INSTALLATION AND OPERATION MANUAL

DR6A
CONTROLLER

DR6V
HIGH VOLTAGE DRIVE

ELECTROGRIP

WARRANTY

LIABILITY. Although all care is taken to ensure stated, safe, and reliable performance, Electrogrip can not be held liable for any direct or consequential damages arising from the use or abuse of this equipment. Detailed descriptive, hazard and use data is provided with each unit. Proper operating and safety procedures must be followed and reasonable care must be taken by the user to avoid hazards.

GUARANTEE. Products manufactured by Electrogrip are warranted against defects in workmanship and components for 1 year after shipment from Electrogrip to the buyer. Liability under this warranty is expressly limited to replacement or repair (at Electrogrip's option) of defective parts. Electrogrip may at any time discharge its warranty as to any of its products by refunding the purchase price and taking back the products.

All warranty replacement or repair of parts shall be limited to equipment malfunctions which, in the sole opinion of Electrogrip, are due or traceable to defects in original materials or workmanship. Malfunctions caused by abuse or neglect of the equipment are expressly not covered by this warranty. One particular such abuse is accessing, attempting to read, or reading the drive unit microcode.

In-warranty repaired or replacement parts are warranted only for the remaining unexpired portion of the original warranty period applicable to the parts which have been repaired or replaced.

After expiration of the applicable warranty period, the buyer shall be charged at Electrogrip's then current prices for parts and labour plus transportation.

Except as stated herein, Electrogrip makes no warranty, expressed or implied (either in fact or by operation of law), statutory or otherwise:

And, except as stated herein, Electrogrip shall have no liability for special or consequential damages of any kind or from any cause arising out of the sale, installation, or use of any of its products. Statements made by any person, including representatives of Electrogrip, which are inconsistent or in conflict with the terms of this warranty shall not be binding upon Electrogrip unless reduced to writing and approved by Electrogrip.

Service contracts are available for Electrogrip products.

For additional assistance, contact Electrogrip or its authorised agent.

DR6A CONTROLLER

DR6V HIGH VOLTAGE DRIVE

This manual refers to Electrogrip Model DR6AControllers
for use with Parallel port (analog and switched signal I/O);
RS-232 Serial; ModBus RS-485; USB; and DeviceNet interfaces;

and DR6V High Voltage Drives for use with
Multidrop powering and communications

Covered by US patents 5,103,367; 5,325,261; 6,922,324; and other issued and pending patents worldwide.

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OPERATIONAL SAFETY

SYMBOLS USED IN THIS MANUAL

Definitions of WARNING, CAUTION, NOTE messages:

The WARNING sign denotes a hazard which could result in injury to personnel.

The CAUTION sign denotes a hazard which could result in product damage.

The NOTE sign denotes important information necessary for correct operation.

SAFETY PROCEDURES AND PRECAUTIONS

Failure to comply with the following precautions or with specific warnings elsewhere in this manual violates safety standards of the intended use of the instrument and may impair the protection provided by the equipment. Electrogrip Co. assumes no liability for the customer's failure to comply with these requirements.

DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT Do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to Electrogrip for service and repair to ensure that all safety features are maintained.

SERVICE BY QUALIFIED PERSONNEL ONLY Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified service personnel only.

KEEP AWAY FROM LIVE CIRCUITS Do not replace components with power cable connected. Under certain conditions, dangerous voltages may exist even with the power cable removed. To avoid injuries, always disconnect power and discharge circuits before touching them.

USE CAUTION WHEN OPERATING WITH HAZARDOUS MATERIALS If hazardous materials are used, users must take responsibility to observe the proper safety precautions, completely purge the instrument when necessary, and ensure that the material used is compatible with sealing materials.

DO NOT OPERATE IN AN EXPLOSIVE ENVIRONMENT Do not operate this product in an explosive environment unless it is certified for such use.

KEEP THE UNIT FREE OF CONTAMINANTS Contaminants such as corrosive gases, depositing and particle-generating gases, dust, dirt, lint, and chips may damage the unit.

ALLOW PROPER WARM UP TIME

Units will only meet specifications when sufficient time is allowed for stability at the designed operating temperature. Do not zero or calibrate the unit until its warm up is complete.

GENERAL INFORMATION

INTRODUCTION

The Electrogrip DR6A controller forms a base station in between a host computer and various attached Modules such as DR6V high voltage drives for electrostatic chucks, DR5M servomotor controllers, and DR5P peripheral GPIO ports with additional high voltage outputs. Since the power for such Modules comes from a radio-frequency source in the DR6A controller, it is possible for the attached but isolated modules to have rotary motions, linear translation, high voltage, and rf power applied while the DR6A controller remains fixed and at ground potential.

The connection between Modules and the DR6A is a single multidrop coaxial cable carrying 455kHz rf power from the DR6A to the Modules, and also carrying full-duplex communications signals between the DR5A and its attached Modules. The total power available from a standard DR6A is 75W, and when coupled through a typical rotary and rf-isolated power coupler up to 50W is available for use by such Modules.

DR6A controllers have their own analog and digital I/O ports available, so a host computer connected to a DR6A controller is able to query and control the DR6A itself, as well as all units attached to the DR6A, using each Module's unique 'multidrop' address.

For radio frequency plasma chamber electrostatic chuck electrodes at rf potential, a DR6V high voltage drive Module would be mounted in or close to the chuck, at rf potential. An isolating "power coupler" in the cable between the DR6V Module and the rack-mounted DR6A controller then would provide the required rf isolation.

