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LVS400 VCO Design Pack
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LVS400 VCO Design Pack

The LVS400 VCO Design Pack provides everything you need to incorporate the LVS400 high performance VCO into your designs. The Design Pack contains:

1. Design Report (containing: LVS400 schematic, design notes, parts list and hard copy of PCB layout)
2. PCB Layout on disk (Protel PCB file, Gerber file, DXF file)
3. Prototype VCO with test results (at 25C) for Tuning Law, Output Power and Phase Noise

Purchase of an LVS400 Design Pack entitles essentially unlimited usage of this design within one organization. There are no ongoing royalties. Visit www.radiolab.com.au for detailed conditions of sale.

LVS400 VCO

The LVS400 is a high-performance, very low phase noise, voltage controlled oscillator design intended for use in high performance communications equipment. Key features are:

- Low phase noise, -120dBc/Hz at 10kHz offset
- Linear tuning over most of frequency range
- LC resonator using surface mount components
- Standard PCB using 1.6mm (60mil) double-sided FR4, also suitable for multilayer boards.
- PCB area required less than 17.5mm x 17.5mm (0.7" x 0.7")
- Uses all standard surface mount components for automated manufacture

The LVS400 VCO fits in a shielded enclosure as small as 0.75" x 0.75" x 0.3" as shown below.

Typical VCO on prototype board as supplied in Design Pack.

PERFORMANCE SUMMARY	
Frequency Range	400–490MHz (see Fig 1)
Output Power (into 50Ω)	+6 dBm (typ)
Output Power Variation with Frequency	±1.5dB (see Fig 3)
Tuning Voltage (V_t)	0 – 28V (see Fig 1)
Tuning Sensitivity (K_v)	6 – 9MHz/V (see Fig 2)
Frequency Pulling ($\lvert\Gamma\rvert = -12$dB)	0.9MHz p-p
Frequency Pushing	0.25MHz/V
Supply Voltage (V_s)	9V
Supply Current (I_s)	22mA

Note that it is not recommended to rely on operation with $V_t<1$V. The LVS400 VCO consists of a single transistor oscillator with resonator and tuning components optimized for linear tuning and low phase noise. An audio transistor is used in an active bias arrangement. All components are rated over –40C to +85C.

IMPLEMENTATION DETAILS	
Components	All surface mount (except optional shield)
Resistors	0603 thick film
Capacitors	0603 NPO Ceramic 0603 X7R Ceramic 1µF Tantalum in bias cct
Inductors	0805 RFC's (decoupling only)
Resonator	Coilcraft "Mini Spring" inductor
RF Transistor	SOT123 BFR93A (Philips/Siemens)
AF Transistor	SOT123 BC849 (Philips/Siemens/Motorola)
Varactor Diodes	SOD323 BB149 (Philips)
Shield (optional)[1]	Leader Tech 24-CBS

Note 1: Some shielding will normally be required to prevent unwanted radiation from the resonator inductor. Whether this is a compact shield over just the VCO as on the prototype board, or whether it is a shield over a larger circuit block (e.g. synthesizer) is a matter of choice in the final design.

Typical performance characteristics (T_{amb} = 25C, V_s = +9V and RF output load of 50Ω unless otherwise specified):

