Model 3231 User's Manual

The High-Voltage Pulse Generator

Warranty

New Focus, Inc. guarantees its products to be free of defects for one year from the date of shipment. This is in lieu of all other guarantees, expressed or implied, and does not cover incidental or consequential loss.

Contents

Introduction

The New Focus Model 3231 is a high-voltage pulse generator capable of driving <50 pF capacitive loads (i.e., Pockels cells and bulk modulators) with amplitudes as high as 300 V. Typical applications using the Model 3231 include pulse pickers, optical choppers, and electronically variable waveplates. It is ideal anywhere a high-voltage, high-speed (up to 1 MHz) pulse generator is required. This pulse generator even includes an input for triggering off of external pulse trains, as from a mode-locked laser, and it provides a monitor output for convenient low-voltage viewing of pulse characteristics.

Safety Precautions

IMPORTANT: Please read through the entire manual before operating the Model 3231.

WARNING: Hazardous shock can result from improper operation. To avoid personal injury, use safety precautions appropriate for high-voltage sources:

- Do not work alone.
- Do not operate with the cover removed.
- Use extreme care when handling output connections. Do not connect or disconnect cables when high voltage is present.
- Be sure the ground conductor of the AC power cord connects the instrument to a solid earth ground.

To prevent equipment damage please observe the following:

CAUTION: Loads connected to the Model 3231 must be able to dissipate up to 2-kW peak power and 20-W average power for 300-V operation. Loads with either lower peak or average power ratings may be damaged or destroyed. The load New Focus provides with this unit meets these criteria.

Theory

The Model 3231 supplies flat-topped pulses of positive or negative polarity. It has output protection for short-circuit, open-circuit, over-current, and over-temperature conditions. The pulses produced from this pulse generator can have a peak level that is adjustable from 20 V to 300 V. The baseline level is fixed at ground. From the front panel, you can adjust the pulse width from 20 ns to 1 µs. The leading-edge transition time is <5 ns, while the trailing-edge transition time is <20 ns. The pulses are triggered either from an internal repetition rate generator which is adjustable from 1 Hz to 1 MHz or from a valid external sync signal (Sync In). The unit automatically synchronizes the output pulses when a valid Sync In signal is provided. In either case, you can adjust the delay from the trigger source from 0 to 100 ns. For convenience, a monitor out signal is provided. It is a scaled down version of the high-voltage output pulse waveform. Use this monitor output for timing alignment and fine adjustment of the output width.

Note: The Model 3231 is designed to operate with a load impedance of 50 Ω. For operation at 300 V, the load must be rated for 2 kW peak power and 20 W average power dissipation. The failure modes for loads with insufficient power ratings may vary. Some loads will arc and behave as a short (either temporarily or permanently). Others, instead, will simply open up.

Operation

POWER UP

Before plugging the instrument in, be sure the selection switch is set for the correct AC operating voltage, and that a fuse of proper value is in place. Refer to Appendix 1 for voltage selection instructions and fuse requirements.

Switching the "Power" switch to the on, or "1", position on the front panel of the Model 3231 applies AC to the unit. All functions, displays, inputs and outputs are functional at this point, except for the "High-Voltage Output" and the "Output Monitor".

To turn on the "High-Voltage Output" and the "Output Monitor", press the "High Voltage On/Off" pushbutton; the green LED adjacent to the "High Voltage On/Off" switch will illuminate.

If AC is turned off and then re-applied, the "High-Voltage Output" will remain off until enabled via the "High Voltage On/Off" switch.

PROTECTION FEATURES

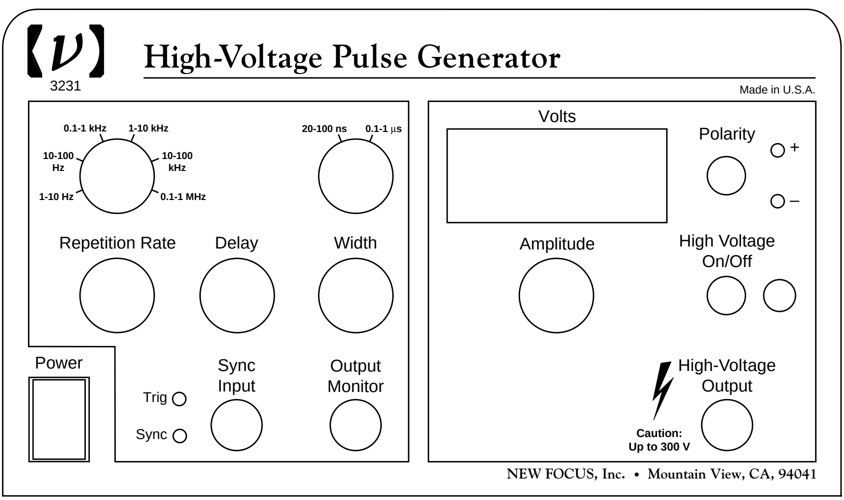
The Model 3231 pulse generator incorporates circuitry to prevent accidental damage to the instrument due to shorts applied to the output, high-voltage reflections, excessive current demand, and over-temperature conditions.

Short-Circuit Protection

If a short or near-short appears at the output while the Model 3231 is producing a pulse, the instrument will respond by rapidly turning off the pulse being generated. This protects the Model 3231 output stage from damage. It takes effect if the short is

Fig. 1

Front panel view of the Model 3231.



present when the pulse begins (even if the short is present before the instrument is turned on) or if the short is applied after the pulse has started.

When the protection circuit turns the pulse off, the active front-panel "Polarity" LED (see LED Indicators p. 15) flashes to alert the user to a fault condition. The output is disabled and held at zero for about four seconds before the instrument tries to put out another pulse. When it does retry, the output level will be raised slowly. If a short-circuit condition is not present, pulses are produced normally. If a short is still present, the output is again disabled, the LED starts blinking and the cycle repeats. The Model 3231 will continue to retry every four seconds until it detects that a short-circuit condition no longer exists.

Over-Voltage Protection

The energy of a high-voltage pulse traveling down a length of cable can be reflected back if the impedance terminating the cable does not match that of the cable itself (50 Ω). An unterminated cable (open circuit) will produce a reflected wave of double the pulse amplitude. For a long cable and a wide pulse, the energy carried back in such a reflection could potentially damage an unprotected output stage. To prevent this, the Model 3231 employs circuitry to clamp such reflections to a safe level. This circuitry does not interrupt the operation of the instrument, and the front-panel LED's are unaffected.

Over-Current Protection

When the specified duty factor maximum for a given pulse level is exceeded (see Duty Factor below), the Model 3231 will go into a current-limit state and the output voltage will drop below the selected value. Using a low-impedance load may have this effect as well, even when duty-factor maximums have not been exceeded. Additionally, dialing in a large change in the level may momentarily cause a current-limit condition.

While the instrument is current limiting, the active front-panel "Polarity" LED will flash. When the cause of the current-limit condition is removed, the Model 3231 output will slowly rise until it again produces pulses of accurate output level.

Over-Temperature Protection

When the specified maximum pulse repetition rate for a given pulse level is exceeded (see Timing Requirements below), overheating of the output stage can result. To prevent this, the Model 3231 incorporates thermal protection circuitry that will slowly lower the output level when the maximum repetition rate is exceeded. The active front-panel "Polarity" LED will flash. When the repetition rate or output level is reduced, the Model 3231 will return to normal operation.

TIMING REQUIREMENTS

Duty Factor

The Model 3231 instrument can operate at a maximum duty factor of 1% at 300 V. For operation at lower peak voltages, the duty factor may be increased. Table 1 shows typical maximum duty factors for various voltage levels. If the duty factor is too high, the Model 3231 over-current circuitry will respond by decreasing the pulse amplitude and flashing the active front-panel "Polarity" LED (as described in Over-Current Protection p. 8).

