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**LMV248**

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# LMV248 Dual Band GSM Power Controller

Check for Samples: **LMV248**

## FEATURES

- **Multi-Band Cellular Operation (Example: GSM, PCN)**
- **Support of GaAs HBT and Bipolar Technology**
- **Shutdown Mode for Power Save in Rx Slot (0.15µA)**
- **Integrated Ramp Filter**
- **Built-In Current Source for Biasing Schottky Diodes**
- **Pre-Biasing of PA Control Gate Voltage ($V_{HOME}$)**
- **GPRS Compliant**
- **External Loop Compensation**
- **Detector Diode Temperature Compensation**
- **Miniature Packaging: WQFN-16: 4mm x 4mm x 0.8mm**

## APPLICATIONS

- **GSM Mobile Phone**
- **TDMA RF Control**
- **Wireless LAN**
- **PC and PDA Modules**
- **GPS Navigation Modules**

## DESCRIPTION

The LMV248 RF power amplifier controller allows simple implementation of transmit power control loops in GSM and DCS/PCS and mobile phones. The LMV248 supports, GaAs HBT and bipolar RF power amplifiers. The device operates from a single supply of 2.5V to 5V. The LMV248 includes an error amplifier with an input summing network, input and output band switches, input filters, and output drivers. Analog input signals processed are:

- Coupler/detector voltages from GSM and PCN band power amplifier outputs.
- Base band DAC ramp signal.
- Temperature compensation diode voltages.
- Pre-bias voltage for faster PA control.

Selection of the GSM or PCN output driver is made using the GSM/PCN band select pin.

The On/OFF pin allows rapid power up or shutdown of the device during Tx or Rx slots. In the off mode, both output drivers are set low for PA shutdown. In the on mode, the non-active driver will remain low for continued PA shutdown. A single external capacitor/resistor combination is used to adjust the closed loop frequency response.

The LMV248 replaces multiple discrete parts, reducing board area and cost. The WQFN leadless package minimizes board footprint and permits flexible optimized PCB placement.
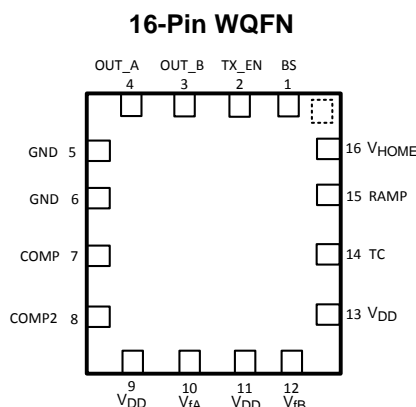
## Connection Diagram

**16-Pin WQFN**



**Figure 1.  Top View**
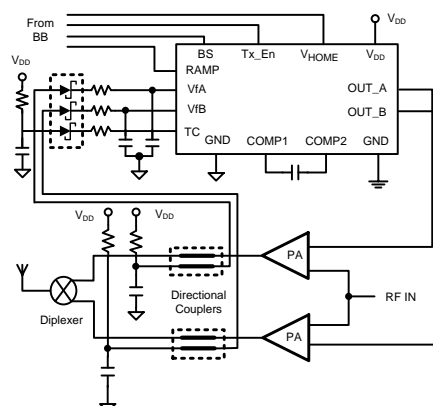
## Typical Application Circuit



**Figure 2.**

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**LMV248**

TEXAS INSTRUMENTS

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]

| | | |
|---|---|---|
| ESD Tolerance | Human Body Model [3] | 1500V |
| | Machine Model | 100V |
| Supply Voltage | $V_{DD}$ to GND | 5.5V |
| Input Voltage Range | VfA, VfB, or TC to GND | 10V |
| | Ramp | 0 to $V_{DD}$ |
| | $V_{HOME}$ | 0 to $V_{DD}$ |
| Junction Temperature | | 150°C max |
| Operating Temperature | | −40°C < $T_J$ < 85°C |
| Storage Temperature Range | | −65°C to 150°C |
| Lead Temperature (solder, 4 sec) | | 260°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 Texas Instruments Sales Office/Distributors for availability and specifications.
(3) Human Body Model (HBM) is 1.5kΩ in series with 100pF.

## Operating Ratings [1]

| | | |
|---|---|---|
| Supply Voltage | $V_{DD}$ to GND | 2.5V to 5V |
| Input Voltage | VfA, VfB, or TC to $V_{DD}$ | 0V to 5V |
| | Ramp | 0.2V to 1.8V |
| | $V_{HOME}$ | 0V to 2V |
| Temperature Range | | −20°C ≤ $T_J$ ≤ 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.

