National Semiconductor

August 2003

LMV225
RF Power Detector for CDMA and WCDMA in micro SMD

General Description

The LMV225 is a 30dB RF power detector intended for use in CDMA and WCDMA applications. The device has an RF frequency range from 450MHz to 2GHz. 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 LMV225 has an integrated filter for low-ripple average power detection of CDMA signals with 30dB dynamic range. Additional filtering can be applied using a single external capacitor.

The LMV225 has an RF power detection range from –30dBm to 0dBm 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.

The LMV225 power detector is offered in the small 1.0mm x 1.0mm x 0.6mm micro SMD package

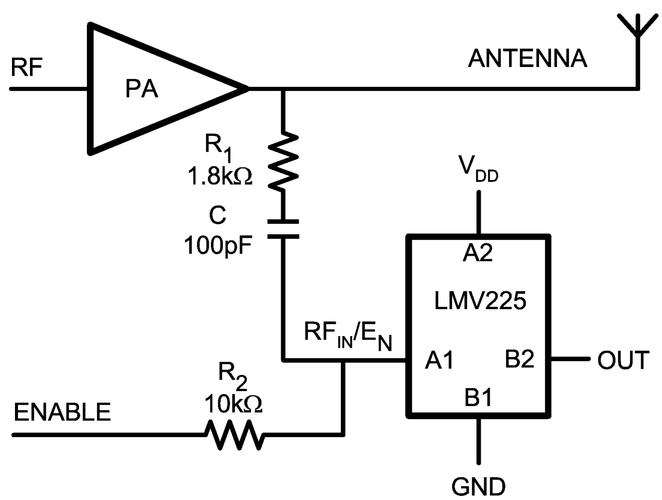
Features

- 30dB linear in dB power detection range
- Output voltage range 0.2 to 2V
- Logic low shutdown
- Multi-band operation from 450MHz to 2000MHz
- Accurate temperature compensation
- micro SMD package 1.0mm x 1.0mm x 0.6mm

Applications

- CDMA RF power control
- WCDMA RF power control
- CDMA2000 RF power control
- PA modules

Typical Application



Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	
V_{DD} - GND	6.0V Max
ESD Tolerance (Note 2)	
Human Body Model	2000V
Machine Model	200V
Storage Temperature Range	−65˚C to 150˚C
Junction Temperature (Note 3)	150˚C Max
Mounting Temperature	
Infrared or convection (20 sec)	235˚C

Operating Ratings (Note 1)

Supply Voltage	2.7V to 5.5V
Temperature Range	−40˚C to +85˚C

2.7 DC and AC Electrical Characteristics

Unless otherwise specified, all limits are guaranteed to V_{DD} = 2.7V; T_J = 25˚C. **Boldface** limits apply at temperature extremes. (Note 4)

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.		4.8	7 **8**	mA
		Shutdown: RF_{IN}/E_N = GND (DC), No RF Input Power Present.		0.32	**4.5**	µA
V_{LOW}	E_N Logic Low Input Level (Note 6)				**0.8**	V
V_{HIGH}	E_N Logic High Input Level (Note 6)		**1.8**			V
t_{on}	Turn-on- Time	No RF Input Power Present		2.1		µs
t_r	Rise Time (Note 7)	Step from No Power to 0dBm Applied		3.5		µs
I_{EN}	Current into RF_{IN}/E_N Pin				**1**	µA
P_{IN}	Input Power Range (Note 5)			−30 0		dBm
				−43 −13		dBV
	Logarithmic Slope (Note 8)	900MHz		44.0		mV/dB
		1800MHz		39.4		
		1900MHz		38.5		
		2000MHz		38.5		
	Logarithmic Intercept (Note 8)	900MHz		−45.5		dBm
		1800MHz		−46.6		
		1900MHz		−46.3		
		2000MHz		−46.7		
V_{OUT}	Output Voltage	No RF Input Power Present		214	**350**	mV
R_{OUT}	Output Impedance	No RF Input Power Present		19.8	29 **34**	kΩ
e_n	Output Referred Noise	RF Input = 1800MHz, −10dBm, Measured at 10kHz		700		$nV/\sqrt{Hz}$
	Variation Due to Temperature	900MHz, RF_{IN} = 0dBm Referred to 25˚C		+0.64 −1.07		dB
		1800MHz, RF_{IN} = 0dBm Referred to 25˚C		+0.09 −0.86		
		1900MHz, RF_{IN} = 0dBm Referred to 25˚C		+0 −0.69		
		2000MHz, RF_{IN} = 0dBm Referred to 25˚C		+0 −0.86		

