

ELECTROGRIP SERIAL COMMUNICATIONS

General Edition

5, 23 June; 22, 30 Aug 2006; 14 Mar 2007

1. GENERAL INFORMATION

Serial communications between a host computer and a large number of peripheral devices is accomplished using 9600 baud, 8 bit, no parity, 1 stop bit RS-232 serial hardware compatible with standard PC serial ports. Host computer character spacing should be a minimum of 5ms; 20ms may be found to be adequate for the normal low-speed communications typically needed.

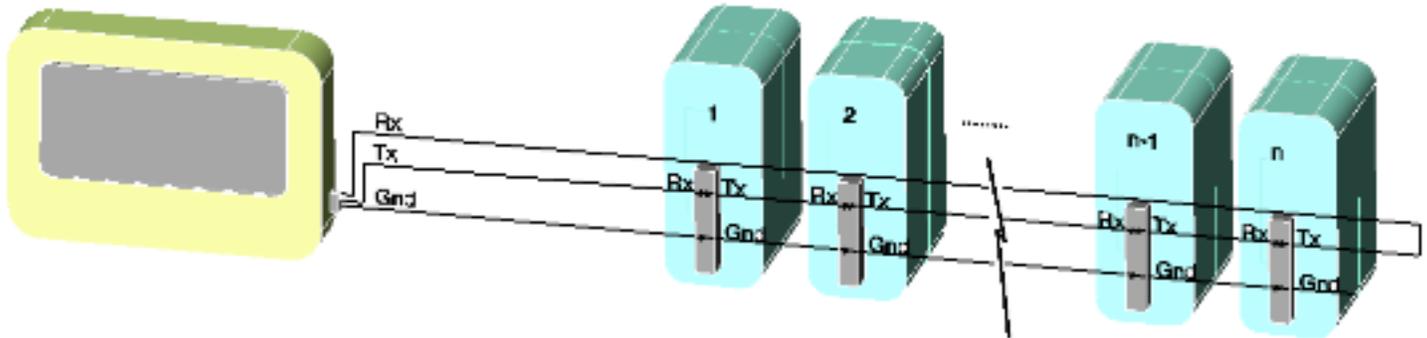


Fig. 1. Daisy chained system. Host computer at left communicating with n (< 9) DR5A, servo drive, and other units at right.

Electrogrip uses a mixture of daisy chaining (Fig. 1) and multidrop (Fig. 2) protocols to obtain control over a virtually unlimited number of devices.

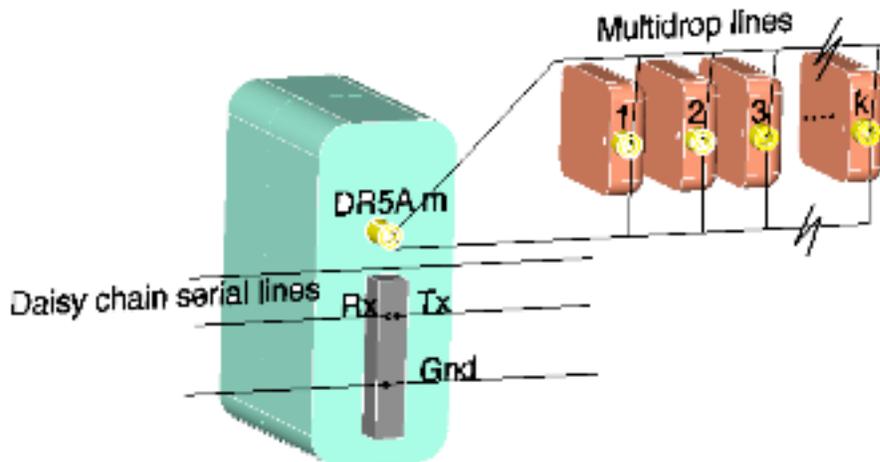


Fig. 2. Multidrop structure. The m -th daisy-chained DR5A unit is shown communicating with, and powering, k (< 240) multidropped units.

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 at system startup using either a ##1 or #1 command. Either 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 either ##n+1 or #n+1 where n is the number of daisy-chained units in the serial line.

Use of the ##1 initial addressing command works only for Electrogrip DR5A daisy-chained systems, and causes all commands subsequent to an addressing command to be processed by the addressed unit, until a further addressing command is received. No

global commands are possible after initial address setup and addressing of one of the units. This addressing command is not compatible with daisy chains including servo controllers.

Use of the #1 initial addressing command is compatible with both the DR5A and some types of servo controllers, and permits global commands to be processed by all units on the daisy chain if not prefixed by an address number. Alternatively, 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". This protocol requires that units connected to a DR5A controller, including itself, must be addressed using the multidrop 2-address methods described below.

Multidropped units obtain both power and bidirectional communications from the rf output connection of a DR5A controller. This power and communications may be transferred as shown in Fig. 2 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 DR5A, 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 DR5A / 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 DR5A 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.

Servo controllers use decimal numbers and permit flexible formatting of the number of digits in a command. DR5A controllers and multidropped units use hexadecimal numbers (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 units to a maximum of 9 addresses.

