

# Specifications for capacitor based power supply for Fy 04 CHI experiments

R. Raman

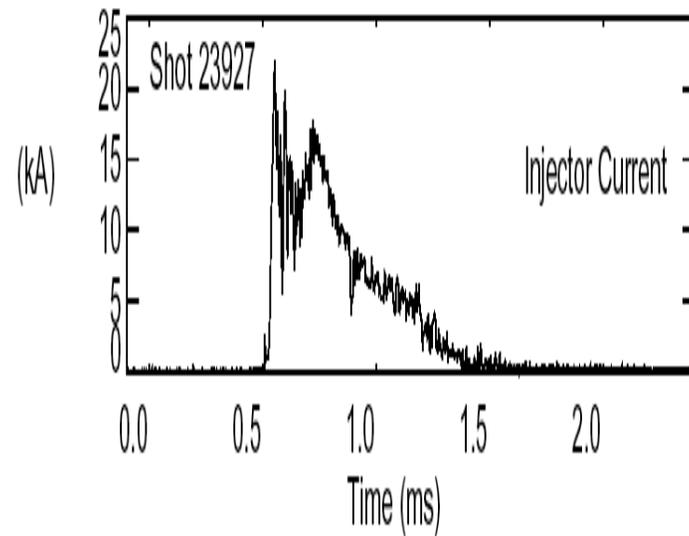
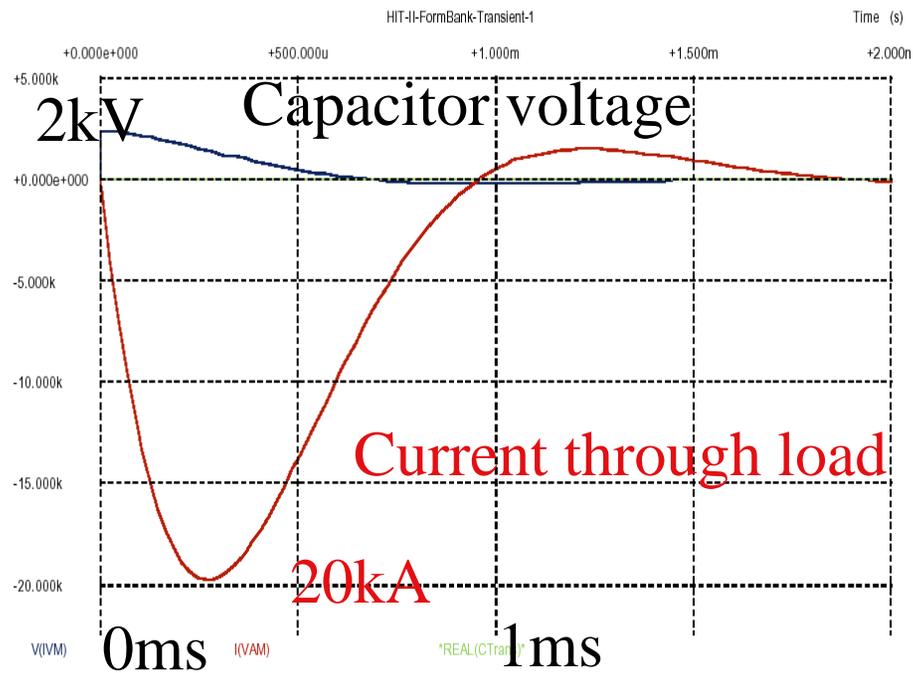
(including discussions with)

R. Hatcher and S. Ramakrishnan

New CHI startup method on HIT-II uses a small capacitor bank for Transient CHI startup

- High voltage on capacitor initiates discharge, which causes CHI plasma column to fill the vessel in about 500 $\mu$ s
- At about 500 $\mu$ s, most of the capacitor energy has depleted causing the transiently expanding plasma column to detach from the electrodes

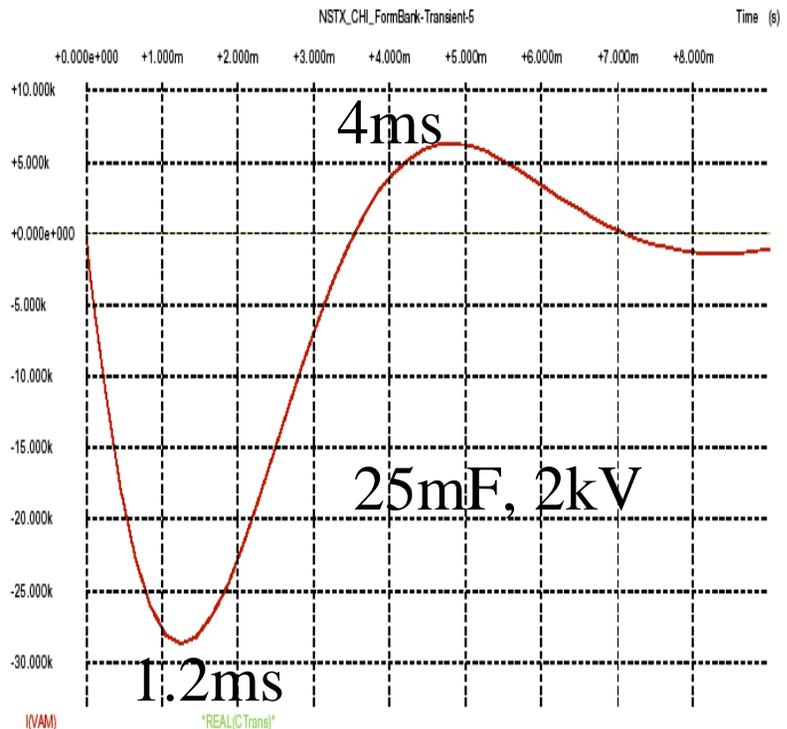
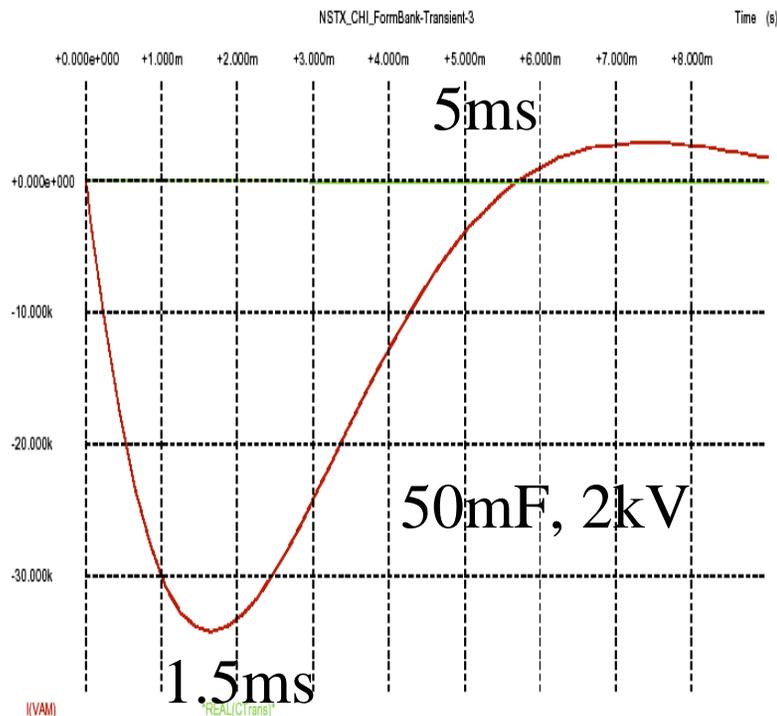
# HIT-II circuit simulation



Measured injector current

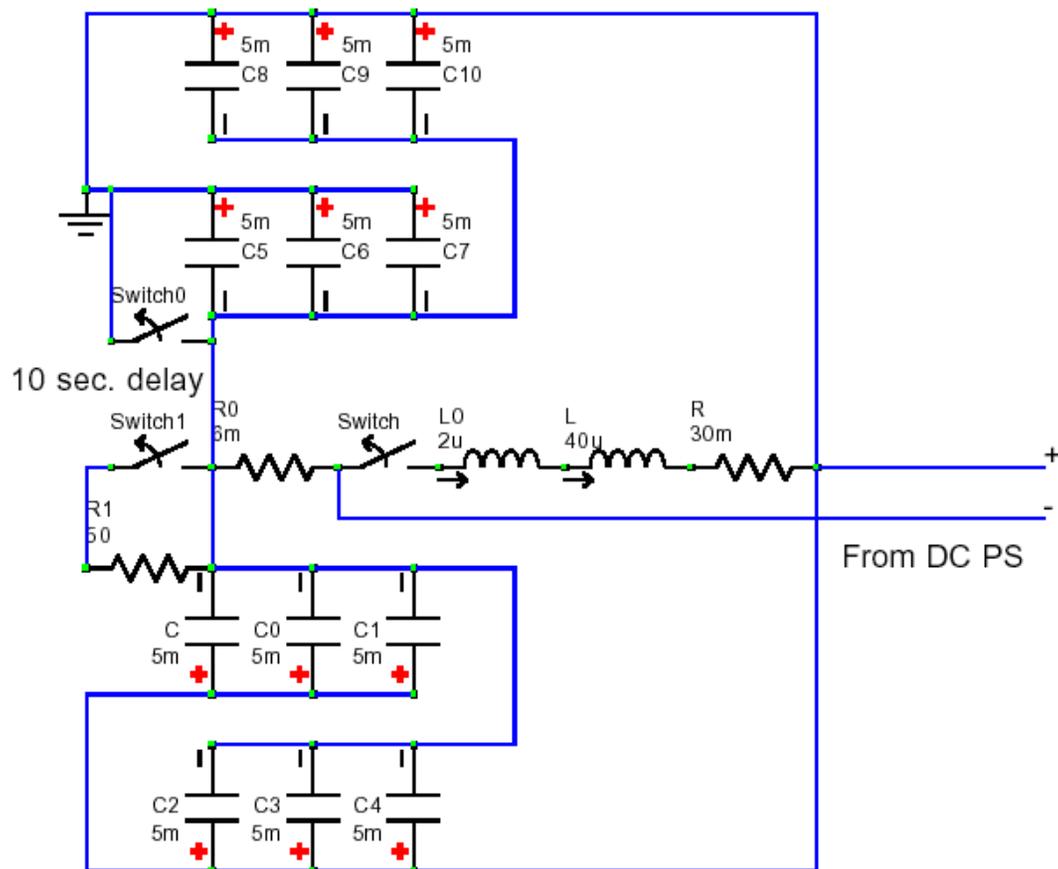
- HIT-II plasma column is about 0.6m tall.
- CHI discharge is fully established in about 0.5ms