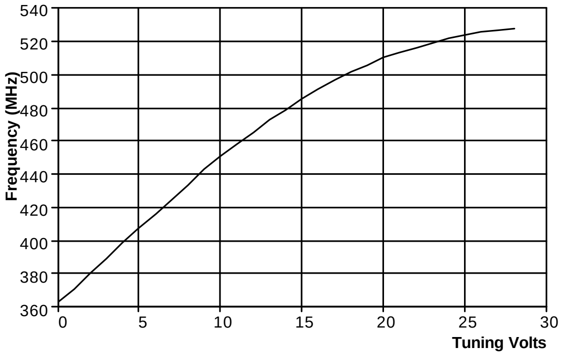


Figure 1 - Tuning Law

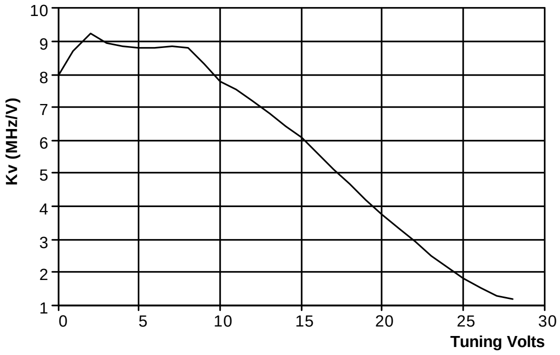


Figure 2 - K_v Variation with Tuning Voltage

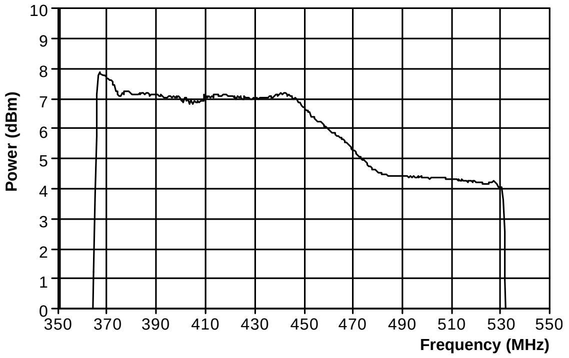


Figure 3 - Output Power vs Frequency

Figure 4 - Phase Noise at 400MHz

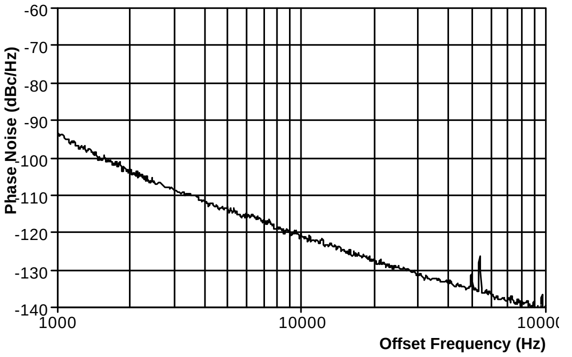


Figure 5 - Phase Noise at 450MHz

Figure 6 - Phase Noise at 500MHz

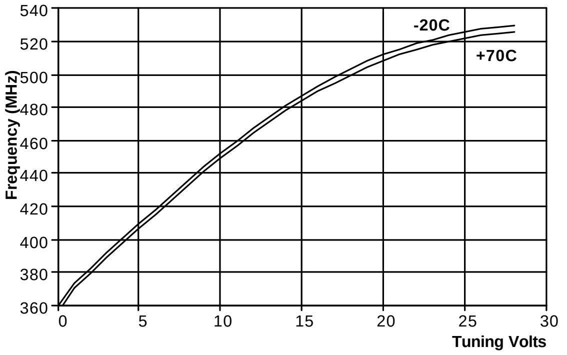


Figure 7 - Tuning Law over Temperature

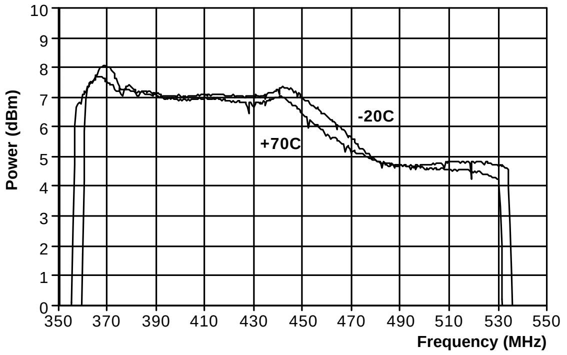


Figure 8 - Output Power over Temperature

Frequency (MHz)	Frequency Pulling	Frequency Pushing	
	|Γ| = -12dB (MHz p-p)	V_s = 8V (kHz)	V_s = 10V (kHz)
400	0.84	+80	-130
450	0.69	+115	-170
500	0.90	+160	-245

Table 1 – Typical Frequency Pushing and Pulling Data

Tuning Range Variation due to Component Tolerances

The nominal tuning range of the LVS400 design (400 to 490MHz) is considerably smaller than the 365 to 525MHz shown in Figure 1. The difference is to account for a likely spread in performance caused by component tolerances. The oscillation frequency is affected by variations in:

1. capacitor values
2. resonator inductor value
3. varactor capacitance
4. transistor parameters
5. other manufacturing variations (PCB, placement etc.)

The effect of variations 1-3 has been modelled. The effect of transistor parameter variations have not been included due to the unavailability of reliable data, however as the transistor f_T is much greater than the oscillation frequency, it is likely that this effect is much smaller than the resonator tolerance effects. Laboratory experience from swapping transistors in VCO's supports this. Other manufacturing variations are likely to have much smaller effect than variations in resonator elements.

The modelling included variations in all capacitors (apart from those used for bypass) in the VCO. These are all NPO ceramic. The tolerances used for these capacitors were:

Value	Tolerance
0.47pF – 4.7pF	± 0.25pF
5.6pF – 8.2pF	± 0.5pF
≥ 10pF	± 5%

Closer tolerance capacitors could be used with a reduction in tuning spread. The resonator inductor is a Coilcraft Mini Spring unit and is available with 2% or 5% tolerance and results are given for both. The only other inductors are RFC's used for decoupling and these were ignored. The tolerance on the varactor capacitance was estimated from the manufacturer's data sheet.

