CIRCUIT CELLAR ONLINE

THE MAGAZINE FOR COMPUTER APPLICATIONS

Circuit Cellar Online offers articles illustrating creative solutions and unique applications through complete projects, practical tutorials, and useful design techniques.

RESOURCE LINKS

A Guide to online information about:

High Voltage

by Bob Paddock

A couple of items set me on the path to look into the realm of High Voltage this month. The first being that I had a simple home experiment project and needed to power a NE2 (A1A) neon bulb, where I needed to get up to 100VDC to get the bulb to strike, the second being I needed to track down some High-Voltage *AC* capacitors for my job in the Real World. So I thought I'd do this month's topic on High Voltage. When I asked Steve what he thought of the idea, he asked in effect what is 'High'? In some systems today 5VDC is a High Voltage.

Is saying High Voltage like saying, "How high is up?" Does an official definition for High Voltage exist?

When I come up against such a high-voltage question, the first place I turn is usually the High Voltage mailing list. The HV list is archived at http://anchorage.ab.umd.edu/hvlist.html and is currently unindexed and unsearchable, but is collected into months and available for download.

If you're interested in joining this mailing list, e-mail Steve Roys, at hvlist@anchorage.ab.umd.edu or sroys@umaryland.edu. You can also find the Richard Hull/TCBOR Budget Electrometer construction project in the HV list archives.

This is the question I posed on the High Voltage list, and the replies that I received. Slightly edited to remove non-pertinent information:

>I thought I'd do a Resource Page that covered the
>topic of High Voltage.
>This begs the question what is High Voltage?
>Is there an official definition or starting voltage?
>In some of today's modern computer
>systems 5VDC would be considered high
>enough voltage to damage the system.
>If any one has any links to High Voltage sites,
>I'd love to have them. Nothing like having lots
>of people help with your homework
>now is there? :-)
From: Jim Lux ---
My site: http://home.earthlink.net/~jimlux/hv/hvmain.htm

The electrical code considers HV anything over 50 V, 300 V or 600 V, depending on where it is.

Most cheap wire is rated at 300 V. My own general guideline is that when corona and surface leakage become a problem, and you can't just use ordinary hookup wire, it is HV, which is around 3-5 kV.

[Jim covers something I've always personally found interesting: *Electro-optical measurements (Kerr, Pockels, and Faraday)*. All of these techniques rely on various mechanisms by which a material rotates the polarization of light passing through. The amount of rotation depends on the electric or magnetic field.]

Jim's page serves as a repository for all the bits and pieces he is collecting towards creating a modern version of the classic 1954 work by Craggs and Meek: *High Voltage Laboratory Technique.* That work, long out of print, but available from good university libraries, provided a wealth of practical information to those interested in experimentation with high voltage, either for itself, or as a necessary component of some other experiment. However, back in 1954, they didn't have high-voltage silicon rectifiers, nor were such modern construction materials as Teflon, Silicone Elastomers, and fiberglass structural components available.

Maybe you have something that you can contribute to the project.

From: Richard Hull --- No definition of high voltage is suitable. It is, of course, relative.

If one figures HV starts where you get a shock or at least feel the voltage on dry skin, then 50-70 V would be HV. I would think this list considers 1 KV the lowest voltage to call HV, with 10 KV being the point where you are really just starting to talk turkey about high voltage. Many of this list's folks who often discuss van Degraf generators, multipliers, or Tesla coils would probably consider 100,000 V a fairly wimpy high voltage.

A good site to add to your list would be Jochen Kronjaegers web page. http://www.mathematik.unimarburg.de/~kronjaeg/hv/ index.html

From: Antonio Carlos M. de Queiroz ---

A reasonable definition would be: High enough to cause sparks.

This means, in air, electric fields greater than about 30 kV/cm, and voltages above ~300 V (there are no sparks in air at voltages below a value close to 300 V [I don't have at hand the exact value, or how it varies], no matter what the electric field is).

My site about electrostatic machines is at: http://www.coe.ufrj.br/~acmq/electrostatic.html [He has more types of Electrostatic Machines than I knew existed.]

From: Robert Michaels --- "It's all relative."

A hundred volts will seem quite high to someone accustomed to working with, say, 3-V integrated circuits.

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I come from the old school. To me a voltage has to be capable of jumping a gap to be considered high. The minimum voltage required to jump a pair of needle gaps in dry air at STP is approximately 350-V. That is the lowest high voltage (or the highest low voltage—take your pick).