# Flexible injector current waveforms can be obtained by a small capacitor bank



- NSTX circuit parameters ( $L_{load} = 40\mu\text{H}$ ,  $R_{load} = 30\text{m}\Omega$ ,  $L_{ext}$  and  $R_{ext} \sim 3\mu\text{H}$  and  $6\text{m}\Omega$ )
- 20 kA obtained with 25mF and 1.5kV

# Simulated circuit schematic



- Charged using present CHI PS
- Circuit similar to HIT-II TF PS
- Double safety grounded
- 500 $\mu$ F snubber capacitor & resistor to be locally connected in place of MOVs

# Capacitors cost about \$12k-\$16k



(manufacturer of Maxwell high voltage capacitors and power supplies)

DATE: June 9, 2003  
NUMBER OF PAGES: 4 (Including Cover Page)  
TO: University of Washington  
ATTN: Roger Raman  
TELEFAX NO.: (206) 543-4719  
FROM: John Gilbert  
G.A.E.P. Proposal No.: 13-0288

Dear Roger:

General Atomics Energy Products (*manufacturer of Maxwell high voltage capacitors and power supplies*) is now manufacturing under Sorrento Electronics, an affiliate company of General Atomics. We will continue to market our high voltage components under the trade name General Atomics Energy Products.

We are pleased to quote, per your request, the following capacitor:

Model	Description	Quantity	Unit Price
130288	5000 $\mu$ F, 2 kV 7 x 8 x 21" Welded Metal Can Single Low Profile Bushing Specification Sheet Attached	10-24 units	\$1580

Terms are Net thirty days, F.O.B. San Diego, Freight Collect. We estimate shipping 12-14 weeks after receipt of your order. Lead-time will be confirmed after receipt of your order. General Atomics Energy Products Conditions of Sale SE0220 apply. This quotation is valid for sixty days.

Purchase orders should be directed to Sorrento Electronics as follows:  
Sorrento Electronics, Inc.  
4949 Greencraig Lane  
San Diego, CA 92123  
Attn: Karen Anderson Ref: GAEP Proposal No. 13-0288

We are proud to affirm that General Atomics Energy Products manufactures with an ISO-9001 certification. Please be aware that we also offer a high quality, cost effective power supply that will satisfy your requirements. For more information, please visit our Web Site at [www.gaep.com](http://www.gaep.com), or contact us. Thank you for your interest in General Atomics Energy Products.

Best Regards,  
General Atomics Energy Products

  
John Gilbert  
Sales Engineer

garzzz@dslextreme.com, 6/2/03 4:48 PM -0400, Capacitor Quota

From: garzzz@dslextreme.com  
Date: Mon, 2 Jun 2003 13:48:59 -0700 (PDT)  
Subject: Capacitor Quotation, 5000uF @ 2000 Volts, 20% Reversal, 5KA PK  
TO: <Raman@aa.washington.edu>  
X-Priority: 3  
Importance: Normal  
Cc: <NewCSI@AOL.com>  
Status:

Dear Roger,

Thank you for your call a littler earlier today. The design is 5000uF @ 2KV per can. Each can will be 11 X 14 X 15 1/2" tall. There will be one insulator with 1/2-13 threaded brass and it will extend 2 1/2" above the can. There will be four 3/8-16 weld nuts, one on each corner of the can for your ground connection. Pricing for 10 pieces is \$1200.00 each. Delivery will be 8 Weeks ARO.

Terms: Net 30 Days (with approved credit)  
F.O.B.: Vista, CA.

