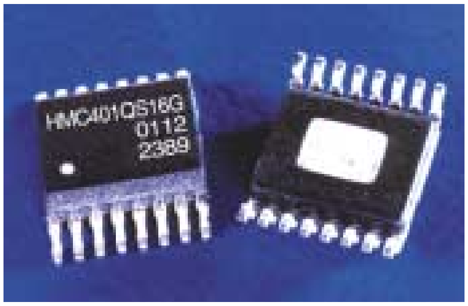

Low Cost Plastic MMIC VCOs

A breakthrough in monolithic microwave integrated circuit (MMIC) design and manufacturing technology has occurred with the introduction of a new multifunction VCO product line. The new VCO's phase noise performance meets commercial communication systems requirements, and the technology is scalable between 3 and 30 GHz. The MMIC VCOs contain the resonator structure, negative resistance circuitry, tuning varactor, a frequency divider to feed the phase locked loop (PLL) and an output buffer amplifier. The center frequency of the VCO is set by the design of the resonator structure, eliminating the need for tuning or staking to set the VCO's center frequency. With the exception of a bypass capacitor on the DC supply line, the MMICs require no external components.

A prescaler brings an output frequency into the range of existing low cost silicon PLLs for phase locking. It is cost efficient to integrate the prescalar onto the VCO, and standard divide ratios (/2, /4 or /8) with single ended or differential outputs are available. The output power delivered from the prescalar is typically 0 to –3 dBm, which is ample for most commercial PLLs. The VCO's primary output signal can be delivered at power levels between –6 dBm and +13 dBm. Integrating the prescalar and buffer amplifier significantly reduces the number of components, size and cost of the synthesizer. Additionally, moving the VCO's output frequency to the desired frequency further reduces size and cost by eliminating an entire multiplier chain.

TABLE I

MMIC VCO STANDARD PRODUCTS

Part Number	Output Frequency (GHz)	Phase Noise at 10 kHz and 100 kHz Offsets (dBc/Hz)	VCO Output Power (dBm)	Features
HMC358MS8G	5.6 to 6.8	–78 –108	+13	high output power with buffer amplifier, +3V operation, SMT package, no external components
HMC398QS16G	13.75 to 14.75 and 1.71875 to 1.84375	–78 –109	+6	buffer amplifier, differential divide by 8 output, SMT package, no external components, single +5V bias
HMC401QS16G	13.1 to 13.8 and 1.6375 to 1.7250	–84 –110	–6	differential divide by 8 output, SMT package, no external components, single +5V bias

STANDARD VCO PRODUCTS

Table 1 summarizes the performance of three standard products that can address a wide range of applications.

The model HMC358MS8G MMIC VCO with a buffer amplifier output operates from 5.6 to 6.8 GHz and is supplied in a MSOP8G package that measures only 3.0 mm × 4.9 mm × 1.0 mm (including leads), which satisfies the PCMCIA height requirements. The oscillator is biased from a single +3 V rail and tunes between 0 and +3 V (up to +8 V possible, depending on the required frequency coverage). Single sideband (SSB) phase noise performance is –78 dBc/Hz and –108 dBc/Hz at 10 kHz and 100 kHz offsets, respectively. The VCO's

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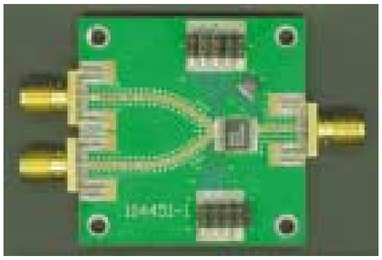
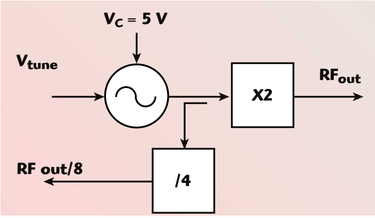
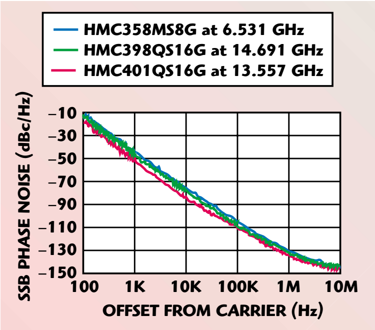
LOW COST PLASTIC MMIC VCOs