DESIGN FEATURES

DR6A Controller

Basic Features

• Two configurations: Half rack width, 2U high, 10 inch deep box; or 1/4 DIN, 6 inch deep box. Cooling fan ventilation clearance is required for both.
• Available with 24Vdc power input (either box type) or universal ac line input (half rack).
• A 15-pin connector with digital inputs and outputs (isolated to ±500V) permits interlock, control, and feedback capability when connected to an appropriate host computer program.
• A non-isolated 26-pin GPIO port is available for further digital and analog I/O.
• Host controller communications, all also isolated to ±500V, may use either a Serial card with RS-232, ModBus RS-485, and USB interfaces; or a DeviceNet card.
• The internal electronics is immune to rf and high voltage impulses in compliance with CE standards, and the rf output is within IEC 60990 safety limits for human contact.
• The output rf circuit is set to match the application. Hard-wired connections require different circuit values from those using a power coupler. Several power couplers may be connected in series to obtain coupling through robot arms, or to permit rf-isolated chucks to be installed without direct electric connections to rf-hot baseplates.

Communication Functions

There are no communications initiated by the DR6A or by its attached modules. All communications are initiated by the host computer, which must poll for status updates across all appropriate addresses. Communications between the host and attached modules use the DR6A as a passive go-between. If hard-wired or visual module status feedback or control is desired, either on the DR6A front panel LEDs or on its 15-pin rear connector, the appropriate ports in the DR6A must be polled or set accordingly.

Usage Cautions

The DR6A dc input is protected against reverse voltage input. The internal rf output stage is protected against overvoltage, overtemperature, transient overcurrent, and fan failure. An internal power line short or long term overcurrent will trip the output stage while maintaining processor power. Power must be cycled off and on again to reset this output stage trip.
Do not block the fan ventilation slots.

DR6V High Voltage Drive Module

Basic Features

• Four configuration options:

Single encapsulated DR6V 2-output module with low outgassing and all EUV vacuum chamber approved materials, or;

Double encapsulated DR6E 6-output module with GPIO analog and digital I/O ports, or;

Single DR6VI 2-output module for rf isolation, mountable outside the shielding interface box around rf-excited chuck rear connections, or;

Specialty DR6V modules mounted inside electrostatic chucks, which may include a GPIO for chuck surface monitoring and control.

Other configurations are available upon request.

Cooling gas or fluid circulation is required for any of these options when operated at high output currents. However with highly resistive loads, the typical <300mW power dissipation of the DR6V module permits simple radiative, conductive, or convective cooling either in vacuum or in air.

• The dual-output DR6V provides high voltage bipolar outputs on two wires. The 'A' output follows the commanded voltage polarity and also is used to sense the corresponding 'A' electrode capacitance. allowing substrate monitoring. The A output may be programmed to ramp to a positive or negative goal, from any starting voltage polarity.

• The B output roughly follows the A output, but at the reverse polarity. Hence the system can be likened to a dual tracking high voltage operational amplifier / power supply.

• Users may program the output voltage desired, the ramp rate to reach that voltage, and the various system stability parameters to achieve the desired voltage in an allotted time. The output resistances and capacitances are required inputs to allow ramp parameters to be calculated.

• The DR6V electronics temperature and internal power supply voltages can be read to assure correct system conditions.

• The output voltages and currents can be read with a 20V and 1nA resolution, respectively. The output current accuracy is at present limited to 10nA due to internal compensation limitations.

• The output capacitance on the A output is inferred from the DR6V sense frequency readout with a sensitivity of ~1.1Hz per pF once per second, with an accuracy of 0.2 Hz, allowing substrate position feedback before and after ramping between voltages.

• Up to 200μA may be obtained from each output at ±3kV.

Usage Cautions

• Available current from DR6V outputs can be as high as 10mA. Ventricular fibrillation currents in humans are ~150mA at dc to 0.1Hz, falling to ~50mA at 20-100Hz. While DR6V current levels by themselves thus should not cause death, movements resulting from electric shock may yield severe injury and should be avoided.

• Shock hazards also arise from stored energy, which may be substantial at high voltages. The stored energy of each of the DR6V outputs is C*V*V / 2, where C is the output capacitance (~100pF internally, plus ~100pF per meter of coaxial cable, plus load electrode capacitance). Hence with a maximum of 6kV on an output and with internal capacitances only, the stored energy of 2mJ is close to or below the sensation threshold. However, with an attached load capacitance of 10nF the stored energy rises to the 'felt but OK' level of 200mJ. A load of 100nF yields an incapacitating 2J and possible death in weakened bodies. Death results from a 1μF load.

{Reference to the above shock levels;

Theodore Bernstein, IEEE Trans. Education ***34*** *(3) Aug 1991 p 216-222.}*

• Power to the DR6V is provided by the DR6A, and in turn by a dc power supply. The voltage of this dc supply is approximately proportional to the 'Raw Voltage' operating the DR6V internal circuits, which are normally at 120V and with a maximum value of 200V before device damage. For 24Vdc nominal input DR6A units this implies a maximum input voltage of 40V. This voltage should not be exceeded under any circumstances. It is recommended that the DR6A and DR6V power levels be adjusted using the DR6A internal power controls provided rather than with the DR6A input dc supply voltage.

• The DR6V outputs are independently controlled digitally and system performance will be continuously updated to make it more responsive, accurate, and adaptive with software upgrades. The purpose of the Mini-DIN 8 connector provided on some DR6V modules is to permit field or factory software upgrades without opening the cases. This connector is not for customer use and must not be accessed by users.

• *The below system operating details are subject to change as our software upgrades. We are planning on better matching between outputs, more adaptive and faster voltage error response. Most of these are software changes but some are in hardware as well.*

• DR6V ramping performance is controlled in an open-loop fashion using the incremented theoretical power requirements of ramping, calculated from the programmed values of output resistance and capacitance on each output. Thus the actual ramp rate observed may differ from the desired value due to output capacitances and resistances being different from those in memory. For example, if the programmed values are 100MΩ and 1nF on each output, but the actual load values are 1GΩ and 100pF, the actual ramp will be much faster than is expected. Hence entry of accurate values will result in accurate ramp rates. Ramping ends when the goal voltage is reached.

