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## ABSTRACT

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This white paper outlines the theory, architecture, physics, and deployment methodologies of the Solid-State Radiant Discharge Circuit (RDC-SS). The RDC-SS represents a modern, wide-bandgap semiconductor modernization of historical high-voltage transient circuits developed in the 1970s and 1980s by inventors such as Edwin Gray. By substituting legacy, unstable mechanical spark gaps with high-speed Silicon Carbide (SiC) switches, the platform achieves sub-10-nanosecond voltage rise times ( $dV/dt$ ). This rapid transition exploits the electrodynamic phenomenon of displacement current, allowing localized energy transfer through dielectric mediums with zero conduction-based thermal losses. This document provides the foundational equations, material interaction matrices, dual-module system topologies, and energy recycling mechanics required for open-source engineering replication and infrastructure scaling.

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## 1. HISTORICAL CONTEXT: LEGACY TRANSIENT PHYSICS

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During the late 20th century, physical research into high-voltage, abrupt transient discharges revealed unique phenomena that deviated from steady-state alternating current (AC) or direct current (DC) systems. Historical prototypes, most notably Edwin Gray's "Electric Element" switching configurations, utilized high-voltage capacitive reservoirs discharged rapidly across pneumatic carbon spark gaps into specialized conversion elements.

While these historical platforms demonstrated unusual material interactions—such as driving mechanical actions or ionizing gases while remaining entirely cold to the touch—they suffered from systemic instability. Mechanical spark gaps are highly sensitive to atmospheric pressure, relative humidity, electrode erosion, and timing jitter. These variables prevented precise frequency control and made reproduction outside a specialized laboratory impossible.

The RDC-SS overcomes these historical limitations by translating legacy electrodynamic mechanics into modern Wide-Bandgap (WBG) solid-state architecture. Utilizing high-voltage Silicon Carbide (SiC) MOSFETs and isolated gate drivers, the system replicates the abrupt, steep-fronted voltage transients of an arc discharge with microsecond timing accuracy and infinite mechanical durability.

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## 2. OPERATIONAL PRINCIPLES & FOUNDATIONAL PHYSICS

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Conventional electrical engineering focuses almost exclusively on conduction current—the physical drift of free electrons through a metallic conductor. The RDC-SS shifts the operational focus to displacement current and spatial electromagnetic energy fields.

## 2.1 The Displacement Current Mechanic

When a high-voltage pulse is applied to an insulator or dielectric material, electrons cannot flow freely through it. Instead, the local atomic structures polarize, stretching their electron clouds in response to the electric field. This dynamic polarization behaves exactly like a current flow and is called displacement current ( $I_d$ ).

The mathematical expression for displacement current is:

$$I_d = C * (dV / dt)$$

Where:

- \*  $I_d$  = Displacement current (Amperes)
- \*  $C$  = Capacitance of the target dielectric geometry (Farads)
- \*  $dV / dt$  = The time-varying rate of change of the voltage (Volts per second)

A related expression for the displacement current density ( $J_d$ ) through a physical medium is:

$$J_d = \epsilon * (dE / dt)$$

Where:

- \*  $J_d$  = Displacement current density vector
- \*  $\epsilon$  = Permittivity of the dielectric material
- \*  $dE / dt$  = The time-varying rate of change of the electric field vector

The Core Engineering Advantage:

In standard electronics, increasing current ( $I_d$ ) requires increasing voltage ( $V$ ) or capacitance ( $C$ ), both of which increase thermal strain and component footprint. The RDC-SS leaves voltage and capacitance at reasonable baselines and instead manipulates the time denominator ( $dt$ ). By executing switching cycles using Silicon Carbide gates that open or close in less than 10 nanoseconds, the value of  $dt$  approaches an infinitely small fraction. This causes the total  $dV/dt$  term to explode mathematically, generating immense displacement currents at the dielectric boundary without flowing physical electrons.

## 2.2 Spatial Energy Flow and the Poynting Vector

According to classical electrodynamics, electrical energy does not travel inside the copper bulk of a wire like water in a pipe. The copper wire acts merely as a guide rail. The actual energy packet travels through the empty space surrounding the outside of the conductor. This spatial power delivery is quantified by the Poynting Vector ( $S$ ):

$$S = E \times H$$

Where:

- \*  $S$  = Poynting Vector, representing the directional energy flux (Watts per square meter)
- \*  $E$  = Electric field vector, generated by the high-voltage potential of the bus
- \*  $H$  = Magnetic field vector, generated by the transient current pulse

\* x = The vector cross-product operator

By generating a square wave with a vertical dV/dt profile, the RDC-SS optimizes the alignment and magnitude of the E and H fields. This forms a high-density electromagnetic shockwave that travels along the exterior boundary of the output lines, directly interfacing with the physical characteristics of the connected load.

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### 3. THE MATERIAL INTERACTION SPECTRUM (THE "COLD EFFECT")

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A critical aspect of the RDC-SS is its ability to interact with different physical materials in vastly different ways depending on their atomic configurations. When the high-speed Poynting Vector wave impacts a substance, the material responds based on whether it permits conduction or forces polarization.

#### 3.1 Conductors (e.g., Tungsten, Copper, Aluminum)

Conductors contain a dense ocean of unbonded, free electrons. When the rapid RDC-SS pulse impacts a conductor, the intense electric field forces these free electrons to move violently, causing an electron stampede. This creates conventional conduction current.

As these electrons slam through the metal lattice, they collide with atoms, generating heavy kinetic friction. This is governed by the Joule Heating equation:  
 $P = I^2 * R$

Where:

\* P = Thermal power dissipated as waste heat (Watts)

\* I = Conduction current (Amperes)

\* R = Internal electrical resistance of the metal (Ohms)

Consequently, conventional metallic loads resist the transient wave, experience heavy Joule heating, and get hot.

#### 3.2 Dielectrics (e.g., Nylon 6/6, Glass, Polycarbonate, Noble Gases)

Dielectrics possess zero free electrons; all their electrons are locked tightly in atomic bonds. When the sub-nanosecond RDC-SS wave arrives, conduction drops to absolute zero, rendering the RDC-SS immune to Joule heating losses ( $I^2 * R = 0$ ).

Instead, the material responds via displacement current. The bound molecules violently polarize, twisting and stretching in place to align with the high-speed E-field.

\* In a solid dielectric core (like a Nylon 6/6 bobbin inside a specialized motor), this molecular polarization manifests as a physical mechanical movement or spatial repulsion ("motor slap") without any thermal rise.

\* In a gaseous dielectric (like Neon, Argon, or low-pressure air), the field instantly ionizes the gas atoms, causing brilliant luminescence.

Because there is no electron drift or atomic friction, the dielectric material

remains entirely at room temperature. This is the origin of the historical "cold electricity" phenomenon: energy transfer via displacement fields rather than thermal electron conduction.

### 3.3 Semiconductors (e.g., Silicon LED Chips)

Solid-state Light Emitting Diodes (LEDs) behave as a hybrid material. Internally, an LED possesses a microscopic physical feature known as junction capacitance. When the high-frequency RDC-SS wave encounters the LED chip, the fast transient bypasses the resistive semiconductor material by cutting cleanly through this internal capacitive space via displacement current.

Because the physical diode structure acts as a one-way electrical check-valve, it self-rectifies the incoming displacement wave internally. This results in highly efficient quantum light emission. Furthermore, because the pulse width is tightly restricted to sub-microsecond territories, the LED chip enjoys long cooling rest periods between cycles, allowing it to output maximum light while remaining totally cold to the touch.

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## 4. DUAL-MODULE HARDWARE ARCHITECTURE & CONTAINMENT

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Operating solid-state switching components at nanosecond speeds creates severe engineering challenges regarding Electromagnetic Interference (EMI) and Radio Frequency Interference (RFI). A high  $dV/dt$  profile can easily generate stray radio waves that back-feed into microcontrollers, causing software lag, memory corruption, or catastrophic hardware failure. To eliminate this risk, the RDC-SS isolates its systems into two physically decoupled enclosures.

### 4.1 Module 1: Logic Control & Boost Engine

Module 1 serves as the low-voltage brain and steady-state power reservoir. It contains the user interface elements and the initial voltage step-up stage.

- \* Input Power: Driven by a pure 12V DC nominal battery source to eliminate 60Hz utility grid hum. It requires an inline 20A safety fuse and a low-drop MOSFET reverse-polarity firewall.
- \* Microcontroller: An Arduino-compatible MCU running on a regulated low-voltage logic rail.
- \* Manual Throttle: A rugged, panel-mounted 10 k $\Omega$  Linear Taper Potentiometer encased in a grounded metal shell. By relying on purely analog mechanical resistance rather than digital rotary pulses, the system is immune to high-frequency software glitches. The MCU maps the analog wiper voltage (0V to 5V) linearly to scale the output frequency from a dead stop (0 Hz safety state) up to a 100 kHz continuous operating ceiling.
- \* DC-DC Booster: An isolated push-pull or flyback transformer network that steps up the 12V DC input up to an adjustable 300V-600V DC high-voltage rail.

### 4.2 Module 2: High-Power Silicon Carbide Switching Engine

Module 2 executes the destructive high-speed switching operations and handles

the raw electrical muscle.

- \* Enclosure Shielding: Must be housed inside a heavy-duty, 1.5mm to 3mm thick die-cast aluminum enclosure. This metal box functions as a total Faraday cage, trapping stray RFI waves inside before they can radiate outward into the room.
- \* Storage Reservoir: A bank of high-voltage, low-ESR (Equivalent Series Resistance) Polypropylene Film Capacitors. These capacitors must be placed within millimeters of the switching pins to eliminate stray wire inductance.
- \* The Switch: A 1200V, 30A Silicon Carbide (SiC) MOSFET. SiC is a wide-bandgap semiconductor that handles extreme thermal loads and switches states significantly faster than standard silicon transistors.
- \* Isolated Gate Driver: The gate of the SiC MOSFET is driven by an optically or capacitively isolated driver chip. The output side of the driver is powered by an asymmetric +15V / -5V isolated DC-DC supply. Delivering a hard negative bias (-5V) during the off-state ensures that transient noise spikes cannot accidentally trigger the MOSFET open.

#### 4.3 Interconnect Topology

The modules communicate exclusively via two separate, heavily shielded lines:

1. High-Voltage DC Link: Shielded 18 AWG cable routing the 300V-600V DC rail from Module 1's booster into Module 2's capacitor reservoir.
2. Low-Voltage Logic Link: A Shielded Twisted Pair (STP) cable routing the Arduino timing signal into the isolated gate driver. This cable must terminate into a metal-shielded GX16 4-pin aviation connector, with the cable's internal braided shield bonded directly to the aluminum chassis ground of Module 2.

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### 5. THE INDUCTIVE ENERGY RECYCLING SYSTEM

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Whenever the high-speed SiC MOSFET snaps shut, the sudden interruption of current through any inductive load or transmission line creates a violent high-voltage inductive kickback pulse. This behavior is governed by the classic equation:

$$V = L * (di / dt)$$

Where:

- \* V = Induced voltage spike (Volts)
- \* L = Circuit inductance (Henries)
- \* di / dt = The rate of change of the current as it drops to zero (Amperes per second)

Because the RDC-SS cuts current in nanoseconds (making dt exceptionally small), the resulting induced voltage spike (V) can easily exceed thousands of volts. In standard power supplies, this spike is burned off as useless heat using a resistor snubber network.

The RDC-SS completely eliminates this thermal waste by integrating a high-speed energy recycling loop. Parallel to the output stage, an array of 1200V Silicon Carbide (SiC) Schottky Rectifier Diodes is installed.

SiC Schottky diodes are unique because they possess zero reverse-recovery time; they snap open and close instantly without a delayed electronic reset phase. When the MOSFET opens and the high-voltage inductive spike kicks back, these Schottky diodes capture the voltage cliff-face instantly. They steer the raw electrical energy away from the switching components and route it back along a dedicated return line directly into the positive terminal of the primary 12V source battery bank. This continually recharges the source reservoir, drastically improving overall system efficiency.

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## 6. GLOBAL INFRASTRUCTURE SCALING: AI DATA CENTERS

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The core mechanics of the open-source RDC-SS reference design can be scaled up from a laboratory bench to address the immense power and water-cooling crises currently facing global computing infrastructure and Artificial Intelligence data centers.

### 6.1 Eliminating Power Supply Conversion Heat

Before grid electricity ever reaches an AI graphics processing unit (GPU), it must be stepped down across multiple phases from thousands of volts down to a 48V DC bus, and eventually down to sub-1V lines at the silicon chip level. Standard silicon-based transformers bleed enormous amounts of energy as heat during these conversion cycles.

By replacing legacy silicon conversion parts with ultra-high frequency SiC and GaN switching topologies optimized for steep  $dV/dt$  boundaries, power conversion switching losses can be reduced by up to 50%. Less energy wasted as upstream heat directly shrinks the baseline air conditioning load of the entire facility.

### 6.2 Cold Solid-State Cooling Pumps

Modern high-density data centers utilize motorized mechanical pumps to cycle water or specialized liquids through server racks to absorb GPU heat. These pumps rely on standard copper-coiled inductive motors that generate intense internal heat during operation, actively warming the exact environment they are tasked with cooling.

By applying RDC-SS drives to pump mechanics designed with high-permittivity solid-state dielectrics (such as nylon or advanced ceramics), fluid movement can be executed via spatial field polarization and dielectric repulsion. The pumping mechanism operates via displacement current, experiencing the "cold effect" and moving cooling fluids at room temperature without contributing any secondary thermal energy to the data center floor.

### 6.3 Advanced Charge-Recycling Compute Logic

While standard digital computing requires electron conduction to shift logic states, semiconductor researchers can adapt the energy-recycling loop of the RDC-SS to develop alternative logic frameworks:

\* Adiabatic Computing: Utilizing resonant pulsed tank circuits to capture the internal capacitance of a logic gate, swinging the charge back into a local power reservoir during bit transitions rather than draining it directly to ground as waste heat.

\* Ferroelectric Gates: Utilizing high-speed electric fields to instantly flip the permanent spatial polarization zones inside advanced crystal dielectrics (such as Hafnium Oxide), allowing binary processing without flowing steady-state rivers of resistive electrons.

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## 7. COMPLIANCE, OPEN-SOURCE HARDWARE, & REPLICATION LICENSE

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This technical documentation is released entirely under the terms of the Open Hardware Repository public domain standards. All schematics, firmware routines, and circuit specifications are free to copy, modify, distribute, and implement without licensing fees or proprietary encumbrances.

Replication must be accompanied by strict adherence to high-voltage safety containment protocols. The high  $dV/dt$  profiles present in this architecture require the implementation of localized Faraday cages, isolated logic lines, and robust indemnification barriers as detailed in the master repository safety guidelines.

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