Specification for the Driver Coil Modules Capacitor Charge/Discharge Power Supply (CCDPS) for FLARE

March 10, 2016

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1 Specifications for Driver Coil (DC-I and -O) bank modules

1.1 Description

Bank schematic is shown in Fig. 1 for each of the two DC bank modules. Starting on the left side of the figure, the module is charged by connecting both positive and negative supply lines. A power supply protection circuit is shown (please refer to the Charge Specification for details). A bleed resistor is connected in parallel with the capacitor and is used to slowly drain bank charge in case of failure of all other dumps (i.e. if left alone overnight the bank will passively discharge below the NFPA 70E safe approach threshold of 50 V). Before each shot, the dump load relays are opened. Then the charging relays are closed and the charging supply charges the caps. When the set-point is reached, the charging switches are opened. The capacitors are then discharged through the inductive and resistive load of the coil, and crowbarred with a delay corresponding to peak current. For DC-I and DC-O, the first swing current will always be greater than zero, and a switch is used to crowbar the circuit. Following a shot, the dump switch is closed to ensure the capacitors are fully discharged. Each of the components will be described in the following sections.

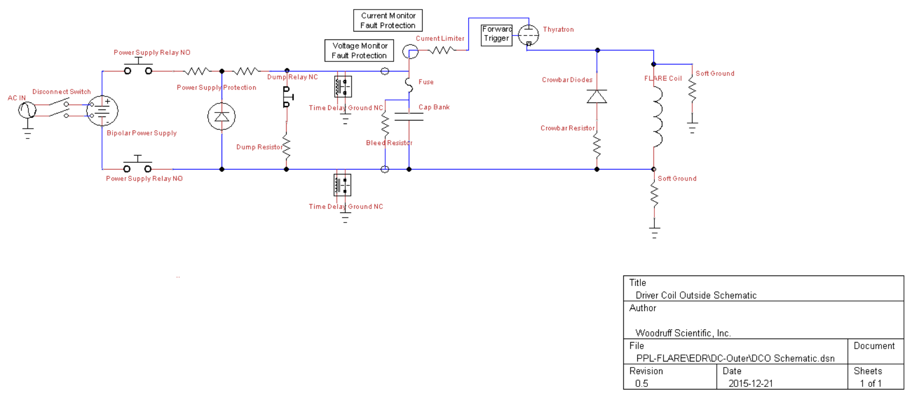


Figure 1: Driver Coil Circuit Schematic

The DC bank modules are designed to energize the inboard and outboard Driver Coil set, providing a current pulse per Fig. 2 and Fig. 3, meeting the specifications in Table 1. The power supply system shall be designed for a minimum of 10 years design life and a minimum of 100,000 full power shots with regular maintenance.

	DC-I	DC-O
# Sub-Coils	2	2
V (Volts)	60000	60000
Imax (A)	50000	50000
Day 1	0	0
Peak I (kA)	50	50
trise (ms)	< 0.01	< 0.03
tcrowbar	Peak	Peak
Swing Imin	+ve	+ve

Table 1: Target parameters for DC bank

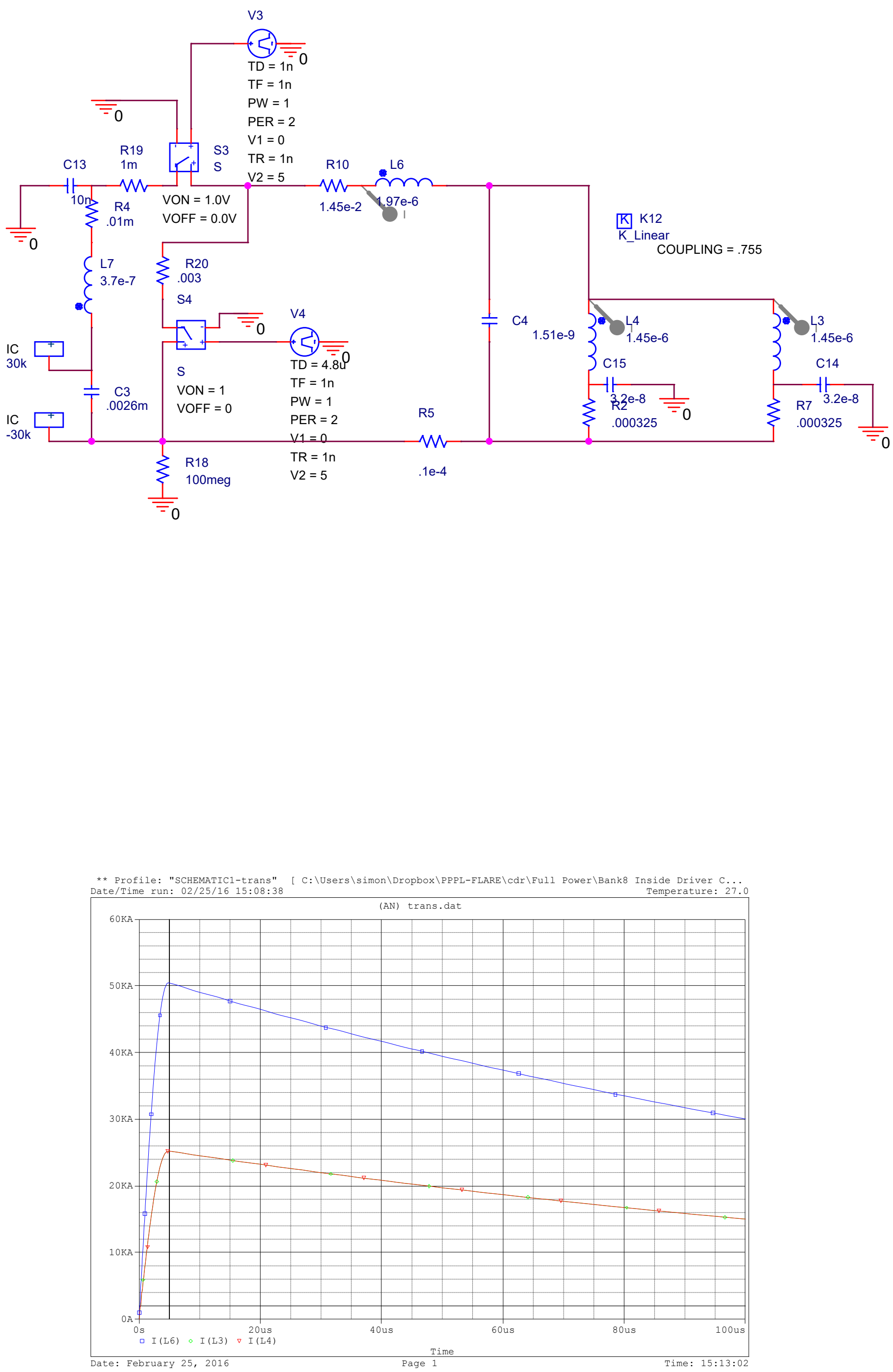


Figure 2: PSpice DCI Schematic and Analysis

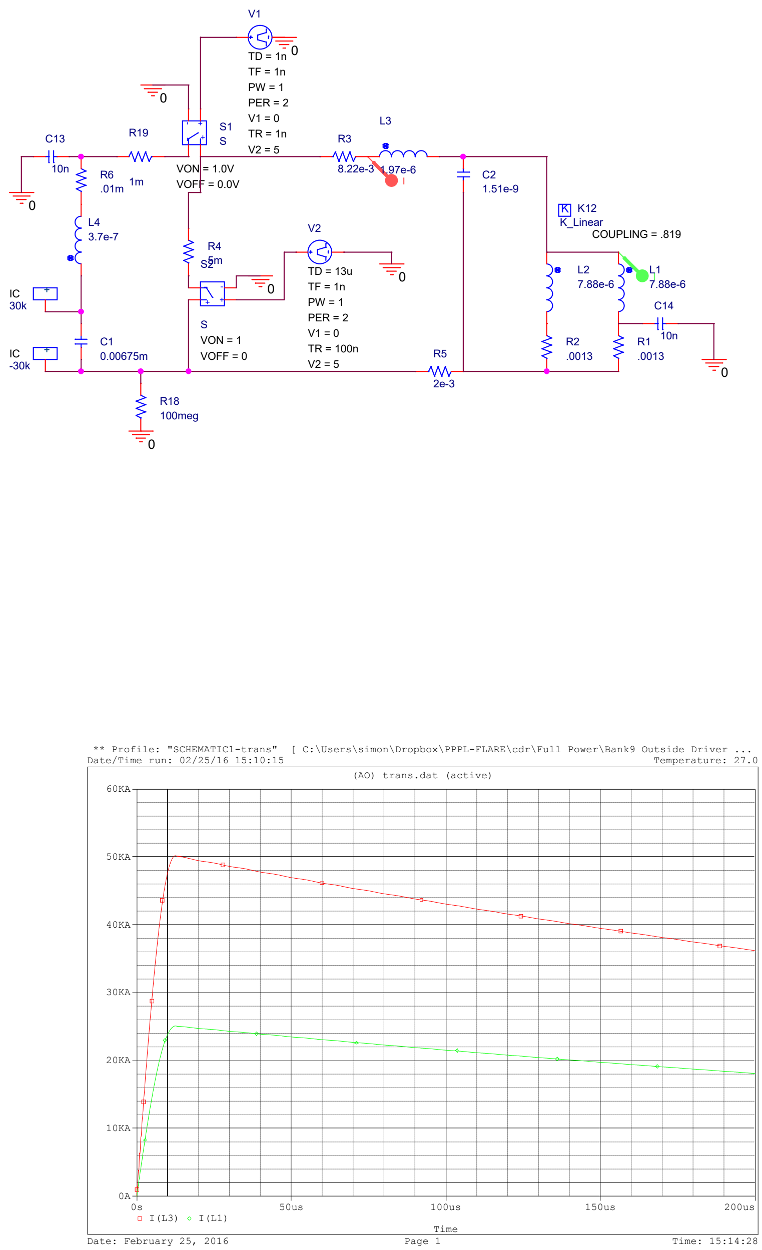


Figure 3: PSpice DCO Schematic and Analysis

1.2 Full Assembly

1.2.1 DC-I module

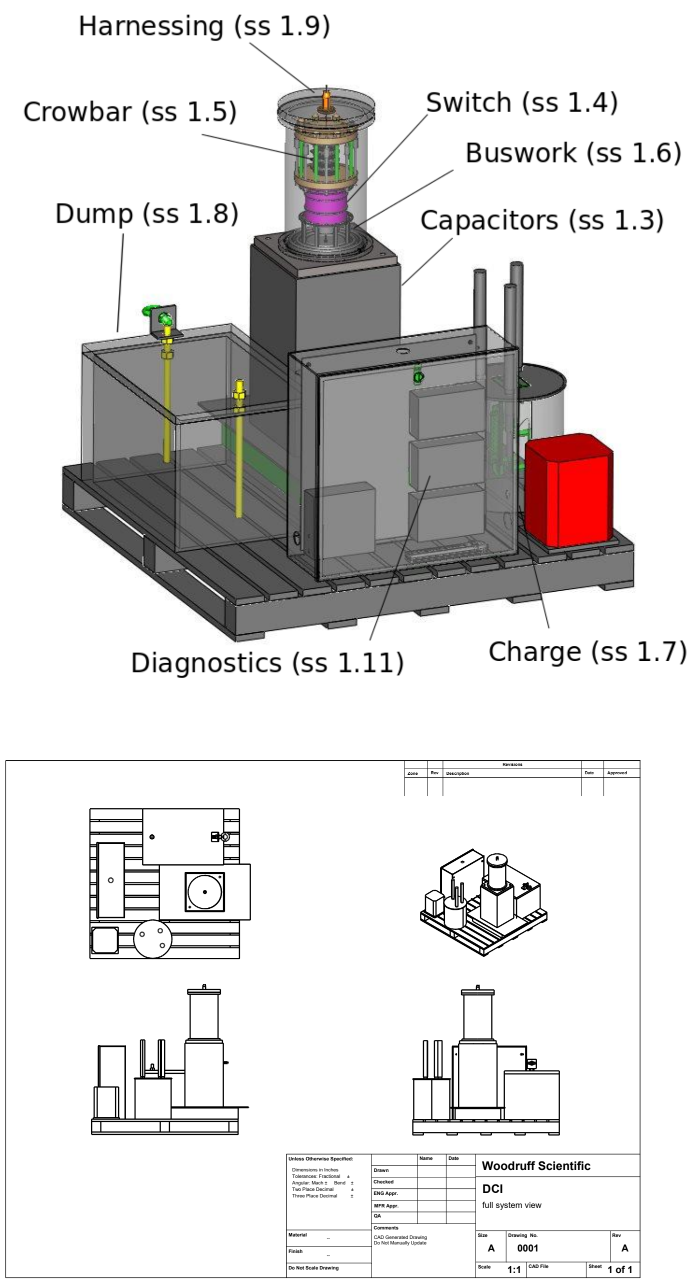


Figure 4: Engineering design point for bank module

Fig. 4 shows the full bank assembly mounted on one 36 inch square steel pallet. The full assembly will have a footprint smaller than 16sqft with a maximum of 64sqft for egress and maintenance (2 feet on each side), and will be engineered as 1 module that can be transported and installed onsite with only a small number of connections (connections for 110V power, hight voltage and trigger lines (see more details below and connection table below)). The DC Bank and all related components will be mounted on 2 36"x36" standard pallets, total height under 50 inches, total weight per pallet of 1200lbs. Assembly instructions will be provided separately.

1.2.2 Full Assembly: DC-O module

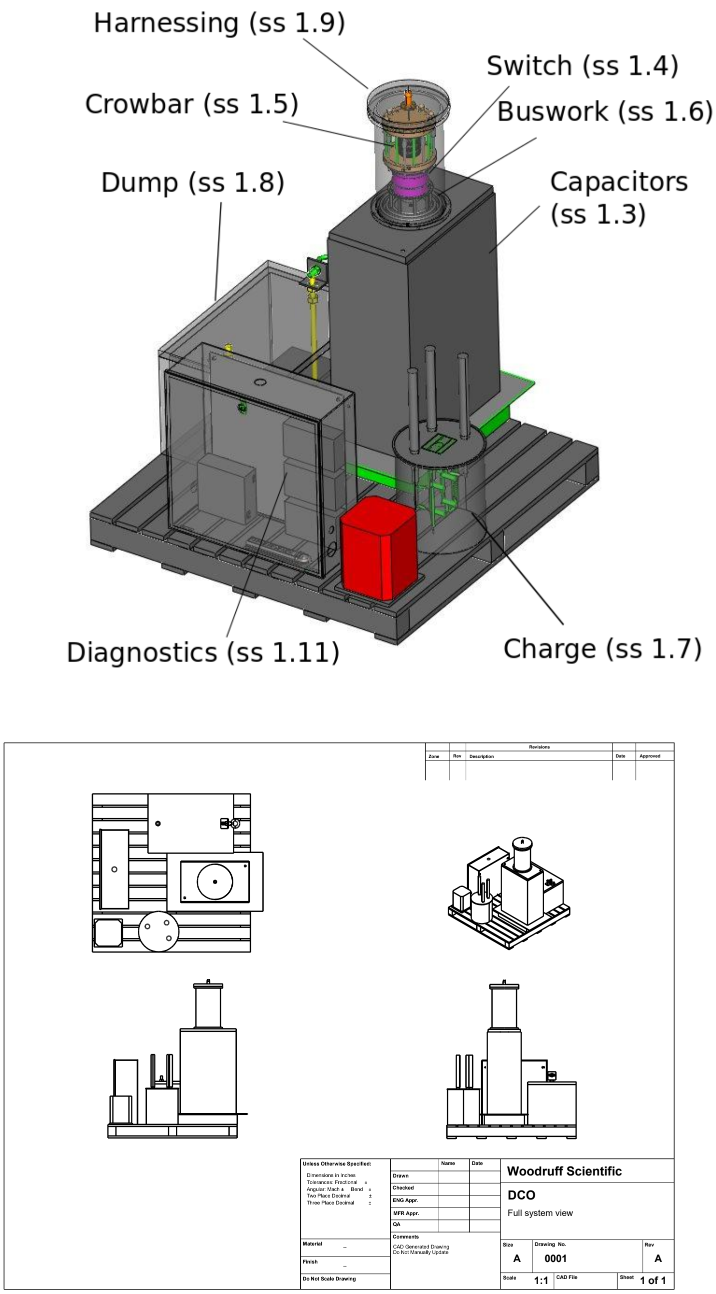


Figure 5: Engineering design point for bank module

Fig. 5 shows the full bank assembly mounted on one 36 inch square steel pallet. The full assembly will have a footprint smaller than 16sqft with a maximum of 64sqft for egress and maintenance (2 feet on each side), and will be engineered as 1 module that can be transported and installed on-site with only a small number of connections (connections for 110V power, height voltage and trigger lines (see more details below and connection table below)). The full DC Bank (DC-I and DC-O) and all related components will be mounted on 2 36"x36" standard pallets, total height under 50 inches, total weight per pallet of 1200lbs. Assembly instructions will be provided separately.