PS: Under reduced pressure, a rather lowish voltage will jump an appreciable gap. For example, 100-V is good for a solid 1/8" jump at around several millimeters of mercury.

This poses quite a problem in the design of airborne electronics for use in high-altitude craft.

It also explains (in part) why cosmic rays can really light up the atmosphere at extreme altitudes but don't do diddly-squat down here at ground level where we could enjoy the show.

Likewise, it's why you have to climb the high mountains (such as Pike's Peak in Colorado) if you want to see really good lightning displays.

From: "Dr. Resonance" ---

In the industrial sense, HV means any potential above 208/220/ 240 VAC. The next level is usually 480 VAC and this is considered high voltage from an industrial standpoint (i.e., for insurance matters, etc.). Companies that sell "Danger: High Voltage" industrial stickers/decals usually start also at the 480-V level (i.e., you can purchase Danger: High Voltage 480 V, but not such stickers for 220 V, etc.).

Rather than the usual disclaimer of **High Voltage Can Lead To Injury**

or Death, I thought I'd put some links to pictures of HV Electrical burns and electrical flash burns, taken from a medical database, to make the point that this hobby (or profession) has the potential to kill those who do not respect the voltages and currents involved.

The pictures gave me nightmares, so I decided against including them. Once you put something like that into your head it is very hard to take it out.

The Department-of-Energy Electrical Safety handbook is worth a review (324 pages, PDF 1543 KB DOE-HDBK-1092-98).

Some other DOE hand books of interest:

DOE Fundamentals Handbook, Classical Physics (142 pages, PDF 1120KB DOE-HDBK-1010-92).

DOE Fundamentals Handbook, Electrical Science, Volume 1 of 4 (166 pages, PDF 4255KB, DOE-HDBK-1011/1-92).

DOE Fundamentals Handbook, Thermodynamics, Heat Transfer, and Fluid Flow, Volume 1 of 3 (138 pages, PDF 2994 KB, DOE-HDBK-1012/1-92).

Other Online Approved DOE Technical Standards can be found here.

To see a good FAQ on High Voltage safety, go to:
http://www.pupman.com/safety.htm

The first approach I tried for my Neon Bulb power supply was to use National Semiconductor's LM317HV part, based on their Linear Brief #47 High Voltage Adjustable Power Supplies (pdf). Although the circuit worked, it had the annoying habit of exploding every once in a while when turning it on. That is the price you pay for using leftover transistors from the junk box. After rebuilding the circuit a couple of times, I decided that there must be alternatives to this High-Voltage regulator circuit.

I found that the Texas Instruments TL783 adjustable three-terminal High-Voltage regulator had the output range of 1.25 V to 125 V that I was looking for. The circuit worked fine, no more random explosions at powerup, but I was still not happy. The TL783 has a minimum load requirement of 15 mA to maintain regulation. My Neon Bulb load required at most 1 mA, leaving me to waste 14 mA. Because I wanted to run off of a series of 9-V batteries, this did not make me a happy camper.

I finally found the solution in Supertex's Constant Current Sources and Depletion-Mode FETs application notes AN-D16 (pdf) and AN-D18 (pdf). [For those not familiar with Depletions-Mode FETs, these FETs are normally on. Most of the FETs you see in 99% of circuits are Enhancement-Mode FETs that are normally off.]

Supertex's entire line of products, such as FETS and ICs, is oriented toward the High-Voltage (up to 500 V) spectrum. They also have a

many useful High Voltage application notes, such as ±500 Volt Protection Circuit and High Voltage Ramp Generator.

High Voltage Component Suppliers:

Bertan High Voltage is the world leader in high-voltage power supplies and can meet virtually every power supply requirement, from lab to OEM. Their industrial customers use Bertan standard and/or custom product in applications as diverse as: medical instrumentation, medical x-ray imaging, analytical x-ray, elemental analysis, semiconductor fabrication, precision CRT displays, biochemistry instrumentation, nuclear instrumentation and detectors, scanning electron microscopes, ATE, E-Beam and I-Beam applications.

Caddock Electronics Inc. manufactures precision resistors and resistor networks. Caddock uses unique film and process technologies to create solutions for harsh environments, high-power density, and long-term stability. The product line consists of over 250 models, including high-voltage resistors, current-sense resistors, chip resistors, high-frequency resistors, RF resistors, load resistors, pulse resistors, non-inductive power resistors. Custom resistors and resistor network solutions are also available.

