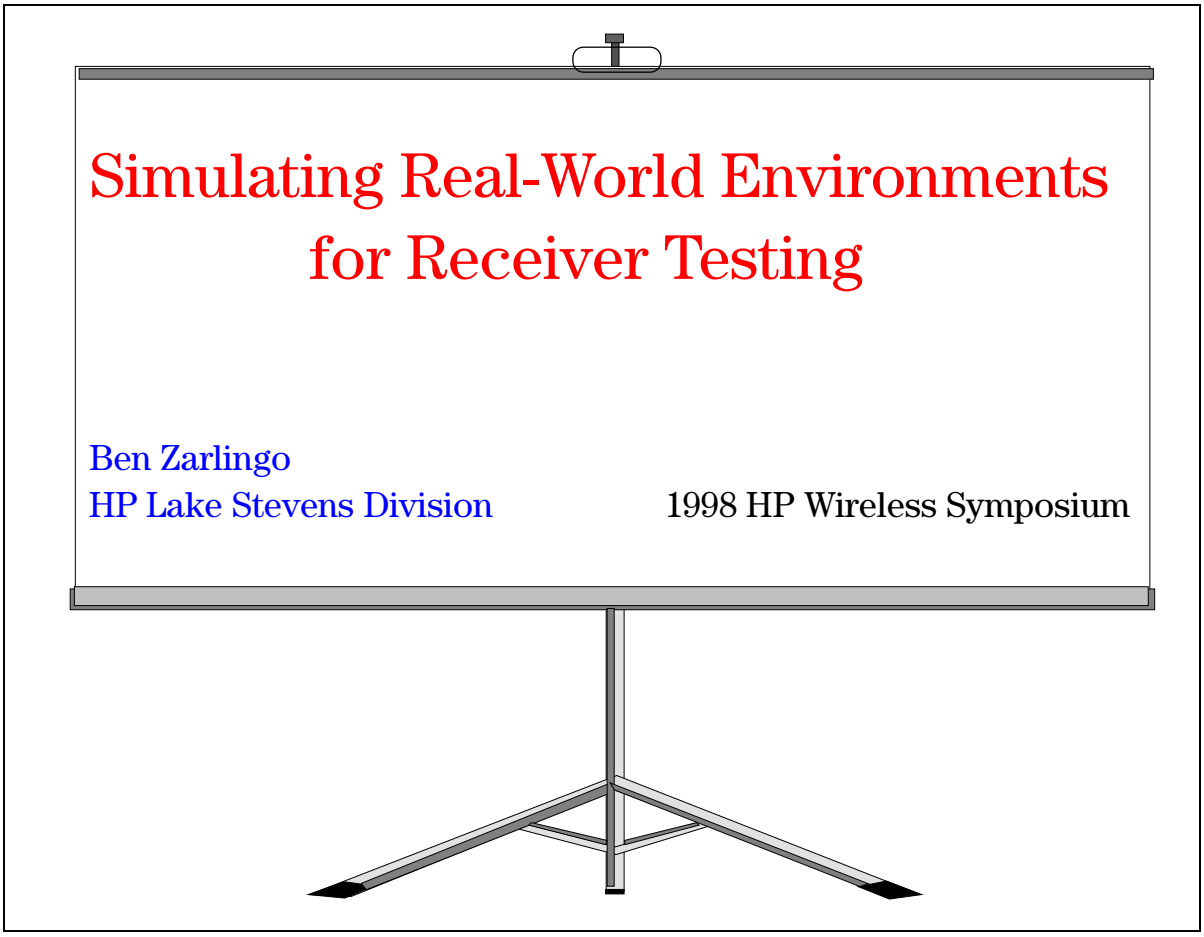

Welcome to the HP Wireless Symposium. During this presentation we will focus on a new solution for simulating real-world signals and signal environments in digital communications.

Simulating digital communications signals presents a number of new challenges in both hardware and software. We will be discussing a new product, the Vector Waveform Generator.

Notes:

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Signal Simulation
Analog Communications

- Baseband Modulation Sources
- Signal Generators
  - AM
  - FM
  - PM
  - Pulse
- Multiple Generators, Channels
- Multipath
- Fading

Signal simulation for analog communications was relatively straightforward. There are only a few basic modulation types and they can be readily generated by a variety of signal generators.

Simulating a signal environment, however, was often much more difficult. Multiple pieces of equipment were usually required, along with more advanced techniques such as the use of DSP.

Notes:

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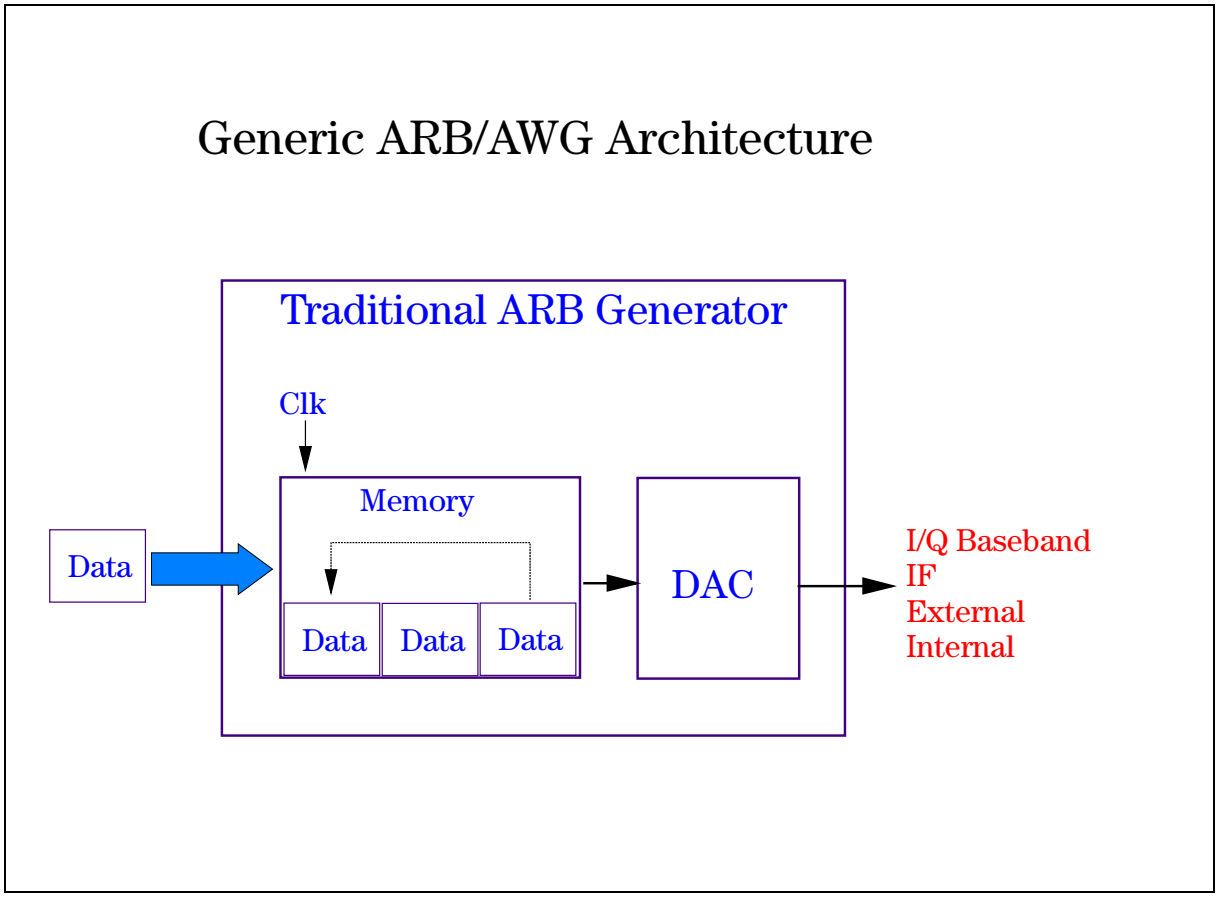
Signal Simulation--The Challenges of Digital Communications

