ANALYSIS OF VCXO

AS PART OF GPS FREQUENCY STANDARD

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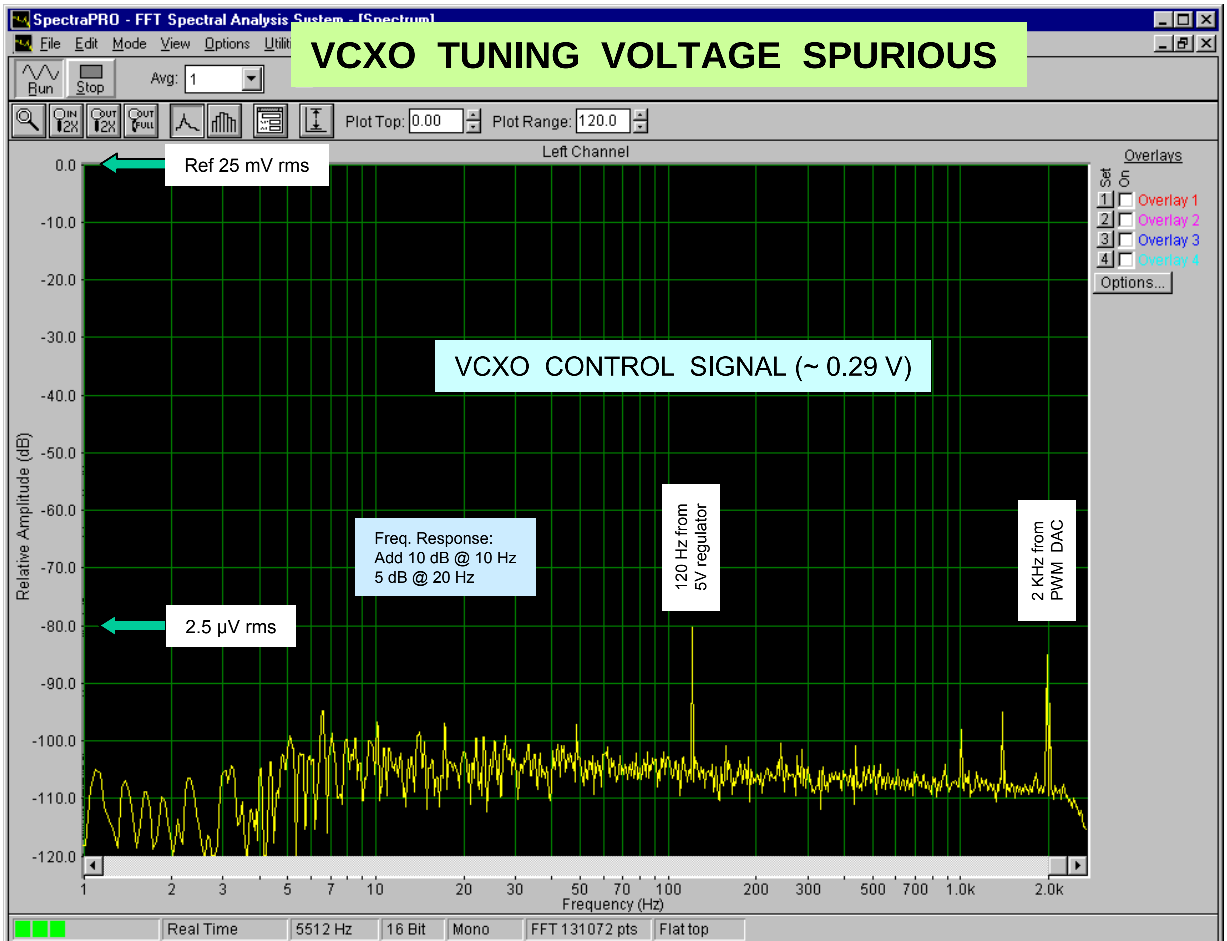
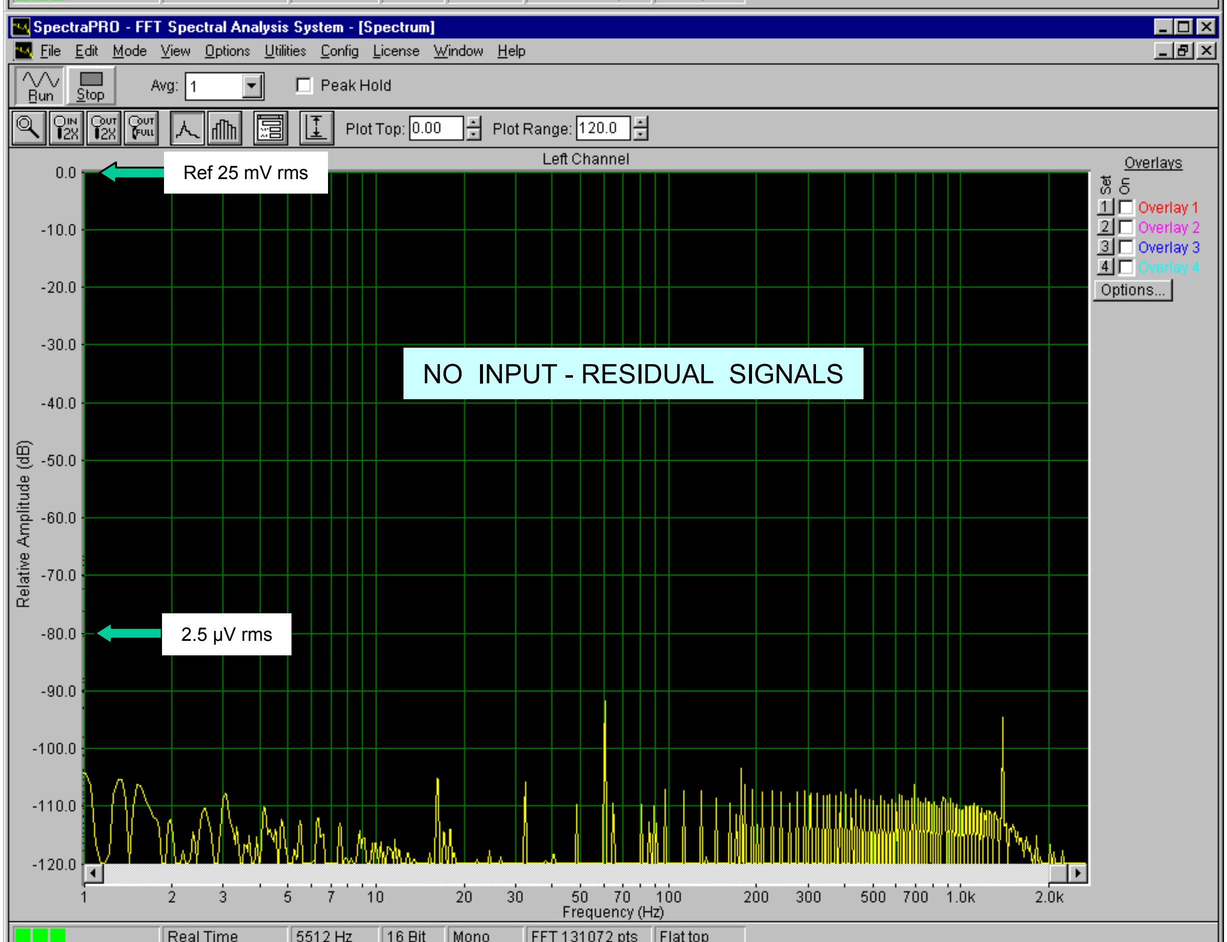
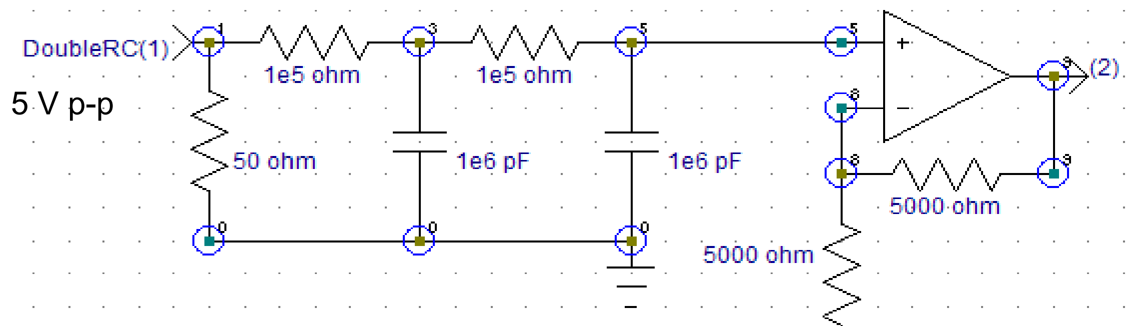
VCXO TUNING VOLTAGE SPURIOUS