CERA-MITE Corporation offers two extensive families of electronic devices—Ceramic Disc Capacitors and PTC Thermistors.

Custom Electronics, Inc. manufactures high-voltage mica paper capacitors and electronic modules.

Citel is now the world's third largest manufacturer of surge arrester gas tubes. Citel is also a major supplier to the wireless industry and has developed a complete surge protection package for AC power, T1, and coaxial cables.

DynaOptic Motion offers a line of High-Voltage Ringactuators.

EBG is a leading manufacturing resource of standardized and customized precision, high-voltage, high-power non-inductive thick film resistors.

EMCO High Voltage Corporation claims to have the world's smallest 5,000-V power supply at just 0.125 cubic inches.

Electronic Devices, Inc. offers High-Voltage diode assemblies, such as 3 A @ 50 kV. They also offer special devices such as night vision diodes and arrays.

HV Component Associates, Inc. and CKE Inc. specialize in custom devices, as well as High-Current rectifiers, Selenium surge suppressers, MOVs, TVPs, and Full Wave Bridges.

Hitachi High Voltage/Fast Recovery Diodes (up to 12 kV).

High Voltage Film Capacitor

High Voltage Technology: High Voltage products for science and industry HVT represents a number of manufacturers worldwide, bringing together an impressive list of principals and serving customers needs with these High Voltage products:

- Capacitors - NWL Inc.
- Cable - Dielectric Sciences Inc.
- Diodes - HVCA Inc.
- Resistors - Victoreen Inc.
- Pulse transformers - Stangenes Industries Inc.
- Isolation transformers
- Attenuators - Barth Electronic Inc.
- Pulse generators - Kentech Instruments Ltd.
- Rotary switches - High Voltage Technology

INSTEC offers High-Voltage multilayer SMT ceramic chip capacitors in voltages up to 5 kV.

The business of John Chubb Instrumentation is the design, development, manufacture, and marketing of high-performance instruments for electrostatic measurements. The JCI 131 Electrostatic Fieldmeter is particularly suitable for long-term continuous monitoring of atmospheric electric field conditions—such as those associated with thunderstorm and volcano activity.

K and M Electronics, Inc. has a number of High Voltage items such as power supplies, electron multipliers, and components—precision high-voltage resistors, ceramic capacitors, diode arrays, voltage dividers, and custom hybrids.

Kilovac is a supplier of all types of high-voltage and radio-frequency relays.

Lambda Electronics, the Lambda Group can provide power solutions ranging from a few watts of DC, to DC on a single chip, to over 1 MW of High Voltage in a turnkey system, as well as capacitor charging power supplies.

Kurt J. Lesker Company deals in vacuum equipment.

Maxwell Energy Products, Inc. makes High-Voltage capacitors, High-Voltage fuses, and High-Voltage resistors. Alas, it took me a long time to actually find the relevant web site from their home page. Surplus Sales of Nebraska gave me the relevant information about Maxwell High-Voltage capacitors that I needed quickly, rather than a lot of non-relevant financial information. Too bad more engineers don't design web sites for these companies.

Maxwell also makes capacitor charging power supplies, spark gap switches, trigger generators, arc lamp power supplies, and nuclear event detectors.

In some areas of High Voltage there are items that don't exist "off the shelf" and you have to build them yourself. Tedd Payne sells some of the most interesting High-Voltage parts you're likely to need. There are

also items wanted (to buy or trade for) and automatic update notification of newly listed items available from Tedd's site. Check his links to other HV sites as well.

Radio Materials Corporation has a nice table to be used as a Ceramic Capacitor Guide.

ROSS Engineering Corporation of Campbell, California, designs, tests, and manufactures High-Voltage Devices. Systems, control, measurement and safety equipment, and energy sources are marketed world-wide. Typical applications are in HV power supplies, cyclotrons, lasers, radar, TV, and high power communication transmitters; almost any equipment, industrial plant or utility where high voltage or high current is utilized.

Spellman High-Voltage Electronics is your source for high-voltage power supplies for OEM, laboratory, and PCB mount applications.

ULTRAVOLT®

UltraVolt, Inc. is a world-leading manufacturer of High-Voltage power supplies ranging from 62 V to 35 kV, in miniature "palm of the hand" sizes for power levels ranging from 4 to 250 Watts.