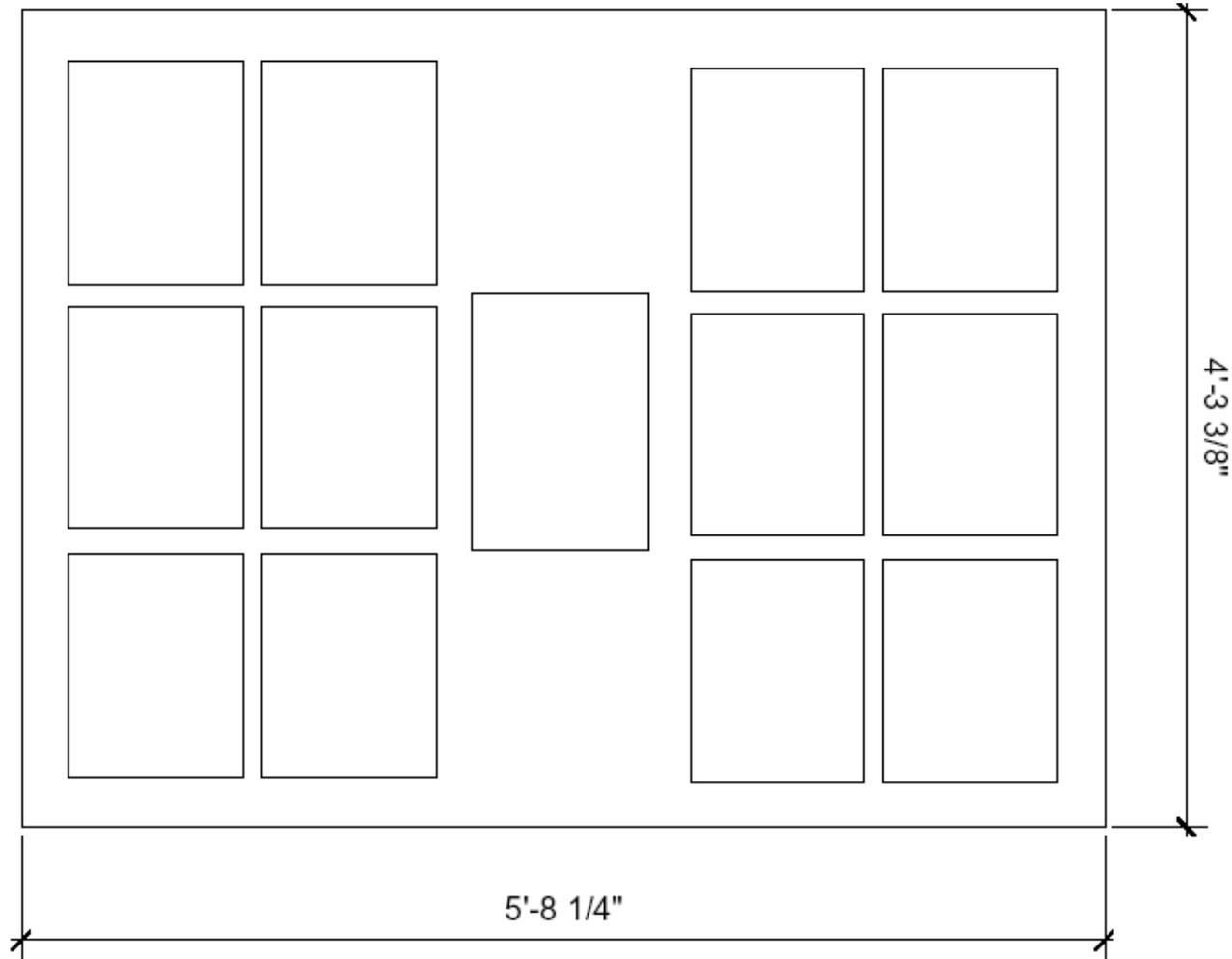
Thanks again and Best Regards,

Gary

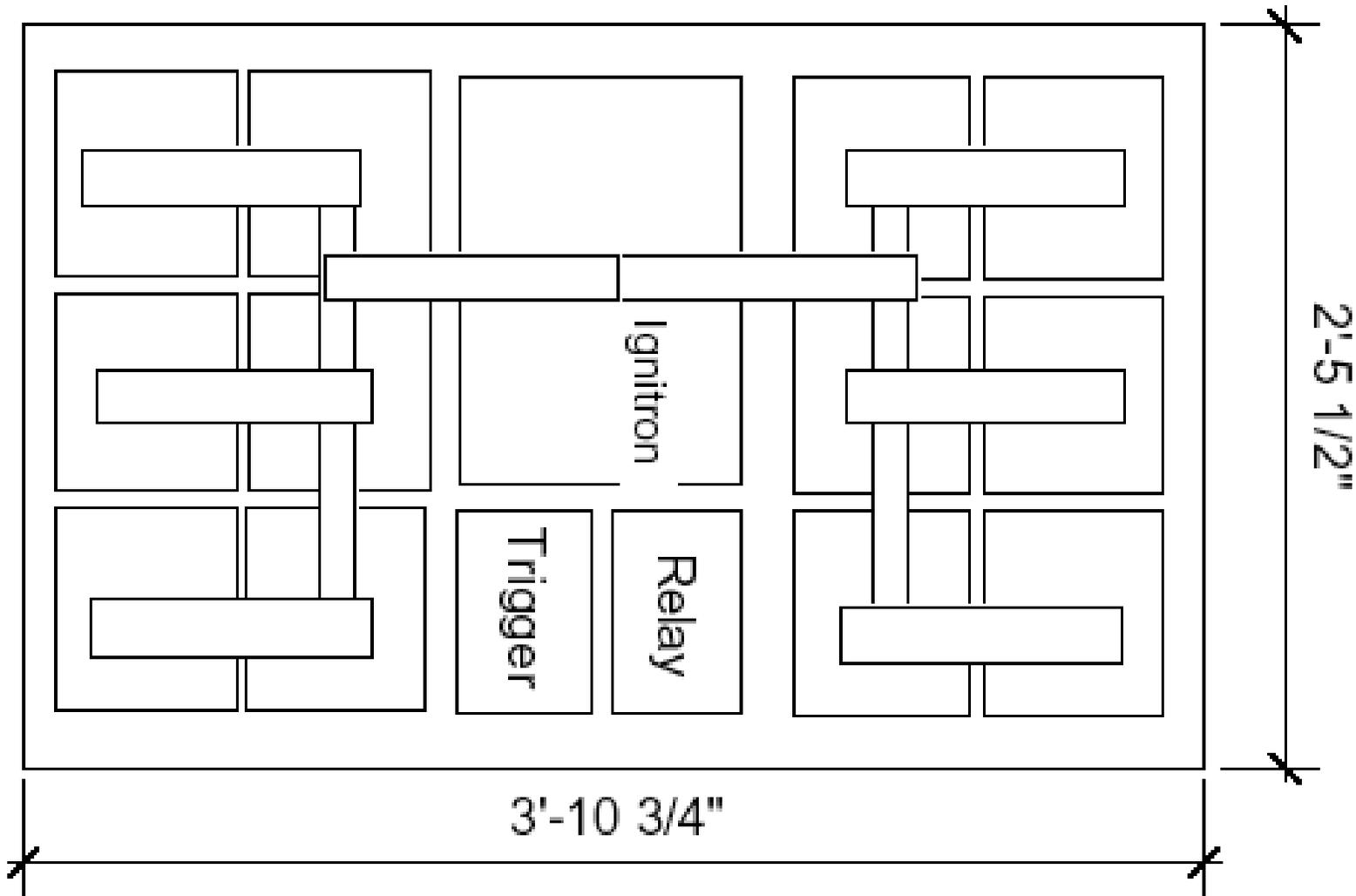
Gary W. Greiser  
Design and Development Engineer  
CSI Technologies  
2595 Commerce Way  
Vista, CA 92083  
Email: [garzzz@DSLExtreme.com](mailto:garzzz@DSLExtreme.com)

- GA: 7 x 8 x 21 inches, 46.73 Lbs (\$1580/cap)
- CSI: 11 x 14 x 15.25 (\$1200/cap)

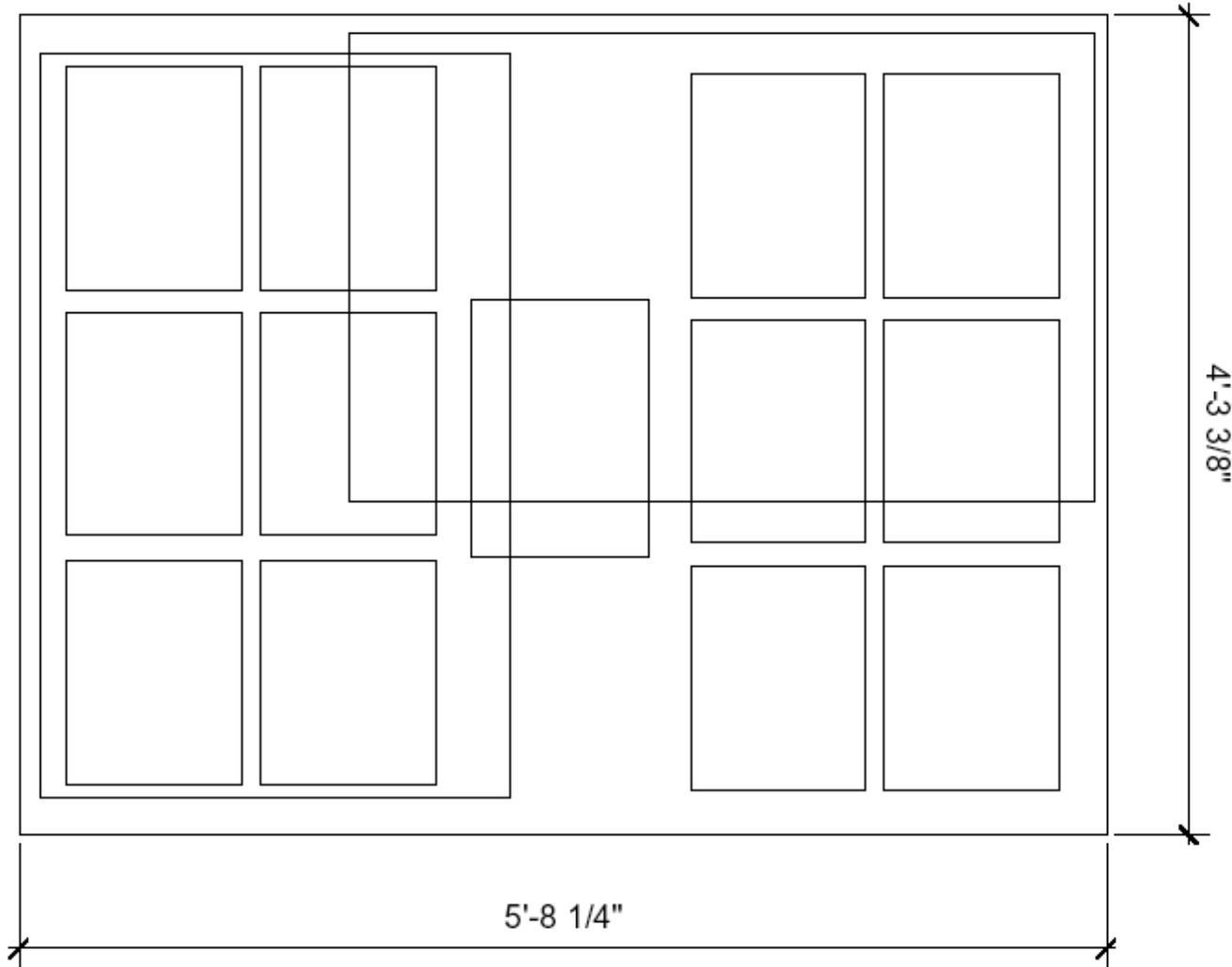
# Floor layout of CSI caps



GA caps occupy the floor space of a small office desk



GA caps occupy about half the floor space of  
CSI caps



## Proposed system will simplify CHI startup

- Transient CHI initiation with appropriately sized capacitor bank is a proven method
- Efficient use of CHI run time
- After initial start-up demonstration, caps can be configured to optimize transient CHI startup (optimum capacitance and voltage to maximize CHI startup current)
- System more safe for NSTX as voltage is applied for a very short duration(<5ms)
- Initial studies will use low energy (25 to 50kJ, then ramp-up to ~100kJ during optimization)
- Discharge time of about 5ms < ground fault detection time of 10ms.

## **CHI Cap bank system specifications**

### **Main capacitors:**

12 caps x 5000 $\mu$ F /cap rated for 2kV,  $\geq$  15kA/cap rating  
(allow space for 16 caps for possible future expansion if needed, 25% more space)

Connection: RG218 or RG217 cables, 25 feet x 5 in parallel

Resistive (100mOhm resistance in series with each cap) of fused protection (if possible) of capacitors

Ignitron switched (size > type A)

Primary dump: 25 Ohm to ground via a Ross Relay  
Fast acting, dump on command (de-energized after each shot), de-energized on power loss

Secondary dump: 5 Ohm to ground via Ross Relay  
Slow acting, 4 second delay after command (usually in an energized state between shots), de-energized on power loss

