

Operation and Service Manual

Precision DC Voltage Source

DC205



Stanford Research Systems

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Certification

Stanford Research Systems certifies that this product met its published specifications at the time of shipment.

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DC205 Precision DC Voltage Source

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General Information

Safety and Preparation for Use



WARNING

Dangerous voltages, capable of causing injury or death, are present in this instrument. These voltages can persist for many minutes after ac power is removed. Do not remove the product covers or panels. Do not apply power or operate the product without all covers and panels in place.

AC line voltage

The DC205 Precision DC Voltage Source operates from a 100 V, 120 V, 220 V–230 V, or 240 V nominal ac power source having a line frequency of 50 Hz or 60 Hz. Before connecting the power cord to a power source, verify that the LINE VOLTAGE SELECTOR, located in the rear panel power-entry module, is set so that the correct ac line voltage value is visible. For operation with 230 V ac power, the LINE VOLTAGE SELECTOR should be set to 220 V.



CAUTION

The DC205 Precision DC Voltage Source will be damaged if operated with the LINE VOLTAGE SELECTOR set for the wrong ac line voltage, or if the wrong fuses are installed. Verify that the correct line fuses are installed before connecting the line cord. Use two (2) metric size 5 × 20 mm fuses. For 100 V/120 V, use 1 A fuses; for 220 V–230 V/240 V, use 0.5 A fuses. See appendix A for detailed instructions.

Line cord






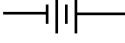



The DC205 Precision DC Voltage Source has a detachable, three-wire power cord for connection to the power source and to a protective ground. The chassis of the instrument is connected to the outlet ground to protect against electrical shock. Always use an outlet which has a properly connected protective ground.

Service

The DC205 Precision DC Voltage Source does not have any user serviceable parts inside. Refer service to a qualified technician.

Do not install substitute parts or perform any unauthorized modifications to this instrument. Contact the factory for instructions on how to return the instrument for authorized service and adjustment.

Symbols you may Find on SRS Products

Symbol	Description
	Alternating current
	Caution - risk of electric shock
	Frame or chassis terminal
	Caution - refer to accompanying documents
	Earth (ground) terminal
	Battery
	Fuse
	On (supply)
	Off (supply)

Notation

The following notation will be used throughout this manual.



WARNING

A warning means that injury or death is possible if the instructions are not obeyed.



CAUTION

A caution means that damage to the instrument or other equipment is possible.

Typesetting conventions used in this manual are:

- Front-panel buttons are set as [Button]
- Front-panel knobs are set as Knob
- Front-panel indicators are set as *Overload*
- Remote command names are set as *IDN?
- Literal text other than command names is set as OFF

Remote command examples will all be set in monospaced font. In these examples, data sent by the host computer to the DC205 are set as `straight teletype font`, while responses received by the host computer from the DC205 are set as *slanted teletype font*.

Warnings

The DC205 is equipped with a safety interlock, which must be closed to energize the ± 100 V output range of the instrument. Details on the safety interlock can be found in section 1.6 on page 1 – 10 .



WARNING

When using banana-to-BNC adapter hardware with the DC205, the ground tab of the adapter must be oriented to the black LO terminal, and the black LO terminal must be grounded. This ensures that the exposed BNC shield parts are at a safe electrical potential. Use of banana-to-BNC adapters is not recommended when the safety interlock is closed or the DC205 is operated on the ± 100 V range.

Specifications

All performance specifications after 2 hour warm-up at 23 °C ±1 °C ambient, unless otherwise specified.

Output

Range	Full scale	Resolution (1 ppm)	Max current	Time const. [†]	Settling time [‡]
	V	μV	mA	μs	ms
1 V	±1.010 000	1	50	160	50
10 V	±10.100 00	10	50	160	50
100 V	±101.000 0	100	25	400	100

[†] Time required to settle to 63 % of final value

[‡] Time to settle to 99.999 % of final value

Settling times measured for full-scale step into 10 MΩ load.

Accuracy and stability

Range	Accuracy (23 °C ±1 °C)			Stability (±1 °C)
	24 h	90 day*	1 year*	24 h
	±(ppm setting + μV)			
1 V	7 + 2	12 + 6	25 + 10	1 + 1
10 V	7 + 12	12 + 20	25 + 20	1 + 3
100 V	8 + 120	12 + 200	25 + 200	1 + 20

* preliminary

Noise and drift

Range	Temperature coefficient	Noise (typical)	
	0 °C – 40 °C ±(ppm setting + μV)/°C	(0.1 – 10) Hz	10 Hz – 100 kHz
		μVrms	
1 V	1 + 1	0.5	9
10 V	1 + 2	1.5	12
100 V	1 + 15	12	50

Remote Interfaces

RS-232	DB-9 connector, baud rates 9600, 19200, 38400, 57600, and 115200
USB	USB type B receptacle; serial port emulation, 115,200 baud
Optical fiber	Connection to SX199 Optical Interface Controller. Provides isolated connectivity to GPIB, RS-232, and Ethernet.
Interlock	Two-position Euroblock-style terminal block, 0.150" (3.81 mm), 180° free hanging (in-line)

General

Parameter	Specification
Temperature	0 °C to 40 °C, non-condensing
Power	< 20 W, 100/120/220/240 VAC, 50/60 Hz
Dimensions	8.3" W × 3.5" H × 13" D
Weight	10 lbs
Fuse	two (2) metric size 5 × 20 mm

1 Getting Started

This chapter provides step-by-step instruction to get started quickly with the DC205 Precision DC Voltage Source. Refer to chapter 2 for a more complete introduction to the DC205.

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1.1 How to use this manual

Two possible starting points are available to new users of the DC205. Those who want to begin with an overview to the functional layout of the instrument should turn to Chapter 2.

Users who prefer to jump in and begin using the DC205 first should continue with this Chapter, where a series of step-by-step procedures are given to verify the basic performance of the instrument. This will also provide a quick introduction to the DC205 and how it is operated.

Chapter 3 provides detailed discussions of the subsystems within the DC205. Technical details, such as circuit topology and input protection for remote sensing, can be found here.

Chapter 4 discusses remote operation of the DC205 over any of the three remote interfaces: USB, RS-232, and optical fiber.

Chapter 5 details the procedure for adjusting the calibration of the DC205 in the field.

Chapter 6 give a method for verifying the output voltage accuracy of the DC205, and contains tables to copy for recording test results.

1.2 Preliminaries

The following sections provide step-by-step instructions for verifying the basic operation of the DC205. In addition to confirming proper operation, it provides a good introduction to operating the current source.

1.2.1 Equipment needed

To perform all the steps described in this chapter, you will need:

1. a collection of stacking banana plug test leads,
2. a precision voltmeter with at least 6 digits resolution,
3. a BNC 50 Ω terminator,
4. a dual banana-to-BNC (banana-male, BNC-female) adapter.

1.3 First example: turning on the instrument

This section describes the initial steps for first operating the DC205. Please pay specific attention to the AC line voltage selector setting.

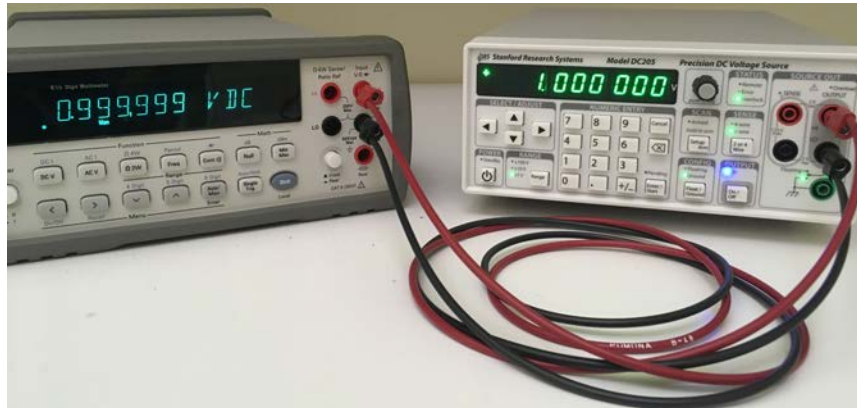
1. Verify the rear-panel power entry module is properly configured for the line voltage in your region. Applying power



CAUTION

with improper setting of the line voltage selector will result in significant damage to the DC205.


2. Plug the AC line cord into the rear-panel power entry module, and then into a grounded wall outlet.
3. Using banana-plug test leads, connect the DC205 OUTPUT terminals (HI and LO) to the voltmeter input terminals (HI and LO). Turn on the voltmeter and set it to DCV, Autorange.
4. Restore the factory default settings by holding down the backspace [\times] button while turning the power off and on again. This will perform the power-on reset, and return the instrument to its factory default state. After several seconds, the display will show d E F C F 9, then the instrument's serial number, and then * 0.000000.
5. Key in the value 1.000000 V. Start by pressing the [1] and notice the display shows the polarity indicator + and digit 1 are shown. Also, the *Pending* indicator begins blinking, indicating the numeric value is awaiting entry.
6. Try pressing another digit, such as [3]. Note the value is not added to the display, as the implied value (13) is out of range for the current setting. Then press the decimal point button, [.] , and then press [0] three times. The display should show * 1.000 and *Pending* should still be flashing.
7. Now press the [7] digit. The display will show * 1.0007. Press the [\times] button to erase the 7.
8. Press the [Enter/Start]. The *Pending* indicator should go dark, and the display now shows * 1.000000. The multi-meter should not yet show any steady reading.
9. Finally, press the OUTPUT [On/Off] button. The *On* indicator should illuminate, and the multimeter should now show a reading very close to +1.00000 V.
10. Allow the unit to warm up for 2 hour for full specified performance. Warm up is not needed to test basic functionality.




1.4 User interface

This section explores the DC205 front-panel interface, and demonstrates the different methods for entering or modifying the voltage setting.

1. If the OUTPUT is still *On*, turn it off by pressing the [On/Off] button.
2. Change the RANGE to ± 10 V by pressing [Range] once. Set the voltage to 0 by pressing [0] and then [Enter/Start]. Enable the output by pressing OUTPUT [On/Off]. The display should show $+ 00.00000$.
3. Push the **knob** in, then release. least significant digit should begin to blink. Now slowly turn the **knob** clockwise. The DC205 will click, and the least significant digit (tens of microvolts) will begin incrementing. Continue turning the knob until the display shows $+ 00.00020$.
4. Press the SELECT/ADJUST [\blacktriangleleft] button two times. Notice that with each press, the blinking digit moves one position to the left. Now slowly turn the **knob** for 3 more clicks clockwise. The display should now show $+ 00.00320$, and the multimeter should show the same voltage.
5. Now clear the output setting by pressing [0] and [Enter/Start]. The display returns to $+ 00.00000$, but notice the millivolts digit is still blinking. Now press the [\blacktriangleup] button three times. The display should now show $+ 00.00300$. Turn the **knob** counterclockwise for 5 clicks. The display should now show $- 00.00200$, and the 2^2 (millivolts position) is still blinking.

6. Press the [Cancel] button—now the blinking should stop. Turn the  clockwise, without pushing it in. Note that there are no clicks, and the setting does not change.

This brief exercise demonstrated the entry modes for the DC205, including the notion of active editing (indicated by the blinking digit), and the use of the [Cancel] button to return to the display-idle state. Note that the [▲] and [▼] buttons provide essentially the same functionality as the .

1.5 Instrument settings

This section will demonstrate the basic configurations of the DC205.

1.5.1 Sense

The SENSE setting selects 2-wire or 4-wire (remote sensing) for the voltage source circuitry.

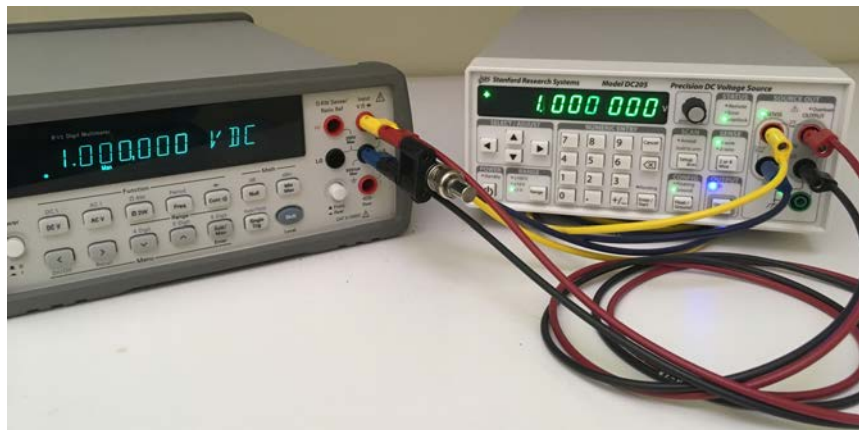
1. If the OUTPUT On indicator is lit, disable the DC205 OUTPUT by pressing the [On/Off] button.
2. Connect a pair of banana test leads from the red and black SENSE terminals on the DC205 to the input HI, LOW terminals on the multimeter.
3. Connect a second pair of banana test leads from the red and black OUTPUT terminals on the DC205, connecting the other end of these test leads to the back of the corresponding stackable sockets on the banana leads at the multimeter. Be sure to connect HI to HI, and LOW to LOW.
4. If not already so configured, press the [Range] button repeatedly until the ± 1 V range is selected. Press [Float/Ground] to select *Ground*, and press [2 or 4 Wire] to select *2-wire*.
5. Plug the banana-to-BNC adapter into the back banana leads at the multimeter (see the following photo). Be sure to align the Ground tab of the adapter with the LOW side banana leads.



WARNING

Whenever using a banana-to-BNC adapter, the operator must ensure that (a) the ground tab of the adapter is oriented to the LO (black) terminal, and (b) that the LO terminal is grounded. Failure to follow this procedure can result in hazardous voltages being accessible on the outer shield of a user-provided BNC cable or connector.

6. Press [1] and [Enter/Start] to program the setting to 1.000 000 V. Press [On/Off] to enable the output. Verify the multimeter displays a voltage very close to 1.000 000 V.
7. Use the SELECT/ADJUST buttons or the knob to adjust the DC205 until the multimeter displays exactly 1.000 000 V, with a minimum of 100 μ V resolution.
8. Attach a 50 Ω BNC terminator to the banana-to-BNC adaptor. Verify that the multimeter display drops by at least one or two millivolts (the actual drop will depend on the length and wire gauge of your banana test leads).
9. Now, press the [2 or 4 Wire] button. Verify that the 4-Wire indicator and the SENSE indicator both become illuminated.
10. The multimeter should again be displaying exactly 1.000 000 V, with a minimum of 100 μ V resolution.