VMI Voltage Multipliers, Inc.
8711 W. Roosevelt Ave. Visalia, CA 93291
Phone: (559) 651-1402 • Fax: (559) 651-0740

With the name of Voltage Multipliers Inc., you can probably guess that they sell voltage multipliers, but they also sell, diodes, rectifier assemblies, and power supplies.

Welwyn Components has High-Voltage/High-Value Resistors (Over 1 GOhms, up to 50 kV).

Charles Brush's electricity page has pictures of HVcomponents as well as covering Tesla Coil, Arc Lamps, Jacob's Ladders, Stress Tests, and

Cooking With HV.

Applications of High Voltage:

We've all seen them as we drive along the road, the big substation transformers. But, if you don't work in the industry you probably never knew where to buy this kind of equipment, until now.

ABB is a globalized technology and engineering company serving customers in power transmission and distribution. They have a paper *Why HVDC?* giving the reasons behind a choice of HVDC instead of AC in the cases of power distribution. You can learn more about HVDC in the tutorial "Understanding HVDC."

The Instrument Transformer of ALSTOM Transmission and distribution satisfies all of the needs for metering or relaying applications in high-voltage networks.

The Electricity Forum Web Site covers, you guessed it, electricity. More accurately, the electricity industry.

ElectricNet[tm] has a link directory, a buyers guide, and a resource locator for the electrical power industry. . . thousands of links . . .

If you design, manufacture, construct, startup, test, repair, service, calibrate, maintain, or sell electrical equipment, power apparatus, plant electrical facilities or generation, transmission or distribution equipment or systems, ElectricNet's 5,500+ pages are your gateway to valuable industry information.

Does your job seem like something right from a Dilbert cartoon? Maybe you'd like training in a new field? Graduates from the High Voltage electricity program can look forward to and expect career opportunities with public service companies, utility construction companies, and power generating companies.

High Voltage control and monitoring tutorial.

Bob Kruger has a tutorial x-ray production, one of the areas where High Voltage is used.

Snock's High Voltage Page covers several items of interest, especially the tables of dielectric and magnet wire.

High Voltage Generating Circuits
• Things you can do with high voltage:

- Plasma globe
- Jacob's ladder
- Electrophotographs Kirlian-like, uses thermal fax paper

• Other information and tables:

- Safety hints
- Flyback types to look for

- Transformers to look for
- Dielectric table of common and not so common materials
- Magnet wire table
- Spark length voltage measurements.

The Department of High Voltage Technique at the Universities of Kosice covers High-Voltage technique, degradation of High-Voltage elements, measuring methods in High-Voltage engineering, Electric eliminators and separators, diagnostics of High-Voltage and ultra High-Voltage equipment, computer networks and electronic equipment over-voltage protection.

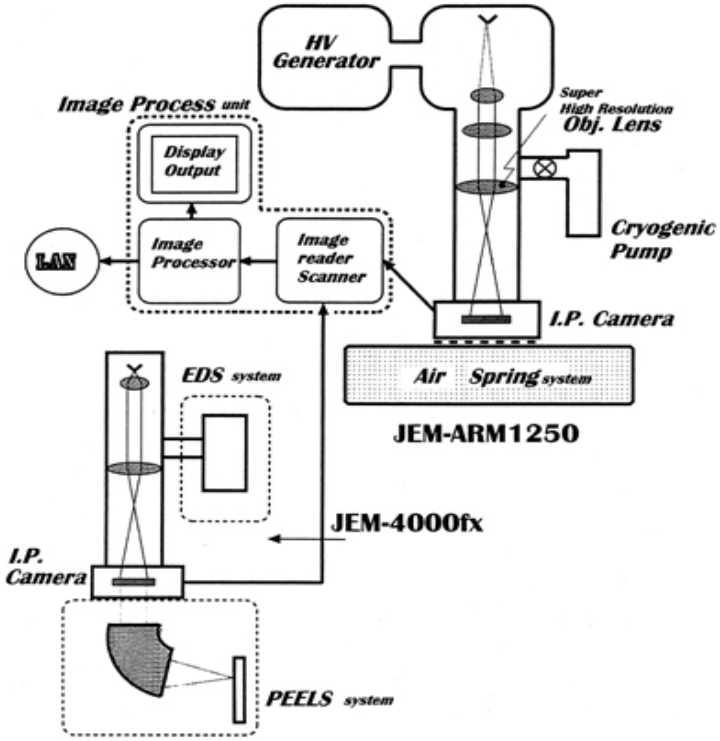
The High-Voltage Association web site is a resource of High-Voltage Information for use within the electronic original equipment Market. They have links to numerous High Voltage supplies, as well as a Message Board.

