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# MAXIM

## 10MHz to 1050MHz Integrated RF Oscillator with Buffered Outputs

MAX2620

### General Description

The MAX2620 combines a low-noise oscillator with two output buffers in a low-cost, plastic surface-mount, ultra-small  $\mu$ MAX package. This device integrates functions typically achieved with discrete components. The oscillator exhibits low-phase noise when properly mated with an external varactor-tuned resonant tank circuit. Two buffered outputs are provided for driving mixers or prescalers. The buffers provide load isolation to the oscillator and prevent frequency pulling due to load-impedance changes. Power consumption is typically just 27mW in operating mode ( $V_{CC} = 3.0V$ ), and drops to less than 0.3 $\mu$ W in standby mode. The MAX2620 operates from a single +2.7V to +5.25V supply.

### Applications

Analog Cellular Phones  
Digital Cellular Phones  
900MHz Cordless Phones  
900MHz ISM-Band Applications  
Land Mobile Radio  
Narrowband PCS (NPCS)

### Features

- ◆ Low-Phase-Noise Oscillator: -110dBc/Hz (25kHz offset from carrier) Attainable
- ◆ Operates from Single +2.7V to +5.25V Supply
- ◆ Low-Cost Silicon Bipolar Design
- ◆ Two Output Buffers Provide Load Isolation
- ◆ Insensitive to Supply Variations
- ◆ Low, 27mW Power Consumption ( $V_{CC} = 3.0V$ )
- ◆ Low-Current Shutdown Mode: 0.1 $\mu$ A (typ)

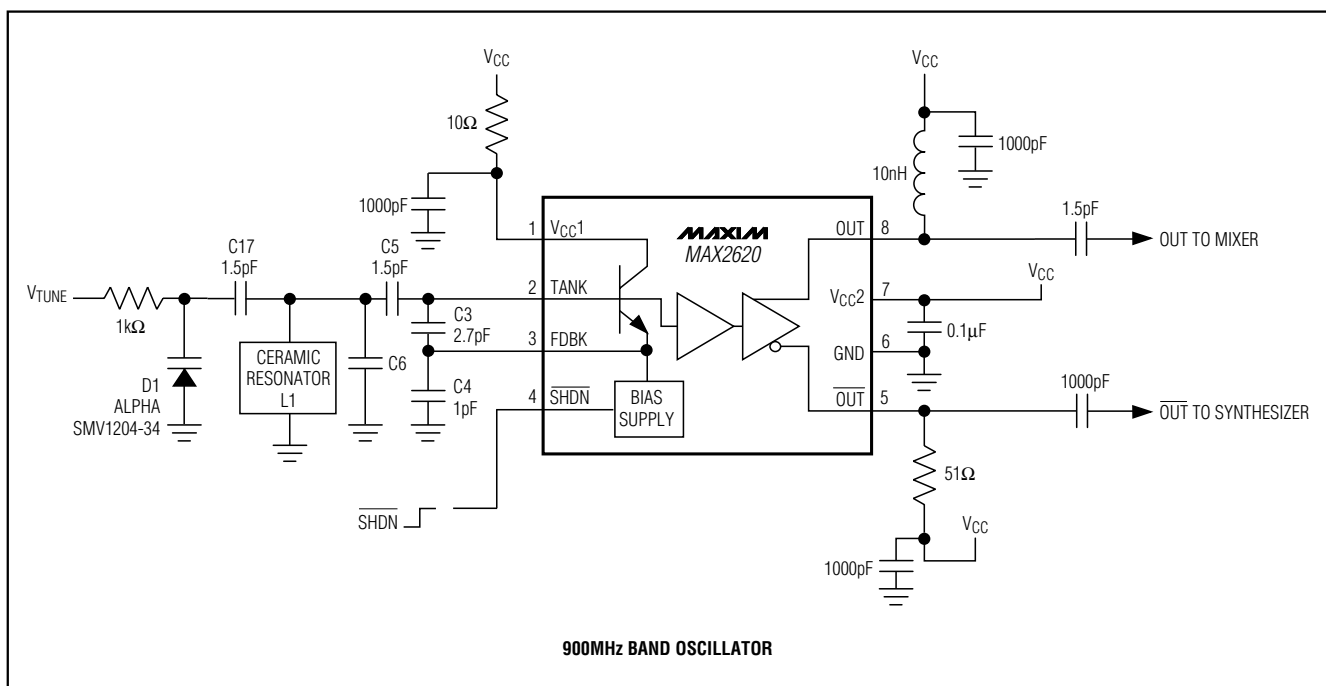
### Ordering Information

| PART       | TEMP RANGE     | PIN-PACKAGE |
|------------|----------------|-------------|
| MAX2620EUA | -40°C to +85°C | 8 $\mu$ MAX |
| MAX2620E/D | -40°C to +85°C | Dice*       |

\*Dice are tested at  $T_A = +25^\circ\text{C}$ , DC parameters only.

Pin Configuration appears at end of data sheet.

### Typical Operating Circuit



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# 10MHz to 1050MHz Integrated RF Oscillator with Buffered Outputs

## ABSOLUTE MAXIMUM RATINGS

|   |  |   |                 |
|---|--|---|-----------------|
| V <sub>CC1</sub> , V <sub>CC2</sub> to GND .....      | -0.3V to +6V   | Operating Temperature Range             |                 |
| TANK, $\overline{\text{SHDN}}$ to GND .....           | -0.3V to (V <sub>CC</sub> + 0.3V)                    | MAX2620EUA .....                        | -40°C to +85°C  |
| OUT, $\overline{\text{OUT}}$ to GND .....             | (V <sub>CC</sub> - 0.6V) to (V <sub>CC</sub> + 0.3V) | Junction Temperature .....              | +150°C          |
| FDBK to GND .....                                     | (V <sub>CC</sub> - 2.0V) to (V <sub>CC</sub> + 0.3V) | Storage Temperature Range .....         | -65°C to +165°C |
| Continuous Power Dissipation (T <sub>A</sub> = +70°C) |  | Lead Temperature (soldering, 10s) ..... | +300°C          |
| μMAX (derate 5.7mW/°C above +70°C) .....              | 457mW  |   |                 |

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## DC ELECTRICAL CHARACTERISTICS

(V<sub>CC1</sub>, V<sub>CC2</sub> = +2.7V to +5.25V, FDBK = open, TANK = open, OUT and  $\overline{\text{OUT}}$  connected to V<sub>CC</sub> through 50Ω,  $\overline{\text{SHDN}}$  = 2V, T<sub>A</sub> = -40°C to +85°C, unless otherwise noted. Typical values measured at V<sub>CC1</sub> = V<sub>CC2</sub> = 3.0V, T<sub>A</sub> = +25°C.) (Note 1)

| PARAMETER                   | CONDITIONS                      | MIN | TYP | MAX  | UNITS |
|-----------------------------|---------------------------------|-----|-----|------|-------|
| Supply Current              |                                 |     | 9.0 | 12.5 | mA    |
| Shutdown Current            | $\overline{\text{SHDN}}$ = 0.6V |     | 0.1 | 2    | μA    |
| Shutdown Input Voltage High |                                 | 2.0 |     |      | V     |
| Shutdown Input Voltage Low  |                                 |     |     | 0.6  | V     |
| Shutdown Bias Current High  | $\overline{\text{SHDN}}$ = 2.0V |     | 5.5 | 20   | μA    |
| Shutdown Bias Current Low   | $\overline{\text{SHDN}}$ = 0.6V |     |     | 0.5  | μA    |

**Note 1:** Specifications are production tested and guaranteed at T<sub>A</sub> = +25°C and T<sub>A</sub> = +85°C. Specifications are guaranteed by design and characterization at T<sub>A</sub> = -40°C.

## AC ELECTRICAL CHARACTERISTICS

(Test Circuit of Figure 1, V<sub>CC</sub> = +3.0V,  $\overline{\text{SHDN}}$  = V<sub>CC</sub>, Z<sub>LOAD</sub> = Z<sub>SOURCE</sub> = 50Ω, P<sub>IN</sub> = -20dBm (50Ω), f<sub>TEST</sub> = 900MHz, T<sub>A</sub> = +25°C, unless otherwise noted.)

| PARAMETER         | CONDITIONS  | MIN | TYP | MAX  | UNITS |
|-------------------|---|-----|-----|------|-------|
| Frequency Range   | T <sub>A</sub> = -40°C to +85°C (Note 2)  | 10  |     | 1050 | MHz   |
| Reverse Isolation | OUT or $\overline{\text{OUT}}$ to TANK; OUT, $\overline{\text{OUT}}$ driven at P = -20dBm |     | 50  |      | dB    |
| Output Isolation  | OUT to $\overline{\text{OUT}}$  |     | 33  |      | dB    |

**Note 2:** Guaranteed by design and characterization at 10MHz, 650MHz, 900MHz, and 1050MHz. Over this frequency range, the magnitude of the negative real impedance measured at TANK is greater than one-tenth the magnitude of the reactive impedances at TANK. This implies proper oscillator start-up when using an external resonator tank circuit with Q > 10. C3 and C4 must be tuned for operation at the desired frequency.

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## TYPICAL OPERATING CIRCUIT PERFORMANCE—900MHz Band Ceramic-Resonator-Based Tank

(Typical Operating Circuit,  $V_{CC} = +3.0V$ ,  $V_{TUNE} = 1.5V$ ,  $\overline{SHDN} = V_{CC}$ , load at OUT = 50 $\Omega$ , load at  $\overline{OUT}$  = 50 $\Omega$ , L1 = coaxial ceramic resonator: Trans-Tech SR8800LPQ1357BY, C6 = 1pF,  $T_A = +25^\circ C$ , unless otherwise noted.)

| PARAMETER                   | CONDITIONS  | MIN | TYP      | MAX | UNITS              |
|-----------------------------|---|-----|----------|-----|--------------------|
| Tuning Range                | $V_{TUNE} = 0.5V$ to 3.0V   |     | $\pm 13$ |     | MHz                |
| Phase Noise                 | SSB at $\Delta f = 25kHz$   |     | -110     |     | dBc/Hz             |
|                             | SSB at $\Delta f = 300kHz$  |     | -132     |     |                    |
| Output Power (Single-Ended) | At OUT (Note 2)   | -6  | -2       |     | dBm                |
|                             | At OUT, per test circuit of Figure 1; $T_A = -40^\circ C$ to $+85^\circ C$ (Note 3) | -11 | -8       |     |                    |
|                             | At $\overline{OUT}$ (Note 3)  | -16 | -12.5    |     |                    |
| Noise Power                 | $f_0 \pm >10MHz$  |     | -147     |     | dBm/Hz             |
| Average Tuning Gain         |   |     | 11       |     | MHz/V              |
| Second-Harmonic Output      |   |     | -29      |     | dBc                |
| Load Pull                   | VSWR = 1.75:1, all phases   |     | 163      |     | kHz <sub>p-p</sub> |
| Supply Pushing              | $V_{CC}$ stepped from 3V to 4V  |     | 71       |     | kHz/V              |

**Note 3:** Guaranteed by design and characterization.

## TYPICAL OPERATING CIRCUIT PERFORMANCE—900MHz Band Inductor-Based Tank

(Typical Operating Circuit,  $V_{CC} = +3.0V$ ,  $V_{TUNE} = 1.5V$ ,  $\overline{SHDN} = V_{CC}$ , load at OUT = 50 $\Omega$ , load at  $\overline{OUT}$  = 50 $\Omega$ , L1 = 5nH (Coilcraft A02T), C6 = 1.5pF,  $T_A = +25^\circ C$ , unless otherwise noted.)

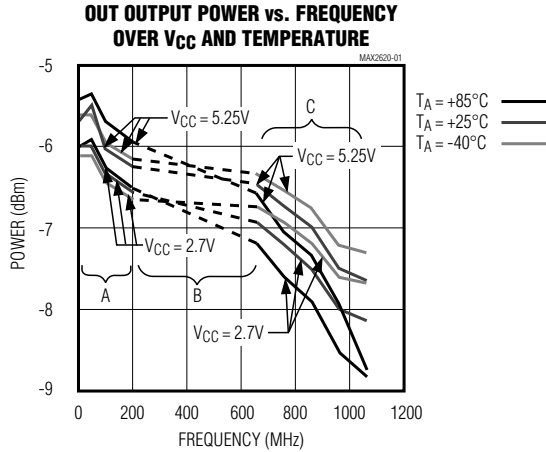
| PARAMETER                   | CONDITIONS  | MIN | TYP      | MAX | UNITS              |
|-----------------------------|---|-----|----------|-----|--------------------|
| Tuning Range                | $V_{TUNE} = 0.5V$ to 3.0V   |     | $\pm 15$ |     | MHz                |
| Phase Noise                 | SSB at $\Delta f = 25kHz$   |     | -107     |     | dBc/Hz             |
|                             | SSB at $\Delta f = 300kHz$  |     | -127     |     |                    |
| Output Power (single-ended) | At OUT (Note 2)   | -6  | -2       |     | dBm                |
|                             | At OUT, per test circuit of Figure 1; $T_A = -40^\circ C$ to $+85^\circ C$ (Note 3) | -11 | -8       |     |                    |
|                             | At $\overline{OUT}$ (Note 3)  | -16 | -12.5    |     |                    |
| Noise Power                 | $f_0 \pm >10MHz$  |     | -147     |     | dBm/Hz             |
| Average Tuning Gain         |   |     | 13       |     | MHz/V              |
| Second-Harmonic Output      |   |     | -29      |     | dBc                |
| Load Pull                   | VSWR = 1.75:1, all phase angles   |     | 340      |     | kHz <sub>p-p</sub> |
| Supply Pushing              | $V_{CC}$ stepped from 3V to 4V  |     | 150      |     | kHz/V              |

**Note 3:** Guaranteed by design and characterization.

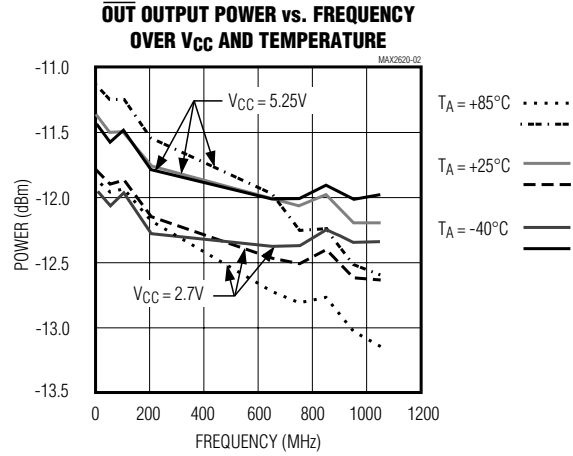
# 10MHz to 1050MHz Integrated RF Oscillator with Buffered Outputs

## Typical Operating Characteristics

(Test Circuit of Figure 1,  $V_{CC} = +3.0V$ ,  $\overline{SHDN} = V_{CC}$ ,  $Z_{LOAD} = Z_{SOURCE} = 50\Omega$ ,  $P_{IN} = -20dBm/50\Omega$ ,  $f_{TEST} = 900MHz$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



A: 10MHz BAND CIRCUIT  
 B: NOT CHARACTERIZED FOR THIS FREQUENCY BAND.  
 EXPECTED PERFORMANCE SHOWN.  
 C: 900MHz BAND CIRCUIT



**Table 1. Recommended Load Impedance at OUT or  $\overline{OUT}$  for Optimum Power Transfer**

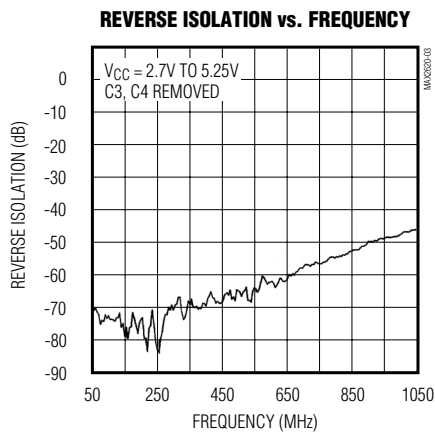
| FREQUENCY (MHz) | REAL COMPONENT (R in $\Omega$ ) | IMAGINARY COMPONENT (X in $\Omega$ ) |
|-----------------|---------------------------------|--------------------------------------|
| 250             | 106                             | 163                                  |
| 350             | 68                              | 102                                  |
| 450             | 60                              | 96                                   |
| 550             | 35                              | 79                                   |
| 650             | 17.5                            | 62.3                                 |
| 750             | 17.2                            | 50.6                                 |
| 850             | 10.9                            | 33.1                                 |
| 950             | 7.3                             | 26.3                                 |
| 1050            | 6.5                             | 22.7                                 |

# 10MHz to 1050MHz Integrated RF Oscillator with Buffered Outputs

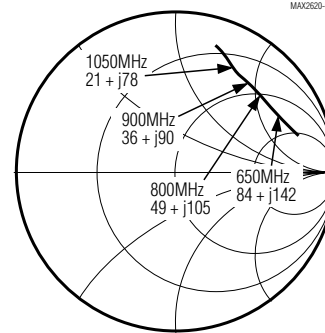
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## Typical Operating Characteristics (continued)

(Typical Operating Circuit,  $V_{CC} = +3.0V$ ,  $V_{TUNE} = 1.5V$ ,  $\overline{SHDN} = V_{CC}$ , load at OUT =  $50\Omega$ , load at  $\overline{OUT} = 50\Omega$ , L1 = coaxial ceramic resonator: Trans-Tech SR8800LPQ1357BY, C6 = 1pF,  $T_A = +25^\circ C$ , unless otherwise noted.)

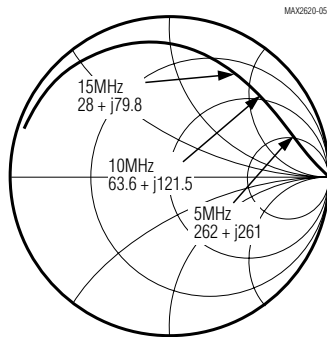


**900MHz BAND CIRCUIT\***  
TYPICAL  $1/S_{11}$  vs. FREQUENCY  
MEASURED AT TEST PORT



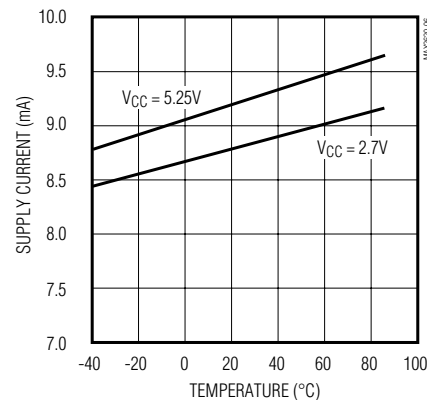
\*SEE FIGURE 1

**10MHz BAND CIRCUIT**  
TYPICAL  $1/S_{11}$  vs. FREQUENCY  
MEASURED AT TEST PORT



C3 = C4 = 270pF  
L3 = 10 $\mu$ H  
C2 = C10 = C13 = 0.01 $\mu$ F

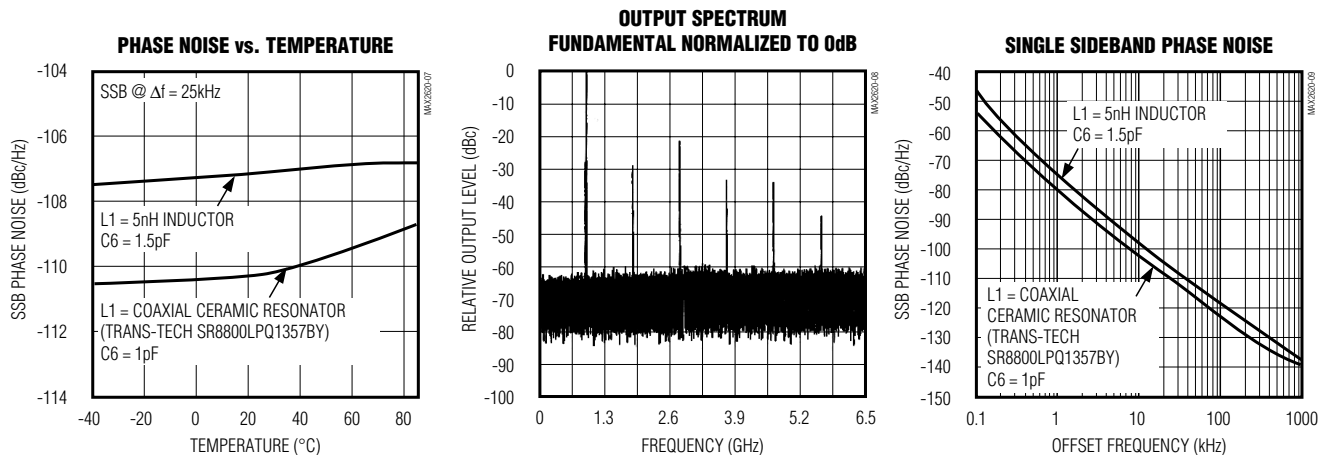
**SUPPLY CURRENT vs. TEMPERATURE**



# 10MHz to 1050MHz Integrated RF Oscillator with Buffered Outputs

## Typical Operating Characteristics (continued)

(Typical Operating Circuit,  $V_{CC} = +3.0V$ ,  $V_{TUNE} = 1.5V$ ,  $\overline{SHDN} = V_{CC}$ , load at  $\overline{OUT} = 50\Omega$ , load at  $OUT = 50\Omega$ ,  $L1 =$  coaxial ceramic resonator: Trans-Tech SR8800LPQ1357BY,  $C6 = 1pF$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



## Pin Description

| PIN | NAME              | FUNCTION  |
|-----|-------------------|---|
| 1   | VCC1              | Oscillator DC Supply Voltage. Decouple VCC1 with 1000pF capacitor to ground. Use a capacitor with low series inductance (size 0805 or smaller). Further power-supply decoupling can be achieved by adding a 10 $\Omega$ resistor in series from VCC1 to the supply. Proper power-supply decoupling is critical to the low noise and spurious performance of any oscillator.   |
| 2   | TANK              | Oscillator Tank Circuit Connection. Refer to the <i>Applications Information</i> section.   |
| 3   | FDBK              | Oscillator Feedback Circuit Connection. Connecting capacitors of the appropriate value between FDBK and TANK and between FDBK and GND tunes the oscillator's reflection gain (negative resistance) to peak at the desired oscillation frequency. Refer to the <i>Applications Information</i> section.  |
| 4   | $\overline{SHDN}$ | Logic-Controlled Input. A low level turns off the entire circuitry such that the IC will draw only leakage current at its supply pins. This is a high-impedance input.  |
| 5   | $\overline{OUT}$  | Open-Collector Output Buffer (complement). Requires external pull-up to the voltage supply. Pull-up can be resistor, choke, or inductor (which is part of a matching network). The matching-circuit approach provides the highest-power output and greatest efficiency. Refer to Table 1 and the <i>Applications Information</i> section. $\overline{OUT}$ can be used with OUT in a differential output configuration. |
| 6   | GND               | Ground Connection. Provide a low-inductance connection to the circuit ground plane.   |
| 7   | VCC2              | Output Buffer DC Supply Voltage. Decouple VCC2 with a 1000pF capacitor to ground. Use a capacitor with low series inductance (size 0805 or smaller).  |
| 8   | OUT               | Open-Collector Output Buffer. Requires external pull-up to the voltage supply. Pull-up can be resistor, choke, or inductor (which is part of a matching network). The matching-circuit approach provides the highest-power output and greatest efficiency. Refer to Table 1 and the <i>Applications Information</i> section. OUT can be used with $\overline{OUT}$ in a differential output configuration.              |

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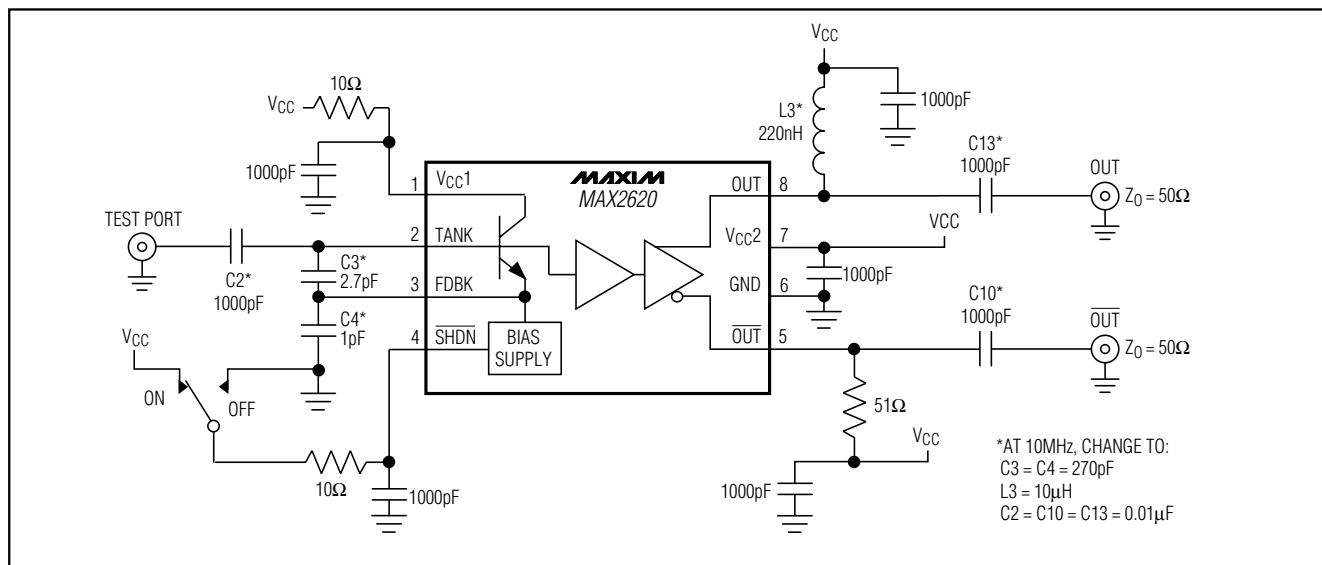


Figure 1. 900MHz Test Circuit

## Detailed Description

### Oscillator

The oscillator is a common-collector, negative-resistance type that uses the IC's internal parasitic elements to create a negative resistance at the base-emitter port. The transistor oscillator has been optimized for low-noise operation. Base and emitter leads are provided as external connections for a feedback capacitor and resonator. A resonant circuit, tuned to the appropriate frequency and connected to the base lead, will cause oscillation. Varactor diodes may be used in the resonant circuit to create a voltage-controlled oscillator (VCO). The oscillator is internally biased to an optimal operating point, and the base and emitter leads need to be capacitively coupled due to the bias voltages present.

### Output Buffers

The output buffers (OUT and  $\overline{\text{OUT}}$ ) are an open-collector, differential-pair configuration and provide load isolation to the oscillator. The outputs can be used differentially to drive an integrated circuit mixer. Alternatively, isolation is provided between the buffer outputs when one output drives a mixer (either up-conversion or down-conversion) and the other output drives a prescaler. The isolation in this configuration prevents prescaler noise from corrupting the oscillator signal's spectral purity.

A logic-controlled  $\overline{\text{SHDN}}$  pin turns off all bias to the IC when pulled low.

## Applications Information

### Design Principles

At the frequency of interest, the MAX2620 portion of Figure 2 shows the one-port circuit model for the TANK pin (test port in Figure 1).

For the circuit to oscillate at a desired frequency, the resonant tank circuit connected to TANK must present an impedance that is a complement to the network (Figure 2). This resonant tank circuit must have a positive real component that is a maximum of one-half the magnitude of the negative real part of the oscillator device, as well as a reactive component that is opposite in sign to the reactive component of the oscillator device.

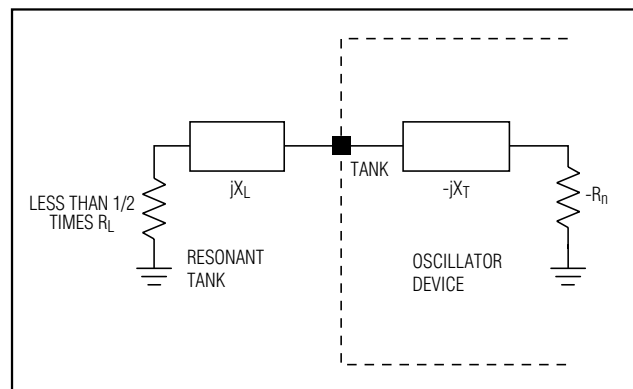


Figure 2. Simplified Oscillator Circuit Model

# 10MHz to 1050MHz Integrated RF Oscillator with Buffered Outputs

Keeping the resonant tank circuit's real component less than one-half the magnitude of the negative real component ensures that oscillations will start. After start-up, the oscillator's negative resistance decreases, primarily due to gain compression, and reaches equilibrium with the real component (the circuit losses) in the resonant tank circuit. Making the resonant tank circuit reactance tunable (e.g., through use of a varactor diode) allows for tuneability of the oscillation frequency, as long as the oscillator exhibits negative resistance over the desired tuning range. See Figures 3 and 4.

The negative resistance of the MAX2620 TANK pin can be optimized at the desired oscillator frequency by proper selection of feedback capacitors C3 and C4. For example, the one-port characteristics of the device are given as a plot of  $1/S_{11}$  in the *Typical Operating Characteristics*.  $1/S_{11}$  is used because it maps inside the unit circle Smith chart when the device exhibits negative resistance (reflection gain).

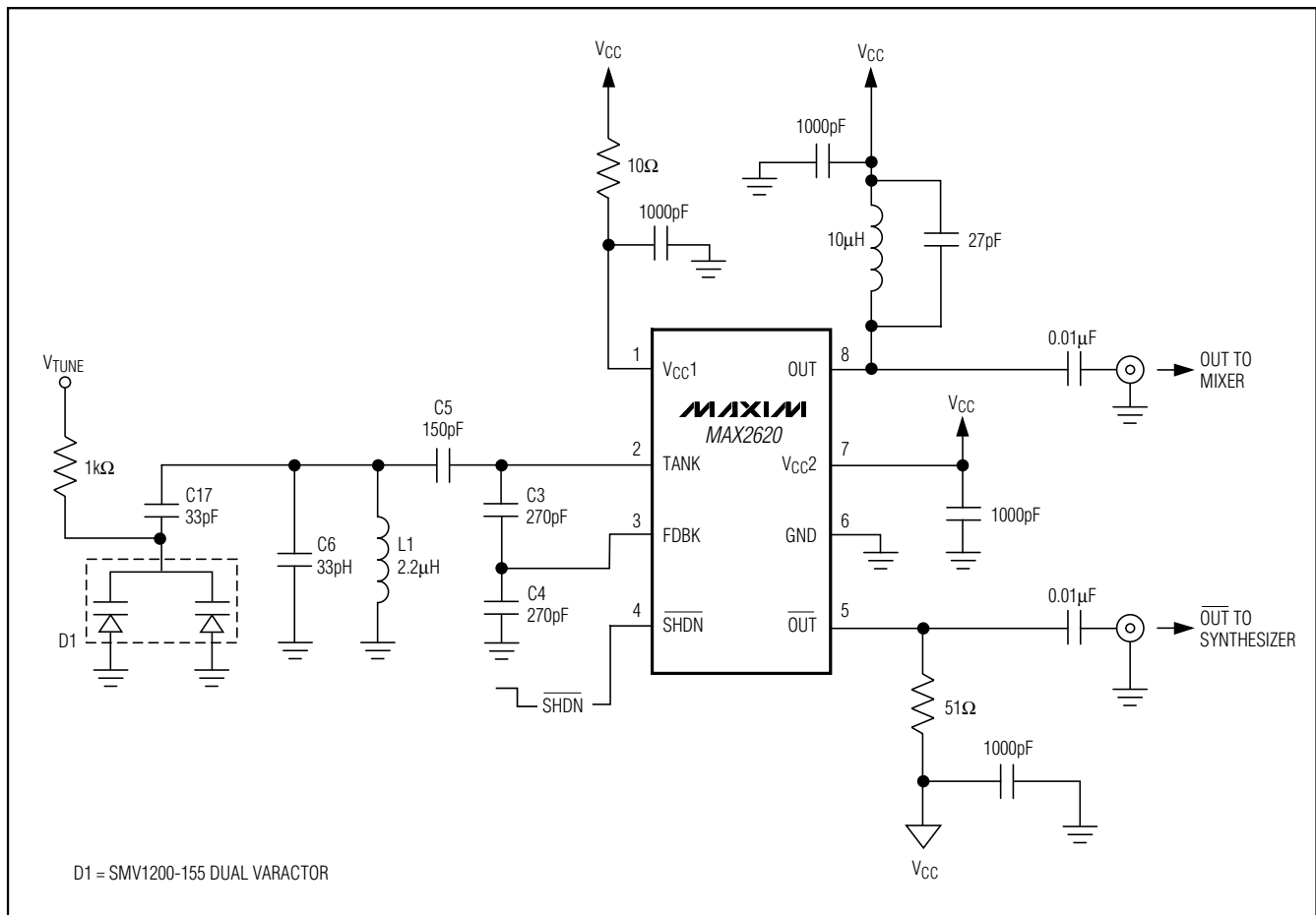


Figure 3. 10MHz VCO LC Resonator



# 10MHz to 1050MHz Integrated RF Oscillator with Buffered Outputs

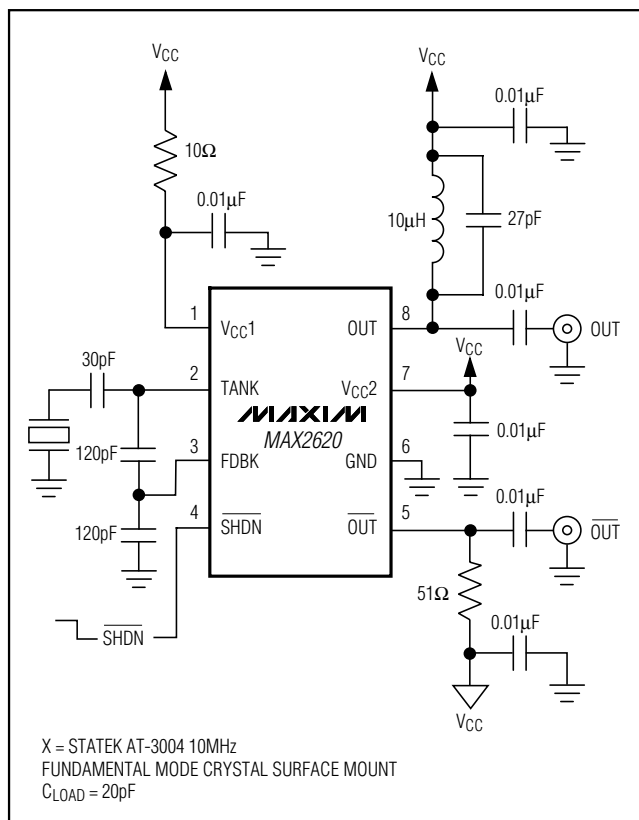


Figure 4. 10MHz Crystal Oscillator

### Sample Calculation

According to the electrical model shown in Figure 5, the resonance frequency can be calculated as:

[Equation 1]

$$f_0 = \frac{1}{2\pi \sqrt{L1 \left[ C_{STRAY} + \frac{C_{17} \times C_{D1}}{C_{17} + C_{D1}} + C_6 + \frac{C_5 \times C_n}{C_5 + C_n} \right]}}$$

$$\text{where } C_n = \frac{(C_3 + C_{03})(C_4 + C_{04})}{C_3 + C_{03} + C_4 + C_{04}}$$

$R_n$ , the negative real impedance, is set by  $C_3$  and  $C_4$  and is approximately:

[Equation 2]

$$R_n = g_m \left( \frac{1}{2\pi f (C_3 + C_{03})} \right) \left( \frac{1}{2\pi f (C_4 + C_{04})} \right)$$

where  $g_m = 18\text{mS}$ .

Using the circuit model of Figure 5, the following example describes the design of an oscillator centered at 900MHz.

Choose:  $L1 = 5\text{nH} \pm 10\%$

$Q = 140$

Calculate:  $R_p = Q \times 2\pi \times f \times L1$

Using Equation 1, solve for varactor capacitance ( $C_{D1}$ ).  $C_{D1}$  is the capacitance of the varactor when the voltage applied to the varactor is approximately at half-supply (the center of the varactor's capacitance range). Assume the following values:

$C_{STRAY} = 2.7\text{pF}$ ,  $C_{17} = 1.5\text{pF}$ ,  $C_6 = 1.5\text{pF}$ ,  $C_5 = 1.5\text{pF}$ ,  $C_{03} = 2.4\text{pF}$ ,  $C_{04} = 2.4\text{pF}$ ,  $C_3 = 2.7\text{pF}$ , and  $C_4 = 1\text{pF}$

The value of  $C_{STRAY}$  is based on approximate performance of the MAX2620 EV kit. Values of  $C_3$  and  $C_4$  are chosen to minimize  $R_n$  (Equation 2) while not loading the resonant circuit with excessive capacitance.  $C_{03}$  and  $C_{04}$  are parasitic capacitors.

The varactor's capacitance range should allow for the desired tuning range. Across the tuning frequency range, ensure that  $R_s < 1/2 |R_n|$ .

The MAX2620's oscillator is optimized for low-phase-noise operation. Achieving lowest phase-noise characteristics requires the use of high-Q (quality factor) components such as ceramic transmission-line type

# 10MHz to 1050MHz Integrated RF Oscillator with Buffered Outputs

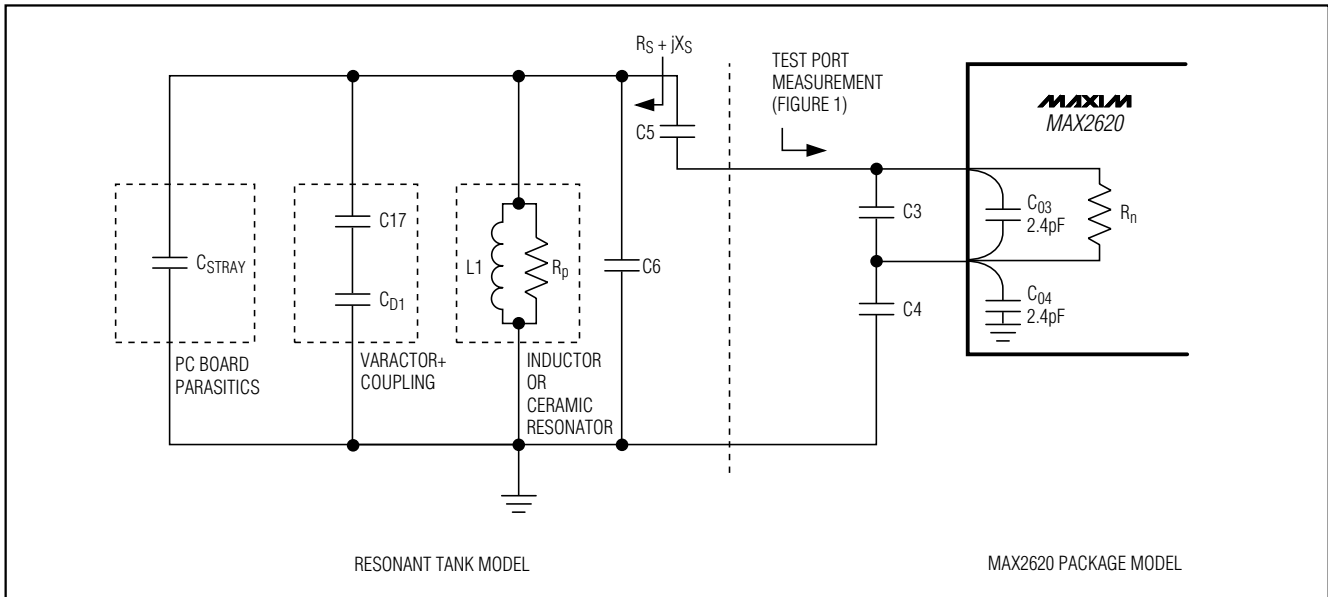


Figure 5. Electrical Model of MAX2620 Circuit

resonators or high-Q inductors. Also, keep C5 and C17 (see the *Typical Operating Circuit*) as small a value as possible while still maintaining desired frequency and tuning range to maximize loaded Q.

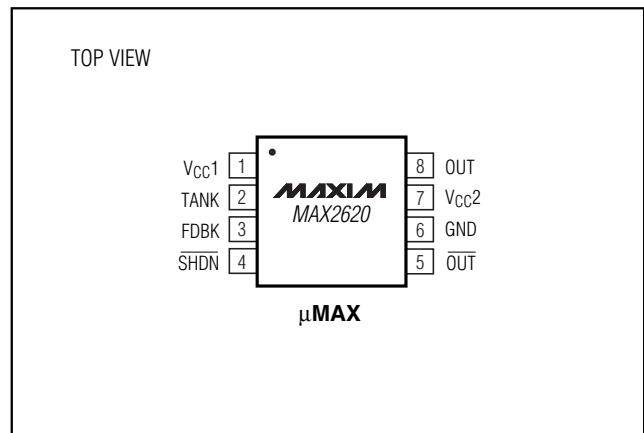
There are many good references on the topic of oscillator design. An excellent reference is “The Oscillator as a Reflection Amplifier, an Intuitive Approach to Oscillator Design,” by John W. Boyles, *Microwave Journal*, June 1986, pp. 83–98.

### Output Matching Configuration

Both of the MAX2620’s outputs (OUT and  $\overline{\text{OUT}}$ ) are open collectors. They need to be pulled up to the supply by external components. An easy approach to this pull-up is a resistor. A  $50\Omega$  resistor value would inherently match the output to a  $50\Omega$  system. The *Typical Operating Circuit* shows  $\overline{\text{OUT}}$  configured this way. Alternatively, a choke pullup (Figure 1), yields greater output power (approximately -8dBm at 900MHz).

When maximum power is required, use an inductor as the supply pull-up, and match the inductor’s output impedance to the desired system impedance. Table 1 in the *Typical Operating Characteristics* shows recommended load impedance presented to OUT and  $\overline{\text{OUT}}$

### Pin Configuration



for maximum power transfer. Using this data and standard matching-network synthesis techniques, a matching network can be constructed that will optimize power output into most load impedances. The value of the inductor used for pullup should be used in the synthesis of the matching network.

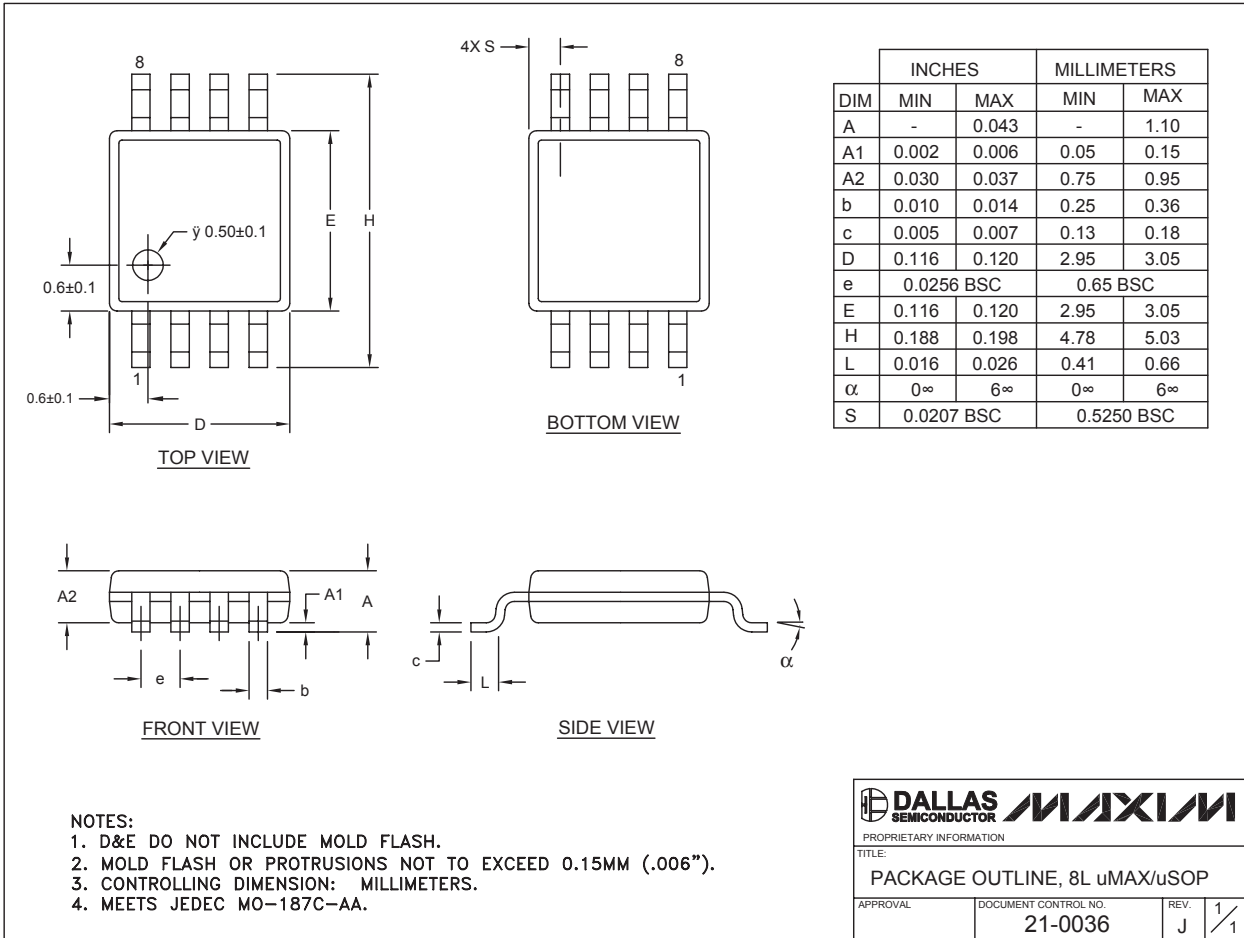
# 10MHz to 1050MHz Integrated RF Oscillator with Buffered Outputs

## Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).)

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