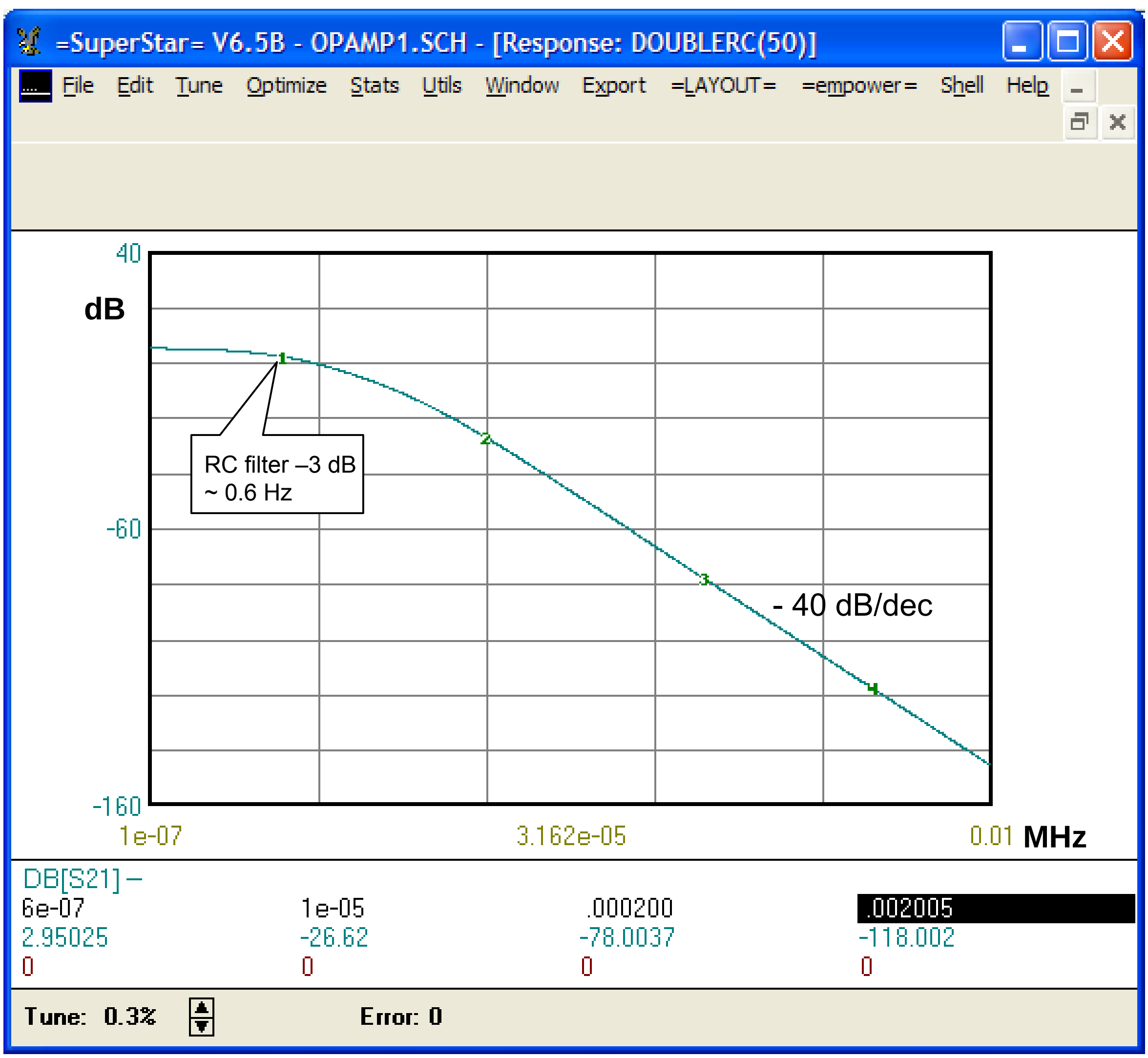




Spurious coming from PWM 5 V p-p drive

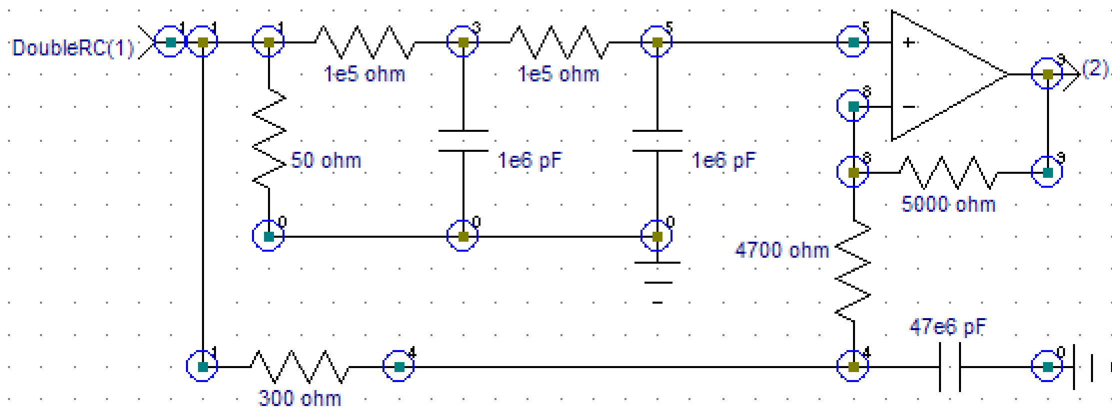


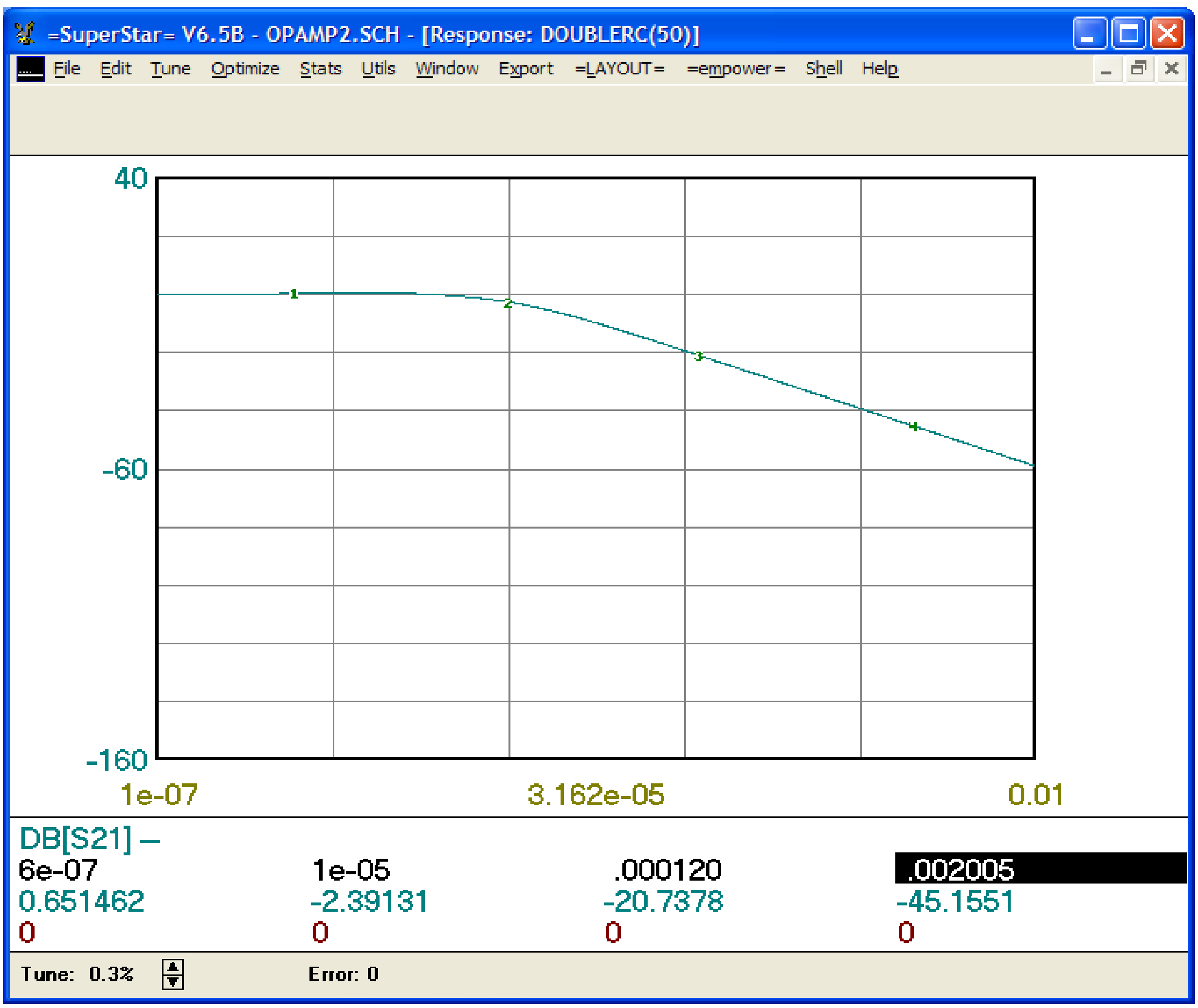
RC Filter circuit simulation for 5 V p-p PWM



Notes: We have 118 dB atten at 2 KHz, With 5 V p-p input, gives 2.2 uV rms at output, 1.4 uV was measured (-85 dB below 25 mV)

Spurious coming from 120 Hz regulator ripple

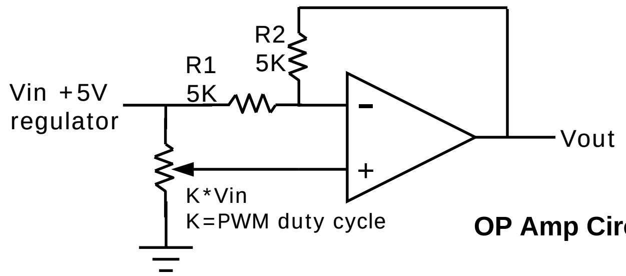




Above circuit gives -20.7 dB attenuation at 120 Hz.

The 7805, 5 V regulator has ~ 1 V p-p ripple at input (measured)
Spec: 80 dB rejection, giving 0.1 mV p-p at output or 35 uV RMS
This is attenuated 20.7 dB, (provided by 300 Ω + 47 μF) giving: 3.2 uV RMS
Measured value = 2.5 uV

Frequency shifts caused by +5V DC stability



OP Amp Circuit Simulation – DC to ~ 0.1 Hz

A divider with a transfer value of K feeds the + input
(represents the PWM duty cycle)

$R1 := 5000$ $\quad\quad$ $R2 := 5000$

$Vin := 5$ $\quad\quad$ $Vout := 0.29$ $\quad$ Operating value

$$Vout = \frac{Vin \cdot K \cdot (R1 + R2)}{R1} - Vin \frac{R2}{R1}$$ Gain equation

Solve for K

$$K = \frac{(Vout \cdot R1 + Vin \cdot R2)}{[Vin \cdot (R1 + R2)]}$$

$$K := \frac{Vout \cdot R1 + Vin \cdot R2}{Vin \cdot (R1 + R2)}$$ $K = 0.529$

Plug the K value into the gain equation:

$$Vout(K) := \frac{Vin \cdot K \cdot (R1 + R2)}{R1} - Vin \cdot \frac{R2}{R1}$$ $Vout(K) = 0.29$

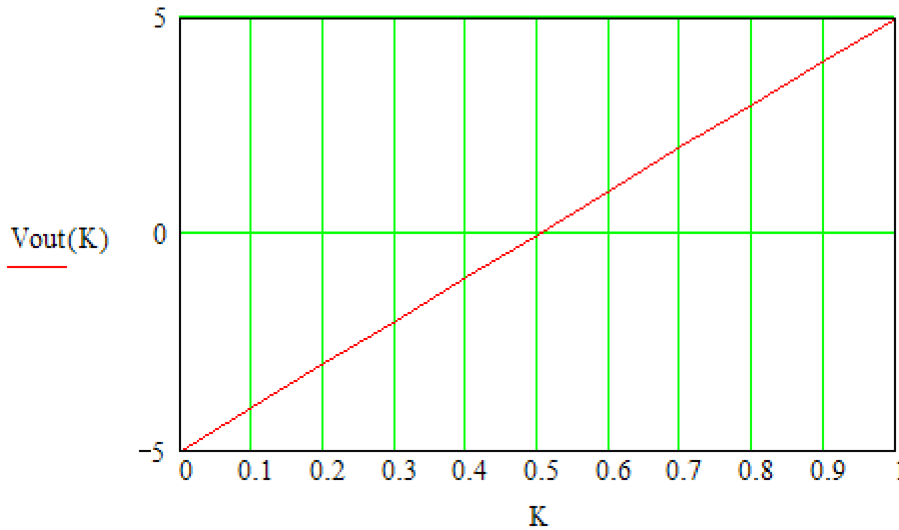
$$\frac{Vout}{Vin} = \frac{K \cdot (R1 + R2) - R2}{R1}$$ Slope of gain equation

$$Slope := \frac{K \cdot (R1 + R2) - R2}{R1}$$ $Slope = 0.058$

The output changes 0.058 mV per mV change of the +5V input (regulator)

DAC Vout vs K value (duty cycle)

$K := 0, 0.1 .. 1$



- When K = 0.5, the output shows zero change. Should try to operate around K=0.5
- The output varies from –5V to +5V as K varies from 0 to 1 (100 % duty cycle)

Tuning Sensitivity: 5 V change causes 1 Hz frequency change of the 10 MHz VCXO

$TS := 0.2$ Tuning Sensitivity in Hz / V

$\Delta f(\Delta V) := TS \cdot \Delta V$ In Hz at 10 MHz

$\Delta F12(\Delta V) := \frac{TS \cdot \Delta V}{10^7} \cdot 10^{12}$ In parts in 10^12

$\Delta F12\left(58 \cdot 10^{-6}\right) = 1.16$ Freq change in parts in 10^12 caused by a 1 mV change in the +5V supply, when Vout = VDAC = 0.29 V

$\Delta F12\left(2.5 \cdot \sqrt{2} \cdot 10^{-6}\right) = 0.071$ Peak Freq change in parts in 10^12 caused by 2.5 uV RMS on the VCXO control voltage

Calculate the Spurious levels on the 10 MHz VCXO

$$Fspur := 120$$

Freq of spurious observed on the VCXO control

$$M\_Index(\Delta V, Fspur) := \frac{\Delta f(\Delta V)}{Fspur}$$

Modulation Index

$$SB\_Level(\Delta V, Fspur) := 20 \cdot \log\left(\frac{M\_Index(\Delta V, Fspur)}{2}\right)$$

Sideband level in dBc

$$SB\_Level\left[\left(2.5 \cdot \sqrt{2} \cdot 10^{-6}\right), Fspur\right] = -170.615$$

Sideband level in dBc
for 2.5 uV, 120 Hz spur

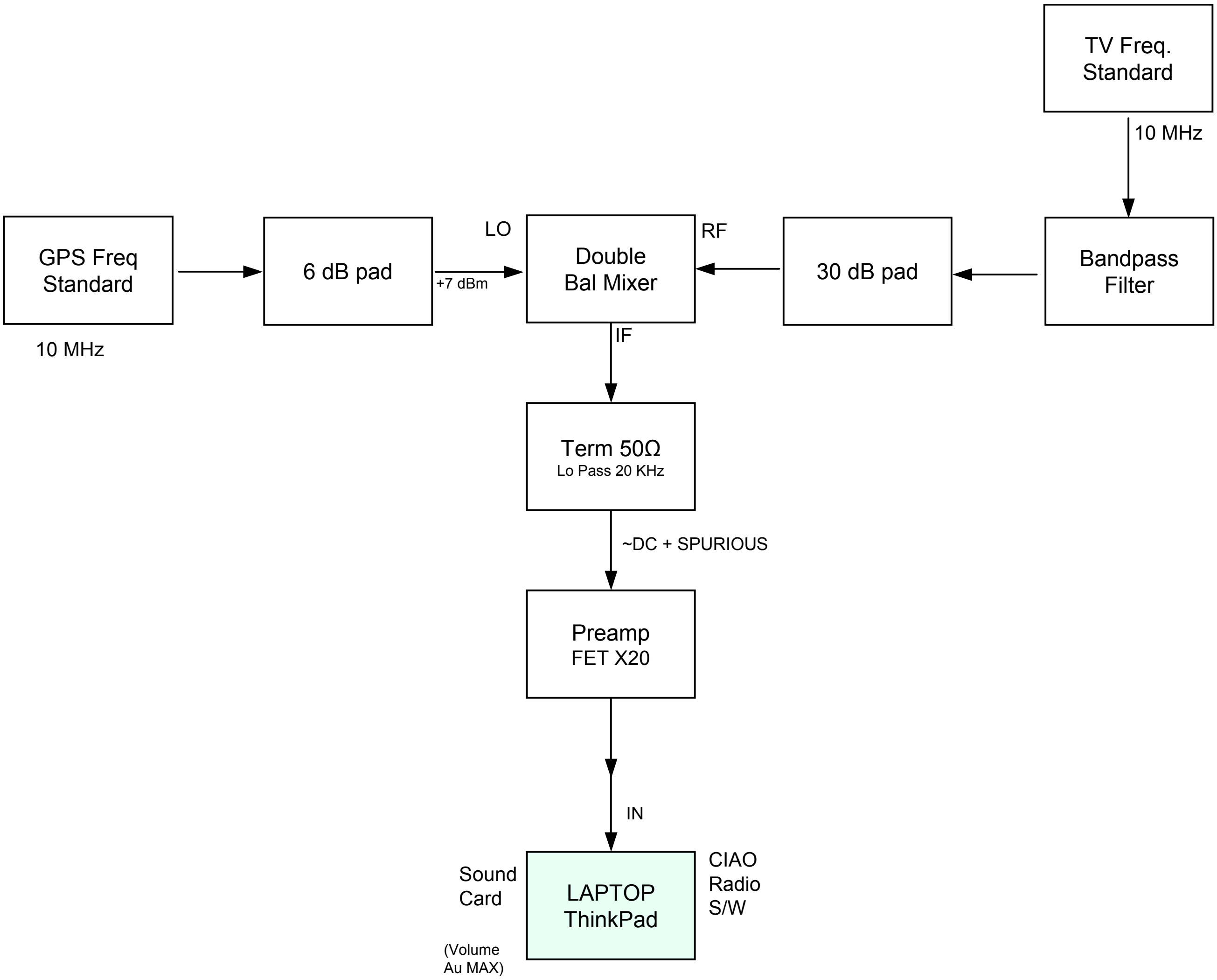
$$Fspur := 2000$$

Freq of spurious observed on the VCXO control

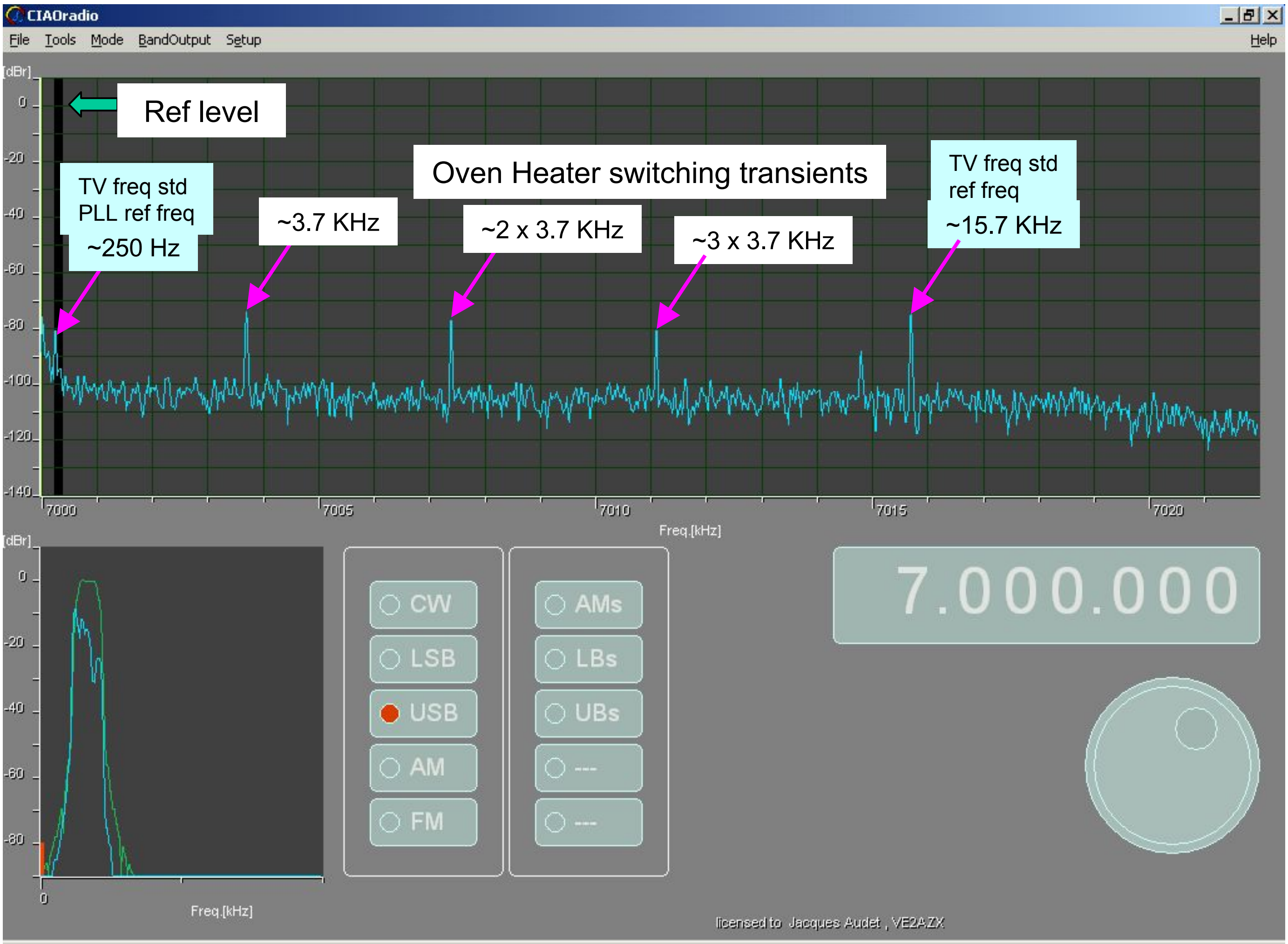
$$SB\_Level\left[\left(2.5 \cdot \sqrt{2} \cdot 10^{-6}\right), Fspur\right] = -195.051$$

No spurious were observed at these frequencies.
Only oven heater transients were present.

