2601B-펄스 시스템 소스미터®
10 µs Pulser/SMU 계측기
데이터 시트

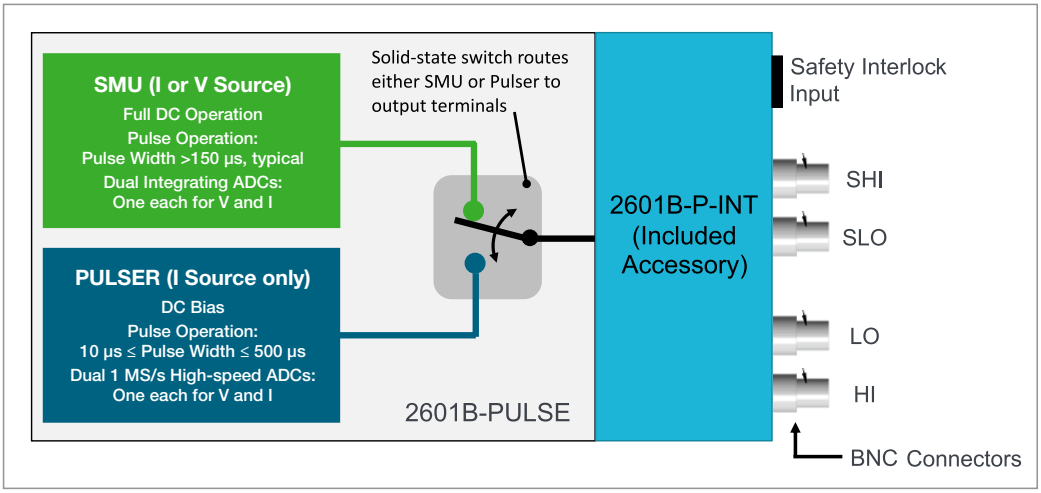
KEITHLEY
A Tektronix Company

PulseMeter™ 기술이 적용된 새로운 2601B-PULSE 시스템 소스미터 10 µs Pulser/SMU 계측기는 기존 SMU의 기능과 측정 기능을 갖춘 업계 최고의 고전류/고속 펄서 입니다. 이 새로운 펄서는 펄스 폭 최소 10µs의 10V에서 선도적인 10A 전류 펄스 출력을 제공하며, LIDAR 및 안면 인식에 사용되는 수직 캐비티 표면 방출 레이저(VCSEL), 조명 및 디스플레이용 LED, 반도체 소자 특성화, 서지 보호 테스트 등에 적합합니다. Pulser의 내장 듀얼 1 메가 샘플/초(MS/s), 18 비트 디지타이저를 사용하면 별도의 계측기를 사용할 필요 없이 펄스 전류와 전압 파형을 동시에 얻을 수 있습니다. 2601B-PULSE는 벤치탑 특성 분석에서 자동화 된 펄스 I-V 생산 테스트에 이르기까지 응용 분야의 생산성을 크게 향상시키는 강력한 솔루션입니다.

자동화된 시스템 애플리케이션의 경우 2601B-PULSE의 테스트 스크립트 프로세서 (TSP®)는 업계 최고의 처리량을 위해 계측기 내부에서 완벽한 테스트 프로그램을 실행합니다. 더 큰 다중 채널 애플리케이션에서 키슬리 TSP-Link® 기술은 TSP 기술과 함께 작동하여 고속 펄스/핀당 SMU 병렬 테스트를 가능하게 합니다. 2601B-PULSE는 메인 프레임이 필요 없는 완벽한 격리 기능을 제공하므로 테스트 애플리케이션이 발전함에 따라 쉽게 재구성 및 재배치 할 수 있습니다.

주요 특징

- 업계 최고의 10A @ 10V, 10 마이크로 초 펄스 출력
- 튜닝이 필요하지 않습니다. 최대 3µH의 유도 부하에서 작동
- 고속 I / V 펄스 측정을 위한 듀얼 1 메가 샘플/초 디지타이저 (펄서 기능 만 해당)
- 최대 ±40V @±1.0A, 40W의 DC 기능
- TSP 기술은 동급 최고의 시스템 수준 처리량을 위해 계측기 내에 완전한 테스트 프로그램을 내장
- 메인 프레임 없이 멀티 채널 병렬 테스트를 위한 TSP-Link 확장 기술
- USB 2.0, LXI Core, GPIB, RS-232 및 디지털 I/O 인터페이스
- 키슬리 KickStart 비 프로그래밍 소프트웨어 도구에서 지원



2601B-PULSE에 포함 된 외부 인터록/커넥터 박스

디바이스 특성 분석을 위한 펄스 테스트

2601B-PULSE SMU를 사용하면 웨이퍼 내 테스트로 실제 장치 작동을 테스트하고 발열 효과를 최소화 할 수 있습니다. 열 관리는 많은 장치, 특히 VCSEL, 레이저 다이오드 및 LED와 같은 반도체 웨이퍼 레벨의 장치를 테스트하는 동안 중요합니다. 펄스 I-V 테스트는 특히 온도 제어 회로가 없는 디바이스가 웨이퍼 레벨에서 테스트되는 경우 디바이스에서 전류의 가열 효과를 최소화합니다.
DC로 테스트하면 특성이 변경되거나 최악의 경우 파괴됩니다. 나중에 생산 단계에서 온도 제어 기능이 있는 모듈로 조립 된 경우 장치를 DC 테스트하고 펄스 테스트의 결과와 비교할 수 있습니다. 일부 장치는 온도 변화로 인한 장치 특성 변화로 인해 DC 테스트를 통과하고 펄스 테스트에 실패합니다. 2601B-PULSE의 10 V / 10 A / 10 µs 출력은 장치에 적절한 출력 펄스를 확보하고 필요할 때 정확한 측정을 보장합니다.

튜닝 불필요

전류 펄스를 출력 할 때 케이블 및 인덕턴스가 문제가 될 수 있습니다. 인덕턴스는 제한적인 효과가 있으며 손상을 입을 수도 있습니다. 웨이퍼에서 레이저 다이오드를 테스트하는 경우에도 인덕턴스는 장치마다 다를 수 있습니다. 전류원에 대한 인덕턴스의 영향은 인덕턴스가 전류 변화에 저항한다는 것입니다. 이로 인해 전류 소스가 출력 전압을 증가시킬 수 있습니다. 펄스가 안정되면 결과가 오버 슈트 되고 울립니다. 테스트에서 허용되지 않을 수 있습니다. 일부 솔루션은 이러한 동작을 보상하기 위해 조정해야 하므로 시간이 오래 걸릴 수 있습니다.

