KEITHLEY

MODEL 2304

QuickStart

USER'S GUIDE

2304

HIGH SPEED PRECISION READBACK

POWER SUPPLY

Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. **Read the operating information carefully before using the product.**

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, digital multimeter measuring circuits (e.g., Keithley Models 175A, 199, 2000, 2001, 2002, and 2010) measuring circuits are Installation Category II. All other instruments' signal terminals are Installation Category I and must not be connected to mains.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The  symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The  symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

This guide is designed to familiarize users of the Keithley Model 2304 High Speed Power Supply with the basic operating features available from the instrument's front panel and via the GPIB Bus. The sequence of instructions reflects the order in which the instrument would be configured for a typical application. As users become more familiar with the Model 2304, it may not be necessary to follow this sequence so strictly. For each Model 2304 operating mode, an example set of bus commands is provided. For a reading to be performed and returned via the bus, the *:read?* command must be sent after the instrument is configured to the desired mode. While the SCPI command strings are generic, the exact programming syntax will depend on the programming language used in the test environment.

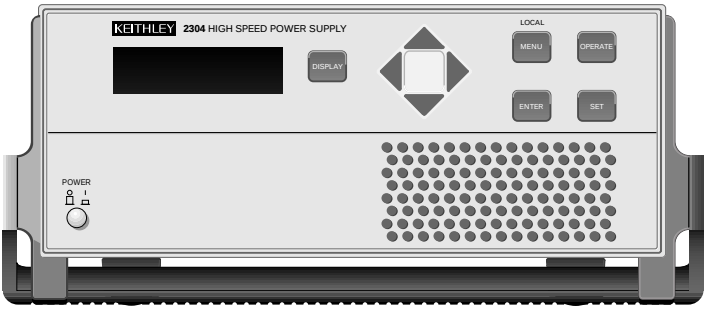

Figure 1. *Model 2304 front panel*

The Model 2304 has three operating (display) modes:

> ACTUAL V AND I — This mode reads back the actual output voltage and current. The instrument defaults to this mode at power up.

> DVM INPUT — This mode displays the DC voltage applied to the power supply's DVM input.

> PULSE CURRENT — This mode is used to display high, low, or average pulse-current measurements or to return up to 5000 measurements from the measurement buffer, i.e., for digitizing a current waveform.

1 Setting the output voltage and current limit:

Output voltage can be set from 0 to 20V. There are two ranges for current output — 5A and 5mA. The current range can be checked or changed using the CURRENT RANGE selection of the MENU.

1. Press the SET key to select the Output Settings Mode. A blinking cursor will appear in the voltage field of the display.
2. Use the ◀, ▶, ▲, ▼ buttons to key in the desired output voltage value, then press SET. The blinking cursor will move to the current field of the display.
3. Use the ◀, ▶, ▲, ▼ buttons to key in the desired current limit, then press SET to exit the Output Settings Mode. The display will return to the actual V and I display mode.

GPIB commands for setting the output voltage and current limit:

```
:source:voltage xx.xxx        ; set output voltage,
                              xx.xxx is between 0 and 20

:source:current:limit x.xxxx ; set output current limit,
                              x.xxxx is between 0 and 5
```

and

```
:sense:current:range minimum ; set to 5 mA range
```

or

```
:sense:current:range maximum ; set to 5 A range
```

2 Turning supply output on/off

The output of the Model 2304 is turned on and off using the front panel OPERATE button. The word “ON” appears on the display when the output is turned on. When the output is turned off, “OFF” is displayed.

GPIB commands for turning the supply output on/off:

```
:output on                    ; turn the supply output on

:output off                   ; turn the supply output off
```

3 Selecting the operating (display) mode:

Actual V and I Mode:

This mode sets the instrument to display steady-state readback current and voltage and to return current or voltage measurements over the GPIB bus. If using the front panel controls, press the DISPLAY button and select the "Actual V and I" mode using the ▲ and ▼ buttons.

GPIB1,2 commands for selecting the Actual V and I mode:

```
:sense:function "voltage"     ; selects voltage
                              measurement function

:sense:average xx             ; the number of readings to
                              average per measurement, up
                              to 10 (optional command)
```

or

```
:sense:function "current"     ; selects current
                              measurement function

:sense:average xx             ; the number of readings to
                              average per measurement, up
                              to 10 (optional command)
```