This exercise demonstrates the function of remote sensing in the DC205. When operated in simple 2-wire mode, the set output voltage is controlled internally. When a significant load is presented (in this case, 50 Ω), a current flows from the voltage source through the circuit created by the output leads. In this case, with 1 V across 50 Ω , a total of 20 mA flows through the output and the banana test leads. Even 10 m Ω of lead resistance in this case will lead to a 200 μ V potential drop.

By enabling remote sensing in the 4-Wire mode, the DC205 controls the potential as measured by the sense leads. By carefully arranging the SENSE wiring to not carry any of the load current, the desired output voltage is applied at the point of interest (in this case, at the multimeter input terminals).

1.5.2 Isolation

The CONFIG setting selects whether the output circuitry of the DC205 is referenced to chassis ground or floating.

1. If the OUTPUT On indicator is lit, disable it by pressing the [On/Off] button.
2. Connect a pair of banana test leads from the red and black OUTPUT terminals on the DC205 to the input HI, LOW terminals on the multimeter.
3. Press the [Range] button to select ± 1 V. Press the [Float/Ground] button to select *Floating*. Press [1] and then [Enter/Start] to set the display to .
4. Press the [On/Off] button to enable the output. Verify that +1.0000 V appears on the multimeter.
5. Connect another banana test lead from the green chassis ground terminal on the DC205 front panel to the red HI banana lead at the DC205.

Notice that the multimeter still displays +1.0000 V, even though the HI terminal is now connected to chassis ground. The output of the DC205 is configured to float; by grounding the HI terminal with the banana lead, the LOW terminal is now at -1.0000 V with respect to ground.

6. Now press the [Float/Ground] button to select *Ground*.

Now notice that the multimeter display has dropped to a value near 0 V (probably a few millivolts). Also, the red *Overload* indicator on the DC205 is illuminated. With the DC205 in *Ground* mode, the LOW terminal is internally tied to ground. By grounding the HI terminal, the outputs are shorted, causing *Overload* to illuminate.

7. Carefully remove the grounded lead from the back of the banana cable at the HI terminal. The *Overload* indicator should turn off, and the meter should measure voltage close to 1.0000 V.

1.5.3 Scanning

In addition to generating a stable DC voltage, the DC205 is also able to create linear sweeps of the output voltage. This example will demonstrate one such sweep.

1. If the OUTPUT On indicator is lit, disable it by pressing the [On/Off] button.
2. Connect a pair of banana test leads from the red and black OUTPUT terminals on the DC205 to the input HI, LOW terminals on the multimeter.
3. Press the [Range] button to select ± 1 V. Press the [Float/Ground] button to select *Ground*. Press the [2 or 4 Wire] button to select *2-wire*.
4. Briefly press the [Setup Arm] button, entering the SCAN setup mode. The display should now show `r n 9. 1`. Press [\blacktriangle], changing the display to `r n 9. 10`. Press [\blacktriangledown] to return the scan range selection to `r n 9. 1`. Press [\blacktriangleright] once.
5. The display now shows the beginning voltage for the scan, indicated with the *b* at the left side of the display. Key in the value [0], [.] , [1], and then press [Enter/Start]. The display should show `* b 0. 100 000`. Press [\blacktriangleright] again.
6. The display now shows the ending voltage for the scan, indicated with the *E* at the left side of the display. Key in the value [0], [.] , [8], and press [Enter/Start]. The display should now show `* E 0. 800 000`. Press [\blacktriangleright] again.
7. The display now shows the time duration for the scan, indicated by the *t* at the left side of the display. Key in the value [1] [0] and press [Enter/Start], to set the scan to 10 seconds. The display should now show `t 0 0 10. 0 5`. Press [\blacktriangleright] again.
8. The display now shows the scan shape setting, indicated by the *Sh* at the left side of the display. The two choices are `Sh o n E d i r` (a unidirectional ramp), and `Sh u p - d n` (a bidirectional ramp). Press [\blacktriangle] and [\blacktriangledown] to switch between these options. Leave the setting at `Sh o n E d i r`, and then press [\blacktriangleright] again.
9. The display now shows the scan repeat mode, indicated by the *C Y C L E* at the left side of the display. The two choices

are `CYCLE onE` (a single scan) and `CYCLE inf` (repeating until cancelled). Press `[▲]` and `[▼]` to switch between these options. Leave the setting at `CYCLE onE`, and then press `[▶]` again.

- The display now shows the scan display mode, indicated by the `dISP` at the left side of the display. The two choices are `dISP on` (display is updated in near realtime during the scan) and `dISP OFF` (display is left static during the scan). Press `[▲]` and `[▼]` to switch between these options. Leave the setting at `dISP on`, and then press `[▶]` again.
- The display will be back to the `rng. 1` setting. Press the `[◀]` to navigate backwards, to the `dISP on` setting. You can navigate forward and backward through the scan parameters with the `[◀]` and `[▶]` select buttons. Note, however, that any time the scan range is modified, both the beginning and ending scan voltages are reset to zero.

Press `[Cancel]` to exit SCAN setup mode. Set the output voltage to 0.5 V by pressing `[0]`, `[.]`, `[5]`, `[Enter/Start]`. Then turn the output On by pressing `[On/Off]`. The multimeter should display a value close to 0.5000 V.

- Now press and hold the `[Setup Arm]` button for at least 2 seconds. The display will briefly show `SCAN rdy`, and then show `* 0. 100 000`, which is the starting voltage for the scan. Also, the *Armed* indicator comes on to show that the scan is armed, and *Pending* is steadily illuminated. Press the `[Enter/Start]` button to start the scan.
- While the scan is running, notice that the multimeter and the DC205 display are both smoothly sweeping from 0.1 V to 0.8 V. After 10 seconds, the scan should end and the output voltage settles at 0.8 V.

1.6 Interlock

WARNING

The DC205 is designed with a safety interlock circuit that must be activated for the ± 100 V output range to be enabled. The interlock is intended to support safe operation of this instrument in a test system. Bypassing the interlock can lead to a hazardous condition, possibly exposing the operator to dangerous electrical potentials up to ± 100 V, capable of causing injury or death.



Figure 1.1: The DC205 rear panel, shown with an interlock defeat plug.

For safety, the ± 100 V range can only be enabled when the interlock signal is closed. To close the interlock, a low impedance circuit must be established between pins 1 and 2 of the rear-panel INTERLOCK header. A mating terminal block plug is provided with the DC205.

When the interlock is closed, the front panel *Interlock* indicator will be illuminated. The interlock must be closed to enable OUTPUT On when the RANGE is ± 100 V.

If the interlock becomes open while operating on the ± 100 V range with OUTPUT On, then the output will trip off and the message `Err Intloc` will be displayed. This message will persist until the user presses [Cancel] or another button, or sends any remote command data.

Note that the ± 1 V and ± 10 V range settings can be enabled independent of the whether the interlock is closed.

2 Operation

This chapter provides a basic overview of the DC205 Precision DC Voltage Source.

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2.1 Navigating the front panel

The front panel of the DC205 is organized into distinct functional sections. The front panel is shown in Figure 2.1, below.

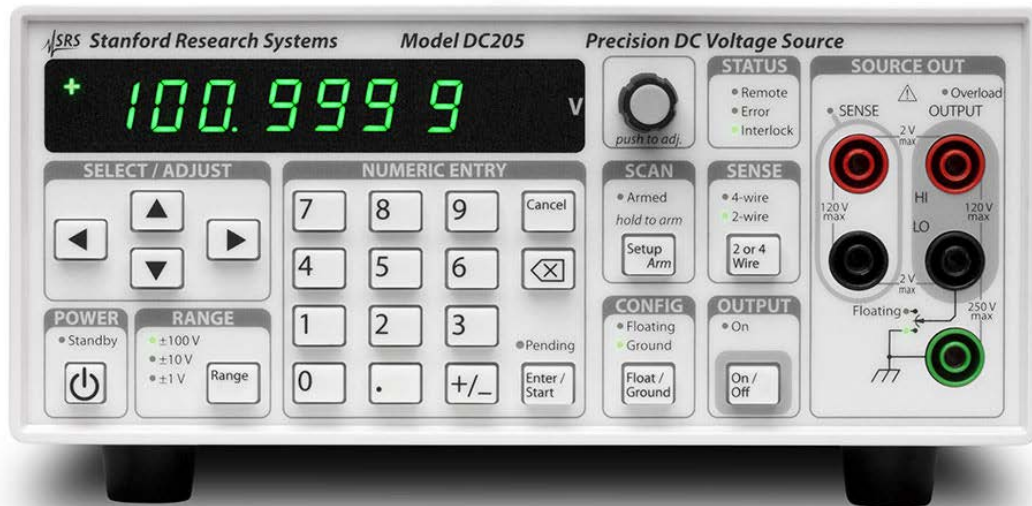


Figure 2.1: The DC205 front panel.

2.1.1 Power

When the DC205 is connected to an AC power source, the power supply will initially be in standby mode, indicated by the *Standby* indicator in the POWER section. To turn the DC205 on, press and hold the [⏻] button until *Standby* is no longer lit, and the rest of the display comes on.



Initially, the DC205 firmware version is displayed, followed by the unit's serial number, and then the unit begins operating normally. There are several special power-on modes accessible by holding a second button depressed while pressing [⏻].

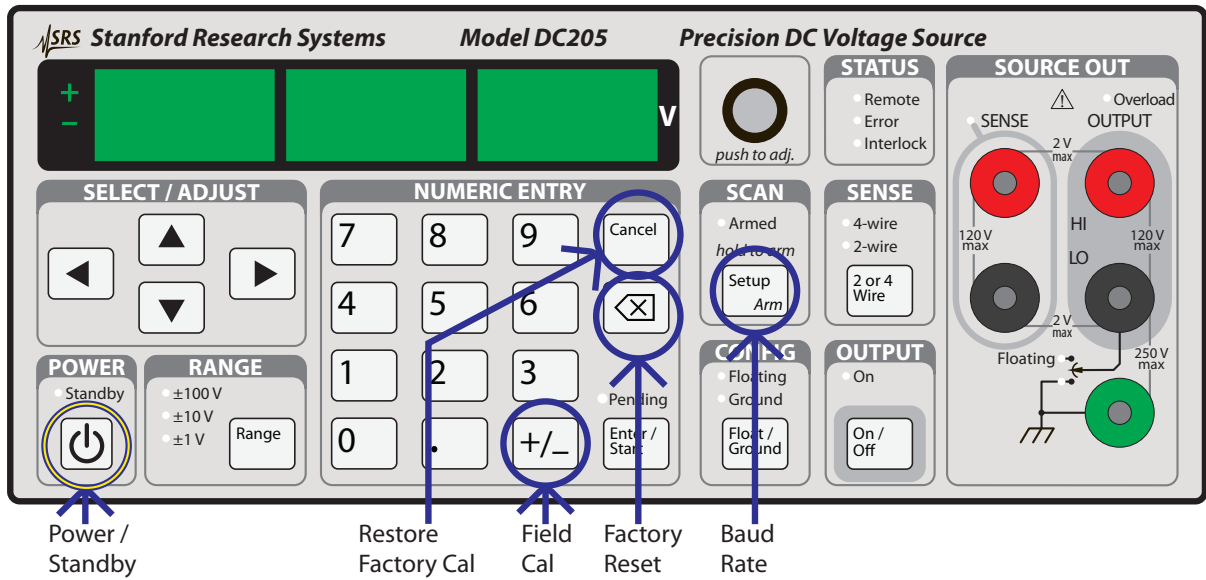


Figure 2.2: Power-on special modes on the DC205 front panel.

2.1.1.1 Power-on factory reset

Pressing and holding the backspace [⌫] button while turning on power will restore the factory default configuration of the DC205. The unit will display the message `DEF CFG` to indicate the default configuration is being restored.

In addition to putting the instrument into the default configuration (see *RST), the DB-9 RS-232 baud rate is set to 9600. Note that Field calibration data is not affected by power-on factory reset—to restore factory calibration, see the “Restore calibration” mode, below.

2.1.1.2 Field calibration

Pressing and holding the [+/-] button while turning on power will place the instrument in Field Calibration mode. You can read more about field calibration of the DC205 in chapter 5 (page 5 – 1).

2.1.1.3 Restore calibration

Pressing and holding the [Cancel] button while turning on power will bring the instrument into Restore Factory Calibration mode. The display will show `RESTOR CAL`. This will erase all field calibration data stored, and restore the factory calibration values.

To confirm restoring the factory calibration, press the [Enter/Start] button. The display will then show `DONE`. The instrument will then perform an internal reset, to return to normal operation. The message `B RESET` will appear on the display indicating the firmware was reset; simply press [Cancel] to clear the message and resume operation.

To cancel from Restore Factory Calibration without erasing field calibration data, press the [Cancel] button. The DC205 will then enter normal operation.

2.1.1.4 Baud rate

Pressing and holding the [Setup Arm] button while turning on power will cause the DC205 baud rate to be displayed on the numeric display. Use the [▲] and [▼] buttons to select between 9600, 19200, 38400, 57600, and 115200 baud. Press [Cancel] to resume normal operation.

The new baud rate is saved, and retained through power cycles.

2.1.1.5 Key clicks

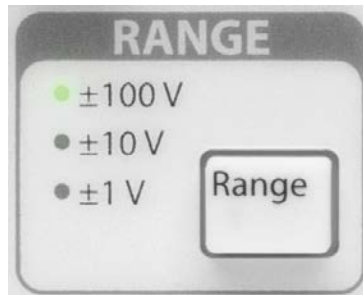
Pressing and holding the [0] button while turning on power will cause toggle whether button presses generate “key click” sounds during operation. This can also be changed remotely with the KCLK command (section 4.4.7, page 4 – 14).

2.1.1.6 Audible alarms

Pressing and holding the [1] button while turning on power will cause toggle whether button presses generate audible alarm sounds in response to errors during operation. This can also be changed remotely with the ALRM command (section 4.4.7, page 4 – 14).