• 'PID' output voltage control is used in the DR6V. When not ramping, and at a non-zero output voltage, the DR6V uses a proportional gain parameter to obtain system stability. Using the output time constant, as calculated from the stored values of output R and C as a correction period, an output power change ∂P = (output voltage error) * (proportional gain) is made. A typical gain would be 0.0005 but may need to be reduced for light loads and low output voltages to retain stability.

• A fixed 'Derivative' term is used to limit output voltage excursions above 1.25*(desired voltage). If voltages go higher, due to a load disconnect or system instability, the output power is reduced in steps, again with an output time constant period between steps.

• The rate of voltage recovery after a load change and consequent derivative term action is controlled by the above proportional gain parameter, and for low gains the recovery rise to full desired voltage takes several seconds.

• The 'Integral' term and a more exact 'Differential' term will be more fully implemented and will use currently named but unused parameters in memory in a later software version.

• Best accuracy will be obtained from all sense signals (volt, current, and capacitance) if maximum use of opportunities to zero sensors is employed. For example, when outputs are at zero, the user should command a zeroing of the voltage and current sensors. When a substrate is removed or gripped in place, running updates should be made of the capacitance (frequency) values observed so that deviations and drift can be monitored. Warmup is not explicitly required, since thermal drifts will be largest during and following a period of high power output irrespective of any earlier 'warm-up' period.

• Current sensing is corrected for internal voltage sensing current using a stored-memory correction parameter for each current channel. The correction is digitally controlled with a step size of 1nA, from the voltage sense resolution of 20V per bit. Hence current readings alter in steps of 1nA with each output voltage change of 20V, although the precision of current readings remains at 1nA.

SERVICE

Any DR6 module may be returned to Electrogrip for repair and recalibration. Electrogrip does not require an RMA (Return Material Authorisation) before return shipment, but does require an accompanying purchase order which may be made out with a 'not to exceed' amount. The order amount may be set to zero for later updating with the actual repair charge (if not in warranty) and the processing/shipping charges. The purchase order must also include or accompany the below safety warranty:

"**All returns to Electrogrip are warranted to be free of harmful materials, including but not limited to toxic, radioactive, and corrosive chemicals.**"

INSTALLATION

INTRODUCTION

This section of the manual describes initial setup and operation of the DR6V high voltage drive with the DR6A controller.
Additional information required for setup will be found under connector pin wiring, programming, and in the DR6V and DR6A specifications.

UNPACKING

Upon receipt, check for defects such as cracks, broken or loose connector parts, or other evidence of shipping damage. If such damage is found, please follow the 'SERVICE' instructions above to return the equipment.

Retain packing materials until above check is completed satisfactorily.

In your package you should find:

(i) DR6A controller
(ii) DR6V high voltage drive
(iii) Connector/cables for powering options chosen
(iv) CD-ROM manual - or by email
(v) Clean room packaging for above items (optional).

Follow standard procedures:

(i) Discard cardboard packaging
(ii) Remove outer plastic sheath, if present, at transfer box and discard
(iii) Wipe down then remove inner plastic covering in clean room
(iv) Final damage inspection
(v) No touching of connector pins with gloves due to ESD from gloves. Connector pins are rated up to 2kV human body model contact ESD but such exposure should be limited to assure continued reliable operation.

INSTALLATION ITEMS

You will require the following items for installation:

(i) Brackets and screws for mounting DR6A into rack or other panel
(ii) M4 screws for mounting DR6V at position close to chuck
(iii) Cable from USB, DeviceNet, ModBus RS485, or RS232 socket to host device
(iv) Cable from DR6A BNC socket to DR6V BNC socket
(v) Cable from DR6A power socket to 24Vdc power source and (if used) HD15 I/O points
(vi) SHV Cables from DR6V output to load electrodes.

INSTALLATION REQUIREMENTS

(i) Atmospheric air operation at 10°C to 45°C. Coolant fan air circulation clearance required; on one side for half rack DR6A units, and on front and rear for 1/4 DIN units.
(ii) No warmup time is required if sense signals are zeroed frequently.
(iii) 24Vdc at 2A
(iv) Host computer communication is required for setup.

The default settings which will always be available are USB port serial emulation at 9600 baud, 8 bit, no parity, 1 stop bit; and addresses of $FF (255) for the DR6A, and $FE (254) for the DR6V. If the DR6 system has been programmed with unknown addresses and baud rate, this USB access enables reading and reprogramming.

- Install the provided USB serial port / direct USB drivers for USB access
- RS-485 / RS-232 serial control is available at the user-programmable baud rate (shipped at the above default 9600 baud setting).

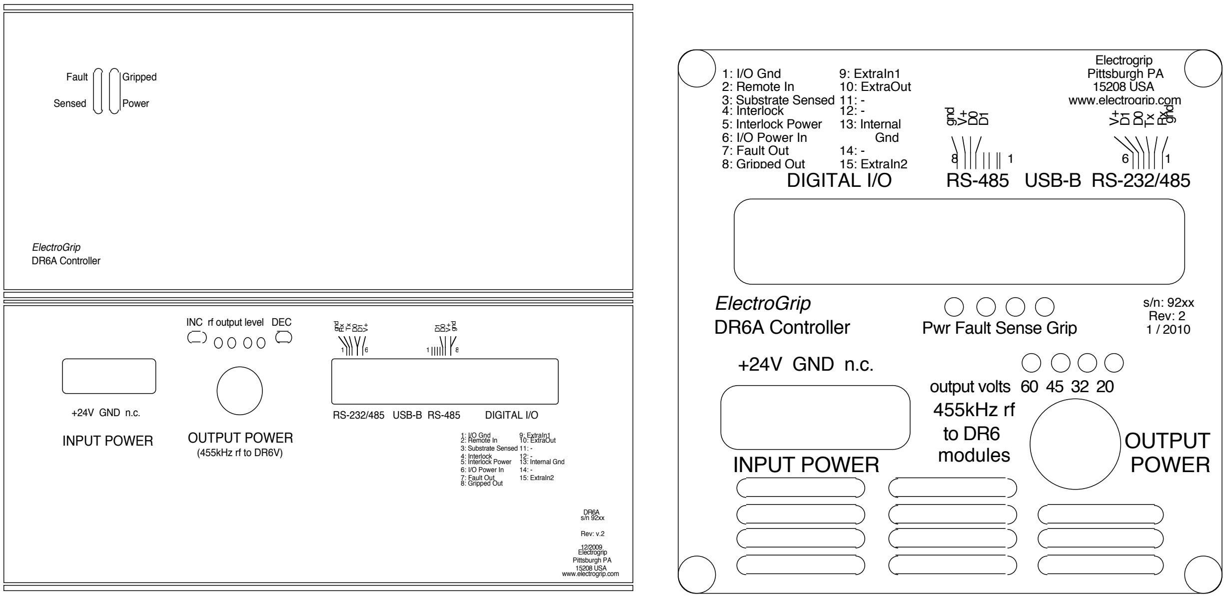

Figure 1. DR6A Front and Rear Panel Layouts (Serial/USB/ModBus versions, 24Vdc power input, manual power control). Half rack; on left. 1/4 DIN; on right. Both versions require clearance for coolant fan air circulation.

ELECTRIC CONNECTIONS

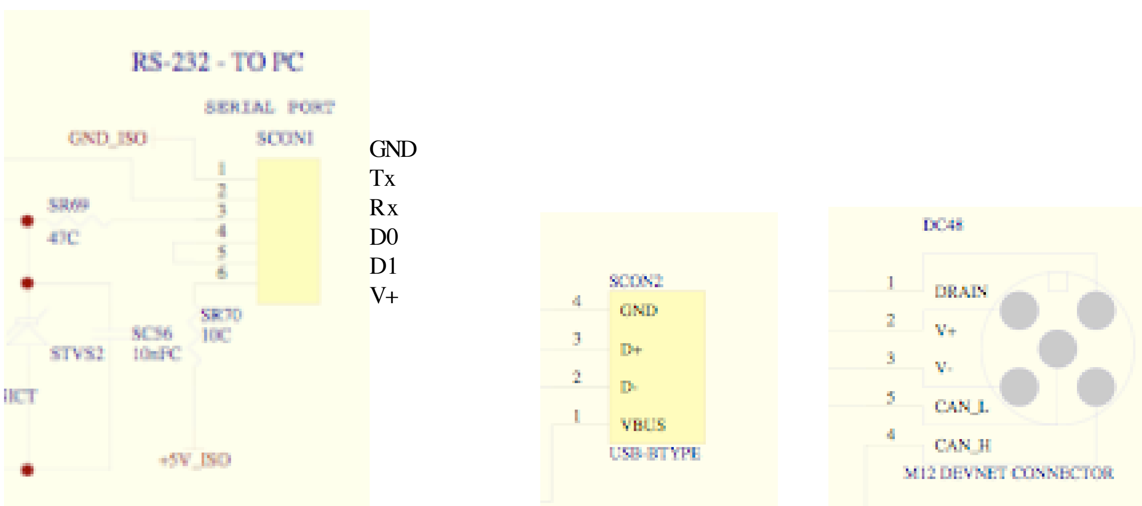

Figure 2. DR6A RS-232 / RS-485 Serial, USB-B, and DeviceNet connections.

1: I/O Gnd	9: ExtraIn1
2: Remote In	10: ExtraOut
3: Substrate Sensed	11: -
4: Interlock	12: -
5: Interlock Power	13: Internal Gnd
6: I/O Power In	14: -
7: Fault Out	15: ExtraIn2
8: Gripped Out	

Figure 3. DR6A HD-15 socket Analog/Power Connections. Female socket on DR6A;use Male for wiring. Outputs pull down when active. Inputs must be pulled down to become active and require a power source between I/O Gnd and I/O Power In of +5V to +24V to be enabled. Inputs, Outputs, front panel LED indicators are read and controlled by the Host computer.

INSTALLATION CHECKOUT AND ADJUSTMENT

(i) Connect host computer and query for the 'Raw Voltage' level at address '11', the initially preprogrammed address of the DR6V. Use :11@664?@@ ↵.

If you receive a result between 100 and 140V, you have good powering and communications between host, DR6A, and DR6V.

If not, check that for running fan(s) in the DR6A and that both the green power LED is on (ie, you have power applied) and a red output power LED is lit, and that the BNC cable is attached at both ends.

(ii) You may also query the DR6A identity (serial number) using its default $FF address (decimal 255) to assure that DR6A operation is correct. Use :FF@016?@@ ↵.

For tests, query non-writable items such as the sense :11@648?@@ ↵.
Output voltages are queried using :11@824?@@ ↵ and :11@832?@@ ↵.

(iii) *Do NOT query the address or serial number of either DR6V or DR6A more than absolutely required, or in a loop repeatedly, without using LRC checksum communications. Especially for address queries, an error in such unprotected communications may wipe out the address and yield an unstable system until it is reprogrammed using the default access settings.*

Your system has been shipped fully working. However the power adjustments may be inadvertently exercised during installation and need to be reset. Follow the guide below if necessary and please contact Electrogrip if there is any evident problem before making significant changes.

(iv) If no response is received, check that the DR6A LED power indicator row has one red LED (weakly) lit. If not, the power level may need to be incremented up using either a pushbutton (if provided) or reprogramming of the DR6A power level using an internal programming command via a serial port. One LED is all that is needed for proper operation.