## DC and AC Electrical Characteristics[1]

Unless otherwise specified, all limits specified for $V_{DD}$ = 2.8V, GND = 0V, $T_J$ = 25°C. **Boldface** limits apply at temperature range extremes of operating conditions.

| Symbol | Parameter | Condition | | Min[2] | Typ[3] | Max[2] | Units |
|---|---|---|---|---|---|---|---|
| $V_{OUT}$ A, B | Positive Output Voltage Swing A, B | Sourcing 6mA, Tx_En = High [1] | | **2.6** | 2.7 | | V |
| $V_{OUT}$ A, B | Negative Output Voltage Swing A, B | Sinking 2mA, Tx_En = High [1][4][5] | $V_{HOME}$ = 0V | | 0.075 | **0.15** | V |
| $V_{OUT}$ A, B | Negative Output Voltage Swing A,B | Sinking 2mA, TX_EN = Low [1][4][5] | | | 0.06 | **0.15** | V |
| $V_{OS}$ | Input Offset Voltage | [6] | | **60** | 80 | **100** | mV |
| BW | Bandwidth (−3dB) | Rf = 50k, No External Frequency Compensation | | | >1 | | MHz |
| SR | Output Slew Rate | No External Frequency Compensation, $V_{HOME}$ = 0V | | **3** | 5.5 | | V/µs |
| $I_{VHOME}$ | Current into $V_{HOME}$ Pin | [2] | | | | **<5** | µA |

(1) The output is not short circuit protected internally. External protection is necessary to prevent overheating and destruction or adverse reliability.
(2) All limits are specified by design or statistical analysis.
(3) Typical values represent the most likely parametric norm.
(4) Transients and spikes during $V_{DD}$ on transition are allowed only as described in the diagram.
(5) No overshoot above 100mV occurs when Tx_En is switched high to low or low to high. The overshoot is influenced by the external compensation capacitor.
(6) Tested in closed loop configuration.

## DC and AC Electrical Characteristics[1] (continued)

Unless otherwise specified, all limits specified for $V_{DD}$ = 2.8V, GND = 0V, $T_J$ = 25°C. **Boldface** limits apply at temperature range extremes of operating conditions.

| Symbol | Parameter | Condition | Min[2] | Typ[3] | Max[2] | Units |
|---|---|---|---|---|---|---|
| $I_{BS}$ | Current into BS Pin | [2] | | | **<5** | µA |
| $I_{Tx\_En}$ | Current into En Pin | [2] | | | **<5** | µA |
| $I_{VfA}$ $I_{VfB}$ | Forward Bias Current Sources | [2] | **7** | 10 | **13** | µA |
| $I_{TC}$ | Temperature Compensation Current Source | [2] | **7** | 10 | **13** | µA |
| $I_{Vf\text{-}TC\ Match}$ | Current Source Matching | $I_{TC}/I_{VfA}$ $I_{TC}/I_{VfB}$ [2] | | ±2% | **±12%** | |
| $V_{LOW}$ | BS or Tx_En Logic Low Input Level | [2] | | | **0.8** | V |
| $V_{HIGH}$ | BS or Tx_En Logic High Input Level | [2] | **1.8** | | | V |
| $I_{SD}$ | Supply Current in Shutdown | Tx_En = 0V | | 0.15 | **<5** | µA |
| $V_{RD}$ | Vramp Deadband | [2] | **160** | 200 | | mV |
| $t_{d:\ Tx\_En}$ | Output Delay: Tx_En to Output[5] | | | 3.5 | **6** | µs |
| $I_{DD}$ | Positive Supply Current | $V_{OUT}$ = $V_{DD/2}$[6] | | 1.1 | **1.8** | mA |
| $V_{OUT}$ A,B | Threshold Select Voltages | Tx_En = High, $V_{HOME}$ = 2V [1][4][5] | **1.60** | 2 | **2.40** | V |

**LMV248**

**TEXAS INSTRUMENTS**

## Typical Performance Characteristics

**Error Amp Closed Loop Gain and Phase**
**(Rf = R_COMP = 137k, A_V −2.8)**



**Figure 3.**

**Error Amp Open Loop Gain and Phase**
**(Rf = R_COMP = 137k, A_V −2.8)**



**Figure 4.**

**I_SUPPLY vs. V_DD**



**Figure 5.**

**Voltage Drop (Sinking)**



**Figure 6.**

**VfA or VfB vs. Ramp**



**Figure 7.**

**Output Fallback Voltage Out A or Out B vs. V_HOME**



**Figure 8.**

Product Folder Links: *LMV248*

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Datasheet of LMV248LQ - IC RF PWR CNTRL DUAL BAND 16WQFN
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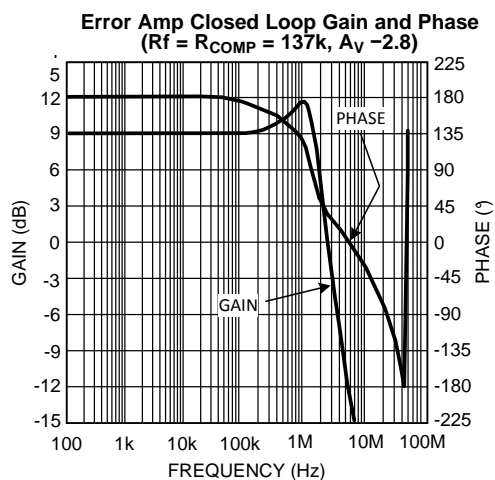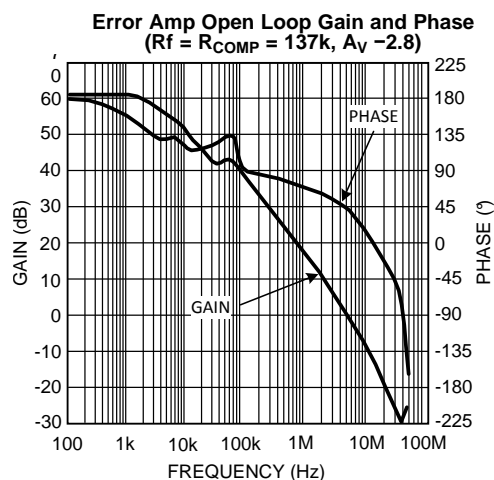
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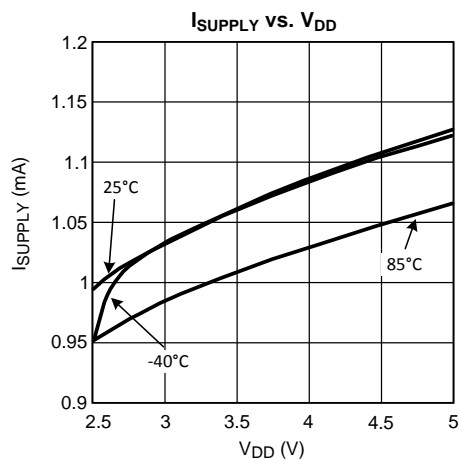
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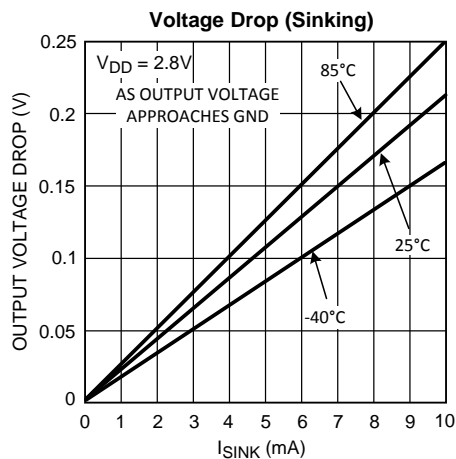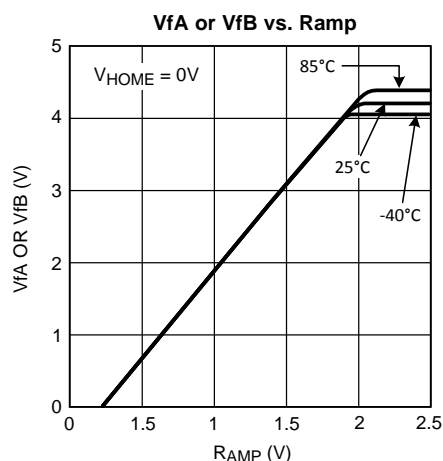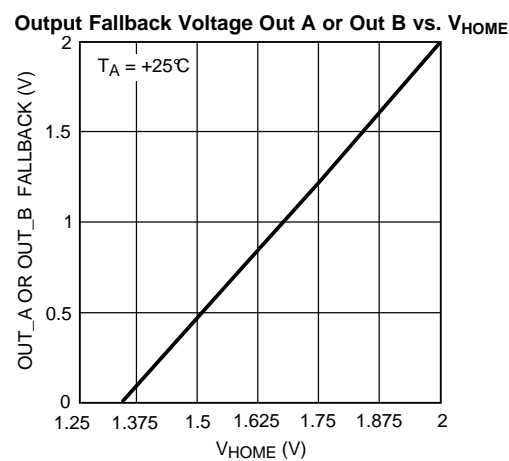
## Typical Performance Characteristics (continued)

**Voltage Drop (Sourcing)**
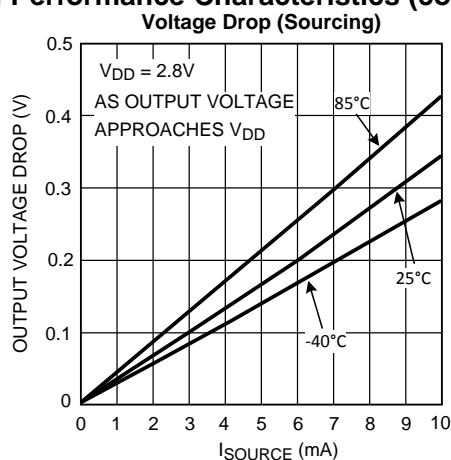


**Figure 9.**

## BLOCK DIAGRAM



**Figure 10.**

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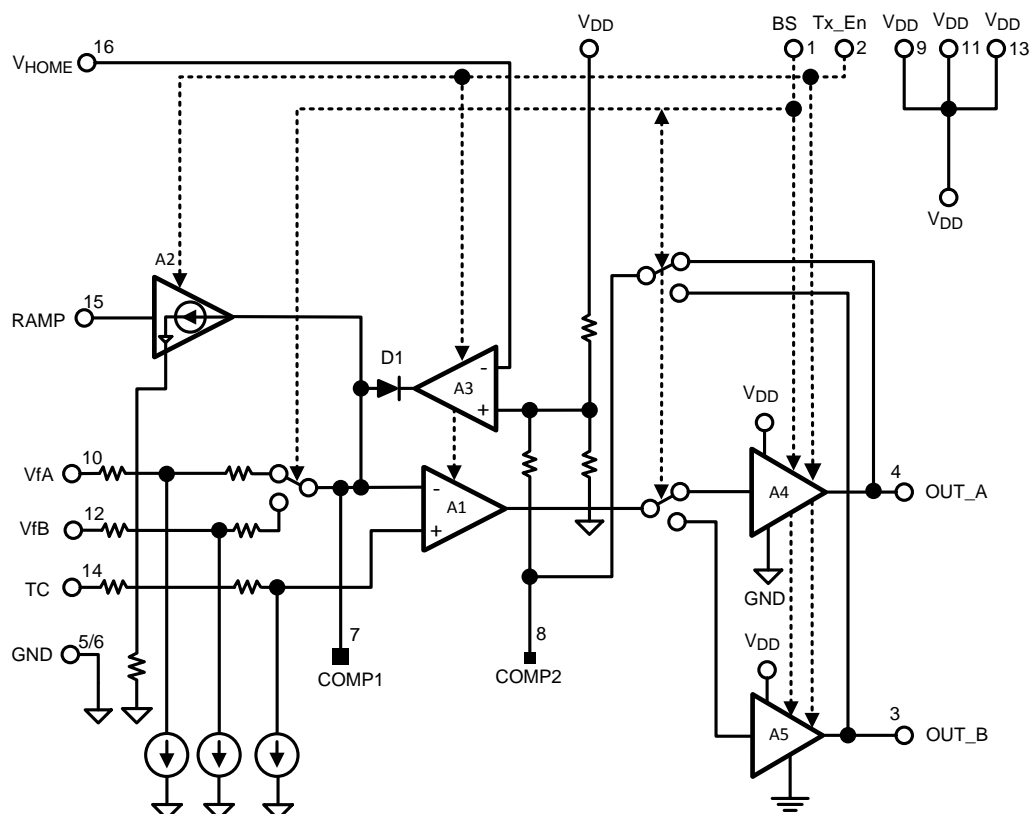
## APPLICATION SECTION

See Figure 2 for the basics of a typical LMV248 dual band application.

See Figure 10 for a simplified block diagram of the LMV248's internal architecture

**Table 1. Pin Descriptions[1][2][3]**

|  | Pin | Name | Description |
|---|---|---|---|
| Power Supply | 5, 6 | GND | Power Ground; both pins must be tied together. |
|  | 9,11, 13 | $V_{DD}$ | Positive Supply Voltage |
| Digital Inputs[2] | 1 | BS | Selects the RF detector input (VfA or VfB) and the corresponding output amplifier (Out_A or Out_B) enabled when the Tx_En is HIGH. The compensation is also connected to the correct amplifier automatically.<br>A HIGH input enables Out_A.<br>A LOW input enables Out_B.<br>The other unselected output is held close to GND. |
|  | 2 | Tx_En | A HIGH input enables the input and output amplifiers (VfA and Out_A or VfB and Out_B) selected by the band select pin, BS. |
| Analog Inputs | 10 | VfA | Detector diodes for the RF power detector are connected here. An internal switch connects a 10µA current sink to the input pin selected by BS to bias the detector diode. This signal is referenced to $V_{DD}$.[1][3] |
|  | 12 | VfB |  |
|  | 14 | TC | The reference diode used for temperature compensation of the VfA and VfB RF power signals is connected here. Internally, a 10µA current sink connects to this pin to bias the reference diode. This signal is referenced to $V_{DD}$.[1][3] |
|  | 15 | Ramp | Sets the RF output power level. The useful input voltage range is from 0.2V to 1.8V, although voltages from 0V to $V_{DD}$ are allowed. An internal filter with a corner frequency of approximately 1.6MHz smooths the Ramp signal, to eliminate step discontinuities from the baseband DAC's output. |
|  | 16 | $V_{HOME}$ | Sets the desired minimum output voltage of the controller (selected by BS) to the threshold voltage of the RF power amplifier. This reduces ramp up time, since a smaller voltage range is slewed across. The recommended input voltage range is from 0V to 2V. |
| Compensation | 7 | Comp1 | Connect an external RC network here for overall loop compensation and to control the closed loop frequency response. In most cases this network will be simply a capacitor. Conventional loop stability techniques can be used in selecting this network, such as Bode plots. |
|  | 8 | Comp2 |  |
| Outputs | 4 | Out A | A rail-to-rail output capable of sourcing is 6mA, sinking 2mA, with less than 200mV drop including over temperature. The output is free from glitches when enabled by Tx_En. When an output is not selected by BS, it is close to GND. When Tx_En is low, output voltages are near GND. |
|  | 3 | Out B |  |

(1)    All inputs and outputs are referenced to GND, except VfA, VfB, and TC, which are referenced to $V_{DD}$.
(2)    For the digital inputs, a LOW is ≤ 0.8V and HIGH is ≥ 1.8V.
(3)    RF power detection is usually via a RF detector diode and a RF power coupler.

**The LMV248 as a RF Power Amplifier (PA) Controller**

The LMV248, a member of Texas Instruments' family of RF power amplifier (PA) power controllers, is used to regulate the RF transmit power in TDMA (GSM, EGSM, PCN, PCS AND DCS) mobile phones. Capable of controlling up to two RF output amplifiers and of triple band operation (GSM, DCS, and PCS) the device supports both bipolar and FET RF power amplifiers including Silicon BJT, CMOS, SiGe HBT, and GaAs HBT.

Figure 2 shows the basics of a typical LMV248 dual band application. The key components are:
• Two power amplifiers, usually for the GSM or DCS/PCS bands.
• RF directional couplers where two single or one dual channel RF coupler could be used.
• Up to three Schottky RF detector diodes, one for each directional coupler output and one for temperature compensation.
• A RF diplexer.
• A dual or tri-band antenna.

The block diagram in Figure 10 shows the LMV248's internal architecture. The LMV248 contains input filters and conditioning amplifiers, an input summing network, detector biasing current source, error amplifier, output band select function, and output drivers.

