# LMV227 Production RF Tested, RF Power Detector for CDMA and WCDMA

**Check for Samples: LMV227**

## FEATURES

- **30 dB Linear in dB Power Detection Range**
- **Output Voltage Range 0.2 to 2V**
- **Logic Low Shutdown**
- **Multi-band Operation from 450 MHz to 2000 MHz**
- **Accurate Temperature Compensation**

## APPLICATIONS

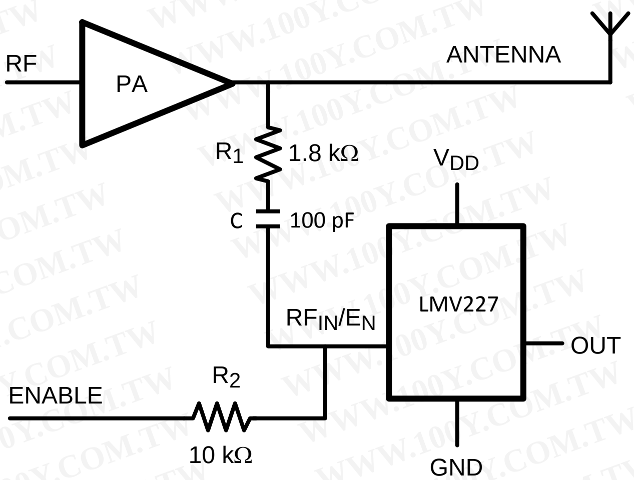
- **CDMA RF Power Control**
- **WCDMA RF Power Control**
- **CDMA2000 RF Power Control**
- **PA Modules**

## DESCRIPTION

The LMV227 is a 30 dB RF power detector intended for use in CDMA and WCDMA applications. The device has an RF frequency range from 450 MHz to 2 GHz. It provides an accurate temperature and supply compensated output voltage that relates linearly to the RF input power in dBm. The circuit operates with a single supply from 2.7V to 5V. The LMV227 has an integrated filter for low-ripple average power detection of CDMA signals with 30 dB dynamic range. Additional filtering can be applied using a single external capacitor.

The LMV227 has an RF power detection range from -30 dBm to 0 dBm and is ideally suited for direct use in combination with resistive taps. The device is active for Enable = HI, otherwise it goes into a low power consumption shutdown mode. During shutdown the output will be LOW. The output voltage ranges from 0.2V to 2V and can be scaled down to meet ADC input range requirements. The output signal bandwidth can optionally be lowered externally as well.

## TYPICAL APPLICATION



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## ABSOLUTE MAXIMUM RATINGS (1)(2)

| | | |
|---|---|---|
| Supply Voltage | $V_{DD}$ - GND | 6.0V Max |
| ESD Tolerance (3) | Human Body Model | 2000V |
| | Machine Model | 200V |
| Storage Temperature Range | | −65°C to 150°C |
| Junction Temperature (4) | | 150°C Max |
| Mounting Temperature | Infrared or convection (20 sec) | 235°C |

(1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not ensured. For ensured specifications and the test conditions, see the Electrical Characteristics.
(2) If Military/Aerospace specified devices are required, please contact the TI Sales Office/ Distributors for availability and specifications.
(3) Human body model: 1.5 kΩ in series with 100 pF. Machine model, 0Ω in series with 100 pF.
(4) The maximum power dissipation is a function of $T_{J(MAX)}$ , $\theta_{JA}$ and $T_A$. The maximum allowable power dissipation at any ambient temperature is $P_D = (T_{J(MAX)} - T_A)/\theta_{JA}$. All numbers apply for packages soldered directly into a PC board

## OPERATING RATINGS (1)

| | | |
|---|---|---|
| Supply Voltage | | 2.7V to 5.5V |
| Temperature Range | | −40°C to +85°C |

(1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not ensured. For ensured specifications and the test conditions, see the Electrical Characteristics.

## 2.7 DC AND AC ELECTRICAL CHARACTERISTICS

Unless otherwise specified, all limits are specified to $V_{DD}$ = 2.7V; $T_J$ = 25°C. **Boldface** limits apply at temperature extremes. (1)

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| $I_{DD}$ | Supply Current | Active mode: $RF_{IN}/E_N$ = $V_{DD}$ (DC), No RF Input Power Present. | | 4.9 | 7<br>**8** | mA |
| | | Shutdown: $RF_{IN}/E_N$ = GND (DC), No RF Input Power Present. | | 0.6 | **4.5** | μA |
| $V_{LOW}$ | $E_N$ Logic Low Input Level (2) | | | | **0.8** | V |
| $V_{HIGH}$ | $E_N$ Logic High Input Level (2) | | **1.8** | | | V |
| $t_{on}$ | Turn-on- Time | No RF Input Power Present | | 2.1 | | μs |
| $t_r$ | Rise Time (3) | Step from No Power to 0 dBm Applied | | 4.5 | | μs |
| $I_{EN}$ | Current into $RF_{IN}/E_N$ Pin | | | | **1** | μA |
| $P_{IN}$ | Input Power Range (4) | | | -30<br>0 | | dBm |
| | | | | -43<br>-13 | | dBV |
| | Logarithmic Slope (5) | 900 MHz | | 43.3 | | |
| | | 1800 MHz | | 43.9 | | |
| | | 1855 MHz | 36 | 43.5 | 51 | mV/dB |
| | | 1900 MHz | | 44.0 | | |
| | | 2000 MHz | | 43.2 | | |

(1) Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that $T_J = T_A$. No ensured specification of parametric performance is indicated in the electrical tables under conditions of internal self-heating where $T_J > T_A$.
(2) All limits are specified by design or statistical analysis
(3) Typical values represent the most likely parametric norm.
(4) Power in dBV = dBm −13 when the impedance is 50Ω.
(5) Device is set in active mode with a 10 kΩ resistor from $V_{DD}$ to $RF_{IN}/E_N$. RF signal is applied using a 50Ω RF signal generator AC coupled to the $RF_{IN}/E_N$ pin using a 100 pF coupling capacitor.