5.0 DC and AC Electrical Characteristics

Unless otherwise specified, all limits are guaranteed to V_{DD} = 5.0V; T_J = 25˚C. **Boldface** limits apply at temperature extremes. (Note 4)

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	7.5 **9**	mA
		Shutdown: RF_{IN}/E_N = GND (DC), No RF Input Power Present.		0.32	**4.5**	μA
V_{LOW}	E_N Logic Low Input Level (Note 6)				**0.8**	V
V_{HIGH}	E_N Logic High Input Level (Note 6)		**1.8**			V
t_{on}	Turn-on- Time	No RF Input Power Present		2.1		μs
t_r	Rise Time (Note 7)	Step from No Power to 0dBm Applied		3.5		μs
I_{EN}	Current Into RF_{IN}/E_N Pin				**1**	μA
P_{IN}	Input Power Range (Note 5)			−30 0		dBm
				−43 −13		dBV
	Logarithmic Slope (Note 8)	900MHz		44.6		mV/dB
		1800MHz		40.6		
		1900MHz		39.6		
		2000MHz		39.7		
	Logarithmic Intercept (Note 8)	900MHz		−47.0		dBm
		1800MHz		−48.5		
		1900MHz		−48.2		
		2000MHz		−48.9		
V_{OUT}	Output Voltage	No RF Input Power Present		222	**400**	mV
R_{OUT}	Output Impedance	No RF Input Power Present		23.7	29 **31**	kΩ
e_n	Output Referred Noise	RF Input = 1800MHz, −10dBm, Measured at 10kHz		700		$nV/\sqrt{Hz}$
	Variation Due to Temperature	900MHz, RF_{IN} = 0dBm Referred to 25˚C		+0.89 −1.16		dB
		1800MHz, RF_{IN} = 0dBm Referred to 25˚C		+0.3 −0.82		
		1900MHz, RF_{IN} = 0dBm Referred to 25˚C		+0.34 −0.63		
		2000MHz RF_{IN} = 0dBm Referred to 25˚C		+0.22 −0.75		

Note 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 guaranteed. For guaranteed specifications and the test conditions, see the Electrical Characteristics.

Note 2: Human body model: 1.5kΩ in series with 100pF. Machine model, 0Ω in series with 100pF.

Note 3: The maximum power dissipation is a function of $T_{J(MAX)}$, θ_{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

Note 4: 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 guarantee of parametric performance is indicated in the electrical tables under conditions of internal self-heating where $T_J > T_A$.

Note 5: Power in dBV = dBm + 13 when the impedance is 50Ω.

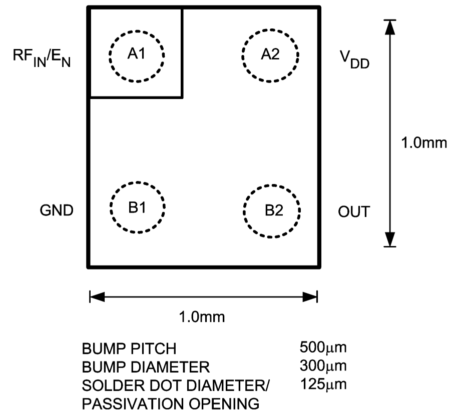
Note 6: All limits are guaranteed by design or statistical analysis

Note 7: Typical values represent the most likely parametric norm.

Note 8: Device is set in active mode with a 10kΩ 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 100pF coupling capacitor.

Connection Diagram

4-Bump micro SMD



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Top View

Pin Description

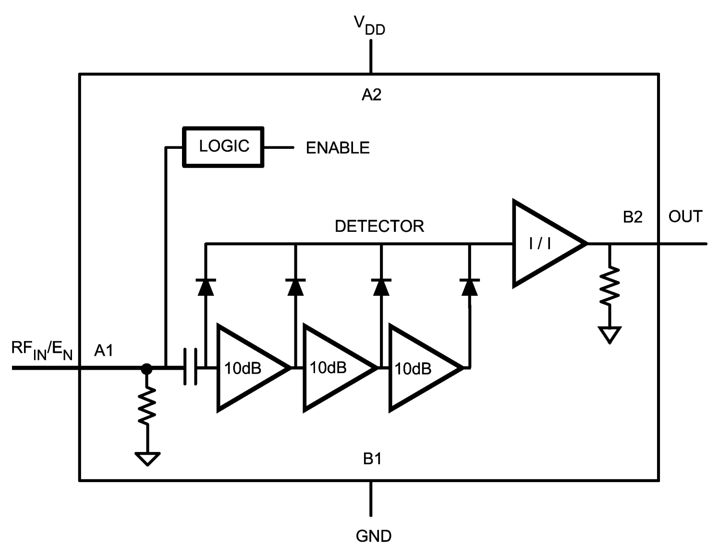
	Pin	Name	Description
Power Supply	A2	V_{DD}	Positive Supply Voltage
	B1	GND	Power Ground
	A1	RF_{IN}/E_N	DC voltage determines enable state of the device (HIGH = device active). AC voltage is the RF input signal to the detector (beyond 450MHz). The RF_{IN}/E_N pin is internally terminated with 50Ω in series with 45pF.
Output	B2	Out	Ground referenced detector output voltage (linear in dBm)