- Complex Modulation
- Multiple Modulation Types
- Multiple Access: TDMA/Pulsed, CDMA, FDMA
- Controlled Power Profiles
- Complex, Precise Filtering
- Coding
- Sync Words, Preambles, Training Sequences, etc.
- I-Q Offsets
- Power Control
- Multiple Generators, Channels
- Multipath
- Fading

Signal and signal environment simulation is much more complicated in digital communications. Many factors contribute to this complexity. They include multiple modulation types, filter types, channel coding, power control, etc.

The difficulty of generating a realistic signal environment is compounded by these factors as well.

Notes:



The arbitrary signal generator (ARB) or arbitrary waveform generator (AWG) has the potential to provide a large variety of signals for digital communications. Its architecture is usually modeled by a data register or registers, and a digital-to-analog converter (DAC).

Generating realistic signals with this architecture, however, proves difficult in some situations.

Notes:

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AWG/ARB Limitations

- Memory Size Limits Time-Bandwidth Product
- Lack of Digital Upconversion Often Requires Separate Analog Converter/Modulator for Each Baseband Signal
- Changing BW (Sample Rate) Requires Changing Analog Reconstruction Filter
- All Signal Components Cyclic with Same Period
- All Signal Components Must Be Computed at a Common Sample Rate
- Pre-Computing Samples Into Memory Precludes Real-Time Data Transmission
- Potentially Limited Spectral Purity
- Need Two Generators & Coordination to Generate I/Q

Some limitations of the traditional AWG/ARB architecture in digital communications are obvious. The resulting signals are static and multiple generators must be coordinated to produce I/Q output pairs.

Other limitations are less obvious, though no less fundamental. They include memory size limitations when producing narrowband modulation, symbol rate vs. sample rate interactions, etc.

Notes:

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New HP E2747A, E2748A
Vector Waveform Generators

- ★ New Source Type for Digital Communications
- ★ Arbitrary Waveform Generator with DSP
- ★ IF & I/Q Outputs
- ★ Multiple Data Sources, Operating Modes
- ★ Digital Communications Signal Generation Software
- ★ PC & VXI Formats, Windows 95, Windows NT
- ★ Expanding Solutions For Digital Communications
  - ► Provide solution where none has existed

The new Vector Waveform Generators are designed for digital communications applications. Hardware and software architecture and analog performance are designed for digital modulation and IF or I/Q outputs.

A primary contribution is the use of sophisticated DSP to compute waveforms live or “on-the-fly.”

Notes:

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Motivations for a Generic Source-- Convergence of Needs, Technology

- Generation of Impaired Signals
  - Controlled deviations of symbol rate, filtering, etc.
- Generating New Signal Types
  - Invent new modulation types, filtering
  - Test coding, error correction, etc.
- Real-World Spectrum/Environment Simulation
- Versatile Operational Transmitter
  - Versatile prototype, easily modified
  - Possible end product
- Fast, Compact DSP
  - Computation, Filtering, Resampling
  - ASICs, gate arrays

As is so often the case, necessity is the mother of invention. Technology is the enabling element. The same sort of DSP technology that makes digital communications possible can also be used to produce a signal source optimized for use in this area.

The potential exists for such a source to serve as a prototype transmitter or even an operational one.

Notes:

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Opportunities for a New Solution

- Signal Generators with Digital Modulation
  - + Good solution for many modulation types
  - + Direct, high-quality RF solution
  - + Increasing flexibility (recent ESG Series enhancements)
  - – Limits to flexibility
  - – Multi-signal, multi-channel requires multiple generators
- Test Sets
  - + Complete solution for a few well-defined standards
  - – Limited flexibility
- Arbitrary Waveform Generators
  - + Ultimate flexibility
  - + Easier multi-signal, multi-channel solution
  - – Difficult to generate complex signals, protocol, etc.
  - – May need modulation, upconversion for RF solution
  - – Dynamic range limitations

Existing approaches provide good solutions for many problems. Signal generators with digital modulation are most common in development environments. Test sets are often used in manufacturing.

Arb generators have been pressed into service where additional flexibility is needed, and serve well within their limits. Generating real-world signals may be difficult, however, and the results are not dynamic.

Notes:

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Opportunities for a New Solution
"Vector Waveform Generator"

- Arbitrary Waveform Generator with DSP, Software
  - + Take advantage of dedicated DSP
  - + Continuously calculated output rather than storage register
  - + DAC, filtering designed for high dynamic range
  - + IF or (dual) I/Q outputs
  - + Structure designed for multi-channel, multi-signal outputs
  - + Modular structure for PC, VXI environments
  - + Dedicated software for generating digital signals
  - – Output is baseband I/Q or IF, so upconversion may be needed
  - – More expensive than simple arbitrary waveform generators
  - – Not a traditional instrument format
  - – Not required for most digital wireless applications

The Vector Waveform Generator is a natural fit to some of the needs of digital communications design, development and testing. This includes a modular structure based on multiple platforms. This structure can support multiple-signal/multiple-channel configurations.

This approach has limitations as well, including low frequency outputs which may require upconversion.

