

# VCO Application Notes

## Hybrid Voltage Controlled Oscillators

### Introduction

APItech VCOs span 25 MHz to 18 GHz. Varactor tuning diodes are carefully characterized to insure excellent linearity. Eutectic substrate and die attachment and carefully controlled bonding schedules produce consistent high quality, high-performance devices. Typically, tuning bandwidths of 20% to 70% are offered and a range of leaded and surface-mount packages are available. Improved performance is achievable for the customer who requests a narrow bandwidth within a tuning range offered in this catalog.

Typical applications for APItech VCOs include transmitters, receivers, local oscillators, synthesizers for avionics, wireless communications, satellite terminals, satellites, instruments, optical communications, and military electronics systems.

Custom devices based on APItech's large design library are available. We urge you to call us or e-mail us at [communications@apitech.com](mailto:communications@apitech.com) so that we may work together to provide you the best VCO solution.

### General Characteristics of APItech's VCOs

VCOs that cover the frequency range from 25 MHz up to 13 GHz are most often silicon bipolar transistor based designs. Some of the higher frequency VCOs may be GaAs based realizations. Excellent phase noise is achieved through the use of silicon, glass passivated abrupt junction diodes for narrow band applications. Hyperabrupt junction diodes provide linear tuning characteristics for broadband applications. Various output power options are available by adjustment of the DC bias voltage and RF output attenuator circuitry in each design or by adding a MMIC buffer amplifier.

Both abrupt junction and hyperabrupt junction varactors are used in APItech VCOs. Abrupt junction varactors tend to have higher Q's and therefore a slightly better phase noise is achievable. Hyperabrupt junction varactors allow the VCO to achieve a greater tuning bandwidth with a lower tuning voltage range and a smaller modulation sensitivity ratio.

### Frequency Range

The APItech line of VCOs covers the frequency range from 25 MHz to 18 GHz in octave and sub-octave bandwidth units. Higher frequency units are available on a custom basis.

### Power Output

Output Power ranges from +7 to +10 dBm minimum. HVA series VCOs include integral amplifiers which can increase output power. The output power of a typical 5 GHz VCO will drop approximately 1 dB as the temperature is increased to +85°C. Conversely, the output power will increase approximately 1 dB as the temperature is reduced to -55°C. Lower frequency units generally exhibit less output power variation with temperature changes.

### Tuning Characteristics

The tuning characteristics of a VCO are determined primarily by the C-V characteristic of the tuning varactor used in the oscillator. Hyperabrupt tuning varactors provide a greater capacitance change than do abrupt junction varactors and have more linear frequency versus voltage characteristics. For these reasons, hyperabrupt varactors are used in all of APItech's octave bandwidth VCOs and many sub-octave bandwidth VCOs.

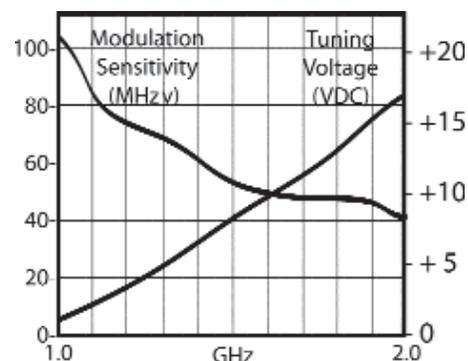


Figure 1

The tuning linearity of VCOs is generally defined as the maximum frequency deviation from the best fit straight line drawn through the actual tuning curve. The tuning linearity can be expressed in MHz or, when

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divided by the VCO frequency, in percentage, e.g.  $\pm 5\%$  from a best fit straight line.

The modulation sensitivity (Mod Sense) of a VCO is the slope of the frequency versus tuning voltage curve at any point on the curve expressed in MHz/V. The ratio of the maximum to minimum Mod Sense is often specified in lieu of linearity. If the Mod Sense ratio is expressed as a percentage it must not be confused with tuning linearity as a percentage from best fit straight line.

Specifying the exact tuning curve, linearity, Mod Sense and/or Mod Sense ratio for a particular VCO can require a very specific varactor C-V profile and can add significantly to the cost of the VCO. Care should be taken to only specify the tuning characteristics actually required by the application.

### Tuning Speed

The tuning speed and the modulation bandwidth of a VCO are generally determined by the internal filter capacitor on the tuning input port and the tuning drive impedance that is being used external to the VCO. The internal filter capacitor is typically 100 - 200 pf. A rough approximation of a VCOs 3dB modulation bandwidth is the reciprocal of the product (6 times the drive resistance times the VCOs input shunt capacitance).

### Phase Noise and Its Effects on Your PLL

Typical SSB phase noise characteristics for an HV87T-4 at room temperature is shown in Figure 2. Phase noise will typically degrade less than 5 dB at the temperature extremes.