Product Folder Links: *LMV248*

### Power Supplies

The LMV248 supports a single supply with the battery voltage at $V_{DD}$.

### Digital Input Signals:

The LMV248 has two digital control signals:
- Transmit enable signal, Tx_En.
- Band select signal, BS.

The band select pin, BS, selects which band (i.e which output and input channel) is active. A high enables Out_A, a low enables Out_B. The transmit enable pin, Tx_En, is used to enable the BS selected output during transmit (Tx) slots and disable the outputs during receive (Rx) slots. Disabling the output during the receive (Rx) slot shuts down the LMV248's output stages and the RF power amplifiers, conserving battery power. A high input on the transmit enable signal, Tx_En, brings the amplifier out of shutdown within about 4µs. The output is glitch-free when enabled by this pin.

When an output is either not selected by BS or Tx_En is low, its level is near GND. Internally, the band select pin, BS, selects the correct input line and output amplifier, and places the external compensation network across the active amplifier using analog switches.

### Error Amplifier/Loop Compensation

The error amplifier (A1) controls the overall loop regulation and response. Frequency compensation and stabilization of the RF output power regulating loop is accomplished by a capacitor (or resistor/capacitor network) across Comp1 and Comp2 of the LMV248. This external network sets the closed loop frequency response. In most cases this network will simply be a capacitor. Conventional loop stability techniques can be used in selecting this network, such as Bode plots.

### Analog Inputs

At VfA and VfB are voltages proportional to the RF power output of channel A and channel B respectively. Each of these signals is derived from the RF output power via a RF directional coupler a capacitor and a Schottky RF detector diode. A single two-channel RF coupler could be used instead of the two single-channel RF couplers shown in Figure 2.

If only one input and output is needed, just connect BS high or low and use the selected channel. At the TC input, a reference diode identical to the detector diodes, and thermally coupled to them, is used for temperature compensation of the VfA and VfB signals.

VfA, VfB and TC are referenced to $V_{DD}$. A 10µA current sink internal to the LMV248 connects to the VfA, VfB and TC pins to bias the diodes. The quiescent voltage on all three pins is one diode drop below $V_{DD}$. The actual Ramp input value sets the RF output power. The recommended Ramp voltage range for RF power control is 0.2V to 1.8V. The Ramp input will tolerate voltages from 0V to $V_{DD}$ without malfunction or damage. This signal usually comes from the baseband controller's DAC (digital to analog converter), its shape being defined by the relevant GSM, PCN, or DCS standard.

The Ramp input does not change the output level from the idle level set by $V_{HOME}$ until the level reaches about 200mV, so offset voltages in the DAC or amplifier supplying the Ramp signal will not cause excess RF signal output and increased power consumption. An internal RC filter with a corner frequency of approximately 1.6MHz smooths the Ramp signal, to eliminate step discontinuities at the baseband DAC's output. Ramp is ground referenced, so supply variations are rejected.

$V_{HOME}$ is used to set the output selected by BS to the threshold voltage of the RF power amplifier. The variable $V_{HOME}$ voltage level supports different PA Shut off thresholds as well as boost output voltage to minimize phase delay at low power levels. The $V_{HOME}$ voltage can be derived from a reference, resistive voltage divider, or DAC output. The recommended $V_{HOME}$ voltage range for threshold control is 0V to 2V. The $V_{HOME}$ input will tolerate voltages from 0V to $V_{DD}$ without malfunction or damage. The minimum output voltage at Out_A or Out_B set by $V_{HOME}$ is approximately $3.0 \times V_{HOME}$. $V_{HOME}$ is ground referenced. $V_{HOME}$ does not affect the minimum voltage of the output not selected by BS.

For maximum performance a fine adjust is needed for $V_{HOME}$, since each individual RF power amplifier's threshold voltage is slightly different from the nominal datasheet value.

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**LMV248**

### Analog Outputs

Outputs Out_A and Out_B are driven by rail-to-rail amplifiers capable of both sourcing and sinking. Either output can source 6mA and sink 2mA with less than 200mV voltage drop over recommended operating conditions. The output is free from glitches when enabled by Tx_En. When an output is not selected by BS, its level is near GND.

### Understanding the LMV248

### Input Structure

The LMV248 simplified block diagram of Figure 10 shows the IC's internal structure. Input VfA goes through a resistor (approximately 48.5kΩ) and analog switch to the inverting input of the error amplifier A1. Input VfB goes through a different resistor (also approximately 48.5kΩ) and analog switch to the inverting input of the error amplifier A1. These two analog switches are controlled by BS. VfA is selected when BS is high and VfB is selected when BS is low. The temperature compensation signal, TC, goes through a series resistance of about 48.5kΩ, to the non-inverting input of the error amplifier A1. This way the relatively large static DC offset of the input signal is mostly removed from the differential signal to be amplified by A1, and the temperature dependency of the external detector diodes is cancelled. (Adding the temperature correction to the non-inverting terminal is identical to subtracting the temperature correction from the inverting terminal). The 10µA current sinks connected to the signal paths for VfA, VfB, and TC provide a bias current for the detector and temperature compensation diodes. An approximate 200mV deadband for the Ramp signal is preset.