Additional safety: Grounding stick

### **Snubber capacitor:**

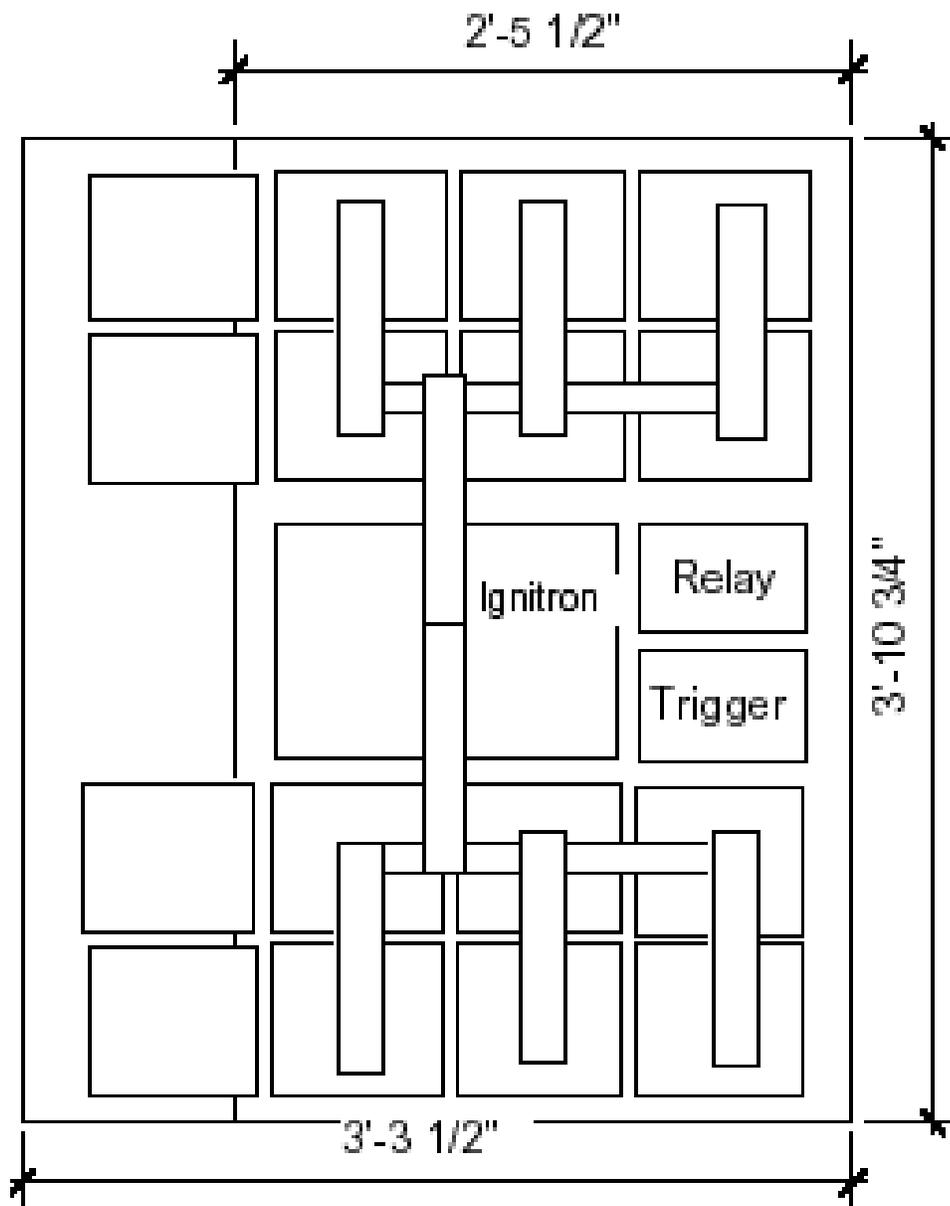
1 x 500 $\mu$ F rated at >5kV (obtain locally from storage)

Connection: RG218 or RG217 cables, 15feet x 5 in parallel, minimize external inductance as much as possible.

100mOhm resistor in series

100-200Ohm resistor across the cap to keep it in a safe state at all times.

# Proposed capacitor layout (allow 25% more space)





(manufacturer of Maxwell high voltage capacitors and power supplies)

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Best Regards,  
General Atomics Energy Products

A handwritten signature in cursive script that reads "John Gilbert".

John Gilbert  
Sales Engineer



**PULSE CAPACITOR SPECIFICATION**

Part Number

130288

<u>Parameter</u>	<u>Value</u>	<u>Units</u>	<u>Q.A.</u>	<u>Method</u>
<b>Capacitance</b>	5000	uF	100%	120 Hz, 32°C
<b>Tolerance</b>	+ 10 -10	%		
<b>Rated Voltage</b>	2	kV		
<b>Test Voltage</b>	3	kV	100%	60 sec Hipot
<b>Rated Energy</b>	1.00E+01	kJ		
<b>Rated voltage Reversal</b>	20	%		
<b>Max. Voltage Reversal</b>	80	(Fault) %		
<b>Rated Peak Current</b>	15	kA		
<b>Max. Peak Current</b>	23	(Fault) kA		
<b>Max. CW RMS Current</b>	90	Amps RMS		
<b>Max. Operating Temp.</b>	65	°C		
<b>Min. Operating Temp.</b>	-20	°C		
<b>Design Life at Rated</b>	2.0E+06	Charge/Discharge cycles		
<b>DC Design Life</b>	5.5E+03	hours		
<b>Reliability at Rated Life</b>	90	% Survival		
<b>Max. Dissipation Factor</b>	1	%	100%	120Hz, 23° C
<b>Maximum Inductance</b>	100	nH	SAMPLE	Standing Wave
<b>Min. Insulation Resistance</b>	1000	Mohm-uF	SAMPLE	Decay Vr/23 °C/120s/120s

**Case Style**

<b>Bushing</b>	1 ea 25 kV LOW PROFILE
<b>Electrode</b>	1/2-13 UNC-2A
<b>Case Terminal</b>	4 ea 3/8-16 UNC x 0.5 DEEP
<b>Dimensions</b>	7 x 8 x 21
	178 x 203 x 533

<b>Approximate Weight</b>	46.73	lbs
	21.24	kg

**Notes** Leak Test: 100% Test and Inspection

IMPREGNANT: RSO (non-PCB)



**GENERAL ATOMICS**

**Energy Products**

A DIVISION OF SORRENTO ELECTRONICS, INC.

**GENERAL ATOMICS ENERGY PRODUCTS**  
A DIVISION OF SORRENTO ELECTRONICS, INC.  
4949 Greencraig Lane, San Diego, CA 92123  
Phone: 858-522-8400 Fax: 858-522-8401

## STANDARD CONDITIONS OF SALE

1. **CONDITIONS OF SALE:** All orders for Sorrento Electronics, Inc. (Company) products or services shall be subject to these conditions of sale which are subject to change without notice. No modified or other conditions will be recognized by Company unless specifically agreed to in writing by an authorized representative of Company. Failure of Company to object to provisions contained in any order or other communication from a purchaser shall not be construed as a waiver of these conditions or an acceptance of any such provisions. Where the word "Company" is used in these conditions of sale, it designates Sorrento Electronics, Inc.

Company's acceptance of an order is made with the condition that it can obtain financial information about the customer which, in Company's opinion, justifies its extending credit to incur production costs.

2. **TERMS OF PAYMENT:** For sales within the United States, Purchaser shall pay Company for Products or Services supplied hereunder within 30 days of the date of the invoice. Sales outside the United States shall be paid in U.S. dollars in advance of shipment or by an irrevocable letter of credit confirmed by United California Bank, 601 S. Figueroa Street, Los Angeles, CA 90017. Past due invoices are subject to late charges equal to one percent (1%) of the invoice value per month.
3. **PUBLICATIONS:** Publications describing the Company's Products are intended to be typical of design, form factor and performance but, in themselves, do not constitute a specific offer to sell in accordance with stated specifications.
4. **QUOTATIONS:** Quotations, written or verbal, are subject to the conditions of sale listed herein. Written quotations automatically expire sixty (60) calendar days from the date issued and are subject to withdrawal by notice within that period. Quotations are valid only in the country to which it is addressed.
5. **PRICES:** Prices are subject to CHANGE WITHOUT NOTICE.
6. **ORDERS:** All orders are subject to approval by the Company.
7. **CONFIDENTIAL INFORMATION:** Each Party agrees to hold in confidence all drawings, diagrams, specifications, or other information furnished by the other Party and identified in writing as confidential or proprietary (hereafter confidential or proprietary information) and use such drawings, diagrams, specifications or other information only for the purpose furnished. Each Party further agrees not to reproduce, distribute, or disclose the other's confidential or proprietary information to a third party without first obtaining the other's written consent. These restrictions shall not apply to information (a) which is or becomes part of the public domain through no fault of Recipient, (b) which Recipient can show was in its possession prior to its receipt from the other Party, (c) which Recipient can show was received by it from a third party not prohibited from disclosing the information or (d) which required by a government authority or is required for the carrying of Recipient's ordinary business, disclosure may be made provided the other Party is notified in writing prior to the disclosure and every reasonable effort is made to protect the other Party's proprietary interests in the information.
8. **TRANSPORTATION:** The Company's products are sold F.O.B. point of shipment. Transportation to destination is the responsibility of the purchaser. Unless specific instructions are given by the purchaser, the Company will: (1) select the most economical method and route of shipment, and (2) forward shipment collect or will ship prepaid and

invoice the purchaser for transportation charges depending upon the best method for each shipment

9. **DELIVERY:** The Company will make every effort to make shipments in accordance with the purchaser's requirements. The Company will not pay or be liable for any penalty, either liquidated or otherwise, for late delivery or installation. Shipping dates are approximate and are dependent upon prompt receipt of all information necessary for the proper execution of the purchaser's order. In case there is any delay in furnishing complete information, the date of shipment may be extended for a reasonable time, based upon the condition at the factory.
10. **TAXES:** Any manufacturers' tax, use tax, sales tax, or tax or duty of any nature whatsoever, which may be assessed against this order, shall be added to the price quoted or invoiced and shall be paid by the purchaser; and in the event Company is required to pay any such tax or duty, the purchaser shall reimburse Company therefore or, in lieu of such payment, shall provide Company at the time the order is submitted with exemption certificate or other document acceptable to taxing or customs authorities.
11. **PENALTY CLAUSE:** No penalty clause of any description, in any specific order, will be effective unless specifically approved in writing by an officer of the Company.
12. **CANCELLATIONS:** In the event of a request to stop work or to cancel the whole or part of an order, the Purchaser shall make payments to Company as follows:
  - a. Any and all work that can be completed within 30 days from date of notification to stop work on account of cancellation shall be completed, shipped, and paid for in full.
  - b. For work in process and any materials and supplies procured or for which definite commitments have been made by Company in connection with the order, the Purchaser shall pay Sorrento Electronics, Inc. the actual costs including burdens determined in accordance with good accounting practice, plus 15%.
13. **PATENTS:** The Company's liability for patent infringement is limited to only those instances where the suit or proceedings brought against the purchaser is based on the claim that the products furnished by the Company in accordance with the Company's design constitute an infringement of a patent of the United States. The Company assumes no responsibility for suits or proceedings brought against the purchaser on the basis of application or use of the Company's products or products built by the Company to the purchaser's designs.
14. **DESIGN CHANGES:** The Company reserves the right to make changes in design of the Company equipment if such changes, in its opinion, tend to improve the performance or otherwise benefit the equipment.
15. **DAMAGE CLAIMS:** The Company takes great care in packing its products and it cannot be held responsible for breakage or damage in transit after having received "in good order" receipts from the transportation companies.

