## DUAL RMS POWER DETECTOR
## 0.1 - 3.9 GHz



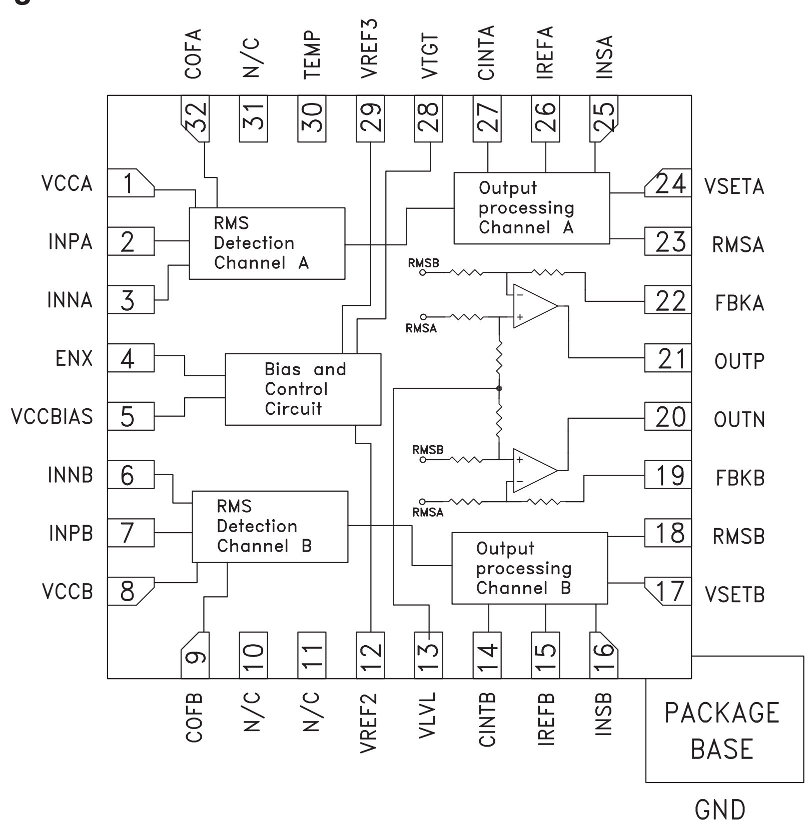
### Features

- Crest Factor (Peak-to-Average Power Ratio) Measurement
- Envelope-to-Average Power Ratio Measurement
- Dual channel and channel difference output ports
- Excellent Channel Matching and Channel Isolation
- RF Signal Wave Shape & Crest Factor Independent
- Supports Controller Mode[1]
- ± 1 dB Detection Accuracy to 3.9 GHz
- Input Dynamic Range -55 dBm to +15 dBm
- +5V Operation from -40° C to +85° C
- Excellent Temperature Stability
- Integrated Temperature Sensor
- Power-Down Mode
- 32 Lead 5x5mm SMT Package: 25mm²

### Typical Applications

- Log -> Root - Mean - Square (RMS) Conversion
- Transmitter Power Control
- Receiver Automatic Gain Control
- Antenna VSWR Monitor
- Received Signal Strength Indication (RSSI)
- Transmitter Signal Strength Indication (TSSI)
- Dual Channel wireless infrastructure radio

### Functional Diagram




[1] For more information regarding controller mode operation, please contact your Hittite sales representative or email sales@hittite.com



For price, delivery, and to place orders, please contact Hittite Microwave Corporation:
20 Alpha Road, Chelmsford, MA 01824 Phone: 978-250-3343 Fax: 978-250-3373
Order On-line at www.hittite.com

RoHS✓ EARTH FRIENDLY

## General Description

The HMC714LP5E is a dual-channel RMS power detector designed for high accuracy RF power signal measurement and control applications over the 0.1 to 3.9 GHz frequency range. The device can be used with input signals having RMS values from -55 dBm to +15 dBm referenced to 50 Ω and large crest factors with no accuracy degradation.

Each RMS detection channel is fully specified for operation up to 3.9 GHz, over a wide dynamic range of 70 dB. The HMC714LP5E operates from a single +5V supply and provides two linear-in-dB detection outputs at the $RMS_A$ and RMSB pins with scaled slopes of 37 mV/dB. The RMSA and RMSB channel outputs provide RMS detection performance in terms of dynamic range, logarithmic linearity and temperature stability similar to Hittite's HMC614LPE RMS Detector. The RMSA and RMSB outputs provide a read of average input signal power, or true-RMS power. Frequency detection up to 5.8 GHz is possible, with excellent channel matching of less than 0.5 dB (for the single-ended configuration), over a wide range of input frequencies and with low temperature drift.

The HMC714LP5E also provides "channel difference" output ports via pins OUTP and OUTN, permitting measurements of the input signal power ratio between the two power detection channels. These outputs may be used in single-ended or differential configurations. An input voltage applied to the VLVL input pin is used to set the common mode voltage reference level for OUTP and OUTN. On the Hittite evaluation board, the VLVL pin is shorted to VREF2 output to provide a nominal bias voltage of 2.5V; but any external bias voltage may be used to set VLVL.

The HMC714LP5E also features INSA and INSB pins which provide a measurement of instantaneous signal power normalized to average power level in each channel. Reading both the INSA/INSB and RMSA/RMSB output voltage signals provides a very informative picture of the RF input signal; providing peak power, average power, peak-to-average power, and RF wave shape.

The device also includes a buffered PTAT temperature sensor output with a temperature scaling factor of 2.2 mV/°C yielding a typical output voltage of 600 mV at 0°C.

The HMC714LP5E operates over the -40 to +85C temperature range, and is available in a compact, 32-lead 4x4 mm leadless QFN package

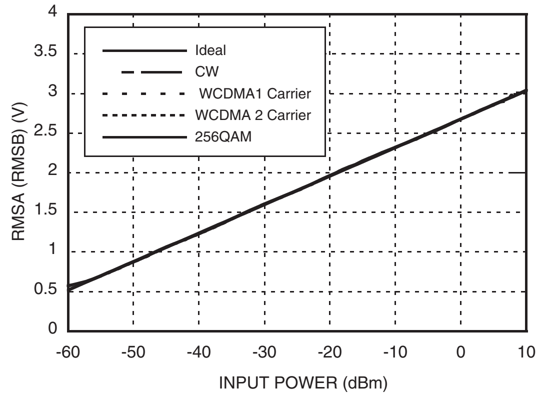
## Electrical Specifications I, $T_A$ = +25°C, VCCA = VCCB = VCCBIAS = 5V, CINT = 0.1 µF

| Parameter | Typ. | Typ. | Typ. | Typ. | Typ. | Typ. | Typ. | Typ. | Units |
|---|---|---|---|---|---|---|---|---|---|
| **Dynamic Range** (± 1 dB measurement error) | | | | | | | | | |
| Input Signal Frequency | 100 | 500 | 900 | 1900 | 2200 | 3000 | 3500 | 3900 | MHz |
| Differential Input Configuration, Channel A | 68 | 68 | 69 | 72 | 71 | 66 | 47 | 42 | dB |
| Differential Input Configuration, Channel B | 68 | 69 | 69 | 71 | 71 | 64 | 45 | 41 | dB |
| Input Signal Frequency | 100 | 900 | 1800 ± 300 | | 2200 ± 300 | | 3600 ± 300 | | MHz |
| Single-Ended Input Configuration, Channel A | 70 | 62 | 71 | | 69 | | 61 | | dB |
| Single-Ended Input Configuration, Channel B | 70 | 62 | 71 | | 69 | | 61 | | dB |
| **Channel Isolations** | | | | | | | | | |
| Input Signal Frequency | 100 | 500 | 900 | 1900 | 2200 | 3000 | 3500 | 3900 | MHz |
| Input A to Input B Isolation (Baluns Macom ETC1-1-13 at both channels) | 72 | 70 | 69 | 53 | 51 | 56 | 48 | 47 | dB |
| Input A to $RMS_B$ Isolation ($PIN_B$ = -45 dBm, $RMS_B$ = $RMSB_{INB}$ ±1 dB) | | 60+ | 56 | 46 | 44 | 47 | | | dB |
| Input B to $RMS_A$ Isolation ($PIN_A$ = -45 dBm, $RMS_A$ = $RMSA_{INA}$ ±1 dB) | | 60+ | 58 | 46 | 44 | 48 | | | dB |
| Input A to $RMS_B$ Isolation ($PIN_B$ = -40 dBm, $RMS_B$ = $RMSB_{INB}$ ±1 dB) | | | | | | | 47 | 39 | dB |
| Input B to $RMS_A$ Isolation ($PIN_A$=-40 dBm, $RMS_A$=$RMSA_{INA}$ ±1 dB) | | | | | | | 43 | 28 | dB |

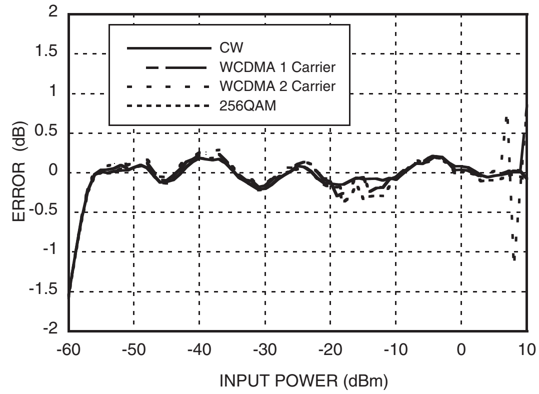
## Electrical Specifications II, $T_A$ = +25°C, VCCA = VCCB = VCCBIAS = 5V, CINT = 0.1 μF

| Parameter | Typ. | Typ. | Typ. | Typ. | Typ. | Typ. | Typ. | Typ. | Units |
|---|---|---|---|---|---|---|---|---|---|
| **Deviation vs Temperature: (Over full temperature range -40°C to 85°C. Deviation is measured from reference, which is CW input at 25°C** | | | | | | | | | |
| Differential Input Interface with 1:1 Balun Transformer (over full input frequency range) | | | | | | | ± 0.6 | | dB |
| Wideband Single-Ended Input Interface suitable for input signal frequencies below 1000 MHz | | | | | | | ± 0.5 | | dB |
| Tuned Single-Ended Input Interface Suitable for input signal frequencies above 1000 MHz | | | | | | | ± 0.6 | | dB |
| **Modulation Deviation (Deviation measured from reference, which is measured with CW input at equivalent input signal power, VTGT=2V)** | | | | | | | | | |
| Input Signal Frequency | 100 | 500 | 900 | 1900 | 2200 | 3000 | 3500 | 3900 | MHz |
| 256QAM (2 Mbps, 8dB Crest Factor) | -0.13 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.3 | -0.3 | mV/dB |
| WCDMA Single Carrier (Test Model 1 with 64DPCH) | -0.3 | -0.2 | -0.2 | -0.2 | -0.2 | -0.2 | -0.2 | -0.2 | dBm |
| WCDMA 2 Carrier (Test Model 1 with 64DPCH) | -0.5 | -0.5 | -0.4 | -0.4 | -0.3 | -0.4 | -0.4 | -0.4 | dBm |
| **Modulation Deviation (Deviation measured from reference, which is measured with CW input at equivalent input signal power, VTGT=1V)** | | | | | | | | | |
| Input Signal Frequency | 100 | 500 | 900 | 1900 | 2200 | 3000 | 3500 | 3900 | MHz |
| 256QAM (2 Mbps, 8dB Crest Factor) | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | -0.2 | -0.1 | dB |
| WCDMA Single Carrier (Test Model 1 with 64DPCH) | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | dB |
| WCDMA 2 Carrier (Test Model 1 with 64DPCH) | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | dB |
| **Differential Input Configuration Logarithmic Slope and Intercept** | | | | | | | | | |
| Input Signal Frequency | 100 | 500 | 900 | 1900 | 2200 | 3000 | 3500 | 3900 | MHz |
| Logarithmic Slope | 37.3 | 37.1 | 37 | 36 | 36 | 36.1 | 36.2 | 38.2 | mV/dB |
| Logarithmic Intercept | -70 | -70 | -69.5 | -72 | -71.5 | -68.5 | -68.5 | -64 | dBm |
| Max. Input Power at +-1dB Error | 12 | 14 | 13 | 15 | 15 | 13 | -5 | -8 | dBm |
| Min. Input Power at +-1dB Error | -56 | -55 | -56 | -56 | -56 | -52 | -52 | -49 | dBm |
| **Single Ended Input Configuration Logarithmic Slope and Intercept** | | | | | | | | | |
| Input Signal Frequency | 100 | 900 | 1800 ± 300 | | 2200 ± 300 | | 3600 ± 300 | | MHz |
| Logarithmic Slope | 38.2 | 37.9 | 36.6 | | 35.4 | | 36.8 | | mV/dB |
| Logarithmic Intercept | -67 | -67.5 | -67 | | -67 | | -64.5 | | dBm |
| Max. Input Power at +-1dB Error | 14 | 6 | 15 | | 15 | | 12 | | dBm |
| Min. Input Power at +-1dB Error | -56 | -56 | -56 | | -54 | | -49 | | dBm |
| **iPAR Feature:** INS[A,B] outputs follow Amplitude Modulated Envelope Power, scaled to Average (RMS) Signal Power | | | | | | | | | |
| INS[A,B] and IREF[A,B] are measured with Rext = 3.9 kΩ and 50 kΩ active scope probe | | | | | | | | | |
| IREF[A,B] Output Voltage | | | | | | | | 1.6 | V |
| INS[A,B] Output Voltage, with CW Input Signal (EAR = 1: Reference Condition)[1] | | | | | | | | 1.6 | V |
| INS[A,B] Scaling Factor (SF) with $V_{TGT}$ = 2V | | | | | | | | 190 | mV |
| INS[A,B] Scaling Factor (SF) with $V_{TGT}$ = 1V | | | | | | | | 95 | mV |
| INS[A,B] Output: Variation over Temperature (-40C to 85C) | | | | | | | | ± 2 | % |
| INS[A,B] Output: 3 dB Video BW | | | | | | | | 35 | MHz |
| [1] EAR: Amplitude Modulated Envelope Signal Power-to-Average (RMS) Signal Power Ratio; EAR = 1 for CW signals | | | | | | | | | |

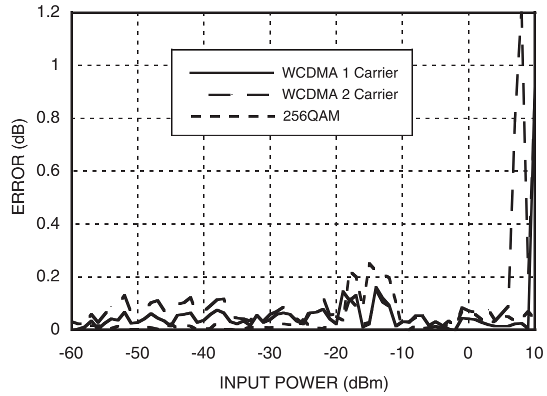
### RMS [A,B] vs. Pin with Different Modulations @ 1900 MHz, VTGT= 1V



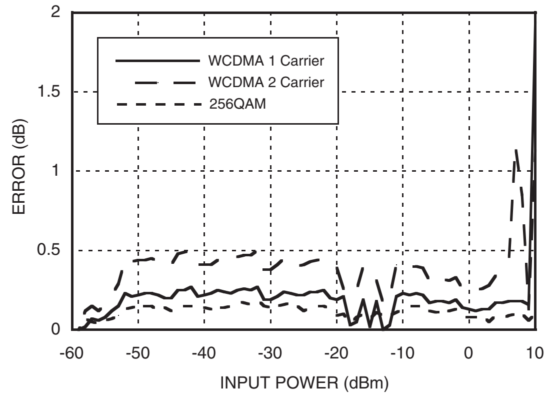

### RMS [A,B] Error vs. Pin with Different Modulations @ 1900 MHz, VTGT= 1V




### Logarithmic Error wrt to CW Response @ 1900 MHz for Different Modulation Schemes, VTGT= 1V




### Logarithmic Error wrt to CW Response @ 1900 MHz for Different Modulation Schemes, VTGT= 2V




### Table 3: Electrical Specifications III,

*HMC714LP5E Differential Configuration, TA=25°C, VCCA = VCCB = VCCBIAS = 5V, Cint = 0.1 uF, unless otherwise noted*

| Parameter | Conditions | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|
| **Differential Input Configuration** | | | | | |
| Input Network Return Loss | up to 2.5 GHz[1] | | > 10 | | dB |
| Input Resistance between $INP_A$ and $INN_A$ | Between pins 2 and 3 | | 220 | | Ohms |
| Input Resistance between $INP_B$ and $INN_B$ | Between pins 6 and 7 | | 220 | | Ohms |
| Input Voltage Range | $V_{DIFFINA} = V_{INPA} - V_{INNA}$ and $V_{DIFFINB} = V_{INPB} - V_{INNB}$ | | | 2.25 | V |
| **RMSOUT [A,B] Output** | | | | | |
| Output Voltage Range | RL = 1kOhm, CL = 4.7pF [2] | | 0.4 to 3.2 | | V |
| Openloop Output Voltage Range | RMS-VSET disconnected for control applications | | 0.4 to Vcc-1 | | V |
| Source/Sink Current Compliance | Measured with 900 MHz input RF signal at -30 dBm power | | 10/1.1 | | mA |
| Output Slew Rate (rise/fall) | With $C_{INT}$=0, Cofs=0 | | 110/6 | | $10^6$ V/sec |

RoHS ✓ EARTH FRIENDLY

## Table 3: Electrical Specifications III,

*HMC714LP5E Differential Configuration, TA=25°C, VCCA = VCCB = VCCBIAS = 5V, Cint = 0.1 uF, unless otherwise noted*

| Parameter | Conditions | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|
| **$V_{SET}$ [A,B] Outputs** | | | | | |
| Input Voltage Range [2] | For control applications with nominal slope/intercept settings | | 0.4 to 3.2 | | V |
| Input Resistance | | | 15 | | kOhm |
| **OUTP and OUTN Outputs** | | | | | |
| Output Voltage Range | RL=1kOhm, CL=4.7pF [2] | | 1 to 3.9 | | V |
| Openloop Output Voltage Range | OUTP-FBKA and OUTN-FBKB disconnected for control applications | | 0.1 to Vcc-0.9 | | V |
| Source/Sink Current Compliance | Measured with 900 MHz input RF signal at -30 dBm power | | 20/4.2 | | mA |
| **$V_{LVL}$, Common Mode Reference Level for OUT[P,N]** | | | | | |
| Voltage Range | OUT[P,N]=FBK[A,B] | 0 | | 5 | V |
| Input Resistance | | | 6 | | kOhm |
| **$V_{REF2}$, Voltage Reference Output** | | | | | |
| Output Voltage | | | 2.43 | | V |
| Temperature Sensitivity | | | 0.15 | | mV/°C |
| Source/Sink Current Compliance | | | 5.5 / 2.6 | | mA |
| **$V_{REF3}$, Voltage Reference Output** | | | | | |
| Output Voltage | | | 2.94 | | V |
| Temperature Sensitivity | | | 0.15 | | mV/°C |
| Source/Sink Current Compliance | | | 0.15 / 0.7 | | mA |
| **TEMP, Temperature Sensor Output** | | | | | |
| Output Voltage | measured at 0°C | | 0.6 | | V |
| Temperature Sensitivity | | | 2.2 | | mV/°C |
| Source/Sink Current Compliance | | | 1.7 / 0.5 | | mA |
| **ENX Logic Input, Power Down Control** | | | | | |
| Input High Voltage | | 0.7*VCC | | | V |
| Input Low Voltage | | | | 0.3*VCC | V |
| Input Capacitance | | | 0.5 | | pF |
| **Power Supply** | | | | | |
| Supply Voltage | | 4.5 | 5 | 5.5 | V |
| Supply Current with no input power | 115 mA nominal at -40°C; 153mA nominal at 85°C | | 138 | | mA |
| Supply Current with 0dBm at one channel | 128 mA nominal at -40°C; 166mA nominal at 85°C | | 150 | | mA |
| Supply Current with 0dBm at both channels | | | 164 | | mA |
| Standby Mode Supply Current | | | 6.5 | | mA |