1.3 Capacitors

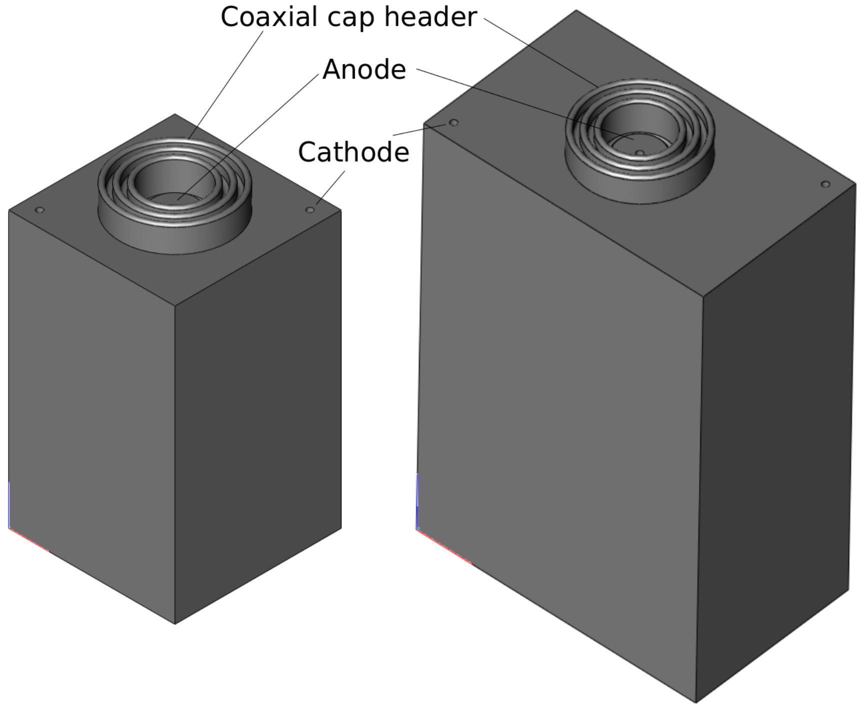


Figure 6: Detail of the cap headers for the DCI (left) and DCO (right) bank modules.

The DC Bank will use 2 60kV Capacitors, with 2.5uF on the DC-I and 7.5uF on the DC-O, by Richardson Electronics. The capacitors are expected to see reversal voltages during the experimental shots. Capacitor casing will be hot, and in bipolar charging operation, will see -30kV. Cap casing is therefore isolated from the pallet (at ground) by multiple layers of mylar, and a 3" thick high density extruded polystyrene sheet (to ensure stand-off and even-distribution of weight on the mylar). The caps are rated for 80% discharge voltage reversal. The capacitors are expected to survive at least 500,000 full power shots without failure, per cap manufacturer specification see appendix for the Richardson specification. Each capacitor unit is self-protected with a resistive load between cap and switch consisting of 8 stainless resistive shunts connecting the anode of the capacitor to the anode of the switch. Fuses are omitted for this bank. Energy dumping resistor(s) shall be specified for safe dissipation of stored energy (see Charge section below). The dissipation time should be limited to the shorter of the relevant industrial standards or the experimental needs.

1.4 Forward Switch

Operation at high voltages and with short current pulses allows for selection of a thyratron switch (see e.g. TDI4-100k/75H THYRATRON, specifications in the Appendix). The thyratrons are expected to see reverse voltage and pulse currents. Life time of the thyratron contact shall not be significantly shortened or the minimum design life of the equipment should be maintained. The thyratrons are expected to survive a minimum of 10,000 full power shots without failure. Thyratrons require heating and optical trigger units, both of which are provided in the BOM. In contrast to all other banks, the switch and diodes are mounted as a single unit, as shown in Fig. 7 - the thyratron is mounted on the anode and return connections are made to the outer conductor.

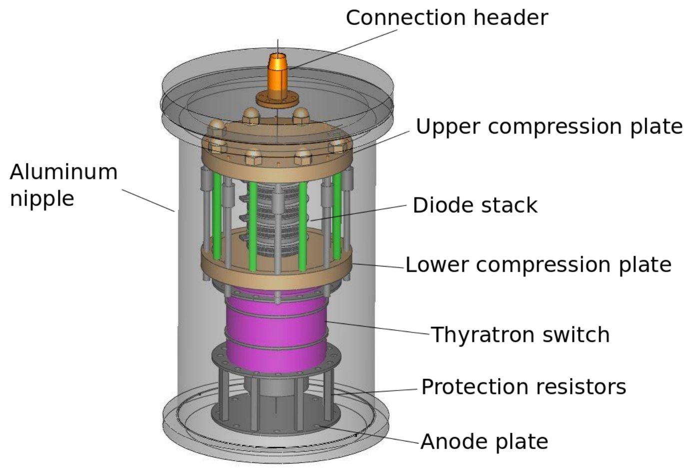


Figure 7: Detail of the switch for the DCI and DCO banks (they are identical).

1.5 Crowbar Diodes

Five high voltage (VRE) diodes rated to 15KV will be used in a series stack to crowbar the circuit. This can be accomplished due to the short duration and relatively low current in the DC-I/O circuits.

1.6 Buswork

The buswork for the DC banks consist of a copper cable header mounted on top of the capacitor, forward switch, and crowbar assembly. Stainless steel posts connecting to the capacitor to the thyratron offer fault protection current limiting resistance.

1.7 Charging

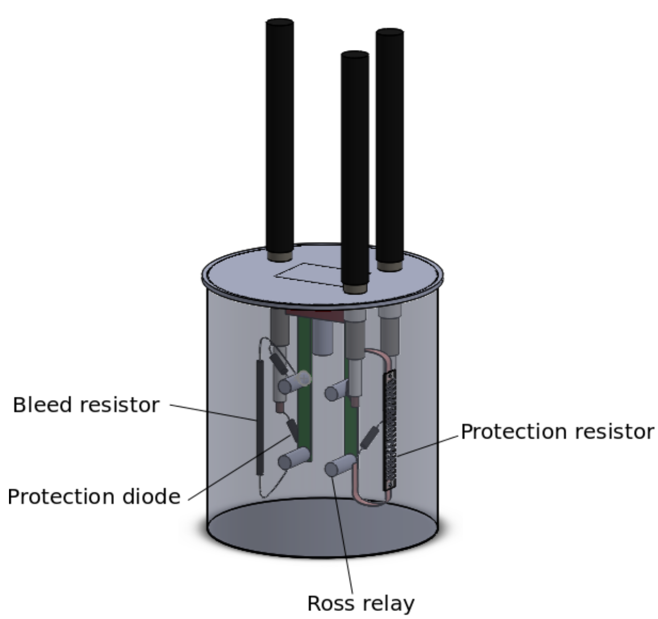


Figure 8: Charge dump relay

The charging supply will consist of two Ultravolt supplies (30C24-P|N125 for DC-O and 30C24-P|N60 for DC-I). The two output lines each include a series resistor to improve regulation and limit output current under fault conditions. The lines are then split to run a cable to each capacitor module. At the capacitor module, the charge cable is connected across a diode that protects the charge supply in the event of a bank pre-fire (when the charge supply is connected to the bank). The diode prevents any bank reversal during pre-fire from imposing a reverse voltage at the charge supply. After the diode is a resistor that limits the charge current for the bank (and limits the protection diode current under reversal). The final connection to the capacitor busswork is made via a normally-open DPST Ross relay which is only connected for charging, and is disconnected immediately prior to programmed discharge. Please refer to the separate specification for the charging supplies (treated as a separate sub-assembly). In parallel with each capacitor is a bleed resistor. These are a redundant dump mechanism for the stored energy. These resistors are sized to discharge the bank to below 50 volts over 12 hours. The bleed resistors are a passive "last resort" safing mechanism in case of failure of the water dump or loss of buswork connections, allowing the operator to leave the bank overnight to dissipate its stored energy. The bleed resistor shown in Fig. 8 is a 90kV 20W Ohmite MOX970 (see spec in appendix), using 2GΩ on the DC-I module and 800MΩ on the DC-O module. Charging cable is terminated at the relay with a custom connector, see Fig. 8.

1.8 Dump

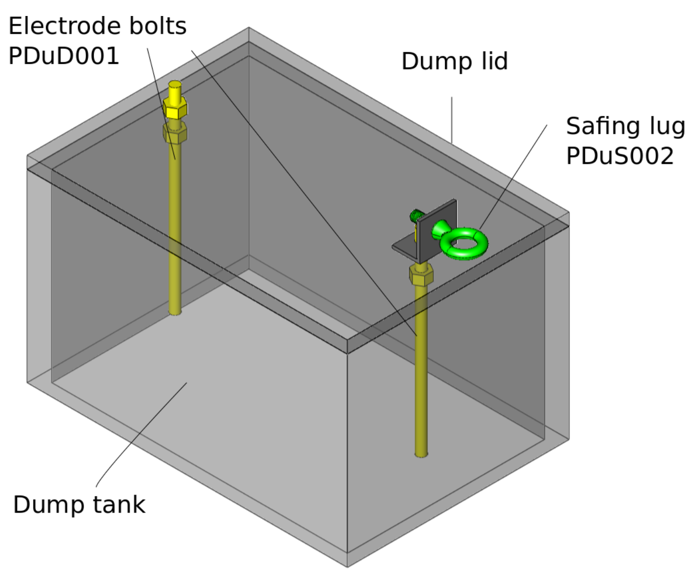


Figure 9: Dump detail for the DC bank module.

Each capacitor module includes a resistor sized to dissipate the full-charge energy of the bank. The resistor material is an aqueous solution of copper sulfate with brass electrodes in a polycarbonate reservoir. The electrolyte concentration is tuned to discharge the bank to below 50 volts (the NFPA 70E safety threshold) within 30 seconds. This dump rate was chosen based upon a conservative estimate of the time required from removal of the Kirk key at the operator station to entry of the bank enclosure. The dump sizing is also designed to allow several sequential full-energy dumps at 3 minute intervals, but in this operation mode the resistor temperature shall be monitored remotely by the operator to ensure the temperature does not exceed 60°C (as per ASTM C1055) and that the water level is maintained. The normally-closed dump relay on each module (Ross E40-NC) will be energized only during charge, and will be de-energized to engage the dump upon removal of the Kirk key or at any emergency stop or interlock break. A temperature sensor is located on the outside lower section of each dump.

1.9 Harnessing

The harnessing sub-assembly comprises all of the interconnecting power cables from the CCDPS to the FLARE machine. The cabling will be triax of suitable current rating (see e.g. Dielectric Sciences specification in the Appendix). On DC-I, 2 cables will connect to the cable header located close to the switches and between the dumps. On DC-O, 3 cables will be used. Cable trays will be used to route cables from the capacitor banks to the device.

1.10 Polarity switching

No polarity switch is required for this module.

1.11 Diagnostics

Diagnostics must be provided to measure the forward current in the bus leading to the forward switch (in this bank it is placed beneath the nipple cap), the voltage of the bank module using a voltage divider, and the temperature of the over-current protection resistor, the temperature in the dump resistor and the temperature at the anode of the ignitrons. Each of these diagnostic measurements must be transmitted along a fiber-optic connection to the DAQ. Please see separate DAQ specifications for further information.

1.12 Safety

Monitoring (analog and digital voltage monitoring) will be required. A voltage divider at the bank will be used to monitor the charging voltage on the control computer (see specification for DAQ), and provide a signal for a panel-mounted analog indicator at the entry to the enclosure. The DC bank modules will be housed in a bay that separated it from other bank modules. Each side of the bank module may be separated by a 1/4 inch steel blast shield. The enclosure will be interlocked and procedures will be present to disable the bank before personnel access.

1.13 Cooling requirements

Water cooling is not required for the DC bank modules.

1.14 Connection schematic

The connection schematic shows all of the connections that need to be made to the bank modules, power and control systems. From the left of Fig. 10, 208 and 110 power is fed to the bank enclosures via a Kirk key controlled isolation switch. This same switch can be energized by an Emergency Stop (E-stop) button located in the control room (this E-stop is digitized by both the FLARE control DAQ and the CCDPS control DAQ). If energized, the switch will drop all power to the enclosure, thereby killing power to the HV dump (normally closed) and charge (normally open) relays, and dumping bank energy into the cap dumps. The 110 and 208 power is delivered to the charging supply rack (located on it's own separate pallet), and 110 is also delivered to an isolation transformer mounted on the bank module pallet. Connections to the load are made by multiple triax cables (described above). Water is connected to the ignitron switches along 1/4" tubes from a shared chiller unit. The charge, dump ground relays are controlled by individual fiber-optic-enabled switches, with pulse signals sent from the CCDPS DAQ rack (Schematic shown in Fig. 11). Temperature sensor data are transmitted by fiber-optics from the pallet to the DAQ after conversion of voltage to frequency, then reconverting at the DAQ. A BNC connection is made from the current sensor integrator to the DAQ fast data acquisition (sampling at at least 1MHz). Timing synchronization is provided by the FLARE control DAQ. Switch firing is controlled here by the FLARE control computer and DAQ, by transmission of fire signal by fiber-optic connection. CCDPS DAQ requires 110V as input. CCDPS control computer requires 110V as input.