The Company's products are shipped F.O.B. point of shipment. The Company's responsibility ceases when it has made delivery to the carrier and received their signed bill of lading, at which time title to the merchandise shipped passes to the consignee. Claims for all shortages, damage, breakage, or delays must be made to the carrier by the consignee. The Company, however, will

within a period of one week or less and that a concealed damage report be obtained from the carrier.

16. WARRANTY

Company warrants that any Company manufactured Products furnished hereunder will be free from defects in material, workmanship, and title and will be of the kind and quality specified in Company's quotation and that any Services furnished hereunder will conform to industry standards. The foregoing warranty shall extend only to (a) Products found by Company to be defective or nonconforming within one (1) year from the date of shipment except for power supplies which shall be warranted for a period of two (2) years from the date of shipment, (b) repair Services on out of warranty Products found to be defective or nonconforming by Company within ninety (90) days from completion of the Services, (c) engineering Services found to be defective or nonconforming within one (1) year from completion, or (d) software found to be defective or nonconforming within ninety (90) days from date of shipment. If any Product fails to meet the foregoing warranty, Company shall correct such failure at its option by (a) repairing the defective Product, (b) delivering a replacement Product to Purchaser, or (c) repaying the portion of the purchase price paid by Purchaser attributed to the defective or nonconforming Product. If any Company service fails to meet the foregoing warranty, Company will properly reperform such nonconforming service or, if reperformance is not feasible, will refund the portion of the purchase price corresponding to the non-conforming service. The forgoing Product warranty will not extend to Products that have been subjected to (a) improper installation or storage by purchaser, (b) accident, damage, abuse or misuse, (c) abnormal or unusual operating conditions or operations or (d) operating conditions or applications above the rated capacity of the Product or not made known to Company prior to the date of this Agreement. The warranties and remedies set forth herein are conditioned upon Purchaser promptly notifying Company of any defects and, if required, promptly making the Product available for correction. At Company's request, Purchaser will return the defective Product, transportation prepaid to Company's San Diego, California facility for repair. Upon correction of any defect, Company will return the Product transportation prepaid (exclusive of taxes, fees and duties) to the Purchaser's facility. After a Product has been repaired or replaced, this warranty shall continue with respect to the repaired or replaced Product for the balance of the original warranty period on the Product. The removal of the defective Product and the reinstallation of the repaired or replacement Product shall be the sole responsibility of Purchaser. If Company's inspection of any Product which Purchaser claims to be defective does not disclose the defect in workmanship or material identified by Purchaser, Company standard repair charges will apply. THE EXPRESS WARRANTIES AND REMEDIES SET FORTH IN THIS ARTICLE 16 ARE EXCLUSIVE AND EXCEPT AS SET FORTH IN ARTICLE 13, "PATENTS", NO OTHER WARRANTIES OR REMEDIES FOR BREACH OF WARRANTY, WHETHER WRITTEN, ORAL, IMPLIED, EXPRESS OR STATUTORY IN THIS AGREEMENT OR OTHERWISE INCLUDING THE WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE OR THE IMPLIED WARRANTY OF MERCHANTABILITY SHALL APPLY. Where Products deteriorate in storage or have a limited life, such as lamps, fuses, filter paper and charcoal cartridges, such deterioration or limited life shall not be considered a defect in workmanship or material.

16a. WARRANTY OF PASS-THROUGH PRODUCTS AND SOFTWARE

Purchaser shall have the benefit of applicable manufacturer's warranties to the extent provided by the subsupplier. THE OTHER WARRANTY ABOVE IS EXCLUSIVE AND NO OTHER WARRANTY WHETHER WRITTEN OR ORAL IS EXPRESSED OR IMPLIED.

17. RETURNING MATERIAL:

- a. IN NO CASE IS MATERIAL TO BE RETURNED WITHOUT FIRST OBTAINING THE COMPANY'S WRITTEN PERMISSION, RETURN INSTRUCTIONS.
- b. Material built to order is not subject to return for credit under any circumstances.

- c. Any material returned and not authorized will remain the property of the sender and the Company will not be liable for its loss by fire, theft or damage.
- d. All transportation charges to be borne by purchaser.
- e. Goods must be securely packed to reach the Company without damage. Any cost incurred by the Company to put goods in first class condition will be charged to the purchaser.

18. GOVERNMENT REGULATIONS: If the material apparatus or equipment is, or hereafter becomes subject to governmental control, allocation, regulation, or restriction, the necessary and proper preferences rating certificate or certificates shall be supplied by the purchaser.
19. PACKING: Prices include the Company's standard packing for domestic shipments. Additional packing expenses for export or special packing to meet the purchaser's specifications will be paid by the purchaser.
20. SPECIAL INSPECTION AND TESTING: Unless specifically included in the company's quotation, orders requiring special inspection and testing are subject to price adjustment to reflect the increased cost.
21. JIGS, DIES, AND TOOLS: Regardless of any charges made for special jigs, dies or tools, such items remain the property of Company unless otherwise specifically agreed. They may be disposed of when, in the Company's opinion they have become obsolete.
22. LIMITATION OF LIABILITY: Company shall not be liable for prospective profits or special, indirect or consequential damages, nor shall recovery of any kind against Company be greater in amount than the purchase price of the specific product sold and causing the alleged damage. Purchaser shall hold Company free and harmless from all risk and liability for expense, loss, damage or injury to persons or property of Purchaser or others arising out of use or possession of any product sold hereunder.
23. ASSIGNMENT: The Purchaser may not assign this Agreement without the prior consent of Company. Company may assign this Agreement.
24. SUCCESSORS: This Agreement and the covenants herein contained shall be binding upon and inure to the benefit of the successors and assigns of each party.
25. DEFAULT: Company shall not be considered in default in performance of its obligations hereunder to the extent that performance is delayed or prevented by causes beyond the control or without the fault of Company including causes such as acts of God, hostilities, strikes, fire, flood, sinking of vessels, acts of the Purchaser, including delay in performing its obligations, or because or by reason of any law, proclamation, regulation or ordinance of any government or governmental agency or other events or occurrences beyond the Company's ability to control or without the fault of the Company.
26. APPLICABLE LAW: This Agreement is entered into in the State of California and shall be interpreted in accordance with the laws of the State of California.

From: John Gilbert <john.gilbert@sorrento.com>  
To: "'Roger Raman'" <raman@aa.washington.edu>  
Subject: RE: Capacitor Quotation  
Date: Wed, 30 Jul 2003 15:46:19 -0700  
X-Virus-Scanned: by amavisd-new at aa.washington.edu  
Status:

Hello Roger,

The material costs will double, the labor will more than double due to the complexity of putting twice the energy in a single can, and since the quantity is decreasing, the price break goes to the 4-9 unit pricing. Any savings you would receive by doubling the energy and reducing the quantity are offset by the above. For a 10,000 uF, 2 kV capacitor with similar electrical specifications to the 5000 uF, 2 kV Model 130288 capacitor previously quoted, the parameters are: 10,000 uF, 2 kV Rated Voltage, size = 7 x 16 x 21", Ipk <= 30 kA, Irms <= 130 Arms, voltage reversal <=20%.

4-9 pcs = \$3620 each.

The oil used in these capacitors is Rapeseed Oil (Canola Oil). The inductance <= 100 nH. The ESR is a function of the discharge waveform frequency.  $ESR = DF/\omega C$ ,  $\omega = \text{frequency} \times 2\pi$ ,  $C = \text{capacitance}$ .  $DF = \text{dissipation factor} \leq .01$

The charging rate and rep-rate are limited by the rms current <= 130 A. On the other end of the spectrum, these are pulse discharge capacitors and have a limited DC lifetime <= 5000 hrs. You don't take a long time to charge them, nor do you hold them at voltage for any length of time.

Regards

John Gilbert

-----Original Message-----

**From:** Roger Raman [<mailto:raman@aa.washington.edu>]  
**Sent:** Tuesday, July 29, 2003 11:09 AM  
**To:** John Gilbert  
**Subject:** Re: Capacitor Quotation

Hello John,

I need another price quote.

It is for the same capacitors as in your Quotation # 130288, but at twice the capacitance per can. 10 milli Farad per can.

The current per can will now be double of the current for the 5 milli Fard can in your Quotation # 130288. We are trying to minimize the number of capacitors.

Could also please provide the internal resistance and inductance for these 10 milli Farad capacitors.

Is this capacitor oil filled? What oil is used?