[1] Performance of differential input configuration is limited by the balun. Baluns used are M/A-COM ETC1-1-13 specified 4.5 MHz to 3000 MHz

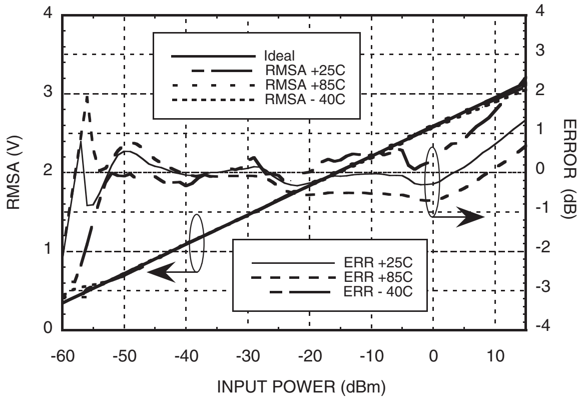
[2] For nominal slope/intercept setting, please see application section to change this range



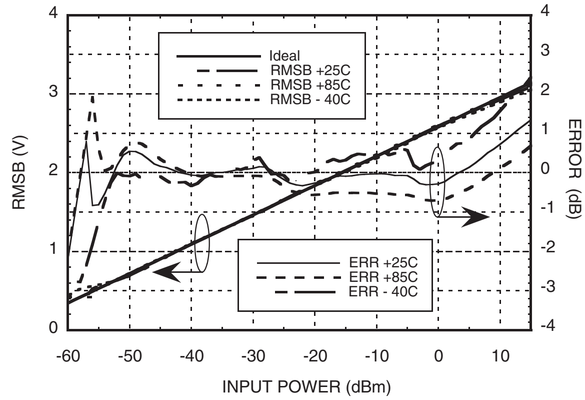


*For price, delivery, and to place orders, please contact Hittite Microwave Corporation:
20 Alpha Road, Chelmsford, MA 01824 Phone: 978-250-3343 Fax: 978-250-3373
Order On-line at www.hittite.com*

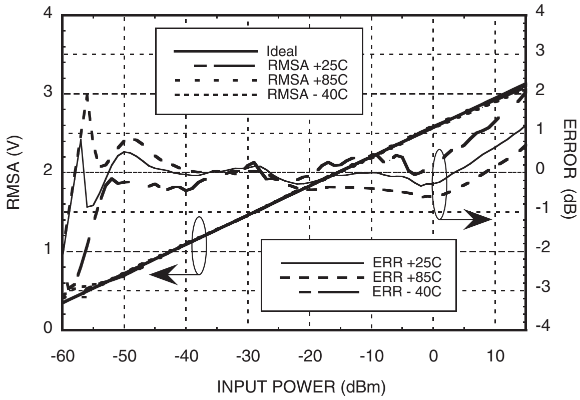
### RMSA & Error vs. Pin @ 100 MHz [1]



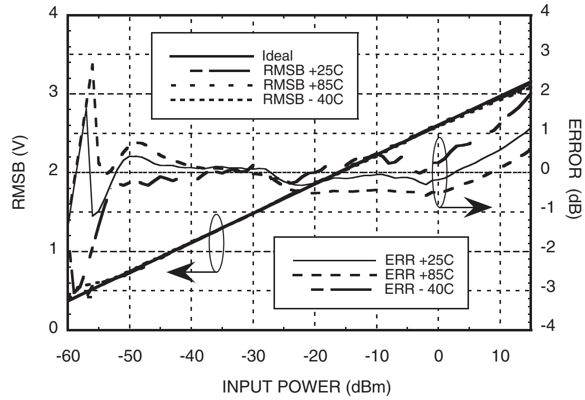

### RMSB & Error vs. Pin @ 100 MHz [1]



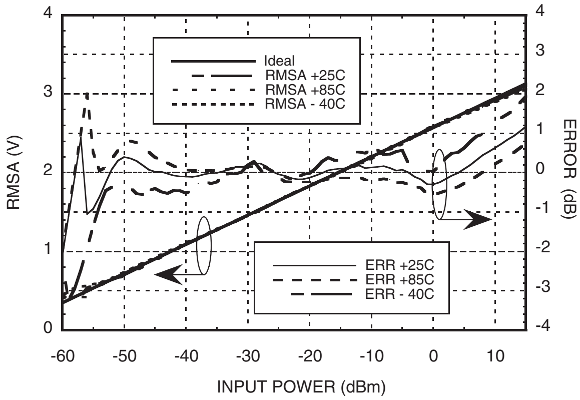

### RMSA & Error vs. Pin @ 500 MHz [1]



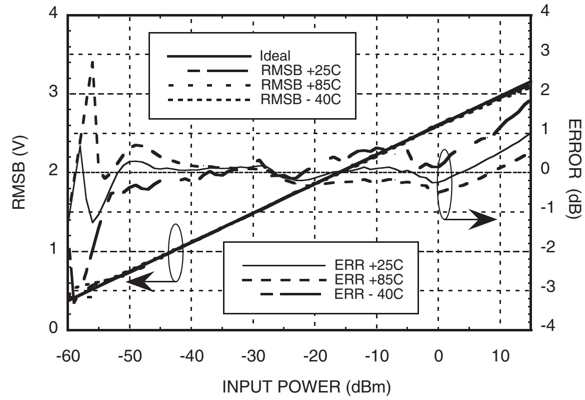

### RMSB & Error vs. Pin @ 500 MHz [1]




### RMSA & Error vs. Pin @ 900 MHz [1]




### RMSB & Error vs. Pin @ 900 MHz [1]



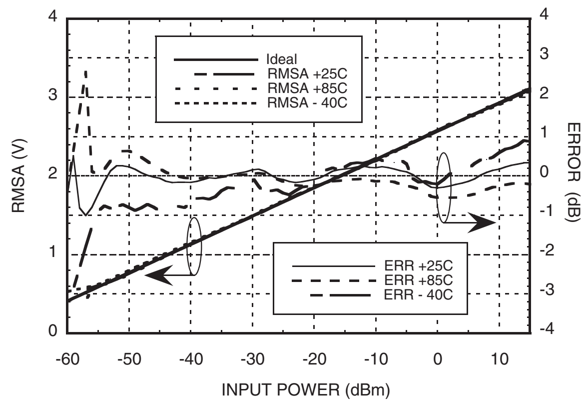

[1] CW Input Waveform

## DUAL RMS POWER DETECTOR 0.1 - 3.9 GHz

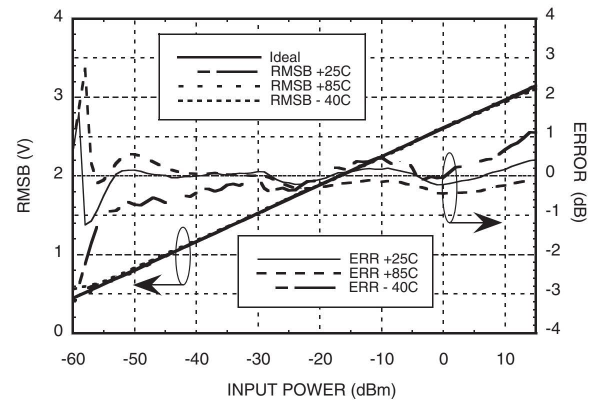
RoHS✓ EARTH FRIENDLY



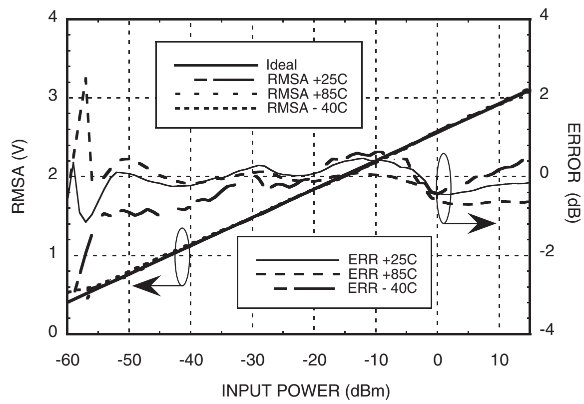
### RMSA & Error vs. Pin @ 1900 MHz [1]



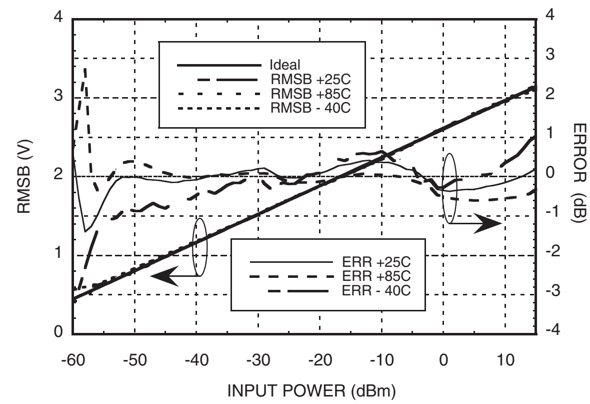

### RMSB & Error vs. Pin @ 1900 MHz [1]



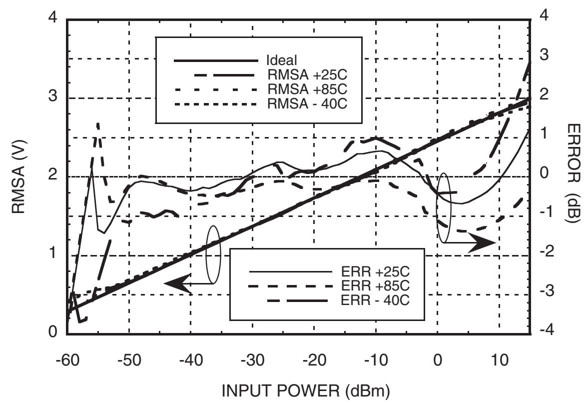

### RMSA & Error vs. Pin @ 2200 MHz [1]



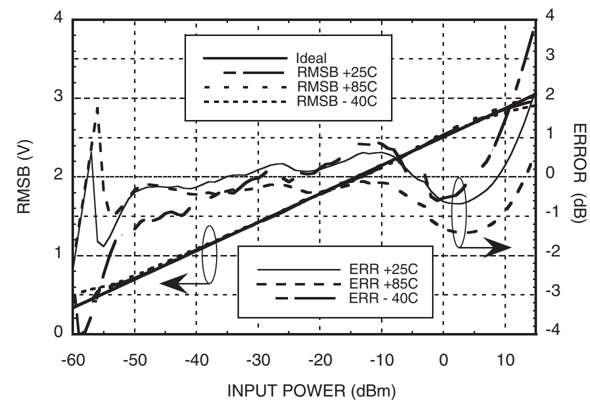

### RMSB & Error vs. Pin @ 2200 MHz [1]




### RMSA & Error vs. Pin @ 3000 MHz [1]

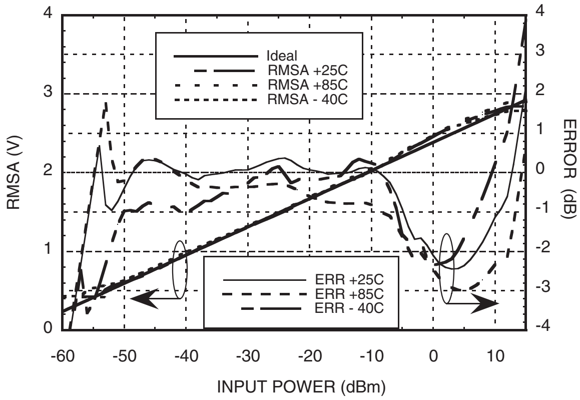



### RMSB & Error vs. Pin @ 3000 MHz [1]

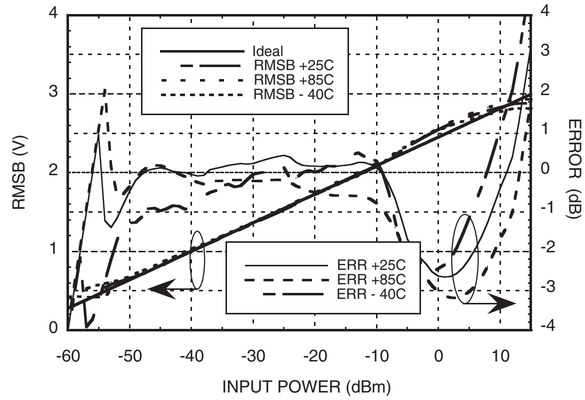



[1] CW Input Waveform

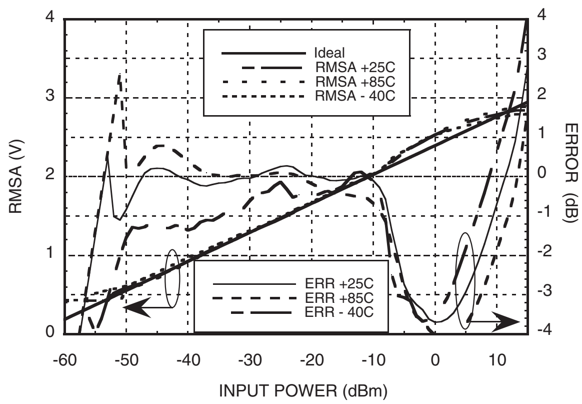
### RMSA & Error vs. Pin @ 3500 MHz [1]



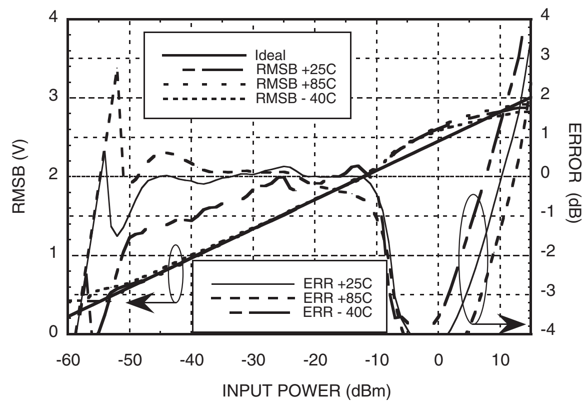

### RMSB & Error vs. Pin @ 3500 MHz [1]



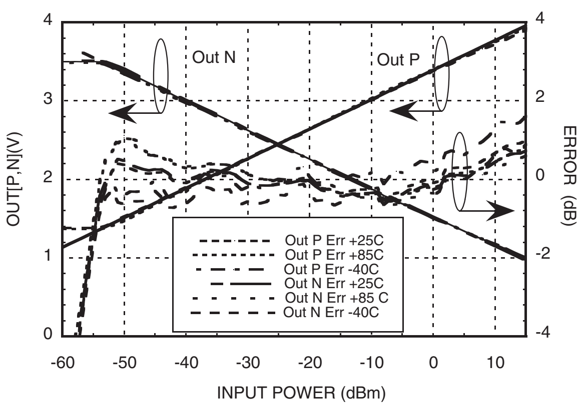

### RMSA & Error vs. Pin @ 3900 MHz [1]



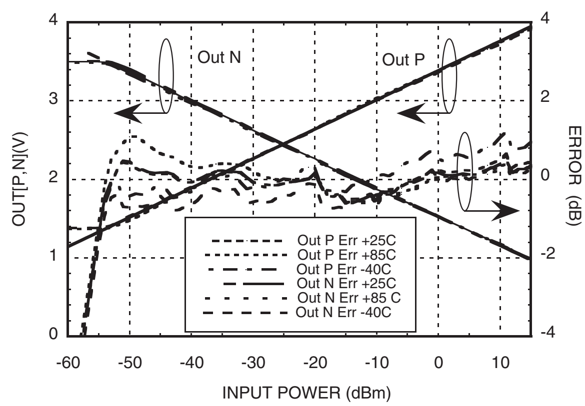

### RMSB & Error vs. Pin @ 3900 MHz [1]




### OUT [P,N] & Error vs. Pin @ 100 MHz, INPA Power Swept, INPB Fixed Power @ -25 dBm [1]

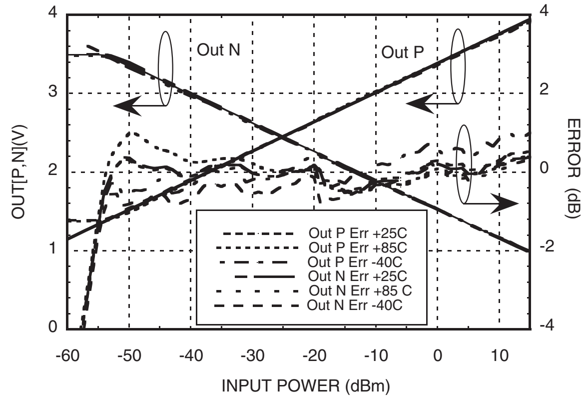



### OUT [P,N] & Error vs. Pin @ 500 MHz, INPA Power Swept, INPB Fixed Power @ -25 dBm [1]

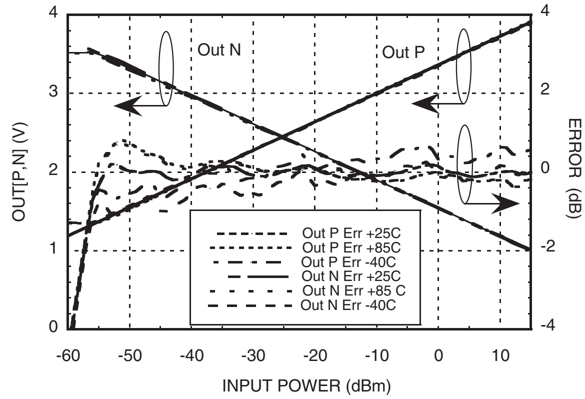



[1] CW Input Waveform

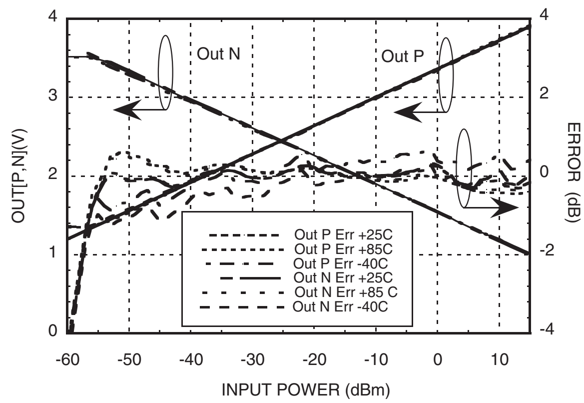
### OUT [P,N] & Error vs. Pin @ 900 MHz, INPA Power Swept, INPB Fixed Power @ -25 dBm [1]



