# THE SPECTRUM ANALYZER

## APPLICATIONS in AMATEUR RADIO

A Vienna Wireless Society Presentation

by


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# MODULE 1

THE

BASICS

# SIGNAL REPRESENTATION

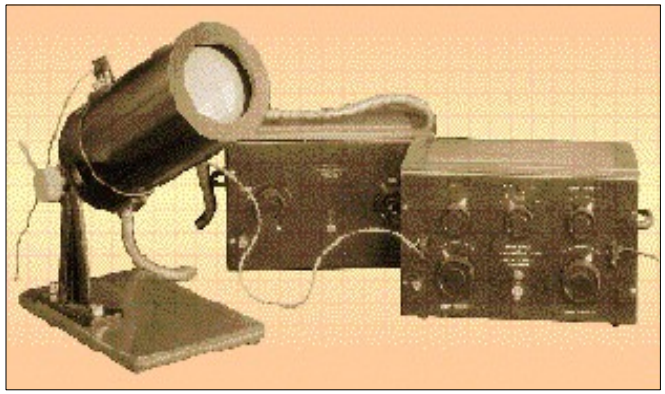
- All time varying signals (audio, ultrasonic, RF, etc.) can be represented and plotted as a function of time or frequency.
  - For a simple sinewave $F(t) = \sin(2\pi ft+\sigma)$ and $F(\omega) = 2\pi f$

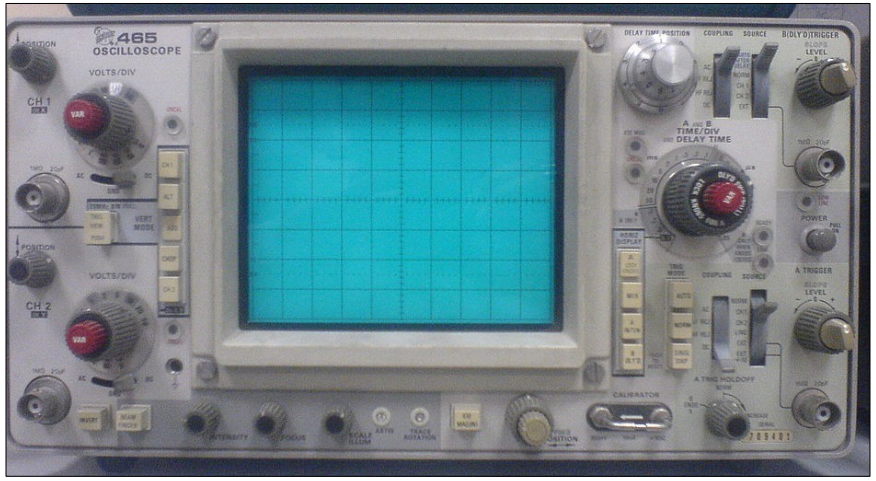
- The principal for converting time domain data to frequency domain data is the Fourier transform developed by Jean-Baptiste Joseph Fourier (1768–1830) who was working on heat transfer.