Papers related to High-Voltage engineering written by faculty and staff members and students affiliated with Mississippi State University High-Voltage laboratory can be found here.

Electrostatic Applications Website provides a broad range of services related to the field of electrostatics. The Electrostatic Source Bookstore is particularly educational.

PV Scientific Instruments is a repository of scientific instruments, information, and technological services relating to the early history of electricity, magnetism, and atomic physics. They also offer a comprehensive selection of reprints of classical masterworks on topics related to the construction and use of early electrical devices.

While you're probably not going to be building a High-Voltage Electron Microscope Laboratory in your garage or basement, it is a interesting mix of technologies.



The Farnsworth Chronicles

Glubco has some of the most detailed pictures of fusors that I came across, but be warned these pictures are big and slow to load. They have this to say about High-Voltage fusor work:

> In the presence of the proper atmosphere and at high enough voltages, the Fusor is capable of actually doing fusion. It was invented by Philo T. Farnsworth, inventor of the television, in the 1960's. Today his research is being rekindled for many reasons. One application currently being utilized is that of neutron generation. Massive accelerators or radioactive material has always been needed for the production of neutrons. However, similar Fusor systems being studied are currently capable of over 10^9 neutrons/second and are small enough to be easily transported. This technique of doing fusion is called Inertial Electrostatic Confinement (IEC). It eliminates the need for massive superconducting magnets and costly facilities for doing simple fusion research. Perhaps one day this method will lead to a better than break-even fusion process for nuclear power.

Fusion Message Board

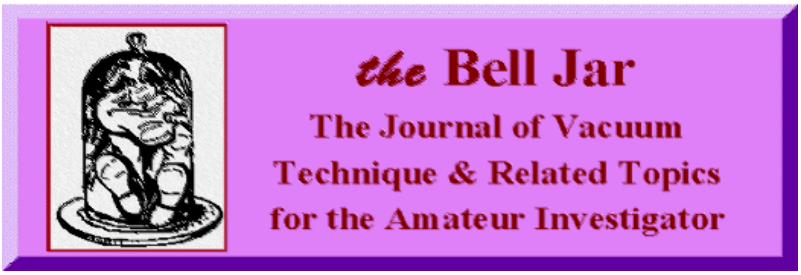
In this space, visitors are invited to post any comments, questions, or skeptical observations about Philo T. Farnsworth's contributions to the field of Nuclear Fusion research.

Bert Pool has information on Philo T. Farnsworth, such as his patents, including ion pumps, and his Nuclear Fusion Plasma devices. Bert has

among his High Voltage construction projects: "Powerful UV Laser Plans: A pulsed cross-field molecular nitrogen laser."

More fusor related links can be found at fus.x0r.com, pronounced fusor.com.

Because air itself can be a conductor, many High Voltage experiments are done in vacuum.



Vacuum enthusiasts can find helpful, practical information, including articles, announcements and more links, on the Bell Jar's home page. The site which is dedicated to the perfection of nothing.

Also check out the bimonthly magazine *Vacuum Solutions* from the *Institute of Physics Publishing*. This magazine is more oriented to the laboratory scientist.

Kurt J. Lesker Company deals in vacuum equipment.

LDS Vacuum Products, Inc. has a useful Conversion Factors For High Vacuum table.

Vacuum Equipment New - Used - Rebuilt.

Vacuum-less Plasma Sphere Secret

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some natural High-Voltage phenomenon:

Red Sprites and Blue Jets http://www.cnn.com/NATURE/9904/05/sprites.enn/

The Global Atmospherics people have some interesting Lightning Information on their site.

David Tweed's unofficial *Circuit Cellar Index* shows that lightning has been a frequent topic in *Circuit Cellar Magazine*.

Photopixels has some beautiful pictures of lightning.

