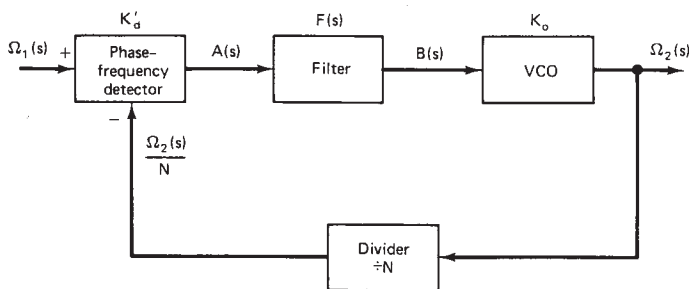
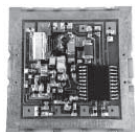


# FREQUENCY SYNTHESIZERS

Voltage controlled oscillators are used as an important part of frequency synthesizers. A frequency synthesizer is a unit that stabilizes the frequency of a free-running oscillator against a stable reference, typically a crystal oscillator. Depending on the reference frequency at the phase detector and the resulting division ratio, the output frequency within the loop bandwidth reflects the properties of the reference. This means that if the division ratio is small and the reference frequency comes from an ultrastable crystal oscillator, the quality of the "locked" VCO frequency is also extremely good. Given a particular phase noise of the crystal oscillator, its performance at the phase-detector level gets multiplied up to the output frequency of the VCO by 20 dB per decade. This means that the phase noise of a 1000-MHz VCO is 20 dB or 10 times noisier than a reference crystal oscillator at 10 MHz at the phase detector. This statement is valid only within the loop bandwidth; outside the loop bandwidth, the properties of the oscillator itself dominate. A vivid example is the application of a ceramic-resonator-based oscillator, which, free-running, exhibits phase noise of -125 dBc/Hz at 10 kHz from the carrier and -153 dBc/Hz at 800 kHz from the carrier, but which, phase-locked, exhibits a phase-noise level determined by noise within the loop bandwidth of 1 kHz.

Figure 1 shows the block diagram of a digital PLL. The reason why it is referred to as "digital" is because the divider is a digital implementation and the phase frequency detector also uses a digital rather than an analog, IC. Analog phase detectors would be double-balanced mixers; a typical digital phase detector is an exclusive OR gate. Given a particular VCO and an integrated circuit as a synthesizer chip, the designer must calculate the values of the loop filter. There are several types of loop filters, and the one with the best performance typically is the type 2, third order. It consists of an active integrator based on an operational amplifier that must exhibit excellent low-noise performance.



Note: The frequency transfer const. of the VCO =  $K_o$   
(not  $\frac{K_o}{s}$ , which is valid for phase transfer only.)

Fig. 1 — Block diagram of a digital PLL before lock is acquired.

Figure 2 shows a loop filter for a type 2 third-order loop. This loop includes *two* integrators: the VCO, and the operational amplifier and its three associated time constants.

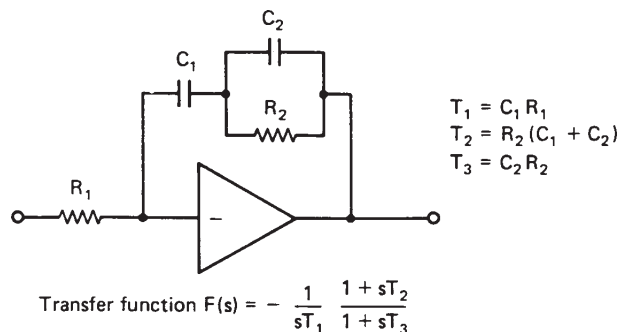


Fig. 2 — Circuit diagram of the loop filter for the third-order loop

This filter can be redrawn as shown in Figure 3. The transfer function for this filter

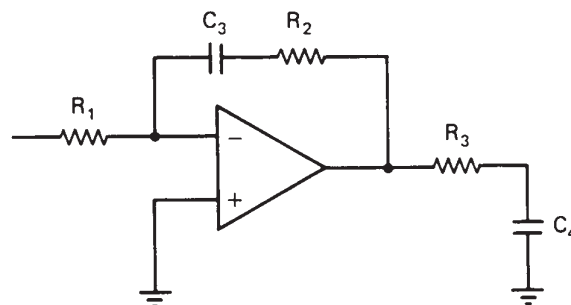
with

$$F(s) = \frac{-1}{s\tau_1} \frac{1+s\tau_2}{1+s\tau_3} \quad (1)$$

$$\tau_1 = C_1 R_1 \quad (2)$$

$$\tau_2 = R_2 (C_1 + C_2) \quad (3)$$

$$\tau_3 = C_2 R_2 \quad (4)$$



$$F(s) = -\frac{1}{C_3 R_1} \frac{1+s/\omega'_z}{s(1+s/\omega_p)} \quad \omega'_z = \frac{1}{R_2 C_3} \quad j\omega_p = \frac{1}{R_3 C_4}$$

Fig. 3 — Circuit diagram of redrawn Figure 2. Note that this is the same type of loop filter as in the type 2 second-order loop with an additional RC time constant.





## DEFINITION OF TERMS

**Output Power** - The output power of a synthesizer, typically expressed in dBm, is measured into a 50 ohm load. The output power varies with frequency and temperature, and is always combined with the specification for output power tolerance.

**Step Size** - The step size frequency in conventional PLL circuits is the same as the reference comparison frequency at the phase detector. It also signifies the change of the output frequency for a step increment or decrement step. In most applications, the step size is dictated by the channel spacing of the radio system.

**Settling Time** - The maximum amount of time required for the output frequency to reach a stable state. The reference and output frequencies reach frequency and phase lock conditions. The major factors that affect settling time are register VCO tuning speed, register loading time, loop filter bandwidth and loop filter order.

**Spurious Reference Frequency Sideband** - Spurious signals that result from unwanted FM modulation in the control lines. The most likely cause is phase detector pulse components that leak through the loop filter.

**Non-Harmonic Spurious** - Spurious sidebands appearing at the output not related to the reference frequency. Modulating signals of any kind at the VCO control line will cause spurious sidebands at the output. Non-Harmonic Sideband spurs usually result from noisy power supply/data lines. Proper AC bypassing and supply decoupling are critical for rejecting non-harmonic sideband spurious. Additionally, good grounding techniques must be exercised.

**Harmonic Output Power** - The harmonic content is measured relative to the output power. Typical harmonic suppression is 10 to 20 dB. In narrow band applications, this parameter can be improved.

**Phase Noise** - affects the system performance in such areas as multiple signal selectivity and signal to noise ratio. The phase noise inside the loop bandwidth of a synthesizer is mainly controlled by the quality of the reference input signal source, loop filter, step size, and noise of the associated circuitry, including the phase detector noise floor. The VCO noise outside the loop is unaffected by the loop parameters.

**Power Supply Requirements** - The VCC1 and VCC2 power supply lines should be well isolated from each other to minimize interference to the VCO control line. The power supply voltage should not change by more than +/-2.5% from the specified specification for proper operation.