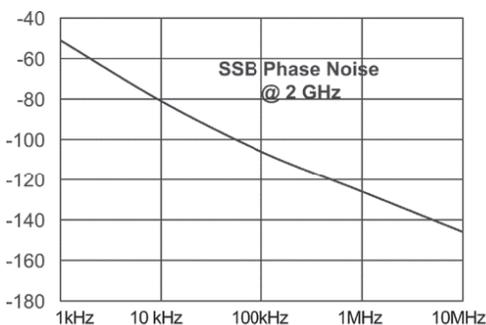


Figure 2 HV87T-4

### High Reliability Options

The design, construction techniques and wide operating temperature range of APITech VCOs make them suitable for applications in military electronics, avionics, spacecraft systems, and a wide variety of commercial wireless systems. The following paragraphs show options available for testing and screening. Contact APITech for price and availability.

**Commercial Products:** Unless otherwise specified by the customer, APITech commercial VCOs are a 100% tested using go/no-go procedures at room temperature. In addition, data on five units from each manufacturing lot are recorded and kept on file at APITech for a minimum of 3 years. This sample data is available for customer inspection on request. If individual unit test data and serialization are required, they can be procured for a charge and a special model number will be assigned.

**Military Grade:** Unless otherwise specified by the customer specifications or purchase order, commercial products will be supplied for military application with special attention given to temperature range and other environmental requirements. Customer specification control drawing requirements can be quoted and usually result in the assignment of a special model number. This insures that unique manufacturing documentation will be created for the specified product and that changes will not be made without customer approval.

### APITech Screening

**"A" Screening:** Adding an "A" to the end of a APITech VCO model number will designate customer specified screening which will be added to the manufacturing procedures for the VCO specified.

**"Q" Screening:** Adding a "Q" to the end of a catalog APITech VCO Model number will add the requirements for the following screening (see Table 1). These procedures are based on the requirements of MIL-PRF-38534 for Class H devices.

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Element parts are selected to maintain a monometallic (gold) system to prevent the formation of intermetallic compounds. Inductors for higher frequency applications are etched on the substrate. For lower frequency applications, inductors and transformers are realized with core and wire structures. The wires are gap welded to the thin film substrate and the cores are attached to the housing with a low outgassing structural adhesive. For products that require PIND testing, a small amount of dielectric gel is often applied to the inside package cover to capture loose particles. The hybrid designs are packaged into standard hermetically sealed gold-plated packages such as T0-8, flatpack, and ceramic surface mount configurations. Element evaluation, process control, screening and quality conformance are implemented per the customer's requirements

### **Phase Noise and Its Effects on Your PLL**

The center of a Phase Locked Loop is a voltage-controlled oscillator which is locked to a reference frequency. The lock is accomplished using the DC output from a Phase Detector in the loop which is amplified and lowpass filtered providing the correction voltage for the VCO. Phase noise of a PLL output is influenced by the reference signal, loop dividers, loop bandwidth (set by the lowpass filter), and of paramount importance, the VCO. While a clean reference source combined with the extremely high low frequency loop gain will "wipe off" noise within the loop bandwidth, divider and reference spurs often dictate a narrow loop bandwidth. This places the burden of low phase noise on the VCO, since the overall phase noise is equal to that of the free running VCO at carrier offsets outside the loop bandwidth.

### **Pushing**

Frequency pushing refers to the change in output frequency due to a variation in supply voltage. Likewise, power pushing refers to a change in output power due to a supply voltage variation. APITech

specifies frequency pushing (in MHz/Volt) due to a small change in supply voltage. Pushing can also be stated as the change caused by a specific variation in supply voltage. Voltage regulators can be integrated into the VCO to minimize pushing should large variations in supply voltage be anticipated. The pushing factor cannot be used to precisely calculate the susceptibility of the VCO to power supply ripple. The susceptibility of the VCO to ripple will depend on the frequency of the ripple, and the amount of filtering within the VCO.

### **Supply Voltage**

The supply voltage of many catalog VCOs is typically +15 VDC. Other supply voltages between +5 and +24 VDC, as well as negative voltages, are commonly accommodated. Bias current required can also be reduced for custom applications. It should be noted that significant reductions in bias current must be traded off against reduced output power or less output isolation, the latter resulting in greater susceptibility to pulling.

### **Spurious and Harmonics**

APITech VCOs are generally free of spurious outputs. Power supply ripple, on either the tuning voltage or bias voltage, can modulate the VCO causing spurious outputs. To the extent size will allow, filtering can be implemented to minimize the effects of bias voltage ripple. Harmonic levels vary from less than -20 dBc for narrow band VCOs to less than -10 dBc for some octave bandwidth units. Filters can be integrated into narrow units to reduce harmonic output. Voltage tunable filters are used to reduce harmonics in octave bandwidth units.

### **Pulling**

The pulling factor of a VCO quantifies its susceptibility to output load variations. Frequency pulling (of power pulling) specifies the change in output frequency (or power) caused by operating the unit into all phases of a specified mismatch. APITech specifies frequency pulling in MHz p-p (peak-to-peak) into all

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phases of a 12 dB return loss (1.67:1 VSWR). Some APITech VCOs contain integral buffer amplifier stages that add output isolation and reduce pulling characteristics.

### **Packaging**

APITech VCOs are available in a variety of packages including TO-8, flatpack, and surface mount, as well as with SMA connectors.