Scientific American, Inc. has covered some interesting areas:

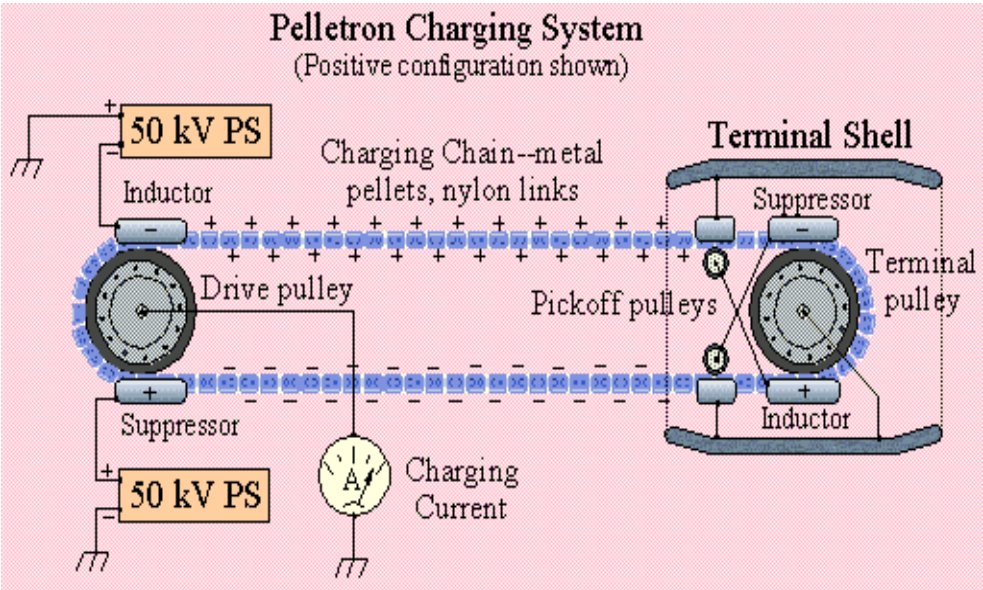
Detecting the Earth's Electricity by Shawn Carlson.

Getting a Charge out of Rain by Shawn Carlson.

Wenzel Associates, Inc. has a few simple-to-build Weather Circuits.

• Lightning Detector (HTML) Detects radio pulses from approaching lightning storms!
• Rain Detector (15k pdf) [12/95] Stick this out the window instead of your hand.
• Liquid Barometer (HTML) This liquid barometer features a temperature-controlled air chamber for excellent accuracy.
• Cloud Charge Monitor (59.4k pdf) [10/96]. Watch the electrical charges dance in the clouds above during a thunderstorm!

The highest man-made voltage that I came across in working on this Resource Page seems to be the Pelletron® charging chain used in NationalElectrostatics Corporation devices. These are an improvement over the older Van de Graff charging belts. The chain does not limit ultimate terminal potential, and it is in use in electrostatic accelerators up to and above 25 MV.



Oak Ridge National Laboratory (ORNL) is one of the users of Pelletron charging systems. Doing a search for "High Voltage" at ORNL yields over 300 related documents. As one example: Compact Arrangement of High Voltage Grading Resistors with Surge Protection.

The High-Voltage and Electromagnetic Compatibility Section at the Eindhoven University of Technology (TUE) in the Netherlands has some interesting abstracts like *Pulsed corona, a new technology to clean gas and liquid flows*.

Y96 DoD SBIR Phase I Awards ---------- Agency: DARPA ----------

ALAMEDA APPLIED SCIENCES CORP.
6250 Bullard Drive
Oakland, CA 94611
PI: Rahul Prasad
Topic#: DARPA 95-008

Title: High Voltage, High Power Diamond Solid-State Switch for Pulsed Power and Other Applications

Abstract:

> Alameda Applied Sciences Corporation (AASC) proposes a three phase effort with the ultimate goal of producing a marketable diamond switch suitable for several pulsed power and other applications in the defense arena. The presently used spark gaps have several drawbacks including switch jitter, large and variable inductance, lifetime and physical size. A low inductance solid-state switch capable of switching 100 kV, 100 kA at a high repetition rate would be desirable. The physical and electrical properties of diamond make it uniquely suited to very high power electrical switching applications. Electron beam controlled diamond switches have been demonstrated at moderate (22 kV) voltages and current densities >5 kA/cm2. Diamond, normally a good insulator, can carry large currents when electron-hole pairs are created by the absorption of an energetic electron beam. The objectives of the Phase I research is to study the switching properties of diamond under high field stress (1-10 MV/cm) to develop a design for a practical diamond switch. The switch will be fabricated and validated in Phase II.
>
> Commercialization is planned for Phase III. Anticipated Benefits: DoD's pulsed power supplies for nuclear weapons effects simulators and other applications including high power lasers would benefit from the low inductance, low jitter, fast rise-time, high-power diamond switch to be developed under the proposed effort. Potential applications include switching systems for the nation's power grid, high power accelerators, the More Electric Aircraft, automobiles, and drilling rigs.