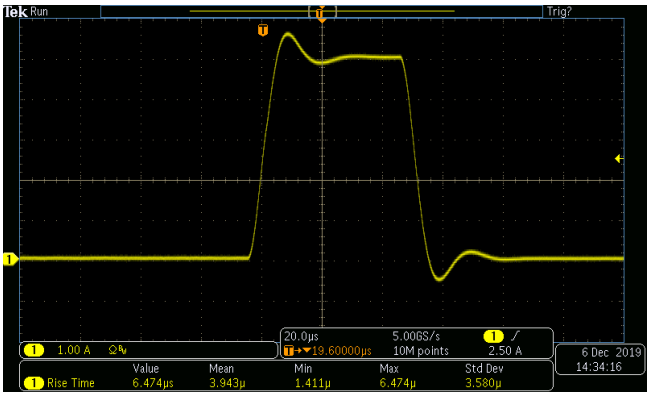
2601B-PULSE의 제어 루프 시스템은 필요성을 제거합니다. 최대 10A 전류에서 10µs ~ 500µs의 펄스를 출력 할 때 펄스에 오버 슈트 및 링잉이 발생하지 않도록 최대 3µH의 부하 변화를 조정합니다. 이렇게하면 빠른 상승 시간이 보장되므로 장치에 전류 펄스가 공급되어 장치 나 회로를 올바르게 특성화 할 수 있습니다.

다음 페이지의 이미지는 3µH의 임피던스를 가진 장치에서 5A, 50µs 펄스를 출력하는 경쟁 모듈 식 SMU와 비교하여 PulseMeter 기술을 사용한 2601B-PULSE의 성능을 보여줍니다.

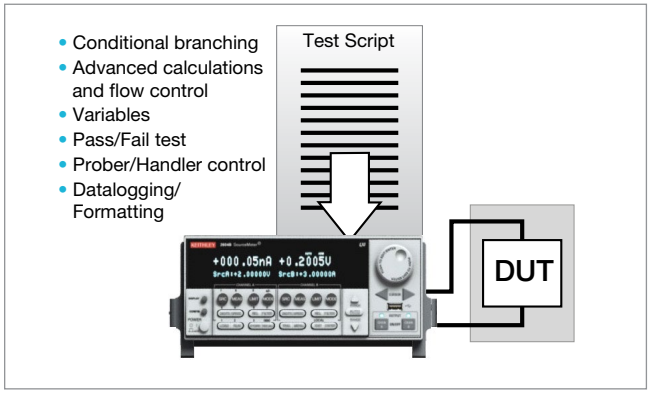
2610B-PULSE SMU의 펄스 출력 성능.

TSP 기술로 자동화 된 테스트를 위한 최고의 처리량

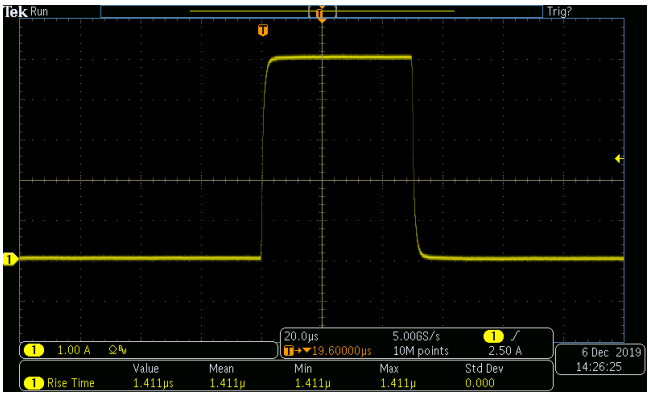
최고 수준의 자동화 및 처리량을 요구하는 테스트 애플리케이션을 위해 2601B-PULSE의 TSP 기술은 업계 최고의 성능을 제공합니다. TSP 기술은 기존의 테스트 명령 시퀀서 보다 훨씬 뛰어납니다. SMU 계측기 자체에서 완전한 테스트 프로그램을 완전히 포함하고 실행합니다. 이를 통해 PC 컨트롤러와의 시간이 많이 걸리는 버스 통신이 실질적으로 제거되므로 전체 테스트 시간이 크게 향상됩니다.



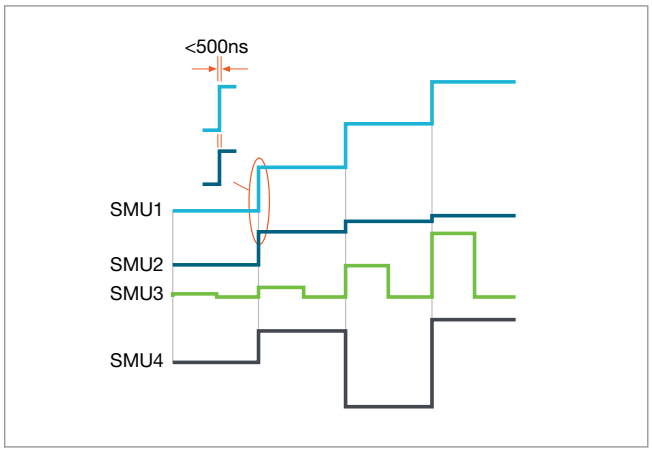
오버 슈트 및 6.47 µs 상승 시간을 가진 경쟁 SMU의 일반적인 펄스 출력.



TSP 기술은 2601B-PULSE의 비 휘발성 메모리에서 완전한 테스트 프로그램을 실행합니다.



오버 슈트 및 1.4µs 상승 시간이없는 2601B-PULSE 출력.

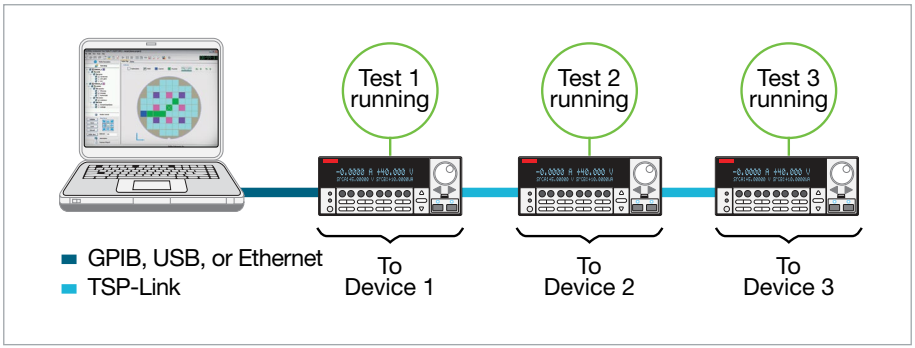


TSP-Link 시스템의 모든 채널은 500ns 미만으로 동기화됩니다.

TSP-Link 기술을 사용한 핀당 SMU 병렬 테스트

TSP-Link는 여러 개의 2601B-PULSE SMU를 서로 연결하여 단단하게 동기화 된 다중 채널 시스템으로 작동 할 수 있는 채널 확장 버스입니다. 2601B-PULSE의 TSP-Link 기술은 TSP 기술과 함께 작동하여 핀당 고속 SMU 병렬 테스트를 지원합니다. 대형 ATE 시스템과 같은 다른 고속 솔루션과 달리 2601B-PULSE는 메인 프레임의 비용이나 부담 없이 병렬 테스트 성능을 달성합니다. TSP-Link 기반 시스템은 뛰어난 유연성을 제공하므로 테스트 요구 사항이 변경 될 때 빠르고 쉽게 시스템을 재구성 할 수 있습니다.