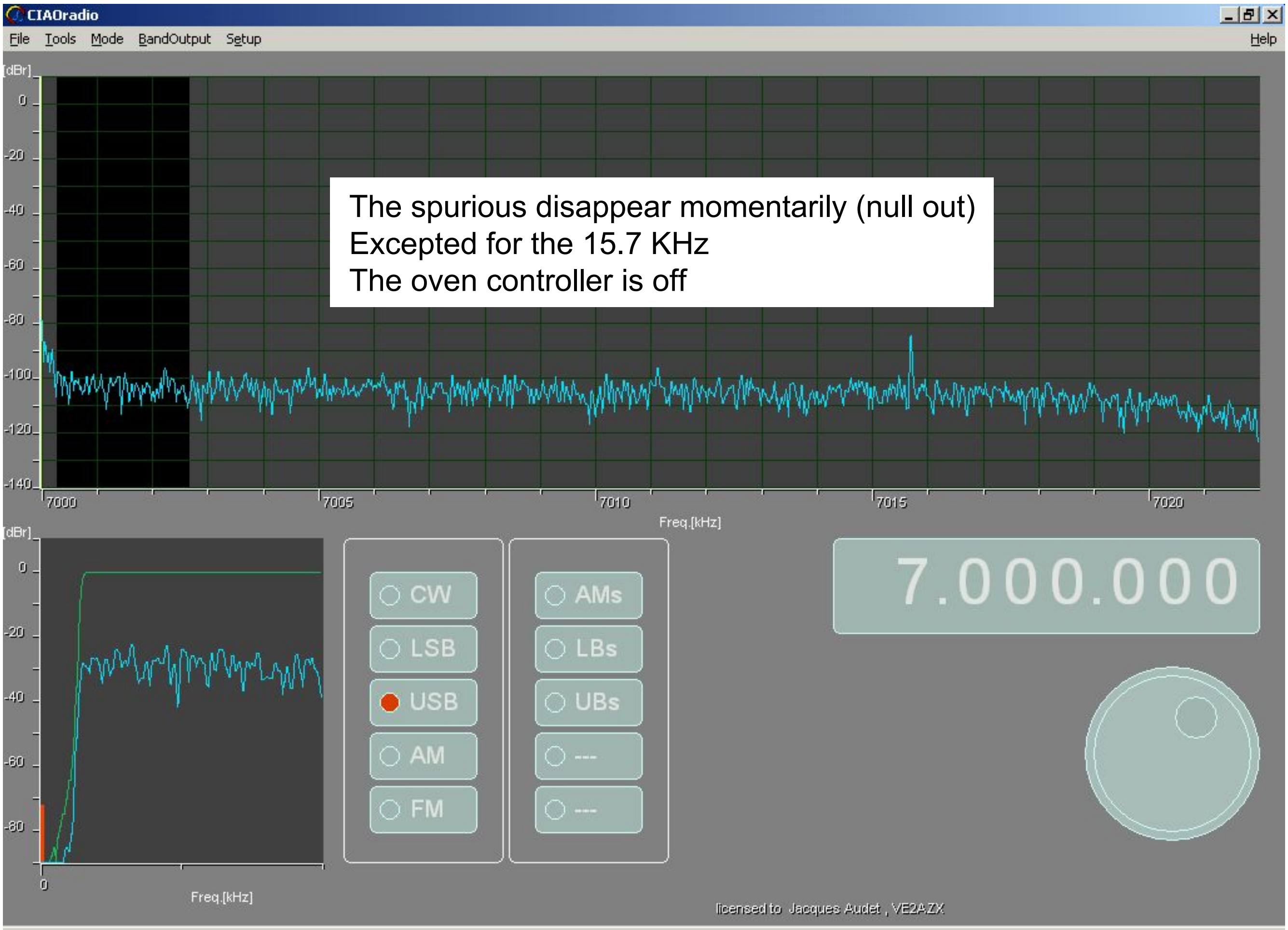
SET UP USED TO MEASURE 10 MHz SPURIOUS



MEASURING 10 MHz SPURIOUS

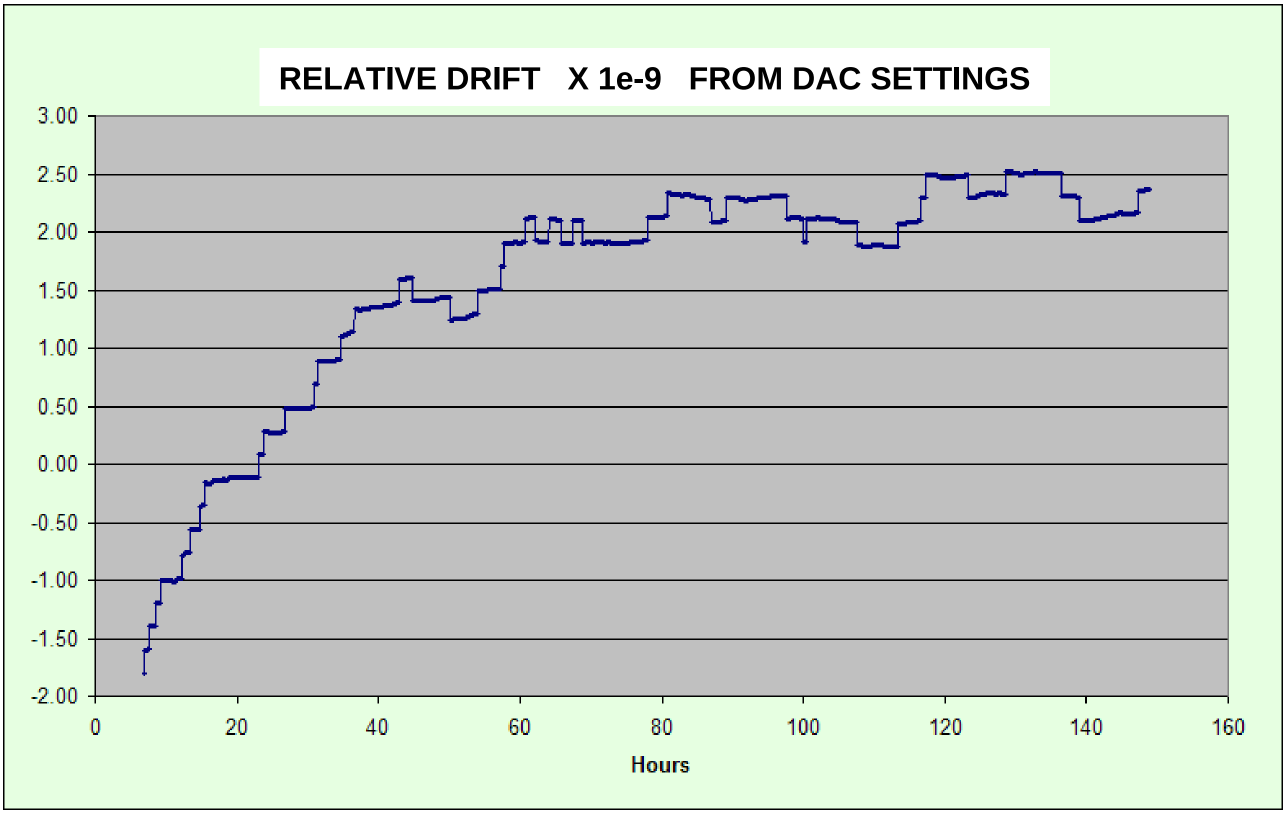


MEASURING 10 MHz SPURIOUS



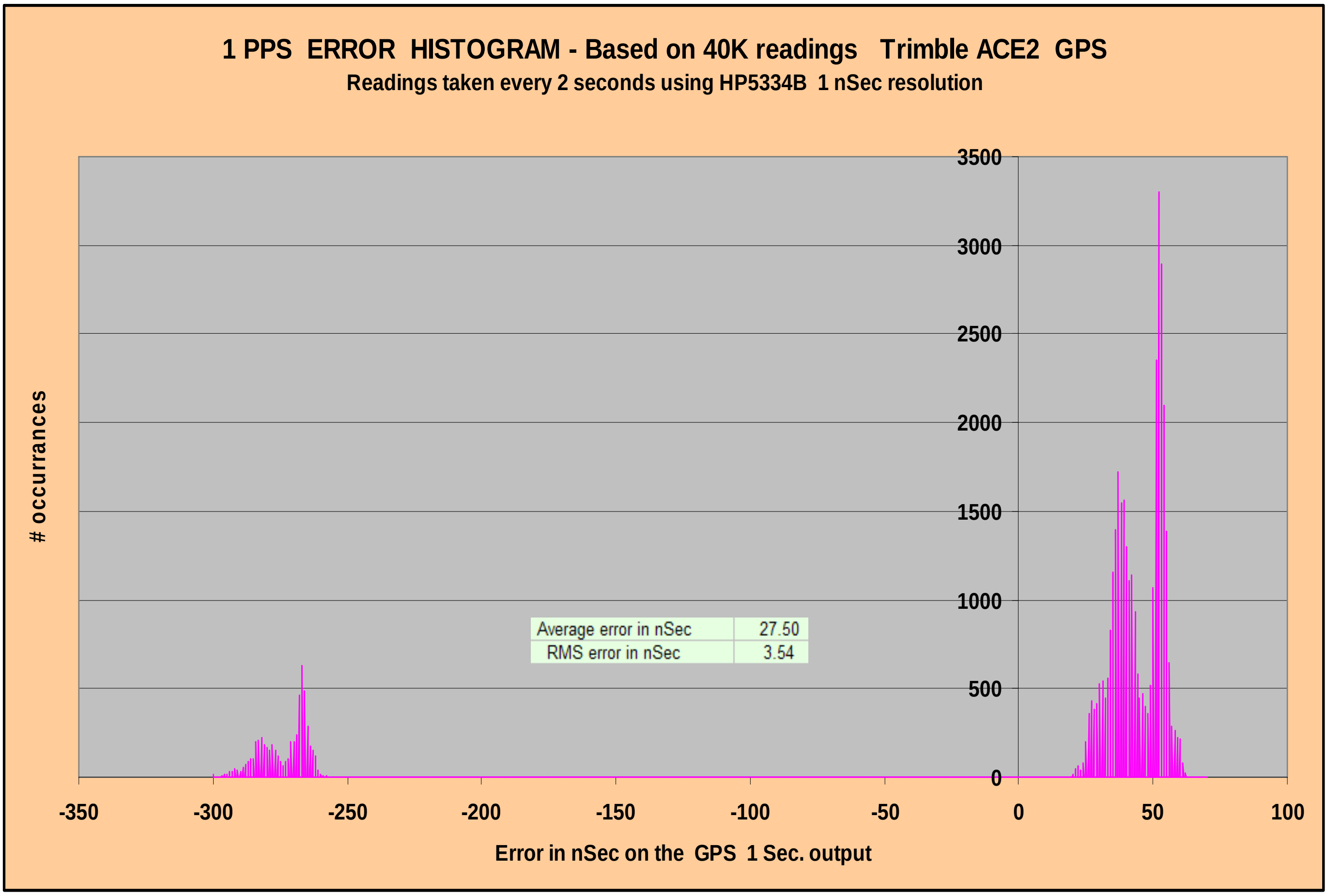
What the data sheet says:

To maximize oven-efficiency in the HP10544A, the heater current is controlled by a switching regulator circuit.
This produces switching transients at about 4 kHz on the input line and a low level spurious signal on the output.
A version of the oscillator with a dc oven controller is available. It should be used when adequate input filtering is difficult or better than -80 dB nonharmonic components on the output are required.



Drift data accumulated with the HP10544A VCXO, from a cold start.
At least 80 hours were required for the DAC to settle close to its final value.
Note that the relative drift was computed from the DAC value.

Measurements on the 1 pps timing



Here is what the Trimble Ace II reference manual says:

The timing accuracy is ± 100 nanosecond (1Σ) and is available only when valid position fixes are being reported. Repeatability checks of 10 sets of 100 one second samples taken over a period of 20 minutes showed an average variation of approximately 100 nanoseconds (not allowing for SA).