Repetition Rate

Independent of duty factor, the maximum pulse rate depends on pulse amplitude, as shown in Table 1. When the maximum pulse rate is exceeded, the output level will drop and a front panel "Polarity" LED will flash (as described in Over-Temperature Protection p. 9).

Duty factor constraints may additionally limit the repetition rate for a given pulse width. As an example, the last column in Table 1 gives the maximum repetition rate when a 100-ns width is used.

Pulse Spacing

A minimum pulse spacing of 200 ns is required between the trailing edge of a pulse and the leading edge of the following pulse. If this minimum spacing is not met, output pulses may disappear.

PERFORMANCE ENHANCEMENTS

Transition Times and Pulse Widths

While the leading-edge transition time remains typically 5 ns or less over the entire range of amplitude levels (20 V to 300 V), the trailing-edge transition time increases as the peak amplitude setting is reduced. The length of the pulse top remains constant when the peak amplitude value is changed. However, as a result of the change in trailing-edge transition time, the pulse width measured at the 50% points increases slightly as peak levels below 300 V are selected. Typical trailing-edge transition

Table 1

Typical Duty Factor Maximums for the Model 3231.

Peak Level	Maximum Duty Factor	Maximum Pulse Rate	Maximum Pulse Rate For 100-ns Width
300 V	1 %	400 kHz	100 kHz
200 V	2 %	800 kHz	200 kHz
150 V	5 %	1 MHz	500 kHz
20 V	25 %	1 MHz	1 MHz

Table 2

Typical Pulse Width Correction Factors.

Peak Level	Trailing Edge Transition Time	Correction Factor (@ 50% points)
300 V	10 ns	—
200 V	11 ns	—
100 V	13 ns	+ 1 ns
20 V	18 ns	+ 4 ns

times and width correction factors are given in Table 2.

Where a high degree of accuracy is required, pulse width should be measured at the levels being used. Note that the output monitor waveform can be used to observe these slight changes in pulse shape. To obtain pulses lower in amplitude than 300 V without increased trailing-edge transition time, set the level to 300 V and use an external attenuator. Be sure that the attenuator presents 50 Ω to the Model 3231 output and that the attenuator and load combination can dissipate 20-W average power and 2-kW peak power.

Non-50-Ω Loads

The Model 3231 is designed to meet all of its specifications when driving capacitive loads as large as 50 pF. A 50-Ω termination, however, must be located at the end of the RF path (i.e., beyond the capacitive load). In most cases best results are obtained when the capacitance is located at a T (with minimal stub length) close to the 50-Ω termination (which should be placed at the most distant end of the cable system). Capacitance will act as a momentary short, and will generate aberrations that depend on the size of the capacitance. A capacitive load larger than 50 pF could increase rise and fall times beyond those specified and could trip the short circuit protection.

The use of a non-50-Ω load, such as a 50-pF bulk modulator in parallel with a 50-Ω termination, will result in an impedance mismatch. This mismatch will result in reflections of the output pulse as it reaches the load. As a result, the waveform will exhibit aberrations depending on the degree of the mismatch. The time position and appearance of the aberrations will vary with pulse width and cable length (cable transit time is approximately 1.3 ns per foot of cable). In the case of a 50-pF load with a 50-Ω termination in parallel, the aberrations will not exceed 15% of the original pulse amplitude.

Resistive loads with an impedance greater than 50 Ω, in addition to generating aberrations, will cause the trailing-edge transition time of the pulse to increase. The larger the load resistance, the longer the trailing-edge transition time will be. The leading edge should not be significantly affected. Another result of using higher impedance loads is that the Model 3231 may allow larger duty factor settings before going into an over-current state. For very high impedance loads, using a 50-Ω termination in parallel with the load may provide a cleaner waveform.