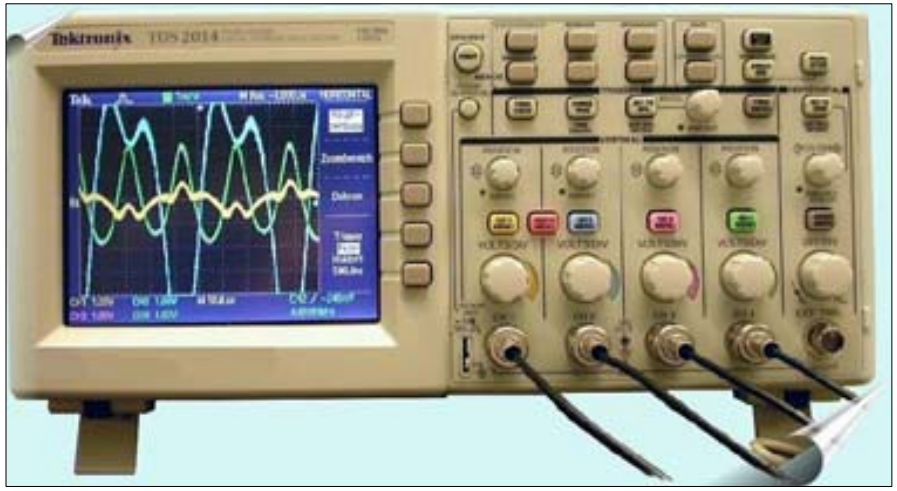
# TIME DOMAIN DISPLAY

- Signals are displayed in the time domain on oscilloscopes.
  - Amplitude on the vertical axis versus time on the horizontal axis.
  - Amplitude is typical linear (volts/division)
- The first oscillographs used a galvanometer to record on a rotating paper drum or film in late 1890s.
- The CRT oscilloscopes first appeared in the WWI era.
- By the 1930s *General Radio* introduced a