At each of two tuning voltages (5V and 15V), two analyses were performed:

1. Worst case analysis: The maximum effect of each component variation was determined and accumulated to give a worst case frequency offset.
2. Monte-Carlo simulation, assuming that the values for each component are **uniformly** distributed over the range {nominal value ± tolerance}. The simulation created 100,000 VCO's with random component values (in accordance with the tolerances). Histograms of frequencies at tuning voltages of 5V and 15V and of the frequency span *f(15)-f(5)* were created, allowing the 99% and 99.9% deviation limits to be determined.

The results are given in the following table:

L Tolerance (%)	V_t = 5V			V_t = 15V		
	99% Frequency Variation (MHz)	99.9% Frequency Variation (MHz)	Worst Case Frequency Variation (MHz)	99% Frequency Variation (MHz)	99.9% Frequency Variation (MHz)	Worst Case Frequency Variation (MHz)
2	10.4	12.4	17	14.4	17	22.2
5	14.6	16.8	22.1	18.8	22	28.2

Table 2 - Simulated Frequency Variations due to Component Tolerances

These results indicate that if a 2% tolerance inductor is used, the VCO frequency with $V_t = 5\text{V}$ should vary by no more than ± 17MHz. However, this would be highly unlikely and 99.9% of the time the frequency should be within ± 12.4MHz. Given the tuning sensitivity of 9MHz/V at this point, the VCO voltage needed to produce a desired frequency should vary by no more than ± 1.4V in 99.9% of the units.

For the same components the deviation of the VCO frequency at $V_t = 15\text{V}$ has a worst case variation of 22.2MHz, but 99.9% of the time would be expected to be within ± 17MHz.

Whilst the prime effect of component variations is to move the tuning curve in Figure 1 up and down, there is also some impact on the slope of the curve. For each combination of component values used in the simulation above, the tuning range *f(15) – f(5)* was also determined. The variations in the tuning range were entered into a histogram enabling their statistics to be determined. The results are given in the following table.

L Tolerance	Simulated Tuning Range *f(15) – f(5)* MHz	99% Tuning Range Variation MHz	99.9% Tuning Range Variation MHz	Worst Case Tuning Range Variation MHz
2%	70	6.0	6.8	8.3
5%	70	6.4	7.4	9.1

Table 3 - Tuning Range Variation

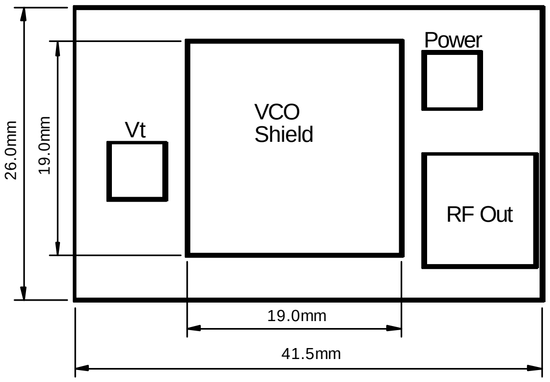
These results indicate that the worst case variation in the tuning range is 8.3MHz (assuming 2% inductor) and that 99.9% of the time it will be less than 6.8MHz.

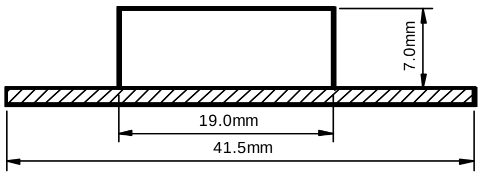
Further details of the sensitivity analysis, along with individual component sensitivities, are provided in the Design Pack.

It is important to note that the actual useful tuning range will vary from application to application.

Note that the modelling process we use is approximate and includes estimations of some significant layout parasitic components. These estimates are chosen to make to simulated performance agree more closely with the measured results. Component values are then changed to estimate the effect of these changes on the output frequency. Whilst we believe that this modelling data gives a reasonably accurate estimate of the frequency variations caused by component variations, independent verification (preferably by a small production run) is essential to provide accurate data in any particular production environment.

Prototype PCB dimensions:





Prototype PCB Connections:

RF Out: SMB male
Power: two-way 0.1" header (Vs, Ground)
Control Voltage: two-way 0.1" header (Vt, Ground)

Shield Dimensions: 19mm x 19mm x 7mm. PCB clearance required for shield is approximately 21mm x 21mm.

Applied Radio Labs reserves the right to make changes, without further notice, to the product described in this document. The suitability of the design for any application must be determined by the customer using normal engineering practices, and must include independent testing and analysis. The customer's technical experts must validate "typical" performance data for each specific application. Applied Radio Labs makes no warranty or representation regarding the suitability of this design for any particular application. Whilst Applied Radio Labs are not aware of any patents covering any aspects of this design, no warranty is provided that the design does not infringe the patent rights of third parties. Applied Radio Labs will not be liable for any damages of any kind incurred from the application or use of this information.

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