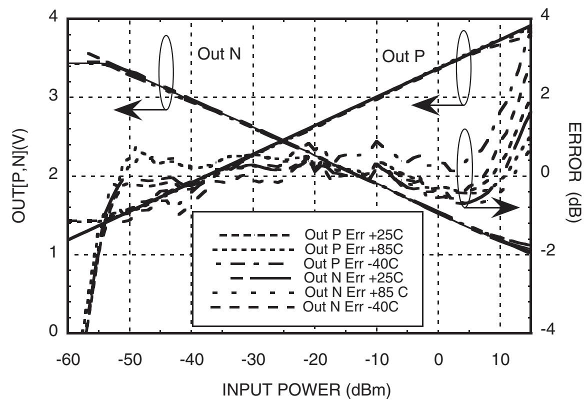

### OUT [P,N] & Error vs. Pin @ 1900 MHz, INPA Power Swept, INPB Fixed Power @ -25 dBm [1]



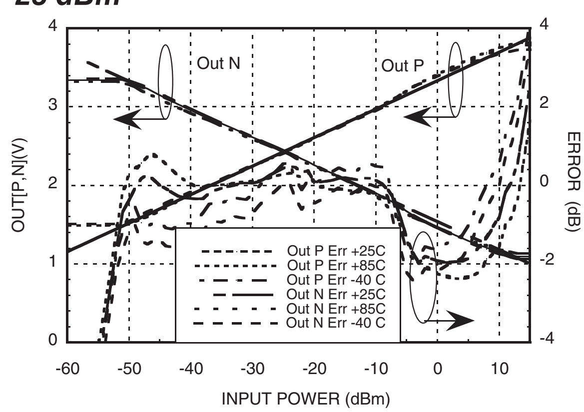

### OUT [P,N] & Error vs. Pin @ 2200 MHz, INPA Power Swept, INPB Fixed Power @ -25 dBm [1]



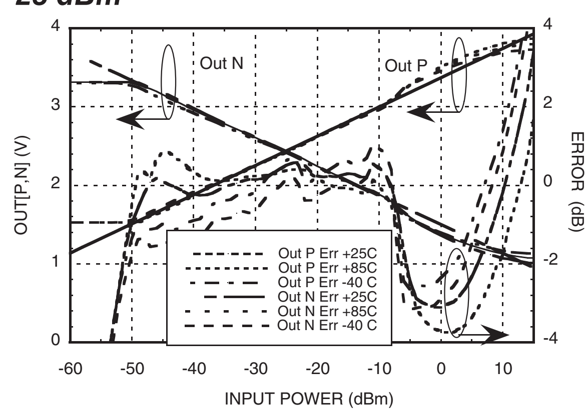

### OUT [P,N] & Error vs. Pin @ 3000 MHz, INPA Power Swept, INPB Fixed Power @ -25 dBm [1]




### OUT [P,N] & Error vs. Pin @ 3500 MHz, INPA Power Swept, INPB Fixed Power @ -25 dBm [1]

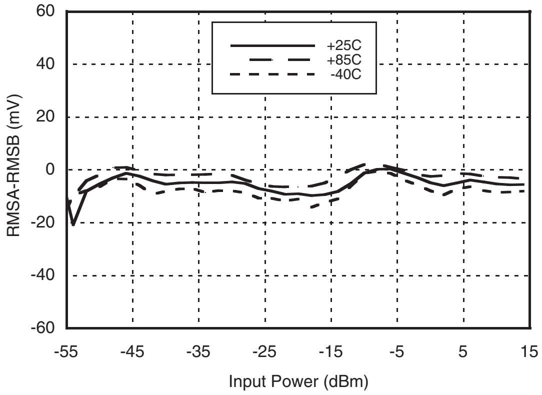



### OUT [P,N] & Error vs. Pin @ 3900 MHz, INPA Power Swept, INPB Fixed Power @ -25 dBm [1]

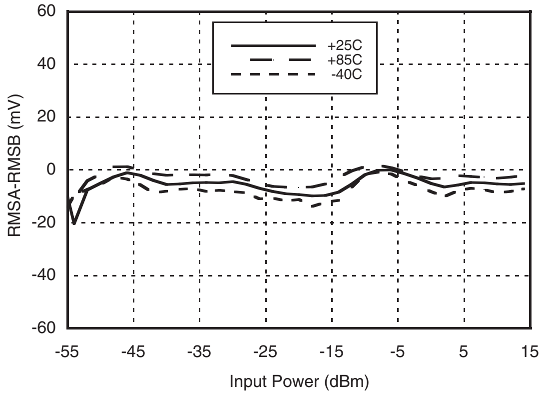



[1] CW Input Waveform

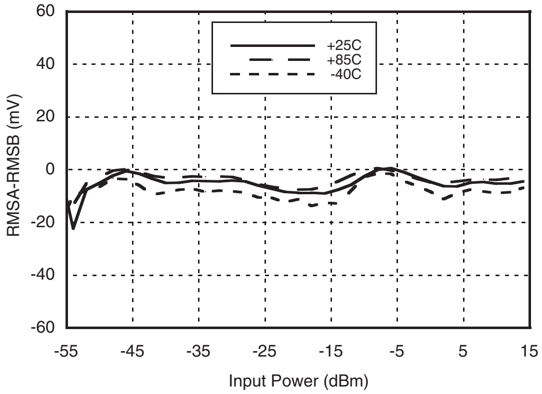
### RMSA-RMSB, Channel Matching vs. Pin over Temperature @ 100 MHz [1][2]



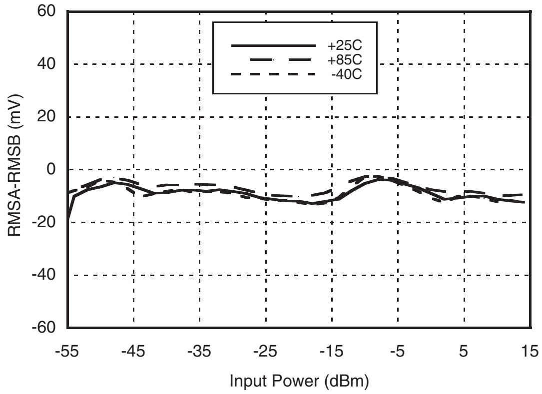

### RMSA-RMSB, Channel Matching vs. Pin over Temperature @ 500 MHz [1][2]



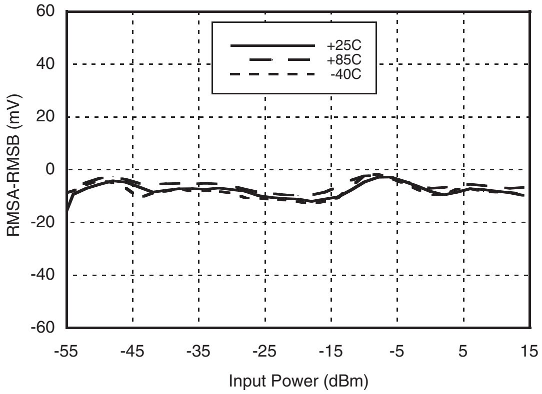

### RMSA-RMSB, Channel Matching vs. Pin over Temperature @ 900 MHz [1][2]



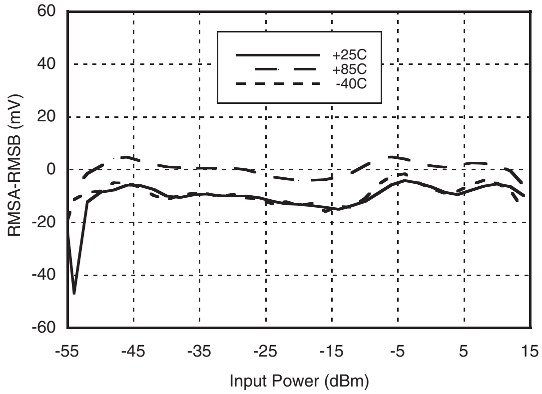

### RMSA-RMSB, Channel Matching vs. Pin over Temperature @ 1900 MHz [1][2]




### RMSA-RMSB, Channel Matching vs. Pin over Temperature @ 2200 MHz [1][2]



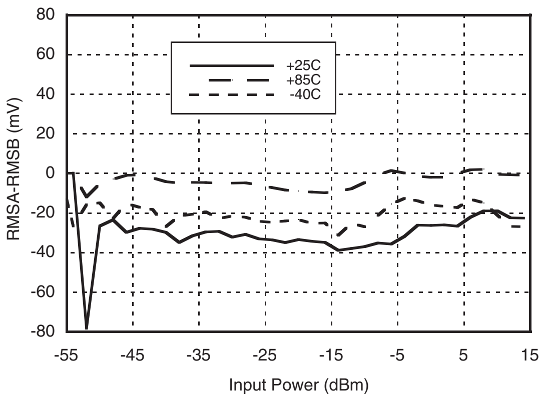

### RMSA-RMSB, Channel Matching vs. Pin over Temperature @ 3000 MHz [1][2]



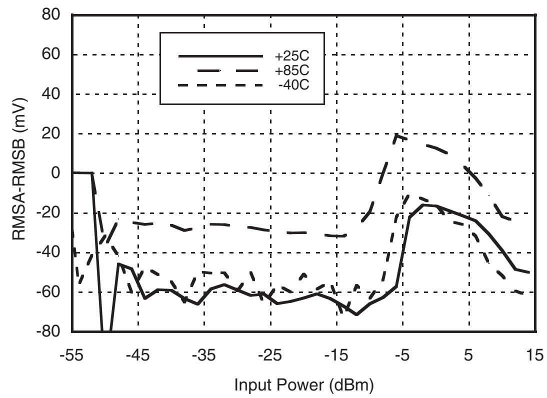

[1] CW Input Waveform

[2] Differential Input Configuration. Baluns selected for matching performance, mismatch between channels is limited by the input baluns.

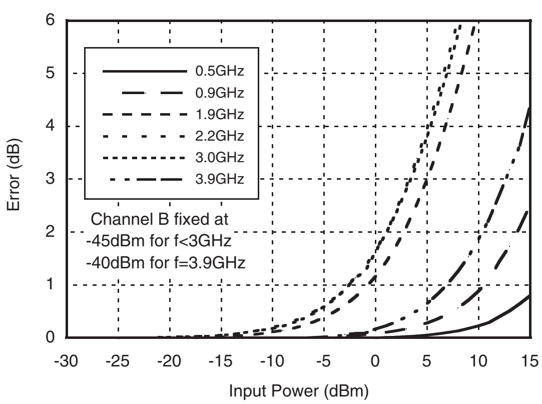
### RMSA-RMSB, Channel Matching vs. Pin over Temperature @ 3500 MHz [1][2]



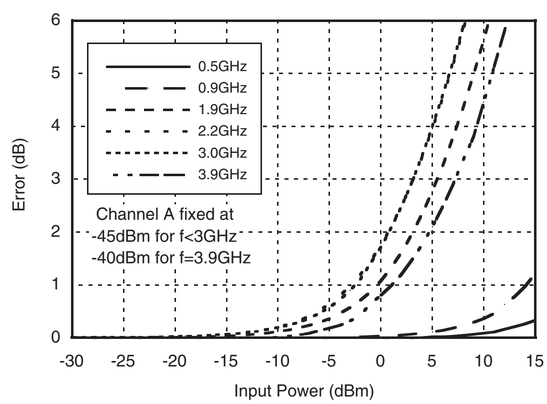

### RMSA-RMSB, Channel Matching vs. Pin over Temperature @ 3900 MHz [1][2]



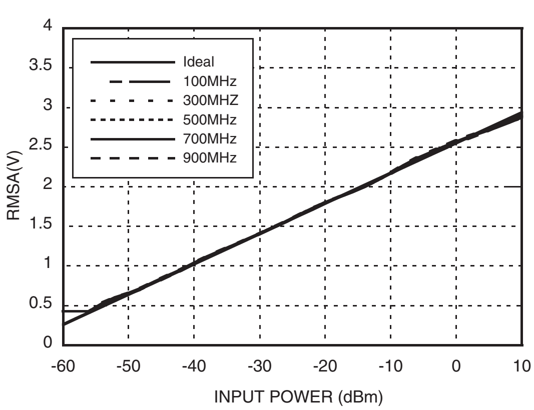

### Interference to an Input Signal (INB Power Fixed) with Interfering Signal on the other Channel (INA Power Swept) [1]



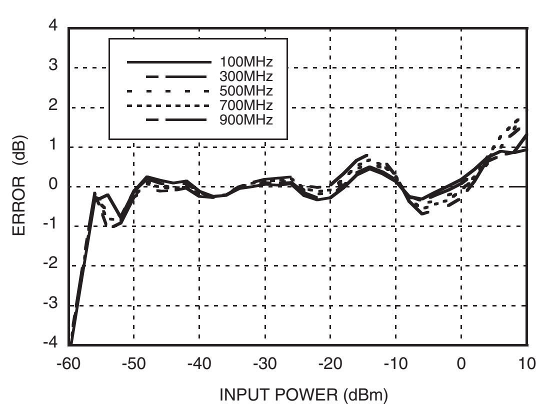

### Interference to an Input Signal (INA Power Fixed) with Interfering Signal on the other Channel (INB Power Swept) [1]




### RMSA Out vs. Pin over Frequency, with SE Wideband Tune [1]




### RMSA Out Error vs. Pin over Frequency, with SE Wideband Tune [1]



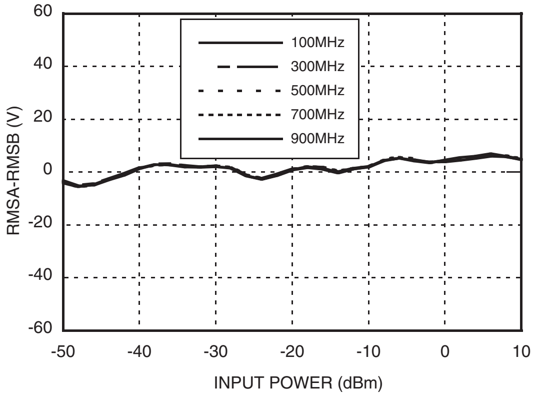

[1] CW Input Waveform

[2] Differential Input Configuration. Baluns selected for matching performance, mismatch between channels is limited by the input baluns.

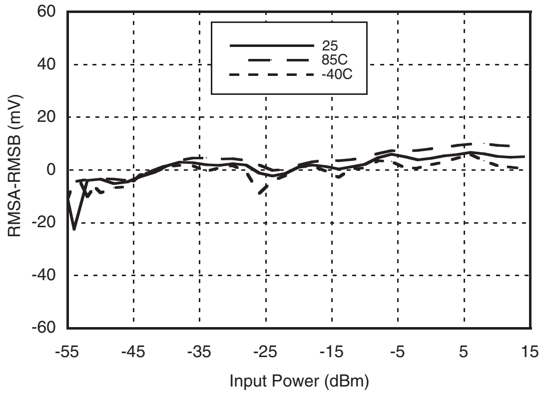


For price, delivery, and to place orders, please contact Hittite Microwave Corporation:
20 Alpha Road, Chelmsford, MA 01824 Phone: 978-250-3343 Fax: 978-250-3373
Order On-line at www.hittite.com

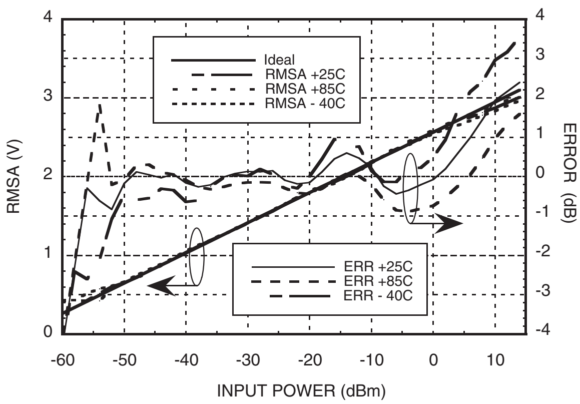
### RMSA-RMSB, Channel Matching vs. Pin over Frequency, with SE Wideband Tune [1]



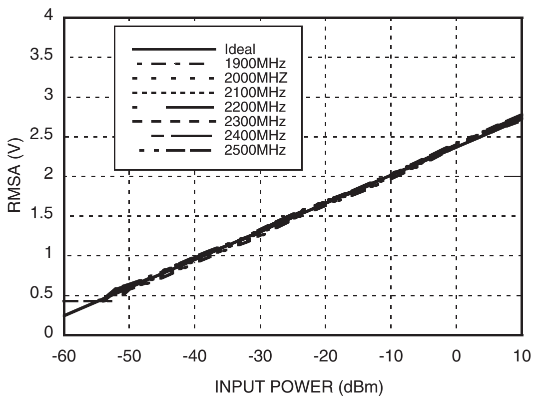

### RMSA-RMSB, Channel Matching vs. Pin over Temperature @ 500 MHz, with SE Wideband Tune [1]



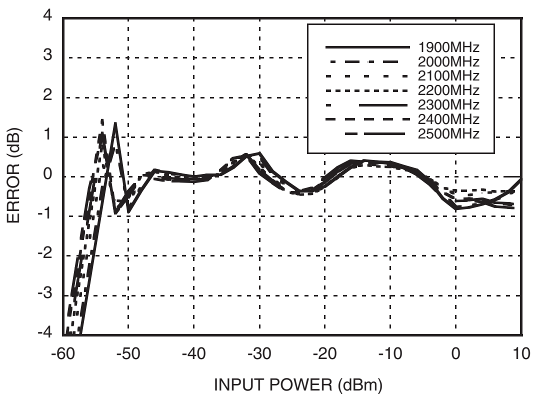

### RMSA Out & Error vs. Pin over Temperature @ 500 MHz with SE Wide-band Tune [1]



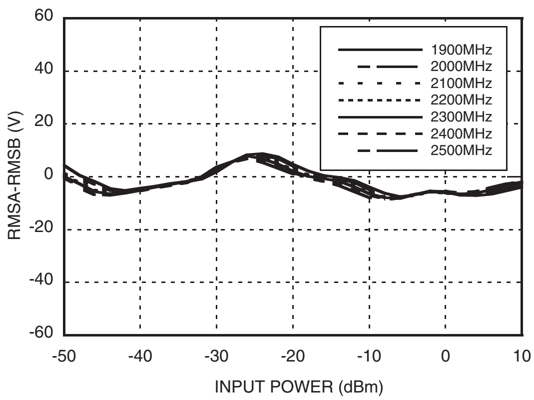

### RMSA Out vs. Pin over Frequency , with 2200 MHz SE Tune [1]




### RMSA Out Error vs. Pin over Frequency with 2200 MHz SE Tune [1]

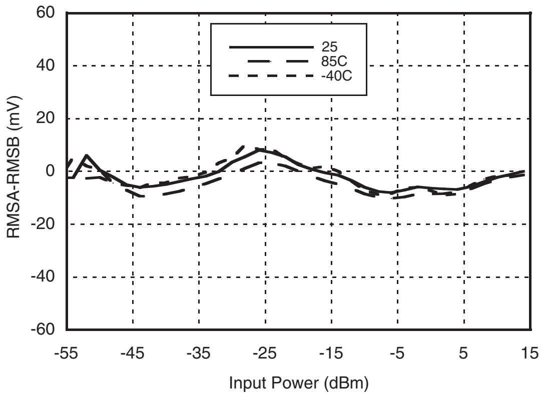



### RMSA-RMSB, Channel Matching vs. Pin over Frequency, with 2200 MHz SE Wide-band Tune [1]

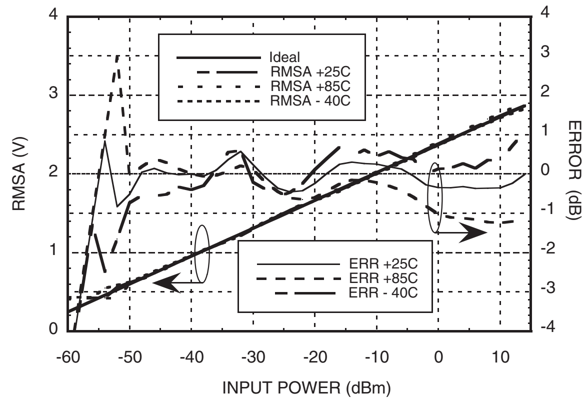



[1] CW Input Waveform

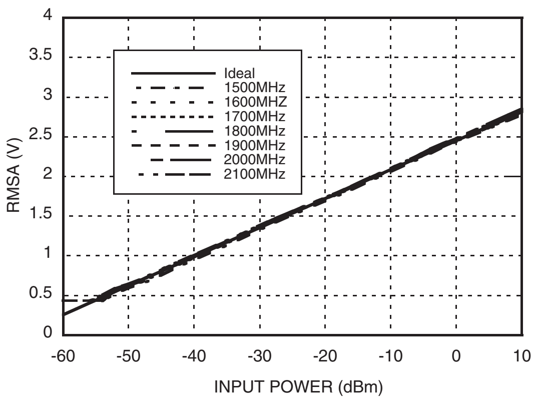
### RMSA-RMSB, Channel Matching vs. Pin over Temperature, with 2200 MHz SE Tune [1]



