

# Low voltage LNA, mixer and VCO — 1GHz

# SA620

## DESCRIPTION

The SA620 is a combined RF amplifier, VCO with tracking bandpass filter and mixer designed for high-performance low-power communication systems from 800-1200MHz. The low-noise preamplifier has a 1.6dB noise figure at 900MHz with 11.5dB gain and an IP3 intercept of -3dBm at the input. The gain is stabilized by on-chip compensation to vary less than  $\pm 0.2$ dB over -40 to +85°C temperature range. The wide-dynamic-range mixer has an 9dB noise figure and IP3 of -6dBm at the input at 900MHz. An external LO can be used in place of the internal VCO for improved mixer input IP3 and a 3mA reduction in current. The chip incorporates a through-mode option so the RF amplifier can be disabled and replaced by an attenuator ( $S_{21} = -7.5$ dB). This is useful for improving the overall dynamic range of the receiver when in an overload situation. The nominal current drawn from a single 3V supply is 10.4mA and 7.2mA in the thru-mode. Additionally, the VCO and Mixer can be powered down to further reduce the supply current to 1.2mA.

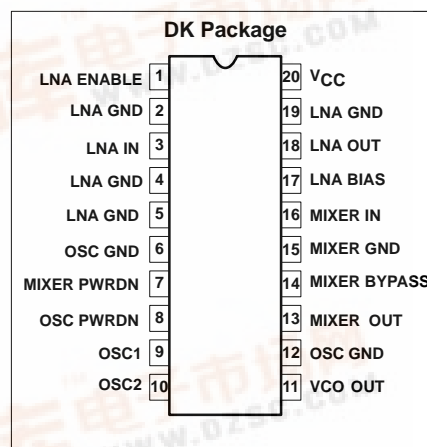
## FEATURES

- Low current consumption: 10.4mA nominal, 7.2mA with thru-mode activated
- Outstanding noise figure: 1.6dB for the amplifier and 9dB for the mixer at 900MHz
- Excellent gain stability versus temperature and supply voltage
- Switchable overload capability
- Independent LNA, mixer and VCO power down capability
- Internal VCO automatic leveling loop
- Monotonic VCO frequency vs control voltage

## APPLICATIONS

- 900MHz cellular front-end
- 900MHz cordless front-end
- Spread spectrum receivers
- RF data links
- UHF frequency conversion
- Portable radio

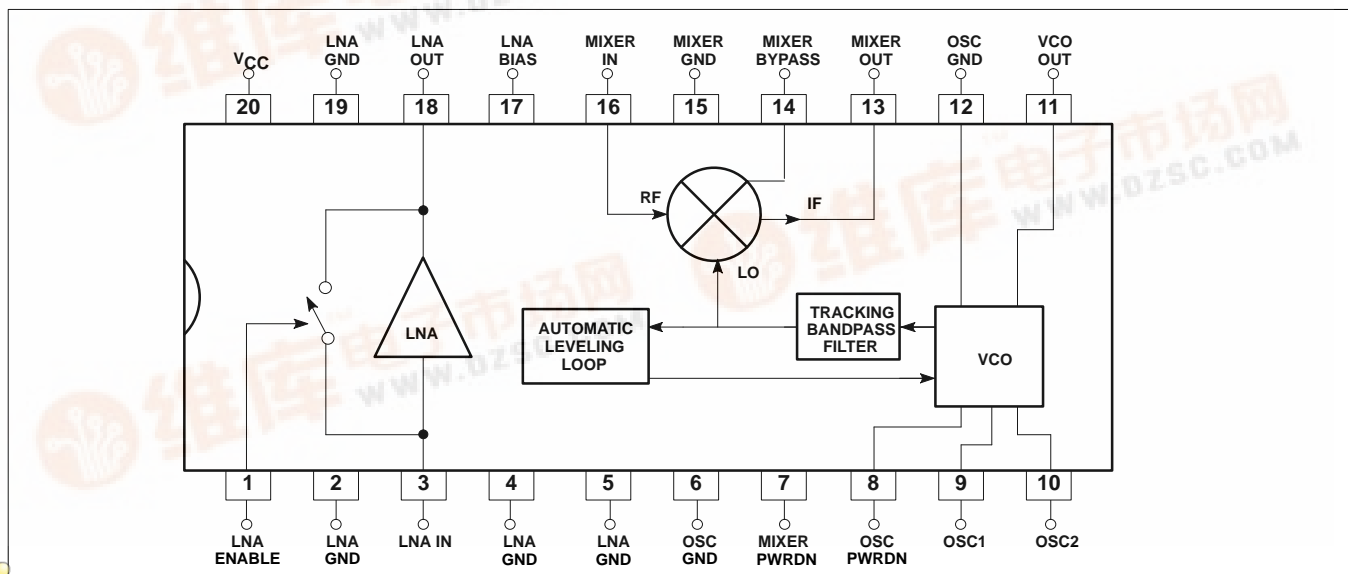
## PIN CONFIGURATION



## ORDERING INFORMATION

| DESCRIPTION   | TEMPERATURE RANGE | ORDER CODE | DWG # |
|---|-------------------|------------|-------|
| 20-Pin Plastic Shrink Small Outline Package (Surface-mount, SSOP) | -40 to +85°C      | SA620DK    | 1563  |

