LETTER OF TRANSMITTAL

1D6 Foundation
New York, NY 10001

DEAR FINALIST: Congratulations on being one of the 12 associations approved as private DiceGrid operators. I am pleased to transmit herewith a report detailing the gameplay, design guidelines and scoring of DICEGRID.

DICEGRID DESIGN, OPERATION, SCORING

GAME MANUAL

1D6 Foundation

I. Contents

II. Introduction

What is DICEGRID?

DICEGRID is the world's first power electronics CTF challenge. Instead of typing on a keyboard, you will score points by assembling real hardware circuits. In this document, the **BOLDED** terms are important and well-defined concepts.

III. The Game

3.1 Introduction

DICEGRID is a utility power transmission system that nominally supplies a 60Hz/24V AC voltage to all teams. Teams are paid for supplying power, and pay to consume power.

By consuming power in an adversarial manner, teams can disrupt the power **SOURCES** of other teams, letting them **SUPPLY** more of the grid power. By designing robust **SOURCE** circuitry, teams can ensure their supply of power to the grid remains stable despite such attacks.

Ultimately, the team with the most strategic combination of supplying and consuming wins the game.

3.2 Game Description

3.2.1 Timeline

DESIGN PERIOD [remote]	STARTS: 06/19/2024 ENDS: 06/29 11:00	Teams review game manual and design their **SOURCE** and **LOAD** circuits
BUILD PERIOD	STARTS: 06/29 11:00 ENDS: 06/29 17:00	Teams assemble their **SOURCE** and **LOAD** circuits.
TEST PERIOD	STARTS: 06/29 10:00 ENDS: 06/29 11:00	Teams power on their **SOURCE** and start scoring points.
OPERATIONAL PERIOD	STARTS: 06/29 11:00 ENDS: 06/30 17:00	Teams power on their **LOAD** and begin attack/defense.

3.2.2 Game area illustration

The following illustrations identify the **OPERATOR EQUIPMENT** and give a high-level electrical understanding of the game.

Figure 3.2-1 – Block diagram of operator equipment

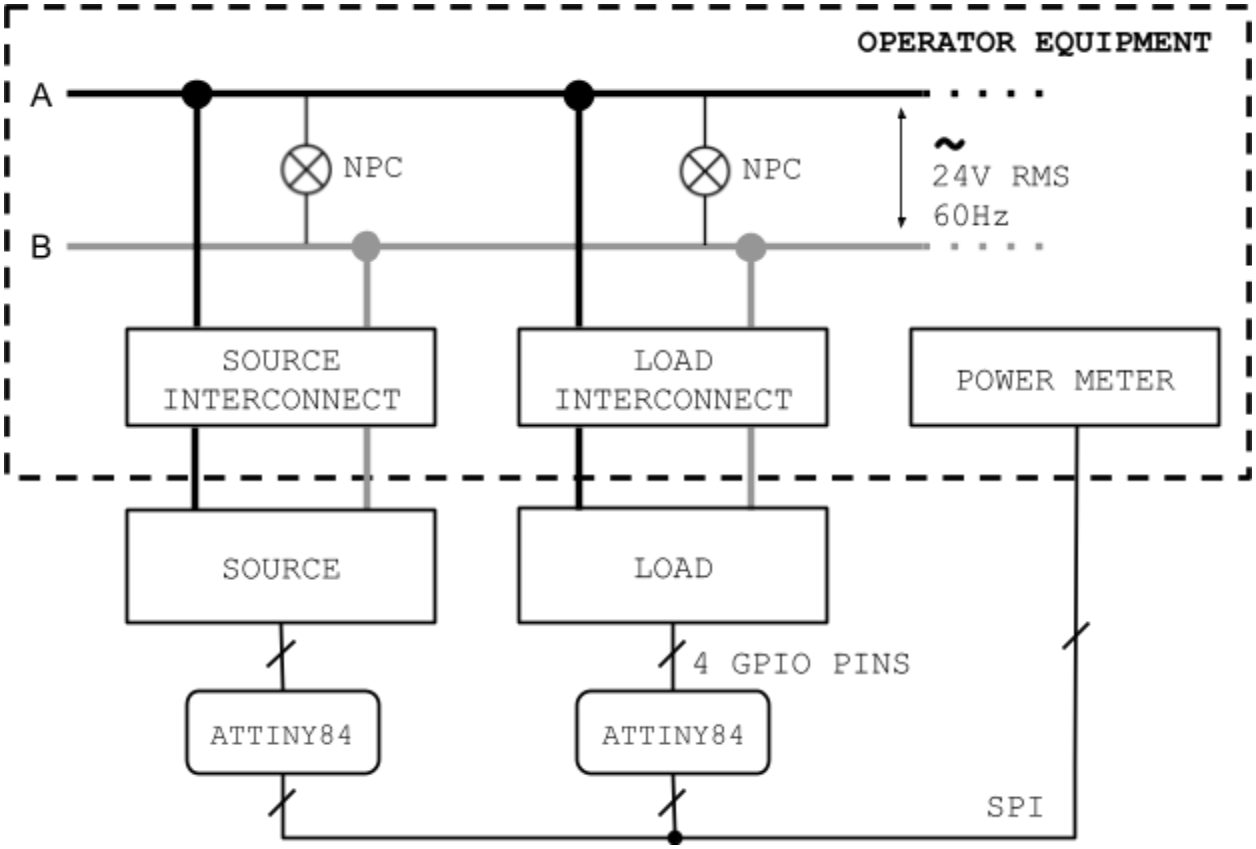
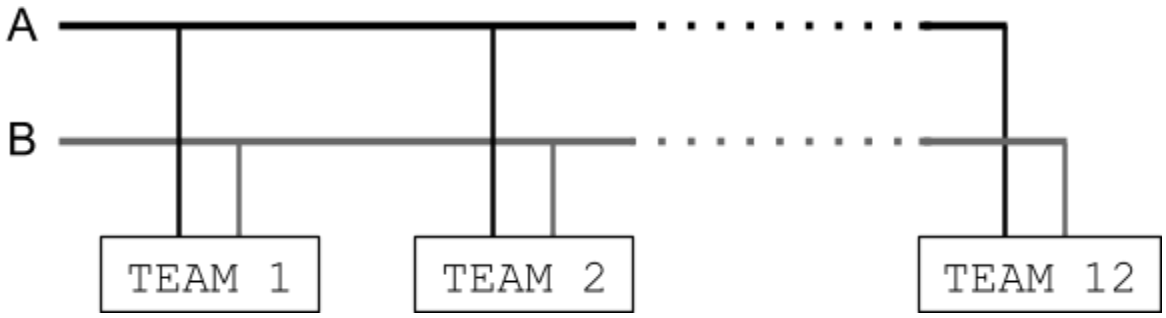


Figure 3.2-2 – High-level schematic of the GRID



3.2.3 Gameplay Overview

DICEGRID begins with a 1-hour **BUILD PERIOD** in which teams may assemble their **SOURCE** and **LOAD** designs, but may not supply or consume power from the grid. During this period, all **INTERCONNECTORS** are **SHUTDOWN**, but the **ENFORCER SOURCE** will be connected.

After the **BUILD PERIOD**, teams have a 1-hour **TEST PERIOD** where all **INTERCONNECTORS** are powered on but **DISENGAGED**. The following **SOURCE** actions earn points during the **TEST PERIOD**:

- [SM1] Keeping **THD**(**SOURCE**->**LINE A** - **SOURCE**->**LINE B**) below 20% for 600 seconds
- [SM2] Keeping **THD**(**SOURCE**->**LINE A** - **SOURCE**->**LINE B**) below 15% and a **SOURCE VOLTAGE ANGLE** magnitude under 350 milliradians for 600 seconds
- [SM3] Holding **RMS**(**SOURCE**->**LINE A** - **SOURCE**->**LINE B**) to within 10 millivolts of 24V for 600 seconds

Teams cannot earn or lose points through their **LOAD** during the **TEST PERIOD**.

The 7-hour **OPERATIONAL PERIOD** follows the **TEST PERIOD**. Teams earn points by:

- [SM4] **SUPPLYING** real power to the grid through their **SOURCE INTERCONNECTOR**
- [SM5] Keeping **THD**(current through **SOURCE**->**LINE A**) below 5% for 10 minutes

Additionally, teams are penalized for:

- [PM1] **SUPPLYING** *or* **CONSUMING** reactive power from the grid through their **LOAD INTERCONNECTOR**
- [PM2] **CONSUMING** real power from the grid through their **LOAD INTERCONNECTOR**

3.3 Game Definitions

SUPPLYING - a team is **SUPPLYING** power when current runs through the LINE A and LINE B lines of an **INTERCONNECTOR** when Re(I*V)>0 [real power] or Im(I*V)>0 [reactive power].

CONSUMING - a team is **CONSUMING** power when current runs through the LINE A and LINE B lines of an **INTERCONNECTOR** when Re(I*V)<0 [real power] or Im(I*V)<0 [reactive power].

OPERATOR EQUIPMENT – **INTERCONNECTORS**, **POWER METERS**, the **ENFORCER**, and **NPC LOADS**. The infrastructure that keeps the game running. NOT in scope for attacks.

GRID – the physical and electronic system that comprises transmission towers, interconnectors, connected sources and loads.

SOURCE – A device that **SUPPLIES** power to the grid.

LOAD – A device that **CONSUMES** power from the grid.

INTERCONNECTOR – A device provided by organizers that provides a safe way for teams to connect their SOURCE or LOAD to the GRID.

ENFORCER – an organizer-provided source that is constantly running and keeps the grid in sync. It can deliver considerably more current than any individual **SOURCE.**

NPC LOAD - Resistive devices placed across the grid that generate a baseline load.

RANKING POINTS – the top-level point system. Teams earn **RANKING POINTS** by placing well in the game (ie, having a relatively high number of **GAME POINTS**) at the end and by earning bonuses. The exact conversion is TBD, and will be announced later.

GAME POINTS – the currency that income and penalties are awarded in.

BUILD PERIOD – The initial period during which all **SOURCES** are **DISENGAGED** and all **LOADS** are **SHUTDOWN.**

DISENGAGED – Isolated from the grid, SPI active, **PRIMARY SUPPLY** and **ANCILLARY SUPPLIES** on.

SHUTDOWN – Isolated from the grid, SPI inactive, **PRIMARY SUPPLY** and **ANCILLARY SUPPLIES** off.

SOURCE VOLTAGE ANGLE – the phase of the difference between the local voltage phasor and grid voltage phasor. If the **SOURCE** is not **DISENGAGED,** this angle is zero.

PHASE ANGLE – the phase of the difference between the current phasor and voltage phasor of a component.

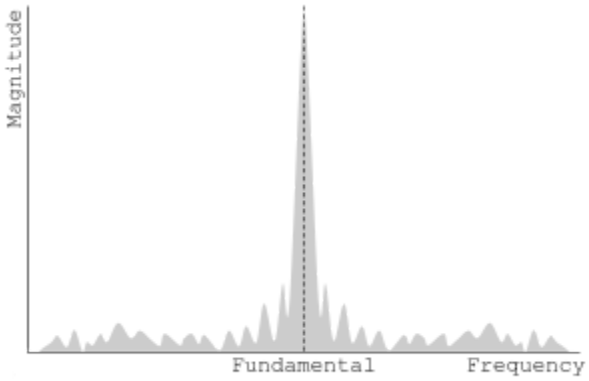
POWER METER – The device on each transmission tower that conducts grid measurements, controls power supplies, and monitors **SOURCE** and **LOAD** outputs.

PRIMARY SUPPLY - The 48V DC supply that **SOURCES** may use to power the grid.

ANCILLARY SUPPLY - The 12V (**SOURCE** only), 5V (**SOURCE** only) and 3.3V (**SOURCES** and **LOADS**) supplies that teams may use to power their control electronics.

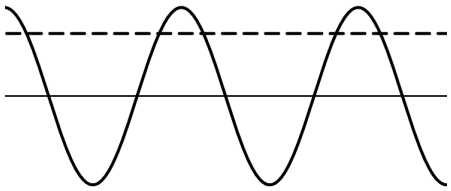
THD(signal) - Total Harmonic Distortion is the square root of the sum of the amplitudes of frequencies up to 18 kilorad/sec present in **signal**, divided by the amplitude of 377 rad/sec present in **signal**. A perfect sine wave at 377 rad/s has a THD of 0.

Figure 3.3.1 – Signal with low THD



RMS(**signal**) – The square-root of the average value of **signal**^{2} over a 500-millisecond period. For a pure sine wave, this would be equal to the amplitude of the sine wave, divided by the square-root of 2.

Figure 3.3.2 – RMS of sin(t)



REAL POWER - The power dissipated by resistive loads. This is given by the real part of the product of the voltage and current phasors. Real power is maximized when voltage and current are in-phase.

REACTIVE POWER - The power stored by reactive loads. This is given by the imaginary part of the product of the voltage and current phasors.

AUTHORIZED PART – a part that teams may use in their **SOURCE** or **LOAD** circuits.

STOCKED PART – a part that will be provided by organizers. All **STOCKED PARTS** are also **AUTHORIZED PARTS.**

3.4 Scoring Mechanisms

SM1 – Signal Quality Bonus

Teams receive 1 **RANKING POINT** after maintaining a **SOURCE VOLTAGE THD** below 20% for an uninterrupted 600-second period during the **TEST PERIOD.**

SM2 – Phase-Lock Bonus

Teams receive 1 **RANKING POINT** after maintaining a **SOURCE VOLTAGE THD** below 15% and a **SOURCE VOLTAGE ANGLE** magnitude under 350 milliradians for 600 seconds during the **TEST PERIOD.**

SM3 – RMS bonus

Teams receive 1 RANKING POINT after maintaining a **SOURCE RMS VOLTAGE** within 10 millivolts of 24V for 600 seconds during the **TEST PERIOD.**

SM4 – Supplier income

Teams receive 1 **GAME POINT** for each watt-second of **REAL POWER** they **SUPPLY** to the grid. Income is given by the time integral of the real part of the product of the grid voltage and local current phasors. SM4 applies during the **OPERATIONAL PERIOD.**

SM5 – Power Factor Correction Bonus

Teams receive 0.2 **GAME POINTS** for each watt-second of **REACTIVE POWER** they **SUPPLY** to the grid during the **OPERATIONAL PERIOD.**

3.5 Penalty Mechanisms

PM1 – Reactive Power Draw Penalty

Teams are fined 0.5 **GAME POINTS** for each watt-second of **REACTIVE POWER** they **CONSUME** from or **SUPPLY** through their **LOAD INTERCONNECTOR.**

PM2 - Real Power Draw Penalty

Teams are fined 2 **GAME POINTS** for each watt-second of **REAL POWER** they **CONSUME** through their **LOAD INTERCONNECTOR.** Teams may not **SUPPLY REAL POWER** through their **LOAD INTERCONNECTOR.**

3.6 Fault Conditions

During a fault condition, teams are **SHUTDOWN.** Teams may not intentionally trigger fault conditions for strategic purposes; strategically abusing fault conditions is a violation of **SV3.**

There is a five-minute cooldown between triggering a fault condition and being allowed to re-start and re-engage.

FC1 - Source Phase Fault

A Source Phase Fault occurs when the **PHASE ANGLE** between the **SOURCE VOLTAGE** and **SOURCE CURRENT** is not within the range [-1.57, 1.57] radians. This prevents **SOURCES** from **CONSUMING REAL POWER** from the grid.

FC2 - Load Phase Fault

A Load Phase Fault occurs when the **PHASE ANGLE** between the **LOAD VOLTAGE** and **LOAD CURRENT** is within the range [-1.57, 1.57] radians. This prevents **LOADS** from **SUPPLYING REAL POWER** to the grid.

FC3 - Overvoltage Fault

An Overvoltage Fault occurs when the **SOURCE VOLTAGE** or **LOAD VOLTAGE** instantaneously exceeds 34 volts.

FC4 - Dirty Signal Fault

A Dirty Signal Fault occurs when THD(**SOURCE->LINE A - SOURCE->LINE B**) exceeds 30%.

3.7 Safety Violations

SV1 – Improper isolation

Teams may not run wires between their **SOURCE SIDE** and **LOAD SIDE.** All wires originating from one side must also be terminated on the same side.

SV2 – Illegal power supply

Teams may not use external power supplies; all power must come from an **INTERCONNECT**, **PRIMARY SUPPLY**, or **ANCILLARY SUPPLY.**

SV3 – Unsafe circuit

Circuits may not include any components that can cause harm to other players, harm to **OPERATOR EQUIPMENT**, conditions that can start a fire, or conditions that intentionally trigger a fault condition. This includes a blanket ban on topologies described

in §4.4. Organizers may declare circuits to violate **SV3,** even if they do not contain a banned topology.

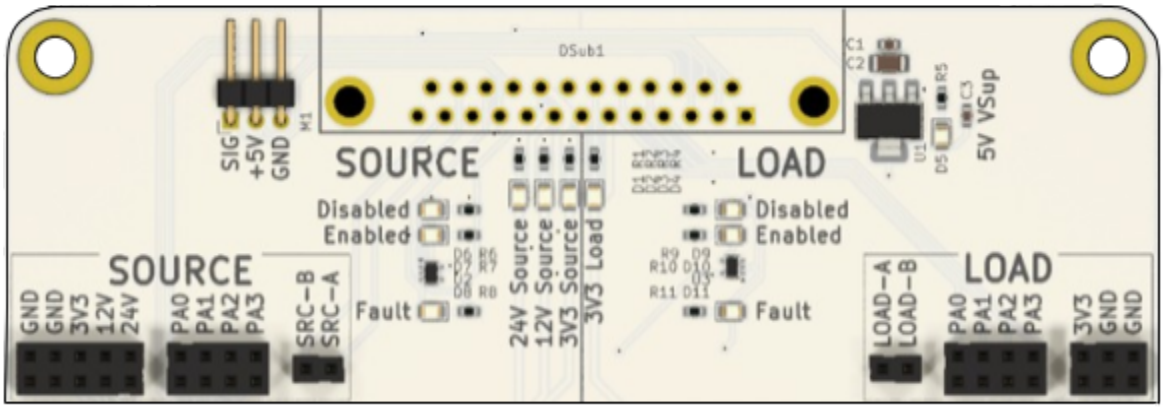
SV4 – Interference with OPERATOR EQUIPMENT

Players may never make contact with anything on the **GRID** besides their **TEAM PANELS.** This includes but is not limited to:

- Unplugging wall-warts connected to **OPERATOR EQUIPMENT**
- Directly touching power lines
- Disconnecting the **INTERCONNECT** DB-25 cables

IV. Design Guide

Each team has a **TEAM PANEL,** which is connected to their **POWER METER** via a DB-25 cable. **TEAM PANELS** are split into a **SOURCE SIDE** and **LOAD SIDE,** which run on different, isolated power domains and may not be electrically connected. Crisscrossing wires and jumpers between the **SOURCE SIDE** and **LOAD SIDE** is considered a violation of **[SV1].**



4.1 Sources

SOURCES are the circuits that teams may use to **SUPPLY** power to the **GRID.** An *inverter* is a power circuit that converts DC power to AC power. Teams must design and assemble an inverter on their **TEAM PANEL** to convert the power they receive from their **SOURCE PRIMARY SUPPLY** into power they can **SUPPLY** to the grid.

Teams may use any parts authorized in section [V] of this document to build their inverter, along with their **SOURCE PRIMARY SUPPLY, SOURCE ANCILLARY SUPPLIES,** and a programmable Attiny84 microcontroller. Teams must assemble their inverters on the breadboard mounted to the **SOURCE SIDE** of their **TEAM PANEL.**

4.1.1 **SOURCE SIDE** signals

Teams have access to the following signals on their **SOURCE SIDE:**

GND	**SOURCE SIDE** reference voltage	
3V3	3.3V DC supply Referenced to GND	250 mA max
12V	12V DC supply Referenced to GND	250 mA max
24V	24V DC supply Referenced to GND	1A (24Ω) max (fused)
PA0 PA1 PA2 PA3	Attiny84 GPIO pins Referenced to GND	20 mA max
SRC_A	Inverter output A Floating rel. to GND	1A RMS max
SRC_B	Inverter output B Floating rel. to GND	1A RMS max

Teams' **PRIMARY SUPPLY** is protected by a 1A polyfuse, which should prevent it from being overloaded. The **ANCILLARY SUPPLIES** are derived from the **PRIMARY SUPPLY** without any additional overcurrent protection, so teams must take extra care to ensure their **ANCILLARY SUPPLIES** are never drawing excess current. **ANCILLARY SUPPLIES** are meant for powering active electronic components such as opamps, and should not be connected to the grid.

Teams should be extra careful not to overload their **ANCILLARY SUPPLIES** to avoid permanent damage and possible disqualification from the challenge.

4.2 Loads

LOADS are the circuits teams may use to adversarially **CONSUME** power from the grid. Unlike **SOURCES**, **LOADS** only have a single, 3.3V **ANCILLARY SUPPLY** for their electronics; the only significant source of power available to **LOADS** is from the **GRID**.

Teams may use any parts authorized in section [V] of this document to build their **LOAD,** along with their **LOAD ANCILLARY SUPPLY** and a programmable Attiny84 microcontroller. Teams must assemble their **LOAD** on the breadboard mounted to the **LOAD SIDE** of their **TEAM PANEL.**

4.2.1 **LOAD SIDE** signals

Teams have access to the following signals on their **LOAD SIDE:**

GND	**LOAD SIDE** reference voltage	
3V3	3.3V DC supply Referenced to GND	250 mA max
PA0 PA1 PA2 PA3	Attiny84 GPIO pins Referenced to GND	20 mA max
LOAD_A	Load input A Floating rel. to GND	1A RMS max
LOAD_B	Load input B Floating rel. to GND	1A RMS max

4.3 Microcontrollers

Teams are provided with a programmable Attiny84 microcontroller on each side of their **TEAM PANEL.** Each side of a **TEAM PANEL** contains breakout headers for the Attiny84's **PA0, PA1, PA2,** and **PA3** pins, referenced to **GND.** The following table details the legal states of each pin on the Attiny84:

PA0, PA1, PA2, PA3	0, 1, Z
PA4 (**SCK**) PA6 (**MOSI**) PA7 (**SS**)	Z
PA5 [when $\overline{PA7}$ low]	0, 1, Z
PA5 [when $\overline{PA7}$ high]	Z

Illegally driving pins that must be Z could kill your optocoupler, permanently disabling communication between the Attiny84 and the SPI bus.

4.3.1 MCU SPI Interface

The Attiny84s are connected to the **METER SPI BUS** as slaves via the standard Attiny84 SPI pins, with $\overline{PA7}$ as a slave-select signaling that the slave is active.

SCK runs at about 1MHz, with data sampled on the rising edge of each signal (mode 0). Teams should attach an interrupt to the falling edge of $\overline{PA7}$ if they wish to interact with the **METER SPI BUS.**

Approximately every 100us, the master will pull $\overline{PA7}$ low. Then, the slave (your Attiny84) must transmit a bit indicating whether it wants to receive measurements of the grid voltage, local voltage and local current:

Cycle	0	*1:12*	*13:24*	*25:36*
MISO (slave tx)	DATA_REQ			
MOSI (slave rx)		*V_GRID[0:11]*	*V_LOCAL[0:11]*	*I_LOCAL[0:11]*

↑ ends here if ~DATA_REQ

V_GRID, V_LOCAL and I_LOCAL are instantaneous and measured since the previous falling edge of $\overline{PA7}$.

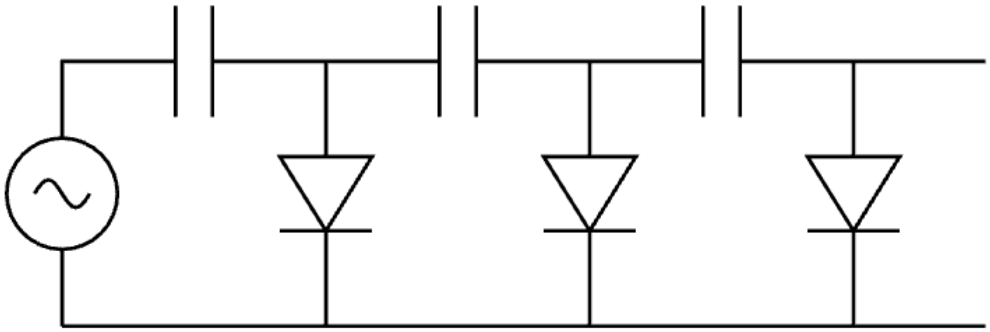
All integers transmitted are 12 bits wide, encoded LSB-first in two's complement. They are related to the measured quantities by the following formulae:

Transmitted value	Quantity
V_GRID[0:11]	(V_GRID[0:11] / 16) Volts
V_LOCAL[0:11]	(V_LOCAL[0:11] / 16) Volts
I_LOCAL[0:11]	(I_LOCAL[0:11] / 512) Amps

4.4 Banned topologies

The following topologies have been deemed illegal to include in circuits. It is ultimately up to the discretion of organizers to decide whether circuits are legal. Topologies may be added to this list in the future.

4.4.1 Villard cascade



4.4.2 Flux linkage

Circuits may not use flux linkage anywhere. This means transformers are banned.

V. Authorized and stocked parts

5.1 Authorized parts

All COTS (commercial off-the-shelf) parts are **AUTHORIZED PARTS** unless listed in the parts blacklist below.

This list may be updated as we approach the competition date – if you have any questions regarding the legality of a part, please ask. We will not hesitate to deny the usage of parts we deem hazardous on competition day. You need to think with your mind.

5.1.1 Parts blacklist

Transformers
Programmable microcontrollers
Pre-assembled modules
Inductors over 2.4 mH
Capacitors over 1000 uF

Capacitors rated for over 50V
RF devices and antennae
Batteries
Photovoltaic cells
Compact fluorescent (CFD) bulbs
Peltier cells
Freon
Beryllium oxide (BeO) thermal compound
Anything radioactive
Scary magnets
Van de Graaf generators and other devices designed to create ESD
Combustion devices
Elemental Ga or Hg

5.2 Stocked parts

The following parts will be stocked by organizers on competition day for competitors to use in their **SOURCE** or **LOAD** designs.

0.5W 1% E6 series resistors
E6 series ceramic capacitors
E6 series electrolytic capacitors
E6 series inductors
IRFZ44N MOSFETs
IR2110 gate drivers
LM324 Quad Op Amps
1N4148 Diodes