Ordering Information

Package	Part Number	Package Marking	Transport Media	NSC Drawing
4-Bump micro SMD	LMV225TL	I	250 Units Tape and Reel	TLA04AAA
	LMV225TLX		3k Units Tape and Reel	

Note: This product is only offered with lead free bumps.

Block Diagram



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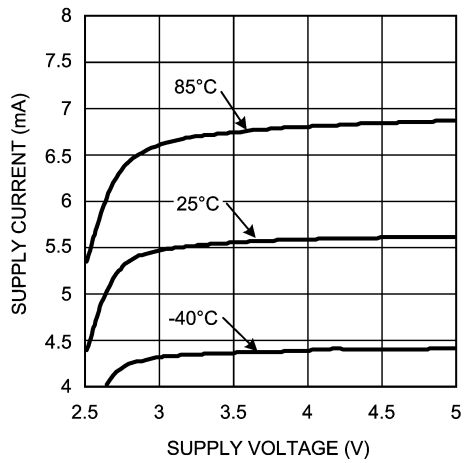
Typical Performance Characteristics
Unless otherwise specified, V_{DD} = 2.7V, T_J = 25°C.

Supply Current vs. Supply Voltage



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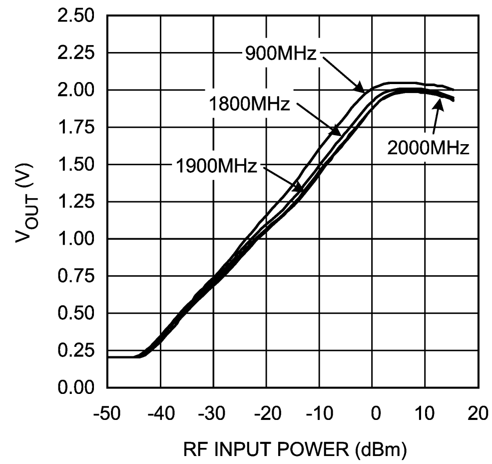
Output Voltage vs. RF Input Power



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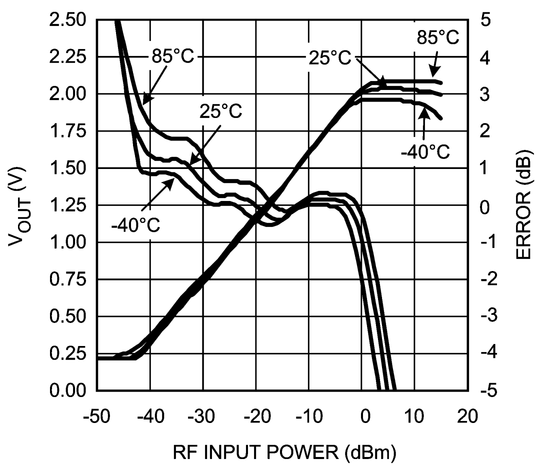
Output Voltage and Log Conformance vs. RF Input Power @ 900MHz



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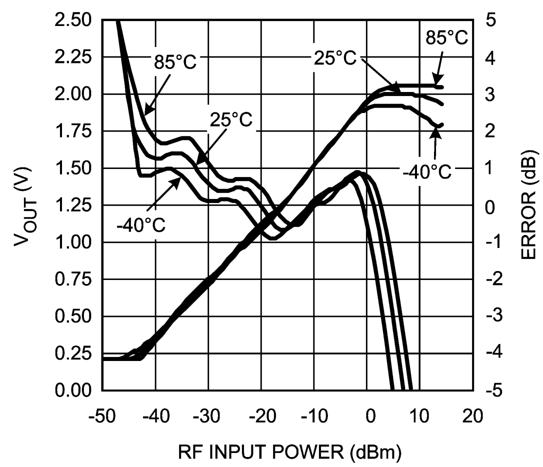
Output Voltage and Log Conformance vs. RF Input Power @ 1800MHz



