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High Power Pulse Generator (ARC-2) Operational Overview

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SAFETY WARNING – SAFETY WARNING – SAFETY WARNING – SAFETY WARNING

SAFETY WARNINGS

(PLEASE READ CAREFULLY BEFORE OPERATION)

1. ELECTRIC SHOCK HAZARD

THE ARC-2 HIGH POWER PULSE GENERATOR PRODUCES DANGEROUS AND POTENTIALLY LETHAL HIGH VOLTAGES AND HIGH INSTANTANEOUS POWER LEVELS AS PART OF ITS NORMAL OPERATION. USERS OF THE ARC-2 SHOULD BE AWARE OF THE POTENTIAL DANGER AND USE APPROPRIATE CAUTION AND PROCEDURES FOR SAFE OPERATION. ONLY PERSONNEL THAT ARE FAMILIAR WITH ARC-2 USER INFORMATION, PROTOCOLS, AND SAFETY FEATURES, SHOULD OPERATE THE ARC-2. THE USE OF THE ARC-2 INTERLOCKS ARE REQUIRED FOR SAFE OPERATION. FAILURE TO FOLLOW RECOMMENDED ARC-2 CONFIGURATION AND OPERATION GUIDELINES COULD RESULT IN INJURY OR DEATH.

2. CONNECTION TO USER'S ELECTRODES

FOR SAFE OPERATION, THE ARC-2 HOUSING MUST BE CONNECTED TO A CONDUCTIVE CONDUIT AROUND THE DISCHARGE PULSE CONDUCTORS, AND THE CONDUCTIVE CONDUIT MUST BE CONNECTED TO A METAL ENCLOSURE SURROUNDING THE ELECTRODES AT THE END OF THE DISCHARGE PULSE CONDUCTORS. THIS SHIELDING CONFIGURATION PROVIDES A SAFE RETURN PATH FOR THE DISCHARGE PULSE IN THE EVENT THAT THE ELECTRODES ARE OR BECOME IMPROPERLY CONNECTED DURING OPERATION. SPECIFICALLY FOR THIS PURPOSE, CASCODIUM HAS MADE PROVISION FOR THE MECHANICAL AND ELECTRICAL ATTACHMENT OF A CONDUIT TO THE ARC-2 HOUSING AT THE DISCHARGE PULSE EXIT. FAILURE TO USE A CONDUCTIVE CONDUIT TO COMPLETELY ENCLOSE THE DISCHARGE PULSE CONDUCTORS BETWEEN THE ARC-2 HOUSING AND THE USER'S METAL ELECTRODE ENCLOSURE COULD RESULT IN INJURY OR DEATH.

THE ARC-2'S POWER INPUT (HOST CONNECTOR) MUST BE DISCONNECTED AT ALL TIMES WHEN HANDLING THE DISCHARGE PULSE CONDUCTORS OR THE ELECTRODES.

3. INSTRUMENT GROUNDING

IT IS ALSO STRONGLY RECOMMENDED THAT THE METAL ENCLOSURE THAT SURROUNDS THE USER'S ELECTRODES BE CONNECTED TO EITHER INSTRUMENT CHASSIS OR EARTH GROUND.

MANUAL NOTATIONS

WARNING – Indicates the possibility of bodily injury or death.

CAUTION – Indicates the possibility of equipment damage.

SAFETY WARNING – SAFETY WARNING – SAFETY WARNING – SAFETY WARNING

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1 Introduction

The ARC-2 High Power Pulse Generator (“ARC-2”) generates electrical discharges when connected to an external pair of closely spaced electrodes (electrodes not supplied). The ARC-2 contains a digital processor that monitors and controls the discharge pulse energy, controls internal operations, monitors internal subsystems, reports faults and warnings over its serial interface, and provides access to diagnostic and lifetime metrics for the ARC-2. Communication with the internal processor is provided via either a text-based serial interface using a PC based terminal application such as Windows HyperTerminal, or a binary machine interface for use with a custom application.