What is the charging rate limit for these caps? What is the shortest time in which the

From: garzzz@dslextre.me.com  
Date: Wed, 4 Jun 2003 14:35:29 -0700 (PDT)  
Subject: Re: ESR and ESL of 5000 uF Capacitor  
To: <raman@aa.washington.edu>  
X-Priority: 3  
Importance: Normal  
Status:

> Dear Gary,  
>  
> Two more questions:  
>  
> 1. I assume the capacitors are oil filled with an environmentally  
> friendly oil (i.e. no PCBs ? and oil is not a flammable?)  
>  
> 2. This question is less important, but are the capacitors self-healing?  
>  
> Thank you,  
>  
> Roger  
>  
>  
>  
>  
>>Dear Roger,  
>>  
>> The ESR will be about 20 miliohms and the ESL will be <50 nH,  
>>probably closer to 20 nH. This design has 72 windings in parallel, so  
>> the ESR and ESL are naturally low, the live case also contributes to  
>> conelation in terms of inductance, (ESL). Hope this helps,  
>>Thanks again, Gary  
>  
> --  
> U Washington @ PPPL, MS34 B255: tel:(609) 243 2855 @ PPPL, (206) 685  
> 6675 @ UW

Hi Roger,

Yes, the parts are self healing metalized polypropylene film. The oil is Soy Bean oil which is fit for human consumption, although I would not recommend drinking it. Thanks again, Gary



# 202A Series

invensys



## Features

- ▶ Patented parallel resonant inverter for low pulse to pulse repeatability
- ▶ Output voltages to 40kV
- ▶ Single phase 220VAC input
- ▶ Standard active electronic power factor correction
- ▶ Compact air cooled package
- ▶ Comprehensive remote control
- ▶ Simple parallel operation for higher power

## A History of Innovation and Leadership

The ALE High Voltage Products Division of Lambda EMI has been designing and manufacturing quality High Voltage DC and Capacitor Charging Power Supplies since 1982. ALE Systems Inc., was conceived and formed to fill the need for a quality supplier of switched mode power supplies for the laser market. In 1987, when ALE was acquired by Electronic Measurements, Inc., the company was already the world leader in its field.

## Applications

Lambda EMI puts great emphasis on full application support, both before you decide to buy and after you receive the product. You will find the most critical information on this data sheet. If you need more information, you can request or download any of our High Voltage APP NOTES. Of course for assistance in solving a problem at any time, you can call, fax or E-mail our team of Application Engineers for prompt and accurate service. Our supplies are used in such applications as:

- Lasers
- NMR
- Modulators
- Lithotrippers
- Electron Beam
- Ion Implantation
- X-Ray
- Sputtering

## Description

The 202A series are High Voltage Power Supplies that are designed to operate in two modes. In their most common format they are constant current Capacitor Charging Supplies which will reliably charge HV capacitors and Pulse Forming Networks (PFNs). They can also operate as constant voltage, continuous output DC power Supplies.

## Repeatability

Most commercially available High Voltage Capacitor Charging Units utilize a Series Resonant inverter topology which was the most efficient means for charging capacitive loads. However they are not the ideal source for maintaining extremely low pulse to pulse voltage variations with small load capacitors, as required by Excimer lasers. ALE's new patented Parallel Resonant Inverter provides repeatability better than 0.2% at repetition rates up to 300Hz with varying capacitance values eliminating the need for re-calibration of the supply.

## Paralleling Units

The 202A supply is designed for simple parallel operation. Input power and HV output connect directly together, and the remote control connectors can be 'daisy chained'. Each power supply will operate independently with the total charge rate equal to the sum of the two units. Only units with the same voltage rating should be connected in parallel. Parallel operation is not recommended in continuous DC applications.

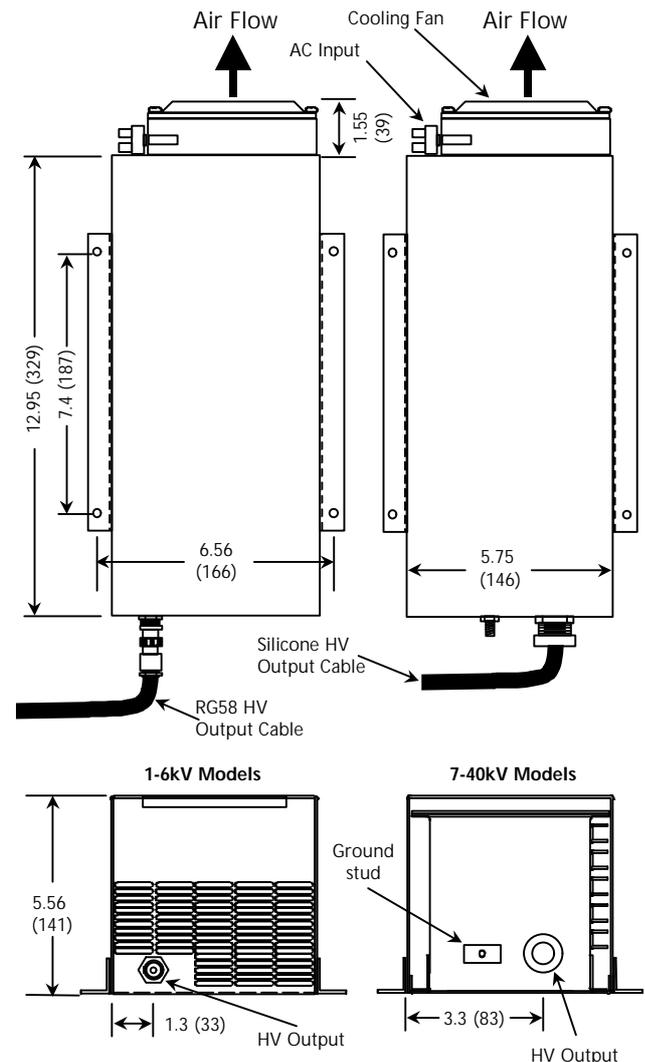


## Continuous Output DC Operation

The 202A supply can be used as a constant voltage supply by the addition of an external filter capacitor or CLC network for low ripple, low stored energy. The value of this capacitor will determine the ripple voltage on the DC output. *Please consult our Applications Department if this type of operation is required.*

## Mechanical Outline

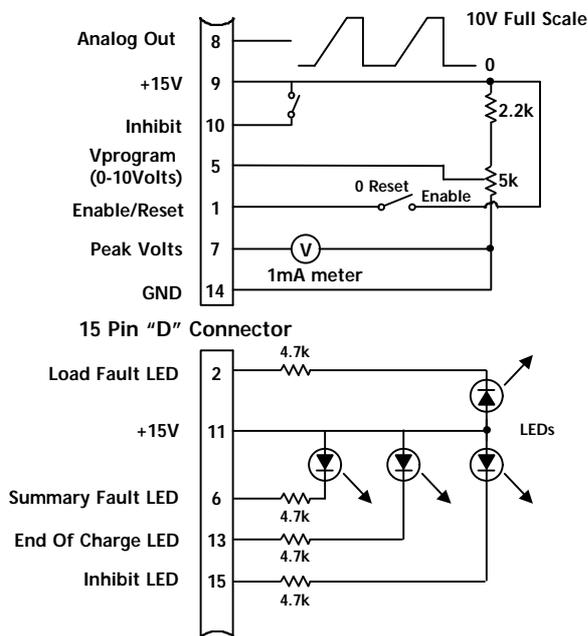
Dimensions shown in inches (metric dimensions in parenthesis)



# 202A Series



## Remote Interface



## 202A Series Specifications

### Average Charging Rate

2kJ/s at 100% of rated Output Voltage

### Peak Charging Rate

2.2kJ/s at 100% of rated Output Voltage

### DC Power Rating

2kW (for DC operation an external filter capacitor is required)

### Standard Voltage Ranges

1kV, 1.5kV, 2kV, 3kV, 4kV, 5kV, 6kV, 10kV, 15kV, 20kV, 30kV, 40 kV.  
All models continuously variable from 0 to 100% of rated voltage.  
Linear to within 1% of full scale. Accuracy 1% of rated.

### Polarity

Available as fixed Positive or Negative. Please specify at time of ordering

### High Voltage Assembly

1 to 6kV Air insulated, RG58 coaxial output cable  
7 to 40kV Oil insulated, 12AWG HV Silicone Insulated

### Input Connector

Via VDE, UL, CSA approved terminal block. Connections are live, neutral, and ground.

### Input Voltage

180-250VAC single phase, 13.5A max (PFC only available)  
AC Input Current figures are valid for repetition rates above 10Hz.

### Inrush

Limited to below full power operating current

### Power factor

0.98 (with active PFC option), 0.65 for non PFC

### Efficiency

Greater than 85% at full power and nominal AC line

### Stored energy

Less than 0.3 J in output stage

### Stability

< +/-0.2%/hr after 1 hr warmup

### Pulse to Pulse repeatability

+/-0.2% to 300Hz – standard, for higher rates contact factory

### Temperature Coefficient

100ppm per °C

### Ambient Temperature

Storage: -40 to +85°C, Operating: -20 to +45°C

### Humidity

90%, non-condensing

### Protection Features

Output short circuit and HV arc-to-ground during operation  
Open circuit at turn-on will not damage supply  
Shutdown on overtemp, overvoltage, and open interlock

### Physical Dimensions

5.56in (141mm) H x 5.75in (146mm) W x 14.5in (368mm) D  
Mounting Brackets supplied (see sketch over)

### Agency Approvals

Designed to meet UL2601.1, CSA C22.1 IEC601-1, EN60601.1

### Accessories

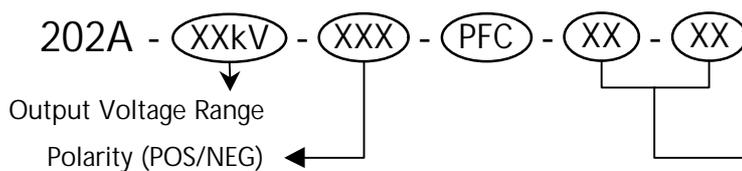
Detachable 8ft HV output cable  
15 pin D-type mating control connector  
Operating manual  
Mounting brackets