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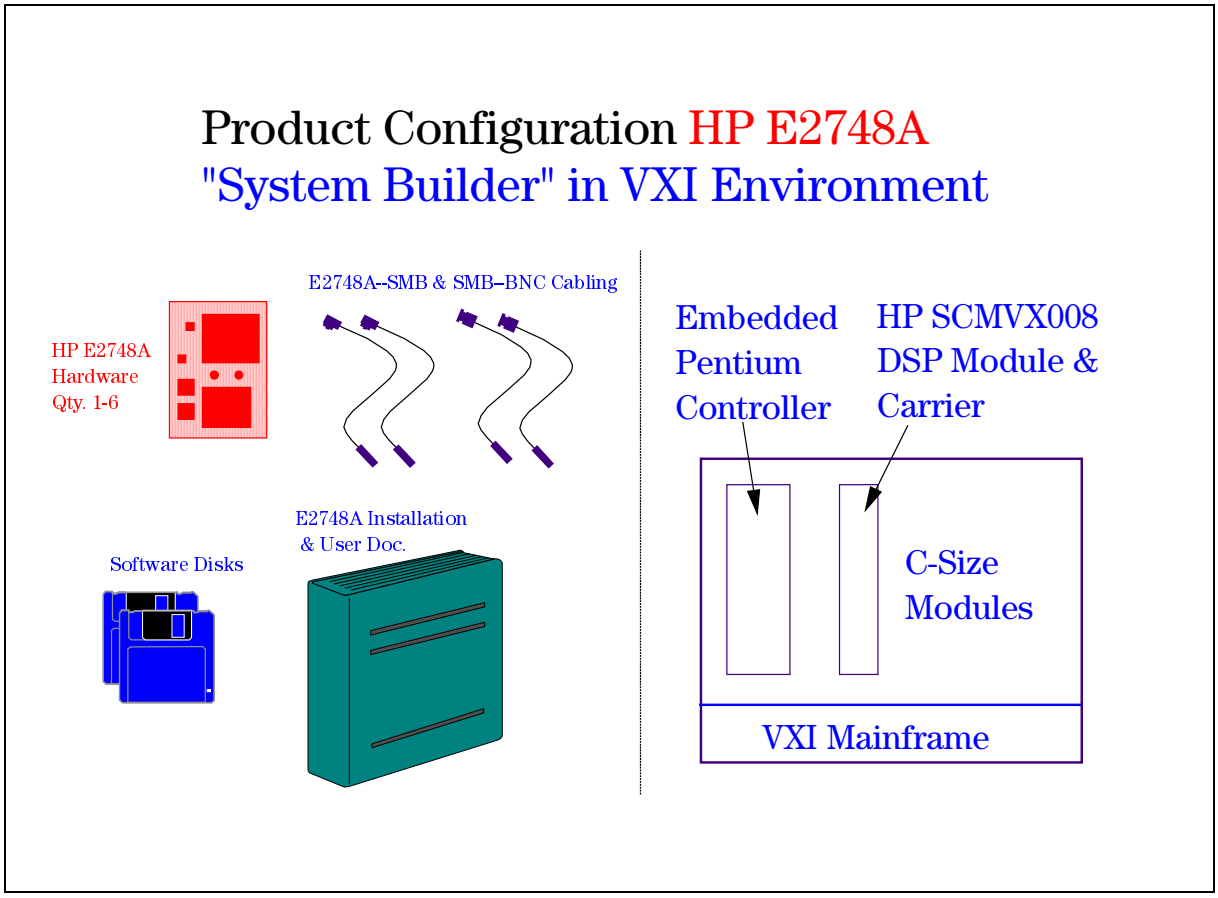
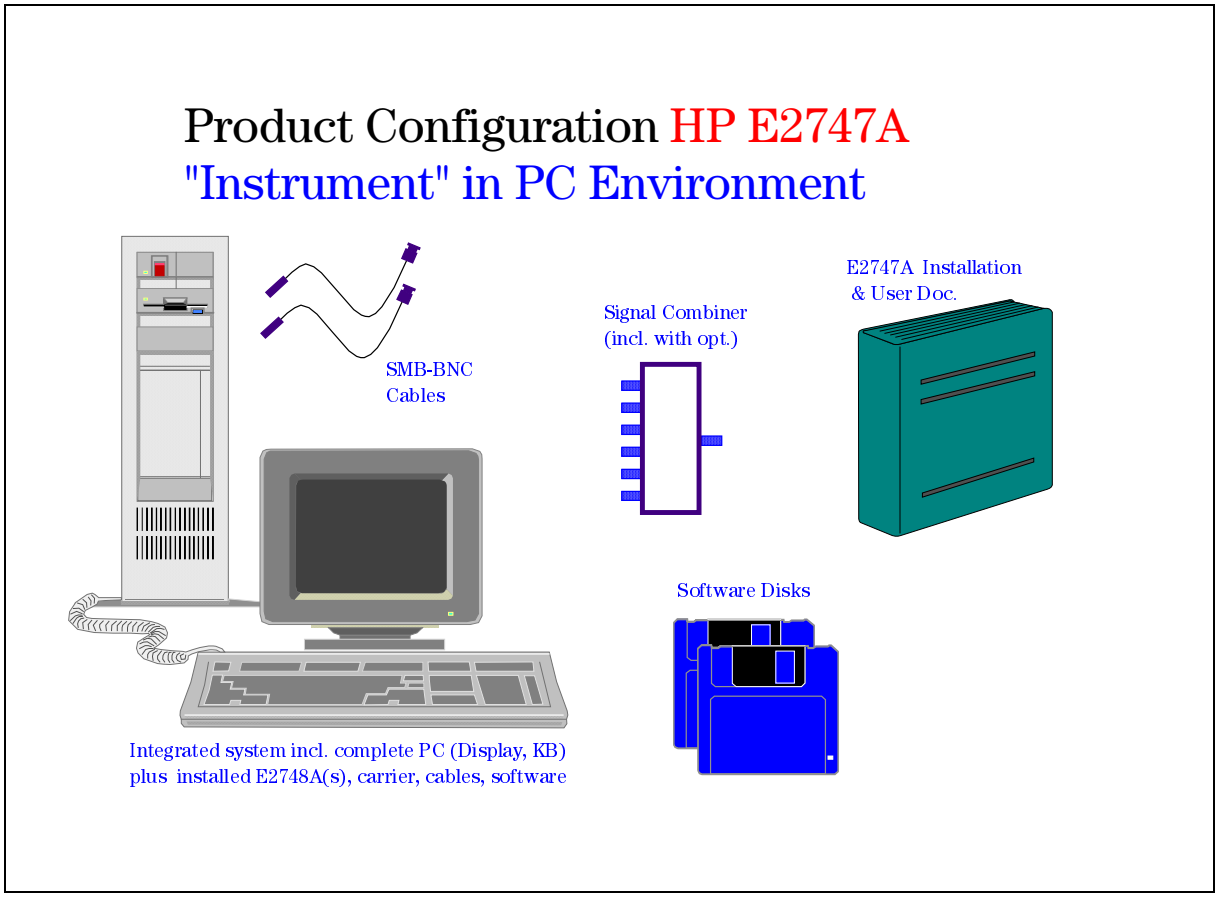


One configuration for the Vector Waveform Generator is the modular or system builder approach. One or more of the core component E2748A modules are installed in a VXI carrier and then in a VXI mainframe. The user interface is a soft front panel which can control multiple Vector Waveform Generator modules.

