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RF Detectors help solve System Design Challenges

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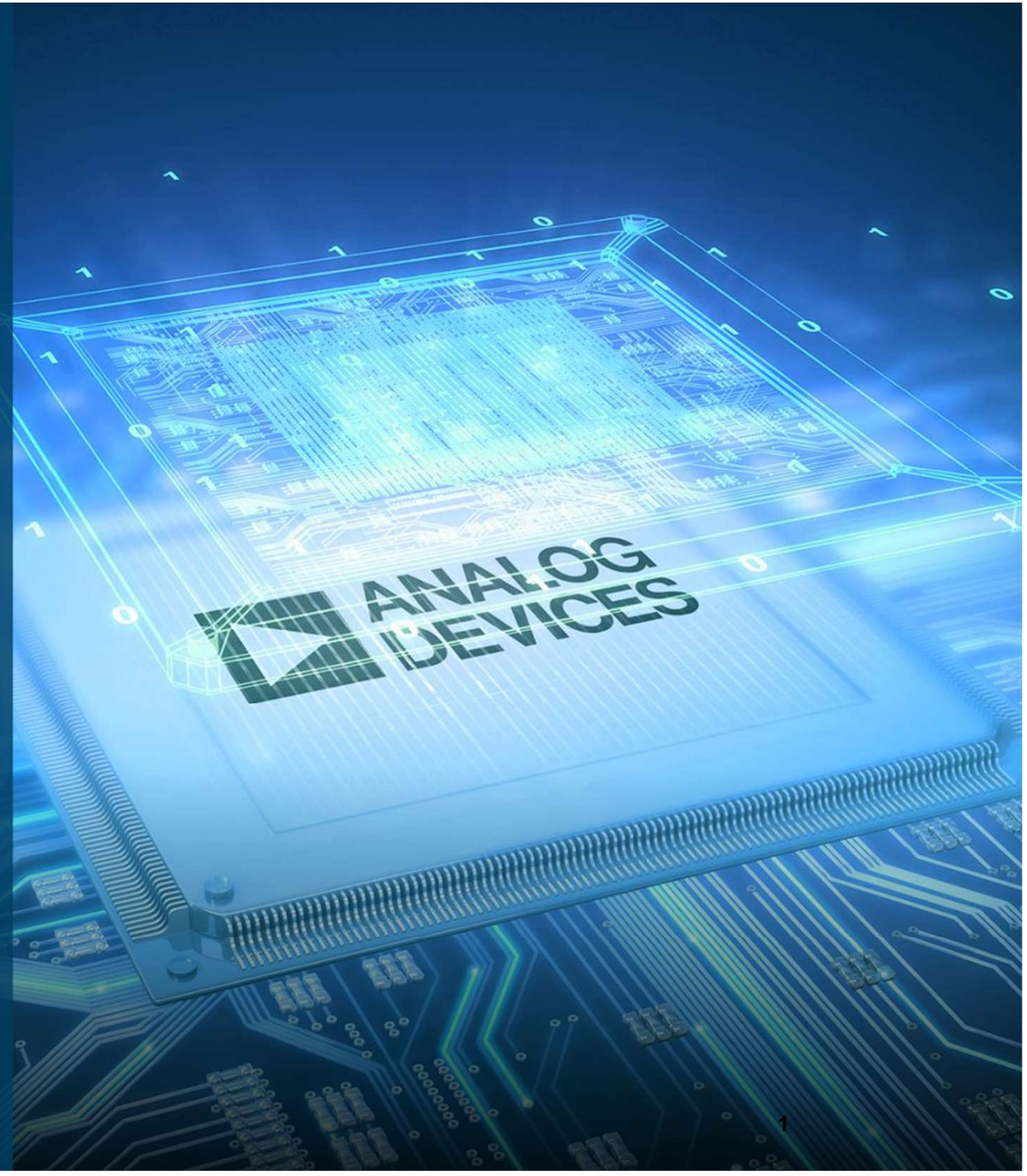

1/30/2019

Agenda: RF Power Detectors

- What functions can detectors perform – Key requirements?
- How to select the best detector for the task?
- Selected applications for detectors
- Web resources
- Q & A

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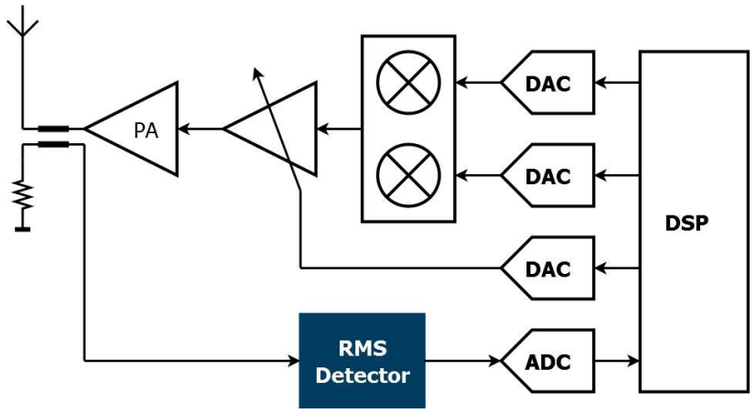
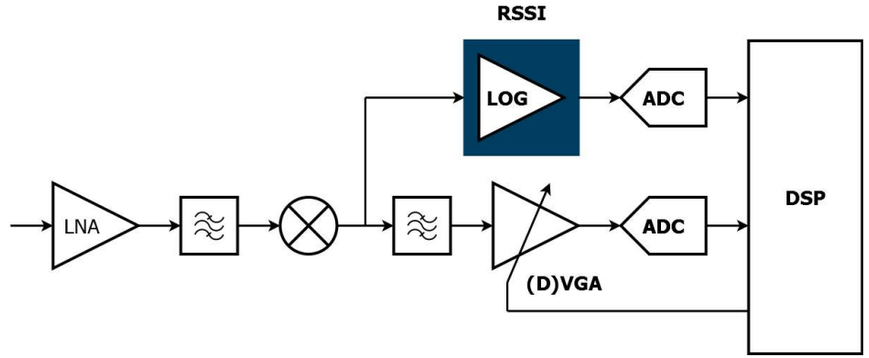
Detectors Overview – What are the Requirements?

Detectors provide Solutions for a Wide Range of System Functions

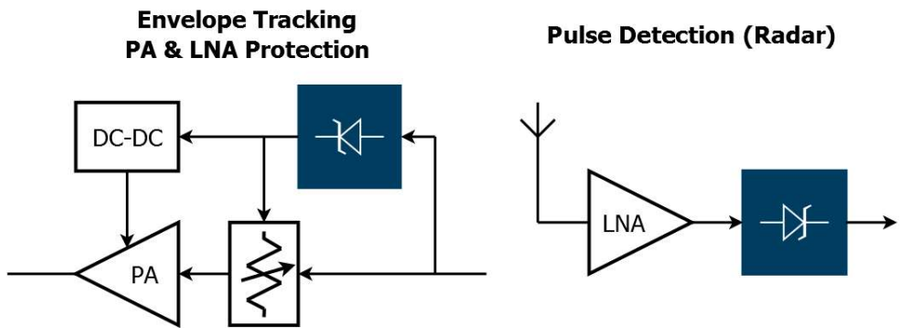
Accurate Power Leveling



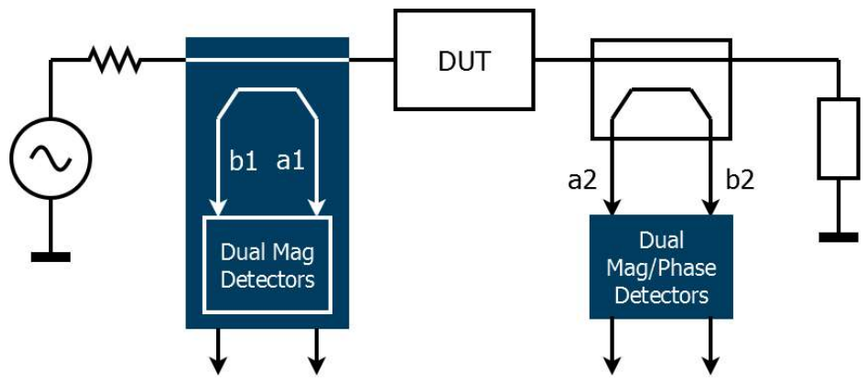
Monitor Receiver Input Levels



Pulse/Envelope Detection & Protection



VSWR & S-Parameter Measurement



Key Requirements – Detector Characteristics

Identify the key requirements for the system function:

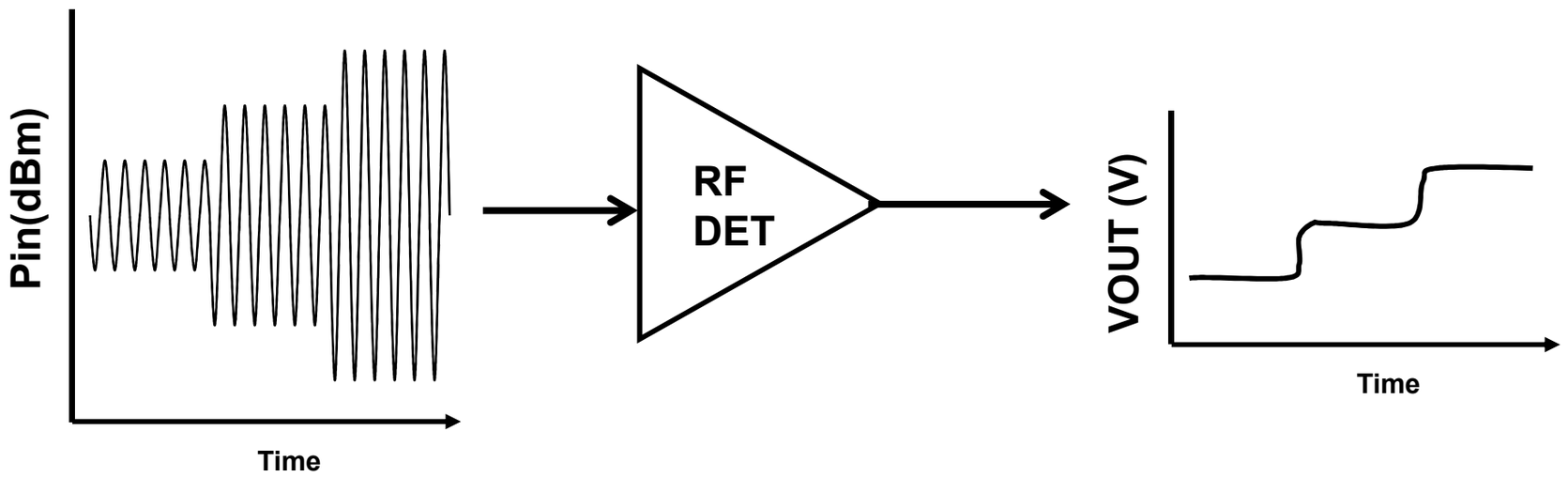
Magnitude Power Detectors:

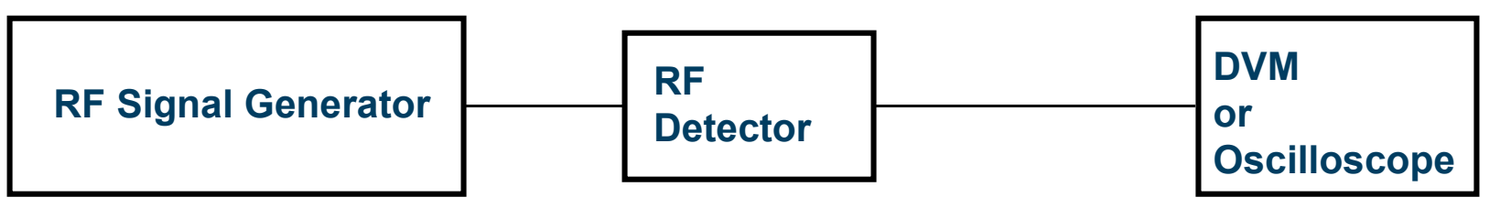
- Transfer Function
- Accuracy (temperature stability, frequency & modulation dependence)
- Dynamic Range and Sensitivity (Minimum power)

Vector Power Detectors:

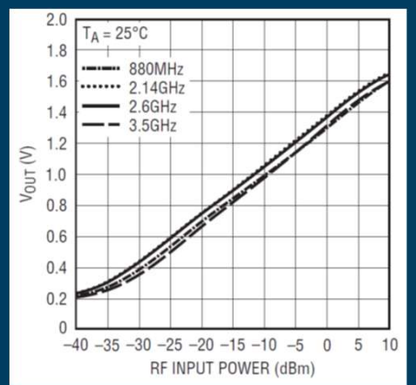
- Dual magnitude (forward and reflected) – directivity, coupling factor, ….
- Magnitude and phase – phase range, ….

What is an RF Detector? – Concept of “Transfer Function”

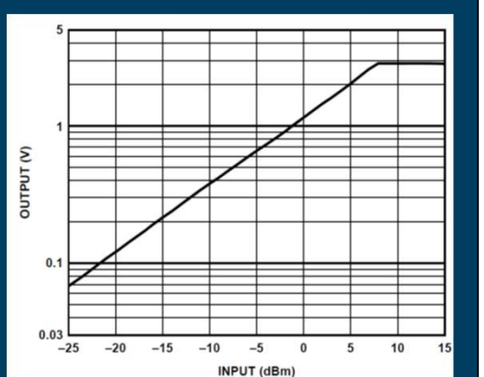




Linear-in-dB



Linear-in-Volt



- An RF Detector is a miniature RF Power Meter
- RF Power IN (dBm) → Volts Out

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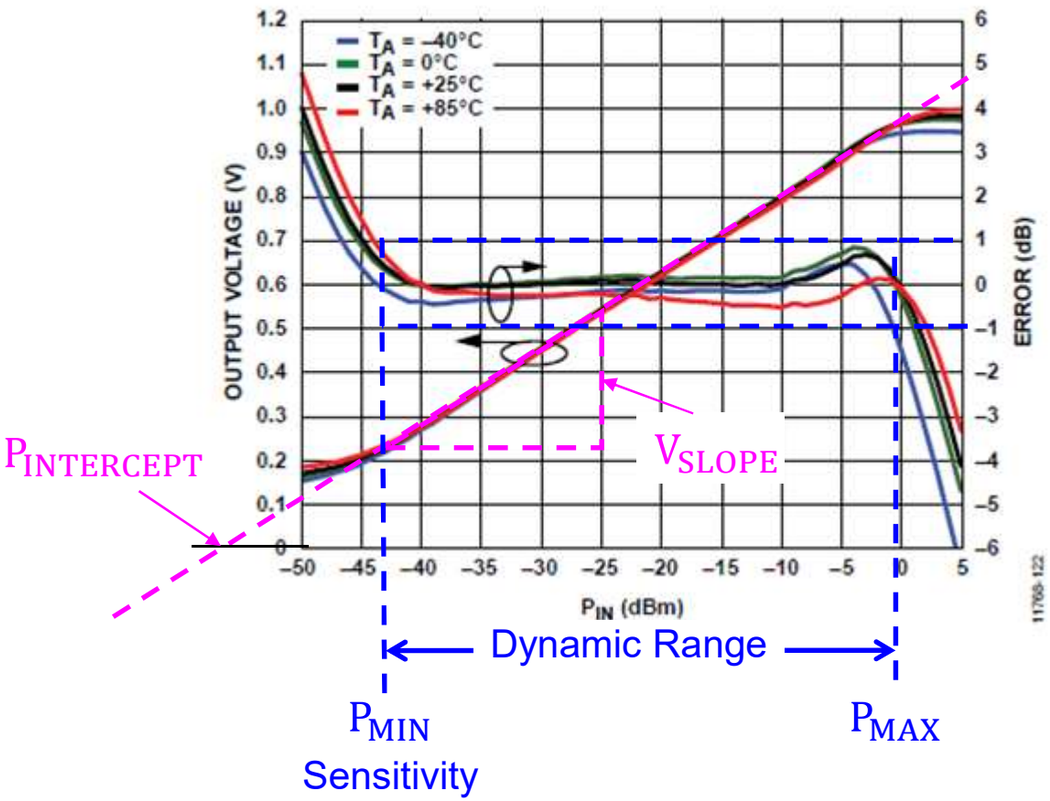
Power Measurement Errors: Law-Conformance & Dynamic Range

Example: Demodulating Logarithmic Amplifier

- **Transfer:** Linear-in-dB
- **Ideal Transfer Function:**
  - $V_{OUT} = SLOPE * (P_{IN} - P_{INTERCEPT})$
  - $P_{INTERCEPT}$ = extrapolated input power where V_{OUT} = 0V.
- **Measurement Error:**
  - Law conformance: deviation from ideal straight line
  - Variation across temperature
  - Variation with respect to waveform (modulation).
- **Dynamic Range (DR):**
  - Power range where ERROR < ± x dB (usually ±1dB)
  - **Sensitivity:** minimum power level in DR, i.e. P_{MIN}



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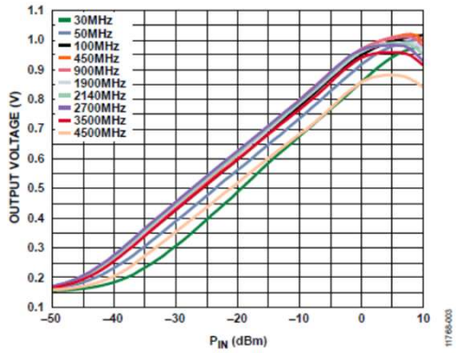
Transfer Variation vs Input Frequency

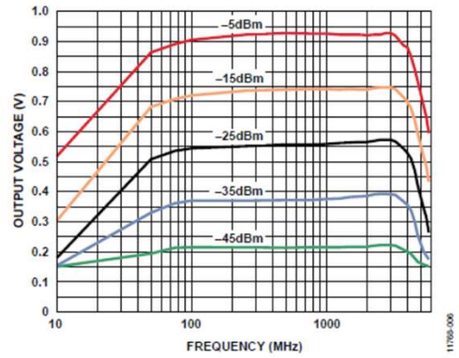
Detector Transfer Changes vs Frequency

- Accurate measurement may require calibration at various frequencies.
- Flat frequency response is desirable when the input frequency is unknown.
- When frequency flatness is most important, consider e.g. an SDLVA.

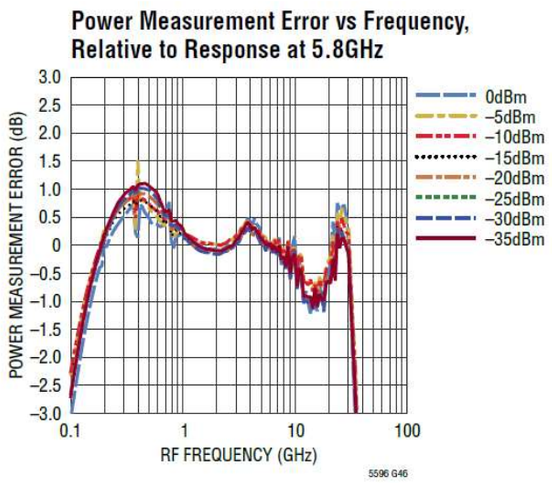
±1dB flat from 150MHz to 30GHz

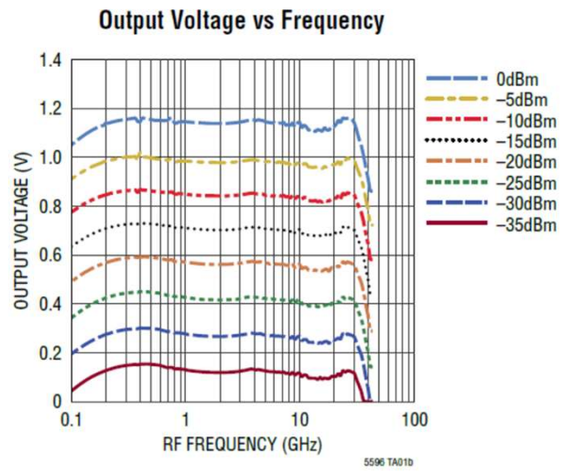
ADL5506 4.5GHz Demodulating Logarithmic Amplifier





LTC5596 40GHz RMS Detector





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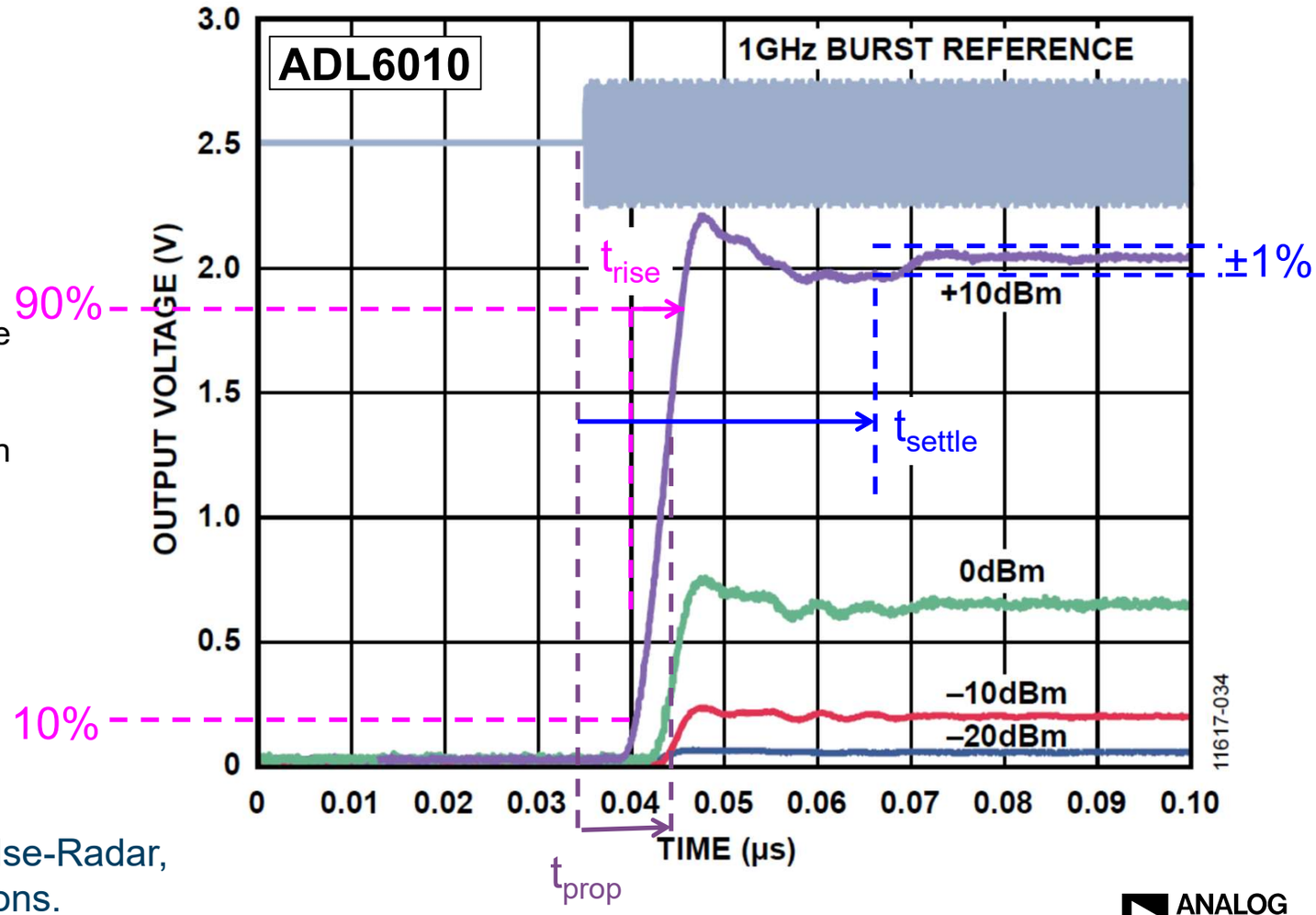
Transient Response

Metrics for Detector Transient Response

- **Rise & Fall Time:**
  - Time needed for 10% - 90% output change (rise), 90% - 10% (fall)
- **Propagation Delay:**
  - Delay between input reaching 50% of final value, and output reaching 50% of final value
- **Settling Time:**
  - Time needed for output to get and stay within (typically) ±1% of final value.
- **Baseband (“Video”) Bandwidth**
  - Bandwidth of the LF ‘ripple’ filter in the LF detector output circuitry (after detection)
  - Can sometimes be adjusted externally.
  - Usually the dominant factor limiting transient response.



Transient Response is important for e.g. Pulse-Radar, ASK Demodulation and Protection applications.

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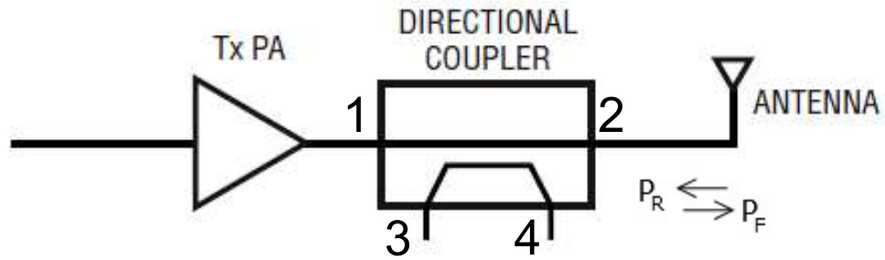
Measuring the Direction of Power Waves: Directivity

- **Separate measurement of Forward & Reflected Power important for:**
  - Transmitter power control (measure forward = transmitted power)
  - PA protection (measure reflected power & avoid PA over voltage)
  - Antenna tuning; change antenna impedance to minimize reflection
  - Generalized Vector-Network Analyzer functions (VNA)



- **Directional Coupler or Directional Bridge separates Forward & Reflected Power**
  - **Insertion Loss** (-S21 in dB) specifies power loss along main line (port 1 to port2).
  - **Coupling Factor** (-S32 in dB) specifies fraction of forward power observed at port 3.
  - **Directivity** specifies how well forward & reflected power measurements are separated:

    D = S31 - S32 + S21 (all in dB)

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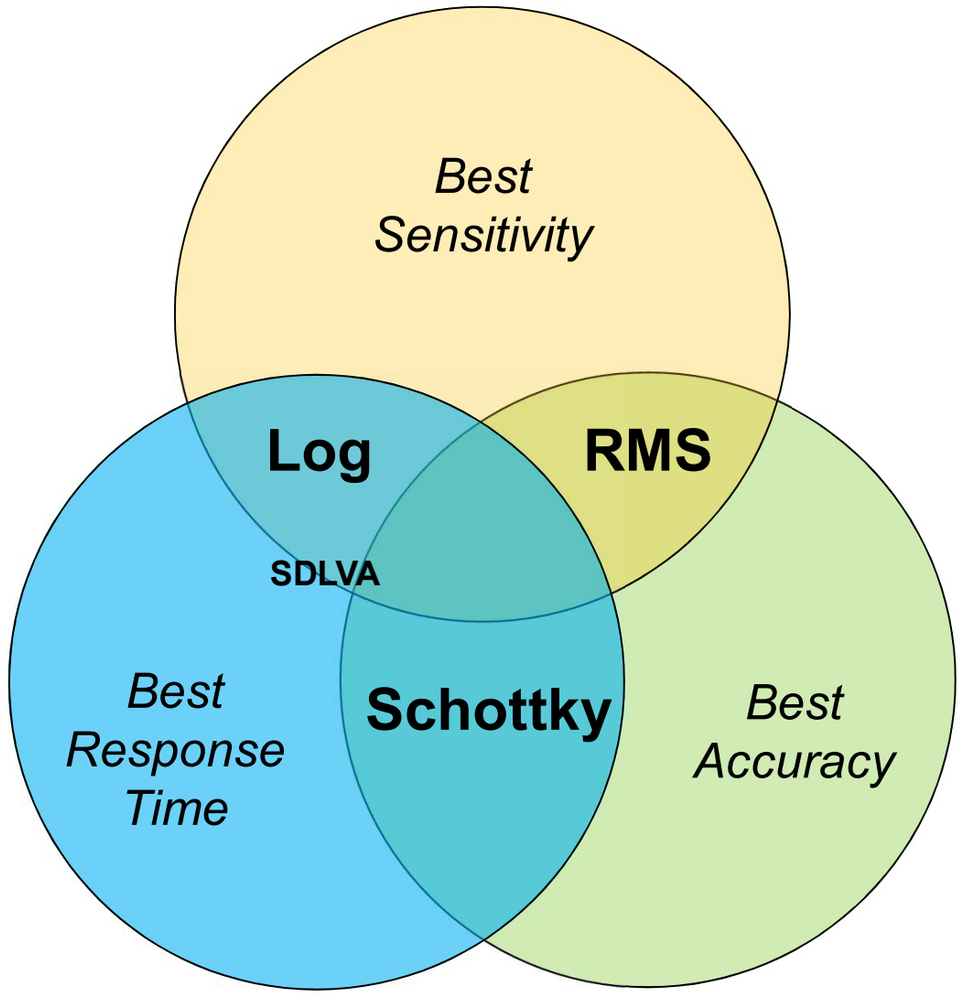
How to Select the Best Suited Detector for the Task?

Which Detector Do I Need – Log? Schottky? RMS?

What's most important?

- Sensitivity
- Response Time
- Accuracy

<u>Pick any Two.</u>



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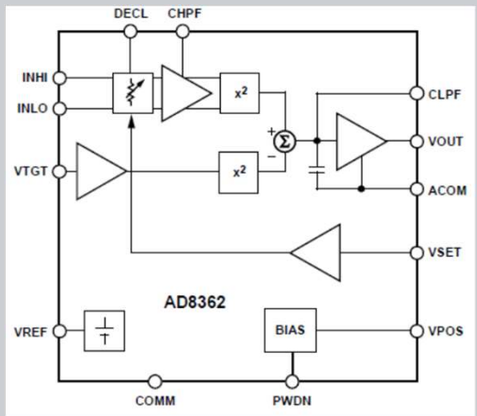
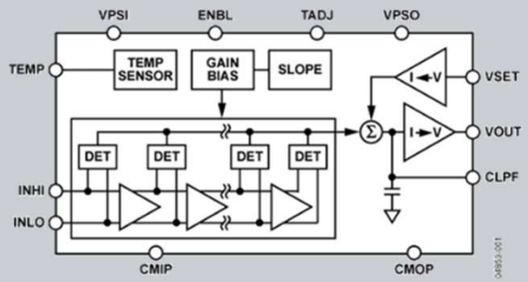
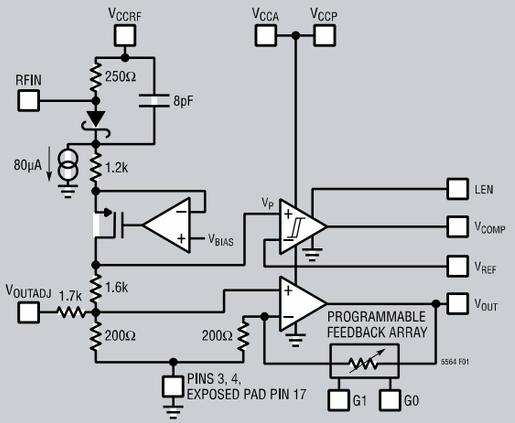
Magnitude Power Detector Categories

	RMS Detectors	Demodulating Log. Amps.	Schottky Detectors
			
Transfer	Linear-in-dB, Linear-in-V	Linear-in-dB	**"Diode",** Linear-in-V
Sensitivity	From -65dBm	**From -78dBm**	**From -25dBm**
Dynamic Range	Up to 70dB	**Up to 100dB**	**Up to 45dB**
Modulation Sensitivity	**Very Insensitive**	**Very Sensitive**	Somewhat Sensitive
Response Time	**Slow: >1µs**	**Fast: 10-100ns**	**Very Fast: <10ns**

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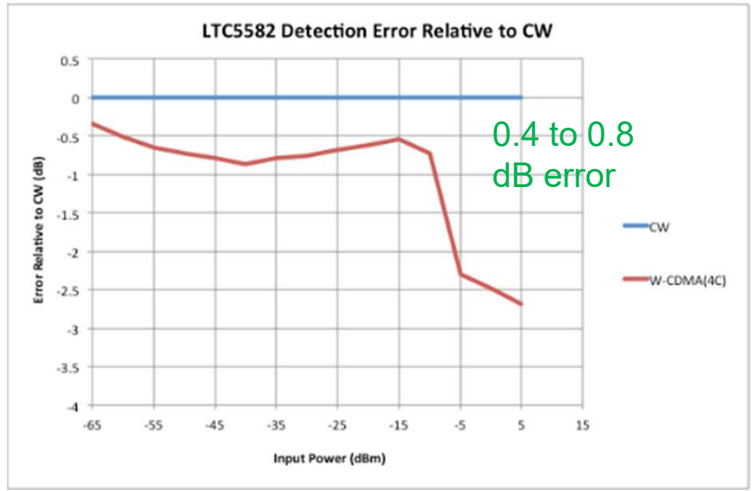
Modulation Sensitivity: RMS vs non-RMS Responding Detectors

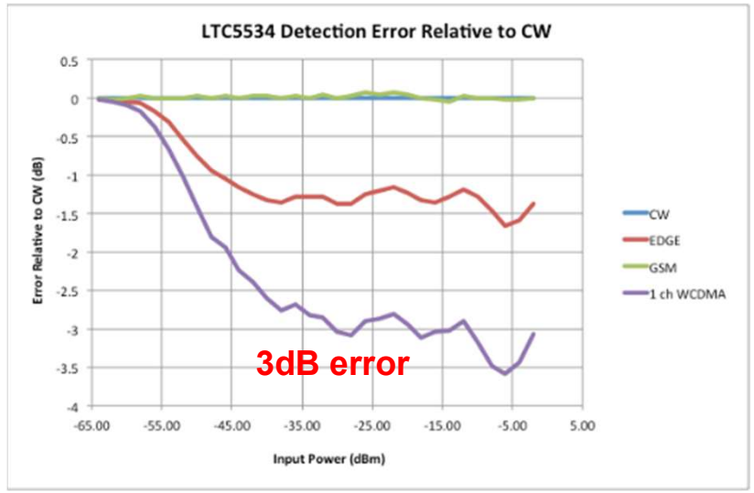
RMS Detectors are Insensitive to Modulation:

- Measure true RMS power for any waveform
- Response is insensitive to input waveform changes
- Suited for signals with large Crest-Factor (CF) and Peak-to-Average Power Ratio (PAPR)
- Use where:
  - Input signal is unknown (e.g. instrumentation)
  - Complex modulation
  - Waveform/modulation changes over time
  - Average or RMS power to be tightly controlled
  - Simplified system calibration is desired

Non-RMS Responding Detectors are Sensitive to Modulation and Waveform Changes



LTC5582
RMS Detector



LT5534
Log Detector

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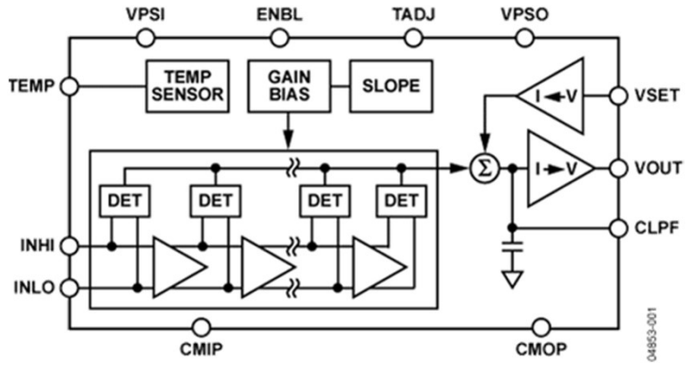
Demodulating Logarithmic Amplifiers & SDVLAs

High Dynamic Range
- Linear-in-dB Response
- Up to 100dB Dynamic Range

Wide Input Frequency Range
- Wide-Band Matched Input
- DC - 30GHz Input Frequencies

Fast Response Time (SDVLA)
- Low ns Propagation Delay
- Low ns Rise/Fall Times

Variety of Configurations
- Single- or Dual-Channel
- With/Without Limiter Output
- Detector and/or Controller



Typical Applications
- RSSI
- Signal Presence Detector
- CW S-Parameter Measurements

SDVLA Applications:
- Military Radar Receivers & RWR
- EW/ECM Systems
- Direction Finders (DF)
- Wideband Instrumentation

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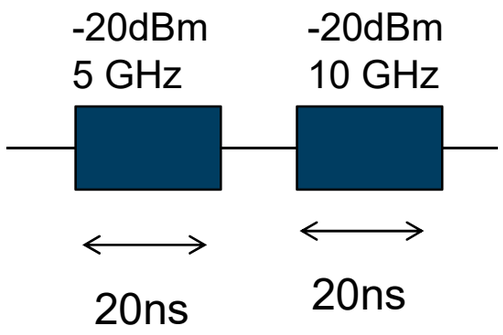
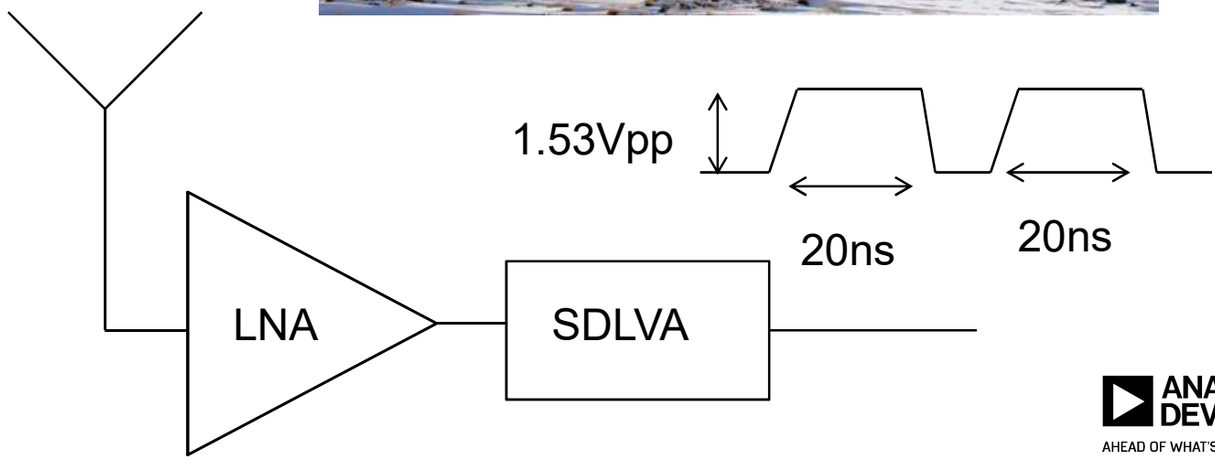
SDLVA Primary Function – Broadband RF Pulse Detection

SDLVA – What is it?

- Special type of Demodulating Logarithmic Amplifier
- Architecturally similar to LOG-Amp Detectors
- Very wide Frequency Range (up to >20GHz)
- Wide Dynamic Range (50-60dB)
- Extremely Flat Frequency Response
- Very Fast Response Time (<10ns)
- Optimized for EW Applications