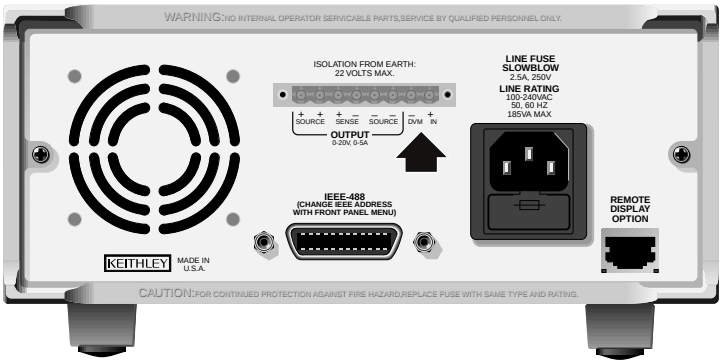

Figure 2. *Rear panel of the Model 2304. Note the location of the digital voltmeter inputs.*

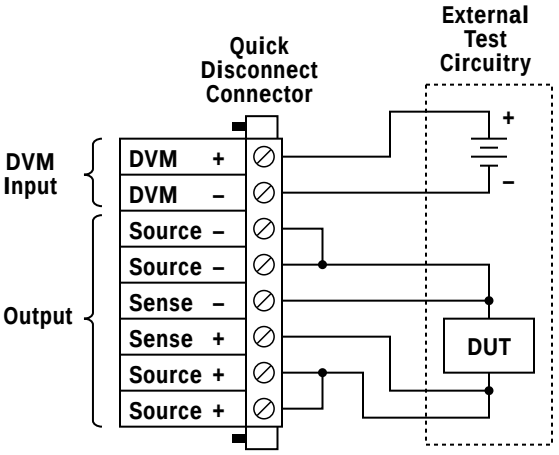

Figure 3. *Typical method of connecting the Model 2304 to a DUT.*

DVM Input Mode:

This operating mode configures the Model 2304 to display the voltage applied to the DVM input terminals and to return these readings via the bus. If using the front panel controls, press the DISPLAY button and select DVM INPUT using the ▲ and ▼ buttons.

GPIB commands for selecting the DVM Input Mode:

```
:sense:function “dvmeter”     ; selects voltage
                                measurement function

:sense:average xx             ; the number of readings to
                                average per measurement, up to 10
```

Pulse Current Mode:

The Pulse Current Mode sets the instrument to display high, low, or average pulse-current measurements and to return these readings over the bus. The Model 2304 can perform current measurements on dynamic loads. The built-in measurements include:

1. Peak measured current — Measures the peak (high) current of the pulse train.
2. Idle measured current — Measures the idle (low) current of the pulse train.
3. Average transmitted current — Measures the average current of the pulse train.

Figure 4 illustrates the high, low, and average measurements of a pulse. The high measurement is triggered on the rising edge of the pulse and an integration is performed for the time specified for the high measurement. The falling edge of the pulse triggers the low measurement and an integration is performed for the time specified for the low measurement. An average measurement is triggered on the rising edge and the integration covers both the high and low periods of the pulse, as specified by the average measurement time settings. The Model 2304 computes one measurement parameter (high, low or average) at a time. The desired measurement mode can be selected with the ▲ and ▼ buttons on the front panel.

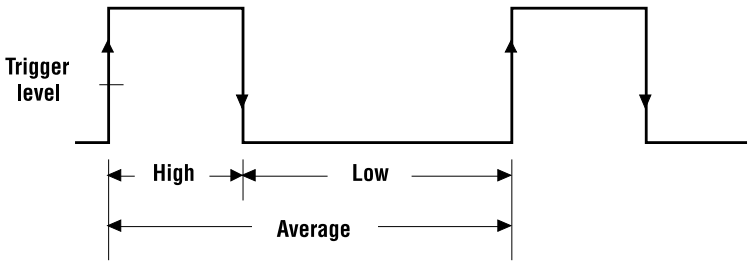

Figure 4. *Pulse current measurement*

Notes:

1. For a reading to be performed and returned via the bus, the *:read?* command must be sent after the instrument is configured to the desired mode.

2. The function "voltage," "current," "pcurrent," and "dvmeter" in the *:sense:function* command *must be in quotes.*

Trigger level — To avoid false pulse detection, use a trigger level of up to 5A. All pulses, noise, or other transients below the set trigger level will be ignored.

Note: Pulsed current levels *must exceed 5mA* (the minimum trigger threshold) to be detected.

Trigger delay — An optional trigger delay can be used to allow leading edge pulse overshoot to settle. The integration period will not start until the trigger delay period expires.

Integration times — The three integration time periods for pulse measurements can be set automatically or manually by the user.