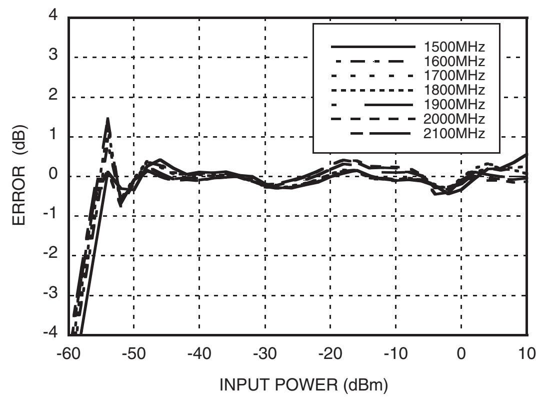

### RMSA Out & Error vs. Pin over Temperature @ 2200 MHz, with 2200 MHz SE Tune [1]



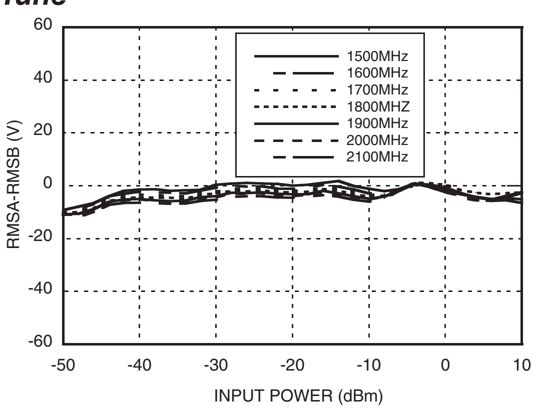

### RMSA Out vs. Pin over Frequency, with 1800 MHz SE Tune [1]



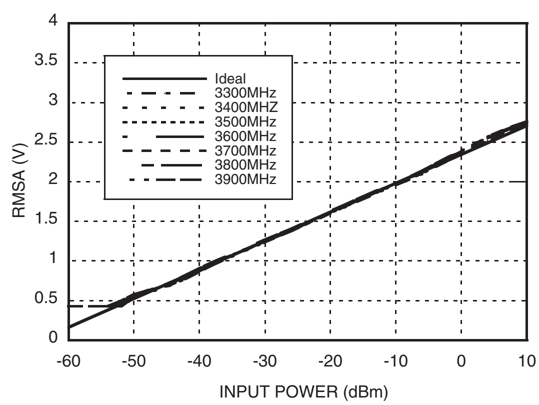

### RMSA Out Error vs. Pin over Frequency, with 1800 MHz SE Tune [1]




### RMSA-RMSB, Channel Matching vs. Pin over Frequency, with 1800 MHz SE Tune [1]




### RMSA Out vs. Pin over Frequency, with 3600 MHz SE Tune [1]

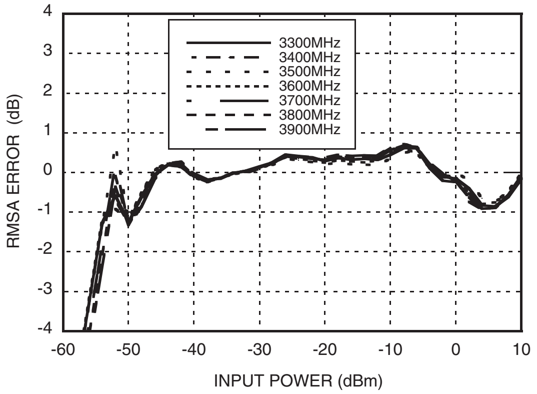



[1] CW Input Waveform

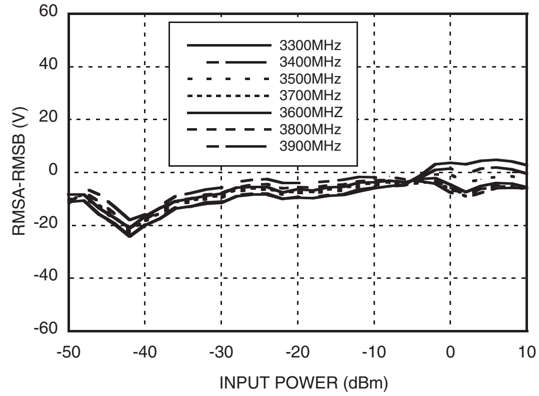


For price, delivery, and to place orders, please contact Hittite Microwave Corporation:
20 Alpha Road, Chelmsford, MA 01824 Phone: 978-250-3343 Fax: 978-250-3373
Order On-line at www.hittite.com

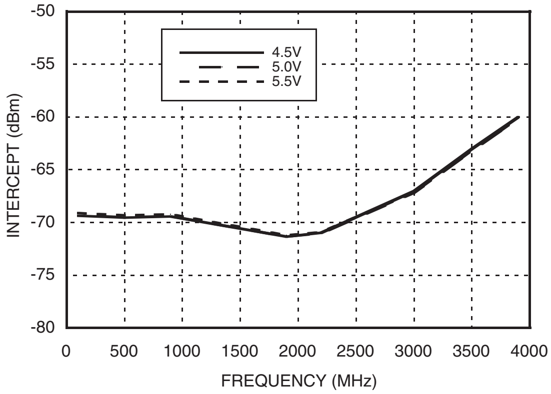
### RMSA Out Error vs. Pin over Frequency, with 3600 MHz SE Tune[1]



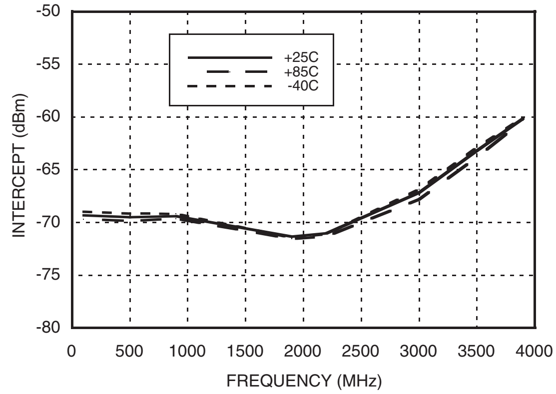

### RMSA - RMSB, Channel Matching vs. Pin over Temperature, with 3600 MHz SE Tune[1]



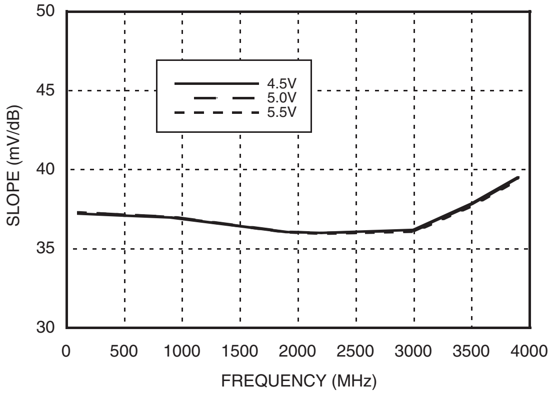

### Intercept vs. Frequency Over Supply Voltage[1]



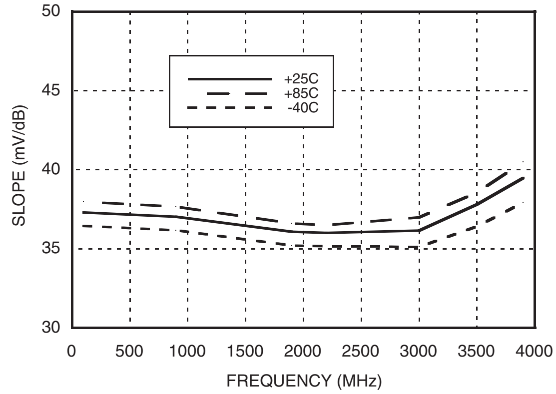

### Intercept vs. Frequency Over Temperature[1]




### Slope vs. Frequency Over Supply Voltage[1]

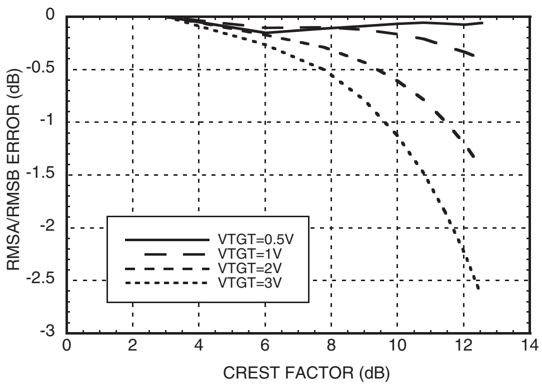



### Slope vs. Frequency Over Temperature[1]

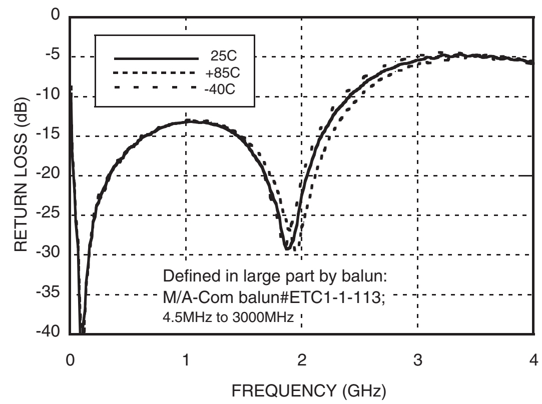



[1] CW Input Waveform

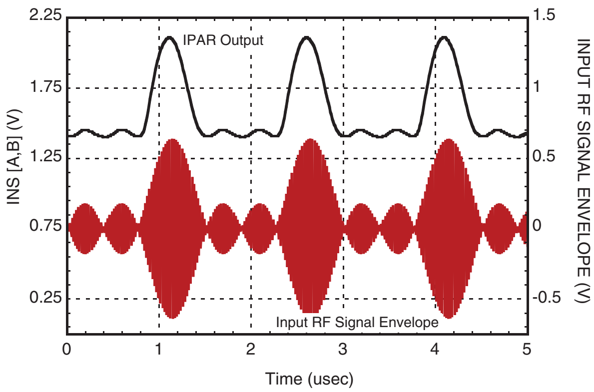
### RMS Error vs. Crest Factor Over VTGT



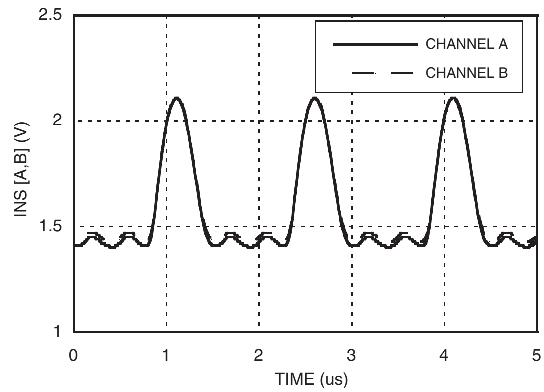

### Input Return Loss [1]



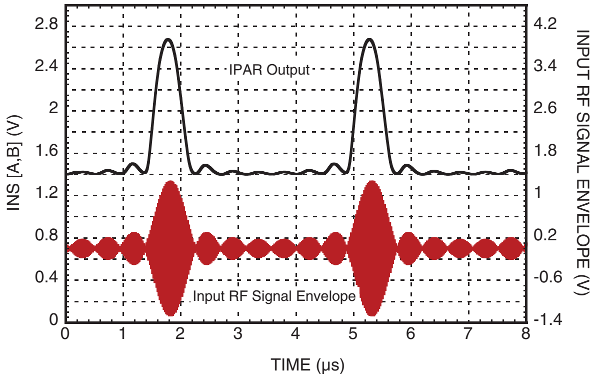

### iPAR Output & Input RF Signal Envelope vs. Time for an Input Crest Factor of 9.03 dB @ 1900 MHz [2]



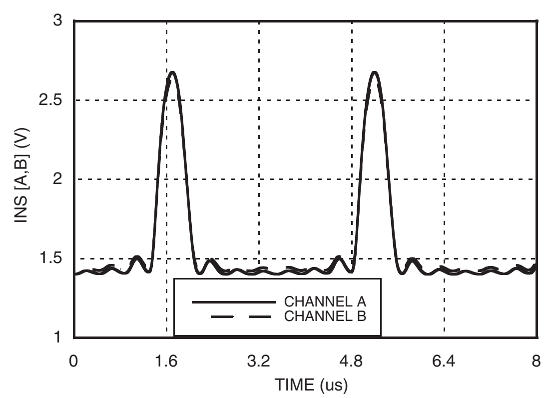

### iPAR Output with an Input Crest Factor of 9.03 dB, Channel [A,B] @ 1900 MHz [2]




### iPAR Output & Input RF Signal Envelope vs. Time for an Input Crest Factor of 12.04 dB @ 1900 MHz [2]



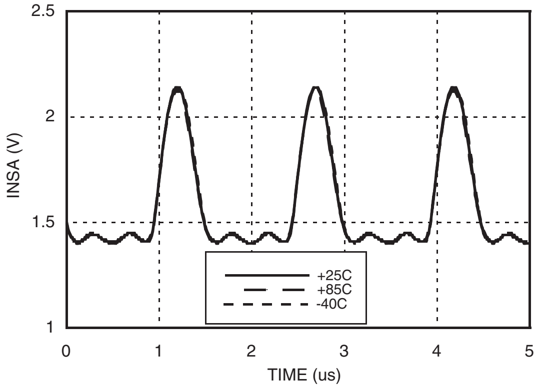

### iPAR Output with an Input Crest Factor of 12.04 dB, Channel [A,B] @ 1900 MHz [2]



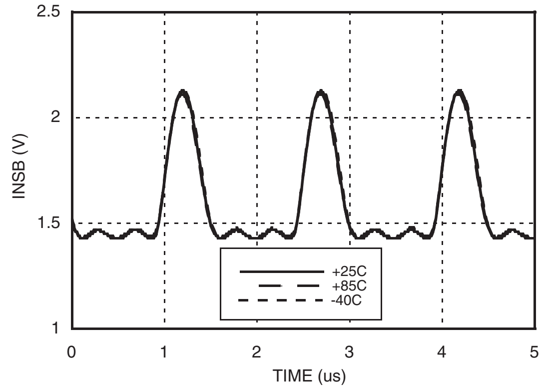

[1] CW Input Waveform
[2] RF Input Power @ -20 dBm

# DUAL RMS POWER DETECTOR 0.1 - 3.9 GHz

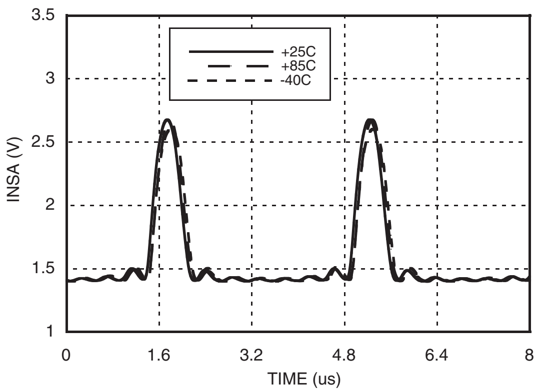
### iPAR Output with an Input Crest Factor of 9.03 dB, Channel A over Temp @ 1900 MHz [1]



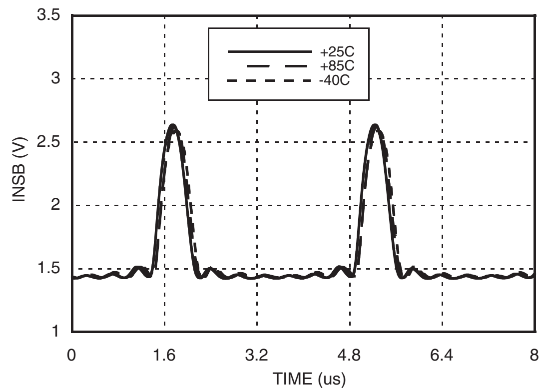

### iPAR Output with an Input Crest Factor of 9.03 dB, Channel B over Temp @ 1900 MHz [1]



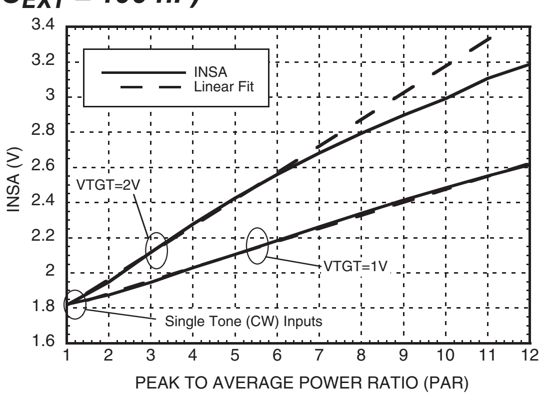

### iPAR Output with an Input Crest Factor of 12.04 dB, Channel A over Temp @ 1900 MHz [1]



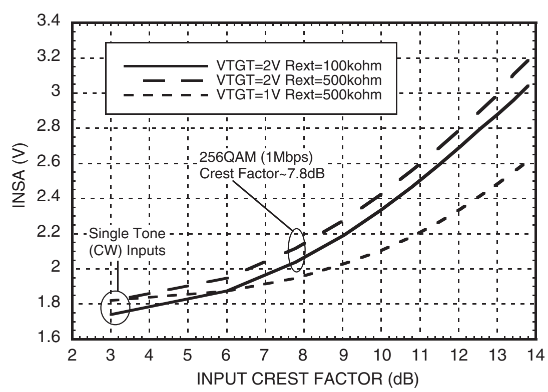

### iPAR Output with an Input Crest Factor of 12.04 dB, Channel B over Temp @ 1900 MHz [1]




### iPAR Feature Peak-to-Average Power Detection Configuration ($R_{EXT}$ = 500kΩ, $C_{EXT}$ = 100 nF)

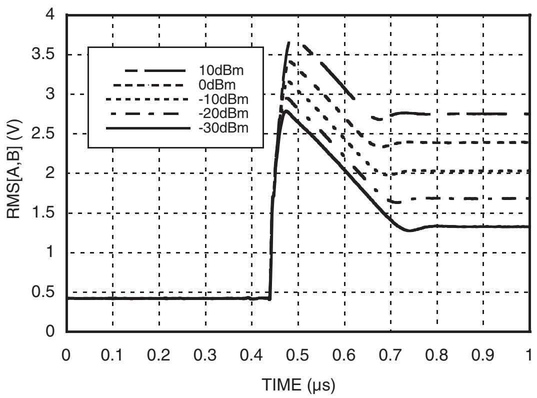



### iPAR Feature Peak-to-Average Power Detection Configuration ($C_{EXT}$ = 100 nF)

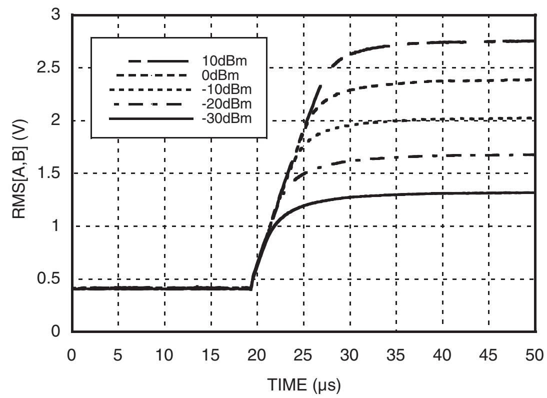



[1] RF Input Power @ -20 dBm

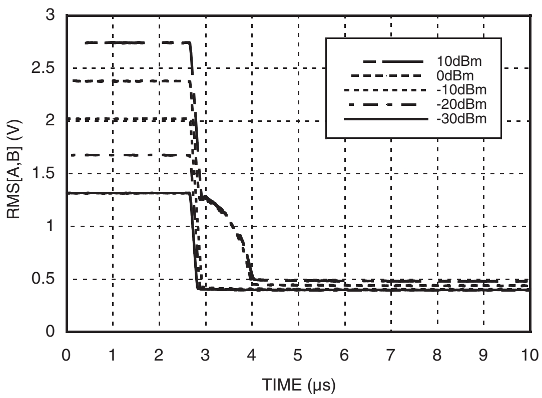
### Output Response Rise Time @ 1900 MHz, $C_{INT}$ [A,B] = Open