- Electrical input requirements: 208V three phase, 110V, less than 50 Amps (total for all banks at full charge is 100A)

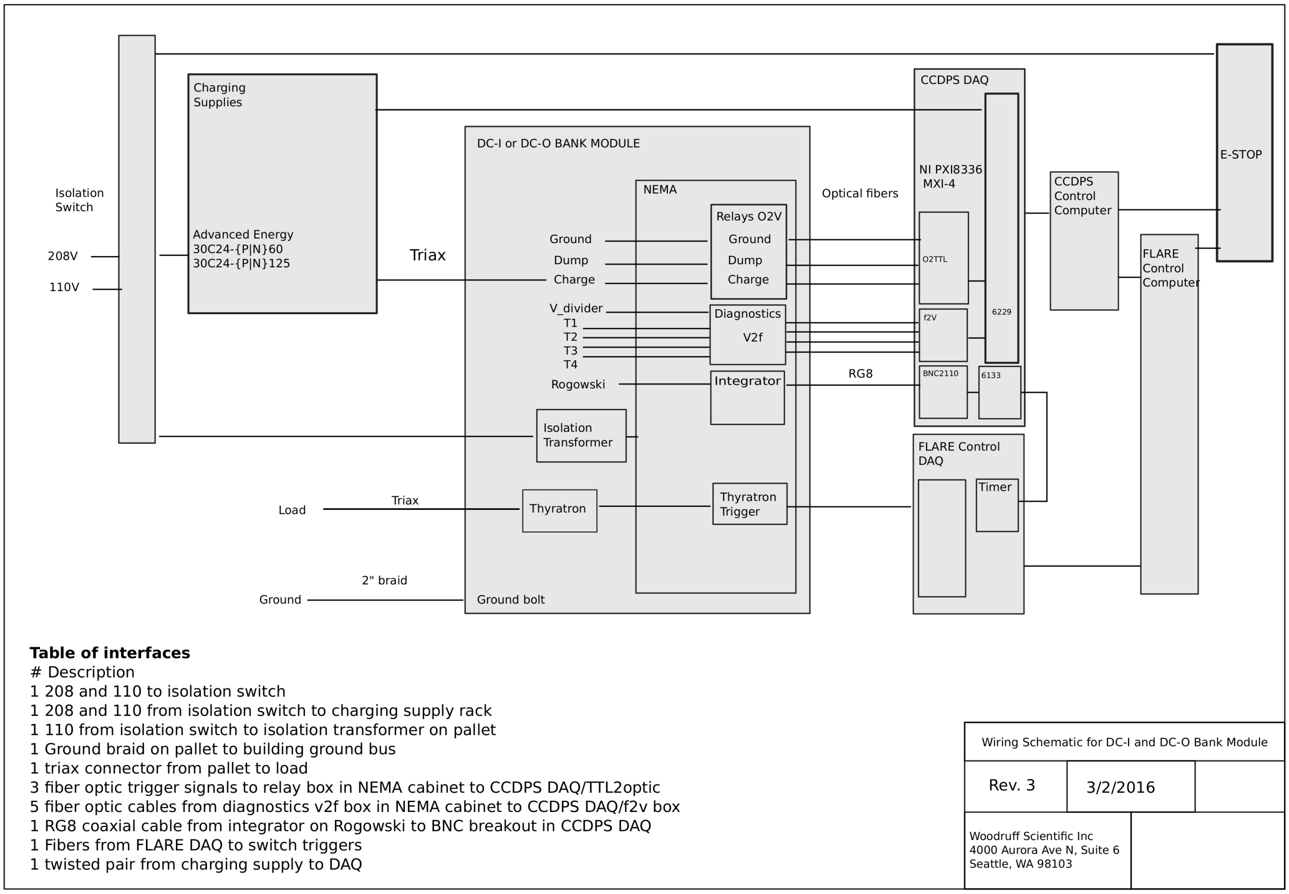


Figure 10: Connections

- Load requirements: as specified in [1]
- Cooling requirements: none.
- Environmental requirements: dust free, see below
- Control signals needed as inputs: ESTOP and triggers (see Fig. 10)
- Control signals as outputs: none.

1.15 Environmental requirements

The entire CCDPS is specified to operate at room temperature, and will tolerate seasonal variations in humidity without the need for any special AC, other than heater connections to the thyratrons. Ideally the banks will be placed in a dust-controlled environment (fans with filters, preferrably with drywall to the ceiling), with minimal traffic to the enclosure.

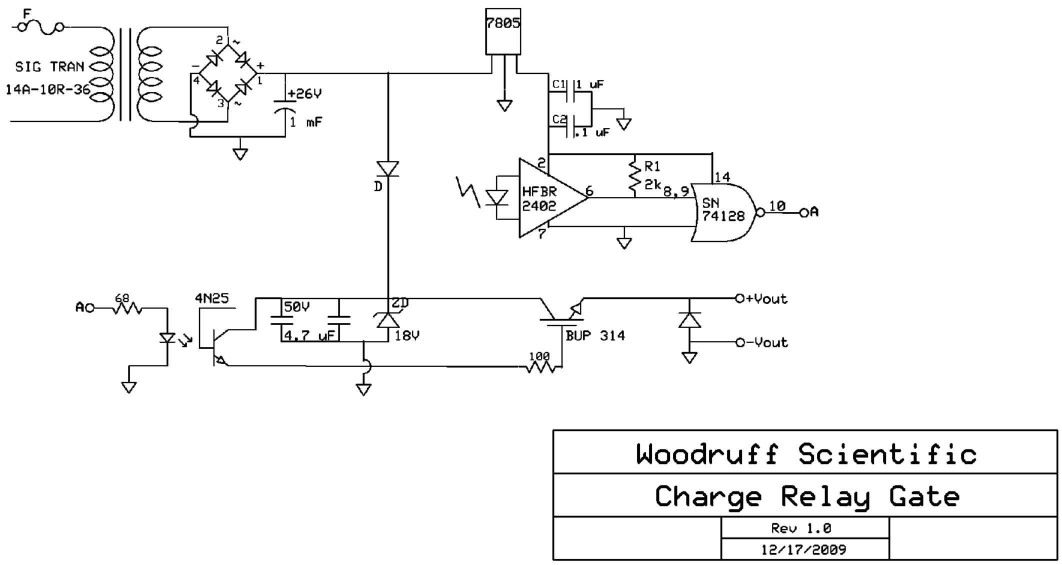


Figure 11: Schematic for charge, dump and ground relay control.

2 References

References

[1] Statement of Work for Design of Capacitor Charge/Discharge Power Supply (CCDPS) for FLARE FLARE-CCDPS-150828, Revision 0, Sept. 9th 2015