2. COMMAND SYNTAX

DAISY CHAIN FRAME

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

CR 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),

CR 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, (CR)** where

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

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

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

LH is the HI half of the LRC byte - (Longitudinal Redundancy Check); here, @ is used.

LL is the LOW half of the LRC byte; here, @ is used.

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

COMBINED DAISY CHAIN + MULTIDROP FRAMES

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

CR is the carriage return ending previous command.

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

CR is carriage return ending this command.

FRAMING ERROR

This may be observed if communication after reset works for the first command but is simply echoed thereafter; the echoing indicating that the command has been simply passed on down the daisy chain because it has not been recognised by any unit. The most likely cause of framing errors is a character spacing that is too short; the host computer should be set to yield a character spacing of at least 5ms. 20ms may be found adequate for the low signalling speeds normally required here.

3. COMMANDS

SERVO DRIVE OEM770X COMMANDS, OPERATION

All Compumotor OEM770X drives are daisy-chained and directly addressed using the standard OEM770X command set after initialisation with the address setup command #1 from the host computer. The numeric data is decimal to and from these drives and variable command formatting is permitted. The OEM770 drives generate their own control circuitry power from the incoming motor power line, and drive a brushed or brushless servo motor with programmed profiled or repetitive motions or speeds. These drives also have fixed and programmable inputs and outputs which share the same ground as the input RS-232 serial command signals, some of which are for commutation sensors (if needed), encoder power and signals, and limit switches. See the OEM770 manual for command and operation details.

DR5A, DR5V, DR5E, DR5M, DR5S OVERALL OPERATION

DR5A controllers provide rf power and communications to DR5V electrostatic chuck drives, DR5M motor drives and DR5P peripheral drive modules, and only rf power without communications to DR5S power supply modules. The rf signal may travel from the DR5A through direct connection or a power coupler such as a high-frequency transformer. Such power couplers / transformers can be used for ground reference isolation, for example to enable rf biasing or high voltage isolation of modules; or atmosphere-vacuum isolation; rotary / linear motion; or ease of module disassembly from a structure.

The DR5A also has digital (5V standard digital signals and open-collector solenoid drive outputs) as well as analog inputs and outputs (0 - 5V) which can be used to control and measure items which share the same ground potential as the DR5A electronics. Control connections to the DR5A are its serial D-sub 9 or RJ12 port; and parallel D-sub 15 port on its front panel. Supplemental I/O ports for analog and digital signals are at the rear, on a 26-pin header.

All modules in the DR5 range operate from the DR5A-derived rf power that may range in rectified voltage levels over a factor of almost 20:1, between 12 and 200V. This rf voltage level received from the DR5A is affected by variations in setup, input supply voltage, power coupling and power loading. Thus the above wide operational voltage range helps to maintain system reliability.

DR5S power supply modules provide up to 30W of motor drive power at 10V from input rf power lines. These power supply modules require an external 12V control circuit power source, which is available from either the DR5V or DR5M modules. There are no commands for these power supplies.

DR5V electrostatic chuck drive modules provide gripping and release voltages to either monopolar or bipolar electrostatic chuck electrodes, monitoring of electrode capacitance for substrate position sensing, and telemetry of local temperature, grip electrode voltages, and grip electrode currents. The DR5V provides adaptive grip and release algorithms which optimise both functions for various electrostatic chuck designs and operating conditions.

DR5P peripheral drive modules can be attached to the DR5V and enable telemetry to and from digital and analog devices such as temperature monitor arrays, current collectors, and valve actuators. Communications are on a high-speed SPI (*a registered Motorola trademark*) bus between the DR5V and DR5P. Commands sent between a main control computer and the DR5P travel through the attached DR5V and are a subset of the DR5V command set.

DR5E modules are an enlargement of the DR5V using the DR5P as a platform for control of the added high voltage outputs, and mechanically is a pair of metal module cases permanently bonded together. This combined DR5E module can power up to 6 electrostatic chuck electrodes, with independent polarity and on/off control over each bipolar pair of 3 electrodes, as well as allowing the use of the remainder of the DR5P capability for additional I/O. DR5E commands are a subset of the DR5V command set.

DR5M motor drive modules feed chopped three-phase power from the DR5S to brushed or brushless motor coils, and to Hall-effect sensors. The sensor outputs are 2-phase digital quadrature for motor position feedback, and can include analog Hall sensor outputs which can be interpolated to yield higher position sensing resolution than is possible from the digital signals. Motor power is adjusted through increased chopper duty cycle until the desired velocity is reached, and then decreased as becomes possible, while maintaining velocity.

DR5A, DR5V, DR5E, DR5M, DR5P COMMANDS

(i) Daisychain initialisation, address setup

All daisy-chained, multidropped Electrogrip DR5A controllers must be initialised using the address setup command #1 from the host computer. This command, incremented with sequential address numbers in its path around the daisy chained units, instructs DR5A controllers to respond with the correct address, and in the correct daisy-chain mode, to the host computer.