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*A Regulated 2400-VDC Power Supply: Look at this great power-supply idea. SCRs on the transformer primary adjust input duty cycle based on output voltage. Output voltage drops about 3 V with a 1 kW Load! by A. R. (Al) Williams, VE6AXW,*appeared in the July/Aug 1999 issue of *QEX*.

QEX is the ARRL's "Forum for Communications Experimenters." Published bimonthly, it features technical articles, columns, and other items of interest to radio amateurs and communications professionals.

Dr. Tesla probably deserves a Resource Page of his own, but one cannot help run into his work when looking for information on High Voltage. So until a Tesla Resource Page comes to light, check out the Tesla Coil WebRing.

A WebRing links member web sites together to form their sites into linked circles. Their purpose: to allow more visitors to reach them quickly and easily. To your benefit, you can locate related sites that don't always show up in the Search Engines.

Some of the following applications of High Voltage are, to say the least, odd. Even if you don't agree that the application is possible in the realm of accepted physics today, don't overlook the fact that the methods used for generating the required High Voltage power supplies are still valid.

Jean-Louis Naudin in France builds some of the coolest experiments I've ever seen. For example, his Poynting Flow Thruster project (PFT motor mk1) runs on 24 uA of current at 28 kVDC (672 mW). His Quest of OVERUNITY and ElectroGravitic Research sites have some interesting High-Voltage applications as well.

One cannot bring up ElectroGravitic Research and not bring up The Thomas Townsend Brown Site.

Brown, as a young student working under Dr. Biefeld, discovered what has become known as the Biefeld-Brown Effect in conventional physics. The tendency for a highly charged (50 kVDC to 300 kVDC), high-K dielectric capacitor to move in the direction of its positive plate. [If anyone has info on high-K dielectric let me know.]

If anyone still has a doubt about electrostatic type motors, you might find some of the items by Dr. Oleg D. Jefimenko at the Department of Physics Morgantown, WV, enlightening.

If none of those items get your head banging then maybe some Electrostatic Loudspeakers will.

KIRLIAN ZONE All aspects of High-Voltage photography

There is also a message board that covers Kirlian Photography.

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electric space craft

The Electric Space Craft Journal. A network of interactive research seeking electrodynamic field propulsion techniques for space travel by investigating electrostatics, electromagnetics, atomic physics, gravity, inertia, energy, and aether concepts. To learn about NASA's visionary program to promote research toward the development of alternatives to jet propulsion, visit the Breakthrough Propulsion Physics pages:

http://www.lerc.nasa.gov/www/bpp or
http://www.lerc.nasa.gov/WWW/PAO/warp.htm

Fred's Wonderful World of Science covers such items as:
- Resonance Spectral Analysis with a home-built Cyclotron
- Demonstrating Particle Mass Resonance with a home-built Cyclotron
- Subatomic Particle Interactions with a 100 keV Linear Accelerator
- Plasma: The Fourth State of Matter

The Science Centre and Planetarium located in Wollongong in New South Wales, Australia, describes the Van de Graaf Generator:

> The Van de Graaf Generator has three main sections, the base platform, the shaft, and the bulb. The shaft has a belt running inside it in a continuous loop. The belt picks up an electric charge at the base of the generator. This charge is carried to the top where it is passed on to the

bulb. The upper section consists of a large metallic bulb, which becomes charged with static electricity.

When a person stands on a sheet of insulating plastic on the platform, the charge is passed on to them. As a result, the person's hair, and sometimes shoelaces, stand on end. Because the body has the same charge all over, in effect certain parts of the body try to repel each other.

Sparkmaker's Page has step by step construction plans for your own Van De Graaf Generator.

If you would like to add any information on this topic or request a specific topic to be covered, contact Bob Paddock.

Circuit Cellar provides up-to-date information for engineers. Visit www.circuitcellar.com for more information and additional articles.