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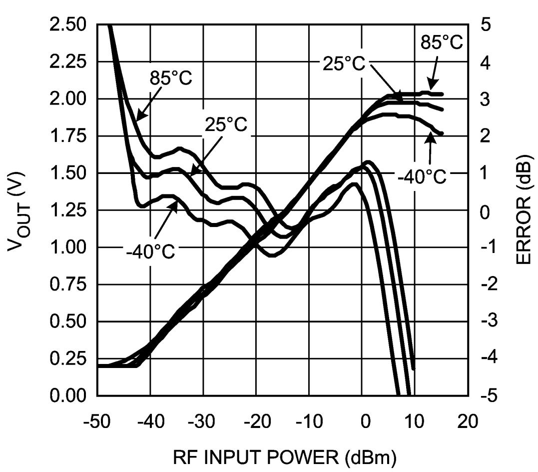
Output Voltage and Log Conformance vs. RF Input Power @ 1900MHz



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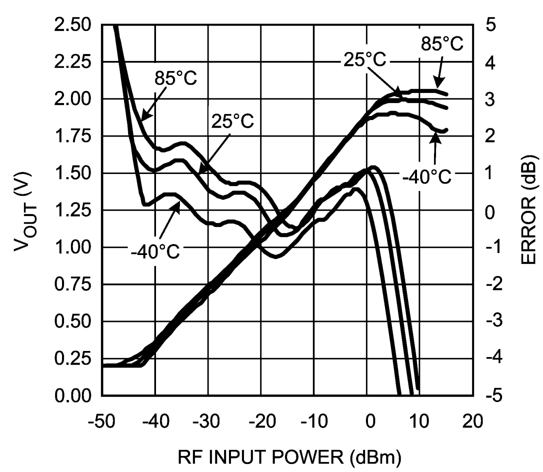
Output Voltage and Log Conformance vs. RF Input Power @ 2000MHz



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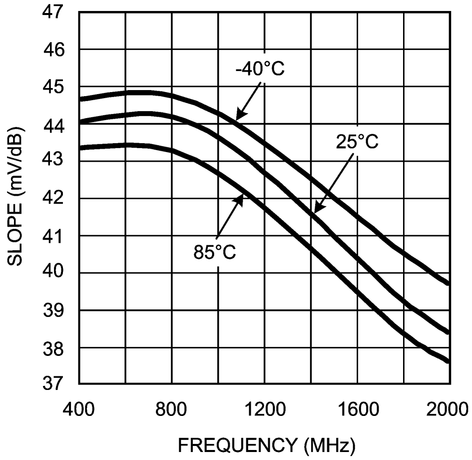
Typical Performance Characteristics Unless otherwise specified, V_{DD} = 2.7V, T_J = 25˚C. (Continued)

Logarithmic Slope vs. Frequency



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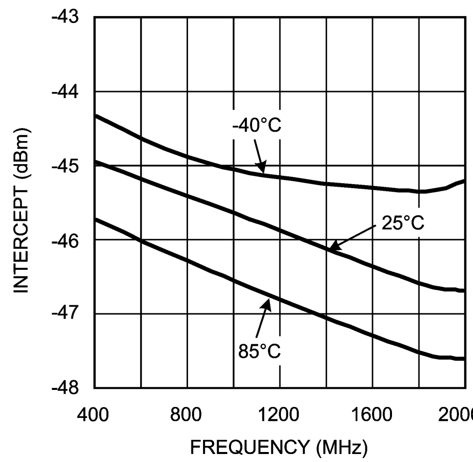
Logarithmic Intercept vs. Frequency



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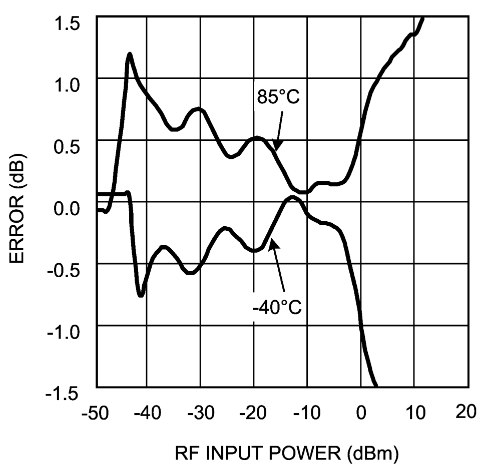
Output Variation vs. RF Input Power Normalized to 25˚C @ 900MHz



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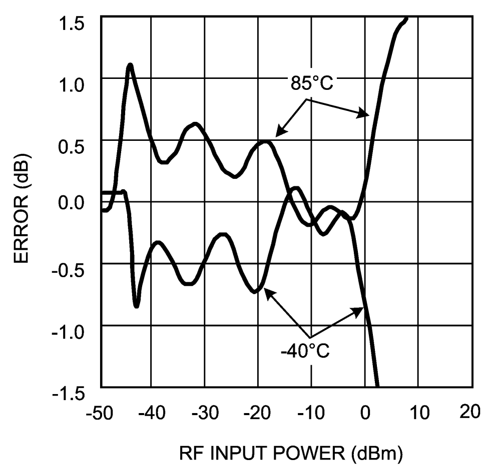
Output Variation vs. RF Input Power Normalized to 25˚C @ 1800MHz