(ii) Multidrop initialisation, address setup

The DR5A must know at powerup whether or not it is in multidrop mode since otherwise it would be barraged by communications coming in from multiple multidropped modules on its rf power line. EXTRAIN2 on the DR5A parallel port connector (pin 15) is held low to cause the DR5A to start in multidrop mode. This initialises all multidropped DR5 modules with several repeated “ : ” commands during their power-up start sequences. After a ‘colon’ character is correctly received by a module, it thereafter responds only to commands addressed to it. DR5V, DR5M, and DR5P modules have their unique addresses preprogrammed in memory before installation in a multidrop setting. DR5A units have the multidrop address FF and will respond to commands only if addressed to them in multidrop mode, after their daisy chain address setup command #n is executed.

MULTIDROP SYNTAX FOR ALL DR5 MODULES, CONTROLLERS

a indicates the device address and is mandatory. It is a hex 2-character number (1 byte, 8 bits), transmitted as two ASCII characters.

Where a sign is shown it is mandatory, and if + is shown, + must be sent. If ± is shown, the sign can be chosen.

Digits sent or received are in the following strict format, and are sent/received without the \$ (hex) symbol:

n1 indicates a hex 2-character number (1 byte), range 00 to FF;

n1n2 indicates a hex 4-character number (2 bytes), range 0000 to FFFF;

n1n2n3 indicates a hex 6-character number (3 bytes), range 000000 to FFFFFFFF; etc.

Control characters are shown as [ctrl-X], where X is the key pressed together with the ‘control’ key, and are one ASCII byte (8 bits).

All data-input and no-data commands can be global for one addressing group if all in a group are to be processed together.

All data-output requests must be addressed to single modules to avoid data collisions.

Operational data in a module is either sent to, or power-up initialised by, that module. Such data is stored in RAM (Random Access Memory) by that module and is not overwritten until a further command changes that RAM variable. Thus data may be sent once at startup, and many operations may be performed without further entry of static values. This RAM data is acted upon by a module during operation of a process, even if the data changes during the process. Thus during a motor movement it is possible to alter the velocity, acceleration, distance goal, etc. on the fly. This could have advantages for profiling motions, but unpredictable results may occur while the new data is being entered byte by byte into RAM at 9600 baud serial link speeds unless only one byte is being altered.

Examples below show only the commands and typical data, and for simplicity omit the required frame structure which has daisy chain address, colon, multidrop address, command and data, two LRC bytes, then final CR.

Two commands are especially important for the DR5A, DR5V, and DR5E modules. [ctrl-P] is used to set port and memory status and is used to control outputs and actions. [ctrl-Q] requests data from a controller or a module, and this returned data may include port information that has been set with a [ctrl-P] command, permitting checking of responses to [ctrl-P] if desired. DR5M modules use commands similar to those used in servo drives to set and check status.

DR5A COMMANDS

Daisychain setup

Two daisychain modes are available, and are triggered by the number of # symbols preceding its first numeric addressing command after startup. The DR5A will switch to:

- Single command (Parker Compumotor servo controller compatible) style daisy chain when address setup is in the #n form, whereby it will react only on commands addressed to it, ignoring the global commands sent to OEM770X units. Such commands are preceded by the numeric DR5A address, which is determined by its position in the daisychain, and appended by a [CR] character.
- Multicommand style daisy chain when address setup is in the ##n form. Thereafter when addressed using a #n[CR] command, an open communication line to the controlling computer is set up and no further daisychain addresses need be sent, until another address command #m[CR] is seen, where $n \neq m$. This format is not compatible with servo controllers from Parker Compumotor.

Multidrop setup

When EXTRAIN2 (pin 15, parallel port) is held low, the DR5A controller starts up in the multidrop mode and must be addressed at its \$FF multidrop address, inside its daisychain addressed command frame if a daisychain is present.

All multidropped modules and controllers become dumb 'slaves' and do not initiate any actions or communications. Thus, when in Multidrop Mode, the DR5A is transparent and passes through all frames with its own Daisy chain address but with a Multidrop address different from \$FF. In addition, the periodic checking of parallel port and module status that the DR5A normally does is no longer performed. Thus the main control 'master' computer must check the status of the parallel port and other input ports periodically and decide which module should perform a required action. Also, the main control 'master' computer must check the status of each multidropped module periodically and determine that it is communicating and that its status is appropriate. This checking is done using a [ctrl-Q] command.

Commands for action are sent by the 'master' control computer using a [ctrl-P] command. This command sets status bits for control of ports, outputs, and actions in controllers and modules.

If a reset occurs for any reason (typically from a low power supply voltage or arc-induced reset) in any multidropped module powered by the rf output of a DR5A controller, that module will send a non-framed [ctrl-Q] to ask the DR5A controller for the INTERLOCK status (parallel port pins 4 and 5 are normally shorted for correct operation) so it can complete initialisation. In multidrop mode the DR5A will not intercept this and it will go directly to the 'master' control computer. Also all other outputs including the Main Menu would go through to the 'master' computer, which would have to parse the data stream to decode what has happened. In such a case, firstly the data stream could be parsed to determine the device address; followed by sending of a : (colon) to recommence multidrop mode, and system recovery attempted. At the end of the Main Menu 4th line, before the final CR character, the 2-character address of the module is displayed. The above sequence of events may be curtailed if a ":" is sent; multidrop character will then resume.