### Application Notes

APP Note 500 Charging Rates  
APP Note 502 Calculating AC Line Currents  
APP Note 505 Charging Units in Continuous DC Applications  
APP Note 507 Charging Large Load Capacitors  
APP Note 509 What is Regulation and Repeatability  
APP Note 513 Power Factor Correction  
APP Note 517 Protection Against Voltage Reversal

**Note:** All specifications are subject to change without notice.

## How to order



Options	
Feature	Suffix
Continuous operation	DC
Low Inhibit	LH
Low Enable	EN
0-5V Programming	5V
Latching overload protection	LP





**Lambda EMI**  
405 Essex Road  
Neptune NJ 07753  
Telephone 732 922 9300  
Email: [gail.kadi@lambda.com](mailto:gail.kadi@lambda.com)  
Facsimile 732 922 9334  
Internet <http://www.lambda-emi.com>

## *Quotation #8087*

To: Roger Raman  
Company: University of Washington  
Phone No 609-243-2855  
Fax No: 609-243-3233  
Email: [raman@aa.washington.edu](mailto:raman@aa.washington.edu)

From: Gail Kadi  
Date: 7/31/03 [Tad Papineau, local Rep. Tel: (253) 838 9263]

Dear Roger:

Thank you for your inquiry regarding our power supplies. I am pleased to quote as follows:

<u>Qty</u>	<u>Model No.</u>	<u>Description</u>	<u>Unit Price</u>	<u>Total</u>
1	202A-2KV-NEG-PFC	202A SERIES CAP CHARGING POWER SUPPLY, OUTPUT 2KV, 2000 J/SEC, NEGATIVE POLARITY, POWER FACTOR CORRECTED.	\$2,720.00	\$2,720.00

**Delivery:** Shipment from Neptune, NJ: 6 Weeks ARO.

Notes:

Orders to be made out to Lambda EMI Inc., 405 Essex Rd., Neptune, NJ 07753.

VALIDITY: 30 Days.

Lambda EMI products are manufactured to order. Purchase orders are subject to charges in the event of a cancellation.

TERMS: Net 30 Days pending Credit Check.

F.O.B. Neptune, NJ.

Freight, Handling and insurance: for Customer's Account and Responsibility.

TAXES: Prices shown do not include any federal, state or local taxes, if applicable.

SHIPMENTS: Via least expensive surface transportation.

WARRANTY: One (1) Year. (Full terms and conditions available upon request.)

Thank you for this opportunity to quote on your needs. Should you require further information, please do not hesitate to contact me.

Yours sincerely,

Gail Kadi

# Global® Non-Inductive Bulk Ceramic Power Resistors

(formerly Cesiwid)

Non-inductive bulk ceramic construction for uniform distribution of energy throughout resistor body. No film or wire to fail.

**Choose Type SP** for great A-C power handling capability, whether it be at power frequency or many megahertz.

**Choose Type AS** for its ability to absorb huge amounts of energy and for its non-inductive property at high voltage.

**Choose Type A** when high resistance is required in a high power non-inductive resistor.

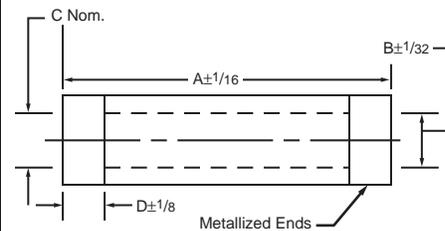
CHARACTERISTICS	Type SP	Type AS	Type A
Maximum Operating Temperature: °C	350	230 150*	230
Temperature Coefficient: Percent per degree C, -55°C to maximum rated temperature	+0.2 -0.08	+0.0 -0.08	+0.0 -0.2
Voltage Coefficient: Maximum percent per kilovolt per inch active length (overall length less termination)	1.0	1.0	-
Short Time Overload: Maximum percent change after 5 cycles 10 times rated power, 5 seconds on, 90 seconds off	2.0	2.0	-
Moisture Resistance: Maximum percent change when tested per MIL-STD-202 method 103	2.5	2.5	2.5

\*With epoxy insulation for use in oil.

## STANDARD SIZES

(Special sizes are also available: consult factory.)

Type	A	B	C (SP & AS)	C (A)	D
884 SP	2.0	0.50	0.22	-	0.25
885 SP, AS, & A	2.5	0.75	0.50	0	0.50
886 SP, AS, & A	5.0	0.75	0.50	0	0.62
887 SP, AS, & A	6.0	1.00	0.75	0.5	0.50
888 SP, AS, & A	8.0	1.00	0.75	0.5	0.88
889 SP, AS, & A	12.0	1.00	0.75	0.5	0.88
890 SP, AS, & A	18.0	1.00	0.75	0.5	0.88
891 SP	18.0	2.00	1.50	-	1.0
892 SP	24.0	2.00	1.50	-	1.0



## SERIES 800 AND 1000

This general line is available in a wide variety of sizes and terminations. They retain the non-inductive and heavy load characteristics of all Global ceramic resistors. These resistors can handle up to 1000 watts, 165 KJ and 165 KV in resistance values from 1 ohm to 1 megohm.



Parts are specified by the four or five character type number (for example 885SP, 888AS, 890A), the first two digits of the resistance, a single digit to indicate the power of ten multiplier, and a "J" for ±5%, a "K" for ±10%, or an "L" for ±20%. Where the resistance is less than ten ohms, the power of ten multiplier is not used, and an "R" replaces the decimal point. Thus R50 = 0.50 ohm, 7R5 = 7.5 ohm, 220 = 22.0 ohm, 152 = 1500 ohm, etc. Standard construction for SP resistors is aluminum metalization. Type A resistors have nickel metalization. Type AS resistors have silver metalization with a dielectric coating. This standard feature is designated by part number suffix "DS." Radial tab ("G") and axial tab ("H") terminations are available on SP and AS resistors. "No Arc" ("N") butt-end terminations are available on Type AS and A resistors for applications requiring high energy or current

## ELECTRICAL SPECIFICATIONS

Length and Diameter	Type	Resistance Available (ohms)		Average Power @ 40 C (watts)	Peak** Energy (joules)	Peak*** Voltage (volts)
		Min.	to Max.			
2" x 1/2"	884SP	1.0	200	22.5	250	1,000
2-1/2" x 3/4"	885SP	1.0	130	45	250	1,000
	885AS	6.0	1200	15	2,800	8,000
	885A	1500	220K	15	750	3,750
5" x 3/4"	886SP	1.0	330	90	500	4,000
	886AS	15.0	3300	30	7,000	20,000
	886A	3900	390K	30	1,500	10,000
6" x 1"	887SP	1.0	330	150	1,600	4,000
	887AS	12.0	3300	50	13,000	30,000
	887A	3900	390k	50	6,000	12,000
6" x 1-1/2"	1026AS	5.0	1200	70	37,000	30,000
8" x 1"	888SP	1.0	390	190	2,100	6,000
	888AS	15.0	3900	75	16,500	45,000
	888A	4700	470K	60	7,500	15,000
8" x 1-1/2"	1028AS	6.5	1875	100	46,000	45,000
12" x 1"	889SP	1.0	680	275	3,200	10,000
	889AS	25.0	6800	100	27,000	75,000
	889A	8200	680K	90	12,500	25,000
12" x 1-1/2"	1032AS	9.0	2500	150	75,000	75,000
18" x 1"	890SP	1.0	1000	375	4,200	16,000
	890AS	40.0	10K	150	43,000	120,000
	890A	12K	1M	125	20,000	40,000
18" x 1-1/2"	1038AS	15.0	3800	225	119,000	120,000
18" x 2"	891SP	1.0	450	750	15,000	16,000
24" x 2"	892SP	1.0	600	1000	17,500	22,000
24" x 1-1/2"	1044AS	20.0	4800	300	164,000	165,000

\*\* Allowable peak energy/voltage will depend on the resistance value. Consult Kanthal Global.

\*\*\* Derate by 50% with epoxy coating.

Energy ratings are based on pulses <10 milliseconds. Type SP ratings can be substantially greater for longer pulses. Consult Kanthal Global.

density performance. Epoxy coating is available on AS and A resistors for use in oil ("O"). Typical part numbers: 889SP501K represents a Type SP, 500 ohm ±10%, 886AS500KDS represents a standard Type AS, 50 ohm ±10%, with dielectric coating

and silver terminations. 890A503L represents Type A, 50,000 ohm ±20%. 886AS500KNO represents Type AS, 50 ohm ±10% with "No Arc" terminal and epoxy coating. Consult plant for termination dimension details and additional options and part number detail.

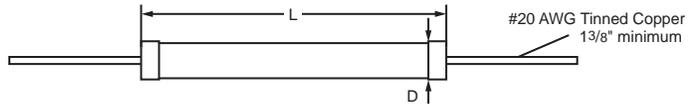
# Global® Non-Inductive Power Resistors For Special Problem Solutions

(formerly Cesiwid)

## SERIES 100/200 TYPE AS & SP AXIAL LEADED RESISTORS

### Candidates for Replacement of Carbon Composition Resistors

Type AS for high voltage and energy applications.  
Type SP for high AC and power handling capabilities.