Resistive loads with less than 50-Ω impedance will generate aberrations and will cause an over-current state at a lower duty factor than that specified for the Model 3231. If the resistance is small enough, the short circuit protection may shut off the output (see Short-Circuit Protection p. 6).

TROUBLESHOOTING

If the output level drops or the front-panel LED's blink, check that a 50-Ω load is being used. Also check that the duty factor and repetition rate maximums are not being exceeded (see Timing Requirements p. 9 and Protection Features p. 6). For problems relating to output pulse aberrations, refer to Performance Enhancements p. 11-13.

FRONT PANEL DESCRIPTION

Switches and Knobs

The "Polarity" toggle switch controls the output pulse peak level polarity. If it is switched while pulses are being produced, the output will slowly drop to zero before the output polarity actually changes. The output will then move quickly to the selected level.

The "High Voltage On/Off" push-button switch enables and disables the "High-Voltage Output" and "Output Monitor" signals. The switch will be in the disable state when the Model 3231 is turned on regardless of its status when the instrument was last powered down.

The "Power" rocker switch turns on and off the AC power to the instrument.

The "Repetition Rate" selector switch determines the range for setting the internal pulse repetition frequency. A continuously variable 10-turn knob provides for adjustment within the range selected.

The "Width" selector switch determines the range for setting the pulse width. A continuously variable 10-turn knob provides for adjustment within the range selected. The selected width should be narrow enough to meet duty factor requirements for the repetition rate being used (see Timing Requirements p. 9).

The "Delay" knob provides for control of the relative time position of the output pulses with respect to the internal trigger. When synchronized to an external "Sync Input" signal, this allows for time positioning the output pulses with respect to the sync signal. This 10-turn knob provides for continuous delay adjustment from 0–100 ns (note that this is in addition to a fixed delay of approximately 90 ns).

The "Amplitude" knob determines the magnitude of the output pulse peak level. This 10-turn control allows for continuous adjustment of pulse height from 0 to 300 V. The selected setting is shown on the "Amplitude" display. Note that specifications do not apply below 20 V. After a level change is entered, the instrument may require a few seconds to settle to the new value.

LED Indicators

The Model 3231 has five LED indicators on the front panel.

The "+" LED will light when the instrument generates pulses of positive polarity.

The "-" LED will light when the instrument generates pulses of negative polarity.

The LED that is active will flash when a short-circuit, over-current, or over-temperature condition occurs (see the section on Protection Features).

The "Trig" LED will light when valid triggers are present at the "Sync Input" connector. This LED will light as long as the level of the triggers is sufficient to be detected, even if the trigger rate is not within range to allow for the output pulse to be synchronized to the trigger pulses.

The "Sync" LED will light when the high-voltage output pulse train is synchronized to the trigger signal present at the "Sync Input" connector.

The "High Voltage On/Off" LED will light when the "High Voltage On/Off" switch has been set to enable the output to produce pulses.

Display

The "Amplitude" display shows the peak level in volts of the high-voltage output pulses. The front panel display only shows the magnitude of the pulse level. Note that this display will show the setting even when the "High Voltage On/Off" switch has been set to disable the output, and no pulses are being generated. When overload protection circuitry activates, the display will show the resultant drop in output amplitude.

Connectors

"High-Voltage Output" is a BNC connector that provides the high-voltage pulsed output from the instrument.

WARNING: Shock hazard. Use extreme care when handling output connections.

"Output Monitor" is a BNC connector that provides a representation of the high-voltage out attenuated by a factor of 100. This output should be terminated into a high impedance (e.g. 1 MΩ).

Appendix 1:

AC Operating Voltages and Fuses

The Model 3231 can operate from 100, 120, 220, and 240 V AC with AC frequencies of 47-63 Hz. The unit is configured at the factory for the standard AC voltage in the user's country. To select a different operating voltage, please refer to Figures 2 and 3 and follow the directions below:

1. Remove the power cord from the power entry module on the rear of the unit.
2. Open the power entry module cover with a small blade screwdriver or similar tool.
3. Set aside cover/fuse block assembly.
4. Using the indicator pin, pull the voltage selector card straight out of the housing.
5. Orient the selector card so the desired voltage is readable at the bottom.
6. Orient the indicator pin to point up when the desired voltage is readable at the bottom (note that when the indicator pin is fixed, successive voltages are selected by rotating the card 90° clockwise).
7. Insert the voltage selector card into the housing with the *printed side of the card facing toward the IEC connector* and the edge containing the desired voltage first.
8. Replace the cover.
9. Verify the indicator pin shows the desired voltage.

Refer to Figure 4 when changing fuses. The power entry module requires two slow-blow (such as Littlefuse Slo-Blo® series) 250-V, 5×20 mm fuses as follows:

AC Voltage	Fuse Rating	Littlefuse P/N
100 V AC	1.0 A	239.500
120 V AC	1.0 A	239.500
220 V AC	0.5 A	239 001
240 V AC	0.5 A	239 001

WARNING: To avoid accidental shock, unplug the line cord and turn the power off before checking or replacing the fuse. For protection against fire, use only the specified fuse value. Do not attempt to bypass or repair the fuses.

Fig. 2

Model 3231 Voltage Selection.

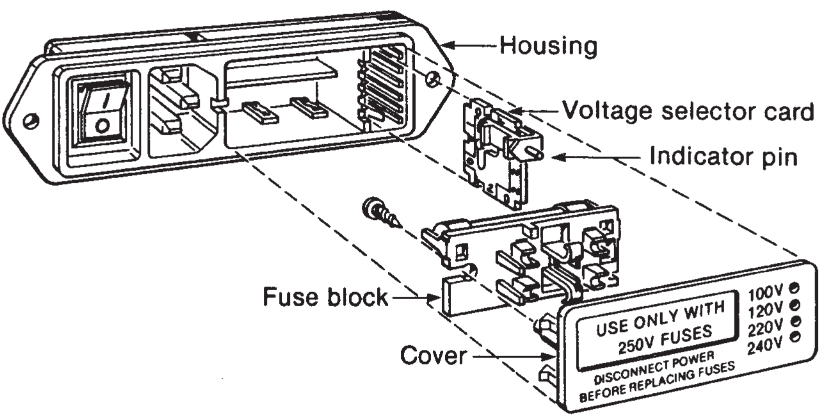


Fig. 3

Voltage Selector Card Orientation.

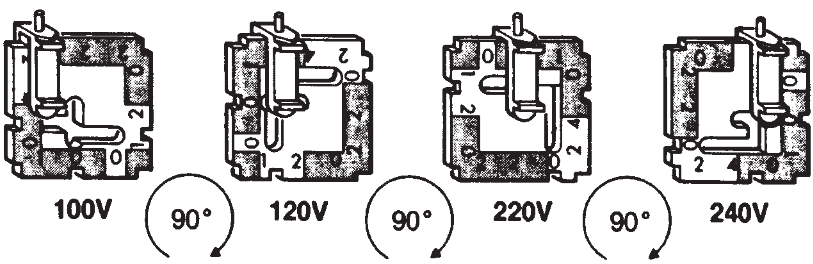
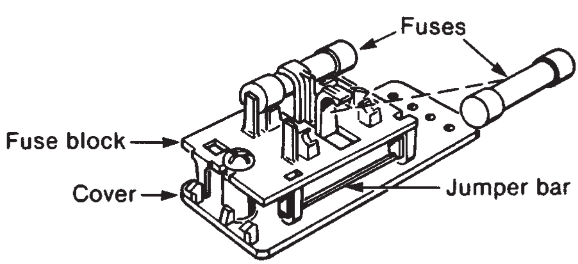


Fig. 4

Model 3231 Fuse Changing.