Ctrl-Q

Request Status a[ctrl-Q]

Response to a[ctrl-Q] ; *a[ctrl-Q]n1n2n3n4n5n6n7n8n.....n16, (2+32 ASCII chars) where
- n1 = Parallel / Logic Inputs byte (2 hex characters): [BIT7, 6, . . 1, 0]. Bits 0,1,2 and 3 are read from the DB15 connector (parallel port, pins 15, 9, 2 and 4);

PLUS a single line from the rear 26-pin connector (LOGIN1 – pin 18)

BIT7 - always = 1

BIT6 - always = 1

BIT5 - always = 1

BIT4 - LOGIN1 – Logic input 1, located on pin 18 of the 26 pin I/O connector (IO26)

BIT3 - INTERLOCK input (pin 4) from PARALLEL PORT

- when changed from 0 to 1, INTERLOCK is broken – turns OFF High

Voltage, prints "fault" message, sends CTL_Q + VAC.STATUS

- when changed from 1 to 0, INTERLOCK is closed – turns ON High

Voltage, sends CTL_Q + VAC.STATUS and starts DEADBAND routine.

BIT2 - REMOTEIN input (pin 2) from PARALLEL PORT – DR5V does not react on it because DR5A translates this change into "GRIP" (CTL_G, if REMOTEIN = 0) and "RELEASE" (CTL_R, if REMOTEIN = 1) commands and sends them to DR5V as serial commands.

BIT1 - EXTRAIN1 input (pin 9) from PARALLEL PORT (0/1)

- when changed from 0 to 1, acts in this order:

1. Acts as a "GRIP" command if the Option "Do you want to use the EXTRAIN1 signal to grip when high?" is set to "YES". If not,
 2. Acts as a "WAFER OFF" signal, if the Option: "Do you want a no-wafer signal on the EXTRAIN1 input?" is set to "YES". Updates WFRGRPDSNS (Wafer Grippped Sense) parameter.
- when changed from 1 to 0, acts in this order:
1. Acts as a "SLOW STEP RELEASE" command if the Option: "Do you want to start Slow Step Release when EXTRAIN1 low?" is set to "YES". If not,
 2. Acts as a "RELEASE" command if the Option "Do you want to use the EXTRAIN1 signal to grip when high?" is set to "YES".
- BIT0 - EXTRAIN2 input (pin 15) from PARALLEL PORT (0/1) – DR5V does no action. Controls DR5A multidrop status, is in multidrop mode when pulled low.

- n2 = LOGICOUT1 - 8 Logic outputs, located on the 26 pin /I/O connector (IO26), pins 3 to 10
- n3 to n16 = hex values of 7 Analog inputs (10 bit resolution), located on the 26 pin /I/O connector (IO26) from ANALOGIN1 (pin 11) to ANALOGIN7 (pin 17), 4 hex digits each.

Ctrl-P

Write to Ports

a[ctrl-P]n1n2n3n4n5n6n7n8n.....n16, (3+32 ASCII chars)

Response to a[ctrl-P] ; none.

- n1 = **DR5A STATUS** byte; the MSB is an expansion character, and the LSB (normally reflects status of DR5V unit in LED and other outputs on the DR5A): [BIT7, 6, . . . 1, 0]
 - BIT7 - ALWAYS ZERO AS ASCII CHAR
 - BIT6 - WFHELD – Wafer held - Grippped (1) / Released (0) DB15, pin 8
 - BIT5 - WFON – Wafer sensed – Present (1) / Missing (0) DB15, pin 3
 - BIT4 - EXTRAOUT – Status of Extra output pin on parallel port – 0 or 1- if the HV current is equal or bigger than the user setting, the EXTRAOUT line goes high for a minimum of 32ms, DB15, pin 10
 - BIT3 - FAULT - Goes into fault when Interlock line is open or when DEADBAND routine can not raise the high voltage, DB15, pin 7
 - BIT2 - set after INIT is done and never cleared
 - BIT1 - High voltage output enabled (1) / disabled (0)
 - BIT0 - MIRRORS PARALLEL INPUT pins 4,5 INTERLOCK (0=CLOSED,1=BROKEN)
- n2 = LOGICOUT1 - 8 Logic outputs, located on the 26 pin /I/O connector (IO26), pins 3 to 10
- n3 to n16 = 7 Analog (PWM) output controls, 2 bytes = 4 ASCII characters each).