## 2.7 DC AND AC ELECTRICAL CHARACTERISTICS (continued)

Unless otherwise specified, all limits are specified to $V_{DD}$ = 2.7V; $T_J$ = 25°C. **Boldface** limits apply at temperature extremes. (1)

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| | Logarithmic Intercept (5) | 900 MHz | | −46.7 | | dBm |
| | | 1800 MHz | | −44.1 | | |
| | | 1855 MHz | −56 | −44.3 | −33 | |
| | | 1900 MHz | | −42.8 | | |
| | | 2000 MHz | | −43.7 | | |
| $V_{OUT}$ | Output Voltage | No RF Input Power Present | | 208 | **350** | mV |
| $R_{OUT}$ | Output Impedance | No RF Input Power Present | | 20.3 | 29<br>**34** | kΩ |
| $e_n$ | Output Referred Noise | RF Input = 1800 MHz, −10 dBm, Measured at 10 kHz | | 700 | | nV/√Hz |
| | Variation over Temperature | 900 MHz, $RF_{IN}$ = 0 dBm Referred to 25°C | | +0.64<br>−1.07 | | dB |
| | | 1800 MHz, $RF_{IN}$ = 0 dBm Referred to 25°C | | +0.09<br>−0.86 | | |
| | | 1900 MHz, $RF_{IN}$ = 0 dBm Referred to 25°C | | +0<br>−0.69 | | |
| | | 2000 MHz, $RF_{IN}$ = 0 dBm Referred to 25°C | | +0<br>−0.86 | | |

## 5.0 DC AND AC ELECTRICAL CHARACTERISTICS

Unless otherwise specified, all limits are specified to $V_{DD}$ = 5.0V; $T_J$ = 25°C. **Boldface** limits apply at temperature extremes. (1)

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| $I_{DD}$ | Supply Current | Active Mode: $RF_{IN}/E_N$ = $V_{DD}$ (DC), No RF Input Power Present. | | 5.3 | 7<br>**9** | mA |
| | | Shutdown: $RF_{IN}/E_N$ = GND (DC), No RF Input Power Present. | | 0.49 | **4.5** | μA |
| $V_{LOW}$ | $E_N$ Logic Low Input Level (2) | | | | **0.8** | V |
| $V_{HIGH}$ | $E_N$ Logic High Input Level (2) | | **1.8** | | | V |
| $t_{on}$ | Turn-on- Time | No RF Input Power Present | | 2.1 | | μs |
| $t_r$ | Rise Time (3) | Step from No Power to 0 dBm Applied | | 4.5 | | μs |
| $I_{EN}$ | Current Into $RF_{IN}/E_N$ Pin | | | | **1** | μA |
| $P_{IN, MIN}$ | Input Power Range (4) | | | -30<br>0 | | dBm |
| | | | | -43<br>-13 | | dBV |
| | Logarithmic Slope (5) | 900 MHz | | 43.6 | | mV/dB |
| | | 1800 MHz | | 44.5 | | |
| | | 1900 MHz | | 44.5 | | |
| | | 2000 MHz | | 43.7 | | |
| | Logarithmic Intercept (5) | 900 MHz | | -48.1 | | dBm |
| | | 1800 MHz | | -45.6 | | |
| | | 1900 MHz | | -44.2 | | |
| | | 2000 MHz | | -45.6 | | |
| $V_{OUT}$ | Output Voltage | No RF Input Power Present | | 211 | **400** | mV |

(1) Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that $T_J = T_A$. No ensured specification of parametric performance is indicated in the electrical tables under conditions of internal self-heating where $T_J > T_A$.
(2) All limits are specified by design or statistical analysis
(3) Typical values represent the most likely parametric norm.
(4) Power in dBV = dBm −13 when the impedance is 50Ω.
(5) Device is set in active mode with a 10 kΩ resistor from $V_{DD}$ to $RF_{IN}/E_N$. RF signal is applied using a 50Ω RF signal generator AC coupled to the $RF_{IN}/E_N$ pin using a 100 pF coupling capacitor.

## 5.0 DC AND AC ELECTRICAL CHARACTERISTICS (continued)

Unless otherwise specified, all limits are specified to $V_{DD}$ = 5.0V; $T_J$ = 25°C. **Boldface** limits apply at temperature extremes. [1]

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| $R_{OUT}$ | Output Impedance | No RF Input Power Present | | 23.4 | 29<br>**31** | kΩ |
| $e_n$ | Output Referred Noise | RF Input = 1800 MHz, −10 dBm, Measured at 10 kHz | | 700 | | $nV/\sqrt{Hz}$ |
| | Variation over Temperature | 900 MHz, $RF_{IN}$ = 0 dBm Referred to 25°C | | +0.89<br>−1.16 | | dB |
| | | 1800 MHz, $RF_{IN}$ = 0 dBm Referred to 25°C | | +0.3<br>−0.82 | | |
| | | 1900 MHz, $RF_{IN}$ = 0 dBm Referred to 25°C | | +0.34<br>−0.63 | | |
| | | 2000 MHz $RF_{IN}$ = 0 dBm Referred to 25°C | | +0.22<br>−0.75 | | |