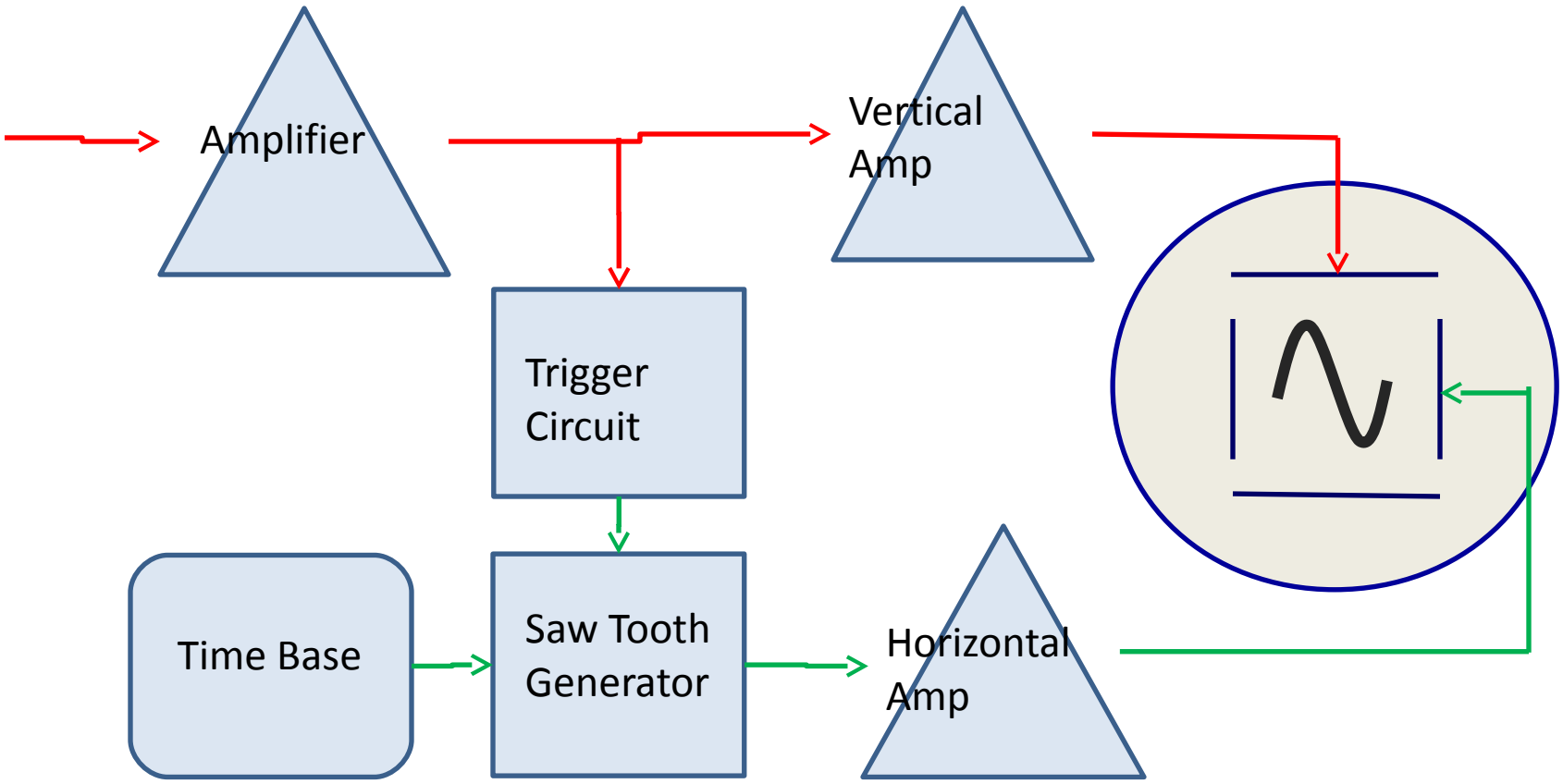
# EVOLUTION of the OSCILLOSCOPE



# A BASIC ANALOG OSCILLOSCOPE



# FREQUENCY DOMAIN DISPLAY

An *Analog Spectrum Analyzer* is basically a SUPERHETERODYNE receiver with a swept local oscillator (LO) and sometime linear detector with a display similar to an oscilloscope.

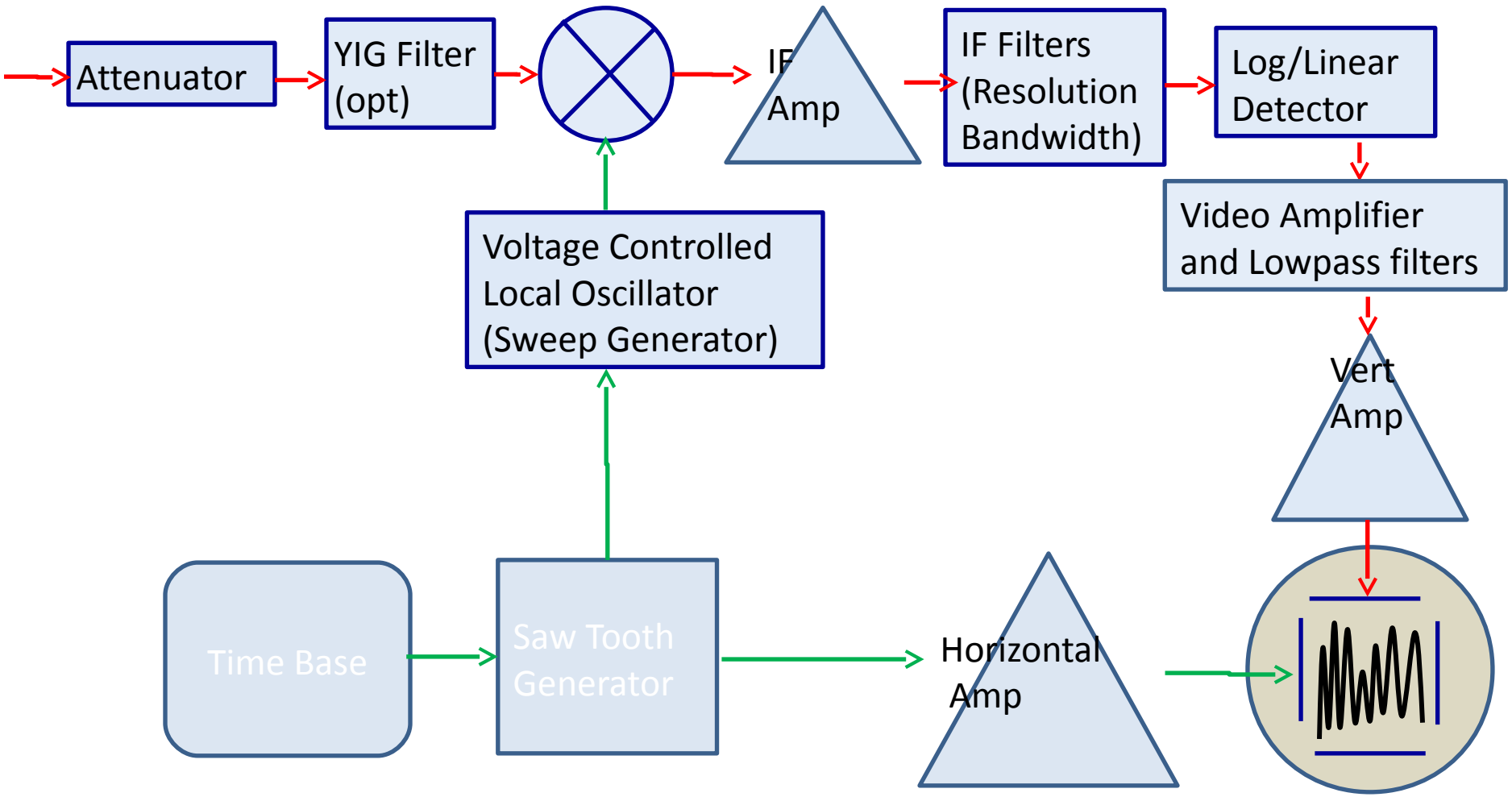
- Displays frequency on the X-AXIS and amplitude in the Y-AXIS.
- Most modern systems have a PEAK-HOLD function.
- Most have “ZERO SPAN” mode: LO is fixed and display is SIGNAL vs. TIME.

# FREQUENCY DOMAIN DISPLAY

*Real Time Spectrum Analyzers* are digital sampling systems that implement a Fast Fourier Transform to display power levels within frequency bins across the display.

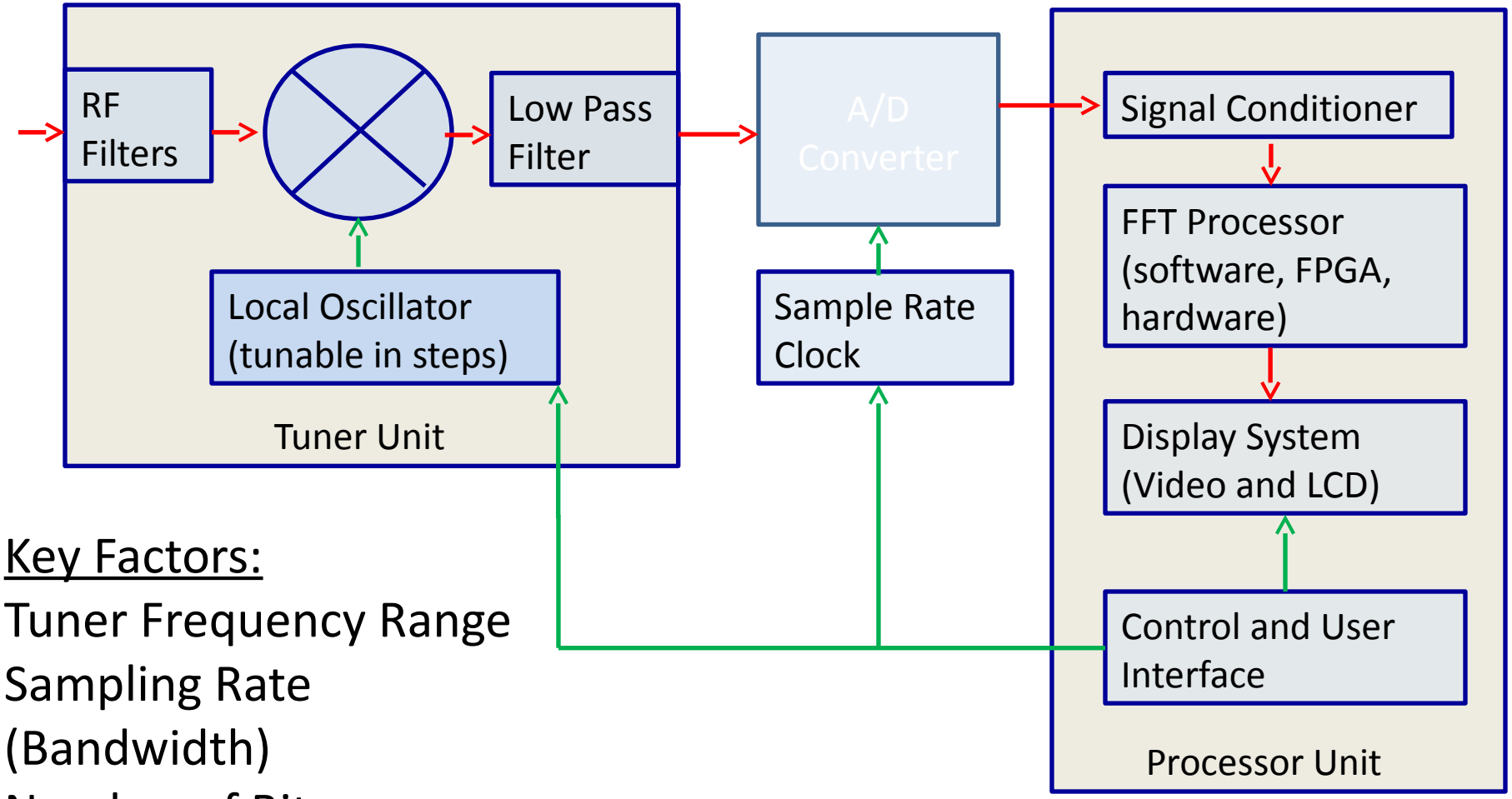
- Can provide AMPLITUDE vs. FREQUENCY display like conventional analog analyzers.
- Can provide a WATERFALL DISPLAY (cascading FFTs over time).
- Most can show sample AMPLITUDE vs. TIME.

# ANALOG SPECTRUM ANALYZER



# EVOLUTION of the ANALOG SPECTRUM ANALYZER

# BASIC REAL-TIME SPECTRUM ANALYZER (SDR)




<u>Key Factors:</u>

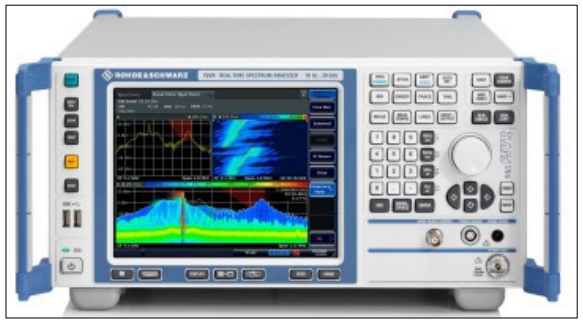
Tuner Frequency Range

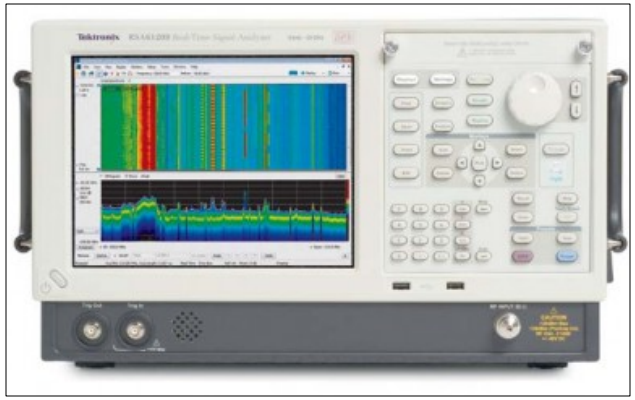
Sampling Rate (Bandwidth)

Number of Bits

Processor Speed for FFTs

# REAL-TIME SPECTRUM ANALYZERS

## COST RANGES

| | | | |
|---|---|---|---|
| $0.00 Software for PC (audio) | $12 for 2 GHz, 8 bit 2 MHz instant β + PC | $3K for 6 GHz, 14 bit , 30 MHz instant β + PC | $250K (26 GHz, 14 bit, 150 MHz instant β) |

# MODULE 2

SPECTRUM ANALYZER CONTROLS and LIMITATIONS

# SPECTRUM ANALYZER CONTROLS

## Major Controls

- REFERENCE LEVEL (maximum displayed amplitude) & Input Attenuation.
- START and STOP Frequencies of Display (or Center Frequency and Span).
- RESOLUTION BANDWIDTH (width of IF filters) and Video Bandwidth.
- SWEEP TIME.
- LOG/LINEAR DISPLAY on some units and dBm/DIVISION.
- ZERO SPAN MODE fixed LO frequency-display

# SPECTRUM ANALYZER CONTROLS

## Limitations

- Span, Resolution Bandwidth, and Sweep Time are interrelated in ANALOG ANALYZERS.
  - Since the analyzer is swept in frequency it needs a finite amount of time to obtain a reading of the amplitude within the resolution bandwidth selected; there is a maximum sweep rate for a given span and resolution bandwidth

- REAL-TIME ANALYZERS need to ensure A/D converter saturation does not occur. Resolution

# MODULE 3

SPECTRUM
ANALYZER
ACCESSORIES

# ACCESSORIES

## #1 TRACKING GENERATOR

- Originally a separate unit for older units like to HP 141.
- Usually an option  on modern units covering up to 1.5 GHz or so.
- Generates an RF signal at the same frequency the Spectrum Analyzer is tuned at an output jack.

## #2 HIGH IMPEDANCE PROBE

- Nominal input impedance of Spectrum Analyzers is 50Ω.
- To use the spectrum analyzer as a circuit probe get

**With A Tracking generator you can consider the Spectrum Analyzer as a Scalar Network Analyzer**

output and high impedance input

# ACCESSORIES (continued)

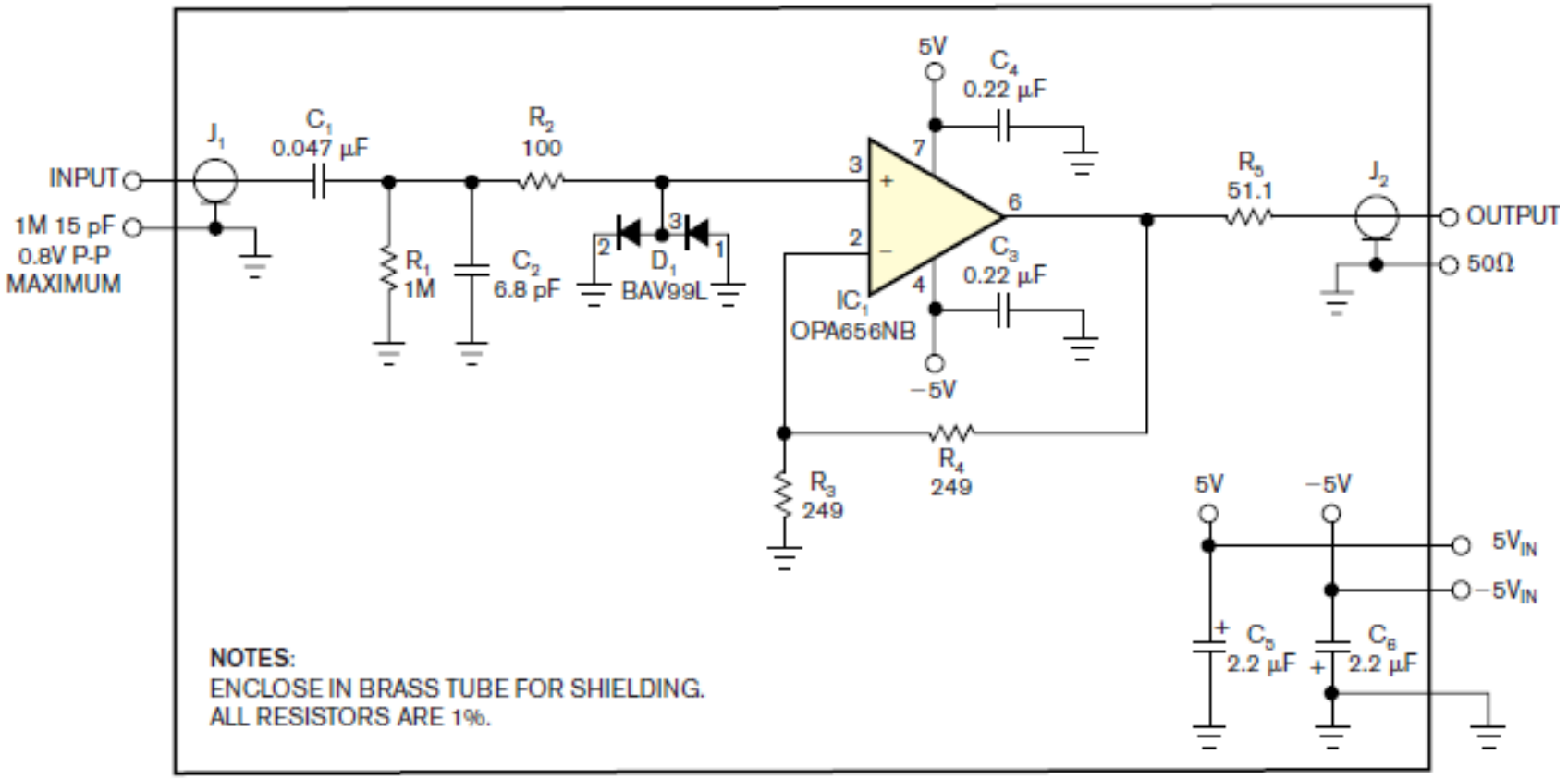
## #3 RETURN LOSS BRIDGE

- With Tracking Generator can measure return loss for any port of a network (such as Antenna VSWR)

## #4 LOW NOISE AMPLIFIER

- Provides increased sensitivity.

# HIGH IMPEDANCE PROBE from *EDN Magazine* 2005 by Steve



# REVIEW

Think of the Spectrum Analyzer as a Precision Calibrated Receiver that can accurately measure INPUT LEVELS vs. FREQUENCY.

- Measure FM DEVIATION and MODULATION characteristics.
- Measure HARMONIC DISTORTION of modulators and amplifiers.
- Measure HARMONIC LEVELS of transmitters, amplifiers, oscillators.
- Measure RESIDUAL NOISE of oscillators.
- With a probe tool for TROUBLESHOOTING RF

# REVIEW (continued)

With a Tracking Generator you can do GAIN/LOSS measurements vs. FREQUENCY.

- Measure LOSS through networks, cables, etc. ; i.e. any two-port device.
- TUNE RF filters (Diplexers, LC, Crystal filters).
- MEASURE CHARACTERISTICS of Crystals for design of filters.
- Measure GAIN of Amplifiers vs. Frequency

- Add a RETURN-LOSS BRIDGE and you can do one port return-loss measurements; i.e. VSWR vs. FREQUENCY.

# MODULE 4

SPECTRUM
ANALYZER
DEMONSTRATION

1. Modulation Measurement.
   - HT with a *Tektronix* 491 S/A.
   - HP UHF SigGen with *Rigol* 851 S/A.

2. Insertion Loss Measurement.
   - 40 Feet RG-58A/U.
   - 10 Feet RG-174/U.
   - 40 Meter VWS Band Pass Filter.

# THANK YOU

## (ARE YOU READY TO BUY A *SPECAN* YET ?)

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## QUESTIONS ?

## COMMENTS ?