PROGRAMMING

INTRODUCTION

This section describes how parameters may be monitored and modified using terminal commands to a DR6A serial, RS-485 ModBus, or USB port. Serial communications between a host computer and a large number of peripheral devices is accomplished using the factory setting of 9600 baud, 8 bit, no parity, 1 stop bit RS-232 serial hardware compatible with standard PC serial ports. The two serial ports may be reprogrammed to higher data rates; however the USB serial emulation remains fixed at 9600Bd. In the below descriptions, USB commands are identical to serial commands using the USB - serial translation software provided for use with PC hosts.

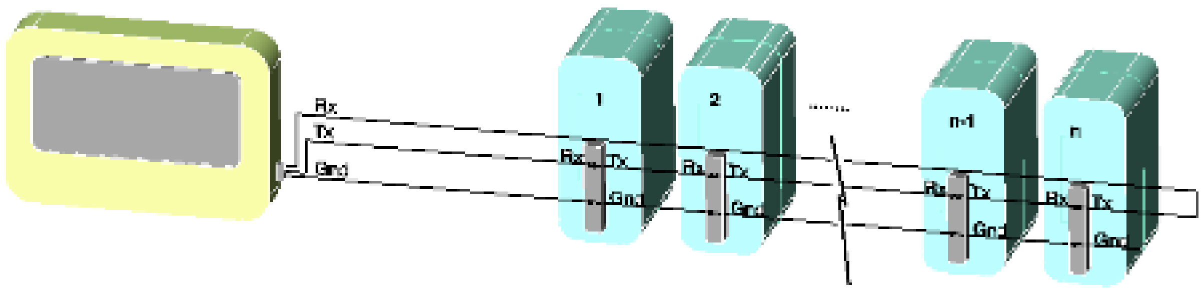

Fig. 4. Daisy chained system. Host computer at left communicating with n (< 9) DR6A, and other units at right.

Electrogrip uses a mixture of daisy chaining (Fig. 4) and multidrop (Fig. 5) protocols to obtain control over a virtually unlimited number of devices.

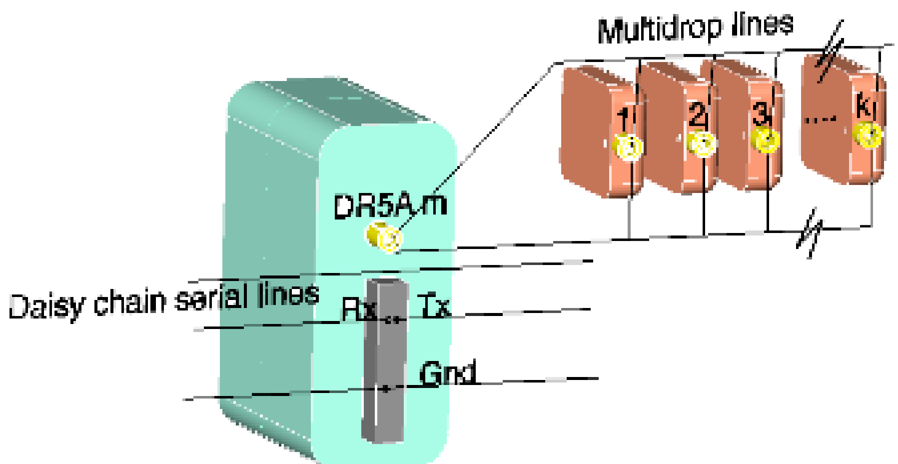

Fig. 5. Multidrop structure. The m-th daisy-chained DR6A unit is shown communicating with, and powering, k (< 240) multidropped units. Such units may alternatively be attached to a RS-485 multidrop line.

In addition to communication with Electrogrip devices the daisy chain protocol is also used by some servo controllers, permitting machine operations of considerable complexity. In cases where the communication speed from one serial port is insufficient, several serial ports may be used, each forming its own separate daisy-chained, multidropped system.

Integer numeric addresses of daisy-chained units are allocated dynamically after system startup using a #1 command. This command is rippled through the serial line, incremented by one inside each unit, causing the address of the next unit in the line to be allocated an address one greater than that of the prior unit. The echoed command that is returned to the host computer is #n+1 where n is the number of daisy-chained units in the serial line.

This daisy chain method is compatible with the DR6A, DR5A, GFC (Electrogrip Gas Flow Controller), and some types of servo controllers, and additionally permits global commands to be processed by all units on the daisy chain if not prefixed by an address number. Normally, commands intended for a specific unit must be prefixed by that unit's address. For example, G causes all servo drives to “go”, while 4G causes only the 4th daisy-chained unit to “go”.

Multidropped units may obtain both power and bidirectional communications from the rf output connection of a DR6A controller. This power and communications may be transferred as shown in Fig. 5 by direct wiring, or through power coupling transformers or other linkage devices. Each multidropped unit must be programmed with a unique address parameter in EEPROM/PROM prior to installation. Up to 15 multidrop units of a given class may be attached to a single DR6A, and up to 16 classes of units may be used. Thus a total of 240 units may be attached. This class structure permits a limited form of global commands to be used. All units in a given class may be addressed simultaneously if desired, by sending the command to the root address of the class.

Communications from the host computer thus have two basic structures. Simple daisy-chained commands with a single address (or no address) are sent to the DR6A / GFC / servo controllers as a ‘daisy chain frame’. More complex two-address [daisy-chain + multidrop] commands are sent to units connected to the rf outputs of DR6A controllers as a combined ‘daisy chain frame’ and ‘multidrop frame’. Data collisions, hence communication errors, would occur if multiple units responded to a command at the same time. Thus care must be taken to never request data from device classes using a global address.

In case of loss of address a module may become inoperable; consequently the addresses $FF for DR6A units, and $00 for DR6V and other DR6A-attached modules, are reserved for emergency reading and reprogramming. In addition an unknown baud rate may be programmed, resulting in inoperability, so the USB serial emulation port baud rate is fixed at 9600 to once again permit access. Since such manual access, as well as initial setup, is most easily done without LRC checksum calculation we also permit the LRC to be substituted with "@@" as a convenience.

Servo controllers use decimal numbers and permit flexible formatting of the number of digits in a command. Some DR5A, DR6A, GFC, and multidropped module commands use hexadecimal numbers ("HEX") in the sequence 0, 1, 2, ... 9, A, B, C, D, E, F, on a base-16 system; and require fixed command formatting. This limits daisy chained systems with DR5A, DR6A, and GFC controllers to a maximum of 9 daisy chain addresses.

ADDRESSING COMMAND SYNTAX

In the below, a carriage return "CR" (ASCII 13), is denoted by ↲.

DAISY CHAIN FRAME

Host PC to all Daisy chain units: **↲ <a> A <s> <n> ↲,** where

↲ is the carriage return ending previous command.

<a> is the **optional ADDRESS** (0-9)

A is a **COMMAND** (1 to 3 capital letters),

<s> is an **optional SIGN** (+/-) for certain commands,

<n> is **optional DATA** (1 to n characters),

↲ is the carriage return ending this command.

MULTIDROP FRAME

This is included in a daisy chain frame and is similar to the MODBUS frame structure.

A Multidrop frame has the syntax: **: a (Multidrop command) LH LL** ↲ where

: is a COLON character, used as a “beginning of frame” character.

a is a mandatory Multidrop ADDRESS, always 2 HEX digits ($00-$FF)

FF is reserved for DR6A, and FE for DR6V, emergency access.

(Multidrop command) may be empty or may contain any control and/or alphanumeric (ASCII) characters

LH is the HIGH half of the LRC byte - (Longitudinal Redundancy Check);

LL is the LOW half of the LRC byte.

If the LRC is calculated, it may be used; if it is not available, use @@ instead and the controller will respond likewise.

↵ is required to end the frame, but is not separately required when embedded in a daisy chain frame that ends with a ↵.

COMBINED DAISY CHAIN + MULTIDROP FRAMES

Host PC to all Multidrop units on a daisy-chained system: **↵, a, (Multidrop frame), ↵**, where

↵ is the carriage return ending previous command.

a is the daisy chained unit address, only required if in a daisy chain,

↵ is carriage return ending this command.

USER INTERFACE FORMAT

CONNECTIONS

USB fixed setting, and initial factory setting for RS-232 and RS-485 serial ports: 9600 Baud [no parity, 8 bit, 1 stop bit] or ["space" parity, 7 bits, 1 stop bit]. No flow control.
Use a "Modem" D-9 computer cable / DS1 Electrogrip terminal with an RJ-12/D-9 adapter; 2-wire RS-485 ModBus RJ-45 connection cable; or a USB 'B' connection cable. RS-485 2-wire ModBus connection is also available on the RJ-12 serial connector.

MEMORY TYPES

The DR6A and DR6V contain three types of memory;
(i) Fixed EPROM program storage
(ii) RAM space for storage of current dynamic parameter values;
(iii) an electrically erasable EEPROM for long-term storage of adjustable parameters.

At power-up, the parameters in EEPROM are copied into 'mirror' locations in RAM for use in calculations. When accessing memory the user has a choice of either reading from RAM or EEPROM for observation of instantaneous/stored values, or writing to either RAM or EEPROM when it is desired to test/store calibration values. Some run-time RAM variables are not mirrored in EEPROM and are only written to RAM. Write operations should be limited to not exceed the EEPROM write/erase lifetime, so in general it is a good idea to load into RAM the regularly altered run-time operating parameters and not rely on EEPROM settings.

COMMAND STRUCTURE: ADDRESSING

DR6A, DR6V permit several types of addressing, with all commands terminated by a carriage return "CR" (ASCII 13), here denoted by ↵:

(i) Serial Daisy Chain (see section, below). Commands are prefixed with address in range of 1-9. Up to 9 daisy chained items are permitted. Addressing required on every command. Initial address setup using a '#n' command.
(ii) Multidrop Mode. Commands are prefixed with a colon, then a two-character hex address, and ended with a two-character '@@' or if available a two-character LRC string before the final ↵ (CR). Up to 240 units may be connected on a single DR6A/RS-485 line using this format. The first hex address digit followed by a zero will write to all items with that first address digit. For example, E0 is the 'root' address for all Ex addresses, and will write to all units with an address beginning with E.
(iv) Combinations of Daisy Chain and Multidrop, as will be shown below.

COMMAND STRUCTURE: MEMORY ACCESS

DR6A, DR6V recognise two types of memory access commands:

(i) "@" command which reads and writes using decimal floating point numbers and integers, and which is the type users will mainly use; and
(ii) "M" command which reads and writes using Hex or ASCII formats over a programmable span of memory, and also enables software resets of various types.

"@" WRITE COMMANDS in multidrop format may look like:

:E0@aaa nnn.nnn@@ ↵, where:

- ':' is the multidrop command prefix;
- 'E0' accesses all modules of address En, where n is 0 to F (hex), if multidrop is used;
  00 accesses any V, E, P, M etc. module and FF accesses any A unit;
- '@'is the command type;
- 'aaa' is a 3 digit decimal address of the module data in memory to be accessed, range 000 - 992, always 3 digits, always divisible by 8 ;
- 'space' after 'aaa'is optional;
- 'nnn.nnn' - decimal number with up to 6 digits before and after the decimal point. The decimal point is optional if sending an integer. An ASCII string ≤ 7 characters may alternatively be sent if appropriate;
- '@@' command suffix used with multidrop addressing; a 2-character LRC code may also be used here;
- ↵ carriage return (ASCII 13);

The WRITE command, when writing to RAM in locations that have an EEPROM mirror, will NOT write to EEPROM. The mirror operation is only done at startup. EEPROM variables have their own name and address for read and write. EEPROM writes should be at final setup, to limit EEPROM write fatigue.

"@" READ COMMANDS in multidrop format may look like:

:E0@aaa ?@@CR, where:

- ':' is a multidrop command prefix;
- 'E0' accesses all modules with an address of En, where n is 0 to F (hex), if multidrop is used;
  00 accesses any V, E, P, M etc. module and FF accesses any A unit;
- '@'is the command type;
- 'aaa' is a 3 digit decimal address 000 - 992, always 3 digits, always divisible by 8 ;
- 'space' after 'aaa'is optional;
- '?' - tells GFC-1 to return the value at module internal data address 'aaa';
- '@@' command suffix used with multidrop addressing; a 2-character LRC code may also be used here;
- ↵ carriage return;

READ commands may be performed on RAM or EEPROM.

LRC Calculation;

Visual Basic programming example; is performed on the characters after the colon and before the LRC↵

```
Public Sub Get_LRC(Comms_String As String, LRC_String as String)
' returns the LRC_String of Comms_String as a two-digit Hex value between 0 and 255
Dim LRC_Sum as Integer
Dim i as Integer

LRC_Sum = 0                                                  ' initially zero the LRC
For i = 1 To Len(Comms_String)
   LRC_Sum = LRC_Sum + Asc((Mid(Comms_String, i, 1)))  ' add the ASCII numeric value of each character
   If LRC_Sum > 255 Then LRC_Sum = LRC_Sum - 256       ' truncate the result to be between 0 and 255
Next i
If LRC_Sum <> 0 Then LRC_Sum = 256 - LRC_Sum             ' take the complement of the truncated sum
LRC_String = Hex(LRC_Sum)                                ' convert to Hex for output
If Len(LRC_String) = 1 Then LRC_String = "0" & LRC_String ' ensure have two characters in the final LRC
End Sub
```

DR6V Parameter List. Note identity parameters are first, followed by device-specific runtime parameters.

[numerical address]_[name of parameter]   Typical Value   Definition

EEPROM:

000_PRODUCT_NAME
008_MULTIDROP_ADDRESS   =FF etc (DR6A); 11 etc (DR6V) address
016_SERIAL_NUMBER
000_VENDOR_ID
000_BAUD_RATE   Baud rate for DeviceNet communications
040_MAC_ID
048_PRODUCT_TYPE
056_PRODUCT_CODE
064_REVISION_MAJOR
072_REV_MINOR_SCI_BAUD   Baud rate for serial RS232/485 communications
080_AIP_class_revision
088_ASM_class_revision
096_IDN_class_revision
104_DVN_class_revision
112_CON_class_revision
120_RTR_class_revision

P128_Volt_Limit_Flt;   Maximum desired output voltage
P136_ReleaseTimeSecFlt;
P144_Ramp_RateFlt;
P152_ElectrodesNumber32;
P160_PolaritySwitchTimeSecFlt;
P168_OutriderBoardOptions32;
P176_TripFractionFlt;
P184_WfrOffSense32;
P192_WfrOnSense32;
P200_WfrGrippedSense32;
P208_SenseNoiseLevel32;
P216_OverCurrentWarnLevel32;
P224_GripReductionTimeSec;
P232_GripReductionPercent;
P240_SystemTimeConstSec;
P248_ReleaseMethod;
P256_ReleaseFraction;
P264_ReleaseStepVolts;
P272_ReleaseRamps;
P280_ReleaseParam1;   Deriv
P288_ReleaseParam2;   SFN Mult
P296_ReleaseParam3;   DacSlowHi
P304_ReleaseParam4;   DacSlowMid
P312_ReleaseParam5;   DacSlowLow
P320_ReleaseParam6;
P328_ReleaseParam7;
P336_ReleaseParam8;
P344_ReleaseParam9;
P352_DischargeDelaySec;   DschrgD0.1s
P360_RelaxMultiplier;   RlxMul
P368_VoltSnsDacDevn;
P376_InvPowerConstFlt;   typ 10,000
P384_LoadCapacitancePF_A_Flt;   Ch. A Capacitive Load (chuck + cables) in pF
P392_LoadCapacitancePF_B_Flt;   Ch. B Capacitive Load (chuck + cables) in pF

P400_LoadResistanceMohm_A_Flt;	Ch. A Resistive Load (chuck + cables)
P408_LoadResistanceMohm_B_Flt;	Ch. B Resistive Load (chuck + cables)
P416_Proportional_GainFlt;	typ. 0.01
P424_Integral_GainFlt;	typ. 0
P432_Differential_GainFlt;	typ. 0
P440_HV_V_Cal_A;	
P448_HV_V_Cal_B;	
P456_HV_V_Cal_C;	
P464_HV_V_Cal_D;	
P472_HV_V_Cal_E;	
P480_HV_V_Cal_F;	
P488_Current_Leak_Comp_PosFlt;	
P496_Current_Leak_Comp_NegFlt;	
P504_HV_I_Cal_Pos_nA;	
P512_HV_I_Cal_Neg_nA;	
P520_Cap_Ratio_FactorFlt;	Sense capacitance calculations; typ. 1.94
P528_Cap_Inherent_pFFlt;	Sense capacitance calculations; typ. 30
P544_Cap_Switched_pFFlt;	Sense capacitance calculations; typ. 34
P584_NumberOfArcs;	
P592_NumberOfGrips;	

RAM:

P624_Ramp_RateFlt;	Volts per second
P632_Current_Positive_Amps;	
P640_Current_Negative_Amps;	
P648_SenseFlt;	Chuck & substrate sensor (Hz); see P688.
P656_Temperature;	Internally sensed electronics temperature, °C.
P664_RAW_Volts32;	100 - 140 V typ range; absolute max 200V
P672_12V_Monitor;	12-13V range OK
P688_ChuckCapacitance.pFFlt;	Chuck sensed capacitance, derived from P648.
P720_Current_Reading_Range32;	Ranges: 1, 1nA-500nA; 2, 50nA-50μA; 3, 5μA-5mA.
P760_Current_Leak_Comp_PosRunFlt;	adjust these two for zero current at HV, no load
P768_Current_Leak_Comp_NegRunFlt;	
P824_Actual_Volts_A_Flt;	A and B are the two outputs for a DR6V
P832_Actual_Volts_B_Flt;	
P840_Actual_Volts_C_Flt;	
P848_Actual_Volts_D_Flt;	
P856_Actual_Volts_E_Flt;	
P864_Actual_Volts_F_Flt;	
P872_New_Volt_CmdFlt;	Volt goal for next ramp command
P880_Volt_ErrorFlt;	
P888_LoadCapacitancePF_A_RunFlt;	Ch. A Capacitive Load (chuck + cables)
P896_LoadCapacitancePF_B_RunFlt;	Ch. B Capacitive Load (chuck + cables)
P904_LoadResistanceMohm_A_RunFlt;	Ch. A Resistive Load (chuck + cables)
P912_LoadResistanceMohm_B_RunFlt;	Ch. B Resistive Load (chuck + cables)
P920_Proportional_GainFlt;	Mirror of P416_Proportional_GainFlt,
P928_Integral_GainFlt;	Mirror of P424_Integral_GainFlt
P936_Differential_GainFlt;	Mirror of P432_Differential_GainFlt
P968_FAULT_STATUS;	Mirror of LED fault and status indicators
P976_SYS_STATUS;	System status; ie, gripped, released, etc;
P984_CMD_STATUS;	Command status. While executing is nonzero.
P992_COMMAND;	Zero at rest; holds action commands while executing.

Commanding An Action; P992_COMMAND values available

0: // do-nothing and waiting state, check for a new command
120: // turn on sense signal
122: // turn off sense signal
180: // zero internal current, voltage signals
280: // ramp to commanded signed voltage P872_Volt_CmdFlt, at the P144_Ramp_Rate (V/s)
290: // ramp to negative of signed voltage P872_Volt_CmdFlt, at the P144_Ramp_Rate (V/s)
320: // ramp to zero voltage at rate P144_Ramp_Rate (V/s)
360: // turn off voltage generator

The following commands give examples of typical use, assuming no Daisy Chaining, and a DR6V Multidrop address = 11.

COMMAND (Single)	RESPONSE
Sense request.	
:11@648?@@ ↲	@648:586609.6875 ↲

COMMAND (Set) RESPONSE

Program that zeroes senses, sets 100pF and 100MΩ as outputs, 1000V/s rate, 1000V to grip, then using 280 does a ramp, reset to 2000V then ramp, etc. to make it go up and down between various positive and negative levels; at end, 360 turns off the high voltage generator.
The CR character is not shown here. Appropriate delays between commands required to permit actions to occur.

:11@992 360@@	*Command to turn off HV generator*
:11@888 100@@	*set pF values of A and B channel load capacitances*
:11@896 100@@	
:11@904 100@@	*set MΩ values of A and B channel load resistances*
:11@912 100@@	
:11@624 1000@@	*Ramp rate setting; 1000V / second*
:11@872 1000@@	*New volt level goal setting; 1000V on A channel*
:11@992 280@@	*Instruction to ramp to that goal*
:11@872 2000@@	*2000V on A channel*
:11@992 280@@	
:11@872 1000@@	*1000V on A channel*
:11@992 280@@	
:11@872 -1000@@	*-1000V on A channel*
:11@992 280@@	
:11@872 -2000@@	*-2000V on A channel*
:11@992 280@@	
:11@872 2000@@	*2000V on A channel*
:11@992 280@@	
:11@872 0@@	*0V on A channel*
:11@992 280@@	
:11@992 360@@	*Command to turn off HV generator*

"M" COMMANDS. All data read/written is in ASCII or HEX format.

There are several types of M commands, distinguished by the number following M. The following examples assume a non-daisy chained single unit on a multidrop line with

- address of Nn, where 'N' is typically 1 for V units, F for A units, E for GFC units, etc; and 'n' is between 0 and F, and accessed with the N0 multidrop general address.
- [aaaa] is the Hex start address for the read or write operation
- The value of [nn], the number of characters to read/write in the M command, always equals the number of ASCII characters in the written data or expected response data, independent of whether ASCII or HEX is transferred. One 8-bit HEX byte corresponds to two ASCII characters in the command or response, in the range of 00 to FF.

"M" RESETS

:11M0@@↲ = Complete reset of a DR6V, starting from INIT

:11M1@@↲ = soft reset of DR6V, retaining all RAM parameter values but resetting internal system states.

"M" READS

:11M6[aaaa][nn]@@↲ = "Read [nn] ASCII chars from RAM"

:11M7[aaaa][nn]@@↲ = "Read ([nn] / 2) HEX bytes from RAM"
nn must be even in this comand

"M" WRITES

:11M8[aaaa][nn][data]...[data]@@↲ = "Write [nn] ASCII chars to RAM" command

:11M9[aaaa][nn][data]...[data]@@↲ = "Write ([nn] / 2) HEX bytes to RAM" command

"M" EEPROM ACCESS

Only Hex transactions are permitted. These commands are not recommended for end users due to the tag characters in between each parameter value which determine the data type.

:11MA[aaaa][nn]@@↲ = "Read ([nn] / 2) HEX bytes from EEPROM"
nn must be even here

:11MB[aaaa][nn][data]...[data]@@↲ = "Write ([nn] / 2) HEX bytes to EEPROM"
nn must be even here