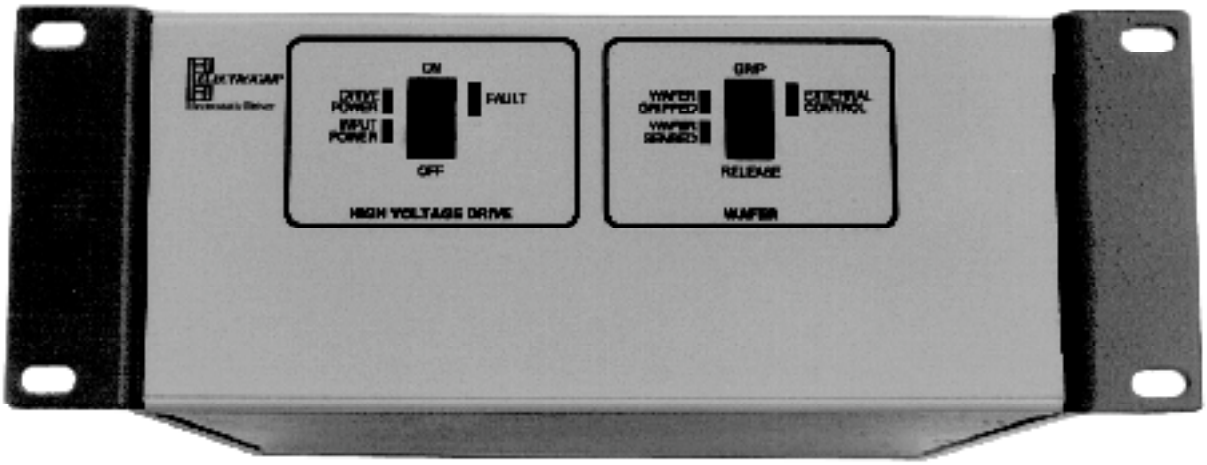
INSTALLATION AND OPERATION MANUAL

ELECTROSTATIC

DRIVER

DR4



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.

ELECTROSTATIC DRIVER

DR4

This manual refers to Electrogrip DR4 Rev C and 6kV models of Electrostatic Driver using v. 8.96 through 9.31 software with serial numbers 1289 and higher

for use with
Bias Decouplers BD2 Rev B and BD3
System Controller GC1 / GC2 / GC3
and Electrogrip Electrostatic Chucks and End Effectors.

Revision _13_ 5 March 2013

Copyright 1996,7,8,9, 2000, 2001, 2006, 2013
ELECTROGRIP
6945 Lynn Way, Pittsburgh PA 15208 USA

CONTENTS

LIST OF ILLUSTRATIONS

OPERATIONAL SAFETY

INPUT POWER, INTERLOCKS

Before applying power ensure that your power input voltage is appropriate for your driver option. The allowable input voltage range is shown on the rear of your driver. The input may be ac or dc of any polarity.

Input voltages between 90V to 400V dc are acceptable for the universal input option, corresponding to the lowest and highest expected ac line voltages worldwide. The low voltage input option accepts input voltages between 18 and 35V dc, and normally would be powered from 24V dc system power.

The DR4 driver is protected against internal faults with surge limiters and self-resetting "fuse" elements and is filtered against rfi emissions. An internal rectifier and capacitor filter allows any dc input polarity, or ac power, to be used.

An interlock switch closure or signal from a control computer must be provided to enable the DR4 driver output. This interlock must be arranged to cut high voltage output when driver output terminals may be exposed. For example, any high-voltage access plate requires a microswitch.

HIGH VOLTAGE CAUTIONS

Operation must be in accordance with instructions given here and with normal safety practices for high voltage systems.

VOLTAGES of up to

- 400VDC IN THE LINE POWER SUPPLY and
- 14,000VDC ACROSS THE OUTPUT TERMINALS are present.

Maintenance and servicing must be done by qualified personnel only.

Full input power supply voltages are always present when the driver line power is connected. **THE FRONT PANEL "HIGH VOLTAGE DRIVE" SWITCH CONTROLS ONLY THE HIGH VOLTAGE OUTPUTS, NOT THE INTERNAL POWER SUPPLY.**

This device generates high voltages when the drive power switch and interlock are enabled. These high voltages are present on the outputs during wafer grip and **after** wafer release.

HIGH DC BIAS VOLTAGES ARE PRESENT ON THE OUTPUT CONNECTOR SHIELDS WITH RF-POWERED CHUCKS.

GENERAL INFORMATION

INTRODUCTION

This section gives a description of the instrument and its specifications.

DESCRIPTION

The Electrogrip DR4 Electrostatic Driver is a computer-controlled high-voltage and low-current power supply for charging the electrodes of an electrostatic gripping system. Such systems are used to hold delicate substrates for semiconductors, liquid crystal displays, thin film heads, etc. Bipolar output voltages from <±100V to ±6kV are available. The DR4 Driver is used in conjunction with electrostatic chucks and robot end effectors and interfaces directly with the Electrogrip GC1 Gas Controller for electrostatic temperature controlling chucks. Connection to rf-powered chucks is through an Electrogrip BD2 Bias Decoupler. Operation may be manual or through a computer. Rear panel control connections override manual front-panel control on the DR4 Driver. Setup programming may be performed using a computer terminal or the Electrogrip DS1 Handheld Terminal. Use a BD2 or BD3 Rev B decoupler with the DR4 Rev B driver version.

The DR4 driver generates accurately related bipolar high voltages on its two outputs. The rate of change of these voltages is controlled to attain the highest operating speed while maintaining low across-wafer voltages to avoid device damage. Wafer position relative to the gripping device surface is also sensed. This position is output via both a logic on/off signal denoting wafer presence, and a serial data string providing a numerical measure of the wafer location. Control outputs and inputs, some of which are user-definable, are provided to allow safe and reliable robotic operation of the entire system incorporating the electrostatic gripper.

The DR4 driver is extensively filtered on both inputs and outputs to minimise the corrupting effects of rf radiation and pickup. 13.56MHz signals of more than 7Vp-p injected directly into any input or output have no effect on DR4 performance.

The DR4 driver with v. 8 and 9 software performs automated self-calibration functions which assist both with rapid installation, and with compensation of long-term drift effects.

For charged particle lithography and electron beam inspection systems, ≥v.8.92 software permits sense signals to be turned off during wafer grip (hardware, software settings).

PANEL LAYOUTS

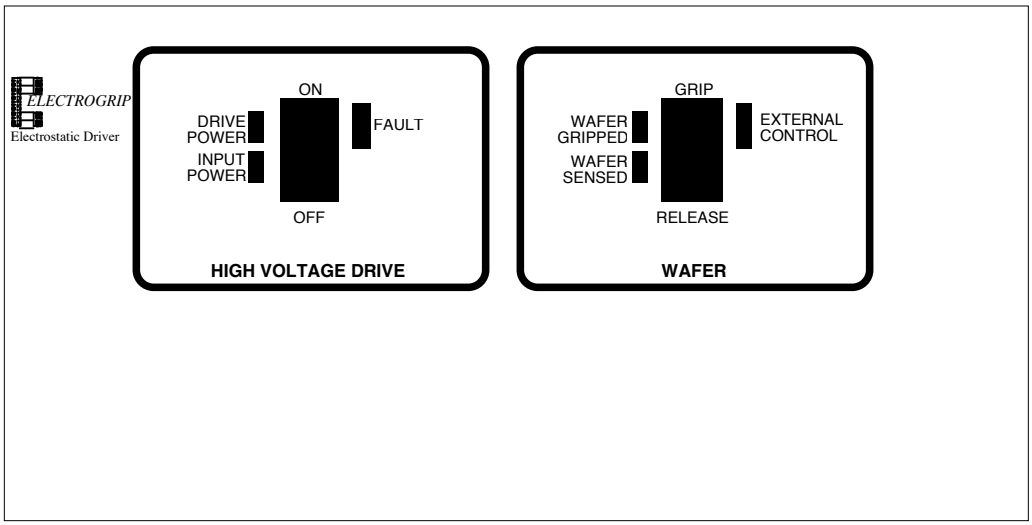


Fig. 1 Front Panel

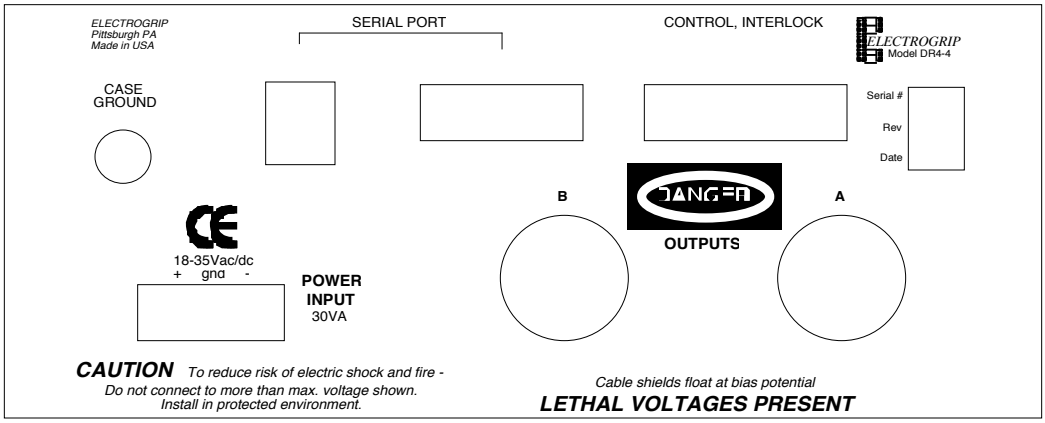


Fig. 2 Rear Panel (low volt input)

NEW FEATURES, DR4 Revs. B, C, v.9.0 software

(i) Use the BD2 Rev. B bias decouplers for rf plasma applications. This revision places 220Ω, 1W resistors in the bias decoupler box, in series with the driver outputs.

(ii) Wafer sensing uses a new type of capacitive coupling to substrates which is less sensitive to system drift, cable lengths, system inductance, and even chuck capacitance. Thus setup is highly reliable with this new method, with greater sense sensitivity using small wafers and chucks.

(iii) A "sense-off" option may be requested to turn the wafer sensing signal off during gripping for ultra-low electrical noise on the gripped wafer, assisting with electron-beam probing without loss of focus. The system takes time to "wake up" the sensing signal before release; the parameter "Held" o/p dly is used to set this time to be long enough for accurate release functions.

(iv) The "DR4semilin" driver option further reduces electrical noise by removing half of the switch-mode power supplies. Without ground isolation, it does not permit substrate bias.

(v) The system no longer requires a wafer to be present for gripping to be initiated. This feature can help save debugging and setup time if a wafer is known to be on a chuck, or if testing is being performed with the wafer sense light out.

Set the "alt:" wafer type using the Options menu if you require wafer sensing before gripping a wafer, for example if wafer sliding is minimised by commanding grip before substrate lowering.

(vi) A new release algorithm has been added, giving the user two release algorithm options; either

• our original release method, a high speed optimisation search for the best release point, or

• our new single-step "point search" method for slower but more accurate final releases.

(vii) Output voltage range switching is now set using internal jumpers.

(viii) The power system temperature is now displayed on the serial port, with overtemp warnings.

(ix) The actual chuck voltage and current on each output is now displayed on the serial port.

(x) Turning the front panel "Drive Power" switch off turns on the "Fault" line and indicator LED.

(xi) The Amp Dly (ms) parameter (influencing release accuracy) can now be set adaptively.

(xii) New options are available that control the operation modes of gripping and releasing. Previously these options were selected through various parameter value or operation mode choices; they are now explicitly called out in the Options menu selections. The new options permit greater accuracy in releasing difficult chuck systems.

(xiii) A new Charge Reduction mode has been implemented after release that allows residual charges to be progressively reduced while substrates remain on chuck surfaces.

(xiv) Comparison of release level attained with goal levels can now be performed with respect to sense levels; previously only electrode voltage levels could be used.

(xv) A Quiet Mode of serial port operation is available that provides individual requested outputs in response to commands from the host computer.

(xvi) Rev. C reduces the substrate sensing voltage level to avoid signal saturation with low frequency BD3 decouplers in the presence of chucks with large capacitances.

All of these new features are compatible with older software settings, methods, and hardware.

SPECIFICATIONS (standard 6kV unit)

DRIVE UNIT DR4 SPECIFICATIONS

VOLTAGE PERFORMANCE

OUTPUT VOLTAGE: Adjustable, 0 to ±6kV (max. 12kV between the A, B outputs)

WAFER VOLTAGE VARIATION w.r.t. output reference: 5Vtyp.

POINT-TO-POINT WAFER VOLTAGE (between any two topside points): <5mV

TIMING PERFORMANCE

GRIP TIME: Adjustable, 0.3 second min. to 80% of final grip force

MINIMUM HOLD TIME: 0.05 second.

RELEASE TIME:
- if wafer allowed to move ≥100μm in vacuum: 0.15 second.
- if stationary in vacuum: 0.75 second.
- In air: 1.2 second.

INPUT POWER

35VA

UNIVERSAL INPUT: 70-250VAC
90-400VDC

LOW VOLT INPUT: 12-24VAC
16-35VDC

(internally surge limited and fault protected; however a 3A fuse is required in series with the 24V dc supply line in case of dc supplies which are current limited in the range of 3-7A)

ISOLATION

High voltage output reference voltage is the [rf bias / gripper baseplate] voltage on the high voltage cable shield.

LINE INPUT - HIGH VOLTAGE OUTPUT 4000V

HIGH VOLTAGE OUTPUT - CONTROL I/O 4000V

CONTROL I/O - CASE GROUND 150V, 22MΩ

HIGH VOLTAGE OUTPUT - CASE GROUND 4000V, ≥68MΩ

INSTALLATION

INTRODUCTION

This section of the manual describes initial setup and operation of the DR4 driver.
Additional information required for setup will be found in the following section for connector pin wiring, and in the chuck / end effector instructions.

UNPACKING

In your package you should find:

(i) Driver unit DR4
(ii) Power connector for DR4 rear panel (includes chassis ground, low volt input option)
(iii) DB15 connector for rear panel control and interlock connections
(iv) Green banana plug connector for chassis ground (universal line power input option)
(v) Two high voltage coaxial cables for DR4 output connections (option).
(vi) Rack mount ears for the cabinet (option).

INSTALLATION TOOLS

You will require the following items for installation:
(i) Attachment hardware for mounting DR4 into rack or other enclosure.
(ii) Chassis grounding wire connected to enclosure.
(iii) Power cable. Polarity unimportant.
(iv) Interlock cable from • microswitch on high voltage wiring enclosure;
OR • computer interlock line (hi for safe, lo for open / unsafe).
This cable connects to the interlock pin(s) on the DB15 connector.
(v) Modem cable from DR4 serial output to terminal or computer,
OR Electrogrip DS1 handheld terminal with RJ-11 connection cable.

INSTALLATION ADJUSTMENTS

(i) Mount DR4 in enclosure. Ensure line input or system input voltage is in correct range for this unit (see rear panel).
(ii) Attach grounding cable from enclosure ground to banana jack in rear of DR4, if is universal input power option; or to central pin on low voltage option power connector.
(iii) Attach high voltage cables from DR4 outputs to gripper (via a bias decoupler if used).
(iv) Ensure that the grip/release switch is at "release" and the drive power switch is "off".
(v) DO NOT yet attach interlock wiring on DB15 connector to rear of DR4
(vi) Plug in the power cable at the DR4 rear. This energises all but the high voltage output.
(vii) Connect the Electrogrip DS1 handheld terminal or a terminal emulator to either of the serial port connections on the DR4 rear. Observe the wafer sense light on the front panel. This light will go on when substrate is on the end effector or chuck, and off when the substrate is taken off, after adjustment of settings.
(viii) You should at least see that the "Sense" level (on the top line of the serial display output) changes when the substrate is put on and off, confirming connection to the gripper.

If you do not observe some change with substrate location, check the wiring by disconnecting the DR4 from the chuck cables, and measuring capacitances on the gripper wires, between gripper drive line and gripper baseplate or the shield of the coaxial gripper drive lines. For this a DVM with a capacitance range of 20nF or less will be adequate. Roughly equal capacitances on each line should be seen, and this capacitance should change when substrates are placed on the gripper face.

(ix) Follow instructions given in the "ADJUSTMENT AND PROGRAMMING" section to "Learn Wafer" sensing levels.
(x) The internal output level jumper setting should be shipped in the correct range. The product of the software multiplier "1Click = ..." and the "Grip kV cal" parameters is directly proportional to output voltage. Thus scaling the product of these numbers downwards will allow decreases of output voltage from the shipped value. Upwards scaling is more difficult; usually a higher jumper setting or combination of settings is preferred, accessed by removing the rear panel of the DR4.
The voltage applied BETWEEN the two outputs is double the number shown on the jumper block as shipped.
(xi) Refer to chuck/end effector instructions for other tests required.
(xii) Connect the interlock cable on the DB15 rear panel connector. Observe that the "fault" light goes out when the high voltage wire termination enclosure is closed, and that it goes on when enclosure covers around the high voltage chuck connections are opened.
(xiii) With the Fault light out, turn on the "drive high voltage" switch. Your gripper will now grip and release wafers under manual control from the front panel switch.
(xiv) If the rear connector is used for grip/release control, note the "external control" light goes on. The control pin must be driven **both** to the high and low logic states.

OUTPUT VOLTAGE CONVERSION EXAMPLES

±6000V to ±800V OUTPUT CONVERSION
Remove the back panel of the DR4 Driver Unit
Remove the two jumpers from 2 and 4kV locations
Place only one jumper in the 1kV location. Other jumper may be stored on a single pin.
Re-insert the back panel. Some force and board movement needed to seat panel correctly.
Turn unit on with drive power off at front panel
Go to the EEPROM settings by pressing "S" twice from the main menu
First line states "1 Click= 100Vx$000A"
Alter the parameter by pressing "A" and enter the value "8" then save by pressing "S"
Exit the EEPROM settings by pressing "X"
Turn on drive power switch on front panel
The output gripping voltages should now output ±800V when gripping.
Label the unit.

±800V to ±6000V OUTPUT CONVERSION
**** CAUTION; this can ONLY be done with drivers labelled on their rear panel "6kV". If older DR4 units are converted as described here they will BLOW UP!! ****
Remove the back panel of the DR4 Driver Unit
Remove the jumper from 1kV location
Place jumpers in the 2kV and 4kV locations
Re-insert the back panel. Some force and board movement needed to seat panel correctly.
Turn unit on with drive power off at front panel
Go to the EEPROM settings by pressing "S" twice from the main menu
First line states "1 Click=100Vx0008"
Alter the parameter by pressing "A"and enter the value "A" then save by pressing "S"
Exit the EEPROM settings by pressing "X"
Turn on drive power switch on front panel
The output gripping voltages should now output ±6000volts when gripping.
Label the unit.

OPERATION

INTRODUCTION

This section describes the DR4 driver front and rear panel controls, indicators, and connectors. It also provides typical wiring diagrams for the rear panel connectors.

FRONT AND REAR PANELS

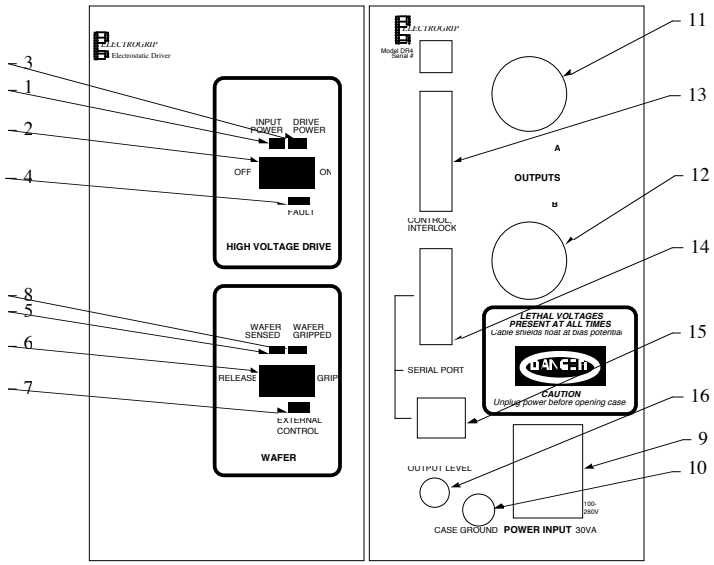


Fig. 3 Controls (vertical)

1. INPUT POWER indicator: Lit when rear input power connector 9 is energised. Indicates operation of all internal circuits except for high voltage output.
2. HIGH VOLTAGE DRIVE switch: Controls high voltage output if fault indicator 4 is off. When this switch is off, "Fault" output signal and "Fault" LED are energised.
3. DRIVE POWER indicator: Lit when high voltage drive is active.
4. FAULT indicator and output: Energised when "Interlock" input on connector 13 is low or HIGH VOLTAGE DRIVE switch off. Disables high voltage output when energised.
5. WAFER SENSED indicator: Lit when substrate is present on gripper. Causes low "Wafer Sensed" output on connector 13 when substrate causes a gripper capacitance rise.
6. WAFER CONTROL switch: Commands grip and release if "External Control" indicator 7 is off. There is a time lag between switch operation and completion of each action.
7. EXTERNAL CONTROL indicator: Lit when "Remote Input" input on connector 13 is driven high or low. Indicates that an external control signal is being used. This pin must be actively driven in each direction to ensure override of Wafer Control 6 at all times.
8. WAFER GRIPPED indicator: Lit when wafer grip operation is complete. Off when wafer release operation is complete. Causes low "Wafer Gripped" output signal on connector 13.
9. POWER INPUT connector: Line input or system input power, ac or dc. Allows case grounding via this connector.
10. CASE GROUND connector: Banana jack. Used to provide an rf ground for case to system enclosure. Use a short wire or strap to assist in reliable wafer sensing and low rfi.

11, 12. A, B OUTPUT connectors: Isolated high voltage outputs to two poles of an electrostatic gripper. Also permit wafer position sensing. A and B outputs differ if poles are not well matched. Otherwise are interchangeable. Connector shields float at average dc potential of electrostatic gripper baseplate which may be at rf bias levels of up to ±4kV. Thus these

connectors are provided with INSULATED OUTER COVERS which must not be removed.

13. CONTROL, INTERLOCK connector: DB-15 female. All pins [*inputs, outputs, "chassis ground" and "chassis power"*] are isolated from case, line input, and high voltage output but not from Serial Port connectors 14, 15. Isolation is 150V to case ground, 4000V to Output Connector 11, 12 shields.
Logic outputs are open-collector LS TTL, pulldown to Chassis Ground, 30V max. rating.
Inputs are ~10kΩ high impedance with adjustable logic level from 5 to 30V.
"Chassis Power" is a dual purpose input and output.
As an **output**, "Chassis Power" may be used as a source of 5V power through a 100Ω source resistance. In this case inputs sense level changes around a 2.5V trip point.
As an **input,** "Chassis Power" may be driven by any system logic power between 5 and 30V. In this case inputs sense level changes around approx. half of the system logic power voltage. This maximises the input logic gate noise margin for high system logic voltages.

14, 15. SERIAL PORT connectors: DB-9 female and RJ-11 6pin modular jack . All pins are isolated from case, line input, and high voltage output but not from Control, Interlock connector 13. Isolation is 150V to case ground, 4000V to Output Connector 11, 12 shields. Provide two independent serial connections to the internal driver controller. One may be used for modifying stored data, another for monitoring communications on the line.

16. OUTPUT LEVEL control: (Is behind the indicated position, on a jumper block.) Sets maximum output level. Maximum output between the A and B connectors 11, 12 is double the level shown on this switch for balanced electrode drive. Parameter settings permit arbitrary fractions of this output level to be set. The newer DR4-6kV model can operate continuously at ±6kV.
Operation above ±4kV is not recommended for the earlier models (see below).

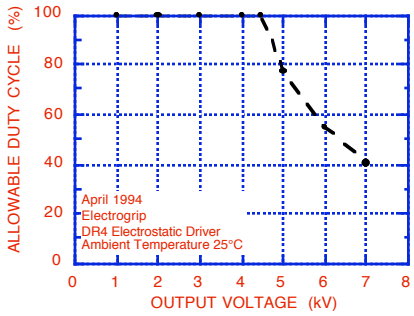


Fig. 4 Allowable duty cycle of DR4 driver as function of output kV setting

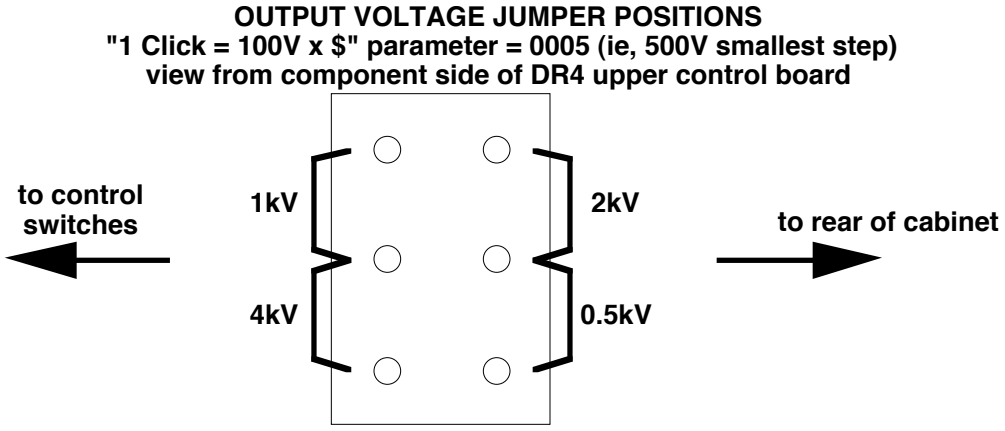


Fig. 5 Jumper positions for various output voltage levels. ±6kV models require the 2 and 4kV jumpers to be installed for full output voltage capability.

CONNECTIONS

PARALLEL PORT

Wiring to the Control, Interlock connector 13 is shown below. Refer also to the description of pin use in the preceding subsection.

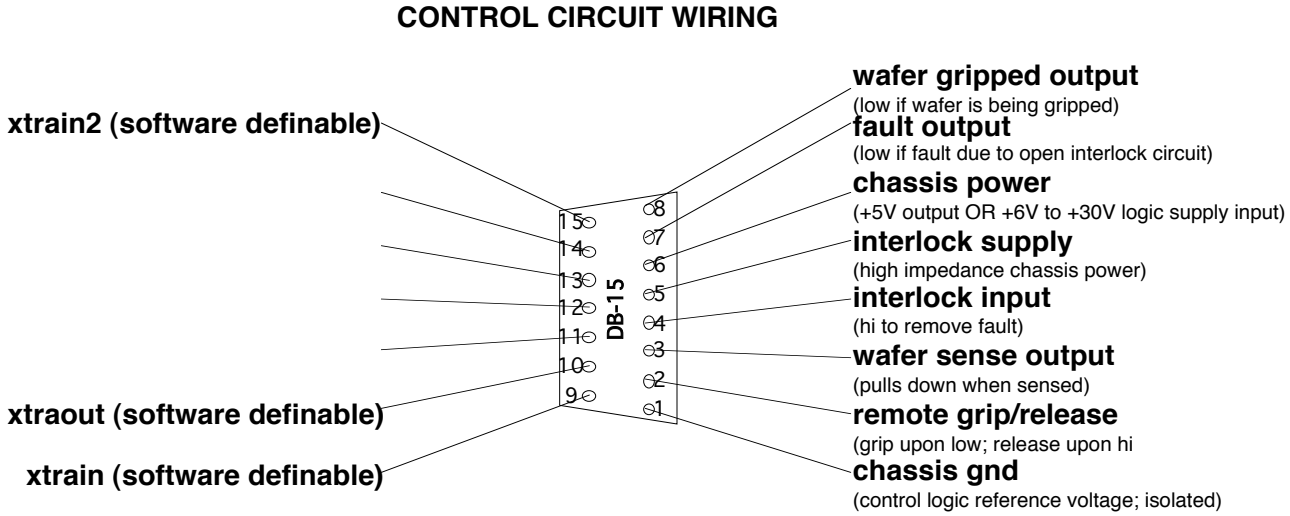


Fig. 6 Control, Interlock connector pins

Minimal wiring for high voltage output: connect pin 4 to pin 5 (or 6) via an access interlock.
(This interlock switch is generally placed on the shield enclosure under an rf chuck.)
Minimal addition for remote control: drive pin 2 both high and low to control release and grip.
(This pin 2 drive then replaces the front panel grip/release switch function.)
Additions for robotic feedback and fault monitoring: Use the Fault, Sense, Gripped outputs.

SERIAL PORTS

Wiring to the Serial Port connectors 14,15 is shown below. The two port connections share common power and ground lines but use separate drivers and receivers for the data lines. 9600 Baud, no parity, 8 bit, one stop and one start bit.

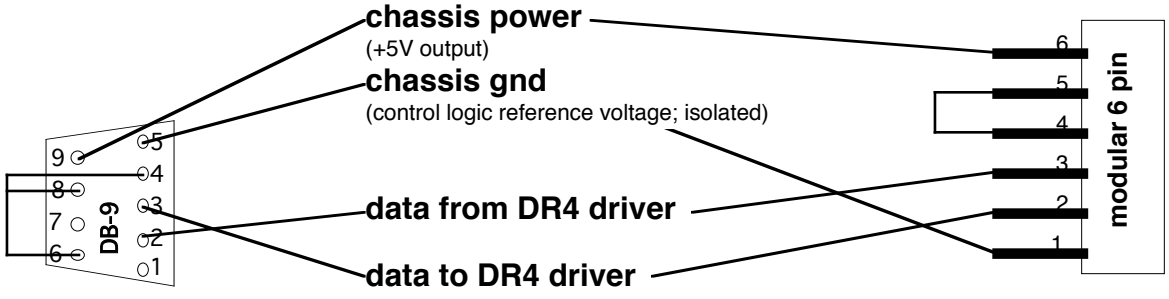


Fig. 7 Serial Port connector pins.
Note for connection to a serial Host computer port, the connections must be made appropriately. A 9-pin host PC computer connection is most easily made with a ribbon cable, and with direct connections pin-for-pin between the connectors.

ISOLATION AND OUTPUT CIRCUIT

Isolation between the driver subsystems is shown below. This degree of isolation permits direct connection of driver logic lines to other system connections without optoisolators, since ground loop errors are eliminated.
The output effective circuit is also shown. The high output impedance limits current flow in case of an output short circuit.
Output voltage and current are monitored on each channel independently and displayed on the serial port. Normal current levels are low (<1μA or one LSB, typ.) on Electrogrip chucks.

OUTPUT CIRCUIT SCHEMATIC

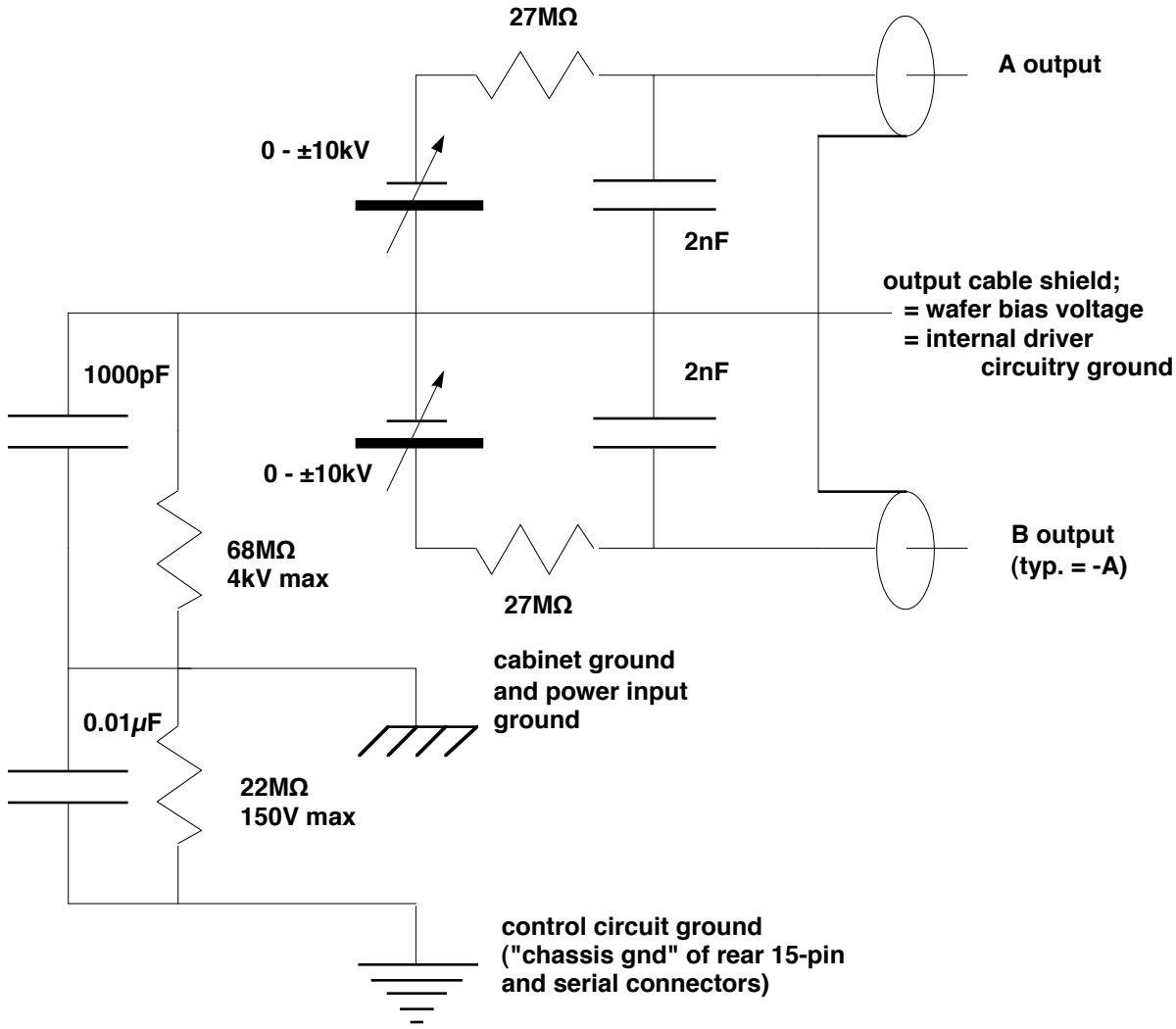


Fig. 8 Isolation between inputs, outputs; and effective output circuit. Note that the 68MΩ resistor may be omitted in the case of high bias source impedance.

ADJUSTMENT AND PROGRAMMING

INTRODUCTION

This section describes how parameters may be monitored and modified using terminal commands to a DR4 driver serial port. Software version 9.0 is described here.

Typical adjustments and parameter settings are:

- Wafer sense levels for wafer position;
- Maximum distance of wafer from gripper that permits gripping to occur;
- Balance of A and B output voltages to compensate for asymmetric gripper electrodes;
- Ramp step time for control of wafer backside current levels;
- Release processing methods to minimise residual gripping forces;
- Control of grip performance in case of errors;
- Control of use of alternate types of wafer with different sense characteristics.

Additional functions performed include:

- Monitoring of system status; including power electronics temperature, output voltages and currents, internal drive voltage, and wafer sense signal;
- Full control of the unit on the serial line, permitting; grip, release, output zeroing, and actuation of the wafer sense LED and output signal.
- Storage of operating parameters in user-configurable memory;
- Rapid changeover of operating modes through "Load" and "Dump" functions;
- Autozeroing of output voltages at turn-on;
- Learning and tracking shifts in sense levels and output zeroing during operation;
- Delays after grip and before release for sense signal switching (lithographic applications);
- Self-testing of driver functions (factory use only);
- Unit history logging during normal operation (factory use only);

USER INTERFACE FORMAT

CONNECTIONS

9600 Baud; [no parity, 8 bit, 1 stop bit] or ["space" parity, 7 bits, 1 stop bit].
Use a "Modem" computer cable on DB-9 socket / DS1 Electrogrip terminal on RJ-11 phone jack.

MEMORY TYPES

The DR4 driver with v. 8 software contains two types of memory;
(i) program storage which includes RAM space for storage of current parameter values;
(ii) an electrically erasable EEPROM for long-term storage of adjustable parameters.
The following user interface information relates to EEPROM and RAM access only.

POWER-UP ACTIONS

When the DR4 driver is first powered up it will:
(i) Do an inital "dump" which will fill RAM although zeroes are displayed to the terminal;
(ii) Autozero high voltage outputs (if high voltage switch is set to "on" and the interlock is in place, i.e., the red front panel LED is not on);
(iii) Display main menu.

MENU FORMAT, NAVIGATION

DR4 driver / v. 8,9 software menus consist of four lines that contain numbers, words and questions, with some letters in words capitalised. These capitalised letters are keys for menu navigation.

-**Capitalised letters** in keywords represent keys that can be pressed to call the function or menu corresponding to that keyword.
- Upper or lower case characters are read identically by v. 8 software.
-**Two dots** ".." following a menu item indicate that it calls up another menu which will give further choices.
-Because of space limitations not **all possible valid entries** are shown. E.g.:
(i) the X and ESC (escape) keys often cause return to the main menu;
(ii) the "space" key or "spacebar", except when the driver is waiting for numeric input, toggles operation of a "running sense monitor" which displays the sense signal level. The driver will still take menu selections and often returns to the running sense monitor after carrying out other commands.
This sense signal display is turned off by:
- Pressing the spacebar;
- Exit to the main menu (pressing X or ESC);
- Activity on external control lines such as a grip command.

NUMERICAL FORMAT, NUMBER ENTRY

All values are in HEXADECIMAL format, not DECIMAL. Numbers use base 16, not base 10, and the additional numerals required are letters. Hence allowable numerals are 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, and F. Single-byte (8-bit) numbers have the format 00 to FF (0 to 255 decimal), while double-byte numbers have the format 0000 to FFFF.

-**Numbers are output** with leading $ signs to denote their hexadecimal base.
-Numeric data for parameter adjustment can be **entered** using:
(i) Numbers (hexadecimal format); or
(ii) +, - (plus and minus) keys for fast one-digit changes to any of the parameters. These changes affect RAM values only. Thus finish with a "Save" to EEPROM when correct parameter values are determined. This "Save" action will save the current parameter ONLY. Other parameters which have been changed but not individually saved will be lost upon power-down of the DR4 driver.
-Numeric data for some parameters is in a format which allows **two types of wafer** to be sensed, using an "alt/main" input line to switch between "alternate" and "main" wafer types. This is appropriate when using two differently sensed wafer types in the one process chamber, such as semi-insulating GaAs, and doped, wafers.
In these cases the first two digits entered (most significant) correspond to the Alt wafer, the second (least significant) two digits to the Main wafer.
Normally these numbers are set by the "Learn wafer" command. Manual resetting is not normally required. You can not enter values for just one wafer type; both must be entered. Hence enter a four-digit number, altering just the pair of numbers corresponding to the wafer type being sensed.
-To **abort a parameter alteration** in progress, press ESC (Escape) or some other non-numeric key (ie, other than 0-9 or A-F) BEFORE entering a number.

MENU FORMATS

MAIN MENU

This periodically refreshed menu is:

```
DAC=$0200Sense=$9247      Output, Sense levels
(c)99ELECTROGRIP9.00      Software version, copyright
Ia00b00 Va80b80  T20      Currents, Voltages,  °C Temp
Set.., Dump, Load:        Main menu line
```

DAC is proportional to the output drive voltage. 200 Hex represents zero output voltage.
Sense is a function of wafer height. The sense number rises as wafer height is increased above the gripper surface, after setup "learning" of the sense system performance.
Ia is the A channel current in μA (hex); **b** for the B channel. Unsigned.
Va, b are the A, B channel output voltages (hex); 80 is zero, higher numbers for positive output, lower numbers for negative output voltage. ±4kV output is typ. D6 and 2A.
T is the main power component heatsink temperature. At room temperature reads 1C to 20 (hex), and at ~100°C reads 64 (hex). At 100°C, an alarm display will be shown every 4 Main Menu cycles, warning of overtemperature.

```
WARNING - HEATSINK
TEMPERATURE IS OVER
100 DEG.C. SHUTDOWN
IS IMMINENT!
```

If the "Drive Power" switch is off, the display shows "T--".
S = Set.. Calls up another menu for calibrations and setup.
D = Dump (i) Lists all values in RAM, which can be captured and later down-loaded into a driver to give it the identical values of all set parameters and options.
(ii) Then dumps all values from EEPROM into RAM.
L = Load (i) Accepts a down-loaded file and stores it into EEPROM.The data transmission rate should be slowed down some-what because programming occurs in realtime. A delay between characters of 1/10th second yields safe timing.
(ii) Stores into RAM the new Loaded values.

SET MENU

The set menu is:

```
Set-parameters.., or      detailed parameter setting
Options.., or learn-      control option setting
Wafer, Zero, Balance      auto adjust choices
or 'X' to eXit:           exit to main menu
```

S = Set-parameters.., Sets numeric parameter values such as rates or time periods. All parameters may be set using this menu but the methods would be less straightforward than using the auto-setting procedures in the menus below.
O = Options.. Enables/disables control options and external control pins.
L or W = learn-Wafer Automatic setup for a new gripper or wafer type. It will prompt you to take the wafer off and put it back on. During this time it will do various internal calibrations and adjust the setting of the wafer presence indicator. The results are stored into EEPROM.
Z = Zero Zeros the high voltage outputs. Performed also during power-up and occasionally during operation. During normal operation including power-up the zero settings are not stored into EEPROM. However this menu selection will store zero values into EEPROM.
B = Balance Turns on an oscillatory output to assist in balancing the bipolar drive, to keep the wafer potential low at all times. See the section "ADJUSTMENT OF BALANCE LEVEL".

SET-PARAMETERS MENU

This menu is:

```
this parameter is                    header line
1 Click= 100Vx$0005                  description of parameter
Next,Back,Alter,Save                 choice of action...
or 'X' to eXit:                      ...or exit to "main"
```

Second line Describes the parameter to be set, with its value being the last item on the line, following the $ (hexadecimal) sign.
See section "PARAMETER DEFINITIONS" for parameter descriptions.

N = Next or <ENTER> Progress to the next parameter. The list wraps around at the end and returns to the first parameter.

B = Back Go to previous parameter. The list wraps around from the list start, going to the last parameter.

A = Alter Modify this parameter IN RAM ONLY. To save to EEPROM use the Save command after modification in RAM.

S = Save Save the value of this parameter now in RAM to EEPROM.

OPTION MENU

The Option menu is of the form:

```
Do you want to
release, if sense is
lost during grip?                    3-line question
Y/N/ENTER? (now YES)                 3 possible responses
```

See the section "OPTION DEFINITIONS" for descriptions of the options.

Three lines ask a question which can be answered Yes or No.

Fourth line prompts for a reply and shows the current state. Enter Y for Yes, N for No, ENTER will leave the answer the way it was previously set and go to the next question.

ESC (escape) OR reaching the end of the option list returns to main menu.

B = Back Back will return to the previous question.

All options get **saved** into EEPROM as you respond to the questions. This will occur EVEN IF YOU ESCAPE out of the list.

OPTION and PARAMETER DEFINITIONS

OPTION DEFINITIONS

Do you want to release, if sense is lost during grip? Rf plasmas can shunt sense signals. Thus for rf chucks, answer NO to hold the wafer while wafer sensing is shunted by the plasma. Sensing will be regained after the plasma is turned off.

Do you want to use the main wafer type as opposed to alt.? Use to switch between substrates with different sense characteristics such as insulators (Semi-Insulating GaAs, glass) and conductors (doped GaAs, Si, conductive ceramics). See next Option for another method of switching this mode.

The "learn-Wafer" process applies to the current wafer type. The Main wafer uses the Least Significant Byte of the stored double-byte sense parameters, Alt the Most Significant.

Do you want a no-wafer signal on the extra input? If YES is chosen, Logic High on the "XTRAIN" pin on the rear DB-15 connector when the substrate is raised off the gripper progressively updates the stored "no wafer" sense value.

Do you want to track the wafer-on level if it drifts? If YES is chosen, the sense level stored during "Wafer Learn" for the wafer on the gripper is updated to follow the average values seen in use. Compensates for sense signal drift.

Do you want to reduce voltage after grip? Reduces electrode voltages after grip has been attained, limiting charge storage in leaky chucks. See the parameters High KV 0.1 sec, Reduction0.1

Do you want to go to zero volts after release? After substrate release has been attained, electrode voltages are ramped to zero. See the parameter Zero step size, and the Option below.

Do you want to discharge after release? Relates to electrode voltages going to zero, in above Option. N will ramp steadily, Y adaptively extracts dielectric charge while a substrate is resting on the gripper.

Do you want to use the measured AMP DLY findings? N uses EEPROM parameter value, Y measures value during release.

Do you want to use POINT search releasing? N will cause the fast release method to be used, Y the slower point-search method.

Do you want to use RELFRACT with sense rather than volts? If N, compares release electrode voltage levels with desired fractional value; if Y, compares release sense levels with desired fractional sense change (resting - grip) value.

Do you want to go to zero volts without releasing? If N, finds best release levels; if Y, zeroes output voltages without searching.

Do you want to use the optimized gripping polarity? N will grip according to choice in below options. Y will measure and choose polarity for strongest substrate grip.

Do you want to alternate the gripping polarity? N will use a constant grip polarity, Y alternating (preferred for leaky dielectrics).

Do you want to grip without a wafer sense? Y permits gripping even without a substrate being sensed on the gripper; used for tests.

Do you want to use the EXTRAIN signal to grip when high? Y causes parallel port pin #9 (see page 14) to act as a reversed polarity grip/release signal; i.e., grip when pin #9 is high. Pin #2 and the front panel grip/release switch are not active if this option is chosen.

Do you want the EXTRAOUT high when IWARN is met? Y causes pin #10 of the parallel port (see page 14) to go high for at least 30ms when either A or B high voltage output microampere current level meets or exceeds the "I WARN" parameter in the EEPROM SET-PARAMETER settings (see pages 18, 22). Transient currents will thus be registered if the DR4 is polled more frequently than every 30ms.

Do you want to zero when sense is lost after release? Y causes the output high voltages to be zeroed after release, 2 seconds after wafer sense is lost. This assists with chuck surface discharge using plasma or an ioniser.

Other options will be added in later versions of the software and you may have custom options for your installation.

PARAMETER DEFINITIONS;

Typical numerical values for the parameters are shown below, following the $ (hexadecimal) sign.

1 Click= 100Vx	**$0005**	Values; 1 to A. Controls grip voltage level, in combination with the rear panel "Output Level" switch. "1" yields 100V/switch step; "A" yields 1,000 V/switch step. Thus "5" (500V/step) and switch position of 8 yields an output grip level of 4kV. DO NOT ALTER WHILE GRIPPING.
Trip in 1/2mms	**$0002**	(see "Trip Calibrate" below). Distance (in 0.5mm increments) from gripper at which wafer sensing (and the wafer sense LED and rear panel output) trips. Hence a setting of 2 results in wafers being sensed ~1mm from the gripper surface, and 1 results in ~0.5mm sensing distance.
I Warn/Grip kV	**$0371**	Upper byte; the current level (μA) to output a high on the EXTRAOUT signal if that OPTION is set. Setting shown trips at 3uA. The lower byte (Grip kV) calibrates the A channel output voltage (and B, through balance adjust below).
Balance adjust	**$0050**	Adjusted by performing Balance test in the "Set" menu; see "ADJUSTMENT OF BALANCE LEVEL" section. Sets B channel relative to A channel.
Relrpt/Relfrac	**$0403**	1st 2 (LHS) digits=release attempts permitted while release volts or sense level diff> (grip voltage or sense level diff÷relfrac). 2nd 2 (RHS) digits = Relfrac.
"Held" o/p dly	**$0010**	Time delay before signals that a wafer is held after gripping; v.8.92 and after; is also the time delay before executes release after release command; 32ms units.
DAC zero	**$0040**	Following three "zero" parameters set by "Zero" in "Set" menu.
A HV zero	**$0080**	
B HV zero	**$0082**	
High KV0.1Sec	**$0032**	For "reduce voltage after grip" option; the time in tenths of seconds that the grip voltage remains high (at switch and software setting) before reduction . For example: $0032 yields a 5 second delay.
Zero step size	**$2625**	For "voltage reduction" option; step time (μs) for the ouput to relax to zero after release. For a 128-step ramp (depends on gripper memory effects), $2625 yields a 10 second ramp time.
Sense Zero	**$005A**	Following two parameters set by learn-Wafer in "Set" menu.
Phase Alt/Main	**$0809**	
Grip step (us)	**$00C0**	Controls ramp timing; increase to reduce substrate current flow.
Rel. step (us)	**$0300**	Electrogrip internal use. Old release method; use 00C0; new method; use 0300.
Rel.Noise/Step	**$0304**	1st 2 (LHS) digits; release noise mask bits; 2nd 2 (RHS) digits; fast release method; $80. Proportional to release error using point search method.
Grip/Rel Crits	**$1010**	1st 2 (LHS) digits set sensitivity of grip cycle to wafer clamp strength; small numbers yield more sensitivity to small changes in clamp strength. Second 2 digits control timing of the "end of release cycle" signal.
Amp Dly (ms)	**$00D0**	Set for best release using point search method; typ. D0. Fast method; $000A.
Release ramps	**$0002**	Electrogrip internal use.
Options 'A'	**$0000**	Set by questions in "Options" menus.
Options 'B'	**$0000**	Set by questions in "Options" menus.
No wafer Main	**$9263**	Following four parameters set by learn-Wafer in "Set" menu.
Wfr.level Main	**$8424**	
Delta Zero	**$001D**	
Delta Sense	**$0EAC**	
No wafer Alt	**$403B**	Following two parameters set by learn-Wafer in "Set" menu.
Wfr.level Alt	**$4037**	
Trip Calibrate	**$0020**	Calibration factor for "Trip in 1/2mms" parameter. Is multiplied by the trip distance for calculation of trip sense level. "Normal" (from simple theory) value is $0020. This value works for lithographic chucks and is the value in v. 8.80 software. Allowable range; $0001 to $00FF to compensate for rf chuck wiring effects. Some chucks require this value to be $0040 to obtain good height calibration. Set "Trip Calibrate" by spacing a wafer 1mm away from the gripper using small spacers, setting "Trip in 1/2mms" to $0002, then adjusting "Trip Calibrate" until sensing just occurs.
Reduction 0.1*	**$0002**	The "voltage reduction" option multiplier. For example: $2 yields multiplier of 0.2 so for a setting of 1KV the voltage will reduce to 200Volts after the time set by "High KV 0.1Sec".

SAMPLE SESSION TEXT
ELECTROGRIP V.9 SOFTWARE OPERATION; SESSION TRANSCRIPT

Comments on the session are shown in italics. User commands may be uppper or lower case.

POWER-UP

```
.HEX                                        startup at power on; hexadecimal
*1 Click= 100Vx$0000                        numbers are to be used
*Trip in 1/2mms$0000
*Grip kV Cal.  $0000                        dump of parameter names; initial values
*Balance adjust$0000                        of parameters is zero. After this dump,
*Relrpt/Relfrac$0403                        parameter values from EEPROM
*"Held" o/p dly$0000                        are loaded into RAM.
*DAC zero      $0000
*A HV zero     $0000
*B HV zero     $0000
*High KV 0.1sec$0000
*Zero step size$0000
*Sense Zero    $0000
*Phase Alt/Main$0000
*Grip step (us)$0000
*Rel. step (us)$0000
*Rel.Noise/Step$0000
*Grip/Rel Crits$0000
*Amp Dly (ms)  $0000
*Release ramps $0000
*Options 'A'   $0000
*Options 'B'   $0000
*No wafer Main $0000
*Wfr.level Main$0000
*Delta Zero    $0001
*Delta Sense   $0000
*No wafer Alt  $0000
*Wfr.level Alt $0000
*Trip Calibrate$0000
*Reduction 0.1*$0000
.END

Sense Zero    $0077

Zeroing Amp. System                         internal autozero of power circuits
-------+
-+
-+
Done.

DAC=$0200Sense=$812A                        repeated prompt message
(c)98ELECTROGRIP9.00
Ia00b00 Va80b80  T1C
Set.., Dump, Load:

DAC=$0200Sense=$8129
(c)98ELECTROGRIP9.00
Ia00b00 Va80b80  T1C
Set.., Dump, Load:

DAC=$0200Sense=$8127
(c)98ELECTROGRIP9.00
Ia00b00 Va80b80  T1C
Set.., Dump, Load:
```

MENU CHANGE AND EXIT TO MAIN MENU

```
 DAC=$0200Sense=$8126
(c)98ELECTROGRIP9.00
Ia00b00 Va80b80  T1C
Set.., Dump, Load:s                                  user command (Set, ie "s")

Set-parameters.., or
Options.., learn-
Wafer, Zero, Balance
or 'X' to eXit:x                                     user command (Exit, ie "x")


DAC=$0200Sense=$811F
(c)98ELECTROGRIP9.00
Ia00b00 Va80b80  T1C
Set.., Dump, Load:

DAC=$0200Sense=$811F
(c)98ELECTROGRIP9.00
Ia00b00 Va80b80  T1C
Set.., Dump, Load:
```

BALANCE ADJUSTMENT

```
DAC=$0200Sense=$811E
(c)98ELECTROGRIP9.00
Ia00b00 Va80b80  T1C
Set.., Dump, Load:s                                  user command (Set, ie "s")


Set-parameters.., or
Options.., learn-
Wafer, Zero, Balance
or 'X' to eXit:b                                     user command (Balance, ie "b")


Meas. wafer volts
and use + & - to
null it. S to Save:+++--+S                           user command sequence while
Balance adjust=$0052                                 monitoring wafer ac voltage;
Done.                                                when finished type "s" to save
```

(see the "ADJUSTMENT OF BALANCE LEVEL" section)

OUTPUT ZEROING

```
Set-parameters.., or
Options.., learn-
Wafer, Zero, Balance
or 'X' to eXit:Z                                     user command (Zero, ie "z")

Zeroing Amp. System                                  repeat of power system autozero
++
--+
-+

Done.
DAC zero      =$0083
A HV zero     =$007B
B HV zero     =$007D
```

WAFER SENSE LEVEL SETTING

```
Set-parameters.., or
Options.., learn-
Wafer, Zero, Balance
or 'X' to eXit:W                          user command (Learn wafer)

Take Wafer Off then press any key         follow this instruction
or 'X' to eXit:

Please Standby.

Sense Zero    $009C
Delta Zero    =$0032
Delta Sense   =$0EEB                      end of this thinking phase

Put Wafer On, press any key               follow this instruction
or 'X' to eXit:

Please Standby.
Wfr.level Main=$7F1A
No wafer Main =$7F20
Phase Alt/Main=$080D
Sense Zero    =$0082                      end of second thinking phase
...............................           wafer on/off cycle is repeated
Done.                                     wafer sensing is optimised
```

OPTION SETTING

```
Set-parameters.., or
Options.., learn-
Wafer, Zero, Balance
or 'X' to eXit:O                          user command (Options, ie "o")

Do you want to
release, if sense is
lost during grip?
Y/N/ENTER? (now YES)NOptions 'A'   =$0080  "Options" word value is shown

Recognized NO                              Confirms that "N" was received

Do you want to use                        Two types of wafer  sensing
the main wafer type                       are available, eg for Si and
as opposed to alt.?                       semi-insulating GaAs; this chooses
Y/N/ENTER? (now YES)NOptions 'A'   =$8080  the wafer type to be sensed using this
                                          software switching with a terminal
Recognized  NO

Do you want                               Wafer sensing switching may
XTRAIN2 hi to                             also be performed using a
select ALT wafers?                        hardware switch (the XTRAIN2
Y/N/ENTER? (now NO)NOptions 'A'  =$8080    pin on the driver rear panel), if
desired.
Recognized  NO

..............

Recognized  YES

No more options.                          End of option setting session
```

INDIVIDUAL PARAMETER SETTING

```
 DAC=$0200Sense=$7F45
(c)98ELECTROGRIP9.00
Ia00b00 Va80b80  T1C
Set.., Dump, Load:

DAC=$0200Sense=$7F46
(c)98ELECTROGRIP9.00
Ia00b00 Va80b80  T1C
Set.., Dump, Load:

DAC=$0200Sense=$7F45
(c)98ELECTROGRIP9.00
Ia00b00 Va80b80  T1C
Set.., Dump, Load:S                          Set individual values in memory

Set-parameters.., or
Options.., learn-
Wafer, Zero, Balance
or 'X' to eXit:S                             ...by selecting Set-parameters

this parameter is
1 Click= 100Vx$0005                          you can set the voltage per
Next,Back,Alter,Save                         "click" of the rear voltage switch
or 'X' to eXit:N                             ...but go on to the next value
.........................
.........................                    (stepping through parameter list)
this parameter is
Balance adjust$0052
Next,Back,Alter,Save
or 'X' to eXit:A
enter a HEX number: $0047                    here decided to enter a new value

this parameter is
Balance adjust$0047
Next,Back,Alter,Save
or 'X' to eXit:+                             can also change with + and - signs

this parameter is
Balance adjust$0048
Next,Back,Alter,Save
or 'X' to eXit:-

this parameter is
Balance adjust$0047
Next,Back,Alter,Save
or 'X' to eXit:-

this parameter is
Balance adjust$0046
Next,Back,Alter,Save                         If press "S" then saves this number
or 'X' to eXit:N                             to permanent memory
.........................
.........................                    (stepping through parameter list)
this parameter is
Ratio Alt/Main$8080
Next,Back,Alter,Save
or 'X' to eXit:X                             exit from parameter setting
```

DUMP OF PARAMETER VALUES TO TERMINAL

```
DAC=$0200Sense=$7F3F
(c)98ELECTROGRIP9.00
Ia00b00 Va80b80  T1C
Set.., Dump, Load:D

.HEX
*1 Click= 100Vx$0005
*Trip in 1/2mms$0002
*Grip kV Cal.  $00EF
*Balance adjust$0045
*Relrpt/Relfrac$0403
*"Held" o/p dly$0002
*DAC zero      $0083
*A HV zero     $00E5
*B HV zero     $00A2
*High KV 0.1sec$0000
*spare dac 4   $0000
*Sense Zero    $0082
*Phase Alt/Main$080D
*Grip step (us)$00C0
*Rel. step (us)$00C0
*Rel.Noise/Step$0080
*Grip/Rel crits$1010
*Amp Dly (ms)  $000A
*Release ramps $0002
*Options 'A'   $80C0
*Options 'B'   $0000
*No wafer Main $7F20
*Wfr.level Main$7F1A
*Delta Zero    $0032
*Delta Sense   $0EEB
*No wafer Alt  $403B
*Wfr.level Alt $4037
*Trip Calibrate$0000
*Reduction 0.1*$0000
.END
```

DR4 SERIAL CONTROLS

KEY	PARAMETER SHOWN	OUTPUT [1st:2nd byte] DISPLAY
Cntrl-F	-	turn on/turn off (toggle) forced wafer sensing
Cntrl-G	-	commence gripping
Cntrl-R	-	release wafer
Cntrl-Z	-	zero output voltages
Cntrl-S	-	starts "quiet" mode
Cntrl-X	-	ends "quiet" mode
P	Wafer sense level	[MSB : LSB]
V	A, B actual output voltage	[V A channel : V B channel]
I	A, B actual output current, μA	[I A channel : I B channel]
T	DR4 main heatsink temperature, °C	[- : T]
U	DAC level (output drive)	[MSB : LSB]

ADJUSTMENT OF BALANCE LEVEL

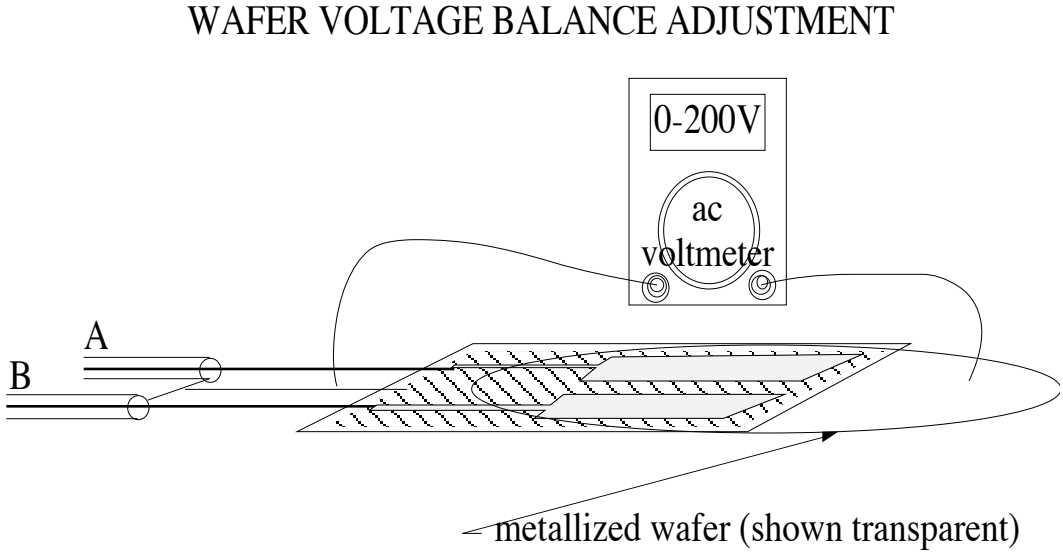


Fig. 9 Wafer voltage balance adjustment

(OPTIONAL - *drivers are shipped with balanced outputs. Adjustment is required if drivers are used with asymmetric grippers.)*

Place a dummy metallized wafer on the gripping surface, and connect a 200V ac DVM with 10MΩ input resistance between this plate and the gripper base potential.

Ensure that the grip high voltage power switch is on, and that the "fault" red light on the DR4 front panel is not on (ie, the rear panel interlock at the DB-15 connector is enabled).

Select "balance" from your terminal "set" menu. The ac voltmeter should register a level of voltage.

Use the + and - keys (or enter a hexadecimal number for large changes) to adjust the balance parameter for a minimum DVM reading. Then Save the result.

Alternate method:

(Equalises A, B outputs; provides balance for equal electrode-wafer capacitances)

1. Adjust "A" output to desired output voltage level, using a high input impedance (≥200MΩ) meter. This is done by setting the "Grip kV Cal." parameter in the "set parameters" menu. Use the + and - keys to change the value to desired level. You will find that you will have a small difference between the positive and negative output levels, but make the average approximately correct. Then Save the result.

2. Adjust "B" output to be 4kV, as was done with the A output, changing the "Balance adjust" parameter in the "set parameters" menu. Then Save the result.

The small differences seen in the outputs are partly due to the "zero" settings of the internal amplifiers and have little effect on the gripping performance.

DEBUGGING CHECKLIST

Observation	Possible causes
Wafer holding behavior:	
No gripping	Fault light on
	Wafer sense not activated
	Gripper drive voltage not sufficient
	Gripper damage
	Arcing in leads to gripper
"Wafer held" light flashing	Arcing in leads or gripper when attempting to grip
Poor releasing	Wafer sensing should be readjusted using learn-Wafer
	Incorrect release parameters set in EEPROM
	Wafer being moved while release is in progress
Erratic with rf power	Move grounding of driver case.
	Ensure match network case grounded securely to chamber.
	Check that connection between match network and chuck is not long and radiating into the room.
	Check that rf generator case ground is not connected to electrostatic driver case ground directly.
	Set Option to retain grip even though sense signal goes out during grip time due to rf plasma operation.
Drive unit behavior:	
Fault light on	Interlock on rear connector not activated
	Internal fault (serious)
Wafer sense not activated	See manual for sense learning of learn-Wafer.
	Check that wiring is connected; "Sense Level" as displayed repeatedly on serial line should change when a wafer is placed on and off a gripper. If this number does not change by more than one or two digits, a wiring or driver fault is indicated.
Drive voltage not sufficient	Set rear panel switch to correct level
	Set EEPROM parameters
Drive voltage not present	Check rear panel switch; ensure is not between settings.
Flickering LED(s)	Poor grounding of "chassis ground" at serial or parallel ports; line frequency hum pickup relative to other pins.
Low voltage on output	Gripper/wiring excess current; or DR4 internal fault.
High current on output	Gripper/wiring short. May appear as transient high readings such as 04, 05 etc. in between "normal" readings of 00 - 02.
Overtemperature	Blocked fan inlet/outlet; faulty fan; excessive high-voltage and hot operation (say at ±6kV for two hours in 40°C ambient).
Gripper faults:	
Gripper damage	Change, send in for repair / replacement.
Arcing in leads to gripper	Change, send in for repair / replacement.