



### Typical Applications

Phase-Locked Oscillator for:

- VSAT Radio
- Point-to-Point & Point-to-Multi-Point Radio
- Test Equipment & Industrial Controls
- Military End-Use

### Features

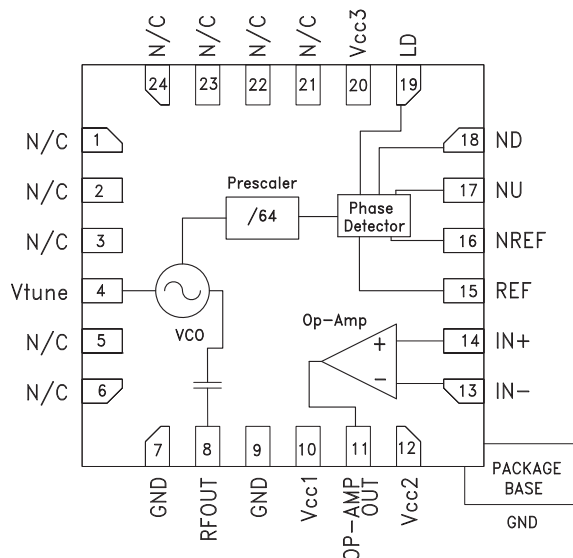
Pout: +9 dBm

Phase Noise: -110 dBc/Hz @100 KHz Typ.

Single Supply: +5V @ 340 mA  
+12V @ 28 mA

24 Lead 4x4mm QFN Package: 9 mm<sup>2</sup>

### Functional Diagram



### General Description

The HMC535LP4 & HMC535LP4E are GaAs InGaP Heterojunction Bipolar Transistor (HBT) MMIC PLOs. The PLO's phase noise performance is excellent over temperature, shock, and process due to the oscillator's monolithic structure. Power output is +9 dBm typical from a +5V supply voltage. All functions (VCO, Op-Amp, PFD, Prescaler) are fully integrated while providing allowances for off-chip customer specific loop components. The PLO MMIC accepts a single-ended or a differential reference oscillator input signal in the range of 230 to 240 MHz, and a digital Lock Detector (LD) output is provided to confirm the status of the loop. The phase-locked oscillator is packaged in a leadless QFN 4 x 4 mm surface mount package.

### Electrical Specifications, $T_A = +25^\circ \text{C}$

| Parameter                     | Min.   | Typ. | Max.   | Units            |
|-------------------------------|--------|------|--------|------------------|
| Power Supplies:               |        |      |        |                  |
| VCO Voltage Vcc1              | —      | 5    | —      | V                |
| VCO Current Icc1              | —      | 172  | —      | mA               |
| Op-Amp Voltage Vcc2           | —      | 12   | —      | V                |
| Op-Amp Current Icc2           | —      | 28   | —      | mA               |
| Digital Voltage Vcc3          | —      | 5    | —      | V                |
| Digital Current Icc3          | —      | 168  | —      | mA               |
| PLO Characteristics:          |        |      |        |                  |
| RF Operating Freq.            | 14.7   | —    | 15.4   | GHz              |
| RF Power                      | 6      | 9    | —      | dBm              |
| Reference Input Freq.         | 229.69 | —    | 240.62 | MHz              |
| Reference Input Power         | 0      | 5    | 10     | dBm              |
| RF Phase Noise 100 KHz offset | —      | -110 | —      | dBc/Hz           |
| Locking Time Loop BW = 1 MHz  | —      | 20   | —      | μs               |
| Lock Detect Output            | —      | 0.3  | 0.5    | V <sub>ave</sub> |
| Locked                        | —      | 0.3  | 0.5    | V <sub>ave</sub> |
| Unlocked                      | 0.7    | 1.0  | —      | V <sub>ave</sub> |



### Electrical Specifications, (Continued)

| Parameter                                   | Min.                                      | Typ.            | Max.         | Units            |
|---------------------------------------------|-------------------------------------------|-----------------|--------------|------------------|
| <b>VCO Characteristics:</b>                 |                                           |                 |              |                  |
| RF Operating Freq.                          | 14.7                                      | —               | 15.4         | GHz              |
| RF Power                                    | 6                                         | 9               | —            | dBm              |
| RF Tuning Sensitivity                       | $V_{tune} +2 \text{ to } +9.5 \text{ V}$  | 160             | —            | MHz/V            |
|                                             | $V_{tune} 0 \text{ to } +2 \text{ V}$     | —               | 590          | MHz/V            |
|                                             | $V_{tune} +9.5 \text{ to } +12 \text{ V}$ | —               | —            | MHz/V            |
| Tuning Voltage Leakage Current              | $V_{tune} +2 \text{ to } +9.5 \text{ V}$  | —               | 25           | $\mu\text{A}$    |
| RF Phase Noise                              | 100 kHz offset                            | -108            | —            | dBc/Hz           |
| RF Harmonics                                | $1/2 F_{OP}$                              | —               | -20          | dBc              |
|                                             | $3/2 F_{OP}$                              | —               | -35          | dBc              |
|                                             | $4/2 F_{OP}$                              | —               | -8           | dBc              |
|                                             | $5/2 F_{OP}$                              | —               | -25          | dBc              |
| RF Pushing                                  | —                                         | —               | -125         | MHz/V            |
| RF Pulling                                  | VSWR 2:1 any phase                        | —               | 10           | MHz              |
| RF Drift Rate                               | $VT_{VCO}$ input                          | —               | 20           | MHz/°C           |
| 3 dB Modulator Bandwidth                    | 30                                        | —               | —            | MHz              |
| <b>Phase Frequency Detector:</b>            |                                           |                 |              |                  |
| REF Input Capacitance                       | —                                         | —               | 10           | pF               |
| REF Input Resistance                        | —                                         | 50              | —            | Ohm              |
| REF Input VSWR                              | Referenced to 50 Ohms                     | —               | 2:1          | —                |
| Output High Voltage                         | —                                         | $V_{CC3}$       | —            | V                |
| Output Low Voltage                          | $V_{CC3} -1.9$                            | $V_{CC3} -1.95$ | $V_{CC3} -2$ | V                |
| Phase Noise                                 | —                                         | -150            | —            | dBc/Hz           |
| <b>Op-Amp Characteristics:</b>              |                                           |                 |              |                  |
| Input Offset Voltage                        | $V_{CM} = 2.5\text{V}, 5.2\text{V}$       | 1               | —            | mV               |
| Input bias Current                          | $V_{CM} = 2.5\text{V}, 5.2\text{V}$       | 5               | —            | $\mu\text{A}$    |
| Large-Signal Voltage Gain                   | Open Loop, No Load                        | 69              | —            | dB               |
| Common Mode Rejection Ratio                 | $V_{CM} = 2.5\text{V}$                    | 104             | —            | dB               |
|                                             | Frequency = 1 MHz                         | —               | —            | —                |
| Input Common Mode Range                     | 2.5                                       | —               | 5.2          | V                |
| Power Supply Rejection Ratio                | $V_{CM} = 2.5\text{V}$                    | 63              | —            | dB               |
|                                             | Frequency = 1 MHz                         | —               | —            | —                |
| Output Voltage Swing Low                    | No Load,                                  | 0.8             | 1.2          | V                |
|                                             | $I_{SINK} = 5 \text{ mA}$                 | 0.81            | 1.2          | V                |
| Output Voltage Swing High                   | No Load                                   | 10.5            | —            | V                |
|                                             | $I_{SOURCE} = 5 \text{ mA}$               | 10.2            | —            | V                |
| Gain Bandwidth Product                      | Frequency = 6 MHz                         | 400             | —            | MHz              |
| Slew Rate                                   | $A_V = 10$ , No Load                      | 146             | —            | V/ $\mu\text{s}$ |
|                                             | $V_O = 10\text{V}$                        | —               | —            | —                |
| Phase Margin                                | Open Loop                                 | 110             | —            | Deg              |
| Input Voltage Noise                         | Frequency = 10 kHz                        | 1.6             | —            | nV / sqrt (Hz)   |
| <b>Prescaler (Divider) Characteristics:</b> |                                           |                 |              |                  |
| Prescaler Division                          | —                                         | 64              | —            | —                |
| Phase Noise                                 | —                                         | -156            | —            | dBc/Hz           |

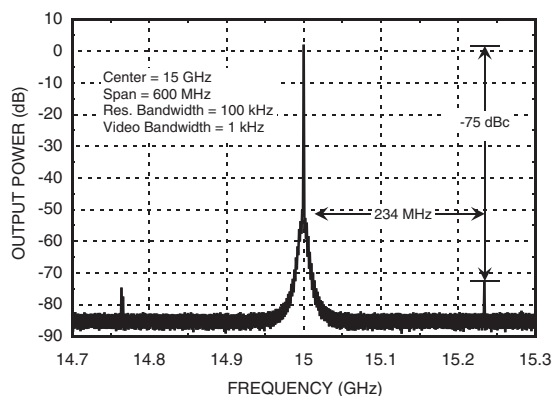


**PHASE-LOCKED OSCILLATOR,  
14.7 - 15.4 GHz**

**PLO Performance Plots**

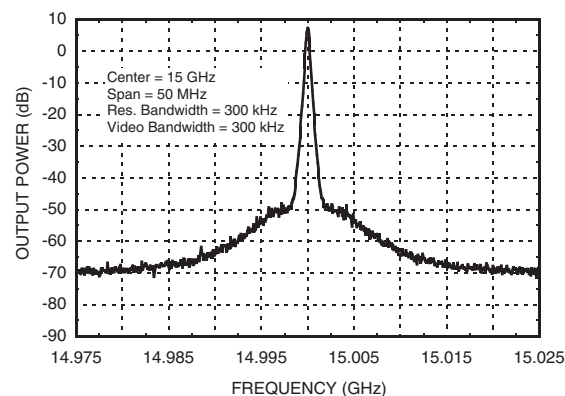
**Reference Spurs @ 15 GHz**

**BW = 1 MHz, Ref. Frequency = 234 MHz**

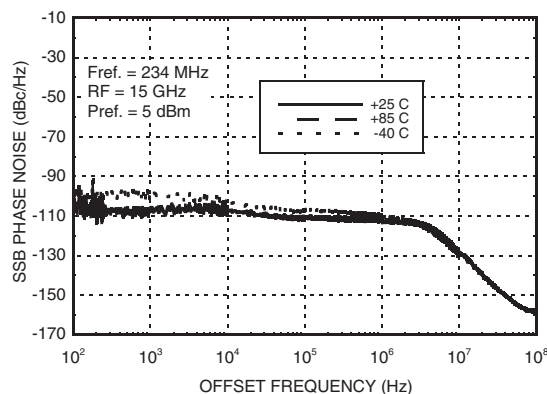


**15 GHz Locked RF Signal**

**BW = 1 MHz, Ref. Frequency = 234 MHz**

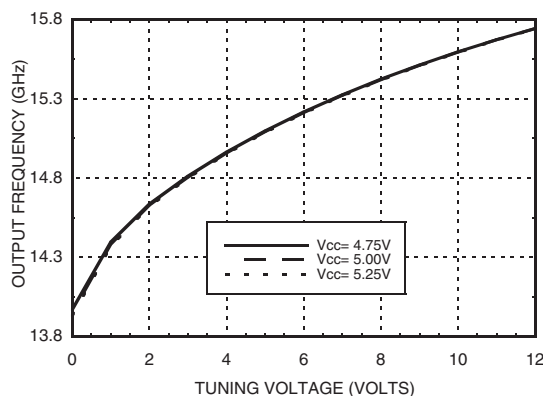


**Phase Noise Performance**

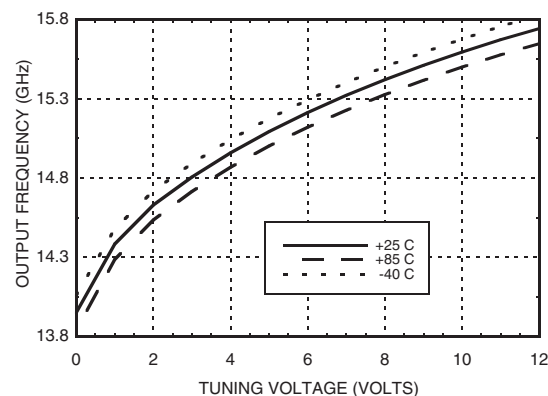


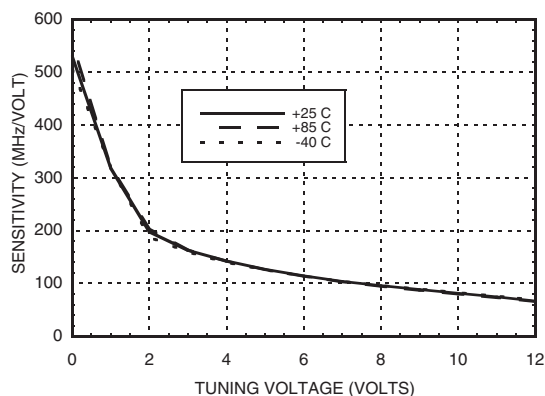
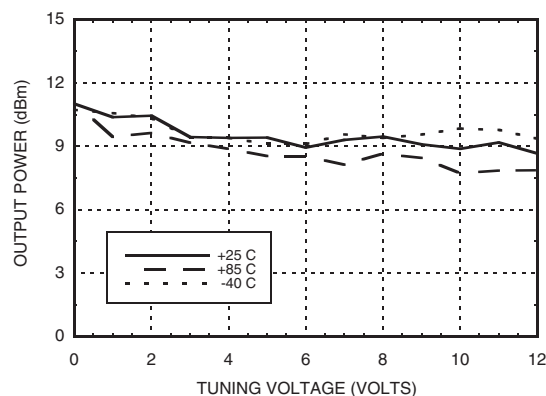
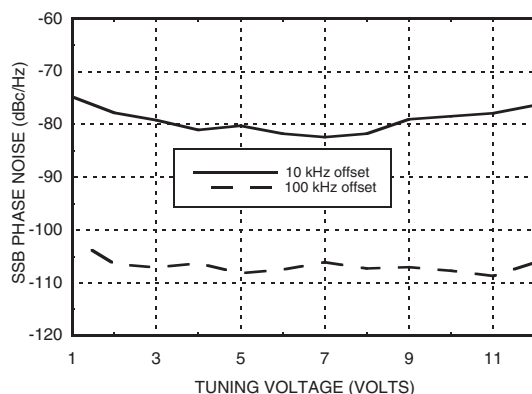
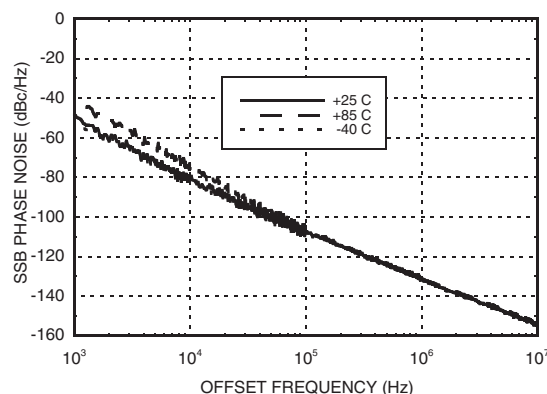
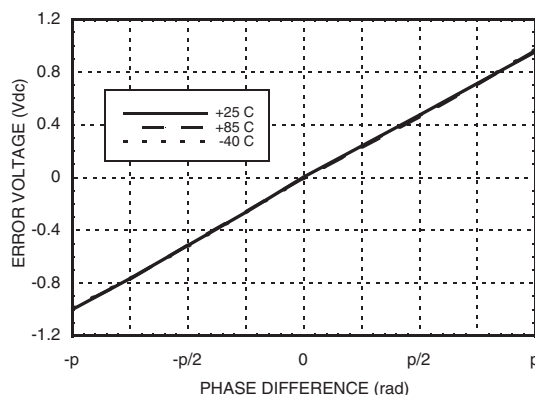
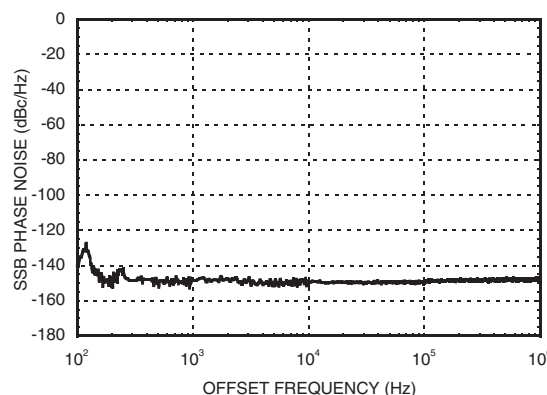
**VCO Performance Plots**

**Frequency vs. Tuning Voltage, T = 25°C**



**Frequency vs. Tuning Voltage, Vcc1 = +5V**



**VCO Performance Plots (continued)**
**Sensitivity vs. Tuning Voltage,  $V_{cc1} = +5V$** 

**Output Power vs. Tuning Voltage,  $V_{cc1} = +5V$** 

**SSB Phase Noise vs. Tuning Voltage**

**SSB Phase Noise @  $V_{tune} = +5V$** 

**Phase-Frequency Detector Performance Plots**
**Error Voltage vs. Temperature  
 $P_{in} = 0$  dBm,  $F_{in} = 235$  MHz**

**SSB Phase Noise Performance  
 $P_{in} = 0$  dBm,  $T = 25^\circ\text{C}$** 


### Absolute Maximum Ratings

|                                                             |                |
|-------------------------------------------------------------|----------------|
| Vcc1                                                        | +5.5 Vdc       |
| Vcc2                                                        | +13 Vdc        |
| Vcc3                                                        | +5.5 Vdc       |
| Reference Input Power                                       | +13 dBm        |
| Vtune                                                       | 0 to +13V      |
| Channel Temperature                                         | 135 °C         |
| Continuous Pdiss (T = 85°C)<br>(derate 47 mW/°C above 85°C) | 2.35 W         |
| Storage Temperature                                         | -55 to +125 °C |
| Operating Temperature                                       | -40 to +85 °C  |

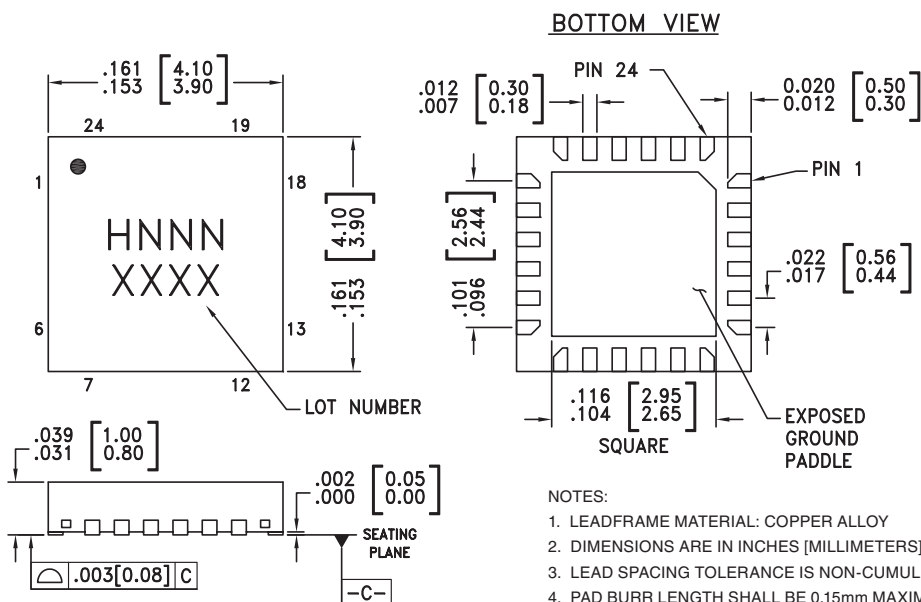


**ELECTROSTATIC SENSITIVE DEVICE  
OBSERVE HANDLING PRECAUTIONS**

### Typical Supply Currents vs. Voltages @ 15 GHz Output

| Vcc1 (V) | Icc1 (mA) |
|----------|-----------|
| 4.75     | 156       |
| 5.0      | 172       |
| 5.25     | 185       |
| Vcc2 (V) | Icc2 (mA) |
| 11.5     | 26        |
| 12       | 28        |
| 12.5     | 30        |
| Vcc3 (V) | Icc3 (mA) |
| 4.75     | 158       |
| 5        | 168       |
| 5.25     | 180       |

### 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 HITTITE APPLICATION NOTE FOR SUGGESTED LAND PATTERN.

### Package Information

| Part Number | Package Body Material                              | Lead Finish   | MSL Rating          | Package Marking <sup>[3]</sup> |
|-------------|----------------------------------------------------|---------------|---------------------|--------------------------------|
| HMC535LP4   | Low Stress Injection Molded Plastic                | Sn/Pb Solder  | MSL1 <sup>[1]</sup> | H535<br>XXXX                   |
| HMC535LP4E  | RoHS-compliant Low Stress Injection Molded Plastic | 100% matte Sn | MSL1 <sup>[2]</sup> | H535<br>XXXX                   |

[1] Max peak reflow temperature of 235 °C

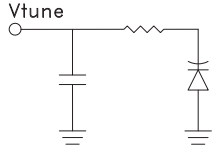
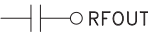
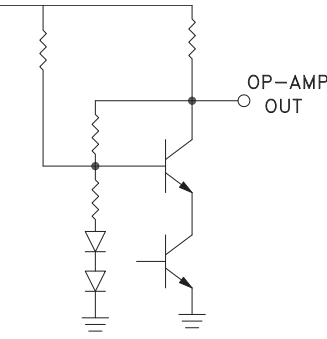
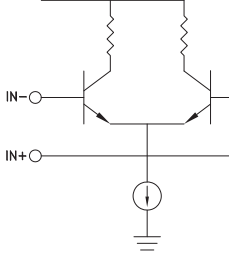
[2] Max peak reflow temperature of 260 °C

[3] 4-Digit lot number XXXX

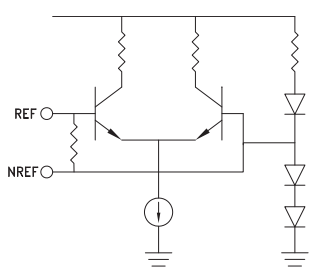
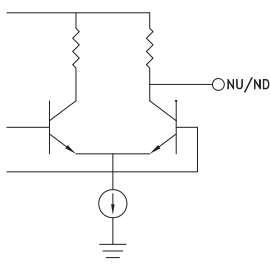
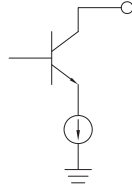
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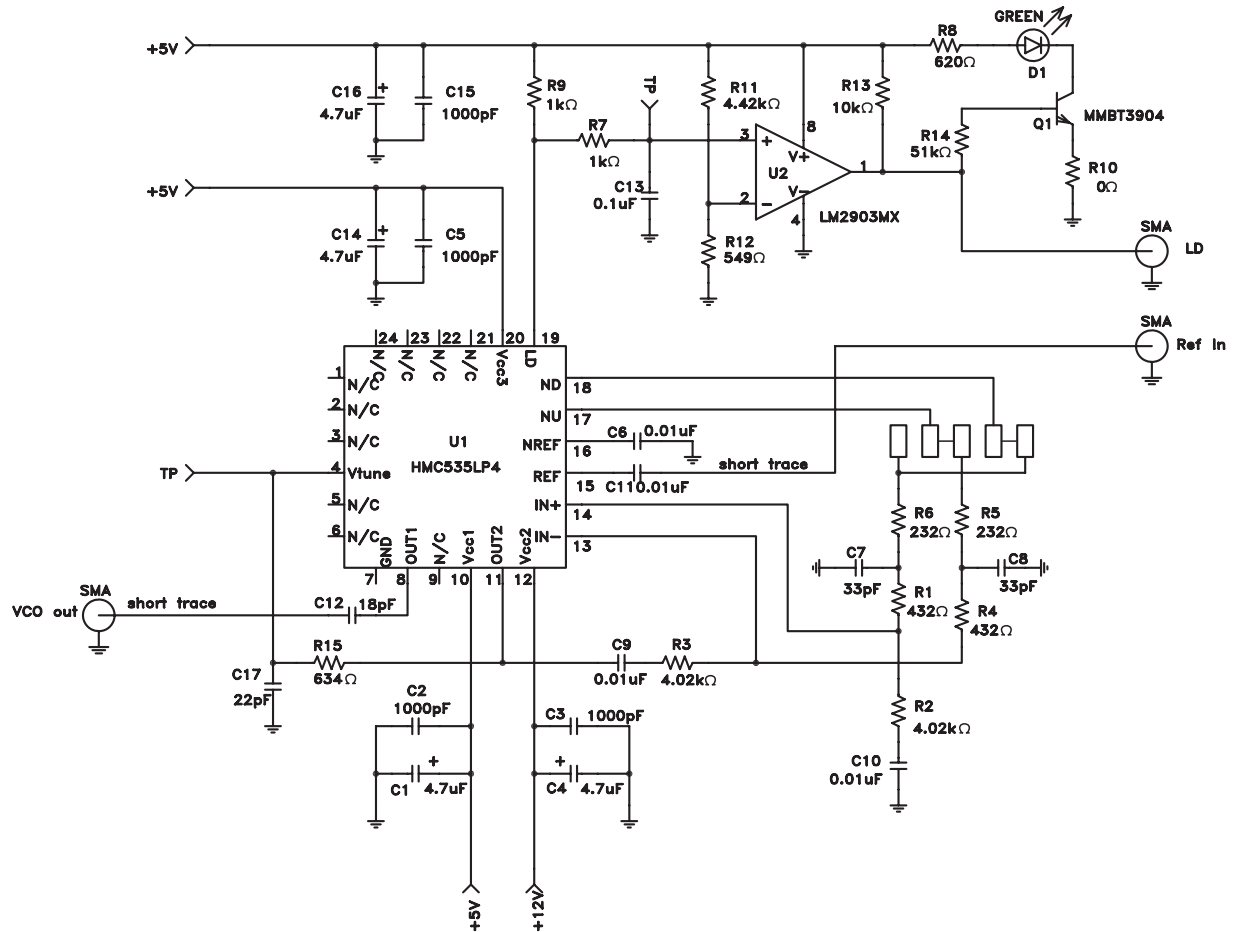
## Pin Descriptions

| Pin Number       | Function   | Description                                                                                   | Interface Schematic                                                                   |
|------------------|------------|-----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| 1-3, 5, 6, 21-24 | N/C        | No Connection. These pins may be connected to RF/DC ground. Performance will not be affected. |                                                                                       |
| 4                | Vtune      | VCO control voltage input.                                                                    |    |
| 7, 9             | GND        | This pin must be connected to RF / DC ground.                                                 |    |
| 8                | RFOUT      | RF output (AC coupled).                                                                       |    |
| 10               | Vcc1       | VCO Supply Voltage, +5V.                                                                      |                                                                                       |
| 11               | OP-AMP OUT | Op-Amp output voltage.                                                                        |   |
| 12               | Vcc2       | Op-amp Supply Voltage, +12V.                                                                  |                                                                                       |
| 13               | IN-        | Op-amp negative input voltage.                                                                |  |
| 14               | IN+        | Op-amp positive input voltage.                                                                |                                                                                       |


**PHASE-LOCKED OSCILLATOR,  
14.7 - 15.4 GHz**
**Pin Descriptions (Continued)**

| Pin Number   | Function | Description                                                                          | Interface Schematic                                                                   |
|--------------|----------|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| 15           | REF      | PFD reference input.<br>(This pin must be DC blocked externally)                     |    |
| 16           | NREF     | PFD reference input complement.<br>(This pin must be DC blocked externally)          |                                                                                       |
| 17           | NU       | PFD not up output.                                                                   |   |
| 18           | ND       | PFD not down output.                                                                 |                                                                                       |
| 19           | LD       | PFD lock detector output.                                                            |  |
| 20           | Vcc3     | Digital circuitry supply voltage, +5V.                                               |                                                                                       |
| Package Base | GND      | Package bottom has an exposed metal paddle that must be connected to RF / DC ground. |  |

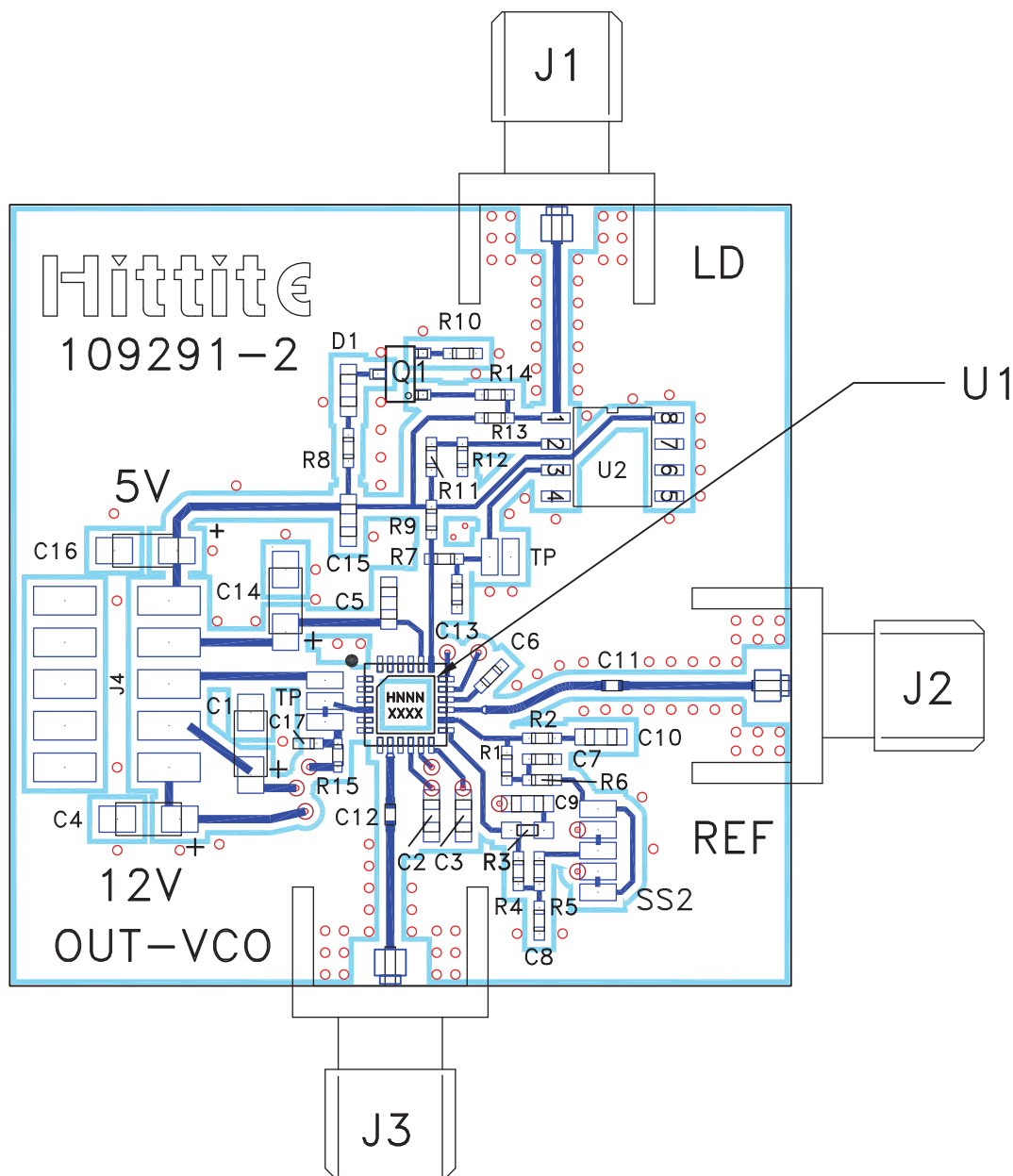
**Application Circuit**





**PHASE-LOCKED OSCILLATOR,  
14.7 - 15.4 GHz**

**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 backside ground 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 board should be mounted to an appropriate heat sink. The evaluation circuit board shown is available from Hittite upon request.


**List of Materials for Evaluation PCB 109293 [1]**

| Item             | Description                       |
|------------------|-----------------------------------|
| J1 - J3          | PCB Mount SMA RF Connector        |
| J4               | DC Pin                            |
| C1, C4, C14, C16 | 4.7 $\mu$ F Tantalum Capacitor    |
| C2, C3, C5, C15  | 1,000 pF Capacitor, 0603 Pkg.     |
| C6, C11          | 0.01 $\mu$ F Capacitor, 0402 Pkg. |
| C7, C8           | 33 pF Capacitor, 0402 Pkg.        |
| C9, C10          | 0.01 $\mu$ F Capacitor, 0603 Pkg. |
| C12              | 18 pF Capacitor, 0402 Pkg.        |
| C13              | 0.1 $\mu$ F Capacitor, 0402 Pkg.  |
| C17              | 22 pF Capacitor, 0402 Pkg.        |
| R1, R4           | 432 Ohm Resistor, 0402 Pkg.       |
| R2, R3           | 4.02 k Ohm Resistor, 0402 Pkg.    |
| R5, R6           | 232 Ohm Resistor, 0402 Pkg.       |
| R7, R9           | 1k Ohm Resistor, 0402 Pkg.        |
| R8               | 620 Ohm Resistor, 0402 Pkg.       |
| R10              | 0 Ohm Resistor, 0402 Pkg.         |
| R11              | 4.42 k Ohm Resistor, 0402 Pkg.    |
| R12              | 549 Ohm Resistor, 0402 Pkg.       |
| R13              | 10 k Ohm Resistor, 0402 Pkg.      |
| R14              | 51 k Ohm Resistor, 0402 Pkg.      |
| R15              | 634 Ohm Resistor, 0402 Pkg.       |
| D1               | Green LED, 0603 Pkg.              |
| Q1               | MMBT3904, SOT26 Pkg.              |
| U1               | HMC535LP4 / HMC535LP4E PLO        |
| U2               | LM2903MX                          |
| PCB [2]          | 109291 Eval Board                 |

[1] Reference this number when ordering complete evaluation PCB

[2] Circuit Board Material: Rogers 4350