1. The PULSE HIGH TIME, PULSE LOW TIME, and PULSE AVG TIME can be set manually from 33µs to 833ms. Make sure an integration period does not extend into the wrong portion of the pulse or into the next pulse. For example, if the pulse is high for 600µs, the high integration time must be less than 600µs. If not, the instrument will integrate a low portion of the pulse, making the high pulse measurement erroneous. ***Always factor in trigger delay when determining integration times.***

2. When the PULSE AUTO TIME operation is performed, the instrument measures the high and low periods of the first detected pulse and sets appropriate integration times. The three integration times apply for all subsequent pulse measurements until another PULSE AUTO TIME is performed or the times are changed manually. The PULSE AUTO TIME feature can detect pulses from 80µs to 833ms.

Pulsed Average readings count — The average readings count specifies how many measurements (integrations) are performed and averaged for each displayed reading. This is a different setting than the average readings count specified for "Actual V and I" and "DVM meter."

Front Panel Pulse-current measurement procedure:

1. Set the output voltage and current limit.
2. Using the PULSE CURRENT selection of the MENU, set the trigger level and delay (optional), integration times, and average readings count (optional).

   Important! — For maximum transient performance, always use the ENHANCED output mode, available from the OUTPUT RESPONSE selection from the MENU and make certain the output sense leads are connected across the load.
3. Press OPERATE.
4. Press the DISPLAY key and select the PULSE CURRENT display type.
5. Use the ▲ and ▼ buttons to display the desired pulse measurement: PULSE HIGH, PULSE LOW, or PULSE AVERAGE.

   NOTE: With the output on, pulses will not be detected if the trigger level is too low (an "A/D PULSE TRIG NOT DETECTED" or "OVERFLOW" message will be displayed). Perform the following procedure to find an appropriate trigger level.

Determining correct trigger level:

1. Turn the output on. If the trigger level is too low or too high, the "A/D PULSE TRIG NOT DETECTED" message will be displayed briefly. If the message does not appear, pulses are being detected, indicating that the trigger level is valid. If so, it is unnecessary to complete this procedure.
2. Go into the MENU, select PULSE CURRENT, then TRIGGER LEVEL.
3. Change the PULSE TRIG LEVEL and press ENTER. If the trigger level is still too low or too high, the "A/D PULSE TRIG NOT DETECTED" message will appear on the display again. It may take a few seconds for the message to appear.
4. If the message appears, repeat Step 3 until a valid trigger level is found.
5. Use the MENU key to back out of the menu structure and display pulse-current measurements.

GPIB commands for making pulse-current measurements:

```
:sense:function “pcurrent”    ; selects pulsed current
                              measurement function

:sense:pcurrent:synchronize: tlevel x.xxxx
                              ; specify trigger level
                              x.xxxx, up to 5 amps

:sense:pcurrent:average x     ; number of readings to
                              average per measurement, up
                              to 100 (optional command)

:output:response enhanced     ; select enhanced output
                              for pulsed current
                              measurements

:output on                    ; turn on supply output
```

and

```
:sense:pcurrent:time:high .xxxxxx
                              ; specify integration time
                              (in sec) for high pulse
                              measurements

:sense:pcurrent:time: low .xxxxxx
                              ; specify integration time
                              (in sec) for low pulse
                              measurements

:sense:pcurrent:time: high .xxxxxx
                              ; specify integration time
                              (in sec) for average pulse
                              measurements
```

or

```
:sense:pcurrent:time:auto     ; Model 2304 sets
                              integration times
```

and

```
:sense:pcurrent:mode high     ; set up Model 2304 to
                              calculate and return high
                              pulse value
```

or

```
:sense:pcurrent:mode low      ; set up Model 2304 to
                              calculate and return low
                              pulse value
```

or

```
:sense:pcurrent:mode average  ; set up Model 2304 to
                              calculate and return
                              average pulse value

:sense:pcurrent:synchronize: delay .xxxxx
                              ; specify trigger delay in
                              sec, 0.1 sec maximum in 10
                              µs increments (optional
                              command)
```

GPIB commands to digitize a current waveform and transfer the readings via the bus:

```
:sense:function “pcurrent”    ; selects pulsed current
                              measurement function

:sense:pcurrent:synchronize:
tlevel x.xxxx                 ; specify trigger level, up
                              to 5 amps

:sense:pcurrent:synchronize:
state off                     ; turn the trigger
                              synchronization off

:sense:pcurrent:average xxxx  ; number of readings to
                              store in the buffer, up to
                              5000

:output:response enhanced     ; select enhanced output
                              for pulsed current
                              measurements

:output on                    ; turn on supply output

:read:array?                  ; command used to return
                              the last array of readings
```

Note: *This command must be used in place of the :read? command.*

Conversion rate is ≈3600 rdgs/s.

KEITHLEY

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