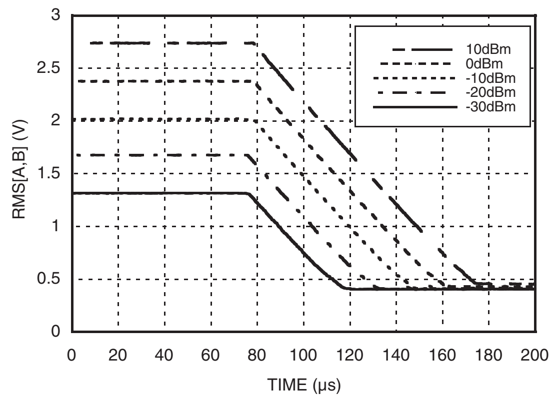

### Output Response Rise Time @ 1900 MHz, $C_{INT}$ [A,B] = 10 nF




### Output Response Fall Time @ 1900 MHz, $C_{INT}$ [A,B] = Open




### Output Response Fall Time @ 1900 MHz, $C_{INT}$ [A,B] = 10 nF




### Absolute Maximum Ratings

| | |
|---|---|
| Supply Voltage | 5.6V |
| RF Input Power | 20 dBm |
| Channel / Junction Temperature | 125 °C |
| Continuous Pdiss (T = 85°C) (Derate 50 mW/°C above 85°C) | 2 Watts |
| Thermal Resistance ($R_{th}$) (junction to ground paddle) | 20 °C/W |
| Storage Temperature | -65 to +150 °C |
| Operating Temperature | -40 to +85 °C |

ELECTROSTATIC SENSITIVE DEVICE
OBSERVE HANDLING PRECAUTIONS

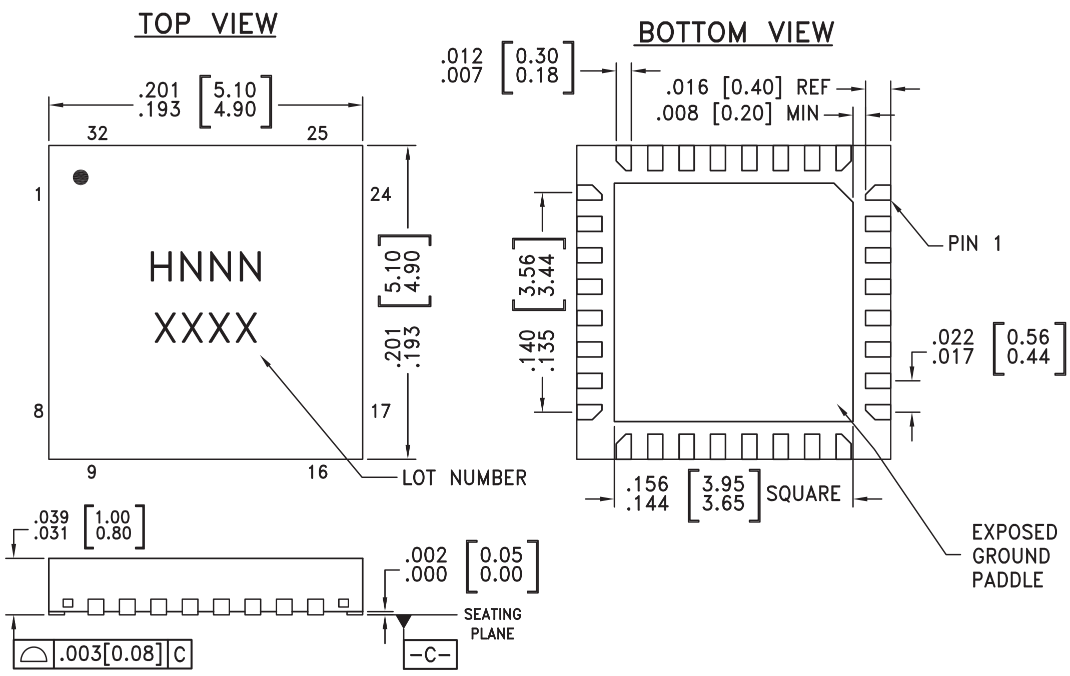


For price, delivery, and to place orders, please contact Hittite Microwave Corporation:
20 Alpha Road, Chelmsford, MA 01824 Phone: 978-250-3343 Fax: 978-250-3373
Order On-line at www.hittite.com

## DUAL RMS POWER DETECTOR 0.1 - 3.9 GHz



### Outline Drawing



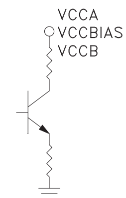
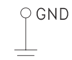
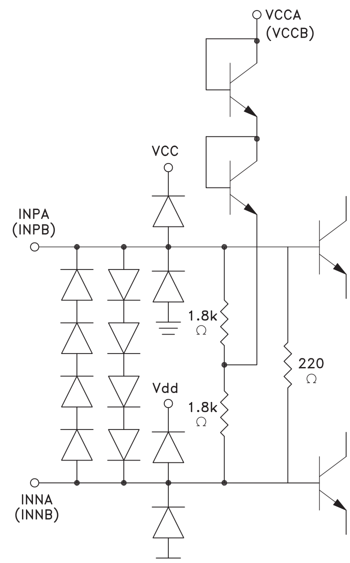
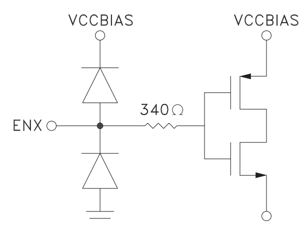
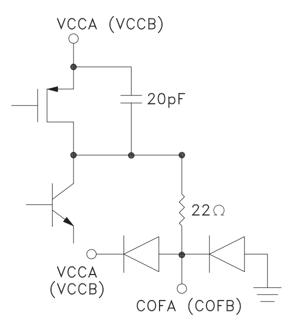

NOTES:
1. LEADFRAME MATERIAL: COPPER ALLOY
2. DIMENSIONS ARE IN INCHES [MILLIMETERS].
3. LEAD SPACING TOLERANCE IS NON-CUMULATIVE
4. PAD BURR LENGTH SHALL BE 0.15mm MAXIMUM.
PAD BURR HEIGHT SHALL BE 0.05mm MAXIMUM.
5. PACKAGE WARP SHALL NOT EXCEED 0.05mm.
6. ALL GROUND LEADS AND GROUND PADDLE MUST BE SOLDERED TO PCB RF GROUND.
7. REFER TO HMC APPLICATION NOTE FOR SUGGESTED PCB LAND PATTERN.

### Package Information

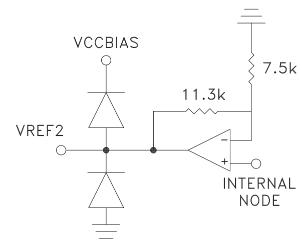
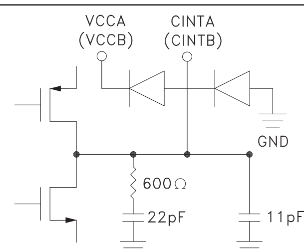
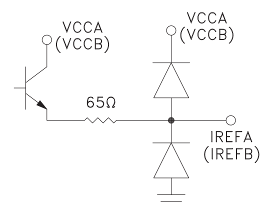
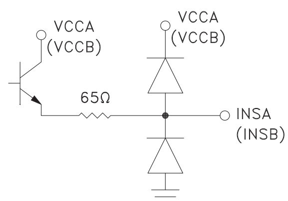
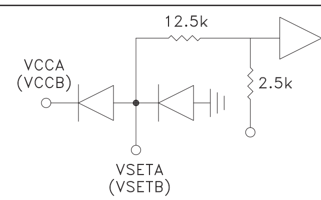
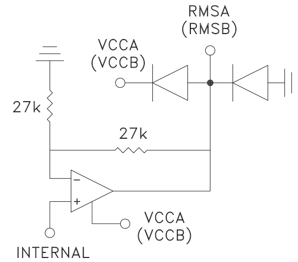
| Part Number | Package Body Material | Lead Finish | MSL Rating | Package Marking [3] |
|---|---|---|---|---|
| HMC714LP5 | Low Stress Injection Molded Plastic | Sn/Pb Solder | MSL1 [1] | H714<br>XXXX |
| HMC714LP5E | RoHS-compliant Low Stress Injection Molded Plastic | 100% matte Sn | MSL1 [2] | H714<br>XXXX |

[1] Max peak reflow temperature of 235 °C
[2] Max peak reflow temperature of 260 °C
[3] 4-Digit lot number XXXX

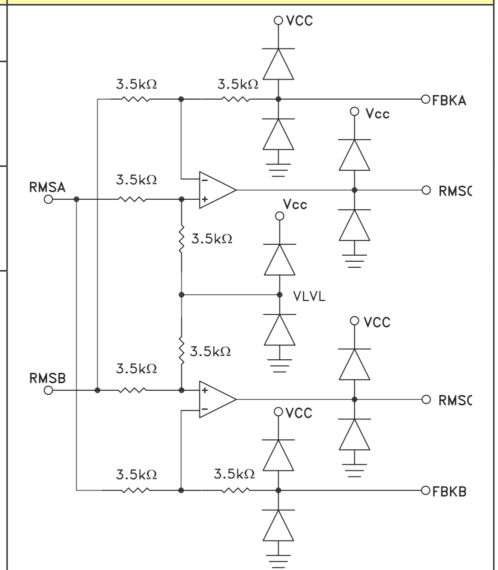
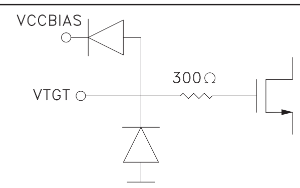
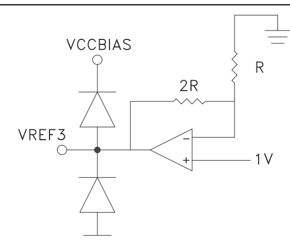
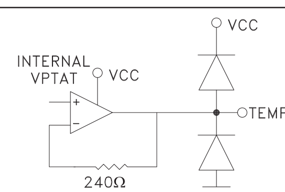
## Pin Descriptions

| Pin Number | Function | Description | Interface Schematic |
|---|---|---|---|
| 1, 5, 8 | VCCA, VCCBIAS, VCCB | Bias Supply. Connect supply voltage to these pins with appropriate filtering. |  |
| | GND | Package bottom has an exposed metal paddle that must be connected to RF/DC ground. |  |
| 2, 3 | INPA, INNA | Channel A RF Inputs, Connect RF to INNA through a 1:1 balun for differential configuration. |  |
| 6, 7 | INNB, INPB | Channel B RF Inputs, Connect RF to INNB through a 1:1 balun for differential configuration. | |
| 4 | ENX | Disable pin. Connect to GND for normal operation. Applying voltage V > 0.8 Vcc will initiate power saving mode. |  |
| 9, 32 | COFB, COFA | Input high pass filter capacitor. Connect to common via a capacitor to determine 3 dB point of input signal high-pass filter. See Application Note section. |  |
| 10, 11 | N/C | These pins are not connected internally. | |

## Pin Descriptions (Continued)

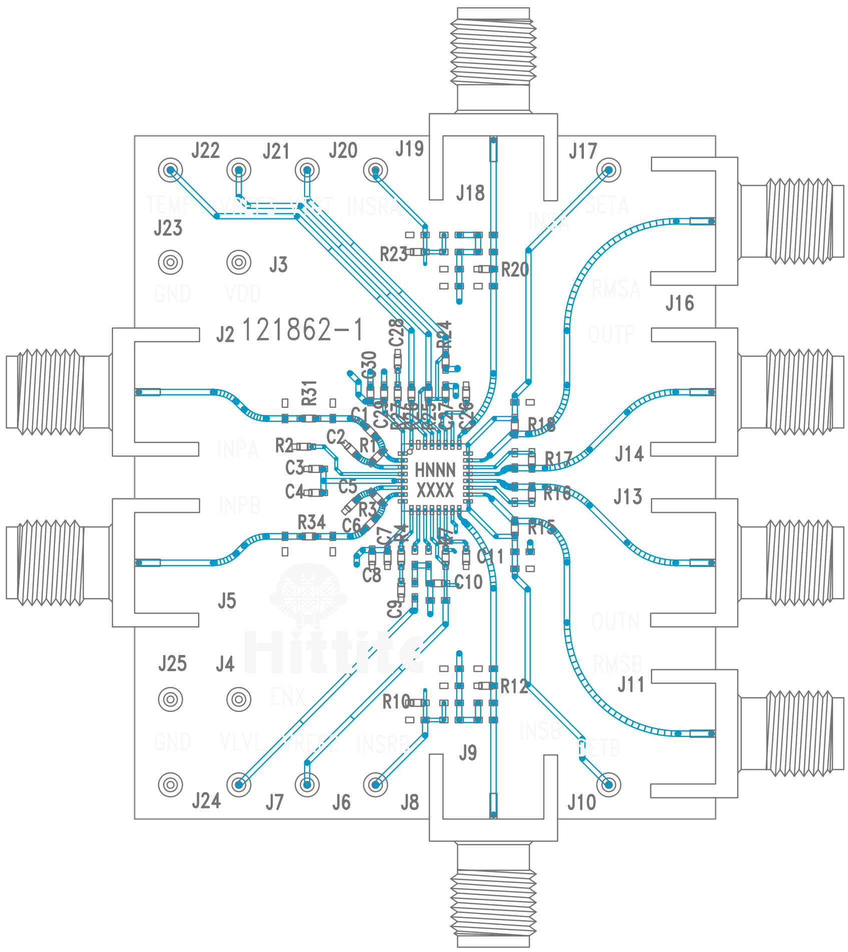
| Pin Number | Function | Description | Interface Schematic |
|---|---|---|---|
| 12 | VREF2 | 2.5V Reference voltage output. |   |
| 13 | VLVL | Reference level input for OUTP and OUTN. Connect to VREF for normal operation. | |
| 14, 27 | CINTB, CINTA | Connection for ground referenced loop filter integration capacitor for channels A and B. See application schematic. |   |
| 15, 26 | IREFB, IREFA | Reference DC Voltage for INSB - INSA to replicate voltage at no input modulation case. |   |
| 16, 25 | INSB, INSA | Instantaneous Power Output for channels A and B continuous tracking of Input Power Envelope. |   |
| 17, 26 | VSETB, VSETA | VSET inputs. Set point inputs for controller mode. |   |
| 18, 23 | RMSB, RMSA | Logarithmic outputs that convert the input power to a DC level for channel A and channel B. |   |

## Pin Descriptions (Continued)

| Pin Number | Function | Description | Interface Schematic |
|---|---|---|---|
| 19 | FBKB | Feedback through 3.5K Ohms to the negative terminal of the integrated Op Amp driving OUTN |  |
| 20 | OUTN | Output providing the difference of RMS outputs using an Op Amp. For normal operation, connected to FBKB to provide the function: OUTN = RMSB - RMSA + VLVL | |
| 21 | OUTP | Output providing the difference of RMS outputs using an Op Amp. For normal operation, connected to FBKA to provide the function: OUTP = RMSA - RMSB + VLVL | |
| 22 | FBKA | Feedback through 3.5K Ohms to the negative terminal of the integrated Op Amp driving OUTP | |
| 28 | VTGT | This voltage input changes the logarithmic intercept point. Use of lower target voltage reduces error for complex signals with large crest factors. Normally connected to VREF3 via resistor voltage divider. See Application Note section. |  |
| 29 | VREF3 | 3V Reference voltage output for use with VTGT. See Application Note section. |  |
| 30 | TEMP | Temperature sensor output. See Application Note section. |  |

## DUAL RMS POWER DETECTOR
## 0.1 - 3.9 GHz

### Evaluation PCB - Wideband Single-Ended




### List of Materials for Evaluation PCB 121864 [1]

| Item | Description |
|---|---|
| J2, J5, J9, J11, J13, J14, J16, J18 | SMA Connector |
| J3, J4, J6 - J8, J10, J17, J19 - J25 | DC Pin |
| C1, C2, C5, C6, C9, C28 | 1 nF Capacitor, 0402 Pkg. |
| C3, C8, C10, C29 | 100 pF Capacitor, 0402 Pkg. |
| C4, C7, C11, C26, C27, C30 | 100 nF Capacitor, 0402 Pkg. |
| R1, R3 | 68 Ohm Resistor, 0402 Pkg. |
| R2 | 10K Ohm Resistor, 0402 Pkg. |
| R4, R7, R15 - R18, R27, R31, R34 | 0 Ohm Resistor, 0402 Pkg. |
| R10, R12, R20, R23 | 3.92K Ohm Resistor, 0402 Pkg. |
| R24 | 61.9K Ohm Resistor, 0402 Pkg. |
| R25 | 33K Ohm Resistor, 0402 Pkg. |
| R26 | 1K Ohm Resistor, 0402 Pkg. |

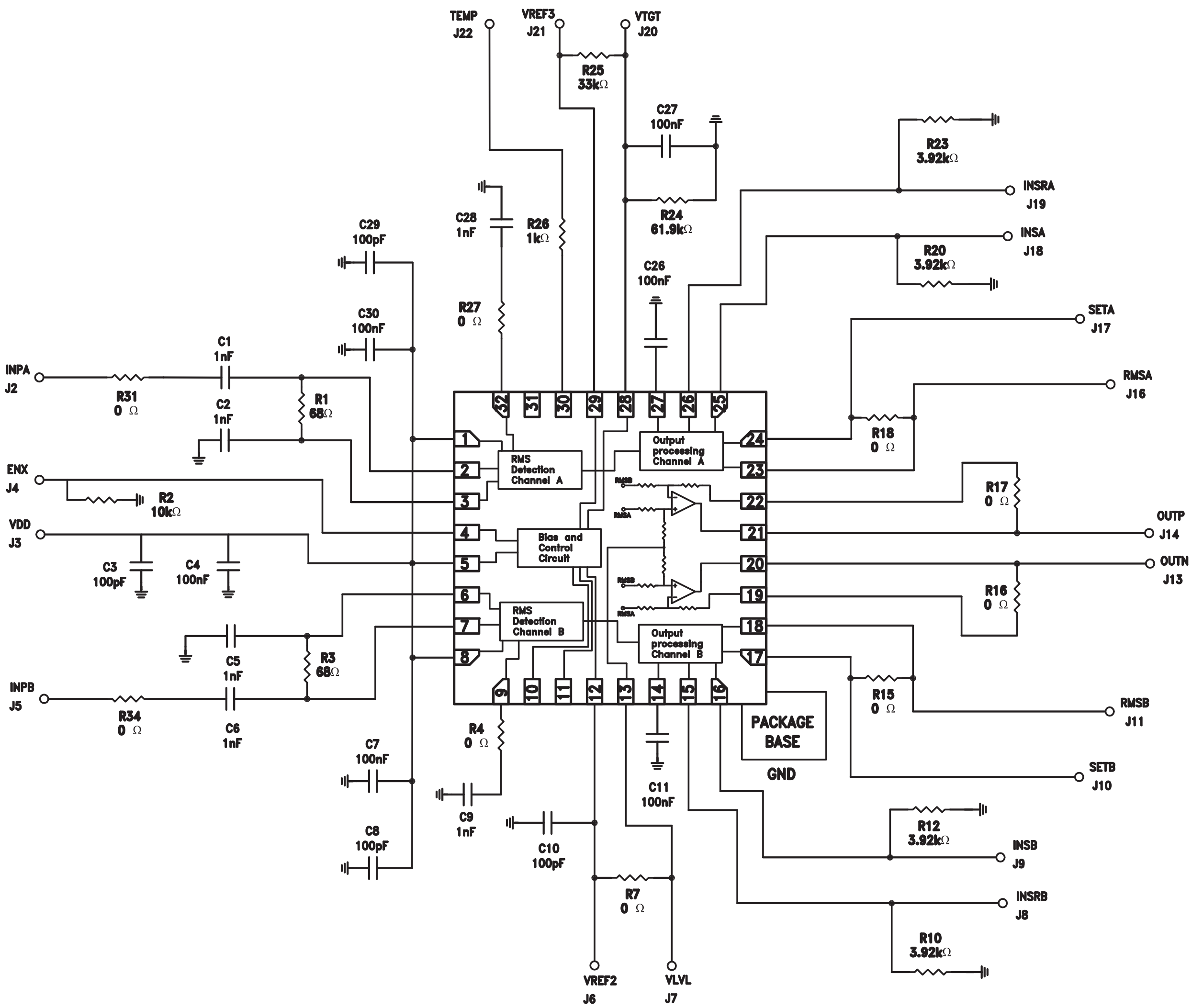
| Item | Description |
|---|---|
| U1 | HMC714LP5(E) Single-Ended Dual RMS Power Detector |
| PCB [2] | 121862 Evaluation PCB |

The circuit board used in the final application should use RF circuit design techniques. Signal lines should have 50 ohm impedance while the package ground leads and exposed paddle should be connected directly to the ground plane similar to that shown. A sufficient number of via holes should be used to connect the top and bottom ground planes. The evaluation circuit board shown is available from Hittite upon request.

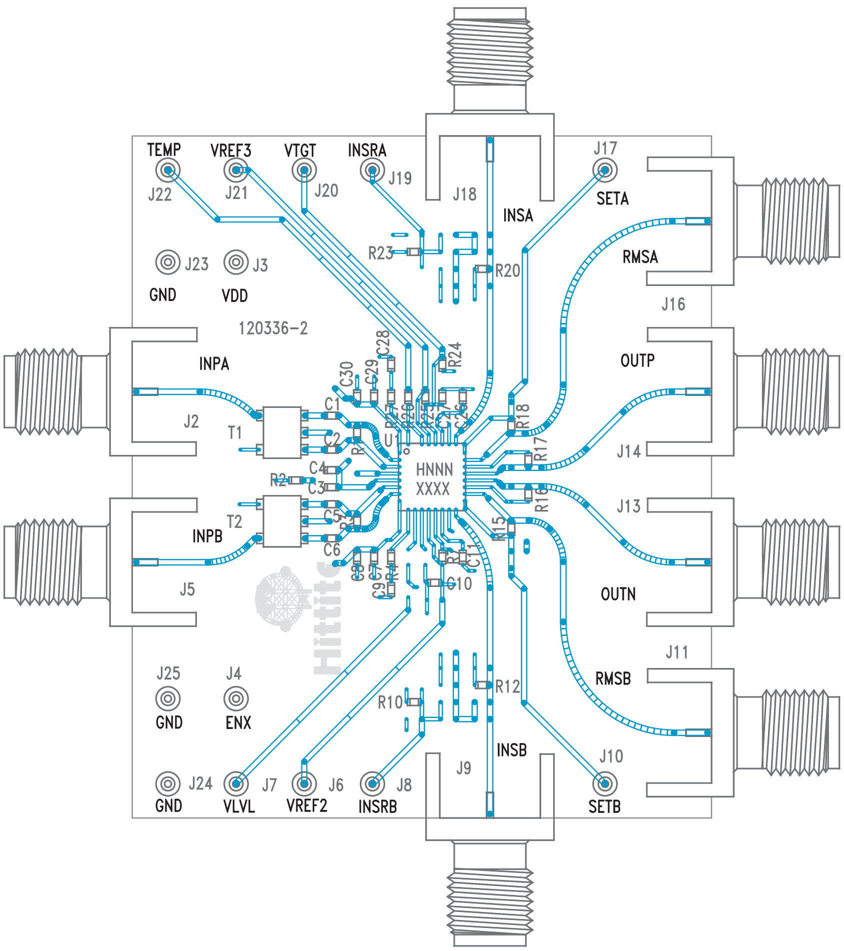
[1] Reference this number when ordering complete evaluation PCB

[2] Circuit Board Material: Rogers 4350

### Application Circuit - Wideband Single-Ended



### Evaluation PCB - Differential




### List of Materials for Evaluation PCB 120339 [1]

| Item | Description |
|---|---|
| J2, J5, J9, J11, J13, J14, J16, J18 | SMA Connector |
| J3, J4, J6 - J8, J10, J17, J19 - J25 | DC Pin |
| C1, C2, C5, C6, C9, C28 | 1 nF Capacitor, 0402 Pkg. |
| C3, C8, C10, C29 | 100 pF Capacitor, 0402 Pkg. |
| C4, C7, C11, C26, C27, C30 | 100 nF Capacitor, 0402 Pkg. |
| R1, R3 | 68.1 Ohm Resistor, 0402 Pkg. |
| R2 | 10K Ohm Resistor, 0402 Pkg. |
| R4, R7, R15 - R18, R27 | 0 Ohm Resistor, 0402 Pkg. |
| R10, R12, R20, R23 | 3.92K Ohm Resistor, 0402 Pkg. |
| R24 | 61.9K Ohm Resistor, 0402 Pkg. |
| R25 | 33K Ohm Resistor, 0402 Pkg. |
| R26 | 1K Ohm Resistor, 0402 Pkg. |

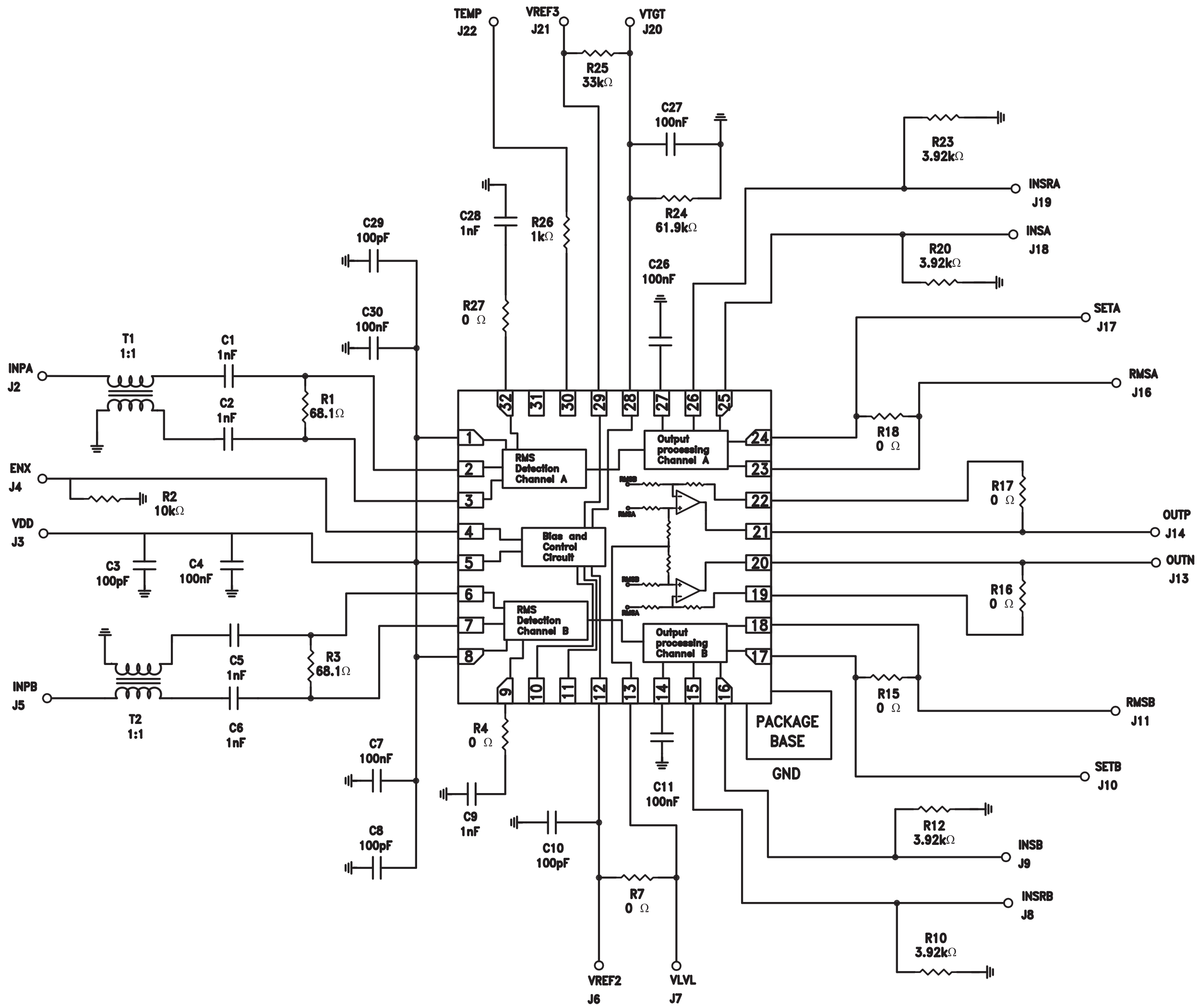
| Item | Description |
|---|---|
| T1, T2 | Transformer, E-Series RF 1:1, |
| U1 | HMC714LP5(E) Differential Dual RMS Power Detector |
| PCB [2] | 120336 Evaluation PCB |

The circuit board used in the final application should use RF circuit design techniques. Signal lines should have 50 ohm impedance while the package ground leads and exposed paddle should be connected directly to the ground plane similar to that shown. A sufficient number of via holes should be used to connect the top and bottom ground planes. The evaluation circuit board shown is available from Hittite upon request.

[1] Reference this number when ordering complete evaluation PCB

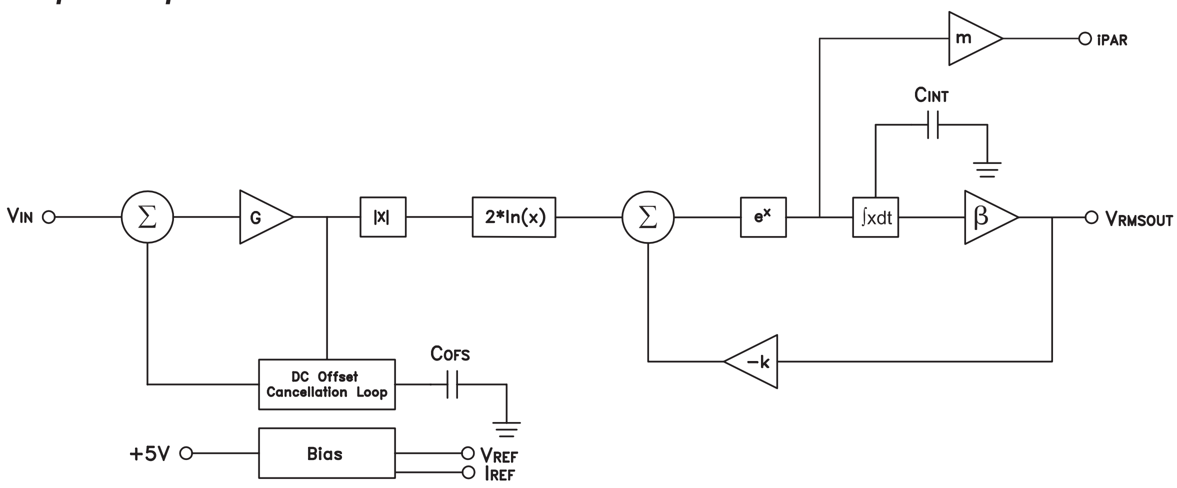
[2] Circuit Board Material: Rogers 4350

### Application Circuit - Differential



## Application Information

### Principle of Operation




$$V_{RMSOUT} = \frac{1}{k} \ln(\beta k G^2 \int V_{IN}^2 dt)$$

$$V_{iPAR} = \frac{m}{\beta k}\left(\frac{V_{IN}^2}{\int V_{IN}^2 dt} - 1\right) + iREF$$

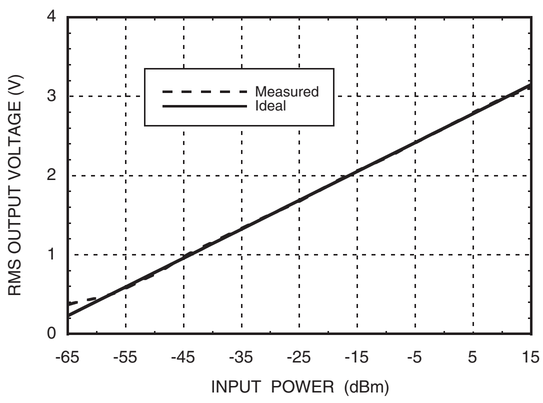
Where ß is op-amp gain set via resistors on the $V_{set}$ pin.

$P_{in} = V_{RMS}$/[log-slope]+[log-intercept], dBm

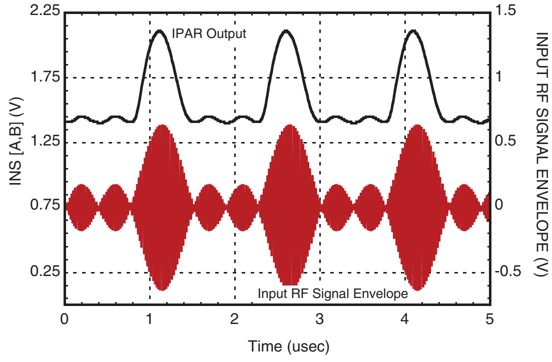
Monolithic true-RMS detectors are in-effect analog calculators, calculating the RMS value of the input signal, unlike other types of power detectors which are designed to respond to the RF signal envelope. At the core of an RMS detector is a full-wave rectifier, log/antilog circuit, and an integrator. The RMS output signal is directly proportional to the logarithm of the time-averaged $V_{IN}2$. The bias block also contains temperature compensation circuits which stabilize output accuracy over the entire operating temperature range. The DC offset cancellation circuit actively cancels internal offsets so that even very small input signals can be measure accurately.

The iPAR feature tracks the RF envelope and provides a signal which is directly proportional to signal power, normalized to average real power calculated by the RMS circuitry. Reading both the iPAR and RMS output voltage signals provides a very informative picture of the RF input signal: peak power, average power, peak-to-average power, and RF wave-shape. Simultaneous measurement of signal power and average power is essential for taking full advantage of a receive signal chain's available dynamic range, while avoiding saturation, or to maximize transmitter efficiency.

### $V_{RMS}$ vs. $P_{IN}$




### iPAR Output & Input RF Signal Envelope vs. Time for an Input Crest Factor of 9.03 dB @ 1900 MHz [2]

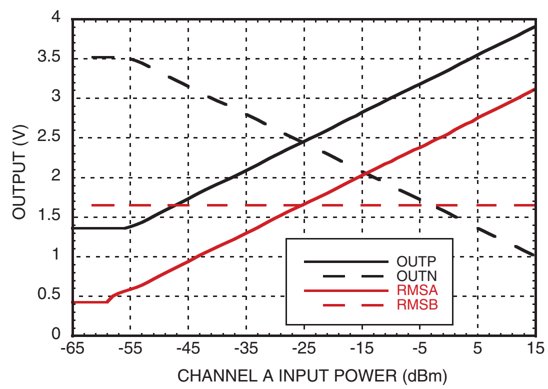


## Dual RMS Detection Channels

The HMC714LP5E integrates two HMC614LP4E RMS detection channels with shared bias and control circuitry. The linear-in-dB channel outputs at the $RMS_A$ and $RMS_B$ pins provide RMS detection performance in terms of dynamic range, temperature stability, and logarithmic linearity similar to Hittite's HMC614LP4E with improved frequency detection range extending up to 5.8 GHz. Proprietary design techniques enable extremely good matching between channels (within less than 0.5 dB with single-ended cnfiguration) over a wide range of input frequencies with low temperature drift.

HMC714LP5E also provides "channel difference" outputs via pins OUTP and OUTN that can be either used differentially or single-ended. The $V_{LVL}$ input is used to set the common mode reference level for those outputs. On the Hittite evaluation board, the $V_{LVL}$ pin is shorted to $V_{REF2}$ output to provide a nominal bias voltage of 2.5V; but any external bias voltage can be used to set $V_{LVL}$.

**Channel Difference Outputs @ 1900 MHz, Channel A Power Swept, Channel B @ -25 dBm**




A ratio of two signal powers is a simple difference in the log domain. The OUTP and OUTN outputs can provide a direct read of input signal power ratio between the signals presented to the two power detection channels.

When OUTP is connected directly to $FBK_A$

$OUTP = RMS_A - RMS_B + V_{LVL}$

And when OUTN is connected directly to $FBK_B$

$OUTN = RMS_B - RMS_A + V_{LVL}$

With the channels of HMC714LP5E having very low mismatch, channel outputs $RMS_A$ and $RMS_B$ track very closely over temperature. The difference operation also allows the OUTP and OUTN to reject common-mode changes in channels A and B.

**HMC714LP5E also features iPAR output on each power detector.** The $RMS_A$ and $RMS_B$ outputs provide a read of average input signal (i.e True RMS power). The $INS_A$ and $INS_B$ pins are iPAR outputs providing a simultaneous read of input signal Peak Power, Peak-to-Average Ratio, and RF waveshape. Refer to the section under "iPAR – Envelope Power Normalized To Average Power" for more details on iPAR measurements.



For price, delivery, and to place orders, please contact Hittite Microwave Corporation:
20 Alpha Road, Chelmsford, MA 01824 Phone: 978-250-3343 Fax: 978-250-3373
Order On-line at www.hittite.com

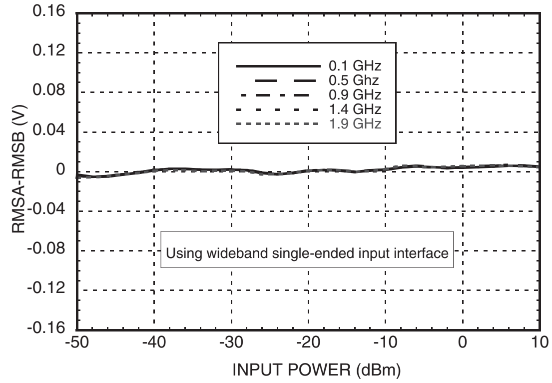
## DUAL RMS POWER DETECTOR 0.1 - 3.9 GHz

### Channel Matching

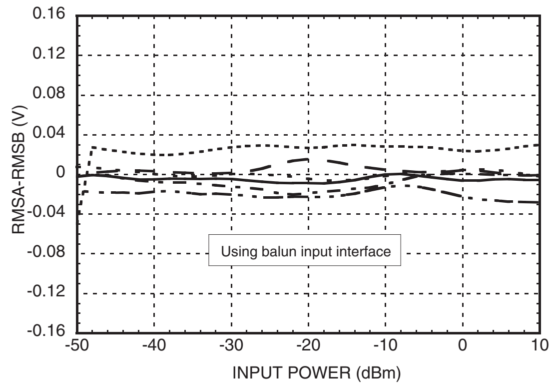
Single channel RMS detectors exhibit part-to-part variations that tend to complicate simultaneous power readings. Simultaneous signal power measurements are particularly useful for automatic gain/level control and VSWR measurements. When separate power detectors are used, the lack of an accurate match between the power detectors will produce measurement errors. Calibration and compensation methods are required to counteract the differences between the separate power detectors. The Dual RMS detector package greatly simplifies that activity, and will reliably produce more accurate measurements.

The HMC714LP5E provides industry leading channel matching performance with the use of proprietary techniques. The channel mismatch is typically less than 20 mV over the specified temperature and frequency range when the single-ended input interface is used. Hittite “differential” evaluation kits use M/A Com’s ETC1-1-13 balun, which are designed to work up to 3 GHz. At frequencies lower than 3 GHz, the mismatch between the two input baluns cause a larger variation between the channels when compared to the single-ended interface (typically ±25 mV up to 900 MHz and ±50 mV up to 2700 MHz). The input impedance mismatch presented by the balun at signal frequencies beyond 3 GHz will further increase the channel-to-channel variation. The “single-ended” input interface does not have this limitation. The “single-ended” interface can utilize the full input signal bandwidth of the power detector; however the “single-ended” input interface is tuned. The differential or balun input interface is best suited to very wideband power measurements (100 MHz to 3 GHz), whereas the single-ended input interface is best suited to signal power measurement over bandwidths up to ±300 MHz (for ±1 dB error tolerance) in the hole RF frequency range.

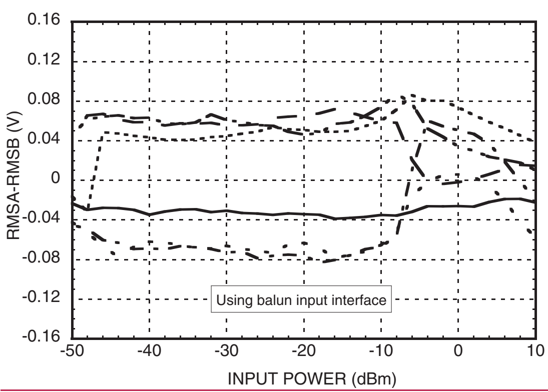
### Channel Matching [RMSA-RMSB] in Wideband Single Ended Configuration



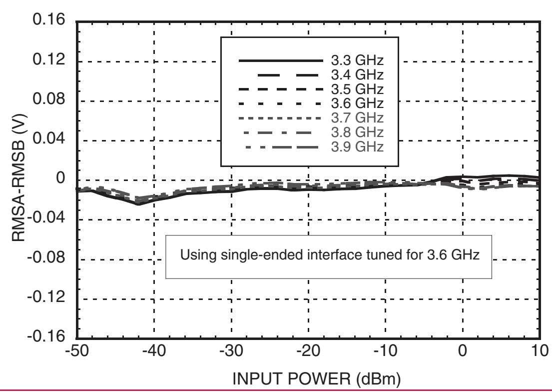

### Channel Matching [RMSA-RMSB] @ 900 MHz




### Channel Matching [RMSA-RMSB] @ 3.5 GHz




### Channel Matching [RMSA-RMSB] in Single Ended Configuration tuned @ 3.6 GHz



### Channel Isolation/Interface

Channel isolation/interference is grouped into two categories:

On-chip inter-channel interference, and

Off-chip inter-channel interference.

Off-chip interference between channels should be considered, especially at small signal levels, since HMC714LP5E is capable of detecting a signal over a very wide dynamic range (70 dB+). There are two main mechanisms through which the interference between the channels may affect measurement accuracy. The first one is the direct coupling of the RF signal from one RF channel input to the other RF channel input. Baluns on the detector inputs usually contribute to inter-channel coupling, as does PC board design and the quality of the soldered connections.

On-chip inter-channel interference, herein referred to as "input-output channel isolation", usually manifests itself as drift on one detector output due to a relatively strong signal present at the other detector input. Quantitatively, the input-output channel isolation is defined as the difference between the input power levels at both channels when the interfering (higher power level) channel causes a 1 dB measurement drift in the interfered (lower power level) channel. Worst case channel interference occurs when one channel has an input signal level just over its detection threshold.

Input-Output Channel isolation for HMC714LP5E is:

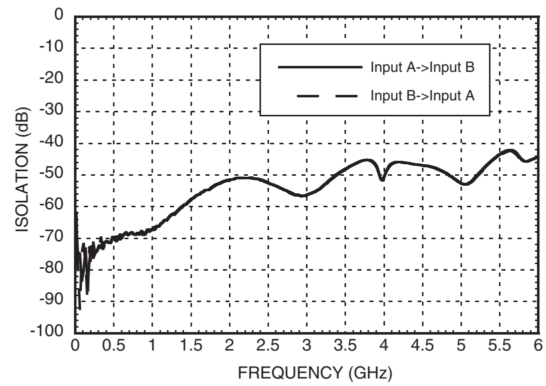
55+ dB input-output isolation at 900 MHz

45 dB input-output isolation up to 2.7 GHz

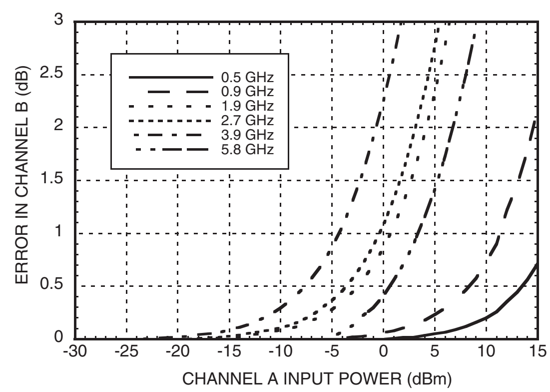
35 dB input-output isolation up to 5.8 GHz.

If the same signal frequency is injected into both channels for this Input-Output Channel Isolation measurement, the interference will manifest as a phase delay. A slight offset in signal frequency between the two channels can be seen as a ripple at the output of the channel with the lower power level applied at its input. Peaks in the output ripple correspond to the worst-case phase shift for input-output interference. The frequency of the output ripple will be equal to the "beat" frequency between the two channels. The magnitude of the output ripple will depend on the integration and offset capacitors connected to $C_{INT}$ and $C_{OFS}$ pins, respectively. The output ripple is reduced by increasing the value of the integration capacitance ($C_{INT}$), thereby decreasing the integrator bandwidth. The data was collected using a 100kHz offset between the channels.

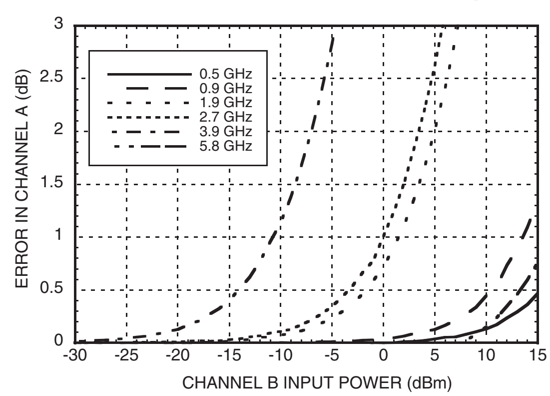
### Input to Input Isolations with ETC1-1-13 Baluns




### Interference to an Input Signal (INB Power Fixed) with Interfering Signal on the other Channel (INA Power Swept) [1]




### Interference to an Input Signal (INA Power Fixed) with Interfering Signal on the other Channel (INB Power Swept) [1]



### *Configuration for the Typical Application*

The RF inputs can be connected in either a differential or single-ended configuration: see "RF Input Interface" section for details on each input configuration. With the appropriate input tuning components, the part can provide the full performance with a single-ended input.

The $RMS_A$ & $RMS_B$ output signals are typically connected directly to $V_{SETA}$ & $V_{SETB}$ inputs, providing a Pin->$V_{RMS}$ transfer characteristic slope of 36.5 mV/dBm at both channels; however the RMS output can be re-scaled to "magnify" a specific portion of the input sensing range, and to fully utilize the dynamic range of the RMS output. Refer to the section under the "log-slope and intercept" for details.

The $INS_A$ & $INS_B$ pins are the instantaneous peak-to-average ratio (iPAR) outputs; on each detector. This iPAR measurement pulls it's signal from the internals of the RMS detector, just before the RMS calculation is processed. Each iPAR output ($INS_A$ & $INS_B$) produces a voltage signal which provides a direct read of the RF signal AM envelope. So between the simultaneous measurement of RMS power and iPAR on each power detector, a system can monitor average power, peak power, peak-to-average power, and the RF waveshape. See the section under "iPAR Envelope Power Normalized to Average Power" for application details.

$V_{TGT}$ with a nominal value of 2V is typically generated from the $V_{REF}$ reference output of 3V; however the $V_{TGT}$ voltage can be adjusted to optimize measurement accuracy, especially when measurement at higher crest factors is important: see "Adjusting $V_{TGT}$ for greater precision" section for technical details.

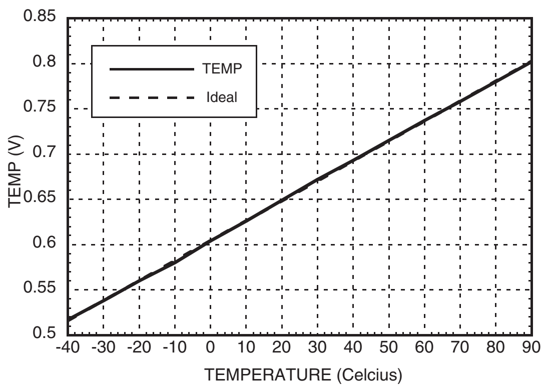
Due to part-to-part variations in log-slope and log-intercept, a system-level calibration is recommended to satisfy absolute accuracy requirements: refer to the "System Calibration" section for more details.

The HMC714LP5E requires a single 5V supply connected to three pins: $V_{CCA}$, $V_{CCB}$, and $V_{CCBIAS}$. Adequate power supply decoupling is required on these pins. The supply pins should be decoupled to ground using two parallel capacitors with the values shown in the application schematic. The capacitors should be placed close to the part (with the smaller value as close as possible to the supply pin) and must provide a low impedance path to RF GND over the entire input frequency range.

### *Temperature Sensor Interface*

The HMC714LP5E provides a buffered PTAT temperature sensor output that provides a temperature scaling factor of 2.2 mV/°C with a typical output voltage of 600 mV at 0°C. The output is capable of sourcing 1.5 mA.

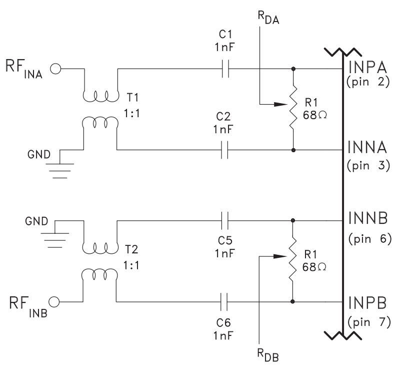
**TEMP Output**



### RF Input Interface

The $INP_A$ and $INN_A$ pins are differential inputs on one of two power detectors, which we will refer to as channel A. $INP_B$ and $INN_B$ pins are differential inputs on the other power detector, channel B. The inputs for both channels can be externally configured with differential or single-ended input. Power match components are placed on these input terminals, along with DC blocking capacitors. The coupling capacitor values also set the lower spectral boundary of the input signal bandwidth. The inputs can be reactively matched (refer to input return loss graphs), but a resistor network should be sufficient for good wideband performance.

Differential Input Interface:

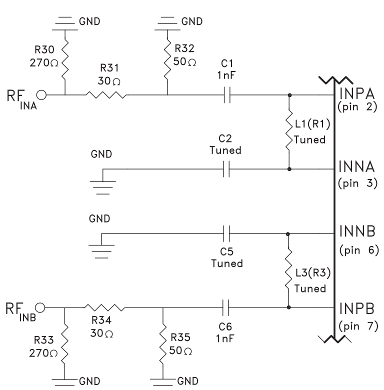



The value of RD (=RDA=RDB) depends on the balun used; if the balun is 50Ω on both sides of the SE-Diff conversion,

then $R_D = \frac{220 * R_M}{220 - R_M}$ where

$R_M$ = the desired power match impedance in ohms.

For $R_M$ = 50Ω, RD = 67Ω ≈ 68Ω




Single-Ended Input Interface:

**Tuned SE-interface**: for signal frequencies > 900MHz

Choose L and C elements from the following graph for narrowband tuning of the SE-interface:

R31/34 = 30Ω, R32/35 = 50Ω, C1/6 =1 nF
R30/33 = 270Ω,

**Wideband SE-interface:** for signal frequencies < 900 MHz

R31/34 = 0Ω, R32/35 = OPEN, R1/R3 = 68Ω,
R30/33 = Open

C2, C5 is 1 nF decoupling caps.

For wideband (un-tuned) input interfaces, choose the input decoupling capacitor values by first determining the lowest spectral component the power detector is required to sense, $f_L$.

Input decoupling capacitor value

$$\approx \frac{1}{p \times f_L \times 3.2}$$

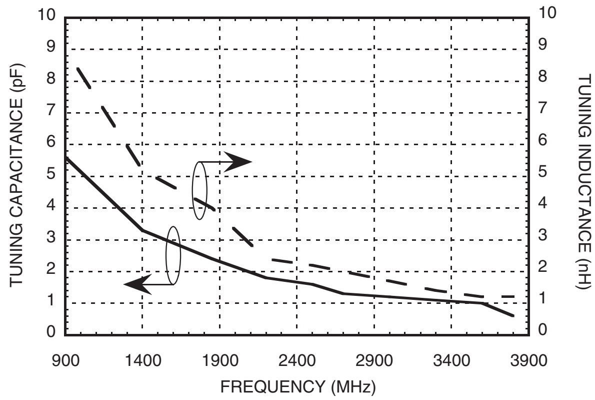
farads, where $f_L$ is in Hertz.

Ex. If the power detector needs to sense down to 10 MHz, the decoupling capacitor value should be 1/(π*10E6*3.2) = 10 nF

A DC bias (Vcc-1.5V) is present on the INP[A,B] and IN[A,B] pins, and should not be overridden.

### RF Input Interface (Continued)

**Tuning, Single Ended Interface: fc ± 300 MHz**




### RMS Output Interface and Transient Response

Output transient response is determined by the integration capacitances $C_{INTA}$ & $C_{INTB}$ and output load conditions. Using larger values of $C_{INT}$ will narrow the operating bandwidth of the integrator, resulting in a longer averaging time-interval and a more filtered output signal; however it will also slow the power detector's transient response. A larger $C_{INT}$ value favors output accuracy over speed. For the fastest possible transient settling times, leave the $C_{INT}$ pins free of any external capacitance. This configuration will operate the integrator at its widest possible bandwidth, resulting in short averaging time-interval and an output signal with little filtering. Most applications will choose to have some external integration capacitance, maintaining a balance between speed and accuracy. Furthermore, error performance over crest factor is degraded when $C_{INT}$ is very small (for $C_{INT}$ < 100 pF).

Modulation and deviation results in Electrical Specification Table 2 are provided with CINT = 0.1 uF.

Start by selecting $C_{INT}$ using the following expression, and then adjust the value as needed, based on the application's preference for faster transient settling or output accuracy.

$C_{INT} = 1500\ uF/(2{*}\pi\ {*}f_{lam})$, in Farads, where $f_{lam}$ = lowest amplitude-modulation component frequency in Hertz

Example: when $f_{lam}$ = 10 kHz, $C_{INT}$ = 1500 µF/(2*π*1000) = 24E-9 Farads ~ 22 nF

**Table: Transient response vs. $C_{INT}$ capacitance: with $C_{OFS}$ = 0**

| $C_{INT}$ | RMS Rise - Time over Dynamic Range Pin = 0 dBm | RMS Fall - Time | | |
|---|---|---|---|---|
| | | Pin = -30 dBm | Pin = -10 dBm | Pin = 0 dBm |
| 0 | 35 nsec | 120 nsec | 200 nsec | 1.18 usec |
| 100 pF | 80 nsec | 410 nsec | 720 nsec | 1.26 usec |
| 1 nF | 780 nsec | 3.3 usec | 5.6 usec | 7 usec |
| 10 nF | 7.8 usec | 32.4 usec | 54 usec | 66.4 usec |

Input signal is 1900 MHz CW-tone switched on and off

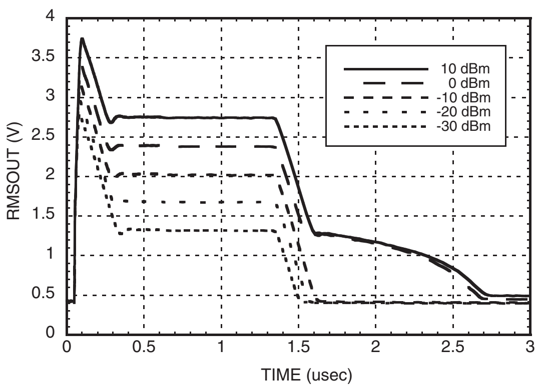
RMS is loaded with 1kΩ, 4 pF, and $V_{TGT}$ = 2V,

### *RMS Output Interface and Transient Response* (Continued)

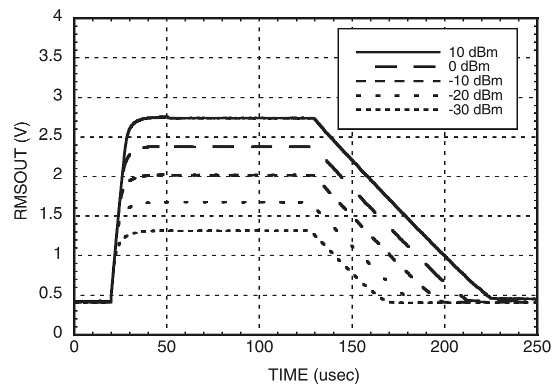
Transient response can also be slewed by the RMS output if it is excessively loaded: keep load resistance above 375Ω. An optimal load resistance of approximately 500Ω to 1kΩ will allow the output to move as quickly as it is able. For increased load drive capability, consider a buffer amplifier on the RMS output.

Using an integrating amplifier on the RMS output allows for an alternative treatment for faster settling times. An external amplifier optimized for transient settling can also provide additional RMS filtering, when operating HMC714LP5E with a lower $C_{INT}$ capacitance value.

**Rise/Fall Characteristics, CINT = 0 pF**




**Rise/Fall Characteristics, CINT = 10 nF**

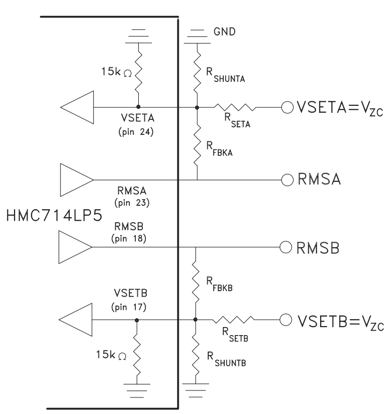



### *LOG-Slope and Intercept*

The HMC714LP5E provides for an adjustment of output scale by controlling the fraction of $RMS_A/RMS_B$ that is fed-back to the setpoint interface at the $V_{SETA}/V_{SETB}$ pins. Log-slope and intercept can be adjusted to “magnify” a specific portion of the input sensing range, and to fully utilize the dynamic range of the RMS output.

A log-slope of 36.5 mV/dBm is set by connecting the $RMS_A/RMS_B$ outputs directly to $V_{SETA}/V_{SETB}$ pins using 0Ω resistors $RFBK_A$ and $RFBK_B$. The log-slope is adjusted by using the appropriate resistors $RFBK_A$, $RFBK_B$, $RSHUNT_A$, $RSHUNT_B$ on the $RMS_A/RMS_B$ and $V_{SETA}/V_{SETB}$ pins. Log-intercept is adjusted by applying a DC voltage to the $V_{SETA}/V_{SETB}$ pins through resistors $R_{SETA}$ and $R_{SETB}$ .

Due to the 15 kΩ input resistance at the $V_{SETA}/V_{SETB}$ pins, moderately low resistance values should be used to minimize the scaling errors. Very low resistor values will reduce the load driving capabilities of $RMS_A/RMS_B$ outputs while larger values will result in scaling errors and increase of the temperature errors because of the mismatch of the on-chip and external resistor temperature coefficients.




Optimized slope = ß * log slope

Optimized intercept = log intercept - $(R_{FBK} / R_{SET})$ * Vzc

$$ß = \frac{R_{FBK}}{R_{FBK} // R_{SHUNT} // R_{SET}}$$

When $R_{FBK}$ = 0 Ohm to set RMS = $V_{SET}$, then ß = 1

Note: Avoid excessive loading of the RMS output; keep $C_{LOAD}$ < 35 pF, and $R_{LOAD}$ > 375Ω

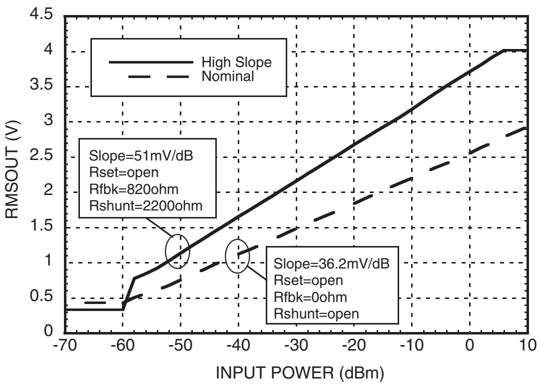
### *LOG-Slope and Intercept* (Continued)

Example: The logarithmic slope can be simply increased by choosing appropriate RFBK and RSHUNT values while not populating the $R_{SET}$ resistor on the evaluation board to keep the intercept at nominal value. Setting RFBK = 820Ω and RSHUNT = 2200Ω results in an optimized slope of:

Optimized Slope = ß * log_slope = 1.42 * 36.5 mV / dB

Optimized Slope = 52 mV / dB

### *Slope Adjustment*




Example: The logarithmic intercept can also be adjusted by choosing appropriate $R_{FBK}$, $R_{SHUNT}$, and $R_{SET}$ values while keeping the logarithmic slope at about 50mV/dB. Setting $R_{FBK}$ = 820 Ohm and $R_{SHUNT}$ = $R_{SET}$ = 4700Ω results in an optimized slope of:

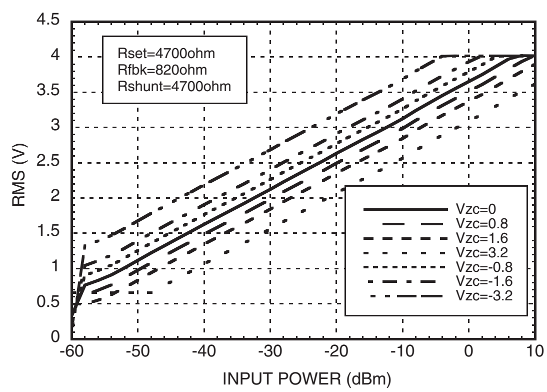
Optimized Slope = ß * log_slope = 1.4 * 36.5 mV / dB

Optimized Slope = 51 mV / dB

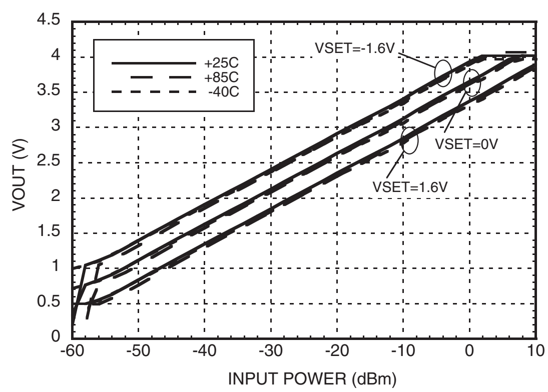
$$\text{Optimized Intercept} = \text{log\_intercept} - \frac{R_{FBK} * V_{ZC}}{R_{SET}}$$

$$\text{Optimized Intercept} = \text{log\_intercept} - 0.174 * V_{ZC}$$

### *Intercept Adjustment*




### *Intercept Adjustment (with Temp)*



## *iPAR – Envelope Power Normalized To Average Power*

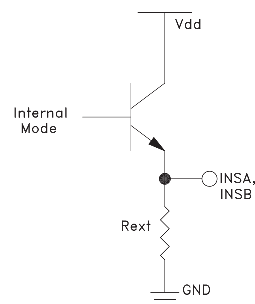
The INSA and INSB are envelope detector outputs for A & B channels that provide a measurement of instantaneous signal power *normalized* average power. This feature is called Instantaneous Peak to Average Ratio **(iPAR)**. The iPAR makes peak-to-average power comparisons immediately obvious. This simultaneous measurement of envelope power and average power in HMC714LP5E has two fundamental advantages over traditional methods of which employ two different power detectors working in parallel.

- Both the iPAR and RMS detectors share the same measurement structures, and
- Both the iPAR and RMS detectors share the same temperature compensation mechanisms.

With traditional implementation of peak-to-average power detection, the dominant source of errors is due to the uncorrelated measurement deviations between the two separate detectors. Both detectors in the HMC714LP5E share the same circuits ($INS_A$-$RMS_A$ pair and $INS_B$-$RMS_B$ pair), so any deviations, however small, are *fully* correlated.

The iPAR feature can be configured to provide two major functions:

1. <u>A measurement of instantaneous signal power normalized to average power</u>




In this most basic measurement mode, $INS_A$ ($INS_B$) output is terminated to ground using an external resistor which forms an output buffer with the internal transistor Q1 connected in emitter-follower configuration. With Rext = 3.9 kOhm (R20 and R12 on the evaluation board for A & B channels), $INS_A$ ($INS_B$) output can track the input envelope up to a modulation bandwidth of 35 MHz at which point the output swing drops by 50%. For an unmodulated input signal with f>>35 MHz, the $INS_A$ ($INS_B$) output will provide a constant value of approximately 1.6V indicating that the instantaneous power is equal to the average power.

The $INS_A$ ($INS_B$) output voltages linearly follow the instantaneous power levels at the detector input with the transfer gain scaled by an external voltage applied to $V_{TGT}$ (pin 28). For a nominal voltage of 2V on $V_{TGT}$ the scaling factor of the $INS_A$ ($INS_B$) output is 200 mV.

$$\mathbf{INS_{[A,B]} = IREF_{[A,B]} + SF^*(EAR_{[A,B]} - 1)}$$

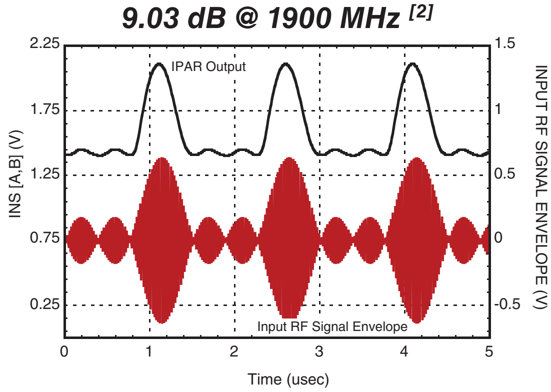
where $IREF_{[A,B]} = (VCC_{[A,B]}{}^*R_{EXT}) /( 3^*(R_{EXT}+65\ \text{Ohm})) \approx 1.6$ V (for VCC = 5V, $R_{EXT} = 2$ kΩ)

where $EAR_{[A,B]}$ = input signal RF AM envelope-to-average power ratio on channel [A,B]

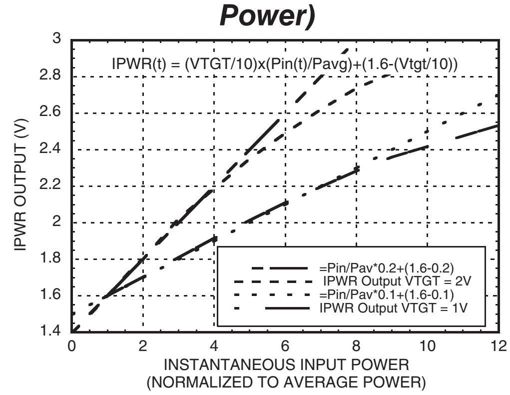
and SF = the scaling factor set by an external voltage applied to $V_{TGT}$ (200 mV when $V_{TGT} = 2.0$V)

For example, the $INS_A$ ($INS_B$) voltage will drop to 1.4 V (1.6-0.2V) when the input power instantaneously drops to zero, and will increase to 2.2V (1.6+0.2*3) when the input power instantaneously increases to 4 times the average power. With lower $V_{TGT}$ values the scaling factor also decreases, allowing $INS_A$ ($INS_B$) to linearly track larger swings of input power.

### *iPAR Output & Input RF Signal Envelope vs. Time for an Input Crest Factor of 9.03 dB @ 1900 MHz [2]*



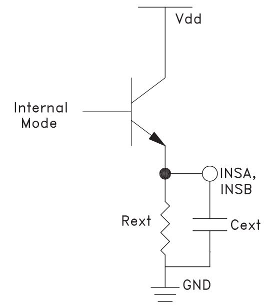

### *INS [A,B] Output vs. Instantaneous Input Power (Normalized to Average Power)*



## PAR – Envelope Power Normalized To Average Power *(Continued)*

The $INS_A$ ($INS_B$) output is highly independent from input signal frequency, input average power, and temperature. Proprietary design techniques assure very little part-to-part variation and maintain a very high degree of match between channels.

2. A measurement of peak-power normalized to average power




To measure peak power, a peak-hold mechanism is required at the $INS_A$ ($INS_B$) output. The peak-hold circuit can be as simple as an RC combination on the $INS_A$ ($INS_B$) pin. In this configuration, peak excursions of the input signal is stored as a peak voltage on the external Cext capacitor. Rext is used to set the quiescent bias point of Q1, and together with Cext will for a time-constant for the peak-hold function. The larger Cext is the longer the peak-detector will "remember" the largest signal excursion; conversely a smaller value of Cext will result in a shorter memory, and less filtering. The value of Rext for this "peak-power" mode of the iPAR function should be much larger than the value used for the iPAR mode described previously (instantaneous power tracking mode) to extend the RextCext time-constant.

$$\mathbf{INS_{[A,B]} = IREF_{[A,B]} + SF*(PAR_{[A,B]} - 1)}$$

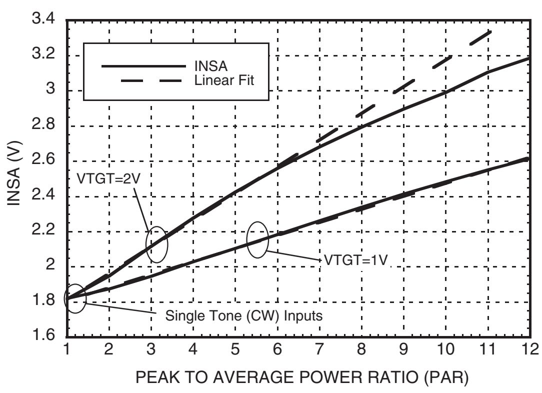
where $IREF_{[A,B]} = VCC_{[A,B]} / 3 + 0.15V \approx 1.82V$ (for VCC = 5V, $R_{EXT}$ = 500 kΩ)

where $PAR_{[A,B]}$ = input signal peak-to-average ratio on channel [A,B]

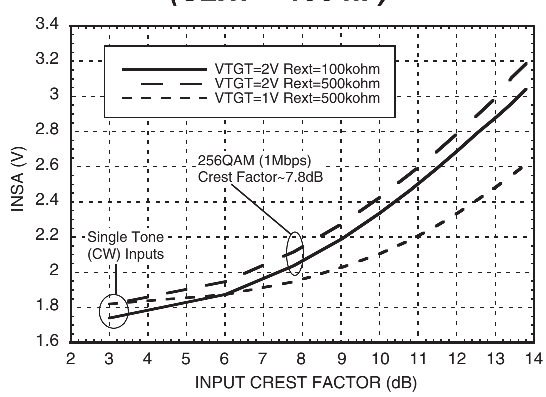
and SF = the scaling factor set by an external voltage applied to $V_{TGT}$ (150 mV when $V_{TGT}$ = 2.0V)

The graphs below describes the $INS_A$ ($INS_B$) peak-hold levels as a function of input peak-to-average ratio (PAR) and also crest factor. Note how the voltage applied at $V_{TGT}$ affects the $INS_A$ ($INS_B$) reading. The voltage applied to the $V_{TGT}$ pin also has a secondary effect on crest-factor performance. The $V_{TGT}$ signal optimizes internal bias points for measurement accuracy at higher crest factors: refer to the section under "Adjusting $V_{TGT}$ for greater precision" for a

### iPAR Feature Peak-to-Average Power Detection Configuration ($R_{EXT}$ = 500Ω, $C_{EXT}$ = 100 nF)




### iPAR Feature Peak-to-Average Power Detection Configuration vc Crest Factor (CEXT = 100 nF)



### PAR – Envelope Power Normalized To Average Power *(Continued)*

full description on crest factor optimization.

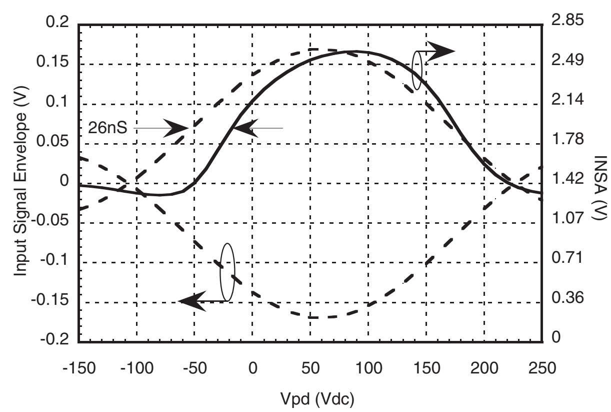
iPAR Reference Outputs: IREFA & IREFB

HMC714LP5E also provides two reference voltage outputs, $IREF_A$ (pin 26) and $IREF_B$ (pin 15) for A & B channels, which when used with the $INS_A/INS_B$ outputs allows cancellation of temperature and supply related variations of the $INS_A/INS_B$ DC offsets. $INS_A/INS_B$ DC offsets are equal to the $IREF_A/IREF_B$ reference voltages, and these levels corresponds to the envelope-to-average ratio (EAR) or peak-to-average ratio (PAR) of an unmodulated carrier (CW-tone crest factor = 3 dB). For the best cancellation of the effects of temperature and supply voltage on $INS_A/INS_B$ DC offsets, load both the $INS_A/INS_B$ and $IREF_A/IREF_B$ outputs with an equivalent RC network.

Propagation Delay of $INS_A$ & $INS_B$

The proper operation of the iPAR feature depends on the proper settling of the RMS outputs because both the iPAR feature and the RMS detection feature share the same internal structures. After internal mechanisms of the detector have settled, the RMS outputs ($RMS_A$ & $RMS_B$) provide a reading of input average power while iPAR outputs ($INS_A$ & $INS_B$) provides the instantaneous (or peak) power value of the input signal. There is of course some finite propagation delay from the instant of input power change to the change of $INS_A$ ($INS_B$). That propagation delay is defined by the external capacitor, Cext. The figure illustrates the propagation delay from a 900 MHz, 6-tone (multi-carrier) input signal at -10 dBm average power to the $INS_A$ output of HMC714LP5E. As illustrated, the propagation delay is 26 nsec with the detector configured with the wideband, single-ended input interface. The use of the differential input interface with the balun increases the propagation delay to 37 nsec under similar test conditions.

**Propagation Delay with Wideband Single Ended Input Itnerface**




### Standby Mode

The ENX can be used to force the power detector into a low-power standby mode. In this mode, the entire power detector is powered-down. As ENX is deactivated, power is restored to all of the circuits. There is no memory of previous conditions. Coming-out of stand-by, $C_{INT}$ and $C_{OFS}$ capacitors will require recharging, so if large capacitor values have been chosen, the wake-up time will be lengthened.

### DC Offset Compensation Loop

Internal DC offsets, which are input signal dependant, require continuous cancellation. Offset cancellation is a critical function needed for maintenance of measurement accuracy and sensitivity. The DC offset cancellation loop performs this function, and its response is largely defined by the capacitance off. Setting DC offset cancellation, loop bandwidth strives to strike a balance between offset cancellation accuracy, and loop response time. A larger value of $C_{OFS}$ results in a more precise offset cancellation, but at the expense of a slower offset cancellation response. A smaller value of $C_{OFS}$ tilts the performance trade-off towards a faster offset cancellation response. The optimal loop bandwidth setting will allow internal offsets to be cancelled at a minimally acceptable speed.


For price, delivery, and to place orders, please contact Hittite Microwave Corporation:
20 Alpha Road, Chelmsford, MA 01824 Phone: 978-250-3343 Fax: 978-250-3373
Order On-line at www.hittite.com

### *DC Offset Compensation Loop* *(Continued)*

DC Offset Cancellation Loop Bandwith $\approx \dfrac{1}{\pi(500)(C_{OFS} + 20 \times 10^{12})}$ Hz

For example: loop bandwidth for DC cancellation with COFS = 1nF, bandwidth is ~62 kHz

Note: The measurement error produced by internal DC offsets cannot be measured repeatably at any single operating point, in terms of input signal frequency and level. Measurement error must be calculated to a best fit line, over the entire range of input signal (again, in terms of signal level and frequency).

### *Adjusting $V_{TGT}$ for Greater Precision*

There are two competing aspects of performance, for which $V_{TGT}$ can be used to set a preference. Depending on which aspect of precision is more important to the application, the $V_{TGT}$ pin can be used to find a compromise between two sources of RMS output error: internal DC offset cancellation error and deviation at high crest factors (>12dB).

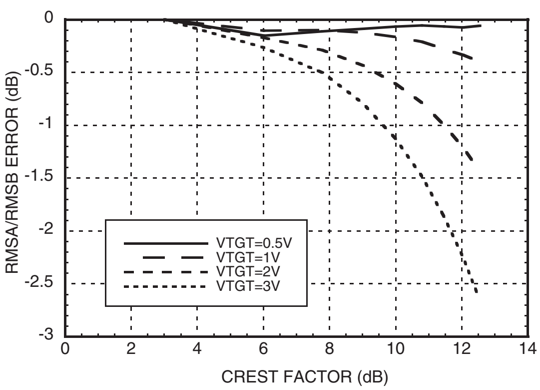
- Increasing $V_{TGT}$ input voltage will reduce the effect of internal DC offsets, but deviation at high crest factors will increase slightly. A 50% increase in $V_{TGT}$ should produce an 18% improvement in RMS precision due to a reduction in internal DC offsets effects.
- Decreasing $V_{TGT}$ input voltage will reduce errors at high crest factors, but internal DC offsets will have more of an effect on measurement accuracy.

If input signal crest factor is not expected to exceed 10dB, you can improve RMS precision by increasing $V_{TGT}$ voltage. Keep in mind that changing $V_{TGT}$ also adjusts the log-intercept point, which shifts the “input dynamic range”. The best set-point for $V_{TGT}$ will be the lowest voltage that still maintains the “input dynamic range” over the required range of input power. This new $V_{TGT}$ set-point should optimize the amount of DC offset related errors.

If error performance at high crest factors requires optimization, set $V_{TGT}$ for the *maximum tolerable error at the highest expected crest factor*. Increasing $V_{TGT}$ beyond that point will unnecessarily compromise internal DC offset cancellation performance. After changing $V_{TGT}$, re-verify that the “input dynamic range” still covers the required range of input power.

$V_{TGT}$ should be referenced to $V_{REF}$ for best performance. It is recommended to use a temperature stable DC amplifier between $V_{TGT}$ and $V_{REF}$ to create $V_{TGT} > V_{REF}$. The $V_{REF}$ pin is a temperature compensated voltage reference output, only intended for use with $V_{TGT}$.

### *RMS Output Error vs. Crest Factor*




### *$V_{TGT}$ influence on DC offset compensation*

| $V_{GTG}$ | Error due to internal DC offsets |
|---|---|
| 1.0 V | nominal + 0.2 dB |
| 1.5 V | nominal + 0.1 dB |
| 2.0 V | nominal |
| 3.0 V | 7.nominal + 0.06 dB |
| 3.5 V | nominal + 0.1 dB |

### System Calibration

Due to part-to-part variations in log-slope and log-intercept, a system-level calibration is recommended to satisfy absolute accuracy requirements. When performing this calibration, choose at least two test points: near the top-end and bottom-end of the measurement range. It is best to measure the calibration points in the regions (of frequency and amplitude) where accuracy is most important. Derive the log-slope and log-intercept, and store them in non-volatile memory. Calibrate iPAR scaling by measuring the peak-to-average ratio of a known signal.

For example if the following two calibration points were measured at 2.35 GHz:

With Vrms = 2.34V at Pin= -7dBm,
and Vrms=1.84V at Pin= -16dBm
Slope Calibration Constant = SCC
SCC = (-16+7)/(1.84-2.34) = 18 dB/V
Intercept Calibration Constant = ICC
ICC = Pin – SCC*Vrms = -7 – 18.0 * 2.34 = -49.12dBm

Now performing a power measurement:
Vrms measures 2.13V
[Measured Pin] = [Measured Vrms]*SCC + ICC
[Measured Pin] = 2.13*18.0 – 49.12 = -10.78dBm
An error of only 0.22dB

Factory system calibration measurements should be made using an input signal representative of the application. If the power detector will operate over a wide range of frequencies, choose a central frequency for calibration.

### Layout Considerations

- Mount RF input coupling capacitors close to the IN+ and IN- pins.
- Solder the heat slug on the package underside to a grounded island which can draw heat away from the die with low thermal impedance. The grounded island should be at RF ground potential.
- Connect power detector ground to the RF ground plane, and mount the supply decoupling capacitors close to the supply pins.

### Definitions:

- Log-slope: slope of $P_{IN}$ –> $V_{RMS}$ transfer characteristic. In units of mV/dB
- Log-intercept: x-axis intercept of $P_{IN}$ –> $V_{RMS}$ transfer characteristic. In units of dBm.
- RMS Output Error: The difference between the measured $P_{IN}$ and actual $P_{IN}$ using a line of best fit.

  [measured_$P_{IN}$] = [measured_$V_{RMS}$] / [best-fit-slope] + [best-fit-intercept], dBm
- Input Dynamic Range: the range of average input power for which there is a corresponding RMS output voltage with “RMS Output Error” falling within a specific error tolerance.
- Crest Factor: Peak power to average power ratio for time-varying signals.



For price, delivery, and to place orders, please contact Hittite Microwave Corporation:
20 Alpha Road, Chelmsford, MA 01824 Phone: 978-250-3343 Fax: 978-250-3373
Order On-line at www.hittite.com

**Notes:**