## CONNECTION DIAGRAM

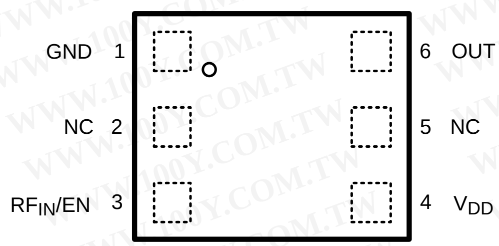
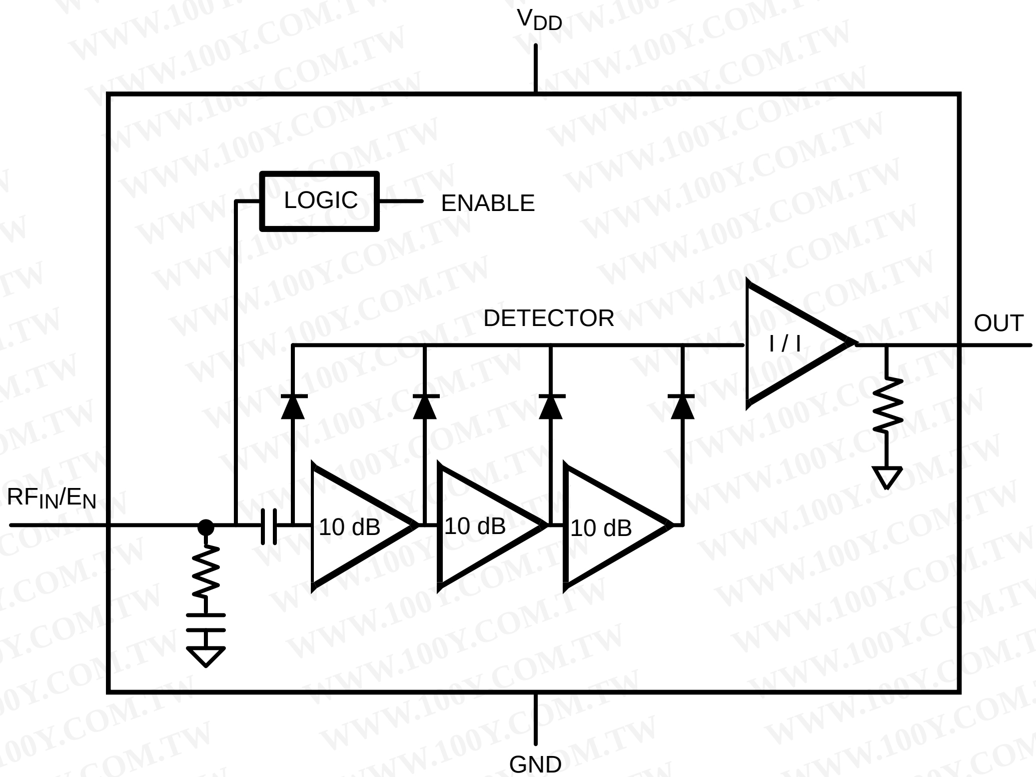



**Figure 1. 6-pin WSON Top View**

## PIN DESCRIPTIONS

| | Pin | Name | Description |
|---|---|---|---|
| Power Supply | 4 | $V_{DD}$ | Positive supply voltage |
| | 1 | GND | Power ground |
| | 3 | $RF_{IN}/E_N$ | DC voltage determines enable state of the device (HIGH = device active). AC voltage is the RF input signal to the detector (beyond 450 MHz). The $RF_{IN}/E_N$ pin is internally terminated with 50Ω in series with 45 pF. |
| Output | 6 | OUT | Ground referenced detector output voltage (linear in dBm) |

## BLOCK DIAGRAM



## TYPICAL PERFORMANCE CHARACTERISTICS

Unless otherwise specified, $V_{DD}$ = 2.7V, $T_J$ = 25°C.