SPECIFICATIONS	TYPE AS	TYPE SP
Short Time Overload, 10 Cycles 1000%		
Rated Power, 5 Sec. On, 90 Sec. Off	±2% Max.	±5% Max.
Life Test, 1000 Hour @ Rated Power	±5% Max	±5% Max.
Temperature Coefficient	+0.0 to -0.08%/°C	+0.2 to -0.08%/°C

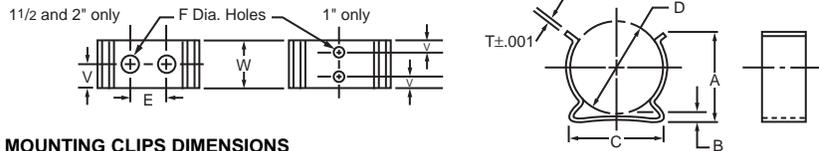
Body Size	Resistance Range, Ohms	Dia. (D) Max. in. (mm)	Length (L) Max. in. (mm)	Rated Peak** Voltage	Average* Power Rating, Watts @ 40°C Amb.	Rated* Peak Energy, Joules	Peak Current Amps
231AS	25-6,350	0.2 (5.1)	0.75 (19.1)	1,500 V	1.5	75	25
231SP	1-1,000	0.2 (5.1)	0.75 (19.1)	375 V	3	15	360
233AS	6-1,800	0.31 (7.9)	0.75 (19.1)	1,100 V	2	170	35
233SP	1-120	0.31 (7.9)	0.75 (19.1)	375V	7	20	550
234AS	12-5,000	0.31 (7.9)	1.125 (28.6)	2,500 KV	3	275	35
234SP	1-330	0.31 (7.9)	1.125 (28.6)	500 V	10	30	550
250AS	4-1,200	0.44 (11.1)	0.75 (19.1)	1,500 V	2.5	260	45
250SP	1-150	0.44 (11.1)	0.75 (19.1)	375 V	8.5	20	700
251AS	8-2,300	0.44 (11.1)	1.125 (28.6)	2,500 V	3.5	400	45
251SP	1-350	0.44 (11.1)	1.125 (28.6)	500 V	12	30	700
102AS	30-9,000	0.31 (7.9)	2.125 (54.0)	3,000 V	5	600	35
102SP	1-700	0.31 (7.9)	2.125 (54.0)	1,000 V	15	50	550
104AS	55-18,000	0.31 (7.9)	4.125 (104.8)	9,000 V	9	1,200	35
104SP	2-1,500	0.31 (7.9)	4.125 (104.8)	3,600 V	25	95	550
106AS	90-30,000	0.31 (7.9)	6.125 (155.6)	15,000 V	13	1,900	35
106SP	3-2,400	0.31 (7.9)	6.125 (155.6)	5,000 V	36	155	550
109AS	150-48,000	0.31 (7.9)	9.125 (231.8)	25,000 V	20	3,000	35
109SP	4-3,800	0.31 (7.9)	9.125 (231.8)	6,600 V	55	250	550

\*Rated Power. Derate linearly to 0 Watts at 230°C for Type AS. Derate linearly to 0 Watts at 350°C for Type SP. \*\*Allowable peak energy/voltage will depend on the resistance value and pulse width. Consult Kanthal Global. Energy ratings are based on pulse <10 milliseconds. Type SP ratings can be substantially greater for longer pulses. Consult Kanthal Global. Peak Current ratings presume pulse energy approaching rated peak energy values. Allowable current can be higher for lower energy values. Consult Kanthal Global.

## TERMINATION AND MOUNTING

Electrical connection to the resistive bodies of resistors is made by metal end bands. The standard metal is aluminum for Type SP, silver for Type AS and nickel for Type A. Special terminations of brass, copper or tinned ends are also available. Add "B", "C," or "T" respectively to the part number to designate these special terminations.

In most cases, connections to the resistors may be made by stock clips and connector caps such as these:



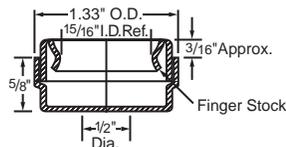
### MOUNTING CLIPS DIMENSIONS

Stock No.	Size	Holes	A	B	C	D	E	F	T	V	W
35370	1/2"	1	0.620	0.090	0.560	0.500		0.093	0.020	0.188	0.375
35267	3/4"	1	0.940	0.155	0.830	0.750		0.144	0.020	0.312	0.625
35268	1"	2	1.230	0.170	1.070	1.000		0.128	0.024	0.156	0.625
35371	1-1/2"	2	1.650	0.100	1.650	1.500	0.925	0.103	0.032	0.250	0.500
35269	2"	2	2.375	0.544	1.080	2.000	0.375	0.125	0.043	0.375	0.750

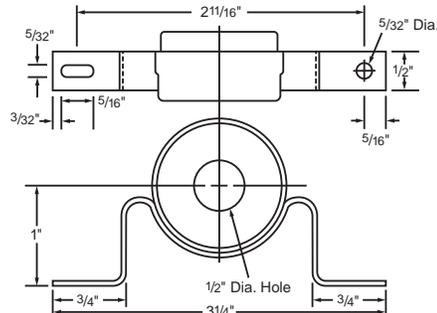
Material: Beryllium Copper

Finish: Electro Tin Plate

## CONNECTOR CAPS



**Part G-4361**  
**Connector Cap Assembly (without strap)**  
Material: Copper Cap, Beryllium-Copper Finger Stock



**Part G-4362**  
**Connector Cap Assembly (with strap)**  
Material: Copper Cap, Beryllium Copper, Finger Stock and Strap

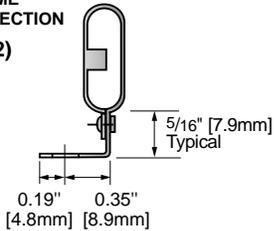
(formerly Cesiwid)

## SERIES 500SP NON-INDUCTIVE BULK CERAMIC SLAB RESISTORS

Series 500SP Slab Resistors provide high power and energy dissipation in a slim, compact size. The Series 500SP design enables the designer to minimize resistor package size and cost while providing unequalled performance and reliability.

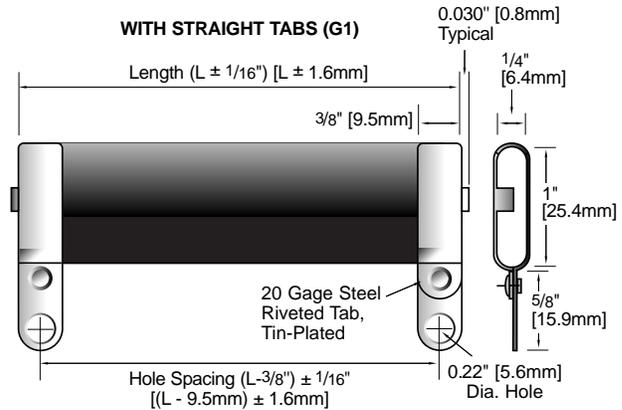
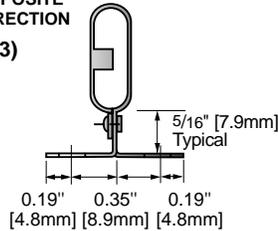
### WITH RIGHT ANGLE TABS

**SAME DIRECTION (G2)**



### WITH RIGHT ANGLE TABS

**OPPOSITE DIRECTION (G3)**

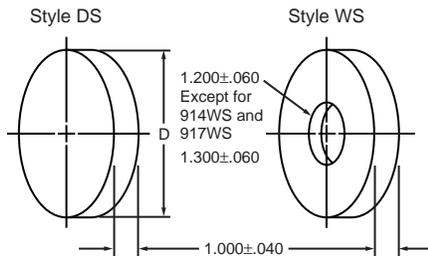


Type	Length (L)	Resistance Range (Ohms)	Average Power @ 40°C Amb. (Watts)	Peak Energy @ 40°C Amb. (Joules*)	Peak Voltage (Volts)	Resistor Element Weight (Grams)
502SP	2" [50.8mm]	0.2 80	30	150	900	15
503SP	3" [76.2mm]	0.3 150	45	290	1900	22.5
504SP	4" [101.6mm]	0.4 210	60	480	2800	30
506SP	6" [152.4mm]	0.8 340	90	800	4700	45
508SP	8" [203.2mm]	1.0 470	120	1100	6700	60
510SP	10" [254.0mm]	1.3 600	150	1400	8500	75

\*Based on energy absorption in less than 10 milliseconds. Energy rating can be substantially greater for longer pulses. Contact Kanthal Global.

## SERIES 900 DISC AND WASHER STYLE RESISTORS

This Type AS high energy series is available in solid discs and washer styles.



### SPECIFICATIONS

Type	Style	Diameter "D" (inches)	Peak Energy (joules)	Available Resistances	
				Minimum	Maximum
911DS	Solid Disc	1.60 ± 0.06	9,000	1.6	100
912DS	Solid Disc	2.37 ± 0.06	21,000	0.7	90
913DS	Solid Disc	3.00 ± 0.08	33,000	0.5	56
914DS	Solid Disc	3.75 ± 0.08	52,500	0.3	36
913WS	Washer	3.00 ± 0.08	27,600	0.5	78
914WS	Washer	3.75 ± 0.08	47,000	0.3	40
915WS	Washer	4.37 ± 0.08	65,500	0.2	28
916WS	Washer	4.75 ± 0.08	79,500	0.2	24
917WS	Washer	5.00 ± 0.08	80,500	0.2	20

### CHARACTERISTICS

Maximum Temperature	230°C
Minimum Peak Voltage	5000 volts
Contacts	Brass metallization on faces
Recommended contact pressure	25 psi minimum; 100-300 psi preferred
Power Rating	Dependent upon mounting. In free air, parts will safely dissipate 2.5 watts per square inch of surface area at 40°C
Temperature coefficient of resistance	-0.1%/°C to 0.0%/°C