This approach offers flexibility, large channel counts and the opportunity to perform other tasks in VXI.

Notes:



The E2747A product configuration is an instrument rather than a system approach. Everything is installed and software is pre-loaded. 1-3 channels/modules are supported and a signal combiner is provided for multi-channel configurations.

The processing load on the computer is normally light or nonexistent, so it can be used for other tasks.

Notes:

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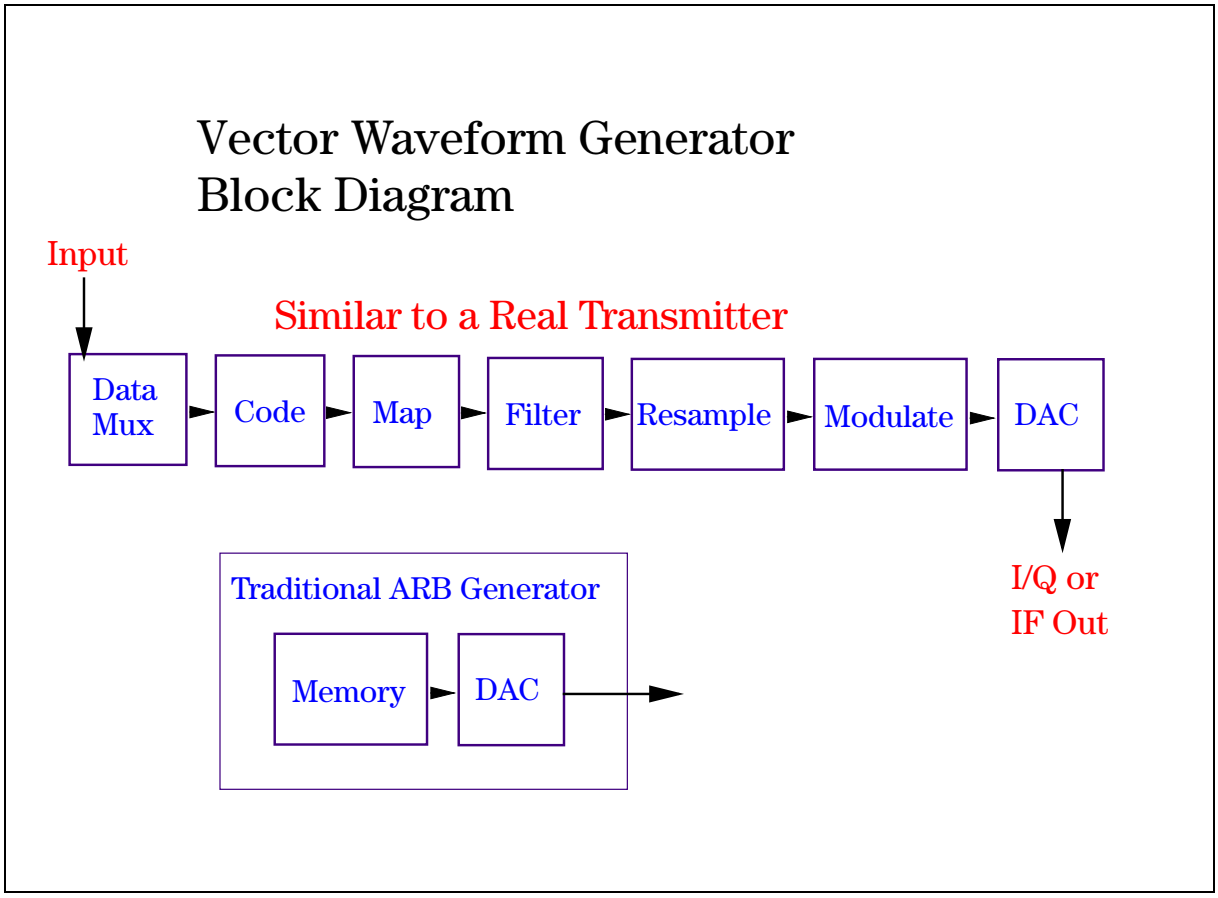

Compared to the traditional ARB generator, the architecture of the Vector Waveform Generator is closer to that of a real transmitter. This makes it easier to offer a closer functional match to the target.

Notes:

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User Interface and Process for Creating Signals

Traditional ARB Approach

- Complicated Math
- Multiple Operations
- Manually Edit Data
- Import Files
  - If available
  - If compatible
- Result is Static Signal

Vector Waveform Generator & Software

- Start with a ".MOD" File
  - Choose similar signal if available
- Follow Logical Sequence
- Window/Spreadsheet Interface
- Choose From Multiple Data Sources
- Result Can be Any Combination

The traditional ARB approach is conceptually simple and straightforward. If ready-made files are available, implementation can be straightforward as well. But ready-made files for novel new signals are often in short supply, making the path to a solution much longer.

In any case the resulting signal is static where the need may exist for a dynamic one.

Notes:

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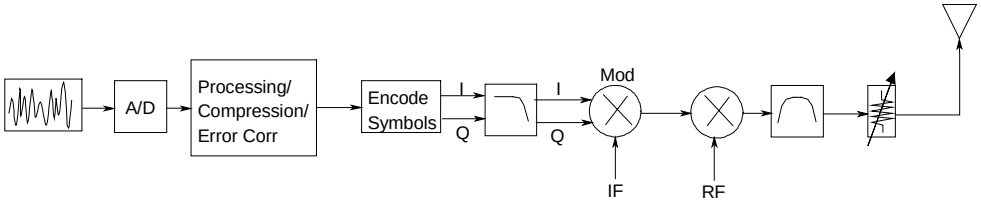
Transmitter Overview



- Convert to Digital if necessary (signal coding)
- DSP, Channel Coding (compression, error corr.)
- Map to I & Q
- Modulation Shaping Filter
- Modulate
- Convert to RF
- Filter, Amplify, Send to Antenna

Creating a signal for transmission involves many operations, generally performed in succession. It also involves multiple signal types and frequencies

Notes:

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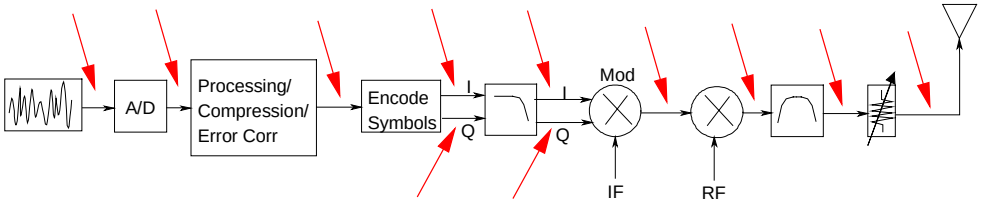
Engineering the Signal Path Using Sources



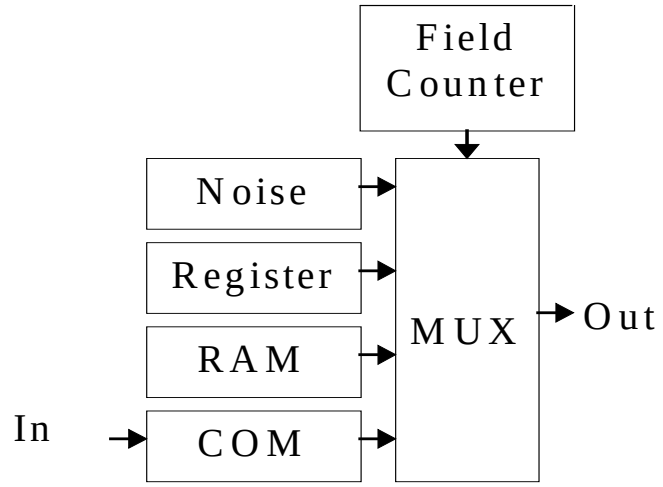
- Provide Known Good Signal At Different Stages
- Substitute for Circuits That Do Not Exist
- Measure Effect of Variations
- Some Operations Analog, Some Digital
  - Different in different systems

The traditional conceptual model for using sources in designing/testing the signal path requires a variety of signals, formats and frequencies. It is useful to be able to insert signals and to probe at almost any point in the block diagram.

Doing this testing thus requires considerable flexibility in data and signal sources and formats.

Notes:

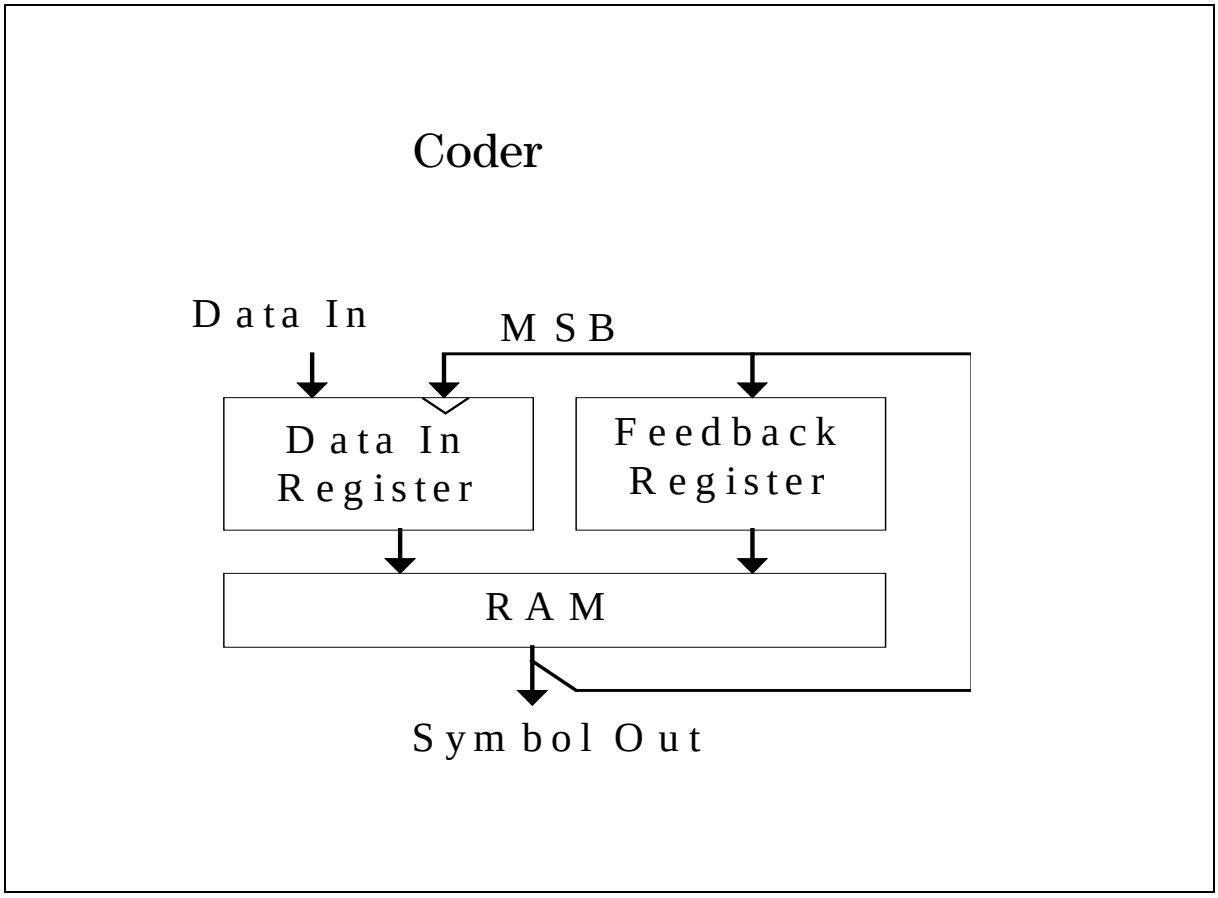
Data Multiplexer



The data multiplexer in the Vector Waveform Generator provides the data source flexibility needed to create real-world signal sequences. Data types can be put together in a sequence using a spreadsheet format to match the required signal data, sequence and structure.

Data can be taken from a COM port to provide for real-time data flow, and combined with other sources.

Notes:



The coder consists of a very general RAM-based state machine. The simplicity of the coder structure belies its inherent power. Great flexibility is possible, though there may still be considerable tedium and effort in creating a coder RAM table to implement a desired function.

The HPE2748A software reduces the difficulty of creating coder tables for some common coding functions.

Notes:

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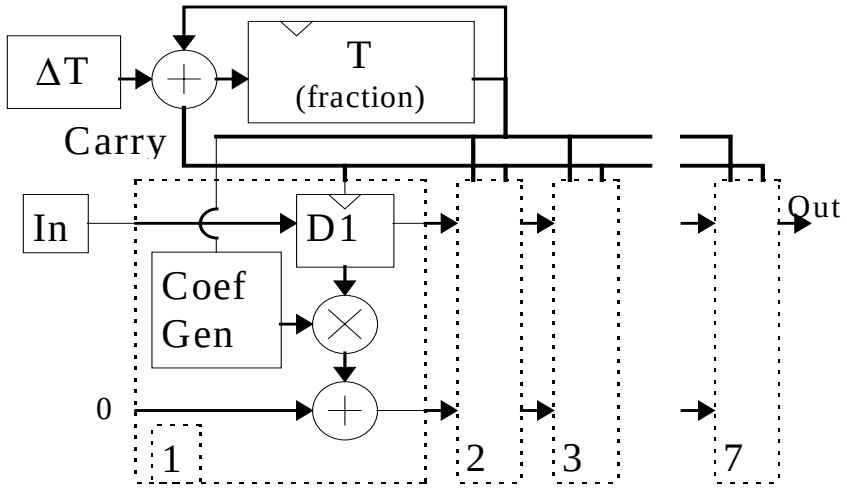
Resampler



The resampler is implemented with an HP-proprietary application-specific IC (ASIC). This consists of a filter which convolves the sampled input sequence with a continuous impulse response.

The output of this continuous convolution may then be computed at arbitrary instants in time. The HP E2748A resampler output runs at a constant 15 MHz.

Notes:

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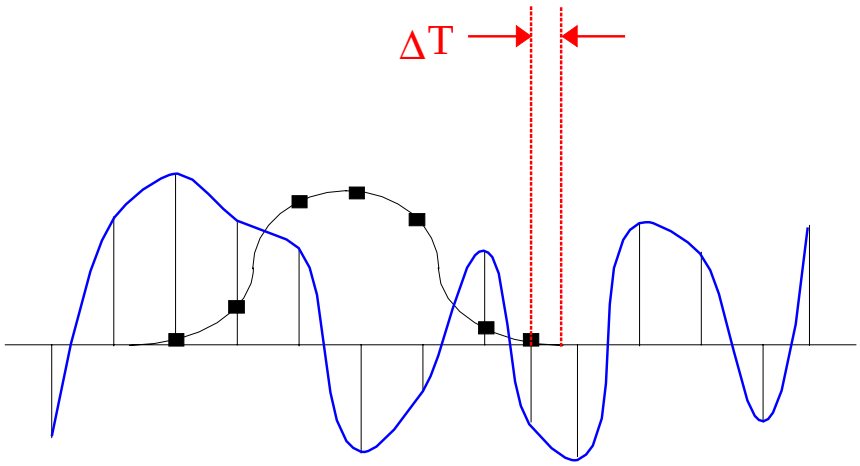
Resampling

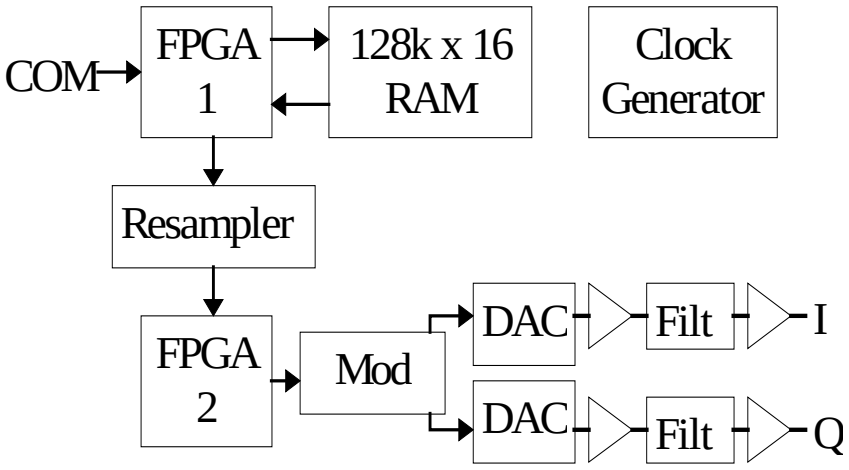


Resampling provides many benefits. Sample and symbol timing now do not need to be related. Precise timing of data from the data source is not required. Data output rates and frequencies can be changed instantly, in minute increments.

In addition, spectral purity is enhanced by the ability to choose an optimum analog reconstruction filter.

Notes:

Hardware Block Diagram



The hardware block diagram allows the RAM-based functions to share the same physical memory, with the user able to select the allocation.

Dual DACs and associated filtering provide the ability to select between IF and I/Q outputs.

Notes:

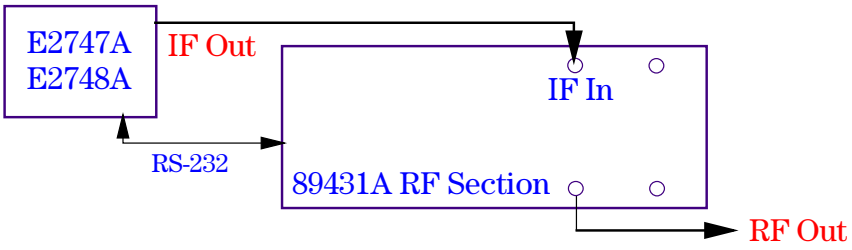
RF Upconversion Using Signal Generator with I/Q Inputs

- Good Solution for Single-Signal Environment
- Wide Range of Available Signal Generators
- Good RF Performance, Flexibility
- Enhancement to Existing Generators
- 3 GHz ESG-Series is Option to HP E2747A

I/Q modulation of a signal generator provides a good solution to the need for a single, modulated RF signal. A variety of these signal generators are available, allowing the user in some cases to expand the use of existing hardware.

Notes:

RF Upconversion Using HP 89431A RF Section, Opt. AY8



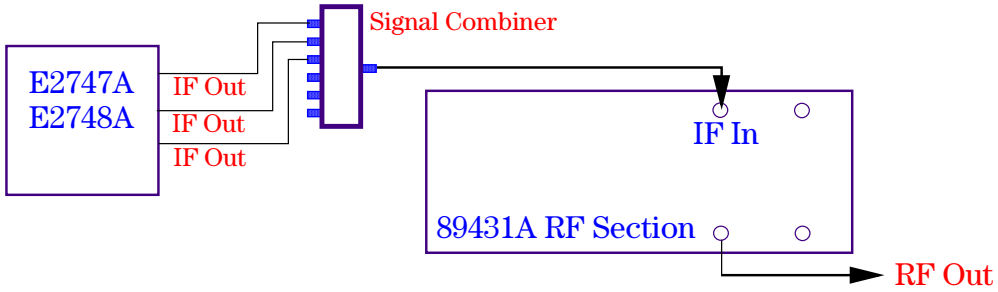
- Good Solution for Single-Signal Environment
- Take Advantage of Existing Hardware
- Expensive for New Purchase of Single-Signal Solution

IF (rather than I/Q) upconversion can be accomplished using the HP 89431A/opt. AY8. This is the RF section of the HP 89441A Vector Signal Analyzer, and may already be available in the test lab.

Purchased solely as a single-channel upconverter, the HP 89431A is a rather expensive solution.

Notes:

Multi-Channel RF Upconversion



- Good Solution for Multiple-Signal Environment
- Take Advantage of Existing Hardware
- Simulate Environment
  - Active Channel
  - Background, Adjacent Channel(s)
  - Interferer(s)
  - Noise

Benefits of IF upconversion using the HP 89431A are realized primarily in multi-channel environments. Multiple IF signals can be combined and upconverted as a group to form a simulated signal environment.

IF upconversion is the preferred method for generating multiple modulated signals from the same RF generator. Using I/Q modulation as an upconversion method in this situation requires considerable care.

Notes:

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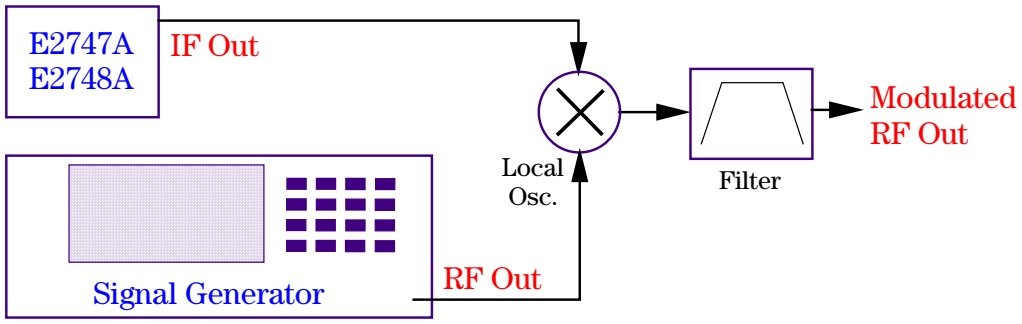
Simple Mixer Upconversion



- Simple, Inexpensive Solution
- Take Advantage of Existing Hardware
- Limited Applications
  - Equal-amplitude signal 2X IF away, other smaller signals
  - Custom solution, may require filtering
  - Not Specified by HP

Where the “extra” signals produced are not a problem, simple upconversion using a mixer and signal generator is an option worth considering. This is an inexpensive approach that can make use of existing hardware.

However implementing this approach requires some design and testing on the part of the user.

Notes:

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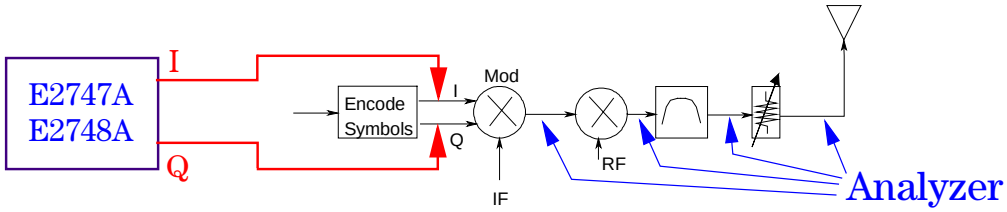
Application: I/Q Modulator Test



- Test Modulator Through RF Stages
  - If I/Q are analog at this stage
- Measure with Spectrum Analyzer or Vector Signal Analyzer
  - Modulation Quality
  - Bandwidth
  - ACP, spectral regrowth, etc.

Where I and Q exist as filtered or unfiltered analog signals in the block diagram, the Vector Waveform Generator can be used in I/Q mode to substitute for them.

Using a spectrum analyzer or a Vector Signal Analyzer, the signal can then be tracked through the rest of the block diagram to measure a variety of signal parameters and component performance.

Notes:

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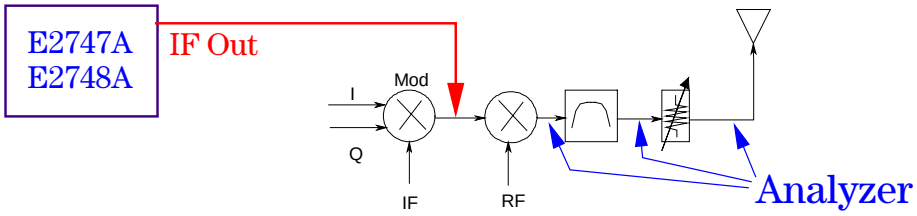
Application:
RF Section & Amplifier Test



- Test Upconversion, Filtering, Amplification
- Measure with Spectrum Analyzer or Vector Signal Analyzer
  - ACP
  - Spectral regrowth
  - Gain, flatness
  - Incremental EVM

The IF output of the Vector Waveform Generator can be used at a later point in the transmitter block diagram to substitute for a modulated IF signal. Parameters such as modulation and filtering can be altered to test their effect on the rest of the system.

As before, spectrum analyzers and Vector Signal Analyzers would be used to test the rest of the system.

Notes:

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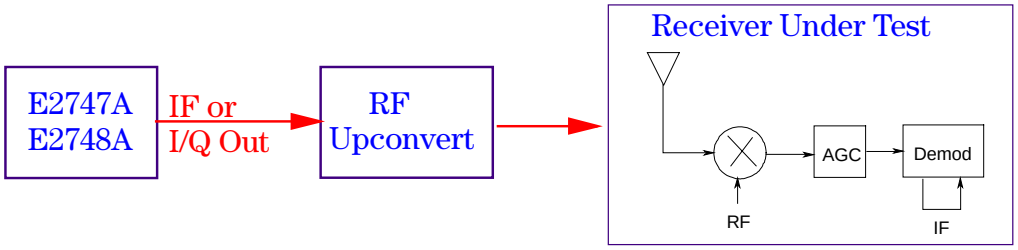
Application:
Receiver Test--Modulated Signal



- Simulate Complex New Signals More Easily
- Provide Real-World Signal
  - Bursts
  - Framing, coding, protocol, etc.
  - Real data, long messages
  - Impairments, defects
- Radio Prototype

Using either method of upconversion, a real-world RF modulated signal can be produced to test a receiver. The characteristics and data of this signal can then be varied to evaluate the performance of the receiver.

With the ability to provide real-world and even real-time data the Vector Waveform Generator can function as a radio prototype after upconversion. This provides a fast path to the prototype design stage.