### Ramp Signal

The Ramp signal, which is positive going and ground referenced, is the reference for the closed loop RF output control. The Ramp signal is smoothed by internal filter with a corner frequency of approximately 1.6MHz, formed from a 20kΩ resistor and 5pF capacitor. This filter eliminates step discontinuities at the baseband DAC's output. Transconductance amplifier A2 provides current sinking proportional to the Ramp signal.

Since the output of A2 connects to the inverting terminal of A1, A1 draws current from VfA or VfB through the 48.5kΩ series resistance previously mentioned. This reduces the voltage seen at the inverting terminal by the voltage drop across the 48.5kΩ series resistance. The transconductance of A2 is $1/(20k\Omega)$. The net differential signal between the non-inverting and inverting terminals of the error amplifier is 2.42 × Ramp-(Vf-TC). This means that the average (Vf-TC) will be regulated to 2.42 × Ramp and that we want to choose the RF directional coupler so that the peak RF detector output at the maximum Ramp satisfies: (Peak Vf)-TC ≤ 2.42 × (maximum Ramp). See "Selecting Coupler/Detector" in the next section. Note that the **recommended** maximum Ramp ≤ 2V.

### V$_{HOME}$

Amplifier A3 and the diode D1 at its output clamp the low value of the active output to the value set by V$_{HOME}$, whenever the outputs are enabled by Tx_En. V$_{HOME}$ connects to the inverting input of amplifier A3. The non-inverting input of amplifier A3 connects to the active output selected by BS, selection being done by analog switches. Also connecting to the non-inverting input of amplifier A3 is a voltage divider. This makes the equation for the minimum output voltage 3.0 × V$_{HOME}$.
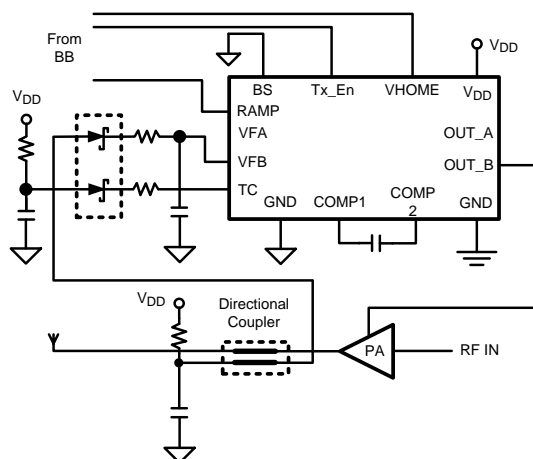
### Outputs

The output amplifiers A4 and A5 are rail-to-rail complementary MOS output stages using Class AB control, and capable of both sourcing and sinking current. The output amplifier not selected by BS is disabled; both output amplifiers are disabled when Tx_En is low. This conserves power.

The single compensation/stabilization network across Comp1 and Comp2 is switched across the correct output amplifier by analog switches controlled by BS.
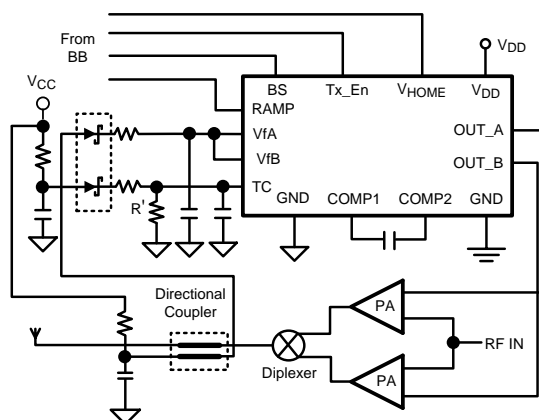
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**Typical LMV248 Configurations:**
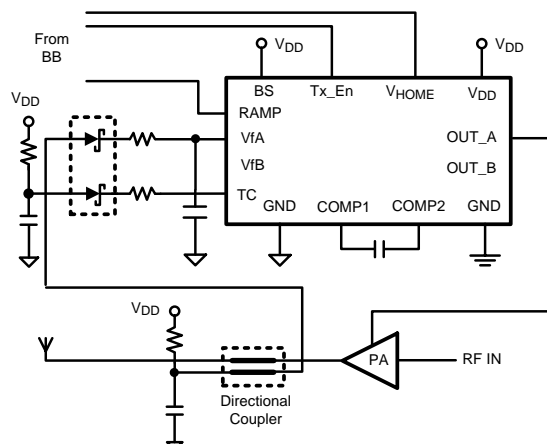


**Figure 11. One Input, One Output (A)**



**Figure 12. One Input, One Output (B)**



**Figure 13. One Input, Two Outputs**

The LMV248 has separate inputs for the coupler/detector feedback signal(s). These may be combined as a single input when using a single coupler/detector that accommodates both RF bands. When the two are combined as shown in Figure 13 internal current sources are placed in parallel. To maintain correct temperature compensation characteristics for the applications circuit, an external biasing resistor, R′ should be added externally. For this arrangement, VfA, VfB, and TC all are returned to a common supply, $V_{CC}$.

## Selecting Coupler/Detector

**Coupler Calculations:**

The applied Ramp voltage controls the RF power output. Because of this the maximum Ramp voltage sets the minimum attenuation that is allowed in the direction coupler used to sense output power.

The basic equation is;

$$P_O = V_{rms}^2/R_O \tag{1}$$

For peak detection it is;

$$P_O = \sqrt{2 \cdot V_{rms}^2/R_O} \tag{2}$$

The coupling factor, at maximum power, is defined as $C_f$

$$V_{rampmax} = \sqrt{(2 \cdot C_f \cdot P_{outmax} \cdot R_O)} \tag{3}$$

or,

$Cf = (V_{rampmax})^2/2 \times (P_{outmax} \times R_O)$ for couplers that sense peak power

The limit conditions for the maximum ramp and max power out is,

$V_{rampmax} = 2.0V$
$P_{outmax} = 2Watts$
$R_O = 50\Omega$
$C_{fdB} = 10 \times \log_{10} [(1/2)(V_{rampmax})2/P_{outmax} \times R_O)]$
$C_{fdB} = -16.98dB$

Attenuation in the directional coupler should be at least −17dB, to assure maximum power out.

## General Device Equations

**Calculation:**

Let Vf be VfA or VfB as selected by BS. Let RVf be the external series resistance from Vf to the Detector diode.

Voltage at the non-inverting terminal of A1 $V_{NI}$ = TC, since current into A2's input is small.

Voltage at the inverting terminal of A1 $V_{INV}$ = Vf - [Ramp/(20k$\Omega$)] × (RVf + 48.5k$\Omega$)

Assuming the external series resistance for VfA and VfB is << 48.5k$\Omega$:

Voltage at the inverting terminal of A1 $V_{INV}$ = Vf – 2.42 × Ramp

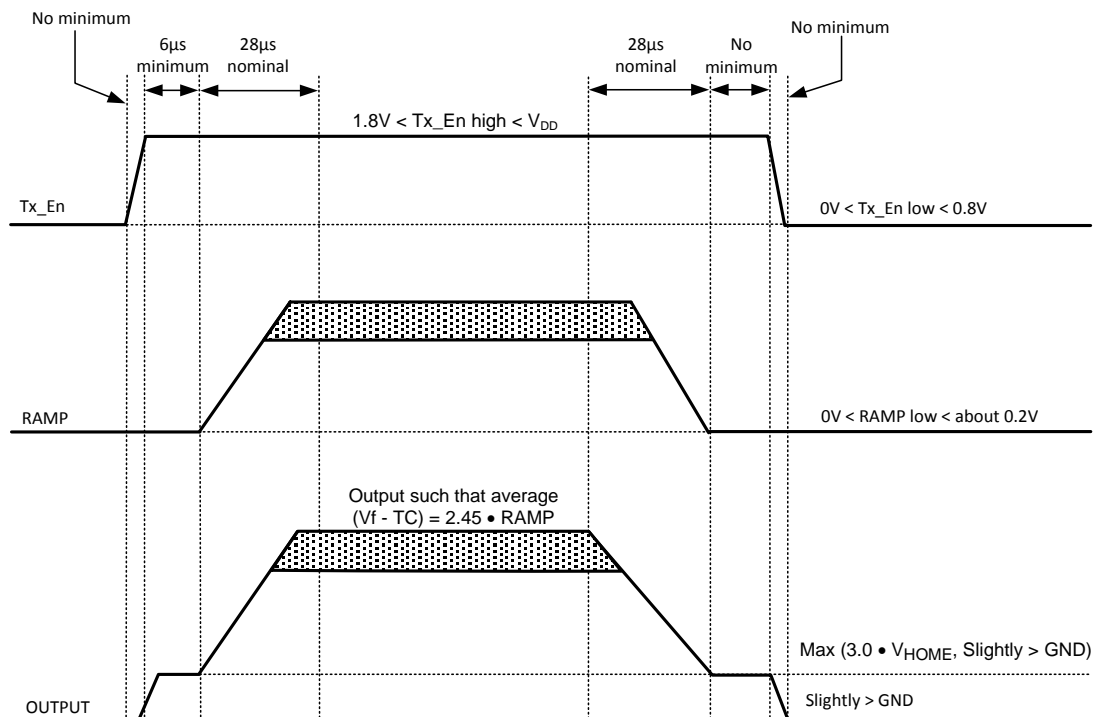Differential voltage at A1 inputs = $V_{NI}$ - $V_{INV}$ = TC - (Vf - 2.42 × Ramp) = 2.42 × Ramp - (Vf - TC).

Closed loop regulation of RF output power will force the average differential voltage at A1 inputs to approach zero:
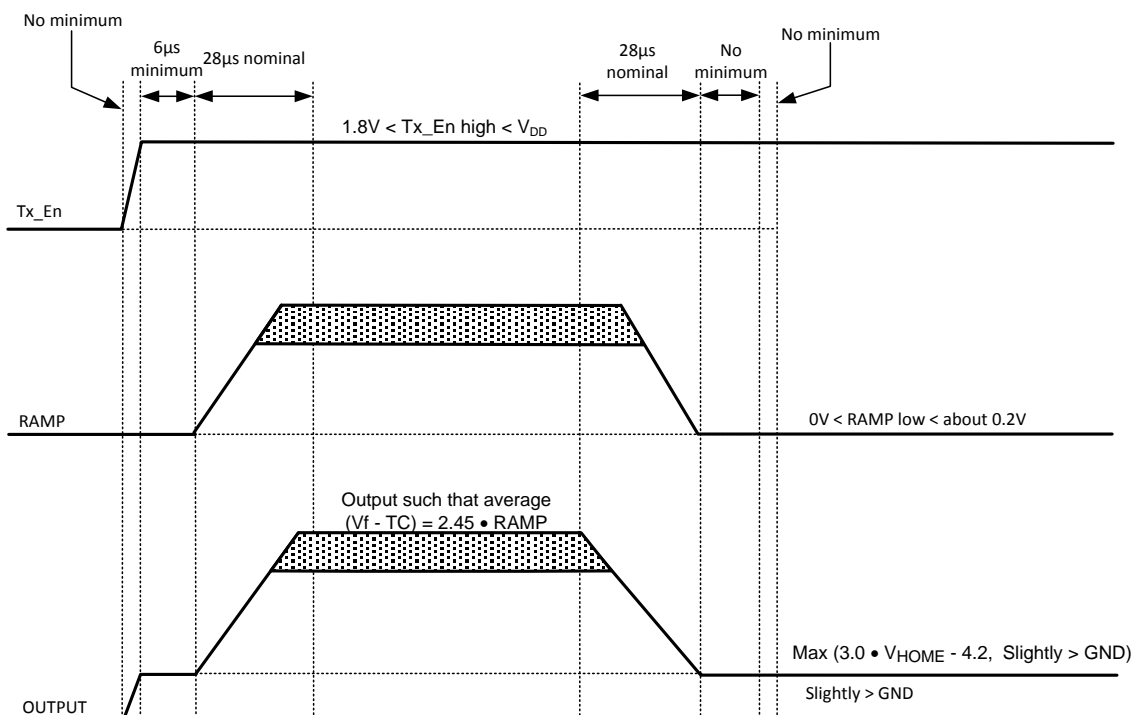
## Average

Including the $V_{ramp}$ deadband and the device offset voltage, the equation for the VfA, B vs. $V_{ramp}$ relationship becomes:

VfA, B = 2.42 × ($V_{ramp}$-200mV) + TC - 80mV, all variables being ground referenced DC voltages.

Product Folder Links: *LMV248*

**Timing Diagram #1**
**Time Slot Enabled**



**Timing Diagram #2**
**Tx/Rx Enabled**

*OBSOLETE*

# REVISION HISTORY

**MECHANICAL DATA**

## NHP0016A

(2.8)
(2.2)
(12X 0.5)

(2.8)
(2.2)

(16X 0.5)
(16X 0.25)
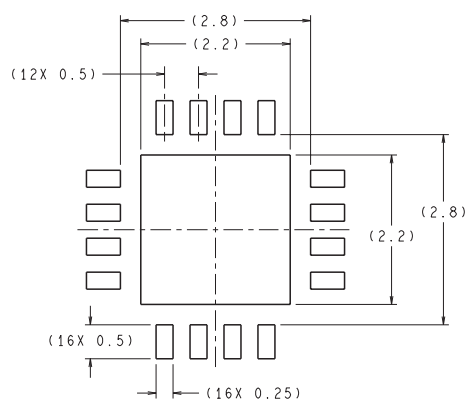
RECOMMENDED LAND PATTERN
1:1 RATION WITH PKG SOLDER PADS

DIMENSIONS ARE IN MILLIMETERS

PIN 1 INDEX AREA

0.8 MAX
(0.2)

C

4±0.1

4±0.1

B          A

PIN 1 ID

2.2±0.1
1          4

0.1 MAX
ALL AROUND

16
2X  1.5
13

5
2.2±0.1
8

12          9

16X 0.25±0.05
⊕ 0.1 Ⓜ C AⓈ BⓈ

16X 0.5±0.1
12X  0.5

2X  1.5
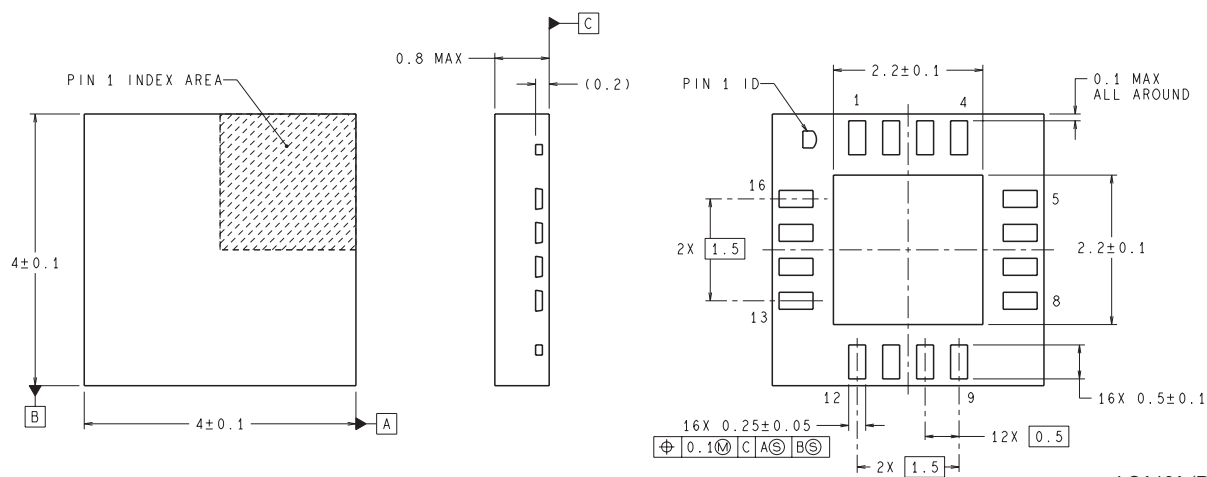
LQA16A (REV A)

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