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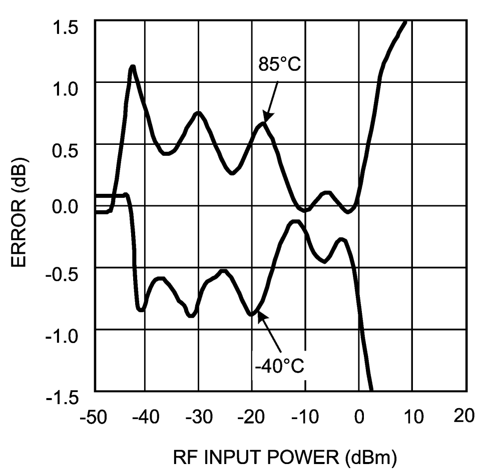
Output Variation vs. RF Input Power Normalized to 25˚C @ 1900MHz



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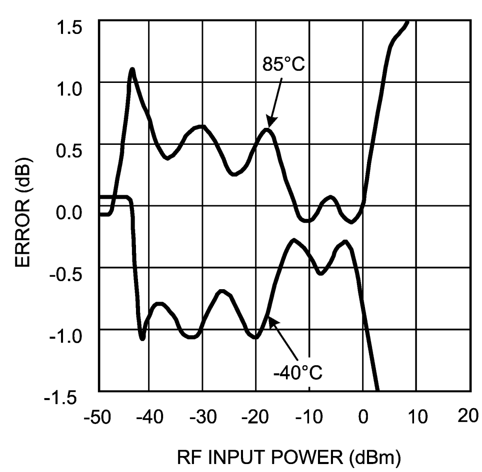
Output Variation vs. RF Input Power Normalized to 25˚C @ 2000MHz



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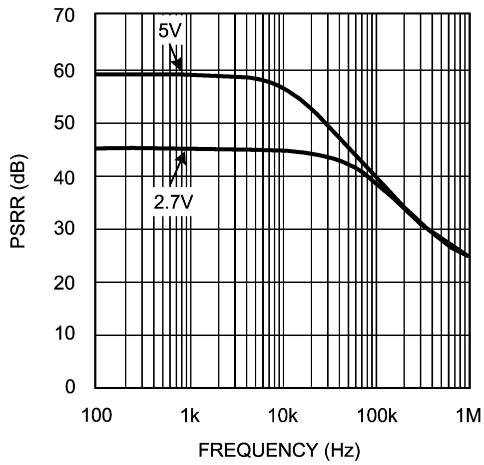
Typical Performance Characteristics Unless otherwise specified, V_{DD} = 2.7V, T_J = 25˚C. (Continued)

PSRR vs. Frequency



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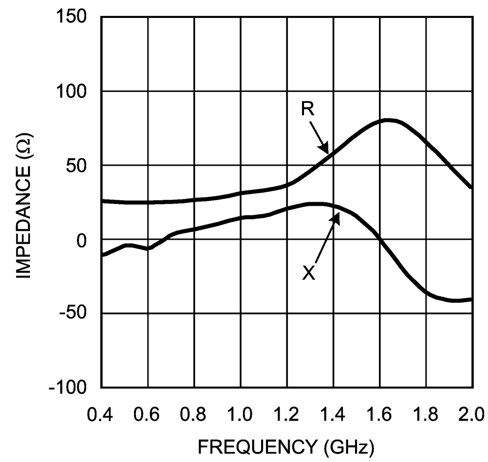
RF Input Impedance vs. Frequency @ Resistance and Reactance



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Application Notes

CONFIGURING A TYPICAL APPLICATION

The LMV225 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 LMV225'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 LMV225'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 1*). 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 +31dBm and the LMV225 can handle input power levels up to 0dBm. Hence, R_1 should realize a minimum attenuation of 31 - 0 = 31dB. The attenuation realized by R_1 and the effective input resistance R_{IN} of the detector equals:

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

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

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

In *Figure 1*, R_1 is set to 1800Ω resulting in an attenuation of 31.4dB

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

The LMV225 RF_{IN}/E_N pin has 2 functions combined:

- Shutdown functionality
- Power detection

The capacitor C and the resistor R_2 of *Figure 1* 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:

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

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

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

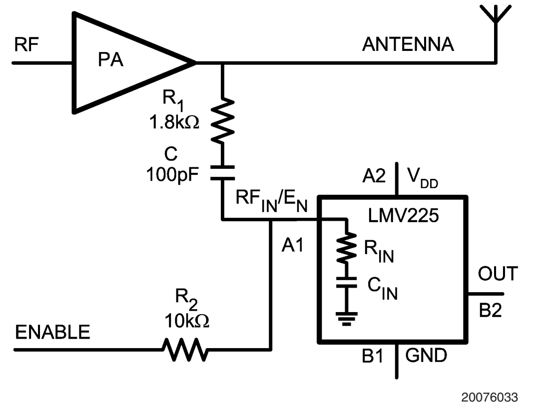


FIGURE 1. Typical Application

The output voltage is linear with the logarithm of the input power, often called "linear-in-dB". *Figure 2* shows the typical output voltage versus PA output power of the LMV225 setup as depicted in *Figure 1*.

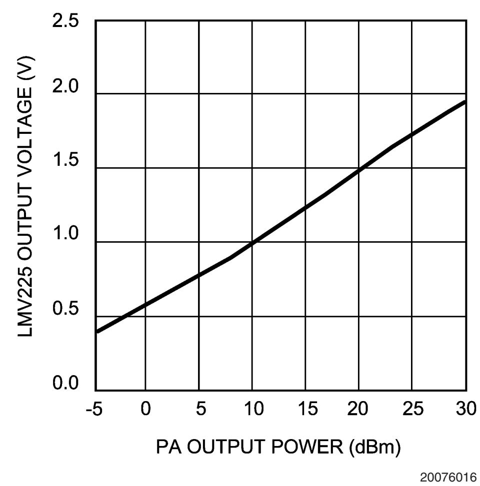


FIGURE 2. Typical Power Detector Response, V_{OUT} vs. PA Output Power

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 LMV225. 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 LMV225 to ground.

Estimating Output Ripple

The CDMA modulated RF input signal of *Figure 3* 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.

Application Notes (Continued)

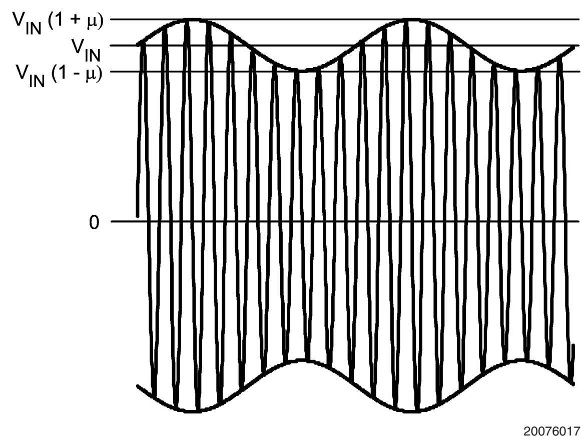


FIGURE 3. AM Modulated RF Signal

The ripple observed on the output of the detector equals the detectors response to variation on the input due to AM modulation (*Figure 3*). This signal has a maximum amplitude $V_{IN}(1+\mu)$ and a minimum amplitude $V_{IN}(1-\mu)$, where $1+\mu$ can be maximum 2 and $1-\mu$ can be minimum 0. The ripple can be described with the formula:

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

where V_Y is the slope of the detection curve (*Figure 4*) and μ is the modulation index. Equation 5 can be reduced to:

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

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 LMV225 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 6dB. Since the transfer is linear in dB, the output voltage V_{OUT} will vary linearly over about 5 to 6dB in the curve (*Figure 4*).

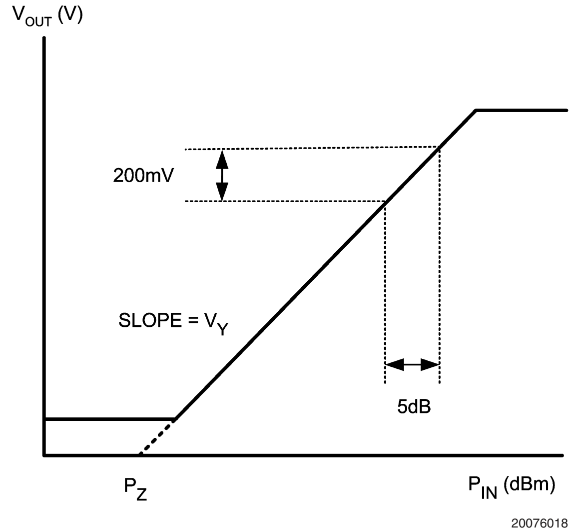


FIGURE 4. V_{OUT} vs. RF Input Power P_{IN}

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 ΔV_{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 LMV225, V_Y = 40mV/dB. With ΔP_{IN} = 5dB for CDMA, the $\Delta V_O = 200mV_{PP}$. 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} = 1.5nF at the output of the LMV225 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 LMV225 R_O = 19.8kΩ typical and C_{OUT} = 1.5nF, the cut-off frequency equals f_C = 5.36kHz. A 100kHz AM signal then gets attenuated by 5.36/100 or 25.4dB. The remaining ripple will be less than 20mV. With a slope of 40mV/dB this translates into an error of less than 0.5dB.

Output Ripple Measurement

Figure 5 shows the ripple reduction that can be achieved by adding additional capacitance on the output of the LMV225. The RF signal of 900MHz is AM modulated with a 100kHz sinewave and a modulation index of 0.3. The RF input power is swept while the modulation index remains unchanged. Without addition capacitance the ripple is about $200mV_{PP}$. Connecting a capacitor of 1.5nF at the output to ground, results in a ripple of $12mV_{PP}$. The attenuation with a 1.5nF capacitor is then 20 · log (200/12) = 24.4dB. This is very close to the number calculated in the previous paragraph.

Application Notes (Continued)

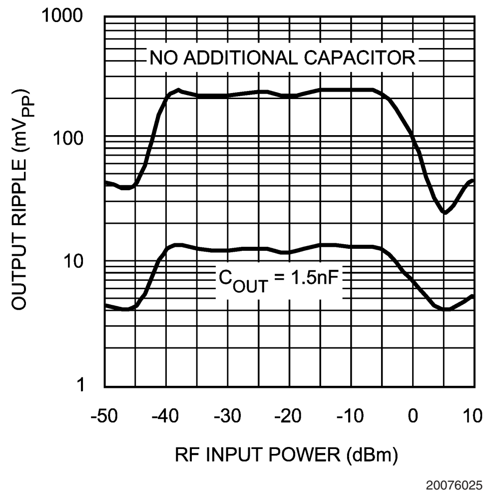


FIGURE 5. Output Ripple vs. RF Input Power

PRINCIPLE OF OPERATION

The logarithmic response of the LMV225 is implemented by a de-modulating logarithmic amplifier as shown in *Figure 6*. 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.

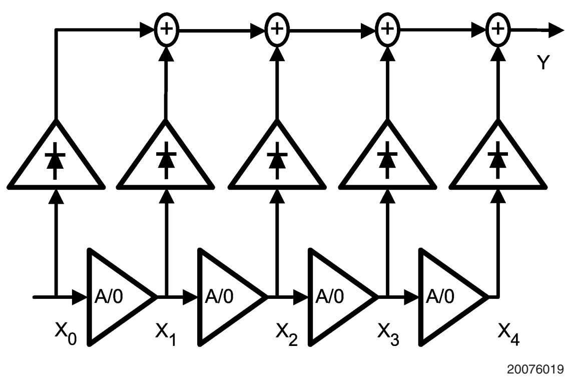


FIGURE 6. Logarithmic Amplifier

Every gain cell has a response according to *Figure 7*. 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.

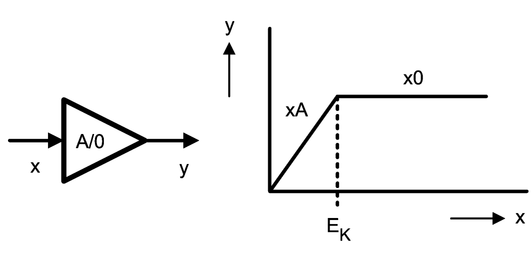


FIGURE 7. Gain Cell

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:

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

where,

n = number of gain cells

A = gain per gaincell

Figure 8 shows a logarithmic function on a linear scale and the piecewise approximation of the logarithmic function.

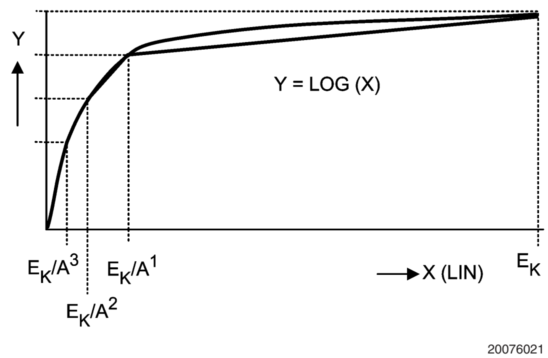


FIGURE 8. Log-Function on Lin Scale

Figure 9 shows a logarithmic function on a logarithmic scale and the piecewise approximation of the logarithmic function.

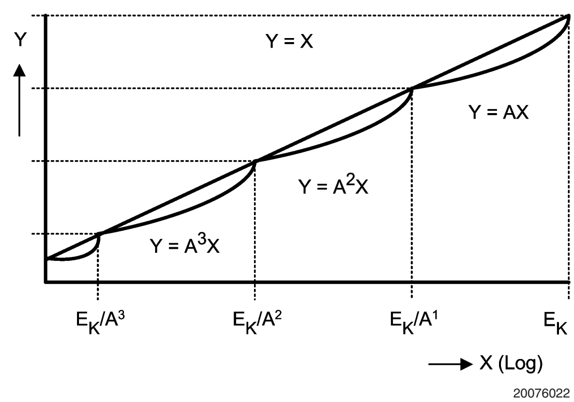


FIGURE 9. Log-Function on Log Scale

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

$$\sqrt{\frac{E_K}{A^2} \cdot \frac{E_K}{A^1}} = \frac{E_K}{A\sqrt{A}}$$

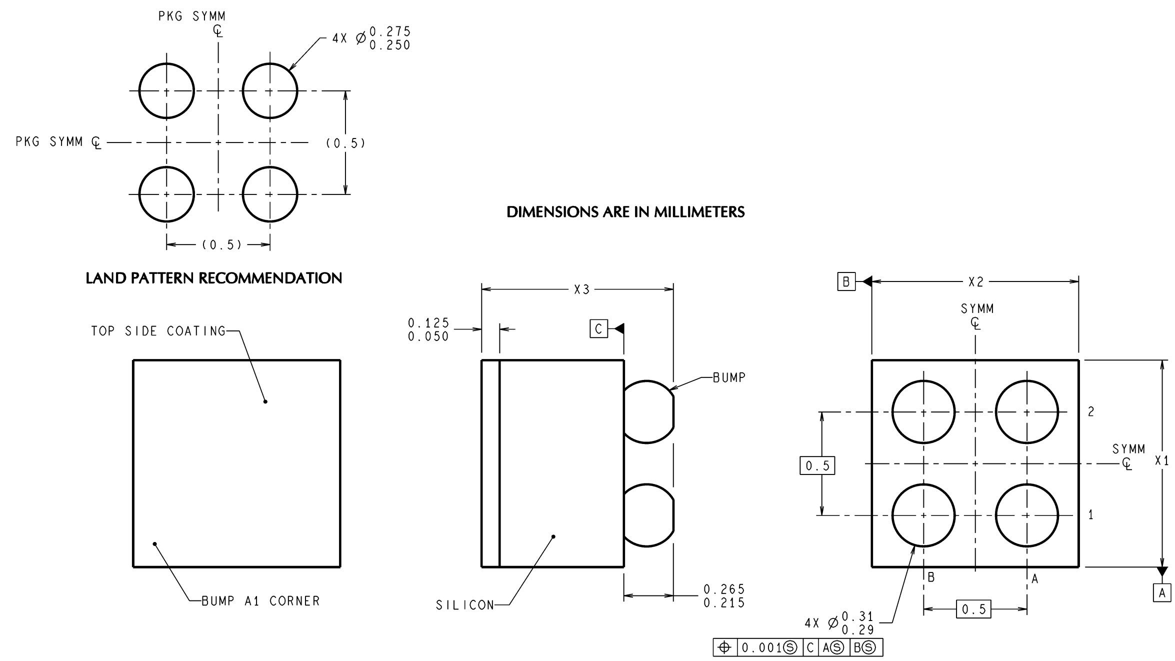
The size of the error increases with distance between the thresholds.

Application Notes (Continued)

LAYOUT CONSIDERATIONS

For a proper functioning part a good board layout is necessary. Special care should be taken for the series resistance R1 (*Figure 1*) 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 to 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 R1, it can be composed of several resistor in series in stead of a single component.

Physical Dimensions inches (millimeters) unless otherwise noted



TLA04XXX (Rev B)

NOTES: UNLESS OTHERWISE SPECIFIED

1. EPOXY COATING
2. Sn/37Pb EUTECTIC BUMP
3. RECOMMEND NON-SOLDER MASK DEFINED LANDING PAD.
4. PIN A1 IS ESTABLISHED BY LOWER LEFT CORNER WITH RESPECT TO TEXT ORIENTATION. REMAINING PINS ARE NUMBERED COUNTER CLOCKWISE.
5. XXX IN DRAWING NUMBER REPRESENTS PACKAGE SIZE VARIATION WHERE X1 IS PACKAGE WIDTH, X2 IS PACKAGE LENGTH AND X3 IS PACKAGE HEIGHT.

REFERENCE JEDEC REGISTRATION MO-211, VARIATION BC.

4-Bump micro SMD
NS Package Number TLA04AAA
X1 = 1.014 ±0.030mm X2 = 1.014 = ±0.030 X3 = 0.600 = ±0.075mm

LIFE SUPPORT POLICY

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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