3 Appendices

3.1 Machining drawings and vendor specifications

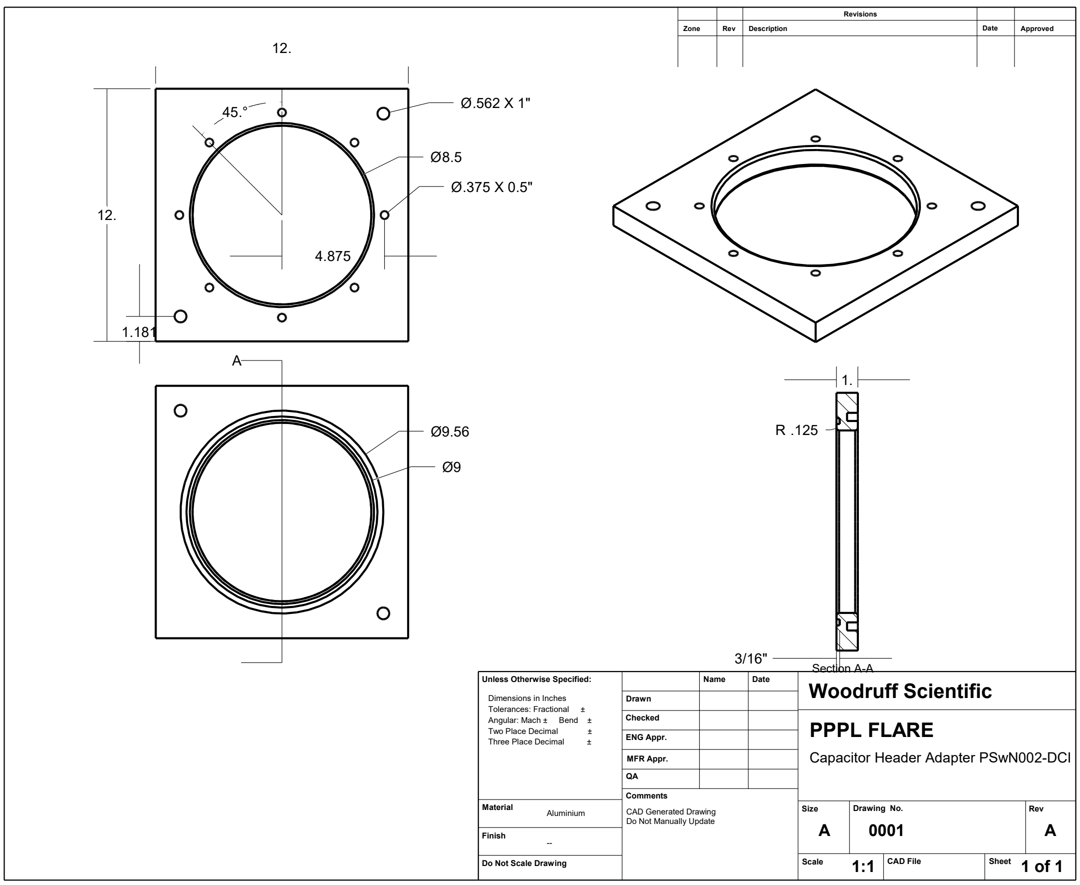


Figure 12: DCI Capacitor Header Adapter for Nipple

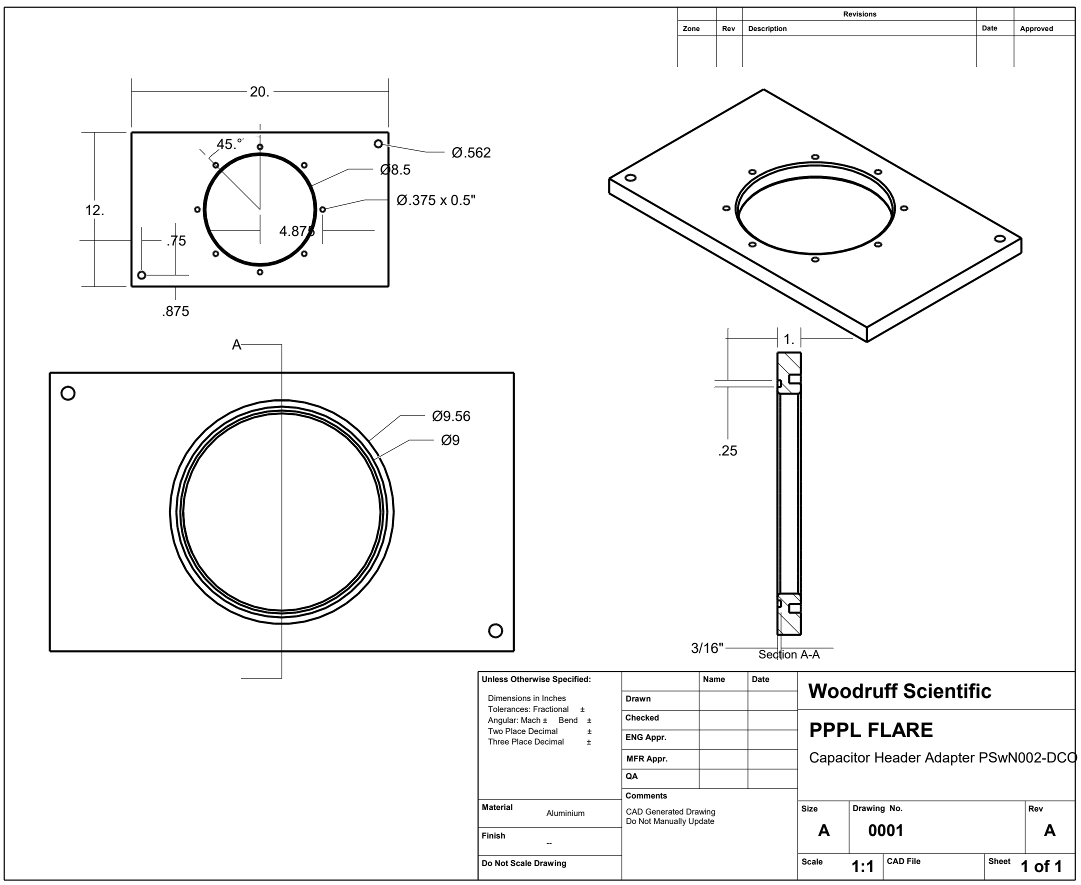


Figure 13: DCO Capacitor Header Adapter for Nipple

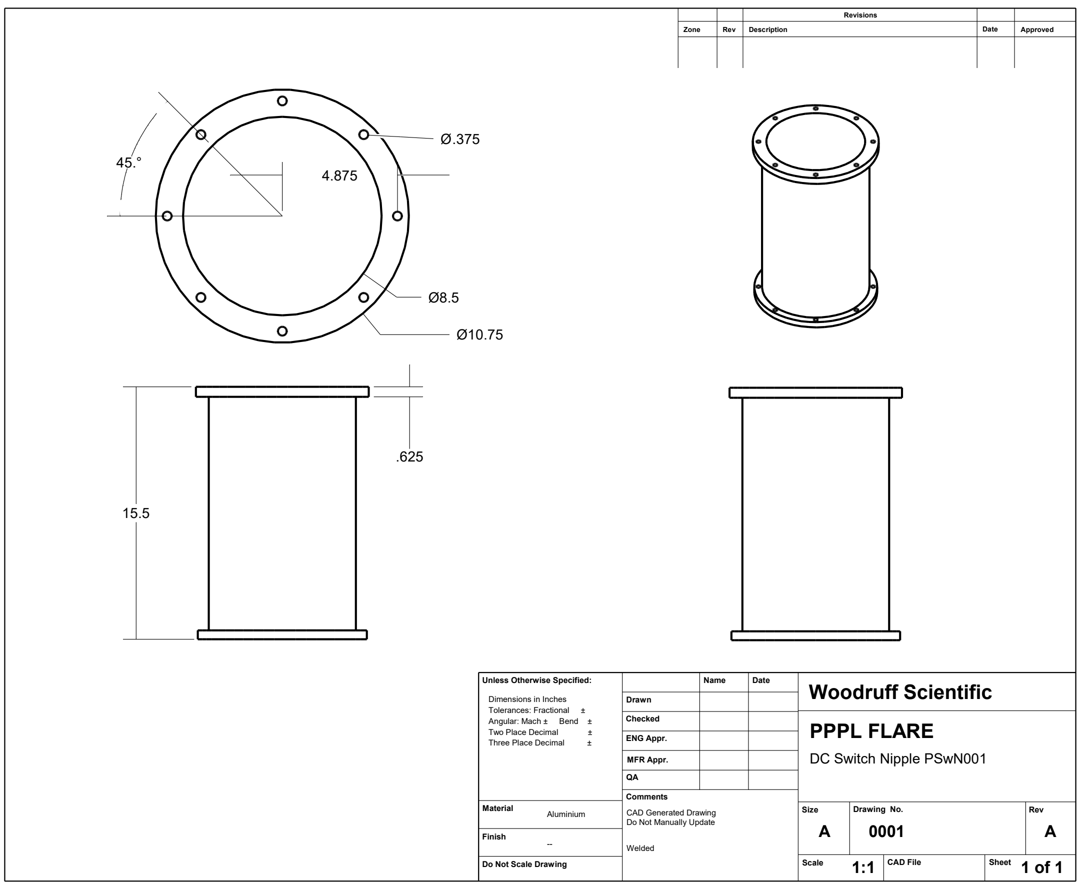


Figure 14: Aluminum Nipple

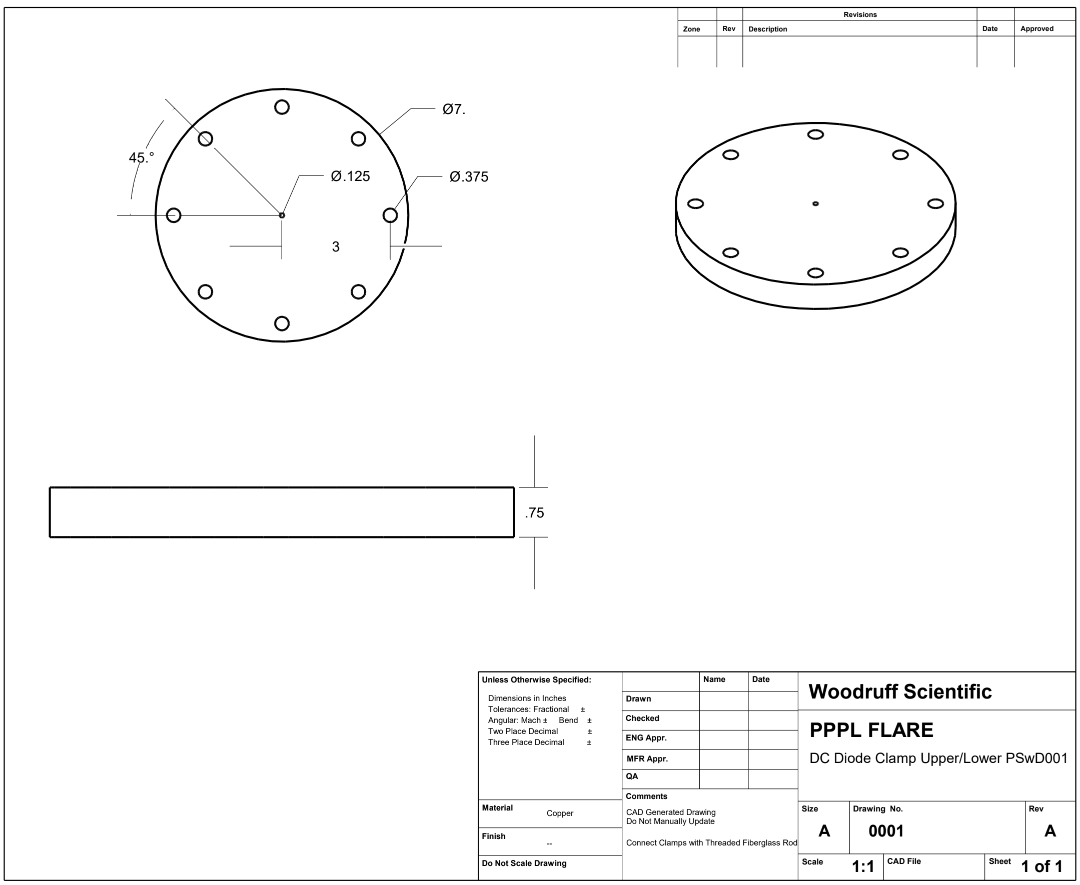


Figure 15: Diode Clamp Upper/Lower

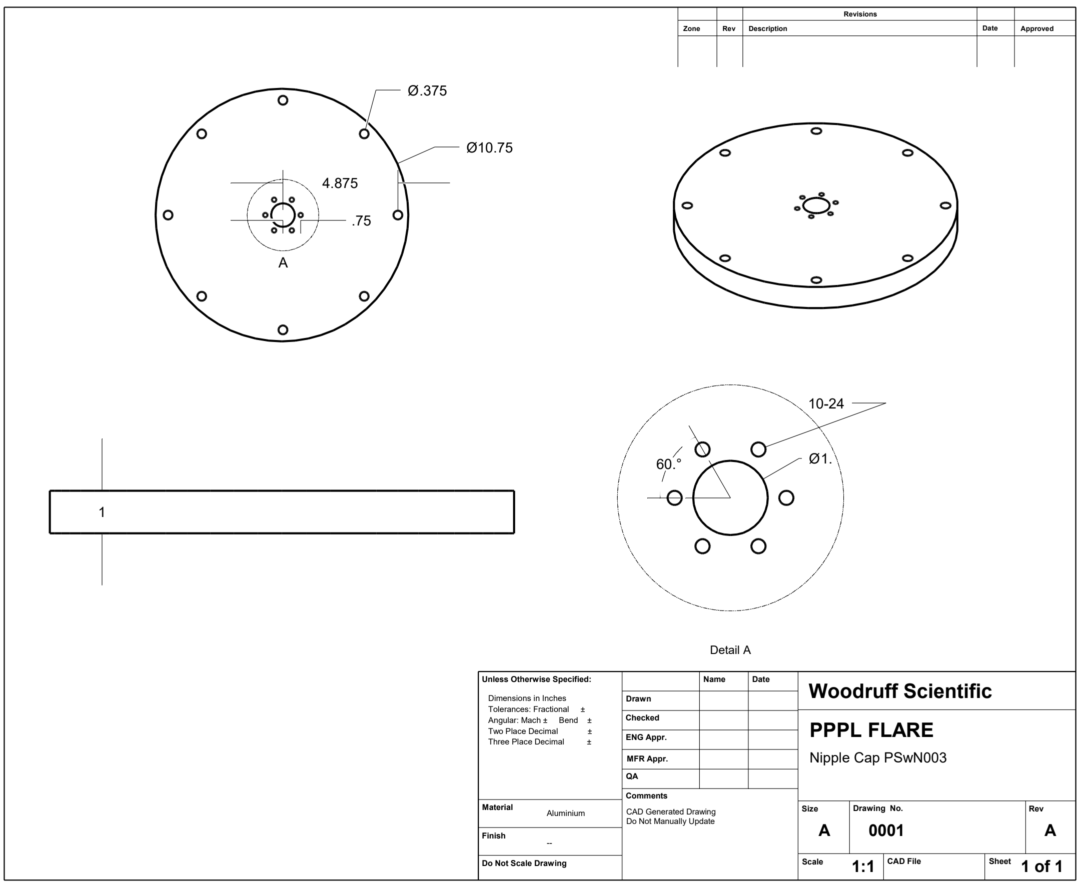


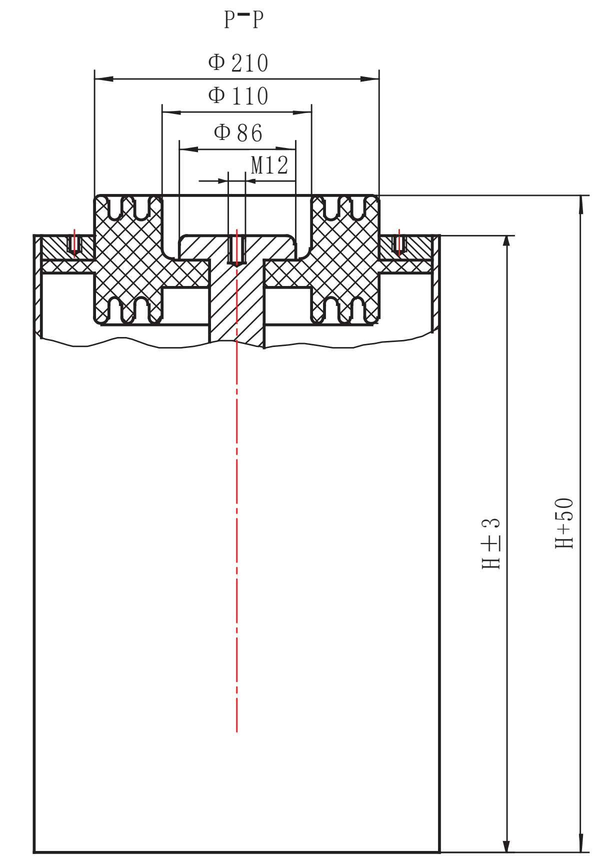
Figure 16: Nipple Cap

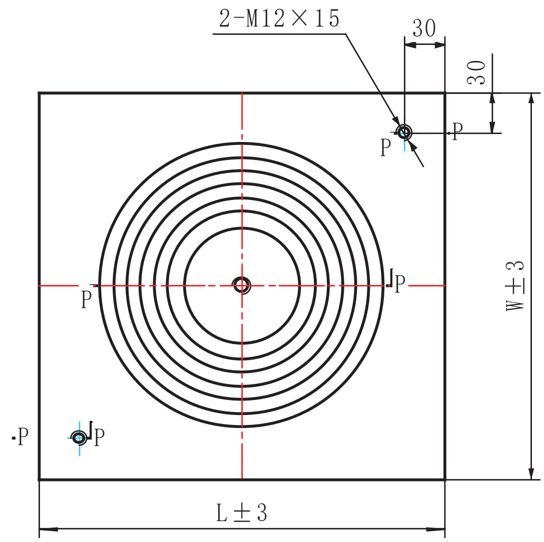
HDCT 60kV 2.8 μF Pulse Capacitor

Type		HDCT
Rated voltage	U_{NDC}	60kVDC
Rated capacitance	C_N	2.8μF
Capacitance tolerance		±5.0%
Rated Discharge Current	I_p	50kA
Max Discharge Current (system fault)	Î	60kA
Rated Discharge Voltage Reversal	%	80%
Self inductance	L_S	< 50 nH
Int. series resistance	R_S	< 10mΩ
Loss factor	tanδ	$< 1.0 \times 10^{-3}$ / 100 Hz
Life Expectancy (90 % survival)		500,000 discharges
Operating temperature	Θmin/ max	-40°C / +70 °C
Technology		Metalized Polypropylene film, dry type, SH
Dimensions(mm^3)		320×320×530

NL2.8-60KVDC

HIGH DENSITY CHARGE TRANSFER CAPACITOR



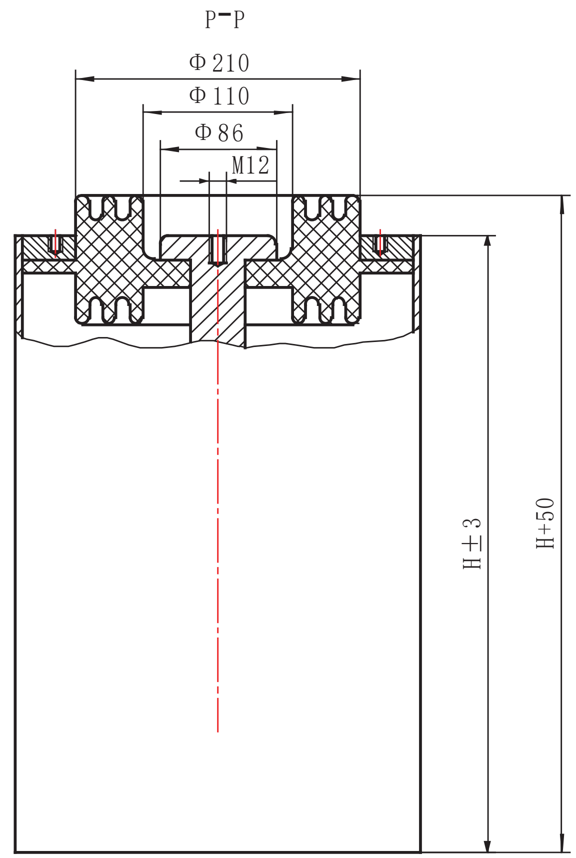


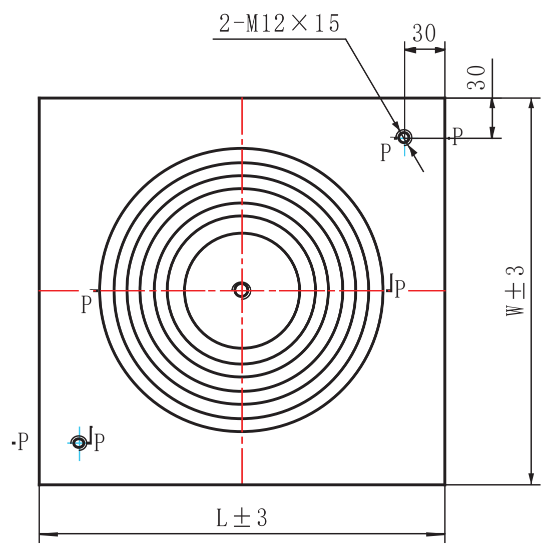
Specification	L（mm）	W（mm）	H（mm）
60kV 2.8μF	320	320	530

Richardson Electronics
www.rell.com | edg@rell.com
40W267 Keslinger Road
PO Box 393, LaFox, IL 60147 USA
1.800.348.5580 (USA & Canada)
1.630.208.2200 (International)

HDCT 60kV 7.5 μF Pulse Capacitor

Type		HDCT
Rated voltage	U_{NDC}	60kVDC
Rated capacitance	C_N	7.5μF
Capacitance tolerance		±5.0%
Rated Discharge Current	I_p	50kA
Max Discharge Current (system fault)	Î	80kA
Rated Discharge Voltage Reversal	%	80%
Self inductance	L_S	< 50 nH
Int. series resistance	R_S	< 10mΩ
Loss factor	tanδ	$< 1.0 \times 10^{-3}$ / 100 Hz
Life Expectancy (90 % survival)		500,000 discharges
Operating temperature	Θmin/ max	-40°C / +70 °C
Technology		Metalized Polypropylene film, dry type, SH
Dimensions(mm^3)		528×320×775





Specification	L（mm）	W（mm）	H（mm）
60kV 7.5μF	528	320	775

4. Warranty

All valves manufactured by "Pulsed Technologies Co. Ltd." (The Manufacturer) are guaranteed to be free of defects in workmanship, materials and construction and are designed to give satisfactory service when used under normal operating conditions. The Manufacturer guarantees conformity of thyratrons to the parameters specified in the appropriate clause of the thyratrons' certificate within a period of 12 months from the date of delivery, confirmed by shipping documents, or within a minimum operating time equal to 5×10^4 pulses, either within a filament life of 1000 hours whichever comes first. The above conditions should be considered provided the thyratrons are treated in accordance with the technical parameters stated in the appropriate clause of the thyratrons' certificate (p.1.1).

For valves failing before expiration of operating time 10^4 pulses, a valve may at the option of Manufacturer be replaced free of charge or credited in full, provided that the filament life guaranteed has not expired. For valves failing with a filament life in excess of the initial period up to operating time 10^4 pulses, but less than the total warranty minimum operating life, replacement or credit will be given on pro rata basis determine by the ratio of the unrealised portion of the warranted operating life to the total warranty minimum operating life. The operating life is considered to start when the valve is first put into service, even though it may subsequently be removed and held as a spare.

Conditions of Warranty. The warranty is valid only if the following conditions are met :

1. The valve is supplied direct from the Manufacturer or via an agency, representative or other selling medium authorized by Manufacturer.
2. The valve is operated within the published minimum and maximum ratings, provided that safety devices for protection against overcurrent in terms of average current are fitted and operation time counter is used.
3. The valve is not subjected to any negligence in use, storage, transportation or handling.
4. The decision of Manufacturer on the cause of failure and on the value and form of any applicable allowances is accepted by the customer.
5. Right of access to equipment for the purpose of checking operating conditions is granted to any representative of Manufacturer where Manufacturer may so require.
6. Manufacturer is notified within 30 days of the valve failure.
7. The valve is withdrawn from service as soon as possible after the failure is alleged to have occurred.

5. Claims Information. In case of a premature failure of a thyratron it should be returned to the Manufacturer within 30 days together with the Certificate stating the following information:

Storage time ____

Date of putting into operation ____

Date of failure____

Specifications of a mode of operation ____

information about operating conditions, cause of failure.

Operating time in the specified mode ___________ of hours (total switched charge).

The reasons for removal of a thyratron from operation _________________

The items of information are filled_____________________________________

(Date, signature)

In case of absence of the filled passport the claim is not accepted.

Individual №___________, Manufacturing date________________

Address: "Pulsed Technologies Co. Ltd." 5, Yablochkova Str., 390023 Ryazan, Russia.
Tel./fax: +7 (4912) 24-9217, tel.: +7(4912)24-0519,
E-mail: pulsetech@mail.ru , info@pulsetech.ru
Web site: http://www.pulsetech.ru

TDI4-100k/75H THYRATRON

Certificate. Certificate of Quality.