**Supply Current vs. Supply Voltage**

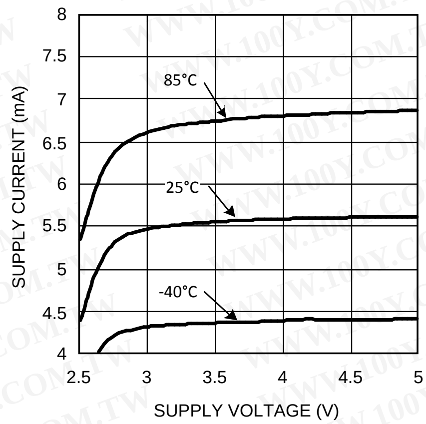



**Figure 2.**

**Output Voltage vs. RF Input Power**

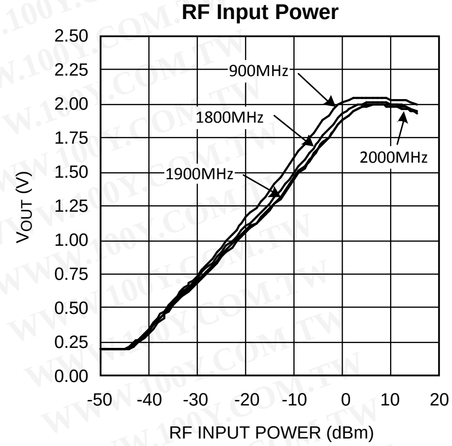



**Figure 3.**

**Output Voltage and Log Conformance vs. RF Input Power @ 900 MHz**

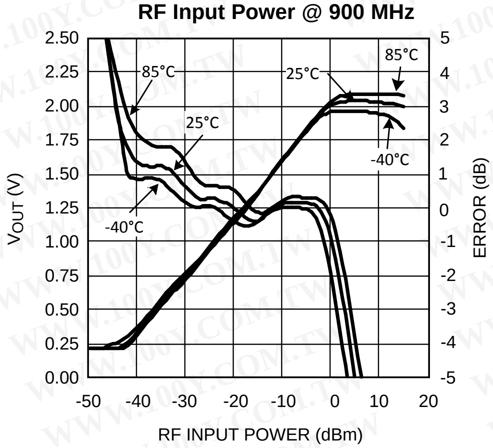



**Figure 4.**

**Output Voltage and Log Conformance vs. RF Input Power @ 1800 MHz**

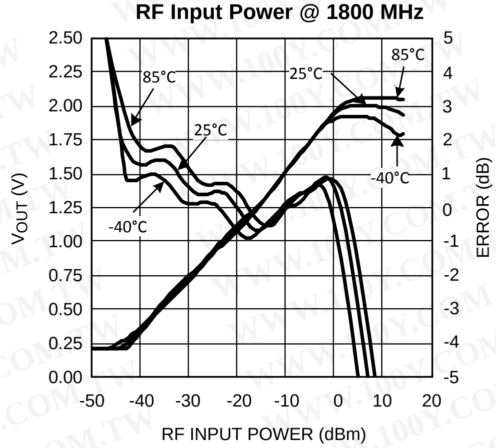



**Figure 5.**

**Output Voltage and Log Conformance vs. RF Input Power @ 1900 MHz**

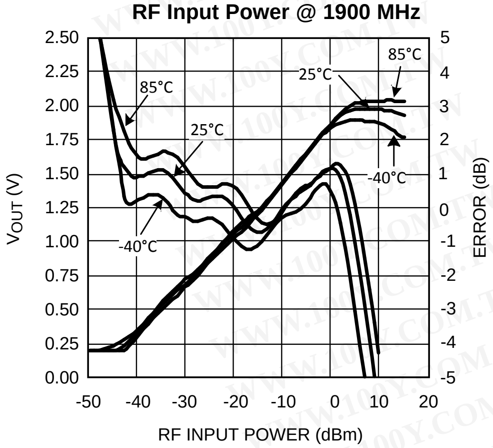



**Figure 6.**

**Output Voltage and Log Conformance vs. RF Input Power @ 2000 MHz**

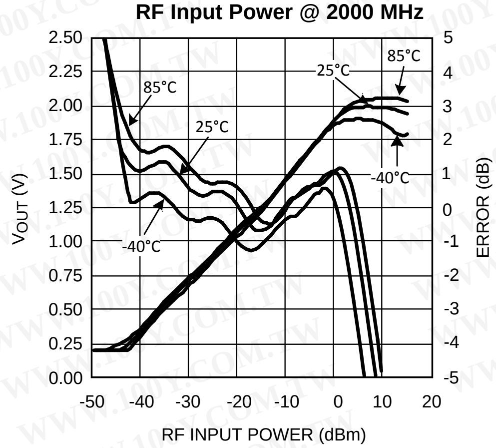



**Figure 7.**

## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Unless otherwise specified, $V_{DD}$ = 2.7V, $T_J$ = 25°C.