Notes:

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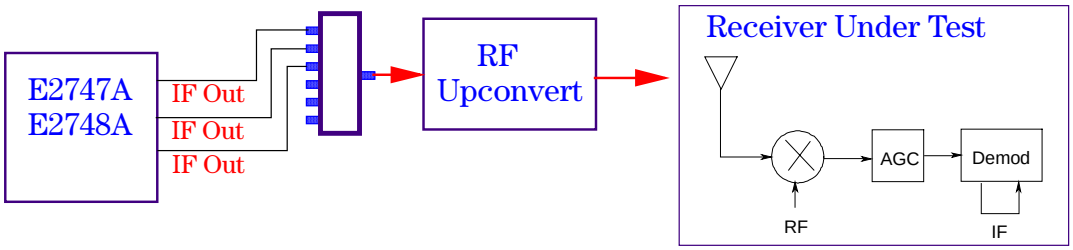
Application:
Receiver Test--Signal Environment



- Simulate Realistic Multiple-Signal Environment More Easily
  - Modulated active channel
  - Other modulated channels, other modulation types
  - Interference
  - Noise

The IF upconversion approach and multiple Vector Waveform Generators provide a way to test a receiver using a complete signal environment. This environment could include multiple modulated channels, CW or modulated interferers and noise.

Notes:

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Vector Waveform Generator Limitations

- Not a Traditional Instrument Product
- Not an RF Signal Generator
  - No direct RF output
  - No built-in attenuator (for wide amplitude range)
  - No external analog modulation
- Generating Some Signals May Still be Complicated
  - Unique modulation types
  - Unusual filters
  - Complex, tedious coding
  - Verifying signals if no demodulators exist

Every technological approach has its benefits and costs. For example, the Vector Waveform Generator does not provide a direct RF output (above 6 MHz).

The task of generating a complete digitally-modulated signal may still be very complicated compared to generating an analog one. This is particularly true of new modulation, coding schemes, etc.

Notes:

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Vector Waveform Generator Advantages

- Easier to Generate "Real-World" Signals
  - Flexible filtering, modulation types, symbol rates
  - Produce TDMA or burst signals
  - Generate specific symbols, protocol easily (a "message")
  - Combine fixed data (framing/protocol) with data from input or file
- Simultaneous I/Q Outputs to Drive Modulators, Signal Generators
- Modulated IF Outputs to Upconvert to RF
- Less Expensive for Multiple Channels/Multiple Outputs
- Both Analog and Digital Modulation
- Output Calculated in Real Time
  - Best use of memory for long signals
  - "Live" calculation, resampling produce exact symbol rate easily
- VXI or PC Format to Fit Application Needs

Because of its architectural similarity to real transmitters, the Vector Waveform Generator can provide important new benefits in digital communications applications.

A more detailed technical paper is available by request or as a PDF file on our web site. The address for that web site is on a slide to follow.

Notes:

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Vector Waveform Generator Specifications

Frequency Range:	DC - 6 MHz
Modulation Bandwidth:	0 - 2 MHz
Output Impedance:	50 Ohms
Output Level:	2V p-p
Memory:	128k - infinite
User Interface:	Soft Front Panel, Funct. Lib.

Detailed specifications are available on the web site whose address is on the following slide.

Notes:

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Specifics

Instrument Product:	HP E2747A Vector Waveform Generator
System Product:	HP E2748A Vector Wave. Gen. Module
Availability:	Price List May 1; Deliv. 4 wks. ARO
Literature:	Overview, Data Sheet, Config. Guide
WWW:	ftp://hpls01.lsid.hp.com/dsp/pdf/E2748A
	▸ PDF files for prelim. lit. prior to May 1

Final literature should be available May 1. Please contact your HP FE or try the web address listed.

The web site contains PDF files for literature including a Product Overview, Configuration Guide, Technical Specifications and a technical paper.

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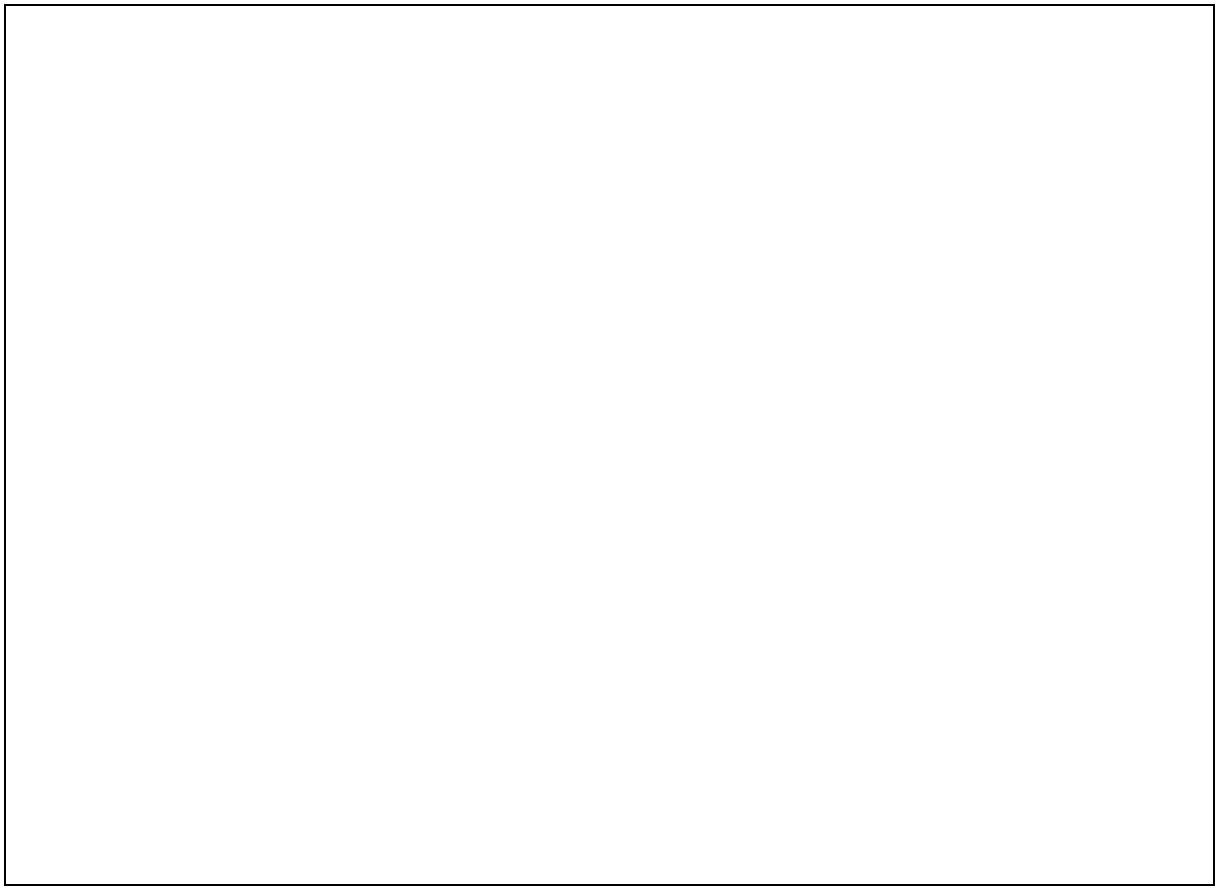

Notes: