

Set Up Radio Frequency (RF) and Microwave Laboratory for Education Purpose

Committed to Excellence in Teaching and Learning

Introduction

In radio frequency (RF) and microwave engineering courses, effective learning in education can only be achieved through an approach that integrates theoretical courses with hands-on laboratory. Choosing the correct laboratory setup is crucial in ensuring effective teaching and learning.

Keysight Technologies offers a wide selection of educational teaching solutions which ranges from hardware to software. These similar solutions are also used in the industry, giving students a head start of being industry-ready. From basic to advanced functionality, each instrument delivers benchmark performances to address design and manufacturing requirements; in areas of RF devices and components and applications ranging from basic RF through wireless communication including Internet of Things (IoT), 5G communications, and millimeter wave radar system.

This document is intended to guide you through the selection of instruments and software solutions that best suit your laboratory and budget.

Table of Contents

What Instruments are included in a RF & Microwave Laboratory 3

Selecting a Keysight Signal Generator 6

Selecting a Keysight Signal Analyzer 9

Selecting a Keysight Network Analyzer 11

Expand Your Laboratory Capabilities with Software Solutions 11

The Next Generation of Electronic Design Automation (EDA) Software – PathWave Design 18

RF and Microwave Industry-Ready Student Certification Program..... 25

What Instruments are included in a RF & Microwave Laboratory

In university labs, students learn how to simulate the functionality of components and devices to ensure that devices do not interfere with other users of the radio frequency spectrum. The top three points of considerations in instruments selection are **performance, upgradability, and remote capability**.

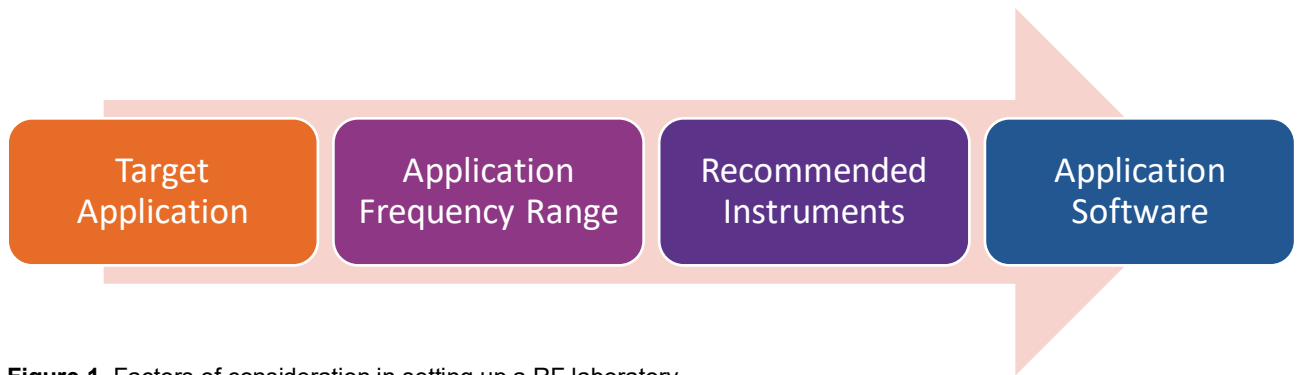


Figure 1. Factors of consideration in setting up a RF laboratory

Application's frequency range

Depending on the targeted application, we need different instruments for different frequency ranges. Here is a quick overview on recommended instruments with frequency range suggested.

Target applications	Instrument's frequency range	Recommended instruments
Basic RF • Frequency modulation demodulate • Amplitude modulation demodulate • Sine wave measurement	9 kHz to 3 GHz	• Analog signal generator • Signal analyzer
Wireless communication • Error vector magnitude test • Transceiver/receiver power and Frequency • Spurious emission	9 kHz to 6 GHz	• Vector signal generator • Signal analyzer
Internet of Things • Error vector magnitude test • Transceiver/receiver power and frequency • Spurious emission	9 kHz to 6 GHz	• Vector signal generator • Signal analyzer
RF component characterization • S-parameter • Gain compression	9 kHz to 6 GHz	• Vector network analyzer • FieldFox
Electromagnetic, and Antenna & Propagation • S-parameter • Phase array • Transceiver/receiver power and frequency	9 kHz to 6 GHz	• FieldFox • Vector network analyzer

Recommended instrument selection options

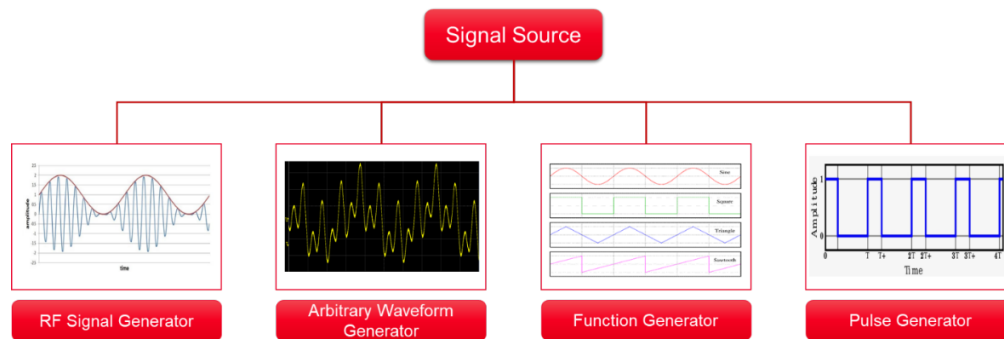


Figure 2. Types of signal sources

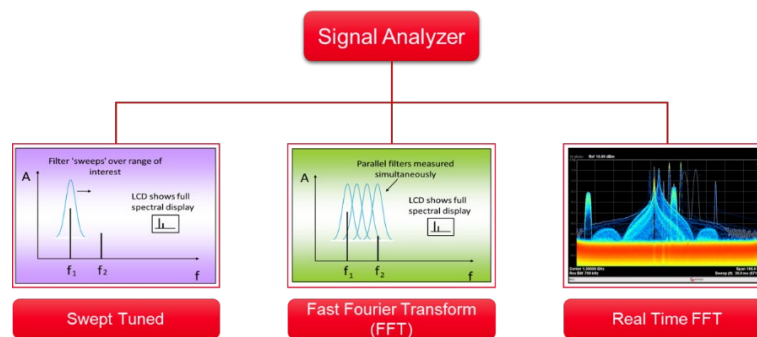


Figure 3. Types of signal analyzers

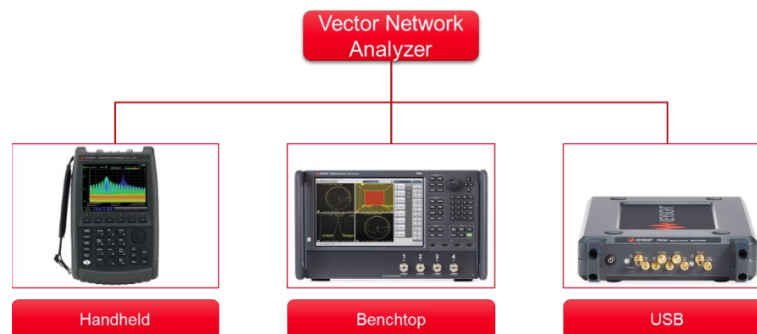


Figure 4. Types of vector network analyzers

Selecting a Keysight Signal Generator

Comparison summary – Benchtop analog signal generators

Specifications model number	MXG MW N5183B	EXG MW N5173B	PSG RF E8663D	MXG RF N5181B	EXG RF N5171B	RF N9310A
Performance	****	***	****	****	***	**
Frequency range (min. to max.)	9 kHz to 40 GHz	9 kHz to 40 GHz	100 kHz to 9 GHz	9 kHz to 6 GHz	9 kHz to 6 GHz	9 kHz to 3 GHz
Frequency switching (list mode)	600 μ s	600 μ s	9 ms	800 μ s	800 μ s	10 ms
Sweep mode	list, step	list, step	list, step, ramp	list, step	list, step	list, step
Output power (minimum)	-130 dBm	-130 dBm	-135 dBm	-144 dBm	-144 dBm	-127 dBm
Output power (at 1 GHz)	+20 dBm (at 20 GHz)	+20 dBm (at 20 GHz)	+23 dBm	+24 dBm	+21 dBm	+13 dBm
Level accuracy	± 0.7 dB (at 20 GHz)	± 0.7 dB (at 10 GHz)	± 0.6 dB	± 0.6 dB	± 0.6 dB	± 1.0 dB
SSB phase noise (1 GHz, 20 kHz offset)	-124 dBc/Hz (at 10 GHz)	-101 dBc/Hz (at 10 GHz)	-143 dBc/Hz (at 10 kHz offset)	-146 dBc/Hz	-122 dBc/Hz	-95 dBc/Hz
Harmonics (at 1 GHz)	-55 dBc (at 10 GHz)	-55 dBc (at 10 GHz)	-55 dBc	-35 dBc	-35 dBc	-30 dBc
Non-harmonics (at 1 GHz)	-100 dBc	-72 dBc	-88 dBc	-96 dBc	-72 dBc	-50 dBc
AM rate	DC to 100 kHz	DC to 100 kHz	DC to 100 kHz	DC to 50 kHz	DC to 50 kHz	20 Hz to 20 kHz
FM deviation (maximum)	1 to 128 MHz	2.5 to 320 MHz	1 to 16 MHz	1 to 16 MHz	2.5 to 40 MHz	100 kHz
PM phase deviation (maximum in normal mode)	0.5 to 64 rad	1.25 to 160 rad	1 to 160 rad	0.5 to 8 rad	1.25 to 20 rad	10 rad
Narrow pulse width	20 ns	20 ns	20 ns	20 ns	20 ns	100 μ s

Comparison Summary – Benchtop vector signal generators

Specifications model number	PSG MW E8267D	MXG RF N5182B	EXG RF N5172B	CXG N5166B
Performance	*****	****	***	**
Frequency range (min. to max.)	100 kHz to 44 GHz	9 kHz to 6 GHz	9 kHz to 6 GHz	9 kHz to 6 GHz
Frequency switching (list mode)	9 ms	800 μ s	800 μ s	5 ms
Sweep mode	Step, list, ramp	Step, list	Step, list	Step, list
Output power (minimum)	-130 dBm	-144 dBm	-144 dBm	-144 dBm
Output power (at 1 GHz)	$\pm$ 21 dBm	$\pm$ 24 dBm	$\pm$ 21 dBm	$\pm$ 18 dBm
Level accuracy	$\pm$ 0.6 dB	$\pm$ 0.6 dB	$\pm$ 0.6 dB	$\pm$ 0.6 dB
SSB phase noise (1 GHz, 20 kHz offset)	-143 dBc/Hz (at 10 kHz offset)	-146 dBc/Hz	-122 dBc/Hz	-119 dBc/Hz
Harmonics (at 1 GHz)	-55 dBc	-35 dBc	-35 dBc	-35 dBc
Non-harmonics (at 1 GHz)	-88 dBc	-96 dBc	-72 dBc	-72 dBc
AM rate	DC to 100 kHz	DC to 50 kHz	DC to 50 kHz	DC to 50 kHz
FM deviation (maximum)	1 to 128 MHz	1 to 16 MHz	2.5 to 40 MHz	2.5 to 40 MHz
PM phase deviation (maximum in normal mode)	1 to 800 rad	0.5 to 8 rad	1.25 to 20 rad	1.25 to 20 rad
Narrow pulse width	20 ns	20 ns	20 ns	20 Msa
EVM (LTE)	0.8%	0.2%	0.2%	0.2°
ACPR (3GP W-CDMA TM1 64 DPCH)	-64 dBc (16QAM, 10 GHz)	-73 dBc	-73 dBc	-70 dBc
Internal baseband generator RF BW	80 MHz	160 MHz	160 MHz	120 MHz
Waveform playback memory	64 Msa	1024 Msa	512 Msa	512 Msa
Baseband generator mode	Waveform playback and real-time	Waveform playback and real-time	Waveform playback and real-time	Waveform playback

Application capability comparison – Analog signal generator

Measurements/applications	MXG MW N5183B	EXG MW N5173B	PSG RF E8663D	MXG RF N5181B	EXG RF N5171B	RF N9310A
Instrument embedded capabilities						
USB power meter	•	•		•	•	
Step/list sweep	•	•	•	•	•	•
Ramp sweep			•			
AM, FM, PM, pulse	•	•	•	•	•	•
LF function generator	•	•	•	•	•	•
Pulse train	•	•		•	•	

Application capability comparison – Vector signal generator

Measurements/applications	PSG MW E8267D	MXG N5182B	EXG N5172B	CXG N5166B
Instrument embedded capabilities				
USB power meter		•	•	•
Step/list sweep	•	•	•	•
Ramp sweep	•			
AM, FM, PM, pulse	•			
LF function generator	•			
Real-time custom modulation (PSK, QAM, FSK)	•			
Phase noise impairments				
Multitone, NPR	•			
Noise (calibrated AWGN)	•			
Pulse train				
BERT				
SystemVue, MATLAB	•	•	•	•
Real-time fading		•	•	
Signal studio software				
Cellular communications				
LTE FDD/TDD	•	•	•	•
LTE-Advanced FDD/TDD	•	•	•	•
W-CDMA/HSPA+, cdma2000®	•	•	•	•
V2X	•	•	•	•
5G NR		•	•	•
Wireless networking				
WLAN 802.11a/b/g/j/p/n/ac/ah, Mobile WiMAX™, Bluetooth®	•	•	•	•
Internet of Things (IoT)	•	•	•	•
DFS radar profiles	•	•	•	•
Mobile WiMAX	•	•	•	
Audio/video broadcast				
DVB-T/H/T2/S/S2, DVB-C (J.83 Annex A/C), J.83 Annex B (DOCSIS DS), ISDB-T/Tmm, ATSC, ATCS-M/H, DTMB (CTTB), CMMB	•	•	•	
T-DMB, DAB/DAB+/DMB-audio, FM stereo with RDS/RBDS		•	•	
Land Mobile Radio (LMR)		•	•	
Detection, positioning, tracking, navigation				
Global Navigation Satellite System (GNSS) GPS, GLONASS, Galileo, Beidou, SBAS, QZSS	•	•	•	•
General RF				
Custom modulation	•	•	•	•
Pulse building	•	•	•	
Multitone distortion, NPR	•	•	•	
Power amplifier	•	•	•	
IQ Waveform Toolkit	•	•	•	•

Selecting a Keysight Signal Analyzer

Comparison summary – Benchtop low cost RF spectrum analyzers

Specifications model number	BSA N9320B	BSA N9321C	BSA N9322C	BSA N9323C	BSA N9324C
Frequency range (min. to max.)	9 kHz to 3 GHz	9 kHz to 4 GHz	9 kHz to 7 GHz	1 MHz to 13.6 GHz	1 MHz to 20 GHz
Maximum analysis bandwidth	1 MHz	1 MHz	1 MHz	1 MHz	1 MHz
Amplitude accuracy	± 0.50 dB	± 0.60 dB	± 0.60 dB	± 0.60 dB	± 0.60 dB
Dynamic range, max third order at 1 GHz	76 dB	83 dB	83 dB	83 dB	83 dB
Displayed Average Noise Level (DANL) at 1 GHz	-145 dB	-152 dBm	-152 dBm	-152 dBm	-152 dBm
Third Order Intercept (TOI) at 1 GHz	13 dBm	15 dBm	15 dBm	15 dBm	15 dBm
Phase noise at 1 GHz, 10 kHz offset	-90 dBc/Hz	-90 dBc/Hz	-90 dBc/Hz	-90 dBc/Hz	-90 dBc/Hz

Comparison summary – Benchtop performance signal analyzers

Specifications model number	CXA N9000B	EXA N9010B	MXA N9020B	MXA N9021B
Frequency range (min. to max.)	9 kHz to 26.5 GHz	10 Hz to 44 GHz (Mixer to 1.1 THz)	10 Hz to 50 GHz (Mixer to 1.1 THz)	10 Hz to 50 GHz (Mixer to 1.1 THz)
Maximum analysis bandwidth	25 MHz	40 MHz	160 MHz	510 MHz
Amplitude accuracy	± 0.50 dB	± 0.27 dB	± 0.23 dB	± 0.41 dB
Dynamic range, max third order at 1 GHz	111 dB	112 dB	116 dB	116 dB
Displayed Average Noise Level (DANL) at 1 GHz	-163 dBm	-172 dBm	-114 dBm	-172 dB,
Third Order Intercept (TOI) at 1 GHz	17 dBm	18 dBm	20 dBm	20 dBm
Phase noise at 1 GHz, 10 kHz offset	-110 dBc/Hz	-109 dBc/Hz	-114 dBc/Hz	-129 dBc/Hz

Application capability comparison – Signal analyzer and spectrum analyzer

Measurements/applications	MXA	EXA	CXA	BSA
General purpose				
AM/FM tune and listen	•	•	•	•
Analog demodulation	•	•	•	•
EMI pre-compliance	•	•	•	
Enhanced display package (spectrogram plus)	•	•	•	•
Stimulus/response measurement	•	•	•	•
Flexible digital modulation analysis	•	•	•	•
MATLAB	•	•	•	
Noise figure	•	•	•	
Phase noise	•	•	•	
Pulse	•	•	•	
Real-time spectrum analysis	•			
856xE/EC and 8566/68	•	•		
SCPI language compatibility	•	•	•	•
Cellular communications				
1xEV-DO	•	•	•	
cdma2000/cdmaOne	•	•	•	
GSM/EDGE/EVO	•	•	•	
iDEN/WiDEN/MotoTalk	•	•		
LTE FDD and TDD	•	•	•	
LTE-Advanced FDD and TDD	•	•		
Multi-standard radio (MSR)	•	•	•	
TD-SCDMA/HSPA	•	•	•	
W-CDMA/HSPA+	•	•	•	
Wireless connectivity				
Bluetooth®	•	•	•	
Fixed WiMAX™	•	•		
Mobile WiMAX™	•	•	•	
WLAN 802.11a/b/g/n/ac	•	•	•	
ZigBee	•	•	•	
Digital video				
CMMB	•	•	•	
Digital cable TV	•	•	•	
DTMB	•	•	•	
DVB-T/H/T2	•	•	•	
ISDB-T/T _{SB} /T _{MM}	•	•	•	
PowerSuite one-button measurements				
Channel power	•	•	•	•
Occupied bandwidth	•	•	•	•
Multicarrier, multi-offset ACP	•	•	•	•
Multicarrier power	•	•	•	
CCDF	•	•	•	
Harmonic distortion	•	•	•	
Burst power	•	•	•	
Intermodulation (TOI)	•	•	•	•
Spurious emissions	•	•	•	
Spectrum emission mask	•	•	•	•

Selecting a Keysight Network Analyzer

Comparison summary – Benchtop, handheld, and USB vector network analyzers

Form factor	Benchtop	Benchtop	Benchtop	USB	USB	Handheld	Handheld
Specifications	ENA	ENA	ENA	VNA	VNA	FieldFox	FieldFox
Model number	E5063A	E5061B	E5080B	P9370A	P9375A	N9913B	N9918B
Frequency range	100 kHz to 18 GHz	5 Hz to 3 GHz	9 kHz to 20 GHz	300 kHz to 4.5 GHz	300 kHz to 26.5 GHz	30 kHz to 4 GHz	30 kHz to 26.5 GHz
Dynamic range	117 dB	120 dB	140 dB	115 dB	115 dB	114 dB	113 dB
Output power (max)	0 dBm	10 dBm	10 dBm	7 dBm	7 dBm	9 dBm	9 dBm
Number of ports	2	2	2, 4	2	2	2	2

Expand Your Laboratory Capabilities with Software Solutions

It is important that lab managers keep their labs updated and relevant, aligned to digital transformation needs. Online learning and lab management solutions have been a part of many educational institutions since the spread of the internet. These days, the adaptability of being able to switch between traditional in-person learning to virtual classes on digital platforms is an advantage. Remote learning offers students the flexibility of learning at any time, from anywhere; while lab management and control solutions also helps lab managers to manage their instruments conveniently.

PathWave lab operations for remote learning

Keysight's PathWave lab operation for remote learning software offers a convenient way to switch to online learning. This end-to-end solution allows the complete remote setup of instrument labs. It covers all your needs, including web-based lab management, scheduling administration, instrument control, and remote access for measurement and analysis.

Features overview

Purpose-built, single-point, cloud-based remote access, and control

- No installation, no maintenance, accessed via a web browser, anytime, anywhere
- Built-in SSO and MFA security options
- Standard 10 benches setup
- Support up to 50 concurrent user access
- On-premises solution – local installation at customer's computer/server

Schedule and manage remote lab session

- User role management
- Student bench grouping
- Email notifications

Smart teaching and learning with intuitive interaction tools

- Chat room for better participation and engagement
- File transfer enables better group collaboration during lab sessions

Integrate learning management system through IMS Global certified LTI learning tool.

Remote desktop control

- Remotely access the lab bench PC
- View available instruments list connected to bench PC
- Connect and start lab session control

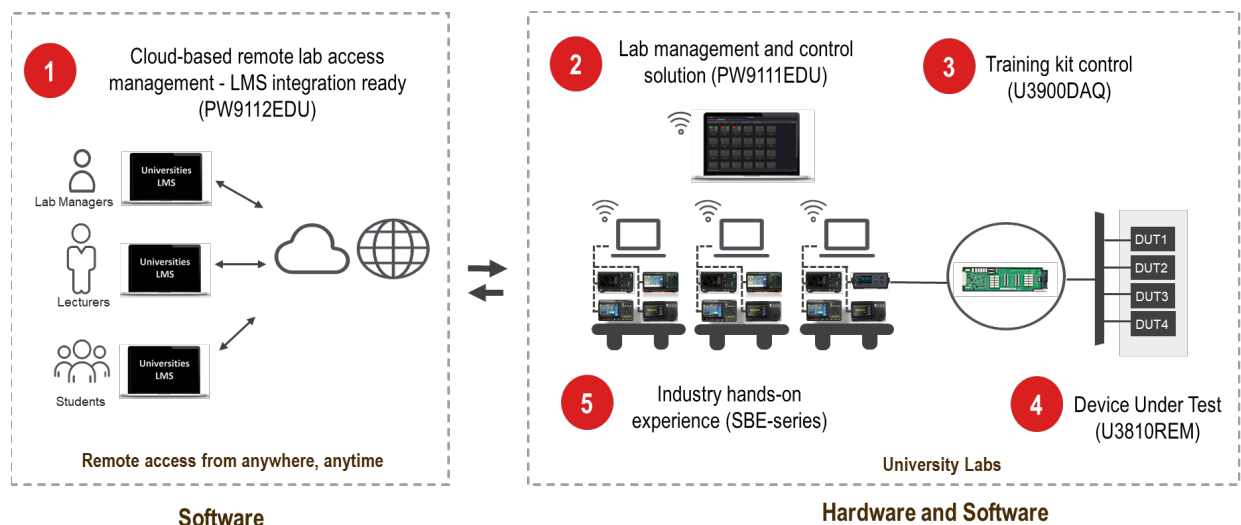


Figure 5. Overview of Keysight's industry-ready remote access lab solution

PathWave BenchVue lab management and control solution

PathWave BenchVue lab management and control solution is a network-based application software that enables all instruments to be interconnected via LAN or WLAN. It provides centralized control for educators to seamlessly connect and monitor all the instruments within the teaching lab.

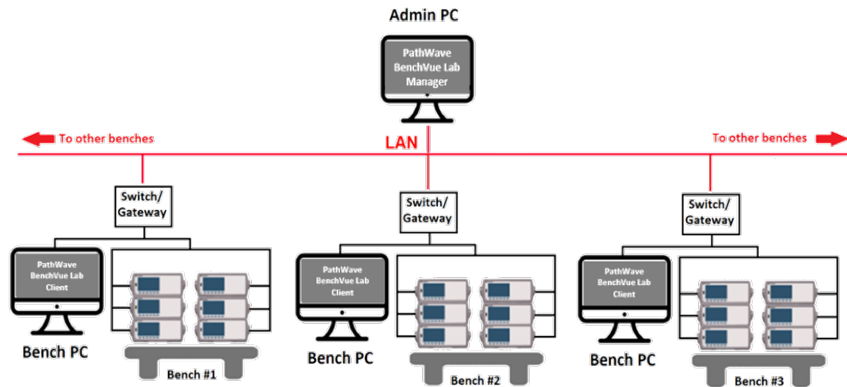


Figure 6. Setup of the PathWave BenchVue lab management and control solution

Features overview

1. Check instruments statuses
2. Configure instruments all at once
3. Asset tracking
4. Instruments mass firmware update
5. Multiple instruments integrated control
6. Test flow for automated sequence measurements (applicable for selected model only)



Figure 7. Multiple instruments integrated control with PathWave BenchVue complete control collection

PathWave BenchVue software

Keysight's PathWave BenchVue software for the PC eliminates many of the issues around bench testing. By making it simple to connect, control instruments, and automate test sequences you can quickly move past the test development phase and access results faster than ever before. Dedicated instruments apps allow you to quickly configure the most used measurements and setups for each instrument family. The Test Flow enabled apps help you drastically shorten your development of automated programs and further streamline your workflow.

Model	Name	Supported instruments
BV9001B	BenchVue complete control collection	Support all apps available in BenchVue with full access
BV0001B	BenchVue digital multimeter control app	34401A, 34405A, 34410A, 34411A, 34420A, 34450A, 34460A, 34461A, 34465A, 34470A, EDU34450A
BV0002B	BenchVue function generator control app	33600 Series, 33509B, 33510B, 33519B, 33520B, 33511B, 33512B, 33521B, 33522B, EDU33211A, EDU33212A
BV0003B	BenchVue power supply control app	B29xxA Series, B2961A/62A, E3600 Series, E36100 Series, E36200 Series, E36300 Series, N5700 Series, N6700A/B/C, N6701A/C, N6702A/C, N6705A/B/C, N6785A, N6786A, N6900 Series, N7900 Series, N8700 Series, N8900 Series, RP7900 Series, B28xxB, B2901BL, B2910BL, N67xxA, N67xxB, EDU36311A
BV0004B	BenchVue oscilloscope control app	1000-X Series, 2000-X Series, 3000-X Series, 4000-X Series, 6000 Series, 7000 Series, 9000 Series, 90000 Series, 90000 X-Series, 90000 DSA Series, P924xA Series, S Series, V Series, Z Series
BV0006B	BenchVue data acquisition control & analysis app	34970A, 34972A, 34980A, DAQ970A, DAQ973A
BV0007B	BenchVue power meter/power sensor control & analysis app	U2021XA, U2022XA, U2404x XA, U205x XA, U206x XA, U2000 Series, U2053/63 Series, L2050/60 Series, U848x Series, N191xA, N8262A
BV0010B	BenchVue FieldFox handheld analyzer control & automation app	N9912A-N9918A, N9923A-N9928A, N9935A-N9938A, N9950A-N9951A, N9960A-N9962A
BV0011B	Universal counter control & automation app	53210A, 53220A, 53230A
BV0012B	BenchVue electronic load control & automation app	N3300A, N3301A, 6060B, 6063B, EL33133A, EL34143A, EL34243A
BV9001B	BenchVue spectrum analyzer control & automation app (exclusively available in the BenchVue complete control collection)	X-Series (N9040B, N9030A/B, N9020A/B, N9010A/B, N9000A/B, M9290A), N934xC, E440xB, L44xxB, E444x, N932xB/C
BV9001B	BenchVue network analyzer control & automation app (exclusively available in the BenchVue complete control collection)	E50xxA/B/C, N5222xA/B, N523xA/B/C, N524xA/B, M37xA, M9485A
BV9001B	BenchVue signal generator control & automation app (exclusively available in the BenchVue complete control collection)	E4428C, E4438C, E8257D, E8267D, E8663D, N517xB, N518xA/B
Free download	BenchVue power analyzer control & automation	PA2201A, PA2203A
BV0013B	BenchVue current analyzer control & analysis app	CX3322A, CX3324A
BV0014B	BenchVue LCR meter control & automation	E4980A, E4980AL
BV0021B	USB modular digital multimeter control pro app	U2741A
BV0022B	USB modular function generator control pro app	U2761A
BV0023B	USB modular Source Measure Unit (SMU) control pro app	U2722A, U2723A
BV0024B	USB modular oscilloscope control pro app	U2701A, U2702A
BV0025B	USB modular data acquisition control pro app	U2351A-U2356A, U2331A, U2521A, U2541A, U2542A, U2651A-U2653A
BV0026B	AC source control app	AC6906L / H, AC6912L / H, AC6918L / H
BV9201B	Advanced power control and analysis for a single instrument	N6705C, N7900 Series, RP7900 Series
BV9200B	Advanced power control and analysis support up to four instruments	N6705C, N7900 Series, RP7900 Series

PathWave Vector Signal Analysis (89600 VSA)

Development becomes more complex when faster data rates intersect with today's crowded spectral environment. Finding a signal problem is essential but achieving the clarity to pinpoint the answer is the crucial challenge. PathWave Vector Signal Analysis (VSA) software is a comprehensive set of tools for demodulation and vector signal analysis. These tools enable you to explore virtually every facet of a signal and optimize your most advanced designs.

Model	Name	Description
Base		
89601200C (required core option)	Basic vector signal analysis and hardware connectivity	• Time and frequency domain analysis with up to 409,601 point of FFT • Flexible traces and displays with simultaneous and multi-measurements • Analog demodulation of AM, FM, PM signals • AM/AM, AM/PM and gain compression for power amplifiers • Trigger with selectable level, slope, delay and hold-off • Record the acquired signal waveforms to playback for troubleshooting • Make group delay measurement using a simple wideband multi-tone stimulus signal (channel quality mod analysis) • Import/export the multi-tone stimulus definition from/to Keysight N7621B Signal Studio software (channel quality mod analysis) • Make multiple measurement with synchronous (simultaneous) or sequenced acquisition mode • Calibrate the input stimulus model with measured signal data (channel quality mod analysis) • Perform simple and repeatable phase and magnitude channel response analysis (channel quality mod analysis) • Links to Keysight EDA PathWave SystemVue and ADS • Connectivity to more than 45 Keysight signal analyzer hardware platforms including X-series signal analyzer, oscilloscopes, logic analyzers, transceivers, digitizer, vector network analyzer, RF sensor, wireless test set, radio test set etc. • Connectivity to Keysight signal generators for source control • Power spectrum with PXIe VSA M9393A/M9391A
General purpose		
89601AYAC	Digital modulation analysis	• Analysis of >40 modulation formats including custom APSK and preset for communication formats like GSM/EDGE, ZigBee FSK, <i>Bluetooth</i>® BR, APCO25 ad SOQPSK • Proprietary and pre-standard, customized IQ constellation signals • TEDS modulation analysis • Channel response measurements such as phase/magnitude response and multi-tone group delay • Flexible frame analysis
89601BHFC	Custom OFDM modulation analysis	Proprietary and pre-standard OFDM formats such as WLAN, DAB, DVB-T/H, DVB-SH, ISDB-T and more
89601PSMC	PowerSuite measurement	Support PowerSuite SEM and ACP measurement with FFT mode
89601101C	Direct data connectivity	Allow user to use their own data input stream for 89600 VSA measurement

Model	Name	Description
Cellular communication		
89601BHNC	5G NR modulation analysis	• 5G NR modulation analysis • Pre-5G modulation analysis
89601BHGC	LTE/LTE-A FDD modulation analysis	• LTE FDD modulation analysis • LTE-Advanced FDD modulation analysis
89601BHHC	LTE/LTE-A TDD modulation analysis	• LTE TDD modulation analysis • LTE-Advanced TDD modulation analysis
89601B7NC	3G modulation analysis bundle	• W-CDMA/HSPA+ modulation analysis • TD-SCDMA/HSPA modulation analysis • cdma2000 modulation analysis • 1xEV-DO modulation analysis • 1xEV-DV modulation analysis
Wireless connectivity		
89601B7RF	Wireless connectivity modulation analysis	• WLAN 802.11a/b/g/j/p modulation analysis • WiMax® modulation analysis
89601BHXC	High throughput WLAN modulation analysis	• WLAN 802.11n/ac modulation analysis • WLAN 802.11ax modulation analysis • WLAN 802.11be modulation analysis
89601BHTC	IoT modulation analysis	• NB-IoT modulation analysis • RFID modulation analysis • IEEE 802.15.4/4z UWB HRP
Radar analysis		
89601BHQC	Pulse analysis	• Pulsed modulated radar signal analysis • Frequency hopping signal analysis
89601BHPC	FMCW radar analysis	For multi-chirp linear FM modulated signals or automotive radar
Other standard formats		
89601BHMC	DOCSIS modulation analysis	DOCSIS3.1 downstream and upstream modulation analysis
89601301C	Multi-vendor hardware connectivity	Connect multi-vendor hardware for modulation analysis
89601EVMC	Cross-correlated EVM	Improve the EM performance by noise cancellation by multiple receivers working with modulation analysis
89601CC1C	Phase coherent channel count expander up to 8-port	Phase coherent channel count expander up to 8-port with sequential acquisition
89601CC2C	Phase coherent channel count expander up to 64-port	Phase coherent channel count expander up to 64-port with sequential acquisition

The Next Generation of Electronic Design Automation (EDA) Software – PathWave Design

Keysight's PathWave design software is a suite of electronic design automation software tools that accelerates product development by reducing the time engineers spend in the design and simulation phases. Its libraries and customized simulators reduce setup time. The software seamlessly integrates circuit design, electromagnetic (EM) simulation, layout capabilities, and system level modeling, reducing time spent in importing and exporting designs and fixing errors associated with changing tools. Improvements in data analytics allow for faster analysis and more timely design decisions.

PathWave design software provides engineers with new tools and software enhancements to bring efficiencies into their RF and microwave, 5G, automotive, and DDR memory design flows, shortening the design cycle and reducing project delays.

Now that students get to learn and master these engineering tools before they start the careers, they can be more efficient and effective in their student projects and be able to integrate seamlessly when they start working.

PathWave Advanced Design System (ADS)

PathWave Advanced Design System (ADS) is Keysight's leading RF, microwave, signal integrity, and power integrity design platform. With multiple libraries, bundles, design guides, and simulation elements, PathWave ADS is the one software tool to help you overcome any design challenge.

PathWave ADS provides a complete, integrated set of easy-to-use 3D EM circuit and system simulators. Designers can perform EM and circuit co-simulation in one single tool. PathWave ADS combines schematic, layout, circuit, electro-thermal co-simulation, and three full-wave 3D EM technologies with integrated circuit (IC), package, laminate, PCB, and 3D EM component co-design in one software tool to dramatically improve productivity and reduce cost.

PathWave ADS bundles comprise of one or more of these key building blocks

Key building block	Description
ADS core	ADS platform, schematic capture, data display and much more
EM design core	A 3D solid modeling environment, formerly called EMPro
Layout	Comprehensive physical design environment including native and links to 3 rd part DRC, LVS and more
HB	Harmonic Balance
RF Ckt Sim	Linear, harmonic balance, circuit envelope, and transient/convolution circuit simulators
RFPro	Simplified EM analysis user interface and Momentum 3D Planar and FEM full 3D EM simulation technologies with predictive expert settings
Sys-Ckt ver	Ptolemy system and verification test bench engine simulators
Comp VTBs	Complete set of verification test benches libraries
Electro-thermal simulator	
HSD Ckt sim	Channel simulation, CILD, and via designer and more
Mem designer	Memory designer and DDR bus simulator
PIPro	PI analysis of PDN, including DC IR drop analysis, AC impedance analysis and power plane resonance analysis
SIPro	SI analysis of complex high-speed PCBs
PEPro	EM-circuit co-simulation platform for SMPS designs
PE Ckt sim	Combines transient convolution simulator with the PE library

Key building block	Base W3600B	Base W3601B	RF W3602B	RF W3603B	RF W3604B	RF W3605B	RF W3606B	RF W3607B	RF W3608B
ADS core	•	•	•	•	•	•	•	•	•
EM design core	•	•	•	•	•	•	•	•	•
Layout		•	•	•	•	•	•	•	•
HB			•			•			
Momentum						•			
RF Ckt sim				•			•	•	•
RFPro					•		•	•	•
Sys-Ckt ver								•	•
Comp VTBs									•

Key building block	High speed digital W3621B	High speed digital W3622B	High speed digital W3623B	High speed digital W3624B	High speed digital W3625B	High speed digital W3626B	High speed digital W3627B	Power electronics W3631B
ADS core	•	•	•	•	•	•	•	•
EM design core	•	•	•	•	•	•	•	•
Layout			•	•	•	•	•	•
HSD Ckt sim	•	•	•	•	•	•	•	
Mem designer		•				•		
PIPro			•		•	•	•	
SIPro				•	•	•	•	
PEPro								•
PE Ckt sim								•
FEM (EMPro)							•	

PathWave EM Design (EMPro)

PathWave EM Design software is a 3D modeling and simulation environment for analyzing the 3D electromagnetic (EM) effects of high-speed and RF/microwave components. EMPro features a modern design, simulation and analysis environment, high-capacity time and frequency domain simulation technologies and integration with ADS, the industry's leading RF/microwave and high-speed design environment.

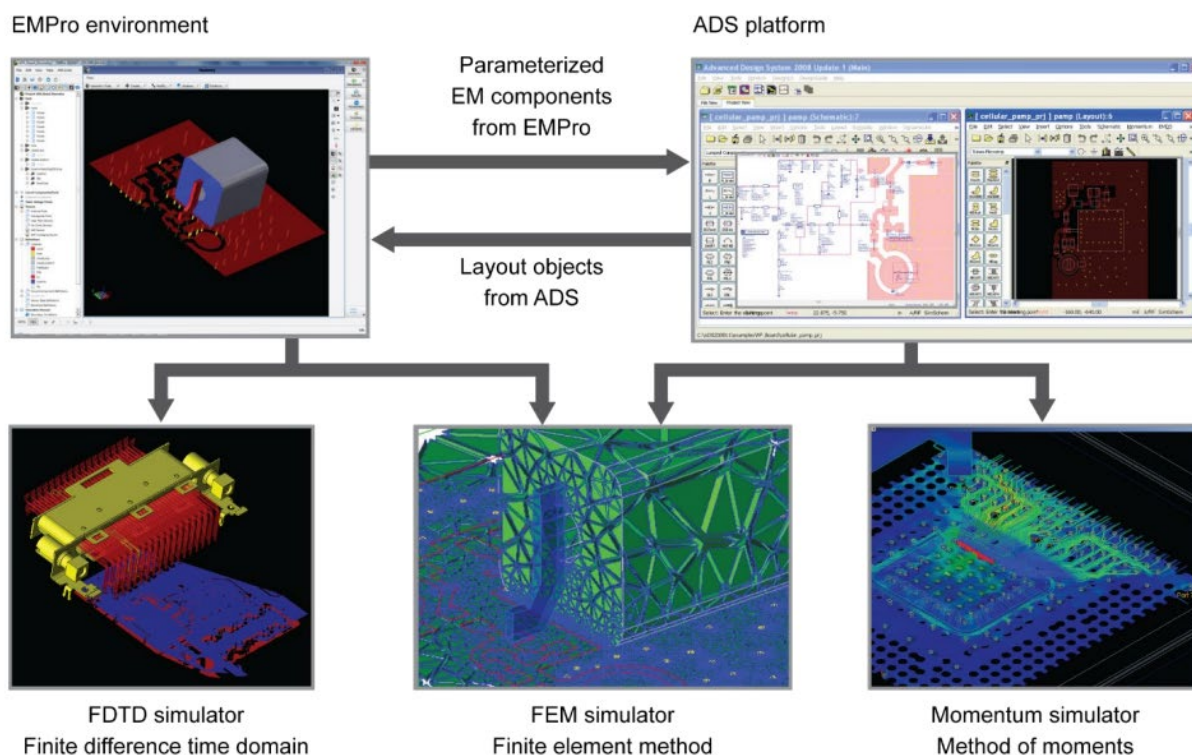


Figure 8. Keysight provides multiple EM simulation technologies integrated with the ADS design flow

Model	Name	Description
EM design bundles		
W4300B	PathWave EM design (EMPro) core	3D solid modeling environment for creating arbitrary 3D objects and importing existing models from other CAD environments. Note: EM Design Core requires a separate EM simulator (e.g. FEM or FDTD) to run EM simulations
W4301B	PathWave EM design (EMPro) core + ADS RFPPro UI + FEM	3D solid modeling environment and Finite Element Method (FEM) simulator; also includes the RFPPro user interface for use in ADS
W4302B	PathWave EM design (EMPro) core + FDTD + Compliance module	3D solid modeling environment, Finite Difference Time Domain (FDTD) simulator and compliance module
W4303B	PathWave EM design (EMPro) core + ADS RFPPro UI + FEM + FDTD + Compliance module	3D solid modeling environment, Finite Difference Time Domain (FDTD) simulator and compliance module. Includes RFPPro user interface for use in ADS
Elements		
W3032E	PathWave FEM	3D Finite Element Method (FEM) simulator; for use with the PathWave EM design (EMPro) core environment and in PathWave ADS core
W4005E	PathWave FDTD	3D EM simulation engine based on the Finite Difference Time Domain (FDTD) modeling technique, for use with the PathWave EM design (EMPro) core
W4006E	Compliance module	Advanced testing algorithms for applications such as hearing aid compatibility (HAC) and specific absorption ratio (SAR)

PathWave RF Synthesis (Genesys)

PathWave RF Synthesis (Genesys) is an affordable, accurate, easy-to-use RF and microwave circuit synthesis and simulation software created for the circuit board and subsystem designer. Providing the optimal balance of capabilities with ease-of-use, designers can quickly attain the skills necessary to operate the tool while realizing unbeatable engineering productivity through multiple powerful automatic RF circuit synthesis technologies.

PathWave RF Synthesis bundles comprise of one or more of these key building blocks

Key building block	Description
Core	Schematic, Layout, Linear Analysis, Optimization, MATLAB script, Instrument links
Synthesis	Filters (active, passive, distributed, custom response), Match, Oscillator, Mixer, Signal Control, Equalizer, Transmission Lines, PLL, Vendor Parts Selection
System	System simulation, Budget analysis & Frequency Planning synthesis
Modulated RF	Modulated RF system analysis of EVM, BER and ACPR with WLAN & LTE verification
Circuit	Harmonic Balance & Transient circuit simulation
EM	3D Planar Electromagnetic simulation of printed circuits and antennas

Key building block	W5300B	W5301B	W5302B	W5303B	W5304B	W5305B	W5306B	W5307B	W5308B	W5309B
Environment										
Genesys core	•	•	•	•	•	•	•	•	•	•
Testlink	•	•	•	•	•	•	•	•	•	•
Synthesis										
Filter		•		•	•	•		•	•	•
M / Filter		•		•	•	•		•	•	•
Match		•		•	•	•		•	•	•
Advanced time		•		•	•	•		•	•	•
S / Filter		•		•	•	•		•	•	•
A / Filter		•		•	•	•		•	•	•
Equalize		•		•	•	•		•	•	•
Oscillator		•		•	•	•		•	•	•
PLL		•		•	•	•		•	•	•
Signal control		•		•	•	•		•	•	•
Mixer		•		•	•	•		•	•	•
Vendor parts		•		•	•	•		•	•	•
Circuit simulator										
Harbec				•		•			•	•
Cayenne				•		•			•	•
System simulator										
Spectrasys			•				•	•	•	•
WhatIF			•				•	•	•	•
Modulated-RF										
Dataflow simulator							•	•	•	•
EVM budget analysis							•	•	•	•
LTE, WLAN Verification							•	•	•	•
EM simulator										
Momentum					•	•				•
EMPro link					•	•				•
Sonnet link					•	•				•

PathWave RFIC Design (GoldenGate)

PathWave RFIC Design (GoldenGate) is the most trusted simulation, analysis and verification solution available for integrated RF circuit design within Cadence Virtuoso. GoldenGate offers unique simulation algorithms that enable full characterization of transceivers prior to tape-out.

Key building block	Description
RFIC design core	ADS platform, schematic capture, data display and much more
EM design core	A 3D solid modeling environment, formerly called EMPro
Layout	Comprehensive physical design environment including native and links to 3 rd part DRC, LVS and more in
HB	Harmonic Balance
RF Ckt Sim	Linear, harmonic balance, circuit envelope, and transient/convolution circuit simulators
RFPro	Simplified EM analysis user interface and Momentum 3D Planar and FEM full 3D EM simulation technologies with predictive expert settings
Sys-Ckt Ver	Ptolemy system and verification test bench engine simulators
Comp VTBs	Complete set of verification test benches libraries

Key building block	W5802B	W5803B	W5804B	W3611B	W3612B	W3613B	W3614B	W3609B
	Virtuoso-only flow			ADS & Virtuoso flow & packaging				
PathWave RFIC design	•	•	•	•	•	•	•	•
Virtual Test Bench (VTB) engine	•		•					•
Comp VTB	•		•					•
RFPro		•	•					•
PathWave ADS core				•	•	•	•	•
EM design core				•	•	•	•	•
RF circuit sim				•	•	•	•	
Layout						•	•	•
RF Ckt sim								•
Sys-Ckt ver								•

PathWave System Design (SystemVue)

RF system design challenges include mmWave frequencies, multiple antennas, complex modulation, beam steering, and sophisticated algorithms. Rough estimates, figures and formulas on spreadsheets, and internal or custom tool have trouble keeping pace.

PathWave System Design (SystemVue) bring teams multi-domain modeling and simulation in one collaborative design environment for complex RF systems. It goes beyond math-based modeling with a complete RF-aware design workflow, plus decades of Keysight measurement science in RF instrumentation, ready for any system architect.

Model	Name	Description
System design		
W4800B	PathWave System Design core	Base environment for PathWave System Design, includes schematic entry, data plotting, and MATLAB code support
W4801B	PathWave System Design core + RF	Adds the RF analysis simulation element giving users access to the SPECTRASYS engine, WhatIF, linear simulation, and RF component model libraries
W4802B	PathWave System Design core + Comms/DSP	A timed dataflow simulation engine to create communications and digital signal processing designs. Includes libraries of general DSP components, digital modulation, SerDes, MIMO, and legacy cellular standards
W4803B	PathWave System Design core + RF + Comms/DSP	Combines both the RF and Comms/DSP analyses, allowing RF Link to connect timed dataflow analysis with accurate RF system models
W4804B	PathWave System Design core + RF + Comms/DSP + Phased array	Adds the advanced phased array analysis simulator for both RF and Comms/DSP applications using beamforming
Algorithm design		
W4806B	PathWave System Design algorithm core	RF and Comms/DSP simulation engines for use by algorithm designers working in a MATLAB-centric environment. Does not include the PathWave System Design core component
High-speed digital		
W4810B	PathWave System Design core + AMI	Complete AMI model generation bundle. Includes the PathWave System Design core, Comms/DSP simulator, AMI modeling kit, and C++ Code generation kit

RF and Microwave Industry-Ready Student Certification Program

The Keysight RF and microwave industry-ready certification indicates competency and proficiency in the use of Keysight's industry-leading PathWave Electronic Design Automation (EDA) software and test and measurement instruments. A key component of this certification program is the use of Keysight's RF and microwave workflow environment: a comprehensive way to simulate, measure and analyze communications components and systems.

Keysight requirements for universities

- The university must use one or more Keysight's PathWave Design Software tools in their curriculum (PathWave Advanced Design System (ADS), PathWave RF Synthesis (Genesys), PathWave System Design (SystemVue), PathWave EM Design (EMPro), The PathWave Design Software should be an essential component of the curriculum
- The university must use Keysight instrumentation for the measurement of their RF and Microwave devices (RF vector network analyzer, signal sources, signal analyzer, oscilloscope and etc). These instruments should be an essential component of the lab exercises
- The ideal curriculum and lab will involve design, building, measurement, and analysis of RF and Microwave component to help students gain real-world understanding of RF and Microwave design and measurement techniques.

Qualification process for universities and students

- University completes and submits Keysight RF and Microwave Industry-Ready Student Certification Program submission form. Additional classroom curriculum and lab material may be required for review by Keysight.
- Keysight certifies that the university course and lab topics meets the program requirements
- Keysight notifies university of acceptance
- Students are notified of certification program by the course professor
- At the end of the course/labs, the top 15-20% of students are eligible for certification
- Class professor provides Keysight with names of students qualifying for certification based on class grade and quality of lab work. A test is required for level 1 proficiency.

Student recognition

- Keysight provides verification of certification with certificate
- Keysight inserts student name into list on Keysight's website:
www.keysight.com/find/student-certification
- Certified students will be invited to join the Keysight's Industry-Ready Students LinkedIn group

Levels of certification

Levels of certification	Example
Level 1	
Basic PathWave design software tool knowledge and basic measurement expertise	PathWave Advanced Design System (ADS) circuit filter design and network analyzer S-parameter measurement of filter
Level 2	
Additional design analysis with PathWave design software (possibly other design tool expertise such as PathWave EM design (EMPro) or PathWave system design (SystemVue) along with more involved measurement expertise.	Use of momentum or PathWave EM design (EMPro) simulation in PathWave Advanced Design System (ADS) with modulated signal creation and measurements with signal source and signal analyzers.