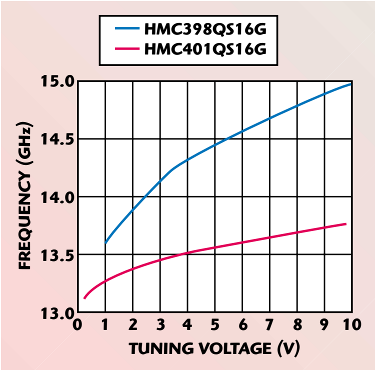
▲ *Fig. 1 Ku-band VCO on an evaluation PCB.*



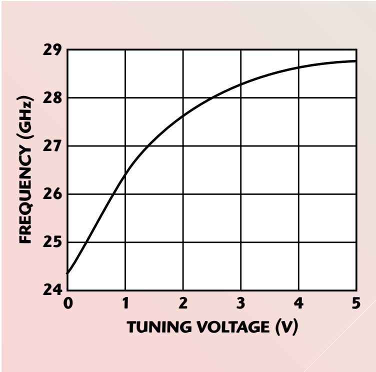
▲ *Fig. 2 HMC398QS16G and HMC401QS16G functional block diagram.*



▲ *Fig. 3 VCO measured phase noise.*

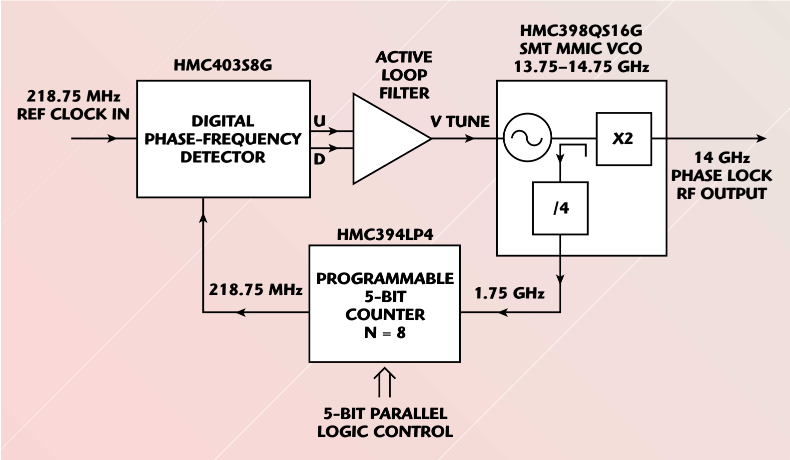


▲ *Fig. 4 Frequency coverage of Ku-band VCOs.*



▲ *Fig. 5 Frequency coverage of 27 GHz VCO.*

▼ *Fig. 6 A 14 GHz PLL circuit using the HMC398QS16G 13.75-14.75 GHz VCO MMIC.*



temperature drift has been measured at 0.5 MHz/°C. This device is ideal for UNII or Hyperlan applications.

The model HMC398QS16G Ku-band VCO operates in a push-push mode at an output frequency of 13.75 to 14.75 GHz and delivers more than +6 dBm. The SSB phase noise for this VCO (V_{tune} = +5V) is –109 dBc/Hz at 100 kHz offset. This VCO has two complementary outputs at one-eighth the output frequency (1.71875 to 1.84375 GHz) for use with a commercially available PLL IC. The drift rate is measured at 1.25 MHz/°C at Ku-band, between –40° to +85° C. Since the resonator for this VCO is operating at one half the output frequency, sub-harmonics at $F_{out}/2$ and $3F_{out}/2$ are present in the output spectrum at a level of less than –25 dBc. Sub-harmonics associated with the prescaler ($nF_{out}/8$) are present in the output spectrum at a level of –70 dBc. The VCO is housed in a plastic QSOP16G occupying an area of only 5.0 mm × 4.0 mm × 1.4 mm. The VCO operates from +5V with a current consumption of 230 mA for the VCO and 65 mA for the prescalar. ***Figure 1*** shows a typical Ku-band VCO mounted on an evaluation PCB.

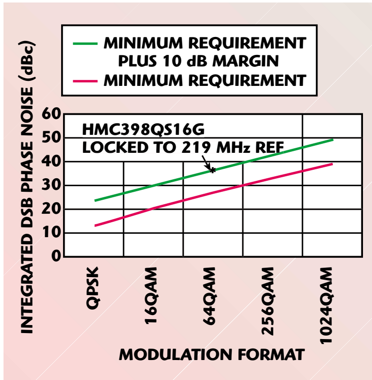
The model HMC401QS16G VCO operates in a push-push mode with an output frequency of 13.1 to 13.8 GHz and delivers –6 dBm. The SSB phase noise for this VCO (V_{tune} = +5V) is –84 dBc/Hz at 10 kHz, and –110 dBc/Hz at 100 kHz offset. This VCO has two complementary outputs at one-eighth the output frequency (1.6375 to 1.725 GHz) for use with a commercially available PLL IC. The VCO is also housed in a plastic QSOP16G. ***Figure 2*** shows a functional block diagram of the models HMC398QS16G and HMC401QS16G, and their associated phase noise and frequency coverage are shown in ***Figures 3*** and ***4***, respectively. Ka-band applications that require sources can also rely on this technology. ***Figure 5*** shows the typical tuning curve of a 27 GHz VCO. Phase noise better than –92 dBc/Hz at 100 kHz at Ka-band has been measured.

MMIC VCO ADVANTAGES

MMIC VCOs can minimize the problems associated with microphonics, vibrations and temperature anomalies because they eliminate chip-to-chip interconnections between the resonator and negative resistance element. These interconnects are often the source of phase transients. Standard plastic packages result in tight quality control on die attach and wire bonding. In addition, these package platforms support high speed electrical test and automated visual inspection of lead co-planarity, package marking, and orientation inside a tape and reel carrier. The packaging processes that are used for these products have previously passed extensive qualification testing, including temperature cycling, autoclave and solderability testing.

LOW COST PLASTIC MMIC VCOs

▲ *Fig. 7 Measured phase noise .*



▲ *Fig. 8 Integrated phase noise requirements for different orders of QAM at 1 × 10e-6 BER.*

AN EXAMPLE 14 GHz MMIC VCO APPLICATION

A 14 GHz phase lock loop using the HMC398QS16G VCO locked to a 218.75 MHz crystal reference oscillator is presented in ***Figure 6***. Using the model HMC403S8G DC to 1.3 GHz digital phase frequency detector that can operate directly with reference oscillators and RF input frequencies up to 1.3 GHz makes phase comparison possible directly at frequencies considerably higher than most other digital phase frequency detectors. This feature allows lower phase noise designs by minimizing the division ratio required with the reference oscillator. Here a 218.75 MHz reference oscillator is utilized directly without frequency division. For this fixed frequency application, the programmable counter is programmed for fixed division by eight. This low parts count design, including decoupling capacitors and a loop filter, takes up less than one square inch of real estate on a printed wiring board. ***Figure 7*** shows the measured phase noise from the free-running VCO and the 14 GHz PLL circuit output.

To determine the suitability of this 14 GHz PLL for high order quadrature amplitude modulation (QAM) in communications systems, the integrated phase noise has been calculated from the plot of measured phase noise versus frequency data. The frequency band used for the integration was 10 kHz to 1 MHz. The double-sided phase noise integrated over this band is –39.2 dBc (corresponding to a 0.5° RMS phase fluctuation). ***Figure 8*** shows the requirements for integrated phase noise to support different orders of QAM for a 1×10^{-6} bit error rate (BER). One plot shows the minimum requirement on phase noise, and the second curve is the same, but shifted up to reflect a 10 dB margin built into the requirement. The chart indicates a –39.2 dBc/Hz integrated phase noise performance from the 14 GHz PLL circuit is suitable for 64 QAM modulation with better than 1×10^{-6} BER.

CONCLUSION

A MMIC VCO product line has been introduced that meets the phase noise performance of today's commercial communication system requirements while featuring low operating voltage, small size and low cost. The new VCOs require no external components and are designed to interface easily with system PLL circuitry. Although the technology is scalable from 3 to 30 GHz, standard versions are currently available in the 5 to 15 GHz frequency range.

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Notes: