Obscurities & Applications of RF Power Detectors

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Why measure RF/IF power?

- Set mobile’s power level (RSSI measurement in BTS receiver)
- Signal Leveling in receivers (high precision generally not required, usually done at IF)
- Prevent interference with other systems and other users in same cell (mobile handset).
- Improve mobile talk time (operate at low end of permissible range, reduce SAR).
- Improve network robustness (operate at high end of permissible range).
- Thermal Dimensioning (mostly HPA)
Typical RF Signal Chain
Typical Detector Applications

**Tx Power Measurement**

- PA
- Detector
- ADC

**Received Power Measurement**

- LO2
- Detector
- ADC

**TX power control**

- PA
- Detector

**Received Power Control**

- LO2
- Vgain for RSSI
- Detector
- ADC
RF Power Detectors
Critical Specifications

- Linearity and Temperature Stability of Output
- Dynamic Range
- Pulse Response
- Variations due to Power Supply and Frequency Changes
- Ease of Use and Calibration
- Change in response vs. signal crest factor
- Size and overall Component Count
RF Power Measurement Techniques
Power Measurement Techniques
Diode Detection

Transfer Function of Diode Detector

Vout vs. Pinput

-25 deg C  25 deg C  +85 deg C  -30 DEG C  -40 DEG C
Diode Detector with Temperature Compensation

Transfer Function of Temperature Compensated Diode Detector

- Excellent temperature stability at high power
- Limited Dynamic Range and poor low end temp. stability
- High Resolution ADC required for low end power measurement
- Lots of patented techniques which probably improve this performance
Logarithmic Amplifiers
Log Amp Block Diagram

- Signal propagates through gain chain until it limits
- Detectors full-wave rectify the signal at the output of each stage
- Outputs of detectors are summed and low-pass filtered
Log Amp Transfer Function in Time Domain
Log Amp Transfer Function - Slope and Intercept

Slope = \((V_{O2} - V_{O1}) / (P_{I2} - P_{I1})\)

Intercept = \(P_{I1} - V_{O1} / \text{Slope}\)

\(V_{out} = \text{Slope} \cdot (P_{in} - \text{Intercept})\)

\(P_{in} = (V_{out} / \text{Slope}) + \text{Intercept}\)
RF Power Detector Calibration

VOUT\text{IDEAL} = \text{SLOPE} \times (\text{PIN} - \text{INTERCEPT})

\text{SLOPE} = (\text{VOUT}_1 - \text{VOUT}_2) / (\text{PIN}_1 - \text{PIN}_2)

\text{INTERCEPT} = \text{PIN}_1 - (\text{VOUT}_1 / \text{SLOPE})

\text{Error (dB)} = (\text{VOUT} - \text{VOUT}_\text{IDEAL}) / \text{SLOPE}
±1 dB Dynamic Range

Temperature Drift can reduce Dynamic Range
Detector Calibration Procedure

- **Factory Calibration:** Using a precise power source, measure output voltage from the detector with two known input powers at top and bottom of desired input range.
- Perform calibration measurements only at room temperature.
- Calculate SLOPE and INTERCEPT and store in non-volatile memory.
- When equipment is in operation measure detector output voltage using ADC.
- Calculate power using “Pin = (Vout/Slope) + Intercept”.
- No temperature compensation necessary.
Adjust Calibration Points for optimal accuracy over a narrow range

Calibrate for highest accuracy at max RF power and degraded accuracy at lower powers
Temperature drift vs. Output Voltage at 25ºC

- Calibration eliminates error due to non-linearity at 25 ºC
Temperature drift vs. Output Voltage at 25°C

- Removes error due to non-linearity at 25°C
- Provides larger dynamic range and improved accuracy
- Method however does not account for non-linearity in the transfer function at room temperature
- For practical implementation, calibration measurements must be taken at multiple input powers (multi-point calibration vs. 2-point calibration)
Log Amp Detectors vs. Diode Detectors

- Log Amps have a higher dynamic range (40 dB or greater vs. 20-30 dB for a diode detector)
- Log Amps provide good temperature stability over a wide dynamic range.
- Diode detectors only provide good temperature stability at max input power (typically +15 dBm)
Log Amp Pulse Response Time

10ns Response Time (10% - 90%)
# 2nd Generation Log Amp Detectors

<table>
<thead>
<tr>
<th>Part No.</th>
<th>RF Freq (MHz)</th>
<th>Dynamic Range (dB)</th>
<th>Temp Drift (dB)</th>
<th>Response Time (ns)</th>
<th>Package</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD8302</td>
<td>dc to 2700</td>
<td>60</td>
<td>±1</td>
<td>60</td>
<td>14-lead TSSOP</td>
<td>Dual gain &amp; phase detector</td>
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<tr>
<td>AD8306</td>
<td>5 to 400</td>
<td>100</td>
<td>±1</td>
<td>73</td>
<td>16-lead SOP</td>
<td>Military specified part available</td>
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<tr>
<td>AD8307</td>
<td>dc to 500</td>
<td>92</td>
<td>±1</td>
<td>400</td>
<td>8-lead SOIC/DIP</td>
<td>-</td>
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<tr>
<td>AD8309</td>
<td>5 to 500</td>
<td>100</td>
<td>±1</td>
<td>67</td>
<td>16-lead TSSOP</td>
<td>Amplitude and limiter outputs</td>
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<tr>
<td>AD8310</td>
<td>dc to 440</td>
<td>95</td>
<td>±1</td>
<td>15</td>
<td>8-lead MSOP</td>
<td>Low cost</td>
</tr>
<tr>
<td>AD8313</td>
<td>100 to 2500</td>
<td>70</td>
<td>±1.25</td>
<td>40</td>
<td>8-lead MSOP</td>
<td>-</td>
</tr>
<tr>
<td>AD8314</td>
<td>100 to 2700</td>
<td>45</td>
<td>±1</td>
<td>70</td>
<td>8-lead MSOP/CSP</td>
<td>Small package, lower power</td>
</tr>
</tbody>
</table>

WIDEST RANGE AND BEST PERFORMANCE IN THE INDUSTRY!
# 3rd Generation Log Amp Detectors

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<thead>
<tr>
<th>Part No.</th>
<th>RF Freq (MHz)</th>
<th>Dynamic Range (dB)</th>
<th>Temp Drift (dB)</th>
<th>Response Time (ns)</th>
<th>Package</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD8317</td>
<td>1 to 10000</td>
<td>50</td>
<td>±0.5</td>
<td>8</td>
<td>8-Lead 3x2 mm CSP</td>
<td>Smaller package, Lower cost version of AD8318</td>
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<tr>
<td>AD8318</td>
<td>1 to 8000</td>
<td>60</td>
<td>±0.5</td>
<td>10</td>
<td>16-Lead 4x4 mm CSP</td>
<td>50 ohm drive, Integrated Temp Sensor</td>
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<tr>
<td>AD8319</td>
<td>1 to 10000</td>
<td>40</td>
<td>±0.5</td>
<td>8</td>
<td>8-Lead 3x2 mm CSP</td>
<td>Reduced dynamic range and lower cost version of AD8317</td>
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<tr>
<td>ADL5519</td>
<td>1 to 10000</td>
<td>50</td>
<td>±0.5</td>
<td>&lt;10</td>
<td>24-Lead LFCSP</td>
<td>Dual Log Detector</td>
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</table>
AD8318: Highest Performance Log Amp

**KEY SPECIFICATIONS**
- Bandwidth 1MHz to 8Ghz
- Stability over temperature: ±0.5 dB
- Pulse response time 10 ns
- Package: 4mm×4mm, 16-pin LFCSP

**FEATURES**
- Integrated temperature sensor
- Low noise measurement/controller output VOUT
- Power-down feature: <1.5 mW at 5 V
- Fabricated using high speed SiGe process
Log Amps - Summary

- Provide power detection over large dynamic range (up to 100 dB)
- Operation from DC to 10 GHz
- With 2-Point Calibration, measurement accuracy of << ±1 dB is achievable.
- Devices are generally configured to provide a broadband 50 Ω match
- Pulse Response times of <10 ns are achievable.
- Power consumption varies from 5 mA to 70 mA
RMS-Responding RF Detectors
Difficult Measurements: Complex Waveforms

W-CDMA Forward Link, 4 Channels

IS-95 Reverse Link

IS-95 Forward Link (8Ch)
Response of a Successive Detection Log Amp to Varying Signals with Various Crest Factors
RMS-Responding RF Detector

![Diagram of ADL5501 circuit]

- **RFIN**
- **VPOS**
- **FLTR**
- **VRMS**
- **ENBL**
- **COMM**

**ADL5501**

- **INTERNAL FILTER CAPACITOR**
- **BAND-GAP REFERENCE**

**Annotations**: x2, TRANS-CONDUCTANCE CELLS, BUFFER 100Ω
RMS Detector Waveform Independence
Output Voltage increases exponentially as input increases in dB (i.e. response is linear in V/V, not logarithmic)

Device achieves best temperature stability at max power (desirable for most applications)
High Dynamic Range
RMS Detection
60 dB TruPwr™ RMS Detector

- Waveform and Modulation Independent
- Linear-in-dB output
Response of AD8362 RMS Detector to CW, QPSK and QAM Signals

@1.9 GHz, Vtgt = 0.625 V
## TruPwr™ RMS Detectors

- **Modulation Independent RF Measurements**

<table>
<thead>
<tr>
<th>Part#</th>
<th>RF Freq (MHz)</th>
<th>Dynamic Range (dB)</th>
<th>Temp Stability (dB)</th>
<th>Voltage Supply (V)</th>
<th>Supply Current (mA)</th>
<th>Package</th>
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<tbody>
<tr>
<td>AD8361</td>
<td>2500</td>
<td>30</td>
<td>±0.25</td>
<td>2.7 to 5.5</td>
<td>1.1</td>
<td>6-Lead SOT-23, 8-Lead uSOIC</td>
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<tr>
<td>ADL5501</td>
<td>4000</td>
<td>30</td>
<td>±0.1</td>
<td>2.7 to 5.5</td>
<td>1.0</td>
<td>SC-70</td>
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<tr>
<td>AD8362</td>
<td>2700</td>
<td>60</td>
<td>±1</td>
<td>4.5 to 5.5</td>
<td>20</td>
<td>16-Lead SOP</td>
</tr>
<tr>
<td>AD8364</td>
<td>2700</td>
<td>60</td>
<td>±0.5</td>
<td>4.5 to 5.5</td>
<td>72</td>
<td>32-Lead LFCSP</td>
</tr>
</tbody>
</table>

*(Dual Channel)*
AD8362 TruPwr™ RMS Detector

KEY SPECIFICATIONS
- Dynamic Range: >60dB
- Temperature Stability: +/-1dB
- Frequency Range: LF to 2.7GHz
- Package: 16 Lead TSSOP

FEATURES
- True RMS responding power detector
- Waveform and Modulation Independent
- Linear-in-dB output
Controlling AGC Loops with RF Detectors
A Typical AGC Loop

- Detector measures output power from a variable gain amplifier or power amplifier
- Measured result is compared to a setpoint value
- Error amplifier/Integrator adjusts gain so that output power corresponds to setpoint
- Integrator capacitor/resistor set response time of loop
- Many of ADI’s detectors have an integrated “Controller Mode”
Setpoint is applied to Detector VSET input
Vout varies up or down to balance loop
Use to set output to a fixed value (fixed VSET, variable input power) or to vary output power (variable VSET, fixed or variable input power)
Set response time of loop by varying Cflt
Controlling Gain with a Dual RMS Detector

- Dual RMS Detector can also operate in Controller Mode
- Detector measures and controls VGA in an analog loop
- Detector tries to balance input power at its two RF inputs
- Gain setpoint is controlled by difference in external attenuators
Gain vs. Input Power for Analog Gain Control Loop

- Gain varies by only +/-0.25 over a 60 dB input range
- Excellent stability over temperature
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