**Logarithmic Slope vs. Frequency**

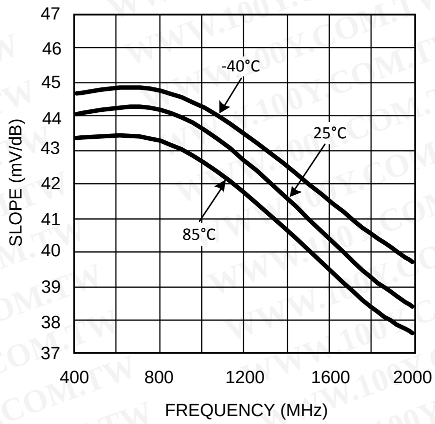



**Figure 8.**

**Logarithmic Intercept vs. Frequency**

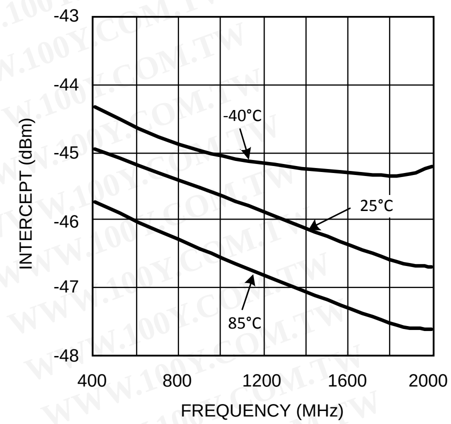



**Figure 9.**

**Output Variation vs. RF Input Power Normalized to 25°C @ 900 MHz**

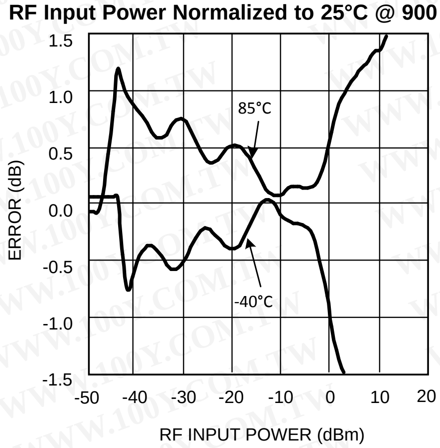



**Figure 10.**

**Output Variation vs. RF Input Power Normalized to 25°C @ 1800 MHz**

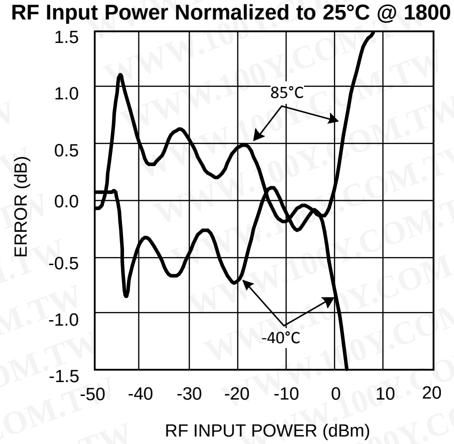



**Figure 11.**

**Output Variation vs. RF Input Power Normalized to 25°C @ 1900 MHz**

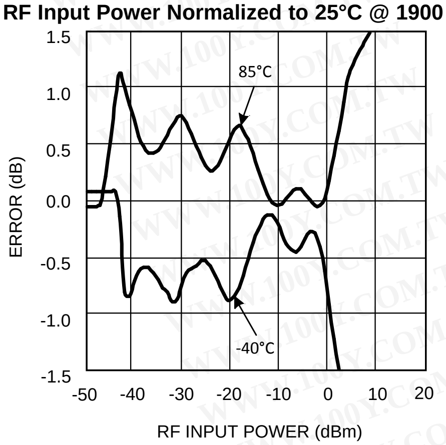



**Figure 12.**

**Output Variation vs. RF Input Power Normalized to 25°C @ 2000 MHz**

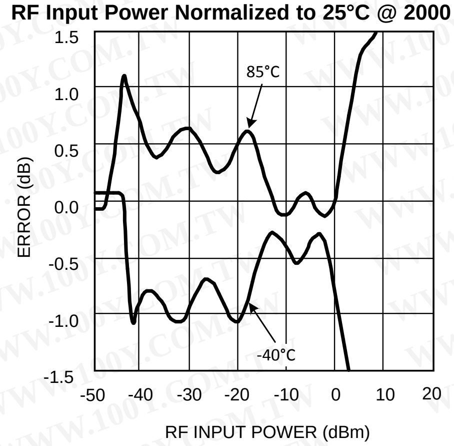



**Figure 13.**

## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Unless otherwise specified, $V_{DD}$ = 2.7V, $T_J$ = 25°C.

**PSRR vs. Frequency**

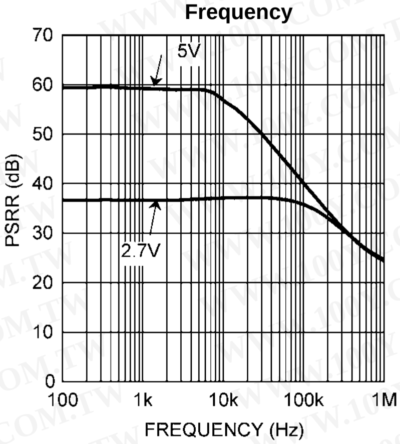



**Figure 14.**

**RF Input Impedance vs. Frequency @ Resistance and Reactance**

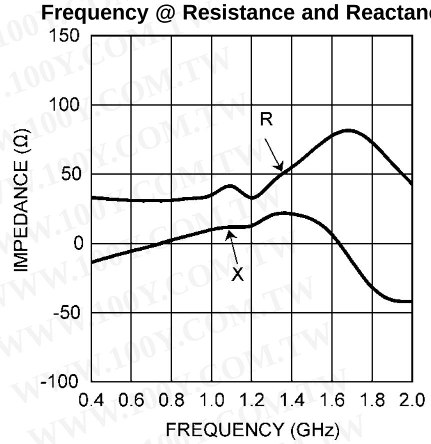



**Figure 15.**

# APPLICATION NOTES

## CONFIGURING A TYPICAL APPLICATION

The LMV227 is a power detector intended for CDMA and WCDMA applications. Power measured on its input translates to a DC voltage on the output through a linear-in-dB response. The detector is especially suited for power measurements via a high-resistive tap, which eliminates the need for a directional coupler. In order to match the dynamic output range of the power amplifier (PA) with the dynamic range of the LMV227's input, the high resistive tap needs to be configured correctly.

### Input Attenuation

The constant input impedance of the device enables the realization of a frequency independent input attenuation to adjust the LMV227's dynamic range to the dynamic range of the PA. Resistor $R_1$ and the 50Ω input resistance of the device realize this attenuation (Figure 16). To minimize insertion loss, resistor $R_1$ needs to be sufficiently large. The following example demonstrates how to determine the proper value for $R_1$.

Suppose the useful output power of the PA ranges up to +31 dBm and the LMV227 can handle input power levels up to 0 dBm. Hence, $R_1$ should realize a minimum attenuation of 31 - 0 = 31 dB. The attenuation realized by $R_1$ and the effective input resistance $R_{IN}$ of the detector equals:

$$A_{dB} = 20 \cdot LOG\left[1 + \frac{R_1}{R_{IN}}\right] = 31 dB \tag{1}$$

Solving this expression for $R_1$, using that $R_{IN}$ = 50Ω, yields:

$$R_1 = \left[10^{\frac{A_{dB}}{20}} - 1\right] \cdot R_{IN} = \left[10^{\frac{31}{20}} - 1\right] \cdot 50 = 1724\Omega \tag{2}$$

In Figure 16, $R_1$ is set to 1800Ω resulting in an attenuation of 31.4 dB

### DC and AC Behavior of the $RF_{IN}/E_N$ Pin

The LMV227 $RF_{IN}/E_N$ pin has 2 functions combined:

- Shutdown functionality
- Power detection

The capacitor C and the resistor $R_2$ of Figure 16 separate the DC shutdown functionality from the AC power measurement. The device is active when Enable = HI, otherwise it goes into a low power consumption shutdown mode. During shutdown the output will be LOW.

Capacitor C should be chosen sufficiently large to ensure a corner frequency far below the lowest input frequency to be measured. The corner frequency can be calculated using:

$$f = \frac{1}{2\pi (R_1 + R_{IN}) \dfrac{C \cdot C_{IN}}{C + C_{IN}}} \tag{3}$$

Where $R_{IN}$ = 50Ω, $C_{IN}$ = 45 pF typical.

With $R_1$ = 1800Ω and C is 100 pF, this results in a corner frequency of 2.8 MHz

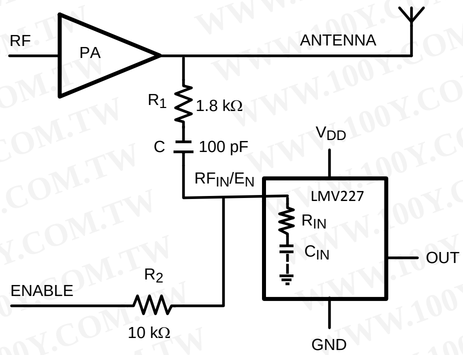



**Figure 16. Typical Application**

The output voltage is linear with the logarithm of the input power, often called "linear-in-dB". Figure 17 shows the typical output voltage versus PA output power of the LMV227 setup as depicted in Figure 16.

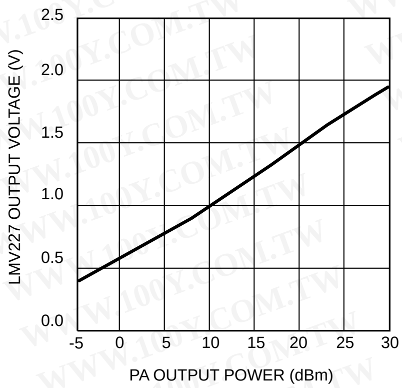



**Figure 17. Typical Power Detector Response, $V_{OUT}$ vs. PA Output Power**

## OUTPUT RIPPLE DUE TO AM MODULATION

A CDMA modulated carrier wave generally contains some amplitude modulation that might disturb the RF power measurement used for controlling the PA. This section explains the relation between amplitude modulation in the RF signal and the ripple on the output of the LMV227. Expressions are provided to estimate this ripple on the output. The ripple can be further reduced by connecting an additional capacitor to the output of the LMV227 to ground.

### Estimating Output Ripple

The CDMA modulated RF input signal of Figure 18 can be described as:

$$V_{IN}(t) = V_{IN}\,[1 + \mu(t)]\cos(2 \cdot \pi \cdot f \cdot t) \quad (4)$$

In which the amplitude modulation μ(t) can be between −1 and 1.

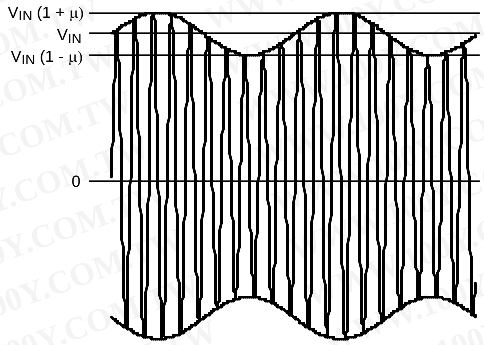



**Figure 18. AM Modulated RF Signal**

The ripple observed on the output of the detector equals the detectors response to variation on the input due to AM modulation (Figure 18). This signal has a maximum amplitude $V_{IN}(1+\mu)$ and a minimum amplitude $V_{IN}(1-\mu)$, where 1+μ can be maximum 2 and 1−μ can be minimum 0. The ripple can be described with the formula:

$$V_{RIPPLE} = V_Y \left[ \underbrace{10\,LOG \left[ \frac{V_{IN}^2 (1+\mu)^2}{2R_{IN}} \right] + 30}_{P_{INMAX}\ IN\ dBm} - V_Y \left[ \underbrace{10\,LOG \left[ \frac{V_{IN}^2 (1-\mu)^2}{2R_{IN}} \right] + 30}_{P_{INMIN}\ IN\ dBm} \right] \right] \quad (5)$$

where $V_Y$ is the slope of the detection curve (Figure 19) and μ is the modulation index. Equation 5 can be reduced to:

$$V_{RIPPLE} = V_Y \cdot 20\,LOG \left[ \frac{1+\mu}{1-\mu} \right] \quad (6)$$

Consequently, the ripple is independent of the average input power of the RF input signal and only depends on the logarithmic slope $V_Y$ and the ratio of the maximum and the minimum input signal amplitude.

For CDMA, the ratio of the maximum and the minimum input signal amplitude modulation is typically in the order of 5 to 6 dB, which is equivalent to a modulation index μ of 0.28 to 0.33.

A further understanding of the equation above can be achieved via the knowledge that the output voltage $V_{OUT}$ of the LMV227 is linear in dB, or proportional to the input power $P_{IN}$ in dBm. As discussed earlier, CDMA contains amplitude modulation in the order of 5 to 6 dB. Since the transfer is linear in dB, the output voltage $V_{OUT}$ will vary linearly over about 5 to 6 dB in the curve (Figure 19).

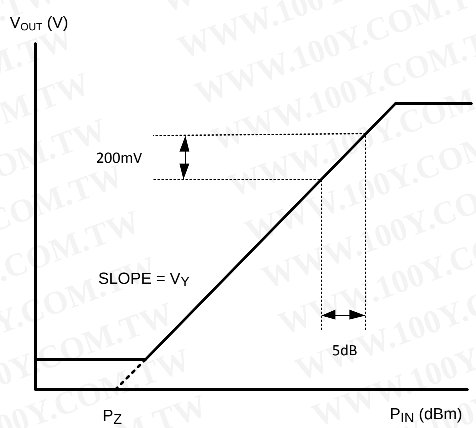



**Figure 19. $V_{OUT}$ vs. RF Input Power $P_{IN}$**

Besides the ripple due to AM modulation, the log- conformance error contributes to a variation in $V_{OUT}$. For details see the typical performance characteristics curves. The output voltage variation $\Delta V_{OUT}$ thus is always the same for RF input signals which fall within the linear range (in dB) of the detector plus the log-conformance error:

$$\Delta V_O = V_Y \cdot \Delta P_{IN} + \text{Log Conformance Error} \quad (7)$$

In which $V_Y$ is the slope of the curve. The log-conformance error is usually much smaller than the ripple due to AM modulation. In case of the LMV227, $V_Y$ = 40 mV/dB. With $\Delta P_{IN}$ = 5 dB for CDMA, the $\Delta V_O$ = 200 $mV_{PP}$. This is valid for all $V_{OUT}$.

### Output Ripple With Additional Filtering

The calculated result above is for an unfiltered configuration. When a low pass filter is used by shunting a capacitor of e.g. $C_{OUT}$ = 1.5 nF at the output of the LMV227 to ground, this ripple is further attenuated. The cut-off frequency follows from:

$$f_C = \frac{1}{2 \pi C_{OUT} R_O} \quad (8)$$

With the output resistance of the LMV227 $R_O$ = 19.8 kΩ typical and $C_{OUT}$ = 1.5 nF, the cut-off frequency equals $f_C$ = 5.36 kHz. A 100 kHz AM signal then gets attenuated by 5.36/100 or 25.4 dB. The remaining ripple will be less than 20 mV. With a slope of 40 mV/dB this translates into an error of less than 0.5 dB.

### Output Ripple Measurement

Figure 20 shows the ripple reduction that can be achieved by adding additional capacitance on the output of the LMV227. The RF signal of 900 MHz is AM modulated with a 100 kHz sinewave and a modulation index of 0.3. The RF input power is swept while the modulation index remains unchanged. Without additional capacitance the ripple is about 200 $mV_{PP}$. Connecting a capacitor of 1.5 nF at the output to ground, results in a ripple of 12 $mV_{PP}$. The attenuation with a 1.5 nF capacitor is then 20 · log (200/12) = 24.4 dB. This is very close to the number calculated in the previous paragraph.

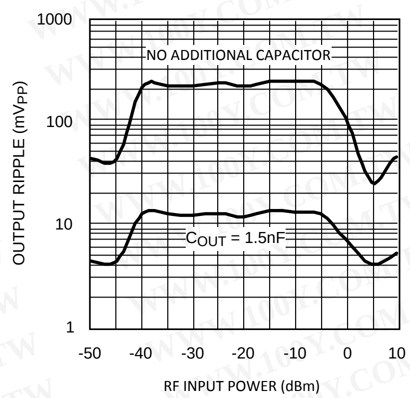



**Figure 20. Output Ripple vs. RF Input Power**

## PRINCIPLE OF OPERATION

The logarithmic response of the LMV227 is implemented by a de-modulating logarithmic amplifier as shown in Figure 21. The logarithmic amplifier consists of a number of cascaded linear gain cells. With these gain cells, a piecewise approximation of the logarithmic function is constructed.

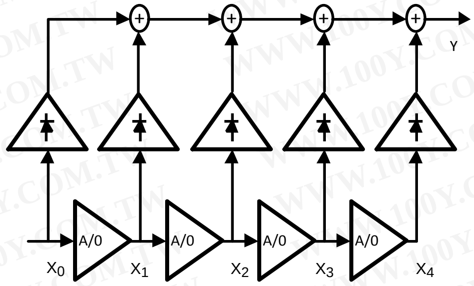



**Figure 21. Logarithmic Amplifier**

Every gain cell has a response according to Figure 22. At a certain threshold ($E_K$), the gain cell starts to saturate, which means that the gain drops to zero. The output of gain cell 1 is connected to the input of gain cell 2 and so on.

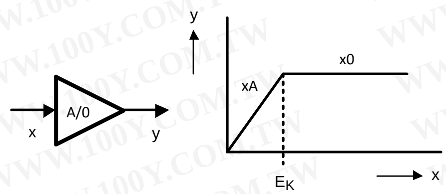



**Figure 22. Gain Cell**

All gain cell outputs are AM-demodulated with a peak detector and summed together. This results in a logarithmic function. The logarithmic range is about:

$$20 \cdot n \cdot \log(A) \quad (9)$$

where,

n = number of gain cells

A = gain per gaincell

Figure 23 shows a logarithmic function on a linear scale and the piecewise approximation of the logarithmic function.

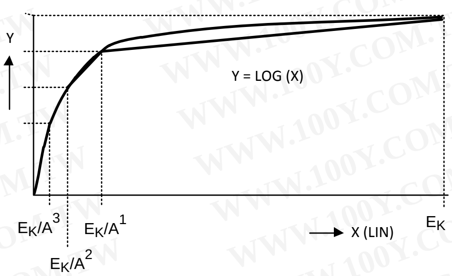



**Figure 23. Log-Function on Lin Scale**

Figure 24 shows a logarithmic function on a logarithmic scale and the piecewise approximation of the logarithmic function.

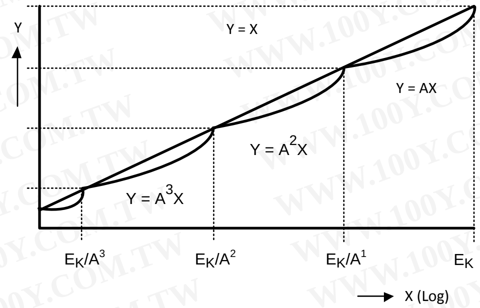



**Figure 24. Log-Function on Log Scale**

The maximum error for this approximation occurs at the geometric mean of a gain section, which is e.g. for the third segment:

$$\sqrt{\frac{E_K}{A^2} \cdot \frac{E_K}{A^1}} = \frac{E_K}{A\sqrt{A}} \quad (10)$$

The size of the error increases with distance between the thresholds.

## LAYOUT CONSIDERATIONS

For a properly functioning part a good board layout is necessary. Special care should be taken for the series resistance $R_1$ (Figure 16) that determines the attenuation. This series resistance should have a sufficiently high bandwidth. The bandwidth will drop when the parasitic capacitance of the resistance is too high, which will cause a significant attenuation drop at the GSM frequencies and can cause non-linear behavior. To reduce the parasitic capacitance across resistor $R_1$, it can be composed of several resistor in series in stead of a single component.

# REVISION HISTORY

| Changes from Revision C (March 2013) to Revision D | Page |
| --- | --- |
| • Changed layout of National Data Sheet to TI format | 14 |

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) | Op Temp (°C) | Top-Side Markings (4) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LMV227SD/NOPB | ACTIVE | WSON | NGF | 6 | 1000 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | | A88 | Samples |
| LMV227SDX/NOPB | ACTIVE | WSON | NGF | 6 | 4500 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | | A88 | Samples |

(1) The marketing status values are defined as follows:
**ACTIVE:** Product device recommended for new designs.
**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.
**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
**TBD:** The Pb-Free/Green conversion plan has not been defined.
**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Top-Side Marking for that device.

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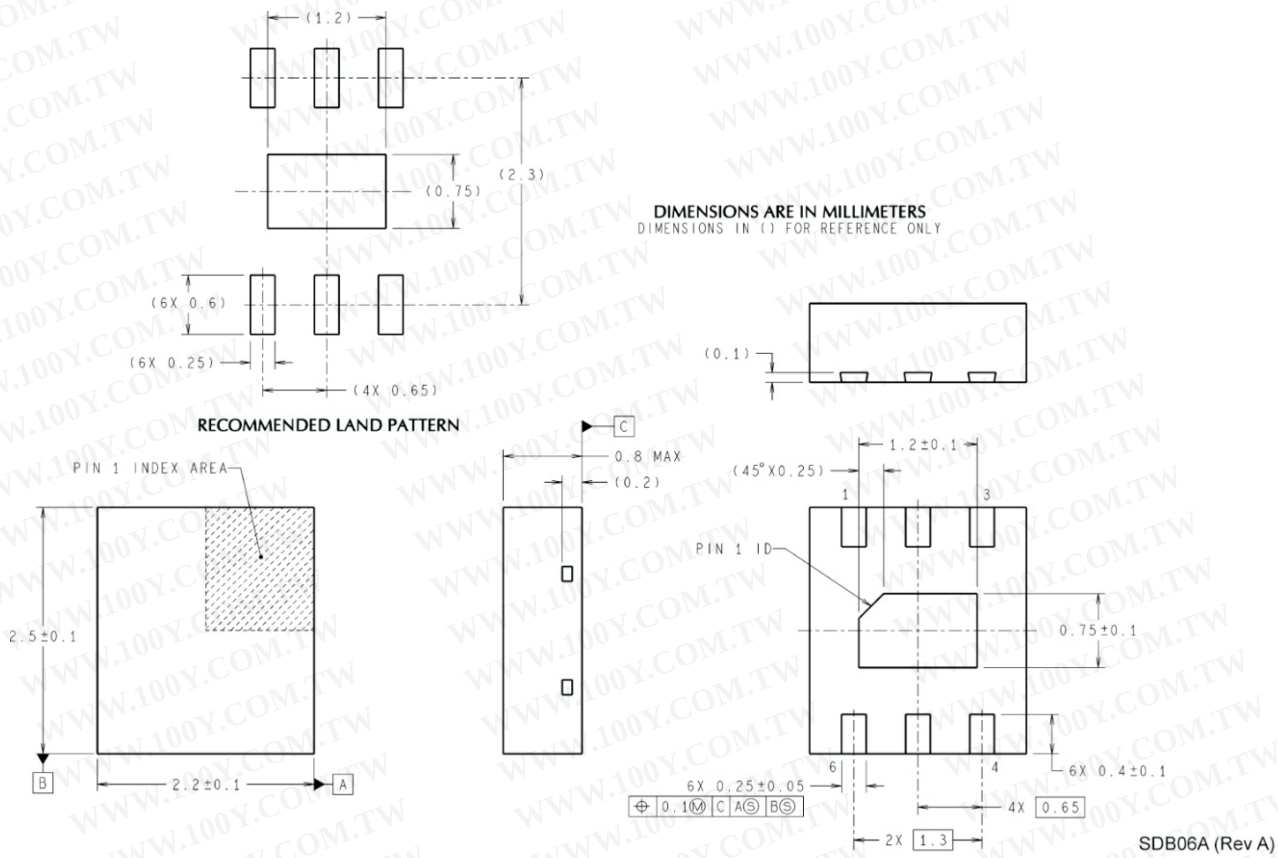
(1.2)
(2.3)
(0.75)
(6X 0.6)
(6X 0.25)
(4X 0.65)
RECOMMENDED LAND PATTERN
DIMENSIONS ARE IN MILLIMETERS
DIMENSIONS IN () FOR REFERENCE ONLY
(0.1)
PIN 1 INDEX AREA
2.5±0.1
2.2±0.1
B
A
C
0.8 MAX
(0.2)
(45°X0.25)
1.2±0.1
PIN 1 ID
0.75±0.1
6X 0.4±0.1
6X 0.25±0.05
0.1 M C A S B S
4X 0.65
2X 1.3
1
3
4
6
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