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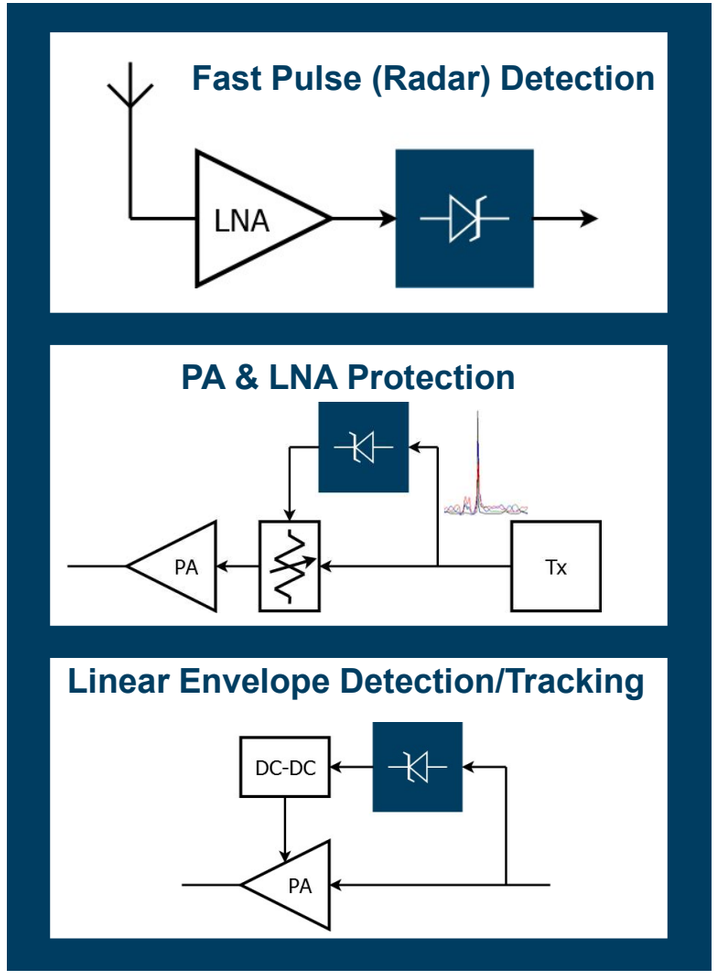
Pulse & Envelope Detection: Schottky Detectors

- **Fast Nano-Second Response Time:**
  - High-resolution pulse detection
  - PA & LNA protection
- **Accurate, Compact Solutions:**
  - Integrated temperature compensation
  - Output driver amplifiers, adjustable gain
  - Fast comparators + latch (some devices)
  - Linearized Transfer Function – ADL6010
  - Wide Envelope BW for Envelope Tracking
- **Limited Sensitivity (input looks into diodes):**
  - Good down to approx. -25 dBm.
  - Input return loss degrades at higher input power levels



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Selected Applications for Detectors

RF Detectors in (Wireless) Transmitter Applications

Transmit Power Control

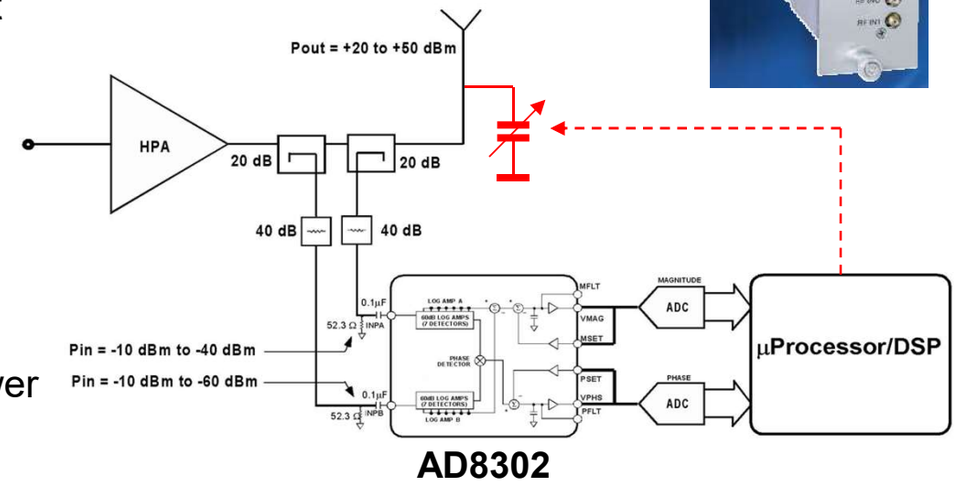
- Accurate control of ‘outbound’ signal (forward) power level
- RMS detectors often best candidate for the job
- Accuracy (temperature stability, modulation insensitivity, …) matters; speed is less important

Power Amplifier Protection

- Protect (expensive) High-Power PA (HPA) from catastrophic antenna fault
- Reflected Power – avoid over-voltage at PA output
- Fast response is critical, accuracy less important
- Schottky detectors are a good candidate

Antenna Tuning

- Tune antenna impedance to maximize transmitted/minimize reflected power
- Measure forward & reflected power (return loss)
- Measure both Magnitude & Phase (AD8302)



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Mil/Aero Applications

- Military and specialized Communication links
- Direction Finding (DF) Receivers
- Electronic Intelligence (ELINT) Receivers
- Electronic Counter Measure (ECM) Systems
- Radar Warning Receivers (RWRs)

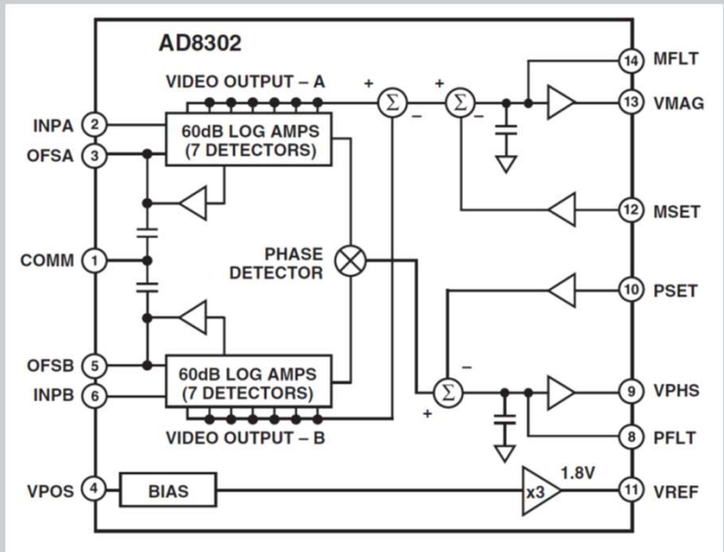
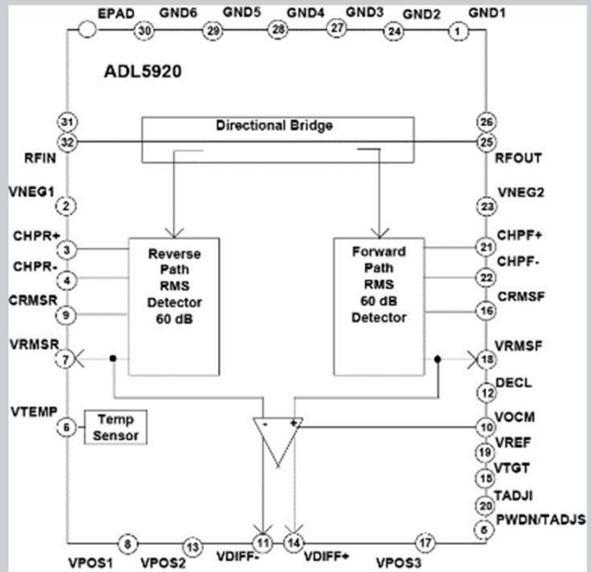
Microwave RMS/Schottky/SDLVA parts can meet a combination of these requirements:

- Wide RF frequency range
- Flat frequency response
- Good dynamic range
- Fast response

S-Parameter Measurement – Vector Power Measurement

Applications

- Test & Measurement
- System Health Monitoring
- Communications
- Industrial Metering

	AD8302	ADL5920
		
Magnitude	Magnitude Ratio (Forward/Reflected)	Magnitude & Magnitude Ratio
Phase	0° to 180°	-
Directional Coupler	External	**Integrated** – saves pcb space!
Measurements	Transmission & Reflection (S21, S11, …)	Reflection (S11, S22)

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Vector Power Measurement in Industrial Environments

Suitable for range of Metering Applications

- Moisture/humidity
- Level monitoring
- Substance identification
- Dirt/pollution detection
- …
- … and much more …

Conclusions

- Power detectors are suited for a wide range of system functions – not just AGC!
- Determine the key application requirements to select the right type of device
- Analog Devices has a very broad portfolio of RF power detectors, suited for a wide range of applications
- Check out our website for more information: http://analog.com

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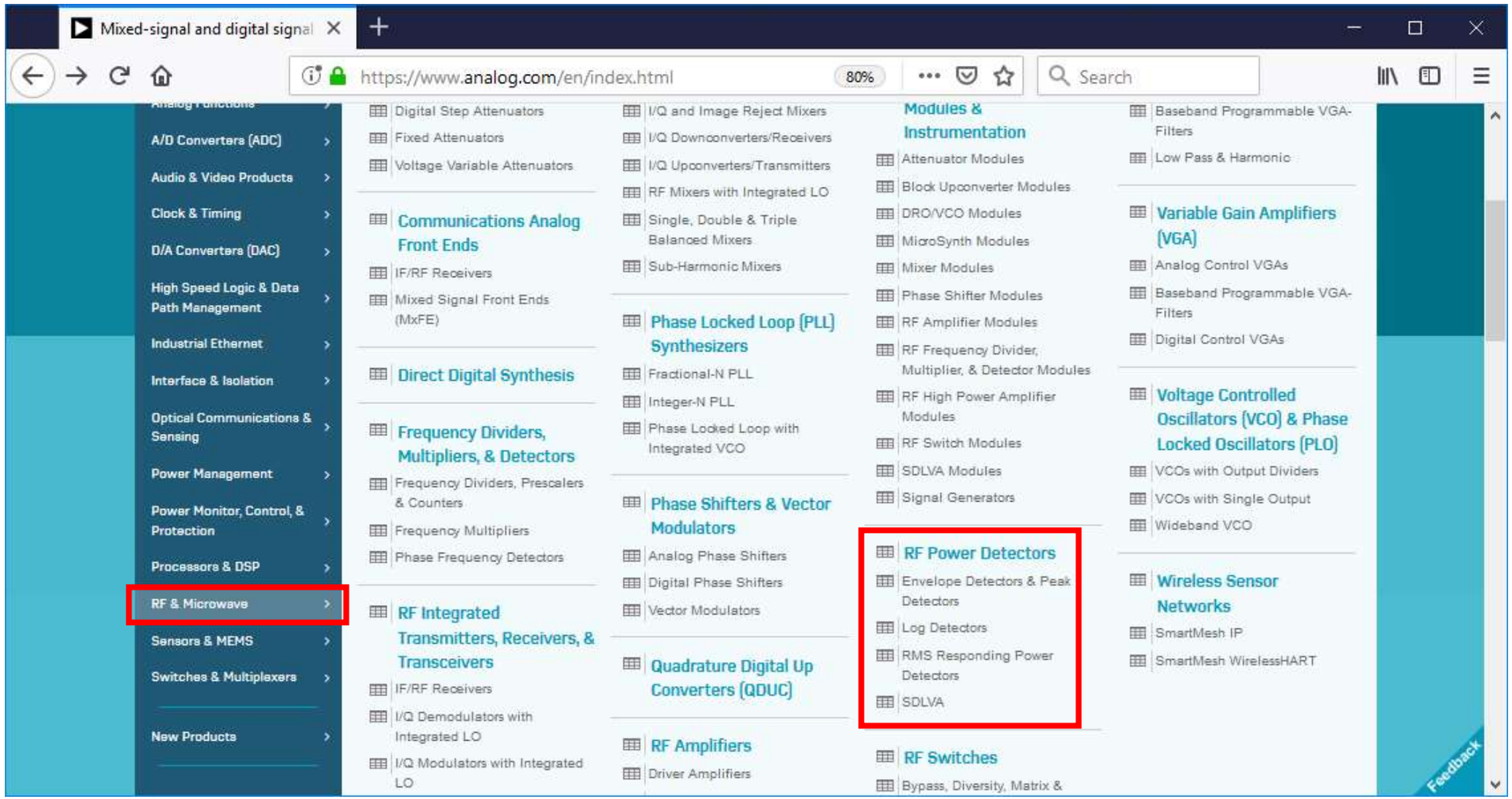
Web resources

Web Resources



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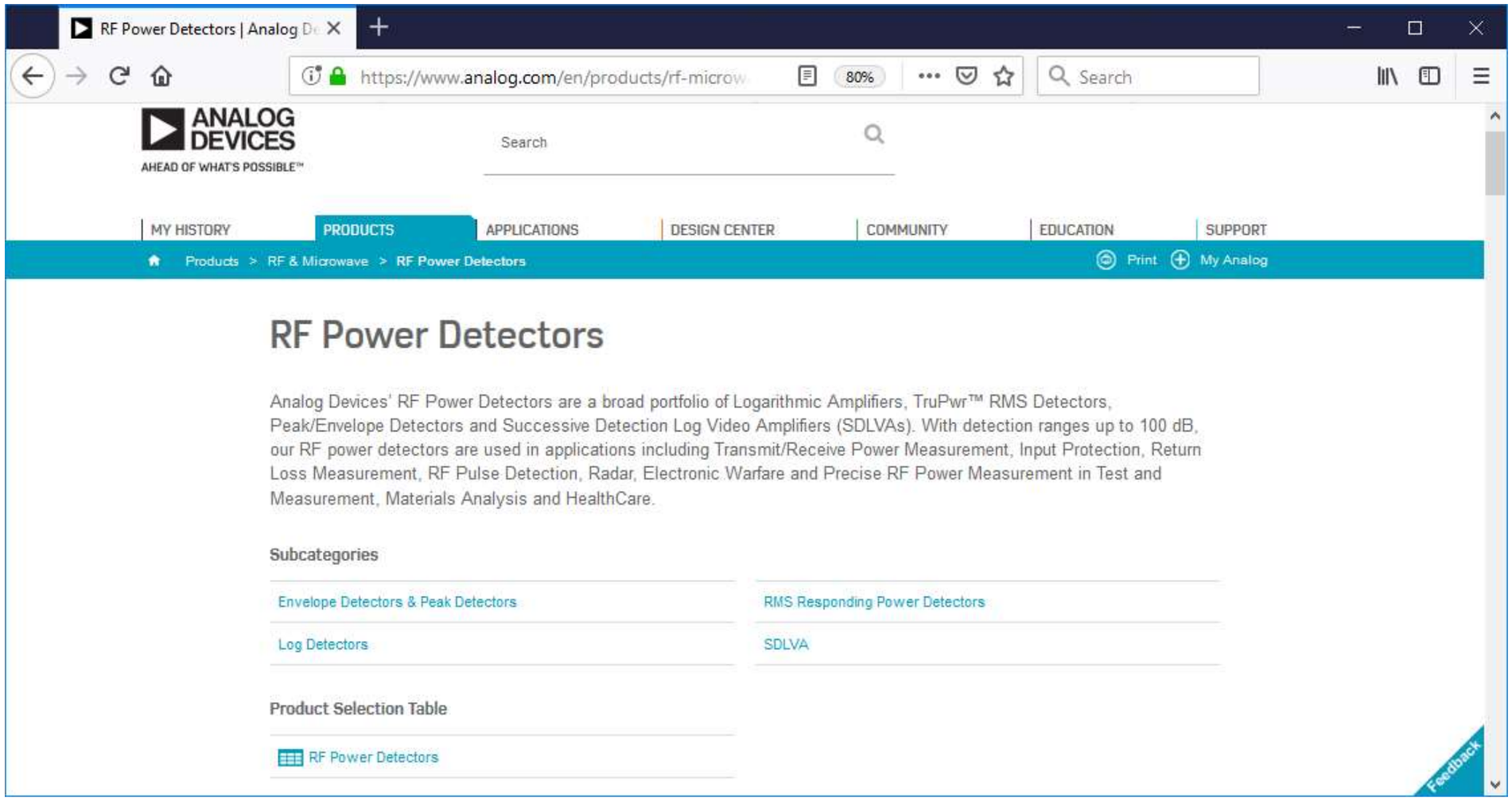
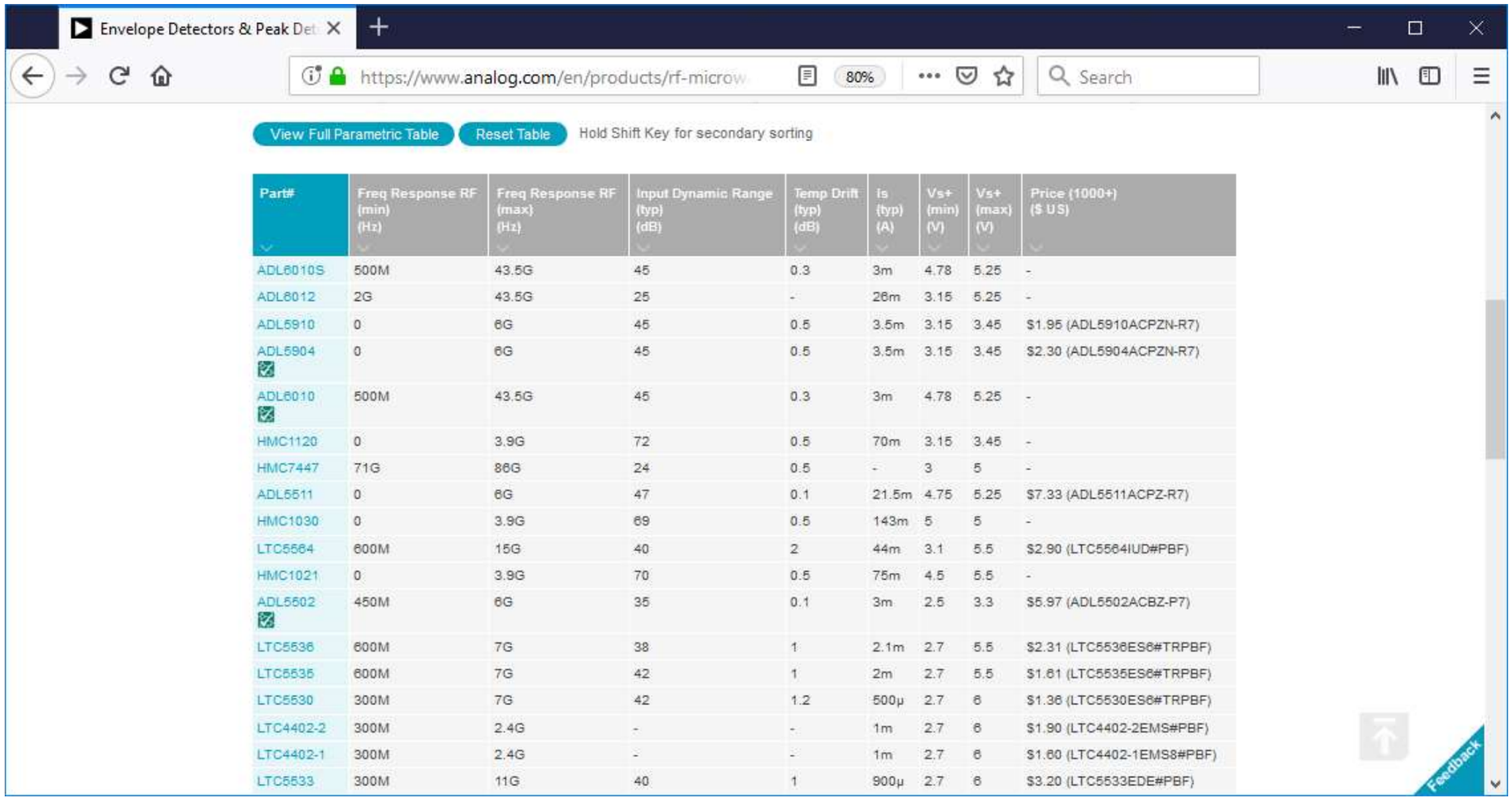
Web Resources



Web Resources



Part#	Freq Response RF (min) (Hz)	Freq Response RF (max) (Hz)	Input Dynamic Range (typ) (dB)	Temp Drift (typ) (dB)	Is (typ) (A)	Vs+ (min) (V)	Vs+ (max) (V)	Price (1000+) ($ US)
ADL6010S	500M	43.5G	45	0.3	3m	4.78	5.25	-
ADL6012	2G	43.5G	25	-	26m	3.15	5.25	-
ADL5910	0	6G	45	0.5	3.5m	3.15	3.45	$1.95 (ADL5910ACPZN-R7)
ADL5904	0	6G	45	0.5	3.5m	3.15	3.45	$2.30 (ADL5904ACPZN-R7)
ADL6010	500M	43.5G	45	0.3	3m	4.78	5.25	-
HMC1120	0	3.9G	72	0.5	70m	3.15	3.45	-
HMC7447	71G	86G	24	0.5	-	3	5	-
ADL5511	0	6G	47	0.1	21.5m	4.75	5.25	$7.33 (ADL5511ACPZ-R7)
HMC1030	0	3.9G	69	0.5	143m	5	5	-
LTC5564	600M	15G	40	2	44m	3.1	5.5	$2.90 (LTC5564IUD#PBF)
HMC1021	0	3.9G	70	0.5	75m	4.5	5.5	-
ADL5602	450M	6G	35	0.1	3m	2.5	3.3	$5.97 (ADL5502ACBZ-P7)
LTC5536	600M	7G	38	1	2.1m	2.7	5.5	$2.31 (LTC5536ES6#TRPBF)
LTC5535	600M	7G	42	1	2m	2.7	5.5	$1.61 (LTC5535ES6#TRPBF)
LTC5530	300M	7G	42	1.2	500µ	2.7	6	$1.36 (LTC5530ES6#TRPBF)
LTC4402-2	300M	2.4G	-	-	1m	2.7	6	$1.90 (LTC4402-2EMS#PBF)
LTC4402-1	300M	2.4G	-	-	1m	2.7	6	$1.60 (LTC4402-1EMS8#PBF)
LTC5533	300M	11G	40	1	900µ	2.7	6	$3.20 (LTC5533EDE#PBF)

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Supplemental Reference Material

Four Shields

- Arduino-based RF power measurement platforms with operation to 40 GHz
- Ideal for fast development of RF and microwave power measurement systems
- Scalar and vector RF power measurement options
- PC-based software GUIs for ADICUP3029 and Linduino
- Interactive development environments for ADICUP3029 and Linduino

Part Number	Generic	Function	Frequency (GHz)
DC2870A-KIT	LTC5596	Microwave RMS Detector	0.1 to 40
DC2847A-KIT	ADL5920	In-Line Scalar Reflectometer	DC to 7
EVAL-AD8302-ARDZ	AD8302	RF Gain and Phase Detector	DC to 2.7
EVAL-ADL5902-ARDZ	ADL5902	RF RMS Detector	0.05 to 9

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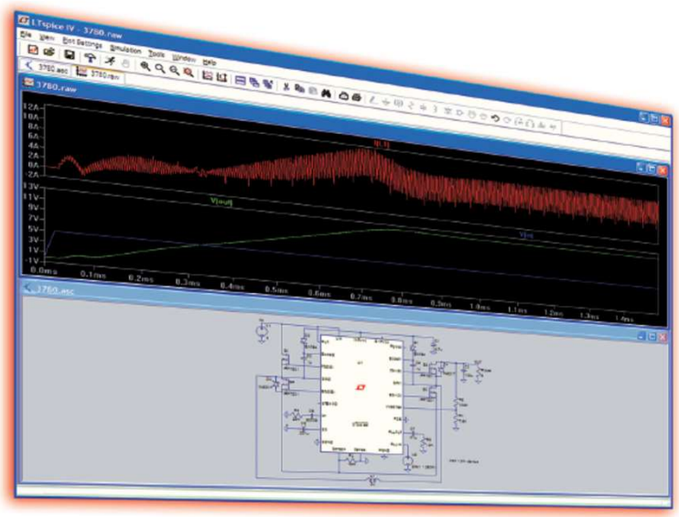
LTspice Models for RF Detectors

LTspice



- Free Analog Circuit Simulator
- Unlimited Nodes/Nets
- Fast Simulations

LTspice Models for RF Detectors

- Requested by wide variety of customers
- Suited for design of pin-interface circuits:
  - RF input network
  - Output interfacing to ADC
- Basic overall transfer functionality
- More models will be added over time

RF Detector Models Currently Released	
LTC5505-1	RF power Detector with Buffered Output and >40dB Dynamic Range
LTC5505-2	RF power Detector with Buffered Output and >40dB Dynamic Range
LTC5507	100kHz to 1GHz RF Power Detector
LTC5532	Precision 300MHz to 7GHz RF Detector with gain and Offset Adjustment
AD8310	DC to 440 MHz, 95 dB Logarithmic Amplifier

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