Instruments variable time base SCR firing. Note how half cycles can be turned on and off providing 0.08 second resolution. Above chart shows 50% output.



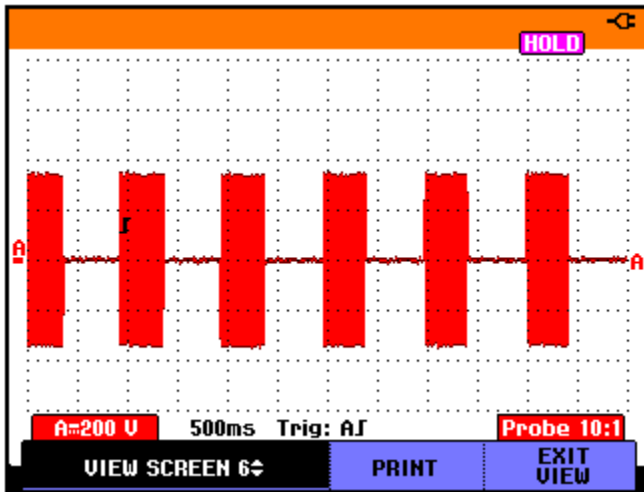
100% output at 240V RMS.

**On/Off controls** function the same way as a mechanical or mercury relay, with the advantage of much faster cycle times. Chart below shows an Avatar Instruments model A1Z SCR output with variable base time proportioning. Compare the output cycles against an SSR with a 1 second time base and a 5 second time base. The superior firing resolution and speed of response of the A1Z SCR is instantly apparent.

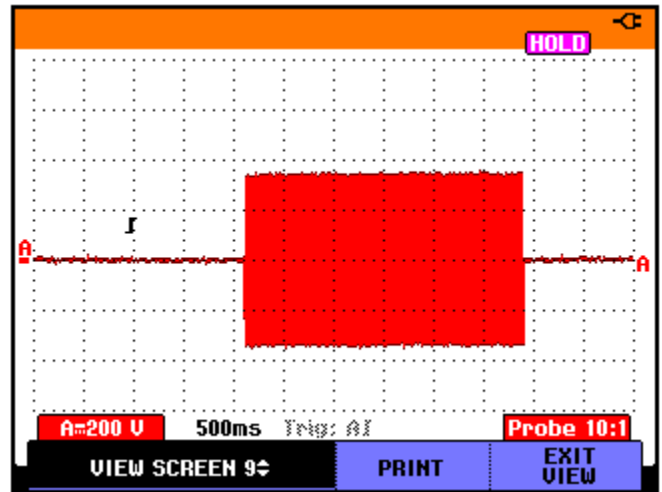
**Avatar Instruments A1Z SCR 50% output with variable time base zero voltage switching.**



To show the full effect, the scope had to be set on a 500ms scale (right hand), or a 5X longer time base than the 100ms screen above on the left. Compare the right hand screen above to the two screens below.



SSR with 1 second on-off time base.



On-Off 5 second on-off time base, which might cause failure if used with mercury displacement relays.



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## POWER CONTROL SELECTON CHART

Chart below shows how to best match SCR power control with typical applications.

Heater/Load Type	Heater/Load Characteristics	Control Type	Typical Applications	Model Number
Constant Resistance Elements. Immersion heaters.	Slow Response	On/Off Zero Voltage Switched	Large tank heating and mechanical relay replacement.	A1Z A3Z A6Z R1 CZ
Medium wave infrared, ceramic, cartridge, duct, strip, and band heaters. Platens.	Faster response. Constant resistance heaters only. NiChrome, Kanthal.	Zero Voltage Switched	Thermoforming, textiles, industrial furnaces and ovens, extrudes, kilns, chemical process heating, fast water heat.	A1Z A3Z CZ D1P 2CP-8CP
Open coil/wire heaters. Medium wave IR quartz. IR panels	Fastest, most precise response.	Phase Angle Fired	Paper and pulp drying, packaging machines, pharmaceutical processes, infrared ovens & dryers.	A1P C1P A3P D1P 2CP-8CP
Silicon Carbide Heaters.	Load changes in resistance with age. High temperature elements.	Phase Fired with Current Limit Option	High temperature ovens and furnaces, glass, ceramics and high temperature alloys.	A1P-CL A3P-CL
Tungsten (T-3) Lamps and heaters. Short wave IR elements. Molybdenum heaters.	High inrush currents High hot: cold resistance ratio Tungsten 14:1 Molybdenum 20:1 Graphite: 20:1	Phase Angle Fired with Soft Start option	High speed paper and ink dryers, high temperature IR heating, high temperature materials processing.	A1P-Sxx A3P-Sxx C1P-S 2CP-S-8CP-S
Transformer coupled loads. Primary driving. Inductive heater loads.	Inductive loads.	Phase Angle Fired with Soft Start option. Current limit option.	Used with transformer-coupled to drive low voltage elements.	B1P B2P B3P

### PRODUCT NOTES

- All A & B series controls have fusing of controlled legs as standard.
- All A, B, & C Series controls have isolated 4-20mA command signal as standard. Other input signals are available. See MAP, MAI series of interface cards.
- All Avatar Power Controls to 600 Amps have isolated & grounded chassis and SCR blocks.
- 4 wire 3 Phase systems should use either A6Z, 3CP or 3 single phase controls.

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## **COMPARING DIFFERENT METHODS OF POWER CONTROL**

There are several methods commonly used to control power to electric heaters. Although some may seem “cheap and easy,” the total costs are not always considered.

### **MECHANICAL RELAYS/CONTACTORS**

The up front cost for a simple relay is low on low power levels. As the power level goes up, the price rises. Since the mechanical relays will get dirty, arc and burn out, the relay has to be replaced every so many cycles. The labor cost associated with this is often overlooked. Due to the slow cycle time inherent for mechanical relays (30 seconds minimum) control is poor, heated process may be damaged and heater life is shortened due to thermal shock.

### **MERCURY DISPLACEMENT RELAYS (MDR)**

The up front cost of a mercury displacement relay, or MDR, is low at low power. The MDR can cycle faster than a mechanical relay, and will not burn out as quickly. MDR's do have to be mounted in one direction. However, the MDR **will explode** if overheated due to cycling too fast, or if overpowered. This results in a Haz-Mat problem. Control is still poor compared with solid state devices. The heater is still receiving full line voltage for several seconds at a time.

### **SOLID STATE RELAYS (SSR)**

The costs of low power Solid State Relays (SSRs), is also low. However, there are several cost factors forgotten about with SSRs. Common to all solid state devices, they generate heat **and have to have heat sinks**. Also, SSRs generate more heat than SCRs due to their packaging, and come without lugs that make a solid electrical connection for higher power levels. The MOVs and fuses needed for protection against electrical shorts and spikes have to be customer installed. Again, this is a hidden cost. Finally, when looking at the SSR data, you must always DERATE THE DEVICE. Manufacturers of SSRs have derating curves published in their catalogs. However, please note that all SSRs are rated for the name plate power rating at 25°C/77°F ambient temperature. So a 50 Amp SSR is not good for 50 Amps if the temperature in the enclosure or work area is above 25°C/77°F (how hot is your facility in July?). The single surge current and voltage spike ratings are not as strong as an SCR. The SSR can cycle once a second and deliver better performance to both process and heaters than mechanical means. However, SSRs can only turn cycles on or off.

### **SILICON CONTROLLED RECTIFIERS (SCR)**

The costs of Silicon Controlled Rectifier (SCR) Controls, is higher at low power, but level out with other methods at mid to high power. All Avatar SCRs come equipped with proper heat sinks, semi-conductor fuses and power lugs installed as an integrated package. With standard MOVs and DV/DT protection for line noise and voltage spikes, an SCR control can operate for decades. There is no routine maintenance to carry out. The level of control that can be achieved with a SCR is unattainable with any other devices.

Phase angle firing and zero voltage switched control offers 0.08 second response times on 60Hz power lines. Heater life can be extended by 7 times. Power to heaters is infinitely variable. Soft Start, Current Limit and Voltage Limit Options give advantages for controlling heaters. Soft Start allows the use of high inrush heaters. Current Limit gives control of high temperature elements for furnaces. Voltage Limit prevents temperature overshoot and extends heater life. Peak power is reduced, saving operators utility costs.

# ELECTRICAL ENCLOSURES AND SCR CONTROLS

## **PROTECTING YOUR SCR CONTROLS FROM FAILURE**

Heat is the main enemy associated with SCR Control Failure. In fact, heat is the main enemy of all solid state devices. Almost all semiconductors, including transistors, IC/s and thyristors (SCRs and TRIACs) will be destroyed at an internal junction temperature of 125°C. Diodes can take a higher internal junction temperature (130-200°C). This is one reason Avatar Instruments uses SCR-Diode combinations whenever possible.

Heat is generated by voltage drops across a power device (SCR/TRIAC). This drop can be anywhere between 1 and 2 volts depending on the device. The more current (amps) put through the device, the higher the watts the device will dissipate in the form of heat. This heat must be removed or the device will fail.

All Avatar SCR Controls are designed to run at full rated amperage at 50°C / 122°F ambient.

## **DETERMINING THE TYPE OF ENCLOSURE FOR YOU SCR POWER CONTROL**

First, determine the heat generated by the SCR Controller. The basic formula is as follows: For each controlled leg (C), multiply the amperage load (I) by 1.2.

**$C \times I \times 1.2 = \text{watts generated @ maximum load}$**

- A single phase 60 Amp device would generate 72 watts of heat.  $60 \times 1.2 = 72$ .
- A 3 phase, 2 leg 60 Amp (A3Z) control would generate 144 watts.  $2 \times 60 \times 1.2 = 144$
- A 3 phase, 3 leg 60 Amp phase angle control would generate 216 watts.  $3 \times 60 \times 1.2 = 216$

The following data applies to a painted steel enclosure. To calculate what size enclosures you need, you must know what the temperature of your work environment will be. When the SCR is turned on, the inside of the enclosure will be warmer than the ambient air outside the enclosure. This temperature rise above ambient temperature is represented by (TR) in our equation. With a maximum working temperature of 122° F, for the SCR, care must be taken. For our example we will use the 216 watts (W) for the 3 leg 60 Amp SCR. And let's use a 10°F temperature rise (TR) over ambient as your target. The final sum is the exposed surface area in square feet (SF) you need to maintain the 10°F rise.

Formula:  **$W \times 4 / TR = SF$**

Example:  **$(216 \times 4) / 10 = 86.4$**

86.4 are the exposed square feet of your enclosure needed to run the SCR Control of an ambient temperature of 112° F. (TR) value in example of 10°F is the allowable rise.  $122^\circ\text{F} (50^\circ\text{C}) - 10^\circ\text{F} = 112^\circ\text{F}$ . If you decide to use a vented enclosure, area 50 (recommended), the basic formula is 10 square inches of inlet and outlet for every area 50 amperes per controlled leg. Since heat rises, vent holes should be at the top and bottom of the enclosure.

## **FAN COOLING**

After looking at the size of the enclosure needed for a large SCR, you may want to consider a fan(s) to keep the enclosure at safe operating temperatures. To determine the size of the fans needed, use this simple formula:

$$\text{Formula: } (W \times 3.16) / TR = \text{CFM}$$

Example: To figure out what size fan you need if using a device generating 216 watts (W) where you want to keep the temperature rise to only 10°F above ambient (TR), use the following formula:

$$\text{Example: } (216 \times 3.16) / 10 = 68.25 \text{ CFM Fan}$$

Remember, you will need air inlet and outlet holes with fan cooling.

Finally, plastic enclosures act as an insulator. You will most likely destroy an SCR control if you install it inside a plastic box. The only reliable way to use a plastic enclosure is to have a “thru-hole mounting” style heat sink, with the heat sink’s cooling fans outside of the box.

## **POWER CALCULATIONS**

When selecting the correct sized SCR power controller, rate the SCR for at least 110% of the heater load. Heaters and power lines have tolerances that can swing on any given day or location.

### **SINGLE PHASE**

$$\text{WATTS} \div \text{VOLTS} = \text{AMPS}$$

$$\text{Example: } 18,000\text{W} \div 240\text{V} = 75\text{A}$$

$$\text{AMPS} \times \text{VOLTS} = \text{WATTS}$$

$$\text{Example: } 60\text{A} \times 480\text{V} = 28,800\text{W}$$

### **3-PHASE**

$$\text{WATTS} \div \text{VOLTS} \div 1.73 = \text{AMPS}$$

$$\text{Example: } 18,000\text{W} \div 240\text{V} = 75 \div 1.73 = 43.35 \text{ A}$$

$$\text{AMPS} \times \text{VOLTS} \times 1.73 = \text{WATTS}$$

$$\text{Example: } 60\text{A} \times 480\text{V} \times 1.73 = 49,824\text{W}$$