TDI4-100k/75H thyratron (Copper Arc Thyratron, Grounded Grid Thyratron) is intended for use as a switch tube in pulse circuits of capacitive storages with sub-microsecond and microsecond pulse duration. The thyratron is manufactured in conformity with technical conditions КВФМ.433.212.026ТУ for use in various installations for domestic as well as export delivery.

1. Basic Technical Data.

Pulse thyratron has a ceramic/metal envelope, three high-voltage sections, filled with hydrogen (deuterium) as buffer gas at 20÷60 Pa in operational mode only. Semiconductor igniter is used to trigger the switch. Special dielectric coating protects internal surface of the envelope against damage in cases when anode reverse voltage achieves 100% of forward voltage. The tube is environmental-friendly product, has internal shield for minimization of X-Ray emission from the region of anode. The double-ended thyratron TDI4-100k/75D is a bi-directional switch. In TDI4-100k/75D variant the thyratron comprises hollow anode incorporating an extra igniter and is used, for example, for operation in modes with oscillating current, as well as for triggering both from cathode and anode part. Design of the thyratron is covered by Russian Federation patents №2300157, 2418339, International Patents PCT/RU2005/000298, PCT/RU2011/000038 and US Patent No.7,825,595 B2.

1.1. Electrical Parameters in Optimum Operation Mode

Parameter	*Value*	*Fact. value*
Forward anode voltage, *kV*	5÷70	
Peak forward anode current, *kA*	50	
Anode current 1st half-wave width, *μs*	5.0	
Pulse repetition rate, *Hz*	0.5	
Reservoir heater (heater R) voltage, *V*, (not less/not more)	3.0/7.0	
Heater R current (at nominal U_{hR} = V), *A*	2.5	
Heater G current (at nominal U_{hG} = V), *A*	2.5	
Peak open circuit trigger voltage, *kV*, (not less/not more)	4.0/6.0	
Peak trigger current, *A*, (not less/not more)	80/200	
Trigger current pulse duration, *μs*	2÷4	
Tube warm-up time, *minutes*	5.0	

1.2.Absolute ratings (maximus, nonsimultaneous)*

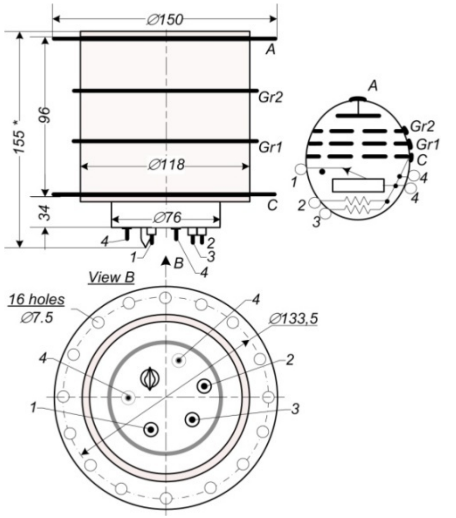
Parameter	*Value*
Peak forward anode voltage, *kV* (Notes 1, 2,3)	2÷80
Peak reverse anode voltage, *kV* (Notes 3)	50
Peak forward anode current, *Ib, kA*	100
Peak reverse anode current, *Ibx, k A* (Note 4)	up to 95% of *Ib*
Maximum anode current rise rate, *A/s* (Note 5)	$1\cdot10^{12}$
Anode current pulse duration, *μs*	0.1÷100.0
Pulse repetition rate, *f, Hz* (Note 6)	300
Switched energy per shot, *J*	20 000
Anode Dissipation Factor *(Pb=V×A×pps)* (Note 6)	$70\cdot10^9$
Root mean square current, $RMS=\sqrt{Ib \times ib}$ $(ib=C\cdot U\cdot f)$ (Note 6)	700
Peak open circuit trigger voltage, *kV*, (not less/not more)	4.0/10.0
Peak trigger current, *A*, (not less/not more)	80/250
Rate of rise of ignition voltage pulse, *kV/μs*, not less	5.0
Time Jitter, *ns* (Note 7)	3

Notes *Operation of the thyratron when two or more parameters listed in p.1.1 are exceeded simultaneously may be permitted only upon agreement with the Manufacturer.

1) *Immerse the tube into SF6, N2 or oil when operating at voltage over 45 kV.*

2) The dwell time at the peak anode voltage should be minimized in order to minimize pre-firing. For operation at the rated peak forward anode current, the dwell time must be less than 0.5 of pulse period, but must not exceed 1 millisecond.
3) After the thyratron anode current ceases and before voltage is reapplied to anode, the anode voltage must be kept between minus (100 -5000) Volts for at least 100 μs for working gas deionization.
4) For hollow anode variants TDI4-100k/75H and. TDI4-100k/75D. For TDI4-100k/75 reverse current <10% of Ib.
5) The ultimate value depends on the external circuit parameters.
6) Pb >3·10^9 and RMS >80 can be achieved in burst mode only (ib=CUaf – average current, C – switching capacitance). Burst and pause durations must be agreed with the Manufacturer.
7) High-rate of rise of trigger voltage pulse trigger system by a cable pulse generator (fig.2).

1.3. Maximum overall dimensions ($\varnothing_{\text{cathode flange}} \times H_{max}$), mm - 152×160. Weight - not more than 4.2 kg.
1.4. Lifetime expectancy specified in item 1.1 - 10^6 Coulomb.



2. Diagram of electrode connections

A - Hollow Anode;
Gr1- Gradient grid 1;
Gr2- Gradient grid 2;
C - Cathode, heater, igniter terminal (+);
1 - trigger <u>negative</u> pulse;
2 - Heater R (cold R_{res}~1Ω);
3 - Heater G (cold R_g~1Ω);
4 - cathode terminals (for driver common only).

<u>ATTENTION!</u> It is required in all circuits to carefully observe <u>polarity of ignition voltage</u> applied to the appropriate pins of the ignitor and to provide **<u>symmetry of current pick-off</u>** from cathode and anode flanges relative to the axis of the device: *(J.Slough, C.Pihl, V.D.Bochkov, et al, «Prospective Pulsed Power Applications Of Pseudospark Switches», 17th IEEE International Pulsed Power Conference, 2009, Washington, DC).*
The thyratrons must be handled carefully in order to prevent mechanical effect onto the pins 1, 2, 3 exceeding 3 kgs in an axial direction and 1kgs in direction perpendicular to the axes. <u>It is strictly forbidden to hit the valve pins</u>.

3. Operation Guidelines

3.1. Trigger <u>negative</u> signal must be applied to the pin 1 of the thyratron. Resistance of igniter within warranty period is 5kΩ÷200 MΩ.
3.2. For reliable operation of the thyratrons use pulse driver PB-3D or PB-3DV, providing powering of auxiliary electrodes in conformity with thyratron ratings. The driver is designed and manufactured by Pulsed Technologies Ltd.
3.3. Switching sequence: a) connect heater voltage power supply output to the appropriate pin; b) allow the heater to warm up for not less than 5 minutes; c) apply pulse trigger voltage to the igniter, then apply anode voltage (30-50% of maximum level) and smoothly increase the anode voltage up to the operating level. It is permitted to simultaneously switch on heater and trigger voltages.
3.4. The maximum-allowed temperature of cathode, anode and grid flanges is +100˚C. If exceeded, a forced air or liquid (oil) cooling must be used. Air flow rate is to be not less than 2.5 m^3/min at 25°C ±10°C of thermofor.
3.5. When switching off, first switch off anode voltage, then all the rest voltages. It is permitted to switch off all voltages simultaneously.
3.6. For ensuring guaranteed period of operation in modes different from those specified in p.1.1 it is necessary to select voltage of the heater subject to conditions of thyratron performance. For this purpose (with nominal load) gradually increase hydrogen reservoir (R) heater voltage in 0.1÷0.3 V increments from the value specified in the certificate staying at each value for 2÷3 minutes before appearance of signs of unstable operation (transition to higher frequency or to continuous discharge). In case of the signs appearance, switch off anode voltage, reduce heater R voltage by 0.1÷0.2 V and within a minute switch on anode voltage and maintain it for 5-10 minutes. At steady operation fix the given heater voltage. Henceforth it is recommended to repeat this procedure after every total 10^4 C of operation.
3.7. After transportation or a long period of storage a regulated seasoning under operation conditions within not less than 30 minutes is required. When conditioning the thyratron, anode voltage must be raised gradually in 3÷5 kV increments from a minimum peak voltage of 10÷15 kV up to peak forward anode voltage. The criteria of successful conditioning at each step will be absence of misfires within 3-5 minutes.

<u>Recommended Circuit for Ignition Pulse Generator</u>

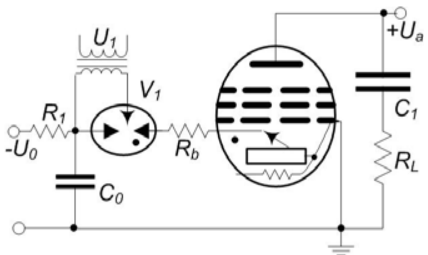


Fig.1. Electrical schematic of a triggered spark gap based trigger pulsedriver.
V_1- RU83-6 Triggered Spark Gap.
R_1=10kΩ, R_b=(0÷50)Ω,
C_o=(0.01÷0.2) μF,

<u>Version of Ignition Pulse Generators</u>

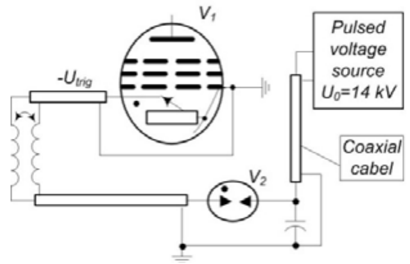


Fig.2. Electrical schematic of low-jitter (<5 ns), low-energy, trigger system cable pulse generator. *(V.A.Gribkov, M.Scholz, V.D.Bochkov, A.V.Dubrovsky, R.Miklaszewski, L.Karpinski, S.Lee, P.Lee, Pseudosparks in nanosecond range of its operation: firing, jitter, and disconnection, Journal of Physics D: Appl. Phys.* ***37,*** *2004, 2107–2111.)*
Uo=8÷12 kV, C_1=(0.01÷0.2) μF
V_1- spark gap; cable length ~ 6 m;

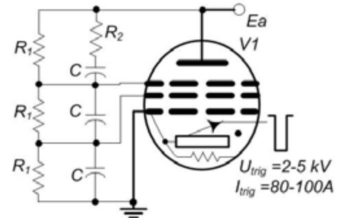


Fig. 3. Principal circuit of gradient grid feed.
C1=(0.3÷0.5) nF, R1=(5÷20)MΩ,
R2=470Ω

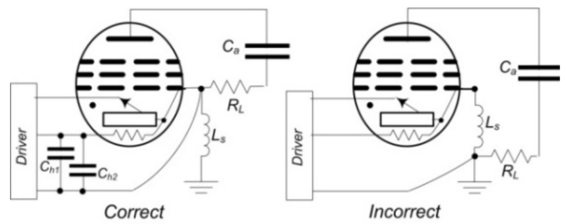


Fig..4. Please make sure that voltage jumps (stray voltage) Us=Ls·dI/dt in ground circuit should be minimized. For that heating voltage cable must be connected to the thyratron connectors directly. Also load circuit must be connected right to the thyratron cathode and equipment case directly. Cathode of the tube must be connected with equipment case by a minimum length cable (stray inductance L_s→0).

C_1, C_2: Reservoir protection capacitors with a voltage rating > 500 V;
C_1 = 1000 pF low inductance (e.g. ceramic), C_2 = 1uF (e.g. polycarbonate).
Components C_1, C_2 should be mounted as close to the tube as possible.

DIOSE ACTION = 0.5 $E^6 I^2 Sec$

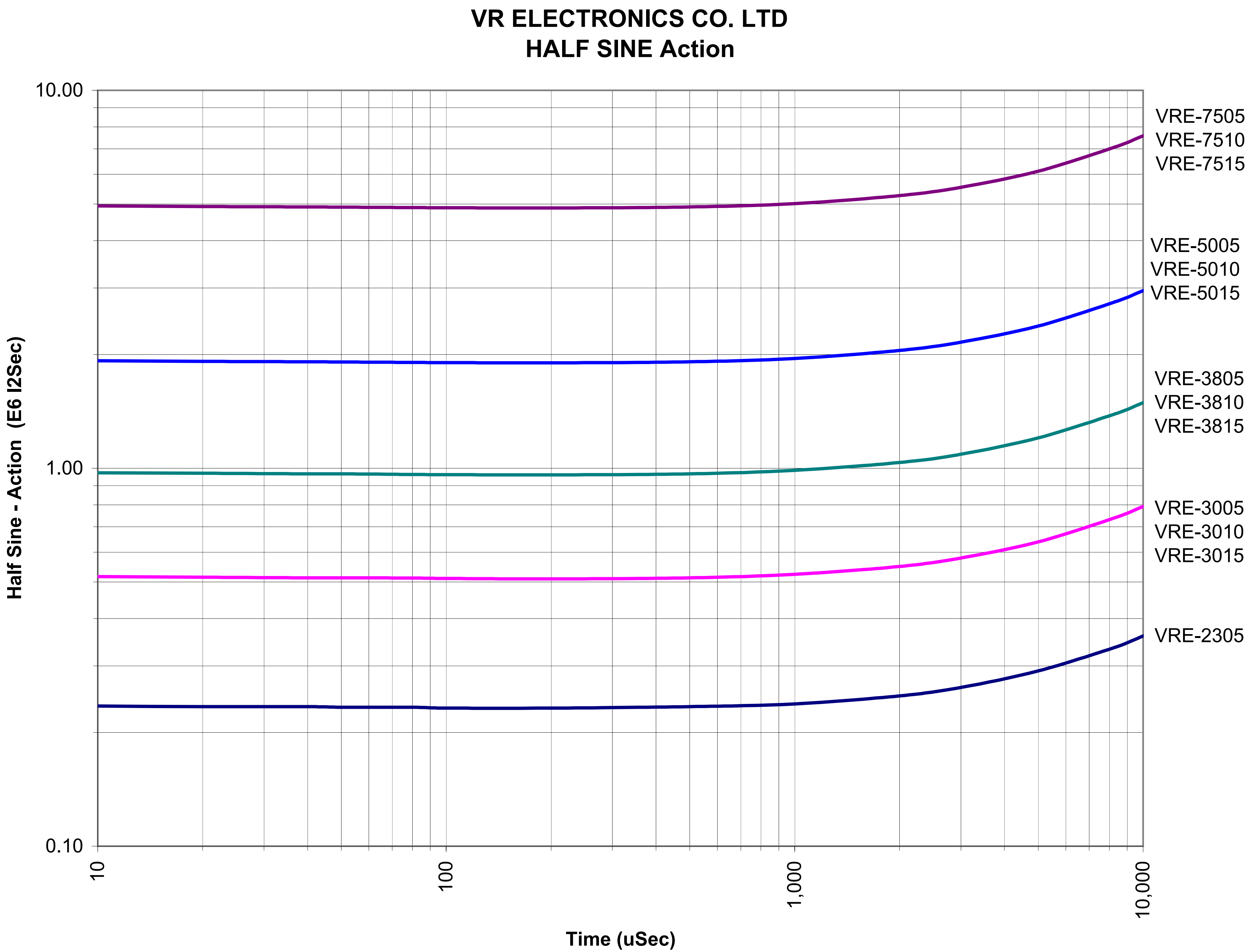
VRE-3005	**5 KV**
VRE-3010	**10 KV**
VRE-3015	**15 KV**

DIODE ACTION = 1.9 $E^6 I^2 Sec$

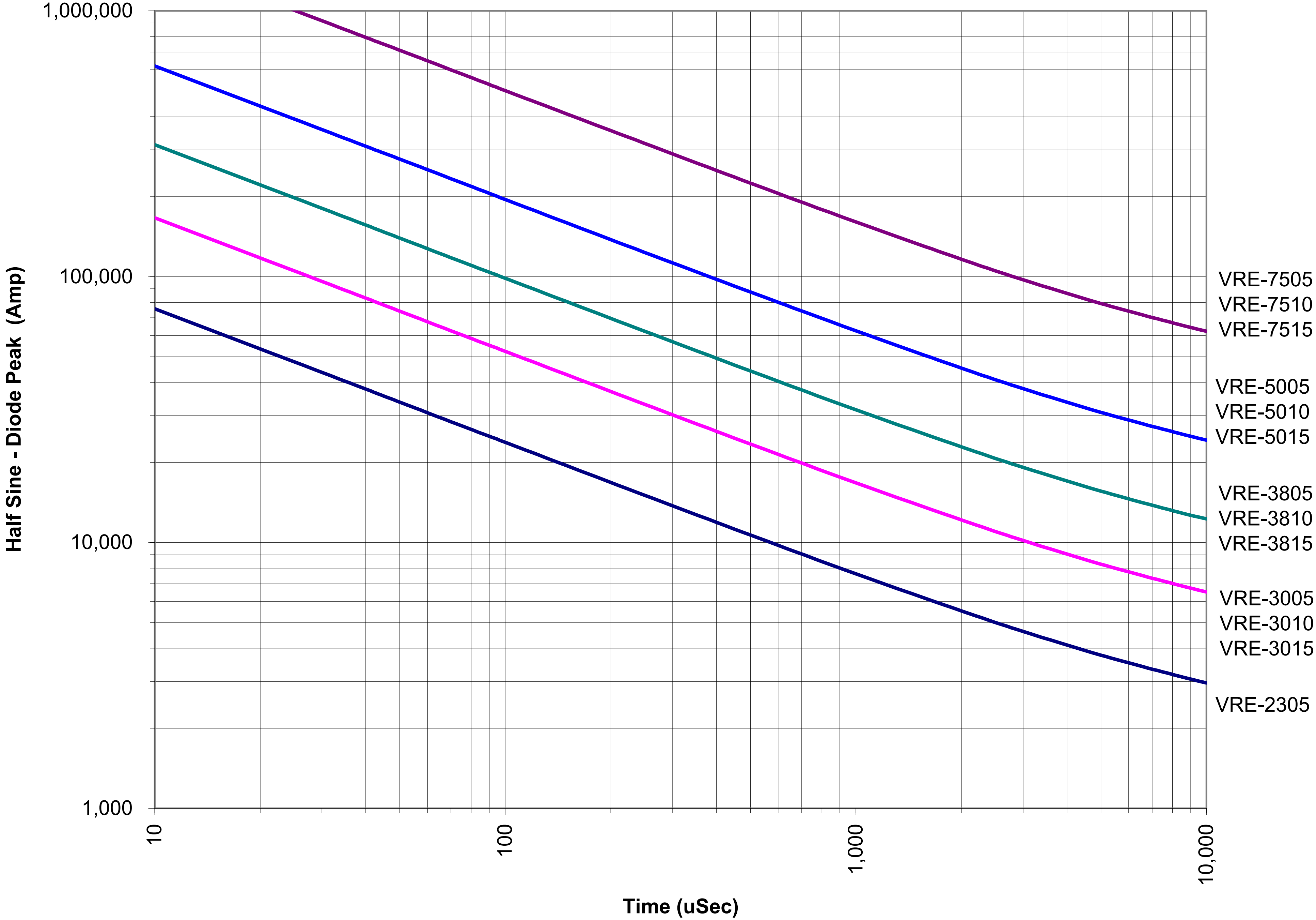
VRE-5005	**5 KV**
VRE-5010	**10 KV**
VRE-5015	**15 KV**

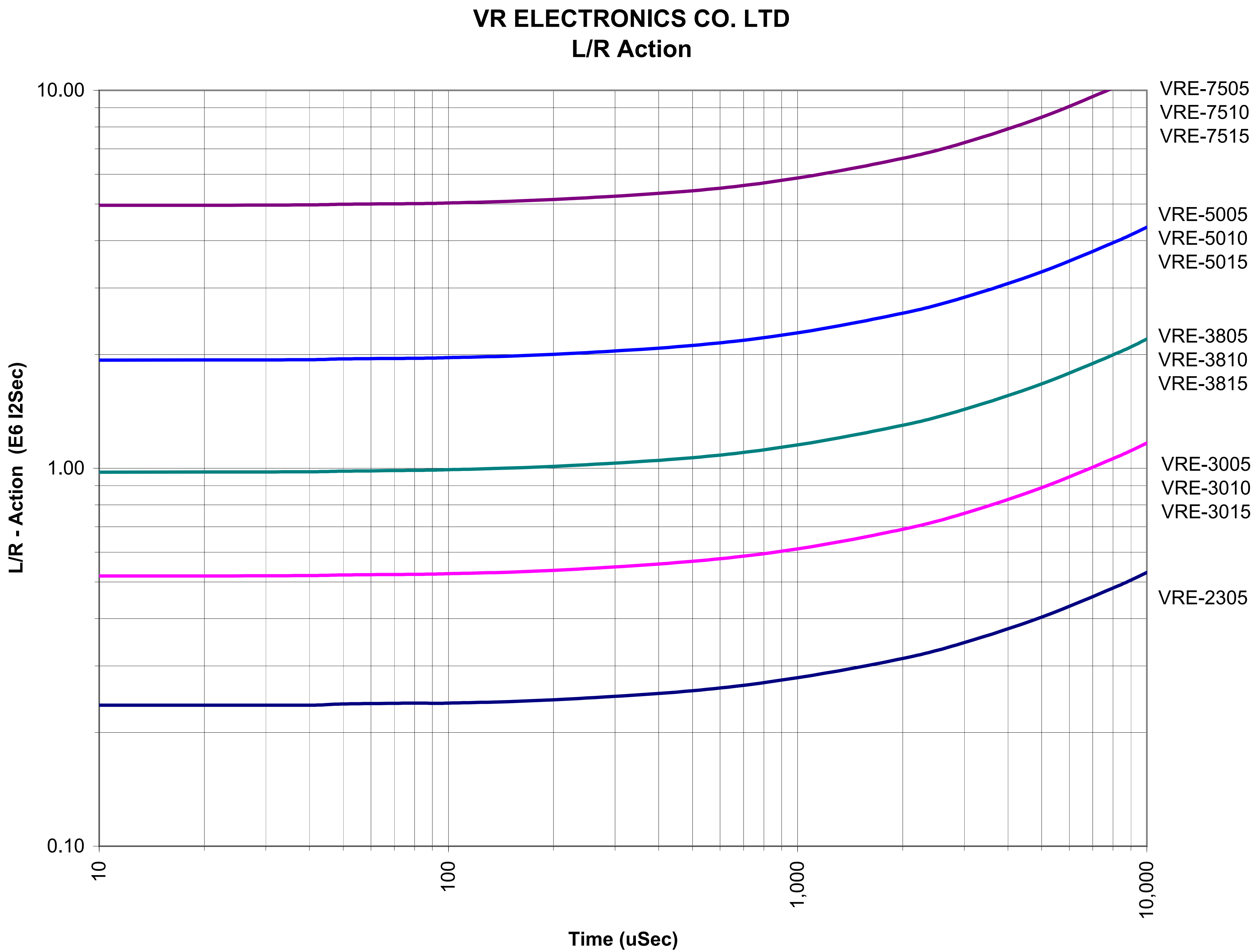
Plus : unlimited series without external components

Plus : unlimited parallel without additional matching


VR ELECTRONICS CO. LTD
HALF SINE Action
Half Sine - Action (E6 I2Sec)
10.00
1.00
0.10
10
100
1,000
10,000
Time (uSec)
VRE-7505
VRE-7510
VRE-7515
VRE-5005
VRE-5010
VRE-5015
VRE-3805
VRE-3810
VRE-3815
VRE-3005
VRE-3010
VRE-3015
VRE-2305

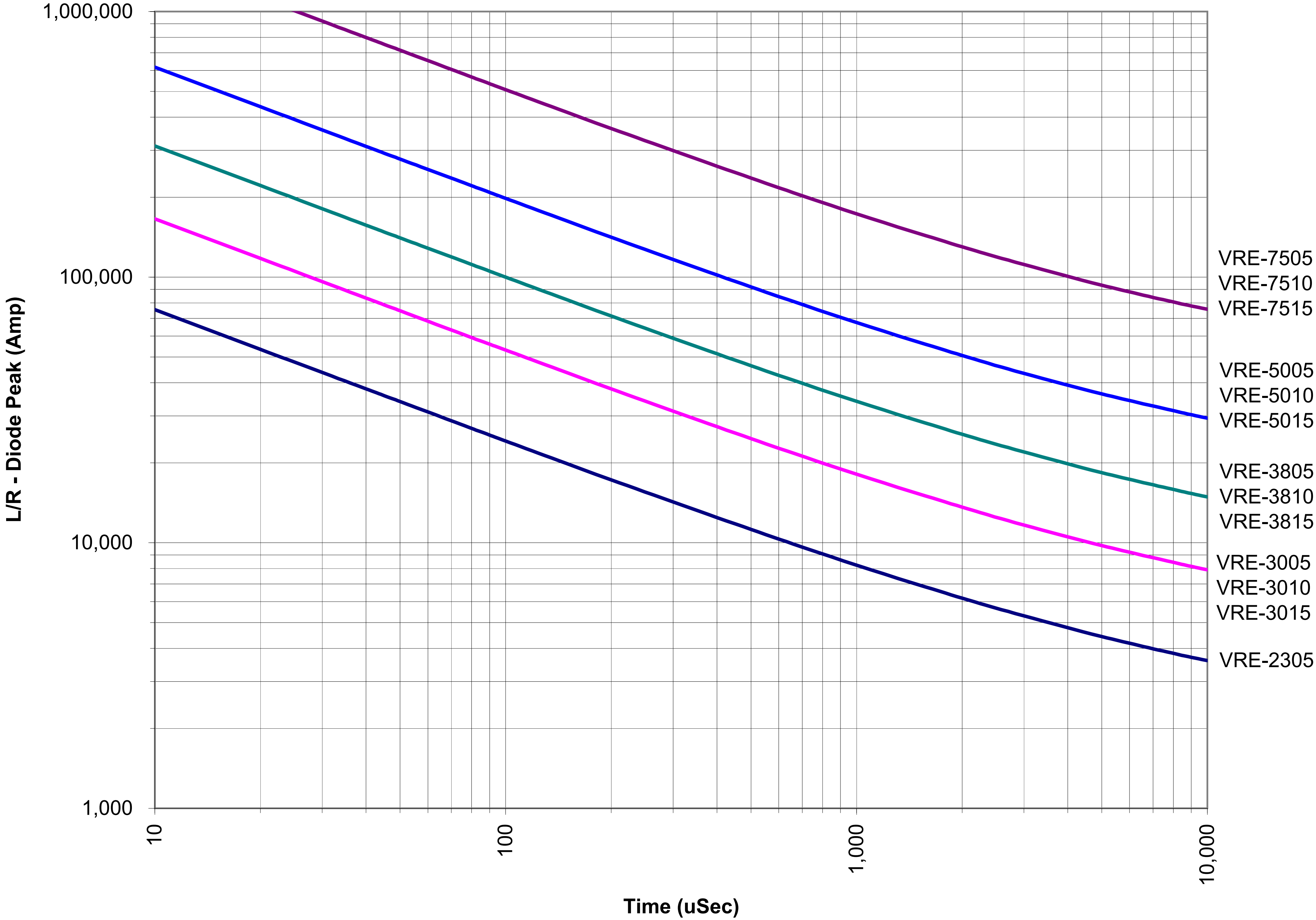
VR ELECTRONICS CO. LTD
HALF SINE Peak Current





VR ELECTRONICS CO. LTD
L/R Action
L/R - Action (E6 I2Sec)
10.00
1.00
0.10
10
100
1,000
10,000
Time (uSec)
VRE-7505
VRE-7510
VRE-7515
VRE-5005
VRE-5010
VRE-5015
VRE-3805
VRE-3810
VRE-3815
VRE-3005
VRE-3010
VRE-3015
VRE-2305

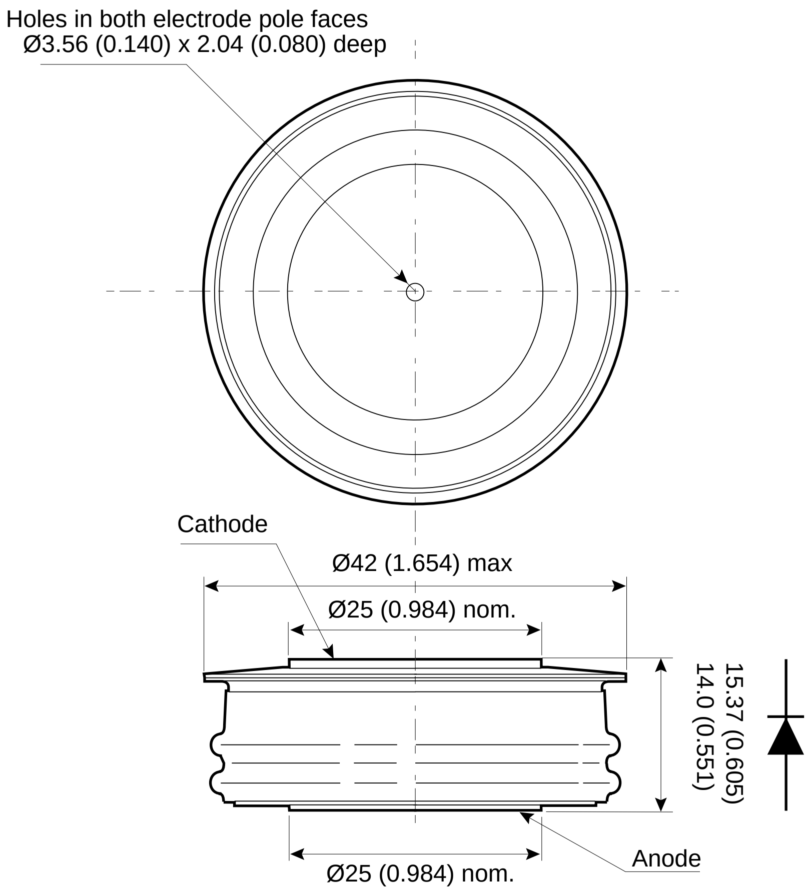
VR ELECTRONICS CO. LTD
L/R Peak Current



PACKAGE OUTLINE

VRE-3005 ,   5 KV (Vrrm)

Vrrm = max peak repetitive and DC voltage



Nominal weight: 85g (0.19 lb)

Clamping force: 8.9 kN (2,000 lb)

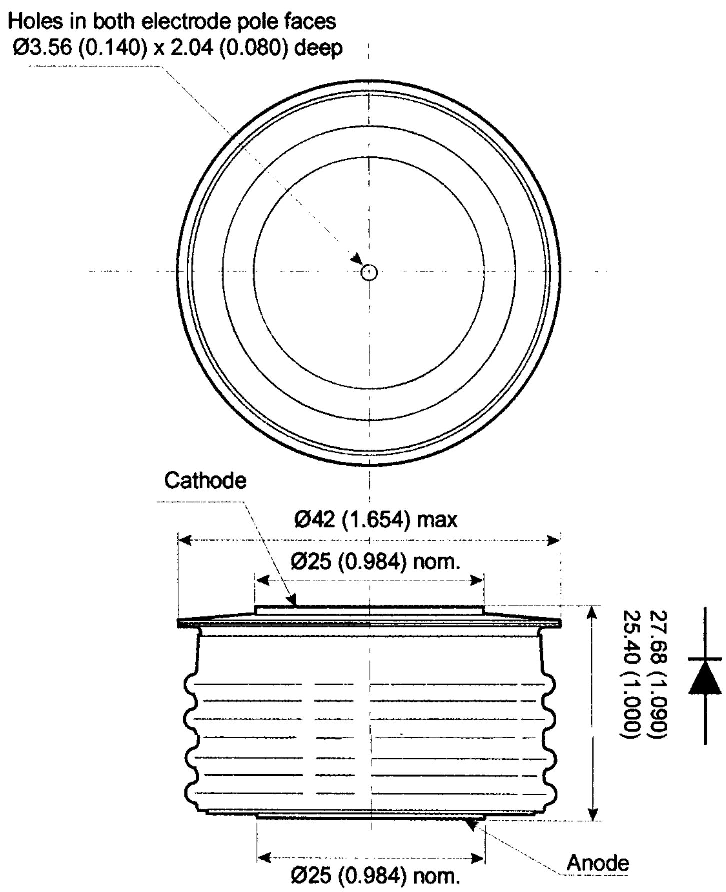
All dimensions are in mm (inches)

PACKAGE OUTLINE

VRE-3010 , 10 KV (Vrrm)

VRE-3015 , 15 KV (Vrrm)

Vrrm = max peak repetitive and DC voltage



Nominal weight: 155g (0.34 lb)

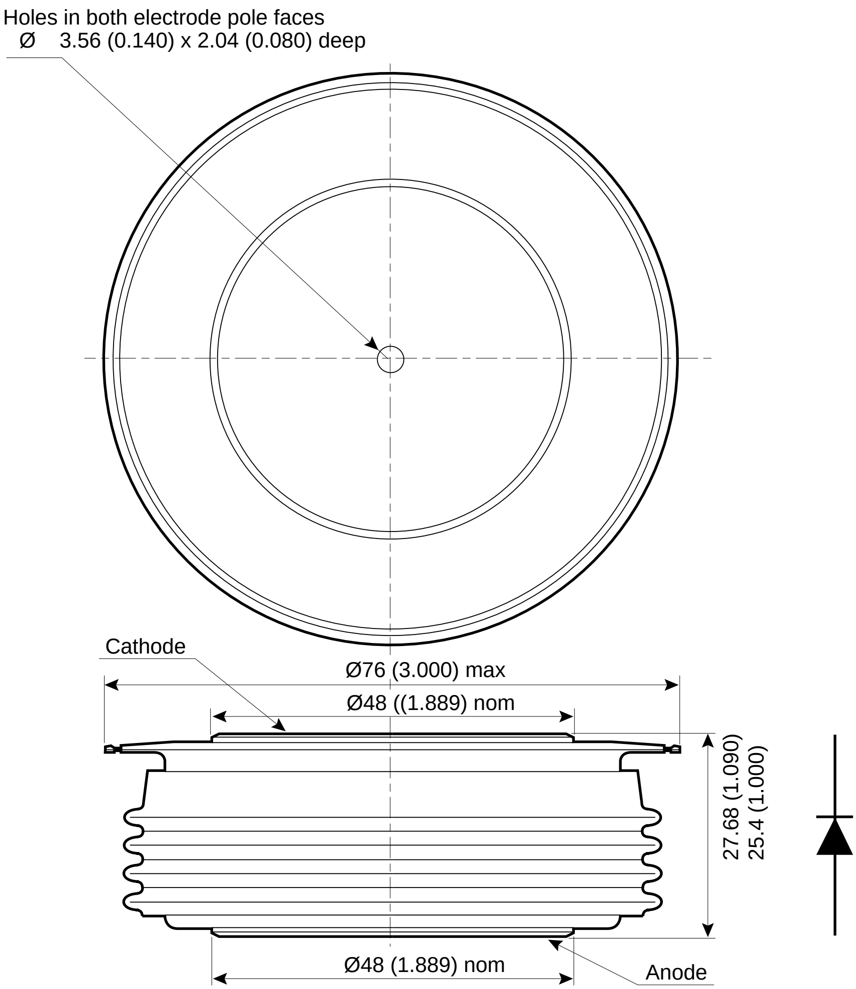
Clamping force: 8.9 kN (2,000 lb)

All dimensions are in mm (inches)

PACKAGE OUTLINE

VRE-5005 ,   5 KV (Vrrm)
VRE-5010 , 10 KV (Vrrm)
VRE-5015 , 15 KV (Vrrm)

Vrrm = max peak repetitive and DC voltage



Nominal weight: 485g (1.07 lb)
Clamping force:22 kN (5,000 lb)± 10%

JEDEC outline DO-200AC

All dimensions in mm (inches)

HIGH POWER 8C-30C SERIES

8kV to 30kV High Voltage Cap-Charging Supplies

This High Power line of high-voltage regulated DC to DC converters is an extension of the C Series, directly addressing the high power density needs of >30 watt applications. High Power 8C - 30C units provide up to 60/125/250 watts. This high power density is especially suited to high-energy systems with large capacitances, fast repetition rates, or high continuous-DC-power requirements. See Application Note 10 for more changing information. Typical applications for the High Power 8C-30C Series include the following: laser, cap-charger, pulse generators, Q-switch, and TDR test equipment.

- 7 models from 0 to 8kV through 0 to 30kV
- 60, 125, or 250 watts of output power
- Maximum Iout capability down to 0 Volts
- Maximum Iout during charge/rise time
- Output short-circuit protection
- Very fast rise with very low overshoot
- High efficiency
- High power to voltage density
- Very low profile
- Output current & voltage monitors
- >200,000 hour MTBF @65°C
- Fixed-frequency, low-stored-energy design
- UL/cUL Recognized Component; CE Mark (LVD & RoHS)

PARAMETER	CONDITIONS		UNITS
INPUT		ALL TYPES	
Voltage Range	Full Power	+ 23 to 30	VDC
Voltage Range	Derated Power Range	60W, 125W: + 11 to 30, 250W: 15-30	VDC
Current	Standby / Disable	< 40	mA
Current	No Load, Max Eout	8C to 15C < 500, 20C to 25C < 600	mA
Current	Max Load, Max Eout	60W: 3.25, 125W: 6.5, 250W: 13	A
AC Ripple Current	Nominal Input, Full Load	< 50	mA p-p

OUTPUT		8C			10C			12C			15C			20C			25C			30C			
Voltage Range	Nominal Input	0 to 8,000			0 to 10,000			0 to 12,000			0 to 15,000			0 to 20,000			0 to 25,000			0 to 30,000			VDC
Power	Nominal Input, Max Eout	60	125	250	60	125	250	60	125	250	60	125	250	60	125	250	60	125	250	60	125	250	Watts
Current	Iout, Entire Output Voltage Range	7.5	15.5	31.2	6	12.5	25	5	10.5	20.8	4	8.3	16.7	3	6.25	12.5	2.4	5	10	2	4.17	8.33	mA
Current Scale Factor	Full Load	4.7	14.2	6.25	4.1	10.9	5	4.0	7.4	4.17	4.0	7.5	3.33	.65	.653	2.5	.65	.650	2	.65	.642	1.67	mA/V
Voltage Monitor Scaling		60W & 125W Models - 1000:1 ± 2% into 10MΩ; 250W Models - 10,000:1 ± 2%																					-
Internal Capacitance	Capacitance / 95% Decay (50Meg Load)	4400/659	2200/330	1500/225	2933/439	1467/220	1500/225	2933/439	1467/220	750/112	2200/330	1100/165	750/112	1320/200	880/132	750/112	1100/165	733/110	500/75	825/125	550/85	500/75	pF/mS
Ripple	Full Load, Max Eout	< 1%												< 1%									V p-p
Rise Time	Max Iout, Various C Loads & Eout	Figure A																					-
Storage Capacitance	Internal	4400	2200	1500	2933	1467	1500	2933	1467	750	2200	1100	750	1320	880	750	1100	733	500	825	550	500	pF
Overshoot	C Load, 0 Eout to Full Eout	< 1%																					V pk
Line Regulation	Nom. Input, Max Eout, Full Power	< 0.01%																					VDC
Static Load Regulation	No Load to Full Load, Max Eout	< 0.01%																					VDC
Stability	30 Min. warmup, per 8 hr/ per day	< 0.01% / < 0.02%																					VDC

PROGRAMMING & CONTROLS		ALL TYPES	
Input Impedance	Nominal Input	+ Output Models 1.1MΩ to GND, - Output Models 1.1MΩ to +5 Vref	MΩ
Adjust Resistance	Typical Potentiometer Values	10K to 100K (Pot across Vref. & Signal GND, Wiper to Adjust)	Ω
Adjust Logic	0 to +5 for +Out, +5 to 0 for - Out	+4.64 VDC for +Output or +0.36 for -Output = Nominal Eout	-
Output Voltage & Impedance	T=+25°C	+ 5.00VDC ± 1%, Zout = 464Ω ± 1%	-
Enable/Disable		0 to +0.8V Disable, +2.0 to 32 Enable (Default = Enable)	VDC

ENVIRONMENTAL		ALL TYPES	
Operating	Full Load, Max E out, Case Temperature	-40 to +65	°C
Coefficient	Over the Specified Temperature	±50 (±25 Optional)	PPM/°C
Thermal Shock	Mil-Std-810, Method 503-4, Proc. II	-40 to +65	°C
Storage	Non-Operating, Case Temp.	-55 to +105	°C
Humidity	All Conditions, Standard Package	0 to 95% non-condensing	-
Altitude	Standard Package, All Conditions	Sea Level through 70,000	ft
Shock	Mil-Std-810, Method 516.5, Proc. IV	20	G's
Vibration	Mil-Std-810, Method 514.5, Fig.514.5C-3	10	G's

Specifications subject to change without notice.

C = uF
V = Volts
I = mA
T = mS

$$T = \frac{C \times V}{I}$$

C = uF
V = kV
I = mA
F = Hz

$$I = C \times V \times F$$

C = uF
V = kV
I = mA
F = Hz

$$F = \frac{I}{C \times V}$$

C = uF
E^2 = kV
J = Ws

$$J = \frac{C \times E^2}{2}$$

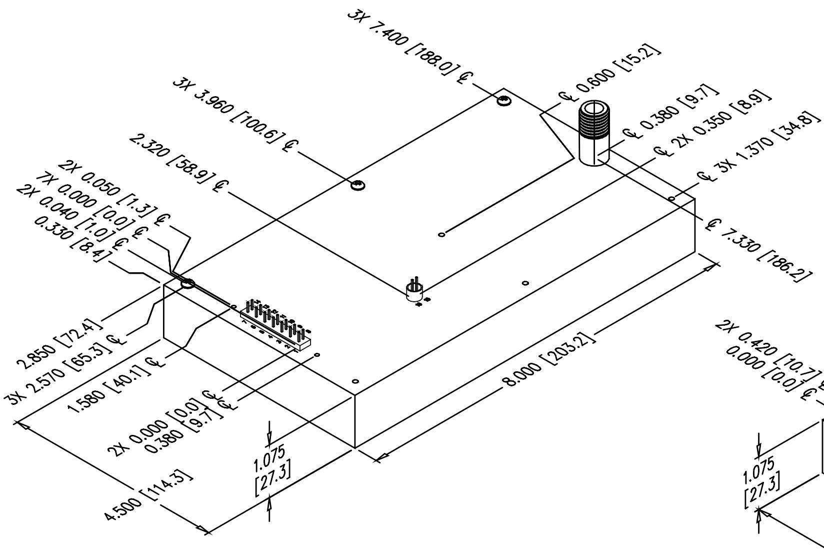
Figure A - Rise Time Formulas

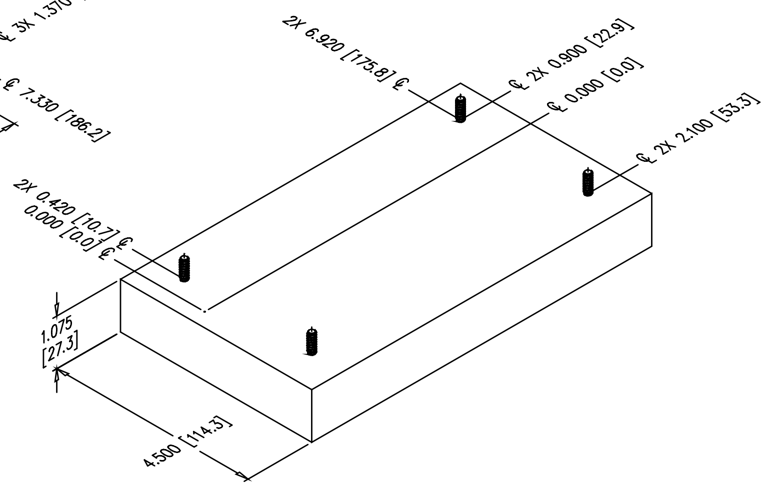
NOTES: Capacitance must include HVPS internal Capacitance.

HIGH POWER 8C-30C SERIES

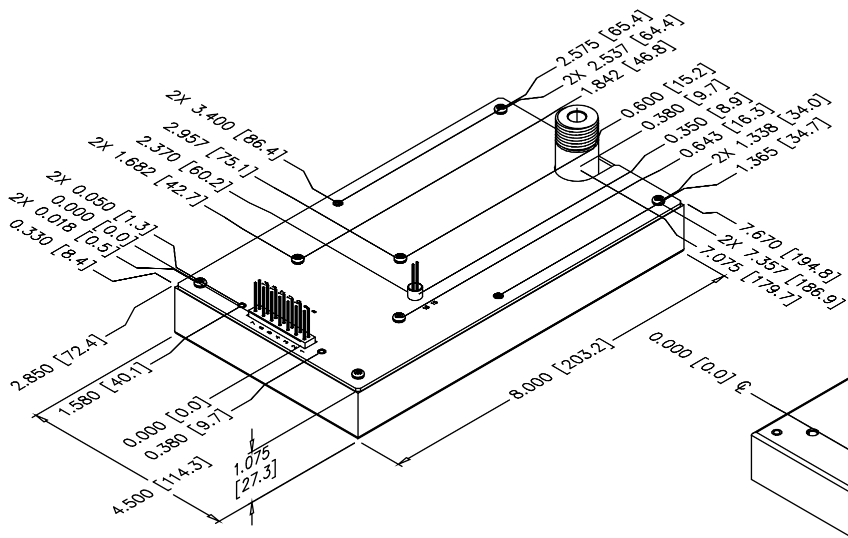
8kV to 30kV High Voltage Cap-Charging Supplies