TSP-Link는 표준 100BASE-T 이더넷 케이블을 사용하여 여러 2601B-PULSE SMU뿐만 아니라 하나의 통합 시스템으로 작동하는 마스터-하위 구성으로 다른 TSP 기반 계측기를 연결할 수 있습니다. TSP 기반 계측기에는 키슬리 그래픽 소스미터 SMU 계측기 (245, 2460, 2461, 2470), 2600B 시리즈 시스템 소스미터 SMU 계측기, DMM7510 및 DMM6500 그래픽 샘플링 멀티미터, 3700A 시리즈 스위치/멀티미터 시스템과 같은 DMM/스위치 계측기 등이 있습니다. TSP-Link 확장 버스는 최대 32개의 TSP-Link 노드를 지원하므로, 애플리케이션의 특정 요구사항에 맞게 시스템을 쉽게 확장할 수 있습니다.



TSP 및 TSP-Link를 사용한 핀당 SMU 병렬 테스트는 테스트 처리량을 향상시키고 테스트 비용을 절감합니다.

기기 제어 스타트 업 소프트웨어

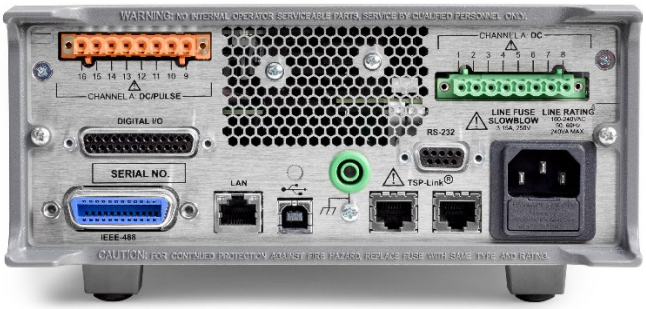
KickStart 기기 제어 / 시동 소프트웨어를 사용하면 프로그래밍없이 몇 분 안에 측정을 시작할 수 있습니다. 대부분의 경우 사용자는 빠른 측정을 수행하고 데이터를 그래프로 표시하며 나중에 Microsoft Excel과 같은 소프트웨어 환경에서 분석하기 위해 데이터를 디스크에 저장하면됩니다.
킥 스타트는 다음을 제공합니다.

- **I-V 특성화를 수행하기 위한 계측기 구성 제어**
- **기본 X-Y 그래프, 패닝 및 확대 / 축소**
- **데이터의 스프레드 시트/표 보기**
- **추가 분석을 위해 데이터 저장 및 내보내기**
- **테스트 설정 저장**
- **그래프 캡처 스크린 샷**
- **테스트 주석**
- **명령 행 대화 상자를 사용하여 데이터 송수신**
- **HTML 도움말**
- **GPIB, USB 2.0, 이더넷 준수**

KickStart 시작 소프트웨어를 사용하면 몇 분만에 측정을 수행 할 수 있습니다.

포괄적인 내장 연결

후면 입력 커넥터, 후면 입력 커넥터, 원격 제어 인터페이스 (GPIB, USB 2.0 및 LXI/이더넷), D-sub 25 핀 디지털 I / O 포트 (내부 / 외부 트리거 신호 및 처리기 제어용) 및 TSP- 링크 커넥터를 사용하면 여러 계측기 테스트 솔루션을 간단하게 구성하고 추가 어댑터 액세서리에 투자 할 필요가 없습니다.



2601-PULSE 후면 패널

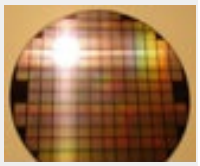
2601B-P-INT 인터록/커넥터 박스는 SMU와 Pulser 기능을 모두 상호 연결하며 후면 패널의 Phoenix 커넥터를 모두 표준 BNC 커넥터로 변환합니다. 또한 인터락/커넥터 박스는 레이저 장치를 테스트할 때 사용할 수 있는 선택적 안전 인터락을 제공합니다.

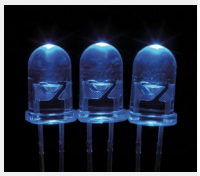
2601B-PULSE 인터락/커넥터(전면/후면), 2601B-PULSE 포함

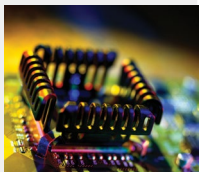
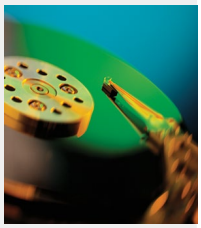
전형적인 응용 분야

다음을 포함한 광범위한 장치의 I-V 기능 테스트 및 특성 분석에 쓰입니다:

- VCSEL (수직 공동 표면 발광 레이저), 레이저 다이오드, 발광 다이오드 (LED), 고휘도 LED (HBLED), 디스플레 이와 같은 광전자 장치
- 센서, 디스크 드라이브 헤드, 금속 산화물 배리스터 (MOV), 다이오드, 제너 다이오드, 센서, 커패시터, 서미스터를 포함한 개별 및 수동 부품
- 간단한 IC – 옵토, 드라이버, 스위치, 센서, 컨버터, 레귤레이터
- 통합 장치 – 소규모 통합 (SSI) 및 대규모 통합 (LSI)
  - 아날로그 IC
  - 무선 주파수 집적 회로 (RFIC)
  - 주문형 집적 회로 (ASIC)
  - 시스템 온 칩 (SOC) 장치
- 웨이퍼 레벨 신뢰성
  - NBTI, TDDB, HCI, 일렉트로마이그레이션
- 배터리
- 고장 분석
- 그리고 더...





Specifications

사양 조건

이 문서에는 2601B-PULSE 시스템 소스미터 10 µs Pulser/SMU 계측기의 사양 및 보충 정보가 포함되어 있습니다.
사양은 2601B-PULSE가 테스트되는 표준입니다. 출고시 2601B-PULSE는 이러한 사양을 충족합니다. 보충 및 일반적인 값은 보증되지 않으며 23°C에서 적용되며 유용한 정보로만 제공됩니다. 정확도 사양은 일반 및 고 정전 용량 모드 모두에 적용됩니다. 소스 및 측정 정확도는 다음과 같은 조건에서 Pulser/SMU 장비의 터미널에서 지정됩니다.

1. 18 °C to 28 °C, <70% relative humidity
2. After 2 hour warm-up
3. Speed normal (1 NPLC)
4. A/D auto-zero enabled
5. Remote sense operation only or properly zeroed local operation
6. Calibration period = 1 year

Pulser feature specification accuracies are specified at the terminals of the instrument under these conditions:

- 10 µs aperture minimum.
- Remote sense operation only.
- Total cable and DUT inductance of ≤3 µH, measured at 100 kHz

Pulser Feature Specifications

Pulser Source Specifications [1, 2]

Current Pulse Termination

The current pulse will terminate within 3 µs after terminal voltages exceed a bipolar, programmable abort threshold. Separate abort thresholds can be programmed for the sense terminals and the source terminals.

The sense threshold can be set from 5% to 200% of the selected Measure Voltage range.

The source threshold can be set from 2 V to 40 V, independent of range. The source threshold ignores normal transients during pulse rise and fall time.

Programmable threshold uncertainty is ±5 %.

Pulser Current Source Specifications

Current Programming Accuracy

Range	Programming Resolution	Accuracy (1 Year) ±(% rdg. + amps)	Typical Noise (RMS) 10 kHz–1 MHz
1 A	100 µA	0.17% + 2.0 mA	380 µA
5 A	100 µA	0.17% + 2.5 mA	1.4 mA
10 A	100 µA	0.22% + 3.0 mA	3.1 mA[3]

Temperature Coefficient (0°–18 °C and 28°–50 °C)

± (0.15 × accuracy specification)/°C.

Pulsing Limits [4, 5]

±10 A @ ± 10 V pulse, 3% duty cycle
±3 A @ ± 10 V pulse, 10% duty cycle
±1.0 A @ ± 10 V pulse, 30% duty cycle
±500 mA @ ± 10 V pulse, 60% duty cycle[6]
±250 mA @ ± 10 V continuous

Current Regulation

Line: 0.01% of range. **Load:** ±100 µA.

Overshoot

< ±0.5% of step size (typical).

NOTES

1. Full power source operation regardless of load to 28 °C ambient. Above 28 °C and/or power sink operation, refer to "Operating Boundaries" in the 2601B-PULSE Reference Manual for additional power derating information.
2. Source valid for steady state output values. See settling time specification defining the steady state output requirement.
3. For pulses longer than 100 µs, there can be a thermal drift of up to 0.004% of source value. This drift is already included in the overall source accuracy specifications.
4. Thermally limited in sink mode (quadrants 2 and 4) and ambient temperatures above 28 °C. See pulse power quadrant diagram for more information.
5. Duty cyles listed can only be achieved if bias current is ≤10 mA.
6. Due to Pulse Width Programming, Minimum t_{off}.

Additional Pulser Source Specifications

Rise Time (10% to 90%)

<1.7 µs for a full-scale step of current into any load voltage (10 V maximum).

Additional Zero-Crossing Delay

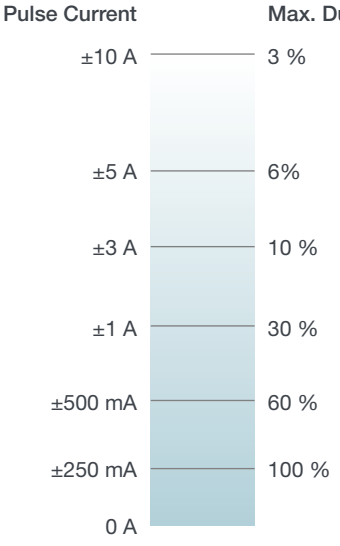
$$1\ \mu s + \frac{200\ (ns \times A)}{\text{Pulse Current (in Amps)}}$$

Pulse Current and Duty Cycle

Maximum duty cycle is given by:

$$\frac{0.3125 - |I_{bias}|}{|I_{pulse}| - |I_{bias}|} * 100\%$$

For $I_{bias} \leq 10$ mA:



Current Source Output Settling Time

Time required to reach specified accuracy after the start of the pulse.

Current Range	Settling Time
1 A	< 9 µs ($V_{load} \leq 10$ V)
5 A	< 9 µs ($V_{load} \leq 10$ V)
10 A	< 9 µs ($V_{load} \leq 10$ V)

Output Off Normal State

Electrical short (< 1 Ω) between HI and LO.
Maximum DC current from external sources during OUTPUT OFF state must be limited to <1 A.

Remote Voltage Sense

Maximum voltage between HI and SENSE HI = ±30 V.
Maximum voltage between LO and SENSE LO = ±30 V.

Over Temperature Protection

Internally sensed temperature overload puts unit in standby mode.

Safety Interlock

Hardware interlock (available, optional).

Bias Current Source Specifications

Current Programming Accuracy

Range	Programming Resolution	Accuracy (1 Year) ±(% rdg. + amps)	Typical Noise (RMS) 0.1 Hz–100 kHz
250 mA	10 µA	0.17% + 1 mA	200 µA

Temperature Coefficient (0°–18 °C and 28°–50 °C)
± (0.15 × accuracy specification)/°C.

Pulse Width Programming Resolution	1 µs.
Pulse Width Programming Maximum	500 µs.
Pulse Width Programming Minimum	10 µs.
Pulse Width Programming Accuracy	±200 ns.
Pulse Width Jitter	110 ns (typical).
Pulse Period Jitter	2 µs (typical).
Pulse Width Programming, Minimum t_{off}	16 µs.

Pulser Feature Measure Specifications

Voltage Measurement Specifications

Voltage Measurement Accuracy

Range	Display Resolution	Accuracy (1 Year) 23 °C ± 5 °C ± (% rdg. + volts)[1]
5 V	1 µV	0.05% + 2.5 mV
10 V	10 µV	0.05% + 4 mV

Voltage Measurement Settling Time

Time required to reach specified accuracy after a source level command is processed on a fixed range.

Voltage Range	Settling Time (typical)
5 V and 10 V	< 9 µs

Temperature Coefficient (0°–18 °C and 28°–50 °C)
± (0.15 × accuracy specification)/C.

Current Measurement Specifications

Current Measurement Accuracy

Range	Display Resolution	Accuracy (1 Year) 23 °C ± 5 °C ± (% rdg. + amps)[1]
1 A	1 µA	0.12% + 0.5 mA
5 A	1 µA	0.12% + 1 mA
10 A	10 µA	0.12% + 1 mA

Current Measure Settling Time

Time required to reach specified accuracy of after source level command is processed on a fixed range.
Current Range: 1 A – 10 A.
Settling Time: < 9 µs (typical).

Temperature Coefficient (0°–18 °C and 28°–50 °C)

± (0.15 × accuracy specification)/°C.

Additional Pulser Characteristics

Maximum Load Inductance	3 µH (cable plus device under test (DUT)), measured at 100 kHz.
Common Mode Isolation	>1 GΩ, <4500 pF.
Overrange	100% of bias range, 101% of source range, 102% of measure range.
Maximum Source/Sense Lead Resistance	0.5 Ω / 100 Ω per lead.
Sense High/Low Input Impedance	2 MΩ (typical).
SMU-to-Pulser Transition Time	<7 ms.

A/D Aperture Characteristics

A/D Converter Speed		1 µs	10 µs	100 µs
Effective Number of Conversions		1	10	100
Effective Number of Bits (ENOB)	Current	12	14	15
	Voltage	14	16	18
Additional Measure Current Noise Uncertainty		±1.5 mA	0 A	0 A
Additional Measure Voltage Noise Uncertainty		±0.03% of measure voltage range	0%	0%

NOTES

1. Accuracies valid for 10 µs aperture, measurement beginning at the end of the settling time. Refer to A/D Aperture Characteristics for other apertures.

SMU Specifications

Voltage Source Specifications

Voltage Accuracy[1]

Range	Programming Resolution	Accuracy (1 Year) ±(% rdg. + volts)	Typical Noise (peak-peak) 0.1 Hz–10 Hz
100 mV	5 µV	0.02% + 250 µV	20 µV
1 V	50 µV	0.02% + 400 µV	50 µV
6 V	50 µV	0.02% + 1.8 mV	100 µV
40 V	500 µV	0.02% + 12 mV	500 µV

Temperature Coefficient (0°–18 °C and 28°–50 °C)[2]

±(0.15 × accuracy specification)/ °C. Applicable for normal mode only. Not applicable for High Capacitance Mode.

Maximum Output Power and Source/Sink Limits[3]

40.4 W maximum. ±40.4 V @ ±1.0 A, ±6.06 V @ ±3.0 A, four quadrant source or sink operation.

NOTES

1. Add 50 µV to source accuracy specifications per volt of HI lead drop.
2. High Capacitance Mode accuracy is applicable at 23 °C ±5 °C only.
3. Full power source operation regardless of load to 28 °C ambient. Above 28 °C and/or power sink operation, refer to "Operating Boundaries" in the 2601B-PULSE Reference Manual for additional power derating information.

Current Source Specifications

Current Accuracy

Range	Programming Resolution	Accuracy (1 Year) ±(% rdg. + amps)	Typical Noise (peak-peak) 0.1Hz–10Hz
100 nA	2 pA	0.1% + 100 pA	5 pA
1 µA	20 pA	0.03% + 800 pA	25 pA
10 µA	200 pA	0.03% + 5 nA	60 pA
100 µA	2 nA	0.03% + 60 nA	3 nA
1 mA	20 nA	0.03% + 300 nA	6 nA
10 mA	200 nA	0.03% + 6 µA	200 nA
100 mA	2 µA	0.03% + 30 µA	600 nA
1 A	20 µA	0.05% + 1.8 mA	70 µA
3 A	20 µA	0.06% + 4 mA	150 µA
10 A[2]	200 µA	0.5% + 40 mA	N/A

Temperature Coefficient (0°–18 °C and 28°–50 °C)[3]

±(0.15 × accuracy specification)/ °C.

Maximum Output Power and Source/Sink Limits[1]

40.4 W maximum. ±1.01 A @ ±40.0 V, ±3.03 A @ ±6.0 V, four quadrant source or sink operation.

NOTES

1. Full power source operation regardless of load to 28 °C ambient. Above 28 °C and/or power sink operation, refer to "Operating Boundaries" in the 2601B-PULSE Reference Manual for additional power derating information.
2. 10 A Range is accessible in SMU extended range mode only. Accuracy specifications for 10 A range are typical.
3. High Capacitance Mode accuracy is applicable at 23 °C ±5 °C only.

Additional Source Characteristics

Noise, 10 Hz to 20 MHz	<20 mV peak-peak, < 3 mVRMS. 6 V range.
Transient Response Time	< 70 µs for the output to recover to within 0.1% for a 10% to 90% step change in load.
Overshoot	
Voltage	<±0.1% + 10 mV. Step size = 10% to 90% of range, resistive load, maximum current limit/compliance.
Current	<±0.1%. Step size = 10% to 90% of range, resistive load. See Current Source output settling time for additional test conditions.
Range Change Overshoot	
Voltage[1]	<300 mV + 0.1% of larger range. Overshoot into a 100 kΩ load, 20 MHz bandwidth
Current[2]	<300 mV/R_{LOAD} + 5% of larger range.
Guard Offset Voltage	< 4 mV. Current <10 mA.
Remote Sense Operating Range[3]	Maximum voltage between HI and SENSE HI = 3 V. Maximum voltage between LO and SENSE LO = 3 V.
Voltage Output Headroom	
40 V Range	Maximum output voltage = 42 V – (total voltage drop across source leads). Maximum 1 Ω per source lead.
6 V Range	Maximum output voltage = 8 V – (total voltage drop across source leads). Maximum 1 Ω per source lead.
Overtemperature Protection	Internally sensed overtemperature condition puts the instrument in standby mode.
Limit/Compliance	Bipolar limit (compliance) set with a single value.
Voltage[4]	Minimum value is 10 mV; accuracy is the same as voltage source.
Current[5]	Minimum value is 10 nA; accuracy is the same as current source.

Voltage Source Output Settling Time

Time required to reach within 0.1% of final value after source level command is processed on a fixed range.

Voltage Range	Settling Time
100 mV	< 50 µs
1 V	< 50 µs
6 V	< 110 µs
40 V[6]	< 150 µs

Current Source Output Settling Time

Time required to reach within 0.1% of final value after source level command is processed on a fixed range. Values below for $I_{OUT} \times R_{LOAD}$ = 1 V unless noted.

Current Range	Settling Time
100 nA	< 20 ms
1 µA	< 2 ms
10 µA	< 500 µs
100 µA	< 150 µs
1 mA	< 100 µs
10 mA to 1 A	< 80 µs (R_{LOAD} > 6 Ω)
3 A	< 80 µs (Current < 2.5 A, R_{LOAD} > 2 Ω)

NOTES

1. Add 200 mV for the 6 V to 40 V change.
2. With source settling set to SETTLE_SMOOTH_100NA.
3. Add 50 µV to source accuracy specifications per volt of HI lead drop.
4. For sink operation (quadrants II and IV) without sink mode enabled, add 10% of compliance range and ±0.02% of limit settling to the corresponding voltage source accuracy specifications. For the 100 mV range, add an additional 60 mV of uncertainty. Specifications apply with sink mode enabled.
5. For sink operation (quadrants II and IV) without sink mode enabled, add 0.06% of limit range to the corresponding current limit accuracy specifications. Specifications apply with sink mode enabled.
6. Add 150 µs when measuring on the 1 A range.

Meter Specifications

Voltage Measurement Accuracy [1]

Range	Default Display Resolution	Accuracy (1 Year)[2], ±(% rdg. + volts)
100 mV	100 nV	0.015% + 150 µV
1 V	1 µV	0.015% + 200 µV
6 V	10 µV	0.015% + 1 mV
40 V	10 µV	0.015% + 8 mV

Temperature Coefficient (0°–18 °C and 28°–50 °C) [3]

±(0.15 × accuracy specification)/ °C.

Current Measurement Accuracy

Range	Default Display Resolution	Accuracy (1 Year)[2], ±(% rdg. + amps)
100 nA	100 fA	0.08% + 100 pA
1 µA	1 pA	0.025% + 500 pA
10 µA	10 pA	0.025% + 1.5 nA
100 µA	100 pA	0.02% + 25 nA
1 mA	1 nA	0.02% + 200 nA
10 mA	10 nA	0.02% + 2.5 µA
100 mA	100 nA	0.02% + 20 µA
1 A	1 µA	0.03% + 1.5 mA
3 A	1 µA	0.05% + 3.5 mA
10 A [4]	10 µA	0.4% + 25 mA

Temperature Coefficient (0°–18 °C and 28°–50 °C) [3]

±(0.15 × accuracy specification/ °C. Applicable for normal mode only. Not applicable for High Capacitance Mode.

NOTES

1. Add 50 µV to source accuracy specifications per volt of HI lead drop.
2. De-rate accuracy specifications for NPLC setting <1 by increasing error term.
   Add appropriate typical percent of reading term for resistive loads using the table below.

NPLC Setting	100 mV Range	1 V–40 V Ranges	100 nA Range	1 µA–100 mA Ranges	1 A–3 A Ranges
0.1	0.01%	0.01%	0.01%	0.01%	0.01%
0.01	0.08%	0.07%	0.1%	0.05%	0.05%
0.001	0.8 %	0.6 %	1%	0.5 %	1.1 %

3. High Capacitance Mode accuracy is applicable for 23 °C ±5 °C only.
4. 10 A Range is accessible in SMU extended range mode only. Accuracy specifications for 10 A range are typical.

Additional Measurement Characteristics

Contact Check Specifications[1]

Speed	Maximum Measurement Time to Memory for 60 Hz (50 Hz)	Accuracy (1 year) ±(% reading + ohms)
Fast	1 ms (1 ms)	5% + 10 Ω
Medium	4 ms (5 ms)	5% + 1 Ω
Slow	35 ms (42 ms)	5% + 0.3 Ω

Current Measure Settling Time[2]

Time required to reach within 0.1% of final value after source level command is processed on a fixed range. Values below for V_{OUT} = 1 V .

Current Range	Settling Time
1 mA	< 100 µs

Input Impedance

> 10 GΩ.

NOTES

1. Includes measurement of SENSE HI to HI and SENSE LO to LO contact resistances.
2. Compliance equal to 100 mA.

Additional Characteristics

Maximum Load Impedance	
Normal Mode	10 nF.
High Capacitance Mode	50 µF.
Overrange	101% of source range, 102% of measure range.
Maximum Sense Lead Resistance	1 kΩ for rated accuracy.
Sense High Input Impedance	>10 GΩ.

High Capacitance Mode [1, 2, 3]

Accuracy Specifications

Accuracy specifications are applicable in both Normal and High Capacitance Modes.

Voltage Source Output Settling Time

Time required to reach 0.1% of final value after source level command is processed on a fixed range. Current limit = 1 A.

Voltage Source Range	Settling Time with C_{load} = 4.7 µF
100 mV	<200 µs
1 V	<200 µs
6 V	<200 µs
40 V	<7 ms

Current Measure Settling Time

Time required to reach 0.1% of final value after voltage source is stabilized on a fixed range. Values below for V_{out} = 1V unless noted.

Current Range	Settling Time
1 µA	< 230 ms
10 µA	< 230 ms
100 µA	< 3 ms
1 mA	< 3 ms
10 mA – 100 mA	<100 µs
1 A – 3 A	<120 µs (R_{load} > 2 Ω)

Capacitor Leakage Performance Using the KIHighC Factory Script [4]

Load = 5 µF||10 MΩ. **Test:** 5 V step and measure. 200 ms (typical) @ 50 nA.

NOTES

1. High Capacitance Mode specifications are for DC measurements only.
2. 100 nA range is not available in High Capacitance Mode.
3. High Capacitance Mode uses locked ranges. Auto Range is disabled.
4. Part of KI Factory scripts. See reference manual for details.

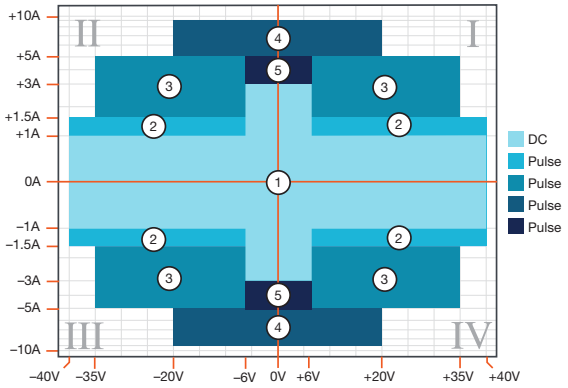
Mode Change Delay	
Current Ranges of 100 µA and Above	Delay into High Capacitance Mode: 11 ms. Delay out of High Capacitance Mode: 11 ms.
Current Ranges Below 100 µA	Delay into High Capacitance Mode: 250 ms. Delay out of High Capacitance Mode: 11 ms.
Voltmeter Input Impedance	10 GΩ in parallel with 3300 pF.
Noise, 10 Hz–20 MHz (6 V Range)	<30 mV peak-peak (typical).

Voltage Source Range Change Overshoot

<400 mV + 0.1% of larger range. Overshoot into a 100 kΩ load, 20 MHz bandwidth.

SMU Pulse Characteristics

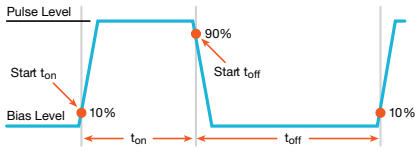
Region	Maximum Current Limit	Maximum Pulse Width [1]	Maximum Duty Cycle [2]
1	1 A @ 40 V	DC, no limit	100%
1	3 A @ 6 V	DC, no limit	100%
2	1.5 A @ 40 V	100 ms	25%
3	5 A @ 35 V	4 ms	4%
4	10 A @ 20 V	1.8 ms	1%
5	5 A @ 6 V	10 ms	10%



Minimum Programmable Width [1, 3]	100 µs. **Note:** Minimum pulse width for settled source at a given I/V output and load can be longer Pulse than 100 µs.
Pulse Width Programming Resolution	1 µs.
Pulse Width Programming Accuracy	±5 µs.
Pulse Width Jitter	2 µs.

NOTES

1. Times measured from the start of pulse to the start off-time; see figure below.



2. Thermally limited in sink mode (quadrants II and IV) and ambient temperatures above 28 °C. See power equations in the reference manual for more information.
3. Typical performance for minimum settled pulse widths:

Source Value	Load	Source Settling (% of range)	Min. Pulse Width
6 V	2 Ω	0.2%	150 µs
20 V	2 Ω	1%	200 µs
35 V	7 Ω	0.5%	500 µs
40 V	27 Ω	0.1%	400 µs
1.5 A	27 Ω	0.1%	1.5 ms
3 A	2 Ω	0.2%	150 µs
5 A	7 Ω	0.5%	500 µs
10 A	2 Ω	0.5%	200 µs

SMU Measurement Speed Characteristics[1]

Maximum Sweep Operation Rates (operations per second) for 60 Hz (50 Hz)

A/D Converter Speed (NPLC)	Trigger Origin	Measure To Memory Using User Scripts	Measure To USB Using User Scripts	Source Measure To Memory Using User Scripts	Source Measure To USB Using User Scripts	Source Measure To Memory Using Sweep API	Source Measure To USB Using Sweep API
0.001	Internal	20000 (20000)	9800 (9600)	6700 (6700)	6600 (6600)	13400 (13400)	6450 (6450)
0.001	Digital I/O	7400 (7400)	7250 (7250)	5500 (5500)	5400 (5400)	13400 (13400)	6500 (6500)
0.01	Internal	5000 (4300)	3900 (3400)	3300 (3000)	3300 (2900)	4400 (3800)	4400 (3800)
0.01	Digital I/O	3400 (3100)	3400 (3000)	2900 (2700)	2900 (2600)	4400 (3800)	4400 (3800)
0.1	Internal	580 (480)	560 (470)	550 (465)	550 (460)	570 (480)	570 (480)
0.1	Digital I/O	550 (460)	550 (460)	520 (450)	540 (450)	570 (480)	570 (480)
1.0	Internal	59 (49)	59 (49)	59 (49)	59 (49)	59 (49)	59 (49)
1.0	Digital I/O	59 (48)	59 (49)	59 (49)	59 (49)	59 (49)	59 (49)

Maximum Single Measurement Rates (operations per second) for 60 Hz (50 Hz)

A/D Converter Speed (NPLC)	Trigger Origin	Measure To USB	Source Measure To USB	Source Measure Pass/Fail To USB
0.001	Internal	2100 (2100)	1600 (1600)	1600 (1600)
0.01	Internal	1650 (1600)	1400 (1200)	1300 (1150)
0.1	Internal	480 (410)	450 (390)	400 (380)
1.0	Internal	58 (48)	57 (48)	57 (48)

Maximum Measurement Range Change Rate
>7000 per second for >10 µA. When changing to or from a range ≥1 A, maximum rate is >2200/second.

Maximum Source Range Change Rate
>400 per second >10 µA. When changing to or from a range ≥1 A, maximum rate is >190/second.

Maximum Source Function Change Rate
>1000 per second.

Command Processing Time
Maximum time required for the output to begin to change following the receipt of the `smua.source.levelv` or `smua.source.leveli` attribute. <1 ms.

NOTES
1. Exclude current measurement ranges less than 1 mA.

Triggering and Synchronization Characteristics

Triggering

Trigger in to Trigger Out 0.5 µs, typical.

Trigger in to Source Change[1] 10 µs, typical.

Trigger Timer Accuracy ±2 µs, typical.

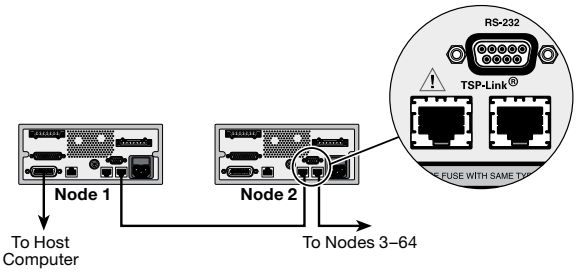
Source Change[1] **After LXI Trigger**
280 µs, typical.

Synchronization
Single-Node Synchronized Source Change[1]**:** <0.5 µs, typical.
Multi-Node Synchronized Source Change[1]**:** <0.5 µs, typical.

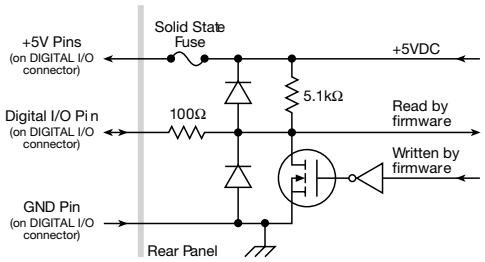
NOTES
1. Fixed source range, with no polarity change.

General

IEEE-488	IEEE-488.1 compliant. Supports IEEE Std 488.2 common commands and status model topology.
USB Control (rear)	USB 2.0 device, USB-TMC488 protocol.
RS-232	Baud rates from 300 bps to 115200 bps.
Ethernet	RJ-45 connector, 10/100BaseT, Auto-MDIX.
Expansion Interface	The TSP-Link expansion interface allows TSP-enabled instruments to trigger and communicate with each other. Cable Type: Category 5e or higher LAN crossover cable. 3 meters (9.84 ft) maximum between each TSP-enabled instrument. A maximum of 32 TSP-Link nodes can be interconnected. Each source-measure instrument uses one TSP-Link node.



LXI Compliance	Version 1.5 LXI Device Specification 2016 compliant.
LXI Timing	**Total Output Trigger Response Time:** 245 µs minimum, 280 µs typical, (not specified) maximum. **Receive LAN[0-7] Event Delay:** Unknown. **Generate LAN[0-7] Event Delay:** Unknown.
Digital I/O Interface	



Connector	25-pin female D.
Input/Output Pins	14 open drain I/O bits.
Absolute Maximum Input Voltage	5.25 V.
Absolute Minimum Input Voltage	–0.25 V.
Maximum Logic Low Input Voltage	0.7 V, +850 µA max.
Minimum Logic High Input Voltage	2.1 V, +570 µA.
Maximum Source Current (flowing out of Digital I/O bit)	+960 µA.
Maximum Sink Current @ Maximum Logic Low Voltage (0.7V)	–5.0 mA.
Absolute Maximum Sink Current (flowing into Digital I/O pin)	–11 mA.
5V Power Supply Pins	Limited to 250 mA total for all three pins, solid-state fuse protected.

USB File System (Front)	**USB 2.0 Host:** Mass storage class device.
Power Supply	100 V to 240 VAC, 50–60 Hz (auto sensing), 240 VA maximum.
Cooling	Forced air. Side intake and rear exhaust. One side must be unobstructed when rack mounted.
EMC	Conforms to European Union EMC Directive.
Safety	NRTL listed to UL61010-1:2008 and CSA C22.2 No. 61010-1. Conforms to European Union Low Voltage Directive.
Dimensions	
2601B-PULSE only	105 mm × 235 mm × 445 mm (4.1 in. high × 9.25 in. wide × 17.5 in. deep).
2601B-PULSE with 2601B-P-INT attached	105 mm × 235 mm × 503 mm (4.1 in. high × 9.25 in. wide × 19.82 in. deep).
Weight	**2601B-PULSE only:** 5.9 kg (13 lb). **2601B-PULSE with 2601B-P-INT attached:** 6.4 kg (14 lb).
Environment	For indoor use only.
Altitude	Maximum 2000 meters above sea level.
Operating	0 °C to 35 °C at up to 70% relative humidity; at 35 °C to 50 °C, derate 3% relative humidity per °C.
Storage	–25 °C to 65 °C.

Supplemental Information

Front Panel Interface	Two-line vacuum fluorescent display (VFD) with keypad and rotary knob.
Display	Show error messages and user defined messages. Display source and limit settings. Show current and voltage measurements. View measurements stored in dedicated reading buffers.
Keypad Operations	Change host interface settings. Save and restore instrument setups. Load and run factory and user defined test scripts (i.e. sequences) that prompt for input and send results to the display. Store measurements into dedicated reading buffers.
Programming	Embedded Test Script Processor (TSP®) accessible from any host interface; responds to high-speed test scripts comprised of remote commands and statements (for example, branching, looping, and math); able to execute test scripts stored in memory without host intervention.
Minimum Memory Available	16 MB (approximately 250,000 lines of TSP code).
Reading Buffers	Nonvolatile memory uses dedicated storage areas reserved for measurement data. Reading buffers are arrays of measurement elements. Each element can store the following items: Measurement Source setting (at the time the measurement was made) Measurement status Range information Timestamp
	Reading buffers can be filled using the front panel STORE key and retrieved using the RECALL key or host interface. **Buffer Size, with timestamp and source setting:** >60,000 samples. **Buffer Size, without timestamp and source setting:** >140,000 samples.
Timer	Free running 47-bit counter with 1 MHz clock input. Reset each time instrument powers up. If the instrument is not turned off, the timer is automatically reset to zero (0) every four years.
Timestamp	TIMER value automatically saved when each measurement is triggered.
Resolution	1 µs.
Accuracy	±100 ppm.

Ordering Information

2601B-PULSE	**2601B-PULSE System SourceMeter 10 µs Pulser/SMU Instrument**

Supplied Accessories

Operators and Programming Manuals	Available at www.tek.com/keithley
2601B-P-INT	2601B-PULSE Rear Panel Interlock and Cable Connector Box
7709-308A	Digital I/O Connector
17469460X	TSP-Link/Ethernet Cable (two per unit)
CS-1616-3	Safety Interlock Mating Connector
2601B-PULSE	QuickStart Guide

Available Accessories

Software

KickStart	Instrument Control Software
LabVIEW and IVI Drivers	Available at www.tek.com/keithley
Test Script Builder Software	Available at www.tek.com/keithley

Rack Mount Kits

4299-1	Single Rack Mount Kit with front and rear support
4299-2	Dual Rack Mount Kit with front and rear support

Cables and Connectors

2600-BAN	Banana Test Leads/Adapter Cable for use with the Channel A: SMU Phoenix Connector ONLY
2600-KIT	Extra screw terminal connector, strain relief, and cover for the Channel A: SMU Phoenix Connector ONLY
2601B-P-INT	2601B-PULSE Rear Panel Interlock and Cable Connector Box
2601B-PULSE-CA1	2601B-PULSE 1.2 meter 50 ohm BNC to BNC Cable Kit
2601B-PULSE-CA2	2601B-PULSE (two per unit) independent 3.0 meter 50 ohm BNC to BNC coax cables used for SHI and SLO. Required accessory for the 2601B-PULSE-CA3 cable set.
2601B-PULSE-CA3	2601B-PULSE 3.0 meter 15 ohm BNC to BNC Cable Kit. The 2601B-PULSE-CA2 option is required with this accessory.
7709-308A	Digital I/O Connector
8606	High Performance Modular Probe Kit. For use with 2600-BAN.
CS-1616-3	Safety Interlock Mating Connector

GPIB Interfaces and Cables

7007-1	Double Shielded GPIB Cable, 1 m (3.3 ft.)
7007-2	Double Shielded GPIB Cable, 2 m (6.6 ft.)
KPCI-488LPA	IEEE-488 Interface/Controller for the PCI Bus
KUSB-488B	IEEE-488 USB-to-GPIB Interface Adapter

Digital I/O, Trigger Link, and TSP-Link

2600-TLINK	Digital I/O to TLINK Adapter Cable, 1 m
17469460X	TSP-Link/Ethernet Cable (two per unit)
CA-126-1A	Digital I/O and Trigger Cable, 1.5 m

Test Fixtures and Adapters

7078-TRX-GND	3-slot make triax to female BNC adapter (guard removed). Used with 8101-PIV and 8101-4TRX test fixtures.
8101-4TRX	4 Pin Transistor Fixture
8101-PIV	DC, Pulse I-V and C-V Component Test Fixture
CS-1252	SMA male to BNC female adapter. Used with 8101-PIV test fixture.

Available Services

Extended Warranties

26xxB-EW	1 Year Factory Warranty extended to 2 years
26xxB-3Y-EW	1 Year Factory Warranty extended to 3 years
26xxB-5Y-EW	1 Year Factory Warranty extended to 5 years

Calibration Contracts

C/26xxB-3Y-STD	3 Calibrations within 3 years
C/26xxB-5Y-STD	5 Calibrations within 5 years
C/26xxB-3Y-DATA	3 Calibrations within 3 years and includes calibration data before and after adjustment
C/26xxB-5Y-DATA	5 Calibrations within 5 years and includes calibration data before and after adjustment
C/26xxB-3Y-17025	3 IS0-17025 accredited calibrations within 3 years
C/26xxB-5Y-17025	5 IS0-17025 accredited calibrations within 5 years

Warranty Information

Warranty Summary	This section summarizes the warranties of the 2601B-PULSE. Any portion of the product that is not manufactured by Keithley is not covered by this warranty and Keithley will have no duty to enforce any other manufacturer's warranties.
Hardware Warranty	Keithley Instruments, LLC. warrants the Keithley manufactured portion of the hardware for a period of one year from defects in materials or workmanship; provided that such defect has not been caused by use of the Keithley hardware which is not in accordance with the hardware instructions. The warranty does not apply upon any modification of Keithley hardware made by the customer or operation of the hardware outside the environmental specifications.
Software Warranty	Keithley warrants for the Keithley produced portion of the software or firmware will conform in all material respects with the published specifications for a period of ninety (90) days; provided the software is used on the product for which it is intended in accordance with the software instructions. Keithley does not warrant that operation of the software will be uninterrupted or error-free, or that the software will be adequate for the customer's intended application. The warranty does not apply upon any modification of the software made by the customer.

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