WARNING

THE ARC-2 PRODUCES DANGEROUS AND POTENTIALLY LETHAL HIGH VOLTAGES AND HIGH INSTANTANEOUS POWER LEVELS AS PART OF ITS NORMAL OPERATION.

Caution must be used when making connections to and operating the ARC-2.

The ARC-2 enters a disarmed mode upon power up in which no high voltages are generated and no triggers are accepted. When the system is armed by means of a serial command, the ARC-2 is energized and awaits trigger signals. When the ARC-2 is triggered, a high voltage pulse is generated across the output leads to break down the matter (generally a gas) between the external electrodes. This pulse may exceed 10 kV. A few microseconds after the initial break down (or arc), the internal stored energy is discharged into the arc. Instantaneous power levels during the discharge can approach 100 kW. Data from each discharge, including potential errors and warnings, is available across the serial interface. Unit status, as well as lifetime and interval counters for triggers and accumulated energy, is accessible via system status requests.

2 Electrical Interfaces

CAUTION

The ARC-2 generates significant electrical and magnetic field transients as part of its normal operation. Failure to ensure continuity of the case/chassis connection between the ARC-2 and external instruments can result in nearby equipment failure. This applies especially to equipment connected to the RS-232 communications interface, the trigger input, and the sync output.

2.1 Power Input

The power, communication, external trigger, and digital interlock interfaces are all provided on a single 10-pin Host Connector. The ARC-2's input power interface receives 12 V DC nominal power. In the disarmed state, average current draw is typically 100 mA with higher currents during triggering.

2.2 Bidirectional Communications Interface

The communications interface consists of a bidirectional serial link for control and status.

2.3 External Trigger Input

The ARC-2 is externally triggered by the rising edge of an active high digital input. Minimum trigger spacing varies by model; for example, the minimum spacing for the ARC2-40C-R20A is 25 milliseconds.

2.4 External Sync Output

When the internal trigger is used, a synchronization output is generated. This output may be used to trigger other devices. The external synchronization output is an active high digital pulse. The rising edge of this pulse that occurs shortly after the rising edge of an input trigger.

2.5 Electrical Discharge Interface

When properly connected and triggered, the ARC-2 generates a high power discharge between a pair of closely-spaced user electrodes. The pulse energy selected is discharged through an internal electrical network and into the load less than one millisecond after receiving a trigger. Pulse energy limits are model dependent.

WARNING

THE ELECTRICAL DISCHARGE OUTPUT PRODUCES HIGH VOLTAGES IN EXCESS OF 10,000 VOLTS DURING NORMAL OPERATION.

Proper connection to this port is essential for safe operation. The ARC-2's power input (Host Connector) must be disconnected at all times when handling the discharge pulse conductors or the electrodes.

CAUTION

The Discharge Pulse and Discharge Pulse Return signal cables are integral to the ARC-2 unit and cannot be replaced. These cables should not be spliced.

2.6 Digital Interlock

The ARC-2 has a digital interlock comprised of two signals: Digital Interlock (A) and Digital Interlock (B). To enable operation, Digital Interlock (A) must be electrically shorted to Digital Interlock (B). If the interlock is not shorted, the ARC-2 cannot be armed. If the unit is already armed and the interlock is subsequently disconnected, the ARC-2 will be disarmed and cannot be rearmed until the interlock connection is restored. Neither Digital Interlock (A) nor Digital Interlock (B) should be electrically connected to any other electrical contact (including but not limited to chassis or earth ground); both signals should be electrically isolated from all other potential electrical contacts at all times.

This interlock pair is intended to be used in conjunction with one or more series connected switches to limit user access and exposure to high voltages and high powers unless the ARC-2 is placed into its disarmed state. The Digital Interlock is an enhancement for safe operation and should not be substituted for the removal of power to the ARC-2 during the handling of ARC-2 discharge cables or the handling of any electrodes that may be attached to these discharge cables.

WARNING

THE DIGITAL INTERLOCK IS A SAFETY FEATURE OF THE ARC-2 AND ITS PROPER USE IS STRONGLY RECOMMENDED FOR SAFE OPERATION.