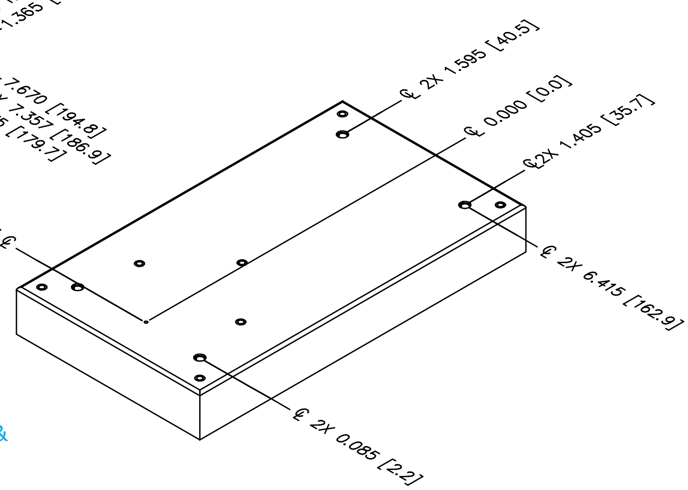
8C TO 15C - 60/125W





20C TO 30C - 60/125W



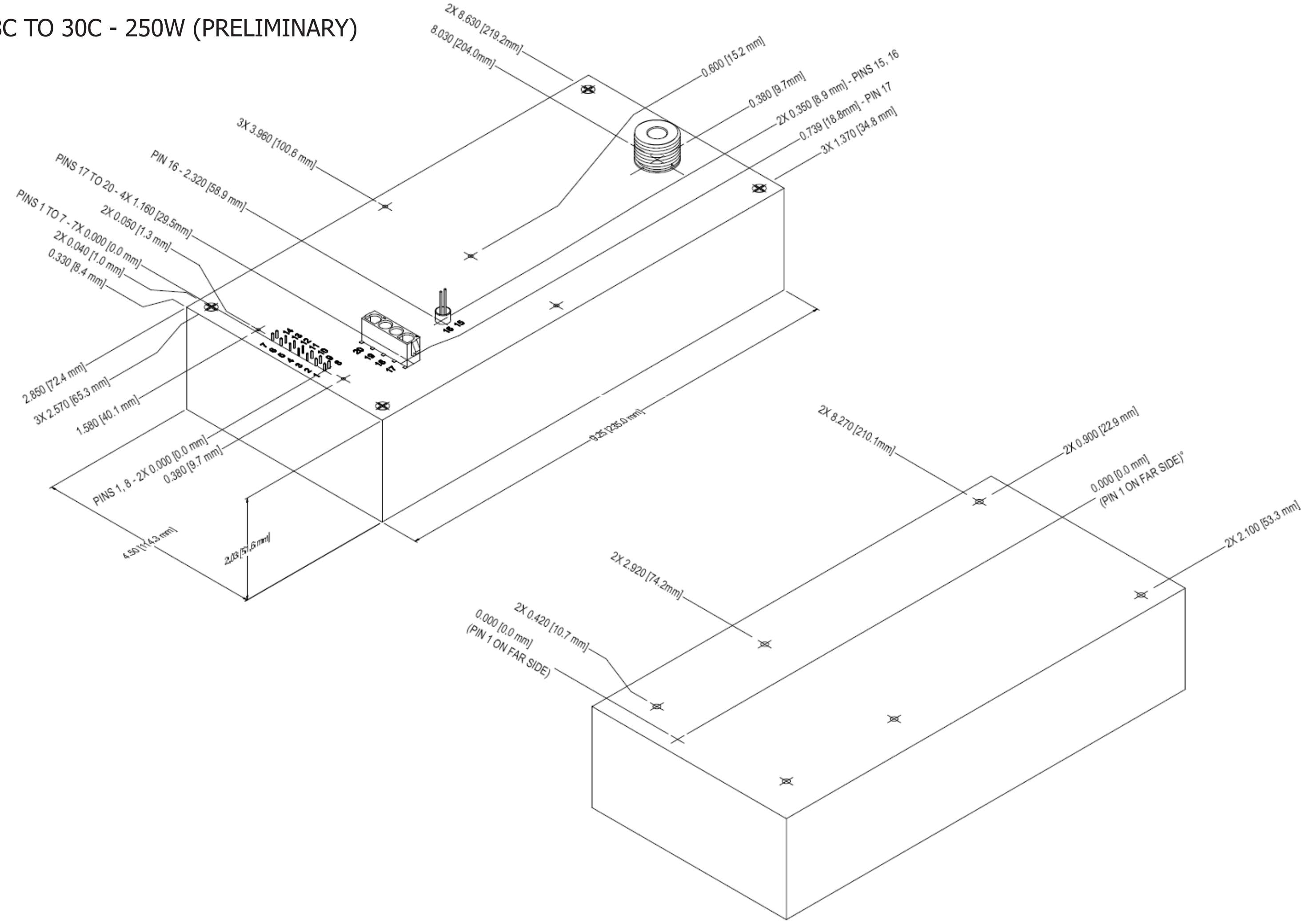


Downloadable drawings (complete with mounting & pin information) and 3D models are available online.

HIGH POWER 8C-30C SERIES

8kV to 30kV High Voltage Cap-Charging Supplies

8C TO 30C - 250W (PRELIMINARY)



CONSTRUCTION

Epoxy-filled Aluminum Box
Chem film per MIL-A-8625 Type II (Anodizing)

SIZE - 60 & 125W MODELS

Volume 38.7 in³ (634cc)
Weight 2.6 lbs. (1.18kg)

SIZE - 250W MODELS

Volume 84.5 in³ (1386cc)
Weight 5.6 lbs. (1.18kg)

TOLERANCE

Overall ±0.025" (0.64)
Pin to Pin ±0.015" (0.38)
Hole to hole location ±0.025" (0.64)

PINS

Gold-plated 0.025 (0.64) sq.
The center of the pins and mounting holes are located from the center of pin 1
Pins 1 thru 14 spacing 0.100 (2.54) x 0.200 (5.08) on center,
height from cover 0.280 (7.11) min
Pins 15 and 16 spacing 0.100 (2.54) on center,
height from cover 0.450 (11.43) min

HV OUTPUT CONNECTION

Unit requires an LGH flying lead connector for proper operation:
8C to 15C (60W & 125W Models) = CA-20KV-1000
20C to 30C (60W & 125W Models) = CA-40KV-1000
8C to 30C (250W Models) = CA-40KV-1000

HIGH POWER 8C-30C SERIES

8kV to 30kV High Voltage Cap-Charging Supplies

CONNECTIONS	
PIN	FUNCTION
1 & 8	Input-Power Ground Return
2 & 9	Positive Power Input
3	Iout Monitor
4	Enable/Disable
5	Signal Ground Return
6	Remote Adjust Input
7	+5VDC Reference Output
10	N/C (or Arc Detect option)
11, 12, & 13	N/C
14	Eout Monitor
15 & 16	HV Ground Return

All grounds joined internally. Power-supply mounting points isolated from internal grounds by >100kΩ, .01uF / 500V (Max).

ORDERING INFORMATION		
Type	0 to 8,000 VDC Output	8C
	0 to 10,000 VDC Output	10C
	0 to 12,000 VDC Output	12C
	0 to 15,000 VDC Output	15C
	0 to 20,000 VDC Output	20C
	0 to 25,000 VDC Output	25C
	0 to 30,000 VDC Output	30C
Input	24VDC Nominal	24
Polarity	Positive Output	-P
	Negative Output	-N
Power	60 Watts Output	60
	125 Watts Output	125
	250 Watts Output	250
Heat Sink	.400” High (sized to fit case)	-H
PCB Support	(5) 0.187" standoffs on top cover	-Z11
Enhanced Interface	5V Controls and Monitors	-I5
	10V Control and Monitors	-I10
Options	Arc Detect	-AD
	Arc Quench	-AQ
	25PPM Temperature Coefficient	-25PPM

Note: For more information on the enhanced interface options, download the I5/I10 Option datasheet.

Example: 8C24-P125

Type: Voltage, Model

Input

Polarity

Power

Popular accessories ordered with this product include CONN-KIT-HP, BR-7 and BR-8 mounting bracket kits and our full range of high voltage output connectors (see Accessories & Connectors datasheet).

IEC-60950-1

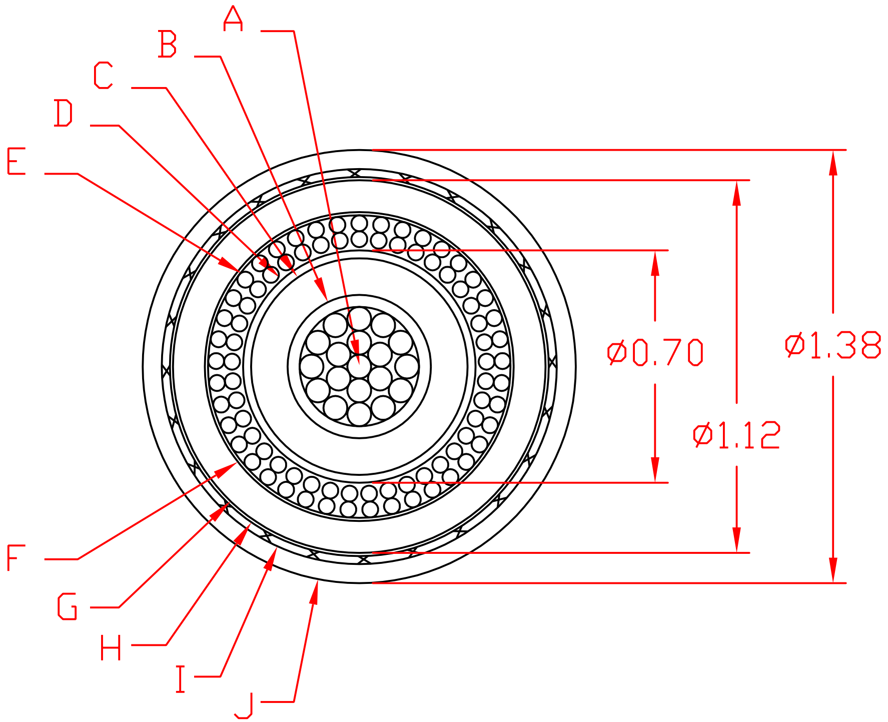
Non-RoHS compliant units are available. Please contact the factory for more information.

Manufactured in USA

Rev. AB 12/14

1800 Ocean Avenue, Ronkonkoma, NY 11779
Phone: 1-631-471-4444 Fax: 1-631-471-4696 www.ultravolt.com

DWG NO. SK160114 REV 1



LEGEND

A. #00 (19 X BARE COPPER COMPACTED), NOMINAL ø 0.376

B. SEMICONDUCTING EPR, ø 0.42

C. INSULATING EPR – ø 0.115 WALL TO ø0.65

D. SEMICONDUCTING EPR, ø 0.70

E. OUTER CONDUCTOR, DOUBLE LAYER, 12 INCH LAY
RHL INNER 41 x #18 AWG (19 x 30AWG T.C.)
LHL OUTER 41 x #18 AWG (19 x 30AWG T.C.)

F. SEMICON TAPE, 2" WIDE, 0.005 THK

G. INSULATING LDHMW POLYETHYLENE 0.100 WALL.

H. SEMICON TAPE, 2" WIDE, 0.005 THK

I. BRAID, #28 AWG T.C., 6 ENDS, 24 CARRIER, 70% COVERAGE.

J. JACKET, PVC, BLACK, 0.06 WALL.

REVISIONS

REV	ECO NUMBER	APPD	DATE

UNLESS OTHERWISE SPECIFIED

DIMENSIONS ARE IN INCHES
TOLERANCE ON

DECIMALS
.XX ±.01
.XXX ±.005

ANGLES
±

CONCENTRICITY .005 TIR
REMOVE BURRS & SHARP EDGES
ALL MACHINE SURFACES 125√

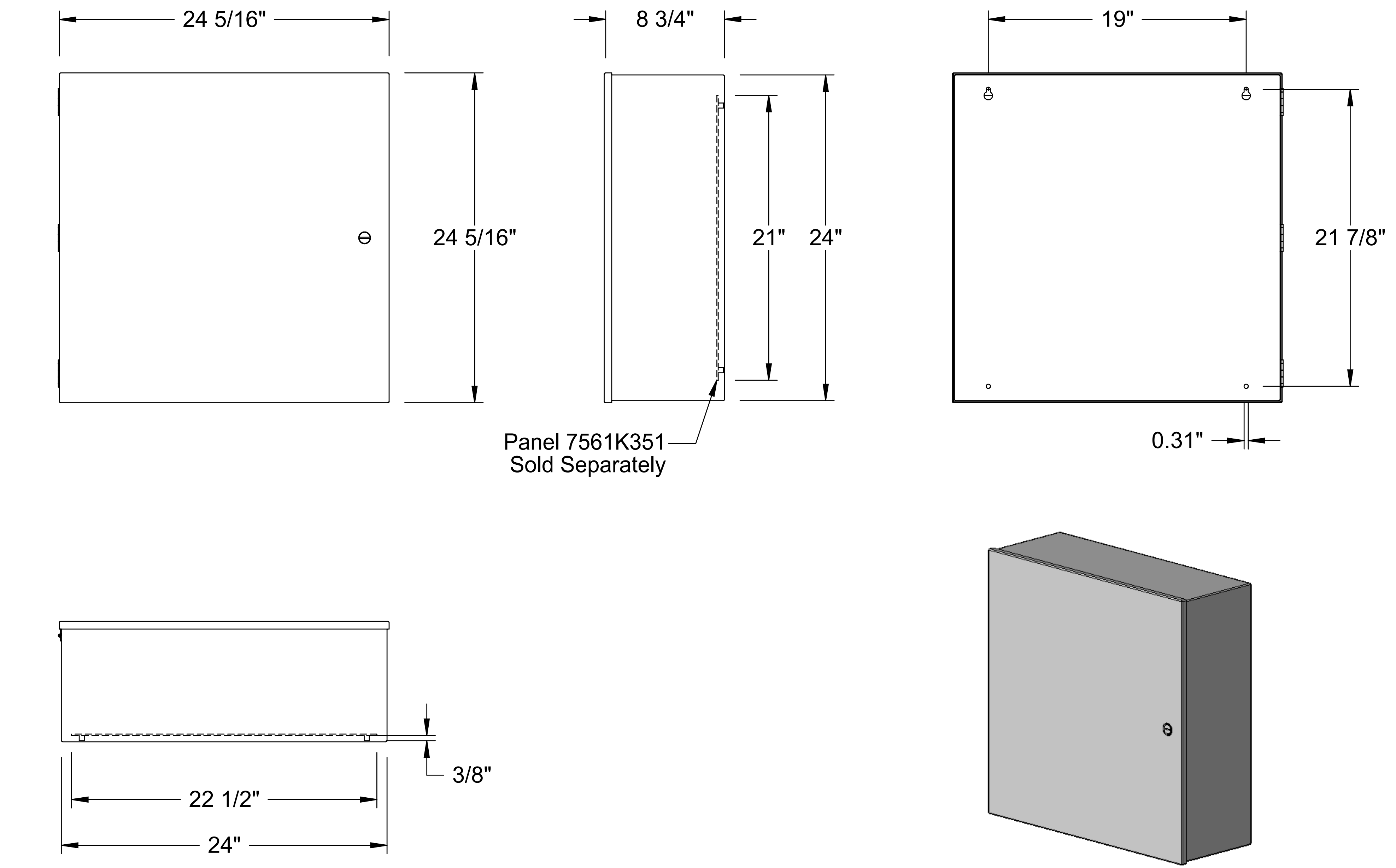
DRAWN D. ABDULKY DATE 14JAN16
CHECKED DATE
APPROVED DATE
MATERIAL
FINISH

DIELECTRIC SCIENCES, INC
CHELMSFORD, MASSACHUSETTS 01824

HV CABLE

SIZE A | FSCM NO. 50509 | DWG NO. SK160114 | REV 1

SCALE | SHEET OF



14-ga Steel (0.0747")
Approximate Internal Dimension: Ht. 23", Wd. 23", Dp. 8 1/8"

McMASTER-CARR	PART NUMBER	7561K64
http://www.mcmaster.com © 2014 McMaster-Carr Supply Company	Indoor Steel Enclosure	
Information in this drawing is provided for reference only.		