Appendix 2:

Calibration

New Focus recommends performing the following Model 3231 calibration procedure every 12 months.

EQUIPMENT REQUIRED

- Peak reading, 300-MHz bandwidth digital oscilloscope (Tektronix TDS 520 or equivalent).
- 3-1/2 digit Digital Volt Meter
- 25-W, 50-Ω, 20-dB attenuator
- 2-W, 50-Ω, 20-dB attenuator
- 50-Ω coaxial cables (RG58 or equivalent wide-bandwidth cable)

WARNING: Hazardous shock can result from improper operation. To avoid personal injury, use safety precautions appropriate for high voltage sources:

- Do not work alone.
- Use extreme care when operating the instrument with the cover off. Use only tools with insulated handles. Do not touch exposed circuitry inside the module since the storage capacitor may hold a high voltage charge even for a few seconds after powering down.
- Never put more than one hand near the module when power is on. Make sure your body is isolated from ground.
- Use extreme care when handling output connections. Do not connect or disconnect cables when high voltage is present.
- Be sure the ground conductor of the AC power cord connects the instrument to a solid earth ground.

PROCEDURE

Calibration should be carried out in the order presented.

Power Supply Voltages

Remove the cover and turn the power on. Verify that the power supply voltages are at the appropriate levels (+12 V, -12 V, +5.0 V, and -5.2 V). Set +5 V and -5.2 V to within 0.05 V and +/-12 V to within 0.1 V. There are test points and adjustment potentiometers on the power supply board (PCB 6040-1) and each is labeled with the appropriate voltage.

Repetition Rate

Leave the "High Voltage On/Off" switch in the off state. Set the "Repetition Rate" selector switch to 0.1-1 MHz and turn the adjustment knob to maximum (fully clockwise). Remove any cable connected to the "Sync Input" connector. Observe the pulse frequency at TP-1 on the Timing board (PCB 3231-3). Adjust C5 on the Timing board to make this frequency 1 MHz.

HIGH VOLTAGE OUTPUT Amplitude

With the "High-Voltage Output" disabled, connect a length of coax cable between the "High-Voltage Out" jack of the Model 3231 and the input of the 20-W, 50-Ω, 10× attenuator. Connect this attenuator output to the 2-W, 50-Ω, 10× attenuator which in turn should be connected to the oscilloscope input. Set the scope terminator to 50 Ω.

Set the amplitude to 300 V, set the repetition rate to 1 kHz, and set the width to 500 ns.

Adjust the scope so that it reads the pulse top amplitude 400 ns after the leading edge of the 300 V pulse (using a gated measurement mode to read the high level, position both scope cursors very close to each other 100 ns before the trailing edge, then read the amplitude within this narrow gate).

Switch the "Polarity" switch to positive. Set the "High Voltage On/Off" switch to the on state, and turn the front panel "Amplitude" control to maximum (fully clockwise). Adjust R1 on the Timing board until the scope indicates a pulse amplitude of 300 V.

Switch the "Polarity" switch to negative. The negative 300 V pulse should vary no more than 1% from the 300 V magnitude of the positive pulse. If necessary, adjust R2 on the Output board (PCB 202H-1) so that the level for both polarities are the same to within ±1%.

Adjust R2 on the front panel board (PCB 3231-2) to make the front panel "Amplitude" display agree with the scope reading.

Width

Set the repetition rate to 400 kHz and the high-voltage output level to 300 V. With the "Width" selector switch set to 20–100 ns, turn the adjustment knob to minimum (fully counterclockwise). Adjust R3 to narrow the high-voltage output pulse width until the amplitude begins to drop. This should be below 20 ns but above 12 ns.

Stepcal Adjustment

Set level to 0 V, the repetition rate to 5 kHz and the width to 1 ms. Set TP-4 on the Output board (PCB 202H-1) for +0.6 V using R1. Check this for amplitude settings of 300 V, 150 V and 20 V. If necessary, readjust R1 to obtain the smallest difference between readings. Note that when the amplitude is changed, the output pulse should be allowed enough time to settle completely before reading TP-4.

Drive Level Adjustment

Switch the "Polarity" switch to POSITIVE.

Set the repetition rate to 1 kHz, set the width to 500 ns, and set the level to 300 V.

Using the DVM, measure the voltage between TP-2 and TP-6 on the output board (PCB 3231-1). This is the voltage directly across the high-voltage power supply, PS1. Compare this reading to the level of the output pulse top shown on the scope. Adjust the FET drive signal with C76 (located in the center of the floating island on the output board) so that the amplitude of the output pulse just stops increasing. This minimizes the power dissipation in the FET. There should be less than 40 V difference between the two levels (representing the drop across the FET and the 1.5 Ω resistor, R14).

If necessary, recalibrate the output pulse amplitude as described above.

Minimum Pulse Width Calibration

Adjust the width to 12 ns. Verify that the width for a +300 V pulse is 12 ns at the 50% amplitude points. If necessary, a very small correction in width can be made by adjusting C76 on the output board (PCB 202H-1).

Change the polarity to negative. Adjust the drive signal with C78 on the output board (near Q21) so that the width for a -300 V pulse is 12 ns at the 50% amplitude points. Note that if C78 is adjusted to the end of its range, the output pulse will disappear.

TIMING CHARACTERISTICS

Internal Repetition Rate:	0 Hz–400 kHz at 300 V 0 Hz–1 MHz at 150 V (See Table 1 for other amplitudes)
External Sync Rate:	1 kHz–250 MHz
Adjustable Delay:	0 ns–100 ns (plus insertion delay of approximately 90 ns)
Jitter:	<1 ns_{rms} (100 ps typical) (between leading or trailing edge of high-voltage output pulse and the nearest sync input pulse)
Insertion Delay:	90 ns, typical (between sync input pulse and the corresponding high-voltage output pulse)
Width:	15 ns–1μs (at 50 % points). At lower amplitudes width increases (see Table 2)
Duty Factor:	1% maximum at 300 V (higher duty factor at lower amplitudes; see Table 1).

OUTPUT CHARACTERISTICS

HIGH VOLTAGE OUTPUT

Amplitude:	20 V to 300 V peak into 50 Ω (Baseline fixed at ground).
Polarity:	Positive or negative (switch selectable)
Max. Power:	18 W average, 1.8 kW peak
Max. Current:	6 A peak
Leading edge: (10%-90%)	5 ns (3 ns typ.) into 50-Ω load 8 ns (5 ns typ.) into 50 pF in parallel with 50 Ω
Trailing edge: (10%-90%)	10 ns at 300 V into 50 Ω load (longer at lower amplitudes; see Table 2). 15 ns (10 ns typical) at 300 V into 50 pF in parallel with 50 Ω
Aberrations:	5% of amplitude (2% typical) into 50-Ω load 15% of amplitude (8% typical) into 50 pF in parallel with 50 Ω
Connector:	BNC
Load:	Specifications apply for 50-Ω terminating resistance with up to 50-pF capacitance in parallel (with cable length from terminator to capacitance no more than 6")

OUTPUT MONITOR

Function:	Represents the high-voltage output waveform attenuated by a factor of 100
Amplitude:	0 to ±3 V into 50 Ω (1% of high-voltage output amplitude)
Connector:	BNC

INPUT CHARACTERISTICS

SYNC INPUT

Range:	1 kHz–250 MHz
Input Impedance:	50 Ω
Min. Signal Level:	300 mV
Max. Signal Level:	±7 V DC or rms
Threshold:	0.2 V, typical
Connector:	BNC

GENERAL

Dimensions:	8.25"W× 5"H×16"D
Weight:	14 lbs
Temperature:	Specifications apply 10°–40° C (50°–104° F)