Failure to properly use the Digital Interlock could result in injury or death.

2.7 Keyed Interlock

The ARC-2 also has a keyed interlock comprised of a key lock on the enclosure. The key lock is in the enabled (“ON”) position when the key is aligned horizontally. If the ARC-2 key lock is not in the enabled position, the converter unit cannot be armed. If the unit is already armed and the key lock is subsequently moved to the disabled (“SAFE”) position, the converter will be disarmed and cannot be rearmed until the key lock is restored to the enabled position.

This interlock is intended to provide a procedural mechanism by which to limit access to an armed ARC-2 only to personnel that are familiar with ARC-2 user information, protocols, and safety features.

WARNING

THE KEYED INTERLOCK IS A SAFETY FEATURE OF THE ARC-2 AND ITS PROPER USE IS STRONGLY RECOMMENDED FOR SAFE OPERATION.

Failure to properly use the Keyed Interlock could result in injury or death.

2.8 Status LED

The status LED indicates the state of the ARC-2. When powered and disarmed, the LED will be continuously lit. When the ARC-2 is armed, the LED will blink twice a second.

3 Physical Interface

3.1 Mechanical

Figure 1 shows the relative locations of the Host Connector (containing power, communication, external trigger, and digital interlock), the key lock, and the status LED on the control face of the ARC-2. Figure 2-A shows the relative location of the high voltage output on the output face of the ARC-2; Figure 2-B shows the recommended use of a conductive conduit completely surrounding the Discharge Pulse and Discharge Pulse Return wires.



Figure 1: ARC-2 Housing – Control Face

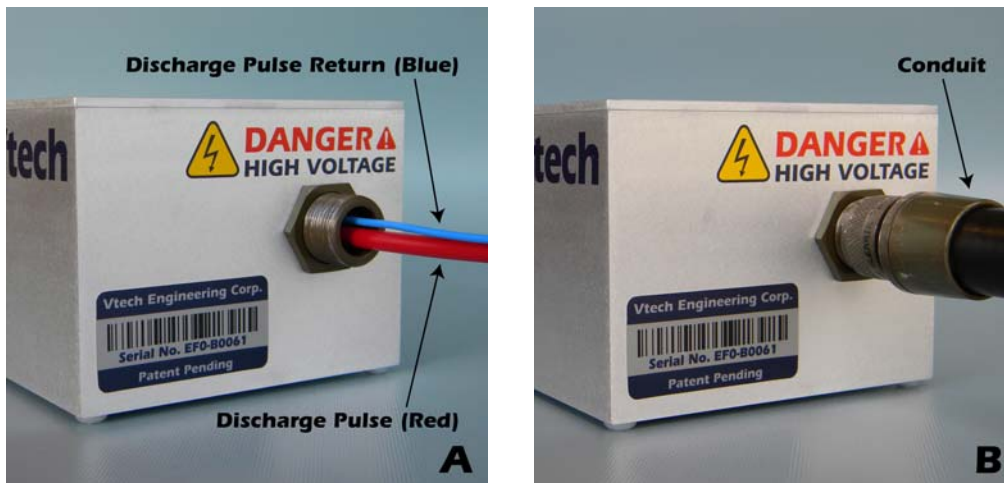


Figure 2: ARC-2 Housing – Output Face

3.2 Discharge Interface

The electrical Discharge Interface is provided on two wires (Discharge Pulse and Discharge Pulse Return) exiting the ARC-2 through an enclosure pass-through component. For safety and EMI reduction, it is required that the discharge wires are then shielded en route to the electrode assembly by a conductive conduit and second enclosure pass-through component mounted to the electrode assembly wall which allows the discharge wires to pass through to the electrodes within. The use of such a conduit extends the ARC-2's case/chassis to the electrode assembly.

Wire	Signal	Description
Red	Discharge Pulse	Electrical Discharge (High Voltage)
Blue	Discharge Pulse Return	Electrical Discharge Return
Conduit	Conductive Conduit	Electrical Continuation of ARC-2 Case/Chassis

Table 1: Discharge Interface Signal Assignments

Note: The Discharge Pulse Return signal should **NOT** be connected by the user to the conduit, to the ARC-2 case/chassis, to the user's metal enclosure, or to earth ground.

CAUTION

The Discharge Pulse and Discharge Pulse Return signal cables are integral to the ARC-2 unit and cannot be replaced. These cables should not be spliced.

3.3 System Connections & Electrodes

The user should fully enclose their electrode assembly within a metal enclosure/housing⁽¹⁾ which must then be solidly connected to the ARC-2 housing, and the metal surface of the electrode enclosure should then be connected to the overall instrument chassis and preferably also to earth ground. In order to feed samples between the electrodes, small holes may be needed in the electrode housing. The size of any such openings should be minimized so as to approximate a completely enclosed system. If large openings are required by the user, then metal screens should be used to cover these openings both to improve user safety and to minimize EMI and EMC related issues.

An example of recommended system interconnect is illustrated in Figure 3 below. In the diagram, the ARC-2 housing, the electrode enclosure, the laptop communications port shell and the trigger source are all electrically connected by means of shielded cables and a conductive conduit. Further, that common potential is also tied to either instrument chassis or

¹ An enclosure thickness of at least 0.075" is recommended. Recommended material is aluminum or copper.

earth ground at the Electrode Enclosure. The ARC-2 enclosure may also be attached to instrument chassis or earth ground. Note that the Discharge Pulse Return conductor should not be electrically attached to the conduit or the electrode enclosure by the user. This Discharge Pulse Return conductor is tied to the ARC-2 case internally as shown in Figure 3 below.

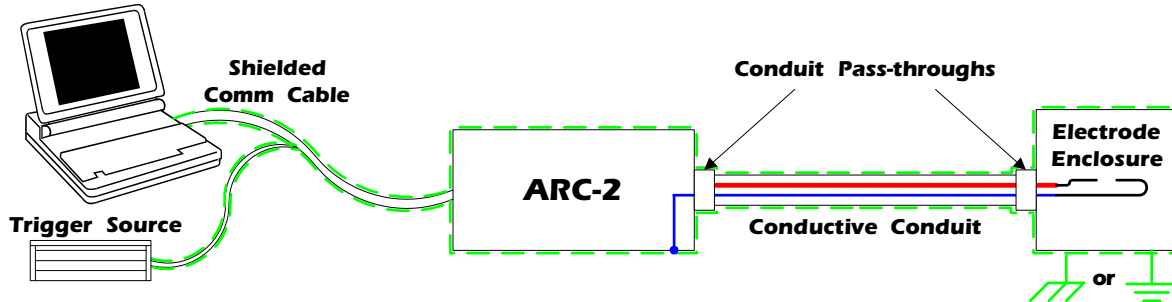


Figure 3: Recommended ARC-2 System Connections

WARNING

THE RECOMMENDED ARC-2 SYSTEM INTERCONNECTIONS MUST BE FOLLOWED FOR SAFE OPERATION.

Failure to follow recommended system interconnections could result in injury or death.

4 Communication Protocols

Two communication protocols are available: a terminal protocol and a machine interface protocol. The terminal protocol is entirely ASCII based and includes no checksums or non-printable characters so that a standard PC based terminal application such as Windows HyperTerminal may be used to communicate with the processor. The machine interface protocol includes error detection and is optimized for use with a custom application. The ARC-2 defaults to the terminal interface on power up. If the machine interface protocol is detected, the terminal protocol will be ignored until the next power cycle. Both the terminal and machine interface protocols use an identifier string and input arguments to create the command string. Only the machine interface protocol uses returned values, as the terminal interface displays informational text instead.

Name	Description
Print Command Menu	Prints the available commands as informational text. Not available when using the machine interface protocol.
Print Version Information	Prints or returns the current firmware revision information.
Print Status Report	Prints or returns the current system configuration.
Set Pulse Energy	Sets the pulse energy setpoint in mJ.
Arm System	Arms the system for pulsing.
Disarm System	Disarms the system and prevents pulses from being discharged.
Trigger System	Uses the internal trigger to generate pulses. Available only when armed.
Toggle Quiet Mode	Toggles the streaming of housekeeping messages. Note: If a fault or a warning is found, the housekeeping message will be transmitted regardless of whether Quiet Mode is enabled.
Reset Interval Counters	Resets the interval trigger and energy counters.
Toggle Spark-less Mode	Toggles Spark-less Mode of operation. While in Spark-less Mode, the system will transmit Output Messages in response to triggers but will not generate high power pulses.

Table 2: Command Descriptions

4.1 Terminal Protocol

A command-line style interface is used, and command and argument entry is variable width terminated by a carriage return. Commands and arguments should be sent as ASCII formatted text, separated by spaces. Commands are insensitive to case. Each command received by the

processor will generate an acknowledgement response mirroring the received string and terminated by a carriage return. After this response, one or more lines of additional text information may be sent, also terminated with a carriage return.

An output message is transmitted to the terminal each time a trigger is received or every two seconds in the absence of triggers. All output messages contain the message type, status flags, most recent stored energy reading, and a pulse energy field. Trigger output messages also contain an incremental trigger count. Numeric values are printed as unsigned integer hexadecimal values. Each fixed width field is separated by a single space character, and each message is terminated with a carriage return and line feed.

4.2 Machine Interface Protocol

The machine interface control protocol adds additional error checking to the terminal output message string and replaces the mirrored response string and informational text with a standardized response format. The additional calculations and reduced informational text of this protocol make it best suited for use with a custom user interface.

5 Operations

The ARC-2 is designed to communicate via a serial terminal program such as Windows HyperTerminal. Full control is implemented using the serial commands, with additional input from the physical key lock, the digital interlock, and the trigger source. Upon power-up the user is greeted with an informational message displaying the header information and firmware version number. After successfully transmitting this message, the supply begins normal operation in the disarmed state. Under normal operation, a housekeeping message is transmitted every 2 seconds which contains the message identifier, status flags, and the stored pulse energy. Initially the discharge energy is set to zero.

5.1 Setting Pulse Energy and Arming the System

When the ARC-2 is powered on, the default pulse energy is set to zero. In order to generate pulses, the pulse energy must be set and the system must be armed. Once in this armed condition, the ARC-2 will accept external triggers and generate discharge pulses.

5.2 Triggering the ARC-2

The ARC-2 is intended to be triggered from an external digital trigger source, and the system will generate a pulse on every rising edge of the external trigger signal applied. For operation when synchronous triggering of the ARC-2 is not needed, the ARC-2 also comes equipped with an internal trigger source that will generate pulses at a user specified fixed rate.

5.3 Disarming the System

The system can be disarmed using a serial command to disarm, hitting the escape key, turning the key lock, or opening the digital interlock pair. Any one of these methods will cause the ARC-2 promptly to stop pulse generation; to discharge all significant, internally stored energy; and to prevent pulses from being generated again until the system can be rearmed.

5.3.1 Active Discharge of Internal Energy Stores

The ARC-2 contains an Active Discharge System (ADS) that discharges the energy stores whenever any of the following events occurs: 1) input power is removed from the ARC-2, 2) the ARC-2 receives a serial command to disarm, 3) the key lock is moved to the “Safe” position, or 4) the Digital Interlock lines are opened. The ADS discharges all energy shortly after initiation of events 2, 3, or 4; and within 500 milliseconds after removal of input power to the ARC-2.

5.3.2 Passive Discharge of Internal Energy Stores

The ARC-2 also contains a Passive Discharge System (PDS) that discharges the internal energy stores within 30 seconds of removal of input power. This supplemental safety system would only be useful in the unlikely event that the ADS fails to discharge the energy stores.

For highest confidence that the energy stores have been discharged, the user should disconnect the ARC-2 Host Connector and then wait for at least 30 seconds before proceeding with any operation involving the handling of ARC-2 discharge cables or the handling of any electrodes that may be attached to these discharge cables.