## BLOCK DIAGRAM



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SA620

## ABSOLUTE MAXIMUM RATINGS

| SYMBOL            | PARAMETER  | RATING                          | UNITS |
|-------------------|--|---------------------------------|-------|
| V <sub>CC</sub>   | Supply voltage <sup>1</sup>  | -0.3 to +6                      | V     |
| V <sub>IN</sub>   | Voltage applied to any other pin   | -0.3 to (V <sub>CC</sub> + 0.3) | V     |
| P <sub>D</sub>    | Power dissipation, T <sub>A</sub> = 25°C (still air) <sup>2</sup><br>20-Pin Plastic SSOP | 980                             | mW    |
| T <sub>JMAX</sub> | Maximum operating junction temperature   | 150                             | °C    |
| P <sub>MAX</sub>  | Maximum power input/output   | +20                             | dBm   |
| T <sub>STG</sub>  | Storage temperature range  | -65 to +150                     | °C    |

## NOTE:

- Transients exceeding 8V on V<sub>CC</sub> pin may damage product.
- Maximum dissipation is determined by the operating ambient temperature and the thermal resistance,  $\theta_{JA}$ : 20-Pin SSOP = 110°C/W

## RECOMMENDED OPERATING CONDITIONS

| SYMBOL          | PARAMETER                           | RATING      | UNITS |
|-----------------|-------------------------------------|-------------|-------|
| V <sub>CC</sub> | Supply voltage                      | 2.7 to 5.5  | V     |
| T <sub>A</sub>  | Operating ambient temperature range | -40 to +85  | °C    |
| T <sub>J</sub>  | Operating junction temperature      | -40 to +105 | °C    |

## DC ELECTRICAL CHARACTERISTICS

V<sub>CC</sub> = +3V, T<sub>A</sub> = 25°C; unless otherwise stated.

| SYMBOL                    | PARAMETER  | TEST CONDITIONS            | LIMITS |      |                 | UNITS |
|---------------------------|--|----------------------------|--------|------|-----------------|-------|
|                           |  |                            | MIN    | TYP  | MAX             |       |
| I <sub>CC</sub>           | Supply current                                   | LNA enable input high      |        | 10.4 |                 | mA    |
|                           |  | LNA enable input low       |        | 7.2  |                 | mA    |
|                           |  | VCO power-down input low   |        | 7.4  |                 | mA    |
|                           |  | Mixer power-down input low |        | 7.4  |                 | mA    |
|                           |  | Full chip power-down       |        | 1.2  |                 | mA    |
| V <sub>T</sub>            | Enable logic threshold voltage <sup>NO TAG</sup> |                            | 1.2    | 1.5  | 1.8             | V     |
| V <sub>IH</sub>           | Logic 1 level                                    | RF amp on                  | 2.0    |      | V <sub>CC</sub> | V     |
| V <sub>IL</sub>           | Logic 0 level                                    | RF amp off                 | -0.3   |      | 0.8             | V     |
| I <sub>IL</sub>           | Enable input current                             | Enable = 0.4V              | -1     | 0    | 1               | μA    |
| I <sub>IH</sub>           | Enable input current                             | Enable = 2.4V              | -1     | 0    | 1               | μA    |
| V <sub>LNA-IN</sub>       | LNA input bias voltage                           | Enable = 2.4V              |        | 0.78 |                 | V     |
| V <sub>LNA-OUT</sub><br>T | LNA output bias voltage                          | Enable = 2.4V              |        | 2.1  |                 | V     |
| V <sub>B</sub>            | LNA bias voltage                                 | Enable = 2.4V              |        | 2.1  |                 | V     |
| V <sub>MX-IN</sub>        | Mixer RF input bias voltage                      |                            |        | 0.94 |                 | V     |

## NOTE:

- The ENABLE input must be connected to a valid logic level for proper operation of the SA620 LNA.

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SA620

**AC ELECTRICAL CHARACTERISTICS** $V_{CC} = +3V$ ,  $T_A = 25^{\circ}C$ ; Enable = +3V; unless otherwise stated.

| SYMBOL                   | PARAMETER   | TEST CONDITIONS   | LIMITS       |        |               | UNITS           |
|--------------------------|---|---|--------------|--------|---------------|-----------------|
|                          |   |   | -3 $\sigma$  | TYP    | +3 $\sigma$   |                 |
| $S_{21}$                 | Amplifier gain  | 900MHz  | 10           | 11.5   | 13            | dB              |
| $S_{21}$                 | Amplifier gain in through mode                          | Enable = 0.4V, 900MHz                                     | -9           | -7.5   | -6            | dB              |
| $\Delta S_{21}/\Delta T$ | Gain temperature sensitivity in pwr-dwn mode            | 900MHz  |              | -0.014 |               | dB/ $^{\circ}C$ |
| $\Delta S_{21}/\Delta T$ | Gain temperature sensitivity enabled                    | 900MHz  |              | 0.003  |               | dB/ $^{\circ}C$ |
| $\Delta S_{21}/\Delta f$ | Gain frequency variation                                | 800MHz - 1.2GHz   |              | 0.01   |               | dB/MHz          |
| $S_{12}$                 | Amplifier reverse isolation                             | 900MHz  |              | -20    |               | dB              |
| $S_{11}$                 | Amplifier input match <sup>1</sup>                      | 900MHz  |              | -10    |               | dB              |
| $S_{22}$                 | Amplifier output match <sup>1</sup>                     | 900MHz  |              | -12    |               | dB              |
| $P_{-1dB}$               | Amplifier input 1dB gain compression                    | 900MHz  |              | -16    |               | dBm             |
| IP3                      | Amplifier input third order intercept                   | 900MHz  | -4.5         | -3     | -1.5          | dBm             |
| NF                       | Amplifier noise figure                                  | 900MHz  | 1.3          | 1.6    | 1.9           | dB              |
| $t_{ON}$                 | Amplifier turn-on time (Enable Lo $\rightarrow$ Hi)     | See Figure 1  |              | 50     |               | $\mu s$         |
| $t_{OFF}$                | Amplifier turn-off time (Enable Hi $\rightarrow$ Lo)    | See Figure 1  |              | 5      |               | $\mu s$         |
| $V_{GC}$                 | Mixer voltage conversion gain: $R_P = R_L = 1k\Omega$ , | $f_S = 0.9GHz$ , $f_{LO} = 0.8GHz$ ,<br>$f_{IF} = 100MHz$ | 14.5         | 16     | 17.5          | dB              |
| $P_{GC}$                 | Mixer power conversion gain: $R_P = R_L = 1k\Omega$ ,   | $f_S = 0.9GHz$ , $f_{LO} = 0.8GHz$ ,<br>$f_{IF} = 100MHz$ | 1.5          | 3      | 4.5           | dB              |
| $S_{11M}$                | Mixer input match <sup>1</sup>                          | 900MHz  |              | -10    |               | dB              |
| $NF_M$                   | Mixer SSB noise figure                                  | 900MHz  | 7.5          | 9      | 10.5          | dB              |
| $P_{-1dB}$               | Mixer input 1dB gain compression                        | 900MHz  |              | -13    |               | dBm             |
| IP3 <sub>M</sub>         | Mixer input third order intercept                       | $f_2 - f_1 = 1MHz$ , 900MHz                               | -7.5         | -6     | -4.5          | dBm             |
| IP2 <sub>INT</sub>       | Mixer input second order intercept                      | 900MHz  |              | 12     |               | dBm             |
| $P_{RFM-IF}$             | Mixer RF feedthrough                                    | 900MHz  |              | -20    |               | dB              |
| $P_{LO-IF}$              | LO feedthrough to IF                                    | 900MHz  |              | -25    |               | dBm             |
| $P_{LO-RFM}$             | LO to mixer input feedthrough                           | 900MHz  |              | -30    |               | dBm             |
| $P_{LO-RF}$              | LO to LNA input feedthrough                             | 900MHz  |              | -45    |               | dBm             |
| $P_{VCO}$                | VCO buffer out  | 900MHz  |              | -16    |               | dBm             |
|                          | VCO frequency range                                     |   | 300<br>(min) |        | 1200<br>(max) | MHz             |
|                          | VCO phase noise   | Offset = 60kHz  |              | -105   |               | dBc/Hz          |

**NOTE:**

1. Simple L/C elements are needed to achieve specified return loss.

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SA620

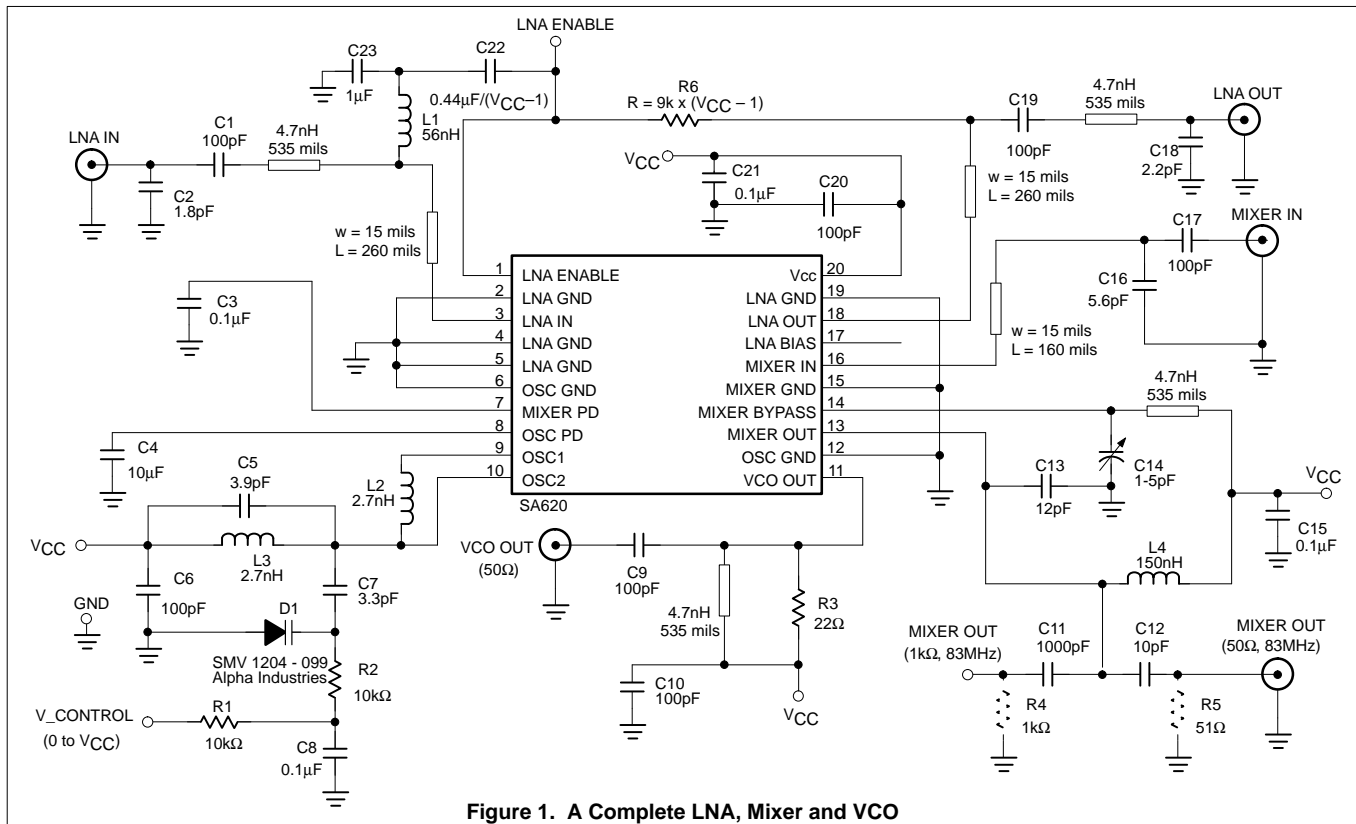


Figure 1. A Complete LNA, Mixer and VCO

## CIRCUIT TECHNOLOGY

## LNA

**Impedance Match:** Intrinsic return loss at the input and output ports is 7dB and 9dB, respectively. With no external matching, the associated LNA gain is  $\approx 10$ dB and the noise figure is  $\approx 1.4$ dB. However, the return loss can be improved at 900MHz using suggested L/C elements (Figure NO TAG) as the LNA is unconditionally stable.

**Noise Match:** The LNA achieves 1.6dB noise figure at 900MHz when  $S_{11} = -10$ dB. Further improvements in  $S_{11}$  will slightly increase the NF and  $S_{21}$ .

**Thru-Mode:** A series switch can be activated to feed RF signals from LNA input to output with an attenuator ( $S_{21} = -7.5$ dB). As a result, the power handling is greatly improved and current consumption is decreased by 3.2mA as well. However, if this mode is not required, C23 and R6 can be deleted.

**Temperature Compensation:** The LNA has a built-in temperature compensation scheme to reduce the gain drift to 0.003dB/°C from  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ .

**Supply Voltage Compensation:** Unique circuitry provides gain stabilization over wide supply voltage range. The gain changes no more than 0.5dB when  $V_{CC}$  increases from 3V to 5V.

## Mixer

**Input Match:** The mixer is configured for maximum gain and best noise figure. The user needs to supply L/C elements to achieve this performance.

**Mixer Bypass:** To optimize the IP3 of the mixer input, one must adjust the value of C14 for the given board layout. The value typically lies between 1 and 5pF. Once a value is selected, a fixed capacitor can be used. Further improvements in mixer IP3 can be achieved by inserting a resistive loss at the mixer input, at the expense of system gain and noise figure.

**Tracking Bandpass Filter:** At the LO input port of the mixer there is a second-order bandpass filter (approx. 50MHz bandwidth) which will track the VCO center frequency. The result is the elimination of low frequency noise injected into the mixer LO port without the need for an external LO filter.

**Power Down:** The mixer can be disabled by connecting Pin 7 to ground. If a Schottky diode is connected between Pin 1 (cathode) and Pin 7 (anode), the LNA disable signal will control both LNA and mixer simultaneously. When the mixer is disabled, 3mA is saved.

**Test Port:** Resistor R5 can be substituted with an external test port of 50Ω input impedance. Since R5 and MIXER OUT have

the same output power, the result is a direct power gain measurement.

## VCO

**Automatic Leveling Loop:** An on-chip detector and loop amplifier will adjust VCO bias current to regulate the VCO amplitude regardless of the Q-factor ( $>10$ ) of the resonator and varactor diode. However, the real current reduction will not occur until the VCO frequency falls below 500MHz. For a typical resonator the steady-state current is 3mA at 800MHz.

**Buffered VCO Output:** The VCO OUT (Pin 11) signal can drive an external prescaler directly (see also the Philips SA7025 low voltage, fractional-N synthesizer). The extracted signal levels need to be limited to  $-16$ dBm or less to maintain mixer IIP3.

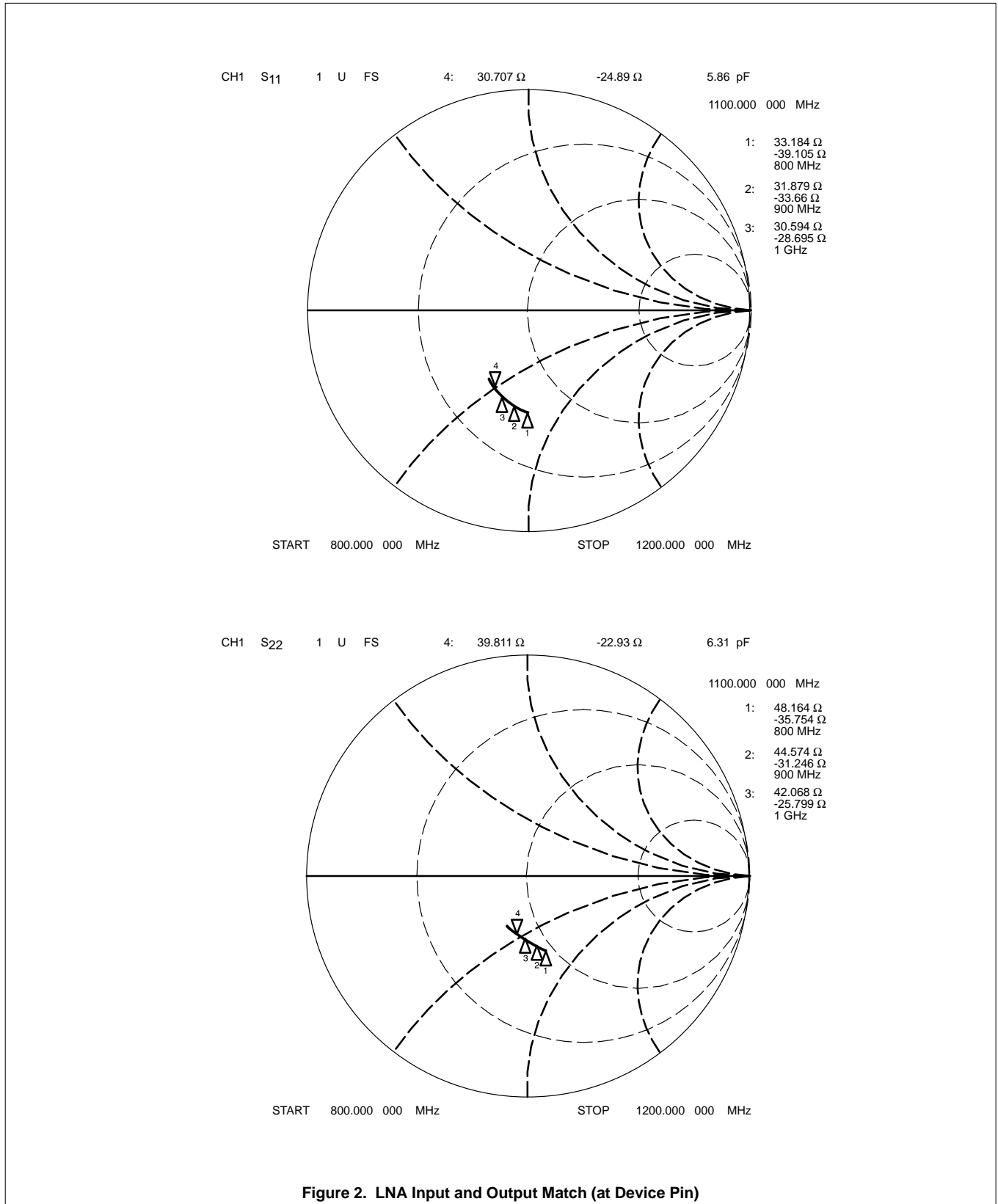
**Phase Noise:** If close-in phase noise is not critical, or if an external synthesizer is used, C4 (Pin 8) can be decreased to a lower value.

**Power-Down:** The VCO can be disabled by connecting Pin 8 to ground. If a Schottky diode is connected between Pin 1 (cathode) and Pin 8 (anode), the LNA disable signal will control both LNA and VCO simultaneously. When the VCO is disabled, 3mA is saved.

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SA620

TYPICAL PERFORMANCE CHARACTERISTICS



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SA620

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

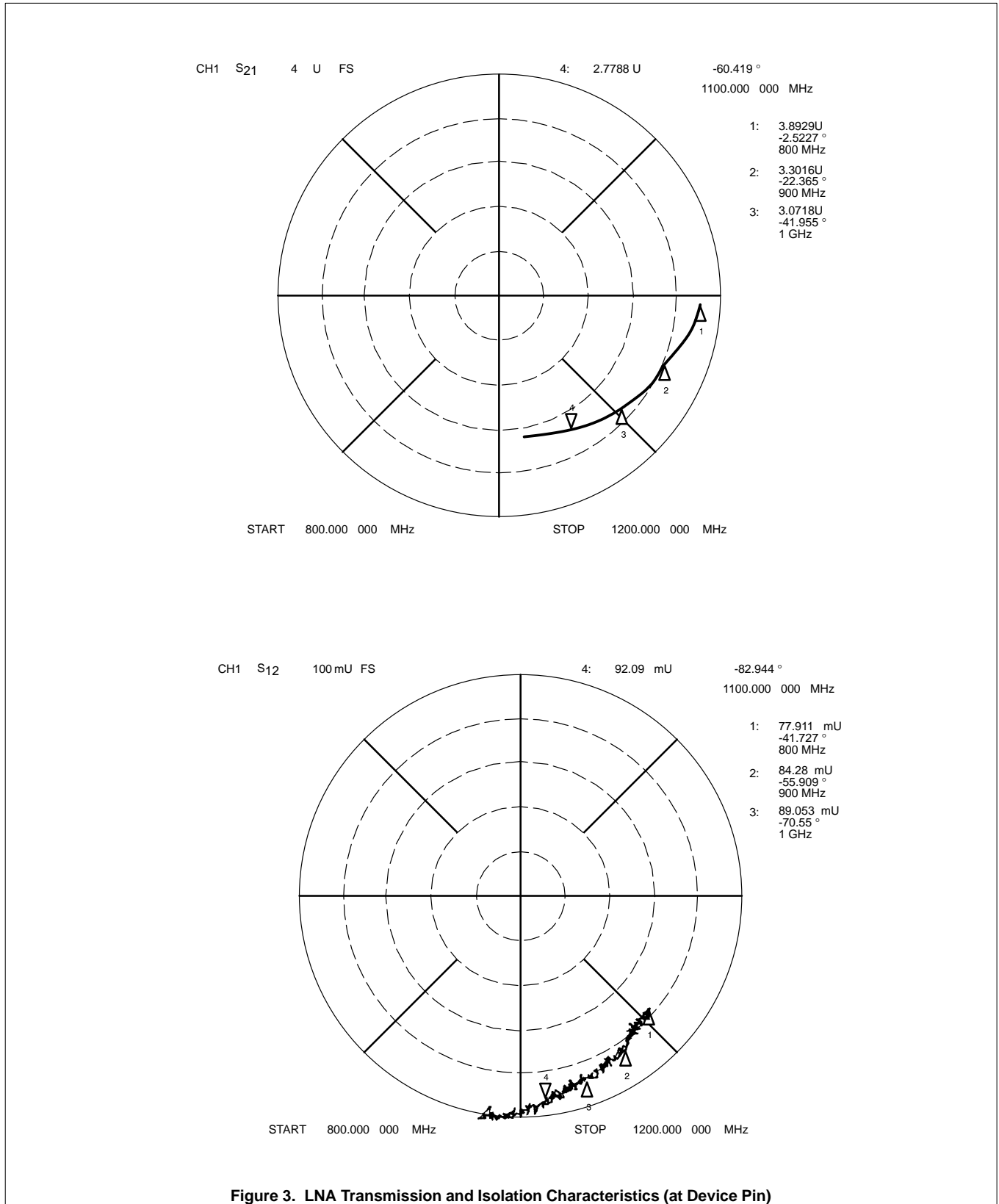
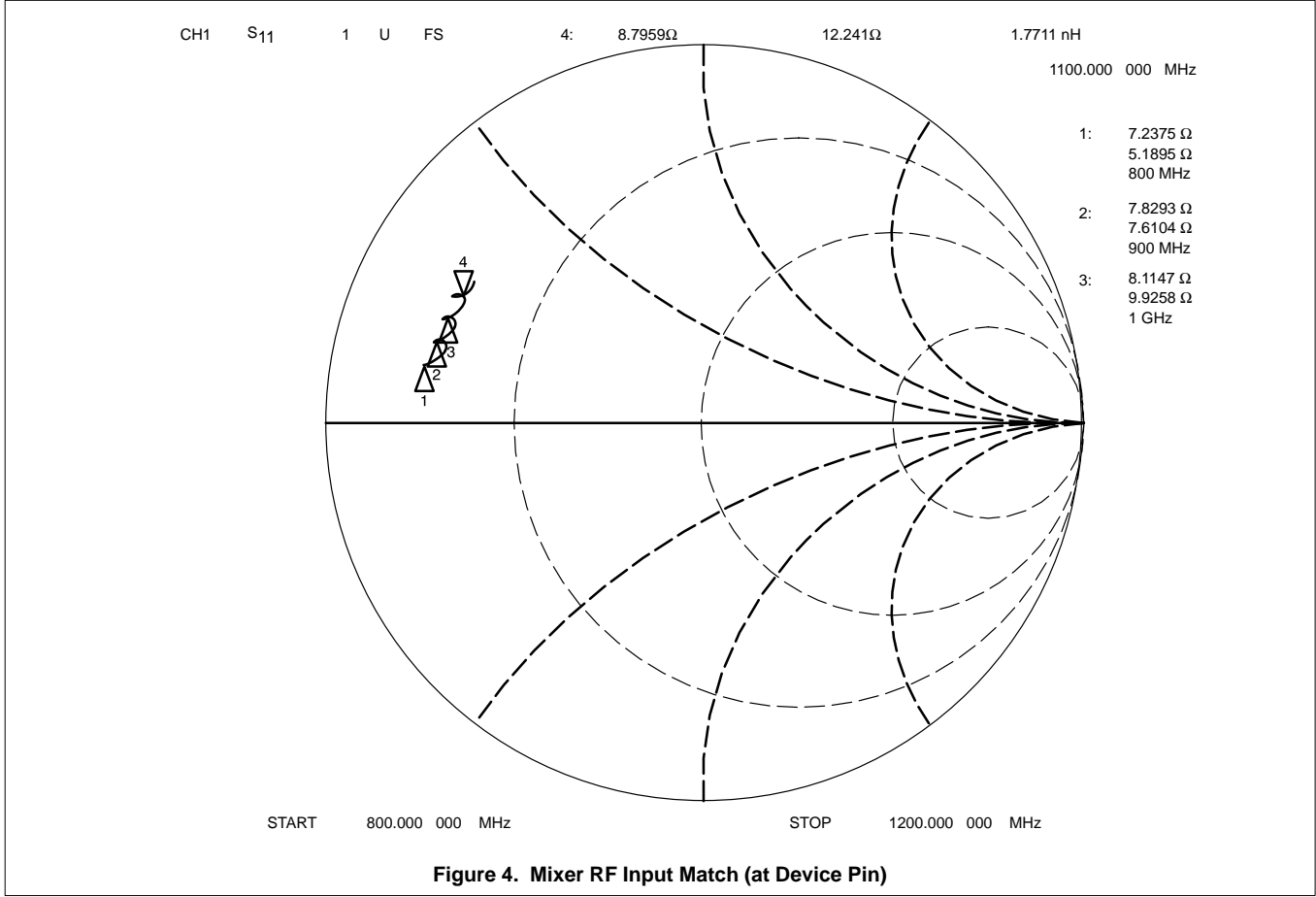


Figure 3. LNA Transmission and Isolation Characteristics (at Device Pin)

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SA620

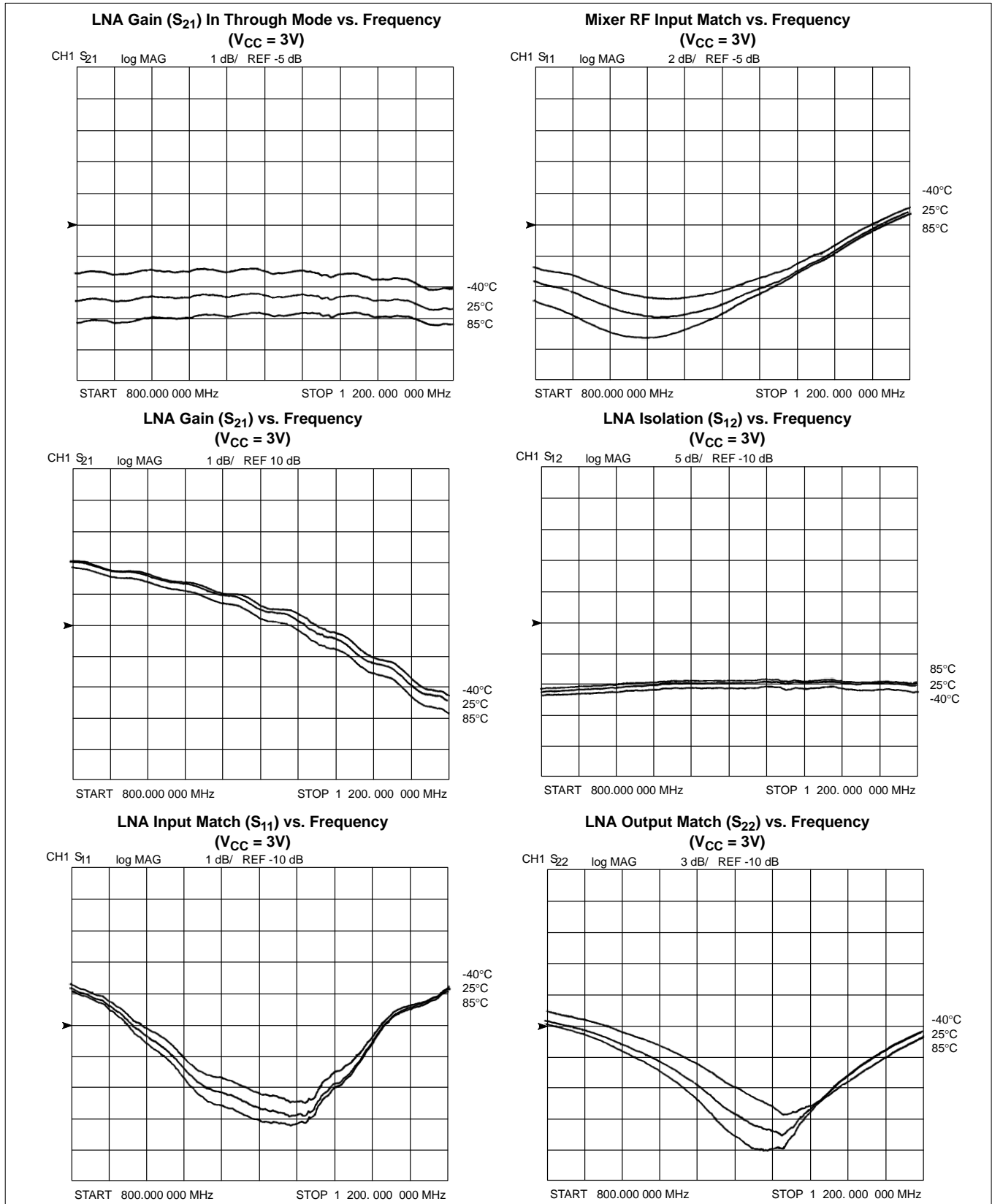
TYPICAL PERFORMANCE CHARACTERISTICS (Continued)



Low voltage LNA, mixer and VCO — 1GHz

SA620

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

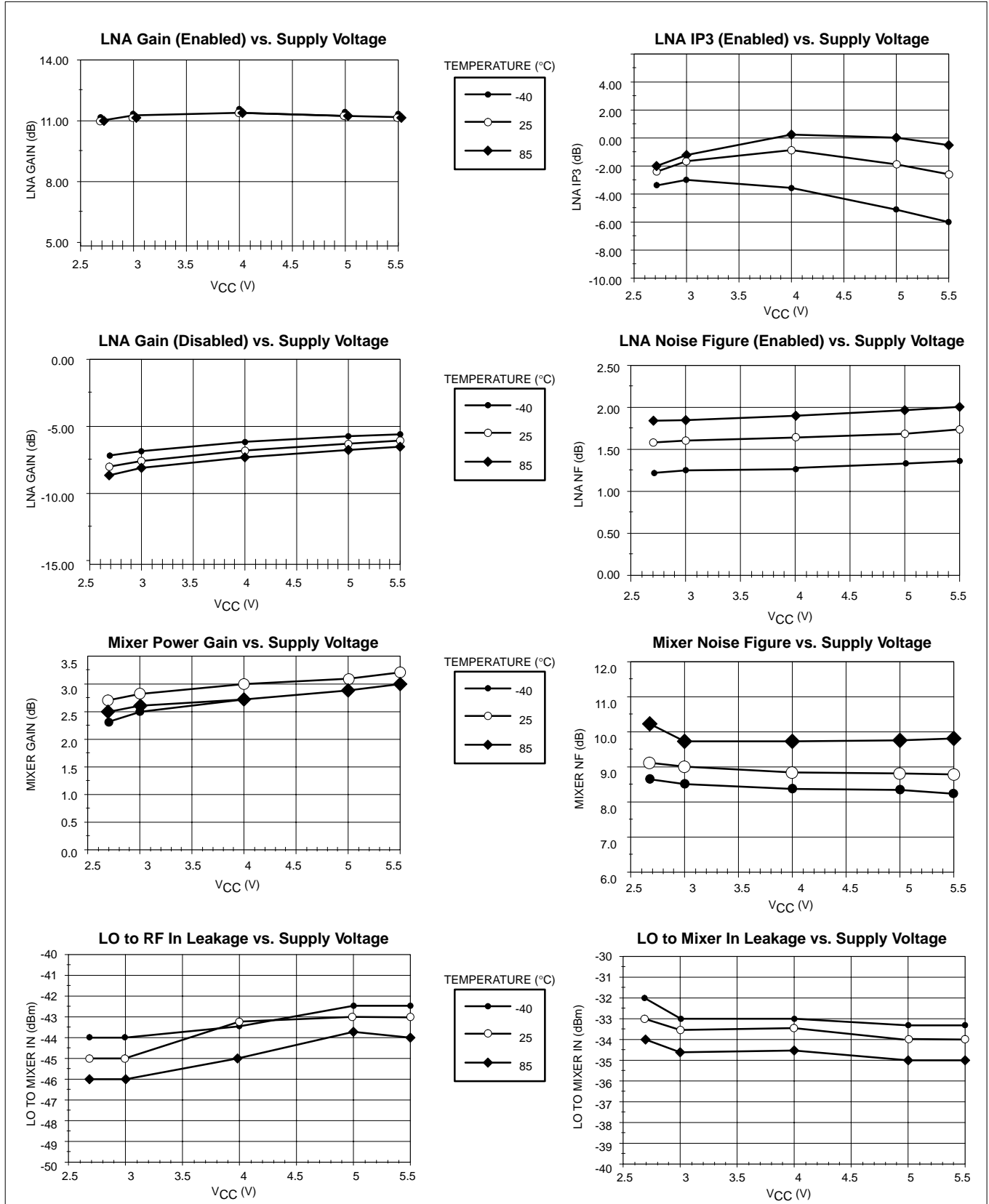




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# SA620

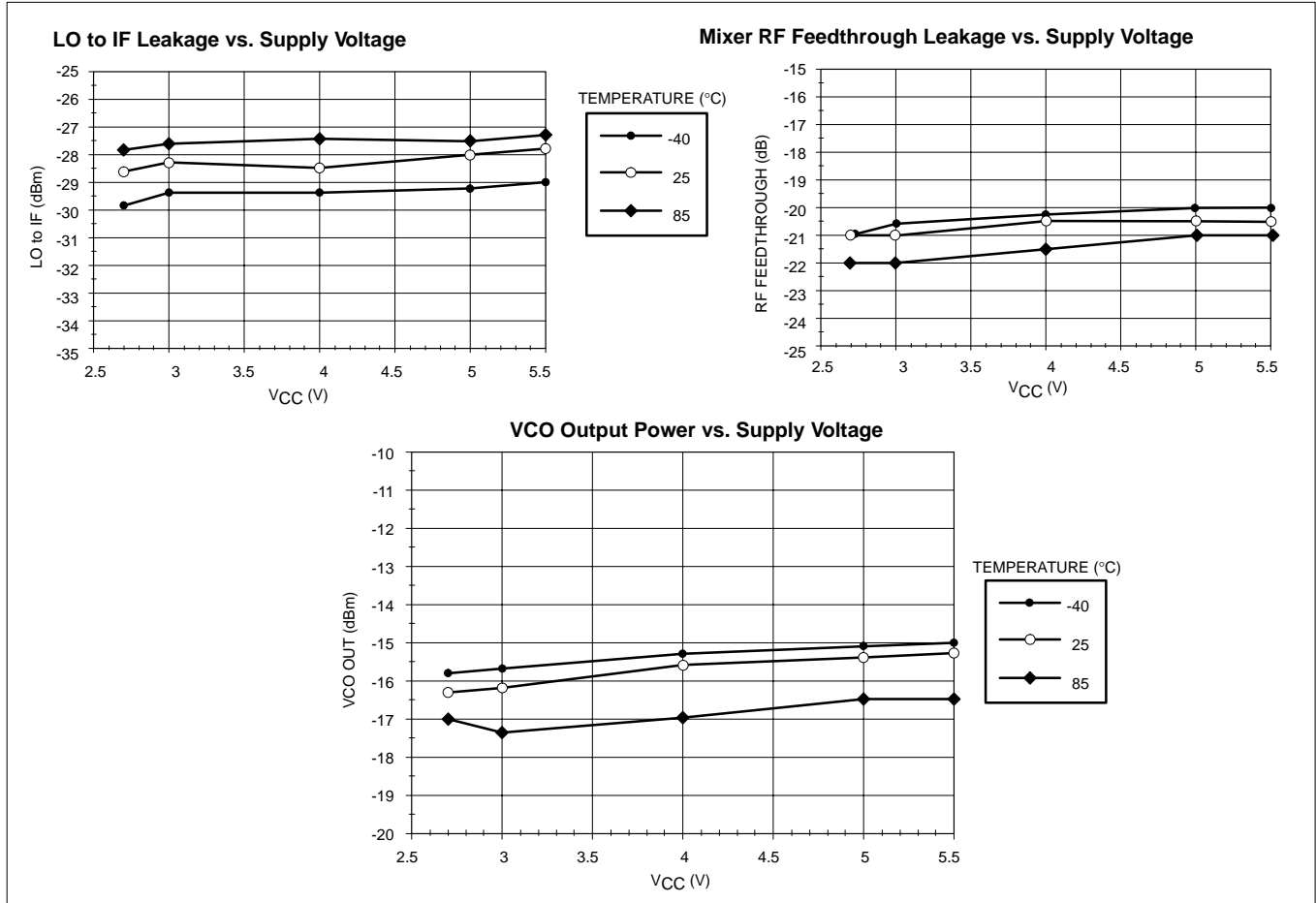
## TYPICAL PERFORMANCE CHARACTERISTICS (Continued)



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## TYPICAL PERFORMANCE CHARACTERISTICS (Continued)



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