2.1.2 Range

The Range button controls the DC205 output range setting. Pressing [Range] advances through the settings $\pm 1\text{ V}$, $\pm 10\text{ V}$, and $\pm 100\text{ V}$. Pressing [Range] while in the $\pm 100\text{ V}$ setting cycles back to $\pm 1\text{ V}$.



Changing the range is only possible when the output is disabled. Pressing [Range] while the output is *On* causes the *Error* indicator to briefly light, and the DC205 will beep.

Note that while any range may be selected so long as the output is off, it is not possible to enable the output on the $\pm 100\text{ V}$ range unless the safety interlock is closed.

2.1.3 Select / Adjust

The cluster of arrow buttons in the SELECT / ADJUST block provides a flexible interface to controlling the voltage setting of the DC205.



When the display is in the “display-idle” state, the voltage setting will be displayed and no digit will be blinking. Pressing any of the four arrow buttons once will cause the most-recently selected digit to begin blinking, indicating the focus for editing the setting.

Once a digit is blinking, that place value can be incremented (in a signed sense) by pressing [▲], and decremented by pressing [▼]. That digit value can also be incremented by turning the **knob** clockwise,

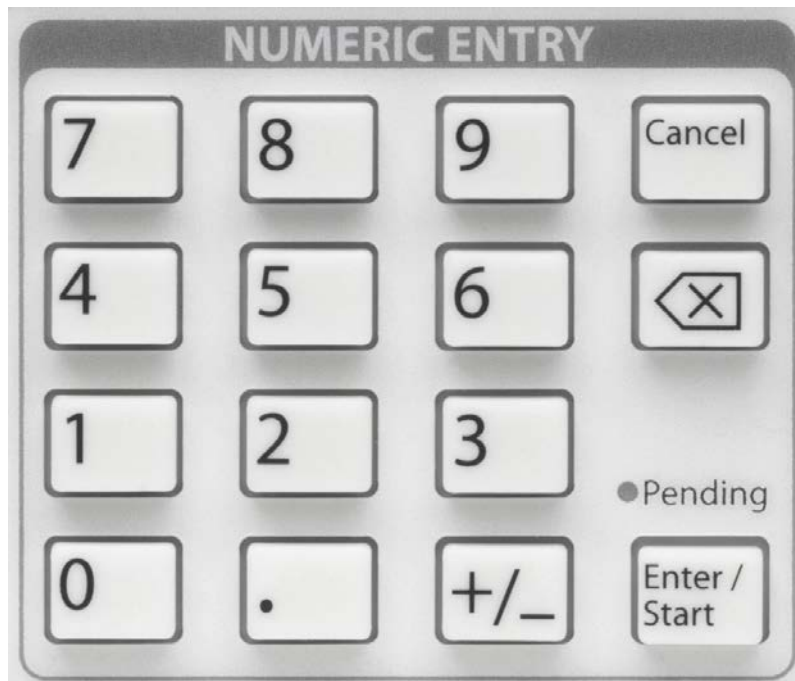
or decremented by turning the **knob** counterclockwise. The selected digit place can be changed by pressing either the [◀] or [▶].

The blinking function can be cancelled, and the display returned to the display-idle state, by pressing [Cancel], or by briefly pressing the **knob** inwards. When no digit is selected (blinking), turning the knob will have no effect.

The arrow buttons are also used when navigating secondary instrument settings, such as scan parameters.

2.1.4 Numeric Entry

The numeric entry keypad is used to directly enter voltage settings to the DC205. Values are implicitly positive unless the [+/-] button is pressed, which will toggle the sign between positive and negative.



When entering a voltage setting through the numeric keypad, the range limits are implicitly enforced during entry. This means, for example, that when configured for the $\pm 10\text{ V}$ range, the keypad will not allow you to enter a magnitude greater than 10.1 at any time.

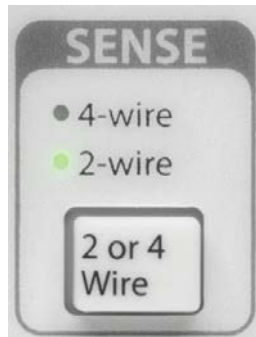
With the first press of either a digit key ([0] through [9]), or the decimal point ([.]) or sign button ([+/-]), the display will switch into numeric entry mode, with digits being added to the display as they are pressed. To back up a single digit, use the [\boxtimes] button.

While in numeric entry mode, the *Pending* indicator will blink. This is to show the numeric value has not yet been set into the instrument.

Pressing the [Enter/Start] button will accept the currently displayed value. To leave a pending numeric entry without causing the value to be set, press the [Cancel] button.

2.1.5 Sense

The [2 or 4 Wire] button in the SENSE block controls whether the DC205 uses local or remote feedback for controlling the voltage at the load.



Pressing [2 or 4 Wire] toggles between 2-wire and 4-wire. This can be performed at any time, regardless of the state of the output.

2.1.6 Config

The [Float/Ground] button in the CONFIG block controls whether the output voltage LO terminal is electrically connected to chassis ground, or isolated.



Pressing the [Float/Ground] button toggles between *Ground* (indicating the LO terminal is tied to chassis ground), and *Floating* (indicating the output is isolated from chassis ground). This operation can be performed at any time, regardless of the state of the output.

2.1.7 Scan

The SCAN block of the front panel is the entry point for voltage scanning for the DC205.



Briefly pressing the [Setup Arm] button will bring the scan parameters onto the display. To navigate between parameters, use the [◀] and [▶] select buttons. Pressing [Cancel] will exit the parameters mode.

Pressing and holding the [Setup Arm] button for more than 2 seconds will attempt to arm the scan. In order to successfully arm a scan, the output must already be on, the beginning and ending voltages of the scan must not be equal to each other, and the instrument range must match the scan range previously selected. Once armed, the output voltage is changed to the beginning scan voltage, and the *Armed* indicator is lit.

The *Pending* indicator is steadily lit, indicating the scan is ready and can be started by pressing the [Enter/Start] button. Pressing [Cancel] when a scan is armed will “disarm” the scan, but the output voltage will remain at the value from the scan beginning. While a scan is running, pressing the [Cancel] button will halt the scan, and the output voltage will remain at the most recent output value from the scan.

Once armed, scans can also be started by applying a falling edge to the –TRIG In BNC connector on the DC205 rear panel, or the remote *TRG command.

2.1.8 Output

The [On/Off] button in the OUTPUT block controls whether the voltage source is active.



Pressing the [On/Off] button toggles between the *On* state and disabled state.

Note that the output cannot be enabled when the range is $\pm 100\text{ V}$ unless the safety interlock is closed.

2.1.9 Status

The STATUS block of the front panel has three indicators to help visualize the condition of the DC205.



The *Remote* indicator illuminates whenever remote commands are received by the DC205 from any of the three remote interfaces. The indicator is not persistent—it will light briefly each time remote command characters are received.

The *Error* indicator will illuminate red, and the instrument beeps an audio alarm, whenever a disallowed operation is attempted, or when an illegal remote command is received. This indicator is also not persistent, and will illuminate for approximately 1 second each time an error occurs.

The *Interlock* indicator will be steadily illuminated any time the safety interlock is closed.

2.1.10 Source Out

The SOURCE OUT block of the front panel contains the output terminals for the voltage source.



The red and black terminals at the right side of the block, labelled OUTPUT, are the HI and LO output terminals of the source. When the output is enabled, the programmed voltage is present between these two nodes, with the red HI terminal at the greater potential (when commanded to positive output).

The output is current limited, based on the range selection. If the user's load begins to draw more than the current limit, the *Overload* indicator will illuminate red to indicate the instrument is current limiting, and the actual output voltage is not the commanded value. Current limit values are shown in the Output specifications table (page viii).

When 4-wire mode is selected for SENSE, the red and black terminals under the SENSE label are used for four-wire (remote) sensing of the output voltage. When these input terminals are active, the *SENSE*

indicator just above the terminals will be illuminated.

Note that when *4-wire* mode is selected, the SENSE terminals are (weakly) connected to the output HI and LO terminals through internal 0.5 M Ω resistors.

The green terminal at the bottom of the SOURCE OUT block is chassis ground. Near the green terminal, two indicators show whether the voltage source is configured as grounded or isolated. When grounded, the lower green indicator is illuminated, graphically showing the connection between the black LO terminal and chassis ground. When isolated, the yellow *Floating* indicator is lit, graphically showing that LO is disconnected from chassis.

2.2 Scanning

Voltage scanning was briefly introduced in the previous chapter, under section 1.5.3. Scanning allows the user to setup and execute linear sweeps of the output voltage of the DC205.

2.2.1 Overview of scanning

Scans are implemented by dividing the time interval of a scan into small steps, of 1 ms duration, and commanding the voltage output in small incremental amplitude steps to simulate a smooth voltage slew. Note that, under careful examination, the stair-step nature of the voltage scans may be seen.

2.2.2 Scan terminology

When configuring a scan, the user selects a scan range, a beginning voltage, V_b , and an ending voltage, V_e , which command the starting and ending values. A scan duration time, Δt , is also selected in the range 100 ms to 9,999.9 s, as the time period to move from V_b to V_e . The effective voltage slew rate is given by $(V_e - V_b)/\Delta t$.

Scans can be configured as either unidirectional (starting at V_b), or bidirectional (starting again at V_b and moving to V_e , then reversing back to V_b). Scans can move towards increasing or decreasing output voltage, depending on whether V_e is greater than or less than V_b . Note that scans cannot be executed if $V_b = V_e$.

Finally, scans can be configured as a single shot or as indefinitely repeating.

The four permutations are shown in Figure 2.3. Note the scan duration time Δt is always the time to scan from V_b to V_e —for bidirectional scans, the overall repeating period is therefore $2 \times \Delta t$.

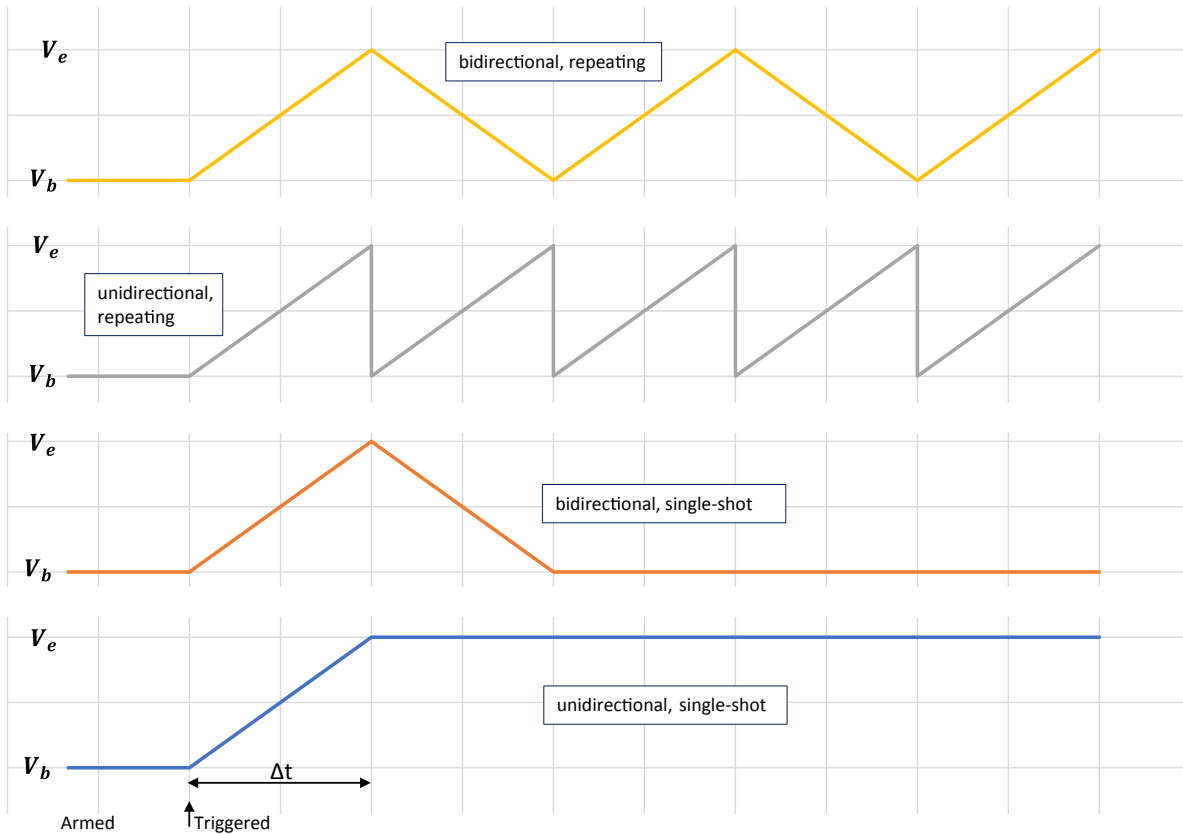


Figure 2.3: The DC205 scan modes, shown schematically. Time flows horizontally from left to right. All four examples are shown starting in the “Armed” state, with the scan beginning at the point marked “Triggered.” The scan duration Δt is indicated near the bottom, and is common for all plots.

One last configuration choice is whether the instrument display will update in near real time during the scan, or statically display the word `SCANNING` on the front panel.

2.2.3 Arming scans

A scan can be “armed” if the following conditions are met:

1. The scan range matches the instrument output range
2. The beginning and ending scan voltages are not equal
3. The output is on

If all three conditions are satisfied, then upon arming the scan, the DC205 output is set to the beginning scan voltage V_b , and the scan is said to be in the armed state.

Scans can be armed from the front panel by pressing and holding the [Setup Arm] button for at least 2 seconds, or by issuing the remote SCAA command (see section 4.4.6 on page 4 – 13).

The armed state is indicated by the *Armed* and *Pending* indicators both being steadily illuminated.

2.2.4 Triggering scans

While armed, a scan can be triggered to start in one of three ways:

1. Pressing the [Enter Start] button
2. Receiving a falling logic level on the –TRIG In rear-panel BNC connector
3. With the remote *TRG command

Once triggered, the scan is now running and no longer considered in the “armed” state. The *Armed* indicator goes off, and additional incoming edges at the –TRIG In connector are ignored for the duration of the scan.

2.2.5 TRIG In and BUSY Out

Two rear panel connectors provide a simple interface to trigger and monitor scans with external hardware. The –TRIG In input is an active-low, TTL-compatible input that can be used to trigger scans once they are armed. This node has a 10 k Ω internal pull-up resistor to +3.3 V. To externally trigger a scan, the user provides a pulse to ground of at least 1 μ s duration on –TRIG In. The scan is triggered by the falling edge of the signal.

Scans may be monitored with the –BUSY Out output. When the scan system is either idle or in the armed state, this output is at +3.3 V. While a scan is running, the –BUSY Out rear panel BNC signal is asserted low (0 V). –BUSY Out is driven through a 330 Ω series impedance.

It is possible to arrange several DC205s in a master-slave arrangement to synchronize scanning. Connect the –BUSY Out signal from the “master” DC205 to the “slave” unit(s) –TRIG In connectors. Configure each DC205 for the desired scan parameters, and then arm each of the units. To begin the synchronized scan, trigger the scan from the master unit using any of the 3 methods listed in section 2.2.4. As soon as the master unit is triggered, it’s –BUSY Out signal will be

asserted low, which in turn will provide the falling edge to the slave unit –TRIG In connectors, triggering their scans as well.

Note that there is a ± 1 ms timing aperture in the scanning system. This means there can be up to 2 ms between the start time of any of the synchronized scans.

2.2.6 Ending or cancelling scans

Single-shot scans will end naturally after the programmed duration (either Δt , for unidirectional scans, or $2 \times \Delta t$, for bidirectional scans). Scans may also be halted asynchronously at any time after starting. For single-shot scans, this may be helpful especially for long Δt scans. For repeating scans, there is no “natural” ending time, so these must always be halted asynchronously.

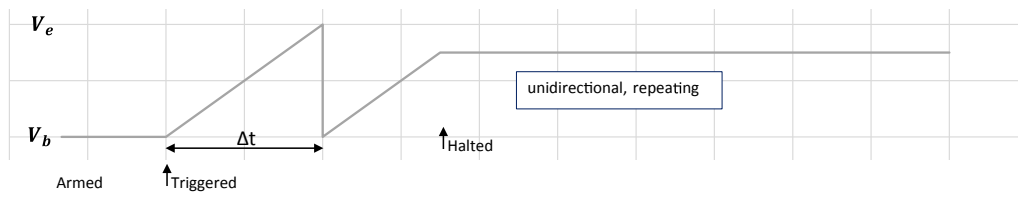


Figure 2.4: Example of a repeating scan, halted asynchronously.

To halt a scan already underway, either press the front-panel [Cancel] button, or send the remote command **SCAA IDLE** (see section 4.4.6).

When a scan is stopped in this way, the output voltage is left at the most-recent setting of the scan, with the output still on. See Figure 2.4.

2.3 Error messages

The following messages may be displayed on the DC205 numeric display. This section provides a key to interpreting the messages.

2.3.1 Messages at power on

When the DC205 successfully powers on, the display will show the firmware revision level, followed by the unit's serial number, and then begin normal operation. A number of internal self-checks are performed before beginning operation. If one of these fails, the following error messages may appear on the numeric display.

2.3.1.1 Firmware corruption

If the non-volatile program memory becomes corrupted, the DC205 may display the message `Err FL` indicating the flash memory is invalid. This failure is unlikely, but the instrument will not operate in this mode and must be returned to the factory for service.

2.3.1.2 Configuration lost

If the memory recording the last configuration of the DC205 is determined to be corrupted upon power-up, the message `Err CF` is displayed. This message may be cleared by pressing any button, after which the instrument will begin operating from the default configuration (as though *RTS had run).

2.3.1.3 Calibration lost

If the stored “working calibration” values becomes corrupted, the DC205 the message `Err CL` will be displayed. This message can be cleared by pressing any button, after which the nominal scale values will be reloaded. In this case, the instrument will operate but will not perform to specification.

Note that the working calibration is stored in a separate page of non-volatile memory from the original factory calibration. A copy of the factory calibration values is stored in a separate page of the non-volatile memory. Depending on the how the working calibration became corrupted, it may be possible to recover proper operation by following the procedure for “Restore calibration” given above, in section 2.1.1.3 (page 2 – 4).

If the restore calibration procedure fails, then the unit should be returned to the factory for service.

2.3.2 Field calibration

During field calibration (see chapter 5), it is possible for the gain or offset adjustment to exceed the hardware range of the DC205. In this case, the message `bAd CAL` is displayed, indicating the adjustments will be discarded.

2.3.3 Scanning

When preparing an output scan by arming the scan, several consistency checks are performed. If any of these fail, one of the following messages will be displayed.

2.3.3.1 Scan range

When the output range does not match the scan range, the message `Err rAnGE` is displayed.

2.3.3.2 Output off

If the output is off when attempting to arm a scan, the message `Err OutOFF` is displayed.

2.3.3.3 Beginning and ending voltages equal

If the beginning and ending voltages for the scan are not distinct, the message `Err b = E` is displayed.

2.3.4 Interlock

If the DC205 is operating on the ± 100 V range with the output on, and the safety interlock opens, then the message `Err IntLoc` will be displayed. This message will persist until the user presses [Cancel] or another button, or sends any remote commanding data.

2.3.5 Unexpected resets

A number of internal protections may cause the DC205 to generate an internal reset in response to a hardware failure. If this occurs, one of the following messages is displayed to indicate the failure. The message will persist until the user presses [Cancel], after which the instrument will (attempt to) resume normal operation.

If any of these are encountered unexpectedly, please contact the factory for possible service.

2.3.5.1 Undervoltage

`1 rESEt` indicates the cpu undervoltage detector was activated.

2.3.5.2 Clock failure

`2 rESEt` indicates the cpu oscillator clock failed.

2.3.5.3 Watchdog

`3 rESEt` indicates the protective watchdog timer expired, which can be a symptom of a firmware failure.

2.3.5.4 Reset pin wakeup

`4 rESEt` indicates the hardware reset node generated a wakeup.

2.3.5.5 Other wakeup

`5 rESEt` indicates a wakeup from a source other than the reset node.

2.3.5.6 Hardware reset

`6 rESEt` indicated the hardware reset node was activated.

2.3.5.7 JTAG

`7 rESEt` indicates the instrument was reset from the JTAG interface.

2.3.5.8 Firmware

`8 rESEt` indicates a firmware reset. This is normal operation following a successful factory-calibration restore operation.

2.3.5.9 Debug

`9 rESEt` indicates a reset generated by the host debugging tool.

2.3.5.10 EZport

`10 rESEt` indicates a reset originating with the cpu's EZ-port.

2.3.5.11 Tamper

`11 rESEt` indicates the cpu tamper detection was triggered.

2.3.5.12 Unknown

`12 rESEt` indicates a reset of unknown origin.

2.3.5.13 Lockup

`13 rESEt` indicates a cpu core lockup failure.

2.3.5.14 Peripheral failure

`14 rESEt` indicates a cpu peripheral failed to acknowledge stop mode.

3 Architecture

This chapter describes the architecture and theory of operation of the DC205 Precision DC Voltage Source.

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3.3 Digital to analog converter	3-3
3.4 Amplifiers	3-4
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3.1 Overview

The DC205 is designed around three core elements that combine to deliver the instrument's performance. These elements are:

1. A low-noise, stable voltage reference
2. A high-resolution digital-to-analog converter
3. A set of low-noise, low-distortion amplifiers

A simplified block diagram of the DC205 is shown in Figure 3.1.

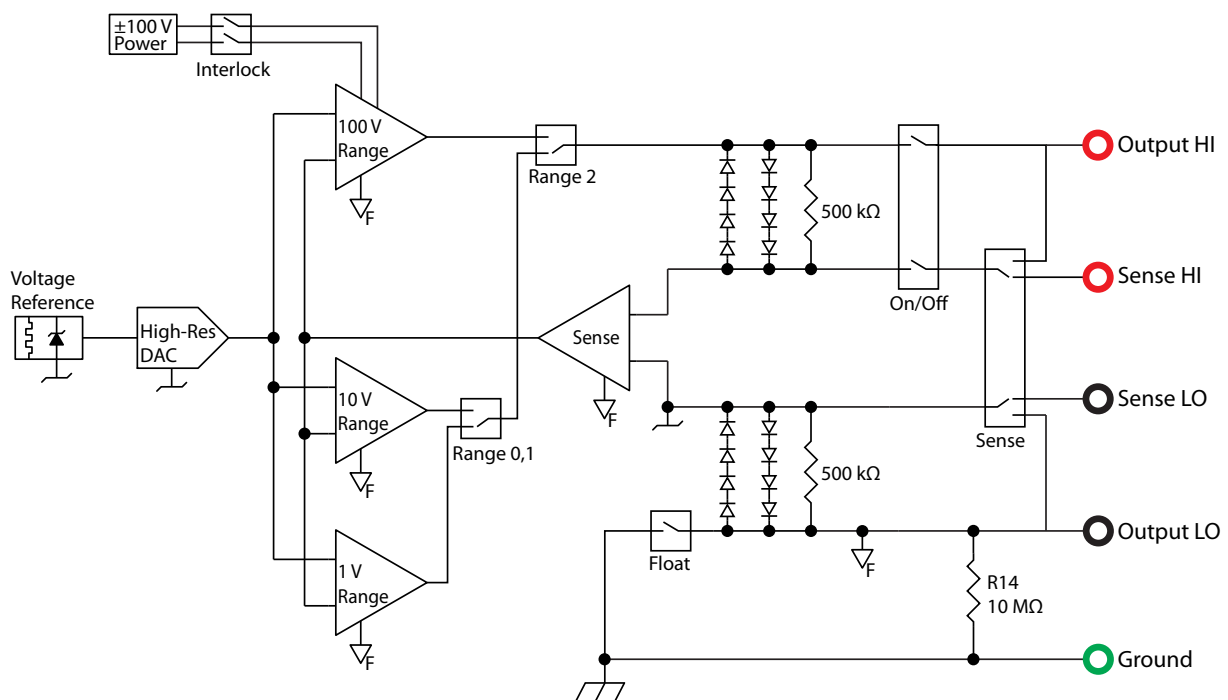


Figure 3.1: The DC205 block diagram.

3.2 Voltage reference

The long-term stability and low-frequency noise performance of the DC205 are determined by the voltage reference, which provides a stable voltage at the start of the signal chain. An ovenized buried-zener reference is used in the DC205 for this purpose. Individual references are subjected to an extended burn-in and screening for stability, temperature coefficient, and noise prior to installation in final assemblies.

The reference has a wide range of operating voltages, with a part to part variation of over $\pm 3\%$. While this is many orders of magnitude worse than the ultimate accuracy specification of the DC205, the important aspect of the voltage reference is not its initial *accuracy* but rather its *stability* over time. The accuracy of the DC205 is established at factory calibration time by reference to a NIST-traceable high precision voltmeter.

The raw reference voltage (typically 6.95 V) is converted to bipolar reference voltages of approximately ± 10.4 V for the DAC stage using low-offset chopper-stabilized op amps and temperature-tracking resistor networks.

Because the voltage reference is ovenized to operate at a stable, elevated temperature, some time is required following power-on before the ultimate performance of the DC205 is achieved. The majority of the output voltage drift will occur during the first minute of operation; however, a full 2 hours must pass before the instrument will be at full specified performance.

3.3 Digital to analog converter

The digital-to-analog converter (DAC) produces a programming voltage, proportional to the commanded output voltage, to send to the amplifier stage. The DAC is a compound circuit based on the AD5791 20-bit “R-2R” converter. This is extended to 21-bit operation with the addition of a least-significant bit at the output of the AD5791. This ensures the least-significant hardware bit approximately corresponds to the least-significant count on the instrument’s voltage setting.

By using bipolar reference voltages, there is no relay switching involved when the output passes through zero. In other words, 0 V output corresponds approximately to mid-scale on the DAC output. This ensures that there are no transients or glitches when passing from negative to positive, or positive to negative, output voltages.

3.4 Amplifiers

Two distinct output amplifiers are incorporated in the DC205 to accommodate the three output voltage ranges.

3.4.1 High-range amplifier

The highest output range, ± 100 V, has a dedicated output circuit powered by ± 120 V supply rails. This entire subsystem, including the power to the high-range amplifier, is enabled only when the safety interlock is closed.

The high-range amplifier operates at a fixed gain of $\times 10$ to allow the output voltage to reach ± 101 V. The amplifier can produce output currents of 30 mA, guaranteeing operation to ± 25 mA output.

3.4.2 Low-range amplifier

The two lower output ranges, ± 1 V and ± 10 V, are supplied by a single low-range amplifier. This amplifier operates independent of the state of the safety interlock, as it is powered by ± 15 V supplies.

The low-range amplifier operates at one of two fixed gains, $\times 1$ or $\times 1/10$, corresponding to the ± 10 V range and ± 1 V range, respectively.¹ This amplifier has an approximate output current limit of 70 mA, guaranteeing operation to ± 50 mA output on both the ± 1 V and ± 10 V ranges.

3.5 Remote sensing

The DC205 can operate in either 2-wire (local sensing) or 4-wire (remote sensing) mode. When operating with remote sensing, the user provides separate connections (Kelvin leads) from the DC205 to the user's load, and the amplifier will servo the output to force the measured voltage on the sense leads to equal the desired setting. While adding some complexity in wiring, operating with remote sensing can eliminate the errors due to resistive voltage drop when a user's load draws current from the DC205.

As indicated in the block diagram, there is input protection circuitry associated with the sense leads. A full understanding of these circuit features can help achieve best results with the DC205.

The sense amplifier itself has a very high input impedance (10^{13} Ω). As can be seen from the block diagram, however, there are 500 k Ω connections between each sense line and the corresponding output

¹ Note that, in the block diagram, these two gain settings are shown as separate amplifiers for simplicity.

line. These resistors ensure that when the DC205 is operating in 4-wire mode but the sense leads are not connected, there remains some local feedback to keep the output regulated. Additionally, there are two antiparallel chains of PN diodes between the sense leads and their corresponding output leads. These effectively clamp the sense leads to within ± 2.5 V of the output leads. This in turn implies the largest ohmic drop which can be corrected with remote sensing is about 2.5 V (per lead).

As a result of the diode strings clamping the sense-to-output voltage at ± 2.5 V, it is possible to estimate the maximum sense lead resistance that can be used in cases where the user load draws high current from the DC205. At the maximum output current, this corresponds to a maximum lead resistance of about $50\ \Omega$ for the ± 1 V and ± 10 V ranges, and $100\ \Omega$ for the ± 100 V range. Note that these limits are for the maximum output current—if the user load draws significantly less current, then higher sense lead resistance can be tolerated without the clamp diodes going into forward conduction. In the limiting case where the load draws negligible current (very high impedance), there is typically no benefit to operating in remote sense mode.

 **WARNING**

As can be seen from the block diagram, when configured for 4-wire operation, the sense leads are electrically connected to the output nodes of the DC205. Although operationally the sense leads are inputs to the instrument, users should be aware that the Sense HI terminal will always be within ± 2.5 V of the Output HI potential. When operating at the ± 100 V range, users must treat the sense terminals with the same caution as the output terminals.

4 Remote Operation

This chapter describes operating the DC205 Precision DC Voltage Source over the remote interfaces.

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4.1 Index of commands

Symbol	Definition
<i>f, g</i>	Floating-point value
<i>i, j</i>	Unsigned integer
<i>z</i>	Literal token
(?)	Required for queries; illegal for set commands
<i>var</i>	Parameter always required
{ <i>var</i> }	Required parameter for set commands; illegal for queries
[<i>var</i>]	Optional parameter for both set and query forms

Configuration

RNGE(?) { <i>z</i> }	4 – 9	Range
ISOL(?) { <i>z</i> }	4 – 9	Output isolation
SENS(?) { <i>z</i> }	4 – 9	Remote Sensing
SOUT(?) { <i>z</i> }	4 – 9	Output

Settings

VOLT(?) { <i>f</i> }	4 – 10	DC Voltage
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Scanning

SCAR(?) { <i>z</i> }	4 – 11	Scan Range
SCAB(?) { <i>f</i> }	4 – 11	Scan Beginning Voltage
SCAE(?) { <i>f</i> }	4 – 11	Scan Ending Voltage
SCAT(?) { <i>f</i> }	4 – 12	Scan Time
SCAS(?) { <i>z</i> }	4 – 12	Scan Shape
SCAC(?) { <i>z</i> }	4 – 12	Scan Cycle
SCAD(?) { <i>z</i> }	4 – 13	Scan Display
SCAA(?) { <i>z</i> }	4 – 13	Scan Arm
*TRG	4 – 14	Remote Trigger

Setup

KCLK(?) { <i>z</i> }	4 – 14	Key Clicks
ALRM(?) { <i>z</i> }	4 – 14	Audible Alarms

Interface

*IDN?	4 – 14	Identify
TOKN(?) { <i>z</i> }	4 – 15	Token Mode
TERM(?) { <i>z</i> }	4 – 15	Response Termination
*OPC(?)	4 – 15	Operation Complete
COPC	4 – 16	Cancel Pending *OPC Flag
BAUD(?) { <i>z</i> }	4 – 16	Serial Baud Rate
*RST	4 – 17	Reset

Status

ILOC?	4-18 Interlock
OVLDT?	4-18 Overload
*STB? [i]	4-18 Status byte
*SRE(?) [i,] {j}	4-18 Service request enable
*ESR? [i]	4-18 Standard event status
*ESE(?) [i,] {j}	4-19 Standard event status enable
*CLS	4-19 Clear Status
LEXE?	4-19 Last Execution Error
LCME?	4-20 Last command error
DCCR? [i]	4-20 DC Source Condition
DCPT(?) [i,] {j}	4-20 DC Source Positive-Transition
DCNT(?) [i,] {j}	4-20 DC Source Negative-Transition
DCEV? [i]	4-21 DC Source Event
DCEN(?) [i,] {j}	4-21 DC Source Event Enable

4.2 Alphabetic list of commands

★	
*CLS	4 – 19 Clear Status
*ESE(?) [i,] {j}	4 – 19 Standard event status enable
*ESR? [i]	4 – 18 Standard event status
*IDN?	4 – 14 Identify
*OPC(?)	4 – 15 Operation Complete
*RST	4 – 17 Reset
*SRE(?) [i,] {j}	4 – 18 Service request enable
*STB? [i]	4 – 18 Status byte
*TRG	4 – 14 Remote Trigger

A	
ALRM(?) {z}	4 – 14 Audible Alarms

B	
BAUD(?) {z}	4 – 16 Serial Baud Rate

C	
COPC	4 – 16 Cancel Pending *OPC Flag

D	
DCCR? [i]	4 – 20 DC Source Condition
DCEN(?) [i,] {j}	4 – 21 DC Source Event Enable
DCEV? [i]	4 – 21 DC Source Event
DCNT(?) [i,] {j}	4 – 20 DC Source Negative-Transition
DCPT(?) [i,] {j}	4 – 20 DC Source Positive-Transition

I	
ILOC?	4 – 18 Interlock
ISOL(?) {z}	4 – 9 Output isolation

K	
KCLK(?) {z}	4 – 14 Key Clicks

L	
LCME?	4 – 20 Last command error
LEXE?	4 – 19 Last Execution Error

O	
OVLD?	4 – 18 Overload

R

RNGE(?) {z} 4-9 Range

S

SCAA(?) {z} 4-13 Scan Arm
SCAB(?) {f} 4-11 Scan Beginning Voltage
SCAC(?) {z} 4-12 Scan Cycle
SCAD(?) {z} 4-13 Scan Display
SCAE(?) {f} 4-11 Scan Ending Voltage
SCAR(?) {z} 4-11 Scan Range
SCAS(?) {z} 4-12 Scan Shape
SCAT(?) {f} 4-12 Scan Time
SENS(?) {z} 4-9 Remote Sensing
SOUT(?) {z} 4-9 Output

T

TERM(?) {z} 4-15 Response Termination
TOKEN(?) {z} 4-15 Token Mode

V

VOLT(?) {f} 4-10 DC Voltage

4.3 Introduction

Remote operation of the DC205 is through a simple command language documented in this chapter. Both set and query forms of most commands are supported, allowing the user complete control of the voltage source from a remote computer through USB or RS-232, or through the optical fiber and the SX199 interface to GPIB, RS-232, or ethernet interfaces.

Where applicable, the corresponding front-panel interface to each command is also indicated. Most instrument settings are retained in non-volatile memory. Upon power-on, these settings are restored to their values before the power was turned off. Where appropriate, the default value for parameters is listed in **boldface** in the command descriptions.

4.3.1 Interface configuration

The USB interface is implemented as a serial port emulator, with fixed baud rate of 115,200. The optical fiber interface is fixed at 9600 baud for operation with the SX199 interface unit. The RS-232 DB-9 interface is configured by default as 9600 baud, 8-bit, no parity or flow control. The RS-232 interface can be commanded to different baud rates under program control with the **BAUD** command, or through the power-on configuration method described in section 2.1.1.4 on page 2 – 4 .

4.3.2 Isolation and computer noise

Whenever the DC205 is directly connected to a computer through the RS-232 or USB interface, there is the potential for high frequency (RF) noise to be injected into the analog circuitry of the instrument. To avoid this when remote commanding is required, use the optical fiber interface together with the SX199 interface unit.

4.3.3 Buffers

The DC205 stores incoming bytes from the remote interfaces in separate 128-byte input buffers. Characters accumulate in the input buffer until a command terminator (<CR> or <LF>) is received, at which point the message is parsed and enqueued for execution. The command queue can hold up to 20 remote commands. Query responses from the DC205 are buffered in interface-specific 256-byte output queues. Queries are returned to the interface from which they were received (RS-232, USB, or optical).

If an input buffer overflows, then all data in the input buffer are discarded, and the DDE bit is recorded in the ESR status register.

4.4 Commands

This section provides syntax and descriptions for remote commands.

4.4.1 Command syntax

The four letter mnemonic (shown in **CAPS**) in each command sequence specifies the command. The command mnemonic is optionally followed by one or more parameters.

Commands may take either *set* or *query* form, depending on whether the “?” character follows the mnemonic. *Set only* commands are listed without the “?”, *query only* commands show the “?” after the mnemonic, and *optionally query* commands are marked with a “(?)”.

Parameters shown in { } and [] are not always required. Parameters in { } are required to set a value, and should be omitted for queries. Parameters in [] are optional in both set and query commands. Parameters listed without surrounding characters are always required.

Do *not* send () or { } or [] as part of the command.

Multiple parameters are separated by commas. Multiple commands may be sent on one command line by separating them with semicolons (;) so long as the input buffer does not overflow. Commands are terminated by either <CR> or <LF> characters. Null commands and whitespaces are ignored. Execution of the command does not begin until the command terminator is received.

tokens *Token* parameters (generically shown as *z* in the command descriptions) can be specified either as a keyword or as an integer value. Command descriptions list the valid keyword options, with each keyword followed by its corresponding integer value. For example, to set the remote sensing mode to 4-wire, the following two commands are equivalent:

SENS FOURWIRE —or— SENS 1

For queries that return token values, the return format (keyword or integer) is specified with the **TOKN** command.

4.4.2 Notation

The following table gives the notation used in the command descriptions:

Symbol	Definition
<i>f</i>	Floating-point value
<i>i, j</i>	Unsigned integer
<i>z</i>	Literal token
(?)	Required for queries; illegal for set commands
<i>var</i>	Parameter always required
{ <i>var</i> }	Required parameter for set commands; illegal for queries
[<i>var</i>]	Optional parameter for both set and query forms

4.4.3 Examples

Each command is provided with a simple example illustrating its usage. In these examples, all data sent by the host computer to the DC205 are set as *straight teletype font*, while responses received by the host computer from the DC205 are set as *slanted teletype font*.

The usage examples vary with respect to set/query, optional parameters, and token formats. They are not exhaustive, and are intended to provide a convenient starting point for user programming.

4.4.4 Configuration commands

RNGE(?) {z}	<p>Range</p> <p>Set (query) the voltage range {to z=(RANGE1 0, RANGE10 1, RANGE100 2)}.</p> <p>The RNGE command is equivalent to pressing the [Range] button. RNGE sets the output range of the DC205 to one of the three range settings: $\pm 1\text{ V}$, $\pm 10\text{ V}$, or $\pm 100\text{ V}$.</p> <p>Note that at each range, the source can be set to $\pm 101\%$ of the nominal full scale.</p> <p>The RNGE command may not be set while the output is enabled.</p> <p><i>Example:</i> RNGE? RANGE1</p>
<hr/>	
ISOL(?) {z}	<p>Output isolation</p> <p>Set (query) the output isolation configuration {to z=(GROUND 0, FLOAT 1)}.</p> <p>The ISOL command is equivalent to pressing the [Float/Ground] button. This command may be sent at any time.</p> <p><i>Example:</i> ISOL 1</p>
<hr/>	
SENS(?) {z}	<p>Remote Sensing</p> <p>Set (query) the remote sensing mode {to z=(TWOWIRE 0, FOURWIRE 1)}.</p> <p>The SENS command is equivalent to pressing the [2 or 4 Wire] button. This command may be sent at any time.</p> <p><i>Example:</i> SENS FOURWIRE</p>
<hr/>	
SOUT(?) {z}	<p>Output</p> <p>Set (query) the voltage source output mode {to z=(OFF 0, ON 1)}.</p> <p>The voltage source output is enabled or disabled using the SOUT command. When set to SOUT OFF, the OUTPUT HI terminal is disconnected from the output circuitry. If the source is configured for ISOL GROUND, then the OUTPUT LO terminal remains connected to chassis ground.</p> <p>If the source range is set to RANG RANGE1 or RANG RANGE10, then SOUT ON may be sent at any time. However, if the source range is set</p>

to RANG RANGE100, then SOUT ON may only be sent while the safety interlock is closed.

The SOUT command is equivalent to pressing the OUTPUT [On/Off] button.

Example: SOUT?
0

4.4.5 Setting commands

VOLT(?) {f}

DC Voltage

Set (query) the commanded source voltage {to f}, in volts. The default value is VOLT 0.0.

Note that the allowable range for VOLT depends on the RNGE setting:

Range	Minimum	Maximum
±1 V	-1.010 000	+1.010 000
±10 V	-10.100 00	+10.100 00
±100 V	-101.000 0	+101.000 0

The VOLT command may be queried at any time, and set any time except when a scan is either armed or running. Queries of VOLT? while a scan is running will reply with the approximate realtime output voltage, updated approximately every 150 ms.

Note also that VOLT? queries always respond with the voltage *setting* of the instrument—no actual measurement of output voltage is ever performed by the DC205.

The VOLT command is equivalent to the front panel numeric entry keypad.

Example: VOLT 1.25e-3; VOLT?
0.001250

4.4.6 Scan commands

The DC205 can perform linear voltage scans, either as a single-shot or indefinitely repeating pattern. The following commands provide the remote interface to this capability.

SCAR(?) {z}	<p>Scan Range</p> <p>Set (query) the scan range {to z=(RANGE1 0, RANGE10 1, RANGE100 2)}</p> <p>Scanning must be configured for a specific output range, which can be set independent of the present value of the active output range (see RNGE). At the time a scan is armed, the scan range SCAR must match the output range RNGE.</p> <p>When SCAR is modified, then both SCAB and SCAE (the beginning and ending voltages for the scan) are reset to 0 V.</p> <p>SCAR cannot be set when a scan is either armed or running.</p> <p>The SCAR command is equivalent to the <i>r n g</i>. entry field under SCAN Setup.</p>
-------------	--

Example: SCAR RANGE10

SCAB(?) {f}	<p>Scan Beginning Voltage</p> <p>Set (query) the scan beginning voltage {to f}, in volts. The default value is SCAB 0.0.</p> <p>The value for SCAB must be within the valid range for the selected scan range, SCAR. Limits are the same as for the VOLT command.</p> <p>SCAB cannot be set when a scan is either armed or running.</p> <p>The SCAB command is equivalent to the <i>b</i> entry field under SCAN Setup.</p>
-------------	--

Example: SCAB 0.125

SCAE(?) {f}	<p>Scan Ending Voltage</p> <p>Set (query) the scan ending {to f}, in volts. The default value is SCAE 1.0.</p> <p>The value for SCAE must be within the valid range for the selected scan range, SCAR. Limits are the same as for the VOLT command.</p> <p>SCAE cannot be set when a scan is either armed or running.</p> <p>The SCAE command is equivalent to the <i>E</i> entry field under SCAN Setup.</p>
-------------	--

SCAT(?) {f} Scan Time

Set (query) the scan duration {to *f*}, in seconds. The default value is **SCAT 1.0**.

The value for **SCAT** must be between **0.1** and **9999.9**. Values are rounded to the nearest 0.1 s.

The duration time set by **SCAT** is defined as the time to scan from the beginning voltage to the ending voltage; if the scan shape is up-down, then the total scan period will be twice the value of **SCAT**.

SCAT cannot be set when a scan is either armed or running.

The **SCAT** command is equivalent to the **t** entry field under **SCAN Setup**.

Example: **SCAT 3600**

SCAS(?) {z} Scan Shape

Set (query) the scan shape {to *z*=(**ONEDIR 0**, **UPDN 1**)}.

Scans can be configured to either slew in one direction only, from **SCAB** to **SCAE** (**SCAS ONEDIR**), or they can operate as a “round trip” from **SCAB** to **SCAE**, and then back to **SCAB** (**SCAS UPDN**).

Note that for either shape, there is no restriction on the the relation between **SCAB** and **SCAE**—the actual scan can begin with voltage either increasing or decreasing.

SCAS cannot be set when a scan is either armed or running.

The **SCAS** command is equivalent to the **Sh** entry field under **SCAN setup**.

Example: **SCAS?**
ONEDIR

SCAC(?) {z} Scan Cycle

Set (query) the scan cycling mode {to *z*=(**ONCE 0**, **REPEAT 1**)}.

Scans can be configured to either execute a single time (**SCAC ONCE**), or to repeat indefinitely (**SCAC REPEAT**).

When **SCAC REPEAT** is set, and the scan shape **SCAS ONEDIR** is selected, then the output voltage will change abruptly, from **SCAE** to **SCAB**, at the conclusion of each cycle.

When **SCAC ONCE** is set, the output voltage remains at **SCAE** at the conclusion of the scan.

It is possible to set SCAC while a scan is in progress. In this way, it is possible, for example, to end a repeating scan at the next natural ending point (either SCAE, if the SCAS=ONEDIR, or SCAB, if SCAS=UPDN).

The SCAC command is equivalent to the `C Y C L E` entry field under SCAN setup.

Example: SCAC 0

SCAD(?) {z}

Scan Display

Set (query) the scan display mode {to z=(OFF 0, ON 1)}.

When a scan is in progress, the display will either show a (near) real time update of the output voltage, or it will remain static, displaying

`S c a n n i n g`.

The SCAD command is equivalent to the `d i S P` entry field under SCAN setup.

SCAA(?) {z}

Scan Arm

Set the scan armed mode {to z=(IDLE 0, ARMED 1)}, or query the scan armed mode as z=(IDLE 0, ARMED 1, or SCANNING 2).

Setting SCAA ARMED will arm the scan. In order to successfully arm the scan, the DC205 must already have the output enabled. Also, the present range setting (RNGE) must match the programmed scan range (SCAR), and the beginning and ending voltages of the scan (SCAB and SCAE) must not be equal. This is equivalent to pressing and holding the [Setup Arm] button.

Sending the SCAA IDLE command will disarm an already-armed scan. SCAA IDLE will also cancel a scan that is currently in progress (that is, in the SCAA SCANNING state). This is equivalent to pressing the [Cancel] button when armed or scanning.

Note that the query SCAA? can return the value SCANNING (or numerical value 2, but this value is illegal for the set version of the command. To begin a scan after arming, use the *TRG command (see below).

When armed, the scan can be started by either pressing [Enter/Start], sending the remote *TRG command, or by a falling logic edge on the rear panel –TRIG In BNC connector.

Example: SCAA ARMED

*TRG	<p>Remote Trigger</p> <p>Remotely start a scan.</p> <p>Note that the scan must already be armed for *TRG to start a scan.</p> <p>The *TRG command is equivalent to the [Enter/Start] button when the scan system is <i>Armed</i>.</p>
------	---

4.4.7 Setup commands

KCLK(?) {z}	<p>Key Clicks</p> <p>Set (query) audible key clicks {to z=(OFF 0, ON 1)}.</p> <p>Key click mode can also be changed through a power-on key press (see section 2.1.1.5 on page 2 – 4).</p>
-------------	--

ALRM(?) {z}	<p>Audible Alarms</p> <p>Set (query) audible alarms {to z=(OFF 0, ON 1)}.</p> <p>Note that all sounds that are not “key clicks” are considered “alarms” for the purpose of the ALRM command. Alarm mode can also be changed through a power-on key press (see section 2.1.1.6 on page 2 – 4).</p>
-------------	--

4.4.8 Interface commands

*IDN?	<p>Identify</p> <p>Query the DC205 identification string.</p> <p>The response is formatted as: Stanford_Research_Systems,DC205,s/n*****,ver#.## where ***** is the 8-digit serial number, and #.## is the firmware revision level.</p>
-------	--

Example: *IDN?
Stanford_Research_Systems,DC205,s/n20512345,ver1.00

TOKN(?) {z}	<p>Token Mode</p> <p>Set (query) the token response mode {to z=(OFF 0, ON 1)}.</p> <p>Token response mode controls the formatting of response messages generated by the DC205 to remote queries of token-type values. When TOKN OFF, the DC205 responds with the numeric version of the token quantity. When TOKN ON, the text version is returned.</p> <p><i>Example:</i> TOKN? ON</p>
<hr/>	
TERM(?) {z}	<p>Response Termination</p> <p>Set (query) the token response mode {to z=(NONE 0, CR 1, LF 2, CRLF 3, LFCR 4)}.</p> <p>Response messages generated by the DC205 will be terminated by the 0-, 1- or 2-character termination sequence specified by TERM. Note that the TERM command is <i>interface specific</i>. In other words, if TERM LF is received on the RS-232 interface, and then TERM CRLF is received on the USB interface, then queries received on the RS-232 interface shall generate response messages terminated with the LF character, while queries received on the ethernet interface shall generate response messages terminated by the CR and LF characters.</p> <p>TERM settings not are saved when the DC205 is powered off. They are not affected by *RST.</p> <p><i>Example:</i> TERM LF</p>
<hr/>	
*OPC(?)	<p>Operation Complete</p> <p>The set form, *OPC, will set the OPC bit in the Standard Event Status register; the query form, *OPC?, will return the value 1.</p> <p>The *OPC? query will not be processed by the command execution of the DC205 until all preceding commands have been executed and completed, and the *OPC command will not set the OPC bit until all preceding commands have been executed.</p> <p>*OPC? can be helpful in combination with scans. If a scan is running (SCAA SCANNING state), then a *OPC? will block all¹ further commands from executing on the DC205 until the scan completes, at which time it will respond with the 1 query response. If the scan is running while SCAC REPEAT, then a *OPC? query will never return and will leave the remote interface blocked, until the front panel</p>

¹ except for the **COPC** command

[Cancel] button is pressed (halting the scan). *OPC? queries can be cancelled with the special COPC command.

The set version of the command, *OPC, does not block the remote command interface—subsequent commands will continue to be processed promptly.

Example: *RST; SCAT 10; SOUT 1; SCAA 1; *TRG; *OPC?
1

This example resets the DC205, then programs the scan time Δt to 10 s, turns the output on, arms the scan, and then triggers the scan. The final *OPC? query requests the DC205 to reply 1 when the scan is finished. The final response (1) does not appear until the scan is finished, 10 s after the scan starts.

COPC

Cancel Pending *OPC Flag

This set-only command will immediately clear the operation pending state of the DC205, effectively canceling a currently pending *OPC? query.

The COPC command is treated specially by the DC205 remote command parser, allowing it to be executed ahead of commands that were received ahead of it but not yet executed. This privileged status is necessary to cancel a *OPC? query, since all other commands are blocked by the *OPC? while it is pending.

Example: SCAC REPEAT; SCAA ARMED; *TRG; *OPC?

At this point, the remote interface is blocked. Because the scan was triggered when armed to repeat indefinitely, the *OPC? will never return. The remote interface can be cleared for new commands with the following:

Example: COPC
1

Note the 1 appears from the previous *OPC? query, as the DC205 is forced by COPC to behave as though the pending command is completed.

BAUD(?) {z}

Serial Baud Rate

Set (query) the RS-232 baud rate {to z=(BD9600 0, BD19200 1, BD38400 2, BD57600 3, BD115200 4)}.

Sets the RS-232 (DB-9 connector) baud rate to one of the five allowed rates. Note that neither the USB, nor the optical fiber, interfaces are modified by the BAUD command.

Note also that BAUD settings are non-volatile, and are retained through power cycles.

Changes to the RS-232 baud rate take place immediately; once changed, the user's communication software should be also change baud rate to maintain communications.

Baud rate may also be changed through a power-on key press (see section 2.1.1.4 on page 2 – 4).

Example: BAUD 4

*RST

Reset

Reset the DC205 to its default configuration.

The following commands are internally executed upon receipt of the *RST command:

- RNGE RANGE1
- ISOL GROUND
- SENS TWOWIRE
- SOUT OFF
- VOLT 0.0
- SCAR RANGE1
- SCAB 0.0
- SCAE 1.0
- SCAT 1.0
- SCAS ONEDIR
- SCAC ONCE
- SCAD ON
- SCAA IDLE
- KCLK ON
- ALRM ON

Note that the RS-232 baud rate is unaffected by *RST.

The same default configuration can be set by performing a power-on reset of the DC205(see section 2.1.1.1 on page 2 – 3). Note, however, that the front-panel power-on reset will also reset the RS-232 baud rate to 9600.

4.4.9 Status commands

ILOC?	<p>Interlock</p> <p>Query the interlock condition as z=(OPEN 0, or CLOSED 1).</p> <p>Reads the current value of the interlock. If the safety interlock is closed, ILOC? returns CLOSED 1; otherwise it returns OPEN 0.</p> <p>Note the ILOC? query corresponds to the Interlock bit in the DCCR condition register.</p> <p><i>Example:</i> ILOC? CLOSED</p>
OVLD?	<p>Overload</p> <p>Query the overload condition as z=(OKAY 0, or OVLD 1).</p> <p>Reads the current value of the signal overload status. Returns OVLD 1 if the output is overloaded (current limit mode), or OKAY 0 otherwise.</p> <p>Note the OVLD? query corresponds to the OVLD bit in the DCCR condition register.</p> <p><i>Example:</i> OVLD? 0</p>
*STB? [i]	<p>Status byte</p> <p>Reads the Status Byte register [bit i].</p> <p><i>Example:</i> *STB? 0</p>
*SRE(?) [i,] {j}	<p>Service request enable</p> <p>Set (query) the Service Request Enable register [bit i] {to j}.</p> <p><i>Example:</i> *SRE 0,1</p>
*ESR? [i]	<p>Standard event status</p> <p>Reads the Standard Event Status Register [bit i].</p> <p>Upon executing *ESR?, the returned bit(s) of the ESR register are cleared.</p> <p><i>Example:</i> *ESR? 64</p>

***ESE(?) [i,] {j}** Standard event status enable
Set (query) the Standard Event Status Enable Register [bit i] {to j}.

Example: *ESE 6,1
ESE?
64

***CLS** Clear Status
*CLS immediately clears all of the event status registers.

Example: *CLS

LEXE? Last Execution Error
Query the last execution error code. A query of LEXE? always clears the error code, so a subsequent LEXE? will return 0. Valid codes are:

Value	Definition
0	No execution error since last LEXE?
1	Illegal value
2	Wrong token
3	Invalid bit
4	Queue full
5	Not compatible

Example: RNGE 0; VOLT 3.1; LEXE?; LEXE?
1;0

The error (1, "Illegal value,") is because the parameter value (3.1) is too large for VOLT on the ± 1 V range. The second read of LEXE? returns 0.

LCME?

Last command error

Query the last command error code. A query of LCME? always clears the error code, so a subsequent LCME? will return 0. Valid codes are:

Value	Definition
0	No execution error since last LCME?
1	Illegal command
2	Undefined command
3	Illegal query
4	Illegal set
5	Missing parameter(s)
6	Extra parameter(s)
7	Null parameter(s)
8	Parameter buffer overflow
9	Bad floating-point
10	Bad integer
11	Bad integer token
12	Bad token value
13	Bad hex block
14	Unknown token

Example: *IDN
LCME?
4
The error (4, “Illegal set”) is due to the missing “?”.

DCCR? [i]

DC Source Condition

Read the DC Source Condition Register [bit i].

DCPT(?) [i,] {j}

DC Source Positive-Transition

Set (query) the DC Source Positive Transition Register [bit i] {to j}.

Example: DCPT 1,1

DCNT(?) [i,] {j}

DC Source Negative-Transition

Set (query) the DC Source Negative Transition Register [bit i] {to j}.

Example: DCNT?
2

DCEV? [i] DC Source Event
Query the DC Source Event Register [bit i].
Upon executing an DCEV? query, the returned bit(s) of the DCEV register are cleared.

Example: DCEV?
2

DCEN(?) [i,] {j} DC Source Event Enable
Set (query) the DC Source Status Enable Register [bit i] {to j}.

Example: DCEN 1,1

4.5 Status model

status registers The DC205 status registers follow the hierarchical IEEE–488.2 format. A block diagram of the status register array is given in Figure 4.1.

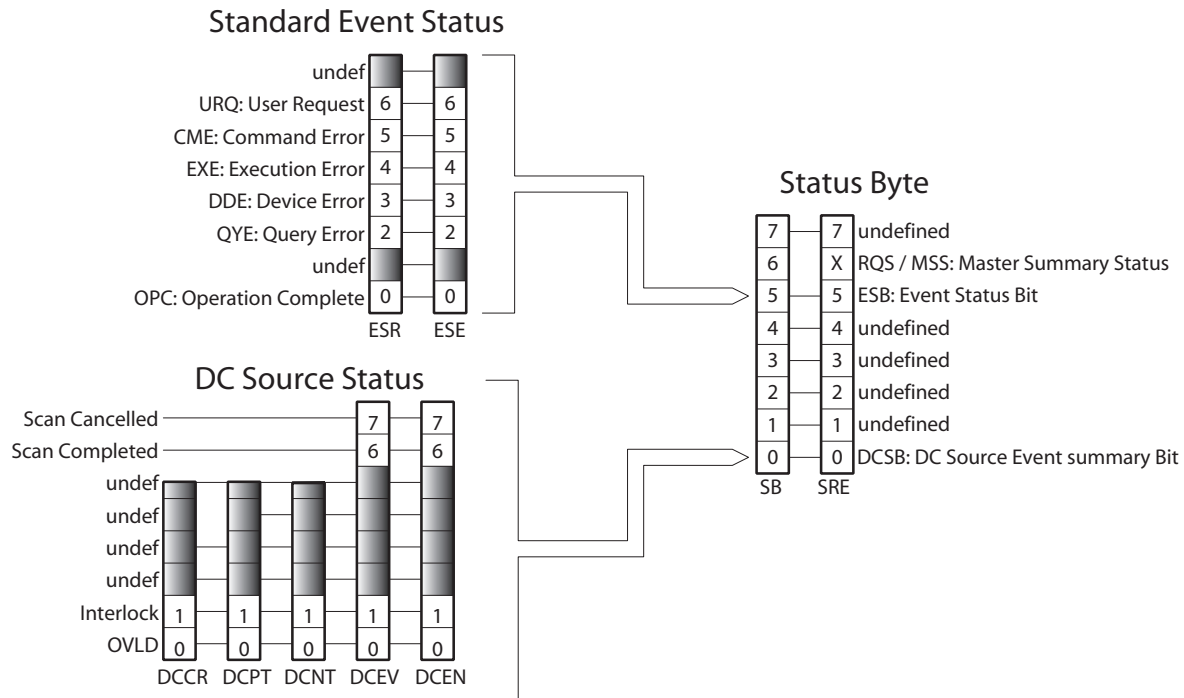


Figure 4.1: Status Model for the DC205 Precision DC Voltage Source

There are five categories of registers in the status model of the voltage source:

Condition Registers : These read-only registers correspond to the real-time condition of some underlying physical property being monitored. Queries return the latest value of the property, and have no further side effects. Condition register names end with CR.

Transition Selection Registers : These read/write registers define specific transition events ($0 \rightarrow 1$ or $1 \rightarrow 0$). The event is then defined by the selected transition in the value of the underlying condition register. Transition register names end with PT or NT.

Event Registers : These read-only registers record the occurrence of defined events within the voltage source. If the event occurs, the corresponding bit is set to 1. Upon querying an event register, any set bits within it are cleared. These are sometimes known as

“sticky bits,” since once set, a bit can only be cleared by reading its value. Event register names end with SR or EV.

Enable Registers : These read/write registers define a bitwise mask for their corresponding event register. If any bit position is set in an event register while the same bit position is also set in the enable register, then the corresponding summary bit message is set in the Status Byte. Enable register names end with SE or EN.

Status Byte : This read-only register represents the top of the status model, and is populated with summary bit messages and interface condition bits. Enabled bits within the Status Byte generate the Master Summary Status bit within the Status Byte register.

At power-on, all status registers are cleared.

4.5.1 Status byte (SB)

The Status Byte is the top-level summary of the DC205 status model. When enabled by the Service Request Enable register, a bit set in the Status Byte causes the MSS (Master Summary Status) bit to be set.

Weight	Bit	Flag
1	0	DCSB
2	1	undef (0)
4	2	undef (0)
8	3	undef (0)
16	4	undef (0)
32	5	ESB
64	6	MSS
128	7	undef (0)

DCSB : DC Source Status Bit. Indicates whether one or more of the enabled events in the DC Source Event Status Register is true.

ESB : Event Status Bit. Indicates whether one or more of the enabled events in the Standard Event Status Register is true.

MSS : Master Summary Status. Indicates whether one or more of the enabled status messages in the Status Byte register is true.

This register is read with the *STB? query.

4.5.2 Service request enable (SRE)

Each bit in the SRE corresponds one-to-one with a bit in the SB register, and acts as a bitwise AND of the SB flags to generate MSS. Bit 6 of the SRE is undefined—setting it has no effect, and reading it always returns 0. This register is set and queried with the *SRE(?) command.

At power-on, this register is cleared.

4.5.3 Standard event status (ESR)

The Standard Event Status Register consists of 8 event flags. These event flags are all “sticky bits” that are set by the corresponding events, and cleared only by reading or with the *CLS command. Reading a single bit (with the *ESR? *i* query) clears only Bit *i*.

Weight	Bit	Flag
1	0	OPC
2	1	undef (0)
4	2	QYE
8	3	DDE
16	4	EXE
32	5	CME
64	6	URQ
128	7	undef (0)

OPC : Operation Complete. Set by the *OPC command.

QYE : Query Error. Indicates data in the output queue has been lost.

DDE : Device-Dependent Error. Indicates an input buffer or internal command queue overflow.

EXE : Execution Error. Indicates the error in a command that was successfully parsed. Out-of-range parameters are an example.

CME : Command Error. Indicates a command parser-detected error.

URQ : User Request. Indicates that a front-panel button was pressed.

4.5.3.1 Standard event status enable (ESE)

The ESE acts as a bitwise AND with the ESR register to produce the single-bit ESB message in the Status Byte Register (SB). The register can be set and queried with the *ESE(?) command.

At power-on, this register is cleared.

4.5.4 DC source status (DCCR/DCEV)

The DC source status is monitored by a real-time condition register (DCCR), a pair of transition selection registers, and the latching event register.

4.5.4.1 DC source condition (DCCR)

The DC Source Condition Register consists of 2 condition flags that reflect the real-time condition of the DC205. Reading the DCCR has no effect on any values.

Weight	Bit	Flag
1	0	OVLD
2	1	Interlock

OVLD : Set when the DC output is overloaded (current limiting).

Interlock : Set when the safety interlock is closed (± 100 V range is permitted for operation).

4.5.4.2 DC source positive/negative transition (DCPT/DCNT)

These two 8-bit wide registers control the mapping of transitions in the DCCR to setting flags in the DCEV register. For any particular event, if the corresponding bit is set in DCPT, then a 0→1 transition in the DCCR causes the bit to be set in the DCEV. Likewise, if a bit is set in DCNT, then a 1→0 transition in the DCCR causes the bit to be set in the DCEV.

All combinations of DCPT and DCNT settings are valid. At power-on, both DCPT and DCNT are cleared.

4.5.4.3 DC source event (DCEV)

This 8-bit wide register monitors selected events in the DCCR, based on transitions selected in DCPT and DCNT. When the selected transition(s) occur, the corresponding bit is set. Reading the register clear it (reading a single bit clears only that bit). This register is cleared by the *CLS command.

In addition to monitored events from the DCCR, two discrete events are directly defined in DCEV without corresponding real-time condition bits in the DCCR. These are:

Weight	Bit	Flag
128	7	Scan Cancelled
64	6	Scan Completed

Scan Cancelled : Indicates that a scan was terminated prior to completion.

Scan Completed : Indicates that a scan ended normally, at the completion of the programmed cycle.

4.5.4.4 DC source status enable (DCSE)

This is an 8-bit wide register that masks the DCEV register. The logical OR of the bitwise AND of DCEV and DCEN produces the DCSB message in the Status Byte register (SB).

5 Field Calibration

This chapter provides instructions for calibrating the DC205 Precision DC Voltage Source in the field.

In This Chapter

5.1	Introduction to field calibration	5-2
5.2	Calibration method	5-2
5.3	Equipment needed	5-3
5.4	Detailed procedure	5-3
5.5	Following field calibration	5-5
5.6	Restoring the factory calibration	5-6

5.1 Introduction to field calibration

The DC205 provides outstanding stability and accuracy for extended periods of time. The factory calibration procedure sets gain and offset coefficients, as well as small non-linear corrections, for all three operating ranges.

As the instrument ages, slow changes in the voltage reference, amplifier gains, and offset voltage can occur, which is in part the reason for accuracy specifications given for 90-day and 1-year periods (see page viii). However, the small nonlinear artifacts that are corrected by the factory calibration are expected to be relatively stable, compared with the voltage reference and gain-setting resistive elements.

As a result, it is typically possible to restore the DC205 to its 24-hour accuracy level by applying a more limited calibration procedure, correcting gain and offset but leaving the small non-linear corrections unchanged from their factory settings.

This chapter describes the process for performing that limited calibration. Note that it is always possible to restore the entire factory calibration by following the procedure described in Section 2.1.1.3 (page 2 – 4).

5.2 Calibration method

Field calibration of the DC205 is performed by placing the instrument into a special calibration mode during start-up. By using a high performance dc voltage measuring instrument, the operator will correct the DC205's output to become the exact value specified for each step in the procedure. Pressing the [Enter Start] button will latch the precise output setting required to achieve the nominal output voltage. The operator then advances to the next settings required, as described below.

Three voltage adjustments are performed to calibrate each output range of the DC205. The first two adjustments, at +90 % and –90 % of nominal full scale, are used to derive a gain adjustment factor. The third adjustment, at zero volts, is used separately to determine the offset voltage for the range. The small corrections for nonlinearity that are saved as part of the factory calibration are retained through the field calibration process, and remain unmodified by the operator adjustments.

After the three adjustments are performed, the operator is required to confirm saving the new calibration with an additional press of the [Enter Start] button.

5.3 Equipment needed

Field calibration of the DC205 requires a high precision voltmeter such as the Keysight model 3458A or Fluke model 8558A multimeter. The meter should be capable of measuring with better than microvolt resolution on the 1 V range, and with specified accuracy of at least $5 \mu\text{V}$ on its 1 V range, $50 \mu\text{V}$ on its 10 V range, and $600 \mu\text{V}$ on its 100 V range.

Two high quality banana leads, ideally with low thermal EMF, should be used. Equal length leads, twisted together, should be used to minimize potential pickup. Field calibration can be successfully performed in 2-wire mode so long as the precision multimeter has $\geq 10 \text{ M}\Omega$ input impedance.

5.4 Detailed procedure

To perform a field recalibration of the DC205:

1. Ensure the DC205 has warmed up for a minimum of 2 hours with the room temperature of $23^\circ\text{C} \pm 1^\circ\text{C}$, for the specified performance temperature range of 22°C and 28°C to apply after calibration.
2. Using high quality banana leads, connect Output HI to the multimeter input HI terminal. Connect Output LO to the meter's LO terminal. Set the multimeter to a minimum integration time of 60 NPLC, and configure the meter for manual range (autorange disabled).
3. If desired, perform a pre-calibration performance test. Record the results on copies of the tables provided in section 6.3. Be sure to label these measurements "pre-calibration" to avoid confusion with the post calibration verification.
4. Turn off power to the DC205 by pressing the front panel [⏻] button. While holding the [+/-] button depressed, press the [⏻] button again to turn on into field calibration mode. Do not allow the DC205 to cool off during this time.
5. The display will show `CAL ADJ`, indicating the source is ready for calibration adjustment. Select the range you wish to calibrate by pressing the [Range] button. If calibrating the entire instrument, typically begin on the $\pm 1 \text{ V}$ range setting, and then proceed to the $\pm 10 \text{ V}$ range, and finally the 100 V range.
6. Press the Output [On/Off] button to begin. The display will show `ADJ 0.9 F5`, indicating you are about to trim the

instrument to 90 % of the range's full-scale output. After several seconds, the display will change to show the target voltage (either +0.900 000, +9.000 00, or +90.000 0, depending on the range). The multimeter should now show a voltage close to the DC205 display value. Adjust the multimeter's manual range setting to closely match the output voltage of the DC205.

7. For the next operation, you may find it convenient to speed up the multimeter by setting the integration time to about 10 NPLC. However, be sure to set this back to at least 60 NPLC prior to finalizing the adjustment at this voltage.
8. To adjust the calibration, you must now make small changes to the DC205 voltage setting to bring the multimeter value to exactly +90 % of nominal full scale. Use the [◀] and [▶] to position the blinking focus to the most significant digit that needs trimming, based on the multimeter's display. Usually this will be the least significant digit, or the next to least significant digit, on the DC205.
9. Now use the [▲] and [▼] buttons to bring the multimeter value closer to +90 % of nominal full scale. When the selected digit is fully corrected, step down in significance by pressing the [▶] to move the focus to the next-finer position. Repeat this procedure until the multimeter shows the proper value with 6 digit of agreement. Be sure to verify this with at least 60 NPLC on the multimeter.
10. To finalize the trimmed output setting, press the [Enter Start] button on the DC205. The display will now show Adj - 0.9 F5, and then after several seconds, the display will change to show the target voltage (either -0.900 000, -9.000 00, or -90.000 0, depending on the range). The multimeter should now show a voltage close to the DC205 display value.
11. Repeat the fine adjustment steps to bring the multimeter value to precisely -90 % of nominal full scale, again with six digits of agreement. Press [Enter Start] to finalize the value and proceed.
12. The display will now show Adj 2Er 0, and then after several seconds show 0.000 000 V. The multimeter should now display a voltage very close to 0 V. Note that, for proper calibration, the multimeter should not be allowed to autorange to a lower operating range (such as a 10 mV or 100 mV full-scale range). For consistent results, a single fixed range should be used for all 3 measurements at one range setting of the DC205.

13. As before, use the arrow buttons to trim the multimeter to zero, to within the display resolution of the DC205. Press [Enter Start] when finished.
14. The display will now show the message `Stor CAL`. At this point, if the operator wishes to commit the new calibration into the DC205's non-volatile memory, press the [Enter Start] button. If the operator wishes instead to abandon these calibration adjustments, and retain the previous settings, the power button [⏻] should be pressed to power-cycle the instrument.
15. Upon pressing [Enter Start], the results are written to non-volatile memory and the instrument returns to the `CAL Adj` stage. Repeat from step 5, above, for the remaining DC205 ranges to be calibrated.
16. In some pathological cases (when the calibration adjustments shifted the output by more than a few percent of full scale), the tentative new calibration values may lead to a hardware "overflow" (or "underflow"), with implied DAC values that are beyond the hardware range of the instrument. In this case, when the operator attempts to confirm storing the calibration, the message `bad CAL` will be displayed. This indicates the tentative calibration has been rejected and not stored in non-volatile memory.

5.5 Following field calibration

Following field calibration of the intended ranges, the DC205 will be back to displaying `CAL Adj`. The field calibration results have been saved to the instrument's nonvolatile memory. To return to normal operation, power cycle by pressing the [⏻] button off and then on again.

The field calibration should be verified immediately after it is performed, by following the performance verification procedure given in Chapter 6 for each of the ranges that was recalibrated. The DC205 should measure within the 24 hour performance limits at this time. In some situations, especially when the calibration has shifted significantly, a second iteration of the field calibration procedure may be needed to achieve the best results. If the performance verification does not pass all the 24 hour limits after a second iteration of the procedure, verify separately that the high precision multimeter is functioning properly and that all banana leads are in good repair. If the results are still out of limit, contact the factory for possible service of the instrument.

5.6 Restoring the factory calibration

Finally, note that the field calibration procedure always begins from the previous calibration as a starting point. As a result, if the calibration is badly mis-entered (for example, the 0 V setting was accidentally programmed to full scale), it may no longer be possible to calibrate the DC205 using the procedure in section 5.4.

Should this happen, the protected factory calibration can be restored. This will provide a reasonable starting point for operation, after which the field calibration procedure of section 5.4 can be applied if desired.

To restore the instrument to its factory calibration, follow the procedure described in section 2.1.1.3 (page 2 – 4).

6 Performance Verification

This chapter provides instructions for verifying the performance of the DC205 Precision DC Voltage Source in the field.

In This Chapter

6.1	Introduction to performance verification	6-2
6.2	Equipment needed	6-2
6.3	Verification procedure	6-2
6.4	Performance test records	6-3

6.1 Introduction to performance verification

The basic functional verification of the DC205 is described in the step-by-step instructions for getting started with the instrument, provided in Chapter 1. This chapter provides a detailed procedure to verify that the output voltage accuracy of the DC205 is within specification limits.

6.2 Equipment needed

Performance verification of the DC205 requires a high precision voltmeter such as the Keysight model 3458A or Fluke model 8558A multimeter. When testing the DC205 against the 1 year accuracy specifications, such a multimeter's specified accuracy is more than sufficient, so long as the meter has a currently-valid calibration itself. Reference should always be made to the meter's accuracy specification, which must be added to the measurement uncertainty when determining the DC205's performance. In the case of the Keysight 3458A, be sure to perform the ACAL procedure within 24 hours of testing, and that room temperature is within ± 1 °C of the last ACAL.

The meter should be capable of performing measurements with at least as much resolution as the DC205 setting display. For 1 year specification limits, the meter should have an accuracy specification of no worse than 10 ppm of Reading; for the 90 day limits, the meter should be at no worse than 5 ppm of Reading.

Two high quality banana leads, ideally with low thermal EMF, should be used. Equal length leads, twisted together, should be used to minimize potential pickup. Performance verification can be successfully performed in 2-wire mode so long as the precision multimeter has ≥ 10 M Ω input impedance.

6.3 Verification procedure

Performance can be verified at any output voltage setting convenient to the user. SRS suggests measurements at 11 evenly spaced values for each range, as shown on the performance test record table that follow. Lower and upper bounds are pre-calculated for each suggested setting using the accuracy specifications listed on page viii. The "ppm of setting" specification is multiplied by the absolute value of each setting, the μ V uncertainty is added to that, and then this quantity is added and subtracted to instrument's nominal setting.

For example, consider the 1 year accuracy specification limits on a -4 V reading on the 10 V Range. The 1 year accuracy specification is:

$$\pm(25\text{ppm} + 20\mu\text{V})$$

The allowable error magnitude ε is calculated as

$$\varepsilon = \left(\frac{25 \times |-4.0\text{ V}|}{10^6} \right) + (20\ \mu\text{V}) = 120\ \mu\text{V}$$

Next, the upper and lower limits are $V_s \pm \varepsilon$, or more specifically -4.00012 V to -3.99988 V .

Note that no allowance has been added for the accuracy specification of the precision multimeter. To expand this treatment to account for the multimeter specifications, simply add the “ppm of Reading” spec from the meter to the “ppm of setting” spec of the DC205, and then add the “ppm of Range” spec of the meter (converted to μV) to the offset spec of the DC205, and repeat the calculation for ε as above.

6.4 Performance test records

Allow the DC205 to warm up for a minimum of 2 hours with the room temperature between 22°C and 24°C for the specifications to apply. Be sure to allow the precision multimeter to warm up according to the manufacturer’s specifications.

Measurements should be performed with the meter set to manual range, to avoid discontinuities in meter performance when autoranging. Set the meter to an integration time of at least 60 NPLC (number of power line cycles) for stable, low-noise results.

Table 6.1: DC205 performance test record, ± 1 V range

DC205 serial number:													
Test (circle one):			Pre-cal	Post-cal	other:								
Performed by:													
Date / time: Room temperature:													
Voltmeter model / serial number / cal date:													
Set	1 year		90 day		24 hour		Measurement	24 hour		90 day		1 year	
	Lower lim.	Upper lim.	Lower lim.	Upper lim.	Lower lim.	Upper lim.		Lower lim.	Upper lim.	Lower lim.	Upper lim.	Lower lim.	Upper lim.
-1.0 V	-1.000 035 V	-1.000 018 V	-1.000 018 V	-1.000 009 V	-0.999 991 V	-0.999 982 V		-0.999 991 V	-0.999 982 V	-0.999 982 V	-0.999 965 V		-0.999 965 V
-0.8 V	-0.800 030 V	-0.800 016 V	-0.800 016 V	-0.800 008 V	-0.799 992 V	-0.799 984 V		-0.799 992 V	-0.799 984 V	-0.799 984 V	-0.799 970 V		-0.799 970 V
-0.6 V	-0.600 025 V	-0.600 013 V	-0.600 013 V	-0.600 006 V	-0.599 994 V	-0.599 987 V		-0.599 994 V	-0.599 987 V	-0.599 987 V	-0.599 975 V		-0.599 975 V
-0.4 V	-0.400 020 V	-0.400 011 V	-0.400 011 V	-0.400 005 V	-0.399 995 V	-0.399 989 V		-0.399 995 V	-0.399 989 V	-0.399 989 V	-0.399 980 V		-0.399 980 V
-0.2 V	-0.200 015 V	-0.200 008 V	-0.200 008 V	-0.200 003 V	-0.199 997 V	-0.199 992 V		-0.199 997 V	-0.199 992 V	-0.199 992 V	-0.199 985 V		-0.199 985 V
0.0 V	-0.000 010 V	-0.000 006 V	-0.000 006 V	-0.000 002 V	0.000 002 V	0.000 006 V		0.000 002 V	0.000 006 V	0.000 006 V	0.000 010 V		0.000 010 V
0.2 V	0.199 985 V	0.199 992 V	0.199 992 V	0.199 997 V	0.200 003 V	0.200 008 V		0.200 003 V	0.200 008 V	0.200 008 V	0.200 015 V		0.200 015 V
0.4 V	0.399 980 V	0.399 989 V	0.399 989 V	0.399 995 V	0.400 005 V	0.400 011 V		0.400 005 V	0.400 011 V	0.400 011 V	0.400 020 V		0.400 020 V
0.6 V	0.599 975 V	0.599 987 V	0.599 987 V	0.599 994 V	0.600 006 V	0.600 013 V		0.600 006 V	0.600 013 V	0.600 013 V	0.600 025 V		0.600 025 V
0.8 V	0.799 970 V	0.799 984 V	0.799 984 V	0.799 992 V	0.800 008 V	0.800 016 V		0.800 008 V	0.800 016 V	0.800 016 V	0.800 030 V		0.800 030 V
1.0 V	0.999 965 V	0.999 982 V	0.999 982 V	0.999 991 V	1.000 009 V	1.000 018 V		1.000 009 V	1.000 018 V	1.000 018 V	1.000 035 V		1.000 035 V

Table 6.2: DC205 performance test record, ± 10 V range

DC205 serial number:									
Test (circle one): Pre-cal Post-cal other:									
Performed by:									
Date / time: Room temperature:									
Voltmeter model / serial number / cal date:									
Set	1 year Lower lim.	90 day Lower lim.	24 hour Lower lim.	Measurement	24 hour Upper lim.	90 day Upper lim.	1 year Upper lim.		
-10.0 V	-10.000 27 V	-10.000 14 V	-10.000 08 V		-9.999 92 V	-9.999 86 V	-9.999 73 V		
-8.0 V	-8.000 22 V	-8.000 12 V	-8.000 07 V		-7.999 93 V	-7.999 88 V	-7.999 78 V		
-6.0 V	-6.000 17 V	-6.000 09 V	-6.000 05 V		-5.999 95 V	-5.999 91 V	-5.999 83 V		
-4.0 V	-4.000 12 V	-4.000 07 V	-4.000 04 V		-3.999 96 V	-3.999 93 V	-3.999 88 V		
-2.0 V	-2.000 07 V	-2.000 04 V	-2.000 03 V		-1.999 97 V	-1.999 96 V	-1.999 93 V		
0.0 V	-0.000 02 V	-0.000 02 V	-0.000 01 V		0.000 01 V	0.000 02 V	0.000 02 V		
2.0 V	1.999 93 V	1.999 96 V	1.999 97 V		2.000 03 V	2.000 04 V	2.000 07 V		
4.0 V	3.999 88 V	3.999 93 V	3.999 96 V		4.000 04 V	4.000 07 V	4.000 12 V		
6.0 V	5.999 83 V	5.999 91 V	5.999 95 V		6.000 05 V	6.000 09 V	6.000 17 V		
8.0 V	7.999 78 V	7.999 88 V	7.999 93 V		8.000 07 V	8.000 12 V	8.000 22 V		
10.0 V	9.999 73 V	9.999 86 V	9.999 92 V		10.000 08 V	10.000 14 V	10.000 27 V		

Table 6.3: DC205 performance test record, ± 100 V range

DC205 serial number:									
Test (circle one):			Pre-cal	Post-cal	other:				
Performed by:									
Date / time: Room temperature:									
Voltmeter model / serial number / cal date:									
Set	1 year Lower lim.	90 day Lower lim.	24 hour Lower lim.	24 hour Upper lim.	Measurement	24 hour Upper lim.	90 day Upper lim.	1 year Upper lim.	
-100.0 V	-100.0026 V	-100.0014 V	-100.0009 V	-99.9991 V		-99.9992 V	-99.9986 V	-99.9974 V	
-80.0 V	-80.0021 V	-80.0012 V	-80.0008 V	-79.9992 V		-79.9994 V	-79.9988 V	-79.9979 V	
-60.0 V	-60.0016 V	-60.0009 V	-60.0006 V	-59.9994 V		-39.9996 V	-59.9991 V	-59.9984 V	
-40.0 V	-40.0011 V	-40.0007 V	-40.0004 V	-39.9996 V		-19.9997 V	-39.9993 V	-39.9989 V	
-20.0 V	-20.0006 V	-20.0004 V	-20.0003 V	-19.9997 V		0.0001 V	-19.9996 V	-19.9994 V	
0.0 V	-0.0001 V	-0.0002 V	-0.0001 V	0.0001 V		20.0003 V	0.0002 V	0.0001 V	
20.0 V	19.9994 V	19.9996 V	19.9997 V	20.0003 V		40.0004 V	20.0004 V	20.0006 V	
40.0 V	39.9989 V	39.9993 V	39.9996 V	40.0004 V		60.0006 V	40.0007 V	40.0011 V	
60.0 V	59.9984 V	59.9991 V	59.9994 V	60.0006 V		80.0008 V	60.0009 V	60.0016 V	
80.0 V	79.9979 V	79.9988 V	79.9992 V	80.0008 V		100.0009 V	80.0012 V	80.0021 V	
100.0 V	99.9974 V	99.9986 V	99.9991 V	100.0009 V		100.0014 V	100.0014 V	100.0026 V	

Appendix A Fuse Installation and ac Line Select

The DC205 operates from 100 V, 120 V, 220 V, or 240 V nominal ac power having a line frequency of 50 Hz or 60 Hz, and requires metric size dual fuses for operation. This appendix provides detailed instructions for modifying the input voltage selection and replacing the line fuse.

A.1 Power Entry module

The line cord receptacle, fuse holder, and line voltage selector are all part of the "power entry module" located on the rear panel of the DC205. Detailed instructions for changing the line voltage selection and fuse replacement follow.



Figure A.1: The DC205 Power Entry module.

A.2 ac voltage selector

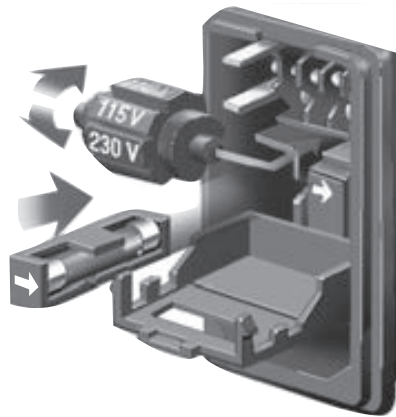
The DC205 line voltage selection is indicated by the white number visible near the top of the power entry module. In the image above, the line voltage selection is showing 120 V. Available settings are 100 V, 120 V, 220 V, and 240 V.

The following steps describe how to change the line voltage selection:

1. Disconnect and remove the power cord.
2. Open the fuse cover using a small blade screwdriver or similar tool, inserted at the point shown.



3. Insert the tool into the voltage selection slot and remove the selector wheel from the housing.



4. Orient the selector wheel so that the desired line voltage will show through the window.
5. Replace the wheel into the power entry module and close the cover door, ensuring the selected voltage appears in the window.
6. If necessary, replace the fuse for the appropriate rating based on line voltage.

A.3 Fuse installation

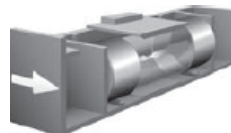
The DC205 uses metric dual fuse installation. When installing or replacing, be sure to replace both fuses.

The following steps describe how to install or replace the fuse:

1. Disconnect and remove the power cord.
2. Open the fuse cover using a small blade screwdriver or similar tool.
3. Insert the tool into the right-hand side of each of the fuse holders, at the locations shown circled below. Gently extract the two fuse holders.



4. Gently pry the old fuses out of the holders, and insert the new fuses in their place. Be sure to use two (2) metric size 5 × 20 mm fuses. The fuse should sit in the holder as shown:



5. Re-insert the fuse holders into the power entry module, being sure to orient the white arrows as shown on the door. Push the fuse holders all the way into the module.
6. Swing and push to snap the door back in place.