DR5V COMMANDS

Commands with data input and/or data output

P	Wafer sense level Response to aP is n1n2n3n4	aP n1n2n3n4 is the raw sense level.
V	A, B output voltage Response to aV is n1n2	aV n1 is A channel voltage, n2 is B channel voltage. These voltages are obtained from resistive dividers at the outputs. Voltage format uses \$80 as zero, 100V per digit, <\$80 negative voltage.
I	A, B output current, μA Response to aI is n1n2	aI n1 is + output current (μ A), n2 is - output current (μ A). These values are derived from source feed currents and have the voltage-sensing resistive divider current subtracted.
T	Temperature, $^{\circ}$C Response to aT is n1	aT Electronics internal temperature. Approx cal table: 0C=\$B9, 25C=\$77, 50C=\$40, 75C=\$1F, 100C=\$12, 125C=\$0F
U	DAC level (output drive) Response to aU is n1n2	aU The output voltage command level. \$0800 is the zero level; below which a negative A output is commanded, and above which a positive A output is commanded. The maximum and minimum levels of \$0FFF and \$0000 command ± 10 kV on the A and B outputs.
Ctrl-Y	Internal variables Response to a[ctrl-Y] is	a[ctrl-Y] See also [ctrl-Q] DEADBAND+\$n1 -\$n2 MAX_DAC_DEV=\$n1n2 TRIP32=\$n1n2n3n4 AVG_SHIFT=\$n1 SNS16NOISE=\$n1n2
Ctrl-Q	Internal status Response to a[ctrl-Q] is n1	a[ctrl-Q] See also [ctrl-Y] and [ctrl-V] n1 is DR5V status which is programmed bitwise. [This command, out of multidrop mode, is executed periodically by the DR5A. In multidrop mode, the host computer must process this command's response, including setting DR5A ports to reflect DR5V status correctly.]

DR5V STATUS byte: [BIT7, 6, . . . 1, 0]

BIT7 - Always zero in ASCII characters

BIT6 - Wafer held - Gripped (1) / Released (0)

BIT5 - Wafer sensed – Present (1) / Missing (0)

BIT4 - EXTRAOUT – Status of Extra output pin on parallel port – 0 or 1

 ;If the HV current is equal or bigger than the user setting,
 ;the EXTRAOUT line goes high for a minimum of 32ms

BIT3 - Fault - Goes into fault when Interlock line between pins 4, 5 on DR5A parallel port is open

 ; or when DEADBAND (high voltage setup) routine can not raise the high voltage sufficiently

BIT2 - set to 1 after INIT is done and never cleared back to 0

BIT1 - High voltage output enabled (1) / disabled (0)

BIT0 - Mirror of DR5A parallel port interlock status between pins 4, 5. (0=closed,1=broken)

Ctrl-W	Export Repeated Data Response to a[ctrl-W] ;	a[ctrl-W] n1n2n3n4n5n6 ;6 one-byte variables addressed in the Parameter list. This text repeats every 310ms and can easily be imported into a spreadsheet for datalog graphing. Repeats of this command toggle the function off & on.
Ctrl-P	Parallel Port Status Response to a[ctrl-P]n1 ; none.	a[ctrl-P]n1 The MSB is an expansion character; LSB is the DR5V parallel port status, used to command a change in DR5V operation. This LSB is; DR5V status byte: [BIT7, 6, . . . 1, 0] BIT7 - always = 1 BIT6 - always = 1 BIT5 - always = 1 BIT4 - always = 1 BIT3 - INTERLOCK input (pin 4) from PARALLEL PORT - when changed from 0 to 1, INTERLOCK is broken – turns OFF High Voltage - when changed from 1 to 0, INTERLOCK is closed – turns ON High Voltage, and starts DEADBAND routine. BIT2 - REMOTEIN input (pin 2) from PARALLEL PORT – DR5V does not react on this but instead responds to direct commands of “GRIP” (CTL_G, corresponding to REMOTEIN = 0) and “RELEASE” (CTL_R, corresponding to REMOTEIN = 1). BIT1 - EXTRAIN1 input (pin 9) from PARALLEL PORT (0/1) has multiple possible uses as follows. - when changed from 0 to 1, acts in this order: 1. Acts as a “GRIP” command if the Option "Do you want to use the EXTRAIN1 signal to grip when high?" is set to “YES”. If not, 2. Acts as a “WAFER OFF” signal, if the Option: "Do you want a no-wafer signal on the EXTRAIN1 input?" is set to “YES”. Updates WFRGRPDSNS (Wafer Grippped Sense) parameter. - when changed from 1 to 0, acts in this order: 1. Acts as a “SLOW STEP RELEASE” command if the Option: "Do you want to start Slow Step Release when EXTRAIN1 low?" is set to “YES”. If not, 2. Acts as a “RELEASE” command if the Option "Do you want to use the EXTRAIN1 signal to grip when high?" is set to “YES”. BIT0 - EXTRAIN2 input (pin 15) from PARALLEL PORT (0/1) – DR5V does not react on it
Ctrl-V	Internal Voltage Levels Response to a[ctrl-V] ;	a[ctrl-V] +RAW =\$n1, +12V =\$n2
L	Load Response to aL or al ;	aL or al See DR5V manual for action. Is Load command for entry of EEPROM data.
D	Dump Response to aD or ad ;	aD or ad See DR5V manual for action. Is Dump command for EEPROM data.
X, Esc	Escape Response to aX or ax or [Esc] ;	aX or ax or [Esc] See DR5V manual for action. Escapes from current action to prior menu.
[space]	Spacebar; Sense Print Response to [Spacebar];	[Spacebar] See DR5V manual for action. Toggles display of substrate sense values.
Menu Actions; Wafer Learn etc.		Character commands as prompted from menu display; see DR5V manual.

Commands without data input/output

- Ctrl-F** **Toggle Wafer Sense** a[ctrl-F]
Response to a[ctrl-F] ; the DR5A parallel port sense output is pulled low and the wafer sense light is on, then on alternate executions of this command these outputs are toggled.
- Ctrl-G** **Grip Substrate** a[ctrl-G]
Response to a[ctrl-G] ; grip is commenced. If wafer sense is required for grip by the Option setting, gripping is delayed until a wafer is sensed.. At end of gripping sequence, when wafer is deemed to be held firmly, the 'wafer gripped' signal line is pulled low.
- Ctrl-R** **Release Wafer** a[ctrl-R]
Response to a[ctrl-R] ; the programmed release algorithm is executed. At its end, the 'wafer gripped' signal line is released (allowed to be pulled high).
- Ctrl-Z** **Zero Outputs** a[ctrl-Z]
Response to a[ctrl-Z] ; the DR5V output voltages are zeroed. If a substrate (wafer) had been gripped, the 'gripped' status remains active. Release must be commanded to turn off 'gripped' status.
- Ctrl-S** **Start Quiet Mode** a[ctrl-S]
Response to a[ctrl-S] ; continuous menu scrolling stopped; enters 'slave' mode. Automatically executed in multidrop mode after reception of the first ':' (colon) character.
- Ctrl-X** **End Quiet Mode** a[ctrl-X]
Response to a[ctrl-X] ; continuous menu scrolling commences. Not executed after entering multidrop mode.
- Ctrl-K** **Slow Step Release** a[ctrl-K]
Response to a[ctrl-K] ; Initiate a 'Slow Step Release' to force substrate release; typ.> 1 minute taken. Typically employed after other release algorithms have failed, for example after 2 months' gripping in air. Also can be activated using EXTRAIN1; see [Ctrl-P], above for this detail.

Special Note on DR5V Commands:

The DR5V will respond to requests immediately a request is sent, rather than waiting for the end of frame characters. Thus when the session with the DR5V is over, a single set of @@CR characters is required only. In addition the host PC must be prepared to accept replies as soon as the request is issued. Multiple requests can be issued, just as would be possible if running the DR5V unit directly from the host PC without daisy chain or multidrop connections. This enables the programming of the DR5V to be maintained either by computer, or if needed, manually - with minimal character entry.

DR5P COMMANDS

The DR5P has extensive pipelining, fast analog data I/O, plus averaging capabilities. However the DR5V standard setup uses only its basic slow, unaveraged input and output methods.

Ctrl-A

Read I/O status

a[Ctrl-A]

Response to a[ctrl-A] ; n1n2n3n4n5n6n7n8.....n30, (60 ASCII chars) where
n1n2 = DR5P internal temperature, 8 bits per °C
n3 to n18 = hex values of 8 Analog inputs (12 bit resolution) located on DB15 connector,
from ANALOGIN0 (pin 8) to ANALOGIN7 (pin 1), 4 hex digits each
n19n20 = Read GPIO Config register of inputs (0)/outputs (1), loaded previously with Ctrl+B;
Configure GPIOs - [C3 : C2: C1: C0: B3: B2: B1: B0: A3: A2: A1: A0: 0 : 0 : 0 : 0]
n21n22 = Data read from GPIO inputs and outputs
Read from GPIOs - [0 : 0 : 0 : 0 : C3: C2: C1: C0: B3: B2: B1: B0: A3: A2: A1: A0]
n23n24 = analog input #9 = feedback from High Voltage ch F
n25n26 = analog input #11 = feedback from High Voltage ch E
n27n28 = analog input #13 = feedback from High Voltage ch D
n29n30 = analog input #15 = feedback from High Voltage ch C

Ctrl-B

Write Output Ports

a[Ctrl-B]n1n2n3n4n5.....n20, (3+40 = 43 ASCII chars)

Response to a[ctrl-B] ; none.
n1n2 to n15n16 = 8 analog outputs.
DAC0 (n1n2), DAC1 (n3n4), DAC6 (n13n14) set internally, no user control
n17n18 = Write to the GPIO Config register - sets GPIOs as inputs (0) or outputs (1)
Configure GPIOs - [C3 : C2: C1: C0: B3: B2: B1: B0: A3: A2: A1: A0: 0 : 0 : 0 : 0]
n19n20 = Write to the GPIO Data register, only outputs are affected
Write to GPIOs - [C3 : C2: C1: C0: B3: B2: B1: B0: A3: A2: A1: A0: 0 : 0 : 0 : 0]
where C3 : C2: C1: C0: B3: B2: B1: B0: A3: A2: A1: A0 are bits 0-3 of GPIO ports A-C.

Ctrl-C

Reset DR5P System

a[Ctrl-C]

Response to a[ctrl-C] ; Prepares DR5P for receiving commands, both from DR5V and host PC
This command must be followed by Ctrl+B only if GPIOs or DAC2,3,4,5 and 7 are used.
DAC0,1 and 6 are configured internally by the Reset command.
May be required if power voltage droops too low during high power (motor) operations.

DR5E CONTROLS

When a DR5V and DR5P are joined to generate up to 6 high voltage outputs for multipole electrostatic chucks, no additional commands are required to activate these outputs. The I/O ports described above are still active, but user alteration of the settings of output ports used by the DR5V for grip and release is overwritten and blocked. Thus the DR5E remains, like a DR5P, an 8-input datalogging device, with 12 GPIO lines, as well as becoming a multi-output high voltage electrostatic chuck driver.

Sensing of wafer/substrate position on Electrode A is retained by the DR5E, as in the DR5V. DR5E paired outputs are [A, B], [C, D], and [E, F]; and are turned on in that order by the Parameter 'ElecNo'. Multiphase switching is performed on two electrodes by reversing polarity, and on 4 and 6 electrodes is done by sequentially rotating which electrode pair is switched, every time a pair is switched.

The DR5V parameters 'ElectNo/Sw100ms' control the output high voltage switching during gripping:

- ElectNo = Number of chuck electrodes - 2, 4, 6... (1 byte)
- Sw100ms = Time between polarity switchings in 100ms increments (1 byte) - if zero, no switching is done.

DR5M COMMANDS

Encoder counts are always the interpolated counts, so EI must be executed before other commands if other than the initialised value is to be used. Commands with data I/O are shown first, followed by no-data commands.

Commands with data input and/or data output

A Acceleration, $aA+n1n2$ counts /sec²
Default Value: A = \$0100
Response to aA is *A+n1n2 Negative accelerations not permitted; min. acceleration set by hardware.
Example;
EI+01 Set encoder interpolation for no interpolation, lowest resolution
A+000A Sets acceleration to 10 counts/sec²
V+0064 Sets velocity to 100 (\$64) counts/sec
D+0007D0 Sets distance to 2,000 (\$0007D0) encoder counts
G Executes the move

D Distance, $aD\pm n1n2n3$ encoder counts
Default Value: \$000000
Response to aD is *D±n1n2n3
This commands the encoder count position to be attained; response is the programmed encoder position, all in interpolated encoder counts. If the motor approaches a maximum number (plus or minus), the controller will not prevent execution of any GO commands that would cause the distance to exceed that maximum. To proceed further, use the PZ command to reset the absolute counter to zero, and then resume operations. If a move is then commanded without specifying a distance, the previously commanded distance will be applied to the move.
Response reports the commanded position, which can be compared with PX to see the position error.
Example; see "A" command; also;
D Commanded position report. (*D+002000)
PX Encoder position report (*002005)
The actual motor position is 5 encoder counts from the commanded position.

V Velocity, $aV+n1n2$ encoder counts/sec
Default Value: \$0010
Response to aV is *V+n1n2
The V command defines the maximum speed at which the motor will run when given the Go (G) command. If the value specified for the V command is not valid, the controller ignores that value and defaults to the value specified in the last V command.

EI Encoder Interpolation, $aEI+n1$ encoder multiplier
Default Value: \$01; ie, no interpolation. Allowed values; \$01, \$02, \$04, \$08, \$10.
Response to aEI is *EI+n1
See also; CPG
The encoder interpolation defines the number of encoder counts the controller will see per basic encoder count. This approximate interpolation of the encoder analog outputs assumes ideal sine and cosine encoder waveforms.
Example;
EI+04 Sets encoder interpolation to 4 counts per basic encoder count
EI Reports Encoder Interpolation (*EI+04)

IS Input Status, aIS
Response to aIS is *n1n2n3n4n5n6n7
The DR5M 25 pin connector has 6 inputs; two digital encoder, 2 analog encoder, HOME and LIMIT.

- n1. Left half = HOME (\$0 or \$1, latched to \$1 at last homing, cleared with the next "HSE" command),
Right half = LIMIT (\$0 or \$1) inputs
- n2. Left half = Encoder 1 Digital input(\$0 or \$1), right half = blank(\$0)
- n3. Left half = Encoder 2 Digital input(\$0 or \$1), right half = blank(\$0)

- n4. Encoder 1 analog value (\$00 - \$FF)
- n5. Encoder 2 analog value (\$00 - \$FF)
- n6. Motor drive's Internal Temperature analog value (\$00 - \$FF)
OVERTEMPERATURE bit in RSE set above 75°C
Approx cal table; 0C=\$B9, 25C=\$77, 50C=\$40, 75C=\$1F, 100C=\$12, 125C=\$0F
- n7. Motor drive's Internal RAW voltage analog value (\$00 - \$FF)
UNDERVOLTAGE bit in RSE set when < 10V

CEW Configure In Position Error Window, aCEW+n1n2 Units: encoder counts

Default Value: \$0010

Response to aCEW is *CEW+n1n2

When within the programmed encoder position region ±(this error size), Output Status from RSE indicates are in position.

CPG Configure Proportional Gain, aCPG+n1

Default Value: \$10

Response to aCPG is *CPG+n1

See also; EI.

The product of this gain and the position error (outside the error window) controls the power applied to the motor at all times. High proportional gain will yield a stiff, responsive system with low position error, but may result in overshoot and oscillation. Once a stable gain setting is determined, increased EI (encoder interpolation) values will require proportionally decreased CPG values.

Example;

CPG+32	Set the proportional gain term to 50(\$32)
CPG	Reports proportional gain term (*CPG+32)

PX Absolute Encoder Position Report, aPX Encoder counts

Response to aPX is *n1n2n3

This is the actual encoder count position, interpolated.

You can reset the encoder position counter to zero by using the position zero (PZ) command or reset (Z). After PZ the encoder position (PX) will be set to zero. This zeroes the detected position, rather than the commanded position. Thus any position error that was known about should be accounted for in the host computer software.

RSE Report Servo Errors, aRSE

Response to aRSE is *n1

This reports general controller status. Any or all bits may be set at any one time, for combinations of below conditions.

- *\$00 No errors
- *\$01 Servo power disabled (bit 1). Is status at reset.
- *\$02 Excessive position error (bit 2)
- *\$04 Undervoltage (bit 3)
- *\$08 Overtemperature (bit 4).

OSA Define Active State of End-of-Travel Limits aOSA+n1

Range: n = \$00 or \$01 Default Value: \$01

See Also: LD, OSC

OSA+00: Normally Closed Contacts, ie normally shorted to ground; pullup to high at limit.

OSA+01: Normally Open Contacts, ie normally pullup to high; short to ground at limit.

This command sets the active state of the CW and CCW end-of-travel limit inputs. It enables you to use either normally closed or normally open switches.

LD—Limit Disable, aLD+n1

Range: n = \$00 - \$01 Default Value: \$00

See Also: OSC

The Limit Disable (LD) command allows you to enable/disable the end-of-travel limit switch protection. The LD0 condition does not allow the motor to turn without properly installing the limit input.

If you want motion without wiring the limit, you must issue aLD+01. Only one limit switch is envisaged, at bottom.

- Enable limit—n = \$00 (Default)
- Disable limit—n = \$01

OSC Define Active State of Home Switch aOSC+n1

Range: nn = \$00 or \$01 Default Value: \$00

OSC+00: Active state of home input is n = 0 (closed), ie a normally open switch is used, with data line pullup to high.

OSC+01: Active state of home input is n=1 (open), ie a normally closed, data line shorted to ground, switch is used.

HSE Home Switch Enable aHSE

Next hit of home switch will stop the motor. Does not zero the position counter; this is a user action if desired.

XNP maX and miN servo Power setting aXNP+n1n2

Range: n = \$00 to \$FF Default Values: \$8040 (ie, max power n1 = \$80, min power n2 = \$40)

Controls how much load and max speed can be attained (n1) and settling characteristics at end of travel (n2).

Commands without data input/output

G Go aG

After setup of initial parameters and issuing numbers D, V, A for a move, issue G to move. If motion does not occur with G, an activated end-of-travel limit switch may be on. Check the hard limit switch.

K Kill aK

Stop an ongoing motion. Keeps motor power on, servo-controls at current actual encoder position.

ON Servo Enable aON

Turn on power to motor coils after OFF command.

OFF Servo Disable aOFF

Turn off power to motor coils.

PZ Set Absolute Counter to Zero aPZ

Set encoder count to zero. Counts are signed. This zeroes the detected position of the motor, not the commanded position.

4. ADDRESS ASSIGNMENTS; Example 7-axis Tool

Daisy chain Address assignments (decimal, 0-9), done dynamically, see # command; Below address values assume #1 is sent from the main control computer through the daisy chain line to initialise addresses.

- No address _ used as a global address for [**Push-pull**], [**Tilt**], [**Spindle**] OEM770X servo controllers.
- 1 [Push-pull] – dynamically assigned
- 2 [Tilt] – dynamically assigned
- 3 [Spindle] – dynamically assigned
- 4 [DR5A] – will not react on a global address. Causes #5 to return to host computer at initial address setup.

Multidrop Address assignments (hexadecimal) for DR5A and all remote units connected to it, preprogrammed:

- \$FF _ [DR5A]

- \$10 _ Group address for [**DR5V / DR5P / DR5E**] units
- \$11 [DR5V or DR5P or DR5E] unit at a chuck
- \$12-\$1F _ Reserved for more [**DR5V / DR5P / DR5E**]

- \$20 _ Group address for [**Wafer Lift DR5M**] if more are used in the future
- \$21 [Wafer Lift] unit
- \$22-\$2F _ Reserved for more [**Wafer Lift**] units

- \$30 _ Group address for [**Other DR5M**] units
- \$31 [Other] #1 unit
- \$32 [Other] #2 unit
- \$33 [Other] #3 unit
- \$34-\$3F _ Reserved for more [**Other DR5M**] units

- \$40 _ Group address for [**Extra DR5M**] units
- \$41 [Extra] #1 unit
- \$42 [Extra] #2 unit
- \$43-\$4F Reserved for more [**Extra DR5M**] units